# Oral Presentation Abstracts

# CLIMAR-II
# Second JCOMM Workshop on Advances in Marine Climatology

*In association with a celebration of the 150th anniversary of the Brussels Maritime Conference of 1853*

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## Contents

# Session I: Cross-cutting Issues

# I-COADS data and products

Steven J. Worley[1], Scott D. Woodruff[2], and Richard W. Reynolds[3]

[1]National Center for Atmospheric Research (NCAR), Boulder CO, USA
[2]Climate Diagnostics Center, NOAA/OAR, Boulder, CO, USA
[3] National Climatic Data Center, NOAA/NESDIS, Asheville, NC, USA

E-mail: worley@ucar.edu

The International Comprehensive Ocean-Atmosphere Data Set (I-COADS) is currently available at Release 2.0, spanning 1784 through 1997. Preliminary data derived from the Global Telecommunication System are updated monthly to supplement I-COADS. The marine observations, data products, and supplemental data and metadata are freely distributed worldwide by the cooperating organizations: the NSF National Center for Atmospheric Research, and the Climate Diagnostics and National Climatic Data Centers of NOAA. A review will be given of the different products and formats offered from these organizations, which address a variety of user requirements.

Highlights about new developments and forthcoming plans will also be given. These include a 1998-2002 update and expanded near-real-time updates, enhancements planned for historical periods based on new international sources, and improved products and metadata such as web-based information about user-detected problems. Under the auspices of the Joint WMO/IOC Commission on Oceanography and Marine Meteorology (JCOMM), an ASCII-based International Maritime Meteorological Archive (IMMA) format is being introduced—this will ease complexity and improve observational data access, both for users and data providers.

**CLIWOC: A database for the world's oceans 1750-1850**

R. García-Herrera[1], D. Wheeler[2] G. Konnen, M.R. Prieto[3] and P.Jones[4]
on behalf of the CLIWOC team

[1] Universidad Complutense, Madrid, Spain
[2] University of Sunderland, Sunderland, UK
[3] Royal Netherlands Meteorological Institute (KNMI)
[4] University of East Anglia, Norwich, UK

E-mail: rgarcia@6000aire.fis.ucm.es, rgarciah@fis.ucm.es

From the earliest days mariners have kept logbook accounts of their voyages. By 1750 the keeping of logbooks was almost universal amongst the officers of European ships. Although not prepared with this purpose, the logbooks and the observations that they contain are today of great scientific value. The UK, France, Spain and the Netherlands all possess notable collections of ships' logs, which in the pre-1850 period comprise the bulk of the observations available over the world oceans.

CLIWOC is a project funded by the European Union with partners from Spain, the UK, the Netherlands and Argentina. Its principal objective is to produce a database of daily oceanic weather observations between 1750 and 1850. It will be completed by December 2003 (estimated 300,000 observations). At that time, the CLIWOC database will be ready for integration with the I-COADS global database of meteorological observations, mainly 1800-present. The CLIWOC database utilises daily observations from logbooks that represent all the major oceanic areas. Data will include the most frequently recorded elements of wind strength and direction, plus weather observations and a meta-database that will also allow enquirers to consult the original sources.

# Measuring the temperature at sea in the 18th century

C. Koninckx
Brussels University (VUB)
vice-president of the Belgian Committee of Maritime History
E-mail: ckoninck@vub.ac.be

During the 18th century, new scientific disciplines were developed from the common tree of natural science. On the ships of the East India companies trading to the Far East, officers, supercargoes, ship's writers and priests, having during these long distance travels plenty of time for 'leisure' and being acquainted with recording data, showed interest for observations dealing with geography, oceanography, meteorology, botany and zoology, and even with the economics of the countries visited. Though basically not related to scientific expeditions at all, the results of the observations made during the voyages were put into the logbooks, the ship's journals of the East Indiamen and in diaries of all kind.

It seems that the first records of measuring systematically the temperature at sea appeared during the 18th century. This paper is dealing with values of temperature recorded on a ship of the Austrian East India Company, the so-called Ostend Company, and on several Swedish East Indiamen. These records are far from being unimportant, especially the Swedish ones, since there was a link with the Swedish *Royal Academy of Sciences* and the attempts at the *Uppsala University* in constructing thermometers by Anders Celsius and his fellows.

The data recorded and analysed are no samples, but continuous series built on daily observations at sea. If systematically noticed values of temperatures precisely are of great interest for scholars, there remain some fundamental questions unsolved as: how those sailing people were reading the temperature, by which instruments and of which calibration they were.

No doubt, the curiousity for the meteorological phenomenon of temperature emerged, but, as a matter of fact, mostly limited to recording the rough data. Of course, no links were put to other phenomena as air pressure and speed of the ship, e.g. But, in the end, the data were handed over to the scholars onshore.

## WMO data collection and archival of VOS observations

Miroslaw Mietus
Chairman of ET on Marine Climatology
Institute of Meteorology and Water Management, Maritime Branch, Gdynia, Poland
Department of Meteorology and Climatology, University of Gdansk, Poland
E-mail: Miroslaw.Mietus@imgw.pl

The international agreement concerning a formalized recording of weather observations from the seas in ships' logbooks was made at the Maritime Conference held in Brussels in 1853. Traditional logbooks were only episodically digitized and exchanged through bilateral agreements. The digitalization and exchange of digitized meteorological journals were not formalized until 1960.

The Commission for Marine Meteorology on its third session in 1960 made several recommendations, which formalized preparation of the marine section of the World Climatic Atlas and created the basements of nowadays existing Marine Climatological Summary Scheme. The Fourth World Meteorological Congress in 1963 finally decided on regular publication of marine climatological summaries and designated the 1st January 1964 as the start of an agreed procedure. By this recommendation for the purpose of preparing the marine climatological summaries and of collecting data with a view to the eventual preparation of a marine characteristics, the world ocean and the seas were divided into several areas of responsibility and several countries volunteered to act as Responsible Members, e.g. being responsible for collecting digitized marine meteorological data from the area of their responsibility, for preparation of marine climatological summary and for supporting society in high quality climatological information. Congress decided that all Responsible Members should prepare annual climatological summaries for their areas of responsibility and in those areas for a number of selected representative sub-areas, as well as for the fixed ship stations within them. Annual summaries should be prepared for particular years of decade 1961-70, 10 years summaries should be prepared systematically starting with the period 1961-70. The scope and layout of summaries has been defined as well as its form of publication. All Contributing Members should ensure that all available observations from marine stations would be digitized, sorted half-yearly and dispatched to the Responsible Members according to their area of responsibility.

The above system developed with time. Several important changes have been introduced taking into account changing boundary conditions, e.g. technological progress etc.

Considering increasing importance of the global marine data collection in support of global climate monitoring, research and prediction, the need to improve the timeless and efficiency in data collection and archival, the need to ensure uniform Minimum Quality Control Standard (MQCS) and finally to improve an appropriate backup of data collection and exchange procedure as well as to ensure continuous global availability of marine data the eleventh session of CMM recommended several changes with MCSS. Two of the RMs (Germany and UK) will act as Global Collecting Centers (GCC) for marine climatological data since 1st January 1994.

There is increasing interest in global marine climatological data due to global warming and intensification of investigations concerning the role of ocean in global processes. Intensification of efforts to digitize results of marine meteorological observations made before 1960 is highly recommended by the marine climatological research community, whereas the accompanying metadata become an important issue. Many of these historical data (and contemporary as well) have been compiled into global collections such as the International Comprehensive Ocean-Atmosphere Data Set (I-COADS). However digitalization of historical logbooks meets several problems, as it is a laborious process, requiring a bulk of resources in time, staff and budgets.

**Quality control of VOS data in Hong Kong**

W. T. Wong
Hong Kong Observatory, Hong Kong, China
E-mail: wtwong@hko.gov.hk

The collection of weather reports from voluntary observing ships (VOS) in Hong Kong dates back to 1949. During the past 50 years, over 1.9 million ship weather reports have been collected, quality checked and archived. The data are compiled into marine climatological summaries under the Marine Climatological Summaries Scheme (MCSS) and exchanged with the Global Collection Centres at the United Kingdom and Germany. All VOS data processed by the Hong Kong Observatory are subject to quality control which checks the positions of the ship, time sequence of reports, and internal consistency of the meteorological parameters reported. This paper describes the quality control scheme, its limitation and future improvements.

**Improved meteorological measurements from merchant ships**

Peter K. Taylor
Southampton Oceanography Centre, UK
E-mail: peter.k.taylor@soc.soton.ac.uk

Improved ship's meteorological reports are required for climate studies and verification of numerical model and remote sensed data. The improvement may take a number of forms. Even having a better understanding of the error characteristics of the present reports represents an advance useful, for example, for designing assimilation schemes or identifying climate trends. The quality of the actual observations may be improved through better metadata and quality control (as in the VOS Climate project, VOSClim), through improved instrumentation (such as the Canadian AVOS or US IMET systems), or through studies designed to quantify unavoidable bias errors. An example of the latter is the use of Computational Fluid Dynamics modelling to study the degree to which the wind at the anemometer site has been altered by the presence of the ship. This talk will summarise the progress in these activities and outline future plans.

**Using metadata to understand VOS meteorological data**

Elizabeth C. Kent, David I. Berry and Peter K. Taylor
Southampton Oceanography Centre, UK
E-mail: Elizabeth.C.Kent@soc.soton.ac.uk

Meteorological reports from Voluntary Observing Ships (VOS), such as those collated in the International - Comprehensive Ocean Atmosphere Dataset (I-COADS), form an important part of the climate record. However these data contain biases and random errors which depend on how the measurement was taken, the type and exposure of the instruments used, the size of the ship, and environmental conditions, amongst other factors. Information is available about some of these important predictors of data quality both from within I-COADS and from external sources, for example the World Meteorological Organisation List of Selected, Supplementary and Auxiliary Ships (Publication 47) or Lloyds Register of Shipping. Examples of how this metadata can provide important information on data biases and random uncertainty will be presented.

**Recommendations from the Workshop on High-Resolution Marine Meteorology**

Shawn R. Smith[1] and R. Michael Reynolds[2]

[1]COAPS, The Florida State University, Tallahassee, FL, USA
[2]Brookhaven National Laboratory, Upton, NY, USA

E-mail: smith@coaps.fsu.edu

Thirteen recommendations from the "Workshop on High-Resolution Marine Meteorology" will be presented to the international community. The workshop was held from 3-5 March 2003 at the Center for Ocean-Atmospheric Prediction Studies (COAPS) in Tallahassee, Florida. The primary workshop goals were to identify scientific objectives that require high-resolution (sampling interval ≤ 1 hr.), high-accuracy marine meteorological observations and to discuss a sustained U.S. effort to obtain and disseminate these data in a manner consistent with the identified scientific goals. The workshop focused on *in-situ* marine meteorological observations from ships and buoys. Participants from U.S. government agencies, the university community, and two international marine institutes discussed data accuracy, calibration and inter-calibration, improved access to quality-assured, high-resolution observations, and a sustained observing system to meet short- and long-term science objectives. Participants noted that only a few ships and buoys can determine air-sea fluxes to the accuracy needed for climate studies. Research vessels are capable of providing the highest quality data; however, this resource is not effectively utilized and data essential to climate studies are being lost.

**Sampling errors in VOS-based sea-air flux climatologies: impact on climate means and variability patterns**

Sergey Gulev[1,3], Thomas Jung[2] and Eberhard Ruprecht[3]

[1]P.P.Shirshov Institute of Oceanology, Moscow, Russia
[2] ECMWF, Reading, UK
[3] Institut fuer Meereskunde, Kiel, Germany

E-mail: gul@sail.msk.ru, thomas.jung@ecmwf.int, eruprecht@ifm.uni-kiel.de

Analysis of sampling errors in the global fields of sea-air turbulent and radiative heat fluxes and flux-related parameters is performed using VOS (Voluntary Observing Ship) observations from COADS (Comprehensive Ocean-Atmosphere Data Set) and NCEP/NCAR Reanalysis for the period from 1948 to 2000. In order to estimate sampling errors, we simulated VOS-like sampling density in the 6-hourly NCEP/NCAR Reanalysis flux data. Random simulation accounts for the so-called random representativeness errors in flux fields. Simulation, which takes into account the actual time of VOS observations, allows also for estimation of the fair-weather biases in flux fields. Global maps of different sampling errors are presented for flux-related individual quantities and different flux components. The largest climatological effect is observed in poorly sampled subpolar areas of the North Atlantic and North Pacific and in the Southern Ocean. Locally high time-dependent sampling uncertainties ranging from 50 to 200 $W/m^2$ are observed in Labrador Sea and some other regions. They may seriously affect long-term variability patterns in the flux fields. Impact of sampling on climate variability is quantified using EOF analysis of fluxes, derived from VOS and Reanalyses. Finally, a simple procedure is proposed to minimize the impact of sampling onto climate variability characteristics. This procedure can be effectively used for estimation of the area-integrated fluxes for relatively large areas.

**Objective analyses of SST and marine meteorological variables for the 20th century using COADS and the Kobe Collection**

Masayoshi Ishii, Akiko Shouji, Satoshi Sugimoto, Takanori Matsumoto
Japan Meteorological Agency
E-mail: maishii@mri-jma.go.jp

Objective analyses of Sea Surface Temperature (SST) and marine meteorological variables have been carried out on a global grid. The analysis database helps us to find inhomogeneity of quality of historical observations. Besides performing the objective analysis, our quality control procedures have been improved. Sizable trends are detected, which are partly related to global warming and partly affected by historical data quality. Among analyzed variables, a trend of total cloud amount globally averaged resembles that of SST and air temperature. We believe that these analyzed data are applicable to climate studies and can be used as boundary conditions or forcing in integrating dynamical models. Some applications with the analyzed data will be introduced. In addition, the quality of the Kobe Collection will be discussed briefly.

**Assessing bias corrections in historical sea surface temperature using a climate model**

Chris Folland
Hadley Centre, Met Office, Bracknell, Berkshire, UK
E-mail: chris.folland@metoffice.com

Time series of sea surface temperature (SST) are strikingly inhomogeneous before 1942 in many parts of the world when compared to those of colocated nighttime air temperatures measured near the ocean surface. Associated with the discontinuity is a sudden change in the assessed annual cycle of SST in many extratropical regions. In the 1990s methods were devised to adjust for the associated inhomogeneities in worldwide SST using an integrated statistical analysis and physical model.

The bias adjustments have been tested using a climate model (HadAM2b) run in ensemble mode forced with two different global time-varying SST data sets, one containing the adjustments and one without. The ability of the model to simulate the global observed land surface air temperature timeseries from 1871 is substantially and highly significantly better with adjusted SST. Many large regions and different phases of the seasonal cycle also show a strong improvement, supporting the use of these adjustments by successive reports of the Intergovernmental Panel on Climate Change. Some differences of behaviour in the new I-COADS data set are mentioned which will require new tests.

**Signal to noise ratio applied to COADS ship-measured variables**

Mark L. Morrissey
University of Oklahoma, Norman, OK, USA
E-mail: mmorriss@ou.edu

Given the large variation in time and space of ship traffic across the world's ocean, there is a need to identify locations where the Comprehensive Ocean Atmosphere Data Set (COADS) can satisfy research requirements for specific objectives. Before embarking on a research project using COADS it is important that the researcher know in advance what the signal to noise ratio of ship box averages is in the area and scales of interest. In an effort to provide such information we have developed a 3 dimensional statistical scheme which can provide COADS box metrics regarding the ratio of the signal variance to the noise variance for any COADS variable over any scale. A measure of the standard error for box averages has also been developed. These metrics could potentially be incorporated into the COADS data base as useful measures for the research community.

Although, the statistical scheme does not apply to measurement bias, it does take into account sampling error as a result of ship position in time and space and the time period to time period variation. The routine has been applied to several COADS box location across the global to illustrate its useful and as a proof of concept.

An example of the metric's use is to put error bounds about long-term trend analysis as a function of varying ship density over time in a given location.

**Temperature in Belgian marine waters: from monitoring to management through modelling**

Georges Pichot, Virginie Pison and J. Ozer
Management Unit of North Sea Mathematical Models, Brussels, Belgium
E-mail: G.Pichot@mumm.ac.be, V.Pison@mumm.ac.be

Temperature plays an important rule in hydrodynamic and biological processes in the North Sea. Since 1984, MUMM collects temperature data in the Belgian coastal waters. In this paper, the temperature is taken just as an example to illustrate how monitoring and modelling are combined to help the management of this maritime zone. Topics that will be addressed include:

i) Collection of the data and their incorporation (with metadata) in a data base that includes statistical and spatial analysis tools (used, amongst others, for the quality control of the data);
ii) the development and application of operational hydrodynamic models and pre-operational biochemical models for the area of interest;
iii) an assessment of the quality of the marine environment;
iv) implementation of the necessary regulations to protect and/or restore this environment.

**Weighted Empirical Orthogonal Function analysis**
**theory and examples**

Pascal Terray
Laboratoire d'Océanographie Dynamique et de Climatologie, Paris, France
E-mail: lea@lodyc.jussieu.fr

Weighted Empirical Orthogonal Function (EOF) analysis is an innovative statistical method explicitly designed to extract climatic signals from noisy and irregularly sampled data (both in space and time). Weighted EOF analysis has a long history and has been studied extensively in applied statistics and numerical analysis. Despite this long history, weighted EOF analysis has not been applied in climatology due to the numerical difficulties involved in its implementation.

Some first examples of the relevance of this statistical method to extract climatic signals from ship's datasets were presented at the International Workshop on Digitization and Preparation of Historical Surface Marine Data and Metadata (Toledo, Spain, 15-17 September. 1997). The main purpose of the current work is to extend this preliminary study and to present improved algorithms as well as new applications of this technique to ship's datasets (I-COADS and blended MOHSST6-Jones land surface air temperature datasets).

A difficult task is the quantitative comparison of the current method with other analyses of global Sea Surface Temperature (ERSST, GISST and HadISST analyses). In a first step toward this goal, we also try to evaluate the robustness and accuracy of weighted EOF analysis by applying historical sampling to a globally complete SST dataset from a 200 years control run of a coupled General Circulation Model. This allows us to derive useful statistics about the accuracy of any reconstruction method and a fair comparison of the various techniques currently available if these techniques are applied to the same complete dataset using the same sampling.

**Detailed SST structures of the North Pacific climatic regime shift in the 1920s and 1940s based on 1-degree SST data compiled from COADS and the Kobe collection**

Shoshiro Minobe [1,2]
[1]Hokkaido University, Sapporo, Japan
[2] Frontier Research System for Global Change Yokohama, Japan
E-mail: minobe@ep.sci.hokudai.ac.jp

Using COADS and the recently digitized Kobe collection, a monthly SST dataset on a 1-degree longitude and latitude grid is produced. The gridded data are used to examine regime shifts in the 1920s and 1940s over the North Pacific. These shifts are two of three major regime shifts in the 20th century along with the 1970s regime shift, but detailed SST distributions have not hitherto been known. The SST difference from one regime to another shows that large amplitudes in the SST warming associated with the 1940s regime shift are limited to the subarctic front and subtropical front in all seasons. For the 1920s regime shift, the subarctic front exhibits substantial SST cooling in the warm season, with much weaker signatures in the cold season. These results show that the subarctic and subtropical front play central roles for the 1940s regime shifts and possibly in the 1920s regime shift, consistent with the well known changes of these fronts in the 1970s regime shift.

**Subseasonal and interannual variability in the Indian Ocean**

Gabriel A. Vecchi
JISAO, U. of Washington, Seattle, WA, USA
E-mail: Gabriel.A.Vecchi@noaa.gov

The tropical Indian air-sea interface exhibits strong non-seasonal variability on a variety of time-scales, from subseasonal to interannual, in many climatically important parameters (e.g. wind stress, precipitation and sea surface temperature). Variability on these timescales connects to significant weather and climate variability over land. Analysis of satellite and in situ data raise questions about our knowledge of climate variability, these results will be presented and discussed.

Indian Ocean regions of strong subseasonal air-sea variability generally correspond to regions of significant interannual variability. The extent to which our understanding of interannual variability is affected by undersampling the subseasonal variability needs to be explored. Subsampling experiments using satellite data indicate that there is potential for such aliasing in historical in situ data.

Analysis of the GTS dataset indicates that there may be systematic problems with even the seasonal description of certain variables. Specifically, in certain regions of the Indian Ocean (actually globally), there is a significant overabundance of ship SST measurements which are whole or half degrees - in some regions as many as 70% of all observations. Analysis of the statistical distribution of these data indicates that many of these whole (and half) degree retrievals show greater scatter than expected from mere truncation or rounding.

Further, the COADS monthly-mean SSTA and wind anomaly variability in the Indian Ocean (and actually in many regions of the world) very strongly show the variability in sampling: the strongest SSTA (and wind anomaly) variability is in regions of lowest sampling. This is suggestive that sampling errors and sub-gridscale variations represent much of the estimate of SSTA variability in the COADS gridded dataset over much of the world. Potential sources and impacts of the SSTA variance / sampling density covariability are examined.

# Session II: Pressure and Wind

**The elimination of spurious trends in marine wind data by calibration with individual pressure differences**

Ralf Lindau
Meteorologisches Institut Universitaet, Bonn, Germany
E-mail: rlindau@uni-bonn.de

Marine wind observations, such as collected in COADS, show considerable trends during the last century. That these trends reflect actually a real climate signal cannot be taken for granted since the observing practices on board merchant ships changed during the times which may well have introduced spurious trends into the data.

In the presented work pressure differences are used as an independent measure to identify and remove such superposed artificial wind trends. The crucial parameter in this context is the mean scalar wind speed rather than the vector mean wind speed, so that individual pressure differences have to be considered instead of gradients in the mean pressure field. The wind correction procedure is applied to COADS wind observation in the North Atlantic and a homogenised time series of the wind speed is presented.

**Joint analysis of marine sea level pressure and surface winds components**

Alexey Kaplan
Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY, USA
E-mail: alexeyk@ldeo.columbia.edu

Reduced space optimal estimation approach is used to produce combined analyses of surface winds and sea level pressure. Geostrophic balance (alternatively, three term frictional balance) is introduced as a weak constraint. This results in improved analyses, compared to the univariate cases. Large-scale aspects of interannual wind variability are faithfully reproduced. Scale of variability plays an important role in the quality of reconstruction: tropical Pacific winds are reconstructed with higher signal-to-noise ratio than those in the tropical Atlantic Ocean. Possibility of detrending wind data by using pressure-based constraints is studied.

**Reduction of uncertainty of marine wind fields for ocean response modeling by utilizing the QuikSCAT dataset**

Vincent J. Cardone
Oceanweather, Inc. Cos Cob, CT, USA
E-mail: vincec@oceanweather.com

The accuracy of marine surface wind fields has been limited intrinsically by the poor coverage and accuracy of in-situ data. Therefore, ocean response model hindcast studies for climate assessment have been forced to either tolerate use of wind fields with bias and poor resolution of the high energy cores of tropical cyclones and intense extratropical cyclones or adopt time consuming interventional kinematic analysis techniques for wind field preparation. While earlier scatterometer marine surface wind data sets from the SEASAT (SASS), ADEOS (NSCAT) and ERS (SCAT) missions demonstrated the promise of such data to the routine production of high quality marine wind fields, the continuous four+ year data base from the SeaWinds instrument on QuikSCAT provides the opportunity not only to produce a very high quality multi-year global marine wind data set, but a means to identify and correct at least the systematic component of errors that continue to characterize the marine wind fields of even the most recent historical atmospheric “reanalysis” project data sets. In this paper we first review the latest evidence on the accuracy and suitability for wind field analysis of wind measurements from in-situ (ships, buoys, platforms, coastal stations) and remotely sensed (satellite altimeters and scatterometers) wind data sources. We present new results on the accuracy and upper limit of the dynamic range of SeaWinds data based on comparisons of SeaWinds with a large number of collocated measurements made by anemometers with “top of derrick” exposure on offshore platforms in the North Sea and Norwegian Sea. Next, we describe how the SeaWinds measurements may be used to identify and minimize systematic errors in the reanalysis products. Finally, we describe an optimum method for wind field analysis which combines wind measurements, after they are properly adjusted for reference height, boundary layer stratification, marine exposure and averaging interval, reanalysis and NWP products, after minimization of systematic errors in same using the QuikSCAT data base, and (where tolerable) analyst expertise, in an interactive objective kinematic analysis (IOKA) approach. Examples are given of the maximum skill achievable in ocean response modeling when such models are forced by accurate winds.

**Quantifying the effects of airflow distortion on wind speed measurements from Voluntary Observing Ships**

Ben Moat
(presented by Peter Taylor)
Southampton Oceanography Centre, UK
E-mail: bim@soc.soton.ac.uk

Wind speed measurements obtained from ship-mounted anemometers are biased by the presence of the ship which distorts the airflow to the anemometer. Until recently this bias had only been quantified for a few well-exposed anemometer sites on individual research ships, whereas the magnitude and even the sign of the bias was unknown for anemometers on Voluntary Observing Ships (VOS). Wind tunnel and numerical model studies have now been performed to quantify the pattern of airflow above the bridge of typical VOS. Typically the flow is accelerated by up to 15% or decelerated by 100% depending on position. Scaling laws have been derived to predict this bias given the anemometer position, the ship type and the ship length. These laws have been validated using measurements from a research ship. In practice, an anemometer should be mounted as high and as far forwards as possible on the wheelhouse top.

**The ERA-40 wind and wave data**

Sofia Caires and Andreas Sterl
Royal Netherlands Meteorological Institute (KNMI), Netherlands
E-mail: sterl@knmi.nl

The European Centre for Medium-Range Weather Forecasts (ECMWF) has recently conducted ERA-40, a reanalysis of global atmospheric conditions for the period from 1957 to 2001. The reanalysis uses ECMWF's Integrated Forecasting System, a coupled atmosphere-wave model with variational data assimilation. This is the first reanalysis in which a wave model is coupled with the system used, and it produced a global wave data set on a 1.5º by 1.5º latitude/longitude grid. We will present results of extensive validations of the ERA-40 ocean wind and wave data and show how, using some modern statistical techniques, the data can be used reliably to estimate parameters pertaining to both short and long time scales, such as percentiles and return values. We will additionally show how climate variability has been influencing ocean waves.

## The WMO AOPC/OOPC Surface Pressure Group

Rob Allan

Hadley Centre, Met Office, Bracknell, Berkshire, UK

E-mail: rob.allan@metoffice.com

The WMO Atmospheric Observation Panel for Climate (AOPC)/Ocean Observations Panel for Climate (OOPC) Surface Pressure Group provides a forum to discuss and act on issues involving the collection, processing, quality control, storage and use of historical atmospheric pressure data within the international scientific community. The focus of this Group extends equally to individual station records, databases and gridded products.

The specific terms of reference of the Group are:

- to promote the analysis of global surface pressure from both real-time and historical sources using both daily and monthly data
- to record and evaluate differences among surface pressure analyses through comparison of basic products
- to recommend actions needed to ensure the quality and consistency of surface pressure analyses based on analysis of those differences
- to promote the recovery of atmospheric pressure data, including issues associated with data access, archiving and maintenance
- to promote the comparison of the various types of barometers and pressure sensors (including satellite estimates) used to measure surface pressure
- to report annually to AOPC and OOPC on progress, recommendations and future plans of the Group

A current aim of the Group is the development of a comprehensive international historical mean sea level pressure (MSLP) database. This encompasses initiatives on both monthly atmospheric pressure data with a global focus plus daily atmospheric pressure data over at least the European to Atlantic sector. Such efforts will be of direct benefit to the development of high quality gridded data sets encompassing terrestrial, island and marine atmospheric pressure data. This includes ongoing work to incorporate I-COADS data with land-based records.

To date, the Group has held an initial meeting at the International Workshop on Advances in the Use of Historical Marine Climate Data, held at Boulder, Colorado, USA in January-February 2002, followed by a workshop at the University of East Anglia, Norwich, UK in November 2002.

**Development of a daily gridded MSLP data set over the North Atlantic region using I-COADS**

Tara Ansell, Rob Allan, David Parker, Philip Brohan and Nick Rayner
Hadley Centre, Met Office, UK
E-mail: tara.ansell@metoffice.com

One of the aims of the EC-funded EMULATE (European and North Atlantic daily to MULtidecadal climATE variability) project is to define characteristic atmospheric circulation patterns over the European and North Atlantic region. Previous studies of this nature have been limited by a lack of gridded mean sea level pressure (MSLP) products of sufficient length. However, the recently released International Comprehensive Ocean-Atmosphere Data Set (I-COADS), with several million new observations, has made projects such as EMULATE feasible.

We discuss the quality control and gridding strategy employed with the I-COADS data to produce daily gridded MSLP fields over the North Atlantic region from 1850 for EMULATE. Techniques previously employed at the Hadley Centre have been re-examined and modified as part of this work. As well as describing these techniques, we present initial efforts to attach uncertainty estimates to each grid box value. A number of important issues pertinent to the I-COADS data, such as previously undetected duplicates and the use of Paris longitude, will also be raised. The overall aim is to highlight the potential benefits of using historical marine data in climatic studies, such as EMULATE.

**Feasibility of reanalysis before the radiosonde era**

Gilbert P. Compo, Jeffrey S. Whitaker, and Prashant D. Sardeshmukh
NOAA-CIRES Climate Diagnostics Center, Boulder, CO, USA
E-mail: compo@colorado.edu

We have investigated the feasibility of using surface pressure observations to create a daily analysis of the tropospheric circulation from the late 19th century to present. We have performed parallel assimilation experiments for November 2001-February 2002 using surface data at observational densities expected for 1893 to 1935. Three systems were compared: statistical optimal interpolation (OI), NCEP-NCAR reanalysis climate DAS (CDAS), and an ensemble square root filter (EnSRF). We have found that OI, using climatology as a first-guess, is extremely competitive with CDAS in the northern hemisphere, with both producing high-quality daily surface pressure fields in our test period. The CDAS is also able to produce realistic lower-tropospheric analyses through the model's dynamics. The EnSRF produces higher quality analyses of the lower troposphere than either OI or CDAS. Surprisingly, the EnSRF is also able to produce useful analyses of the large-scale flow up to 300mb using only surface pressure observations.

**Different sources of errors and uncertainties in the visual wave estimates**

Vika Grigorieva[1], Sergey Gulev[1], Andreas Sterl[2], David Woolf [3]

[1] P.P.Shirshov Institute of Oceanology, Moscow, Russia
[2] Royal Netherlands Meteorological Institute, De Bilt, Netherlands
[3] Southampton Oceanography Centre, United Kingdom

E-mail: vika@sail.msk.ru, gul@sail.msk.ru, sterl@knmi.nl,dkw@soc.soton.ac.uk

Different sources of errors and uncertainties in visual wave observations are estimates on the basis of visual wave data from the COADS collection of marine variables. Visually observed wind wave heights and periods were extracted from COADS for the 50-year period from 1950s onwards. These data were used for the development of a global climatology of wave variables. Significant wave height has been derived from separate sea and swell estimates by different methods. Uncertainty in estimation of SWH with respect to the directions of propagation of sea and swell is estimated. Some regional recommendations for a proper estimation of SWH were derived. Special algorithms of corrections were applied to minimize some biases, inherent in visual wave data. Particularly, we corrected overestimation of small seas, underestimation of periods, and also analysed separation between sea and swell. Further analysis included estimation of random observational errors, day minus night biases and sampling errors on the basis of buoy observations and model data. Estimates of random observational errors show that for most of the locations observational uncertainties are within 20% of mean values. The highest sampling biases are observed in the South Ocean, where wave height may be underestimated by 1-1.5 m due to poor sampling, primarily associated with a fair-weather bias of ship routing and observation. Elimination of sampling bias allows for an accurate comparison of VOS wave data and model wave hindcasts.

# 20th century climate changes in ocean wind waves over the Northern Hemisphere from visual wave data

Sergey Gulev [1], Vika Grigorieva[1], Olga Zolina[2], Scott Woodruff[3]

[1] P.P.Shirshov Institute of Oceanology, Moscow, Russia

[2]Meteorologisches Institut, Universitatet Bonn, Germany

[3] Climate Diagnostics Center, Boulder, CO, USA

E-mail: gul@sail.msk.ru, olga.zolina@uni-bonn.de, Scott.D.Woodruff@noaa.gov

Variability in the characteristics of the wind waves over the Northern Hemisphere is studied on the basis of the Global Climatology of Ocean Waves, derived from the Voluntary Observing Ship (VOS) data for the period from the end of 19th century to present. Wave observations in VOS are taken visually by marine officers, and to a lesser degree than winds are influenced by historical changes in observational practices. An outstanding feature of visual wave observations is the availability of separate estimates of the wind sea, associated with the local wind, and swell, integrating the wind forcing over the larger domain. Traditionally analysed from the model and satellite data significant wave height (SWH) results from these two components and does not allow for the understanding of mechanisms driven the variations on surface roughness. We studied long-term trends in wind sea, swell, and SWH for the period from 1880 to 1940s along the major ship routes and from 1950s to present over the whole North Atlantic and North Pacific. Decadal scale variations were studied for the last 50 years using EOF and SVD analysis. Special attention is given to the effects of sampling errors in variability of ocean waves. Wind sea and swell demonstrate different patterns of variability, associated with the North Atlantic Oscillation (NAO) and Pacific Oscillation. In particular, swell variability is clearly associated with the storm frequency, while wind sea reflects the local wind signal. In order to project the NAO signals onto wave variability, joint analysis of the climate variability in the characteristics of atmospheric cyclones over the Northern Hemisphere and of the wind wave parameters has been performed.

**Forecasting dangerous sea-states: beyond Hs and Tp**

Jaak Monbaliu and Alessandro Toffoli
Hydraulics Laboratory K.U.Leuven
Hydraulics Laboratory, Department of Civil Engineering, Belgium
E-mail: jaak.monbaliu@bwk.kuleuven.ac.be

Ships that founder represent a great disaster both from an economical and from a human point of view. For dangerous sea-states, the best possible warnings should therefore be given to mariners.

A forecasted wave height and peak period is routine information. Also swell conditions are often provided. But a forecasted wave spectrum contains a lot more information, unfortunately information that is difficult to translate into warnings. Within the framework of the E.U.-project MaxWave, a data base with information about ship accidents for the period 1995-1999 and reported as being caused by heavy seas was provided by Lloyd's Marine Information Service (LMIS). Consequently concurrent wave spectra and wave spectral parameters were extracted from the ECMWF-archive and analysed. The findings might eventually lead to the formulation of risk indicators or warning criteria, i.e. combinations of thresholds and bounds for parameters characterising both the complex sea-state and the marine structure.

key words: wave spectra, forecast, heavy seas, ship accidents; warning criteria

**Mean sea level pressure and wind climatology over the North Indian Ocean: quality control, validation and biases**

M. Rajeevan and S.K.Dikshit

India Meteorological Department, Pune, India

E-mail: rajeevan61@yahoo.co.in

As a responsible member country of the World Meteorological Organization (WMO), India Meteorological Department has been collecting and archiving marine meteorological data of Indian Ocean north of $15^0$ S. Using the archived data of 1961-2000, climatological charts of mean sea level pressure, and wind speed were prepared and validated.

Observations obtained from the meteorological logbooks of the VOF were scrutinized to eliminate instrumental, positional & coding errors. These data together with those received from other WMO members were examined & the corrected data were injected into the data bank for the further processing. As per the WMO guidelines, the data were subjected to further quality control like duplicate observations, internal consistency, highest and lowest values etc. More than 3.5 million records of marine data were used to prepare the climatology of north Indian Ocean.

The area of responsibility is divided into boxes with constant grid spacing of $2.5^0$ each in latitude and longitude. All available quality controlled observations are averaged in each box for each month during the 40-year period. The monthly mean fields were then objectively analyzed to filter out spatial noise. The objective analysis scheme used to filter out the spatial noise is an iterative difference-correction scheme with a Barnes weight function.

The monthly mean climatology of Mean sea level pressure, wind speed (10 metre) and wave height are analyzed and compared with the NCEP/NCAR reanalysis data. It has been found that the differences between the reanalysis mean pressure (mean for the same period, 1961-2000) and marine climatological pressure were of the order of 0.5 hPa. However, there were no systematic biases between the two data sets. For the wind speed, both the climatologies agree with each other except over south Bay of Bengal. Over this region, NCEP/NCAR reanalysis data over estimates the wind speed. This difference was found to be a systematic bias in the reanalysis data. The absolute differences over other parts of the region are less than 1 metre per second.

Quality control, uncertainty etc. are discussed in detail in the paper. The results of inter-annual variability of pressure and wind speed and its relationship with El Nino/Southern Oscillation are also discussed.

**Nature of marine winds, waves and swells over West African coasts - case study of Victoria Island beach in Lagos, Nigeria**

S. O. Gbuyiro and E. Olaniyan
Marine Unit, Nigeria Meteorological Agency, Lagos, Nigeria
E-mail: samuel_gbuyiro@yahoo.com

Beaches and bays are essential in the economic development of any nation around the world. One of the natural forces eroding beaches and threatening the coastal environment is the wave caused by the prevailing ocean winds. Over the years Victoria Island in Lagos had suffered massive erosion from the action of the wave energy.

This paper therefore investigates the nature and characteristics of the marine winds, generated waves and the corresponding coastal swells for the months of January-March from 1998 –2002 using a parametric wave model.

Results showed that:

a. Winds from the fetch area (lat. 10 degree South - 20 degree South and long. 0–10 degree East) generally lie between 7-20 knots in strength. The weakest and strongest winds were observed in January and March.
b. The corresponding significant wave heights were less than 0.3 meters and more than 2.2 meters with period ranging between 2.0 and 7.5 seconds. It takes the lowest generated wave about 10-12 days and the highest 3-4 days to reach the coast as swells. Swells of about 0.4 meters resulting from winds of about 10 knots grazed the coast frequently during the period.
c. Rate of erosion from 1998–2002 was observed to be 27m/year.

# Session III: Marine Temperatures and Sea Ice

**Historical and modern marine surface temperatures: improved analyses and estimation of uncertainties**

David Parker[1], Nick Rayner[1], Philip Brohan[1], Chris Folland[1], Jen Hardwick[1], Elizabeth Kent[2], Simon Tett[1] and Michal Vanicek[1].

[1]Hadley Centre, Met Office, Bracknell, UK
[2]Southampton Oceanography Centre, UK

E-mail: david.parker@metoffice.com

We have created new analyses of marine surface temperatures spanning the last 150 years, using the new International Comprehensive Ocean Atmosphere Dataset (I-COADS). This dataset provides much better coverage than previously available, especially in the 1850s and 1910s. However, uncertainties remain in the analyses owing to sampling and measurement errors and, most importantly, imperfections in the bias-corrections applied to the data to ensure a homogeneous time series for climate change studies. We discuss these sources of uncertainty, the construction of the analyses, and the methods used to assign estimates of uncertainty to each gridded temperature.

We also present some analyses of climate variability and change since the 1850s, including uncertainties in global and regional averages due to data gaps as well as to the abovementioned uncertainties. Where appropriate, the new time series are compared to those published in the Third Assessment Report of the Intergovernmental Panel on Climate Change.

**Uncertainties in corrections applied to marine temperature data to account for changing measurement practices**

Nick Rayner[1], Jen Hardwick[1], David Parker[1], Chris Folland[1] and Liz Kent[2]

[1]Hadley Centre for Climate Prediction and Research, Met Office, UK
[2]James Rennell Division, Southampton Oceanography Centre, UK

E-mail: nick.rayner@metoffice.com

We apply corrections to monthly anomaly fields of (a) SST, to account for the effect on measurements of changing methods for collecting sea water (b) night marine air temperature (NMAT), to account for the effect of the changing height of the observing platform through the record and (c) NMAT, to correct for periods of non-standard measurement or shipping practice, e.g. between 1939 and 1945 and in the nineteenth century around the Suez Canal. All these corrections act to bring the affected data into line with those from a modern reference period and all are uncertain to some degree. Here we quantify that uncertainty, using documentary evidence and experiments to test the effects on the corrections of the likely limits of the assumptions made. Uncertainties in bias corrections make the largest contribution to the overall uncertainty in global mean marine temperatures, because of both their magnitude and the covariance between grid boxes.

**Combined estimates of uncertainties in gridded marine temperature fields due to measurement errors and under-sampling of variability**

Philip Brohan[1], Nick Rayner[1], Michal Vanicek[1], Simon Tett[1] and Liz Kent[2]

[1]Hadley Centre for Climate Prediction and Research, Met Office, UK
[2]James Rennell Division, Southampton Oceanography Centre, UK

E-mail: nick.rayner@metoffice.com

Gridded marine temperature fields based mostly on the I-COADS data base have been created for 1851-2002. Inevitably, these measurements do not sample the full range of variability within each grid box, as they are taken at set times of day from moving platforms. Compounded into this uncertainty is a small contribution from random measurement errors. Sampling/measurement errors are found to be independent between grid boxes and are quantified by fitting certain relationships to high-pass filtered data binned by number of constituent observations. The fit in the limit of an infinite number of observations determines the true variance and allows the spurious variance to be estimated. Once the error in using only one observation in a grid box has been quantified, this can be translated into the uncertainty in the actual monthly value using the number of independent observations in the box.

**Correction of daytime marine air temperatures for climate studies**

David I. Berry, Elizabeth C. Kent and Peter K. Taylor
Southampton Oceanography Centre, UK
E-mail: dyb@soc.soton.ac.uk

Marine air temperatures measured on ships can be several degrees too warm if there is strong sunshine and the ship's instruments are poorly exposed. Since the ship heats up as the day progresses, these errors are larger in the afternoon than in the morning. However previous attempts to correct the error did not allow for this heat storage. A new correction based on the analytical solution of the heat budget for an idealised ship will be presented. A method is proposed for estimating the heating errors and the correction fitted to observations. The correction will then be applied to merchant ship air temperature observations from the North Atlantic. The impact of the correction on climatological temperature time series and surface flux fields will be demonstrated.

**Objective analyses of temperature and salinity for the world ocean on a 1/4 degree grid**

Boyer T., J. Antonov, H. Garcia, S. Levitus, R. Locarnini, and C. Stephens
NOAA-NODC Ocean Climate Laboratory, Silver Spring, MD, USA
E-mail: Hernan.Garcia@noaa.gov

Objectively analyzed mean temperature and salinity fields have been calculated and quality controlled both on annual and seasonal time scales on a 1/4° grid using techniques previously used to compute the 1° gridded mean fields in the World Ocean Atlas 2001.

The quarter degree analyzed fields retain the large-scale oceanic features that exist in the one degree analysis while better resolving smaller scale features such as the Loop Current in the Gulf of Mexico and the Agulhas Retroflection. Quality control of the quarter degree analysis has also enhanced the one degree analysis as well. However, limitations exist in the quarter degree analysis at deeper depths due to lack of data available.

**Sea surface temperature analyses for climate and their errors**

Richard W. Reynolds, Thomas M. Smith, Hui-Min Zhang
National Climatic Data Center/NESDIS/NOAA, Asheville, NC, USA
E-mail: Richard.W.Reynolds@noaa.gov

Sea surface temperature (SST) analyses used for climate use in situ SST data and may or may not use satellite SST data when available. These analyses are often used on seasonal and interannual scales for monitoring and prediction of El Niño events and on decadal and centennial scales for climate trend detection. For these purposes it is important that analysis methods be constant with time and not influenced by temporal changes in SST data. Methods of producing climate SST analyses are discussed. To determine their accuracy, analysis errors are estimated for three types of errors; sampling, random and bias errors. Examples are shown of these three types of errors during the entire period of record. Bias errors gradually decrease with time until the period with satellite data when they often increase again. Once satellite data become available, the primary need for in situ data is to decrease any satellite biases.

**A framework for combining in situ and satellite SST data:**
**the Global Ocean Data Assimilation Experiment (GODAE)**
**High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP)**

Craig Donlon
Director of the GHRSST-PP International Project Office, Met Office, UK
E-mail: craig.donlon@cmetoffice.com

The primary aim of the Global Ocean Data Assimilation Experiment (GODAE) High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP) is to develop and operate a demonstration system that will deliver high-resolution (better than 10 km and ~ 6 hourly) global coverage SST data products operationally in near real time for the diverse needs of GODAE and the wider scientific community. A new generation of global coverage SST data products will be derived and served to the international user community by combining complementary Level-2 (L2) satellite and in situ observations in real time (6 hourly).

There are obvious synergy benefits to such an approach but their practical realisation is complicated by characteristic differences that exist between measurements of SST obtained from subsurface situ sensors, satellite microwave radiometers and, infrared radiometer systems. Furthermore, diurnal variability of SST within a 24 hour period, manifest as both warm layer and cool skin deviations, introduces additional uncertainty for direct inter-comparison and the implementation of data merging strategies.

Definitions of SST in the upper 10 m of the water column provide a necessary theoretical framework to understand the information content and relationships between complementary measurements of SST. The framework developed by the GHRSST-PP Science Team is presented which attempts to achieve the closest possible coincidence between definitions of SST and what can be measured operationally using in situ and satellite systems, bearing in mind current scientific knowledge and understanding of how the near surface thermal structure of the ocean behaves in nature. Finally, the GHRSST-PP diagnostic and validation strategy that has been designed to provide a virtual laboratory for the inter-comparison and development of satellite SST bias correction statistics is presented.

**Improvements to a satellite derived SST climatology**

Edward Armstrong and Jorge Vazquez
Jet Propulsion Laboratory/Caltech,Pasadena, CA, USA
Email: ed@seastar.jpl.nasa.gov

Sea surface temperature (SST) climatologies derived from high resolution satellite measurements have demonstrated good performance in representing SST variability while reducing climatic noise. Here we focus on improvements to the JPL AVHRR Pathfinder SST climatology with regards to aerosol contamination. In this study, data from AVHRR Pathfinder Atmosphere (PATMOS) data set are used to flag and remove those satellite SST measurements that are deemed contaminated with high aerosol concentrations. Preliminary results indicate that improvements of several tenths of a degree Celsius are achievable using a simple linear flagging for aerosols. After flagging the climatology is recomputed and improvement is documented with comparisons to SST in situ observations from the World Ocean Database 2002. Further improvements by including the SST measurements from the ATSR-2 instrument are examined. The relevance of understanding biases between the AVHRR and ATSR derived SSTs will be discussed with respect to future merging strategies and the impact on climate data records.

**Comparing sea surface temperature climatologies from a new high-resolution satellite dataset and I-COADS: reciprocal feedback and insights**

Kenneth S. Casey
NOAA/NESDIS National Oceanographic Data Center, USA
E-mail : Kenneth.Casey@noaa.gov

While relatively short compared to the historical ship-based SST record, satellite-based time series from the Advanced Very High Resolution Radiometer are exceeding 20 years in length and have been shown to provide accurate and useful climatological information. A new reprocessing based on an improved Pathfinder algorithm by the University of Miami and the NOAA National Oceanographic Data Center has resulted in a global time series of SST at 4 km resolution dating back to 1985. Climatologies derived from this new satellite product are compared with those from I-COADS and other in situ and blended datasets to reveal insights on the strengths and weaknesses of each. Results indicate useful information can be gained on the quality of not only the satellite observations as is customary with satellite and in situ comparisons, but on the nature of the in situ datasets as well.

**Reprocessing of the 20-year satellite record of SST**

Andrew Harris
NOAA/NESDIS and UMD/CICS, USA
E-mail : Andy.Haris@noaa.gov

The AVHRR sensors carried on board the NOAA polar orbiting satellites offer the longest continuous dataset for spaceborne retrievals of sea surface temperature. Although short in comparison with the historical in situ record, the satellite data provide a vast number of observations with frequent and regular global coverage. It is essential that such a dataset be processed in as uniform a manner as possible, accounting for all known sources of bias and with a good description of the quality of the output. Previous efforts have used direct matches to *in situ* data in order to specify the retrieval algorithm, thereby eliminating some potential sources of error but intrinsically combining others into the final product. One particular difficulty has been the variation in retrieval quality due to the dramatic changes in availability of *in situ* data over the past two decades. We are now engaged in a project that makes use of radiative transfer methodology to specify the retrieval algorithms independent of *in situ* data coverage. This not only allows error estimates to be made for all regions and times but also permits independent evaluation via the available in situ data. Furthermore, surface effects (skin effect and diurnal thermocline) and aerosols can now be dealt with explicitly. A preliminary version is expected to be available for evaluation in 2004, with the final dataset being released by the end of 2005.

**Progress in geostationary SSTs and cloud detection**

Andrew Harris
NOAA/NESDIS and UMD/CICS, USA
Andy.Haris@noaa.gov

The high temporal sampling rate of geostationary sensors offers a number of advantages for remotely sensed sea surface temperatures. Firstly, there is the prospect of combining multiple passes to obtain greater spatial coverage of ocean areas that have significant cloud cover. This is particularly advantageous in active regions such as western boundary currents where features change rapidly. Furthermore, there is the opportunity to obtain significant information on the diurnal cycle of ocean surface temperature. We have commenced a project to reprocess all of the GOES-Imager data back to 1994, using state-of-the-art radiative transfer techniques to produce a uniform dataset for community use. As part of this project, new approaches to cloud detection based on combined probabilities, are being explored. The paper highlights both the main characteristics of the geostationary SST data and the methods being employed in their production.

## TMI and AMSR-E microwave SSTs

Chelle Gentemann* and Frank Wentz
*Remote Sensing Systems, CA, USA
E-mail: gentemann@remss.com

On May 4, 2002, NASDA's AMSR-E was launched aboard NASA's AQUA spacecraft. AMSR-E represents an important global extension to the TRMM TMI retrievals. Geophysical parameters, such as SST, wind speed, atmospheric water vapor, cloud water, and rain rate, are measured by TMI and AMSR-E. These environmental variables are calculated using a multi-stage linear regression algorithm derived through comprehensive radiative transfer model simulations. SST retrieval is prevented only in regions with sun-glitter, rain, and close to land where there is side-lobe contamination. Since only a small number of retrievals are unsuccessful, the wide swath provides almost complete global coverage daily.

**Diurnal signals in satellite sea surface temperature measurements**

Chelle L. Gentemann*, Craig J. Donlon, Alice Stuart-Menteth, and Frank J. Wentz
*Remote Sensing Systems,CA, USA
E-mail: gentemann@remss.com

The formation of a near-surface diurnal warm layer, particularly in regions with low wind speeds, is clearly present in daytime satellite sea surface temperature (SST) measurements. TMI, AMSR-E, and AVHRR satellite SST retrievals reveal significant diurnal amplitudes covering large oceanic regions, with regional distribution and amplitude of warming varying significantly within annual cycles. The onset of warming sometimes begins as early as 8 AM and generally peaks near 3 PM, with a magnitude of 2.8 K during favorable conditions. After this peak, the signal decays, but sometimes extends until 11 PM. Evidence of warming exists up to wind speeds of 10 m/s, affecting most daytime retrievals, and resulting in a globally average warming of 0.2 K in AVHRR daytime SSTs. This has consequences for any analysis utilizing daytime SSTs. A simple empirical model was calculated from satellite SSTs, satellite wind speeds, and modeled insolation. This model appears to accurately model diurnal warming and nocturnal cooling present in the satellite retrievals. A better understanding of how wind, insolation, and clouds affect diurnal variability is necessary for optimal fusion of satellite retrievals with different ascending node times.

**Global comparisons of satellite derived SSTs with in-situ observations from the World Ocean Database**

Jorge Vazquez and Ed Armstrong
JPL/Caltech M/S 300/323. Pasadena, CA, USA
E-mail : jv@pacific.jpl.nasa.gov,ed@seanet.jpl.nasa.gov

Comparisons are done between the Modified Pathfinder Sea Surface Temperature Data Set (PFSST) and SSTs derived from the Along-Track Scanning Radiometer (ASST2) with in-situ data SST from the World Ocean Database (WSST). The PFSST and the ASST2 were co-located with the WSST within an 18km and 6 hour space-time window. The WOD was chosen because of its independence from the PFSST matchup database, which is used in the calculation of the PFSST coefficients. Mean differences were defined as MPFSST-WSST and ASST2-WSST.

Preliminary results indicate that the largest global mean difference of -0.3 degrees C (ASST2 cooler than WSST) occurs for daytime comparisons between ASST2 and WSST, possibly indicative of skin-bulk temperature differences. The smallest global mean difference of 0 degrees Celsius occurs between the daytime PFSST and the WSST. In all cases rms differences are around 0.8 degrees C, but these values vary regionally.

Statistics will be calculated regionally to determine the space-time characteristics of the differences and possible explanations. Differences will be examined with respect to impacts on using these data sets in climate studies.

**New high resolution combined analysis of historical sea surface temperatures and sea ice concentrations**

Alexey Kaplan
Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY, USA
E-mail: alexeyk@ldeo.columbia.edu

We present an enhanced data set of historical surface temperatures (SST) and sea ice concentrations (SIC). The technique of reduced space optimal estimation was modified to produce a globally complete high resolution (1x1 degree for the world ocean) objective analysis of monthly surface temperatures and sea ice concentrations with verifiable uncertainty estimates. Covariance matrix is modeled as a sum of two pieces: low-rank large-scale part and a small-scale localized covariance correction. Long-term variability is separated by an iterative procedure. We use multivariate (SIC and SST) reduced space optimal estimation for analyzing sea ice concentrations.

**JCOMM Expert Team on Sea Ice: practical results for 2002-2003**

Vasily Smolyanitsky
Arctic and Antarctic Research Institute (AARI) St. Petersburg, Russia
E-mail: vms@aari.nw.ru

JCOMM ETSI now incorporates experts from the 11 major ice services and centers dealing both with Arctic, Sub-Arctic and Antarctic sea ice and “review and advise [JCOMM] on scientific, technical and operational aspects of sea ice observations and forecasting, oversight operations of the GDSIDB, coordinate services development and training and linkages with major international programmes.” The first session of the group combined with the ninth session of the WMO project “Global Digital Sea ice Data Bank” (GDSIDB) was held in October 2002 in Buenos-Aires, Argentina. More recently an ad-hoc meeting of ETSI was held in April 2003 in St. Petersburg during the fourth session of the International Ice Charting Working Group (IICWG). Both meetings are by all means valuable for the sea ice community; full reports of the meetings are available from the WMO Secretariat and IICWG Committee correspondingly. Nowadays ETSI in collaboration with IICWG finalized or develops a number of the technical documents, including new format for data exchange (SIGRID-3), color standards for ice charts, proposals for a revised WMO Sea Ice Terminology and Marine Glossary et al., which are intended both for the operative sea ice community and other marine meteorology specialists.

**Investigation of Arctic ice cover variance using XX-century historical ice charts information and last decades' microwave data**

Vasily Smolyanitsky
Arctic and Antarctic Research Institute (AARI) St. Petersburg, Russia
E-mail : vms@aari.nw.ru

Arctic ice cover along with the other natural phenomena simultaneously undergoes both short-term and long-term decadal and centennial variability, assessments of its scale and spectrum being dependant on the data involved into the statistical analysis. A significant and vast collection of mostly airborne expert-controlled ice charts from international ice services (Canada, USA and Russia) for second half of the XX century, prepared in digital formats under the WMO auspices (within the "Global Digital Sea Ice Data Bank" project), provides an opportunity to construct blended (multi-agency) datasets. Blending technique provides incorporation of the "best guess" information from each agency into the final dataset and in many cases makes it possible to eliminate numerous temporal and spatial gaps in individual datasets. That subsequently provides opportunity to describe Arctic ice cover as a two-dimensional stochastic process, assess corresponding statistics and to introduce various time scale (monthly, annual, decadal) WMO sea ice norms for 1950-2000.

The same analysis but for a shorter period of the last two and a half decades (1978-2003) may be done on a basis of modern daily SSMR/SSMI ice extent dataset, statistically independent from the first one. Given dataset is constantly expanding and presently is the prime source of search for a signal of modern climate change in sea ice. Investigation of the Arctic ice extent variances assessed separately on a basis of ice charts and Bootstrap version of SSMR/SSMI ice extent dataset reveals congruency in most cases. However as usually the case for statistical analysis, a number of differences was also observed for areas with predominance of certain structural elements of ice cover, such as fast ice and flaw polynyas of Siberian shelf seas. It is evident that such statistical cross-investigation would reduce uncertainties in dealing with DMSP SSMI data in seasonal cycle and improve quality of sea ice data for numerical modeling.

**Antarctic sea ice variability in the Weddell, the Bellinghausen and the Amundsen Seas**

Sandra Barreira[1] and Rosa Compagnucci[2]

[1] Argentine Navy Meteorological Service
[2] University of Buenos Aires - College of Exact and Natural Sciences - Department of Atmospheric Science and Oceanography

E-mail: barreira@ara.mil.ar

Sea ice is an important, highly variable feature of the Earth's surface, both reflecting and influencing climatic conditions. Sea ice covers approximately 7 percent of the world oceans, significantly reduces the amount of solar radiation absorbed at the Earth's surface, greatly restricts the transfer of heat from the ocean to the atmosphere in winter, and influences global atmospheric and oceanic circulation. In this paper, monthly through interannual variability of the sea ice between 0° and 120°W is analysed for the 23-year period 1979 through 2000.

The monthly Polar Gridded Sea Ice Concentrations data set derived from the Nimbus-7 Scanning Multichannel Microwave Radiometer (SMMR) and the Defense Meteorological Satellite Program's (DMSP) DMSP-F8, F11 and F13, Special Sensor Microwave/Imager (SSM/I) generated by NASA team algorithm were used. This data were acquired from the National Snow and Ice Data Center (NSIDC) and are gridded on the SSM/I polar stereographic grid (25 x 25 km) provided in two-byte integer format.

Principal Components Analysis in S-Mode was performed on pre-processed sea ice data (anomalies from which have been removed continent and perennial open water), in order to provide a regionalization of the selected Antarctic region in several areas of similar temporal behaviour. The temporal patterns were correlated to Southern Hemisphere surface air and sea temperature and climatic variability indices like SOI, RSOI and PDO.