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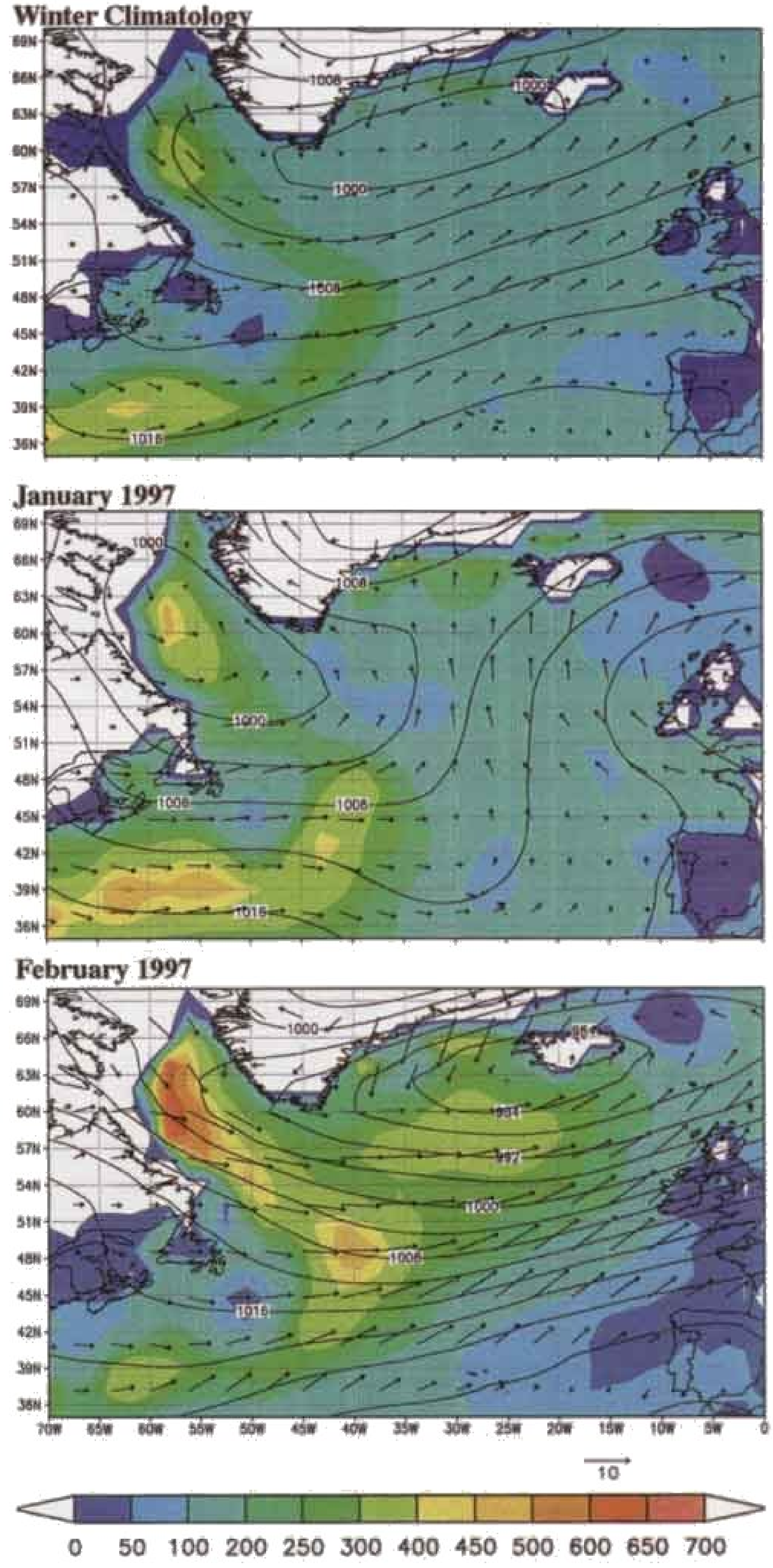
APPLICATION OF REANALYSIS PRODUCTS TO THE ATMOSPHERIC FORCING OF DEEP CONVECTION IN THE LABRADOR SEA



Monthly mean sea-level pressure (mb), 10-meter wind (m/sec) and total heat flux (W/m^2) as determined from NCEP/NCAR reanalysis. See article on page 6.

FRONTS AND ATLANTIC STORM-TRACK EXPERIMENT (FASTEX): A SHORT OVERVIEW AND THE GCSS CONNECTION

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Improving the understanding and modeling of the interaction between clouds and radiative processes is an important goal of GEWEX, especially the GEWEX Cloud System Study (GCSS) component (Browning, 1994). The GCSS is a program that addresses this problem by adapting an overall strategy to the various types of clouds. Midlatitude cloud systems form one such important category. A special feature of these clouds, which are predominantly stratiform, is their close interaction with dynamical processes. Therefore, the study of midlatitude cloud systems is closely related to the problem of cyclogenesis in the vicinity of the so-called "storm-tracks."

The internal organization of these systems is highly complex. Some of the outstanding issues are, for example, related to the vertical structure. Synoptic scale ascents are relatively simple, with often a single well-defined maximum somewhere in the lower half of the troposphere and yet the

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WHAT'S NEW IN GEWEX

GEWEX CSEs Plan Coordinated IOP (See back page for details)

Workshop Defines Broader GVaP Objectives

PILPS Shows Good Results With Observed Data

Ocean Studies Illustrate GEWEX Connection

COMMENTARY

THE FUTURE DIRECTION OF THE GEWEX GLOBAL WATER VAPOR PROJECT (GVaP)

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Since its inception, GEWEX has recognized the need to improve the observation and documentation of the distribution of water vapor in the atmosphere, both vertically and horizontally. Water vapor exerts great control over the dynamics, thermodynamics and the chemistry of the atmosphere, involving complex feedback processes with clouds and radiation. Many aspects of climate research depend on accurate knowledge of water vapor. In 1992, GEWEX initiated a pilot study to determine the feasibility of developing an accurate global water vapor climatology data set from current operational weather observations. The first 5 years of data (1988–1992) were released in 1995, with additional years (1993–1995) becoming available during 1997. Recently, a CD-ROM was issued containing selected data sets (1988–1994), including animations of daily averaged global fields, monthly averaged data and sample months of daily averaged fields.

The pilot study was successfully completed and in 1996 GEWEX asked Prof. Thomas Vonder Haar (Colorado State University) to undertake a comprehensive study to define a strategic plan for the next phase of GVaP. Two international workshops were conducted in the fall of 1996 (Geneva) and the summer of 1997 (Washington, D.C.), involving representatives from IPMET (Brazil); Eumetsat, Max-Planck, ESA, CNRS (Europe); JMA, NASDA (Japan); NASA, NOAA, NCAR (USA) and the university community, to name just some of the organizations involved. Three other programs of WCRP, the Climate Variability and Predictability Study (CLIVAR), Stratospheric Processes and their Role in Climate (SPARC) and the Arctic Climate System Study (ACSYS) participated and helped determine the requirements for the future activities of the GVaP program.

From the recommendations of these workshops, GVaP has taken the responsibility to (a) improve the models and related tools that predict global and regional climate and hydrology, including (long-term) variations in extreme hydrological events (e.g. floods and droughts); (b) establish an accurate and validated water vapor climatology on the relevant time and space scales; and (c) identify the horizontal and vertical fluxes of water vapor and the processes that control these fluxes and the associated phase changes of atmospheric water.

In addition, GVaP is planning to considerably upgrade the accuracy and reliability of atmospheric moisture determination using *in situ* measurements, such as those obtained by the Commercial Aircraft Sensing of Humidity program pioneered by NOAA and the US Federal Aviation Administration on commercial aircraft; the Global Positioning Satellite System (GPS); and the new generation of sounders such as the Atmospheric Infrared Sounder and similar high spectral resolution sounders on the Earth Observing System and operational meteorological satellites.

GEWEX will depend on support from the international community at large, including research/operational facilities, climate analysis centers, funding agencies, and the continuing involvement of other WCRP research programs to ensure calibration and validation of the data and the success of the GVaP program in meeting the research needs of climate studies.

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FASTEX: A SHORT OVERVIEW AND THE GCSS CONNECTION

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distribution of the microphysical components appears to be organized into multiple layers. This complex process will influence the overall radiative budget of the cloud as a whole as well as its feedback, through latent heating with the synoptic dynamics. Another area where progress is needed is the calculation of the precipitation efficiency of these systems, which is probably controlled by the presence of melting or similar layers of enhanced liquid or solid water "capacity."

An aspect of the complexity is the existence of areas of mesoscale dynamical activity: bands of enhanced ascent or of convection, spread amongst the system. **How is this mesoscale activity controlled by the larger scale properties and how is it influenced by the presence of the cloud processes themselves? And how, in turn, does the presence of this activity modify the averaged properties of the cloud system**? These areas of self-organization are indeed zones of very strong diabatic activity that clearly ruin the homogeneity of the system, and the contribution to the water and energy budgets may be significant. The GCSS program thus identified a need for a multiscale approach to the collection of new sets of measurements as the first step towards the definition of a new representation of midlatitude cloud systems within climate models. These observations must include an important dynamical component of different scales at the same time.

A field experiment project that has been partly designed to address the GCSS requirements is FASTEX (Joly et al., 1997), a relatively large international program associating most countries of the North Atlantic basin. It originated in France and the United Kingdom in 1994, but key scientific and practical contributions were quickly added by groups from the United States, Canada and many others. FASTEX links the study of climate with the forecasting of cyclogenesis. FASTEX is also supported by the World Meteorological Organization.

The scientific objectives of FASTEX are to: (1) document cyclone cloud systems in the spirit explained above, (2) enable progress in the knowledge of the dynamics of "second generation" cyclones that form over the ocean (away from the coasts), at the end of the storm-track rather than at its entrance, (3) perform a feasibility study of an "adaptive observation strategy" (Snyder, 1996) with a view to improve cyclone predictability, (4) document turbulent air-sea exchanges in the presence of strong winds and relate these to the subsequent involvement of these air masses in the process of cyclone and cloud generation. Succinctly, the focus of FASTEX is on the life cycle of cyclones (on the synoptic and subsynoptic scales), as well as of some of their components such as clouds, cloud bands, and precipitating structures.

The basic observational strategy of FASTEX is to employ (successively but over the same weather system) the various facilities distributed over the North Atlantic area. These facilities included airplanes and ships. Aircraft funded by the United States National Science Foundation and National Oceanic and Atmospheric Administration were based in Newfoundland and provided dropwindsondes during early stages of cyclogenesis. These aircraft measurements enhanced the frequent soundings taken by ships. The ships involved were: (1) Icelandic Coast-Guard ship *Ægir* (funded by the European Commission), (2) the US RV *Knorr* (funded by NOAA), (3) the French RV *Suroit* (funded by Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) and Centre National de la Recherche Scientifique (CNRS), and (4) the Ukrainian RV *Victor Bugaev* (funded by Météo-France). The ships were kept in the vicinity of the main baroclinic zone. Finally, mature cyclones and waves were observed in great detail by a small fleet of instrumented aircraft: the UKMO C-130, mostly equipped for dropsounding, and the NOAA P-3 and National Center for Atmospheric Research (NCAR) Electra, essentially using radars and *in situ* microphysical instruments. However, the overall environment of the systems of interest was also sampled in greater detail than is usual; most upper-air observing stations, including ships equipped for semi-automatic en route radiosounding, performed 6-hourly soundings throughout the FASTEX field season. Operations were directed from a center located at Shannon Airport, Ireland.

The FASTEX field phase took place in January and February 1997. In terms of weather activity, this period was characterized by three successive large-scale regimes: in January, the storm-track was located to the south, with a rather short maximum. This was followed by a blocking period, with very little cyclone activity in the Eastern Atlantic. Then, a zonal regime established itself in February. Between 40 and 50 storms occurred during these 2 months, most of them running over the ships, making life and work on board difficult.

FASTEX Intensive Observing Periods (IOPs) were declared on 19 occasions. Most of the cases represent various forms of baroclinic developments, illustrating at the same time the importance of this mechanism and the diversity in its realizations, including a wide range of scales. These include a straightforward life cycle (development followed by slow decay), multiple developments, upscale growth near jet-stream exit, as well as "bomb-like" deepening. Other systems include a frontal wave, a cold air cyclone interacting with the jet-stream, cold-air vortices. There are also "control cases" of repressed frontal waves.

During the FASTEX experiment, two airborne Doppler radars (the US NOAA P3-43 airborne Doppler radar with the French dual beam antenna and the US NCAR Electra aircraft equipped with the US/French ASTRAIA/ELDORA Doppler radar) were involved in the eastern area of the FASTEX setting where the aim was to sample cloudy and precipitating areas of storms. The multiscale sampling strategy of these aircraft, in coordination with the British C-130 aircraft launching dropsondes, was designed to cover the overall area such that the resulting data set can be used in different ways. Measurements from aircraft will provide needed information to describe three dimensional (3-D) dynamical, thermodynamical (pressure and temperature) and microphysical fields (precipitation production, cloud or saturation deficit, precipitation mixing ratio, snow mixing ratio, rain mixing ratio, etc.); to estimate crucial physical parameters (such as potential vorticity forcings, and ageostrophic winds); and to quantify budgets of mass, momentum, heat and moisture at different scales. These fields can indeed be derived from the measurements performed during the experiment and achieved in at least 7 out of the 19 FASTEX cases.

Doppler radar data collected during FASTEX are presently processed to obtain a composite ensemble of elaborate fields (dynamic, thermodynamic and microphysical fields) at various scales of motion in order to study multiscale interaction involved in waves, cyclones and rapid secondary cyclogenesis sampled during this experiment, and to provide a rather unique set of validation data of nearly all the aspects of organization of midlatitude precipitating systems. The first step of this work concerns the detailed validation of the raw data, the retrieval of 3-D dynamical fields and their validation for each IOP. Let us recall that these dynamical fields are used as input data of the thermodynamical and microphysical retrieval techniques, allowing access to quantities used in radiative transfer models or to vertical heating profiles. This first step of work has been accomplished for IOP-12 (February 9, 1997), a rapidly deepening cyclone (Figure 1). The cloud head rolling up around the low pressure center is well evidenced in this picture.

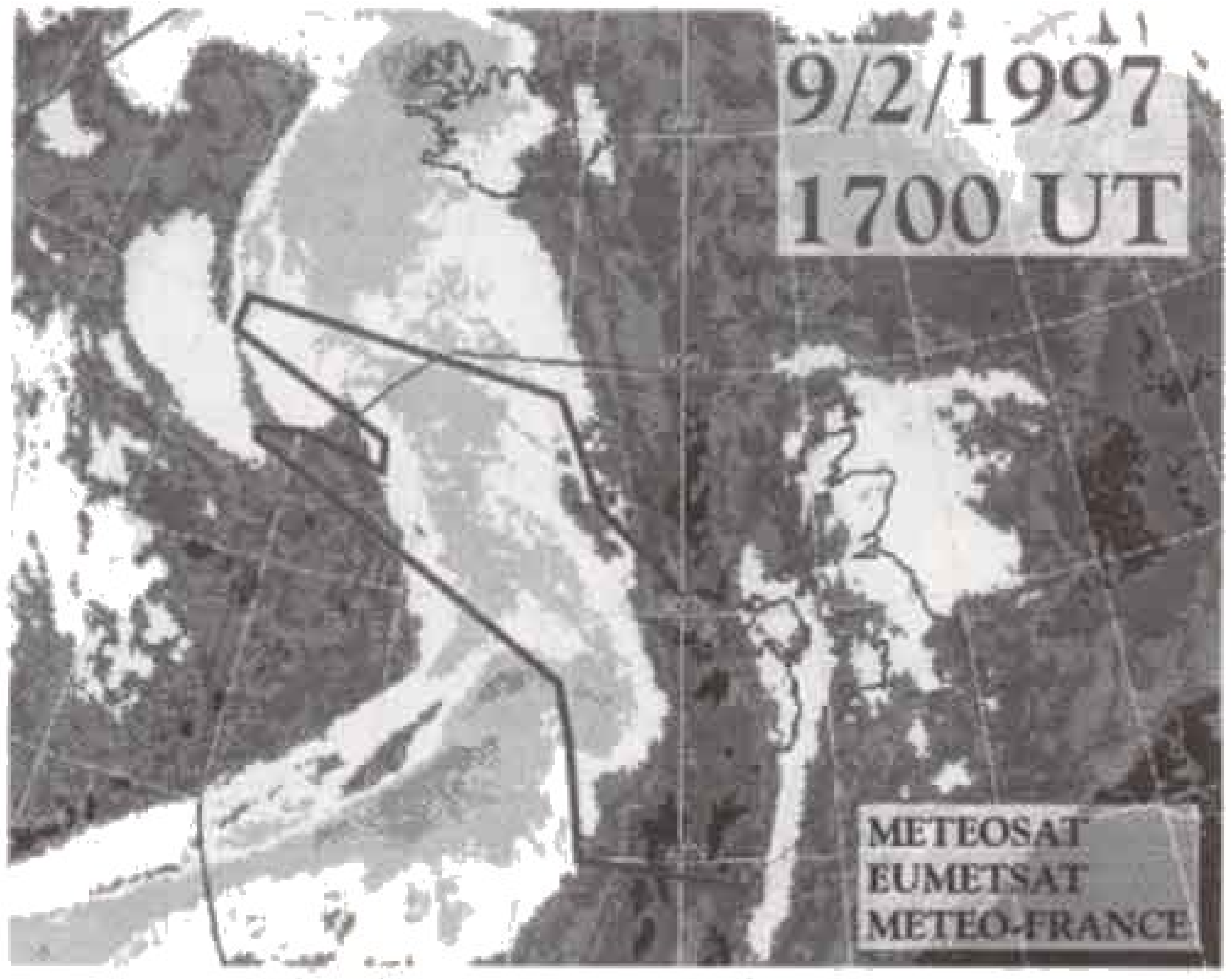

***Figure 1:* METEOSAT infrared image of the FASTEX IOP-12 storm west of the British Isles and south of Iceland. The heavy line is the flight track of a P-3 aircraft.**

The P-3 aircraft trajectory gives the associated overall horizontal mean structure of precipitation (as deduced from the lower fuselage radar) within the system along the absolute trajectory (relative to the ground) followed by the aircraft and selected *in situ* wind measurements which showed the cyclonic dynamical structure of the system. As explained previously, the sampling strategy was designed to get an overall view of the system. Combining several legs we can obtain a picture of the low feature on the mesoscale. The aircraft data provided details on some dynamical aspects of the warm front, of the low pressure area for the IOP-12, and of the so-called cloud head region. The figure on the back page of this issue gives a zooming view of this latter area in the cloud head region as deduced from the tail Doppler radar data. Several features are well identified, such as the strong airflow associated with the dry intrusion, and the cyclonic airflow around the cloud head. The comparison between these preliminary winds deduced from radar data and *in situ* measurements shows a very good agreement which qualifies the dynamical retrieval.

Figure 2 gives an example of vertical profiles of wind, terminal fall velocity, and reflectivity obtained in the cloud head region. This first case study will allow testing on a real case the various analyses and multiscale approaches developed during the preparation phase of the FASTEX experiment to respond to the two-scale scientific objectives previously described, which will be extensively used on selected cases of this experiment.

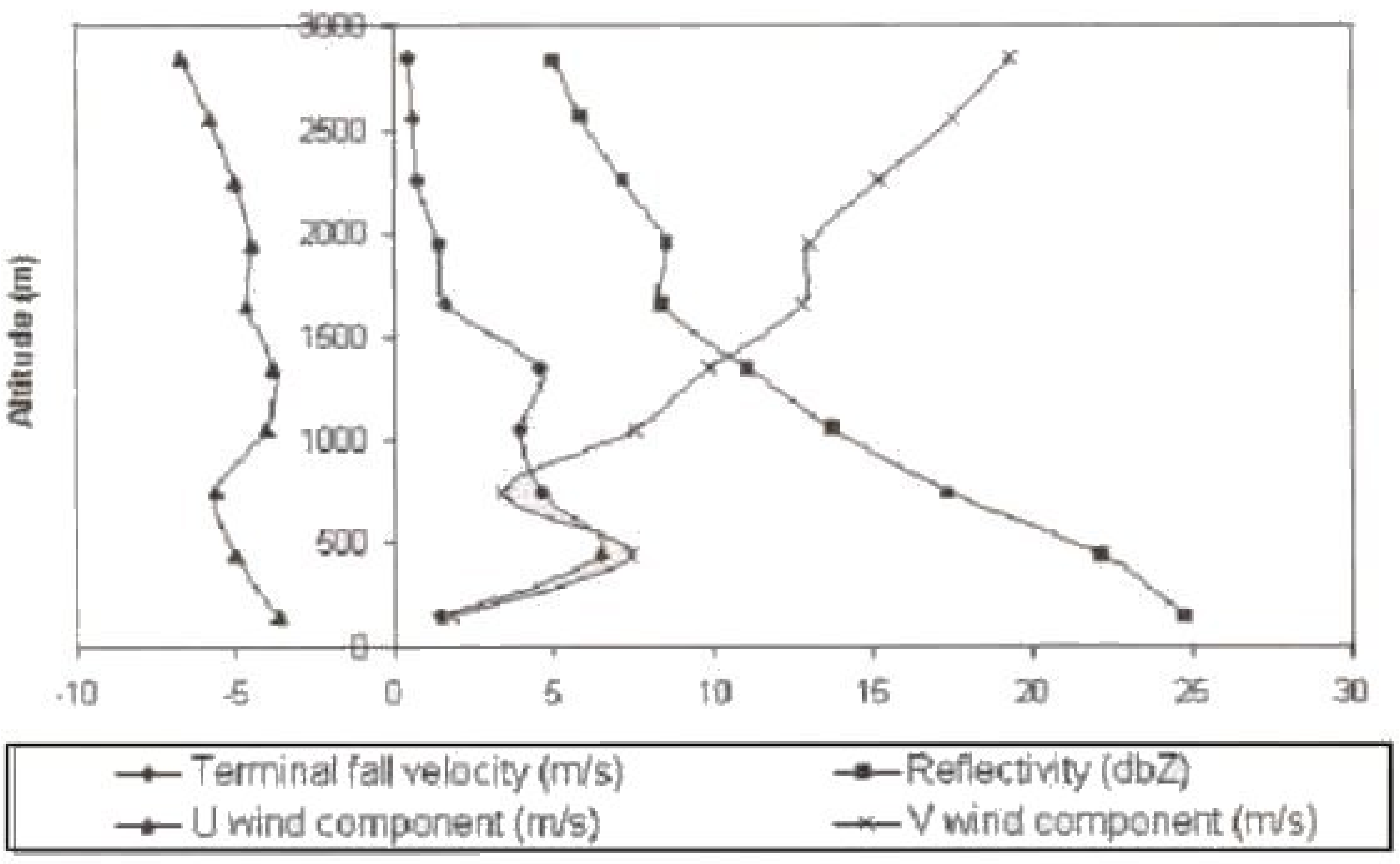

Figure 2: Vertical profiles of wind, terminal fall velocity and reflectivity.

The detailed study of all these cases is only beginning. The data, however, are already available to the scientific community, organized in a network of databases around a FASTEX Central Archive. The latter is a database built and located in Toulouse by Météo-France. It can be accessed at http://www.cnrm.meteo.fr:8000/dbfastex/. Some important data sets are available (for research and educational purpose only) directly from the web site as well as complete documentation FASTEX, the instruments and the operations.

Acknowledgments: The FASTEX project involves many groups and scientists. During the FASTEX operations the Principal Investigators on the ships were L. Eymard, G. Caniaux and P.O.G. Persson. The aircraft operations were conducted, from a scientific point of view, by J.P. Cammas, S. Clough, K. Emanuel, R. Gall, D. Jorgensen, R. Langland, M. Shapiro, C. Snyder, and R. Wakimoto. Field operations were coordinated by P. Bessemoulin, K. Browning, J.P. Chalon, R. Dirks, P. Mascart, and J. Moore. The database project is led by G. Jaubert. The FASTEX field phase has been supported mostly by the Centre National de la Recherche Scientifique, Institut National des Sciences de l'Univers, France; the European Commission, under the Environment and Climate Program, Météo-France; National Oceanic and Atmospheric Administration, USA; Naval Research Laboratory, USA; National Science Foundation, USA; and the UK Meteorological Office.

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EDITOR'S NOTE

The preceding North Atlantic and the following Labrador Sea articles illustrate how coordination of resources and cooperation in science planning can be effective in maximizing scientific objectives. The data sets derived from the joint use of aircraft, ship and mutually supporting upper air soundings will continue to benefit scientific teams on both the Labrador Sea and the Fronts and Atlantic Storm-Track Experiments. In addition, these data sets will be of benefit to other investigators.

ATMOSPHERIC FORCING OF DEEP CONVECTION IN THE LABRADOR SEA

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The exchange of heat and moisture across the air-sea boundary represents an important coupling between the ocean and atmosphere. During the winter at high latitudes, the cooling and salinization of surface waters that occur as a result of this exchange can result in vertical motions that ventilate the deep water. This newly formed cold, dense water then spreads away from formation sites to renew the intermediate, deep and bottom waters of the world's oceans. This process, which is referred to as deep convection or deep water formation, is an integral component of the thermohaline circulation of the ocean. Deep convection is a process that is highly localized in both space and time. In the Northern Hemisphere, the main regions of deep water formation are the Labrador Sea and the Greenland, Iceland and Norwegian (GIN) Seas (Killworth, 1983). The atmosphere, through the heat and moisture exchange with the ocean, plays an important role in determining the location, frequency and intensity of convection. This exchange is strongly modulated by the passage of transient weather systems such as the one shown in Figure 1. The atmospheric forcing of deep convection represents a vital coupling between the fast and slow climate systems that is of interest to the GEWEX community.

Many details of the atmospheric forcing and the resulting convective activity in the ocean remain largely unknown, as they are difficult to observe. In addition, the resolution of general circulation models is such that they are unable to resolve the atmospheric and oceanic processes involved. As a result, deep convection is often poorly represented in these models. To ameliorate this situation, the Office of Naval Research has established an Accelerated Research Initiative on Deep Convection. The objective of this initiative, known as the Labrador Sea Deep Convection Experiment, is to improve our understanding of the convective dynamics in the ocean and thereby better represent this convection in large scale models. This is being achieved through a combination of modeling studies, laboratory experiments and meteorological and oceanographic field work. The Labrador Sea was chosen as the location for the experimental work which began last winter and will continue through this coming winter. Detailed information on the experiment can be found: www.ldeo.columbia.edu/~visbeck/labsea/.

The Labrador Sea is a region in which there are unfortunately few measurements of the fluxes of heat and moisture across the air-sea interface. An important component of the field program is therefore to collect *in situ* data regarding these fluxes that can be used to improve our understanding of the physics of air-sea interaction in this climatologically important region and to thus facilitate model validation efforts. Towards this end, surface and aircraft measurements were made in the region during January and February 1997. The existence of FASTEX assisted the experiment through the enhanced radiosonde launches that were made from North American sites. The experiment also benefited from NASA scatterometer calibration/validation activities that were also taking place in the region.

One of the aircraft missions flown was to investigate the spatial variation in the fluxes of sensible and latent heat and the associated convective roll clouds on the southern flank of the cyclone shown in Figure 1. This is the region of the storm where the heat fluxes are highest as

***Figure 1: NOAA AVHRR Infrared Satellite Image at 11:19 GMT on February 8, 1997, showing an extratropical cyclone over the Labrador Sea. An aircraft mission was flown on this day to investigate the structure of the linear cloud bands over the Labrador Sea and to measure the exchange of heat across the air-sea interface. The three low-level stacks (1,2,3) that were flown are indicated. Also shown is the 12 GMT position of the RV* Knorr.**

cold and dry arctic air first comes into contact with the relatively warm waters of the Labrador Sea. Three low-level stacks were flown as indicated on the figure. In addition, a high-level dropsonde run was flown perpendicular to the stacks to obtain information on the evolution of the boundary layer as it underwent surface heating. Simultaneous measurements of the various surface fluxes were made from the RV *Knorr* whose position is also indicated. We have only begun to analyze the data collected for this and the other cases, but is clear that much will be learned from the meteorological component of the experiment regarding the atmospheric forcing of deep ocean convection.

By its very nature, field work is limited to a few all too short periods of time. To put the data collected in its proper context, it is therefore important to know if the conditions observed were typical, or more or less extreme than what would be expected from climatology. In this regard, the winter of 1997 was an interesting one for air-sea interaction in the Labrador Sea. The figure on the cover shows the sea-level pressure, 10-m wind and total heat flux fields over the North Atlantic as determined from the NCEP/NCAR reanalysis (Kalnay et al., 1996) for an average over all winter months (December, January, February and March) during the period from 1968–1997; the month of January 1997; and the month of February 1997. The upper panel of the figure shows that the typical circulation pattern during the winter is dominated by low pressure in the region between Greenland and Iceland, the "Icelandic Low," and the concomitant cyclonic flow that advects cold and dry air from the Canadian Arctic out over the Labrador Sea where it subsequently undergoes surface heating. The climatological winter mean total heat flux at 56°N, 51°W (historic site of Ocean Weather Ship Bravo in the center of the Labrador Sea) is on the order of 220 W/m^2. The middle panel of the figure shows that January 1997 was a month in which the circulation over the North Atlantic was significantly different from the winter climatology. To be precise, the presence of a blocking high over Europe resulted in a significant westward shift in the center of cyclonic activity. It is interesting to note that even with this weakening of the cyclonic flow over the North Atlantic, the average total heat loss for January in the center of the Labrador Sea was, at 260 W/m^2, larger than the climatological winter mean. We will return to this point below. In contrast to what took place during January, the lower panel of the figure shows that February 1997 was a month in which the circulation pattern over the North Atlantic was significantly stronger than is typical. As one might expect in such a flow configuration, the average heat loss in the center of the Labrador Sea was, at approximately 420 W/m^2, significantly above the climatological winter mean. When taken as a whole, the winter of 1997 was one in which the average heat loss from the Labrador Sea was, at approximately 270 W/m^2, above the climatological winter mean. The extremely high oceanic heat losses during February contributed to making what might otherwise have been a lacklustre winter, from the perspective of forcing deep convection, into a "good" winter.

Although a period of one month is a convenient period of time to average over, the influence and phasing of individual events tends to be lost in such an averaging. Another and perhaps more illuminating view of the variability in cyclonic activity during the winter of 1997 is depicted in Figure 2. This figure shows the variation in daily average sea level pressure at 62°N, 30°W during the winter of 1997 as determined from the NCEP/NCAR reanalysis. It is clear that the North Atlantic flow regime in December 1996 and early January 1997 was significantly different from that in the latter part of the winter. The generally high sea-level pressure and weak cyclonic activity in the early part of the winter can be classified, according to the work of Vautard (1990), as a "blocking" regime, while the low sea-level pressure

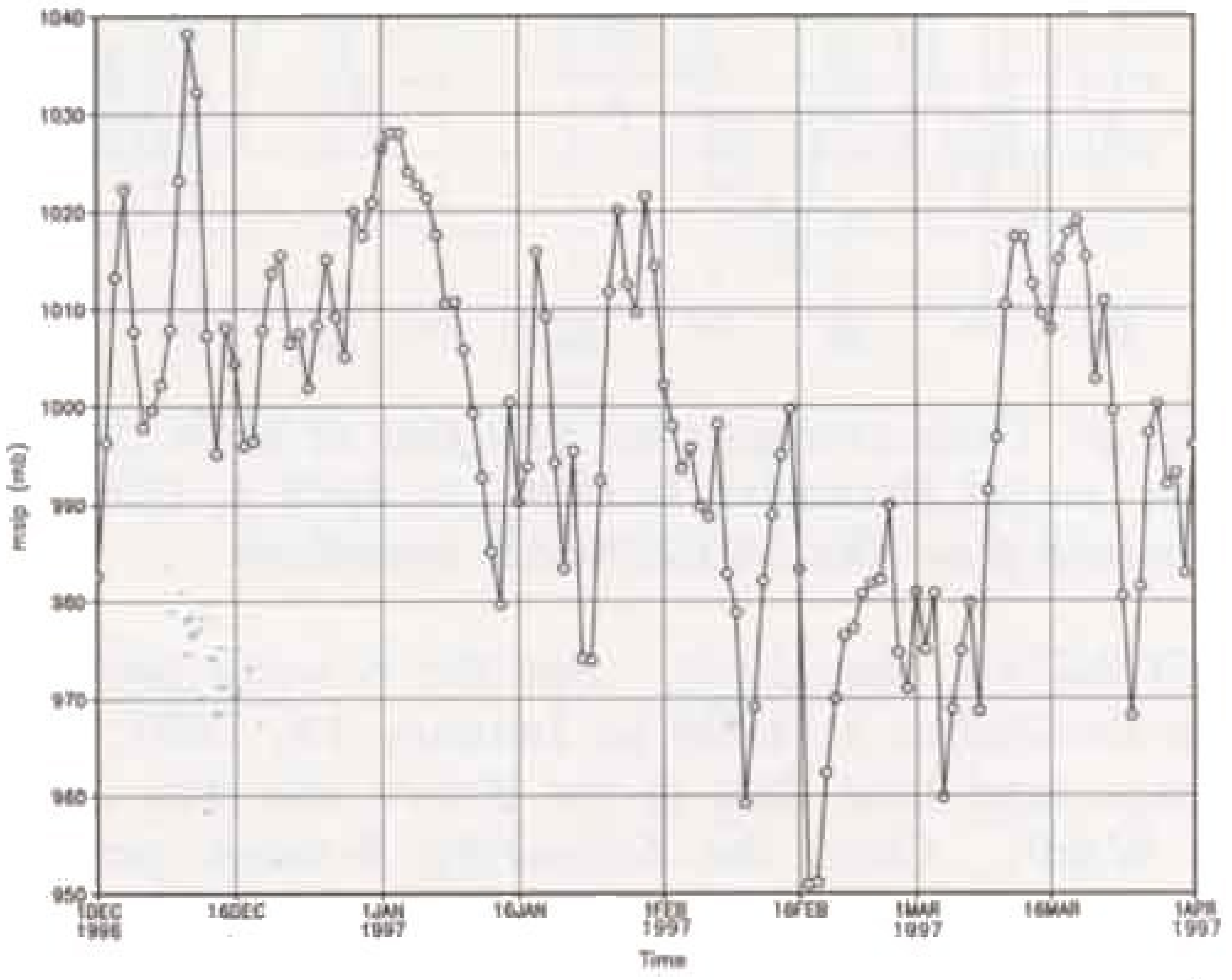

***Figure 2:* Daily average sea-level pressure at 62 °N, 30 °W for the period December 1, 1996 to April 1, 1997 as determined from the NCEP/NCAR reanalysis.**

and strong cyclonic activity during the latter part of the winter belongs to a more "zonal" flow regime.

It is therefore clear that January 1997 was a month in which a significant transition in the flow regime occurred over the North Atlantic. The more vigourous cyclonic circulation that developed after the middle of the month and the concomitant elevated heat fluxes lead to an average heat flux for January that was above the long-term climatological mean. The impact of this transition on the heat fluxes over the Labrador Sea can be seen in Figure 3 which shows the daily average total heat flux at the Bravo site during the winter of 1997 as determined from the NCEP/NCAR reanalysis. For the 6-week period, from December 1, 1996 to January 15, 1997, the average total heat flux at the Bravo site was only 150 W/m^2. Over the following 6-week period ending on February 28, 1997, it was in excess of 420 W/m^2 with peak fluxes greater than 900 W/m^2. What is also clear from the figure is the significant high frequency variability in the magnitude of the total heat flux. This is a signature of strong impact that the passage of North Atlantic cyclones has on air-sea interaction in the Labrador Sea. This can be seen from the high degree of anti-correlation that exists between the two time series shown in Figures 2 and 3. According to the conceptual model of Killworth (1983) it is the high oceanic heat loss that occurs during these events that initiates convective overturning of the water column.

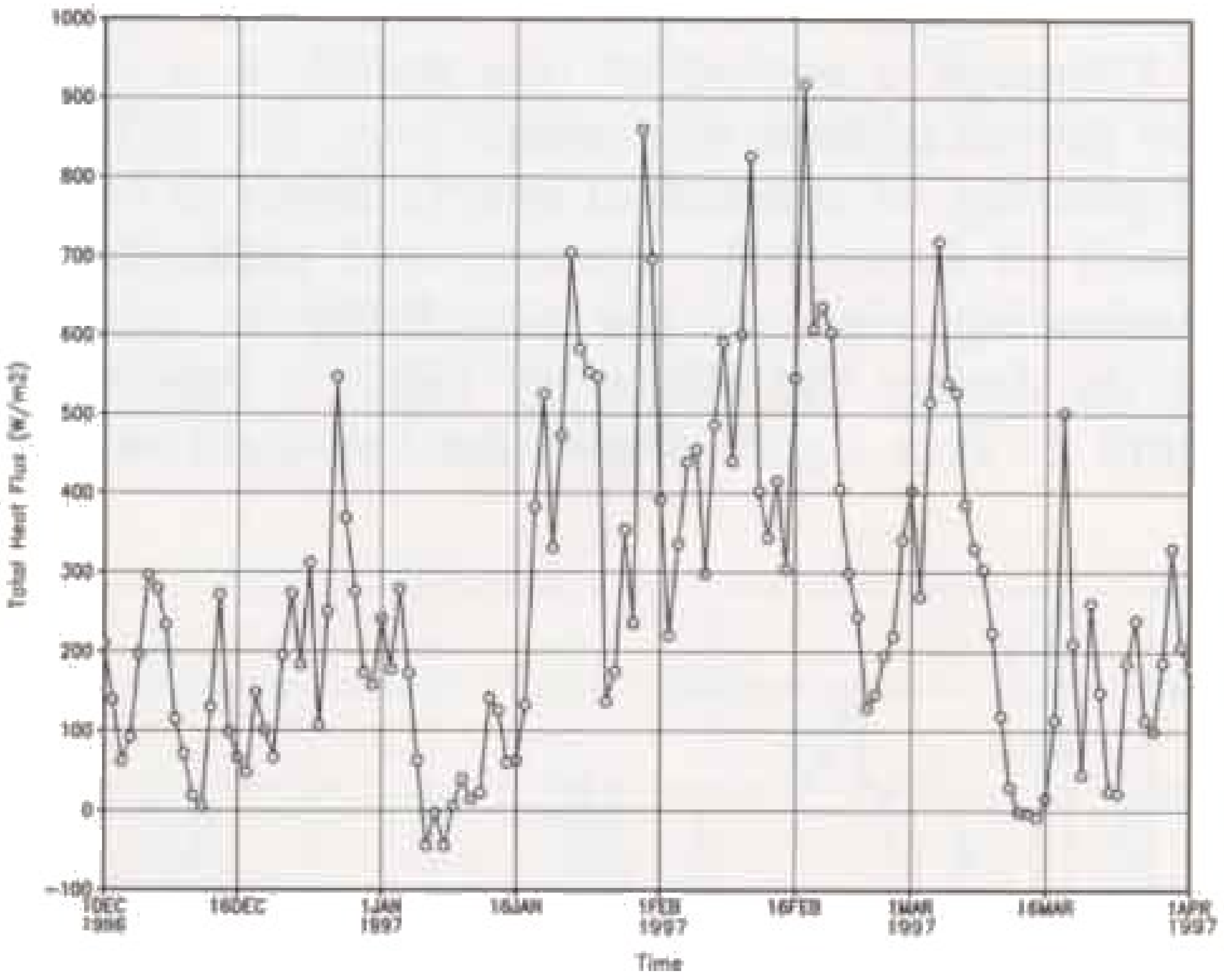

Figure 3: Daily average total heat flux at 56 °N, 51 °W for the period December 1, 1996 to April 1, 1997 as determined from the NCEP/NCAR reanalysis.

There is clearly much still to be learned regarding the role that the atmosphere plays in forcing deep ocean convection. An example of this is the under-appreciation of the role that precipitation plays in the process. This article has, like most on this subject, focussed on the role that oceanic heat loss plays in forcing deep ocean convection. Recently Moore et al. (1997) have argued that non-linearity in the equation of state for sea water allows for the possibility that precipitation can have an impact on the density of the surface waters as large as, but of opposite sign, to that associated with surface cooling. This arises from the reduction in the magnitude of the thermal expansion coefficient that occurs at cold sea surface temperatures typically found in regions where deep convection occurs. At sea surface temperatures typical of the Labrador Sea in winter, Moore et al. (1997) calculate that a precipitation rate of 1 mm/hr has the same magnitude of effect on the density of the surface waters as does a heat flux of 400 W/m^2. Given the magnitude of the heat fluxes and precipitation rates that are typical in the region, the effect that precipitation has on the density of the surface waters cannot be discounted.

In the coming years, I fully anticipate that the research being undertaken under the auspices of the Labrador Sea Deep Convection Experiment will provide additional knowledge on the role that the atmosphere plays in the process and will serve to highlight this interesting coupling that exists between the fast and slow climate systems.

Acknowledgments: I would like to acknowledge the support of the Office of Naval Research for funding my group's participation in the Labrador Sea Deep Convection Experiment and the 53rd Weather Reconnaissance Squadron of the USAF. Finally, I would like to thank the other meteorologists and oceanographers who are involved in the experiment for their guidance and input.

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EXPERIMENTAL DESIGN AND PRELIMINARY RESULTS FROM PILPS PHASE 2(d)

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To begin the process of comparing land surface models used in General Circulation Models (GCM) and Numerical Weather Prediction (NWP) models, the Working Group on Numerical Experimentation (WGNE) and the Science Panel of the GEWEX Continental-scale International Project (GCIP) launched the Project for the Intercomparison of Land-surface Parameterization Schemes (PILPS). A key objective of PILPS (Henderson-Sellers et al., 1995) is to achieve greater understanding of the capabilities of land-surface schemes in atmospheric models. In an attempt to realize this objective, Phase 1 of PILPS was initiated where a series of land surface models were forced "off-line" with a single year of data generated from a GCM. This was followed by Phase 2 where observed forcing was used, again for single years and equilibrium simulations reported (e.g., Chen et al., 1997). This update reports on the latest stage of PILPS and describes the experiments we have conducted, the results we have and the subsequent analysis we intend to perform. The results and experiments conducted as part of Phase 2(d) represent a significant effort on the part of the wider PILPS community.

In Phase 2(d) we chose to use observed atmospheric forcing data from Valdai, Russia (57.9°N, 33.1°E; Schlosser et al., 1997) because of its availability, impressive length of record, reasonable matching observational data for validation and because Valdai experiences a very seasonal climate with high snow accumulation and soil freezing. This kind of midlatitude location is believed to be particularly sensitive to climate change, hence the ability of land surface schemes to simulate the climate and interannual variability is important.

In Phase 2(d) of PILPS, observed data from Valdai was used to force a suite of land surface schemes ranging in complexity from the simple Bucket (Robock et al., 1995) to dedicated snow models (e.g., Brun et al., 1989). A list of the models is provided in Table 1. Both meteorological forcing data and hydrological validation data come from a small grassland catchment (Usadievskiy, 0.36 km^2) and covers an 18-year period (1966–1983) which allows us the opportunity to investigate how land surface schemes simulate change over a long period, instead of an equilibrium to a single year.

While the meteorological forcing data were quite complete (e.g., rainfall, air temperature, wind speed, etc.), incoming radiation was unavailable and had to be simulated. For shortwave radiation we used a method proposed by Berlyand (1961) which had been tested for other Russian stations (Schlosser et al., 1997). For the incoming longwave we used two methods: one after Idso (1981) and one after Brutsaert (1975). This permits us to estimate the sensitivity of the land surface schemes to incoming longwave radiation.

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AMBETI	H. Braden	FAL, Braunschweig, Germany
BASE	A. Slater, C. Desborough	Macquarie University, Australia
BATS	Z.L. Yang	University of Arizona, USA
BUCK	C.A. Schlosser	GFDL, USA
CLASS	D. Verseghy	Atmospheric Environment Service, Canada
CROCUS	P. Etchevers	CNRM, France
CSIRO	E. Kowalczyk	Division of Atmospheric Research, Australia
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MOSES	P. Cox	Hadley Centre, UK
NCEP	K. Mitchell, Q. Duan	Natl. Center for Environmental Prediction, USA
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SLAM	C. Desborough	Macquarie University, Australia
SPS/LLNL	J. Kim	Lawrence Livermore National Lab., USA
SPONSOR	A. Shmakin	Institute of Geography, Russia
SSiB	C.A. Schlosser, Y. Xue	University of Maryland, USA
SWAP	O. Nasonova, Y. Gusev	Institute of Water Problems, Russia
UGAMP	N. Gedney	Reading University, UK
UKMO	P. Cox	Hadley Centre, UK

Table 1: Models that have provided results as part of Phase 2(d) of PILPS.

In all simulations, models were set up using parameter data consistent with observed catchment properties. Snow parameterizations were given "freedom of complexity" in that we did not attempt to constrain these parts of the models using measured data. In the control run we used a recursive spin-up technique against the first year of data (1966). Models were not supplied with validation data so there could not be any "calibration."

The principle aims of the Phase 2(d) study are to investigate the ability of models to simulate hydrological processes in cold climates over a long period, especially those dealing with snow and frozen soil, as well as gain some understanding of model sensitivity to simulation techniques. These aims can be achieved through the use of the validation data (Table 2), and through the use of sensitivity experiments. We performed several sensitivity runs including a simulation which did not use a recursive spin-up over the first year, a run where the longwave forcing was derived from Brutsaert (1975) and three recursive runs against individual years. The specific years were 1972 (a drought year), 1974 (a wet year) and 1983 (the last year of the observational record).

Validation Data	Measurement Method	Time Period
Total soil moisture	Thermostat-weight, top 1 m 11 sites	monthly
Evaporation	lysimeter & residual	monthly
Runoff	catchment outflow	monthly
Water equivalent Snow depth	Snow auger	random

Table 2: Types of validation data, measurement method and time period of available data.

We are only at an early stage of analyzing results. We are aware of some inconsistencies in the values some modelers have sent us and we are following these up. However, a preliminary analysis of results has been conducted and we have selected two figures to show the kind of performance obtained. Figure 1 shows the seasonal cycles of water equivalent snow depth averaged over the 18 years of record simulated by the models. There is about a 1-month difference in the time the models simulate final snowmelt in spring but good agreement in when snow begins to accumulate. At the peak of the snow depth in March, there is a range of about 50 mm between the models. All models are within 40 mm of the observed data although the observed data are towards the lower range of the model estimates until April, and in the upper range of the modelled estimates from April until the end of the snow season.

Figure 2 shows the total evaporation simulated by the schemes. We have omitted three models from this graphic since we believe there may be problems with the results submitted to us. There is about a 1 mm/d (~30 W m^{-2}) range in the total evaporation which is better than we have found in earlier phases of PILPS. While this is encouraging, further analysis needs to be performed since this finding may be due to the long period of averaging, lower net radiation, or a number of other factors. However, compared to the observed data, the models appear to be reasonable.

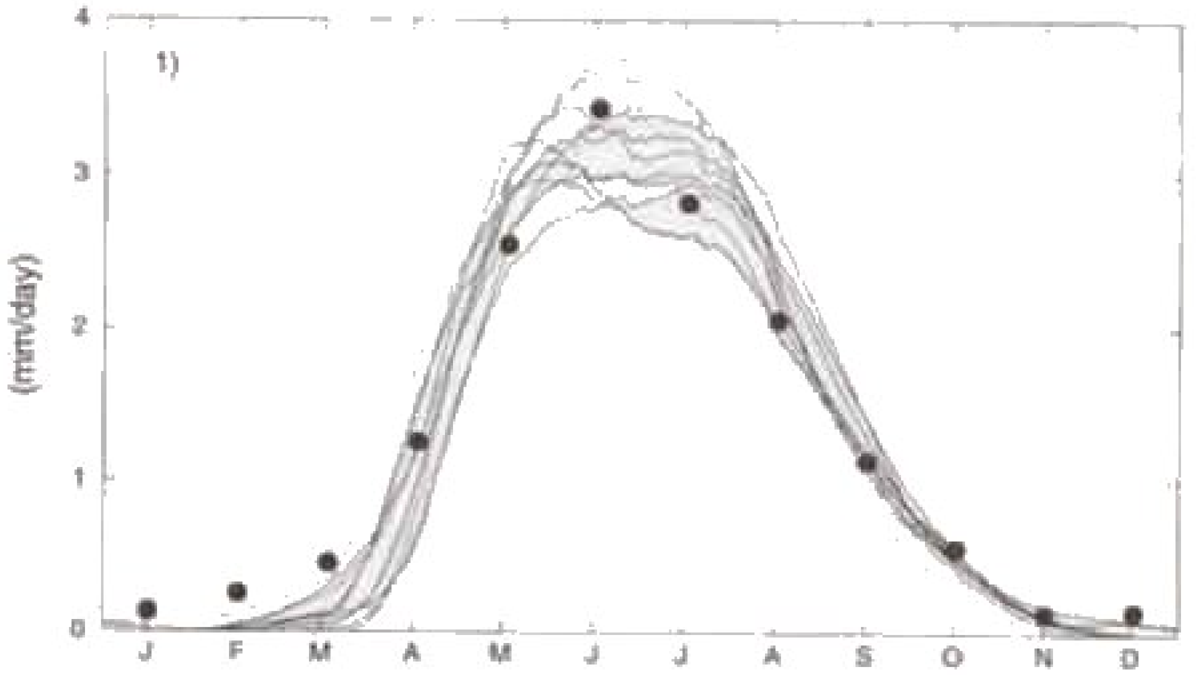

Figure 1: Evaporation simulated by the models participating in Phase 2(d) of PILPS. The 18 years of data have been averaged and plotted with a 30-day running mean. The observed data are plotted as solid circles. Note that the observed data are monthly averages estimated in a variety of ways (see Schlosser et al., 1997 for further details).

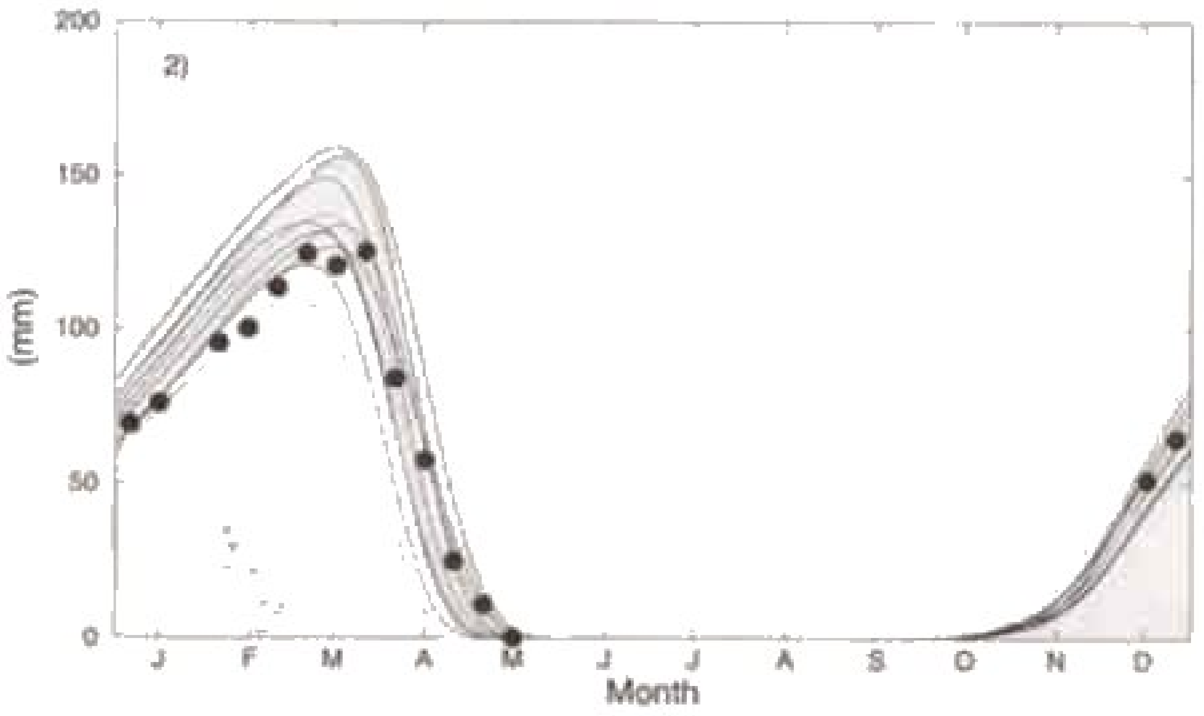

Figure 2: As for Figure 1 but for water equivalent snow depth. Observations are taken at random times through the 18-year period and have been averaged to 5-day periods to give a general idea of the seasonality in snow cover.

In summary, we have received simulations from 20 models, most of which have performed all the experiments successfully. For the entire simulation period (1966–1983), most models produce more evaporation than runoff (which appears consistent with the observational data). Averaged over the full length of record, the various schemes appear to have some similarities between their simulations and in respect of water equivalent snow depth with observed data, which is encouraging, but we expect to find larger differences when we analyse the individual years of the record.

In the immediate future we have plans to investigate a variety of aspects of these experiments. We are aware of some inconsistencies in model results that need correction. We wish to investigate the ability of models to simulate the observed interannual hydrological variability. The reasonably high quality observed snow data provide an opportunity to investigate the relationship between complexity and performance in the snow schemes. Some of the years contain droughts and it will be interesting to see if different models respond to these droughts in similar ways. Finally, we are particularly interested in the mechanisms of interannual and seasonal variability. We hope to find why the various models may differ on the annual timescale (a result from earlier phases of PILPS) and if the models simulate consistent changes in quantities from one year to the next. This would give us increased confidence in the abilities of these models to simulate change due to, for instance, global warming.

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WATER VAPOR FEEDBACK DURING AN ENHANCED HYDROLOGICAL CYCLE

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NOAA/ERL

The earth's hydrological cycle moderates the climate, making this planet hospitable to a wide variety of life. It also greatly complicates understanding and prediction of climate since the water and energy cycles interact in a non-linear way on all time and space scales. In general circulation model simulations of global warming, the water vapor feedback greatly enhances the projected temperature increases originated by anthropogenic greenhouse gases. Many of these models also suggest that the hydrological cycle will be enhanced in a warmer climate and will lead to a higher frequency of large-scale floods and droughts. Although there is little controversy about how the lower tropospheric water vapor equilibrates rapidly to the underlying surface temperature, there is considerable controversy about how the upper tropospheric water vapor may change. Changes in the upper tropospheric water vapor, particularly within the dry areas of the tropics and subtropics, have a very large influence on the longwave radiation budget. An analysis of the variability of global upper tropospheric water vapor from satellite data during the 1982–1983 El Niño–Southern Oscillation (ENSO) shows clear evidence of a negative water vapor feedback. These observations suggest that water vapor cycling through the global monsoons acts to constrain the hydrological cycle and climate within rather narrow bounds.

In the past 20 years of global observations with continuous NOAA operational satellites, the ENSO event of 1982–1983 clearly stands out as the most dramatic example of an enhanced hydrological cycle. During this event, extreme droughts occurred in southern Africa, southern India and Sri Lanka, and in the Australian-Indonesian region. Devastating floods occurred in Ecuador and Peru, in California, and along the U.S. Gulf coast, and exceptionally heavy snowfall occurred in the mountainous areas of the U.S. Great Basin. Also, the southern oscillation index recorded its greatest value in this century.

The spatial pattern of the leading empirical orthogonal function (EOF) mode of interannual variability of an Upper Tropospheric Humidity Index (UTHI) derived from NOAA polar-orbiter satellite data (Bates et al., 1996), indicates the tropical monsoon-desert system during ENSO warm and cold events. This spatial pattern shows an increase in the upper tropospheric moisture index over the central and eastern equatorial Pacific, over western Australia and extending west into the southern Indian ocean, and over smaller regions in the North and South Atlantic. Decreases in upper tropospheric humidity are found in the north and south subtropics of the Pacific, over the western equatorial Pacific, over northeast Brazil, and over the Gulf of Guinea. Of these, however, the largest decrease is found over the subtropical North Pacific between Hawaii and Baja California. This is an area where the upper tropospheric humidity is already low.

The time series of sea surface temperature anomalies in the central equatorial Pacific (Figure 1a) is highly correlated with the leading EOF mode principal component time series. A measure of the intensity of the tropical Hadley cell overturning, or hydrological cycle, has been computed from NCEP reanalysis data (Kalnay et al., 1996). This meridional mass stream function has been computed for the northern winter season (December-January-February) when the effects of ENSO warm events are most pronounced in the northern hemisphere midlatitudes. This index shows that the tropical hydrological cycle intensifies during ENSO warm events and that it was very intense during the 1982–1983 warm event.

Anomaly time series (Figure 1b) of tropical areal average upper tropospheric humidity index and clear-sky greenhouse effect (Slingo et al., 1997) are significantly correlated. However, during the 1982–1983 ENSO warm event, the upper tropospheric humidity index shows a dramatic decrease and the clear-sky greenhouse increases by over 2 Wm^{-2}, indicating greater heat lost to space during this event. There are only minor changes in the upper tropospheric humidity index and the clear-sky greenhouse during the 1986–1987 and 1991–1992 warm events. The other notable feature of the clear-sky greenhouse time series is the large decrease during 1988–1989. Thus, the response of the tropical water and energy cycles to extreme ENSO events seems to be a negative water vapor feedback to restore the current climate balance.

Although the response of the tropical atmosphere is not symmetric for ENSO warm and cold event extremes, these observations suggest that the cycling of water vapor through the tropical hydrological cycle provides a natural thermostat on the water and energy cycles. I propose the following hypothesis to explain these observa-

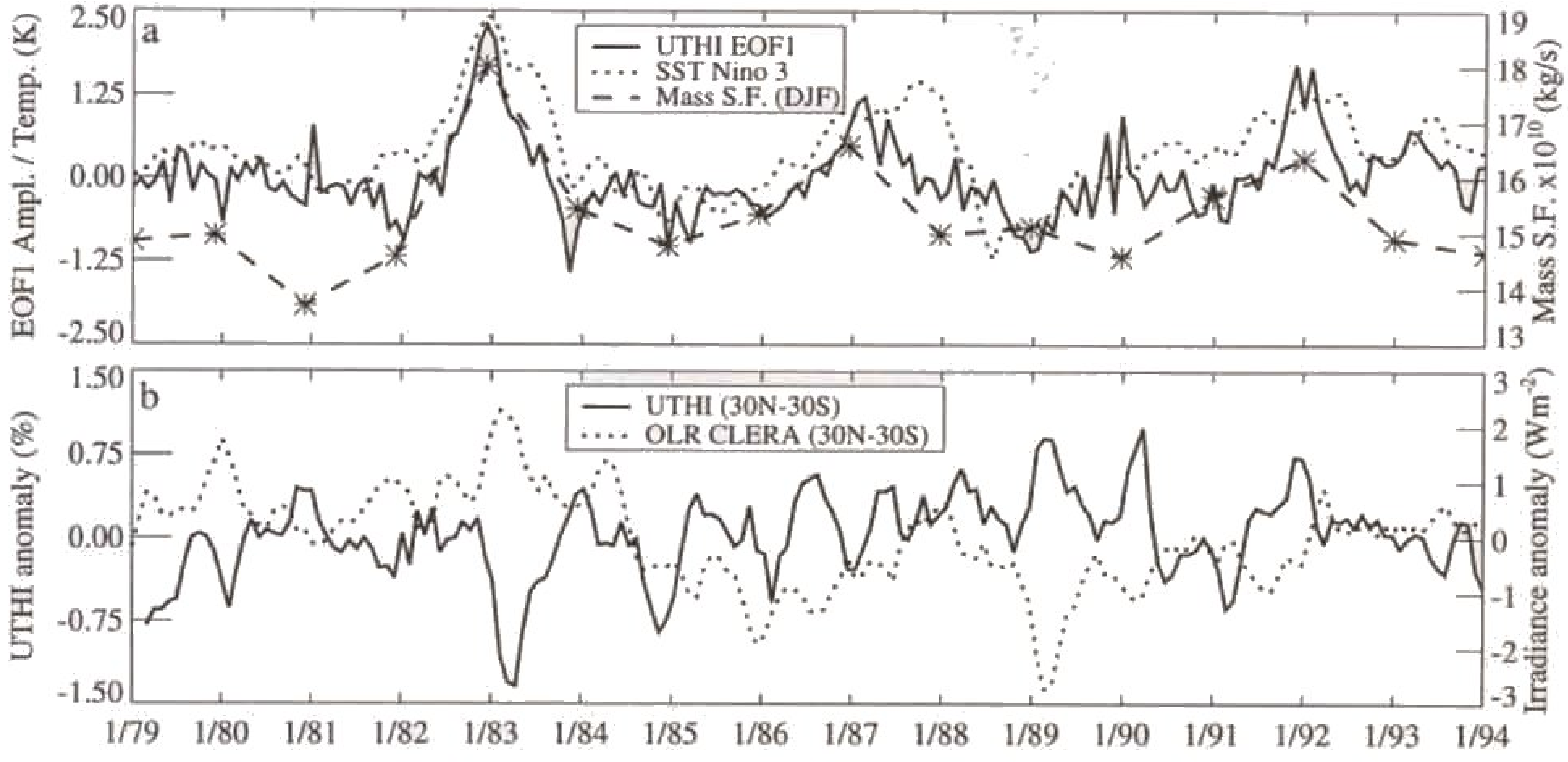

***Figure 1:** (a) Time series of leading mode EOF of the interannual UTHI, SST anomalies for the central equatorial Pacific Niño 3 region, and DJF average meridional mass stream function. (b) Anomaly time series of tropical areal average UTHI and clear-sky OLR.*

tions. During extreme ENSO warm events, the upper troposphere above the anomalous deep convection becomes saturated and thus the upper tropospheric humidity and clear-sky outgoing longwave radiation anomalies reach a limit. In the descending branches of the Hadley cell, however, there is not such a strict limit and the upper troposphere can become extremely dry. Since the clear-sky outgoing longwave radiation (OLR) is a strong function of base upper tropospheric humidity, drying already dry areas has a much greater impact on the radiation budget than moistening already moist areas. The net result is that as the intensity of the Hadley cell exceeds some threshold, the water vapor feedback becomes negative and provides a natural limit to the radiation budget within the tropics. ENSO cold events are not symmetric with warm events. Nevertheless, I propose that during the 1988-89 cold event the suppression of convection caused the tropical upper troposphere to be much less saturation limited. During this time, water vapor is still supplied to the upper troposphere by deep convection but the drying of the dry areas is not intense, leading to a net increase in the clear-sky greenhouse. Thus, the tropical clear-sky greenhouse is a function of how water vapor is cycled through the monsoon desert system and this provides a natural thermostat that keeps the tropical climate within narrow bounds.

These observations raise many more questions than they answer, but they suggest that the main scientific theme of the GEWEX Global Water Vapor Project (GVaP) should be focussed on improving our understanding of mechanisms that control how water vapor is cycled through the global monsoon desert system.

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MEETING SUMMARIES

ANNUAL CMOS CONGRESS
1–5 June 1997

Geoff Strong
Canadian GEWEX/MAGS Secretariat

GEWEX was a major focus of the 31st Annual Congress of the Canadian Meteorological and Oceanographic Society (CMOS), held in Saskatoon with almost 200 presentations in 43 sessions plus 4 plenaries. The theme of the Congress, "energy and water cycles," was appropriate for four GEWEX sessions comprised of 20 presentations. Dr. Gordon McBean provided an overview of MAGS with the GEWEX plenary paper, and Rick Lawford of the GCIP office presented two invited papers, one summarizing the challenges that GCIP has encountered in attempting to quantify individual water budget components and closing the water balance for the Mississippi River Basin, the other describing the Large-Scale Biosphere-Atmosphere Experiment in Amazonia project. There was discussion on whether existing radiosonde networks, with twice-daily soundings at 1200 and 0000 UTC, can adequately account for diurnal signatures in summertime moisture budgets. Related issues raised in other presentations included the distribution of snow and snowmelt, stream-flow measurement issues, new remote sensing techniques, validation of hydrologic and atmospheric models, and problems of land cover variation, underscored the unique challenges for MAGS observational strategy and data management in a data-sparse region.

GVaP WORKSHOP

18–20 June 1997

Thomas Vonder Haar
Colorado State University

The GEWEX Global Water Vapor Project (GVaP) International Working Group on Science and Data (WGSD) met in Silver Spring on 18–20 June 1997 with the goal to characterize GVaP scientific issues in terms of specific and implementation questions. At the meeting the group recommended that GEWEX and WCRP incorporate understanding and predicting water vapor variability, forcing and feedback in the Earth's weather and climate into the goals of GVaP; add improving predictions of (i) weather, (ii) seasonal and interannual climate variability, and

(iii) long-term climate changes into the objectives of GVaP; and ensure these objectives are met by assigning GVaP the following responsibilities:

- *To improve the models and related tools that predict global and regional climate and hydrology including (long-term) variations in extreme hydrological events (floods and droughts),*
- *To establish an accurate and validated water vapor climatology on the relevant time and space scales,*
- *To identify the horizontal and vertical fluxes of water vapor and the processes that control those fluxes and the associated phase changes of atmospheric water.*

Deliberations at the meeting focused on specific science and implementation topics that were narrowed to three issues or questions. (1) How does the water vapor amount and distribution vary on long time-scales, how does it respond to changes in temperature, and is there a global trend? (2) What is the variability of water vapor on shorter time-scales? (3) What is the 3-dimensional distribution of water vapor in the upper troposphere/lower stratosphere and its seasonal and interannual variations? From these questions evolved a list of problems related to water vapor process. For example, vertical distribution of water vapor due to convection, ocean surface fluxes, role of water vapor in determining clouds? Other problems were related to regional analyses and modeling and included questions such as: (1) What is the impact of episodic moisture intrusions on seasonal to interannual occurrence of severe storms or drought? (2) Can the Continental Scale Experiments and GEWEX Cloud System Study activities lead to improvements in the global modeling of rainfall patterns and their dependence on intermittent water vapor fluxes?

In order to address the scope of what could be realistic to accomplish, the participants were organized into three groups: (1) science rationale, (2) climatology and (3) calibration and validation. These three groups were given the charge to emphasize implementation issues related to ways of developing accurate and validated data sets identifying the processes that control the horizontal and vertical fluxes of water vapor and applying improved understanding to enhance models and related predictive tools at all time- and space-scales.

The Science Rationale Group identified, for example, studies of the processes and mechanisms that link the hydrological cycle to large-scale circulation, with a specific study to focus on Hadley and Walker circulations and monsoon systems. The Climatological Group addressed data set uncertainties in understanding the role of water vapor in climate research. The Data Calibration/Validation Group developed detailed plans for climatology reference sites to routinely collect data with advanced instrumentation. One site is the USA Atmospheric Radiation Measurement (ARM) Cloud and Radiation Testbed (CART); other sites were identified in Germany and Japan.

The scheduling of the next WGSD meeting will follow the collection of comments from the international community on the draft GVaP science and implementation plan.

ISLSCP SCIENCE PANEL MEETING

10–11 July 1997

Pavel Kabat
Winand Staring Centre, Netherlands

The International Satellite Land Surface Climatology Project (ISLSCP) Science Panel (ISP) met in Silver Spring, Maryland, USA. The objectives of the meeting were achieved, namely to develop a strategy for the ISLSCP Initiative II Global Data Project and review the status of ISLSCP related projects. The success of Initiative I continues to grow. It was reported that over 3000 Initiative I CD-ROMs have been distributed and 53,512 files have been pulled by anonymous ftp users. Response to an Initiative I user survey now in progress will provide guidance on organizing an Initiative I user workshop. Highlights of recent ISLSCP science results included the Boreal Ecosystem-Atmosphere Study (BOREAS) albedo correction product for use by operational weather forecasting models. For the winter snow covered boreal forests it was reported operational models surface temperature estimates improved by as much as 10°C.

Initiative II products are planned to include 0.5 degree data grid for the years 1986 to 1995 and include: land cover, river runoff, precipitation, topography, soils, snow depth/sea ice, snow water equivalent (after 1987), carbon, radiation, and surface albedo. The data sources are from other GEWEX activities and international IGBP products.

The ISP members planning Initiative II benefited from the presentations on related activities. These included the GEWEX Continental-scale International Project (GCIP) which has ongoing and planned joint projects with ISLSCP on land/vegetation/atmospheric interaction. In addition, there were presentations on the GEWEX Asian Monsoon Experiment, GEWEX Soil Wetness Project, and the Large-Scale Biosphere Atmosphere Experiment in Amazonia (LBA) project (1997–2003), and one on the joint IGBP/GEWEX Workshop on Soil Vegetation-Atmosphere Transfer Schemes/Land Surface Parameterizations (SVAT-LSP) held in LaJolla, California in February 1997. Throughout this ISP meeting, there was emphasis on collaboration between GEWEX ISLSCP activities and IGBP-BAHC activities.

There will be another ISP meeting in December 1997 in the Washington, D.C. area. Also, plans were initiated on a Spring 1998 back-to-back GEWEX ISLSCP Science Panel Meeting and a Biosphere Aspects of the Hydrological Cycle (BAHC) Program meeting in Paris on 27 April to 5 May 1998.

WCRP/GEWEX MEETINGS CALENDAR

For calendar updates consult GEWEX Web Site http://www.cais.com/gewex/

3-5 November 1997—SECOND MEETING OF THE LBA INTERIM SCIENCE STEERING COMMITTEE, Hotel Tropical Manaus, Brazil.

3-6 November 1997—POLAR PROCESSES AND GLOBAL CLIMATE, Orcas Island, Washington, USA (about 120km Northwest of Seattle). For further information contact ACSYS IPO, Norway. Tel: 47-22-95-96-05; Fax: 47-22-95-96-01.

3-7 November 1997—13TH SESSION OF WGNE, NOAA Science Center (World Weather Building), National Centers for Environmental Prediction, Camp Springs, Maryland, USA.

16-19 November 1997—INTERNATIONAL WORKSHOP ON PROSPECTS FOR COORDINATED ACTIVITIES IN CORE PROJECTS OF GCTE, BAHC AND LUCC, Wageningen, The Netherlands. For information contact Irene Gosselink or Lyanne Brouwer, GCTE-BAHC-LUCC Workshop. Tel: 31 317 475700/475731, Fax: 31 317 423110, E-mail: IGBP97@ab.dlo.nl.

17-19 November 1997—THIRD CANADIAN GEWEX/MAGS WORKSHOP, Toronto, Canada. More information at http://www.tor.ec.gc.ca/GEWEX/MAGS.html, or contact Secretariat at Geoff.Strong@ec.gc.ca.

1-5 December 1997—GCSS SCIENCE PANEL MEETING, Boulder, Colorado, USA.

10-16 January 1998—AMERICAN METEOROLOGICAL SOCIETY ANNUAL MEETING, Phoenix, Arizona.

2-6 February 1998—GEWEX SCIENTIFIC STEERING GROUP, Brazil.

22-24 April 1998—INTERNATIONAL CONFERENCE ON MONSOON AND HYDROLOGIC CYCLE, Kyongju, Korea. For conference information contact Sung-Euii Moon, Pursan National Univ., Korea. Fax: 82 51 515-1689; E-mail: semoon@hyowon.pusan.ac.kr or Paul Try, IGPO, Silver Spring, Maryland, USA, Fax: 301-427-2222, E-mail: gewex@cais.com.

24-29 May 1998—OCEAN CIRCULATION AND CLIMATE: THE 1998 WOCE CONFERENCE, Halifax, Nova Scotia, Canada. For conference information, WOCE IPO, UK, Tel: 44 1703 596789; Fax: 44 1703 596204; E-mail: woceipo@soc.soton.ac.uk.

25-29 May 1998—2ND STUDY CONFERENCE ON BALTEX, Island of Ruegen, Germany. For information contact Dr. Hans-Joerg Isemer, International BALTEX Secretariat, GKSS Forschungszentrum Geesthacht, Germany. Phone: +49 4152 87 1536, Fax: +49 4152 87 2020, E-mail: isemer@gkss.de.

8-12 June 1998—GCIP MISSISSIPPI RIVER HYDROMETEOROLOGY CONFERENCE, St. Louis, Missouri, USA. For information contact Adrienne Calhoun or Rick Lawford, GCIP Project Office, NOAA Office of Global Programs, 1100 Wayne Avenue, Suite 1210, Silver Spring, Maryland, 20910, USA. Tel: 301-427-2089 ext. 511; Fax: 301-427-2222, or for general information on the Mississippi River Celebration visit the web site at: http://www.opg.noaa.gov/gcip/miss/missceleb.html.

17-21 August 1998—INTERNATIONAL CONFERENCE ON SATELLITES, OCEANOGRAPHY AND SOCIETY, Lisbon, Portugal. For information contact D. Halpern, Jet Propulsion Laboratory, MS 300-323, California Institute of Technology, Pasadena, CA 91109-8099; Fax: 818/393-6720; E-mail: halpern@pacific.jpl.nasa.gov.

GEWEX REPORTS AND DOCUMENTS

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GEWEX NEWS

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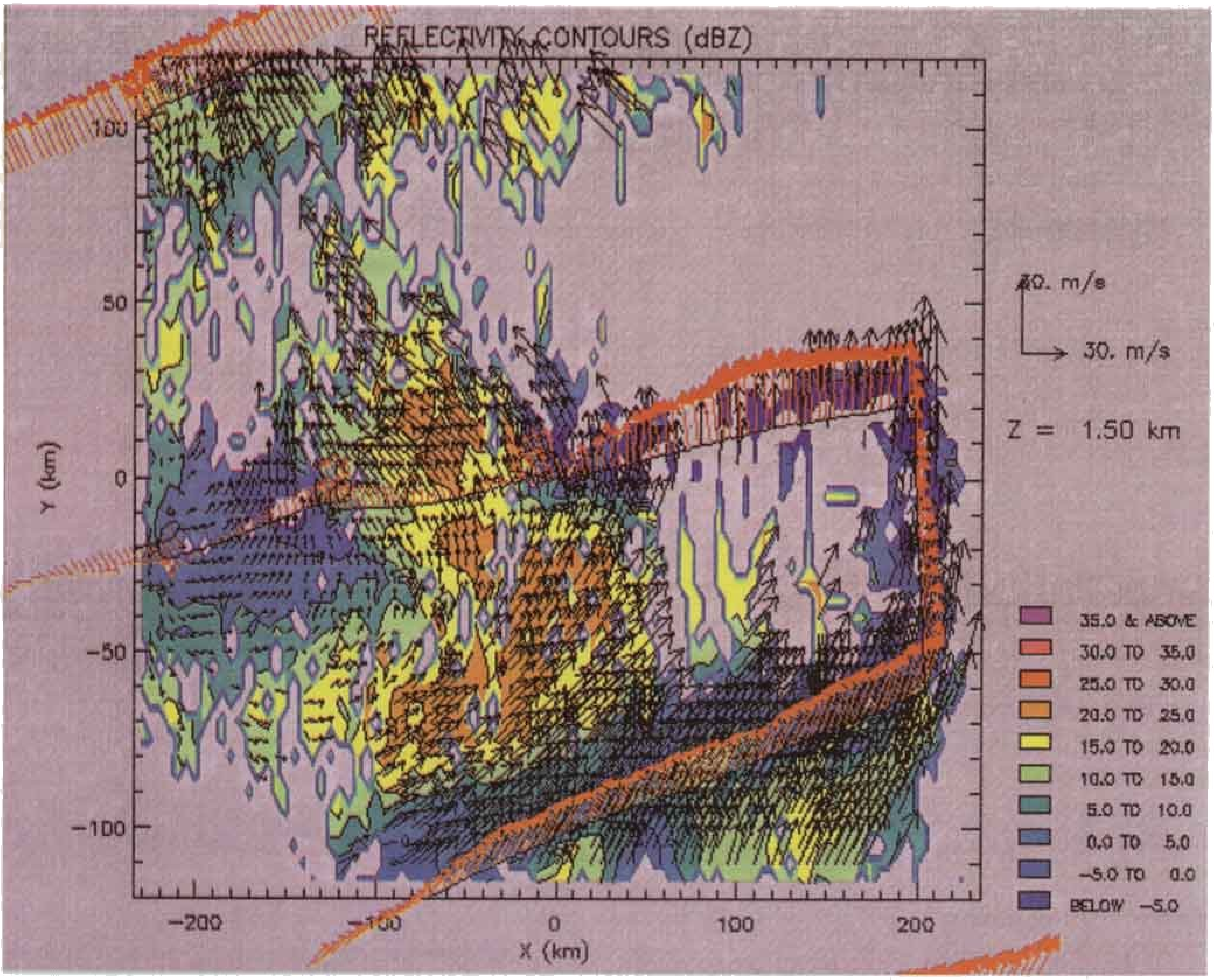
GEWEX CSEs PLANNING A "COORDINATED IOP" FOR THE 2000-2001 TIME FRAME

To begin Phase II of GEWEX and to take maximum advantage of the new suite of satellites/instruments (i.e., TRMM, EOS-AM, ENVISAT, ADEOS II, and EOS-PM) and the latest global 4-Dimensional Data Assimilation (4DDA) models, all GEWEX Continental-Scale Experiments (CSE) [BALTEX, GAME, GCIP, LBA and MAGS] would conduct an Intensive Observing Period of coordinated measurements within a 12–18 month timeframe. This Coordinated Intensive Observing Period (CIOP) would provide a unique opportunity for global calibration/validation measurements in the full range of climatic regimes and would take advantage of stable configurations of global 4DDA techniques and prediction models. This leveraging of already planned and funded satellite and CSE basic activities would minimize costs while maximizing the opportunity for improving satellite retrieval algorithms, and global and mesoscale model physics and parameterization packages. A major focus of GEWEX research in Phase II would link together the CIOP results from all the CSEs with the new satellite data and transfer these results into improvements in global climate prediction models optimized for regional water resource applications. As the GEWEX Hydrometeorology Panel and the Science Steering Group further develop this proposal, we will provide further details in later issues of *GEWEX News*.



Horizontal cross section of the reflectivity field and of the wind field deduced from (Tail) Doppler radar data for IOP-12 at 1.5 km. The P-3 aircraft trajectory and selected in situ wind measurements are superimposed. (See FASTEX article on page 1.)