WESP Major Activities

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1. Background

The scientific objective for CEOP WESP is --- *To use enhanced observations to diagnose, simulate and predict water and energy fluxes and reservoirs over land on diurnal to annual temporal scales as well as apply these predictions for water resource applications.* WESP studies are designed to understand what components of the global water and energy cycles can be measured, simulated, and predicted at regional and global scales? In particular: (1) what are the gaps in our measurements? (2) What are the deficiencies in our models? (3) What is our skill in predicting hydroclimatological water and energy budgets?

Starting from the current efforts to close simplified vertically integrated water and energy budgets with observations and analyses, and beginning efforts to simulate these budgets regionally, CEOP will begin the effort to transfer this knowledge to global scales, include more water and energy cycle processes, and begin to examine the vertical structure in the atmosphere and land. Specific tasks for the WESP working group during CEOP include:

- Summarizing component and coupled system modelling studies currently underway.
- Articulating scientific issues that need to be addressed in light of advances in each CSE.
- Defining guidelines for commonality and standards in the background fields and measure of progress.
- Devising the detailed nature of the experimental periods.

Below, we describe the initial WEBS (**sec. 2**) and transferability projects (**sec. 3**) that currently have a direct link to CEOP, recognizing that additional projects will eventually become entrained within the CEOP WESP framework. Land data assimilation projects are discussed in **sec. 4**. We also discuss the nature of the data being requested from the NWP centers (**sec. 5**). Our eventual goal is to identify the processes and state variables that can be compared to in situ and satellite measurements and to then develop community intercomparison projects that can help to define and quantify measured and modelled processes.

2. WEBS

During the past several years, the Global Energy and Water Cycle Experiment (GEWEX) continental-scale experiments (CSEs) have started to develop regional hydroclimatological datasets and Water and Energy Balance (WEBS) studies and will be reporting on these studies at a special WEBS session at the 2003 AGU/EGS spring meeting in Nice, France and a special WEBS session at the 2003 IUGG summer meeting in Saporo, Japan. These studies will be summarized in Sept. at a WEBS workshop at GISS in the fall of 2002, where GHP will move toward developing a global synthesis as a prototype for future CEOP WESP syntheses.

2.1 BALTEX

The BALTIMOS project (http://www.baltimos.de/) coordinated by Daniela Jacob, is aiming at: (1) development of a coupled model system for the Baltic Sea and its catchment area in order to understand and model exchange processes between atmosphere, sea, land surface, and lakes including hydrology; (2) validation and improvement of the model system following a validation strategy to be developed jointly by all partners; (3) investigation of the water and energy cycles in the Baltic Sea area for present and changed climate conditions; (4) investigation of the water and energy budgets during the BRIDGE phase and their relation to long time series; (5) development of a strategy to achieve the transferability of methods and results from the proposed project to other GEWEX - continental scale experiments

Carl Fortelius is coordinating a study of the HIRLAM limited area NWP system with emphasis on: (1) quantifying the components of the climatic energy and water cycles during one year of the BALTEX BRIDGE period (Sept 1999-Sept 2000) in BALTEX region through delayed mode data assimilation using a limited area NWP system. (2002); (2) validating model-generated precipitation data using in situ and remote-sensing measurements (ongoing); (3) validating boundary layer parameters by comparing MOLTS data with available observations, including CEOP reference stations Cabauw, Lindenberg, and Sodankylä. This work is closely tied to the commitments of FMI as a national weather service.

2.2 GCIP/GAPP

Roads et al. (2002a), Roads (2002) described vertically integrated global and regional water and energy budgets from the National Centers for Environmental Prediction – Dept. of Energy (NCEP-DOE) reanalysis II (NCEPRII). Maintaining the NCEPRII close to observations requires some nudging to the short-range model forecast and this nudging is an important component of analysis budgets. Still, to first order we could discern important hydroclimatological mechanisms in the reanalysis. For example, during summer, atmospheric water vapor, precipitation and evaporation as well as surface and atmospheric radiative heating increase and the dry static energy convergence decrease almost everywhere over the land regions. We can further distinguish differences between hydrologic cycles in midlatitudes and monsoon regions. The monsoon hydrologic cycle has increased moisture convergence, soil moisture, runoff, but decreased sensible heating with increasing surface temperature. The midlatitude hydrologic cycle, on the other hand, has decreased moisture convergence and surface water and increased sensible heating.

Roads et al. (2002b,c) developed a water and energy budget synthesis for GCIP, which includes the best available data and model simulations for the period 1996-1999. This WEBS includes a general description of the Mississippi River Basin climate, physiographic characteristics, available observations, representative types of models used for GCIP investigations, and a comparison of water and energy variables and budgets from models and observations. Besides a summary paper, a companion CD-ROM (with the CEOP logo) with more extensive discussion, figures, tables, and raw data was also made available to the interested researcher. Briefly, observations cannot adequately “close” budgets since too many fundamental processes are missing. Models that properly represent the many complicated atmospheric and near-surface interactions are required for overall descriptions of the budgets. Models will also be needed for eventual predictions of these water and energy processes. Therefore, different classes of models have also been compared with available observations. The comparison includes a representative global general circulation model, regional climate model, and a macroscale hydrologic model.

2.3 LBA

Marengo et al (2002a) used a combination ob station rainfall and the NCEP re-analysis to characterize the annual cycle of critical water budget parameters and their variations for the northern and southern sections of the Amazon River Basin. In the entire Amazonia, precipitation exceeds evaporation representing a sink of moisture (P>E). Our estimates of the Amazon region's water balance do not show a closure of the budget, with an average imbalance of almost 44%, meaning that some of the moisture that converges in the Amazon region is not unaccounted for. The uncertainties come basically from the estimation of the E and moisture convergence term using the NCEP reanalyses, as well as the rainfall indices from observed precipitation across the basin. Estimates of rainfall from other data sets such as those from CMAP or even the NCEP rainfall show some systematic differences with the observed rainfall, and some studies ob climate predictability and model skill suggest the better predictability of the water balance components in the northern part of the basin (the wettest part) as compared to Southern Amazonia.

Analyses from observations from field experiments in the basin have been able to show some diurnal and intraseasonal variability of rainfall and circulation in the Amazon basin, especially the differences on the timing of the diurnal maximum of rainfall associated to westerly or easterly circulations affecting the basin (Marengo et al. 2002b), or to the moisture transport from the Amazon basin during summer-autumn linked to the so called Low Level Jet east of the Andes, that features a moisture corridor that import atmospheric moisture from tropical to subtropical regions to the East of the Andes, such as southern Brazil-Northern Argentina. This in fact regulates rainfall in the Parana-La Plata River basin (Marengo et al. 2002c).

Model experiences have shown also some systematic errors in the modeling of the water balance terms for the Amazon Basin. The model tends to underestimate rainfall in the northern Amazonia, which also reflects in the low model runoff estimates, which in some cases are up to 60% lower than the observed runoff near the mouth of the Amazon in Obidos. The fact that the model does not capture the observed timing of the peak of the runoff is due to the effect that the model has not included a routing runoff scheme on its parameterization of land surface.

3. Transferability

Within GHP, there has been much discussion about the transferability of coupled atmosphere/soil regional models to different regions on the globe. As noted in the summary of the 2001 GHP meeting, "*The transferability of regional models between regions and/or the validation of global models over continental-scale experimental regions and other regions is being addressed on a case by case basis. A list of models being used in different regions continues to be updated each year and made available through the GHP web site.* There are four possible types of model transferability studies that could be used by GHP:

1. "Home-based" global model using CEOP validation data
2. "Home-based" global model and embedded regional model -- comparative evaluation with "home-based" regional model output (e.g. other models with Eta over GCIP region) plus CEOP validation data

3. Model transferability inter-comparison using a "neutral global model" (e.g. ECMWF or NCEP/NCAR re-analyses)
4. Regional model embedded in different global models to evaluate the effects of initial and boundary conditions from different global models

Research priorities for transferability studies are:

- *Evaluate and improve the representations of the effects of seasonally varying land-use, soil moisture, vegetation cover, and other soil characteristics forcing and their spatial heterogeneity in regional coupled models.*
- *Determine and model the multiscale responses of complex terrain on the regional hydroclimates at seasonal and diurnal time scales.*
- *Examine the model's surface energy budgets to evaluate the performance of the parameterizations in physical terms.*
- *Characterize and model the temporal and spatial distribution of different land surface conditions, such as snow cover including its accumulation/melt and the impact of frozen ground, on atmosphere/hydrology interactions.*

Characteristics of possible coupled hydrometeorological model case studies:

- A relative simple geographic region without major topographic complexities which has sufficient observations for data assimilation as well as model evaluation studies, such as the Mississippi River basin being studied by the GCIP CSE.
- A complex geographic region, such as the Baltic Sea and surrounding land areas now being studied by the BALTEX CSE.
- A neutral geographic region, which has not been studied by any of the CEOP participants, such as the region of the Niger river basin of west Africa, CATCH. “

3.1 BALTEX Bridge

The Max-Planck-Institute for Meteorology in Hamburg (MPIH) is hosting a BALTEX Bridge study with support of the GKSS research centre as a possible prototype for making use of and contributing to CEOP data. The area for this study is the Baltic Sea and its catchment area (shown as magenta line in figure 1). The time period is August to October 1995. This is the period where the BALTEX pilot experiment PIDCAP (Pilot study of Intensive Data Collection and Analysis of precipitation) took place. The description of the synoptic situation during this period has been described by Isemer, 1996. Within BALTEX an inter-comparison study of several European regional atmospheric models has already been carried out with data from the PIDCAP period. The focus was on components of the energy and water budget over the Baltic Sea and its catchment area. Precipitation, precipitable water, total cloud cover, surface radiation, surface sensible heat flux, evaporation, run off, as well as 2m temperature and 10m winds where compared between the models and with measurements. For more detailed description see Jacob et al., 2001. The experience from this inter-comparison study will be the background for the transferability study. This study may eventually be extended as a five-year simulation during CEOP.

HIRLAM analysis data from the Danish Meteorological Institute (DMI) are available on a rotated lat/lon grid with 24 vertical hybrid (sigma-pressure) levels as boundary data for the study. Resolution: horizontal ~ 24 km, temporal 6 hourly. The models should run with a horizontal resolution of about 18kmx18km in either of the following modes: (a) Forecast mode, i.e. daily forecast for each day. The forecast starts at 00 UTC and runs for 24h+spin up time (the spin up time may differ for each model and will be typically 6 hours or 12 hours); (b) Continuous mode, i.e. a 3 month simulation with initialization at the 1st of August 1995. The soil parameters (temperature and water content) should only be used in the initialization data of the 1st of August. This applies also for the forecast mode. For the 2nd, 3rd of August and so forth for the initialization of the soil parameters the values of the forecast of the day before should be used.

For the intercomparison the following data are available from measurements, except evaporation (see also Jacob et al., 2001). In the following BSC stands for "Baltic Sea Catchment" (magenta outline in **Fig. 3**).
(i) Total Precipitation
Mean daily precipitation [mm/day] from 6h – 6h.
BSC area weighted value for (a) land points only (including lakes), (b) Baltic Sea only, (c) total area. Total number of values: 3x92
(ii) Runoff
Mean daily runoff [mm/day] from 6h – 6h. BSC area weighted value for (a) land points only. Total number of values: 92
(iii) Integrated Water Vapor (i.e. Precipitable Water)
Mean 6h-average of IWV [kg/m^2] of selected GPS stations. Use of the simulated value for the nearest corresponding grid point of the station. Total number of values: 368 per Station
(iv) Evaporation
Mean daily evaporation [mm/day] from 6h – 6h.
BSC area weighted value for (a) land points only (including lakes), (b) Baltic Sea only, (c) total area. Total number of values: 3x92
(v) Sensible Heat Flux
Mean daily heat flux [W/m^2] from 6h –6h.
BSC area weighted value for (a) land points only (including lakes), (b) Baltic Sea only, (c) total area. Total number of values: 3x92
(vi) Radiation
Mean daily downwelling shortwave and longwave radiation terms [W/m^2] at the surface for selected stations from 0h – 0h. Use of the simulated value for the nearest corresponding grid point of the station.
(vii) Total Cloud Cover
Daily total cloud cover [0-1], instantaneous value between 12h and 15h BSC area weighted value for (a) land points only (including lakes), (b) Baltic Sea only, (c) total area. Total number of values: 3x9
(viii) Synop Data
Instantaneous values of 2-meter temperature [ºC], 2meter relative humidity [%], and 10-meter wind speed [m/s] 4 times a day for selected stations. Use the simulated value for the nearest corresponding grid point of the station.

3.2 La Plata

The La Plata Basin is second in size only to the Amazon basin in South America, and plays a critical role in the economies of the region. It is a primary factor in energy production, water resources, transportation, agriculture and livestock. For comparison, the annual mean river discharge of the La Plata River is about 25% larger than that of the Mississippi River, and has a distinctly different annual cycle (Berbery and Barros 2002). The amplitude of the annual cycle of La Plata River discharge is small: it is slightly larger during late summer, but continues with large volumes even during winter. However, further analysis of the main rivers contributing to La Plata reveals that each contributing river basin has a well defined annual cycle, but with different phases that can be traced primarily to different precipitation regimes. The more important ones are: (a) a summer monsoon regime affecting the northern area; (b) precipitation originated in Mesoscale Convective Complexes (MCCs) toward the central area of the basin; and (c) winter synoptic activity, producing mostly liquid precipitation. The Low-level Jet east of the Andes that supplies moisture from tropical South America to La Plata Basin is present throughout the year (Berbery and Barros 2002; Nogués-Paegle et al. 2002). This is an uncommon feature not observed in other regions like the Great Plains of the United States, where the Low-level Jet develops only during the warm season. Thus, the La Plata Basin has a steady supply of moisture and heat from warmer regions at all times of the year, favoring precipitation during both the warm and cold seasons.

The goal of this transferability experiment is to evaluate the annual cycle of the hydrologic cycle components in various regional models, and when relevant, compare them to those of other basins. Regional models will be evaluated systematically using a special data set of daily observed precipitation. The low-level jet east of the Andes is strongest over Bolivia, a region where data are sparse. This might pose a problem in assessing how realistic the circulation is at low levels, but the field program to be conducted with PACS support by M. Douglas (NSSL) should be critical for further evaluation of the models. A network of pilot balloons has been deployed and measurements, already under way, will expand during CEOP. CEOP could play a critical role by ensuring that this data are distributed to the community in a timely manner.

The transferability experiment will include evaluations of regional models': (a) performance in terms of precipitation and winds in the La Plata basin; (b) potential to reproduce the low-level jet east of the Andes; and, lastly, (c) functioning over complex mountainous terrain. Initial results with the Eta model have been encouraging for all seasons, even in subtropical regions. Selected information of this model is being provided to Steve Williams to distribute through UCAR/JOSS. See also http://www.meto.umd.edu/~berbery/etasam.

4. Land Data Assimilation

Traditional coupled land-atmosphere 4-D data assimilation systems (4DDA) often yield significant errors and drift in a) soil moisture and temperature and b) surface energy and water fluxes owing to substantial biases in the surface forcing fields from the parent atmospheric model, especially biases in precipitation and surface solar insolation. Hence, as an uncoupled land-surface alternative to coupled 4DDA, there are a number of regional as well as a global Land Data Assimilation System projects.

4.1 GLDAS

A Global Land Data Assimilation System (GLDAS) that uses various new satellite and ground based observation systems within a land data assimilation framework to produce optimal output fields of land surface states and fluxes has been developed under the leadership of Drs. Paul Houser and Matthew Rodell at NASA’s Goddard Space Flight Center. GLDAS includes four components implemented globally at ¼ degree resolution (higher resolutions are planned) in near real time: land modeling, land surface observation, land surface data assimilation and calibration and validation. The core advantage of GLDAS is its use of satellite-derived observations (including precipitation, solar radiation, snow cover, surface temperature, and soil moisture) to realistically constrain the system dynamics. This allows it to avoid the biases that exist in near-surface atmosphere fields produced by atmospheric forecast models, minimize the impact of simplified land parameterizations, and to identify and mitigate errors satellite observations used in data assimilation procedures. These value-added GLDAS data will improve land surface, weather, and climate predictions by providing global fields of land surface energy and moisture stores for initialization. Through its Japanese and European collaborations, CEOP will likely benefit GLDAS by enabling access to remotely sensed data from international space agencies.

GLDAS is a natural and important tool for CEOP because in a globally consistent manner, it will integrate the information from multiple models and observation platforms to provide the best available assessment of the current state of the land surface. The international GEWEX and CEOP communities have recognized that GLDAS can be leveraged and further developed to provide optimal integration of CEOP data. CEOP is specifically interested in the generation and application of GLDAS results in regional climate analysis, model initialization, and comparison with results from field campaigns and modeling experiments. The use of model location time series (MOLTS), which are time series of land surface model output for points of interest, will be one of the primary tools to enable this globally-consistent intercomparison. Each GLDAS MOLTS will be particularly relevant because it will be generated based on a GLDAS subgrid "tile" with a vegetation class that matches that of the observation. Furthermore, MOLTS can be produced using each of the land surface models that GLDAS drives (currently three; five planned). These comparison exercises and the data produced by the continental scale experiments also will provide much-needed validation for the GLDAS project.

CEOP has requested that NASA further develop GLDAS as a central "CEOP data integration center", which will include: a testbed for evaluating multiple land surface models, long term land model baseline experiments and intercomparisons, linking and inclusion of reference site observations with globally consistent observation and modeling to enable GEWEX-CSE land transferability studies, and initialization for seasonal-to-interannual coupled predictions, evaluation of NWP and climate predictions for land, integrating remote sensing land observations in land/atmospheric modeling for use in CEOP and higher level understanding, producing a quality control check on observations, producing 4DDA "value-added" GLDAS-CEOP datasets, producing GLDAS MOLTS, expanding GLDAS to include selected atmosphere and ocean observations, and developing a long-term archive.

The GLDAS contribution to CEOP is expected to have the following timeline:

- Data Integration Period (2002-2005)
    - Compile the forcing data (obs and analyses) and assimilation data
        - Including radiance observations (level 1), high-level satellite data products, in-situ observations, and NWP land analyses.
    - Develop long term archive (Goddard DAAC, NCAR, Japan)
    - Develop MLDAS (Molts LDAS)
        - Reconfigure GLDAS to run only MOLTS points

        - Access the global forcing for flexibility in point definition
        - Smaller computing requirements, easier turnaround time. Good for R&D, land model intercomparison
        - Link to CSE reference sites
- Reanalysis Period (2006-2007)
    - 1/8 degree resolution; global land, CEOP time domain
    - Land model products (NOAH, CLM, VIC, others?)
    - Data assimilated value-added analysis

4.2 US LDA
NCEP/EMC, NCEP/CPC, NASA/GSFC, NWS/OHD, NESDIS/ORA, Princeton University, University of Washington, Rutgers University, University of Maryland, and University of Oklahoma; see http://ldas.gsfc.nasa.gov). have undertaken the development and demonstration of a National (N-LDAS) -- a realtime, hourly, distributed, uncoupled, land-surface simulation and assimilation system executing on a horizontal grid spanning the U.S. CONUS domain at 0.125 degree resolution. The N-LDAS project represents a major component of the GAPP/GCIP continental-scale experiment, which is a primary sponsoring program of the N-LDAS project.

The N-LDAS project is applying four different LSMs. These four LSMs are: (1) NOAH (Koren et al., 1999), (2) MOSAIC (Koster and Suarez, 1996), 3) VIC-3L (Liang et al., 1996), and (4) SAC-SWA (Sacramento Model; Burnash et al. 1973). One or two additional LSMs may be added in the near future (e.g. SSiB, CLM). In the N-LDAS, these LSMs execute in parallel in real time on a common grid, using common terrain heights and land mask, and all driven by common surface forcing -- the latter highlighted by model-independent, observation-based precipitation and solar insolation fields. Also, a common streamflow routing model is applied to each LSM's gridded runoff to provide parallel streamflow simulations over selected basins across the CONUS.

Several of the collaborating partners are providing various sources of retrospective forcing that focus on three different periods spanning 1) several years (1996-present), 2) roughly one decade (1987-1998), and 3) the 50-plus years of the NCEP/NCAR Global Reanalysis (1948-present). In all three cases, model independent precipitation analyses are provided. Using these sets of retrospective forcing, the N-LDAS partners are executing retrospective companions to the realtime N-LDAS. One of many applications of the retrospective runs will be to characterize the current realtime land states of soil moisture and snowpack of a particular LSM in terms of percentile departures or anomalies from a multi-year climatology of that LSM.

The N-LDAS project will contribute to CEOP by providing both validation fields and the initial conditions for the land states for regional climate model predictions. In particular, N-LDAS evaluates the utility of the new generation of experimental satellites in land area and hydrological research to improve NWP and climate predictions and prepares land data assimilation products. The realtime execution of the N-LDAS began before the start of CEOP will continue at least through the CEOP period (2004) and beyond.

Four central scientific questions are being addressed by N-LDAS: (1) What is the relative impact of land-surface boundary conditions versus sea-surface boundary conditions on seasonal-to-annual predictability of the continental water cycle in coupled regional land/atmosphere climate models? Is the land-surface impact increased by utilizing initial land states from an uncoupled versus coupled LDAS (such as the NCEP Regional Reanalysis)? Is the land-surface impact increased by employing the same LSM in both the coupled climate prediction model and the LDAS that generates the initial conditions for the climate model? (2) How can calibration methods for LSMs be extended or relaxed from local point-wise or small-catchment measurements to widespread satellite measurements over large spatial domains? (3) Does the assimilation of satellite data improve the simulated states and fluxes of an LDAS? What satellite data types and assimilation methods are most effective and operationally feasible? (4) Can distributed LSMs running at grid resolutions feasible over a national domain simulate streamflow with accuracies on par with catchment-specific, calibrated lumped models?

5. WESP Data

Three spatial scales (local, regional, global) are of interest to the CEOP community. At local scales, in situ data from several international tower sites, along with level II and level III satellite data plus numerical model and 4DDA output for these same sites, will be consolidated into useful data sets for studying water and energy budgets. At regional and global scales, regional and global networks of more standard observations, as well as model and 4DDA output, are also needed for closing regional and global water and energy budgets and understanding monsoon interactions over land and ocean.

In the GEWEX community, the first type of output above is referred to as Model Output Location Time Series or MOLTS. At some numerical weather prediction centers, this type of output is also referred to as "meteograms" and is typically output in the World Meteorological Organization (WMO) format standard known as BUFR. Our goal is to translate the BUFR output into column ASCII format, which can be easily utilized by the research community. In any case, this type of output refers to model output at individual sites in vertical model columns (including the earth surface and subsurface) at 3-hourly or more frequent intervals. Hence, MOLTS represents the model-output analog of "observing station" time series and such output is needed by researchers to augment in situ data and for studying local processes. The locations of the proposed in situ MOLTS sites are provided in **Table 1** and **Fig. 1**. There are now 34 identified sites in a broad array of climatic regions. A P and T diagram for the CEOP MOLTS sites is provided in **Fig. 2**.

Equally important, 3D and 2D gridded output processed as synoptic snapshots at a minimum of six hourly intervals (three hourly intervals strongly preferred if possible). At NWP centers, such gridded synoptic snapshots are often output in the WMO format standard known as GRIB. An example of 2D gridded output is earth-surface specific states or fluxes (e.g. snow pack water content), which are not defined throughout the atmospheric or subsurface medium. The 3D gridded output is typically provided as a set of 2D gridded fields spanning the vertical levels.

CEOP has requested 3-hourly (or more frequent) analysis values for several hydroclimatic variables and processes (**Table 2**). Some of these values should be accumulated over the previous 3 hours, although approximations to the accumulation, such as averages over the previous 3 hours would be acceptable. These values will be provided on the model vertical grid, and we will then provide both the native vertical grid as well as interpolated values to the research community. Interpolated values will be provided every 5 mb in the vertical. In addition, 1-day forecasts initialized at 0 UTC and output every 3 hours for the same variables are also requested so that we can better understand how models are adjusting from the initial analysis. As may be seen from **Table 2**, the total number of 2-d grids are (3+23+3+7). The total number of 3-d atmospheric grids are (26). The total number 3-d subsurface grids are (2). The total number of values at a single MOLTS station for a single time will therefore be (3+23+3+7)*1+(26)*200+(2)*6=5248 or 10496 for both initial analysis and forecast. For a single day (8 3 hour analysis times) this will be 83968 words. For the 2-year period this will be 60 x 10^6 words. At 4 bytes per word this is 240 mb per molts station. For 34 stations this will be 8 gb per model. There are likely to be about 10 models and thus the 200 level CEOP MOLTS data set should be on the order of 80gb. For a global grid of 192x94 (T62) there will be about 18048 grid points but a decrease in number of levels, to say 40, or equivalently each model gridded data set (at this resolution) will be 100 times the MOLTS. The model data will be archived by the individual centers initially although MPI has agreed in principle to archive the gridded model output data.

A number of other NWP centers have been requested to provide these products, and NCEP has already responded in part by indicating that many of these variables and processes can be derived from the basic global and regional analyses. However, despite the availability of NWP data, it is clear that major efforts will need to be undertaken in order to fully realize WESP goals. Such efforts are being offered as a challenge to the research community.

5.1 NCEP Contributions

NCEP global and regional reanalysis products will be available during CEOP. Data sets include: (1) Global Reanalysis I (L28T62 grid); Global Reanalysis II (L28T62 grid); Regional Reanalysis (32-km, 45-layer); operational Eta/EDAS forecasts and 4DDA (MOLTS point-wise time series, and MORDS 40-km gridded fields); operational MRF/GDAS forecasts and 4DDA (committed only to MOLTS at this time, and adding CEOP MOLTS cites thereto; weekly global SST (1-deg resolution); daily sea-ice cover (N.H., nominally 50-km, provided via NESDIS). Also during CEOP, NCEP will contribute analyses of precipitation, SST, snow cover and sea-ice, as follows: A) global, 2.5-degree, 5-day, gage/satellite precipitation analysis in real-time, and reanalysis to January 1979; B) U.S., 0.25-degree, daily, gage-only precipitation analysis in real-time, and reanalysis to January 1948; C) U.S., 4-km, hourly, radar/gage precipitation analysis in real-time, with archive to July 1996; D) Mexico, 1.0-degree, daily, gage-only precipitation analysis in real-time, and reanalysis to January 1948; E) global, 1.0-degree, weekly, SST analysis in real-time, and reanalysis to November 1981; and F) N. Hemisphere, 25-km, daily, snow cover and sea ice analysis in real-time, with archive to January 1997 (via NESDIS partner). **Fig. 2** shows the annual mean (1988-1999) NCEP/NCAR precipitation and temperature associated with the MOLTS sites given in **Table 1**.

5.2 NASA DAO contributions

The NASA Data Assimilation Office (DAO) will make available operational analyses for the CEOP period. The data will include complete energy and water cycle budgets including observational analysis terms. The operational analysis is still under development and will eventually include precipitation and land temperature assimilation. The DAO is undertaking a

CEOP Reanalysis Project in order to produce a consisitent global data analysis product for the CEOP period.

References

Baetghen, W., V. Barros, E.. Berbery, R.Clarke, H. Cullen, C. Ereño, B. Grassi, D.P. Lettenmaier, R. Mechoso, and P. Silva Dias, 2001: Climatology and hydrology of the Plata Basin, WCRP/VAMOS, 2001.

Berbery, E. H., and V. R. Barros, 2002: The hydrological cycle of the La Plata basin in South America. Journal of Hydrometeorology, accepted.

Burnash, R.J.C., R.L. Ferral, and R.A. McGuire, 1973, A generalized streamflow simulation system: conceptual models for digital computers, Joint Fed.-State River Forecast Center.,Sacramento, California

Isemer, H.-J., 1996: Weather Patterns and Selected Precipitation Records in the PIDCAP period, August to November 1995. A Preliminary Overview. GKSS-Forschungszentrum Geesthachtpp. 92.

Jacob, D., B.J.J.v.d. Hurk, U. Andrœ, G. Elgered, C. Fortelius, L.P. Graham, S.D. Jackson, U. Karstens, C. Köpken, R. Lindau, R. Podzun, B. Rockel, F. Rubel, B.H. Sass, R.N.B. Smith and X. Yang, 2001: A comprehensive model inter-comparison study investigating the water budget during the BALTEX-PIDCAP period. Meteor. Atmos. Phys., 77, 19-44.

Koren, V., J. Schaake, K. Mitchell, Q. Duan, F. Chen, and J. Baker, 1999: A parameterization of snowpack and frozen ground intended for NCEP weather and climate models. J. Geophys. Res., 104, 19569-19585.

Koster, R., a nd M. Suarez, 1996: Energy and Water Balance Calculations in the MOSAIC LSM. NASA Tech Memo 104606, Vol 9.

Liang, X., E. Wood, and D. Lettenmaier, 1996: Surface and soil moisture parameterization of the VIC-2L model: Evaluation and modifications. Global Planet. Change, 13, 195-206.

Marengo, J,. Nobre, C., Sanches, M., 2002a: On the atmospheric water budget and moisture cycling in the Amazon basin: Characteristics and space-time variability. To be submitted to Int. J. Vlimatol.

Marengo, J., Fisch, G., Vendrame, I., Cervantes, I., Morales, C., 2002b: On the diurnal and day-to-day variability of rainfall in Southwest Amazônia during the LBA-TRMM and LBA-WET AMC Campaigns of summer 1999. Submetedo Theoret. Applied. Climatology.

Marengo, J., Douglas, M., Silva Dias, P., 2002c: The South American Low-Level Jet East of the Andes during the LBA-TRMM and WET AMC campaign of January-April 1999. Aceito J. Geophys Research.

Nogués-Paegle, J., C. R. Mechoso, R. Fu, E. H. Berbery, and coauthors, 2002: Progress in Pan American CLIVAR research: Understanding the South American monsoon. Meteorologica, submitted.

Roads, J., 2002. Closing the Water Cycle. GEWEX Newsletter. February 2002. 8 pages.

Roads, J., M. Kanamitsu, R. Stewart, 2002a: CSE Water and Energy Budgets in the NCEP-DOE Reanalysis II. J. Hydrometeorology Vol. 3, Issue 3. June 2002. p. 128-165.

Roads, J., R. Lawford, E. Bainto, H. Berbery, B. Fekete, K. Gallo, A. Grundstein, W. Higgins, J. Janowiak, M. Kanamitsu, V. Lakshmi, D. Leathers, D. Lettenmaier, Q. Li, L. Luo, E. Maurer, T. Meyers, D. Miller, K. Mitchell, T. Mote, R. Pinker, T. Reichler, D. Robinson, A. Robock, J. Smith, G. Srinivasan, K. Vinnikov, T. von der Haar, C. Vorosmarty, S.

Williams, E. Yarosh, GCIP Water and Energy Budget Synthesis (WEBS), 2002b, [CD-ROM] (available from GAPP program office).
Roads, J., R. Lawford, E. Bainto, H. Berbery, B. Fekete, K. Gallo, A. Grundstein, W. Higgins, J. Janowiak, M. Kanamitsu, V. Lakshmi, D. Leathers, D. Lettenmaier, Q. Li, L. Luo, E. Maurer, T. Meyers, D. Miller, K. Mitchell, T. Mote, R. Pinker, T. Reichler, D. Robinson, A. Robock, J. Smith, G. Srinivasan, K. Vinnikov, T. von der Haar, C. Vorosmarty, S. Williams, E. Yarosh, 2002c: GCIP Water and Energy Budget Synthesis (WEBS). J. Geophys. Res. (submitted)

Table I. CEOP reference and MOLTS sites

	Site	**Latitude**	**Longitude**
	CAMP		
1	Eastern Siberian Tundra (Tiki)	71.62	128.75
2	Eastern Siberian Taiga (Yakutsk)	62.25	129.62
3	Mongolia	45.74	106.26
4	Tibet	31.37	91.90
5	Yangtze River	32.00	116.00
6	Inner Mongolia	44.46	122.12
7	Northern South China Sea-Southern Japan	24.97	121.18
8	Himalayas	27.96	86.81
9	Korean Jeju	33.17	126.10
10	Korean Peninsula	37.10	123.12
11	Chao-Phraya River	17.16	99.87
12	North-East Thailand	14.47	102.38
13	Western Pacific Ocean	07.05	134.27
14	Equatorial Island	-00.02	100.32
15	Tropical Western Pacific (Manus)	-02.06	147.43
	LBA		
16	Rondonia (Forest Site)	-10.08	-61.93
17	Manaus	-02.61	-60.21
18	Santarem (Primary Forest)	-03.02	-54.97
19	Caxiuana	-01.71	-51.51
20	Pantanol	-19.56	-57.01
21	Brasilia (Cerrado)	-15.93	-47.92
	GAPP		
22	Southern Great Plains	36.61	-97.49
23	Bondville	40.01	-88.29
24	Fort Peck	48.31	-105.10
25	Oak Ridge	35.96	-84.29
26	Mt. Bigelow	32.42	-110.73
	MAGS		
27	BERMS (Old Aspen)	53.63	-106.20
28	BERMS (Old Black Spruce)	53.99	-105.12
	BALTEX		
29	Lindenberg	52.20	14.12

30	Cabauw	51.97	04.93
31	Sodankyla	67.37	26.65
	CATCH		
32	Oueme	09.50	02.00
33	Niamey	13.50	02.50
	OTHER		
34	North Slope of Alaska (Barrow)	71.32	-156.62

Table II. MOLTS and Gridded Output Variables for the top of the atmosphere, the atmosphere, surface and subsurface. A=accumulated over the previous 3 hours, I=instantaneous. S=in situ measurement, R=satellite remotely sensed.

	Top of Atmosphere	**Units**	**A,I**	**S**	**R**
1	shortwave downward flux	W/m^2	A		X
2	shortwave upward flux	W/m^2	A		X
3	longwave upward flux	W/m^2	A		X
	Atmosphere				
1	Temperature	K	I		X
2	Humidity	kg/kg	I		X
3	Cloud water	kg/kg	I		X
4	Kinetic Energy	W/m^2			
5	Zonal wind	m/s	I		
6	Meridional wind	m/s	I		
7	Pressure velocity	Pa/s	I		
8	geopotential (gZ)	m^2/s^2	I		
9	convective latent heating rate	W/m^2	A		
10	stable latent heating rate	W/m^2	A		
11	convective moistening rate	$kg/(m^2s)$	A		
12	stable moistening rate	$kg/(m^2s)$	A		
13	diffusive moistening rate	$kg/(m^2s)$	A		
14	diffusive heating rate	W/m^2	A		
15	short-wave heating rate	W/m^2	A		
16	long-wave heating rate	W/m^2	A		
17	water vapor zonal flux	kg/(ms)	A		
18	water vapor meridional flux	kg/(ms)	A		
19	water vapor vertical flux	kg/(ms)	A		
20	water vapor flux divergence	$kg/(m^2s)$	A		
21	energy (CpT+gZ+KE) zonal flux	W/m	A		
22	energy (CpT+gZ+KE) meridional flux	W/m	A		
23	energy (CpT+gZ+KE) vertical flux	W/m	A		
24	dry static energy flux divergence	W/m^2	A		
25	Local time tendency of temperature	W/m^2	A		X
26	Local time tendency of moisture	$kg/(m^2s)$	A		X
	Surface Values				
1	Local time tendency of surface pressure	Pa/s	A		
2	surface pressure	Pa	I		

3	skin temperature	K	I		X
4	2-meter temperature	K	I		X
5	2-meter specific humidity	kg/kg	I		
6	u-component at 10 m	m/s	I		
7	v_component at 10 m	m/s	I		
8	potential temperature at 10 m	K	I		
9	specific humidity at 10 m	kg/kg	I		
10	snow water equivalent	m	I		X
11	vegetation water	kg/m**2	I		
12	shortwave downward flux (+:downward)	W/m^2	A	X	X
13	shortwave upward flux (+:downward)	W/m^2	A	X	X
14	longwave downward flux (+:downward)	W/m^2	A	X	
15	longwave upward flux (+:downward)	W/m^2	A	X	X
16	sensible heating	W/m^2	A	X	
17	latent heating	W/m^2	A	X	
18	snow phase change heat	W/m^2	A		
19	meridional wind stress	W/m^2	A		
20	zonal wind stress	W/m^2	A		
21	10 m turbulent kin energy in a layer	m^2/s^2	A	X	
22	surface runoff	$kg/(m^2s)$	A		
23	base flow runoff	$kg/(m^2s)$	A		
	Below Surface Values				
1	soil moisture	%	I	X	X
2	temperature	K	I	X	
	Bottom of Subsurface				
1	Soil Moisture	%	I	X	
2	Temperature	K	I	X	
3	Ground Heat Flux	W/m^2	I		
	Miscellaneous				
1	Precipitation type 1rain or 2snow		I	X	
2	station land/sea/ice mask 0(land)or1(sea)or(2)ice		I	X	X
3	Total cloud cover	%	I	X	X
4	planetary boundary layer height	m	I		
5	surface exchange coefficient	m/s	I		
6	roughness length	m	I		
7	green vegetation cover	%	I		

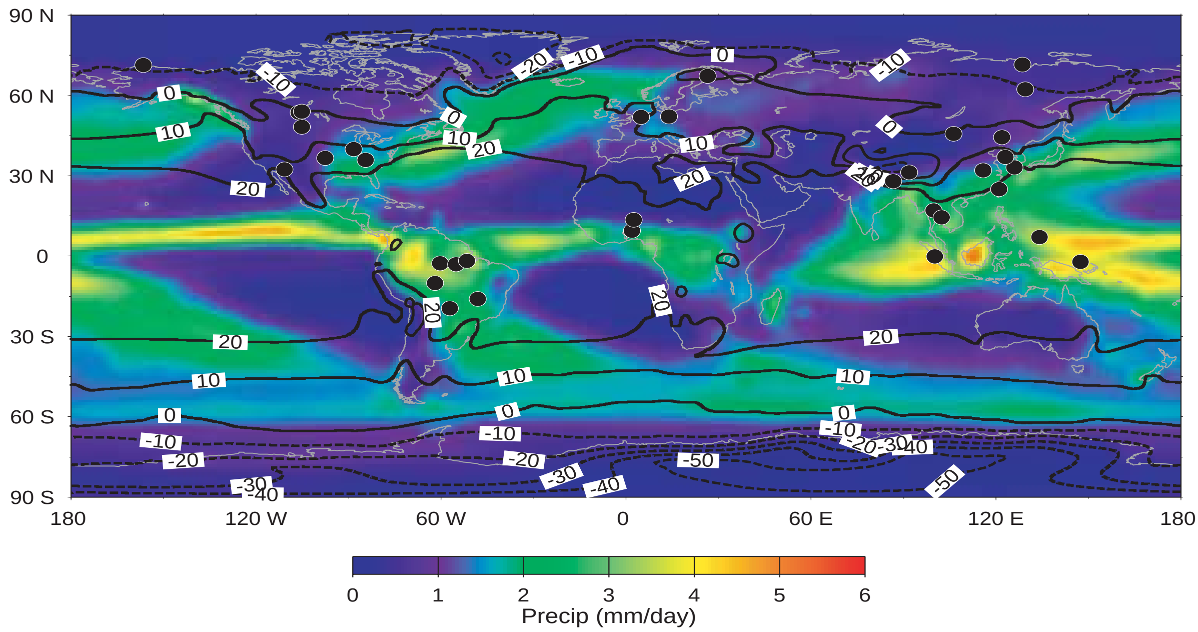

Fig. 1 CEOP in situ reference and MOLTS sites.

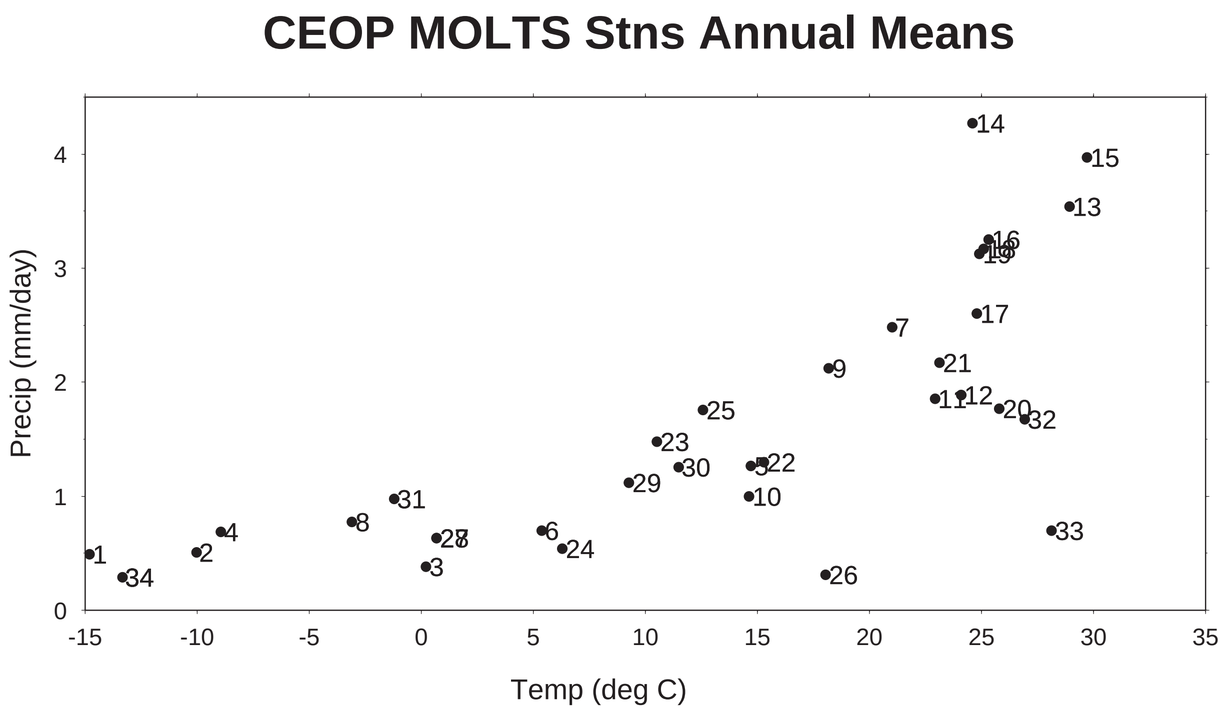

Fig. 2 P and T diagram for MOLTS sites from NCEP/NCAR Reanalysis

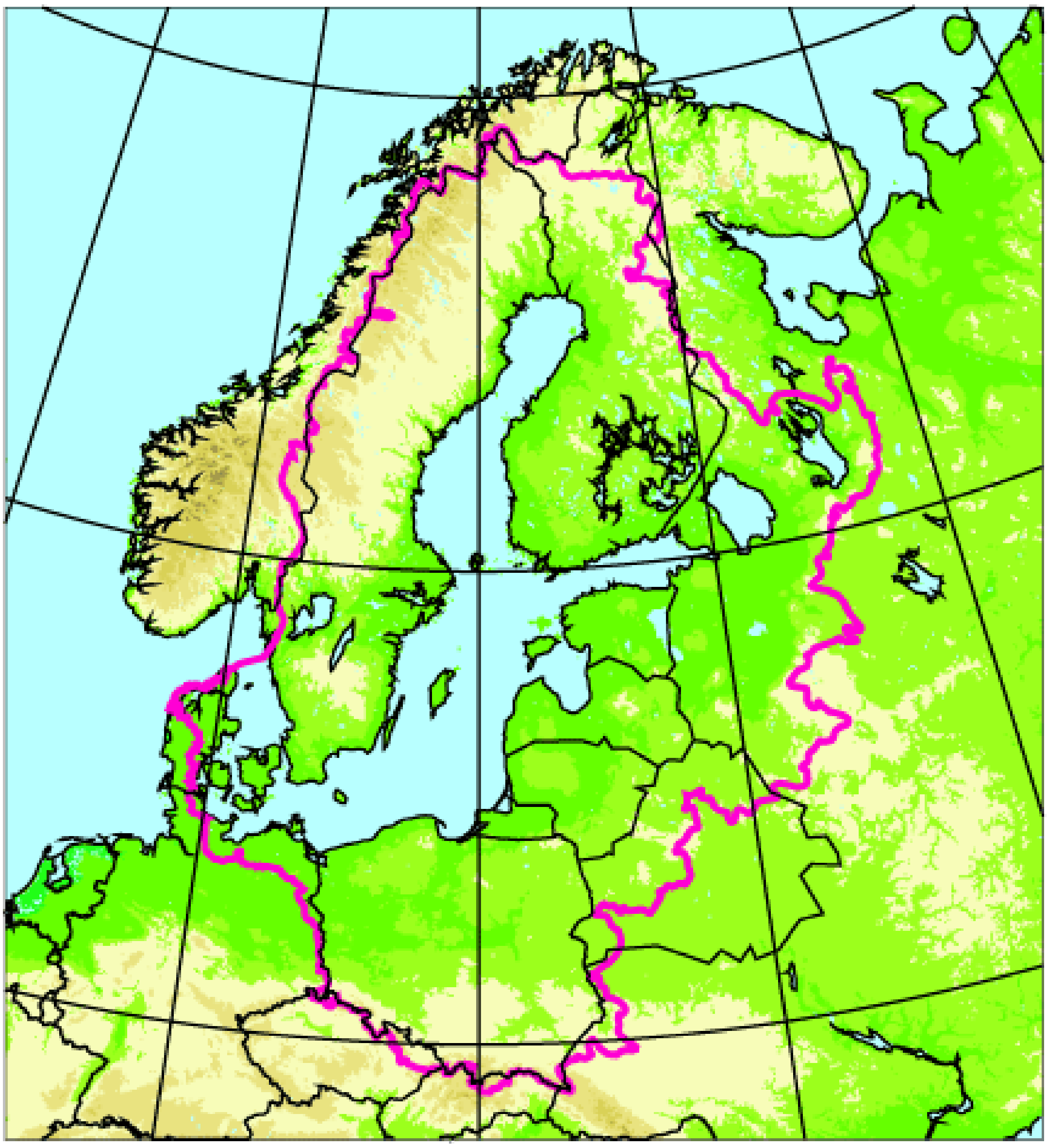

Figure 3: The Baltic Sea catchment area (magenta outline) to be used for the BALTEX Bridge transferability experiment.