Aerosols, Lidar and IR Imaging during Duck and RED

Gerrit de Leeuw
TNO Physics and Electronics Laboratory
P.O. Box 96864
2509 JG The Hague
The Netherlands
phone: +31 70 3740462 FAX: +31 70 3740654 email: deleeuw@fel.tno.nl

Marcel Moerman, Leo Cohen, Gerard Kunz
TNO Physics and Electronics Laboratory
P.O. Box 96864
2509 JG The Hague
The Netherlands

Grant Number: N00014-96-1-0581

http://www.tno.nl

LONG TERM GOALS

The long-term goals of the research are to understand and assess the effects of the atmosphere on the detection of targets at low altitudes over sea in coastal regions using IR and radar systems. Effects considered are transmission losses due to aerosols and water vapor, effects of turbulent fluctuations of the air temperature on blurring and scintillation, and effects of vertical temperature and water vapor gradients on IR and rf refractivity.

OBJECTIVES

The objectives of the research performed in the framework of the present grant are to further analyze and validate results obtained in the EOPACE experiments, in particular:

- to validate the aerosol source function in the surf zone;
- to quantify the effect of the surf zone on the aerosol concentrations in the coastal atmosphere, in relation to surface-produced sea spray aerosol and anthropogenic aerosol;
- to determine the turbulence and refractivity in the inhomogeneous coastal boundary layer and their effects on imaging of low altitude point targets;
- to improve the description of the aerosol size distribution as function of height and meteorological parameters;

and to participate in the RED (Rough Evapoaration Duct) experiments in Hawaii to:

- determine effects of scintillation and refraction in the MW IR band as function of environmental conditions through measurements with a camera mounted ashore at a range of levels above the sea surface, looking at a source mounted on FLIP;
- determine the effect of sea spray aerosol on IR propagation as function of environmental conditions, i.e. the generation of sea spray aerosol from breaking wind waves by the bubble-mediated mechanism and by

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2002**	2. REPORT TYPE	3. DATES COVERED **00-00-2002 to 00-00-2002**

4. TITLE AND SUBTITLE **Aerosols, Lidar and IR Imaging during Duck and RED**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **TNO Physics and Electronics Laboratory,,P.O. Box 96864,2509 JG The Hague,The Netherlands, , ,**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The long-term goals of the research are to understand and assess the effects of the atmosphere on the detection of targets at low altitudes over sea in coastal regions using IR and radar systems. Effects considered are transmission losses due to aerosols and water vapor, effects of turbulent fluctuations of the air temperature on blurring and scintillation, and effects of vertical temperature and water vapor gradients on IR and rf refractivity.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**14**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

direct tearing from the wave tops, the dispersal of freshly produced aerosol in the surface layer and the influence of wave induced turbulent phenomena, and the subsequent transport of the aerosol throughout the atmospheric boundary layer.

APPROACH

Data from the EOPACE IOP's (1-9) in 1996-1999 are further analyzed and interpreted. During the EOPACE experiments in Duck, North Carolina, aerosol particle size distributions were measured at three levels at the base of the pier, with the aim to derive surf-aerosol source functions and parameterize the results as function of ambient parameters. This effort is undertaken in cooperation with Prof. M. Smith from the University of Leeds (UK) who measured particle size distributions at the end of the pier. The results will be compared with those obtained at the California coast. In addition, lidar measurements were made on the aerosol plumes generated by waves breaking in the surf zone.

Furthermore, a boat was equipped with optical particle counters, a sonic, a lidar system and meteorological instrumentation to obtain data on the evolution of the aerosol size distributions and the coastal atmospheric boundary layer in off-shore winds. The goals were to study coastal aerosol transport and to validate the Coastal Aerosol Transport model (CAT) [Vignati et al., 2001], among others to determine the effects of surf-produced aerosol.

TNO-FEL prepared for and participated in the RED experiments on R/P FLIP off Oahu (HI) in August/September 2001, with aerosol and lidar experiments, and a limited set of IR propagation measurements between Oahu sites and FLIP thus covering different lines of sight. The TNO-FEL aerosol and lidar measurements were particularly focused on determination of the aerosol source function. For this reason, also an optical bubble measuring system was deployed to measure bubble spectra at about 0.5 m below the instantaneous sea surface, in combination with aerosol measurements (size distributions and profiles) between 0.5 and 10 m above the sea surface. In a cooperation with the University of Stockholm an aerosol flux system, consisting of a CPC and a sonic that was earlier used in the Arctic [Nilsson et al., 2001], was deployed from FLIP. They were complemented by simultaneous measurements of particle size distributions and, in cooperation with the University of Leeds, aerosol volatility spectra (e.g., Smith [2001]).

WORK COMPLETED

Work completed in years prior to FY01 was summarized in earlier reports. In FY01 the following work was completed:

- The results from the analysis of IOP4 have been published in Applied Optics [Doss-Hammel et al., 2002]. A publication with results from other IOP's, focussing on refraction effects, is planned for submission by in FY2003 [De Jong et al., 2002].
- TNO-FEL contributed to an EOPACE overview paper that has been published in Opt. Eng. in [Jensen et al., 2001].
- The analysis of the Duck 1999 data has been continued. A publication on the aerosol and lidar data is in preparation.
- The data from the Rough Evaporation Duct (RED) experiments off Oahu (HI) in August/September 2001 have been partly analyzed. Initial results were presented at several scientific conferences (see listing in 'Publications').

RESULTS

In a cooperation with Prof M.H. Smith (Univ. of Leeds) and Dr. S. Gathman (Science and Technology Corporation, San Diego, CA) aerosols measured during the EOPACE IOP4 and IOP7 at Naval Amphibious Base (NAB) and Imperial beach Pier (IBP) are analyzed to determine the impact of surf aerosols and urban pollution upon visibility and IR transmission in a coastal region. An intensive working meeting was held in Leeds in May 2002 during which much progress was made in the data analysis. Results will be published in a refereed journal [Gathhman et al., 2003]. The work with CAT on the intermittent production of sea spray from breaking waves [Vignati and de Leeuw, 2001] has been scheduled for FY2003.

During the Rough Evaporation Duct (RED) experiments off Oahu (HI) in August/September 2001 aerosol particle size distributions were measured with optical particle counters and a volatility system, particle size distribution profiles were measured with Rotorod impaction samplers [De Leeuw, 1986], bubble size distributions were measured with an optical bubble measuring system [De Leeuw and Cohen, 2001], lidar measurements were made to characterise the boundary layer structure (cf. Kunz et al. [2002] for a description of the lidar system and the type of measurements). All these measurements were made from FLIP. IR propagation measurements were made between FLIP and a number of sites ashore [De Jong, 2002].

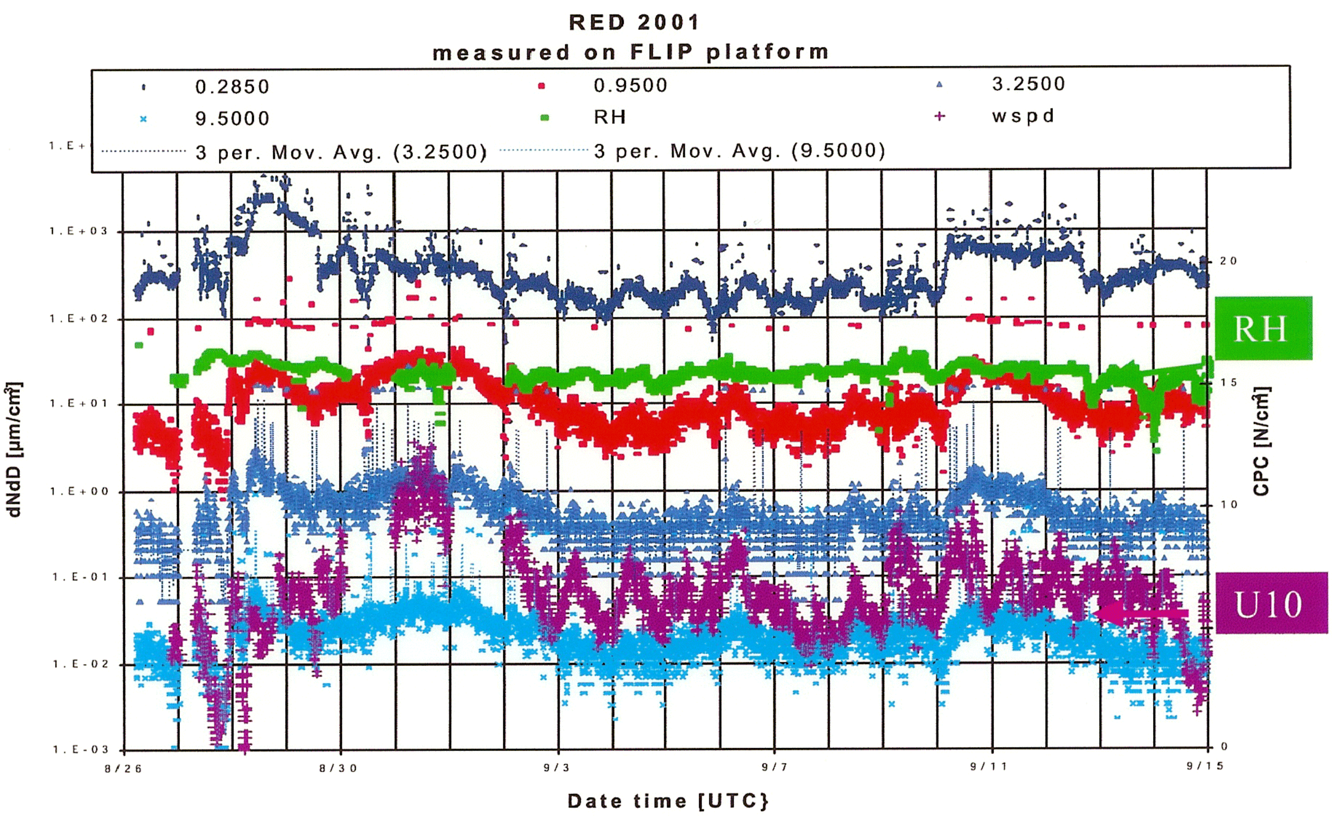

Figure 1. Aerosol time series measured on FLIP during the 3-weeks deployment off Ohau (Hl, USA) show rather constant concentrations with a modulation indicating diurnal effects, not related to RH effects. In addition, three periods can be identified with increased concentrations. The first period, 28-30 August, is associated with pollution induced by Hawaii, as indicated by air mass trajectories. The enhanced concentrations are mainly visible in the small (sub-micron) particle range. The second period with enhanced

aerosol concentrations, around 31 August, was associated with elevated wind speeds resulting in more whitecapping and thus production of sea spray aerosol. The latter is the subject of this study.

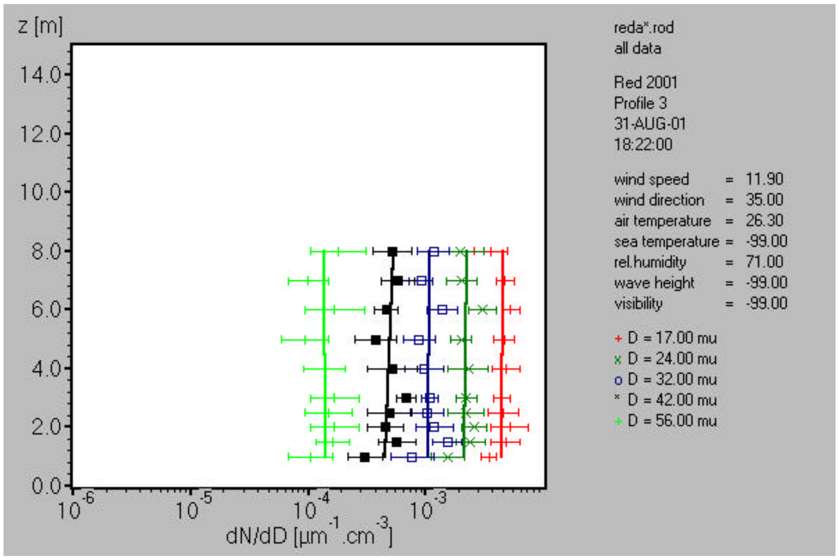

Figure 2. Because sea spray is produced at the sea surface, the concentrations are commonly expected to show distinct near-surface gradients. However, numerous measurements of aerosol profiles in the atmospheric surface layer show that usually such gradients do not exist (e.g., De Leeuw [1993]). Also during RED no clear gradients were detected. In view of the relatively low wind speeds (12 ms^{-1} max.) bubble-mediated sea spray aerosol production will have been the controlling mechanism.

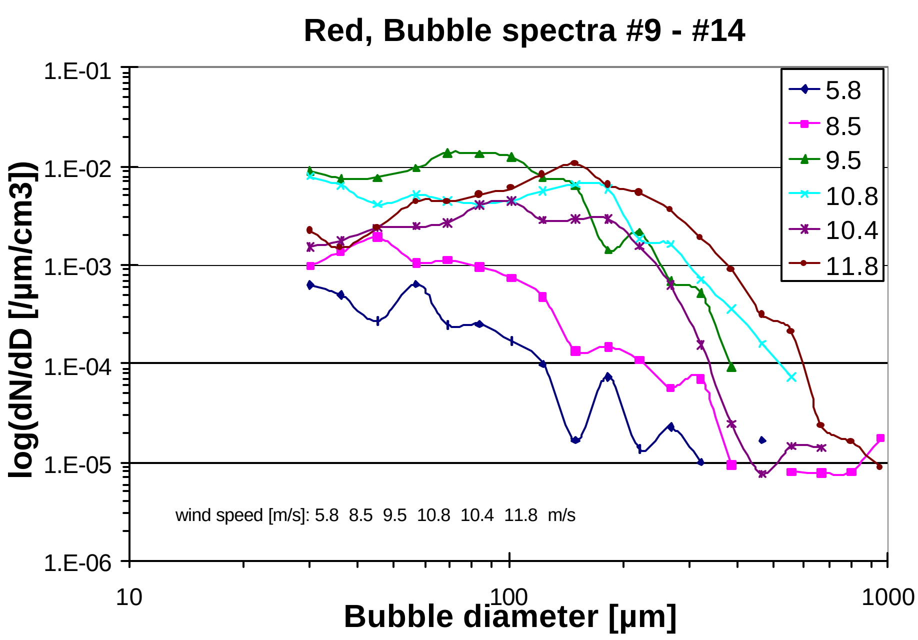

Figure 3: Bubble size distributions. Bubble spectra in the diameter range of 30-1000 µm were measured with a calibrated optical bubble measuring system (Mini-BMS) [Leifer et al., submitted]. Bubble spectra were measured every three hours, as 15-minute averages, in in wind speeds varying from 6 to 12 ms^{-1}. Over this range of wind speeds, the bubble concentrations vary by about 2 orders of magnitude, depending on the

bubble size. It is noted that these spectra are 'background spectra', i.e. representative for the average bubble concentration. Laboratory measurements show that the concentrations immediately after wave breaking are much higher, and the evolution of the bubble spectra depends on parameters such as fetch, bubble size, penetrations depth and plume type [De Leeuw et al., 2001; Leifer and De Leeuw, 2001].

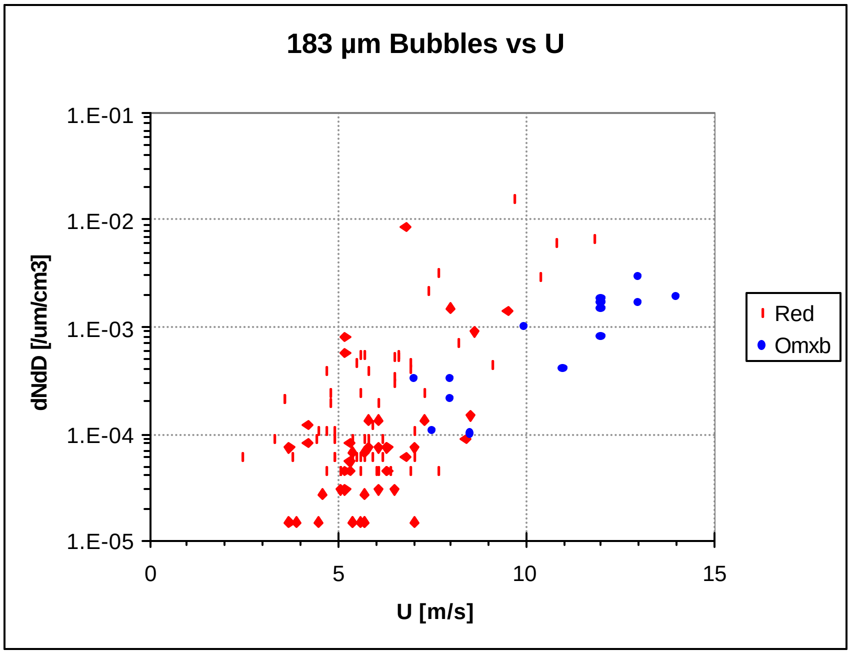

Figure 4. The wind speed dependence of the oceanic 'background' bubble concentrations at various locations has been presented before, cf. De Leeuw and Cohen [2001] for an overview. The bubble concentrations measured during RED show an explicit wind speed dependence which is different from that observed from the Omex measurements in the colder water of the North Atlantic (12°C as compared to the water temperature of 28°C during RED).

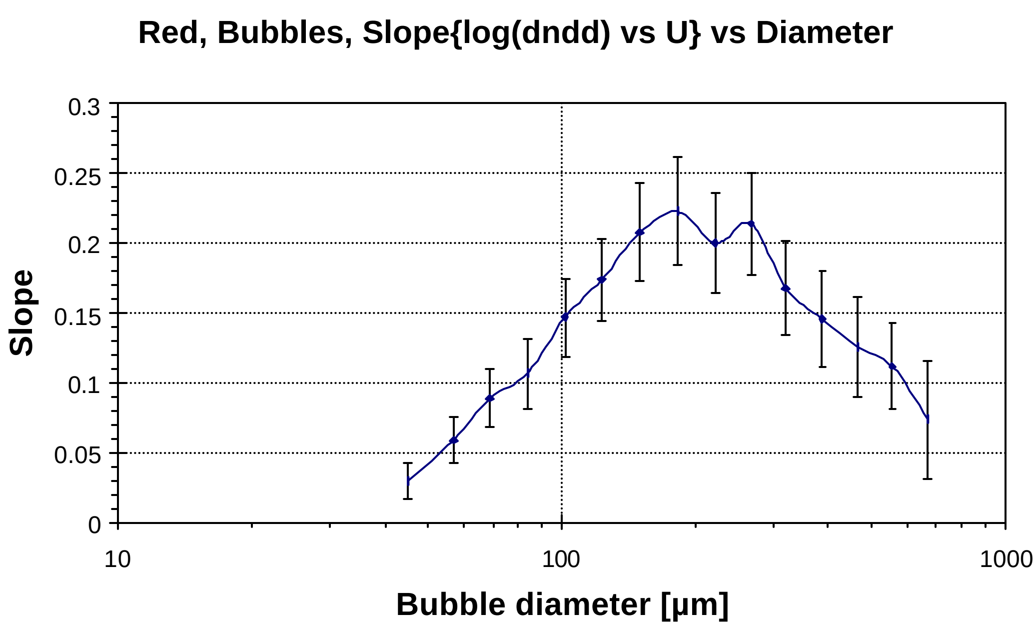

Figure 5. Fitting an exponential function, $log\left(\frac{dB}{dD}\right) = a + bu_{10}$, yields the slopes b describing the variation of the bubble concentrations with wind speed. The Figure clearly shows the strong variation of the wind speed dependence with the bubble size.

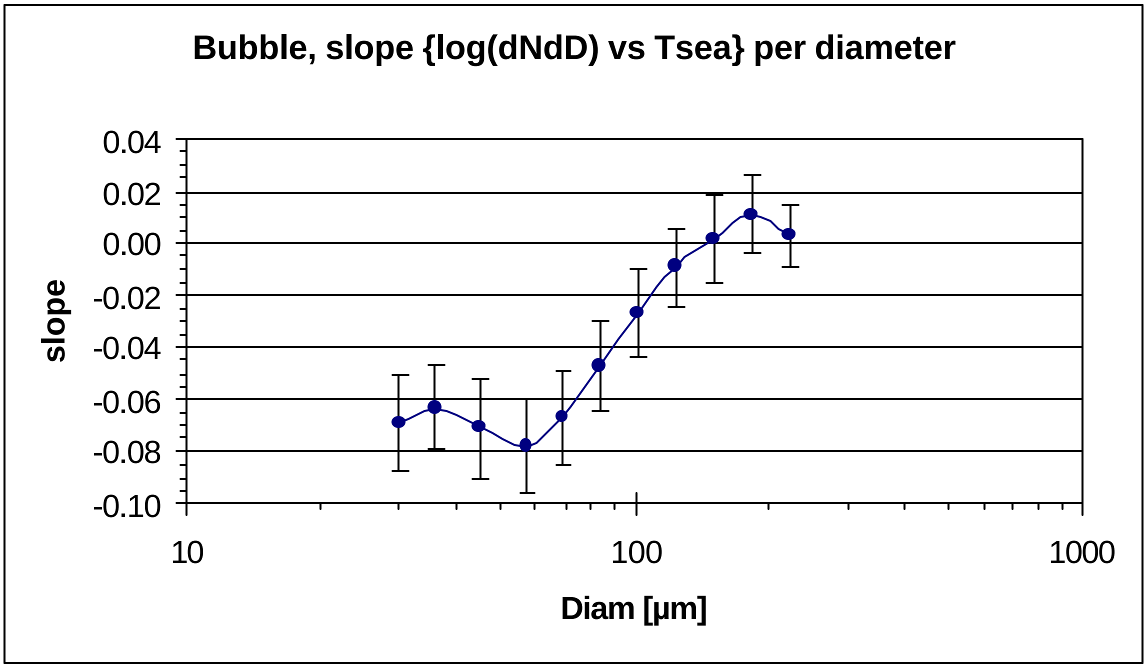

Figure 6. The concentrations and their wind speed dependence depend on the water temperature. The RED experiments took place in water with a temperature of 28°C. In Figure 4 also OMEX data are plotted which were measured in the North Atlantic with a temperature of about 12°C. Figure 6 shows an attempt to relate the variation of the concentrations with the water temperature, for wind speeds of 8-10 ms^{-1}, with data from 8 experiments in which the water temperature varied between 9 and 28 °C.

Conclusions

1. Bubble concentrations are strongly variable due to a variety of environmental factors; indicated here are effects of wind speed and water temperature:

- Increase with wind speed
- Decrease with sea temperature for small bubbles, increase with sea temperature for large bubbles
- Spectral shape changes with wind speed and sea temperature

Other effects are surfactants, salinity, viscosity, Langmuir circulations, turbulence, wave breaking characteristics influenced by fetch and swell, water saturation, atmospheric thermal stratification, …

2. Wave breaking is intermittent, and thus the bubble concentrations and subsequent sea spray aerosol production vary in time

3. Aerosol gradients depend on atmospheric transport and transformation and removal processes.

All these processes carry uncertainties. With the rather simple methods to derive the aerosol source function, either from the number of aerosols produced per unit whitecap, or from the balance between production and removal, it cannot be expected that a single universal sea spray source function can be obtained in terms of only few parameters. Yet current formulations for the sea spray source function are converging to within less than one order of magnitude.

IMPACT

The results can be used to assess the effects of the atmosphere on the performance of thermal imagers over sea, and in particular the performance of LR-IRST systems. Another important appplication is in the field of numerical weather forecasting because of the influence on the solar irradiation at the Earth surface: sea spray aerosol has been estimated to contribute 44% to the total aerosol optical depth, but with an uncertainty of a factor of three (IPCC, 2001). The surf-produced aerosol affects atmospheric processes involving sea spray particles, such as heterogeneous reactions, at fetches of at least 10 km in off-shore winds. Reaction between sea spray and HNO_3 has consequences for atmospheric inputs of nitrogen compounds in coastal waters, and thus eutrophication [De Leeuw et al., 2001]. Over land, sea spray influences fragile coastal eco-systems, and the corrosive properties cause damage to buildings, structures and cultural heritage.

TRANSITIONS

The EOPACE and RED results of TNO-FEL are exchanged with other EOPACE and RED participants, for common analysis combining all required expertise to achieve the EOPACE and RED goals. Common EOPACE publications have been published, others are submitted or in preparation.

RELATED PROJECTS

The efforts described above are in conjunction with other projects addressing electro-optical propagation over sea, in part basic research, in part applied research. The EOPACE efforts take place in conjunction with EOPACE studies funded by the Netherlands Ministry of Defense, including work on long-range transmission, IRST and backgrounds. Data from other areas, e.g. the North Sea, the North Atlantic, the Mediterranean and the Baltic, are from other projects supported by the Netherlands Ministry of Defense, the EU or other funding agencies.

SUMMARY

New knowledge has been acquired on the effect of the surf zone on aerosol concentrations in the coastal zone. Explanations for the lack of vertical variation of the concentrations of sea salt produced at the sea surface from breaking waves are provided from model simulations. Observed effects of refractivity on propagation over the coastal ocean seas have been explained with models. New data have been collected near Oahu (HI), from which it is hoped to derive direct information on the aerosol transported from or to the sea surface. Measured bubble size distributions have been analysed in conjunction with similar data from other areas to derive information on the variation of the bublbe concentrations with wind speed and water temperature. Aerosol eddy correlation measurements are analyzed to determine surface fluxes.

REFERENCES

- De Jong, A.N., TNO Physics and Electronics Laboratory, Report, *in print*, 2002.
- De Jong, A.N., M. Moerman and G. de Leeuw. *In preparation,* 2003.
- De Leeuw, G. Vertical profiles of giant particles close above the sea surface. *Tellus* 38B, 51-61, 1986.
- De Leeuw, G., Aerosols near the air-sea interface. Trends in Geophys. Res. 2, 55-70, 1993.
- De Leeuw, G., and L.H. Cohen. Bubble size distributions on the North Atlantic and the North Sea. *in Gas Transfer and water Surfaces*, edited by M.A. Donelan, W.M. Drennan, E.S. Salzman, and R. Wanninkhof, pp. 271-277, AGU, 2001.
- De Leeuw, G., G.J. Kunz, G. Caulliez, D.K. Woolf, P. Bowyer, I. Leifer, P. Nightingale, M. Liddicoat, T.S. Rhee, M.O. Andreae, S.E. Larsen, F.A. Hansen and S. Lund, LUMINY - An overview. *in Gas Transfer and water Surfaces,* edited by M.A. Donelan, W.M. Drennan, E.S. Salzman, and R. Wanninkhof, pp. 291-294, AGU, 2001.
- De Leeuw, G., L.H. Cohen, L.M. Frohn, G. Geernaert, O. Hertel, B. Jensen, T. Jickells, L. Klein, G. J. Kunz, S. Lund, M.M. Moerman, F. Müller, B. Pedersen, K. von Salzen, K. H. Schlünzen, M. Schulz, C. A. Skjøth, L.L. Sorensen, L. Spokes, S. Tamm and E. Vignati. Atmospheric input of nitrogen into the North Sea: ANICE project overview. *Continental Shelf Research*, (21) 18-19 (2001),pp. 2073-2094, 2001.
- Doss-Hammel, S.M., C.R. Zeisse, A.E. Barrios, G. de Leeuw, M.Moerman, A.N. de Jong, P. A. Frederickson, and K. L. Davidson, Low altitude infrared propagation in a coastal zone: refraction and scattering. *Accepted for publication in Appl. Opt*., 2002
- Gathman, S.G., M.H. Smith and G. de Leeuw. Influence of Surf and Urban Aerosols on Coastal Visibility, *in preparation*, 2003
- Jensen, D.R., S.G. Gathman, C.R. Zeisse, C.P. McGrath, G. de Leeuw, M.H. Smith, P.A. Frederickson and K.L. Davidson (2001). Electrooptical propagation assessment in coastal environments (EOPACE): Overview and initial accomplishments. *Optical Engineering,* Vol. 40 (8), pp. 1486-1498, 2001.
- Kunz, G.J., G. de Leeuw, C. O'Dowd and E. Becker, LIDAR studies of atmospheric boundary layer structure and sea spray aerosol plumes generation and transport at Mace Head, Ireland (PARFORCE experiment). *J. Geophys. Res., special issue on PARFORCE*, doi:10.1029/2001JD001240, 2002.
- Leifer, I. , G. de Leeuw and L.H. Cohen (2000). Optical measurement of bubbles: system design. *Sumitted for publication, 2002.*

- Leifer, I., and G. de Leeuw. Bubble measurements in breaking-wave generated bubble plumes during the LUMINY wind-wave experiment. *In Gas Transfer and water Surfaces*, edited by M.A. Donelan, W.M. Drennan, E.S. Salzman, and R. Wanninkhof, pp. 303-309, AGU, 2001.

- Nilsson, E.D., Ü. Rannik, E. Swietlicki, C.Leck, P.P. Aalto, J. Zhou and M. Norman, Turbulent aerosol fluxes over the Arctic Ocean 2. Wind-driven sources from the sea, *J. Geophys. Res.*, 106, 32139-32154, 2001.

- Smith, M.H. Contribution of surf-generated particles to coastal aerosol loadings, University of Leeds, School of the Environment, Technical Report Contract No: SSDW3/0049, 2001.

- Vignati, E., and G. de Leeuw. Removal of HNO_3 in the Marine Atmosphere by Heterogeneous Reaction with Sea Spray Aerosol, in: A changing atmosphere, 8th European Symposium on the Physico-Chemical behaviour of Atmospheric Pollutants, Torino, 17-20 September 2001.

- Vignati, E., G. de Leeuw and R. Berkowicz. Modeling coastal aerosol transport and effects of surf-produced aerosols on processes in the marine atmospheric boundary layer, *JGR-Atmospheres*, 106, 20225-20238, 2001.

PUBLICATIONS

Refereed Journals:

R.1 De Leeuw, G., L.H. Cohen, L.M. Frohn, G. Geernaert, O. Hertel, B. Jensen, T. Jickells, L. Klein, G. J. Kunz, S. Lund, M.M. Moerman, F. Müller, B. Pedersen, K. von Salzen, K. H. Schlünzen, M. Schulz, C. A. Skjøth, L.L. Sorensen, L. Spokes, S. Tamm and E. Vignati (2000). Atmospheric input of nitrogen into the North Sea: ANICE project overview. *Continental Shelf Research*, (21) 18-19 (2001),pp. 2073-2094.

R.2 Jensen, D.R., S.G. Gathman, C.R. Zeisse, C.P. McGrath, G. de Leeuw, M.H. Smith, P.A. Frederickson and K.L. Davidson (2001). Electrooptical propagation assessment in coastal environments (EOPACE): Overview and initial accomplishments. *Optical Engineering*, Vol. 40 (8), pp. 1486-1498, 2001.

R.3 Kusmierczyk–Michulec, J., G. de Leeuw and C. Robles Gonzalez, Empirical relationships between aerosol mass concentrations and Ångström parameter, Geophys. Res. Lett. 29(7), paper 2001GL014128 (2002).

R.4 Doss-Hammel, S.M., C.R. Zeisse, A.E. Barrios, G. de Leeuw, M.Moerman, A.N. de Jong, P. A. Frederickson, and K. L. Davidson (2002), Low altitude infrared propagation in a coastal zone: refraction and scattering. *Accepted for publication in Appl. Opt.*, 2002

R.5 O'Dowd, C.D., K. Hämeri, J. Mäkelä, M. Väkeva, P. Aalto, G. de Leeuw, G. Kunz, E. Becker, H.-C. Hansson, E. Becker, A.G. Allen, R.M. Harrison, C. Kleefeld, M. Geever, S.G. Jennings and M. Kulmala, Coastal new particle formation: Environmental conditions and aerosol physico-chemical characteristics during nucleation bursts, *J. Geophys. Res., special issue on PARFORCE*, in press, June 2002.

R.6 O'Dowd, C.D., K. Hämeri, J. Mäkelä, L. Pirjola, M. Kulmala, S.G. Jennings, H. Berresheim, H.-C. Hansson, G. de Leeuw, G.J. Kunz, A.G. Allen, C.N. Hewitt, A. Stroh, Y. Viisanen and T. Hoffmann, A dedicated study of new particle formation and fate in the coastal environment (PARFORCE): Overview of objectives and initial achievements, *J. Geophys. Res., special issue on PARFORCE*, in press, June 2002.

R.7 Kleefeld, C., C.D. O'Dowd, S. O'Reilly, S. G. Jennings, P. Aalto, E. Becker, G. Kunz and G. de Leeuw, The relative contribution of sub and super micron particles to aerosol light scattering in the marine boundary layer (MBL). *J. Geophys. Res., special issue on PARFORCE,* in press, June 2002.

R.8 Kunz, G.J., G. de Leeuw, C. O'Dowd and E. Becker, LIDAR studies of atmospheric boundary layer structure and sea spray aerosol plumes generation and transport at Mace Head, Ireland (PARFORCE experiment). *J. Geophys. Res., special issue on PARFORCE*, doi:10.1029/2001JD001240, 2002.

R.9 De Leeuw, G., G.J. Kunz, G. Buzorius and C. O'Dowd (2001). Meteorological influences on coastal new particle formation. *J. Geophys. Res., special issue on PARFORCE,* in press, June 2002.

R.10 Hertel, O., C. Ambelas Skjøth, L.M. Frohn, E. Vignati, J. Frydendall, G. de Leeuw, Uwe Schwarz and Stefan Reis, 2002. Assessment of the Atmospheric Nitrogen Inputs into the North Sea using a Lagrangian model. Proceedings of the EGS meeting in Nice 2001. Accepted for publication in *Physics and Chemistry of the Earth* (July, 2002).

R.11 Schmid, B., J. Redemann, P. B. Russell, P. V. Hobbs, D. L. Hlavka, M. McGill, W. Hart, B. N. Holben, E. J. Welton, J. Campbell, O. Torres, R. Kahn, D. Diner, M. Helmlinger, D. A. Chu, L. A. Remer, C. Robles Gonzalez, G. de Leeuw (2002). Coordinated airborne, space borne, and ground based measurements of massive, thick aerosol layers during the SAFARI-2000 Dry Season Campaign, *Accepted for publication in JGR-Atmospheres*, (15 March 2002).

R.12 Mårtensson, M., E. D. Nilsson, G. de Leeuw, L.H. Cohen, and H-C Hansson, Laboratory simulations of the primary marine aerosol generated by bubble bursting, *Accepted for publication in JGR-Atmospheres (August, 2002).*

R.13 Leifer, I., G. de Leeuw and L.H. Cohen. Calibrating optical bubble size by the displaced mass method. *Accepted for publication in Chem. Eng. Sci. with revision* (June 2002).

R.14 Leifer, I. , G. de Leeuw and L.H. Cohen (2000). Optical measurement of bubbles: system design. *Accepted for publication in J. Atm and Ocean. Tech, with revision (Nov. 2001).*

R.15 De Leeuw, G., C.Ambelas Skjøth, O. Hertel, T. Jickells, L. Spokes, E. Vignati, L. Frohn, J. Frydendall, M. Schulz, S. Tamm, L.L. Sørensen and G.J. Kunz, Deposition of Nitrogen into the North Sea, Submission to Atm. Env., ELOISE Special Issue 2002.

R.16 De Leeuw, G., L. Spokes, T. Jickells, C. Ambelas Skjøth, O. Hertel, E. Vignati, S. Tamm, M. Schulz, L.-L. Sorensen, B. Pedersen, L. Klein, and K. H. Schlünzen (2002). Atmospheric Nitrogen Inputs into the North Sea: Effect on Productivity. Submitted for publication in *Continental Shelf Research*, ELOISE Special Issue, 2002.

R.17 Piazzola, J., F. Bouchara, A.M.J. van Eijk and G. de Leeuw (200) Development of the Mediterranean extinction code (MEDEX), *Submitted for publication in Opt. Eng.*, June 2002.

Proceedings:

P.1 De Leeuw, G., G.J. Kunz, G. Caulliez, D.K. Woolf, P. Bowyer, I. Leifer, P. Nightingale, M. Liddicoat, T.S. Rhee, M.O. Andreae, S.E. Larsen, F.A. Hansen and S. Lund, LUMINY - An overview. *in Gas Transfer and water Surfaces*, edited by M.A. Donelan, W.M. Drennan, E.S. Salzman, and R. Wanninkhof, pp. 291-294, AGU, 2001.

P.2 De Leeuw, G., and L.H. Cohen. Bubble size distributions on the North Atlantic and the North Sea. *in Gas Transfer and water Surfaces*, edited by M.A. Donelan, W.M. Drennan, E.S. Salzman, and R. Wanninkhof, pp. 271-277, AGU, 2001.

P.3 De Leeuw, G., and I. Leifer. Bubbles outside the plume during the LUMINY wind wave experiment. Gas transfer at water interfaces. *in Gas Transfer and water Surfaces*, edited by M.A. Donelan, W.M. Drennan, E.S. Salzman, and R. Wanninkhof, pp. 295-301, AGU, 2001.

P.4 Leifer, I., and G. de Leeuw. Gas transfer at water interfaces. *in Gas Transfer and water Surfaces*, edited by M.A. Donelan, W.M. Drennan, E.S. Salzman, and R. Wanninkhof, pp. 303-309, AGU, 2001.

P.5 De Leeuw, G., L.H. Cohen, L.M. Frohn, G. Geernaert, O. Hertel, B. Jensen, T. Jickells, L. Klein, G.J. Kunz, S. Lund, M. Moerman, F. Müller, B. Pedersen, K. von Salzen, K.H. Schlünzen, M. Schulz, C.A. , L.L. Sorensen, L. Spokes, S. Tamm and E.Vignati, ANICE: Atmospheric Inputs of Nitrogen Compounds into the North Sea, First results, In: Transport and Chemical Transformation in the Troposhere, *Proceedings from the EUROTRAC Symposium 2000*, edited by P.M. Midgley, M. Reuther, and M. Williams, Springer Verlag Berlin, Heidelberg, pp. 476-480, 2001.

P.6 Hertel, O., E. Vignati, C. Ambelas Skjøth, and G. de. Leeuw, Study on Atmospheric Nitrogen Inputs into the North Sea using a trajectory, EGS, Nice, 2001

P.7 G. de Leeuw, G. J. Kunz, L.H. Cohen, M. Moerman, G. Geernaert, O. Hertel, L.-M. Frohn, C. A. Skjøth, B. Pedersen, B. Jensen, L.-L. Sorensen, S. Lund, K. Heinke Schlünzen, L. Klein, K. von Salzen, Tim Jickells, L. Spokes, M. Schulz, S. Tamm, E. Vignati, Atmospheric input of nitrogen into the North Sea: ANICE results. In: N. Pirrone, C. Fragikis and H. Barth (Eds.), European Land-Ocean Interaction Studies, ELOISE, 4th Open Science Meeting, 5-7 September 2001, Rende, Italy, pp. 107-108.

P.8 De Leeuw, G., C. Robles Gonzalez, J. Kusmierczyk-Michulec, R. Decae and P. Veefkind. Satellite Retrieval of Aerosol Properties, in: A changing atmosphere, 8th European Symposium on the Physico-Chemical behaviour of Atmospheric Pollutants, Torino, 17-20 September 2001, p. AP91.

P.9 Vignati, E. and G. de Leeuw. Removal of HNO_3 in the Marine Atmosphere by Heterogeneous Reaction with Sea Spray Aerosol, in: A changing atmosphere, 8th European Symposium on the Physico-Chemical behaviour of Atmospheric Pollutants, Torino, 17-20 September 2001, p. MO3.

P.10 Decae, R.J., J.P. Veefkind, O. Torres and G. de Leeuw. Multi-Component Aerosol Retrieval Using OMI, in: A changing atmosphere, 8th European Symposium on the Physico-Chemical behaviour of Atmospheric Pollutants, Torino, 17-20 September 2001, p. AP88

P.11 Builtjes, P., G. de Leeuw and M. van Loon. Combining Observations and Model Results by Data-Assimilation, Application to Aerosols, in: A changing atmosphere, 8th European Symposium on the Physico-Chemical behaviour of Atmospheric Pollutants, Torino, 17-20 September 2001, p. AP90.

P.12 Veefkind, J.P, P.F. Levelt, G.H.J. van den Oord, G. de Leeuw and H. Kelder, The ozone monitoring instrument (OMI), in: A changing atmosphere, 8^{th} European Symposium on the Physico-Chemical behaviour of Atmospheric Pollutants, Torino, 17-20 September 2001, p. UP11.

P.13 Mårtensson, E.M., E. D. Nilsson, G. de Leeuw, L. H. Cohen, H.-C. Hansson, Laboratory simulations and parameterization of the primary marine aerosol production, (NOSA Aerosol Symposium, Lund, Sweden, 8-9 November 2001)

P.14 G. de Leeuw, C. Robles Gonzalez, J. Kusmierczyk-Michulec and R. Decae (2002). Satellite Retrieval of Aerosol Properties, EGS, Nice, April 2002.

P.15 G. de Leeuw, L.- M. Frohn, G. Geernaert, O. Hertel, T. Jickells, L. Klein, G. J. Kunz, B. Pedersen, K.H. Schlünzen, M. Schulz, C.A. Skjøth, L. –L. Sorensen, L. Spokes, S Tamm and E. Vignati (2002). Atmospheric Nitrogen Inputs to the North Sea, EGS, Nice, April 2002.

P.16 G.J Kunz and G. de Leeuw (2002). Aerosol plumes in a coastal environment revealed by lidar. SPIE AerosoSense 2002: 'Targets and backgrounds VIII: Characterization and Representation', 1-5 April, Orlando, Fl, USA, paper 4718-22.

P.17 De Leeuw, G., C. Robles Gonzalez, J. Kusmierczyk-Michulec and R. Decae (2002). Retrieval of aerosol properties and their use in chemistry transport models, Workshop on Chemical Weather Forecasting, DLR, Oberpfaffenhofen, Germany, 7-8 May, 2002.

P.18 De Leeuw, G., C. Robles Gonzalez, J. Kusmierczyk-Michulec and R. Decae (2002). Retrieval of aerosol properties on regional and global scales from satellites, WMO-GAW, Riga, May 2002

P.19 Kusmierczyk-Michulec, J., G. de Leeuw and M. Moerman (2002). Application of the Empirical Orthogonal Function Method to Aerosol Optical Thickness Data. AGU Spring meeting, AERONET conference, Washington D.C. (USA), June 2002.

P.20 Robles Gonzalez, C., G. de Leeuw, R. Decae and J. Kusmierczyk-Michulec (2002). Uisng the ATSR-2 dual view for the retrieval of aerosol properties. IWMMM-3, Third International workshop on multiangular measurements and models, Steamboat Springs, Colorado, 10-12 June 2002, p. 45.

P.21 J. Kusmierczyk – Michulec and G. de Leeuw (2002). Novel aerosol retrieval algorithms for SCIAMACHY for application over water and land. In: Air Pollution X (eds. C.A. Brebbia and J.F. Martin-Duque), WIT Press, Southhampton (UK), 445-450, 2002.

P.22 C. Robles-Gonzalez, G. de Leeuw, R. Decae, J. Kusmierczyk-Michulec (2002). A new algorithm to retrieve AOD with ATSR-2 data. In: Air Pollution X (eds. C.A. Brebbia and J.F. Martin-Duque), WIT Press, Southhampton (UK), 481-4489, 2002.

P.23 Russchenberg, H., F. Bosveld, D. Swart, H. ten Brink, M. Herben, G. de Leeuw, H. Stricker, B. Arbesser-Rastburg and H. van der Marel (2002). *CESAR* : Cabauw experimental site for atmospheric research, URSI, Maastricht, August 2002.

P.24 Mårtensson, E.M., E. D. Nilsson, G. de Leeuw, L. H. Cohen, H.-C. Hansson, Laboratory simulations and parameterization of the primary marine aerosol production, J. Aerosol Sci., in press, (Abstracts of the 6th IAC in Taiwan, 9-13 September 2002).

P.25 De Leeuw, G., M. Moerman, B. Brooks, M.H. Smith and E. Vignati (2002). Aerosols in the marine atmosphere: concentrations and production of sea spray. IAMAS/CACGP/IGAC2002, Crete, 18-25 September, 2002.

P.26 Russchenberg, H., F Bosveld, D. Swart, H. Ten Brink, G. de Leeuw, G. Brussaard, Han Stricker, B. Arbesser-Rastburg (2002). CESAR: Cabauw Experimental Site for Atmospheric Remote Sensing. IAMAS/CACGP/IGAC2002, Crete, 18-25 September, 2002.

P.27 Kusmierczyk-Michulec, J., G. de Leeuw, C. Robles Gonazalez and R. Decae (2002). Aerosol observations from space. IAMAS/CACGP/IGAC2002, Crete, 18-25 September, 2002.

P.28 Robles-Gonzalez, C., G. de Leeuw, R. Decae, J. Kusmierczyk–Michulec (2002). A new algorithm to retrieve AOD with ATSR-2 data. IAMAS/CACGP/IGAC2002, Crete, 18-25 September, 2002.

P.29 De Leeuw, G. (2002). SOLAS talk. IAMAS/CACGP/IGAC2002, Crete, 18-25 September, 2002.

P.30 Van Eijk, A.M.J., L.H. Cohen, L.J. Navarro and G. de Leeuw (2002). Near-surface aerosol transmission. SPIE conference 'Optics in Atmospheric Propagation and Adaptive Systems V, Crete, 23-27 September 2002.

P.31 De Leeuw, G., C. Robles Gonzalez, J. Kusmierczyk-Michulec, R. Decae and P.J. Veefkind (2002). Retrieval of aerosol optical depth from satellite measurements ujsing single and dual view algorithms. SPIE Conference RS04 Remote Sensing of Clouds and the Atmosphere VII, Crete, 23-37 September 2002.