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A Note From the IGAC Chair: *Guy Brasseur*

Aerosols and Photooxidants

Over recent decades, the atmospheric chemistry community has devoted great effort to quantify the gas phase processes that control the formation and destruction of photooxidants in the troposphere. The focus has been on ozone and hydroxyl radical formation and destruction, with emphasis on the role played by precursors such as the nitrogen oxides, carbon monoxide, methane and nonmethane hydrocarbons. This approach has highlighted the importance of biogenic emissions from oceans, soils, and vegetation (including biomass burning), as well as anthropogenic perturbations.

More recently, it has become evident that atmospheric aerosols could affect the processes that control the budget of photooxidants. Several studies have shown, for example, that conversion of nitrogen oxides into nitric acid on sulfate aerosols could be a very efficient mechanism, especially during nighttime. Other mechanisms affecting ozone and other photooxidants in the troposphere have been proposed, including the uptake of peroxy radicals on sulfate particles, the destruction of ozone on soot particles, the release of active forms of halogens from seasalt, and the heterogeneous formation of nitrous acid in highly polluted areas. The role of such multiphase reactions remains controversial, making them deserving of considerable attention.

It is clear today that the simple representation of sulfate aerosols in global and regional models has become insufficient to account for important chemical and climate effects. Modern approaches must consider the effects not only of sulfate and nitrate aerosols, but also of mineral dust, soot, organic particles, sea-salt, and probably other types of particles. Challenging work to measure the chemical composition of particles in the boundary layer and in the free troposphere is underway, often under IGAC sponsorship. More detailed representations of aerosols are being implemented in the most advanced models, including climate models.

The present issue of *IGAC Activities* focuses on microphysical processes that lead to the formation of new particles in the atmosphere. Several studies sponsored by the European Commission are summarized that have been conducted to understand nucleation processes in different environments. New and exciting science has resulted from these studies.

Science Features

New Particle Formation

Contributed by **Colin O'Dowd** (colin.odowd@cmas.demon.co.uk), University of Sunderland, England, **Markku Kulmala** (markku.kulmala@helsinki.fi), University of Helsinki, Finland, and **Thorsten Hoffmann** (hoffmann@isas-dortmund.de), ISAS, Germany.

Aerosol particles are ubiquitous in the Earth's atmosphere and contribute significantly to the biogeochemical cycling of trace gas species and the Earth's radiative flux budget. One of the largest uncertainties relating to anthropogenic climate forcing concerns atmospheric aerosols [Houghton *et al.*, 1995]. Until their natural background source is quantified, the influence of anthropogenic aerosols cannot be determined. Additionally, until the mechanisms leading to background and anthropogenic aerosol formation are understood within a theoretical framework, the ability to predict climate change due to atmospheric aerosols will not be achieved.

The number concentration of atmospheric particles is determined primarily by the formation rate of new particles, typically of the order of 1-2 nm in size, formed through gas-to-particle conversion processes. Once stable particle clusters are formed, they can grow through coagulation and condensation processes to quasi-stable sizes of 50-100 nm where they can directly (and indirectly through cloud formation) influence the radiative budget.

Due to measurement limitations associated with particle sizes down to <1 nm, the source regions and production mechanisms of natural secondary (gas-to-particle conversion) aerosols have proven somewhat difficult to elucidate. Current instrumentation allows measurements down to about 3 nm, so in reality we are measuring only recently formed "ultrafine" particles rather than actual new particles. Similar difficulties limit measurements of gas phase precursors at very low mixing ratios. Additionally, in the natural background environment, intensive bursts with significant new particle formation appear to occur infrequently and are difficult to predict. In consequence, field experiments aimed at elucidating the mechanisms and species involved in nucleation have been difficult to design.

Similar obstacles have slowed development of theoretical frameworks to explain nucleation. A lack of thermodynamic and surface tension data on the multiplicity of possible nucleation species has limited the accuracy of nucleation models; however, significant advances in the development of more thermodynamically consistent binary and ternary nucleation models have been achieved [Kulmala *et al.*, 1998; Korhonen *et al.*, 1999].

Although natural particle formation in the boundary layer appears to be infrequent in most background environments (such as the marine boundary layer and remote

continental sites), two environments have been identified as regions of significant new particle production and form the focus of this newsletter: The coastal zone, which can produce extended nucleation events lasting several hours, with peak particle concentrations exceeding $1,000,000 \text{ cm}^{-3}$ [O'Dowd *et al.*, 1998]; and forested regions, where nucleation is observed to occur over spatial scales greater than 1000 km [Mäkelä *et al.*, 1997].

The European Commission has funded three dedicated pan-European aerosol nucleation research programs under its "4th Framework Environment & Climate Research Programme (1998-2000)." Two of these focus on *in situ* atmospheric field measurements at locations where natural new particle formation is known to occur on a regular basis: (1) New Particle Formation and Fate in the Coastal Environment (PARFORCE), which examines nucleation in the coastal environment (at the Mace Head Atmospheric Monitoring Station), and (2) Biogenic Aerosol Formation in the Boreal Forest (BIOFOR), which examines nucleation in the forested environment (at the Hyytiälä SMEAR II research station). The third, Nucleation Processes from Oxidation of Biogenic Volatile Organic Compounds (NUCVOC), examines through laboratory studies the nucleation potential of various common atmospheric VOCs.

The following articles summarize the preliminary progress achieved on all three projects. Two additional articles summarize the facilities and characteristics of the research stations: Mace Head, Ireland and Hyytiälä, Finland. To avoid repetition of similar experimental and modeling techniques used on both BIOFOR and PARFORCE projects, these are discussed only in the PARFORCE article.

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New particle formation and fate in the coastal environment (PARFORCE)

Contributed by **Colin O'Dowd** (*colin.odowd@emas.demon.co.uk*), University of Sunderland, England.

Homogeneous heteromolecular nucleation of natural atmospheric aerosols was first observed in the coastal environment more than 100 years ago. Aitken [1897] reported elevated condensation nucleus (CN) concentrations close to the shoreline on the west Scottish coast, where he observed particle concentrations to rise from a background level of $\approx 300 \text{ cm}^{-3}$ to $\approx 150,000 \text{ cm}^{-3}$ during clean marine air flow under sunny conditions. The cause of these new particles was thought to be photochemical breakdown of gases released from the shore biota, though the nucleating species were never identified. These 'nucleation' events were also observed at other coastal sites around western Europe, including the Mace Head Atmospheric Research Station in Ireland, where new particle events have been found to be related to the oceanic tidal cycle [O'Dowd *et al.*, 1998].

The coastal environment is a strong and frequently active source of natural atmospheric aerosol particles and, consequently, serves as an excellent natural laboratory to study the conditions under which particle formation occurs. The PARFORCE consortium and program was set up to focus on the processes and conditions which promote and control homogeneous heteromolecular nucleation in the coastal boundary layer. These goals are being achieved through a long-term continuous aerosol monitoring program at Mace Head, along with two intensive field campaigns (September 1998 & June 1999) comprised of detailed atmospheric chemistry measurements. In parallel with the experimental program, aerosol nucleation and growth models are being developed for use in conjunction with the experimental data to identify the primary mechanisms involved.

Primary objectives

- To determine the environmental conditions and rates under which homogeneous heteromolecular nucleation occurs in the coastal boundary layer (i.e., pre-existing aerosol surface area, precursor gas concentration, and micro- and macro-scale meteorology).
- To examine whether these nucleation events can be explained by binary or ternary heteromolecular nucleation via the following schemes: $\text{H}_2\text{SO}_4\text{-H}_2\text{O}$ or $\text{NH}_3\text{-H}_2\text{SO}_4\text{-H}_2\text{O}$ or $\text{NH}_3\text{-H}_2\text{O-MSA/HCl/HNO}_3$, or whether alternative nucleation schemes are more likely to explain the observed events (i.e., organic/halocarbon embryo formation followed by organic/halogen and/or sulfate growth).

Description of the experiment

The Mace Head Research Station was chosen as the experiment site primarily due to the known high frequency of nucleation events. Additionally, its comprehensive facilities are suited to these studies: two main laboratories are situated less than 100 m from the tidal regions and are adjacent to 10 m and 20 m sampling towers. The primary sample duct is taken from a community aerosol sampler adjacent to the 10 m tower. A third laboratory is situated approximately 300 m from the shoreline.

Detailed meteorological data on atmospheric structure and turbulent fluxes at the coastal interface were acquired through use of Lidar measurements and micro meteorological flux packages. Ultrafine particle concentrations were measured using an array of condensation particle counters (CPC's), each measuring total particle concentration above a certain cut-off size (3, 5, 10 nm). This combination of measurements allows fast response source rates to be determined by examining differences between pairs of total particle counts. A pyramid array of particle counters was deployed around the station to elucidate the spatial scales over which these events occur. Within this array, the horizontal distances were of the order of 300 m apart while vertical gradient measurements were taken at 10 and 20 m. Size distributions of ultrafine and fine mode particles, using Differential Mobility Particle Sizer techniques, were also taken with 10 minute time resolution to examine the growth of this mode. Aerosol size distributions were measured through use of optical particle counters up to sizes of $300 \mu\text{m}$ to determine the existing aerosol condensation sink.

Continuous measurements were made of relevant inorganic precursor gases: SO_2 , NH_3 , HCl , OH , H_2SO_4 and MSA , the latter three compounds measured by chemical ionization mass spectrometry (CIMMS). Additional measurements were made of halocarbon species, DMS , DMDS , and VOCs ($\text{C}_6\text{-C}_{20}$). Seaweed stressing experiments were also carried out to examine how the emissions of various biogenic gases depend on environmental stressing.

Preliminary results

A continuous measurement program of ultrafine particle concentrations and size distributions was initiated at Mace Head in February 1998. These long-term measurements illustrate the frequency of the nucleation events. In Figure 1, a contour plot of particle concentration (1-hour average) as a function of day-of-year and time-of-day is plotted for a 3-month period. Low tide occurrences are also highlighted. From the current database it is evident that these tidal particle events occur almost daily, all year round and do not appear to be seasonal in any way.

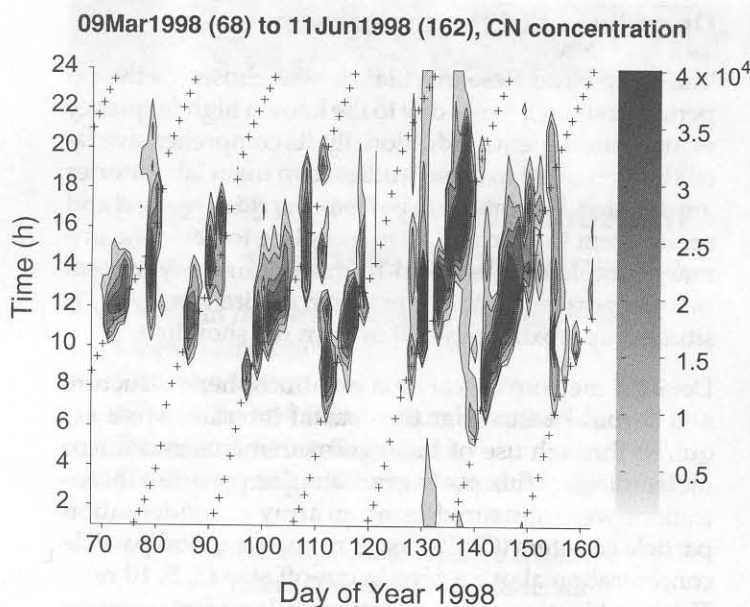


Figure 1. Contour plot of ultrafine particles as a function of day-of-year and time-of-day. The map scale is in units of particles cm^{-3} . Occurrence of low tide is marked by '+'. It can be seen that during daylight hours, the occurrence of elevated particle concentrations follows closely the low tide cycle.

Aerosol physical characteristics

The number of new, ultrafine aerosols was measured by taking the difference in concentration between 3 and 10 nm sized particles. A typical nucleation event is illustrated in Figure 2a which shows particle concentrations from $0.6\text{--}1.1 \times 10^6 \text{ cm}^{-3}$ over a duration of a few hours. The peninsular location of the Mace Head station (see accompanying article) allows sampling in the tidal plume at distances ranging from $\approx 100 \text{ m}$ up to $\approx 10 \text{ km}$ from the tidal source region, depending on wind direction [O'Dowd *et al.*, 1999]. For moderate wind speeds, these distances correspond to point measurements at ≈ 30 seconds and ≈ 30 minutes into the evolving coastal plume. Two characteristic differences are observed depending on distance from the plume source. For the measurements corresponding to 30 seconds into plume evolution, ultrafine (3–10 nm) particle concentration increases to about $10,000 \text{ cm}^{-3}$, while no enhancement is seen at sizes larger than 10 nm. By comparison, 30 minutes into the plume evolution, concentrations at sizes larger than 3 nm reach levels $>600,000 \text{ cm}^{-3}$ with approximately $50,000 \text{ cm}^{-3}$ of these having grown into sizes larger than 10 nm.

Aerosol Precursor characteristics

A wide variety of possible aerosol precursors has been measured during both campaigns; however, no clear pattern linking any one species with aerosol formation and low tide occurrence has been observed. During the intensive field campaigns, no observable tidal signal was

observed between NH_3 , DMS, SO_2 , or VOCs ($\text{C}_2\text{--C}_{16}$), although some heavier organics were present at low tide; however, these remain to be identified. Gaseous H_2SO_4 exhibited a typical diurnal cycle, following OH concentrations, and was found to be independent of low tide conditions. Figure 2b illustrates the typical diurnal variation of H_2SO_4 with peak concentration occurring around midday. MSA is also shown in this figure and, although there appears to be some coherence between both acid concentrations on this day, it should be noted that, for the most part, MSA concentrations showed little correlation with H_2SO_4 concentrations. Preliminary interpretation suggests that there is a significant source of MSA in the absence of the OH radical. Typical peak marine air concentrations of OH, H_2SO_4 and MSA were of the order of $4\text{--}8 \times 10^6 \text{ cm}^{-3}$, $1.5\text{--}3 \times 10^7 \text{ cm}^{-3}$ and $1\text{--}2 \times 10^7 \text{ cm}^{-3}$, respectively.

Aerosol chemical characteristics

The chemical composition of new particles must first be characterized in order to identify particular nucleating species. This task is quite difficult as it requires separating out sufficient new particle mass from existing particles, which otherwise would contaminate the chemical sample. One technique to elucidate ultrafine particle chemical characteristics involves examination of a particle's hygroscopic properties. Although indirect, this technique can reveal important aerosol properties in near-real time. The technique generally involves examining the hygroscopic growth of a particle of known size between two fixed relative humidities (typically 50–90%). The so-called growth factor over this range of humidities is well known for common aerosol species. The smallest size that could be conditioned for hygroscopic growth analysis was 8 nm, consequently this technique elucidates only the nature of the primary condensing vapor leading to growth of new particles into ultrafine sizes rather than the actual new particle composition.

For example, at 90% relative humidity, an 8 nm ammonium sulfate particle will exhibit an increase in diameter of 1.4 over its size at 40% humidity. Sulfuric acid particles of this size exhibit a slightly higher growth factor of 1.5 and less soluble organic aerosol will typically have a growth factor of the order of 1.1 or less. Thus, using this technique we were able to determine if the recently formed ultrafine particles were composed of sulfate mass or a less-soluble organic mass. Preliminary findings indicate the new particles are primarily composed of less soluble material, probably organic in nature, possessing a growth-factor of $\approx 1.05\text{--}1.1$. However, when very high concentrations of H_2SO_4 vapor coincided with the occurrence of ultrafine particles, the growth factor indicated a particle composition between that of organic mass and ammonium sulfate, suggesting that sometimes H_2SO_4 can also contribute to ultrafine aerosol growth.

Modeling of aerosol formation and growth

In the absence of direct chemical and physical characterization of new particles, a combination of modeling tools and experimental data must be used to elucidate the nucleation mechanisms and species involved. From the experimental results, we have measurements at two stages in the coastal plume development: ≈ 30 seconds and ≈ 30 minutes from the plume source. If, using an aerosol dynamics and condensation growth model, we can accurately predict the observed aerosol growth at these two stages of plume evolution, then we can determine the initial nucleation rates and condensation vapor source strength required to produce the observed particle concentrations. O'Dowd *et al.* [1999] concluded that, in order to explain a particle concentration of $10,000 \text{ cm}^{-3}$ after 30 seconds into the plume, and of the order of $600,000 \text{ cm}^{-3}$ after 30 minutes, with $50,000 \text{ cm}^{-3}$ of these at sizes larger than 10 nm , a nucleation rate of the order of $10^7 \text{ cm}^{-3} \text{ s}^{-1}$ was required, followed by condensation from a continuous vapor concentration of $5 \times 10^7 \text{ cm}^{-3}$.

Revised nucleation theory [Kulmala *et al.*, 1998] indicates that for binary nucleation of $\text{H}_2\text{SO}_4\text{-H}_2\text{O}$, an acid concentration of $>10^9 \text{ cm}^{-3}$ would be required to sustain such nucleation rates. Thus, we can rule out binary nucleation as a feasible explanation. In the presence of NH_3 , the free energy barrier to nucleation is removed, thus suggesting that a ternary nucleation system involving NH_3 would be more likely. Recent theoretical development of ternary nucleation models indicates that to achieve nucleation rates of $10^7 \text{ cm}^{-3} \text{ s}^{-1}$, NH_3 concentrations of the order of 20 ppt, and H_2SO_4 concentrations of 10^7 cm^{-3} are required [Korhonen *et al.*, 1999]. Additionally, under higher NH_3 concentrations of 100-200 ppt, a H_2SO_4 concentration of the order of $1\text{-}4 \times 10^6 \text{ cm}^{-3}$ is required to achieve the same nucleation rate. Given the range of NH_3 (20-2500 ppt) and H_2SO_4 concentrations (10^5 to $> 1.5 \times 10^7 \text{ cm}^{-3}$) encountered, this mechanism appears likely to explain the predicted nucleation rates. However, although the ternary $\text{H}_2\text{SO}_4\text{-H}_2\text{O-NH}_3$ system can explain nucleation rates of this magnitude, these concentrations of H_2SO_4 are insufficient to explain the growth of the new particles into detectable sizes of 3 nm . A fourth species, X, is required to provide the condensing material. X is

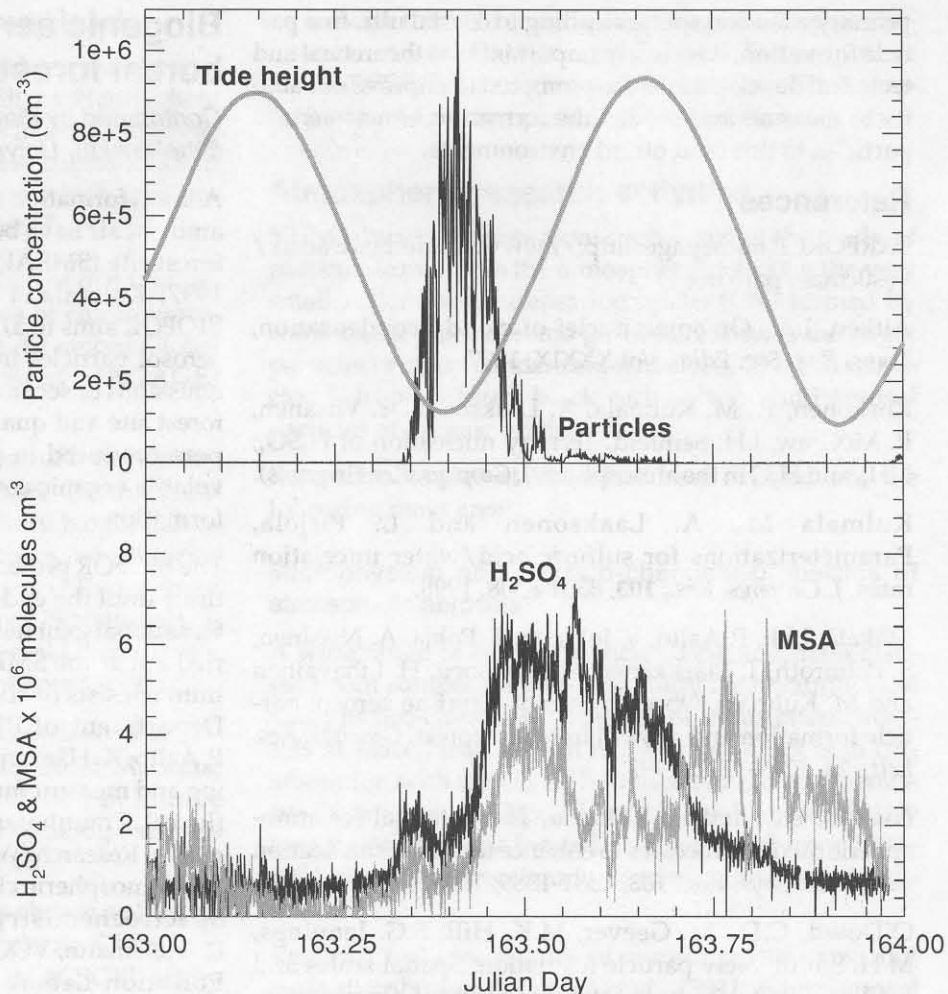


Figure 2: (a) Ultrafine particle concentration and tidal height variation (from University of Sunderland). The units on the gray-scale bar are cm^{-3} . (b) H_2SO_4 and MSA concentrations (from H. Berresheim, Deutscher Wetterdienst).

thought to be an organic acid possessing a very low vapor pressure and is a product of biogenic emissions from the tidal region. Given the range of H_2SO_4 and NH_3 concentrations encountered in this environment, ternary nucleation theory suggests that nucleation is happening more often than we can detect ultrafine particles. We only detect nucleation when there is a sufficient source of condensable material to grow these new particles to detectable sizes of larger than 3 nm [O'Dowd *et al.*, 1999]. Although X remains to be identified, the hypothesis of an organic condensing species is consistent with the growth factor analysis of ultrafine particles.

The coastal environment appears to be a very strong and frequent source of natural particles and is likely to significantly influence the natural background aerosol population on a regional scale. However, there are still many unanswered questions concerning the chemical species involved in nucleation and growth of new natural particles in this environment. While there is a considerable amount of data analysis to be conducted in conjunction with numerical simulations before we can determine the

primary chemical species leading to coastal ultrafine particle formation, it is clearly important that theoretical and technical developments are promoted to improve our ability to measure and predict the formation of new aerosol particles in this (and other) environments.

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PARFORCE Consortium

Jyrki Makela, Markku Kulmala (*University of Helsinki*), **Hans-Christen Hansson, Johan Strom** (*ITM, Stockholm University*), **Gerard Jennings** (*NUI, Galway*), **Harald Berresheim** (*DWD Meteorological Observatory Hohenpeissenberg*), **Gerrit de Leeuw** (*TNO, The Netherlands*), **Roy Harrison** (*University of Birmingham*), **Nick Hewitt** (*Lancaster University*), **Yrjo Viisanen** (*Finnish Meteorological Institute*), **Andrea Jackson, Alistair Lewis** (*Leeds University*), **Spyros Rapsomanikis** (*Demokritos University of Thrace*).

Collaborators

Peter Liss, Lucy Carpenter (*University of East Anglia*), **Peter Simmonds** (*Bristol University*), **Thorsten Hoffman**, (*ISAS, Dortmund*), **Keith Bigg** (*not affiliated*), **Jochen Stutz, Ulrich Platt** (*University of Heidelberg*).

Biogenic aerosol formation in the boreal forest (BIOFOR)

Contributed by **Markku Kulmala** (markku.kulmala@helsinki.fi), *University of Helsinki, Finland*.

Aerosol formation and subsequent particle growth in the ambient air have been frequently observed at the boreal forest site (SMEAR II), Southern Finland [Mäkelä *et al.*, 1997; Kulmala *et al.*, 1998]. The EU-funded project BIOFOR aims to a) determine formation mechanisms of aerosol particles in the boreal forest site, and b) verify emissions of secondary organic aerosols from the boreal forest site and quantify the amount of condensable vapors produced in photochemical reactions of biogenic volatile organic compounds (BVOC) leading to aerosol formation.

The BIOFOR project started in October 1997 and will continue until the end of 1999. During the project three international joint measurement campaigns have been carried out at the SMEAR II station. The BIOFOR Consortium consists of six laboratories: University of Helsinki Department of Physics (M. Kulmala, J.M. Mäkelä, P. Aalto, K. Hämeri, L. Pirjola; aerosol dynamics, modeling and measurements, inorganic gases, gas and aerosol fluxes), Fraunhofer-Institute for Atmospheric Environmental Research (W. Seidl; modelling of particulate phase and atmospheric chemistry, canopy model), Institute of Spectrochemistry and Applied Spectroscopy (T. Hoffmann; VOC profiles), Stockholm University Air Pollution Laboratory (H.-C. Hansson, R. Jansson, E.D. Nilsson (aerosol and gas measurements, boundary layer meteorology), University of Sunderland, Centre for Marine and Atmospheric Sciences (C.D. O'Dowd; aerosol measurements) and Finnish Meteorological Institute Air Quality Research (Y. Viisanen, R. Hillamo; trajectories, soundings, aerosol phase chemistry). Additionally, there are several individual researchers participating during the intensive campaigns: K. Bigg (single particle analysis), R. Weber (ultrafine aerosol measurements), J. Salm (ion measurements), and A. Laaksonen (nucleation modeling).

At SMEAR II, continuous measurements of submicron aerosol number size distribution have been carried out since January 1996 (every 10 min). They show approximately 40 days per year with clearly detectable aerosol particle formation events. As seen in Figure 1, the most typical time for these events is March-April. Subsequent to the new particle formation, significant particle growth is usually observed. Almost 20% of the events will continue sufficiently long to produce particles with diameter over 80 nm, which can then become effective cloud condensation nuclei (CCN).

When the particle formation event occurs, the mode of the fresh particles appears into the measurement range. Figure 2 shows a typical aerosol size distribution spec-

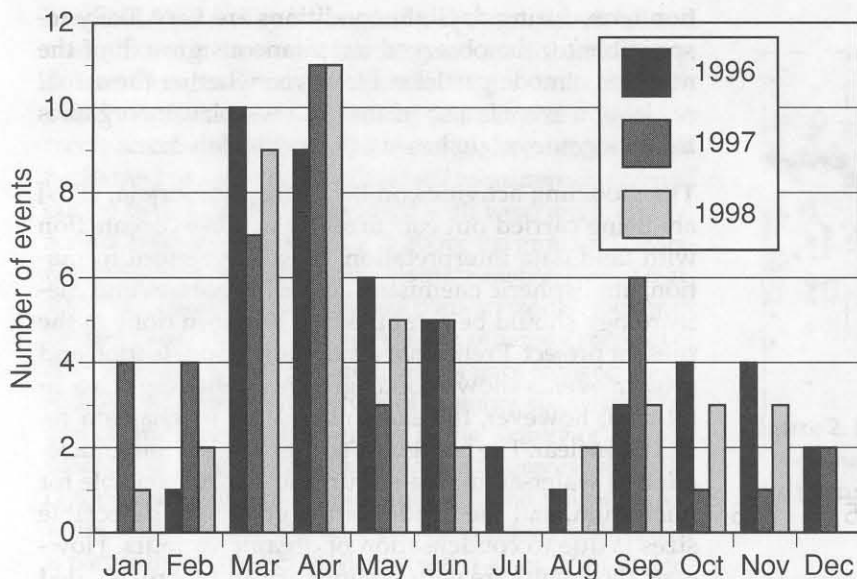


Figure 1. Monthly frequency of nucleation events during three years [J.M. Mäkelä and M. dal Maso, unpublished results].

trum measured using DMPS (Differential Mobility Particle Sizing) during the event. Here, three log-normal modes have been used to explain the spectrum's structure. The nucleation mode, which has already reached the size of 17.5 nm, practically dominates the spectrum with its high number concentration. Figure 3 shows the evolution of the modal mean diameters of nucleation, Aitken, and accumulation mode particles during the particle production bursts, and subsequent growth. The fitting procedure, by which the modes have been obtained from the measurement data, has been presented by Mäkelä *et al.* [1999]. In Figure 3, an extended growth event is illustrated following a nucleation burst on July 20th 1996. For this event, particle growth from nucleation mode up to accumulation mode during the subsequent days is clearly observable.

Meteorological data including radiation is available for interpretation of weather conditions typically encountered during particle production events (see BIOFOR homepage). Vertical distributions (4–67 m) of different inorganic gases (SO_2 , NO_x and O_3) are also available.

During the BIOFOR project three campaigns have been performed, measuring hygroscopicity, composition and vertical profiles of particles. The atmospheric concentrations of organic and inorganic gases are also available during the campaign.

Measurements carried out so far demonstrate the capability of combining more detailed campaign measurements with continuous ones, e.g., the detailed chemical analysis will provide insight into composition of newly formed particles. However, the task to analyze chemical composition of nucleation mode particles is very difficult. On the other hand, the hygroscopicity of nucleation mode particles tells us their soluble fraction and

changes in particle composition *in situ*. Some changes have already been seen during the growth process.

As a summary, two different cases can be compared (for more details see BIOFOR homepage):

a) *Nucleation day in spring*, when 5,000–10,000 new particles cm^{-3} are usually formed coinciding with moderate hydrocarbon emissions from the forest. General meteorological conditions comprise northwest (polar) air trajectories, relatively low ambient temperatures, and large night and day temperature differences.

b) *Typical clear sunny summer day*, with no nucleation observed; however, high hydrocarbon emissions from the forest are encountered. Ambient temperatures are typically high, while temperature difference between day and night is relatively low.

From particle flux data, using the eddy covariance method [Buzorius *et al.*, 1998], a small overall downward flux is usually observed. This clearly increases during nucleation events, with an exception of the cases when the surface wind was from direction of 220–250° (direction of the city Tampere and the Hyytiälä institute buildings); then a strong upward particle flux is observed.

Hyytiälä 13.4.1996 15:39–15:49 p.m.

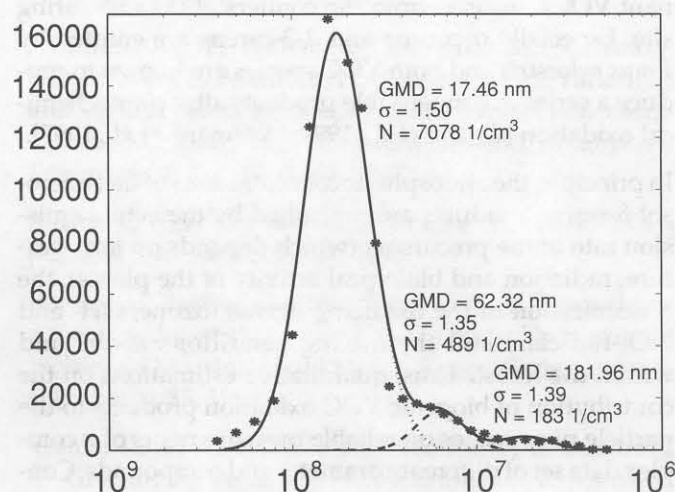


Figure 2. Typical number size distribution during the particle production and growth event. A sum of three log-normal size distributions (solid curve) has been numerically fitted into the measured spectrum (*). The characteristic numbers for the three modes (dashed curves)—i.e., number concentration, mean particle diameter and geometric standard deviation—for each mode are shown with the modes.

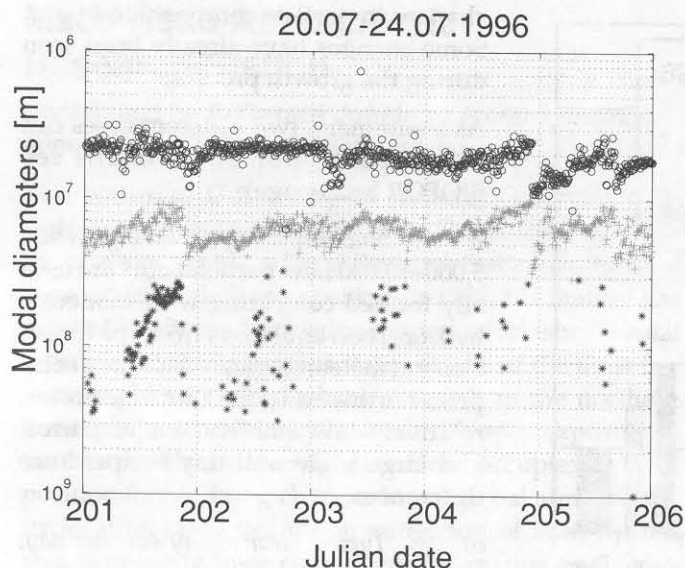


Figure 3. Evolution of the mean diameters of nucleation (*), Aitken (+) and accumulation (o) mode particles during a period of five days in Hyytiälä. The values for modal mean diameters have been obtained by numerical fitting procedure.

As mentioned above, one of the specific scientific goals of the BIOFOR project is to investigate the connection between the observed nanometer particle formation events and the subsequent particle growth at the SMEAR station with the biogenic activity of the surrounding Scotch pine forest. From the emission and concentration measurements realized so far as well as from earlier studies, it is known that various monoterpenes are the dominant VOCs released from the conifers at the measuring site. Especially α -pinene and d-3-carene are emitted by *Pinus sylvestris* and both VOC species are known to produce a series of condensable products after photochemical oxidation [Griffin *et al.*, 1999; Hoffmann *et al.*, 1997].

In principle, the atmospheric concentrations of these aerosol forming products are controlled by the actual emission rate of the precursors (which depends on temperature, radiation and biological activity of the plants), the concentration of the oxidizing agents (ozone, OH- and NO₃-radicals) and the mixing conditions above and within the forest. Thus, quantitative estimations on the contribution of biogenic VOC oxidation products to the particle phase relies on reliable measurements of a complex data set of different parameter and compounds. Consequently, emissions studies (branch enclosure technique) and VOC flux measurements using the gradient technique were carried out during the three BIOFOR campaigns. Although it is too early to finalize the results, it appears evident that especially the OH reaction of the biogenic VOCs is connected with the measured particle growth process. Maximum emission rates and fluxes of biogenic VOCs as well as a high photochemical produc-

tion term during daylight conditions are very likely responsible for the observed simultaneous growth of the nucleation mode particles. However, whether the actual nucleation event is also related to low-volatility organics from biogenic origin has yet to be elucidated.

The modeling activities on BIOFOR [e.g., Pirjola, 1999] are being carried out concurrently in close conjunction with field data interpretation. To study aerosol formation, atmospheric chemistry, aerosol processes and meteorology should be combined, as has been done in the present project. Preliminary modeling of nucleation and growth events shows good agreement with experimental data; however, the exact nucleation mechanism remains unclear. The best guess so far is that ternary nucleation of water-ammonia-sulfuric acid is responsible for nucleation, and the condensation growth to detectable sizes is due to condensation of organic vapours. However, the results are very preliminary and more detailed data analysis and modeling activities are ongoing in order to elucidate the primary formation and growth processes.

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Laboratory studies on new particle formation processes induced by hydrocarbon oxidation (NUCVOC)

Contributed by **Thorsten Hoffmann** (hoffmann@isas-dortmund.de), Institute of Spectrochemistry and Applied Spectroscopy, Dortmund, Germany.

Current aerosol climate models focus mainly on sulfur chemistry, especially when considering the formation of new particles in the troposphere. Nucleation events are usually discussed in terms of sulfuric acid nucleation, either as a binary ($\text{H}_2\text{SO}_4/\text{H}_2\text{O}$) or ternary ($\text{H}_2\text{SO}_4/\text{NH}_3/\text{H}_2\text{O}$) system. However, recent aerosol formation studies at rural sites indicate a link between new particle formation and oxidation of volatile organic compounds (VOCs). Measurements of nanometer size particles at the SMEAR station in southern Finland provide an example of particle formation events over boreal pine forests [Mäkelä *et al.*, 1997]. Similar observations have been made in other forested areas in Portugal [Kavouras *et al.*, 1998], Greece [Kavouras *et al.*, 1999], Canada [Leitch *et al.*, 1999] and the US [Marti *et al.*, 1997]. In each case the observation of nucleation events took place in remote forested areas, where the release of highly reactive VOCs from trees followed by a rapid oxidation to less volatile products has to be considered a potential source of nucleating vapors. Unfortunately, the amount of condensable material needed to form nanometer particles is extremely small and the chemical identification of the nucleating species is rather difficult. Therefore, the present project, Nucleation Processes from Oxidation of Biogenic Volatile Organic Compounds (NUCVOC), concentrates on a series of laboratory studies to model the chemical transformation of natural VOCs into condensable species, and to predict their atmospheric fate and relevance in the formation of particulate matter.

The effort to understand particle formation from biogenic VOC oxidation is driven not only by the field observations mentioned above, but also by certain characteristics of this group of hydrocarbons. First, it is well established that terrestrial vegetation releases into the atmosphere a tremendous amount of organic compounds (e.g., isoprene, monoterpenes, sesquiterpenes, oxygen-containing compounds). The large quantities of biogenic VOCs emitted globally in comparison with the release of anthropogenic VOCs stimulated the research into the atmospheric chemistry of these compounds. Secondly, the aerosol formation potential of biogenic VOCs with more than six carbon atoms, as measured in various smog chamber experiments, is generally high and, for specific biogenics, the major fraction of products can convert to the particle phase [Griffin *et al.*, 1999; Hoffmann *et al.*, 1997]. Based on information regarding fractional aerosol yields and on available emission inventories, the global production of secondary organic aerosols (SOA)

from oxidation of natural VOC is estimated to be between 30–270 Tg per year [Andreae and Crutzen, 1997]. Since aerosol formation from biogenic VOC oxidation represents a natural source contributing to the continental background aerosol, knowledge of its contribution to the total particle burden of the troposphere is crucial in order to determine the relative importance of anthropogenic versus natural particle production. The question of whether the oxidation products of VOCs simply add to the tropospheric aerosol mass by condensation on pre-existing particles, or whether they also contribute to the aerosol number concentration by homogeneous nucleation of non-volatile products, has to be answered to evaluate climatic effects of tropospheric aerosols.

The NUCVOC project

Since dozens of precursors are involved in particle formation from VOC oxidation, an experimental approach based on a set of well-defined laboratory studies was chosen to examine the role of low-volatility organics in tropospheric nucleation processes. Likewise, the fact that the production of condensable species from unsaturated VOCs is associated with three major oxidation pathways (ozonolysis, OH, and NO_3 -initiated VOC degradation) favors experiments in reaction chambers. The primary objectives of the NUCVOC project can be summarized as follows:

- Systematic investigation of the particle formation of selected model compounds in laboratory studies (considering oxidation by NO_3 , OH, O_3 reactions)
- Chemical analysis of the organic particle phase, focusing on the non-volatile fraction of biogenic oxidation products
- Development of chemical mechanisms describing the routes to formation of condensable species
- Experimental verification of the nucleating abilities of certain products
- Modeling the particle formation process (homogeneous nucleation, condensation, coagulation, etc.)

Preliminary results

Results to date represent essential steps towards a better understanding of aerosol formation from hydrocarbon oxidation. For example, the application of newly developed analytical methodologies, designed to sample, separate and detect very low volatility compounds, resulted in the identification of numerous individual oxidation products. Gas-phase ozonolysis has been investigated in detail and new products identified, such as multifunctional carboxylic acids, including various dicarboxylic acids [e.g., C_8 - and C_9 -diacids (Fig. 1)] [Christofferson *et al.*, 1998; Glasius *et al.*, 1998; Calogirou

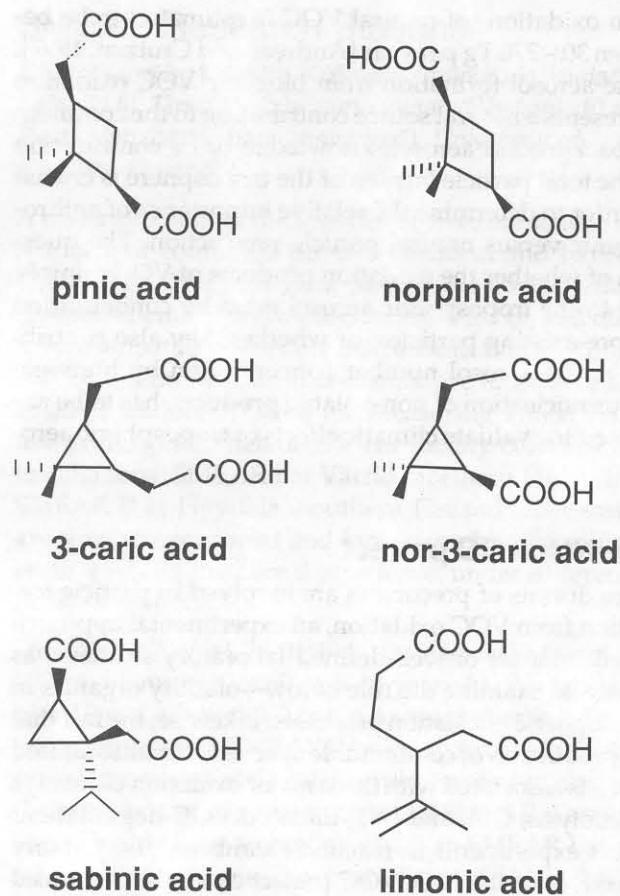


Figure 1. Family of low volatility products formed from the oxidation of α -pinene, β -pinene, d-3-carene, sabinene and d-limonene.

et al., 1999]. These acids were produced from all investigated precursor molecules, a finding recently confirmed by other groups [Yu *et al.*, 1999; Jang and Kamens, 1999]. Degradation mechanisms capable of explaining the formation of carboxylic diacids from the gas phase reaction of biogenic VOCs with ozone have been developed and attempts to estimate their vapor pressure are in progress [Winterhalter *et al.*, 1999]. Due to their low volatility, the diacids are particularly interesting candidates in terms of their ability to form new particles by homogeneous nucleation.

Clearly, formation of condensable vapors such as dicarboxylic acids (described above) is a necessary prerequisite for new particle formation by homogeneous nucleation. However, condensation of existing aerosol products is always in competition with the nucleation of new aerosols. Therefore, the production rate for new particles depends upon the formation rate of condensable vapors, temperature, and characteristics of pre-existing aerosol particles (i.e., their number concentration and size distribution). Furthermore, classical homogeneous nucleation theory assumes a free energy barrier during the initial phase of particle formation, inhibiting the build up of

small clusters in the gas phase. Considering the products observed from the gas phase oxidation of biogenic VOCs, it seems worthwhile to ask if this model accurately describes new particle formation from biogenic systems.

In addition to isolated diacids, remarkably stable diacid adducts (dimers) were identified by on-line and off-line mass spectrometric investigations of biogenic SOA during the NUCVOC laboratory studies [Hoffmann *et al.*, 1998]. This observational evidence supports the theory that particle formation from biogenic VOC oxidation products is best described assuming barrierless nucleation, since the observed biogenic diacid "clusters" are stable (unlike the case of homogeneous nucleation of non-associated molecules). Moreover, mixed dimers were observed to be formed from the primary oxidation products, pointing to a heteromolecular nucleation process. Due to strong intermolecular forces between the C_8 -, C_9 - and C_{10} - carboxylic acids, the initial step in the formation of a new phase, the dimer formation, is strongly influenced, increasing the tendency of such a system to form new particles [Lushnikov and Kulmala, 1998]. Since several products are involved in the nucleation process, high supersaturations with respect to a single compound are no longer necessary, and particle formation can occur even if biogenic precursor concentrations are fairly small. In principle, the subsequent growth process of such dimer embryos could again be driven by intermolecular forces, which retard the loss of added monomers from clusters.

As mentioned above, the occurrence of nucleation in the atmosphere is also dependent upon a variety of conditions such as the number concentration and size distribution of the pre-existing atmospheric aerosol. Nevertheless, fast reacting biogenic VOCs are again suitable potential candidates, since the time scale of the formation of condensable species from these systems might be shorter than the characteristic time scale to reach gas/particle equilibrium, resulting in supersaturated gas phase concentrations [Bowman *et al.*, 1997]. Therefore, heteromolecular homogeneous nucleation of natural VOC oxidation products might provide the basic mechanism in the formation of new terrestrial biogenic particles. However, although progress has been made to understanding the fundamental reactions and products involved in aerosol formation from VOC oxidation, the whole process of new particle production is still poorly understood, primarily due to the large number of gas phase species which can participate and the difficulties of modeling the underlying processes.

Considering the above discussion, there is little doubt that research into new particle formation processes from natural precursors has to be intensified. A key aspect is the connection of the available laboratory data with field observations, such as from PARFORCE and BIOFOR campaigns. This seems especially important because present aerosol climate models ignore organic aerosols and be-

cause pressing scientific questions—e.g., to what extent anthropogenic aerosols counteract radiative forcing by greenhouse gases—can only be answered if the organic aerosol phase, although difficult to measure, is taken into account.

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NUCVOC Consortium

Laboratory Studies On Aerosol Formation

R. Zellner, UGE Essen (NO₃); R. Lesclaux, UBI Bordeaux (OH); G. Moortgat, MPG Mainz (O₃).

Chemical Characterization of Organic Aerosols

T. Hoffmann, ISAS Dortmund; B. Larsen, D. Kotzias, JRC Ispra; G. Moortgat, MPG Mainz.

Experimental Nucleation Studies

P. Mirabel, CNRS Strasbourg.

Modeling

P. Mirabel, CNRS Strasbourg (Nucleation & Aerosol Formation); M. Jenkin, AEAT Oxon (Chemical Modeling).

SMEAR Research Stations

Contributed by **Markku Kulmala** (markku.kulmala@helsinki.fi), **Timo Vesala** (timo.vesala@helsinki.fi) and **Pertti Hari** (pertte.hari@helsinki.fi), University of Helsinki, Finland.

A major problem in the analysis of environmental issues is a lack of combined physico-chemical and biological knowledge. Practical examples of the combination of physico-chemical and biological knowledge, and utilization of versatile up-to-date instrumentation for continuous long-term field measurements, are illustrated at the SMEAR stations (Station for Measuring Forest Ecosystem-Atmosphere Relations). The facility comprises two installations: SMEAR I at Värriö (northern Finland) and SMEAR II at Hyytiälä (southern Finland). The stations are similarly equipped and form a combined facility operating within the boreal pine forest under different climatic conditions.

SMEAR I (67°46'N, 29°35'E) is situated at the top of a hill (400 m above sea level) in a 40-year old, 7m tall Scotch pine (*Pinus sylvestris* L.) in the Arctic timberline. The station complements SMEAR II by being situated under different (more arctic) climatic conditions but representing the same boreal vegetation type. All SMEAR II activities (described below) are not available in SMEAR I; during intensive campaigns, however, many of SMEAR II's atmospheric and tree measurement facilities can be made available at SMEAR I. The different arctic conditions cause additional challenges to the arrangement of measurements.

The main emphasis at SMEAR I is on interactions between trees and atmosphere, air quality and aerosols [e.g., Ahonen *et al.*, 1997]. Information on air quality as influenced by the Kola industrial areas (located less than 200 km away) and on the effects on photosynthesis in sub-arctic conditions is also obtained. Practically no sources of pollutants exist close to the station; however, regularly occurring episodes of heavy sulfur dioxide and aerosol pollution are observed when winds are northeasterly.

SMEAR II is located in a rather homogenous Scotch pine stand on a flat terrain at Hyytiälä Forestry Field Station, University of Helsinki (61°51'N, 24°17'E, 181 m above sea level), 220 km northwest of Helsinki. The most homogeneous fetch covers 1200 m x 600 m (60°) and the homogeneous fetch in the prevailing wind direction is 250 m x 200 m. The natural managed stand was established in 1962 by sowing after the area had been treated with prescribed burning and light soil preparation. Besides Scotch pine, the stand consists of only 1% other species. The mean height of the trees is 12 m, the mean diameter at chest level is 13 cm, and the projected leaf area is 3 m² (8 m² in the case of total area) per unit area of soil. The zero-plane displacement is about 6 m and the roughness length is 0.8 m. The wood biomass is 45 t ha⁻¹ and the tree density is 2500 ha⁻¹. Nitrogen leaf content is 1.3%. The soil material is sandy and coarse silty glacial till. The region's annual average mean temperature is 3.0°C and the annual mean precipitation is 690 mm. The air quality at the site represents typical background conditions.

SMEAR II

Station for Measuring Forest Ecosystem - Atmosphere Relations
University of Helsinki, Forestry Field Station Hyytiälä

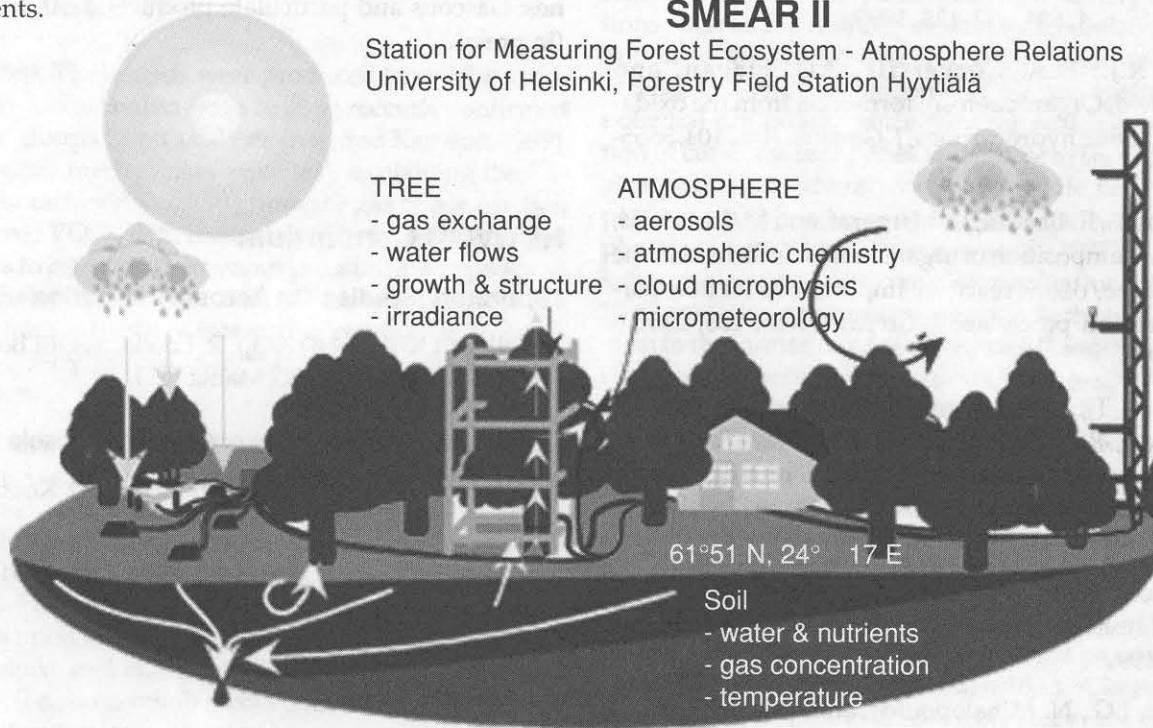


Figure 1. Overview of the SMEAR II station and the measurements carried out there [<http://honeybee.helsinki.fi/HYYTIALA/smear>].

The SMEAR II facility is designed to determine material and energy flows in the atmosphere-vegetation-soil continuum at different temporal and spatial scales (Figure 1). It can be divided into four operational blocks: i) atmospheric measurements accomplished using a 72 m mast, ii) tree measurements performed using a 15 m tower, iii) soil measurements carried out on two catchment (watershed with weir) areas, and iv) aerosol measurements from 2 m above the ground. The station includes some outstanding instrumentation [Vesala *et al.*, 1998] for measurements of aerosol particle size distribution in the size range of 3-500 nm, vertical flux of aerosol particles of diameters down to 12 nm, exchange of trace gases on shoot-scale and soil surface at intervals of 1 minute, spatial distribution of irradiance by 800 sensors in the vicinity of a shoot, spatial distribution of irradiance with 200 sensors within the canopy, and two soil catchment areas (890 and 300 m²) for soil water, dissolved ions and organic carbon balances. SMEAR II is part of the global FLUXNET project [Kaiser, 1998], and international measurement campaigns are frequently organized at the station. FLUXNET is an investigation of the carbon cycle of terrestrial ecosystems using the eddy-covariance technique by which the net ecosystem exchange can be estimated. Figure 2 presents the daily CO₂ exchange time series measured at SMEAR II [see also Rannik, 1998]. The daily sums are calculated only for days when no more than an hour of data is missing. Therefore, in addition to longer gaps, there are also gaps of shorter duration. Negative fluxes correspond to uptake of CO₂ by the forest. This boreal forest acts as a sink for CO₂ during the summer (May-September) and a rather significant source in winter.

The objectives of the atmospheric measurements done from the mast are i) to determine the exchange rates of CO₂ and H₂O (latent heat), as well as deposition or emission rates of SO₂, NO_x and O₃ at the stand scale, ii) to determine the sensible heat flux, iii) to determine the concentrations of trace gases, iv) to give information on meteorological conditions (including radiation), and v) to detect episodes of low-level clouds and conditions within them.

The objectives of the tree measurements are i) to determine the exchange rates of CO₂ and H₂O as well as the deposition or emission rates of SO₂, NO_x and O₃ at the shoot scale, ii) to determine the accurate photosynthetic light response, iii) to determine the sap flow rate, and iv) to link the tree structure to functions and growth. The canopy PAR distribution measurements are aimed at i) determining light variations at small spatial and short temporal scales, and ii) supporting the scaling procedure from photosynthesis and transpiration rates of shoots to that of the canopy.

The objectives of the soil measurements are i) to analyze water, carbon and nutrient budgets at a stand level, ii) to monitor soil temperatures and determine the soil heat flux, iii) to follow bacterial, fine root and mycorrhizal activities, and iv) to follow soil/soil solution chemical equilibria.

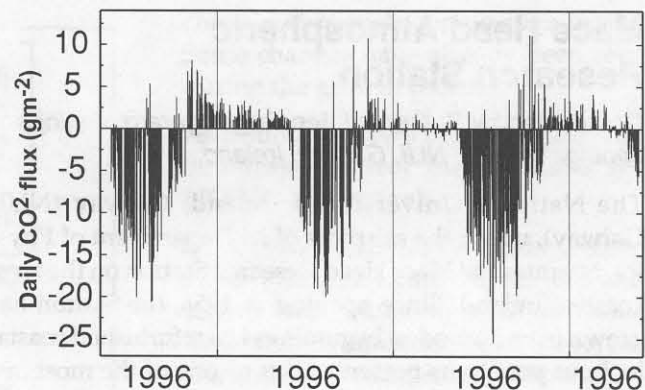


Figure 2. Daily sums of carbon dioxide flux (net ecosystem exchange) for a Scotch pine forest at SMEAR II station [Rannik, unpublished data].

The objectives of aerosol measurements are i) to find out the frequency of the aerosol formation events in the boundary layer, ii) to find out how aerosol size distribution will respond to different meteorological conditions, and iii) to analyze how aerosol dynamics are connected to atmospheric chemistry and biological processes.

In sum, research at SMEAR I and II is focused on continuous measurements using different kinds of data simultaneously. Different data sets support each other effectively [see, e.g., Vesala *et al.*, 1998].

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Mace Head Atmospheric Research Station

Contributed by **S. Gerard Jennings** (*gerard.jennings@nuigalway.ie*), NUI, Galway, Ireland.

The National University of Ireland, Galway (NUI-Galway), under the auspices of its Department of Physics, operates the Mace Head Research Station on the west coast of Ireland. Since opening in 1958, the Station has grown from its modest beginnings in a refurbished coastal lookout post to its present status as one of the most important sites for atmospheric research in the northern hemisphere. Strategically located with open exposure to the North Atlantic Ocean, Mace Head occupies an ideal position for studying changes in the global atmosphere. Its location facilitates the investigation of both natural and man-made trace constituents in marine and continental air masses. Long-term measurement of such substances can detect trends in background concentrations, which may influence our weather and climate.

Key dates in Mace Head's history

- 1958 Renting and refurbishing a coastal lookout post on Mace Head.
- 1973 Purchase of a ruined cottage and seven acres extending to the shore.
- 1985 Refurbishment of the cottage by the University as a laboratory.
- 1987 Commencement of continuous measurements by international groups, such as CFC gases in the

Global Atmospheric Gases Experiment (GAGE).

1988 Expansion for the US-based Atmosphere-Ocean Chemistry Experiment (AEROCE) and construction of first shore laboratory and sampling tower.

1990 Enlargement of the cottage and construction of second laboratory near the shore.

The station is overseen by a Management Committee drawn from NUI's Atmospheric Research Group, Department of Physics, which carries out research with the help of research assistants, postgraduate students and post-doctoral researchers. Throughout the year, many scientists visit the station for long-term measurement campaigns, shorter-term projects, and international workshops. Research performed at Mace Head is documented widely in the international scientific literature.

International dimension

Atmospheric pollution is a complex problem that transcends national boundaries, thus research into its causes requires international collaboration and a sharing of resources and expertise. Mace Head is recognised worldwide as a key location in the study of climate change. Its facilities have been used by scientists from over one hundred universities and institutions in twenty countries. It is central to a number of international research networks and is a baseline station for the Global Atmosphere Watch of the World Meteorological Organization since 1994. It is an important point of contact between European and American scientists and has achieved a high profile in atmospheric research.

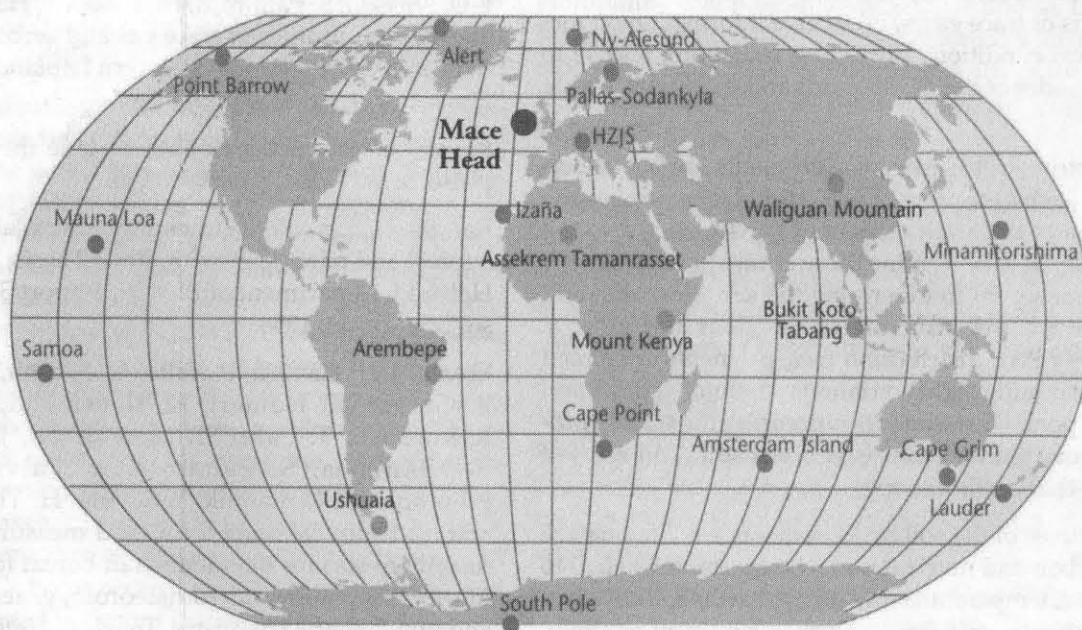


Figure 1: World map of Global Atmosphere Watch (GAW) baseline stations with the location of Mace Head highlighted.

Atmospheric research at Mace Head

Research activities at Mace Head have been mainly concerned with measurements of Northern Hemisphere background levels of trace substances in air from the Atlantic Ocean. Sources and sinks of these substances and the complex biogeochemical processes which they undergo in the atmosphere are investigated.

- Since 1987, Mace Head has been one of five international sites studying the life cycles of chlorofluorocarbon (CFC) gases as part of the Advanced Global Atmospheric Gases Experiment (AGAGE) [Simmonds *et al.*, 1996].
- Since 1987, Mace Head has been one of four primary sites participating in the Atmosphere Ocean Chemistry Experiment (AEROCE) to study biogeochemical cycles in the North Atlantic Ocean, which forms part of the North Atlantic Regional Experiment (NARE). AEROCE is funded by the US National Science Foundation and involves several US university and governmental institutions [Prospero, 1997].
- In 1994 and 1995, NUI-Galway coordinated a EU-funded project to assess the Background Maritime Contribution to Atmospheric Pollution in Europe (BMCAPE), which involved six sites along Europe's Atlantic coast, including Mace Head.
- In 1996 and 1997, Mace Head was chosen as the primary measuring site for Atmospheric Chemistry Studies in the Marine Environment (ACSOE), led by the University of East Anglia [Broadgate *et al.*, 1998].
- Since 1987, Mace Head has been part of the European Tropospheric Ozone Research (TOR) network and still contributes to European and American studies of ground level ozone concentrations [Simmonds *et al.*, 1997].
- Since 1989, extensive studies of heavy metals in the atmosphere, including elemental mercury, have been undertaken under the auspices of an Irish-German collaboration. In 1995, the first international workshop for field intercomparison of measurement techniques for mercury in air and precipitation brought together participants from 12 European and North American laboratories [Ebinghaus *et al.*, 1999].
- Ongoing studies of methane and carbon dioxide (since 1992) include the collection of flask samples which are analysed for isotopic constitution to try to identify their origin from fossil fuels or more recent organic processes [Bousquet *et al.*, 1997].
- Since the late 1980s, a NOAA collaborative trace gas (CO₂ and isotopes) long-term flask sampling program has been in operation at Mace Head.
- From 1998-2000, Mace Head has been the host loca-

tion for the EU-funded program, New Particle Formation and Fate in the Coastal Environment (PARFORCE), bringing with it continuous measurements of ultrafine particle characteristics.

Atmospheric research activities

NUI-Galway scientists have specialized in the study of particulate matter in the atmosphere including the very small Aitken or condensation nuclei (CN) formed by combustion processes and gaseous reactions, the larger particles or cloud condensation nuclei (CCN) on which cloud droplets form, black carbon/soot, and aerosol particles of organic origin.

Research activities at Mace Head are divided into the following main areas:

Microphysical and physico-chemical properties of atmospheric aerosols

A wide range of aerosol particle sizing and mass measurement equipment is used to study the microphysical and physico-chemical properties of atmospheric aerosols at Mace Head. Begun in 1987, this work is in collaboration with the US NSF-funded Air Ocean Chemistry Experiment (AEROCE), which has had its primary eastern Atlantic site located at Mace Head from 1988-1994 to study biogeochemical cycles in the North Atlantic.

Research includes studies of aerosol particle size and mass distribution [Jennings *et al.*, 1991]. While aerosol volatility at Mace Head was first reported by Jennings and O'Dowd [1990], more emphasis was then placed on extension of the technique to the inference of sea-salt particles. More recent work [Jennings *et al.*, 1997a] has included number concentration of inferred aerosol chemical constituents including elemental carbon [Jennings *et al.*, 1994].

Nucleation of atmospheric particles in the coastal environment

Rapid particle nucleation events are being studied under a wide variety of conditions at Mace Head. The newly funded European Union Environment and Climate Program, "New Particle Formation and Fate in the Coastal Environment" (PARFORCE), investigates the processes which control and promote new-particle nucleation in the marine boundary layer. Nucleation of new, ultrafine aerosol particles has been observed in the clean marine coastal environment under a variety of conditions at Mace Head [O'Dowd *et al.*, 1998]. These nucleation events were observed to occur almost daily, lasting up to several hours, and were found to be linked to the occurrence of low tides. Peak particle concentrations achieved during these clean-air nucleation events can approach 1,000,000 cm⁻³.

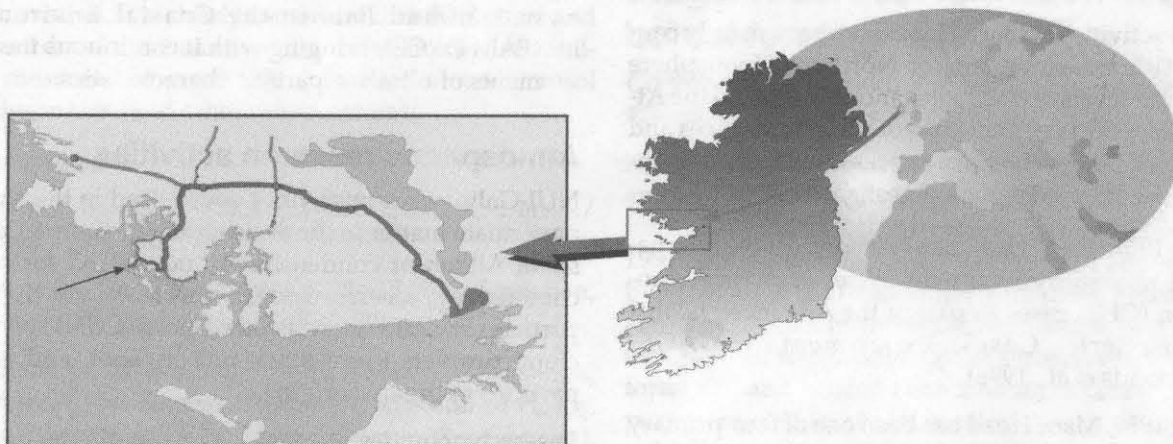


Figure 2: Close-up view of Mace Head location and coastal features.

Cloud condensation nuclei (CCN) measurements

Long-term measurement of cloud condensation nuclei (CCN)—which have as yet an un-quantified influence on the radiative properties of cloud, and hence on global climate—have been ongoing at Mace Head since January 1994. The station's CCN counter was manufactured by DH Associates (model M1) and compares well (within 15%) to a CSIRO custom built counter [Gras *et al.*, 1996]. Air mass and meteorological effects on the CCN population are being studied. Recent work has found evidence for enhanced CCN concentrations with increasing wind speed [Jennings *et al.*, 1997b].

Aerosol radiative properties

Field research at Mace Head is also directed to the measurement of black carbon absorption (and mass concentration), ongoing since 1989 [Jennings *et al.*, 1993; Cooke *et al.*, 1997]. Seasonal and air mass influence on black carbon levels are being investigated. Measurements of aerosol scattering coefficients were recently (January 1997) initiated at Mace Head. This permits the determination of aerosol single scattering albedo. The direct measurement of particulate mass concentration for particle diameter $<2.5 \mu\text{m}$ ($\text{PM}_{2.5}$) allows the determination of the mass scattering efficiency, a .

Trace gases research at Mace Head

Since 1987, continuous measurements of chlorofluorocarbons (CFC's)—CFC-11, CFC-12, CH_3CCl_3 , CFC-113, as well as CCl_4 , CH_4 , N_2O , CO , and O_3 —have been made at Mace Head as part of the Global Atmospheric Gases Experiment (GAGE) [Simmonds *et al.*, 1997]. The GAGE program was superseded in 1995 by Advanced GAGE (AGAGE). T.G. Spain has been maintaining the operation of the GAGE and AGAGE research program at Mace Head. Measurement of CFC substitutes—HFC's and

HCFC's—by an automated gas chromatograph-mass spectrometer was initiated in 1995. In addition, a flask sampling network for CH_4 isotope measurements has been undertaken by NUI-Galway and other EU participants [Nisbet *et al.*, 1998].

Since 1992 a collaborative CO_2 measurement program has been underway with CNRS, Gif sur Yvette, France and the University of Bristol [Biraud *et al.*, 1999]. The work has been extended to include radon and CO_2 isotope measurements under the EU ESCOBA research project.

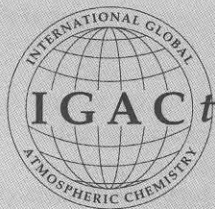
Additional Research Programs and supporting activities

- Intensive field research at Mace Head has included the UK Community Research Programme of the Natural Environment Research Council: Atmospheric Chemistry Studies in the Oceanic Environment (ACSOE) which centred its ground based measurements at the station over the periods June–August 1996 and April–May 1997 for two of its consortia: OXICOA (OXidizing Capacity of the Ocean Atmosphere) and MAGE (Marine Aerosol and Gas Exchange).
- In September 1995, Mace Head was host to the first international workshop, involving some 12 laboratories from North America and Europe, for the field intercomparison of measurement techniques for atmospheric mercury species in ambient air and precipitation. Since then, continuous total gaseous mercury measurements have been taken at Mace Head as a function of air mass and meteorological conditions and are being analysed.

More details on the Mace Head Station and its research activities may be found on the web site (<http://macehead.physics.nuigalway.ie>).

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IGAC *tivities* Newsletter

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Tel: (+1-617) 253-9887, Fax: (+1-617) 253-9886, Email: igac@mit.edu,
WWW: <http://web.mit.edu/igac/www/>



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Announcements

International Ozone Symposium

21-22 October 1999, Basle, Switzerland

- Ozone in the Stratosphere and Troposphere
- Ozone Generation
- Ozone in Water
(Oxidation and Disinfection Processes)
- Ozone and living Organisms
(Toxicology, Agriculture, Medical Applications)

For more information, please contact:
International Ozone Association
"Schönbein Jubiläum"
c/o Wasserversorgung Zürich
Hardhof 9, Postfach
CH 8023 Zürich
SWITZERLAND

Tel: (+ 41) 1 435 22 12; Fax: (+ 41) 1 435 25 57
E-mail: ioa@swissonline.ch

7th IGAC Scientific Conference

January 2001, Bangkok, Thailand

For information, please contact:
Professor Jariya Boonjawat
Institute of Environmental Research
Chulalongkorn University, Phayathai Road
Bangkok 10330
THAILAND

Fax: (+66-2) 255-4967
E-mail: jariya@start.or.th

Further details will appear in the next issue of IGAC*tivities*.

Second General Assembly of the WCRP project on STRATOSPHERIC PROCESSES AND THEIR ROLE IN CLIMATE (SPARC)



6-10 November 2000
Mar del Plata, Argentina

<http://www.sparc2000.at.fcen.uba.ar/>
E-mail: sparc2000@at1.fcen.uba.ar
Telephone / Fax : 54 (0) 11 4373 0552

**Deadline for submission of abstracts:
30 April 2000**

Scientific Program

The second General Assembly of the SPARC project will review current research on the role of the stratosphere in the climate system and in global change. The four sessions will be on the following themes:

- Stratospheric processes and their role in climate;
- Stratospheric indicators of climate change;
- Modeling and diagnosis of stratospheric effects on climate;
- UV observations and modeling.

Conveners

Alan O'Neill (Chair), S. Diaz, R. McKenzie,
V. Ramaswamy, T. Shepherd, S. Yoden

Invited Speakers

P. Crutzen, A. Bias, G. Brasseur(*), M. Chipperfield, J. Haigh,
J. Herman, P. Haynes, D. Karoly, T. Peter, W. Randel,
A.R. Ravishankara, G. Seckmeyer, D. Shindell, T. Tsuda,
J.M. Wallace. (* confirmation pending)

SPARC Office

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Surface Ocean Lower Atmosphere Study:

SOLAS Open Science Conference

20-24 February 2000

Damp, Schleswig-Holstein, Germany

SOLAS is a potential new interdisciplinary research project, sponsored by SCOR and IGBP. A Planning Committee has been appointed by IGBP and SCOR, and includes representatives from JGOFS, IGAC, GLOBEC, CACGP, and WCRP.

The focus is the interaction between the atmosphere, climate, and marine biogeochemical processes. SOLAS would build extensively on the work of other projects and programmes, principally IGAC, JGOFS, and WOCE, and would also be closely linked to CLIVAR. Its uniqueness would be the bringing together of atmospheric and marine researchers, together with the biogeochemical and physical communities.

Further information can be found at the SOLAS website (<http://www.ifm.uni-kiel.de/ch/solas/main.html>).

The conference will be hosted by the Institut für Meereskunde in Kiel, Germany, and will be held in Damp on the Baltic coast just north of Kiel. The meeting will start on Sunday morning, 20 February 2000 and finish at midday on Thursday, 24 February. We are endeavouring to raise some funds to help support costs for selected participants at the meeting. We are also hoping to support the attendance of younger scientists, as well as those from developing countries.

Enquiries about the conference or registration procedure can be directed towards the local host for the SOLAS Open Science Meeting, atsolas@ifm.uni-kiel.de.

The registration materials and conference information can also be downloaded from the SOLAS web-site. Please share this message with any colleagues who you believe would be interested in attending the conference.

Sincerely yours,

R.A. Duce (rduce@ocean.tamu.edu)

P.S. Liss (p.liss@uea.ac.uk)

Co-Chairs SOLAS Planning Committee

JGOFS 2nd Open Science Conference

"Ocean Biogeochemistry: A New Paradigm"

April 13-17, 2000, Bergen, Norway

Focused on the challenges of the JGOFS Synthesis and Modeling phase, this conference is an opportunity for scientists involved in observational and modeling activities to present and discuss the results of JGOFS' 10-year field program to the broader ocean, atmosphere and terrestrial science communities.

JGOFS INTERNATIONAL PROJECT OFFICE
Centre for Studies of Environment and Resources

University of Bergen

High-Technology Centre, Ltd.

N-5020 Bergen

NORWAY

Further information can be found at the JGOFS website:
<http://ads.smr.uib.no/jgofs/conference.htm>

Global Wetlands and Greenhouse Gases

INTECOL VI International Wetland Conference
Quebec 2000: Millenium Wetland Event

Co-chairs:

Donald D. Adams

Center for Earth and Environmental Science

State University of New York

Plattsburgh, New York, U.S.A. 12901

Tel: (518) 564-2028 Fax: (518) 564-3152

Donald.Adams@plattsburgh.edu

Bernhard Wehrli

Limnological Research Center, EAWAG/ETH

CH-6047 Kastanienbaum, Switzerland

Tel: 41-41-3492117 Fax: 41-41-3492168

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