WGSF

Newsletter
of the WCRP Working Group
on Surface Fluxes

WCRP

FLUX NEWS

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ICSU International Council for Science

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Welcome to the first WGSF Newsletter!

After several months of preparation, we are finally able to present the first issue of ***FLUX News***. It is envisaged as a biannual publication of the Working Group on Surface Fluxes (WGSF) of the World Climate Research Programme (WCRP) for communicating new surface-flux results, issues, requirements and related events throughout the WCRP and wider research communities.

WGSF has already functioned for 2 years, assisting the other WCRP programmes (CLIVAR[1], GEWEX[2], CLIC[3], and SPARC[4]) and two other Working Groups (WGNE[5] and WGCM[6]) in the areas of parameterization of energy exchanges between the ocean and the atmosphere, quantitative estimation of air-sea energy fluxes and the global and regional flux field production.

Moreover, the Working Group on Surface Fluxes is expected to build a bridge between WCRP and the International Geosphere-Biosphere Programme (IGBP), primarily through communication with the interdisciplinary SOLAS[7] programme (addressed in detail in C. Fairall's article).

Surface fluxes stand also as an essential component of the Coordinated Observation and Prediction of the Earth System (COPES) — the WCRP strategic framework for 2005—2015. In this respect the WGSF coordinates its activities with COPES through the JSC modelling and observational panels.

The Working Group on Surface Fluxes (WGSF) was established in 2004 by the JSC World Climate Research Programme (WCRP) to deal with air-sea energy and mass exchanges. It aims to address all the requirements of research, observations, analysis and modeling of surface fluxes across the WCRP.

Consequently, a very wide range of topics becomes relevant to ***FLUX News***. Hence, we will be very glad to receive contributions, be they new articles on 'hot' results and ideas, information on field activities, model experiments or cooperation with other WCRP and IGBP programmes. Similarly to GEWEX News and CLIVAR Exchanges, we would like, in the future, to publish topical issues, covering particular aspects of air-sea flux science. There is no peer reviewing procedure of contributions and the editors (S. Gulev and C. Fairall) take responsibility for editorial procedure and acceptance of the coming materials.

WGSF, like the other WCRP Working Groups, but not quite like its programmes (CLIVAR and GEWEX), operates without funding for office or editorial staff. Despite this we will strive to maintain ***FLUX News*** as a board of communication for the flux community.

We invite all the interested scientists around the world to cooperate with us and make this newsletter a long-lasting, reputable and valuable source of information. For our part, we will do our best to achieve this goal.

Sergey Gulev, WCRP Liaison with WGSF
Chris Fairall, WGSF Chair

1 Climate Variability and Predictability Programme
2 Global Energy and Water Cycle Experiment
3 Climate and Cryosphere Project
4 Stratospheric Processes And their Role in Climate
5 Working Group on Numerical Experimentation
6 Working Group on Coupled Models
7 Surface Ocean–Lower Atmosphere Study

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Foreword

David Carson,
WCRP Director in 2000—2005,
and
Peter Lemke,
Chairman of the JSC for WCRP

With great pleasure, we welcome and introduce this first issue of the FLUX Newsletter. Fluxes between the atmosphere and the surface of the Earth (ocean, ice and land, including vegetation) represent the interactions within the climate and wider Earth system. Determination and understanding of their variability are prime concerns of climate research and, therefore, of the World Climate Research Programme (WCRP).

The WCRP Working Group on Surface Fluxes (WGSF) was formed in 2004 under the Chairmanship of Dr Chris Fairall, NOAA Environmental Technology Laboratory, Boulder, Colorado, USA. This is a direct follow-up to the earlier joint SCOR/WCRP Working Group on Air-Sea Fluxes (WGASF), which had been co-chaired by Drs Peter K Taylor and Sergey Gulev and which had produced a comprehensive and authoritative assessment of the state of the art in 2000 with regard to air-sea flux determination (published in the WCRP report series, WCRP-112, Intercomparison and Validation of Ocean-Atmosphere Energy Flux Fields). This report has proved to be very useful and has been widely appreciated. The WGASF subsequently organized a major workshop (Washington, DC, May 2001) bringing together the different scientific communities interested in air-sea fluxes to review its report and to consider what still needed to be done to determine surface fluxes more accurately. The full report of that workshop, including all the main findings, conclusions and recommendations, and extended abstracts of the presentations was published as WCRP-115, Intercomparison and Validation of Ocean-Atmosphere Flux Fields.

The WGASF came to the end of its mandate following the Washington workshop. However, its evaluation of existing flux fields identified significant gaps in our knowledge including, the lack of closure for global- and regional-scale energy balances, large regional biases in flux components, details of seasonal and interannual variability of fluxes, and inherent error characteristics. At the same time, the Joint Scientific Committee (JSC) for the WCRP decided that the WCRP should become a co-sponsor, with IGBP, SCOR[1] and CACGP[2], of the Surface Ocean — Lower Atmosphere Study (SOLAS). The net result was the establishment of the new WCRP WGSF with the general challenging remit to address all the requirements of research, observations, analysis and modelling of surface fluxes across WCRP, taking account of WCRP's interests in closely related programmes (e.g. GCOS[3], GOOS[4], GODAE[5]).

Building on the earlier excellent work of the WGASF, the WGSF is focusing initially on air-sea fluxes but, in support of the wider need throughout the WCRP, the intention is that attention should also be given in due course to the interactions between the atmosphere and all types of land surface and with sea-ice. An initial task for the WGSF is to conduct with SOLAS a major review of biogeochemical fluxes at the ocean surface. Another immediate challenge is to develop a close working relationship with the modelling components of the WCRP so as to understand better the

1 Scientific Committee on Oceanic Research
2 Commission on Atmospheric Chemistry and Global Pollution.
3 Global Climate Observing System
4 Global Ocean Observing System
5 Global Ocean Data Assimilation Experiment

modellers' needs and uses of surface flux measurements and how these relate to modelled surface fluxes.

Quantitative analysis and understanding of the underlying physical mechanisms as well as intercomparison and validation of surface energy, momentum and mass fluxes are needed in a wide range of WCRP projects. The new strategic framework for WCRP for 2005—2015, called Coordinated Observation and Prediction of the Earth System (COPES) seeks, amongst other things, to provide the unifying context and agenda for the wide range of climate science coordinated by, and performed through, WCRP projects and activities and for demonstrating their relevance to society. The WCRP-wide role that has been asked of the WGSF to review and coordinate requirements and efforts on all relevant fluxes resulting from the interaction of the atmosphere with all types of underlying surface is fully compatible with the rationale and spirit of COPES. In that context, the new FLUX Newsletter has a very important role to play in communicating new surface-flux results, issues, requirements and related events throughout the WCRP and wider research communities in a clear and timely fashion.

We are therefore delighted to help launch this first issue of the WCRP FLUX Newsletter and look forward to future editions.

Call for contributions:
We would like to invite the sea-air flux community to submit papers to FLUX News for Issue 2. It will focus primarily on co-operation with the SOLAS programme.
The deadline for this issue will be 30 April 2006.

WGSF: A BRIEF HISTORY AND THE OPENING MEETING IN HALIFAX

Chris Fairall, WGSF Chair

1. Background. At its 24th meeting, held in Reading, UK, in March 2003, the WMO JSC for WCRP decided to establish a new working group on surface fluxes. This working group is a follow-up to a limited-life SCOR/WCRP WorkingGroup on Air-Sea Fluxes (WGASF) previously chaired by Dr Peter Taylor (Southhampton Oceanography Centre, UK) and Dr Sergey Gulev (Shirshov Institute of Oceanology, Russia). The website located at http://www.soc.soton.ac.uk/JRD/MET/WGASF contains detail from the WGASF. The new working group is charged with reviewing and coordinating requirements of the various WCRP programs for air-sea fluxes (initially) and air-land fluxes (in a few years), promoting research in air-sea fluxes, and facilitating communication of research advances. The terms of reference for the WG were drafted and approved by the JSC session in Reading:

Terms of reference of the WCRP Working Group on Surface Fluxes

- ***to review the requirements of the different WCRP programmes for air-sea fluxes;***
- ***to develop communication and co-ordination between the research initiatives of WCRP and IGBP on air sea-fluxes;***
- ***to encourage research and operational activities aimed at improving the knowledge of air-sea fluxes;***
- ***to keep the scientific community and the JSC informed of progress achieved through regular reports, World Wide Web, and as necessary, scientific workshops.***

Specific objectives that fall within the purview of the WG include: developing flux data sets available from different sources (in-situ, remotely sensed, NWP[1]-based); improving measurement technologies, parameterizations and flux field production algorithms; and assessments of sensitivity of climate models and limits of predictability associated with uncertainties in surface fluxes. The WGSF will also serve as a bridge between WCRP and the Surface Ocean — Lower Atmosphere Study (SOLAS) of the International Geosphere-Biosphere Programme (IGBP), Scientific Committee on Oceanic Research (SCOR), Commission on Atmospheric Chemistry and Global Pollution (CACGP) and WCRP. A powerpoint file that gives more background can be obtained from the reports link at http://www.etl.noaa.gov/et6/wgsf/.

2. Starting the WG. Following my appointment as the WGSF chair in mid-2003, I began working with Drs Taylor, Gulev, and Ryabinin (Joint Planning Staff WCRP) to get the WG up and running. Initial tasks for the WG involved organizational issues: websites, communication issues, a WG meeting, etc. Our first steps were to open communications with the various WCRP projects and working groups, to initiate direct contact with SOLAS, and to populate the WG with members. To get a flavour for WCRP project activities, in October 2003 I attended

[1] Numerical weather prediction

The WG now has a full complement of 14 members plus the chairman:

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Ex Officio	Peter Taylor, SOC	UK	Peter.K.Taylor@soc.soton.ac.uk
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GCM/NWP	Andreas Sterl, KNMI	Holland	andreas.sterl@knmi.nl
Buoys	Bob Weller, WHOI	USA	rweller@whoi.edu
VOS/GLOBAL	Elizabeth Kent, NOC	UK	eck@noc.soton.ac.uk
Ice/Snow	Ed Andreas, CRREL	USA	Edgar.L.Andreas@erdc.usace.army.mil
Precipitation	Frank Bradley, CSIRO	Australia	Frank.Bradley@csiro.au
Satellite	Abderrahim Bentamy, IFREMER	France	abderrahim.bentamy@ifremer.fr
Ocean/Assimilation	Bernard Barnier, LEGI	France	bernard.barnier@hmg.inpg.fr
Data Base	Shawn Smith, FSU	USA	smith@coaps.fsu.edu
Waves	Will Drennan, U Mia	USA	wdrennan@rsmas.miami.edu
Gas fluxes	Wade McGillis, Colombia U.	USA	wrm2102@columbia.edu
Ocean microphys.	Christoph Garbe, U. Heidelberg	Germany	christoph.garbe@iwr.uni-heidelberg.de
Aerosol production	Gerritt DeLeuw, TNO	Holland	deleeuw@fel.tno.nl

the ACYS/CliC Joint Panel Meeting in Victoria, BC. In early December a letter introducing the WG was sent to chairs of other WCRP enterprises. A separate letter was sent to SOLAS Scientific Steering Group Chair Prof. Peter Liss to open dialogue with SOLAS.

Cooperation with SOLAS is a major priority for the WG. The first step here was to set up some joint memberships. Dr Wade McGillis (Chair of the Implementation Group for SOLAS Focus 2, which is where most of the overlap in input between SOLAS and the WGSF occurs), Christoph Garbe, and Gerritt DeLeuw were appointed as members of WGSF.

3. Halifax Meeting in October 2004. The principal activity of the WG in 2004 was the convening of its first meeting. This meeting was held on the two days (11—12 October 2004) prior to the International SOLAS Science Conference (13—16 October 2004) in Halifax, Canada. The meeting was attended by all members (except A. Sterl, who was not a member in October) plus JSC liaisons Ken Denman and Sergey Gulev. In addition, the meeting was attended by a number of SOLAS representatives: Peter Liss (SOLAS Chair), Casey Ryan, Norman Mc Farlane, Daniela Turk, Caroline-Renae Alexander, Allyn Clarke and William Perrie.

A detailed agenda, background materials, a summary, and some 23 presentations made by attendees on specific WG tasks are available at the WGSF website. Various points of action came out of the meeting in Halifax.

3.1. The SURFA Project (on evaluation and intercomparison of global surface flux products of global surface and numerical weather predictions). Bob Weller (WHOI[1], USA) presented results from consultation with the WGNE representative Peter Gleckler (PCMDI[2], Livermore, USA). The original concept for SURFA was deemed too ambitious for the given resources. The plan now is to archive data at PCMDI in the form of monthly averages (and other statistics) from buoys and participating NWP centers (providing those centers adhere to the standards of IPCC AR4). Fluxes and all variables used to derive them will be saved (e.g., air temperature, wind speed, etc). Data from four buoys will be archived.

- *North of Oahu (22 N, 158W)* R. Lukas, University of Hawaii
- *Chilean Stratus (20S, 85W)* R. Weller, WHOI
- *North Atlantic Trade Wind site (15N, 51W)* A. Plueddemann, WHOI
- *Kuroshio Extension (32.3N, 144.5E)* M. Cronin, NOAA PMEL[3]

While the WGSF welcomed the news that SURFA might commence, there was concern that the new plans were overly restricted. The group discussed the possibility of including data from the VOS Climate programme, UK Met Office model output, the IFREMER[4] satellite flux related product, and other sources.

3.2. Review of gas and particle transfer parameterizations. After some discussion, it was decided that a formal symposium on this topic was unnecessary. The topics will be carefully researched and the results will

1 Woods Hole Oceanographic Institution
2 Program for Climate Model Diagnosis and Intercomparison
3 Pacific Marine Environmental Laboratory
4 L'Institut Francais de Recherche pour l'Exploitation de la Mer

appear in the form of two review articles submitted to Reviews of Geophysics (or some other appropriate journal): gas transfer — lead author Wade McGillis; particle transfer — lead author Gerrit De Leeuw. The gas transfer publication will include a short section on comparisons of standard meteorological air-sea flux routines (principally taken from the literature) to evaluate their accuracy. The WG will also compile a toolbox of computer routines for bulk flux calculations that will reside on the WGSF website for the SOLAS/WCRP community.

3.3. Handbook on best practices of ship/buoy flux measurements. Frank Bradley has produced a detailed outline for a handbook intended for operators and users of data systems on research vessels (outgrowth of the SAMOS project[1]). This handbook is intended for data acquired for bulk turbulent flux methods. Bradley and Fairall will work on the document and will distribute chapters to selected members of the WG for their input.

3.4. Radiative fluxes. It was noted that radiative fluxes might offer the most potential for improvements in the near term. ICOADS-based products do not use radiative measurements but estimate the radiation from measurements of temperature, humidity, and cloud cover. They typically use quite crude parameterizations which do not account for the cloud types, but only for the total cloud cover. Also, present seagoing flux instruments are not usually pitch/roll stabilized and do not use the most accurate methods (i.e., suntrackers and diffuse radiation sensors) now in service in the ARM program and BSRN[2]. The WG sees the need for evaluating present buoy and ship measurement methods against a BSRN standard (perhaps a site on an offshore platform) and developing a seagoing radiative flux standard for a research vessel. Rolf Phillipona will investigate BSRN connection. A review of the accuracy of present indirect models needs to be done. Also, a review of the present state-of-the-art in specifying the emissivity and albedo of the ocean is needed. As the SAMOS project comes on line, the data base of radiative flux measurements at sea will be greatly increased.

3.5. Flux products. Because of the urgent needs of the ocean reanalysis and assimilation community, the WGSF addressed at length the issue of flux products, their accuracy, and the possible creation of an optimal blended product. A great deal of work was done and reported on by the original SCOR/WCRP WGSF (in fact that was their charge). The WGSF is considering an update of that report but it was decided that more is required. Because different products cannot be optimally blended without knowledge of their properties, it is clear that biases and error-covariance properties for the flux components of each product are needed. This is a large undertaking that requires a database at least as comprehensive as the SeaFlux project (Curry et al., *Bull. Am. Met. Soc*., **85**, 409—424, 2004) and a lot of resources for careful processing and analysis.

4. WGSF Website. A modest website for the WGSF now resides at NOAA/ETL in Boulder, CO, USA. The URL is http://www.etl.noaa.gov/et6/wgsf/. Most of the material is made available by linking to an ftp site. The site currently contains background information, detailed contact information for the WG members, material from meetings, reports, and a few publications relevant to the WG work. Space is being saved for the a variety of flux measurement materials including the Handbook, computer programs, publications, data sets and links.

5. WG Member Liaisons and Activities. In order to facilitate the effective co-operation of the WGSF with the other WCRP programmes and working groups it has been decided to appoint some of WGSF members to be liaison persons for these programmes. These WGSF members will provide feedbacks with the programmes that will allow WGSF properly meet the requirements of different WCRP programmes in the surface flux — related areas. The following is a list of present liaison assignments for WG members to WCRP activities: B. Barnier (WCRP Modelling Panel), R. Phillipona (BSRN), B.Weller (CLIVAR), F. Bradley (GEWEX), E. Kent (WCRP Observational Panel) and E. Andreas (CliC).

6. WG Plans. The immediate priorities for the WG are the completion of the flux handbook and the writing and submission of the review articles on parameterizations for gas and particle air-sea transfer. The draft of the handbook titled The Guide to Making Climate Quality Flux Measurements by Frank Bradley and Chris Fairall is still available on the WGSF website for comments by the Group members.

The Review articles are scheduled for submission prior to the 27th JSC meeting in March 2006. The next physical meeting of the WG will probably be the fall of 2006 but until then the members will stay in a close e-mail contact discussing flux product issues. It has also been proposed by Bernard Barnier that the WGSF will organize summer school on fluxes and flux methods within the next 2 years.

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1 The Shipboard Automated Meteorological and Oceanographic System

2 Baseline Surface Radiation Network

The WGSF aspire to meet the requirements of different WCRP Programmes and Working Groups in air-sea interaction. For the first issue of FLUX NEWS we invited Chairs and representatives of CLIVAR Working Group on Seasonal to Interannual Prediction (Tim Stockdale), WGNE (Martin Miller) and CLIC (Vladimir Ryabinin) to express their views on the potentials of co-operation between WGSF and these programmes. We will continue to publish similar views of the representatives of the other WCRP programmes in the next issues.

Surface fluxes for CLIVAR science

Tim Stockdale
The European Centre for Medium range Weather Forecasts
ECMWF, United Kingdom

CLIVAR aims to increase our understanding of and predictive skill for climate variability and climate change on timescales of months to centuries. The main emphasis is on the ocean and on the troposphere, although the role of land surface and the stratosphere as potential drivers of climate variability are very much included.

Interaction between the ocean and atmosphere is key to much of CLIVAR science. The ocean influences the atmosphere via the sea surface temperature (SST) and the surface roughness created by the surface waves. The ocean is driven primarily by the surface stress applied by the atmosphere. The atmosphere is also a source of mixing energy and heat fluxes which affect the structure of the ocean mixed layer and the evolution of SST, and of freshwater fluxes which are important across a range of timescales.

Much CLIVAR science can be done with the quality of data which presently exists. Observational and reanalysis datasets are generally sufficient to describe the interannual variability of SST and, at least to first order, the variations in winds which help to drive them. Nonetheless, there is a real desire for better surface flux related data for at least two important areas: the initialization of forecast models, and the improvement of models, both for forecasting and for scientific studies.

Coupled ocean-atmosphere forecasts for monthly timescales and beyond depend critically on the quality of the oceanic initial conditions. These are typically created by driving an ocean model with specified surface fluxes, while relaxing the surface temperature to an analysed SST product, and assimilating sub-surface temperature and salinity observations. Even with today's ocean observing system, the forcing fields are important, and for creating ocean reanalyses for the past, the forcing becomes the dominant input. Note that the well-observed SST field can be used as a strong surface constraint, so that the specified surface heat fluxes play only a secondary role. Uncertainty in freshwater fluxes is a complicating factor in ocean analyses, given the relative paucity of constraining salinity data, especially in the past. Overall, though, it is the momentum fluxes which are critical.

Work to improve coupled models needs two sorts of surface flux data. The representation of the atmospheric boundary layer and the exchange of heat and momentum with the ocean is an essentially local problem, which needs very high quality data over a wide range of physical conditions, but only for selected locations or regions. Issues such as the physics of the interaction with the surface wave field, surface currents and resolved vs sub-grid scale effects are all important for developing genuinely accurate representations of surface fluxes within numerical models.

Identifying and quantifying errors in ocean circulation models requires globally complete flux datasets - or at least, complete for individual ocean basins. The primary requirement is for highly accurate surface stress fields. Uncertainties in tropical wind stress of order 1% rather than order 10% would be valuable if they could be achieved. Even if the ocean model is constrained to produce a good SST field by relaxation to analysed values, a good knowledge of the surface heat flux budget is still needed. Firstly, to enable assessment of whether the heat balances simulated by the model are consistent with the observations. Secondly, to allow investigation and assessment of the model representation of the mixed layer, it is important to know the forcing terms well. In this latter case, the diurnal cycle must be specified. The accuracy required for surface heat fluxes depends on the details of what is being studied, and how well the model already simulates the processes concerned.

In most model-based work, there is a need for global fields with a high spatial and temporal resolution - 100km or better, and daily or 6 hourly. Only satellite or NWP/reanalysis products can provide this sort of coverage. NWP analyses have the best representation of near surface synoptic variability; satellite data on clouds (and possibly surface stress) is at the moment still better than the NWP analyses which use the data; in situ data, properly interpreted, provides the ultimate calibration data for surface fluxes. One of the practical challenges for the community is to make readily available to researchers global high resolution optimized surface flux strengths of these different flux estimation methods (NWP, satellite and in-situ).

This discussion has concentrated on two key areas (model initialization and model improvement) where higher quality surface fluxes will be beneficial. Surface fluxes can be used in a range of scientific studies including ocean reanalyses, and it is expected that improved flux fields would find other applications. The rationale of better prediction is nonetheless a key motive for improved knowledge of air-sea fluxes.

WGNE and surface fluxes

Martin Miller
WGNE Chair, The European Centre for Medium range Weather Forecasts, United Kingdom

The Working Group on Numerical Experimentation (WGNE) serves both the WMO Commission for Atmospheric Sciences (CAS) and the Joint Scientific Committee (JSC) of the WCRP, the latter being the body to which the WGSF also reports. The membership of WGNE comprises representatives of virtually all the main operational NWP centres together with additional climate modelling expertise and invited experts. Consequently the importance of surface fluxes to WGNE is primarily that of the interests of NWP and hence includes data assimilation, reanalysis, and weather (and ocean wave) forecasting at all time ranges.

Since the ocean surface fluxes are the interactive lower boundary condition for all larger-scale atmospheric modelling studies, these fluxes are relevant to many aspects of NWP. It is primarily through the surface fluxes that the atmosphere "knows" about SST, and whereby air mass transformation takes place. Surface energy input into the atmosphere can be particularly large in cold air outbreaks over relatively warm water and it is well known that numerical weather prediction is sensitive to the details of air-sea exchange in such cases. Likewise surface fluxes are crucial for controlling key parts of the global-scale circulation such as the Trade wind regions with their intimate linkage to the ITCZ and Hadley circulations. Turbulent moisture fluxes, and to a lesser extent, turbulent heat fluxes into the atmosphere are obviously a key component of the global water and energy cycles.

At synoptic scales, surface fluxes are a critical process, for example, in determining rapid cyclogenesis in mid-latitudes and the intensity of tropical cyclones. Momentum fluxes (surface drag) are important not only in the general circulation, but also at the scale of weather systems through damping on vorticity.

The importance of surface fluxes in coupled atmosphere-ocean modelling will be discussed by others, but the crucial nature of the atmosphere-ocean surface interaction in ocean wave forecasting is very much an NWP issue. The accuracy of wave models is dominated by the quality of the surface winds, which through the appropriate stresses, drive the wave model. In state-of-the-art systems the resulting waves continually modulate the surface winds also through their effect on the surface roughness (via the Charnock parameter).

What are the issues?

Bulk formulae for computing ocean fluxes focus attention on a) the parametrization of the air-sea transfer coefficients themselves, and, b) the modelling of low level wind, temperature and humidity which needs to be very accurate since it is the (small) difference with the ocean surface value that controls the flux.

The parametrization of air-sea transfer coefficients is an active area of research and it is believed by some in the community that the transfer coefficients are accurate within 5% for wind speeds up to 20 m/s. However, recent papers seem to disagree and the precise wind speed dependence and sea state dependence (e.g. the effect of swell propagating from the extra-tropics into the tropics) of transfer coefficients remains an issue. In the high wind speed range with spray and foam effects, observations become very difficult and little is known. Transfer coefficients in storm conditions are obviously important for cyclone development.

The requirement of an accurate representation of near-surface gradients of wind, temperature and moisture widens the topic to boundary layer and cloud processes that control the near surface variables and ocean process that affect the ocean SST and currents. With the increased accuracy of air-sea transfer estimates in NWP, more subtle processes have to be considered. These are ocean currents, boundary layer stability effects (also in relation to horizontal gradients), horizontal advection, and diffusion in the boundary layer. Furthermore, we need to account for counter-gradient effects in the boundary layer, which impact on the shape of the profiles and boundary layer top ventilation and radiative effects influencing the equilibrium in the boundary layer.

Historically, WGNE has been closely involved in model inter-comparisons including comparisons and validation of surface fluxes, and is currently helping to extend this to assess the quality of short-range NWP model fluxes. Such endeavours should be in close collaboration with the WGSF.

Why surface fluxes are of interest to CliC

Vladimir Ryabinin
Joint Planning Staff for WCRP, WMO, Geneva, Switzerland

The WCRP established the Climate and Cryosphere (CliC) project in 2000. In 2004, the Scientific Committee on Antarctic Research (SCAR) became a co-sponsor of the project. CliC studies the entire cryosphere (i.e., snow cover, sea-, lake- and river- ice, glaciers, ice sheets, ice caps and ice shelves, and frozen ground including permafrost) and its relation to climate. The principal goal of CliC is to assess and quantify the impacts that climate variability and change have on components of the cryosphere, and the consequences of these impacts for the climate system. CliC seeks to enhance and coordinate efforts to monitor the cryosphere, to study climate-related processes involving the cryosphere, to model and understand it's role in the climate system, and to develop cryosphere-based indicators of the global change.

We should anticipate that the climate warming will be especially pronounced in the Arctic. It will affect the future of the Arctic Ocean sea-ice cover. Reduction of the perennial ice and the area covered by the first-year ice will result in significant changes in surface flux climatology. More open water means less surface friction, and the whole dynamics of weather in the Arctic may change in the future. Therefore, we need more accurate means of computing surface fluxes through sea-ice and in the ice-cover with polynyas.

Changes of the fresh water balance are the origin of the scientific problem of the thermohaline circulation stability and implications of its changes for the world and particularly European climate. Increasing river run-off, the thawing of the Greenland Ice Sheet, shifts in the sea-ice formation are all disturbing the balance. We need accurate evaporation data to reduce the error in the water balance closure.

The extreme stability of the Arctic surface layer and the existence of melt ponds are challenges for satellite data retrieval. They adversely affect the quality of temperature and humidity profiles obtained from polar orbiting satellites. Corresponding uncertainties in the objective analysis of meteorological data reduce the skill of medium range weather prediction, not only in high but also in mid latitudes. According to A. Hollingsworth (personal communication), solving this problem can increase the range of practically useful forecast in Europe for approximately one day.

There are some other very interesting projects acting in the polar areas. For example, Ocean — Atmosphere — Sea Ice — Snowpack interactions (OASIS) and Air — Ice Chemical Interactions (AICI) are addressing surface fluxes of chemicals. Southern and Arctic ocean carbon balance, emissions from the methane clathrates, all the chemical transformations occurring in the vicinity of the sea-ice edge and affecting cloud formation and ozone depletion are only few of the unknowns to be addressed by modern science.

The generation of data products, which WGSF might facilitate, is of very significant interest to CliC. We encourage the WGSF to address the noted challenges and are ready to work actively with the Group. The International Polar Year 2007/2008 provides a unique and very timely opportunity to seek support for such activities.

FLUX Science

The Role of Increased Precipitation in Recent Freshening of the North Atlantic Subpolar Gyre

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It is now well recognised from various observational studies that the mid-high latitude North Atlantic has undergone a significant freshening in recent decades (e.g. Dickson et al., 2002; Reverdin et al., 2002; Curry et al., 2003; Curry and Mauritzen, 2005). A range of mechanisms are likely to have played a role in this freshening, these include changes in the export of ice and freshwater from the Arctic Ocean (Belkin, 2004), variations in river runoff (Peterson et al., 2002; Wu et al., 2005) and an increase in the atmospheric freshwater flux to the ocean in the sub-polar gyre caused by higher precipitation rates. In this article we focus on the last of these processes by describing recent and ongoing research which aims to quantify the changes in the air-sea freshwater flux (equivalently precipitation-evaporation, P-E) and link them to the observed freshening (Josey and Marsh, 2005; Myers et al., 2005).

We have primarily used output fields from the major atmospheric reanalysis datasets (NCEP-NCAR and ERA40) to study changes in P-E. Broadly similar results are obtained from either reanalysis with each revealing a major increase in the net surface freshwater flux to the North Atlantic subpolar gyre over the last 40 years. The change in P-E over the 25 year period 1975—2000 relative to the earlier period 1960—1974 with NCEP/NCAR is shown in Fig.1. Increased P-E is evident over much of the gyre region with local maxima in the eastern gyre and the Labrador Sea.

The changes in the eastern subpolar gyre are discussed in detail by Josey and Marsh (2005). They find an increase in P-E from about 0.10 m yr^{-1} in the 1960s and early 1970s to 0.27 m yr^{-1} in the period from 1980-present. The increase is primarily driven by stronger precipitation as opposed to reduced evaporation. Further analysis of rain gauge measurements supports the increase in precipitation found with the reanalyses. When integrated over the eastern gyre, the atmosphere to ocean freshwater flux in the period 1975—89 is about 4000 km^3 greater than 1960—74. This increase is twice the amount that has been estimated for the Great Salinity Anomaly (GSA). Thus, at these timescales, the atmosphere gives rise to an air-sea freshwater flux anomaly which is greater in magnitude than that associated with the major advective event in the North Atlantic over the last 40 years.

Potential links between the increase in P-E and the two major modes of atmospheric variability in the eastern gyre region, the North Atlantic Oscillation (NAO) and the East Atlantic Pattern (EAP) have also been explored. Variations in the EAP were found to be most strongly linked to the increase with the NAO playing a secondary role. The P-E increase for the eastern subpolar gyre for a unit positive EAP during Sep-Mar is 0.021 m mon^{-1} which is more than twice as large as the corresponding value, 0.010 m mon^{-1}, for the NAO. In addition, observations of sea surface freshening at 60° N by Reverdin et al. (2002) can be largely explained as a direct response to changes in the air-sea freshwater exchange. The correlation coefficient between SSS and P-E is r = 0.77 / 0.82 for the NCEP and ERA40 reanalyses respectively. Furthermore, the correlation between SSS and the EAP / NAO index is r = 0.75 / 0.44. Hence, EAP related changes in precipitation potentially account for 56% of the salinity variability for this section compared with 19% for the NAO.

The change in P-E over the Labrador Sea is investigated in detail by Myers et al. (2005). As is the case for the eastern part of the gyre the increase in P-E is driven by a rise in precipitation rates in the mid-1970s. However, a seasonal analysis reveals that changes during spring and summer are the dominant factor in the increase. In contrast, for the eastern gyre, significant contributions to the increase occurred in all months of the year and changes in net precipitation were largest in winter. The changes in the Labrador Sea thus show a different seasonal dependence to the eastern gyre which suggests that they may be linked to a different mode of atmospheric variability. However, no clear link to any of the major modes of variability could be found which suggests that the Labrador Sea P-E increase is a response to local changes in the freshwater forcing of the basin by the atmosphere. Further analysis of daily precipitation rates suggests that the increase may be related to a greater frequency of intense precipitation events in recent decades.

Over the period 1975-2000, an extra 2250 km^3 of freshwater is provided to the Labrador Sea. However, it is difficult to attribute the observed freshening of the Labrador Sea directly to this increase as its flushing timescale is such that additional freshwater can easily be removed within a few years and thus its contribution to the longer term (25 year) storage is difficult to determine. However, it is likely that the enhanced atmospheric freshwater flux plays a significant role in the Labrador Sea freshening. Note that the combined increase in the atmospheric flux of freshwater to the Labrador Sea and eastern gyre region is of the same order as the additional freshwater flux of 5000 km^3 to the gyre post-GSA deduced by Curry and Mauritzen (2005). Thus changes in the atmospheric forcing have the potential to play a major role in the observed changes.

Both the eastern gyre and Labrador Sea studies have shown that an increase in precipitation is a major driving factor for sea surface freshening. Establishing whether there is a relationship between the precipitation increase and freshening of deeper waters in the mid-high latitude North Atlantic is a complex task requiring further work. In particular, it will be necessary to take into account the advection of the surface waters to sites of deep water formation and the roles played by other processes, particularly variations in the export of freshwater from the Arctic Ocean. Understanding the various causes of the freshening is important because some of the freshened water will be advected into regions of deep convection, for example the Greenland Sea, with potential consequences for the rate of deep water formation and hence the strength of the thermohaline circulation. Furthermore, a stronger hydrological cycle is one of the expected consequences of anthropogenic climate change. Thus, the increased freshwater flux to the mid-high latitude North Atlantic discussed here may be a regional expression of global climate change.

Acknowledgements

The research of Josey and Marsh has been carried out in part under the Rapid Climate Change programme of the UK Natural Environment Research Council. Myers was funded by NSERC and CFCAS grants (GR-019 and the Canadian CLIVAR network).

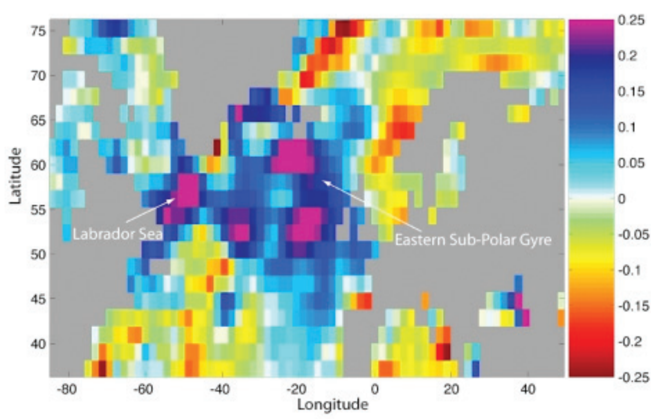

Figure 1. Difference in the NCEP/NCAR annual mean P-E field (units m/yr) for 1975-2000 from 1960-1974. The arrows indicate the eastern subpolar gyre and Labrador Sea regions discussed in the text.

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Ocean Fluxes and ICOADS: A Status Report

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1. Introduction

Shipboard marine meteorological observations, which now are managed via the JCOMM[1] Voluntary Observing Ship (VOS) Scheme, are among the few ocean data that span centuries. The world's largest collection of digital ship logbook data, beginning in the late 18th century, has been assembled in the International Comprehensive Ocean-Atmosphere Data Set (ICOADS[2]) (Worley et al., 2005).

In recent decades, the VOS observations have been complemented by in situ measurements from moored and drifting buoys, near-surface ocean profile temperatures, observations from research vessels, and other Ocean Data Acquisition Systems (ODAS) (Fig. 1). There has been a detrimental decline in VOS observations since 1989 (Fig. 1).

This undesirable trend is degrading the climate baseline record to which other ODAS are compared and is limiting the ability to compute ocean surface fluxes. The spatial coverage for some flux variables has fallen about 30% globally (Fig. 2).

2. Recent ICOADS Updates

ICOADS Release 2.1 (Worley et al., 2005), which covered 1784—2002, was recently updated and extended for 1998—2004 (Release 2.2). This update included replacement of some ODAS data received via the Global Telecommunication System (GTS) with higher quality data, specifically: worldwide drifting buoy data from Canada's Marine Environmental Data Service (MEDS), tropical Pacific and Atlantic moored buoy data from the NOAA Pacific Marine Environmental Laboratory (PMEL) and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and coastal US moored buoy data from the NOAA National Data Buoy Center (NDBC). These delayed mode data also include dew point temperatures that are

[1] Joint World Meteorological Organization (WMO)/Intergovernmental Oceanographic Commission (IOC) Technical Commission for Oceanography and Marine Meteorology (JCOMM).

[2] In recognition of increasing international contributions, the Comprehensive Ocean-Atmosphere Data Set (COADS) was renamed the International COADS (ICOADS) in 2002 (Diaz et al., 2002).

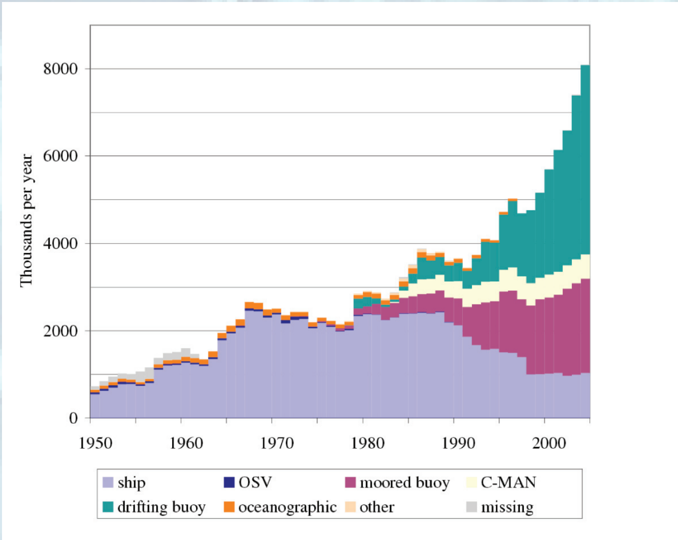

Figure 1. Annual number of reports stratified by platform type in ICOADS release 2.2 for 1950-2004 ("OSV" indicates ocean station vessels, and "C-MAN" indicates NDBC automated land–ocean boundary zone reports. This is an update through 2004 of Fig. 2 in Worley et al. (2005), which provides additional details.

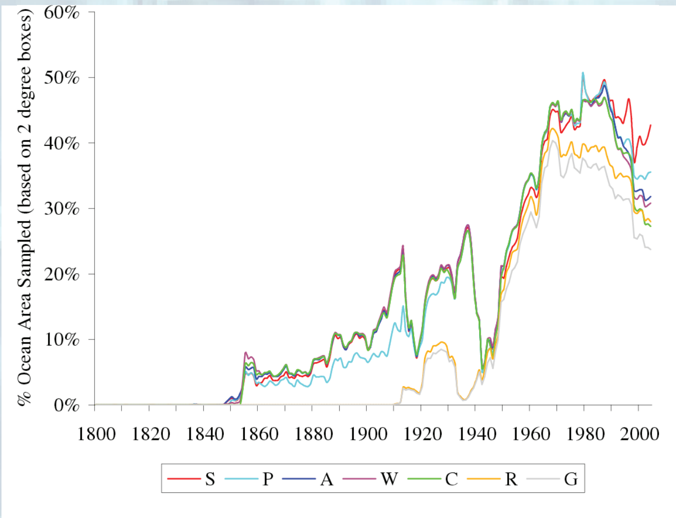

Figure 2. Percentage global ocean and coastal area sampled based on area-weighted 2° boxes (smoothed). This compares the sea surface temperature (S) coverage, at five observations per month, with that for sea-level pressure (P), air temperature (A), wind speed (W), total cloudiness (C), and relative humidity (R). Also plotted is an evaporation parameter (G), which is computed from S, P, A, W, and R, and thus illustrates the extent to which surface fluxes can be computed from the individual observations. This is an update through 2004 of Fig. 5 in Worley et al. (2005), which provides additional details.

important for flux estimates and were not previously available in ICOADS.

Inhomogeneities introduced by changing observing systems, temporal and spatial coverages, and data handling procedures impact this complex and evolving historical data mixture. Platform metadata are one key for mitigating inhomogenities. Substantial progress has been made, by attaching WMO ship platform and instrument metadata for 1973—2004 (Kent et al., 2005), to the ICOADS observations.

3. Data and Product Access

A new International Maritime Meteorological Archive (IMMA) format was recently introduced for the ICOADS individual observations. IMMA is a versatile ASCII format, which is suitable for archiving marine data that span centuries, and is proposed for eventual adoption by JCOMM. All the ICOADS observations and products are freely and openly available internationally, with unified access provided via the project web portal (icoads.noaa.gov) (Worley et al., 2005). In the portal users have access to web-based tools that enable temporal, spatial, and variable subsetting, and data output in several standard formats.

4. Future Plans

A large number of new or improved candidate datasets exist in digital form and should be blended into ICOADS (Worley et al. 2005). This would enhance both the historical record, including in time back to approximately 1750 (Woodruff et al., 2005), as well as recent periods. A few improvements to ICOADS that would favor better flux estimates are:

- *Regular updates focusing initially on annual GTS-based extensions*
- *Digitization and blending of untapped logbook data from the UK and other European archives (Woodruff et al., 2004)*
- *Digitization and blending of additional ship metadata (1955—72)*
- *Generation of climate-quality surface fields and uncertainties from ICOADS using the best knowledge for bias adjustments to variables*

Developments of very long historical archives, like ICOADS, are inevitably complex. The complexity surrounding format translations, unit conversions, parameter adjustments, and overlapping data sources requires extensive testing, analysis, and documentation before the data can be combined. This value-added data stewardship is critically important for all data users and requires significant time and resources to accomplish. On very small budgets, including significant in-kind collaborations, the COADS (ICOADS) development has spanned over 20 years. Currently, the support is lower than ever, particularly from NOAA, and we therefore are hopeful for continuing and strengthened international cooperation through JCOMM and other organizations to help make improvements.

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MORE cruises launched

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What is MORE?

The Meridional Oceanic Radiative Experiment (MORE) is a joint initiative of the P.Shirshov Institute of Oceanology (IORAS) and the Leibniz Institute of Marine Sciences at the University of Kiel (IFM-GEOMAR) with some contributions from the UK Met Office and the Meteorological Institute of the University of Bonn). MORE is set up to conduct long-term, high quality measurements of surface parameters and fluxes in the Atlantic Ocean with a particular emphasis on short wave (SW) and long-wave (LW) radiation fluxes. These are needed for proper quantification of the global ocean heat balance.

The MORE plan written by S. Gulev and A. Macke in 2003 proposed to utilize for this purpose the spare capacity of existing cruises. Every year two Russian research vessels

“Academician Vavilov” and “Academician Ioffe” carry out oceanographic research in the South Atlantic Ocean during the austral summer (December to March). On the way to the South Atlantic and back (in October-November and April-May) these RVs are short of research work and, therefore, have excellent opportunities for making extra measurements. Map 1 shows the meridional ship routes on which the measurements can be carried out, and where some have already been taken in accordance with the MORE plan. These ships cross many climate zones in several seasons, so that the observations cover various cloud, temperature and humidity conditions.

The concept of the MORE experiment is to utilize the capacity of the cruise ships “Vavilov” and “Ioffe” for measuring radiative fluxes at sea surface and developing new parameterizations of the SW and LW radiation.

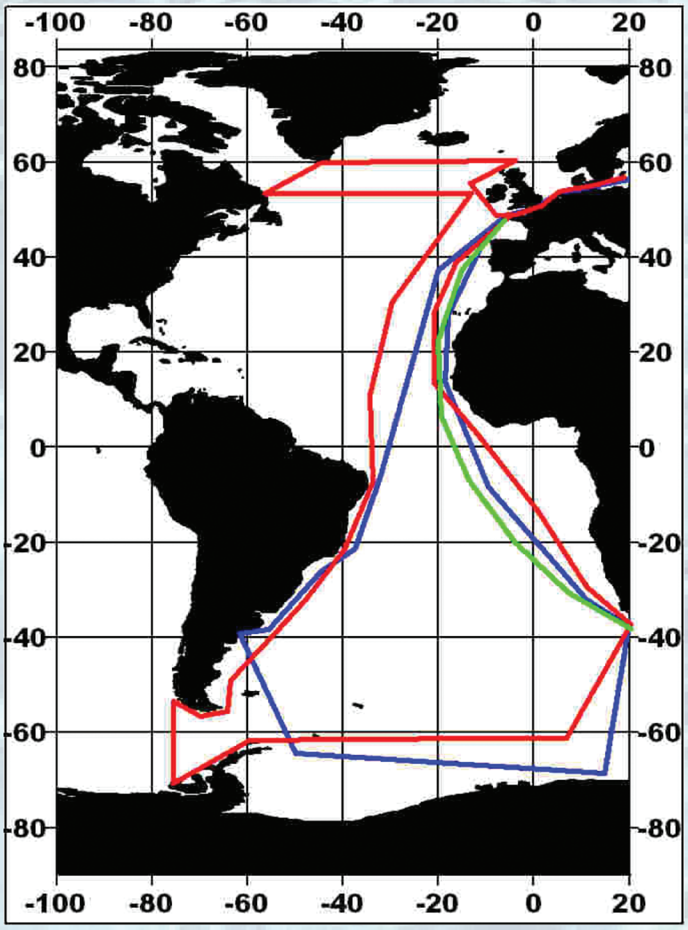
First MORE cruises

Four MORE cruises have already taken place in 2004 and 2005 (see Map 1). From 17 October to 11 November 2004 the RV “Vavilov” sailed south from Bremerhaven to Cape Town. Then, from 12 November to 5 December she cruised from Cape Town to Ushuaia. The second MORE cruise on “Ioffe” took place on 16—30 June 2005 along the Atlantic hydrographic section AR7, which stretches from Northern Scotland to Greenland. Finally, in the autumn of 2005 “Vavilov” sailed from Bremerhaven to Cape Town (29 Spetember — 20 October) and “Ioffe” cruised from Bremerhaven to Ushuaia (29 September — 25 November).

In addition to the standard meteorological observations of wind, SST, air temperature and humidity, meteorological teams on board these RVs conducted radiation flux measurements using the Kipp&Zonen Net Radiometer CNR-1 with four equal sensitivity sensors: two pyranometers (0.3—3 μm) for solar radiation measurements and two pyrgeometers (5—42 μm) for infrared measurements. These measurements provided continuous data for downwelling and upwelling SW and LW radiation. Infrared measurements of the skin SST were made by self-calibrating radiometer RAL (SISTeR). Visual cloud characteristics were recorded by cloud cameras from IFM-GEOMAR. Cloud base height — the important characteristic for LW downward flux — was obtained using the IFM-GEOMAR ceilometer.

Figure 1 shows the installation of radiation instruments on “Vavilov”. All instruments were connected to the data acquisition system based on the PC-platform with PCI-interface ADC L-761, manufactured by JSC L-Card. Time resolution of measurements for all instruments was set to 0.1 Hz, and a 10-minute averaging window was applied to compute the time-averaged output. Ship velocity, heading and the sun azimuth were recorded simultaneously using the onboard navigation and GPS systems.

At the same time, the cruise meteorologists carried out routine visual meteorological observations of the cloud cover and dominant cloud types. The total and low cloud cover (two major parameters reported by Voluntary Observing Ships) were estimated simultaneously by 3 to 6 independent observers, and these data can be used for statistical analysis of uncertainties inherent in these observations.



Map 1. First MORE cruises. Green line shows 2004 cruise, red lines mark the 2005 activities and blue line tentatively marks the planned 2006—2007 activities.

Further scientific strategy

The main limitations of the widely-used parameterizations of SW radiation (Reed 1977, Dobson and Smith 1988, Malevsky et al. 1992) result from the existing practice of associating the SW radiation flux with the fractional cloud cover, without taking into account the cloud types and their thermodynamic properties. Similarly, the problems of parameterizations of LW radiation that still exist after 70 years of their development (e.g. Clark 1974, Josey et al. 2003) can also be attributed to the fact that only the fractional total cloud cover along with its temperature and humidity conditions have been statistically analysed to derive the best possible statistical relationships. The reasoning behind such a simplified approach is that only the total cloud cover is readily available from marine ship reports, and not the more detailed cloud characteristics (cloud types, cloudiness of different layers).

However, recently the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) has been updated and considerably enlarged (see the Woodruff and Worley report in this Newsletter), and it now provides all basic cloud characteristics with almost the same sampling density as for the total cloud cover (e.g. Bedacht et al. 2005). Nevertheless, these new types of data provided by ICOADS cannot be incorporated into the existing, relatively crude, parameterizations. In order to make use of ICOADS the existing parameterizations of SW and LW radiation at sea surface need to be critically reviewed, and some new ones should be developed to accommodate a considerably wider range of atmospheric parameters.

In order to fit these new parameters into new parameterizations we will need to achieve a higher level of physical understanding of radiative transfer in the cloudy atmosphere. For this purpose we will employ the 3D radiative transfer model MC-UNIK developed by IFM-GEOMAR (Macke et al. 1999, Scheirer and Macke 2003). Then the physical description of the mechanisms of radiative transfer will be considered along with in-situ and satellite measurements, the latter mostly from the new Meteosat Second Generation instruments which are ideally suited for this purpose This will allow for future development of a new generation of SW and LW radiation fluxes at sea surface on the basis of multivariative statistical modelling. The new parameterizations, which will be physically justified and accurately tuned, will then be applied to further develop the new climatology of surface solar radiation fluxes over the global ocean from 1948 onwards.

Continuous observations of vertical temperature and humidity profiles as well as the liquid water path from a ship-born multi-channel microwave radiometer (IFM-GEOMAR) are planned for 2007 and beyond. These measurements will substantially enhance the physical description of the atmosphere, and will also serve as validation points for satellite based retrievals over the Atlantic.

We welcome all interested researchers to co-operate with the MORE teams in devising the best possible observation techniques and instrumentation for understanding air-sea radiative exchange.

Acknowledgements. The MORE experiment is currently supported by the Russian Ministry of Science and Education, the Russian Ministry of Economical Development and Trade, the Russian Academy of Science, IFM-GEOMAR (Kiel) and MIUB (Bonn).

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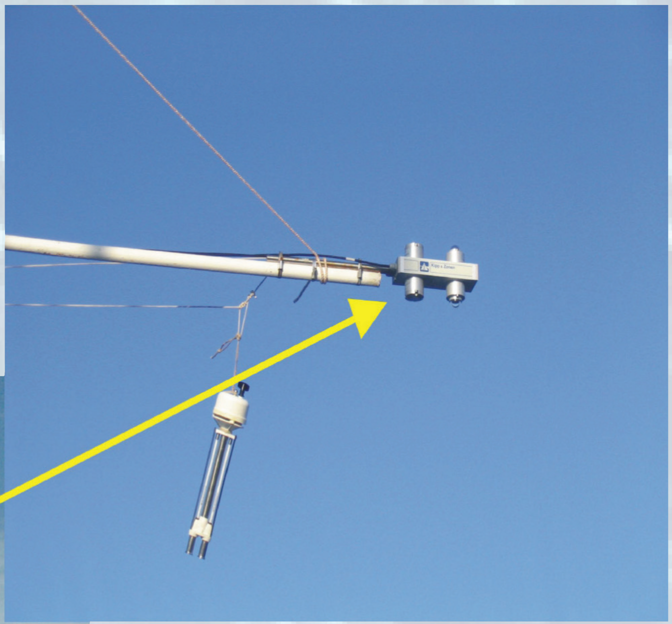
The concept of the MORE experiment is to utilize the spare capacity of cruise ships for conducting high quality measurements of radiative fluxes at sea surface and developing new parameterizations of short wave and long-wave radiation fluxes.



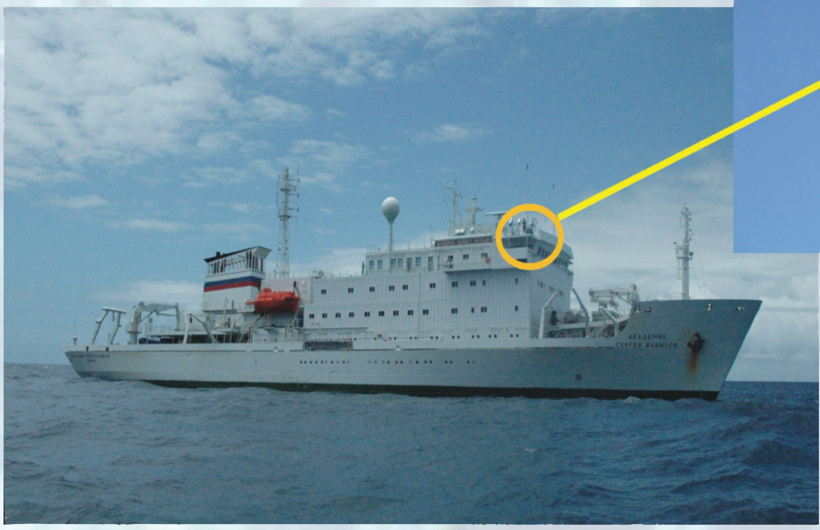


Figure 1. Research vessel “Academician Vavilov” with one of the radiative packages on board.

Second International Workshop on Advances in the Use of Historical Marine Climate Data (MARCDAT-II)

Met Office Hadley Centre for Climate Prediction and Research
Exeter, UK, 17-20 October 2005

Elizabeth Kent, National Oceanography Centre, Southampton, UK
and Nick Rayner, Met Office, Exeter, UK

The 2nd MARCDAT workshop on marine climate data was hosted by the Met Office in October 2005. The workshop was the latest in a series of international marine workshops held approximately every two years since 1999. MARCDAT (Boulder 2002 and Exeter 2005) alternates with the more formal JCOMM[1] CLIMAR Workshops on Advances in Marine Climatology (Vancouver 1999 and Brussels 2003).

These workshops have brought together a wide spectrum of marine data users, and managers of marine data and products, and have included an underlying focus on the continuing evaluation, utilization, and improvement of the International Comprehensive Ocean-Atmosphere Data Set (ICOADS, Worley et al. 2005). In addition to a number of published outcomes (Diaz et al., 2002, WMO 2003, Parker et al., 2004) the previous workshops have produced and actively tracked a consolidated set of past recommendations to help guide the work of this group and provide feedback for the broader research community.

MARCDAT-II attracted more than 60 participants from eight countries for four days of oral presentations, posters and discussion. The WCRP Working Group on Surface Fluxes (WGSF) was well represented with four members attending. The overall aim of the meeting was "To set priorities for the future development of marine climate data and products over the next four years". The meeting had four specific goals, to: (1) develop the timetable for enhancing *in situ* marine data bases, with a focus on ICOADS, taking account of plans for further digitization and improved processing of the basic observational data; (2) develop strategies for the creation of multi-decadal, homogeneous, gridded data sets for climate applications, and identify priorities for improvement in particular variables; (3) discuss methods for quantifying uncertainties in marine data and create a timetable for the assembly of a suite of gridded marine datasets with associated uncertainties; (4) consider how to define future data requirements. The meeting also reviewed progress against the scientific and technical recommendations made at MARCDAT-I and CLIMAR-II.

Discussions were held in small groups which considered different ocean and meteorological variables: (i) SST, marine air temperature and humidity; (ii) sea ice concentration and extent; (iii) sea level pressure and winds and (iv) sub-surface ocean, waves, fluxes and clouds. Professor Sergey Gulev, ex-officio chair of the WGASF, led breakout group IV which discussed the research, documentation, metadata and dataset development thought necessary to advance surface flux climatology.

There was concern expressed that the marine observation system, vital for the routine production of *in situ* surface flux datasets, is in decline. Observations from Voluntary Observing Ships (VOS) which form the backbone of *in situ* flux datasets have reduced by more than a half since 1990 and we now have less than a third of the number of VOS participating in the observing program. As a result the uncertainty of *in situ* surface products is increasing over time. All of the breakout groups were concerned about the diminishing data quantities which is a huge challenge for the future.

The availability of comprehensive metadata on observational method was thought to be key to the production of high quality *in situ* flux datasets. The availability of metadata from the WMO "List of Selected, Supplementary and Auxiliary Ships", Publication No. 47, associated with individual ICOADS ship reports was welcomed. Further progress was reported by the NOAA Climate Database Modernisation Program which is in the process of digitising previously unavailable versions of Publication No. 47 going back to 1955. Resources are required to make buoy observational method metadata available, and research is needed to attempt to assign measurement methods to observations with no available metadata. The need for further research to determine the applicability of flux parameterisations to routine weather observations was also called for. Flux parameterisations are developed using research-quality datasets containing many different parameters and some require a time history of observations. The best flux parameterisation to use will depend on application and the availability and quality of a wide range of meteorological and oceanographic information. The group stressed the need for uncertainty estimates for fluxes and flux products, including a comparison of random uncertainties for bias corrected and uncorrected surface fluxes.

Breakout group IV also considered requirements for subsurface climatology, ocean waves and clouds. This

[1] JCOMM is the Joint World Meteorological Organisation/Intergovernmental Oceanographic Commission Technical Commission on Oceanography and Marine Meteorology

FLUX Calendar

2—7 April 2006 — General Session AS2.02 “Air-Sea Interactions” at the General Assembly of European Geosciences Union, Vienna, Austria, http://www.copernicus.org

2—6 May 2006 — 37th International Liège Colloquium on Ocean Dynamics: Gas Transfer at Water Surfaces Liège, Belgium, http://www.ulg.ac.be/oceanbio/co2/2005.html

8—10 May 2006 — U.S. CLIVAR Salinity Workshop — Woods Hole Oceanographic Institution, Woods Hole, USA, http://www.usclivar.org/Organization/Salinity_WG/Salinity2006.html

Call for contributions:
We would like to invite the sea-air flux community to submit papers to FLUX News for Issue 2. It will focus primarily on co-operation with the SOLAS programme. The deadline for this issue will be 30 April 2006.

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