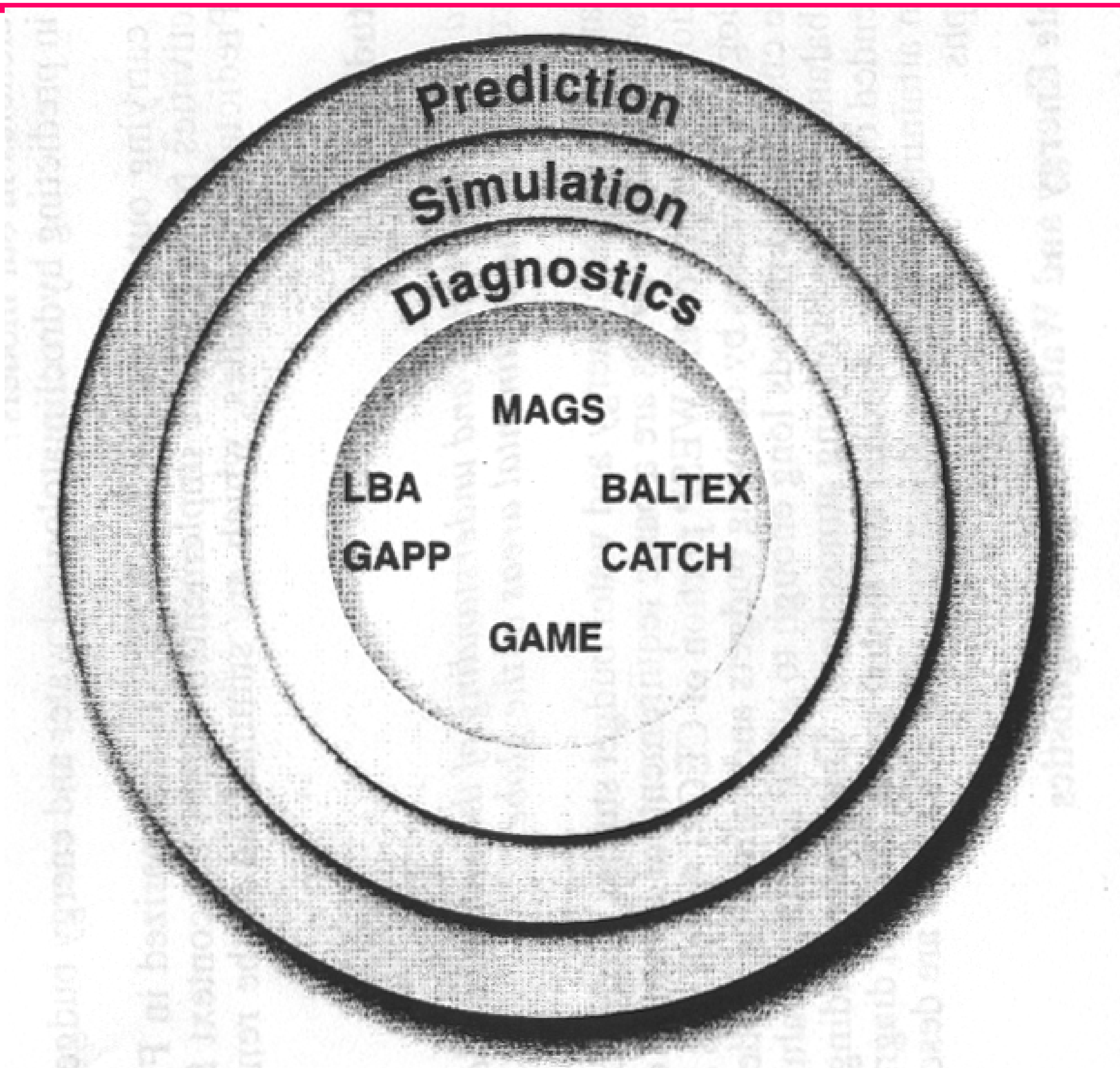
# Water and Energy Cycle Simulation and Prediction Studies (WESP)

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- TBD, representatives from some other other NWP centers

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# CEOP (An element of WCRP)

- To use enhanced observations to better document and simulate water and energy fluxes and reservoirs over land on diurnal to annual scales and to better predict these up to seasonal for water resource applications (WESP portion of CEOP)

- To document the seasonal march of the monsoon systems, and their driving mechanisms, and investigate their possible physical connections (Monsoon Systems Studies)

# Research Plans: WESP portion of CEOP

- Conduct a pilot 2-year synoptic climatological case study of regional CSE and global water and energy budgets as a guide to the interpretation of longer-term past and future global and regional analyses and data sets.
- Starting with the current efforts to close simplified vertically integrated water and energy budgets with observations and analysis and models, 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 and diurnal land-atmosphere-ocean hydroclimatological characteristics in observations and models.

# WESP Activities

- **Water and Energy Budget Studies (WEBS)**
  - Characterize and attempt to close atmospheric and land water and energy budgets
- **Land Data Assimilation studies**
  - Develop global and regional (NLDAS & ELDAS) land data assimilation
- **Transferability Studies**
  - Transfer modelling techniques for water and energy fluxes and budgets between various continental-scale areas (GAPP, BALTEX, La Plata
- **Develop data requirements from in situ, satellite, models**
  - Sampling frequency, variables, budgets, model requirements, composite data sets

# WESP Activities

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  - Balance water and energy budgets over land areas and, as appropriate, over associated oceanic areas
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# Pre-CEOP Water and Energy Budgets

**Atmospheric Mass**

$$\frac{\partial \pi}{\partial t} = -\nabla \bullet \pi v$$

**Atmospheric Water Vapor**

$$\frac{\partial \{q\}}{\partial t} = -\nabla \bullet \{vq\} + E - P + \{RSQ\}'$$

**Surface Water**

$$\frac{\partial (m+s)}{\partial t} = P - E - N + RSW'$$

**Atmospheric Energy**

$$\frac{\partial \{C_p T + KE + \phi_s\}}{\partial t} = -\nabla \bullet \{v(C_p T + \phi + KE)\} + SH + LP + \{QR\} - \{QF\} + RST'$$

**Surface Energy**

$$C_v \frac{\partial Ts}{\partial t} = QRS - SH - LE - L_f C_{sm} + QF_s + G'$$

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# Pre-CEOP Water & Energy Budget Studies (WEBS)

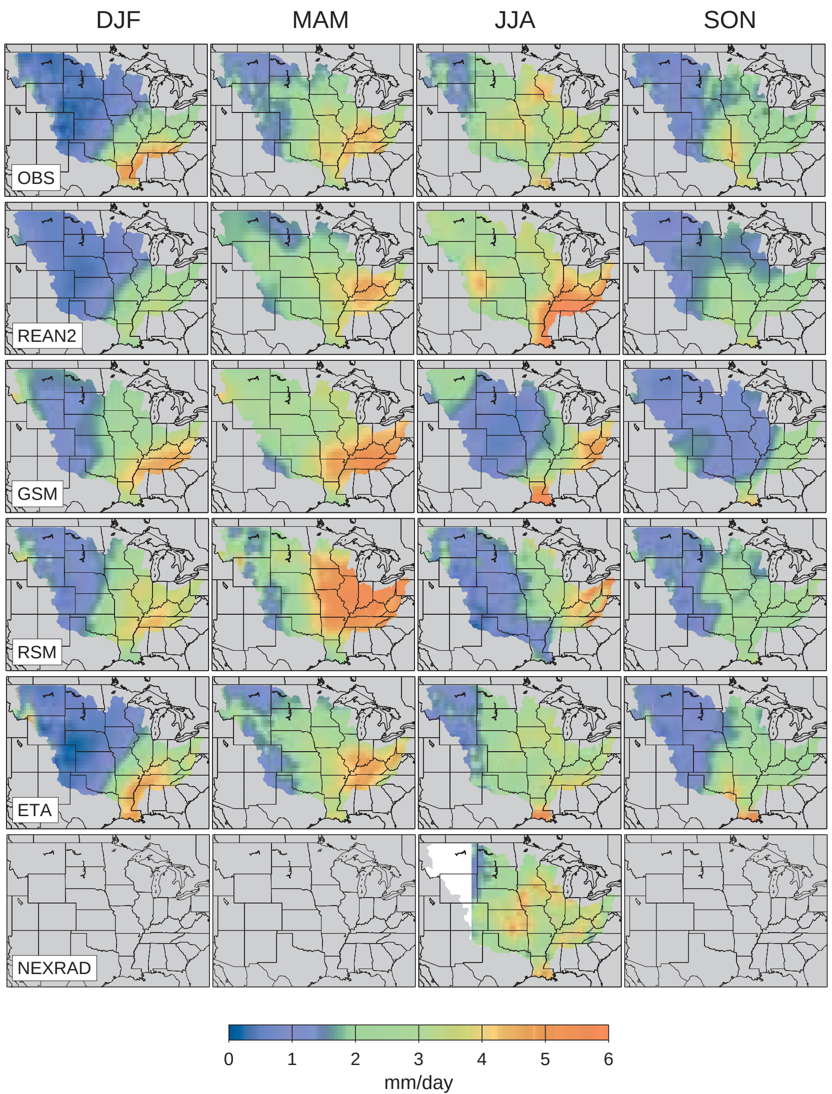
- GCIP/GAPP
  - Roads et al. (2002b) are developing a GCIP WEBS from representative models, available observations and various reanalyses. Maurer et al. (2002) are developing a corresponding 50-year LDAS legacy data set.
- MAGS
  - Budget studies using regional climate models show general agreement with available measurements for some parameters but problems with others (such as orographic precipitation).
- LBA
  - Marengo et al (2002) 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.
- BALTEX
  - Omstedt and Rutgersson (2000), Omstedt et al. (2000) provided WEBS for the BALTIC Sea. Jacob (2001; Jacob et al. (2001) described regional model simulations of WEBS.
- GAME
  - GAME is developing a comprehensive dataset through a special re-analysis effort by JMA and the bringing together of many observational measurements taken over many regions of Asia. Model studies are using operational and re-analysis products
- GHP
  - A global synthesis is being developed that will make use of pre-CEOP data. This will help to set the stage for global syntheses developed from CEOP data

# GCIP WEBS

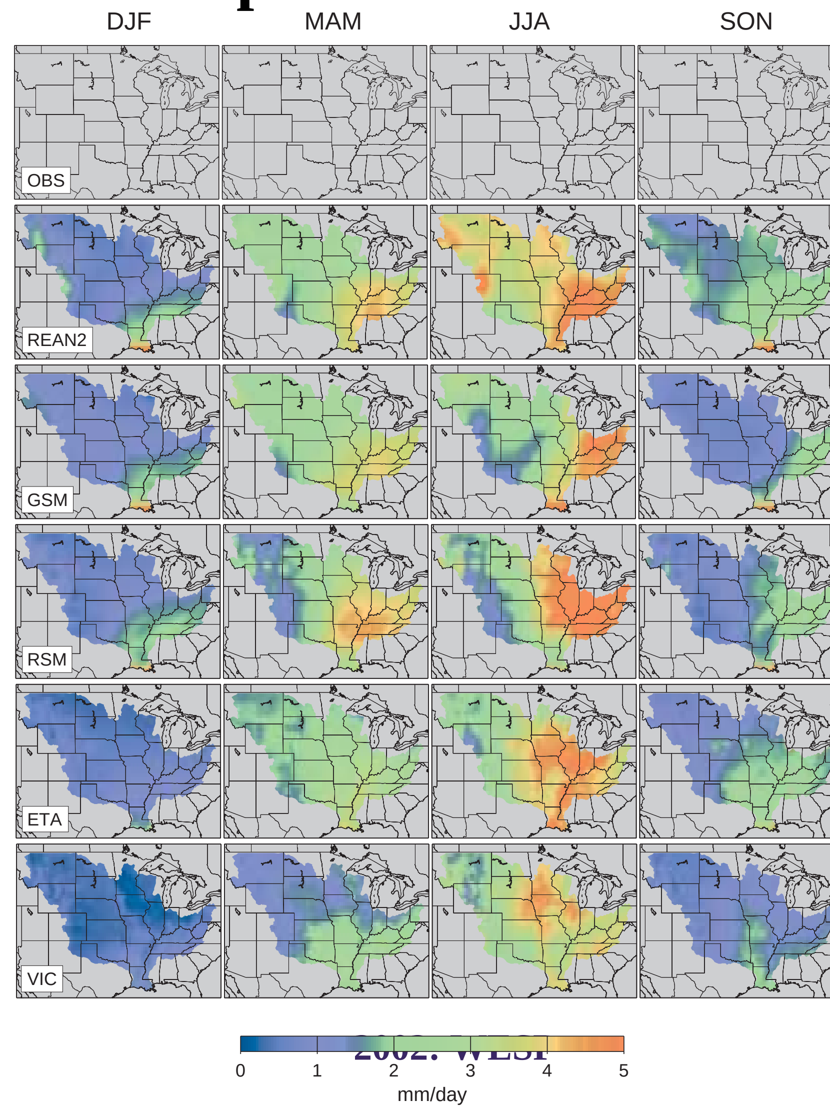
Roads, J., 30 coauthors, 2002: GCIP Water and Energy Budget Synthesis (WEBS). CD-ROM (available from GEWEX office)

Roads, J., 30 coauthors, 2002: GCIP Water and Energy Budget Synthesis (WEBS). *J. Geophys. Res*. (submitted to, and almost in press, GCIP3 special issue)

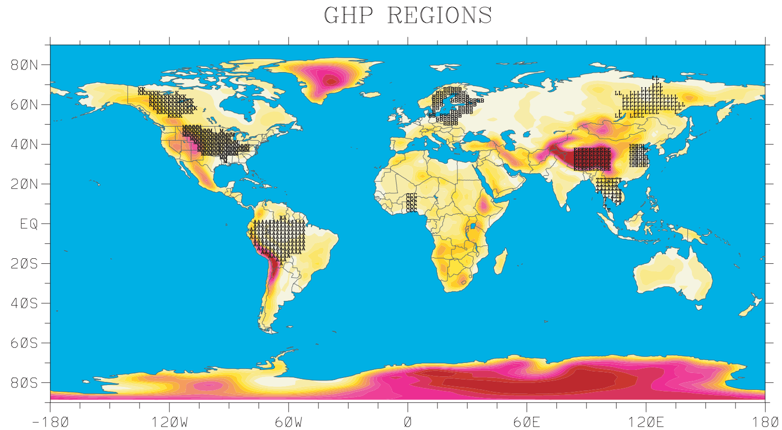
## Precipitation

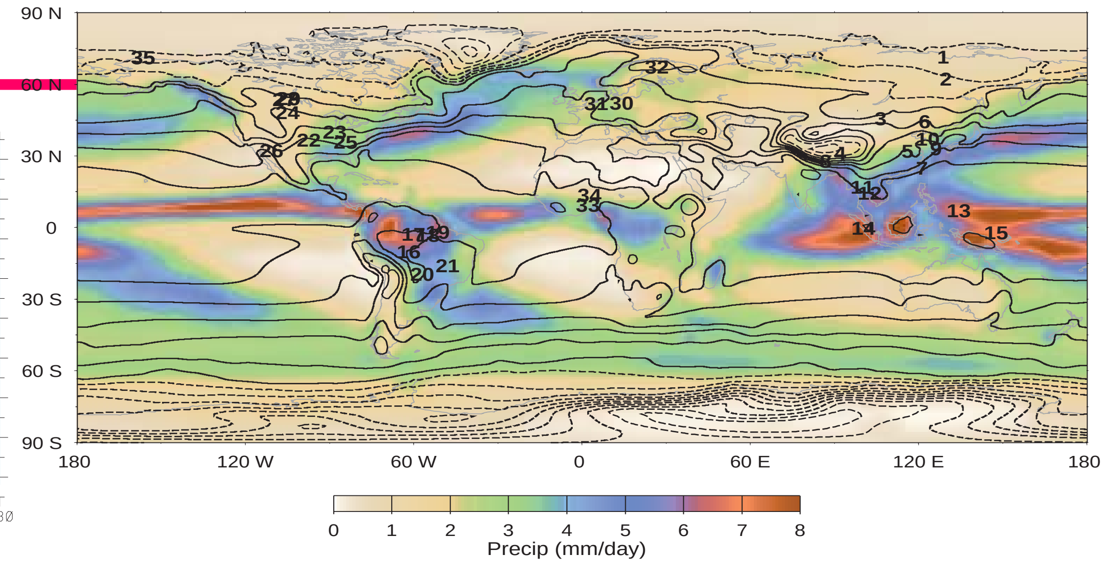


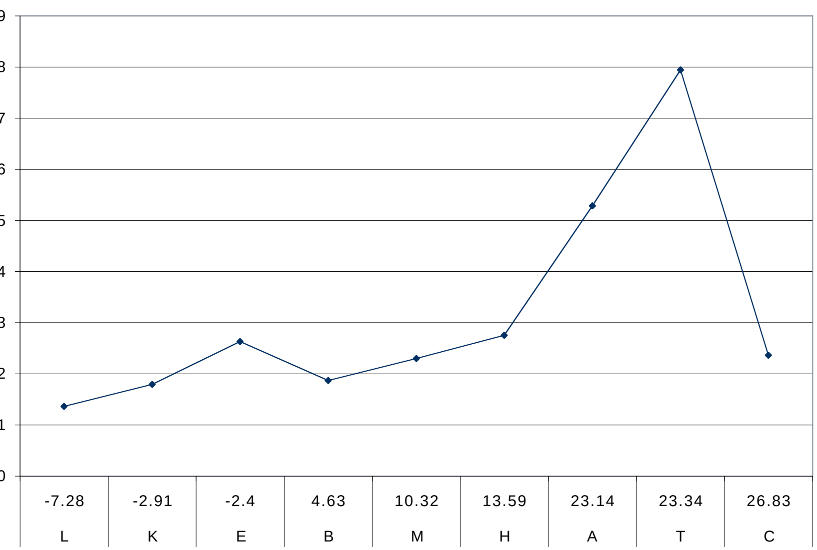

## Evaporation

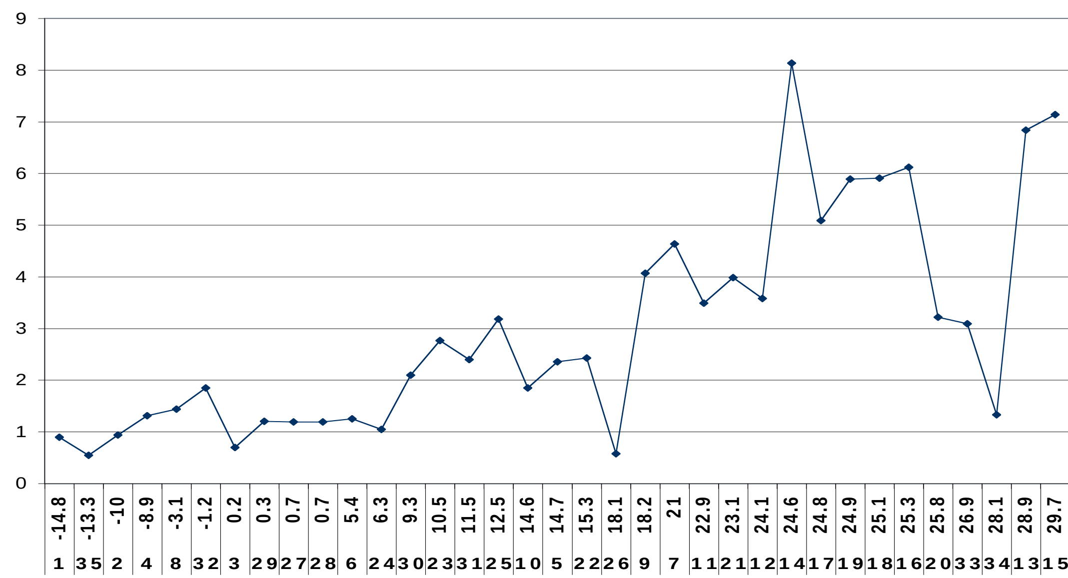


**GHP TP** Roads, J., M. Kanamitsu, R. Stewart, 2002: CSE Water and Energy Budgets in the NCEP-DOE Reanalysis II. *J. Hydrometeorology* , Vol. 3, Issue 3, p. 227-248.




**2002: WESP**

# WESP Activities

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# LDAS

**PILPS**

- The GCIP regional PILPS-2C experiment (Wood et al., 1998) and the ISLSCP Global Soil Wetness Project (Dirmeyer et al., 1999) demonstrated the viability of executing physically based, distributed, and, uncoupled land-surface models over large spatial domains and multi-year periods, provided that moderately dense observations of precipitation were available. CEOP will thus be important for future PILPS.

**GLOBAL LDAS**

- The goal is to develop a 1/4 degree resolution, near-real time Global Land Data Assimilation Scheme (GLDAS), which makes use of various new satellite- and ground-based observation systems within a land data assimilation framework, in order to produce optimal output fields of land surface states and fluxes.

**US LDAS**

- A number of NOAA, NASA and university partners are developing a US Land Data Assimilation System (N-LDAS) -- a real-time, hourly, distributed, uncoupled, land-surface simulation and assimilation system executing on a horizontal grid spanning the continental portion of the USA (CONUS) at 0.125 degree resolution (Mitchell et al (2001). Following the PILPS-2C and GSWP approach of land-surface model (LSM) intercomparisons over large spatial domains, the N-LDAS project is applying four different LSMs: NOAH (Mitchell et al., 2001), MOSAIC (Koster and Suarez, 1996) VIC (Liang et al. 1994);SAC-SWA (Sacramento Model)

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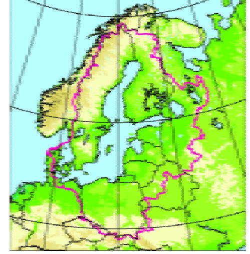
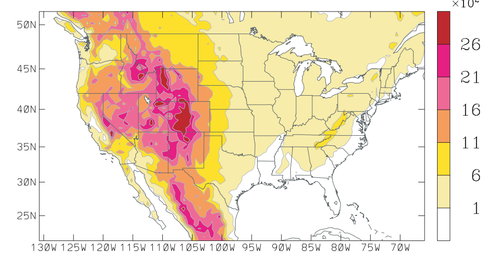
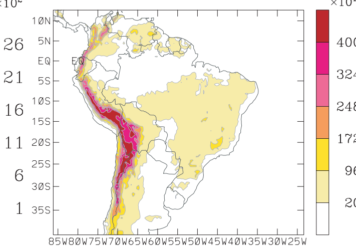
# Transferability Studies






*What is the performance of coupled hydrologic/atmospheric models in different geographical and climate regions as well as over the same region at different temporal and spatial scales. Can CEOP data help to compare the models?*

- **BALTEX**
  - BALTEX has recently invited global participation in a model intercomparison as part of the BALTEX PIDCAP experiment. Comparisons will be made at 18 km resolution.
- **PIRCS**
  - PIRCS developed one of the original regional model intercomparison and transferability experiments They are now planning on developing a followon covering the period June 1986-end of CEOP. Comparisons will be made at 50 km resolution.

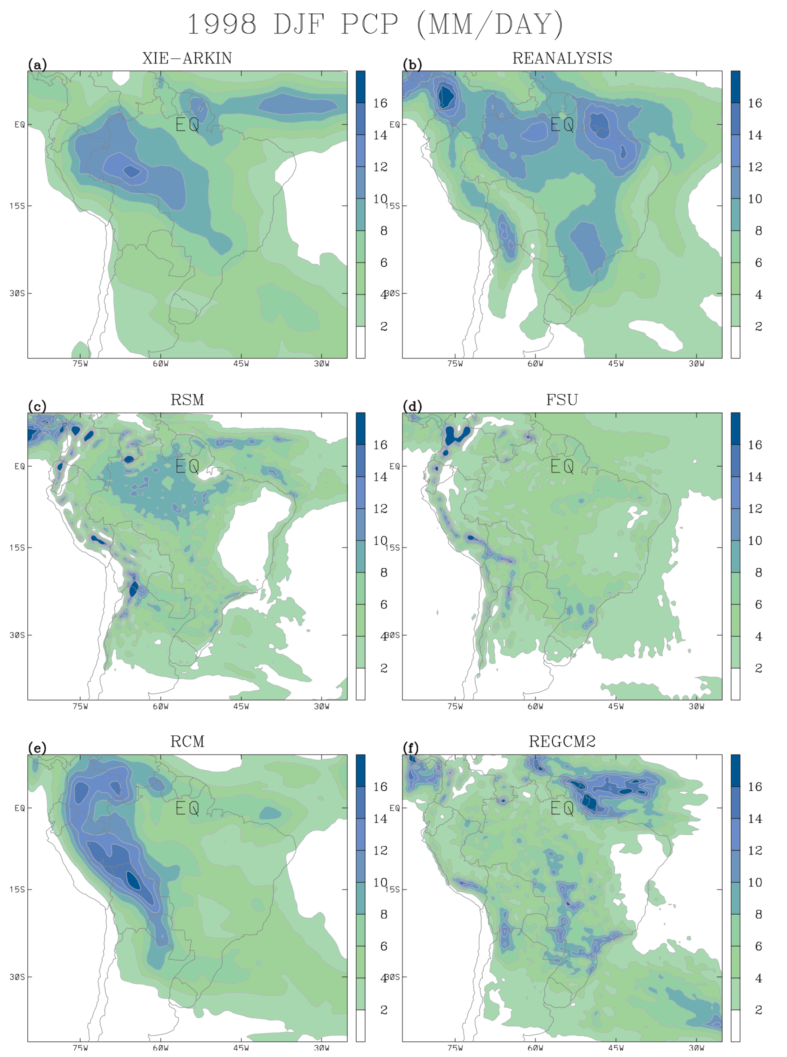
- **The La Plata River-basin Model Evaluation and Research Applications**
  - The objective is to carry out a demonstration test of the degree to which our understanding and model capability that has been developed in GCIP is sufficient to also account for the La Plata basin's climate system. This initiative would link the GEWEX interests on hydrological issues with CLIVAR/VAMOS concerns in monsoon circulations. So far only the Eta Model is participating.

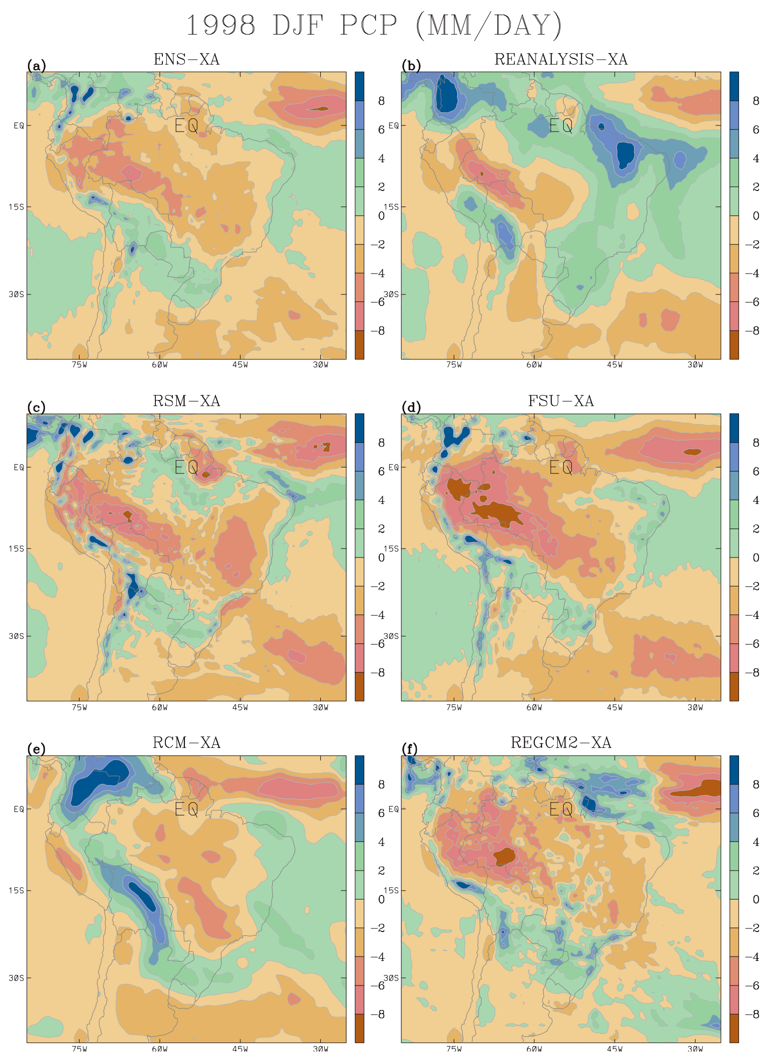
- **Others?**
  - In a sense, GLDAS is a global transferability experiment, Also, the global model analyses are another transferability experiment.

# Pre-CEOP IRI/ARCS Regional Model Intercomparisons

| Model | Reanalysis | Scripps RSM | FSUNRSM | GISS RCM | IRI RegCM2 |
|---|---|---|---|---|---|
| **Levels** | 28 | 28 | 27 | 16 | 14 |
| **Type** | spectral | spectral | spectral | grid | grid |
| **SW. Rad.** | Lacis and Hansen (1974) | Chou and Lee (1996) | CCM 3.6 (Kiehl et al. 1998) | Davies (1982) | CCM 3.3 (Kiehl et al. 1998) |
| **LW Rad.** | GFDL (Schwartzkopf et al. 1994) | GFDL (Schwartzkopf et al. 1994) | CCM 3.6 (Kiehl et al. 1998) | Harshvardhan and Corsetti (1984) | CCM 3.6 (Kiehl et al. 1998) |
| **Convective Param.** | SAS (Kalnay et al. 1996) | SAS* (Hong and Pan 1996) | Zhang-McFarlane (1995) | modified Kuo (Krishnamurti et al., 1990) | Grell (1993) |
| **PBL** | Louis et al. (1982) | Hong and Pan (1996) | Holtslag and Boville (1993) | Krishnamurti et al. (1990) | Holtslag et al. 1990 |
| **Land Surface** | NOAA (Kalnay et al. 1996) | NOAA* (see Chen and Roads 2002) | FSU (Cocke and LaRow 2000) | Fulakeza et al. (2002) | BATS (Dickinson et al. 1993) |

# Pre-CEOP IRI/ARCS Regional Model Intercomparisons

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# A number of NWP Centers are being asked for analyses and short term forecast output

- **There have previously been a number of extensive model intercomparisons that have helped to improve the models.**
  - global atmospheric model comparisons (AMIP)
  - regional model comparisons (PIRCS)
  - land surface model comparisons (PILPS)
  - ocean, coupled ocean, seasonal forecast models (etc.) comparisons
- **By contrast, there has not been any systematic comparison made for analyses.**
  - Can we trust these analyses?
  - What are their intrinsic differences?
  - What are their errors in comparison to observations?
  - Is the error small enough that we can use them in place of sparse observations for many variables?
  - What is the difference between the analyses and short term forecasts?

# WESP Data Requirements

- **Spatial Scales**
  - At local scales, in situ data from several international tower and first order stations along with level II and level III satellite data, and numerical model output for these same sites need to be consolidated into useful data sets for studying water and energy budgets.
  - Regional and global networks of more standard observations and model simulations are also needed for developing WEBS and understanding monsoon interactions.
- **Two types of basic output have been requested from major numerical weather prediction centers:**
  - MOLTS (water and energy budget processes in vertical model columns at 3-hourly or more frequent intervals.) at 15 international reference sites, which will have corresponding in situ tower and surface station measurements and satellite data.
  - 3D gridded output processed as synoptic snapshots. Gridded global data should have a resolution of 2.5 deg. or higher. Higher resolution for specific regions is desirable.
- **Sampling frequency**
  - Both molts and gridded data are requested every 3 hours or less.
    - Given that most analysis cycles are every 6 hours, this output will include pure forecasts as well as analyses.
  - In addition, we request two day forecasts every 2 days. Such data will further help to diagnose model errors, which contribute to analyses errors.

# WESP 3-D

**Atmospheric Mass**

$$\frac{\partial \pi}{\partial t} = -\nabla \bullet v\pi - \frac{\partial \pi \dot{\sigma}}{\partial \sigma}$$

**Atmospheric Water Vapor**

$$\frac{\partial \pi q}{\partial t} = -\nabla \bullet \pi v q - \frac{\partial \pi \dot{\sigma} q}{\partial \sigma} + \frac{\partial F_q}{\partial \sigma} - \pi CQ + RSQ'$$

**Cloud Water**

$$\frac{\partial \pi q_c}{\partial t} = -\nabla \bullet \pi v q_c - \frac{\partial \pi \dot{\sigma} q_c}{\partial \sigma} + \pi CQ - \pi CP$$

**Atmospheric Energy**

$$\frac{\partial \pi (C_p T + KE + \phi_s)}{\partial t} = -\nabla \bullet \pi v (C_p T + \phi + KE) - \frac{\partial \pi \dot{\sigma} (C_p T + \phi + KE)}{\partial \sigma}$$

$$+ \frac{\partial F_T}{\partial \sigma} + \pi CT + \frac{\partial F_R}{\partial \sigma} - QF + RST'$$

**Soil Moisture**

$$\frac{\partial m}{\partial t} = P - E - N + C_{sm} + RSW'$$

**Snow**

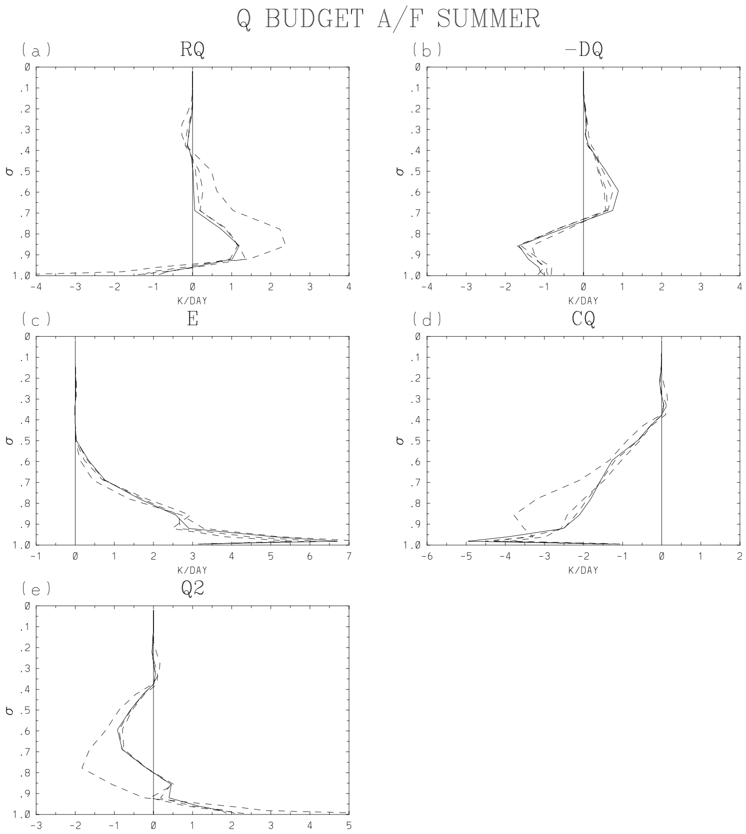
$$\frac{\partial (s)}{\partial t} = P_s - E_s - C_{sm}$$

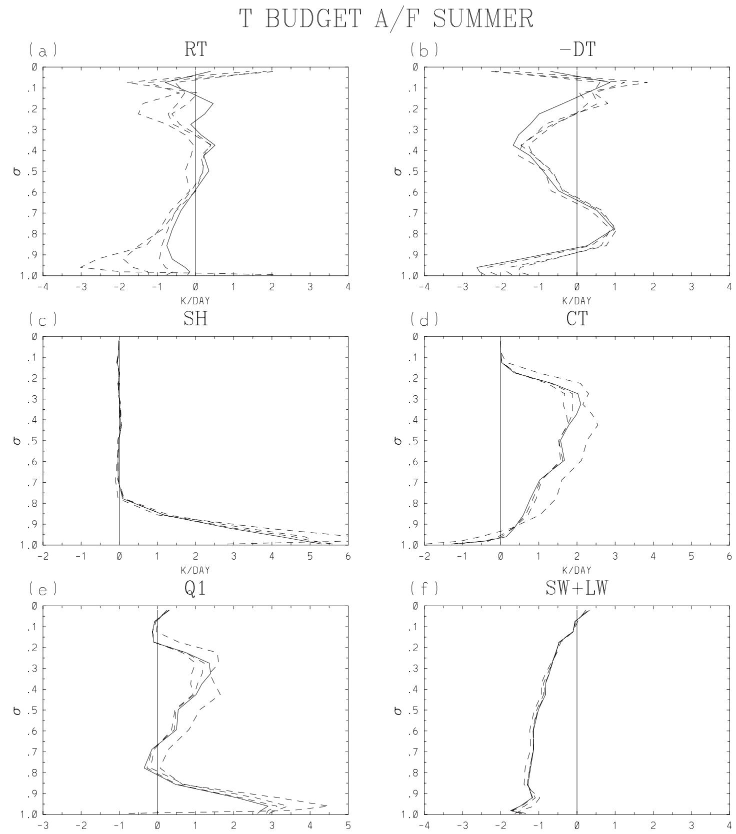
**Surface Energy**

$$Cv \frac{\partial Ts}{\partial t} = QRS - SH - LE - L_f C_{sm} + QF_s + G'$$

# Vertical Water and Energy Budgets,

Roads, J. O., S-C., Chen, M. Kanamitsu, and H. Juang, 1998: Vertical structure of humidity and temperature budget residuals over the Mississippi River basin. *J. Geophys. Res.*, 103, 3741-3759.

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# CEOP Variables

- **Top of atmosphere**
  - –radiation fluxes (3)
- **Atmosphere**
  - –Standard variables (sufficient to initialize regional and global scale models.
  - –Large-scale and turbulent water and energy fluxes and divergences, diabatic heating
  - –clouds
- **Surface**
  - –radiation fluxes (4), turbulent fluxes, albedo, land cover, snowfall, snow lwe, total pcp.
- **Subsurface**
  - –Temperature, moisture, subsurface processes
- Miscellaneous
  - –Cloud cover, vegetation,

# NCEP surface variables

- sea level and surface pressure
- skin and lowest model lvl temperature
- total soil moisture
- snow water equivalent
- 1-hr accumulated total precip
- 1-hr accum.  convective precip
- 1-hr average flux of latent heat
- 1-hr avg potential flux of latent heat
- 1-hr average flux of sensible heat
- 1-hr average flux of sub-surface heat
- 1-hr avg flux of snow phase change heat
- 1-hr average shortwave downward flux
- 1-hr average shortwave upward flux
- 1-hr average longwave downward flux
- 1-hr average longwave upward flux
- 1-hr average net longwave flux at top
- 1-hr average net shortwave flux at top
- 1-hr accumulated snow fall
- 1-hr accum. snow melt
- 1-hr accum. surface runoff
- 1-hr accum. baseflow-groundwater runoff

- bottom soil temperature
- roughness length
- u and v component at 10 m
- potential temperature at 10 m
- specific humidity at 10m
- 2-meter temperature
- 2-meter specific humidity
- surface exchange coefficient
- green vegetation cover
- canopy water
- layer volumetric soil moisture
- layer  soil temperature
- station land/sea mask
- total cloud cover
- snow ratio from explicit cloud scheme
- snow precip type
- ice pellet precip type
- freezing rain precip type
- rain precip type
- u-component of storm motion
- v_component of storm motion

# 3-D variables

**NCEP Standard output**

- pressure
- Virtual temperature
- u wind
- v wind
- omega velocity
- Specific humidity
- cloud water mixing ratio
- cloud layer fractional cover
- convective latent heating rate
- stable latent heating rate
- short-wave heating rate
  long-wave heating rate
  turbulent kin. energy

**Additional requested variables**

- geopotential (gZ)
- Kinetic energy (KE)
- 3-d water vapor flux
- water vapor flux divergence
- 3-d dry energy (CpT+gZ+KE) flux
- dry static energy flux divergence
- planetary boundary layer height
- Moisture analysis increment
- Energy analysis increment
- Surface analysis increment

# Data Archive Centers

- **UCAR**
  - in situ and MOLTS
- **Univ. Tokyo**
  - Remote sensing products, level II, and MOLTS
- **GLDAS (Goddard)**
  - Land surface products and model output and MOLTS
- **MPI**
  - Global model output and MOLTS
- **Others**
  - Each individual center responsible for archiving own data before transmitting to archive center
  - Regional analyses archived locally within CSEs

# What do we still need to do?

- **ASAP we need to:**
  - Fully define the diagnostic CEOP equations
  - Fully define the needed model output molts and gridded data.
  - Define what in situ and remotely sensed variables can be compared.
  - Set up functioning data centers to begin archiving and compositing CEOP data and distributing this data to research community.
  - Develop a time line of activities, with achievable milestones
- **During CEOP we need to:**
  - Develop studies utilizing in situ, remotely sensed, and CEOP model output
  - Clarify and organize specific research efforts
    - WEBS
    - Transferability studies
    - Analyses comparisons
    - Prediction studies
  - Better articulate CEOP WESP's scientific challenges

# Why is CEOP important?

- A natural extension to current CSE efforts, which are working with past data to develop a global WEBS.
- Incorporates global models and analyses, which have been underemphasized by the CSE regional experiments, which have focused on regional models
- Brings together all the other GEWEX projects, which have not been adequately coordinated with the CSEs.
- Brings together GEWEX and CLIVAR projects (monsoon studies)
- Begins pilot global hydroclimatological data sets, which could be continued, depending upon CEOP success.
- Provides new global research opportunities for other ongoing regional and global research efforts.
- Will develop an improved understanding of global water and energy components, which should lead to improved climate prediction.