

The Analysis, Numerical Simulation, and Diagnosis of Extratropical Weather Systems

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LONG-TERM GOAL

My long-term goal is to contribute to the advancement of the observations, structural analysis, dynamical diagnosis, and numerical prediction of the life cycles of synoptic-scale and mesoscale weather systems. This includes the influence of planetary-scale, inter-annual and intra-seasonal variability on their evolution. These weather systems include: mid-latitude and arctic oceanic and land-falling cyclones, fronts and their associated cloud, wind, and precipitation systems; upper-level jet streams and clear-air turbulence, extreme topographic flows and their interactions with the ocean.

OBJECTIVES

My work over the past year has focused on four primary objectives: i) the direction, coordination and planning of THORPEX: A Global Atmospheric Research Programme; ii) the numerical simulation and observational validation of high-spatial resolution (~200 m; vertical and ~10 km; horizontal) numerical forecasts of lower-stratospheric inertia-gravity waves and associated turbulence, iv) the role of large-scale topography in the initiation of inertia-gravity waves and Rossby wave trains, and v) the life cycles and predictability of extratropical cyclones.

APPROACH

My approach toward achieving the above objectives has been to foster national and international scientific interactions, and by doing so, develop the research teams required to address the above complex objectives. The support that I have received through my ONR-sponsored grant (N0001499F0068) has been applied to my NOAA salary, visits with my collaborators, the publication of findings, THORPEX organizational meetings, and research presentations at national and international symposia, universities, and workshops.

The following identifies selected tasks related to my contribution THORPEX and Ongoing Research:

1. THORPEX: A Global Atmospheric Research Programme

Background: The primary goal of THORPEX is to improve operational short-range (0-2 day), medium-range (3-7 day), and extended-range (week-two) weather forecasts of high-impact weather through international collaboration between operational and research communities. In 2000 and 2001, Rolf Langland and I coordinated the preparation of the THORPEX Science Proposal that was

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presented by the THORPEX/International Science Steering Committee (ISCC) to the World Meteorological Organization/World Weather Research Program (WMO/WWRP) and Working Group on Numerical Experimentation (WGNE). This effort set the stage for THORPEX becoming a priority Program of the WMO and US Weather Research Program. During 2002, THORPEX established its International Core Steering Committee (ICSC) with representatives from Australia, North America, Europe, and Asia. The current The ONR support provided to me through this grant contributed to ONR's continued participation and leadership in the development of THORPEX.

Critical elements in my contribution to the development of THORPEX in 2003 include:

- i) Science directorship planning and leadership of THORPEX: I currently serve as Co-chair (with Alan Thorpe, Univ. Reading, UK and Hajime Nakamura, Japan) of the THORPE/International Science Steering Committee and as an *ex-officio* member of the THORPE/International Core Steering Committee (ICSC). This year's accomplished tasks include:
- ii) Preparation and presentation of the THORPEX International Science Plan: Version 2 for the WMO/World weather Research Programme/Science Steering Committee (WWRP/SSC) in Oslo, Norway, September 2003. The Science Plan may be viewed at:
<http://www.wmo.ch/web/arep/wwrp/THORPEX/THORPEX.htm>
http://www.mmm.ucar.edu/uswrp/thorpex/THORpex_wmo.pdf
- iii) Organizing and convening the Second THORPEX/International Workshop and International Science Steering Committee Meeting, Monterey CA, hosted by The US Weather Research Program and Naval Research Laboratory/ Monterey, December 2002.
- iv) Attended the First Asian THORPEX Workshop, Tokyo, Japan, February 2003.
- v) Participated in the Pacific-THORPEX Observing-Systems Test (P-TOST), carried out over the eastern Pacific Ocean by US groups, February-March 2003. This experiment carried out coordinated aircraft flights to evaluate experimental airborne remote sensors for future deployment on next generation satellites.
- vi) Presented an invited THORPEX lecture EGS/AGU Meeting, Nice France, April 2003.
- vii) Attended the Second Meeting of the THORPEX/International core steering committee (ICSC), Paris, France, April 2003.
- viii) Participated in the first international meeting to organize the North-Atlantic THORPEX Regional Campaign (NA-TReC), Reading UK, May 2003.
- ix) Two invited THORPEX overview lectures presented at the IUGG Meeting, Saporro, Japan, July 2003.
- x) Attended the meeting of the THORPEX North-American Regional Committee (NARC) at the University of Maryland, August 2003.

- xi) Second international meeting to organize the North-Atlantic THORPEX Regional Campaign (NA- TReC), Montreal, CA, September 2003.

2. Ongoing Research

My ongoing research interests and contributions include:

The excitation of Rossby-wave trains and the associated development and predictability of high-impact weather events. This work is being carried out in collaboration with Takeshi Enemoto (Frontier Research Center for Climate Change), Federico Gratzini (ECMWF). It involves predictability studies using the Earth Simulator super computer in Yokohama, Japan and the diagnosis of operational forecasts at ECMWF. See Figure 1.

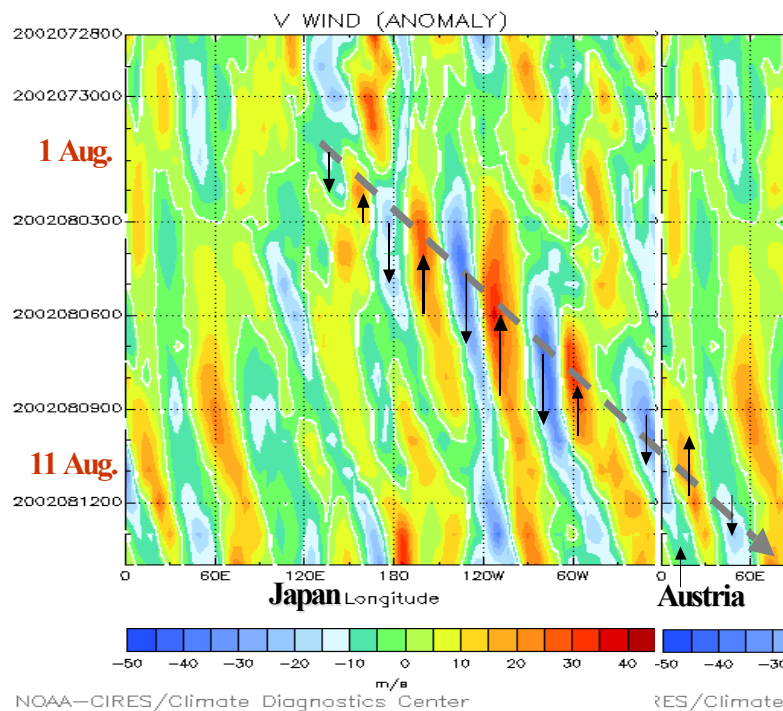


Fig. 1: Hovmöller (time-longitude) diagram of the 250-mb meridional wind component (ms^{-1}) for the period 28 July - 14 August 2002 and the latitudinal belt $40\text{--}60^\circ\text{N}$. Extreme flooding in central Europe occurred at the end of this period. A Rossby wave train was excited by cyclogenesis off Japan, followed by rapid downstream development of high-amplitude Rossby waves, culminating in the severe weather in Europe. A skillful forecast of the cyclogenesis east of Japan is necessary to obtain skillful medium-range forecasts over Europe.

The excitation of vertically-propagating inertia-gravity waves during extra-tropical jet-stream development. This includes observations from the ONR-sponsored NORPEX 1998 field experiment over the North Pacific Ocean and mesoscale numerical simulations with COAMPS and MM-5. This effort shows the ability of mesoscale models to predict gravity waves at jet-stream levels and within the lower stratosphere. This is collaborative effort with Andreas Dörnbrack (DLR), Oberpfaffenhoven,

Germany, and James Doyle (NRL/Monterey). Results from this study will be presented as an invited paper at the December 2002, AGU Meeting, San Francisco, California.

The role of large-scale topography on the predictability of cyclogenesis in the lee of Greenland and the associated topographic excitation of downstream Rossby-wave trains. This is a collaborative effort with Simon Low-Nam (NCAR/MMM), Andreas Dörnbrack (DLR, Germany), Haraldur Olafsson (Icelandic Met. Service) and Piotr Smolarkiewicz (NCAR/MMM).

Breaking gravity waves over Greenland. This represents a continuation of my work with James Doyle (NRL/Monterey). Results include idealized and actual simulations verified against mesoscale analyses of FASTEX dropsondes over Greenland (journal publication, in preparation).

Observations and numerical simulations from the Severe Clear-Air Turbulence encounters with Commercial Air Traffic (SCATCAT) turbulence field experiment. This work is an ongoing collaboration with NOAA/FSL, NCAR/ATD, NCAR/MMM, and NRL/Monterey. Analysis and simulations are completed for the study the 17 February 2001 turbulence event measured with high-spatial-resolution (40 km) dropsondes and flight-level measurements taken with the NOAA/G-4 research aircraft flight from Honolulu, HI. The numerical simulations were performed by Jim Doyle (NRL/MRY) and Todd Lane (NCAR/MMM). I coordinated and participated in directing the G-4 observations and the preparation of the manuscript (see Publications, below).

WORK COMPLETED

The work completed this year is described in the results below.

RESULTS

The following are selected significant research results from this year appearing (to appear) in the formal and informal literature (see PUBLICATIONS, below):

The assimilation of TOMS total ozone for improved prediction of extratropical weather systems. This collaborative effort with Jang, Kun-Il, X. Zou, Q. Zhao, A. Kruger presents a method and results of incorporating TOMS satellite observations of total columnar ozone into the data assimilation and prediction of extratropical cyclones. Results suggest that the assimilation of satellite measurements of ozone can improve the skill of operational weather forecasts.

Large-amplitude gravity-wave breaking over the Greenland lee and the subsequent formation of downstream synoptic-scale tropopause folding and stratospheric-tropospheric exchange. The most important findings in this study are: i) the major influence of large-amplitude topographic gravity waves in the development of downstream tropopause based jet streams and subsequent explosive lee cyclone development; ii) the topographic excitation of Rossby-wave packets by Greenland and their effect on forecast skill over Europe and North Africa on 24-72-h time scales; ii) the role of topographic gravity waves in the exchange of air and trace constituents between the stratosphere and troposphere.

IMPACT/APPLICATION

The work that my collaborators and I have been carrying out is at the frontiers of meteorological research and operational forecasting. We have made contributions to: i) the development of THORPEX, ii) targeted observing strategies and identification of sensitive regions from which forecast errors originate, iii) arctic mesoscale flows, and iv) four-dimensional data assimilation, and dynamical and predictability aspects of Rossby-wave excitation and propagation. The presentation of our findings in the articles, reports, scientific meetings, university and Agency seminars, and THORPEX and USWRP workshops has had a significant impact in shaping future directions in atmospheric observing systems, and advancing basic knowledge of synoptic-scale and mesoscale weather systems, their associated dynamical processes and predictability. The most important application of our work is its contribution to the improvement of operational weather forecasting.

TRANSITIONS

My collaboration with Rolf Langland and Carolyn Renolds (NRL/Monterey) and other scientists has contributed to the accelerated national and international planning for THORPEX. I hope to continue to represent and assist ONR in further development of THORPEX and to participate in future ONR Research initiatives on the predictability of high-impact weather systems

My continuing work with Jim Doyle on the simulation and field study validation of complex mesoscale flows will continue to be used to demonstrate the capabilities of the Navy operational mesoscale prediction system (COAMPS). These results are of critical value for development and verification of COAMPS.

PUBLICATIONS

Jang, Kun-Il, X. Zou, Q. Zhao, A. Kruger, and **M. Shapiro**, 2003: Incorporating TOMS ozone data into the prediction of the Washington January 2000 winter storm. *J. Appl. Meteor.* **42**, 797-812.

Lane, Todd, P., J. Doyle, R. Plougonven, R. Sharman, and **M. Shapiro**, 2003: Numerical modeling of gravity waves and shearing instabilities above an observed jet stream. *Mon. Wea. Rev.* (to be submitted)