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13. SUPPLEMENTARY NOTES					
14. ABSTRACT The Final Proceedings for 3rd IAGA/ICMA Workshop on Vertical Coupling in the Atmosphere/Ionosphere, 18 September 2006 - 22 September 2006. The 3rd IAGA/ICMA Workshop will focus primarily on those forcing mechanisms that originate in the lower atmosphere, on their transmission into the atmosphere-ionosphere system and the ways in which these are influenced by changing solar, geomagnetic and anthropogenic drivers. The workshop will address recent studies on atmospheric coupling, with special emphasis on the following topics: (i) coupling by mean circulation, atmospheric tides and planetary and gravity waves; (ii) coupling by transport of atmospheric constituents and feedback of chemistry on dynamics; (iii) electrodynamic coupling and atmospheric electricity; (iv) modelling utilized for understanding the coupling processes. The workshop aims to stimulate the integration of observations and models to provide physical explanations for, and new insights into, the range of phenomena that result from coupling and feedbacks in the atmosphere-ionosphere system. The symposium will provide the next opportunity for the international research community to review the progress made so far and suggest some future directions in the investigation of all significant couplings (dynamic and electrodynamic, radiative, transport and chemistry of atmospheric constituents), trigger mechanisms and feedback processes.					
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CONFERENCE REPORT

3rd IAGA/ICMA Workshop on Vertical Coupling in the Atmosphere/Ionosphere System

September 18 – 22, 2006, Varna, Bulgaria

The 3rd IAGA/ICMA Workshop on “**Vertical Coupling in the Atmosphere/Ionosphere System**” was held at the five-star “Grand Hotel Varna” located in the famous Bulgarian seaside resort “St Konstantin and Elena” near Varna, Bulgaria, during September 18 – 22, 2006. The meeting was attended by a total of 77 senior and young scientists from 17 countries. During the 5 days of the workshop the participants presented 85 papers, from which 34 were solicited presentations.

The aim of this workshop was not only to address the physics behind the forcing mechanisms that originate in the lower atmosphere and play an important role on the upper atmosphere and ionosphere, but also to show the solutions of some of the problems which were only formulated during the 2nd IAGA/ICMA Workshop held two years ago in Bath, UK. The meeting was designed so that research experts from both the middle and upper neutral atmosphere and ionosphere communities come together in order to present their work and assess/debate ongoing issues relating to the theoretical, modelling and observational aspects of all kind of processes which transfer energy and momentum from the lower atmosphere to the upper atmosphere and ionosphere and vice versa.

The programme focussed on various aspects and topics of neutral dynamics as well as ionospheric electrodynamics and plasma physics. These included:

1) Coupling processes in the middle atmosphere

- Coupling through planetary waves, mean flows and temperature variability
- Gravity wave and tidal forcing of the middle atmosphere
- The role of dynamics, solar variability and greenhouse gasses on the chemical structure and feedback processes

2) Coupling processes in the atmosphere/ionosphere system

- Dynamical forcing of the ionosphere from below
- Electrodynamical coupling and plasma instabilities; the role of electrical processes in the coupling

This workshop brought together a mix of scientists doing mostly independent research on the fields of the MLT neutral atmosphere and the ionosphere, that is, on two collocated “spheres” of the near earth environment which remain closely coupled and on a continuous interaction. The meeting provided an excellent opportunity for these research communities to interact in a supplementary manner in reviewing and debating the progress done to date in the field of the upper atmosphere-ionosphere and come up with suggestions and ideas for further research on the vertical coupling of the atmosphere-ionosphere system.

Financial contributions to the workshop were made by the following organisations: the **US Airforce European Office for Aerospace and Development (EOARD)**, International Association of Geomagnetism and Aeronomy (IAGA), International Commission on the Middle Atmosphere (ICMA), International Union of Geodesy and Geophysics (IUGG) and International Union of Radio Science (URSI). In particular, the **EOARD** contributed with a grant of 5500 USD. This grant was used for supporting the travel and living expenses of two solicited speakers and for preparing the conference materials. The solicited speakers were: (i) Prof. Alexander Pogoreltsev from Russian

State Hydrometeorological University, St. Petersburg, Russia, and (ii) Prof. Giorgi Aburjania from Tbilisi State University, Tbilisi, Georgia.

The presentations at this Workshop will be published in a special issue of JASTP. The team of Guest Editors includes: Daniel Marsh (NCAR, Boulder, USA), Mike Taylor (Utah State University, Logan, USA), Christos Haldoupis (University of Crete, Iraklion, Greece) and Dora Pancheva (University of Bath, Bath, UK).

Dr. Dora Pancheva

Chair of the Programme Committee

Note From George York, EOARD LO:

1. The papers presented at the Workshop in Varna will be published in a special issue of JASTP, similarly to the previous Workshop at Bath in 2004. When the new issue of JASTP is published Dr Pancheva will send EOARD a copy.
2. Following is the Conference Program, containing the Agenda and Abstracts from the conference.

3rd IAGA/ICMA Workshop
on

Vertical Coupling in the Atmosphere/ Ionosphere System

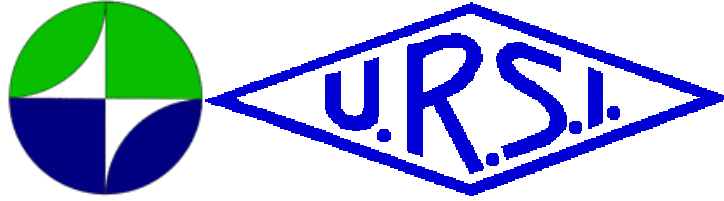
18-22 September, 2006, Varna, Bulgaria



- **Dynamical coupling:**
 - mean circulation and planetary waves
 - atmospheric tides
 - gravity waves, turbulence and plasma instabilities
- **Transport of atmospheric constituents.**

- Solar effects on the chemical structure and variability.
- Electro-dynamical coupling of the atmosphere and ionosphere.
- Observations, theory and modeling.





3rd IAGA/ICMA Workshop

Vertical Coupling in the Atmosphere/Ionosphere System

September 18 – 22, 2006
Varna, Bulgaria



Introduction

The Earth's atmosphere and ionosphere form a coupled system in which influences that originate at one height or region can have profound influences elsewhere in the system. Well-known examples include the wave driving of the mesosphere and lower thermosphere by gravity waves launched from the troposphere. This symposium will focus primarily on those forcing mechanisms that originate in the lower atmosphere and on their transmission into the atmosphere-ionosphere system above.

This workshop will address the theoretical, modelling and observational study of all aspects of these coupling processes, including studies of the different waves and tides, their generation, propagation and dissipation mechanisms. It is hoped that this symposium will provide an opportunity for the international research community to review progress to date and to suggest future directions in the investigation of all significant couplings (dynamic, electrodynamic and radiative, transport of atmospheric constituents), trigger mechanisms and feedback processes.

Scientific Committee

Dora Pancheva (*UoB*) - chair, Kevin Hamilton (*UoH*), Jan Lastovicka (*IAP*), Franz-Josef Lübken (*Liebnitz*) & Robert Vincent (*UoA*)

Local Organising Committee

Nikolai Miloshev (*GPhI*) - chair, Natalia Kilifarska & Borislav Andonov (*GPhI*)

UoB: University of Bath, *UoH*: University of Hawaii, *IAP*: Institute of Atmospheric Physics, *Liebnitz*: Leibnitz-Institute of Meteorology, *UoA*: University of Adelaide, *GPhI*: Geophysical Institute

Sponsors

The organisers wish to thank the International Association of Geomagnetism and Aeronomy (**IAGA**) and the International Commission on the Middle Atmosphere (**ICMA**). Their generous contributions and guidance made this workshop possible.

The organisers also wish to thank the following for their contribution to the success of this conference:

- European Office of Aerospace Research and Development (**EOARD**), Air Force Office of Scientific Research, United States Air Force Research Laboratory,
- International Union of Geodesy and Geophysics (**IUGG**),
- Union Radio-Scientifique International (**URSI**),

Workshop Schedule

September 17 (Sunday) 14:00 – 21:00	Registration at Grand Hotel Varna	
September 18 (Monday)	07:00 – 09:00	Registration
	09:00 – 10:00	Opening Ceremony
	10:00 – 10:15	Coffee
	10:15 – 12:00	Morning Session
	12:00 – 14:00	Lunch (buffet style)
	14:00 – 15:45	Afternoon Session 1
	15:45 – 16:00	Coffee
	16:00 – 18:00	Afternoon Session 2
September 19 (Tuesday)	19:00 – 21:00	Welcome Reception at GHV
	08:30 – 10:00	Morning Session 1
	10:00 – 10:15	Coffee
	10:15 – 12:00	Morning Session 2
	12:00 – 14:00	Lunch
	14:00 – 15:45	Afternoon Session 1
	15:45 – 16:00	Coffee
	16:00 – 18:00	Afternoon Session 2
September 20 (Wednesday)	18:30 – 20:30	Evening Reception
	08:30 – 10:15	Morning Session 1
	10:15 – 10:30	Coffee
	11:00 – 19:00	Trip to Nessebar
September 21 (Thursday)	12:30 – 13:30	Lunch
	08:30 – 10:00	Morning Session 1
	10:00 – 10:15	Coffee
	10:15 – 12:00	Morning Session 2
	12:00 – 14:00	Lunch
	14:00 – 15:45	Afternoon Session 1
	15:45 – 16:00	Coffee
	16:00 – 18:00	Afternoon Session 2
September 22 (Friday)	19:00	Gala Dinner at GHV
	08:30 – 10:00	Morning Session 1
	10:00 – 10:15	Coffee
	10:15 – 12:00	Morning Session 2
	12:00 – 14:00	Lunch
	14:00 – 15:45	Afternoon Session 1
	15:45 – 16:00	Coffee
	16:00 – 18:30	Afternoon Session 2 and Poster Session
	18:30	Closing Remarks

Session Timetables

September 17 (Sunday)

14:00 Registration

September 18 (Monday)

Morning Session (9:00 – 12:00)

7:00 Registration

9:00 Opening ceremony

Chairperson: Rolando Garcia

10:15 **M. Baldwin**

Stratosphere-troposphere coupling and climate change

10:45 K. Ivanova

Turbulence in the upper troposphere. Fokker-Planck equation approach

11:00 **L. L. Hood** and B. Soukharev

The solar cycle variation of stratospheric ozone and odd nitrogen: Implications for vertical coupling

11:30 N. A. Kilifarska and P. J. Mukhtarov

Quantitative estimation of 11 year solar variability contribution to the thermodynamic regime of the upper troposphere-lower stratosphere (UTLS)

11:45 M. Paluš and D. Novotná

Searching for phase synchronization in tropospheric temperature and solar and geomagnetic activity

Afternoon Sessions (14:00 – 18:00)

Chairperson: Lon Hood

14:00 **S. Panchev** and M. Tsekov

Empirical evidences of persistence and dynamical chaos in solar-terrestrial phenomena

14:30 **D.R. Marsh**, F.M. Vitt, R.R. Garcia and C.H. Jackman

A modeled response of the whole atmosphere to solar proton events

15:00 V. M. Aushev, V.V. Lyahov and Dryn E.A

Mesosphere response on the solar eclipse registered at March 29, 2006 by MORTI over Almaty (43.2°N, 76.9°E)

15:15 **R. Garcia**, D. Marsh and D. Kinnison

The response of the mesosphere and lower thermosphere to solar cycle variability and increases in greenhouse gases

Coffee break

Chairperson: Jeffrey Forbes

- 16:00 **A. I. Pogoreltsev**
Planetary waves in coupling the lower and upper atmosphere
- 16:30 **Han-Li Liu**
Atmospheric coupling as shown in the stratospheric sudden warming
- 17:00 K. Coughlin
Isolating stratospheric warmings -from the mesosphere to the troposphere
- 17:15 Hoffmann, P., W. Singer, E. Becker, R. Latteck, C. E. Meek, A. H. Manson,
W. K. Hocking and Y. Murayama
Variability of mesospheric winds and temperatures during stratospheric
warming events
- 17:30 P. J. Mukhtarov, B. Andonov and D. Pancheva
The large-scale thermodynamics of the stratosphere and mesosphere during
the major stratospheric warming in 2003/2004
- 17:45 D. Pancheva, P. J. Mukhtarov, B. Andonov and E. Merzlyakov
Planetary wave coupling of the stratosphere and mesosphere during the major
stratospheric warming in 2003/2004
- 19:00 **Welcome Reception at GHV**

September 19 (Tuesday)

Morning Sessions (8:30 – 12:00)

Chairperson: Robert Vincent

- 08:30 **Franz- Josef Lübken**
Ice layers in the mesosphere: Sensitive indicators of atmospheric changes
- 09:00 P. T. Younger and N. J. Mitchell
Sporadic meteors observed by radar at Arctic, equatorial and Antarctic
latitudes: Sporadic radiants and the distribution of radio meteors in the
atmosphere
- 09:15 **W. Singer**, R. Latteck and E. Becker
Characteristics of middle-atmosphere turbulence deduced from three years of
continuous measurements with a 3-MHz Doppler radar at 69°N
- 09:45 I. E. Suleimenov
Interactions between acoustically active layers in atmosphere

Coffee break

Chairperson: Franz-Josef Lübken

- 10:15 **J. M. Forbes**, S. E. Palo, X. Zhang, J. Russell, C. J. Mertens and M. Mlynchak
Vertical coupling by planetary waves as revealed by the SABER instrument
on TIMED
- 10:45 D. Offermann, J. Oberheide, M. Jarisch, K-U. Grossmann, H. Schmidt, J.M.
Russell III and M.G. Mlynchak
The wave turbopause: A mesosphere/thermosphere structure
- 11:00 **E.G. Merzlyakov** and D. Pancheva
1.5-5 day eastward propagating waves in the upper stratosphere through the

upper mesosphere as observed by the Esrange meteor radar and the SABER instrument

11:30 **M. G. Shepherd**

Planetary scale perturbations in O₂ and OH nightglow emission rates and temperatures at Northern mid-latitudes

Afternoon Sessions (14:00 – 18:00)

Chairperson: Dave Fritts

14:00 **M. J. Taylor**

Utilizing simultaneous OH and O₂ data to investigate vertical wave coupling over a broad spectral range

14:30 M. J. Lopez-Gonzalez, Rodriguez, E., Lopez-Puertas, M., Garcia-Comas, M., Shepherd, M.G. Shepherd, G.G., Sargoytchev, S. Aushev, V.M., Smith, S.M, Mlynczak, M.G., Russell, J.M., Brown, S. Cho, Y.-M. and Wiens, R.H.

Ground-based mesospheric temperatures at mid-latitude derived from O₂ and OH airglow SATI data: Comparison with SABER measurements

14:45 **G. G. Shepherd** and Young-Min Cho

Correlations of variability for the investigation of vertical coupling

15:15 G. G. Didebulidze, N. B. Gudadze, G. Sh. Javakhishvili, M. G. Shepherd and M. V. Vardosanidze

Some specifications of the annual distribution of the oxygen green 557.7 nm and red 630 nm line total nightglow intensities

15:30 N. B. Gudadze, G. G. Didebulidze, L.N. Lomidze, G. Sh. Javakhishvili, M. G. Shepherd and M. V. Vardosanidze

The influence of the meridional wind field changes on the oxygen red 630 nm line nightglow intensity

Coffee break

Chairperson: Anne Smith

16:00 **N. J. Mitchell**, P. T. Younger, C. L. Beldon and D. J. Sandford

Dynamics of the Arctic and Antarctic mesosphere at Esrange (68°N) and Rothera (68°S)

16:30 **R.A. Vincent**

Vertical coupling in the polar middle atmosphere

17:00 B. P. Williams, D. C. Fritts and J. D. Vance

Measurements of gravity wave zonal momentum flux with the Weber sodium lidar at ALOMAR in northern Norway

17:15 R. Werner, K. Stebel, G.H. Hansen, U. Blum, K.H. Fricke, M Gausa and U.-P. Hoppe

Wavelet application to determine wavelengths and phase velocities of gravity waves observed by lidar measurements

17:30 E. Yigit, A.D. Aylward and M. Harris

Importance of gravity wave parameterizations in the understanding of wave phenomena in the mesosphere lower thermosphere

17:45 K. Fröhlich, A. de la Torre, T. Schmidt, M. Ern, P. Preusse, J. Wickert and Ch. Jacobi

The influence of global dependence of gravity wave energy in the troposphere derived from GPS data on a model parameterization

18:30 **Evening Reception**

September 20 (Wednesday)

Morning Session (08:30 – 10:15)

Chairperson: Donald Farley

- 08:30 **M. Rycroft**, A. Odzimek, N. Arnold and M. Füllekrug
Charging and discharging the global atmospheric electric circuit: the role of lightning, sprites and jets
- 09:00 P.T. Tonev and P.I. Velinov
Electric atmosphere-ionosphere vertical coupling above thunderstorms with different intensity
- 09:15 C. Haldoupis, R. J. Steiner, Á. Mika, S. Shalimov and R. A. Marshall
Early/slow events: a new category of VLF perturbations observed in relation with sprites
- 09:30 **G.D. Aburjania** and A.G. Khantadze
New generation mechanism of the planetary-scale internal vortical electric field in the ionosphere
- 10:00 Kh. Z. Chargazia, G. D. Aburjania and A. G. Khantadze
Dynamics of the global weather-forming ULF electromagnetic wave structures in the ionosphere

Coffee break

11:00 **Trip to Nessebar**

September 21 (Thursday)

Morning Sessions (8:30 – 12:00)

Chairperson: Maura Hagan

- 08:30 **J. Oberheide**
Nonmigrating tides: Forcing mechanisms and climatology
- 09:00 **W.E. Ward**, J. Forbes, N. Grieger, S. Gurubaran, M. Hagan, K. Hamilton, R. Lieberman, D. Marsh, M. Mlynczak, T. Nakamura, J. Oberheide, D. Pancheva and H. Takahashi
Tides and their consequences: Challenges and achievements of the CAWSES tidal campaigns
- 09:30 **D. M. Rigg**, R. S. Lieberman and D. C. Fritts
Observations of the semidiurnal tide in the high latitude mesosphere

Coffee break

Chairperson: Nick Mitchell

- 10:15 **M. E. Hagan**, A. Maute, R. G. Roble and A. D. Richmond
Nonmigrating tidal effects in the Earth's upper atmosphere
- 10:45 **A. K. Smith**, D. Pancheva, N. J. Mitchell and D. R. Marsh
Variability of the mesospheric semidiurnal tide associated with planetary waves in the stratosphere
- 11:15 **D. Murphy**, T. Aso, D. Fritts, R. Hibbins, M. Jarvis, D. Riggin, M. Tsutsumi and R. Vincent
Interactions between planetary waves and tides in the middle atmosphere
- 11:30 **C.L. Beldon** and N.J. Mitchell
Inter-hemispheric comparisons of the 8-hour (terdiurnal) tide in the mesosphere and lower thermosphere
- 11:45 **D. J. Sandford**, N. J. Mitchell and R. A. Vincent
Lunar tides in the Arctic, Antarctic and equatorial mesosphere and lower thermosphere

Afternoon Sessions (14:00 – 18:00)

Chairperson: Erhan Kudeki

- 14:00 **D. T. Farley**
Mid-latitude E-region plasma instabilities: Large and small scale structures
- 14:30 **C. Haldoupis**
Midlatitude sporadic E layers. A review of recent progress and remaining questions
- 15:00 **O. N. Sherstyukov**, A. D. Akchurin and E. Yu. Ryabchenko
Diurnal and seasonal features of sporadic E-layer height in connection with complex structure of atmospheric tides.
- 15:15 **E. Yu. Ryabchenko** and O. N. Sherstyukov
Influence of quasi-biennial oscillation of atmospheric circulations on sporadic E layer 2–32-day variations
- 15:30 **S. Hawlitschka**
A classification of ionospheric waves as observed by a HF super-resolution direction finding system

Coffee break

Chairperson: Christos Haldoupis

- 16:00 **D. Fritts**
New aspects in modelling and theory of gravity waves and their effects on the thermosphere
- 16:30 **G. Lizunov**, Yu. Yampolski, V. Korepanov, A. Fedorenko and A. Zalizovsky
Acoustic-gravity channel of troposphere-ionosphere coupling
- 16:45 **S. Fukao**
A review on the Coupling Processes in the Equatorial Atmosphere (CPEA)
- 17:15 **E. Kudeki**
Gravity wave effects in the equatorial F-region
- 17:45 **T. K. Ramkumar**, D. Nath, D. N. Rao, Y. B. Kumar, S. Gurubaran, S. S. Kumar, P. Vishnu Prasanth, R. Rajaram and V. K. Anandan

Multi-instrumental observation of influences of lower atmospheric high frequency gravity waves on ionospheric current systems

19:00 **Gala Dinner at GHV**

September 22 (Friday)

Morning Sessions (08:30 – 12:00)

Chairperson: M. Abdu

08:30 **M. J. Jarvis**

Detecting vertical interaction through middle and upper atmosphere variations

09:00 **D. Altadill**

Time/altitude electron density variability at mid-latitudes over Europe: Further indication of dynamic coupling

09:30 C. Borries, N. Jakowski, Ch. Jacobi, P. Hoffmann and A. Pogoreltsev

Preliminary results of spherical analysis of planetary waves seen in ionospheric total electron content (TEC)

09:45 G.I. Gordienko, I.N. Fedulina, D. Altadill and M.G. Shepherd

The upper ionosphere variability over Alma-Ata and Observatorio del Ebro using the foF2 data obtained during the winter/spring period of 2003-2004

Coffee break

Chairperson: Jan Lastovicka

10:15 **M. Abdu**

Planetary wave effects on equatorial ionospheric electrodynamics: variabilities in spread F/plasma bubbles and pre-reversal electric fields.

10:45 L.B. Vanina-Dart, I.V. Pokrovskaya and E.A. Sharkov

Investigations of the interactions between the equatorial lower ionosphere and tropical cyclones using remote sensing and rocket soundings

11:00 **P. Lognonné**, G. Occhipinti, E. Alam Kherani, H. Hebert and D. Mimoun

Detection and modelling of the ionospheric gravity/tsunami waves and perspective for future tsunami remote sensing systems

11:30 T. Moffat-Griffin, M. Jarvis and R. Hibbins

Wavelet analysis of imaging riometer data: Detecting gravity waves

11:45 Z. Nechutný, P. Šauli, S. Roux and P. Abry

Study of “Scaling phenomena” in the ionosphere

Afternoon Sessions (14:00 – 17:00)

Chairperson: Martin Jarvis

14:00 **A. L. Aruliah**, E. A.K. Ford and E. M. Griffin

Thermosphere/ionosphere coupling by gravity waves: Multi-instrument observations

14:30 P. Šauli, P. Abry, S. Roux, J. Boška, D. Kouba and Z. Nechutný

Effects of solar eclipses events in the ionospheric plasma – acoustic-gravity waves generation and detection

14:45 **J. Lastovicka**, D. Buresova, V.M. Krasnov, Ya.V. Drobzheva, J. Chum, F. Hruska and T. Sindelarova

- Recent progress in investigation of effects of infrasound on the ionosphere and upper atmosphere
- 15:15 T. Sindelarova, D. Buresova, J. Chum and F. Hruska
Doppler observations of infrasonic and gravity waves of different origin at ionospheric heights
- 15:30 O.V. Martynenko, M.M. Gladkikh and I.V. Artamonov
Object-oriented hierarchical data structure for framework atmosphere model

Coffee break

Chairperson: Dora Pancheva

- 16:00 D. Kouba, P. Šauli, J. Boška and O. Santolik
Ionospheric F-region drift measurements in observatory Pruhonice: Seasonal quiet day patterns
- 16:15 J.Boška, D.Kouba and P.Šauli.
Ionospheric E and F region drifts during high and low geomagnetic activity.

Poster Session

- P01 N.A. Kilifarska and P.J. Mukhtarov
Stratospheric Warmings – deterministic or chaotic events
- P02 M.J. Lopez-Gonzalez, E. Rodriguez, M.G. Shepherd, G.G. Shepherd, M. Lopez-Puertas, M. Garcia-Comas, S. Sargoytchev, V.M. Aushev, S.M. Smith, S. Brown, Y.-M. Cho and R.H. Wiens
Ground-based mesospheric temperatures at mid-latitude derived from O₂ and OH airglow SATI data
- P03 V.M. Aushev, G.I. Gordiyenko, A.F. Yakovets and E.A Dryn
Phase relationship between tidal waves observed in the ionosphere and mesosphere over Almaty
- P04 A. M. Atanassov
Image processing of spectrograms produced by SATI with O₂ filter
- P05 G.G. Didebulidze, M.M. Todua and G.Sh. Javakhishvili
Correlation between cloudless days/nights and magnetic disturbances as a possible reason of space weather influence on climate
- P06 D. Murphy , J. French and R. Vincent
Long period wave activity in the MLT above Davis, Antarctica
- P07 A.N. Oleynikov, D.M. Sosnovchik, V.D. Kukush, Ch. Jacobi, K. Fröhlich and D. Kürschner
Seasonal variation of space-time parameters of internal gravity waves over Kharkiv (49°30'N, 36°51'E)
- P08 O. N. Sherstyukov, A. D. Akchurin, V. L. Linyuchkin and E. Yu. Ryabchenko
Investigation of short-period variations of virtual heights of the middle ionosphere by vertical ionospheric sounding with enhanced precision
- P09 O.A. Kharshiladze
Dynamical chaos and order-disorder transition in the large-scale ionospheric motions
- P10 L.B. Vanina-Dart
Relation between the ionospheric F2 region and stratosphere in various

- geomagnetic and solar conditions
- P11 I.A. Ansari
The phase structure of Pc3 geomagnetic pulsations at low latitudes
- P12 L. Korniychuk, E. Korobeynikova, N. Koshkin, S. Strakhova and L. Shakun
Atmospheric drag of low orbit satellites

Closing Remarks

Abstracts

September 18 (Monday)

Morning Session (9:00 – 12:00)

Stratosphere-troposphere coupling and climate change

Mark Baldwin

Northwest Research Associates, USA
Email: mark@nwra.com

The paradigm of a separate stratosphere and troposphere is advantageous when describing quantities such as humidity, ozone, lapse rate, and potential vorticity. However, the continuous atmosphere allows vertical wave propagation, exchange of mass, and other interactions between these layers. In many respects the distinction between the stratosphere and troposphere is artificial. The dynamical coupling of the stratosphere and troposphere is primarily mediated by waves that propagate upwards, into the stratosphere, where they dissipate causing variability of the stratospheric flow.

The conventional view is that of a one-way interaction in which tropospheric waves drive stratospheric variability. Recently, this view has given way to a more sophisticated understanding of a two-way interaction. Observations and model studies show that the stratosphere organizes chaotic wave forcing from below to create long-lived changes to the stratospheric circulation. These stratospheric changes can feed back to affect weather and climate in the troposphere.

Another recent development is an understanding that planetary wave propagation into the stratosphere depends not just on the phase and amplitude of tropospheric waves, but mostly on the configuration of the stratosphere. The details of planetary wave propagation and dissipation are complex, and predictions of future climate rely on models that simulate these waves.

There are three primary areas in which stratosphere-troposphere coupling is important: 1) extended-range weather forecasts, 2) climate predictions, and 3) predictions of the evolution and recovery of the ozone layer. In this talk, I will provide an overview of stratosphere-troposphere coupling and discuss aspects of these three topics.

Turbulence in the upper troposphere. Fokker-Planck equation approach

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Characteristic feature of the troposphere is the existence of cirrus clouds. Cirrus clouds play an important role in the climate system owing not only to their upper most position in the troposphere and thus being at the front line of interaction with the solar radiation, but also owing to their interwoven microphysical, dynamical, and radiative properties.

The objective of this study is not only to characterize, but most importantly to quantify the different dynamical regimes in layers having different stratification defined on the basis of the thermodynamical properties of the cirrus cloud system [Ivanova et al., 2006]. Using 35 GHz millimeter wave radar observations collected at the Southern Great Plains site of the Atmospheric Radiation Measurements (ARM) program, in Oklahoma, USA, we study physical processes in the upper troposphere cirrus cloud layers having different stratifications. The backscattering cross-section signal is non-stationary, with

highly irregular and clustered fluctuations owing to a set of various influences governing the particle motions at different temporal and spatial scales. Thus, it is of interest to distinguish and quantify from first principles the deterministic and stochastic influences on the backscattering cross-section signal in cirrus clouds. The time-dependent probability distribution functions of the backscattering cross section within different layers in the cloud describe the dynamics of the pertinent physical processes. The time-dependent tails of the probability distribution functions provide the signature of intermittency characterizing turbulent flows.

Thus, it is the objective of this study to present a method for deriving an underlying mathematical or model-free equation – the Fokker-Planck equation – that governs the time-dependent probability distribution functions of the fluctuations at different delay times starting from observations of the backscattering cross-section. In the framework of the Fokker-Planck equation approach, we derive the behavior of the drift and diffusion terms of the equation for the probability distribution functions that characterize the deterministic and stochastic parts, respectively, of the dynamics of the system.

We derive directly from observational data the Langevin equation that governs the increments of the backscattering cross-section in layers having different stratification. Based on the requirements of the Kolmogorov -4/5 law for fully developed turbulence we obtain a relationship between the drift and diffusion coefficients and then find that this relationship holds true for the well-mixed upper layer of the cloud.

Reference

K. Ivanova, H.N. Shirer, E.E. Clothiaux, Internal variability and pattern identification in cirrus cloud structure: The Fokker-Planck equation approach, *J. Geophys. Res. – Atmospheres*, **111**, (2006) D07203, doi:10.1029/2005JD006364

The solar cycle variation of stratospheric ozone and odd nitrogen: Implications for vertical coupling

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We report multiple regression analyses of the solar cycle variation of stratospheric ozone and odd nitrogen using long-term satellite data records. For ozone, we use data sets (SBUV/2, SAGE II and UARS HALOE) with lengths ranging from 12 to 25 years. For odd nitrogen, we use the 12-year UARS HALOE record. Results for ozone show that the vertical structure of the tropical solar cycle response has been consistently characterized by statistically significant positive responses in the upper and lower stratosphere and by insignificant responses in the middle stratosphere (28 to 38 km altitude). The similar vertical structure in the tropics for separate time intervals (with minimum response near 10 hPa) is difficult to explain by random interference from the QBO and volcanic eruptions in the statistical analysis. The observed increase in tropical total ozone approaching the cycle 23 maximum during the late 1990's (with no volcanic eruptions) occurred primarily in the lower stratosphere below the 30 hPa level. A mainly dynamical origin for the solar cycle variation of total ozone at low latitudes is therefore likely. We suggest that solar cycle changes in the tropical upwelling branch of the Brewer-Dobson circulation (first proposed by K. Kodera) are responsible. The latter may be caused by changes in the occurrence and timing of major stratospheric warmings (influenced by the QBO as well as the solar cycle). The analysis of UARS HALOE data yields evidence for a strong positive annual mean NO_x solar cycle variation at the highest available latitudes (60 to 70 degrees). This variation, which is most statistically significant in the Southern Hemisphere, is probably caused by downward transport during the polar night of thermospheric odd nitrogen produced by lower-energy electron precipitation and solar extreme UV fluxes. However, at low and middle latitudes, no statistically significant NO_x solar cycle variation is obtained except near and above the tropical stratopause. This indicates that, during the 1992-2003 period, decadal NO_x variations did not play a major role in modifying the solar cycle variation of stratospheric ozone outside of the polar regions.

Quantitative estimation of 11 year solar variability contribution to the thermodynamical regime of the upper troposphere-lower stratosphere (UTLS)

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The impact of solar variability into the Upper Troposphere-Lower Stratosphere (UTLS) is still questionable, due not only to insufficient length but also to non stationarity of the existing data records. One of the most frequently used is NCEP reanalysis' time series. Their sensitivity to truncation from the beginning and the end is well known, which hints on data nonstationarity. To examine how the length and the start point of data record influence the solar regression coefficient, several statistical experiments have been performed. It was found that solar influence on temperature variability is nonstationary process, especially at the altitudes of maximum effect, i.e. 150-50 hPa. Thus the solar regression coefficients, calculated at the equator from samples with 20 years length and different starting points, varies from 0.6 [K] per 100 units of F10.7, when starting year is 1951, to negative value -0.4 [K] (start year 1955) and having a maximum of 1.3 [K], when data record start at 1960. This may explain the great variety of results based on the same NCEP analysis, but derived over the records with different length and start year.

Calculated lower and upper limits of solar contribution show that at 90% confidence level, it can not be less than 8% and more than 50 % of total data variability, with maximum probability density of about 30 % at UTLS.

Multiple regression analysis of UTLS temperature, zonal and meridional winds was applies over the whole 56 year record and the solar influence is separated from QBO, SOI, NOI and trend signals. The maximum solar effect on temperature and zonal wind is located near or just below the tropical tropopause, having amplitude of 0.5[K] and 2 [m/s] per 100 units of solar F_{10.7}, correspondingly. The maximum contribution to the meridional wind is shifted at 250 hPa reducing the wind velocity by 0.2 m/s for 100 unit enhancement of F_{10.7}. However, near tropopause its effect is slightly positive.

Searching for phase synchronization in tropospheric temperature and solar and geomagnetic activity

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Enhanced Monte Carlo Singular Space Analysis was used to detect possible oscillatory modes in long term daily mean near surface air temperature series from several European locations and in the series of solar (Wolf numbers) and geomagnetic (Kp, aa indices) characteristics. These modes are extracted from the raw data (expressed in the SSA/EOF basis), their instantaneous phases are computed and their relations are studied using the tools of synchronization analysis. Significance of possible phase association is statistically tested using the concept of surrogate data.

Afternoon Session (14:00 – 18:00)

Empirical evidences of persistence and dynamical chaos in solar-terrestrial phenomena

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This paper presents a brief review of selected publications on the topic formulated in the title, and also some our results. It aims to point attention to this advanced approach, known in many other research areas (meteorology, hydrology, biology, economics etc.) but still not enough used in Solar-Terrestrial physics. We first introduce the concept for Dynamical (Deterministic) chaos (DC) by integrating an extremely simple nonlinear system of three deterministic ordinary differential equations. Its solutions exhibit nonperiodic random-like temporal behavior, resembling time series records of many natural phenomena, including those of interest here. We discuss appropriate methods (fluctuation and chaos analysis) for treatment of such data.

Section 2 is devoted to presentation of selected empirical evidences for DC in the: Solar activity, Solar wind, Magnetosphere and Ionosphere, Weather and Climate.

Our main conclusion is that the phenomena under consideration are likely to be inherently nonlinear and possibly chaotic, forced by nonlinear and possibly chaotic solar dynamics. They are not a linear response to this forcing.

A modeled response of the whole atmosphere to solar proton events

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NCAR's Whole Atmosphere Community Climate Model (WACCM) is used to study the response of the atmosphere from the surface to ~130 km to solar proton events (SPEs). WACCM is a general circulation model that incorporates interactive chemistry that solves for both neutral and ion species. It includes realistic solar and geomagnetic forcing, and observed trends in radiatively active gases. WACCM is used in this study to examine the short and long-term effects of including solar proton influences on the middle atmosphere in retrospective simulations beginning in 1963. SPEs are known to produce significant amounts of odd nitrogen (NO_y) and odd hydrogen

(HO_x) species that affect stratospheric and mesospheric ozone concentrations. In particular, very large SPEs occurred in 1972, 1989, 2000, 2001, and 2003 and led to significant polar middle atmospheric changes. The extent to which these changes persist and propagate to lower atmospheric regions is examined.

Mesosphere response on the solar eclipse registered at March 29, 2006 by MORTI over Almaty (43.2°N, 76.9°E)

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On March 29, 2006 total solar eclipse took place with the Moon positioned directly between the Sun and the Earth. The Moon's shadow descended on the eastern part of Brazil, running eastward across the Atlantic, through Northern Africa, across the Mediterranean, Turkey, Georgia, Russia and Kazakhstan. The period of March 27-30, 2006 is examined to study the mesosphere response to the total Solar Eclipse event at the time of its pass over northern Kazakhstan. The night time volume emission rates and rotational temperatures, obtained from MORTI measurements demonstrate appreciable differences in the pattern of wavelike oscillations observed during this period. Using a periodogram method the spectra of these wave-like oscillations observed in the mesosphere are examined. A physical mechanism is proposed to interpret the effects observed in terms of the mesosphere response on the total Solar Eclipse.

The response of the mesosphere and lower thermosphere to solar cycle variability and increases in greenhouse gases

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The mesosphere and lower thermosphere (MLT) are strongly influenced by solar flux variations; in addition, emissions of greenhouse gases (GHG) and chlorine compounds have the potential to alter the climate and composition of this region. We have carried out an ensemble of chemistry-climate model simulations designed to study the effect of natural and anthropogenic variability on the atmosphere from the 1950 to 2050. In this presentation we focus on model predictions for the MLT and show that both solar variability and changes in the abundance of anthropogenic compounds have a marked impact in the composition and temperature structure of the MLT.

The results of the simulations are compared with available observations; they confirm and help interpret some puzzling observations, such as the apparent lack of temperature trends near the mesopause.

Planetary waves in coupling the lower and upper atmosphere

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A set of global-scale waves playing an important role in formation of the zonal mean state and circulation exists within the lower and middle atmosphere. These planetary waves are responsible for the most interesting events in the middle atmosphere, for instance, sudden stratospheric warming, vacillations of the mean flow, and so on. To answer the question if these waves are capable of propagating into the thermosphere, the simplest vertical structure equation of the classic tidal theory taking into account the realistic vertical profile of the temperature is considered. Analysis and simulation with a simple model show that the well-known normal atmospheric modes which are trapped in the lower and middle atmosphere have the wave-like vertical structure with a large vertical wavelength in the thermosphere. Moreover, the reflection of these modes form the vertical temperature gradient in the lower thermosphere causing appearance of the wave energy upward flux in the middle atmosphere, and in a linearized formulation this flux is constant above the source region. A role of the secondary waves arising as a result of nonlinear interaction between the primary waves is discussed. To check a possibility of the propagation of different planetary waves up to the height of the upper thermosphere, the simulation with a mechanistic Middle and Upper Atmosphere Model (MUAM) has been performed. The results of simulation show that quasi-stationary and longer-period planetary waves are not capable of penetrating into the thermosphere. The shorter-period normal modes and ultra-fast Kelvin wave propagate into the lower thermosphere. However, above the altitude around of

150 km they are strongly suppressed by dissipative processes (mainly by the molecular thermal conduction and viscosity). The conclusion made is that planetary waves are not capable of propagating directly up to the heights of the ionospheric F2 region is made. It is suggested that other physical processes (for instance, the electromagnetic field disturbances and/or diffusive waves) have to be taken into account to explain the observed planetary wave-like structures of ionospheric parameters.

Atmospheric coupling as shown in the stratospheric sudden warming

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Stratospheric sudden warming (SSW) is a dramatic departure of the winter hemisphere from its climatological mean state, characterized by the westward reversal of the zonal wind and rapid temperature increase in the stratosphere within about a week. It has been recognized that SSW results from strong interactions between the quasi-stationary planetary waves and the stratospheric circulation. There are also increasing evidences indicating that the thermal and compositional structures of the mesosphere and lower thermosphere, as well as gravity wave activities in the middle and upper atmosphere, undergo significant changes during SSW episodes. SSW is thus likely a process that involves couplings from the troposphere to the lower thermosphere on various spatial and temporal scales, and it presents a case to obtain insights into such atmospheric coupling. In this talk, I will discuss several aspects of atmospheric couplings that are relevant to the study of SSW: The amplification of planetary wave(s) prior to SSW; impacts of SSW on the mesosphere and lower thermosphere; possible feedback interactions between the upper and lower atmosphere during SSW; and the general characteristics of chaotic divergence in a whole atmosphere model, which affect the predictability of SSW.

Isolating stratospheric warmings -- from the mesosphere to the troposphere

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Stratospheric Warming events exhibit the most dramatic changes seen in the stratosphere and yet the categorization of these events continues to be adhoc. Understandably, the definitions of major warming, minor warmings and/or Canadian warmings often depend on the scientific problem at hand. And yet, we show here that these events are statistically separated from the rest of the days in the winter stratosphere. By optimizing the separation between warming events and other winter days, we can define these events in a more rigorous manner. Furthermore, we are then able to show the evolution of these warmings from the mesosphere down to the troposphere.

Variability of mesospheric winds and temperatures during stratospheric warming events

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Continuous MF and meteor radar observations allow detailed studies of winds and temperatures in the upper mesosphere and lower thermosphere. This height region is characterised by a strong variability especially in winter due to enhanced planetary wave activity and related stratospheric warming events. Here the variability of mesospheric winds and temperatures is discussed in relation with major and minor stratospheric warmings as observed in the winters since 1998. Our studies are basing on MF radar wind measurements at Andenes (69°N, 16°E), Poker Flat (65°N, 147°W), Juliusruh (55°N, 13°E), and Saskatoon (52°N, 107°W) as well as on meteor radar observations of winds and temperature at Andenes (69°N, 16°E), Resolute Bay (75°N, 95°W) and Juliusruh (55°N, 13°E). Comparisons with results of the Kühlungsborn Mechanistic general Circulation Model (KMCM) confirm the observed latitudinal dependence of the reversal or weakening of the zonal wind whereas the effect decreases equator wards.

Observations and model results show an enhancement of planetary wave 1 activity at high latitudes during major stratospheric warmings. Daily mean temperatures derived from meteor decay times indicate that strong warming events are connected with a cooling of the 90-km region by about 10-20 K or even more. The onset of these cooling processes and the short term reversals of the mesospheric circulation to easterly winds occur some days before the changes of the zonal circulation in the stratosphere indicating a downward control of the influence of stratospheric warming events. The activity of gravity waves during these periods is discussed.

The large-scale thermodynamics of the stratosphere and mesosphere during the major stratospheric warming in 2003/2004

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Stratospheric warmings (SWs) can dramatically change the structure of the entire middle atmosphere including significant perturbations of the mesospheric temperature and neutral winds. These changes are usually characterized by mesospheric cooling and deceleration or even reversal of the mesospheric zonal wind. The present study is focused on the large-scale temperature and zonal wind disturbances observed in the stratosphere and mesosphere during the major SW beginning in early January 2004. The UK Met Office temperature and zonal wind data have been used to identify the vertical and latitudinal structure of the large-scale anomalies in thermodynamics of the Northern Hemisphere up to altitudes slightly above the stratopause. The zonal mean temperature and zonal wind anomalies are revealed by removing the climatology of the UKMO data obtained for the period of time between 1992 and 2005, or 14 years. The mesosphere zonal wind is measured by two MF and three meteor radars located between latitudes 52°N and 69°N and longitudes 21°E and 147°W. The mesosphere temperature around 90 km height is determined by using radar-meteor decay times. The major SW in the winter 2003/2004 is defined by a clear mesosphere response expressed by cooling and a reversal of the mean mesosphere zonal wind. This occurs a few weeks before the onset of the major SW at 10 hPa geopotential height.

Planetary wave coupling of the stratosphere and mesosphere during the major stratospheric warming in 2003/2004

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It is known that the stratospheric warmings are generated by the upward propagation of transient packet of planetary-scale disturbances originating predominantly from the troposphere and their non-linear

interaction with the zonal mean flow. The present study is focused on the vertical coupling due to transient travelling and stationary planetary waves observed in the middle atmosphere during the winter 2003/2004. The emphasis is on the major stratospheric warming (SW) beginning in late December/early January which led to nearly two months of vortex disruption. The UK Met Office data have been used to identify the planetary waves in the Northern Hemisphere up to altitude of about 52 km. The 2003/2004 major SW was accompanying by strong zonally symmetric (0) waves which couple the high and low latitudes, especially in the upper stratosphere. Results for the zonal wind are discussed in this presentation. The planetary waves observed in the mesosphere-lower thermosphere (~65-100 km height) have been determined by radar wind measurements at eight stations located between latitudes 52°N and 69°N and longitudes 37°E and 147°W. The results for the 16-18- and 23-25-day planetary-scale disturbances are particularly discussed here. Some additional information about the stationary planetary waves revealed from the temperatures between 20 and 105 km height measured by the SABER instrument on the TIMED satellite has been used as well.

September 19 (Tuesday)

Morning Session (8:30 – 12:00)

Ice layers in the mesosphere: Sensitive indicators of atmospheric changes

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Ice layers in the summer mesosphere at middle and polar latitudes are very sensitive to background conditions, such as temperatures, water vapor, and transport. These layers are called 'noctilucent clouds' (NLC) or 'polar mesosphere clouds'(PMC) when they are observed by optical methods from the ground or from satellites, respectively. The same ice particles lead to very strong radar echoes called 'polar mesosphere summer echoes'

(PMSE) which allows permanent observations even during bad weather conditions. Some observations now cover more than a solar cycle and therefore allow to study the effect of long term changes on the morphology and characteristics of ice layers. Indeed, variations on decadal time scales of different layer parameters (occurrence frequency, layer brightness etc.) have been reported. However, the physical and photo-chemical processes involved are not understood and some of the observations contradict expectations. Since ice layer formation is very sensitive to the thermal structure of the mesopause region the morphology of NLC/PMC/PMSE is frequently used to study, for example, inter-hemispheric differences of upper mesosphere temperatures.

In this presentation a summary of observations and theories related to mesospheric layers is presented. Highly sophisticated lidars and satellite instruments are used to study year-to-year and long term variations of NLC and PMC and their potential causes. Chemistry/transport models and microphysical simulations have recently been further developed and combined to study the effect of atmospheric coupling and small scale processes on the spatial and temporal morphology of ice layers.

For example, we can now explain the occasional occurrence of NLC at mid latitudes where mean temperatures are too large for ice particles to exist. Feed back mechanisms, e. g. through freeze drying, are demonstrated to have a significant effect on the atmosphere.

Sporadic meteors observed by radar at Arctic, equatorial and Antarctic latitudes: Sporadic radiants and the distribution of radio meteors in the atmosphere

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Meteors provide a significant flux of extraterrestrial material into the Mesosphere and Lower Thermosphere. They contribute towards the formation of noctilucent clouds and provide the chemical input for the mesospheric metal layers.

Previous observations made by meteor radar have revealed higher meteor count rates in summer than in winter. Explanations proposed for this phenomenon have included the astronomical distribution of sporadic meteor radiants and/or seasonal changes in the scale height of the atmosphere.

Simultaneous observations made by meteor radars at Arctic, Equatorial and Antarctic latitudes have been used to study the seasonal variation in the flux of radio meteors. Both high latitude sites show a conspicuous summertime maximum in meteor counts. It is found that meteor count rates depend upon the density structure of the atmosphere, the location of the radar and the position of the sporadic radiants on the sky.

Two particular results are presented. Firstly, we show that the flux of sporadic meteors is dominated by the apex, helion, anti-helion and Toroidal sources. Secondly, we propose that the seasonal variation in meteor counts can be explained purely in terms of the rising and setting above the local horizon of the sporadic radiants.

Characteristics of middle-atmosphere turbulence deduced from three years of continuous measurements with a 3-MHz Doppler radar at 69°N

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Turbulent energy dissipation rates have been derived from the width of the observed signal spectra obtained with a narrow beam Doppler radar operated at 3.17 MHz in Andenes (69°N). Vertical and oblique beams with a minimum half-power full-beam width of 6.6° are used. The turbulent spectral width is estimated with a computationally intensive correction method to remove contributions from non-turbulent processes. The radar provides estimates of turbulent energy dissipation rates in an altitude range from about 55 to 90 km with a time resolution of 1 h and a range resolution of 1 km since September 2003.

The energy dissipation rates based on radar observations vary in the order of 2-10 mW/kg around 70 km and between about 10 and 200 mW/kg around 85 km in dependence on season. The lowest energy dissipation rates are found in summer at altitudes below about 80 km. The largest dissipation rates of about 200 mW/kg occur above 80-85 km in summer in agreement with the insitu measurements. In addition, observations under disturbed conditions (stratospheric warming events, solar proton events) are presented. During the occurrence of strong VHF radar echoes from the polar winter mesosphere energy dissipation rates between 30 and about 100 mW/kg are observed at altitudes from 55 to 65 km in January 2005.

The seasonal variation of the estimated turbulent energy dissipation rates is discussed in relation with insitu measurements and model results. The radar estimates are in reasonable agreement with climatologically winter and summer data from previous rocket soundings at Andenes as well as with time-resolved results (1-h resolution) from the Kuehlungsborn Mechanistic General Circulation Model (KMCM) model for summer and winter conditions.

Interactions between acoustically active layers in atmosphere

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Recently we reported [1] that a number of important properties of wave structure in atmosphere, particularly, of mesopause region are due to acoustical activity of the media. (A media, which demonstrating the effect of acoustic wave intensification during its propagation, was called in [1] acoustically active ones). For example, it was shown that complicated structure of spectra of oscillations of night sky emission at mesopause altitudes is closely connected with wave-to-wave interactions caused by intensification of the waves.

In present paper it is shown that there are at least three acoustically active layers in atmosphere. Each such layer is connected with definite set of photochemical reactions, which determine the concrete mechanism of conversion of sun radiation energy into energy of wave motion. The first one is ozone layer, the second – mesopause region investigated in [1], and the third – ionosphere.

In this paper we show that the real wave-to-wave interactions have much more complicated set of resonances than it was reported earlier. Namely, it is shown that the waves generated in one acoustically active layer can reach another one. Intensification of the waves having some other frequency than it is determined by own parameters of the layer under consideration leads to appearance of additional combinational frequencies in spectra of observable oscillations. Moreover the response of upper acoustically active layer (in particular, of ionosphere) on the disturbances generated in down ones may be quite strong. Such pronounceable response appears, for example, when caustic point of wave front formed in down acoustical active layer belongs to upper one.

In particular, we show that the appearance of sprites (as quite rare and interest type of specific atmospheric gas discharge) may be explained as a result of formation of low-pressure regions in caustic points of wave structures.

The theory of radiation of waves by acoustically active layers was build up in the report in order to describe layer-to-layer interactions quantitatively. This theory allows description of propagation of internal gravity and acoustic-gravity waves generated in acoustically active layers in atmosphere as whole.

On the base of this theory it is shown that the disturbances in stratospheric ozone layer may cause significant breaking of wave structures in mesopause region. In other words any event, which causes some changes in parameters of ozone layer immediately cause pronounceable response in wave structures in mesopause region. The fact is closely connected with the type of diagram of propagation of acoustical-gravity waves, which carry energy mainly in vertical direction.

1. Suleimenov I.E. et. al. <http://dx.doi.org/10.1134/S0016793206030121>

Vertical coupling by planetary waves as revealed by the SABER instrument on TIMED

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The SABER instrument on the TIMED satellite provides temperature measurements from about 20 km to 120 km, and at latitudes extending as high as 83 degrees in both hemispheres. Near-continuous data are available from 2002 through present. In this paper, we present a survey of eastward- and westward-propagating planetary waves in these data, with emphasis on wave periods greater than about 5 days

and zonal wavenumbers $s = 1$ and $s = 2$. The aim is to identify the most prominent waves that repeat from year to year, and for these waves to answer the following questions: (1) Which of these waves are normal modes, and which are forced waves? (2) What are the likely forcing mechanisms, i.e., nonlinear interactions or instability? (3) Are there normal modes of significant amplitude other than the traditional 5-, 10- and 16-day waves? (4) What are their seasonal-latitudinal and vertical characteristics? (5) In particular for this workshop, which of these waves is most likely to penetrate into the thermosphere-ionosphere system?

The wave turbopause: A mesosphere/thermosphere structure

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Vertical profiles of temperature and wave activity have been measured by the space borne instruments CRISTA and SABER. Wave breaking is found to be strongly reduced above a specific altitude in the upper mesosphere/lower thermosphere which is named the "wave turbopause".

This altitude level varies between 80 and 105 km. It shows strong seasonal variations. Latitudinal variations are also substantial.

The wave turbopause is found near the zero-wind lines in the upper atmosphere. Comparisons with other turbulence measurements are given as well as with results from the HAMMONIA general circulation model.

1.5-5 day eastward propagating waves in the upper stratosphere through the upper mesosphere as observed by the Esrange meteor radar and the SABER instrument

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Data of neutral wind obtained by meteor radar at Esrange and synchronous data of temperature and pressure measurements obtained by the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on board the Thermosphere–Ionosphere–Mesosphere Energetics and Dynamics (TIMED) spacecraft were studied with respect to a day-to-day atmospheric variability with periods from 1.5 to 5 days. The detailed analysis was carried out for February 2004. Perturbations of the atmospheric parameters at the considered periods appeared mainly as eastward and downward propagating waves of zonal wavenumbers 1 and 2. These waves are excited by the jet instability at both sides of the polar jet in the upper stratosphere and the mesosphere, interacted with each other and generated secondary waves. The radar observed the primary and secondary waves at heights of the mesosphere. Under conditions of a weak instability observed in February 2003 perturbations of atmospheric parameters of periods from 1.5 to 5 days occupy significantly smaller atmospheric layers and have smaller amplitudes at heights of the mesosphere. The Eliassen-Palm fluxes of waves generated by the jet instability are mainly downward. This means an influence of upper atmospheric layers on the lower ones.

Planetary scale perturbations in O₂ and OH nightglow emission rates and temperatures at Northern mid-latitudes

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Nightglow emission rate and rotational temperature observations of O₂ (0-1) Atmospheric and OH(6-2) Meinel bands observed by a series of SATI (Spectral Airglow Rotational Temperature Imager) instruments have been carried out at three ground-based stations at Northern mid-latitudes: the Delaware Observatory, Canada, (42.9°N, 278.6°E), Sierra Nevada, Spain (37.1°N, 356.6°E) and Stara Zagora, Bulgaria (42.4°N, 25.7°E) during the period of December 2003 – May 2006. The data are employed in the study of planetary scale perturbations (e.g quasi 2-day, 5-day, 18-day waves) and acoustic gravity waves (AGWs) at the three locations and their zonal and temporal correlation at 87 km and 94 km height. Wave propagation characteristics derived from these observations are presented and discussed.

Afternoon Session (14:00 – 18:00)

Utilizing simultaneous OH and O₂ data to investigate vertical wave coupling over a broad spectral range

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A variety of remote sensing techniques have now revealed a rich spectrum of wave activity in the upper atmosphere. Many of these perturbations, with periodicities ranging from ~5 min to several days and horizontal wavelengths of a few ten's of km to global scales, are due to freely propagating atmospheric gravity waves, tidal oscillations, and planetary waves. In particular, long-term, passive optical observations of the coupling of these waves into the mesosphere and lower thermosphere (MLT) region (~80-100 km) are facilitated by several naturally occurring, vertically distinct nightglow layers. This paper focuses on airglow measurements using the CEDAR Mesospheric Temperature Mapper (MTM) which is capable of high-resolution observations of a broad spectrum of waves in both intensity and rotational temperature using the near infrared OH (6,2) band (peak altitude ~87 km) and O₂ (0,1) band (altitude ~94 km) emissions. Over 1000 nights of high-quality data have been obtained by the MTM (Nov. 2001-to date), operating near continuously (~24 nights/month centered on the new moon) from the high altitude observatory at Maui, Hawaii (20.8°N) as part of the US Maui-MALT program. Simultaneous OH and O₂ measurements have provided unique information on the amplitude and phase relationships of a broad spectrum of quasi-monochromatic gravity waves, tidal oscillations and planetary waves which have been used to investigate their seasonal variability at low-latitudes including the characterization of a semi-annual oscillation in mesospheric temperature. Example events will be discussed in detail illustrating the coherence, but diverse nature of these waves and emphasizing the large night-to-night and seasonal variability that occurs in the vertical wave coupling at mesospheric heights as measured independently using both emission layers.

Ground-based mesospheric temperatures at mid-latitude derived from O₂ and OH airglow SATI data: Comparison with SABER measurements

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Atmospheric temperatures deduced from ground-based airglow observations with a Spectral Airglow Temperature Imager (SATI) at Sierra Nevada Observatory (37.06°N, 3.38°W) at 2900 m height and from satellite observations with the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on board of the TIMED satellite, during 2002, have been compared. Similar patterns of seasonal and day to day variations are found in the temperatures retrieved from both instruments at latitude of 37°N. The temperatures obtained with SATI and SABER at 95 km are similar (within 2 K). However, the temperatures deduced from SATI at 87 km are slightly larger (about 8 K) than those measured by SABER.

Correlations of variability for the investigation of vertical coupling

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In 1972 Krassovsky noted that perturbations in airglow emission rates and in rotational temperatures determined from the same airglow emission were coherent, suggesting the passage of gravity waves through airglow layers. Hines and Tarasick developed a formal description of this process in 1987, noting that the so-called Krassovsky ratio, the ratio of the fractional emission rate perturbation to the fractional temperature perturbation, was determined by one parameter that described the photochemistry and a complex parameter that derived from the dynamics and allowed a phase shift between the two observables. The goal was to make determinations of gravity wave characteristics from measurements of the complex Krassovsky ratio but measurements available at that time were not adequate for useful applications of the method. With the introduction of CCD detectors, measurements of airglow emission rate and temperature perturbations have become much more accurate and four years of such data have now been acquired for the O₂ Atmospheric and OH Meinel bands at Resolute Bay in Northern Canada, 74° N. What has been found is that a high degree of correlation between emission rate and temperature exists, not just for perturbations, but for the absolute values of these quantities. This correlation is consistent with the Krassovsky ratio, but holds for variations observed during one day, over one month, during an entire winter and even from winter to winter. All of this is consistent with vertical adiabatic motions; altitude perturbations of the airglow observed with satellite data and predicted with a simple model. These results are described and the relevance to atmospheric coupling is discussed.

Some specifications of the annual distribution of the oxygen green 557.7 nm and red 630 nm line total nightglow intensities

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The mean decadal (ten-day) annual distribution of the oxygen green 557.7 nm and red 630.0 nm line total nightglow intensities observed at Abastumani (41.75°N, 42.82°N) during 1957-1993 is investigated. A specific modulation of the mean annual, semi-annual and seasonal characteristic distribution of the green (emitted mainly from the mesosphere-lower thermosphere) and red (emitted from the ionosphere F2 region) line intensities up to 20-50% from their mean values is revealed close to equinoctial and solstice times. The increase in the green line intensity during the 9-10th decades of year (close to spring equinox) is followed by a significant decrease (about 50% from its mean value) during the 11th decade of year. For the same time of year the red line intensity behaviour is opposite - its lower value occurred during the 10th decade and increased during the 11th decade of year. Similar behaviour (an increase in the green line intensity is accompanied with a decrease in the red line intensity with a larger duration than it was close to spring equinox) takes place in the 25-29th decades of year. Important changes for the 18-19th decades of year (close to solstice) in the green and red line intensities are also noticed. These phenomena are considered to be typical of the mesosphere-thermosphere-ionosphere F2 region dynamical coupling processes during the equinox and solstice periods.

The influence of the meridional wind field changes on the oxygen red 630 nm line nightglow intensity

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The wave-like disturbances in the mid-latitude total nightglow intensity of the oxygen red 630.0 nm line observed at Abastumani (41.75°N, 42.82°N) is considered as a possible result of the thermosphere wind field changes. The magnetically quiet and disturbed days are considered. The atmospheric gravity wave (AGW) like behaviour and relatively rare impulse-like disturbances in the red line intensity are noted on magnetically disturbed days. The main reason of the dynamical changes in the mid-latitude region thermosphere-ionosphere coupling processes during magnetically disturbed days is the increase both in the equatorward thermosphere wind and the amplitude of AGWs. In some cases the impulse increase in the red line intensity with duration about 1 hour and more occurred on magnetically quiet period after twilight for different seasons. The impulse behaviour of the red line intensity is considered as a characteristic to the thermosphere-ionosphere F2 region coupling processes during the wind field changes. The theoretical explanation of this phenomenon is based on the time dependent simple Chapman-type layer taking into account the presence of AGWs and meridional wind field reversal.

Dynamics of the Arctic and Antarctic mesosphere over Esrange (68N) and Rothera (68S)

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Two meteor radars are sited at ESRANGE (68N) in the Arctic and Rothera (68S) in the Antarctic. The radars are at conjugate geographical latitudes and the identical instrument design allows investigation of differences between the Arctic and Antarctic MLT regions, free from problems of measurement bias. Data from February 2005 to May 2006 have been examined using identical analysis techniques to compare the climatological properties of the mean winds, tides and planetary waves observed over the two high-latitude sites. Systematic differences are revealed in several aspects of the dynamics of the MLT region, including variations in the shears of the summer-time zonal winds and the structure of corresponding equatorward flows. The 12- and 24-hour tides exhibit notable differences, with the wintertime Arctic 12-hour tide over ESRANGE reaching significantly larger amplitudes than over Rothera and also exhibiting a shorter vertical wavelength. In the case of the 24-hour tide, the amplitudes are generally larger over ESRANGE through out most of the year. Simple analyses of planetary waves are used to investigate Arctic/Antarctic differences in their seasonal behaviour.

Vertical coupling in the polar middle atmosphere

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Planetary and small-scale gravity waves both play important roles in determining the basic state of the polar middle atmosphere as well as in transient phenomena such as major stratospheric warmings. In recent years there has been an increased deployment of ground-based radars located at polar latitudes in both hemispheres. This has led to a better understanding of dynamical processes in the polar MLT. Here, recent observations will be reviewed with a particular emphasis on a comparison of major stratospheric warming events in each hemisphere and on gravity wave coupling. In-situ observations made with superpressure balloons launched as part of the VORCORE campaign in the Antarctic spring of 2006 will also be discussed. Drifting at heights near 20 km these balloon measurements provide a unique insight into gravity wave variability and on momentum fluxes.

Measurements of gravity wave zonal momentum flux with the Weber sodium lidar at ALOMAR in northern Norway

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The zonal momentum flux divergence in the mesosphere and lower thermosphere region is an important driver of the meridional circulation and temperature structure, but measuring the flux requires higher temporal resolution than most radars and lidars can obtain. The Weber sodium lidar has been making wind and temperature measurements at ALOMAR, Norway since August 2000, including zonal momentum flux measurements during the winters of 2002, 2004, 2005, and 2006. The number of measurements has been limited by weather, transmitter reliability, and receiver efficiency. The transmitter is now stable and the ALOMAR 1.8m telescopes were upgraded in September 2005 to gain a factor of 1.5 to 2 in signal. This should allow momentum flux measurements on any clear night. We will present the momentum flux results from three recent 13-15 hour long data sets: 5-6 November 2005, 04-05 February 2006 and 16-17 February 2006. We also have lower resolution daytime data giving 24 hour continuous coverage for 04-05 February 2006 and 3 day coverage from 16-19 February

2006, which will allow us to determine the tides on these days and investigate the effect of the tides on momentum flux deposition.

Wavelet application to determine wavelengths and phase velocities of gravity waves observed by lidar measurements

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During the last two decades important advances have been achieved by the investigation of gravity waves. However, more efforts are needed to study certain aspects of the gravity waves. For example, their spectrum is rather intermittent, making it difficult to estimate. In the real atmosphere, the gravity waves occur with different properties at different altitudes, often simultaneously. In the case when there is more than one dominant wave, the determination of gravity wave parameters such as the vertical wavelength and phase velocity is difficult. Their exact knowledge is important not only for the determination of the other parameters, for example the horizontal wave components but also for the study of the waves' climatology. To examine the waves' location in space and time, wavelet spectra of a time series of temperature profiles, observed with the ALOMAR Ozone Lidar at Andoya, Norway, and by the Bonn University Lidar system at ESRANGE, Sweden, are calculated. The wavelet spectra were filtered and the so-called temperature colour plot for dominant wavelengths was reconstructed, thus allowing to specify the vertical wavelengths and the vertical component of the phase velocities.

Importance of gravity wave parameterizations in the understanding of wave phenomena in the mesosphere lower thermosphere

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The importance and presence of vertically propagating small-scale unresolved internal gravity waves (IGWs) has been known for over four decades, since the early work of Hines (1960). The physical significance of waves is in the dynamical modulations of the mesosphere and lower thermosphere (MLT) region via momentum and energy deposition, this in turn following from a series of possible ambiguously defined dissipation phenomena. Existence of numerous gravity wave parameterizations with individual theoretical foundations is a sign of lack of precision in the quantitative description of IGW energetics.

In this work, two of the existing gravity wave parameterizations, HLM (Hybrid Matsuno Lindzen - 1999) and Medvedev & Klaassen (2000) are implemented and included in UCL's general circulation model (GCM), CMAT2 (Coupled Middle Atmosphere Thermosphere model). This GCM is briefly introduced and the implementation of the gravity wave schemes described. The sensitivity and response of the GCM results to variation of the initial wave spectrum are demonstrated.

The underpinning results of this study strongly suggest that uncertainty in the initial gravity wave spectrum and its precise geographical structure remains one of the challenges for IGW modellers. Despite this fact, with a model spectrum it is possible to simulate the general morphology of middle atmospheric dynamics.

The influence of global dependence of gravity wave energy in the troposphere derived from GPS data on a model parameterization

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The Warner-McIntyre (WM) gravity wave (GW) parameterization scheme and alternatively a Lindzen-type GW scheme has been implemented into the COMMA-LIM middle atmosphere circulation model in order to study GW processes. However, still there remain several unknown parameters to be tuned in this parameterizations. One important factor is the initial value of gravity wave energy and its latitudinal and longitudinal distribution. There exist already global estimates of gravity wave energy in the troposphere and lower stratosphere. These data are retrieved from radio occultations made by CHAMP (Challenging Minisatellite Payload) and SAC-C (Satelite de Aplicaciones Cientificas-C) and comprise more than 2 years. This GPS data set is used to deduce the global characteristics of gravity wave activity. At this stage it is not possible to transfer the information of GPS data straightforward to the model since several limitations have to be taken into account as, for instance, the restricted satellite visibility and the missing information about horizontal wavelengths. Therefore, the global allocated GW energy will be analyzed and compared to the GW flux in the model and the input parameters of the parameterization scheme will be adapted towards a more realistic distribution.

September 20 (Wednesday)

Morning Session (08:30 – 10:15)

Charging and discharging the global atmospheric electric circuit: the role of lightning, sprites and jets

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This paper follows on from an overview of electrical processes coupling the atmosphere and ionosphere (Rycroft, 2006a) and from an introduction to the physics of sprites, elves and intense lightning discharges (Rycroft, 2006b). Here, we use PSpice, a commercially available software package, to produce a realistic model of atmospheric electrical phenomena using various current generators, resistances, capacitances and switches, and an appropriate conductivity profile. We simulate both the spatial distribution of electric potential and the electric currents (up to 100 kA) flowing in, and above, thunderclouds and through the global atmospheric electric circuit (~ 1 kA). Our aim is to understand the electrical coupling through the atmosphere better and, in particular, the nature of cloud top-to-ionosphere discharges, which sometimes follow positive cloud-to-ground lightning discharges, and also the impact which they might have on the global circuit

The results obtained with the model to date are as follows.

A moderate negative cloud-to-ground (-CG) lightning discharge from the base of a thunderstorm at 5 km, with a peak current of 25 kA, increases the ionospheric potential above the thundercloud from 300 kV to 870 kV, a 190% increase. Assuming the ionosphere to be an equipotential surface, this discharge increases the current flowing in the global circuit (~ 1 kA), also by 190%.

A strong negative cloud-to-ground (-CG) lightning discharge from the base of a convective thunderstorm, with a peak current of 75 kA, increases the ionospheric potential above the thundercloud from about 300 kV to 1960 kV, a 550% increase, and a similar % increase in the current flowing in the global circuit.

A moderate positive cloud-to-ground (+CG) lightning discharge from the top of a thunderstorm at 15 km, with a peak current of 25 kA, decreases the ionospheric potential above the thundercloud from about 300 kV to -920 kV, a 400% decrease. This discharge decreases the current flowing in the global circuit by the same percentage.

A strong positive cloud-to-ground (+CG) lightning discharge from the top of a thunderstorm, with a peak current of 75 kA, decreases the ionospheric potential above the thundercloud from about 300 kV to -2480 kV, a 930% decrease, and a similar change in the current flowing.

Stronger +CG discharges may trigger sprites, which cause the ionospheric potential above them to decrease. A sprite event of 5kA current, between 55 and 75km, about 0.5ms after the 75kA +CG could decrease the ionospheric potential by about 20% of its value before the discharge.

The time scales for the recovery of the ionospheric potential are about 0.1 ms.

Electric atmosphere-ionosphere vertical coupling above thunderstorms with different intensity

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We investigate theoretically the ‘troposphere - middle atmosphere - ionosphere’ coupling, realized by electric currents generated by a thunderstorm (TS), which flow into the ionosphere. The currents below a thunderstorm and above it, respectively, are an important part of the global atmospheric electric circuit and cause the formation of the ionospheric potential of few hundreds kilovolts related to the ground. The columnar electric resistance in the region above TS becomes a critical parameter in the global atmospheric circuit during a cloud-to-ground lightning discharge, when a shortcut is created below the cloud. This shows the need of investigation of the electric currents and related dynamical processes in the atmospheric regions above a thunderstorm and how they depend on different factors. These factors concern, on one side, the conductivity in these regions, and, on the other side, the thunderstorm dynamics itself. We provide an analytical model of both conduction current and the Maxwell current from the cloud base up to ~ 90 km. The model is based on the Maxwell equations in quasi-electrostatic conditions when the displacement current can be significant. TS with recurrent negative and positive cloud-to-ground discharges and intracloud lightning discharges are considered. In this model the electric currents into the ionosphere during TS are studied together with the temporal behavior of atmospheric spatial electric charges, as dependent on the atmospheric conductivity profile and on the thunderstorm dynamics. These currents are influenced also by the dynamics of the screening layer at the thundercloud edge, formed as a result of the significantly reduced conductivity within the cloud, thus they are studied as dependent also on the cloud boundaries and on the reduction of its conductivity, related to the adjacent air. We study the variations of the electric currents over the cloud system due to changes of the TS intensity (presented by the frequency of the discharges of different types), as a function of the charge separation current in separate thundercloud cells. It is shown that the total current from a thunderstorm to the ionosphere increases nonlinearly with the intensification of the separation current. The benefit of lightning discharges of each type to the total current is analyzed with respect to the height and horizontal size of the destroyed charges. The spatial distribution of currents in the lower ionosphere is shown to depend considerably on the magnetic latitude.

Early/slow events: a new category of VLF perturbations observed in relation with sprites

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High resolution analysis of subionospheric VLF transmissions, observed in relation with sprites, led to the identification of a new category of VLF perturbations caused by the direct effects of tropospheric lightning on the overlying lower ionosphere. They constitute a subset of the so called “early/fast” events where now the term “fast”, which implies rapid onset durations less than ~20 ms, is not applicable. In contrast with early/fast, the perturbations have a gradual growth and thus “slow” onset durations ranging from about 0.5 to 2.5 s, thus these events are labelled herein as “early/slow”. Such long onsets are indicative of a new physical process at work which, following a sprite-causative cloud-to-ground discharge, leads to a gradual build up of conductivity changes in the lower ionosphere which are responsible for the long onset durations of the observed perturbations. Analysis of broadband VLF spheric recordings, made with a two-channel receiver near the sprite producing storms, shows that the growth phase of an early/slow event coincides with the occurrence of complex and dynamic lightning action. This is comprised of a few sequential cloud-to-ground lightning strokes, and clusters (bursts) of sferics which are attributable to intra-cloud lighting. We postulate that the long onset durations are due to secondary ionization build-up in the upper D region below the nighttime VLF reflection heights, caused mainly by the impact on sprite-produced electrons of sequential electromagnetic pulses radiated upwards from horizontal in-cloud discharges.

New generation mechanism of the planetary-scale internal vortical electric field in the ionosphere

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The physical mechanism and corresponding mathematical model for large-scale internal vortex electric field generation in the ionospheric E-and F-layers is suggested. It is shown that in the ionosphere the planetary-scale, synoptic short period (from several seconds to several hours), fast (with propagation velocity higher than 1 km/s) processes excite planetary scale internal vortical electric field, which by its value may be much higher than the dynamo-field generated in the same ionospheric layer by local wind motion. It is established that in the ionosphere a source of the vortical electric field generation is spatial inhomogeneity of the geomagnetic field. On the global network of ionospheric and magnetic observatories such large-scale vortex electric fields usually are observed as eigen electromagnetic oscillations of the ionospheric resonator, also as the ionospheric response on the natural processes (the earthquakes) and on the artificial activities (explosions).

Dynamics of the global weather-forming ULF electromagnetic wave structures in the ionosphere

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In the present article the results of theoretical investigation of the dynamics of generation and propagation of planetary ultra-low frequency (ULF) electromagnetic wave structures in the dissipative ionosphere are given. The physical mechanism of generation of the planetary electromagnetic waves is proposed. It is established, that the global factor, acting permanently in the ionosphere – inhomogeneity of the geomagnetic field and angular velocity of the earth's rotation – generates the fast and slow planetary ULF electromagnetic waves. The waves propagate along the parallels to the east as well as to the west. In E-region the fast waves have phase velocities $(2\div 20) \text{ km}\cdot\text{s}^{-1}$ and frequencies $(10^{-1}\div 10^{-4}) \text{ s}^{-1}$; the slow waves propagate with local winds velocities and have frequencies $(10^{-4}\div 10^{-6}) \text{ s}^{-1}$. In F-region the fast ULF electromagnetic waves propagate with phase velocities tens-hundreds $\text{km}\cdot\text{s}^{-1}$ and their frequencies are in the range of $(10\div 10^3) \text{ s}^{-1}$. The slow mode is produced by the dynamo electric field; it represents a generalization of the ordinary Rossby type waves in the rotating ionosphere and is caused by the Hall effect in the E-layer. The fast disturbances are the new modes, which are associated with oscillations of the ionospheric electrons frozen in the geomagnetic field and are connected with the large –scale internal vortical electric field generation in the ionosphere. The large-scale waves are weakly damped. It is established, that because of relevance of Coriolis and electromagnetic forces, generation of slow planetary electromagnetic waves at the fixed latitude in the ionosphere can give rise to the reverse of local wind structures and to the direction change of general ionospheric circulation. It is considered one more class of the waves, called as the slow magnetohydrodynamic (MHD) waves, on which inhomogeneity of the Coriolis and Ampere forces do not influence. These waves appear as an admixture of the slow Alfvén and whistler type perturbations. The waves generate the geomagnetic field from several tens to several hundreds nT and more. Nonlinear interaction of the considered waves with the local ionospheric zonal shear winds is studied. It is established, that planetary ULF electromagnetic waves, at their interaction with the local shear winds, can self-localize in the form of nonlinear solitary vortices, moving along the latitude circles westward as well as eastward with velocity, different from phase velocity of corresponding linear waves. The vortices are weakly damped and long-lived. They cause the geomagnetic pulsations stronger than the linear waves by one order. The vortex structures transfer the trapped particles of medium and also energy and heat. That is why such nonlinear vortex structures can be the structural elements of strong macroturbulence of the ionosphere.

September 21 (Thursday)

Morning Session (08:30 – 12:00)

Nonmigrating tides: Forcing mechanisms and climatology

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With the launch of the TIMED satellite in December 2001, continuous temperature and wind data sets amenable to MLT tidal analyses became available. The wind measuring instrument, the TIMED Doppler interferometer (TIDI), is operating since early 2002. Its day- and nighttime capability allows to derive nonmigrating tidal wind climatologies over a range of MLT altitudes. Limitations of previous space-borne wind instruments have restricted such climatologies to 95 km altitude before. Hence, the TIDI results represent the first evidence of the vertical structure of nonmigrating tides over a 20-km range in the mesopause region.

Climatologies of monthly mean amplitudes and phases for 14 diurnal and 12 semidiurnal tidal components are derived at altitude between 85 and 105 km and latitudes between 45S and 45N. A comparative analysis of the TIDI climatologies with models of differing character provides insight into nonmigrating tidal forcing: latent heat release in the tropical troposphere and the interaction between

the migrating tide and quasi-stationary planetary waves. The seasonal variability of the tidal wind fields in the MLT is also discussed.

Tides and their consequences: Challenges and achievements of the CAWSES tidal campaigns

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Atmospheric tides are global scale waves which are a direct consequence of solar heating in various regions of the atmosphere. They modulate winds, temperatures, constituents, airglow, and the ionized components of the ionosphere at frequencies that are harmonics of a day. They also cause much of the variability in the local character of the dynamics in the mesosphere and lower thermosphere. In spite of their having been observed for over 50 years, their form and role in the atmosphere remains incomplete.

In large part these uncertainties remain because of the difficulties associated with observing global scale structures. This issue is particularly acute for tides because space based observations precess slowly through local time and single site ground based observations do not provide any information on the large scale structures of tidal signatures. Model results suggest the simultaneous existence of several components and modes for each tidal frequency and the possibility of nonlinear interactions amongst the various components and planetary waves. Unravelling the superposition of and interaction between these waves requires a sampling which is suitably dense in local time and space. A coordinated observation effort, which includes ground based and satellite measurements, is needed along with model results to assist in the interpretation.

The CAWSES global tidal campaign has been organized to coordinate and facilitate work by various groups around the world to help resolve some of these outstanding issues. It is one of the projects sponsored under Theme 3, Atmospheric Coupling Processes, of the international program, Climate and Weather of the Sun Earth System (CAWSES, a SCOSTEP sponsored program). The overall goal of this project is to provide global data sets for several concentrated time periods over the next few years. These will allow the characterization of the heating sources, tidal components, and tidal effects from the surface of the Earth to the ionosphere, and support and stimulate the use of models to simulate the conditions during these campaigns.

The first tidal campaign took place from September 1 to October 31, 2005 to coincide with the "World Month" campaign undertaken by the Incoherent Scatter Radar community. Radar, optical instrumentation, ionospheric observations and satellite data were collected during this time period and are now starting to be analysed. In this paper we describe the organization of this effort, plans for the incorporation of various observation types, results from the first campaign and future plans.

Observations of the semidiurnal tide in the high latitude mesosphere

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The semidiurnal tide reaches large amplitudes and exhibits considerable variability in the high latitude mesosphere. A number of ground-based studies have demonstrated that non-migrating components are important contributors to the total semidiurnal tidal field and its variability.

Eastward and westward propagating modes of zonal wavenumber up to three have been reported in previous studies and there are inevitable ambiguities in resolving the different modes with a limited number of ground-based sites. The semidiurnal tide is also difficult to study from slowly precessing satellite platforms. In this study we combine data from the SABER instrument aboard the TIMED satellite and the MLS instrument aboard the EOS/Aura satellite to obtain enhanced sampling of semidiurnal temperatures. The enhanced sampling can reduce aliasing from other waves and allow us to resolve the wavenumber components of the semidiurnal tide on shorter timescales. Much of the high-latitude ground-based data is in the form of winds, and we discuss strategies for relating the tidal wind and temperature fields.

Nonmigrating tidal effects in the Earth's upper atmosphere

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We investigate the effects of nonmigrating tides on the thermosphere-ionosphere system using the thermosphere-ionosphere-electrodynamics general circulation model (TIE-GCM) and the global-scale wave model (GSWM) developed at the National Center for Atmospheric Research (NCAR). Hagan and Forbes (2002, 2003) previously provided evidence that nonmigrating tides excited by latent heat release associated with deep convection in the tropical troposphere could propagate into the mesosphere and lower thermosphere (MLT) and produce measurable longitudinal tidal variability. In a series of numerical experiments we extend this work in an attempt to determine whether these tidal variations can modulate E-region dynamo processes and affect the ionosphere aloft. We report on our efforts to account for the tropospheric source of nonmigrating tides in the TIE-GCM by introducing GSWM tidal perturbations at the new lower boundary near 80 km. The effects that we explore include longitudinal variability of vertical drifts and the behavior of the F-region peak density.

Hagan, M. E. and J. M. Forbes, Migrating and nonmigrating semidiurnal tides in the upper atmosphere excited by tropospheric latent heat release, *J. Geophys. Res.*, 108(A2), 1062, doi:10.1029/2002JA009466, 2003

Hagan, M. E. and J. M. Forbes, Migrating and nonmigrating diurnal tides in the middle and upper atmosphere excited by tropospheric latent heat release, *J. Geophys. Res.*, 107(D24), 4754, doi:10.1029/2001JD001236, 2002

Variability of the mesospheric semidiurnal tide associated with planetary waves in the stratosphere

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Observations and a numerical model are used to investigate the coupling between planetary waves in the stratosphere and the semidiurnal tide in the upper mesosphere. Observations are daily semidiurnal tidal structure in horizontal wind measured by the meteor radar at Esrange (68°N) and near-global observations of temperature and geopotential from SABER throughout the entire middle atmosphere. During NH summer and fall, the temporal variability of the semidiurnal tide at Esrange is found to be well correlated with the amplitude of planetary wavenumber 1 in the middle stratosphere in high southern latitudes (i.e., in the opposite hemisphere). The correlation indicates that the tidal variations at Esrange are due to dynamical interactions in the Southern Hemisphere. The 3-dimensional ROSE model also simulates this correlation. Analysis of model results indicates that the correlation is the result of planetary wave variations and the tidal variability is primarily from two components: the westward traveling wavenumber 1 and the migrating (westward traveling wavenumber 2) components of the semidiurnal tide.

Interactions between planetary waves and tides in the middle atmosphere

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Atmospheric radars operated in Antarctica by Australia (Davis), Japan (Syowa), the United Kingdom and the United States of America (Rothera) form a ring of observing sites at a latitude of 69 degrees South that can track planetary scale waves in the mesosphere and lower thermosphere (MLT, 70-100km) as they propagate around the planet. Interactions between atmospheric tides and longer period waves yield variations in the MLT wind that have high spatial and temporal variability. This variability needs to be investigated if we are to understand the dynamics and chemistry of this region and represent it in atmospheric models.

Recent observations have shown that the polar semidiurnal tide contains an ensemble of zonal wavenumber components. Using the common latitude characteristic of the Antarctic radars, it is possible to separate the total tidal amplitude into local-time locked (migrating) and non local-time locked (non-migrating) components by differencing the tidal amplitude vectors. The variation of the tidal amplitudes in these categories can then be used to identify interactions with other planetary waves, and to investigate the mechanisms that produced the variation.

Data obtained between 2002 and the present show that the non-migrating content of atmospheric tides varies on a seasonal time scale as well as one consistent with modulation of the tides by long period planetary waves. The characteristics of the tidal time of maximum also vary in a systematic way. The relationship between the parameters obtained using the above techniques and the tidal and planetary waves themselves is considered and the results are interpreted.

Inter-hemispheric comparisons of the 8-hour (terdiurnal) tide in the mesosphere and lower thermosphere

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Horizontal winds in the mesosphere and lower thermosphere have been measured by two identical meteor radars based at conjugate latitudes (68°N, 68°S). Continuous measurements have been made since October 1999 in ESRANGE, Arctic Sweden (68°N, 21°E) and since February 2005 in Rothera, Antarctica (68°S, 68°W). At both these latitudes the largest tides are the 12- and 24-hour, however the smaller 8-hour (terdiurnal) tide appears as a persistent feature. These datasets have been used to investigate the 8-hour tide and to examine inter-hemispheric differences in the behaviour of the tide.

The 8-hour is shown to be circularly polarised upwardly propagating at both locations and can reach instantaneous amplitudes of $\sim 25 \text{ ms}^{-1}$. However monthly-mean amplitudes are smaller and range from ~ 1 to 10 ms^{-1} at both locations. There is a clear seasonal cycle that is very similar in both hemispheres, largest amplitudes are observed in autumn and early winter for both locations.

Lunar tides in the Arctic, Antarctic and equatorial mesosphere and lower thermosphere

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The lunar semidiurnal tide in the MLT region has been measured over five locations using a common data analysis method applied to data from four meteor wind radars and an MF radar. The stations range from the Arctic to the Antarctic. These stations are ESRANGE in the Arctic (68°N, 21°E), Castle Eaton in the UK (55°N, 2°W), Ascension Island near the equator (8°S, 14°W) and two Antarctic stations at Rothera (68°S, 68°W) and Davis (68°S, 78°E). Monthly – mean observations of the lunar tide from these locations show amplitudes have a very different seasonal behaviour between the northern and southern hemispheres, with maximum monthly-mean amplitude of 11 ms^{-1} at Arctic latitudes. In the northern hemisphere the seasonal behaviour is very similar to that of the solar S_2 tide, but not for the southern.

The phase behaviour shows upwardly propagating, circularly polarized tides in both the northern and southern hemispheres. An elliptically polarized predominantly meridional tide is found at the equator. Differences in the comparison with other low latitude sites strongly suggest that there could exist “non-migrating” lunar tidal components. Both the amplitudes and phases are also compared with the Vial and Forbes (1994) lunar M_2 tidal model, which show very good agreement throughout.

Afternoon Session (14:00 – 18:00)

Mid-latitude E-region plasma instabilities: Large and small scale structures

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Two recent papers (JASTP, November, 2004) have shown that nighttime VHF echoes from mid-latitude E-region unstable plasma waves can be explained by a non-local theory that does not rely on any major, highly specific deformation of a conventional, thin metallic ion sporadic-E layer. The meter-scale waves will be generated only on the unstable (top or bottom) side of the layer and will not couple well to the unstable side, for a layer thickness of at least a kilometer or so. All that is required is a fairly strong driving term, namely a substantial electron drift through the ions (i.e., a current). Such a current can be driven by an ambient wind and/or electric field, but only if the current can somehow, somewhere close. For example, a uniform wind blowing through an isolated patch of ionization will

almost instantly set up polarization electric fields such that no current whatsoever will flow. We know that metallic ion layers (and regions generating VHF echoes) are usually “patchy,” sometimes exhibiting quasi-periodic (QP) structure, and also that the E and F regions of the ionosphere are strongly electrically coupled along magnetic field lines for scale sizes of several kilometers (not meters) or more. Furthermore, the mid-latitude F region itself sometimes exhibits very irregular structure. To what extent (if any) are all these phenomena related? Does the E region generate F region structure, or vice versa, or neither, given that the winds in the two regions are likely to be quite different? This talk will review and comment on this active and controversial area of research.

Midlatitude sporadic E layers. A review of recent progress and remaining questions

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The midlatitude sporadic E (E_s) layers are dense layers of metallic ions which form in the lower thermosphere between about 90 and 130 km, that is, in a region characterized by complicated atmospheric dynamics and nonlinear plasma processes. There is now mounting evidence suggesting that E_s is the effect of a deterministic rather than a sporadic process, which involves regular wind shear plasma convergence and downward transport in the context of the global system of thermospheric tides. In addition, recent results suggested that planetary waves (PW) must be involved on E_s generation as well, a fact that had gone unnoticed in the long-going research of sporadic E. Also, gravity waves with periods from a few hours down to the Brunt-Vaisala period of 5 minutes must also play a role on E_s formation. The gravity waves can alter the regular tidal forcing of E_s since their confluence with the tidal waves can reinforce or disrupt the convergence of metallic plasma into a layer and thus can impose a sporadic character in E_s occurrence. Also, in recent years a lot of work is done on midlatitude coherent radar backscatter which occur in connection with destabilized midlatitude sporadic E layer plasmas. These studies led to several new results, e.g., the observation of characteristic strong periodicities in backscatter, and subsequently on sporadic E, with periods from a few minutes to about 30 minutes, which implied a wave-like modulation mechanism of the midlatitude E_s plasma, and the detection of pure Farley - Buneman waves (Type 1 echoes) which implied the existence at times of large electric fields at least an order of magnitude higher than the ambient electric fields at midlatitude. These recent studies enhanced our knowledge on sporadic E but also revealed the presence of more physical mechanisms, operating at different scales that need to be identified and understood. The present survey does not purport to give a complete account of the large volume of work done on this topic, but aims rather at presenting a synthesis of recent findings which leads to an integrated picture of our present physical understanding. In addition we update what we consider to be as the remaining problems that require further study.

Diurnal and seasonal features of sporadic E-layer height in connection with complex structure of atmospheric tides.

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A comprehensive analysis of neutral wind dynamics in MLT-region and variations of vertical sounding Es-layer parameters was conducted. Wind measurement data was obtained from meteor radars in Kazan (56°N, 49°E) (with altitude measurer) and Obninsk (55°N, 37°E) (without altitude measurer); ionospheric measurement data was obtained from Kazan and Gorky (56°N, 44°E) ionosondes in 1987. Daily variations of the Es-layer appearance probability and the average virtual height were considered in connection with tidal wind and its complex structure. On the base of wind-shear theory the influence of semidiurnal tide on Es-layer was analysed. We discovered that one should consider the mode structure of the semidiurnal tide to explain variations of Es-layer height. Heretofore the problem of

mode contribution in semidiurnal tidal movements of lower thermosphere at the 80–110 km heights was solved. On the average, it was revealed that the main mode (2,2) plays a significant role at the MLT-heights as well as the higher order modes (2,4) and (2,6). As it was shown, since the mode (2,2) has the highest wavelength it affects the Es-layer height variations, while the modes (2,4) and (2,6) make the large wind gradients due to the shorter wavelength, thus they affect the daily variations of Es-layer intensity.

We investigated the following parameters: 1) diurnal and seasonal variations of the probability of Es-layer appearance $P(X)$ with the highest frequency f_oEs larger than X , where $X=1.5$ and 2 MHz for April–August and $X=0.5$ and 1 MHz for other months, 2) diurnal and seasonal variations of the average virtual height of Es-layer. The diurnal and seasonal features of Es-layer parameters were analysed together with the time instants corresponded to the phase of the converging node of semidiurnal tide for modes (2,2), (2,4) and (2,6) of zonal component for the 110 km altitude.

Coincidence of the $P(X)$ maxima and the appearance of converging node of semidiurnal tide for mode (2,6) was observed; moreover, $P(X)$ values were lower in the morning rather than in the evening. Coincidence of the morning maxima of the average Es-layer virtual height and the phase of converging node of mode (2,2) zonal component was also discovered, while in the evening such coincidence was observed only for April–September. An absence of the evening maxima in January–March and October–December is explained by fact that the passing of the converging node of mode (2,6) zonal component outstrips the corresponding node of mode (2,2) at 1–3 hours in these months. The significant increase of $P(X)$ occurs when at first, more rapid mode (2,2) “trawled” metallic ions from 130–110 km heights, and then slower mode (2,6) (with higher zonal wind gradient) rounded ions up into the narrow Es-layers.

Influence of quasi-biennial oscillation of atmospheric circulations on sporadic *E* layer 2–32-day variations

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The “windshear theory” explains many features of *Es* layer dynamics connected with meteorological effects and global atmospheric phenomena, e. g. planetary and gravity waves. Observed *Es* layer parameter variations with periods from 2 to 30 days apparently connected with planetary wave influence. This effect may be modulated by another global processes such as the quasi-biennial oscillation of atmospheric circulation (QBOAC). Eastern or western phase of QBOAC is determined by the direction of prevailing zonal wind in the equatorial stratosphere. As the latest works showed, equatorial QBOAC influence on sporadic *E* layer may be observed in the middle latitudes as well as in the polar latitudes.

In this work an investigation of QBOAC influence on *Es* layer dynamics in the Northern hemisphere was carried out. Using the NGDC data of *Es* layer highest frequency (f_oEs) measurements during 1965–1989, daily averaged f_oEs values and wavelet amplitudes of f_oEs 2–32-day oscillations were interpolated on the one-degree geographical grid in the latitudes 15–75°N. An adapted three-dimensional variant of the multi-quadric method (Hardy, R.L., 1971) was used for interpolation of experimental data of about 122 ionospheric stations situated over the whole Northern hemisphere. Wavelet amplitudes were computed as the absolute values of continuous wavelet transform based on Morlet wavelet according to the developed technique. The selected scales 4, 16 and 24 days span the whole 2–32 days range of periods.

The main index of QBOAC is the monthly values $\langle u \rangle$ of the average wind velocity in the 19–31 km layer over equator. An analysis of correlation between the year-averaged $\langle u \rangle$ values and the year-averaged values of interpolated f_oEs and f_oEs 4–24-day oscillation amplitudes was carried out. The obtained correlation coefficients for f_oEs and f_oEs quasi 16-day oscillation are shown in the table 1. The significant correlation between $\langle u \rangle$ and f_oEs was determined in the longitude sector 60–270° (to the East of Greenwich) in the latitudes 15–45°N and 75°N. The significant correlation between $\langle u \rangle$ and f_oEs quasi 16-day oscillation was determined in the longitude sector 90–270° in the latitudes 15–45°N. Significant correlation areas for 4 and 24 day periods (not shown here) are very similar to the presented

areas in the table 1. It is noticeable that the sign of the correlation coefficients is constant and negative. It shows that E_s layer intensity and f_oE_s 4–24-day oscillation amplitudes are usually higher when the equatorial stratospheric wind has the westward direction, i. e. during the eastern phase of QBOAC and lower during the western phase (when the wind has the eastward direction).

Table 1. Coefficients of correlation between the year-averaged values of equatorial stratospheric wind velocity $\langle u \rangle$ and the interpolated values of f_oE_s and wavelet amplitude of f_oE_s quasi 16-day oscillation (1965–1989). The bold font emphasizes significant correlation areas.

	Longitude (to the East of Greenwich)											
Latitude	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
	f_oE_s											
15°	-0.09	-0.20	-0.27	-0.38	-0.45	-0.54	-0.51	-0.41	-0.41	-0.33	-0.27	-0.17
30°	-0.15	-0.20	-0.34	-0.42	-0.51	-0.46	-0.49	-0.47	-0.47	-0.39	-0.32	-0.26
45°	-0.05	-0.13	-0.34	-0.37	-0.45	-0.16	-0.23	-0.26	-0.24	-0.11	-0.23	-0.28
60°	-0.13	0.08	-0.17	-0.21	-0.28	-0.11	-0.35	-0.17	0.04	0.21	-0.09	-0.20
75°	-0.26	-0.27	-0.24	-0.20	-0.34	-0.39	-0.41	-0.39	-0.24	-0.16	-0.17	-0.23
	f_oE_s quasi 16-day oscillation											
15°	-0.04	-0.15	-0.27	-0.49	-0.55	-0.56	-0.41	-0.27	-0.34	-0.29	-0.16	-0.12
30°	-0.10	0.01	-0.09	-0.44	-0.49	-0.42	-0.37	-0.24	-0.29	-0.34	-0.13	-0.14
45°	-0.09	0.06	-0.08	-0.26	-0.20	-0.05	-0.36	-0.20	-0.29	-0.19	-0.10	-0.12
60°	0.03	0.12	-0.05	0.10	-0.10	-0.22	-0.28	0.09	-0.13	-0.19	-0.02	-0.01
75°	-0.03	-0.12	-0.16	-0.10	-0.18	-0.18	-0.08	-0.04	0.01	0.02	-0.00	-0.00

Discovered connection between QBOAC and E_s layer dynamics may be conditioned by the following processes: 1) probable QBOAC influence on E_s layer ionization intensity under the solar radiation action; 2) E_s layer 2–32-day oscillations may be under the influence of planetary wave dynamics, the latter may be controlled by QBOAC.

Obtained results give us new evidence for a relationship between dynamics of neutral atmosphere and ionosphere. Once again, we remark that stratospheric and mesospheric processes may play a considerable role of formation of E_s layer with 2–32-day variations at the MLT-altitudes.

A classification of ionospheric waves as observed by a HF super-resolution direction finding system

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It is a common concept to describe ionospheric irregularities as waves propagating through the ionosphere. These waves correspond to variations of the density of free electrons in the ionosphere. As a consequence HF waves are deflected from great circle path propagation. From analysis of the temporal profiles of the variations of their incidence angles onto an antenna array and from analysis of their power spectra, a systematics will be presented that comprises (1) *travelling wave packets* (TWP), (2) *wave trains* (WTs), (3) *interference of individual waves* (IIW), (4) *terminator driven large-scale TIDs* (TLSTIDS), (5) a *chaotic*, white noise like state and (6) *quiet* ionosphere. TWP are a monochromatic or quasi-monochromatic TID with several periods, WTs equally exhibit several non-interfering periods of different frequencies and an IIW event is composed of several interfering waves which are nonetheless well pronounced in the spectrum and well visible in the temporal profile of the

bearings. The chaotic and the quiet states are characterised by a nearly continuous power spectrum because there are contained nearly all periods. But the energy of the spectrum is lower in the case of the quiet state and the deviations of the bearings are only of the order of half a degree. The shortest time-scale that has been investigated is from 10 minutes to three hours. The occurrence of events of the classes is compared to the local geomagnetic index K , time of day and layer of reflection.

New aspects in modelling and theory of gravity waves and their effects on the thermosphere

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We will describe two aspects of our recent gravity wave (GW) modelling that have impacts on their roles at high altitudes. The first is the influences of instability processes and nonlinear dynamics on the evolution of GW amplitudes and spectra and their implications for turbulence and mixing. The second is the influences of viscosity and thermal diffusivity on GW structure and propagation to very high altitudes. High-resolution DNS modelling has revealed complex pathways for energy exchanges accompanying GW instability and wave "breaking". These include both a transition through instability to turbulence at smaller scales of motion and wave-wave interactions that play a pronounced role in energy exchanges. These interactions are found to be significant components of the evolution even when instability and turbulence dynamics appears to be the dominant process. A new formulation of the GW dispersion relation was found to have significant impacts on GW structure and propagation at the highest altitudes to which they propagate. These also impact the evolution of the GW spectrum in the thermosphere and the implications for mean flow interactions at these altitudes.

Acoustic-gravity channel of troposphere-ionosphere coupling

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The data of satellite and ground-based observations of atmospheric gravity waves (AGW) responsible for the transfer of troposphere perturbations to the ionosphere altitudes is analyzed. We prove that atmosphere plays a role of nonlinear filter that transmits to above the middle-scale perturbations with horizontal wavelengths of several hundred km, phase velocities of hundreds m/s, vertical group velocities of tens m/s. The method for experimental study of seismic and meteorological effects in the ionosphere is suggested.

We know only a few publications where the statistical analysis of interrelations between the tropospheric and ionospheric disturbances is given. The major number of other publications is devoted to the investigation of a single events. Let's list the questions, the answers to which need statistical approach: 1) what are the typical parameters of troposphere-ionosphere disturbances and limits of their changes, and 2) how studied phenomena are widespread. Evidently, the real efficiency of troposphere-ionosphere coupling is necessary to estimate taking into account the statistically valid number of events.

Our first steps for the realization of this experimental program were concentrated on the analysis of measurements at "Atmosphere Explorer - E" satellite and contemporary experiments at Ukrainian Antarctic station. We found that AGW and traveling ionospheric disturbances (TID) caused by seismic and meteorological processes have the following parameters:

Horizontal wavelength is $\lambda_x \sim 400...700$ km, period $T \sim 1$ hour;

Relative AGW amplitude near the Earth surface is about 0.01% , at ionospheric heights about 1...10% ;

Relative TID amplitude reaches 20%, in variation of magnetic field component $\delta B \sim 1...20$ nT;

At F-region altitudes the length of AGW/TID wave train is approximately 3000 km (five-six wave periods).

These experimental results evidence that ionospheric response to seismic and meteorological processes occurs in a definite range of parameters that are characteristic for the middle-scale AGW/TID. According to the law of wave refraction in plane-layered medium (in our case – in atmosphere), during the upwards AGW propagation some parameters remain constant: AGW horizontal phase velocity ω/k_x and wavelength λ_x . So, tropospheric sources have to generate AGW with spectral characteristics of observed TID: length λ_x about several hundreds km and phase velocity ω/k_x about several hundreds m/sec. So, we found that:

Atmosphere plays the role of filter that transmits upwards only sufficiently long and quick AGW.

Seismic and meteorological AGW sources excite middle-scale TIDs in ionosphere.

Some theoretical ideas explaining experimental results will be reported.

A review on the Coupling Processes in the Equatorial Atmosphere (CPEA)

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The Coupling Processes in the Equatorial Atmosphere is a six-year project to study dynamical and electrodynamical coupling processes in the equatorial atmosphere by conducting various observations in the Indonesian equatorial region. The region known as the Indonesian Archipelago is the center of intense atmospheric motion and global atmospheric change. CPEA vertically covers a wide height range from near to the Earth's surface to the thermosphere and ionosphere. The mechanisms of these atmospheric changes and fluctuations, however, have not yet been made clear due to the sparseness of observational data in that region. In the present paper we describe the outline of this project and show highlights from its first campaign conducted from March to May 2004. It includes observations of interesting features of cumulus convections over the Indonesian Archipelago, generation of equatorial atmospheric waves, impact of cumulus convections on dynamics in the mesosphere and lower thermosphere, and possible generation of equatorial ionospheric irregularities by atmospheric gravity waves.

Gravity wave effects in the equatorial F-region

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Main question to be addressed: Do gravity waves play a critical role in seeding or modulating the growth of spread-F bubbles in the equatorial ionosphere?

It is well established --- by direct observations as well as theory and modeling --- that gravity waves are among the principal drivers of mid-latitude E- and F-region electrodynamics and variability --- e.g., sporadic E layer formation and destabilization, TIDs, mid-latitude spread-F. However, the extent of gravity-wave impact on equatorial ionosphere, and, in particular, on the generation of equatorial

instabilities, remains relatively unclear. In this talk we will review (i) direct observations of gravity wave effects in the equatorial E- and F-region ionosphere and (ii) correlative studies suggesting a possible impact of gravity wave activity on equatorial spread-F occurrence. We will also describe our emerging understanding of velocity-shear driven pre-conditioning of the equatorial ionosphere prior to spread-F bubble formation and present supporting evidence for the suggested mechanism obtained with Jicamarca and ALTAIR radars. Finally we will examine whether vertical shear-driven excitation of spread-F bubbles can be reconciled with the idea of gravity-wave control of spread-F seeding which has been suggested to account for correlations (seasonal and longitudinal) noted between gravity-wave activity (or tropospheric convection) and equatorial spread-F.

Multi-instrumental observation of influences of lower atmospheric high frequency gravity waves on ionospheric current systems

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Small time scale (say few tens of minutes to few hours) oscillations observed in the Earth's geomagnetic field, associated with ionospheric current systems (say equatorial electrojet flowing at about 105 km and Solar Quiet {Sq} current systems flowing at about 130 km above the surface of the Earth), during geomagnetically quiet times are often speculated to be due to the atmospheric gravity waves generated in the lower atmosphere (say troposphere). Not only the fluctuations in the ionospheric current systems but also other ionospheric processes like counter equatorial electrojets, triggering of Spread-F events, traveling ionospheric disturbances, 150 km echoes, puzzling quasi-periodic echoes etc. are thought of associated with these lower atmospheric gravity waves. They can be generated by many mechanisms such as latent heating of the atmosphere associated with deep convection, wind flows over topography, strong shearing winds etc. To characterize the atmospheric gravity waves that are propagating vertically up into the upper atmosphere above about 100 km, it is essential to observe the dynamics associated with these waves all through the heights from ground to above the mesosphere region. In this regard, we have made such attempts by using the Indian MST radar (~ 53 MHz, all the three wind components measurements covering heights from 3.5 to 20 km), Nd-Yag lidar (~ 532 nm, temperature measurements covering heights from 25 to 80 km), both collocated at the Indian tropical station of Gadanki (13.5°N, 79°E geographic), and MF radar (~ 2 MHz, horizontal wind measurements covering heights from 80 to 100 km) and Geomagnetic field measurements collocated at the Indian dip equatorial station of Tirunelveli (8.7°N, 77.8°E geographic) to diagnose the characteristics of atmospheric gravity waves and their influences on ionospheric current systems. On some geomagnetically quiet days, we found that high frequency (few tens of minutes) gravity waves are seen almost all through the heights from about 8 or 10 km to 90 km and also in the geomagnetic field measurements, indicating that high frequency atmospheric gravity waves can pass through the middle atmosphere from lower atmosphere to upper atmosphere and then they can take part in the wind dynamo mechanisms. More and extensive studies are being carried out using also lower atmospheric wind profiler (1357 MHz) and Boundary Layer Lidar both at Gadanki and Doppler Weather Radars at the Gadanki nearby locations (located within about 150 km) of Chennai and Sri Harikota to determine whether these vertically propagating gravity waves are associated with deep convective events. The next two pages illustrates on the presence of gravity waves (~ 40, 60 and 110 minutes periodicity) from ~10 km to 90 km and in the H and Z components of geomagnetic field associated with EEJ at ~105 km.

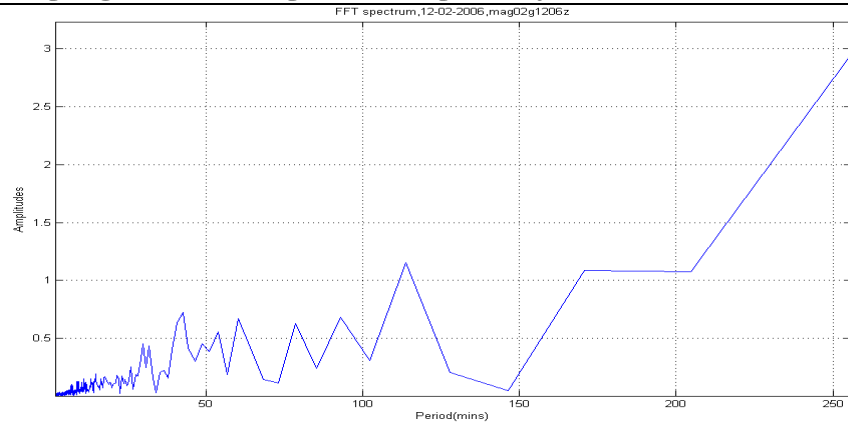


Fig. 1. Amplitude spectrum (nT) of Z component of Geomagnetic field (y axis) associated with Equatorial Electrojet on 12 FEB 2006 versus periodicity (minutes, x axis)

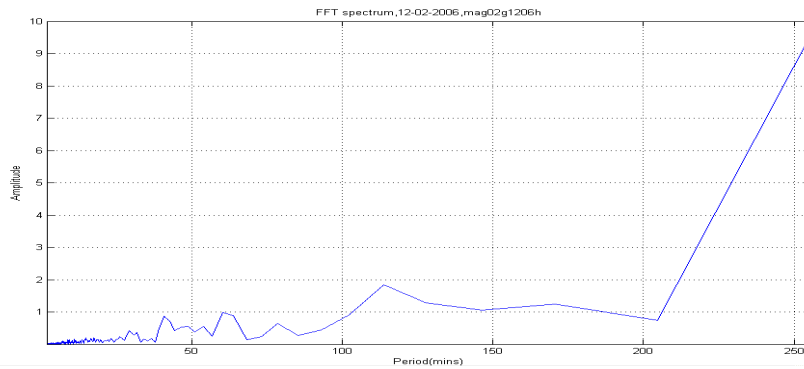


Fig. 2. Same as Fig1. but for H component of Geomagnetic field

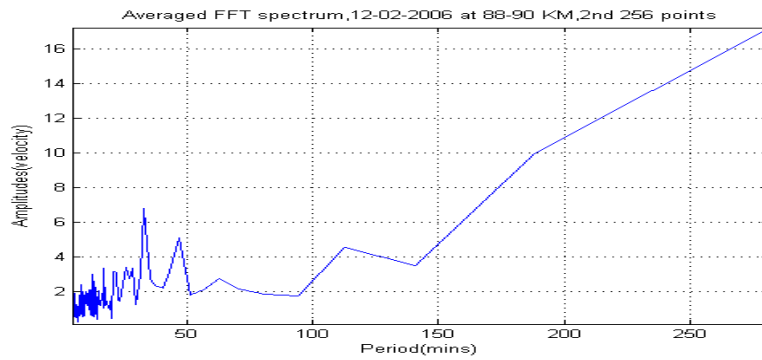


Fig. 3. Same as Fig2. but for zonal wind at 88-90 km

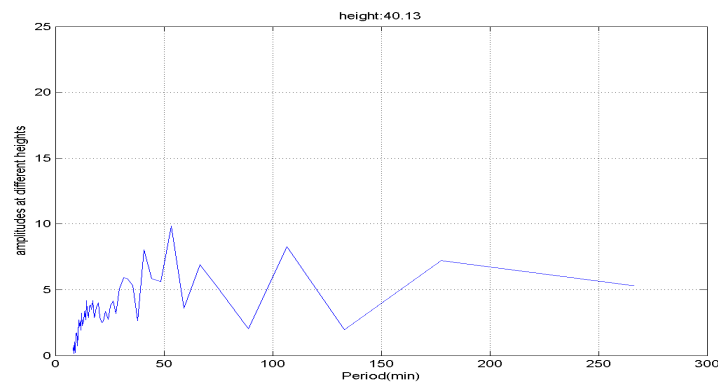


Fig. 4. Same as Fig3. but for temperature at 40 km

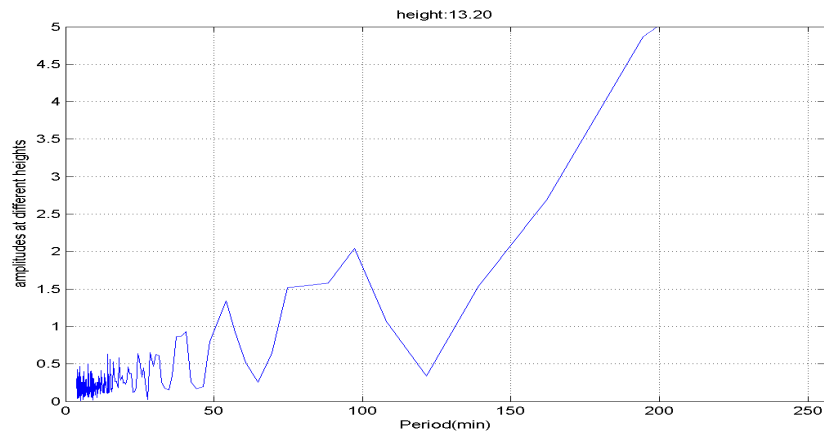


Fig. 5. Same as Fig4. but for zonal wind at 13.2 km

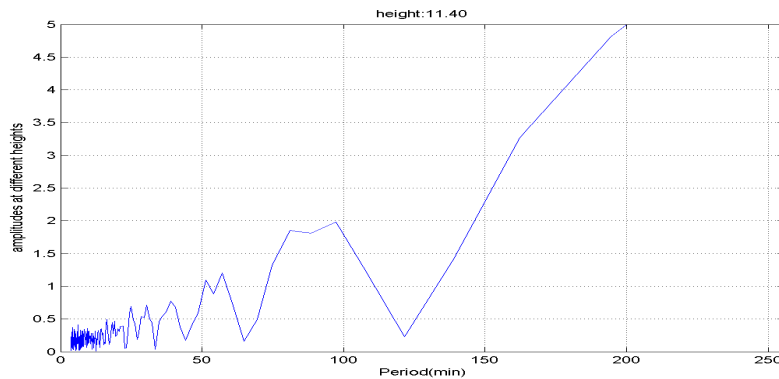


Fig. 6. Same as Fig5. but for zonal wind at 11.4 km

September 22 (Friday)

Morning Session (08:30 – 12:00)

Detecting vertical interaction through middle and upper atmosphere variations

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The atmosphere is a single entity with links between all levels from the Earth's surface to the thermosphere, and beyond to the solar wind and Sun. These physical links can transfer change from the surface to the upper atmosphere or vice versa and understanding these linkages is critical to the attribution and apportionment of climate change drivers. This presentation will discuss recent analysis at BAS aimed at understanding the relationships between atmospheric change and these vertical links, and briefly mention plans for instrument deployment in the near future.

Time/altitude electron density variability at mid-latitudes over Europe: Further indication of dynamic coupling

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The daily and vertical pattern of the ionospheric electron density at mid-latitude over Europe has been obtained on a monthly basis in order to investigate the typical time/altitude variability of the ionosphere. This variability reflects the contribution from different sources at periods lower than 30 days. The largest variability occurs at the base of the F region during night-time, and it shows different long-term (solar cycle) and seasonal pattern depending on time. Particularly, the largest variability at the base of the F region occurs from sunset to midnight, when upward F region drifts dominate, it displays a clear summer half-year maximum pattern and it does not show solar cycle dependence. The lack of photochemical control during night-time indicates more important role of dynamics as variability contributor. The coupling from below by the wave activity in the mesosphere/lower thermosphere is discussed as potential driver of the observed time/altitude pattern of the ionospheric variability.

Preliminary results of spherical analysis of planetary waves seen in ionospheric total electron content (TEC)

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The coupling of stratosphere and ionosphere through planetary waves (zonal wavenumber 0-5 and periods of several days) is investigated by spherical harmonic analyses of the ionospheric total electron content (TEC). These analyses detect mean variations, standing and in east and west direction travelling waves which are assumed to be planetary waves. Data basis for TEC are hourly regional TEC maps of three years covering the higher middle and polar latitudes. They are regularly produced by DLR Neustrelitz. The obtained results are compared with planetary wave analyses using stratospheric reanalyses data. Case studies show that planetary waves are simultaneously found in the middle atmosphere and ionosphere.

The upper ionosphere variability over Alma-Ata and Observatorio del Ebro using the foF2 data obtained during the winter/spring period of 2003-2004

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The foF2 data obtained at Alma-Ata and Observatorio del Ebro during the winter/spring 2003-2004 are analyzed to investigate and do a comparison the upper ionosphere variability at the two selected sites. The geomagnetic activity and the middle stratosphere dynamics, involving the planetary wave activity, are analyzed to draw more conclusions on this investigation and make an attempt for understanding physical conditions and processes that can act upon the ionosphere. By applying the same method of wavelet analysis in the data sets and doing a direct comparison of the results two types of the foF2 disturbances were found: (1) 2-7-day oscillations in the ΔfoF2 observed over both stations are found to

be generated by geomagnetic activity; (2) the 9-13-day and 8-10-day oscillations occurred on mostly quiet level of geomagnetic activity indicate a likely close relation with those in the geopotential height at 1 hPa level for westward-propagating waves at 40°N strengthened during stratosphere warming events. Most probably that the times delay of the oscillations in the Δf_oF_2 to that in the geopotential height is about 10 days. It seems that the assumed ionosphere response can occurred under weakened westerly zonal wind or not strong easterlies ($V \leq 30 \text{ ms}^{-1}$).

Planetary wave effects on equatorial ionospheric electrodynamics: Variabilities in spread F/plasma bubbles and prereversal electric fields.

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Electrodynamics of the evening equatorial ionosphere is responsible for the post sunset weather and climatology of this region. The changing degree of the electrical coupling of the E and F layers under the decaying E layer density is a basic condition for the development of the prereversal zonal electric field enhancement that controls the post sunset spread F plasma irregularities and ionization anomaly developments. The thermospheric zonal and meridional winds and the longitudinal/local time gradient in the integrated E- and F- layer conductivities are important factors that produce significant modulations in their intensities. While the atmospheric tides propagating up from lower atmosphere and the local solar thermal tides are the drivers of the basic electric fields, the upward propagating planetary waves are believed to be responsible for significant modulation of these waves. Recent results from a variety of observational techniques have provided evidences of significant PW modulation in the intensities of the post sunset phenomenology of the equatorial region; an aspect that introduces a new dimension to the study of the day-to-day variability of the equatorial spread F/plasma bubble irregularity development conditions. This paper will present an overview of our existing knowledge on the causes and sources of the widely observed variabilities in the equatorial evening electric fields, spread F/plasma bubble irregularities, and ionization anomaly features based on the available results. Some new results of observations from widely separated longitude sectors will also be presented.

Investigations of the interactions between the equatorial lower ionosphere and tropical cyclones using remote sensing and rocket soundings

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This paper presents the special processing results of rocket-borne measurements of the electron density in the equatorial ionospheric D layer over the troposphere catastrophes (tropical cyclones) area at the rocket testing ground Tumba (India). Remote sensing observations for tropical cyclones were performed over the North Indian Ocean, the West North Pacific and the South Indian Ocean. It was detected that possible large-scale response of ionospheric state can be the “fast” depletion (2-4 times) in electron density at heights of 50 – 80 km during the action of the active phase of a tropical cyclone. It is the first observed finding of the “high-rate” action on ionosphere layer by troposphere intensive vortical systems.

We suppose that the wide-spread influence of tropical cyclone is carried in the wide latitude zone.

We propose, that the lower ionosphere in the Tumba region (8° N, 77° E) has more than only “local” influence of tropical cyclones in the North Indian Ocean – the lower ionosphere of this region has global influence from the West North Pacific to the South Indian Ocean.

Some variants of physical mechanisms of “fast” interaction between troposphere perturbation and ionosphere state were proposed. First of all, we note the chains of connections through fast spatial variations of an ozonosphere and photo-chemical connections through radical groups of OH.

Detection and modelling of the ionospheric gravity/tsunami waves and perspective for future tsunami remote sensing systems

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³ Commissariat à l'Energie Atomique, France

Propagating ionospheric gravity waves associated to tsunami have been observed for the Sumatra, December 26th, 2004 and the Peru, June 23, 2001 events. These waves, detected by the dual frequency altimeters onboard in the Jason-1 and Topex/Poseidon satellites for Sumatra and by GPS receivers in both cases, confirm that the ionosphere is affected by tsunamis and that the ionospheric signals can be used for tsunami monitoring.

We present here the first comparison between synthetics ionospheric signals and the associated observations. We model first the tsunami using a finite difference scheme that resolves the hydrodynamical equations on a 2' bathymetric grid. A realistic seismic source is used, constrained by the Topex and Jason altimetry data. We then use a 3D pseudo-spectral modeling of gravity waves in a non-isothermal atmosphere for computing the generated gravity wave. The response of the ionospheric plasma to the consequent neutral motion is then computed. The model solves the hydromagnetic equations for three ions: O²⁺, NO⁺ and O⁺ and electrons to obtain the perturbed density and polarization electric field respectively. We reproduce with a good agreement the Total Electron Content (TEC) perturbations observed by Topex/Poseidon and Jason-1 in the case of the Sumatra tsunami.

We then discuss the effect of the magnetic latitude, local time, activity of the ionosphere and amplitude of the tsunami in the signal to noise ratio, as well as the detection delay, associated to the propagation of the internal gravity wave from the sea level to the ionosphere. We finally conclude with the perspective of this technique for possible tsunami warning and present different concepts for performing real time and continuous monitoring of the ionosphere, either from space or from the ground.

Wavelet analysis of imaging riometer data: Detecting gravity waves

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The Imaging Riometer for Ionospheric Studies (IRIS), based at Halley (76°S 27°W), responds to changes in the absorption of cosmic radio noise in the ionosphere at ~90km. The compression and rarefaction of the atmosphere caused by gravity waves at this altitude is also detectable by IRIS. Initial work in applying wavelet analysis techniques to the IRIS data has resulted in extraction of the temporal and spatial characteristics of polar mesospheric gravity waves. Comparisons with gravity waves observed in a co-located airglow imager have been performed to verify this wavelet technique.

Study of “Scaling phenomena” in the ionosphere

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² Laboratoire de Physique (UMR5672), CNRS, Ecole Normale Supérieure, Lyon, France

Satellite and ground ionospheric measurements show variability due to various factors (solar activity, geomagnetic field, neutral atmosphere influences). Scaling invariance in these data predicates self-similarity of geophysical (including ionospheric) processes. Self-similarity means that an object is composed of sub-units and sub-sub-units on multiple levels that (statistically) resemble the structure of the whole object. Parts of this object obey a power law spectrum f^α over large interval of frequencies. Spectral analyses are computed by Fourier Analysis and Wavelet Analysis. Similar fractal structure of data of different origin (indices of solar activity and geomagnetic activity, ionospheric critical frequencies) may imply common matter of investigated processes. Time – series analyses of solar wind, magnetosphere and ionosphere provide us better understanding of interactions between these systems.

This presentation will bring short introduction to the Scaling Analysis, further will show summary of used models and methods as well as will demonstrate examples of using this analyses in ionospheric research.

Afternoon Session (14:00 – 17:00)

Thermosphere/ionosphere coupling by gravity waves: Multi-instrument observations

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Atmospheric gravity waves have been studied extensively in the lower atmosphere. They are an important means of transporting energy and momentum. Their signature in the ionosphere has been observed for a long time as travelling ionospheric disturbances (TIDs), but they have only recently been observed in the thermosphere by satellite and ground-based instruments. The aim has been to identify sources and source regions in order to understand the coupling mechanism between the thermosphere and ionosphere. This controls the amount of magnetospheric energy that can be transferred via gravity waves outside the auroral region. Gravity waves in the upper atmosphere are capable of transporting energy and momentum over very large distances horizontally, i.e., from auroral regions to the equator. The observations presented here were made within the Scandinavian sector. Three Fabry-Perot Interferometers measure thermospheric parameters and the EISCAT and STARE radars plus magnetometers and ionosondes measure ionospheric parameters. Case and statistical studies indicate that the gravity waves presented in this talk are generated by auroral mechanisms; namely particle precipitation and Joule heating from the auroral electrojets. Lomb-Scargle analysis of the FPI data show that gravity waves exist at all times and for all periodicities. However, there are significant differences in the range of periods found in the neutral winds, temperatures and intensities largely owing to their different response times to imposed perturbations. The inertia of the winds and temperatures suppresses the shorter period waves that are seen in the 630nm emission intensities. There is no solar cycle dependence and only a small geomagnetic activity dependence. Comparison of Svalbard and KEOPS FPIs indicates that the gravity waves are moving from the auroral region towards the pole because Svalbard shows fewer shorter period waves; the implication being that the shorter period waves have dissipated en route from the auroral region.

Effects of solar eclipses events in the ionospheric plasma – acoustic-gravity waves generation and detection

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This study deals with Acoustic-Gravity Waves generation during solar eclipses events. In the contribution we concentrate on the three solar eclipses; August 11, 1999; October 3, 2005 and March 29, 2006 as they were observed in Průhonice Observatory (50N, 14.6E). We show the difference between gravity wave generation during total solar eclipses (August 11, 1999; March 29, 2006) and annular eclipse (October 3, 2005). Using high sampling rate (5 minute, 2minute, 1minute) vertical ionospheric sounding we demonstrate precise characterization of the Acoustic-Gravity Waves pulses as they propagate through ionosphere. In order to obtain complete set of propagation characteristics of the moving structure we employ the dispersion relation of Acoustic-Gravity Waves together with neutral atmosphere model and wavelet based tool for capturing wave oscillations within electron concentration. We show how the method can be potentially used for monitoring and classification of the Acoustic-Gravity Wave pulses within electron density variation.

Recent progress in investigation of effects of infrasound on the ionosphere and upper atmosphere

J. Lastovicka¹, D. Buresova¹, V.M. Krasnov², Ya.V. Drobzheva², J. Chum¹, F. Hruska¹ and T. Sindelarova¹

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² Institute of the Ionosphere, Almaty, Kazakstan

The impact of infrasonic waves on the ionosphere has little been studied in the last twenty years but in the last few years a revival of interest to this topic have appeared. Here we will summarize our recent results in investigating effects of infrasound on the ionosphere, and we will briefly mention also some other results.

The infrasonic waves from surface or the lower troposphere carry the major part of their energy upwards to the upper atmosphere due to focusing property of the lower and middle atmosphere caused by its vertical profile of temperature. The propagation of sinusoidal signals of different (among others meteorological) origin is simulated with a new model that takes into account the inhomogeneity of the atmosphere, non-linear effects, absorption, divergence of wave front due to the long-range acoustic wave propagation, etc. The calculations show that nonlinear processes destroy sinusoidal signal during its upward propagation; it transforms into two, initial and final, impulses. The location of the “transformation region”, where most of wave energy is deposited into the atmosphere, depends on frequency; its height increases with decreasing frequency. Thus the acoustic waves can in principle selectively deposit the energy in the upper atmosphere. The acoustic waves were found to heat the thermosphere via viscous dissipation, sensible heat flux divergence, and Eulerian drift work (Schubert et al., JGR, 2005).

The only possibility to monitor ionospheric effects of infrasonic waves is to use Doppler shift measurements. Since January 2004 the Doppler sounding system has been in operation to perform common volume measurement with a digisonde at Pruhonice (50°N, 15°E). We will present examples, some statistics, and possible explanation of two strange phenomena, short time S-shaped traces in the spectrograms, and patterns having quasi-linear shape in the time-frequency space with Doppler shift corresponding to the objects moving with velocities up to several hundreds m/s. These phenomena, both with lifetimes of tens of seconds, can affect the ionospheric radio wave propagation, including HF channels. As a by-product of common volume measurements, possibility to improve electron density profile derivation from ionograms with the use of Doppler system measurements will be shown.

Doppler observations of infrasonic and gravity waves of different origin at ionospheric heights

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The Doppler type measurements enable us to study wave phenomena of different origin and different wavelength, in particular infrasonic and gravity waves. Since March 2003 measurements of the new Doppler type system have been carried out at Pruhonice ionospheric observatory (49.99°N, 14.54°E). We used a Doppler-sounding technique (the continuous radio wave transmission and recording of the variations in received frequency) to determine mainly what kinds of motions are most effective in producing Doppler effects at ionospheric heights. Infrasonic waves are one of the most effective ways of energy transport from the lower atmosphere into the upper atmosphere. Due to temperature profile in the lower atmosphere the infrasonic waves are focused upwards and the most of the radiated energy can propagate to the upper atmosphere (Laštovička, JASTP, 2006). Meteorological activity in the troposphere can be considered as a long term or continuous source of infrasound. Although the intensity of this source is substantially lower than e.g. intensity of an explosive source, the meteorological activity can in the result provide a large amount of energy due to its continuous nature. In middle latitudes, one of the most common and thus one of the most important sources of tropospheric infrasound are passages of cold fronts, which in the warm half of the year can bring severe thunderstorms. In the ionosphere the Doppler shifts can be caused not only by the vertical motion of the reflecting height, but also by variations of the refractive index (electron density) below reflection point. Some results of the observations of infrasonic and gravity wave activity caused by strong thunderstorms connected with passage of distinct cold fronts are presented and compared with wave activity caused by geomagnetic storms.

Object-oriented hierarchical data structure for framework atmosphere model

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The universal modelling tool is being developed on the basis of the global Upper Atmosphere Model (UAM) for the research of interrelation of the broad range of various processes and the phenomena in the Earth's upper atmosphere. For this purpose the UAM structure was reorganized into the OPEN FRAMEWORK of several independent models of separate atmospheric regions and processes. Each included model calculates the certain set of physical parameters of the modelling object and use the standardized interface to exchange data with other models. This approach allows easy integration of wide range of different data sources of both experimental and modelling origin.

The framework is being created with the object-oriented approach. The object hierarchy and obligatory functional and interface specifications have been developed for each object. The compliance to these specifications allows the object to be connected to the framework model. One of the hierarchical objects is the DATA DEPOSITORY. It "knows how" to save necessary data (numerical parameter values in the grid nodes) to the disk file and to load data from there with the complete information about parameters, the grid and which model provided them.

The created object structure allows storing and correctly interpreting the data, which are in various spatial grids. The grids can be of different dimensions, regular or irregular, Cartesian, polar, spherical, cylindrical, dipole etc., bind to geographic or geomagnetic Earth axis. Moreover, it is possible to set data in arbitrary grid nodes or in some other intermediate way when different grids are mixed for one task.

The presented work contains the detailed description of internal logical organization of the Data Depository, which provides the possibility to store various range of data with full description in a

standardized way. The particular attention is given to methods of formal description of various spatial grids.

Such data storage system organization allows using the same software for data access and data processing and in particular, to represent in a uniform way the data, that was obtained by various methods, to simplify the comparison and analysis.

Ionospheric F-region drift measurements in observatory Pruhonice; seasonal quiet day patterns

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We present analysis of ionospheric drift measurements in observatory Pruhonice (50.0N, 14.6E). Data collected during 2005-2006 under low geomagnetic and solar activity allow us to study plasma drifts in the quiet ionosphere. Step by step we describe a newly improved method of drift velocity evaluation: (i) height range selection, (ii) Doppler frequency shift value limitation, and (iii) choice of the maximum incidence angle. Our preliminary results describe behavior of three velocity components, their diurnal variability during quiet geomagnetic conditions and typical velocity amplitudes for the different seasons. We show that it is important to know how to plasma moves under quiet geomagnetic conditions in order to be able to estimate the influence of geomagnetic storms on the ionosphere.

Ionospheric E and F region drifts during high and low geomagnetic activity

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New digisonde drift measurements with DPS 4 equipment started at observatory Průhonice in January 2004. The paper deals with effects of high solar and geomagnetic activity, which were observed at observatory Průhonice in ionospheric drift measurements during 2004 – 2005 year. Interesting changes of the ionospheric drifts were observed during several periods of suddenly enhanced solar and geomagnetic activity. The analyse of the ionospheric drifts measured during disturbed conditions, shows that vertical drift velocity reaches, from typical value 50 m/s for quiet conditions, up to –250 m/s during disturbed conditions. The variations in horizontal components are a result of increasing of TID activity during storm.

In standard autodrift measurements, the velocity of F region drifts is usually determined near peak of electron concentration profile. From 2005 we measure at Průhonice ionospheric drifts in the height interval 90 – 150 km In second part of this paper we report the results of measurements of the drift velocity in E region during disturbed conditions at midlatitude station Pruhonice.

Poster Session (18:30 – 20:30)

Stratospheric warmings – deterministic or chaotic events

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The mechanisms of the sudden, abrupt enhancement of the winter time stratospheric temperature is still not fully understood. The appearance of conditions favouring the vertical propagation of tropospheric planetary wave is still the half answer of the generation mechanism of this remarkable phenomenon. It is not clear whether there is some trigger forcing (i.e. dynamical advection of heat or momentum, intense cosmic rays precipitation, etc.) or modulation from other factors (QBO in stratospheric equatorial wind, 11 year solar variability, ocean-atmospheric interactions, etc.).

In order to elucidate the generation mechanisms and the problem with very poor predictability of sudden stratospheric warmings, a thorough statistical analysis of 36 years record of Antarctic Syowa station temperature profiles were performed. The remain temperature anomalies (dT) - after removing the linear trend and the mean annual cycle – can be described by a *deterministic seasonal cycle* found in 31 days running averages, and two stochastic components – *random seasonal variability* (with periods more than a month) and *short periodic noise*. Vertical profile of dT dispersion shows that in the troposphere the contribution of *short periodic noise* is up to 45% of total T variability, while the impact of *random seasonal variability* is less than 10%. Above 200 hPa the relative contribution of the both stochastic processes is comparable and explains only about 7% of the whole T variability. This means that with accuracy of $\pm 7\%$ Antarctic spring stratospheric warmings may be assessed by mean annual cycle of T (averaged over the whole data record) and seasonal cycle in 31 days running averages of dT . Detailed statistical analysis of temperature anomalies does not reveal any other periodicities related to QBO, ENSO, etc. There is a hint for multi-decadal variability in dT , but the length of data records do not allow do define it.

Ground-based mesospheric temperatures at mid-latitude derived from O₂ and OH airglow SATI data

Lopez-Gonzalez, M.J.¹, Rodriguez, E.¹, Shepherd, M.G.² Shepherd, G.G.²
Lopez-Puertas, M.¹, Garcia-Comas, M.¹, Sargoytchev, S.² Aushev, V.M.³,
Smith, S.M.⁴, Brown, S.², Cho, Y.-M.² and Wiens, R.H.⁵

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Rotational temperatures obtained from the O₂ Atmospheric (0-1) nightglow band and from the OH Meinel (6-2) band, with a Spectral Airglow Temperature Imager (SATI) instrument at Sierra Nevada Observatory (37.06°N, 3.38°W) are presented. The measurements analysed have been taken from 1998 to 2005. A revision of the temperatures obtained from the Q branch of the (6-2) Meinel band has been undertaken in this new analysis. First, new experimental Einstein coefficients for these lines have been introduced in the temperature derivation. In addition, the temperatures derived from the Q lines (1-3) of the (6-2) OH Meinel band have been compared to those deduced from the P lines (2-4) of the same band for spectra taken by a meridional imaging spectrograph at Boston University. The new set of SATI data has been used to test the seasonal behaviour of the mesospheric and lower thermospheric temperatures.

The phase relationships between tidal waves observed in the ionosphere and mesosphere over Almaty.

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Night observations of TIDs in the F region of the ionosphere and mesosphere are carried out by an digital ionosonde Parus set at Almaty (76°55' E, 43°15' N) and optical instrument for emission rate / temperature measurements (MORTI) installed near Almaty in a mountain region at the altitude of 2750 m above the sea level during November 2005-May 2006 time period. An observation session was about 12 hours by winter and 8 hour by summer in order to eliminate periods of sunset and sunrise and provide observations in conditions of the stationary ionosphere. The ionograms were analyzed for virtual heights ($h'(t)$) and critical frequency ($f_0 F_2(t)$). Using a periodogram method the phases relationship of the tidal waves registered in mesosphere and ionosphere by both instruments were studied.

Image processing of spectrograms produced by SATI with O2 filter.

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The SATI instrument in STIL - Stara Zagora, registers the O₂ emissions in the form of spectrograms for comparatively narrow spectral regions. The processing of these spectrograms allows to determine the average rotational temperature $\overline{T}_{rot}$ and the intensity of the $\overline{E}$ emission as well as the

respective sector values. The SATI is actual as a result of the opportunities to analyze the obtained time series for the separate sectors in order to investigate the fluctuation processes at the mesopause height, being some of the mechanisms for energy transfer.

The measurements are performed in the conditions of different disturbing factors. The focus is on the processing and interpretation of the images-spectrograms, obtained by SATI, which allow in one or another extent to overcome some issues. A preliminary analysis is suggested of the dark current drift for each pixel separately. The correction of the "hot pixels" and the traces of charged particles in the dark current images and the interferograms is made on the basis of values distribution for all pixels.

The application of the preliminary bidimensional-double moving image filtration is examined, which is characterized by a good frequency-amplitude characteristics, for which a fast filtration algorithm is developed, using less memory. Algorithms are developed with elements of artificial intelligence as well as a statistical analysis for determination of the interference rings parameters, which are involved in the calculation of the interference filter parameters (μ, λ_0).

An approach is suggested for treatment of the spatial information in the spectrograms, in which the number ($N \gg 12$) and the sector parameters can be selected within certain limits according to statistical criteria. The choice of sector parameters and their number allows to determine T_{rot} and E in arbitrary directions. Thus, the average temperature $\overline{T}_{rot}$ and emission $\overline{E}$ can be determined as average

values of the respective magnitudes in different directions and not on the basis of average interference spectrum. Using statistical analysis, the "bad" values are rejected, being qualified as containing rough errors. In this way, when determining the average $\overline{T}_{rot}$ and $\overline{E}$ values, those parts of the

spectrogram, which contain rough errors, will not be included. An efficient algorithm is developed to retrieve information from the spectrograms for a given sector with parameters, set out in arbitrary way.

Correlation between cloudless days/nights and magnetic disturbances as a possible reason of space weather influence on climate

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The semi-annual and seasonal-like distribution of cloudless days and nights at Abastumani Astrophysical Observatory (41.75oN, 42.82oE) are revealed. Visual cloudless days and nights during which total ozone content and mesosphere-thermosphere nightglow parameters measurements carried out since 1957 are investigated. The semi-annual distribution of cloudless days and seasonal-like distribution of cloudless nights correlate with the planetary geomagnetic (Ap and Kp) indices. The values of the long-term trends of cloudless days and nights for different values of planetary geomagnetic Ap indices are greater than those for the total dataset of these indices for the same values during the same period of time. The correlation obtained between the cloudless days/nights and planetary geomagnetic indices is considered as a possible result of space weather influence on regional and global climate.

Long period wave activity in the MLT above Davis, Antarctica

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A MF radar and an OH spectrometer have operated at Davis, Antarctica (69S, 78E) since the early 1990's and have yielded an extensive set of MLT winds and dark-time temperatures. However, the different nature of these instruments and their data has meant that their data sets have generally been analysed independently. Recently, a set of time domain filters has been applied to both data sets to produce time series of winds and temperatures with equivalent band-pass characteristics. These time series can now be used to investigate the nature of Antarctic planetary waves.

The characteristics of waves with periods longer than a day in the MLT have been measured and a climatology of wind and temperature has been formed. Minima in wave activity with periods near 3 days are apparent in the winds at the equinoxes. These minima are less apparent for periods near 14 days and a late winter peak in wave amplitude is evident. The temperature variation, although limited to the non-summer months, is consistent with the wind observations.

In this poster, the filter technique is described and the yearly variation is presented. Links to filtering mechanisms that may explain the observations are sought.

Seasonal variation of space-time parameters of internal gravity waves over Kharkiv (49°30'N, 36°51'E)

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Internal gravity waves (IGW) have been studied using radio meteor data at Kharkiv (49°30'N, 36°51'E) by an automatic goniometer of a meteor radar (AG MR), with its antenna directed to the East. The AG MR carries out Doppler measurement of the radial drift velocity and the position of the reflecting area of meteor trails. The algorithm to process the AG MR wind data in order to obtain information about IGW parameters includes division of the measuring volume into several subvolumes, and wavelet analysis of wind variations in these areas.

Results of processing one year (1987) of AG MR data show a good qualitative correspondence with Collm LF D1 short-period lower ionospheric drift variations. There is an increase of IGW activity during the spring and autumn change of the zonal background wind. The results are compared with those from a numerical model. Results from analyses of measurements show that the mean IGW horizontal phase velocity and predominating horizontal propagation direction change with season, whereas the mean period of 1.5h, the dominant amplitude around 30 m/s and the vertical phase velocity does not strongly vary in the course of the year. Mean spatial and time parameter of the IGWs could be determined as, e.g., the mean vertical wavelength being 40km, a mean horizontal wavelength of 250km, and a mean period of 1.5 hours.

Investigation of short-period variations of virtual heights of the middle ionosphere by vertical ionospheric sounding with enhanced precision

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In the present work an impure structure of ionospheric E- and F-regions is investigated on the basis of measurements obtained using the “Cyclone” digital ionosonde with virtual height estimation by an enhanced precision method. The technique of multi-pulse sounding realized on “Cyclone” ionosonde allows receiving the altitude resolution up to 300 m. Such resolution permits investigation of more thin elements of impure ionospheric structure.

All measurements of height of reflection from E- and F-layers on the fixed frequencies concern to quiet diurnal time conditions in spring 2006. Measurements were carried out on three different frequencies with five-minute and one-minute intervals. The analysis of time series of virtual heights (on the fixed working frequencies) was performed by an estimation of power spectral density on the basis of algorithm of multiple signal classification (MUSIC). This method of spectral estimation concerns to a class of the spectral methods based on the analysis of proper values of an autocorrelation matrix. It provides better characteristics of resolution and estimation of frequencies in comparison with the autoregressive method and Prony method. The MUSIC algorithm is especially effective in case of a low signal-to-noise ratio when the other methods are not able to resolve sinusoids with near frequencies or other narrow-band spectral components.

The maxima close to 11–13, 15–16, 21–29 minutes practically on all considered working frequencies were revealed by the spectral analysis for a session of measurements in May 4, 2006. Also it is necessary to note, that peaks in spectra were expressed less precisely when the reflection heights of o-mode and x-mode components were close to each other. When the working frequency was close to the critical frequency of F1-layer, time delays for this working frequency were greatly sensitive to changes in the inter-layer E-F-region. This explains such a dissimilarity of spectral picture on the given working frequency with others. A displacement of the spectral peaks into the lower frequency area with increase of working frequency is also noticeable. The observed spectral maxima may be explained by the passing of internal gravity waves through the E- and F-layer of ionosphere.

Dynamical chaos and order-disorder transition in the large-scale ionospheric motions

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In the given work the large-scale flows, caused by spatial inhomogeneous geomagnetic field, are studied. The closed system of nonlinear Lorentz –type equations is obtained. On the basis of numerical calculations of these equations transition to chaos and formation of order-disorder is observed. Characteristics of the strange attractors are defined. The dynamics of interaction of two-dimensional structures with harmonic perturbation and chaotic advection of vortex particles is studied.

Relation between the ionospheric F2 region and stratosphere in various geomagnetic and solar conditions

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Our previous studies of the mechanism of stratosphere-ionosphere relations have shown that there is a dependence of the correlation coefficient $r(h,fo)$ (between the stratospheric parameter $h(100)$ and the critical frequency of the ionosphere, $foF2$) on space weather parameters. In this paper we analyze the dependence of $r(h,fo)$ on geomagnetic and solar activity. A detailed statistical analysis of the effect of the $r(h,fo)$ dependence on the limitations to the A_p index for the analyzed days was performed. We considered days with a wide range of the boundary values of A_p ($4 \leq A_p \leq 40$) for 5 stations at middle and low latitudes in the years of high (1980) and low (1987) solar activity. We discuss character of the dependence of $r(h,fo)$ on geomagnetic activity. We demonstrate that the dependence is very complicated and depends on solar activity, time of the day, and latitude.

The phase structure of Pc3 geomagnetic pulsations at low latitudes

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The use of ground based magnetometer arrays has proved to be one of the most successful methods of studying the spatial structure of hydromagnetic waves in the earth's magnetosphere. The spatial and temporal variations observed in wave polarization and signal phase are vitally important since they provide evidence which can be directly related to wave generation mechanisms both inside and external to the magnetosphere and propagation modes inside the magnetosphere.

An array of four low latitude induction coil magnetometer stations ($L = 1.7-2.8$) has been used to study longitudinal and latitudinal variations in Pc3 pulsation interstation phase and polarization characteristics. Studies on ten days of data indicate an east-west phase pattern which shows left-hand polarization associated with westward propagation in the afternoon. Similar polarization is seen on latitudinal station pair but propagation is always from north to south away from the equator. Low latitude wave sources are discussed and these results are considered to be consistent with a field line resonance situated at $L > 3$.

Atmospheric drag of low orbit satellites

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In this work the variations of orbital parameters of the low orbit satellites of the Earth are analyzed. The upper atmosphere of the Earth is subject to influence of the various space factors and its condition depends on solar activity. Changes of temperature and density of atmosphere at heights of 200-900 km above the Earth surface have results in appreciable change of atmospheric braking (drag) of space objects (SO) on these heights.

Observable meanings of rate of the "mean movement" change (change of the orbital revolutions numbers per day) characterize rate of loss of potential energy of satellite. Decrease of its orbit is result of braking in rarefied atmosphere. On the basis of the orbits catalogue data (NORAD catalogue of SO) and own surveillance of SO and account of their orbital parameters, the dependence of "satellites drag – time" are received. For the analysis by us are selected 10 SO on low circular orbits and 10 SO - on eccentric orbits ($e > 0.1$).

High temporary correlation of increase of braking various satellites can be caused only by global variations of the Earth atmosphere density. Thus the moments of strong increase of satellite braking follow after sharp bursts of solar activity. For all analyzed low-orbit SO in the period since October, 2003 till December, 2005 the modulation of braking with the periods about 1 month and less is marked. For high-elliptic SO, besides is appreciable seasonal cyclicity with the period about 65-75 day.

The analysis of frequency spectra of dependence "rate of braking – time" is carried out. It has shown, that most powerful (and rather wide) the peak on periodogramme is close to 27 days. Peaks close to $P_3 = 8.9^d$ и $P_5 = 5.3^d$ also are well expressed usually. They are, apparently, third and fifth harmonics of the basic period $P = 26.66$ days. This period is validly exists on the frequency spectra of drag, as one of component of the peak close to 27^d . The second component corresponds to the period $P = 29.6^d$, that, probably, is connected with synodical period of the Moon orbital revolution ($P_{\text{syn}} = 29.53^d$).

In frequency spectra of parameters, which characterize solar activity, as a rule, the period 27 days is poorly expressed, though there are strong "harmonics" with the periods 13.3^d , 8.9^d and 5.3^d . It testifies about complex character of interaction of external forces, which influence on upper atmosphere of the Earth and on movement of all ensemble of low-orbit SO.

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