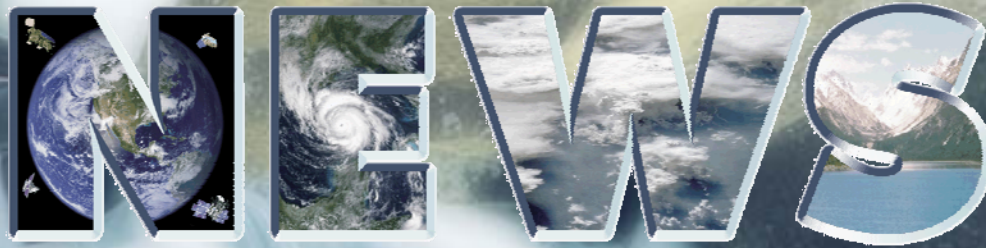# NASA ENERGY AND WATER CYCLE STUDY
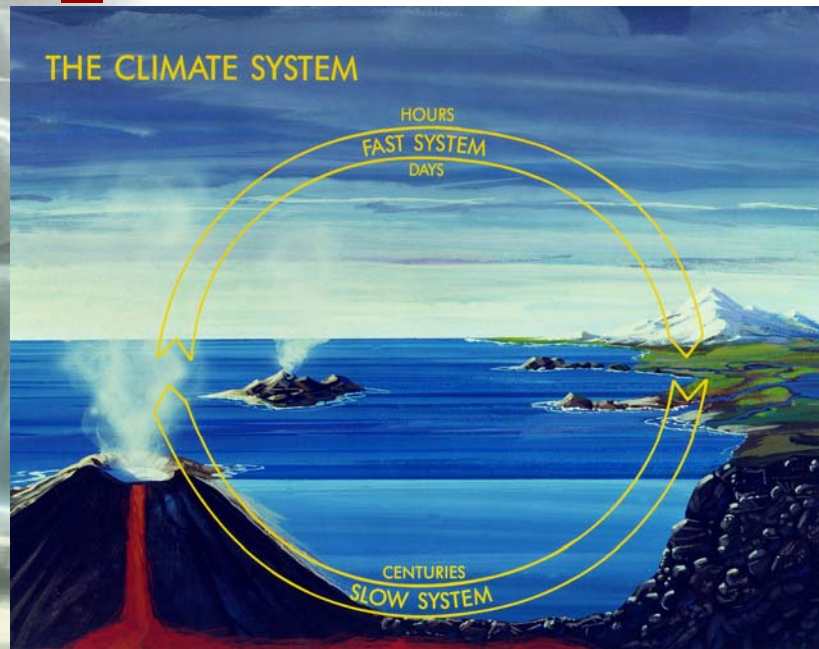
NEWS

NEWS Challenge:
Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.

The Water and Energy Cycle

Water in the climate system functions on all time scales: From hours to centuries

THE CLIMATE SYSTEM

HOURS
FAST SYSTEM
DAYS

CENTURIES
SLOW SYSTEM

The Energy and Water Cycles are _tightly intertwined_ – Solar radiation drives and feedbacks with the water cycle, and energy is transferred through water movement and phase change.

•*Water exists in all three phases in the climate system and the phase transitions are a significant factor in the regulation of the global and regional energy balances*

•*Water vapor in the atmosphere is the principal greenhouse gas and clouds at various levels and composition in the atmosphere represent both positive and negative feedback in climate system response*

•*Water is the ultimate solvent and global biogeochemical and element cycles are mediated by the dynamics of the water cycle*

•*Water is the element of the Earth system that most directly impacts and constraint human society and its well-being.*

Why study the water and energy cycle?...

Variations in greenhouse gases, aerosols, and solar activity force changes in climate…

…but, <u>consequences</u> of climate change are realized through the water cycle.

Thus, we must **<u>characterize</u>**, **<u>understand</u>**, and **<u>predict</u>** variations in the global water cycle.

Water and Energy -- linked to many <all> end-use applications.

Agricultural Efficiency

Coastal Management

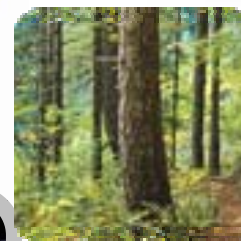**Homeland Security**

Air Quality

Disaster Management

Invasive Species

Aviation

Ecological Forecasting
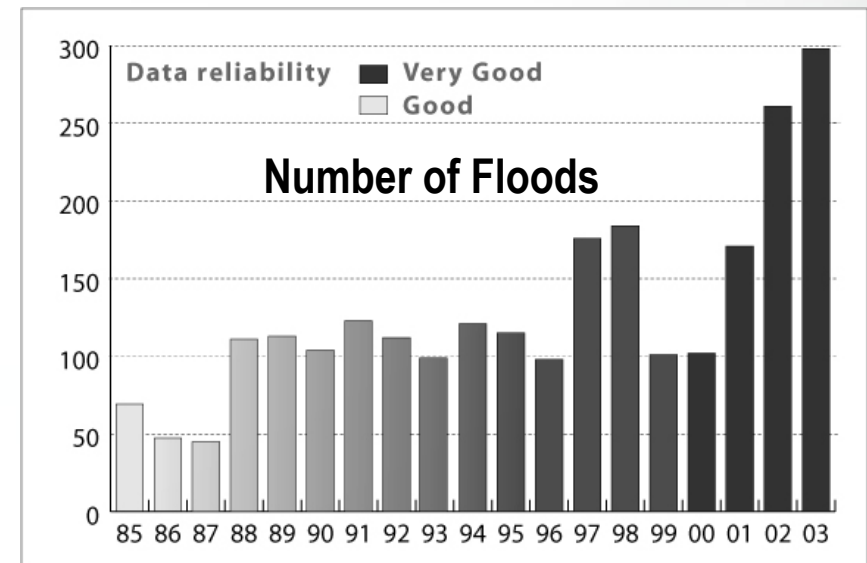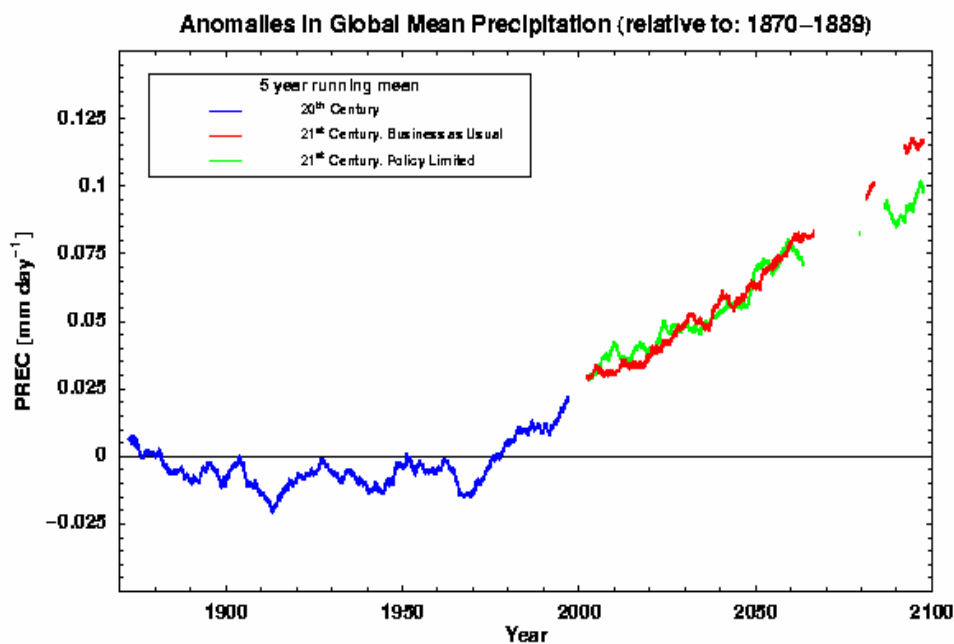
Public Health
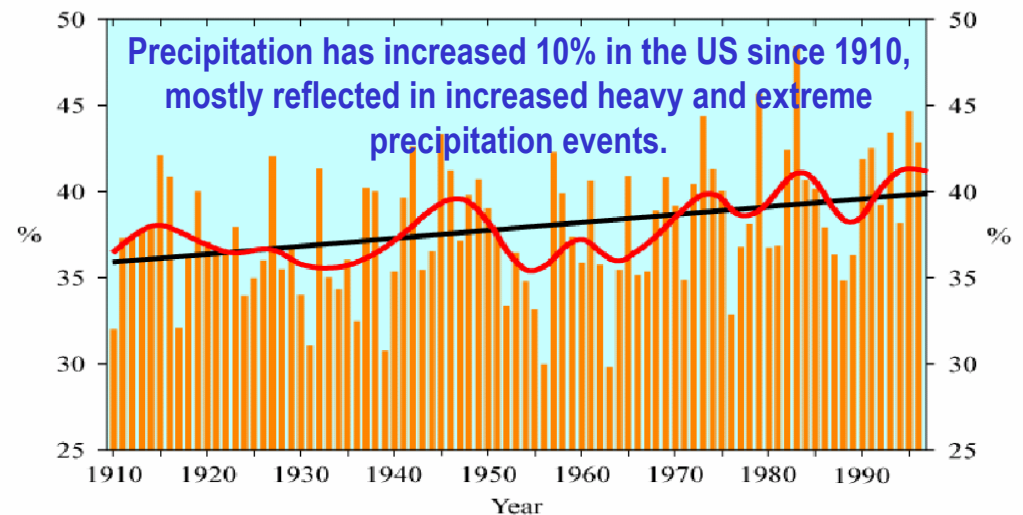
Carbon Management

Energy Management

Water Management

A generally accepted hypothesis regarding global water cycle changes:

"According to model predictions, the *most significant manifestation of climate change would be an acceleration of the global water cycle, leading to … a general exacerbation of extreme hydrologic regimes, floods and droughts*" (NASA-GWEC, 2000).
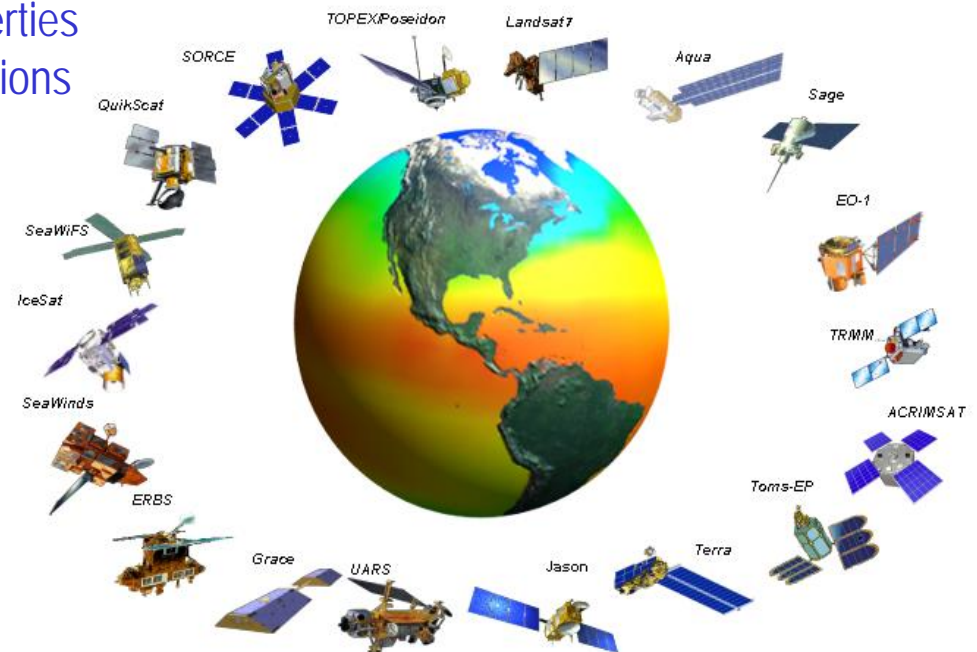

Precipitation has increased 10% in the US since 1910, mostly reflected in increased heavy and extreme precipitation events.

Anomalies in Global Mean Precipitation (relative to: 1870–1889)
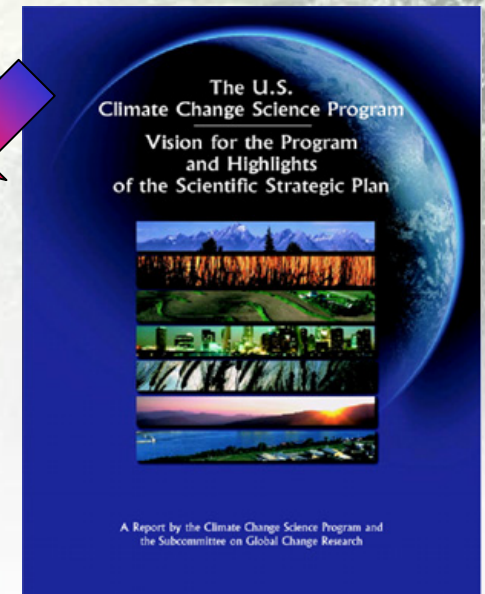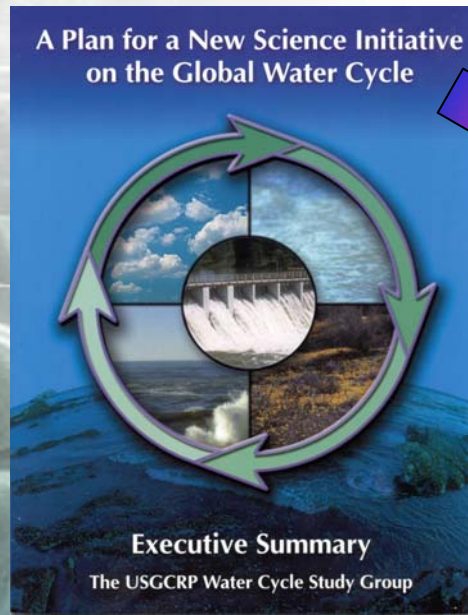

Number of Floods

From Dartmouth

What we know

- global atmospheric and surface temperature distributions
- top-of-the-atmosphere radiation fluxes
- point processes

What we need to know

- global precipitation and water vapor distributions
- cloud radiation absorption and scattering properties
- global soil moisture, snow cover/depth distributions
- surface runoff
- evaporation
- land surface/atmosphere feedbacks
- uncertainties in integrated E&WC processes

A Plan for a New Science Initiative on the Global Water Cycle

Executive Summary
The USGCRP Water Cycle Study Group

NASA ENERGY AND WATER CYCLE STUDY
NEWS

The U.S. Climate Change Science Program
Vision for the Program and Highlights of the Scientific Strategic Plan

A Report by the Climate Change Science Program and the Subcommittee on Global Change Research

What are the causes of water cycle variations?

Are variations in the global and regional water cycle predictable?

How are water and nutrient cycles linked?

NASA Earth Science Program Water & Energy Cycle Science Questions (7 of 24 questions):

How are global precipitation, evaporation and the cycling of water changing?

What are the effects of clouds and surface hydrologic processes on Earth's climate?

How are variations in local weather, precipitation and water resources related to climate variation?

What are the consequences of climate change and increased human activities for coastal regions?

How can weather forecast duration and reliability be improved?

How can predictions of climate variability and change be improved?

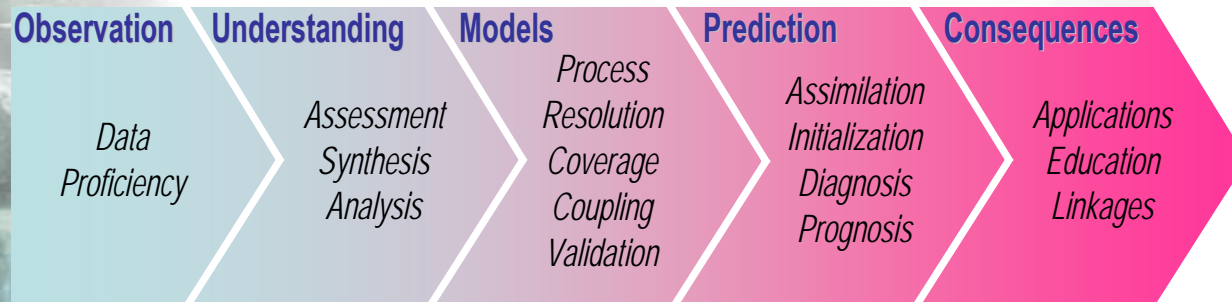How will water cycle dynamics change in the future?

NASA Water and Energy cycle Study (NEWS) Challenge:

Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.

NEWS Integrated Water and Energy Cycle Research

From Observations to Consequences

The NEWS challenge is **global** in scale and requires the integration of NASA **system components** to **make decisive progress toward the NEWS challenge** in an **end-to-end program**
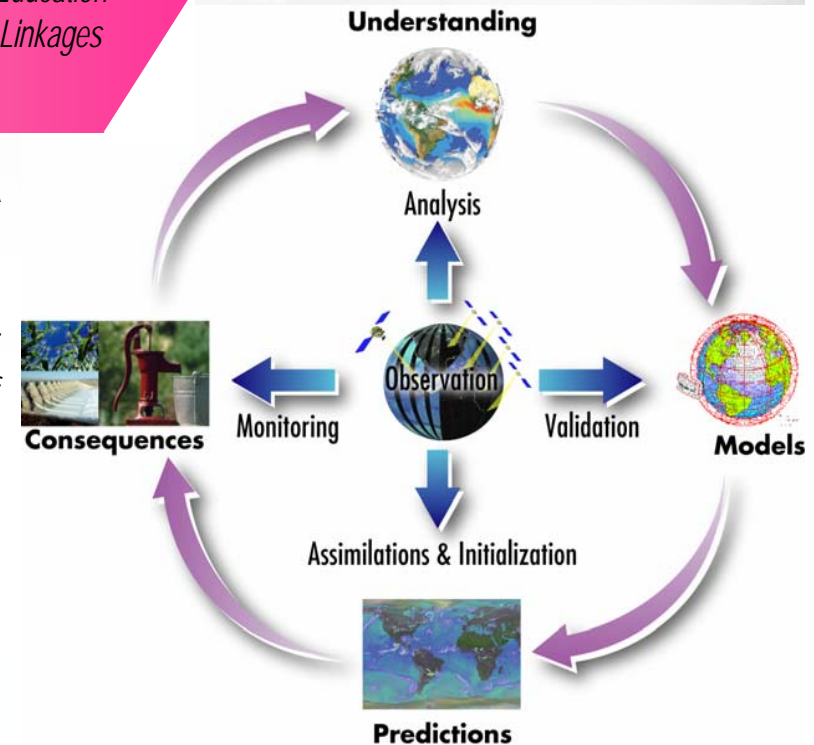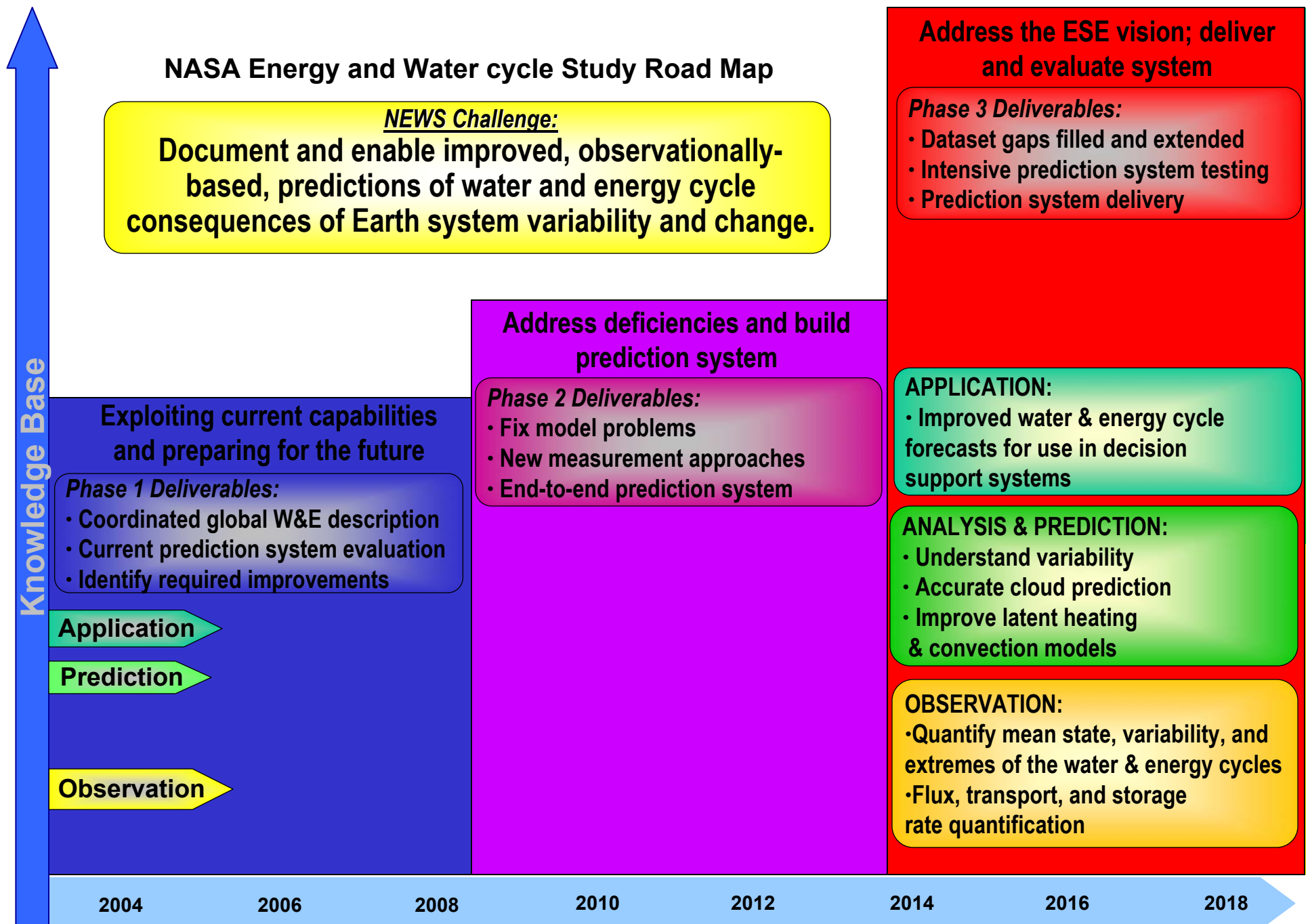
Observation	Understanding	Models	Prediction	Consequences
Data Proficiency	Assessment Synthesis Analysis	Process Resolution Coverage Coupling Validation	Assimilation Initialization Diagnosis Prognosis	Applications Education Linkages

Product-driven NEWS investigations directly cooperate with NASA to produce a coordinated cross-discipline comprehensive solution.

Discovery-driven NEWS investigations carried out by individuals or small groups of scientists to make advances in our understanding of key Earth-science processes.

NEWS is a interdisciplinary program: Discipline-based research will be performed by existing NASA disciplinary programs.

NEWS Science Integration Team: Support NEWS investigations and integrate their research results to address NASA-ESE science questions. The NEWS integration group will work with NEWS investigations to implement their results into a larger coordinated product, such as a NASA model, data system, etc.
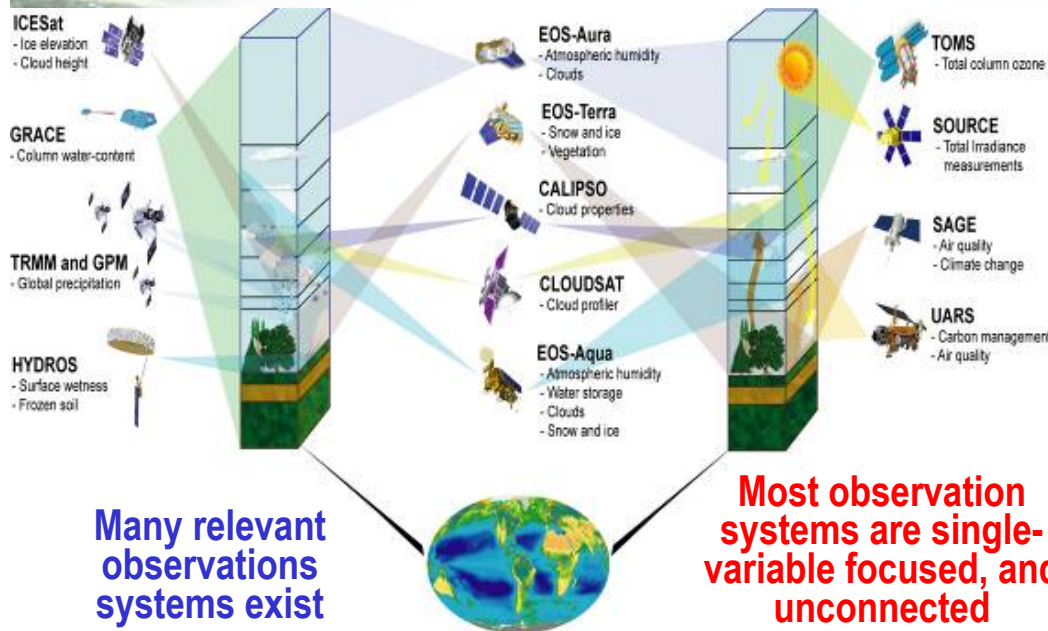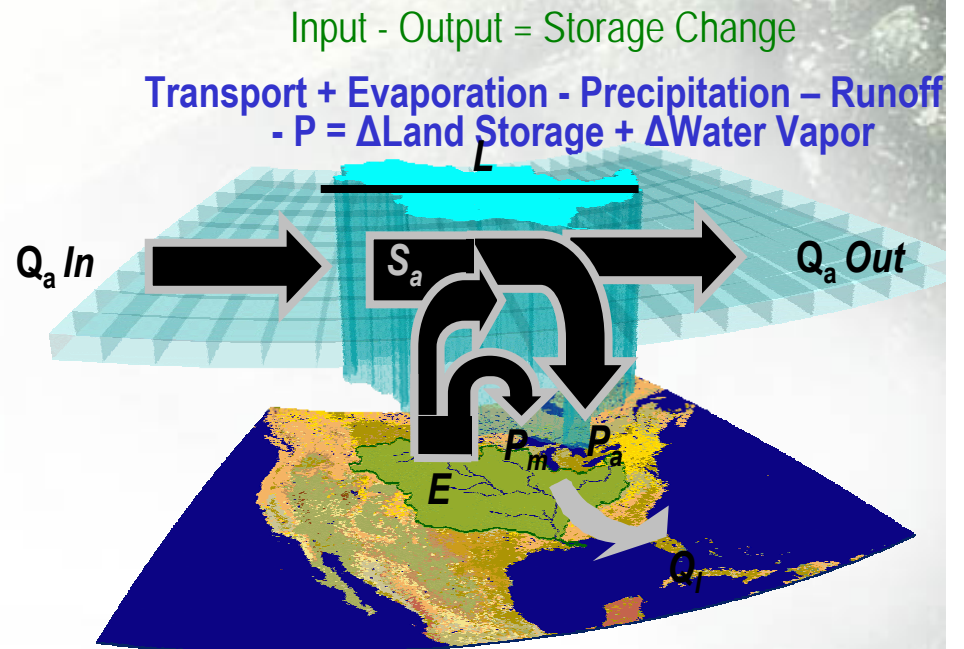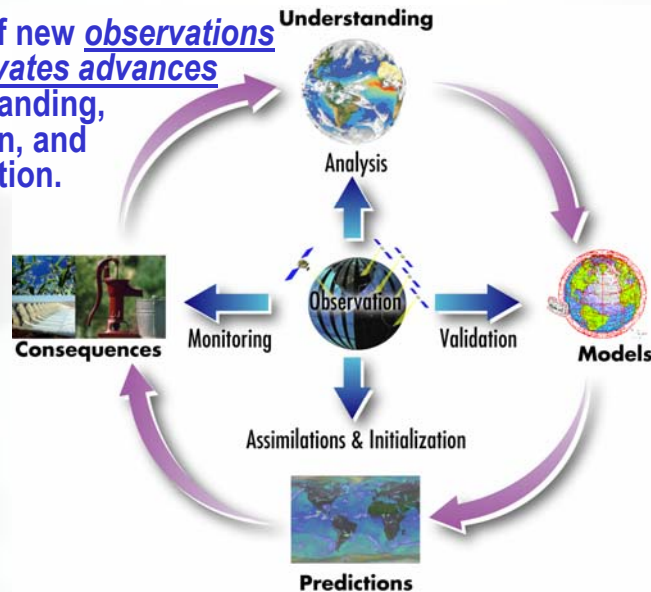

Understanding — Analysis — Observation — Monitoring — Consequences — Validation — Models — Assimilations & Initialization — Predictions

Paul R. Houser, Page 7

NASA Energy and Water cycle Study Road Map

NEWS Challenge:
Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.

Address the ESE vision; deliver and evaluate system

Phase 3 Deliverables:
- Dataset gaps filled and extended
- Intensive prediction system testing
- Prediction system delivery

Address deficiencies and build prediction system

Phase 2 Deliverables:
- Fix model problems
- New measurement approaches
- End-to-end prediction system

Exploiting current capabilities and preparing for the future

Phase 1 Deliverables:
- Coordinated global W&E description
- Current prediction system evaluation
- Identify required improvements

APPLICATION:
- Improved water & energy cycle forecasts for use in decision support systems

ANALYSIS & PREDICTION:
- Understand variability
- Accurate cloud prediction
- Improve latent heating & convection models

OBSERVATION:
- Quantify mean state, variability, and extremes of the water & energy cycles
- Flux, transport, and storage rate quantification

Application

Prediction

Observation

Knowledge Base

2004   2006   2008   2010   2012   2014   2016   2018

NEWS Components

NEWS Constraints
- Focus on water and energy processes and dynamics in the climate system.
- The NEWS challenge is a **global scale** objective
- Integrate water and energy cycle system components (observations and predictions)
- NEWS elements: **Observation, Understanding, Models, Prediction and Consequences**
- Make **decisive progress** toward NEWS challenge
- NASA administers the water and energy cycle focus area as an **end-to-end program**
- DSS development is not supported by NEWS

NEWS Objectives:
- Develop and deploy experimental **E&WC global observing system**
- **Document the global E&WC** by obtaining complete observational record of all associated relevant geophysical properties
- Build **fully interactive global climate model** that encompasses process-level E&WC forcings and feedbacks – *Climate models that can predict weather-scale extremes*
- Create global surface and atmosphere **data assimilation system for E&WC variables**
- **Assess variability of the global E&WC** on time scales ranging from seasonal to decadal, and space scales ranging from regional to continental to global
- Support the **application of climate prediction capabilities** for estimating the impact of climate variability and change on water resources

NEWS Observation Strategy

The availability of new _observations strongly motivates advances_ in understanding, prediction, and application.

Understanding

Analysis

Observation

Consequences — Monitoring — Validation — Models

Assimilations & Initialization

Predictions

Input - Output = Storage Change

Transport + Evaporation - Precipitation – Runoff - P = ΔLand Storage + ΔWater Vapor

L

Q_a *In* S_a Q_a *Out*

E P_m P_a

Q_r

ICESat
- Ice elevation
- Cloud height

GRACE
- Column water-content

TRMM and GPM
- Global precipitation

HYDROS
- Surface wetness
- Frozen soil

EOS-Aura
- Atmospheric humidity
- Clouds

EOS-Terra
- Snow and ice
- Vegetation

CALIPSO
- Cloud properties

CLOUDSAT
- Cloud profiler

EOS-Aqua
- Atmospheric humidity
- Water storage
- Clouds
- Snow and ice

TOMS
- Total column ozone

SOURCE
- Total Irradiance measurements

SAGE
- Air quality
- Climate change

UARS
- Carbon management
- Air quality

Many relevant observations systems exist

Most observation systems are single-variable focused, and unconnected

We must define and develop an _integrated_ user-focused water observation system that can not only detect climate trends but also local variation of extremes

We must _preserve_ critical _in-situ_ benchmark observations that enable us to detect trends & extremes.

NASA ENERGY AND WATER CYCLE STUDY
NEWS

State of the Water & Energy Cycle

Evaluate the research community's current ability to detect, analyze, understand and explain global water cycle change, variability, prediction and predictability.

Water and Energy Cycle Data Integration

Atmosphere

Storages:
Water Vapor
Cloud Liquid/Frozen Water Content

States:
Cloud Cover
Cloud Physical/Radiative Properties

Intra-system Fluxes:
Water Vapor Transport (Vertical and Horizontal)
Convective Heating
Radiative Heating

Precipitation
Evaporation
Turbulent Heat Fluxes

Inter-System Fluxes

Precipitation
Evaporation
Turbulent Heat Fluxes

Land

Storage:
Lakes/Reservoirs
Soil/Ground Water
Snow/Glaciers/Ice
Vegetation/Interception

States:
Albedo
Land Cover
Vegetation Properties
Soil Properties

Intra-system Fluxes:
Streamflow
Groundwater Flow
Ground Heat Flux

River Discharge
Saline Intrusion

Ocean

States:
Salinity
Heat Content
Sea-ice (extent/storage)
Albedo/Sea-color

Intra-System Fluxes:
Thernohaline Flow
Ocean Currents

Figure 1: Major global water and energy cycle storages and fluxes to be included in the integration center.
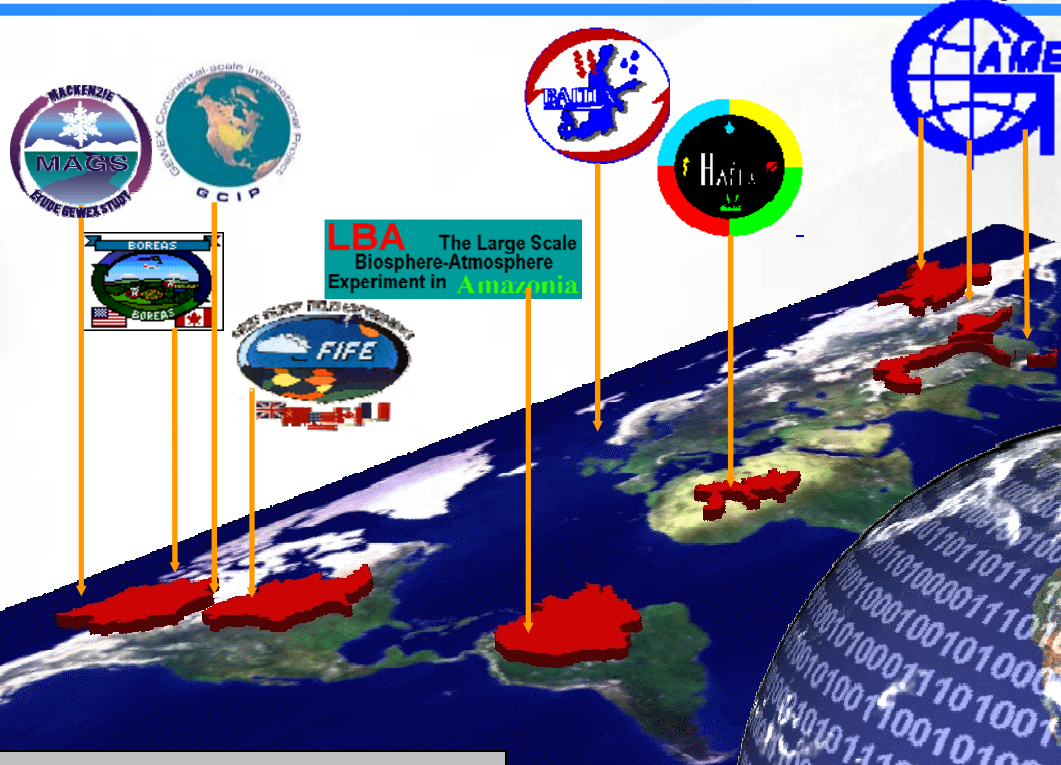
Paul R. Houser, Page 11

NASA ENERGY AND WATER CYCLE STUDY
NEWS

NEWS Prediction Strategy

▪**Useful prediction is critical – it is the link to stakeholders.**

▪**We must move towards a new paradigm of climate models that produce useful weather-scale, process-scale, and application-scale prediction of local extremes (not just mean states).**

▪**We must more fully constrain climate models with observations.**

Paul R. Houser, Page 12

Water & Energy Cycle Prediction Strategy
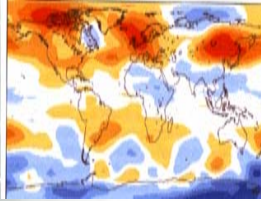
Global Warming Scenarios
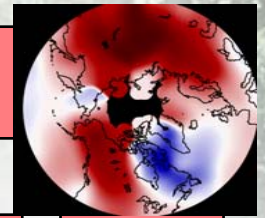
Operational Climate Models (MAP,GMAO,WRF,etc.)

Integrated Water-Cycle Observation System:
Ground- and Space-Based Observing Programs
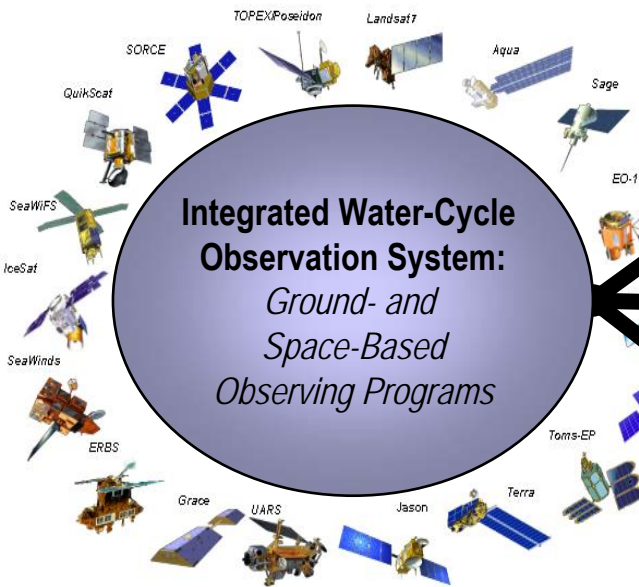
Advance Understanding and Model Physics

Improve Initialization & Assimilation

Diagnose and Identify Predictable Changes

Next-generation Global Water& Energy Cycle Prediction System

Water & Energy Cycle Prediction
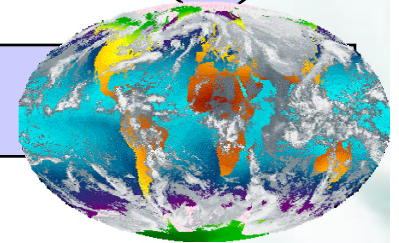
Climate models' grid-box representation of Earth's processes...
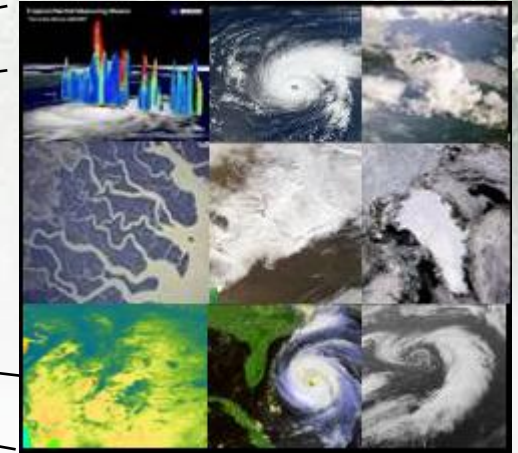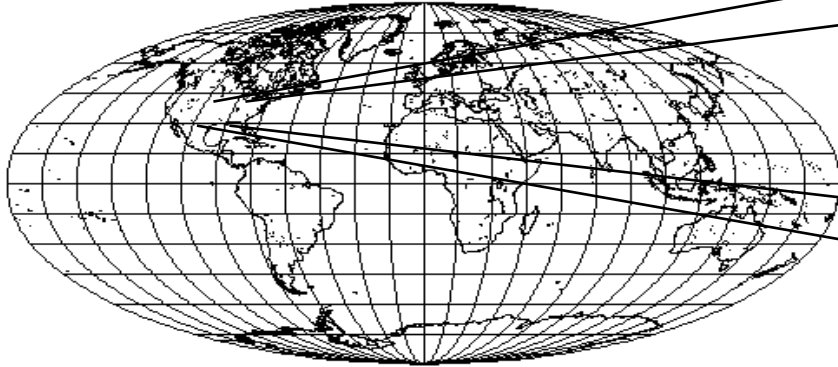
Each grid-box can only represent the "average" conditions of its area.

However, controlling processes of the water cycle (e.g. precipitation) vary over much smaller areas.

Developing Advanced Process-Resolving Models

- Useful prediction is critical – it is the link to stakeholders.

- We must move towards a new paradigm of climate models that produce useful weather-scale, process-scale, and application-scale prediction of local extremes (not just mean states).

- We must more fully constrain climate models with observations, to improve their realism and believability.
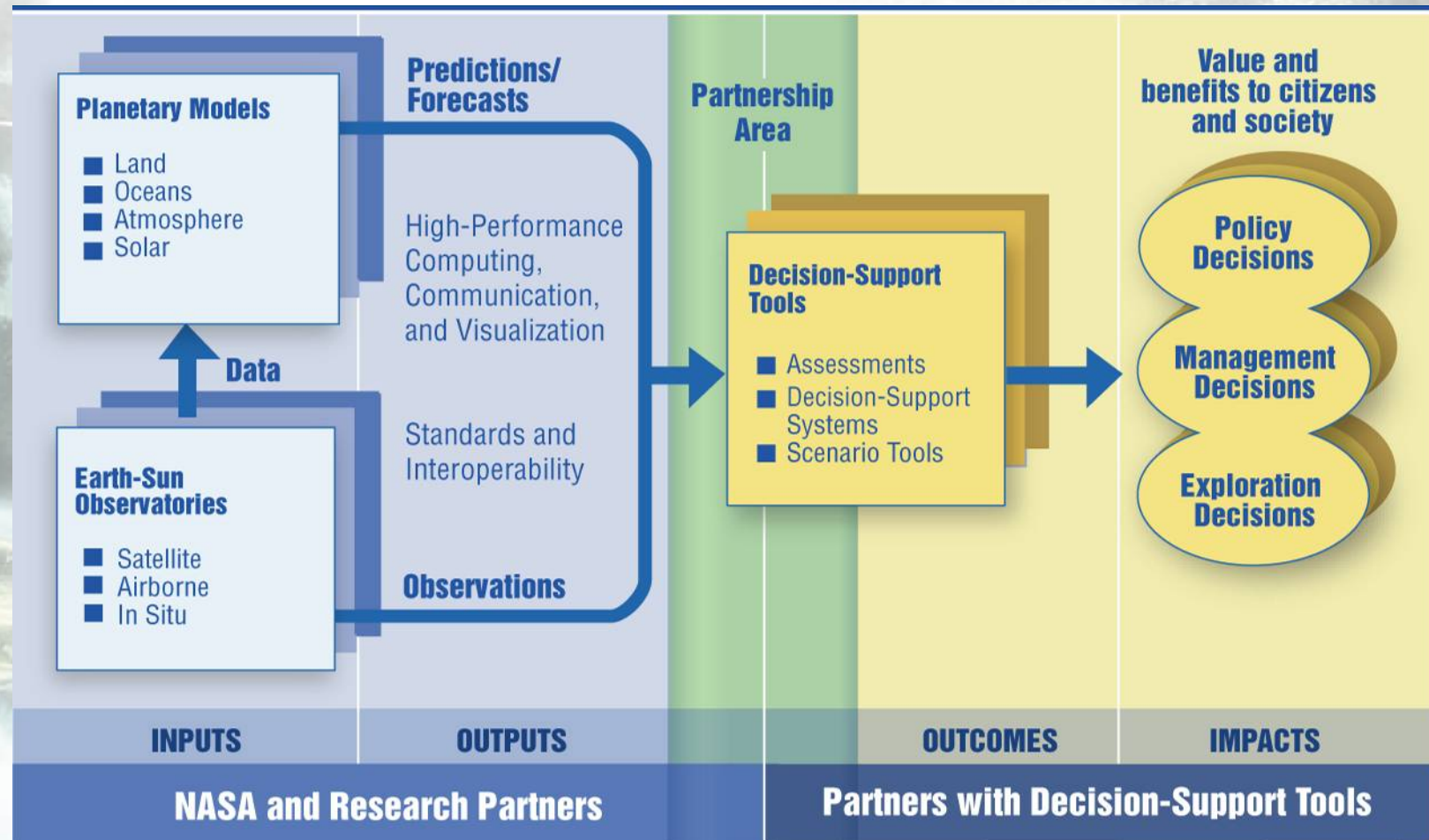
To deliver social, economic and environmental benefit to stakeholders through sustainable and appropriate use of water by directing towards improved integrated water system management

WaterNet: **Concept**

Improve and optimize the sustained ability of water cycle researchers, stakeholders, organizations and networks to interact, identify, harness, and extend NASA research results to augment decision support tools.

1. *Evolve a network of partners:* identify and analyze partner organizations to define collaboration pathways.
2. *Routinely identify, prioritize, mine and communicate relevant research products and results.*
3. *Optimize water cycle partner access* to research results and products to create a self-sustaining network.
4. *Analyze and document* the network effectiveness through metrics, resource estimates and documentation.
5. *Education and outreach* is important to help society understand and use the research in every-day application.

NASA Water Cycle Research

Earth-Sun Applied Science Program

WaterNet
The NASA Water Cycle Solutions Network

Water Cycle User Community

Science Community Guidance

National Science Programs

communication

Actionable *WaterNet* database

Pathway Discovery (MIT)

Requirements and Feedback

Earth-Sun System Gateway

Data and Model Products

Benchmarking

Evaluation

Verification and Validation

Network Optimization (OSSEs)

Satellite Data Providers

Planning & Formulation

Modeling Labs

Commercial Data Providers

DAACS

(EarthSat, Digital Globe…)

Science Discovery & Results

Educational Organizations

USGS science for a changing world

USDA

NPA/DSTs

Aviation: AWRP

Air Quality: CMAQ

Water Management: BASINS,Riverware

Coastal Management: CREWS

Serving the Nation

Policy Decision Makers

NEWS Linkages

Interdisciplinary Research

Atmosphere Science

Ocean Science

Terrestrial Bio/Geo/Chemo Hydrology
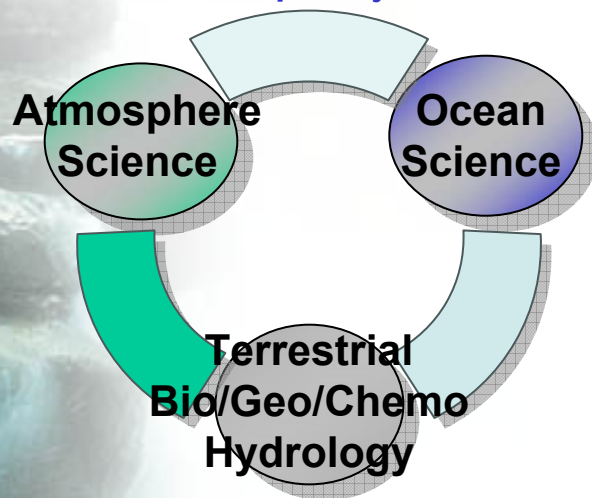
NEWS can't solve these problems alone – must partner:

- World Climate Research Program (WCRP)
  - Global Energy and Water Experiment (GEWEX)
  - Climate Variability (CLIVAR)
  - Climate and Cryosphere (CLIC)
- IGOS-Partners Water Cycle Theme
- Global Observing system (GCOS)
- Global Earth Observation (GEO and IWGEO)
- International Geosphere-Biosphere Programme (IGBP)
- Hydrology for Environment, Life, and Policy (HELP)
- Global Water System Project (GWSP)

Researchers must work in close __partnership__ with end-users, and define their research priorities based on user needs.

·*Observations:*
→Define an _integrated_ water & energy observation system that can detect global mean trends _and_ local variation of extremes
→_Preserve_ critical *in-situ* observations that enable trends & extreme detection.

·*Research:*

→*Develop climate models that produce useful weather-scale, process-scale, and application-scale prediction of local extremes.*

→*More fully constrain climate models with observations, to improve their realism.*

Improved __prediction__ of consequences is a key to meet user needs.

NEWS Science and Integration Team (NSIT)

NEWS Science Integration Team: Support NEWS investigations and integrate their research results to address NASA-ESE science questions. The NEWS integration group will work with NEWS investigations to implement their results into a larger coordinated product, such as a NASA model, data system, etc.

-Established by the Associate Administrator for Earth Science
-Will address all elements of WEC research and technology requirements and mission development.
-Provides a liaison with the other NASA Earth Science research focus areas.
-Serves as an interface to NASA system components.
-Focuses, coordinates and integrates the results of the NEWS investigations.

Current Members:
Bing Lin, Bill Rossow, Adam Schlosser, Bob Schiffer, Bill Lapenta, Eni Njoku, Paul Houser

NSIT Activities:
(1) **NEWS science integration:** Data product integration, PI coordination, Linkages to NASA system components, Interdiciplinary science
(2) **NEWS science gap filling:** Doing science that must be done, but was not proposed and/or funded
(3) **NEWS administration:** Organize meetings, NEWS planning & vision, POC responsibilities, Implementation plan updates, Representing NEWS to national and international partners

Year 1 Results

Variations in Global Precipitation (1979-2005)

Global annual mean rainfall anomalies

+0.0078 (mm day⁻¹/10yr) (Ocean & Land)
+0.0215 (mm day⁻¹/10yr) (Ocean)
−0.0218 (mm day⁻¹/10yr) (Land)
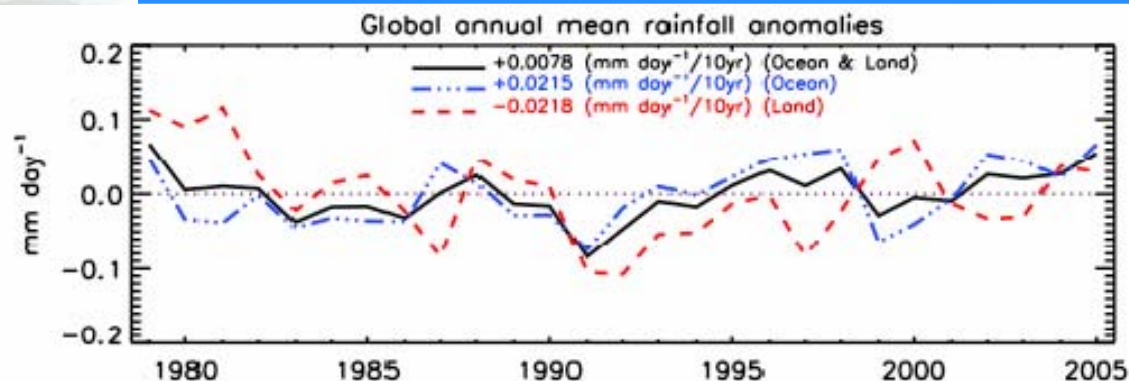
Little or no linear change during period--ocean and land precipitation tend to compensate

Gu et al. (2006)

Pattern of Linear change (1979-2005)
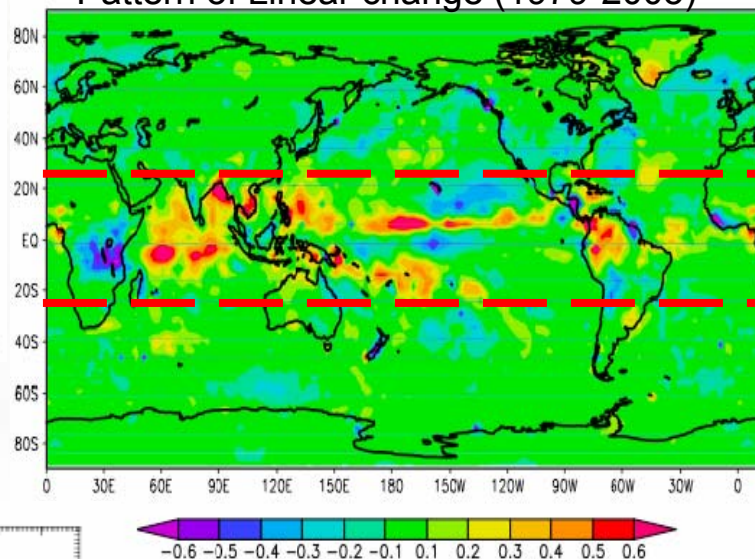
Relationship between extreme precipitation (both dry and wet) frequency (curve) over the globe and tropics and ENSO (measured by absolute value of Nino 3.4; red = El Niño, blue = La Niña).

This is also the case for the frequency of <u>daily extremes</u> (dots) calculated from TRMM multi-satellite analysis.

Daily extremes are limited to the wet end of the distribution

Curtis et al., 2006b

a) Globe

r = 0.48

b) Tropics

r = 0.61 (r = 0.64)
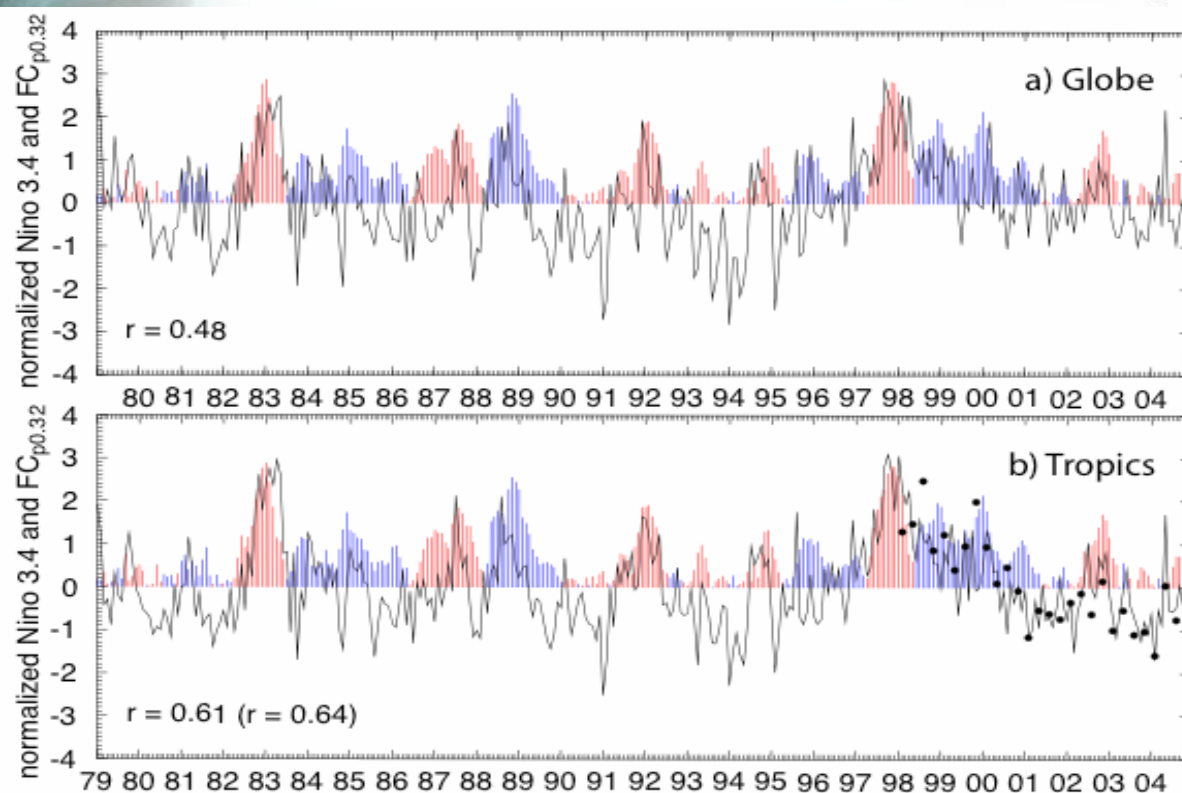
Analysis of historical precipitation and streamflow data shows a decreasing trend in the orographic enhancement factor in mountains downwind of polluted cities

The ratio between Wishka to Aberdeen
Ending / Starting ratio = 1.66 / 1.50 = 1.10

$y = -1.6804 + 0.001x$ $R= 0.27$

Winter: The ratio between cluster of gauges in Seattle to Palmer
Ending / Starting ratio = 2.05 / 2.32 = 0.88

$y = 11.26 - 0.005x$ $R= 0.30$ $P = 0.0$
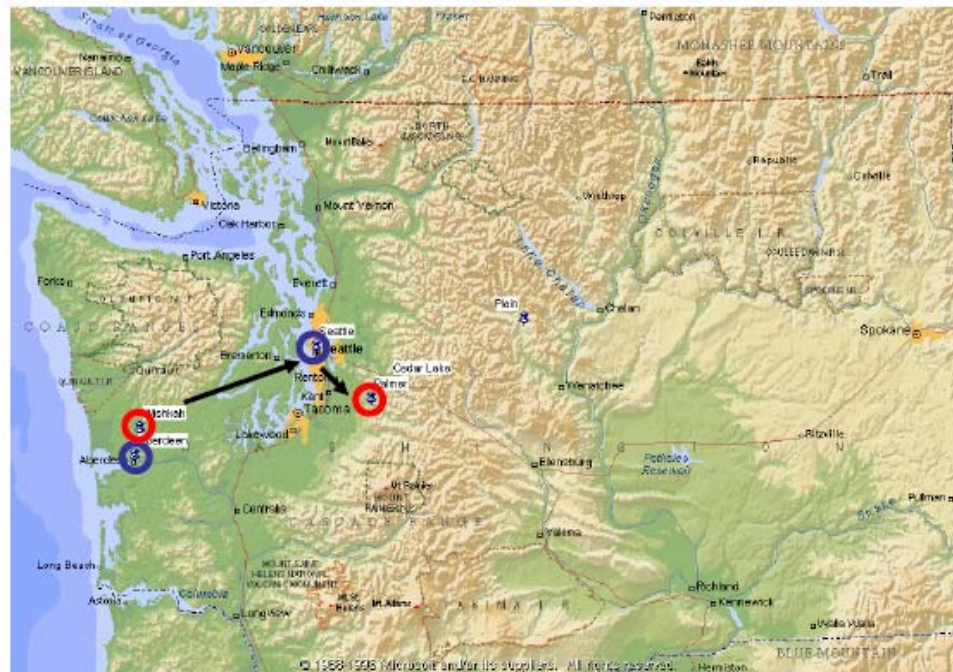
Above: The locations of hilly and plain rain gauges in the relatively pristine area of the Olympic peninsula, Washington state: Wishka (hilly) vs. Aberdeen (plain) gauge, and the relatively polluted Seattle area: Palmer (hilly) vs. cluster of gauges in Seattle (plain)

Right: The ratio of annual precipitation in the relatively pristine Olympic peninsula: (top) Wishka vs. Aberdeen, and the ratio in relatively polluted area: (bottom) Palmer vs. Seattle.

Paul R. Houser, Page 21
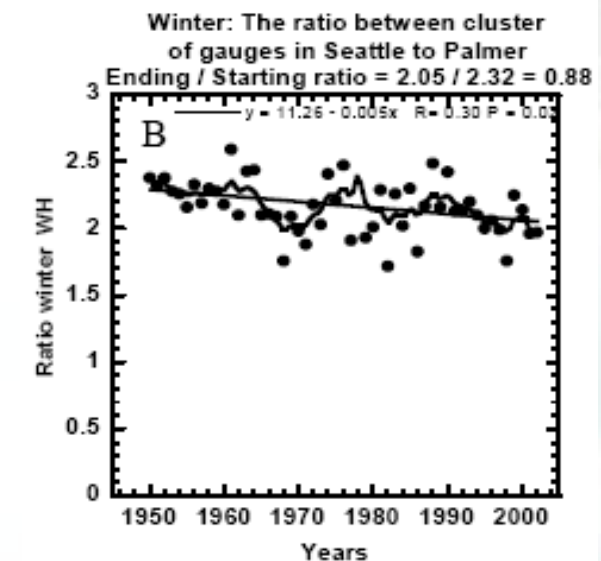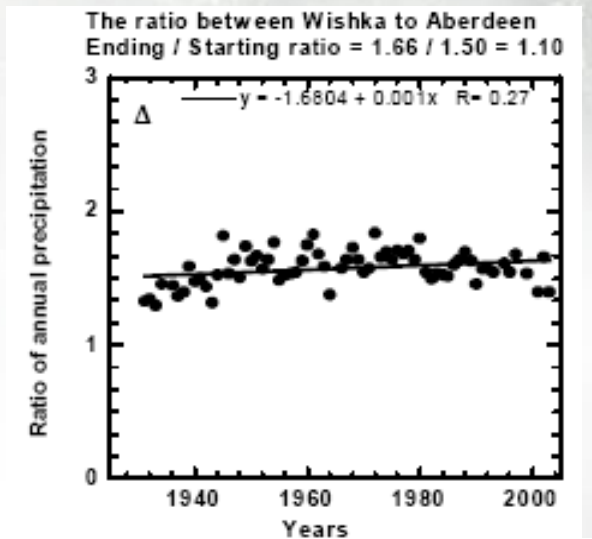
Evidence of aerosol effects on cloud drop size from satellite and aircraft measurements during the SUPRECIP-2 field campaign

NEWS (Leung)
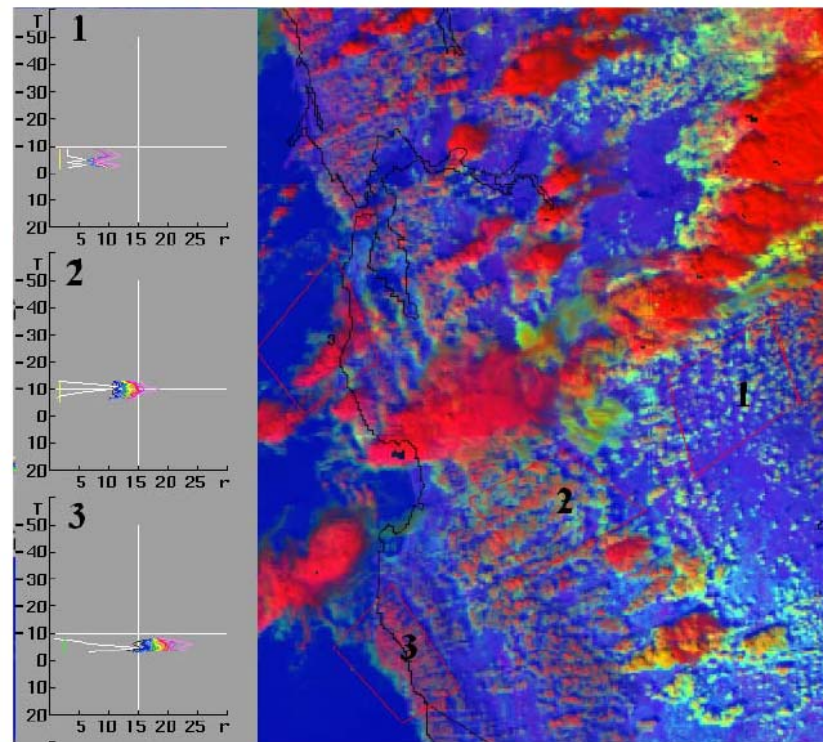
Aqua MODIS image of the clouds in the San-Francisco-Sacramento area on 2006 02 28 21:00Z. Polluted clouds with small drops appear yellow (see Area 1), whereas the ice clouds appear red. Pristine water clouds appear magenta (see Area 3). The line graphs provide the relations between the satellite indicated cloud top temperatures and the cloud top particle effective radii. The effective radius near cloud top is much smaller than the precipitation threshold of 14 µm at the foothills in Area 1, but over the coastline in Area 3, the effective radius is much larger than the precipitation threshold of 14 µm.
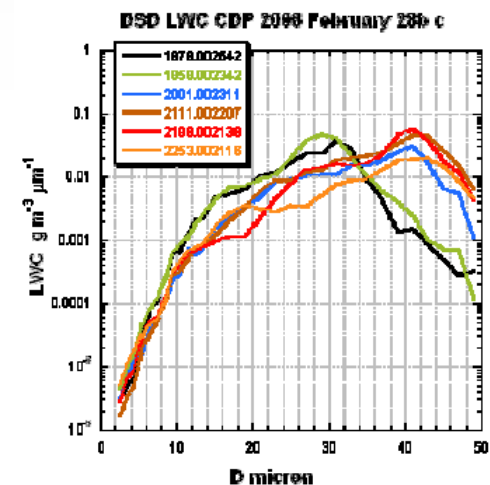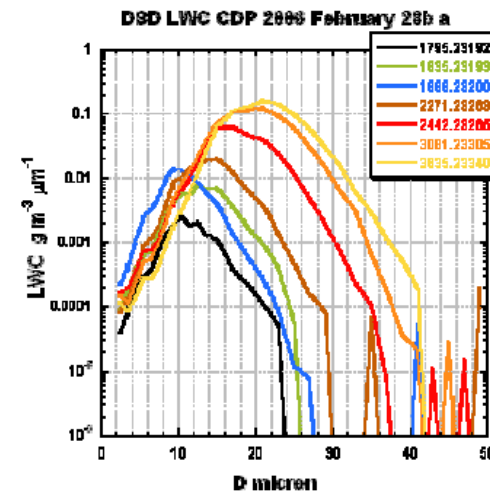
Top: Cloud 1 over the western slopes of the Sierra Nevada. Each line represents the gross cloud drop size distribution of a whole cloud pass. The passes are ordered in ascending altitude. Bottom: Cloud 3 over the hills near Big Sur. The contrast between the small (Cloud 1) and large (Cloud 3) drop size is evident.

Latent Heating Estimation by Satellite Microwave Radiometry

Method

The satellite technique uses combined spaceborne radar (PR) and passive microwave (TMI) estimates of high-resolution precipitation and latent heating vertical structures to "train" a TMI-only algorithm for retrieving latent heating vertical profiles.
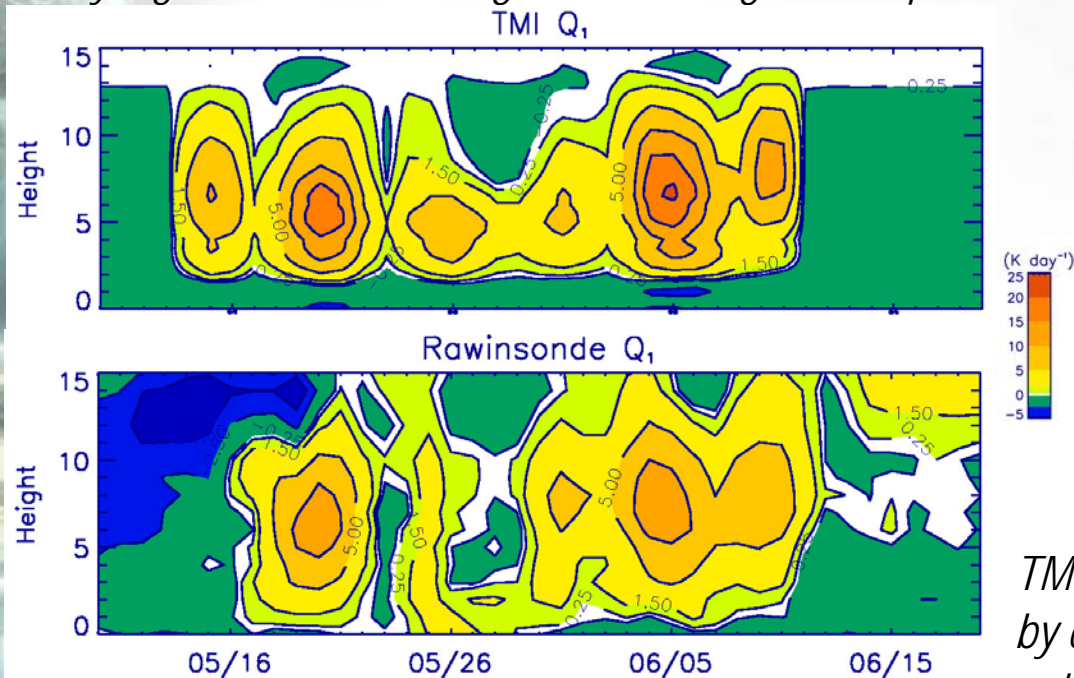
rawinsonde estimates from Johnson and Ciesielski (2002)

M. Grecu and W. Olson, UMBC/NASA GSFC
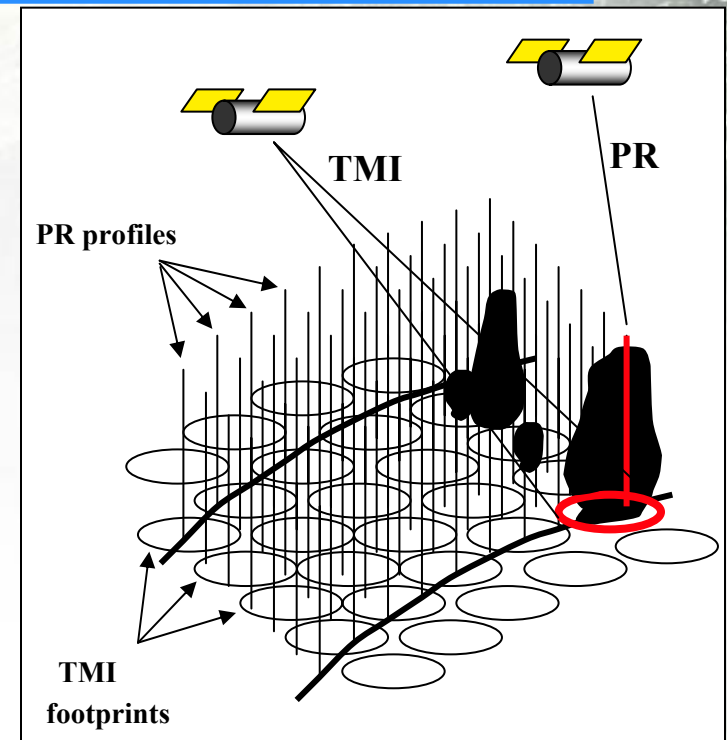
Validation

TMI estimates of latent heating are augmented by climatological radiative heating to obtain estimates of total diabatic heating (Q_1).

Comparisons to rawinsonde Q_1 estimates from the SCSMEX campaign show reasonable agreement, *considering the limited temporal sampling of the TMI (~1.4 d^{-1}).*

Annual mean latent heat flux (W/m²) from R1, R2, ERA40, JRA, Noah, CLM, Mosaic and ensemble means for GHP CSE regions as well as for the Global Land (-60 to + 60), Ocean (-90 to 90), and the entire Globe. The areas are ordered from left to right by their annual mean surface air temperatures in the R1. Note the dry MDB and AMMA areas bracketing the wetter tropical areas.

1986-95 Annual Means, LE
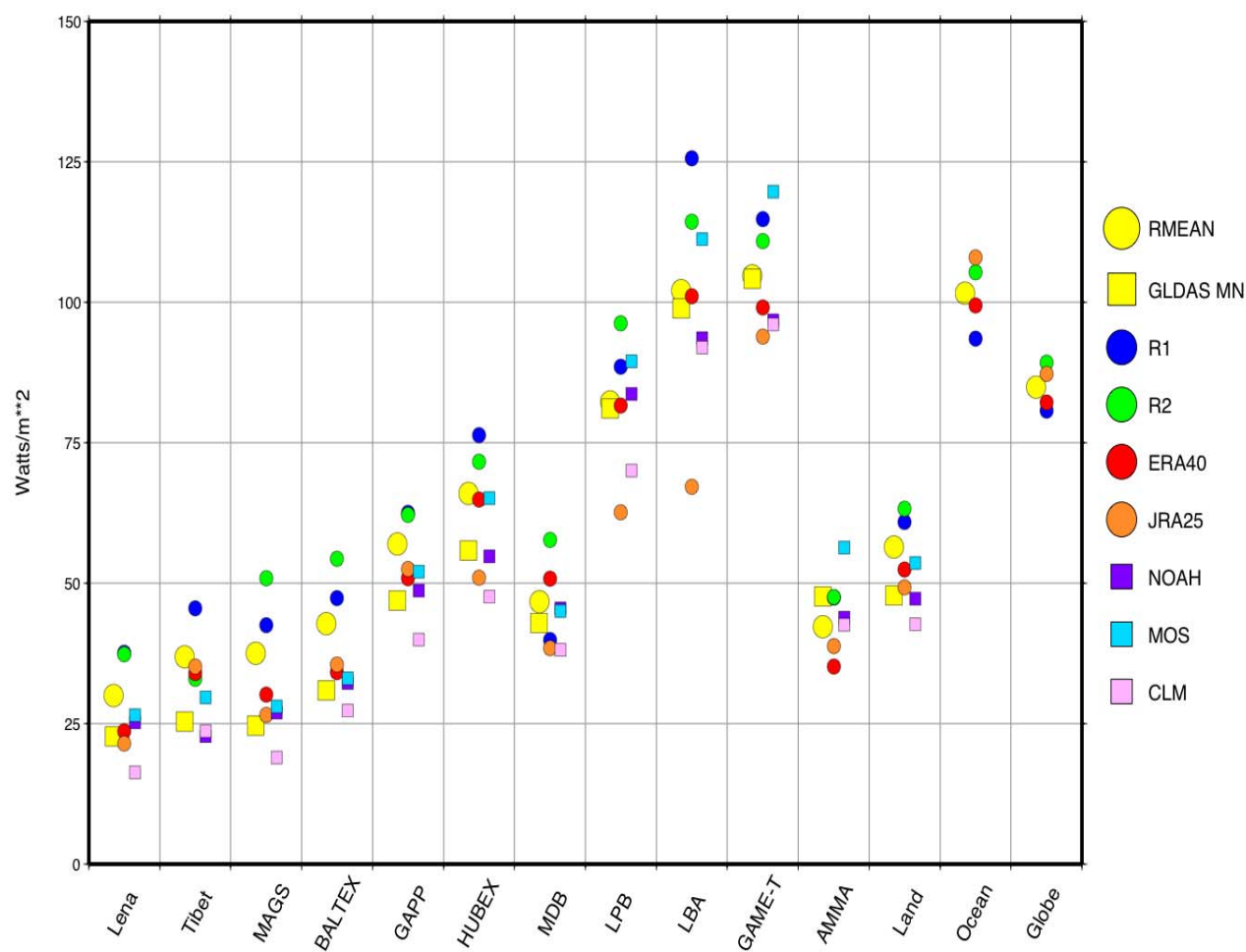
Assessing techniques for calculating water vapor transport using simulation

simulation (truth)

Water vapor transport for January 2003
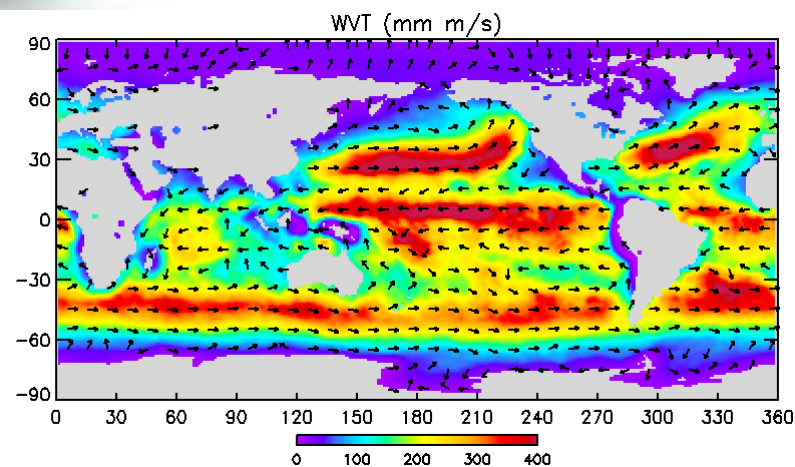
feature tracking
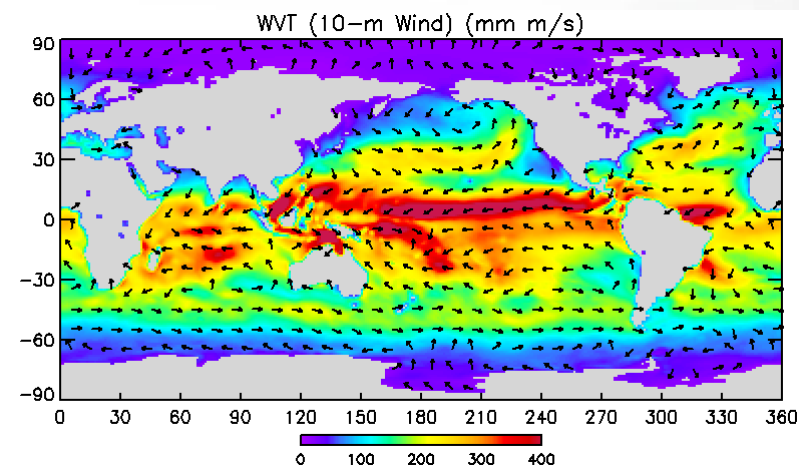
surface wind

Assessing the impacts of uncertainties on evaporation estimates

Evaporation (mm/day) for January 2003
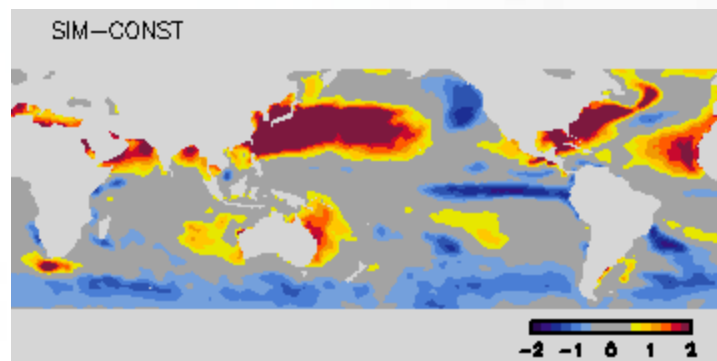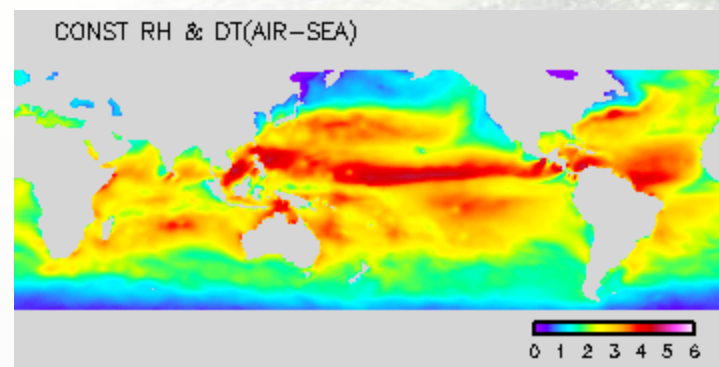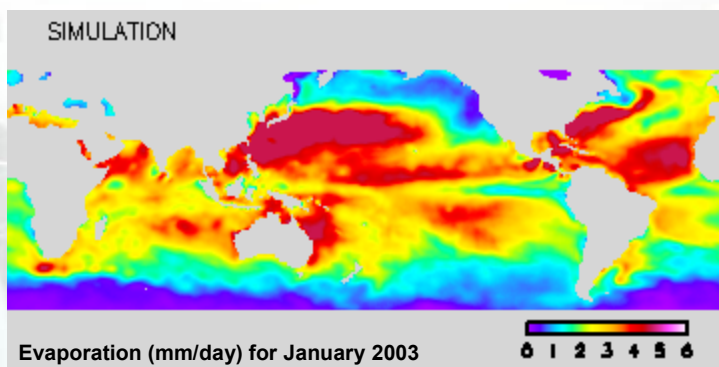
Remote Sensing Systems
www.remss.com
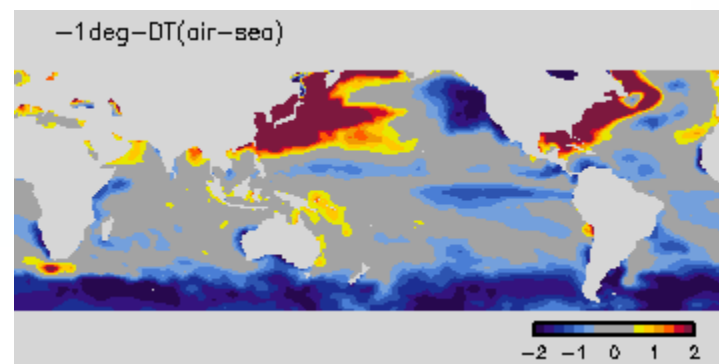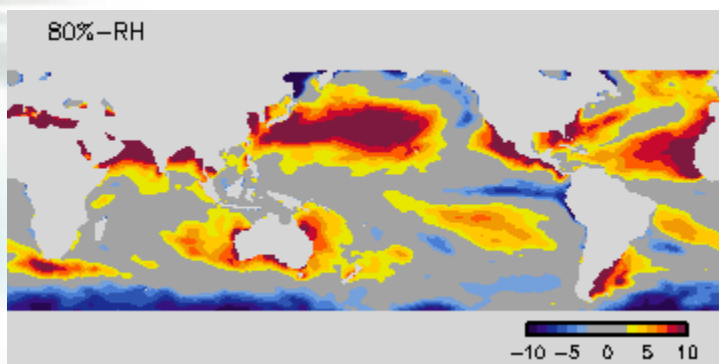
Long-wave radiation controls the diurnal temperature range and the strength of the nocturnal boundary layer
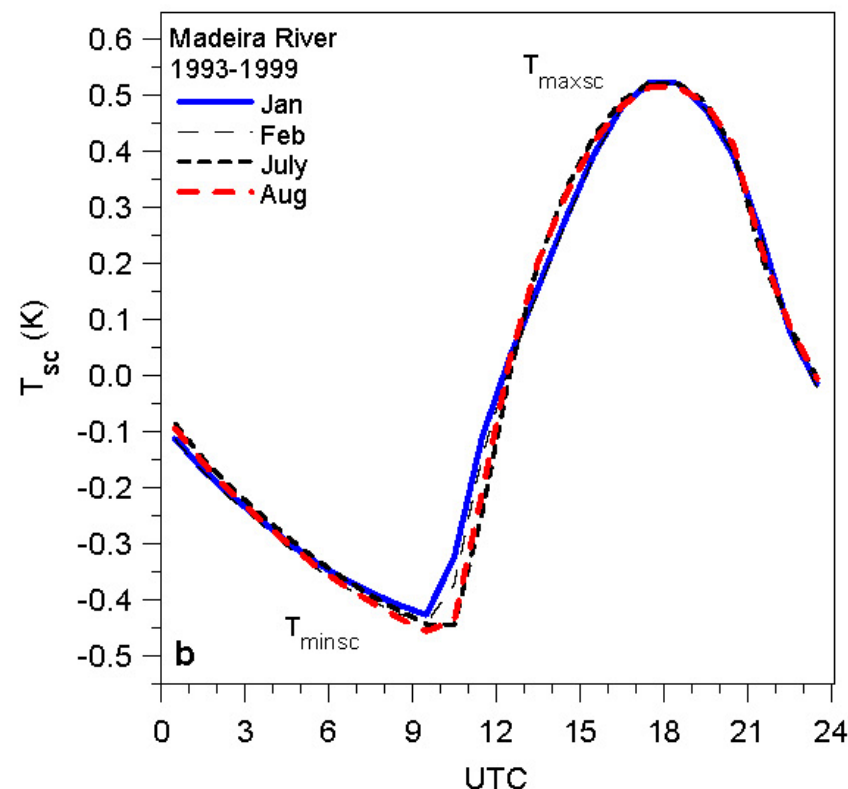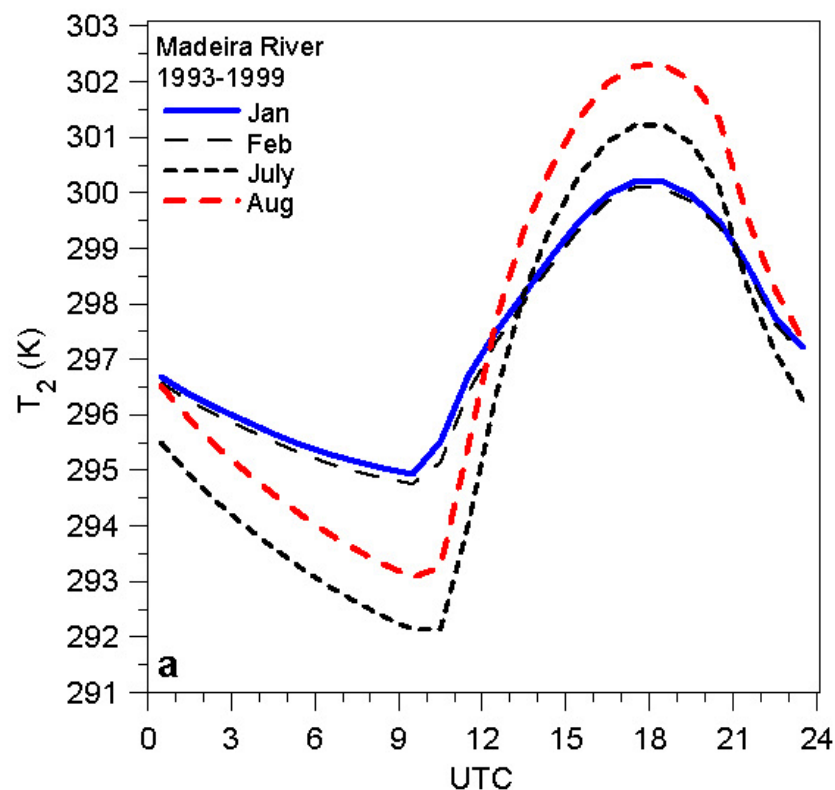
a) Seasonal variation of diurnal cycle over Amazon

b) A single curve when scaled by net LW radiation [*Betts, JGR, 2006*]

Land-surface interaction at northern latitudes differs over agricultural and forest regions

- Annual cycle of mean SW_{down}, R_{net} for conifer and grass sites and their difference

- **Surface albedo [and the coupling to the cloud field] both change surface energy balance**

[Betts et al., Ag. For. Met., 2006]
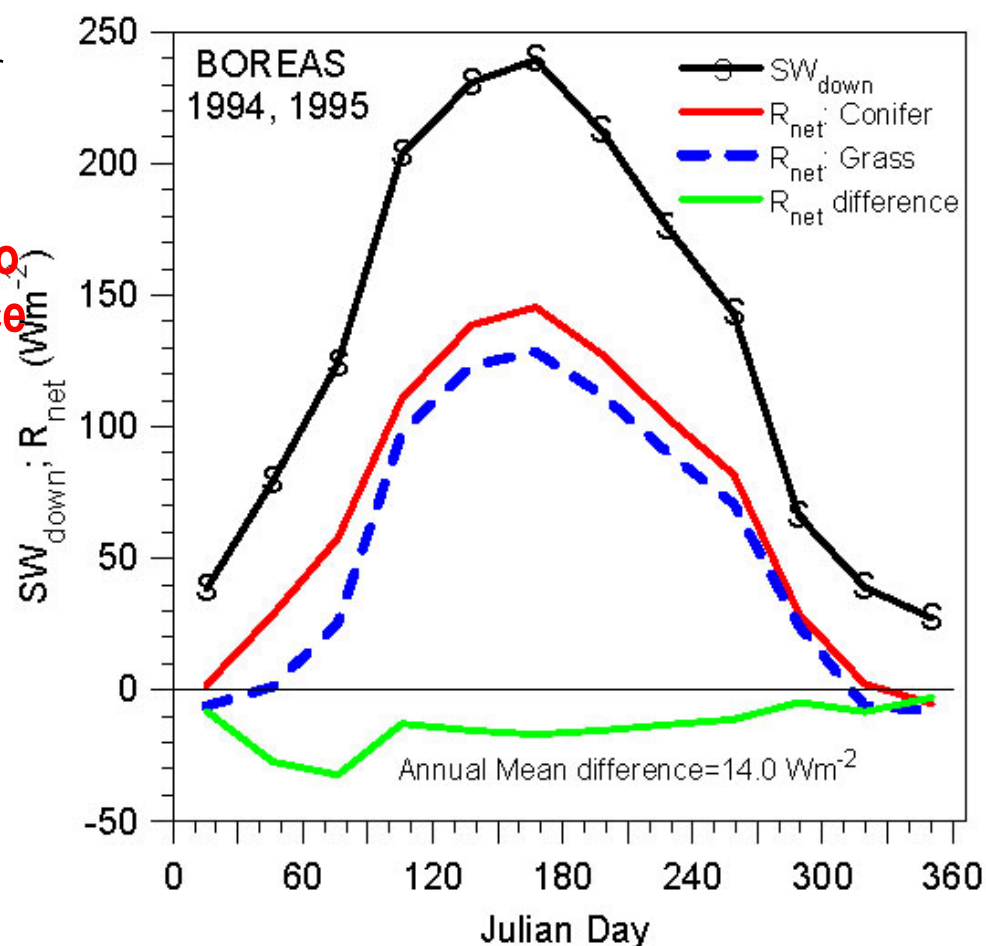
Assessing land-surface-atmosphere coupling in the ERA-40 reanalysis with boreal forest data.
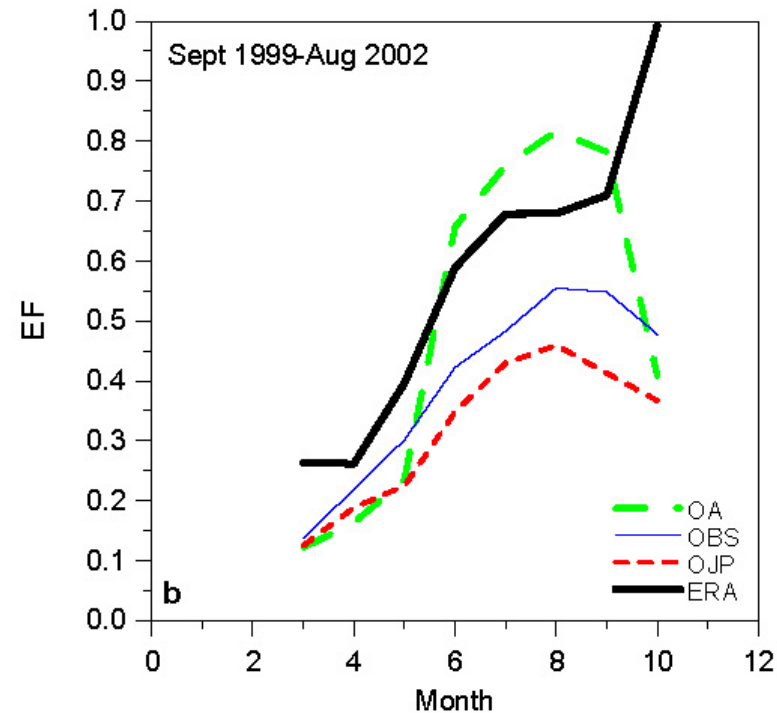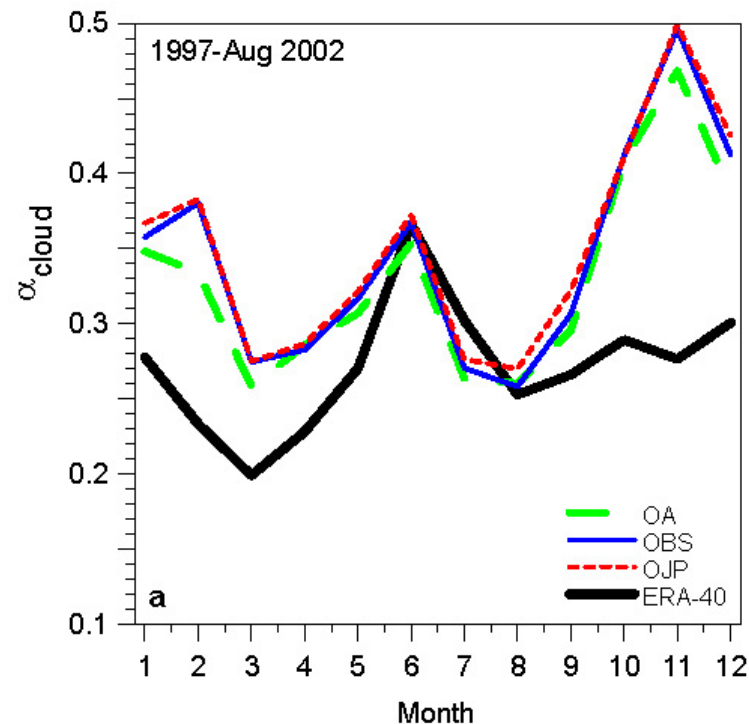
a) Model bias in cloud albedo against BERMS forest sites
b) Bias in evaporative fraction *[Betts et al., Ag. For. Met., 2006b]*

a) ERA40 Anom., DJF, 1991–1992; Precip (mm/d), step=24–36

d) ERA40 Anom., JJA, 1988; Precip (mm/d), step=24–36
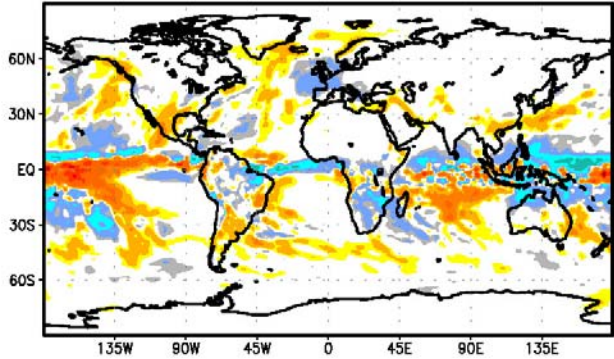
b) NCEP2 Anom., DJF, 1991–1992; Precip (mm/d), step=24–36
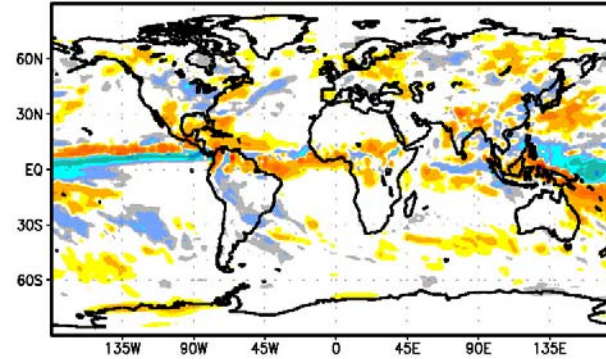
e) NCEP2 Anom., JJA, 1988; Precip (mm/d), step=24–36

c) GPCP Anom., DJF, 1991–1992; Precip (mm/d)
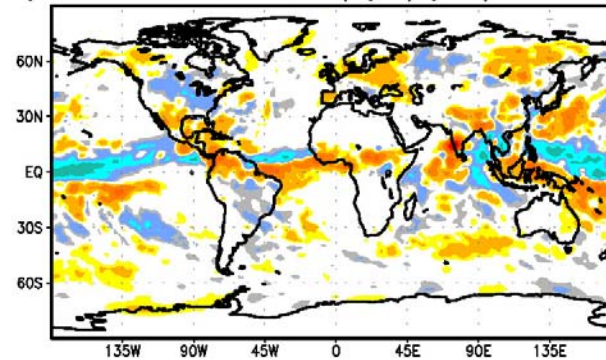
f) GPCP Anom., JJA, 1988; Precip (mm/d)
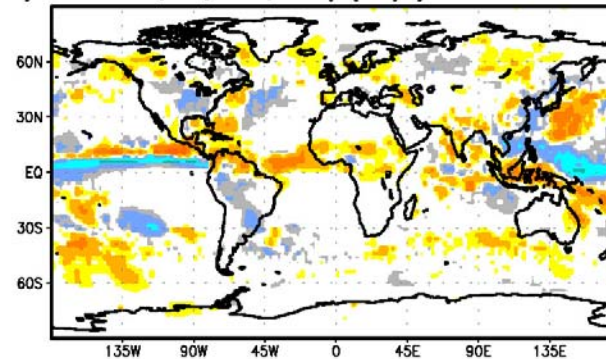
Despite biases, seasonal anomalies are similar in reanalyses and GPCP precipitation

[Betts et al., JGR, 2006c]

Paul R. Houser, Page 30

mm/day

+4
+3
+2
+1
0
-1
-2
-3

QUIKSCAT MOISTURE FLUX ___

QMF minus RIVER DISCHARGE ___

GRACE MASS CHANGE RATE ___

JAN 2003   JUL 2003   JAN 2004   JUL 2004
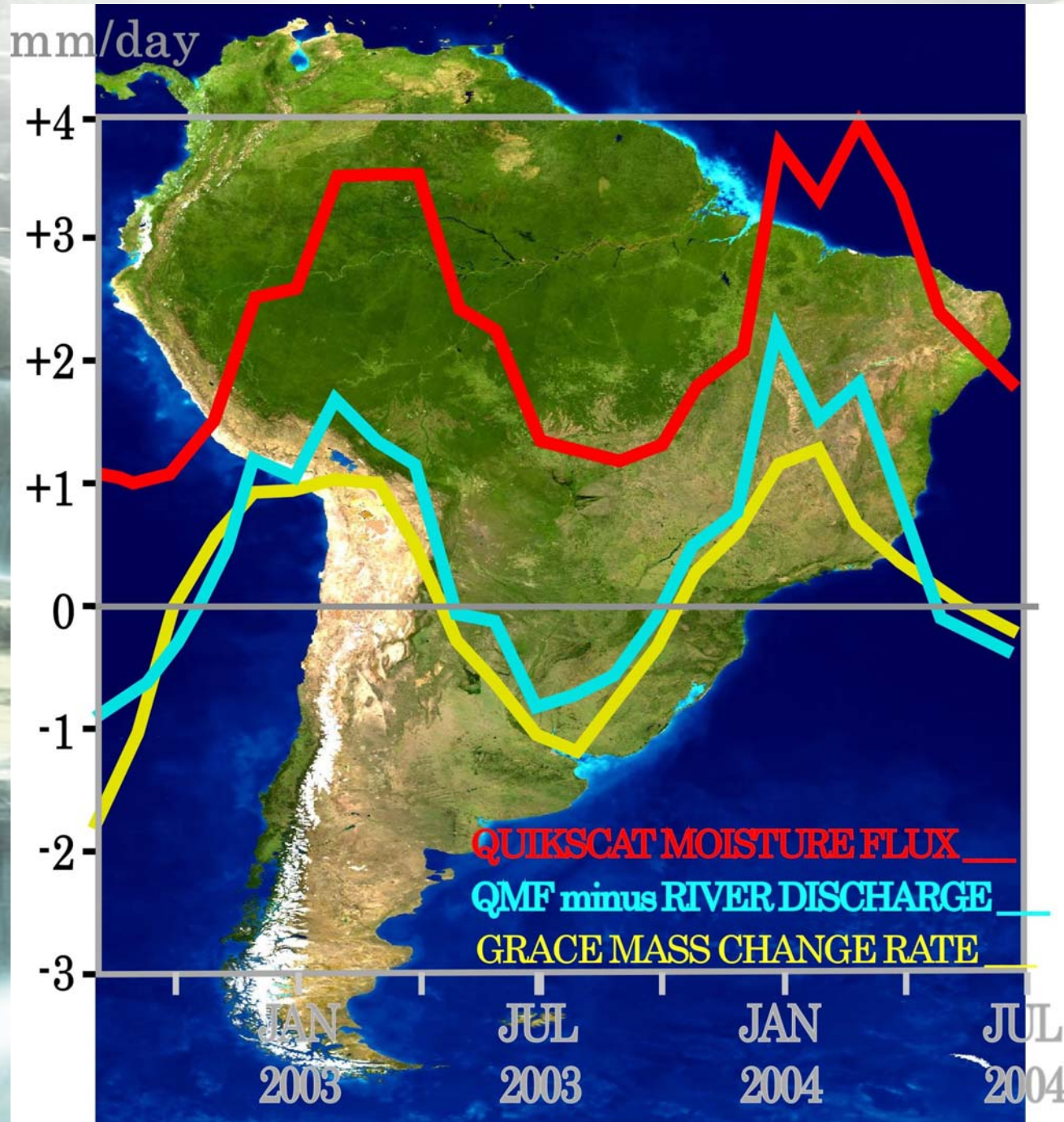
Ocean plays a dominant role over the seasonal changes of continental water balance and regional rainfall of South America, as revealed by combining the monthly rate of mass change from GRACE data, the transport of moisture across the coastline from QuikSCAT wind vector and SSM/I water vapor, rainfall by TRMM, and river discharge climatology.

NASA P.I. :W. Timothy Liu-GRL,2006.

NASA ENERGY AND WATER CYCLE STUDY
NEWS

(a) TRMM rain (>8 mm/day) & QuikSCAT wind vector, Jun–Aug 2000–2003

(b) Topography
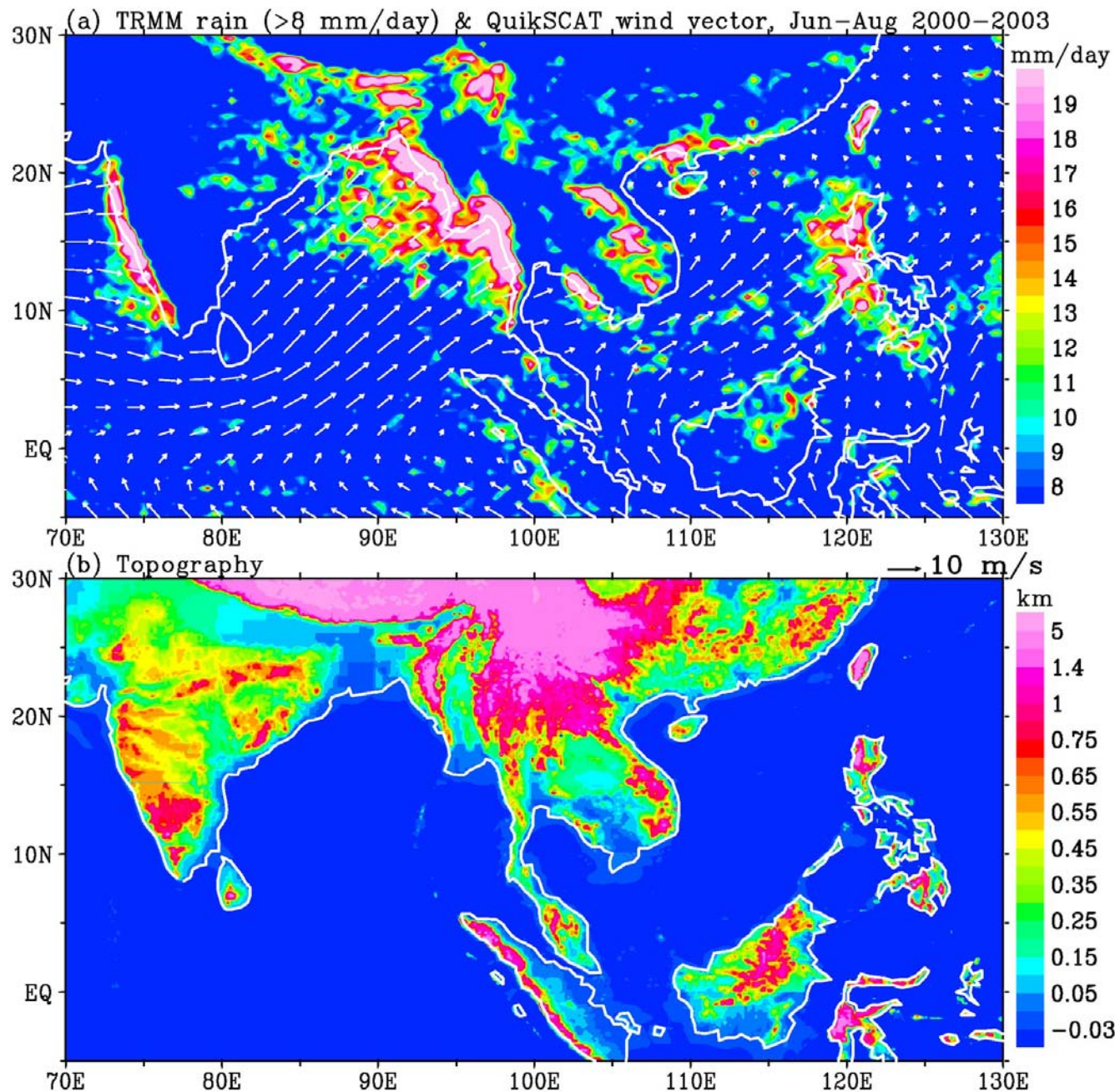
QuikSCAT and TRMM observations reveal the <u>narrow mountain ranges in Asia as centers of local monsoon rainfall.</u> We postulate that the mountains anchor terrain-forced centers of convection and have far reaching effects on the continental-scale monsoon system, in a numerical experiment .

NASA P.I.: Shang-Ping Xie & W. Timothy Liu, JC 2006

MMF Precipitation Analysis
Local Time of Maximum Precipitation Frequency (Summer)

MMF
JJA
1998-1999
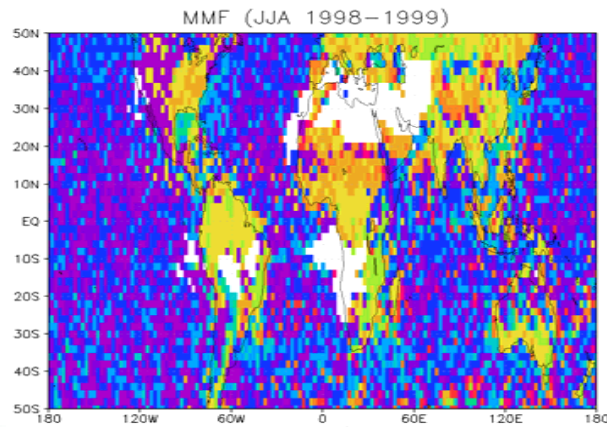
	Land	Ocean
MW	1600-1800	0200-0600
MMF	1600-1800	0200-0600
fvGCM	0800-1000	0000-0400

Merged MW
JJA
1998-2005
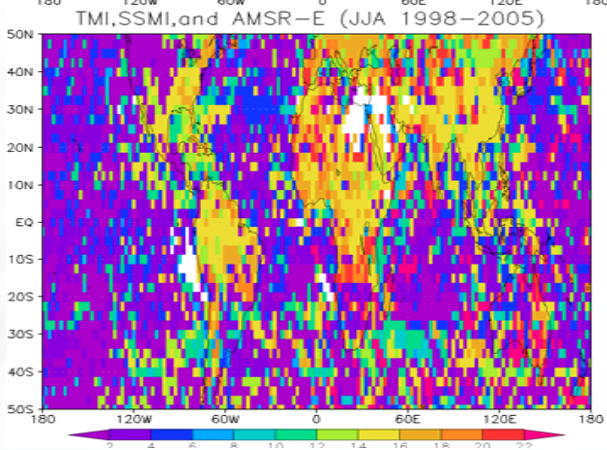
fvGCM
JJA
1998-1999
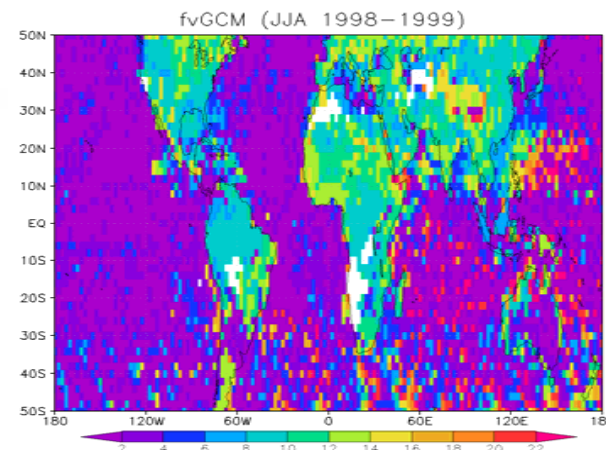
The geographical distribution of the local solar time (LST) of summer (JJA) precipitation frequency maximum from 2-year (1998-1999) simulations with the Goddard MMF and the fvGCM and the 8-year (1998-2005) merged satellite microwave only observation. **The MMF reproduces the correct timing of diurnal cycle maximum over the land (1600-1800 LST) and over the oceans (0200-0600) while the diurnal cycle of the fvGCM simulation peaks too early.**

Paul R. Houser, Page 33

YSU w/3 LSMs

MYJ w/3 LSMs
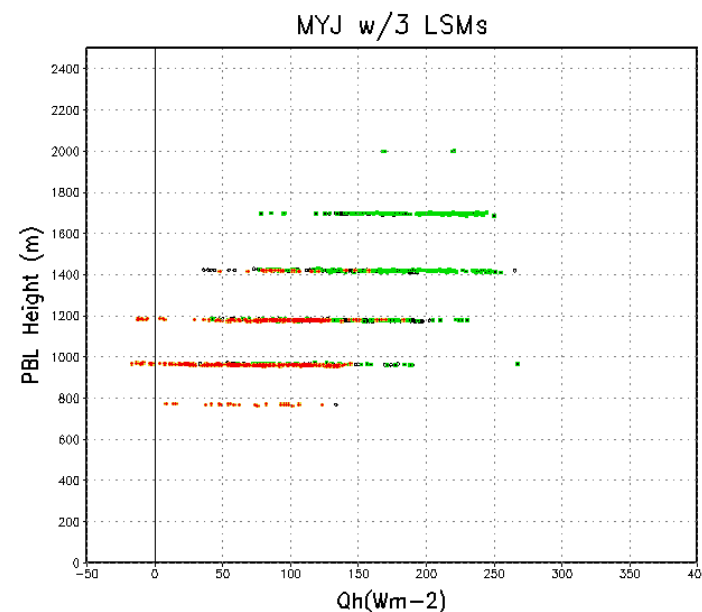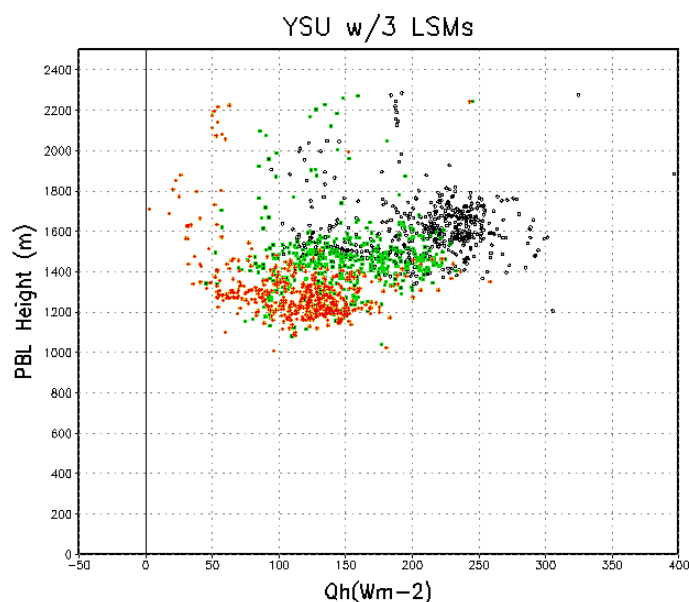
MRF w/3 LSMs

Boundary Layer Schemes=

1. YSU 2. MYJ 3. MRF

Land Surface Schemes=

● **= 5-layer Diffusion**

● **= NOAH**

● **= RUC**
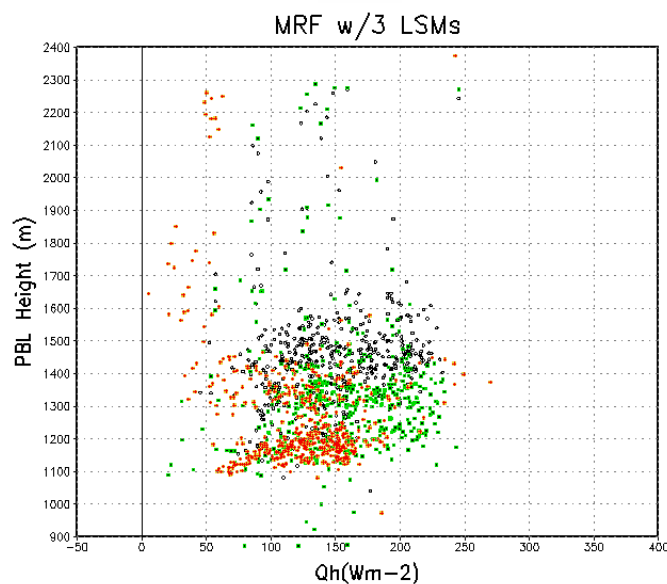
18Z Aug 28 2005

─ Katrina case study using a single domain with 30 km resolution: Land points – SE U.S.

Paul R. Houser, Page 34

Impact of Ocean SST and Soil Moisture Feedbacks on JJA Precipitation

Major drought

A

CW

Interactive soil

WC

mm/day

B

CW

No soil moisture feedbacks

WC

Warm Pacific

C
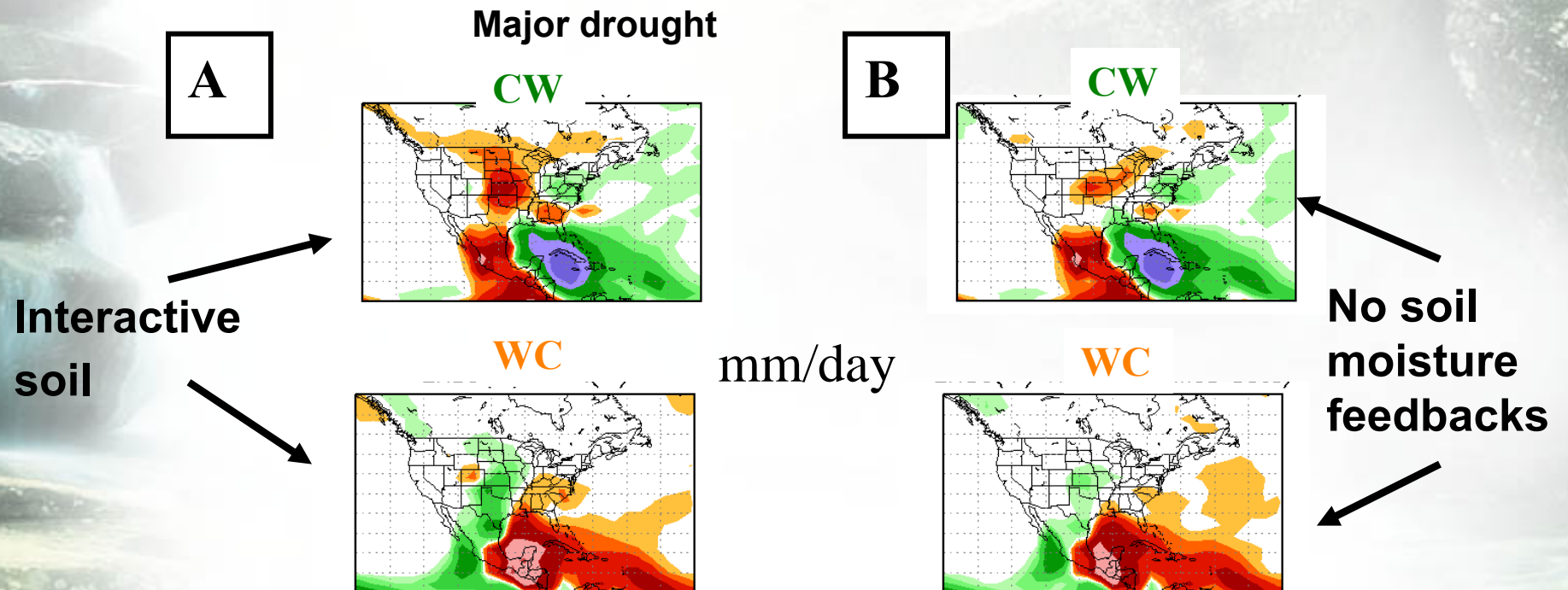
TIFF (Uncompress
are needed to s

CW Cold Pacific, Warm Atlantic
WC Warm Pacific, Cold Atlantic

QuickTime™

NEWS A-train Merged Data Product

Accomplished first year:

- Coordinated tests with GSFC on full res MODIS 201km subset
- Implemented MODIS full resolution in CERES cloud algorithms
- CALIPSO lidar Vertical Feature Mask merged into CERES code
- First merged CALIPSO/CERES cloud test data produced (image)

Work plan for next year:

- CALIPSO aerosol and cloud extinction profiles will be added
- Cloudsat cloud profiles will be added
- Regular ingesting of MODIS full res (MAC02, 03, and 04 products)
- Merge retrievals for every CERES field of view

19S, 53E   June 10, 2006, UTC 10.   5000km of A-train orbit track   27N, 43E
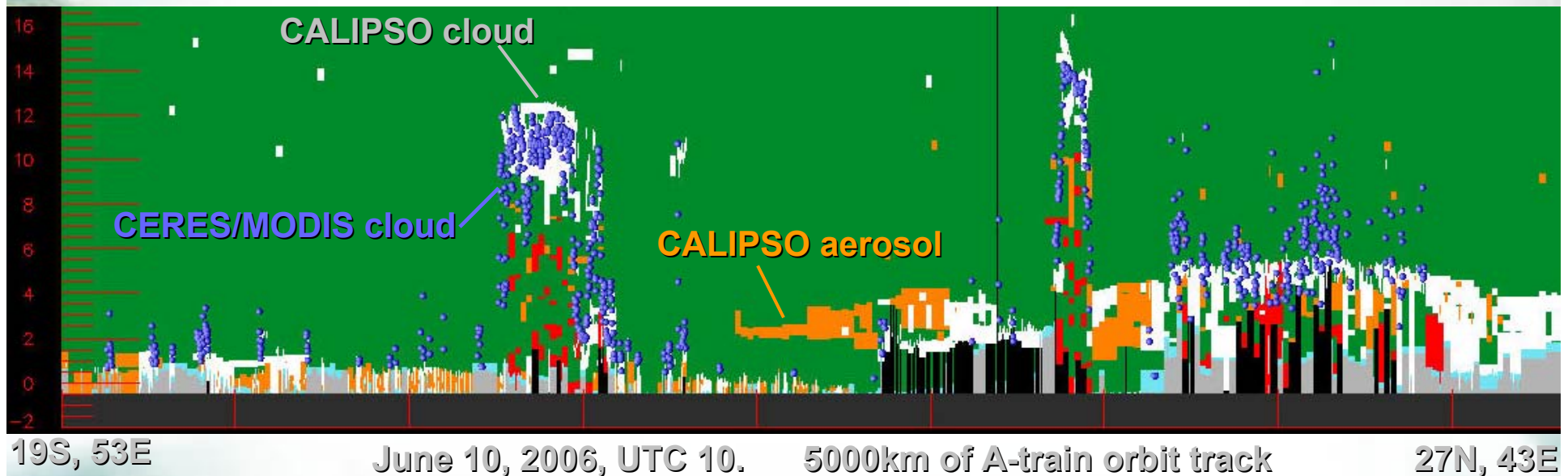
Energy Budget Response to ENSO

T. S. L'Ecuyer, G. L. Stephens, Z. Luo

Observed Regional Heat Budgets

IPCC-AR4 Model Heat Budgets
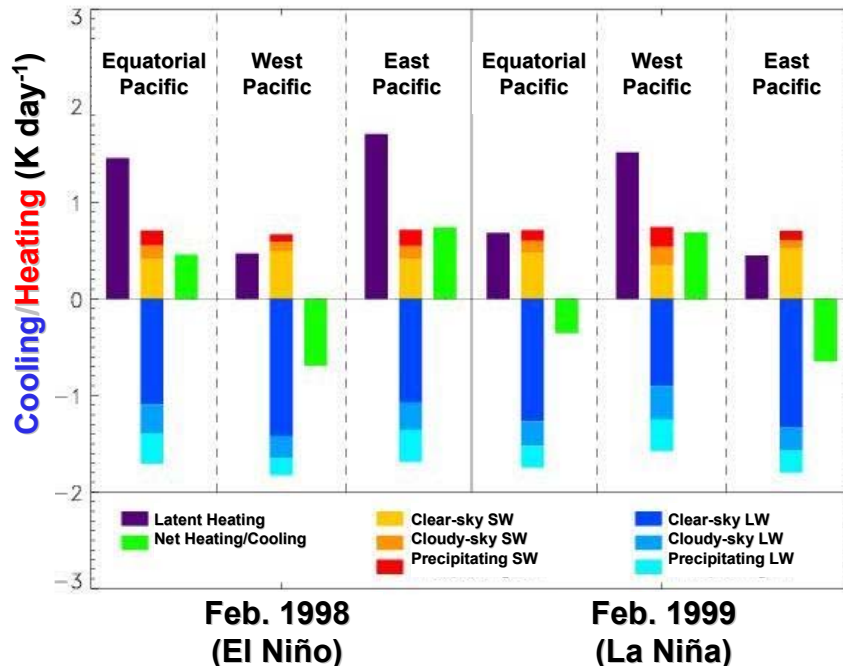
- ➤ **Atmospheric diabatic heating estimates from the TRMM satellite quantify the response of regional energy budgets** in the Tropical Pacific to the 1998 El Niño event (top).

- ➤ Similar fields extracted from the latest IPCC climate model simulations indicate that **today's GCMs still have difficulty modeling the response of diabatic heating in the Tropical West Pacific to ENSO (right).**

Paul R. Houser, Page 37

'Ecuyer, G. L. Stephens, Z. Luo

500 mb Pressure Tendency

Surface Rainfall

TRMM Obs.
CNRM
INM-CM3
IPSL-CM4
CGCM2

$N = - C_{SW}/C_{LW}$

N > 1 indicates cooling
N < 1 indicates heating
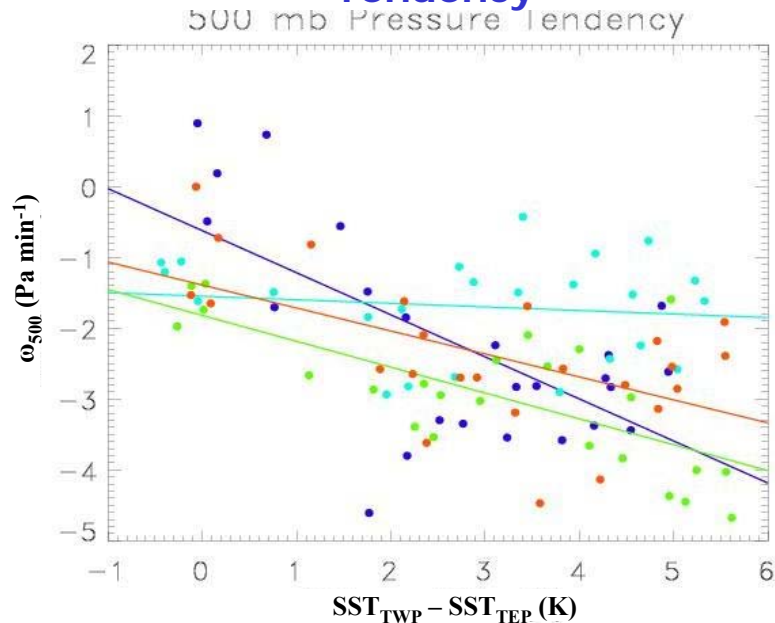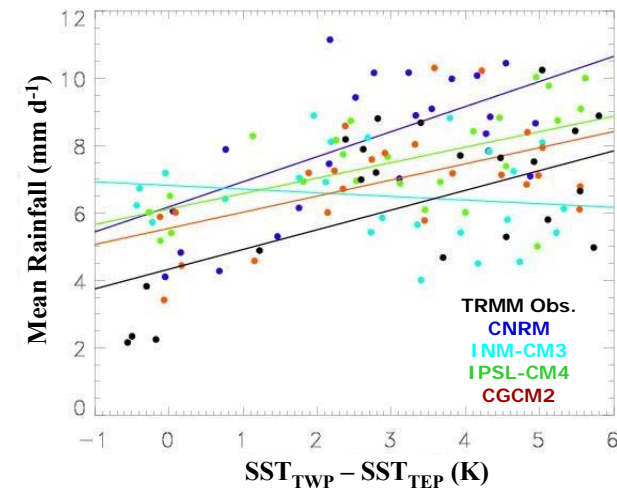
> **Uncertainties in the energy budgets from the IPCC-AR4 models can be traced to disagreement among models concerning the response of the large-scale Walker Circulation to El Niño (top).**

> As a result, **responses of both precipitation and the vertical distribution of cloud impacts to ENSO are poorly modeled (right).**

> These errors have direct implications for atmospheric diabatic heating through the misrepresentation of latent heat release and cloud radiative effects.
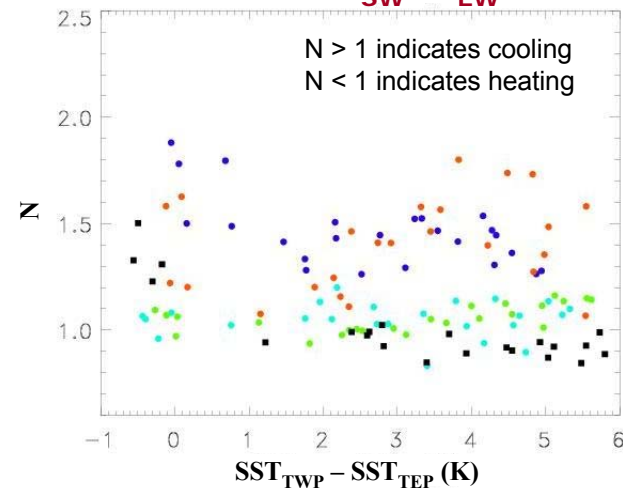
Anomaly time series (30N-60N)
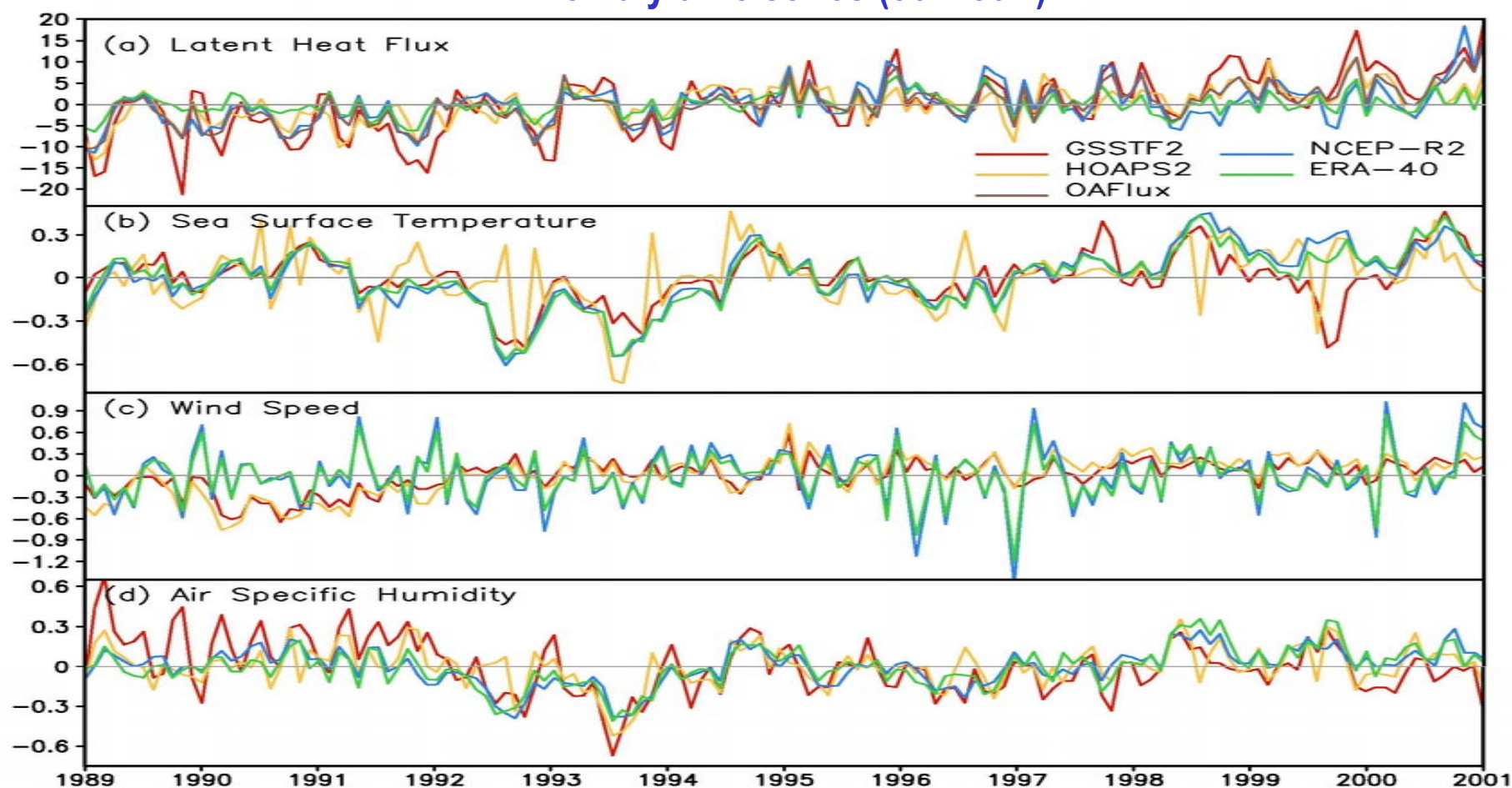
Trends of LHF andmeteorological state variables (30N-60N)

(Trends exceeding 95% confidence level are in red)

Trend (Per Decade)	Satellite			Reanalysis	
	GSSTF2	HOAPS2	OAFlux	NCEP-R2	ERA-40
LHF (W/m²)	12.78	7.27	8.53	6.68	1.88
SST (°C)	0.1	0.14		0.27	0.23
U (m/s)	0.36	0.53		0.11	0.06
q (kg/kg)	-0.17	0.03		0.09	0.14

Paul R. Houser, Page 39

(a) Latent Heat Flux

(b) Sea Surface Temperature

(c) Wind Speed

(d) Air Specific Humidity

Legend: GSSTF2, HOAPS2, OAFlux, NCEP-R2, ERA-40
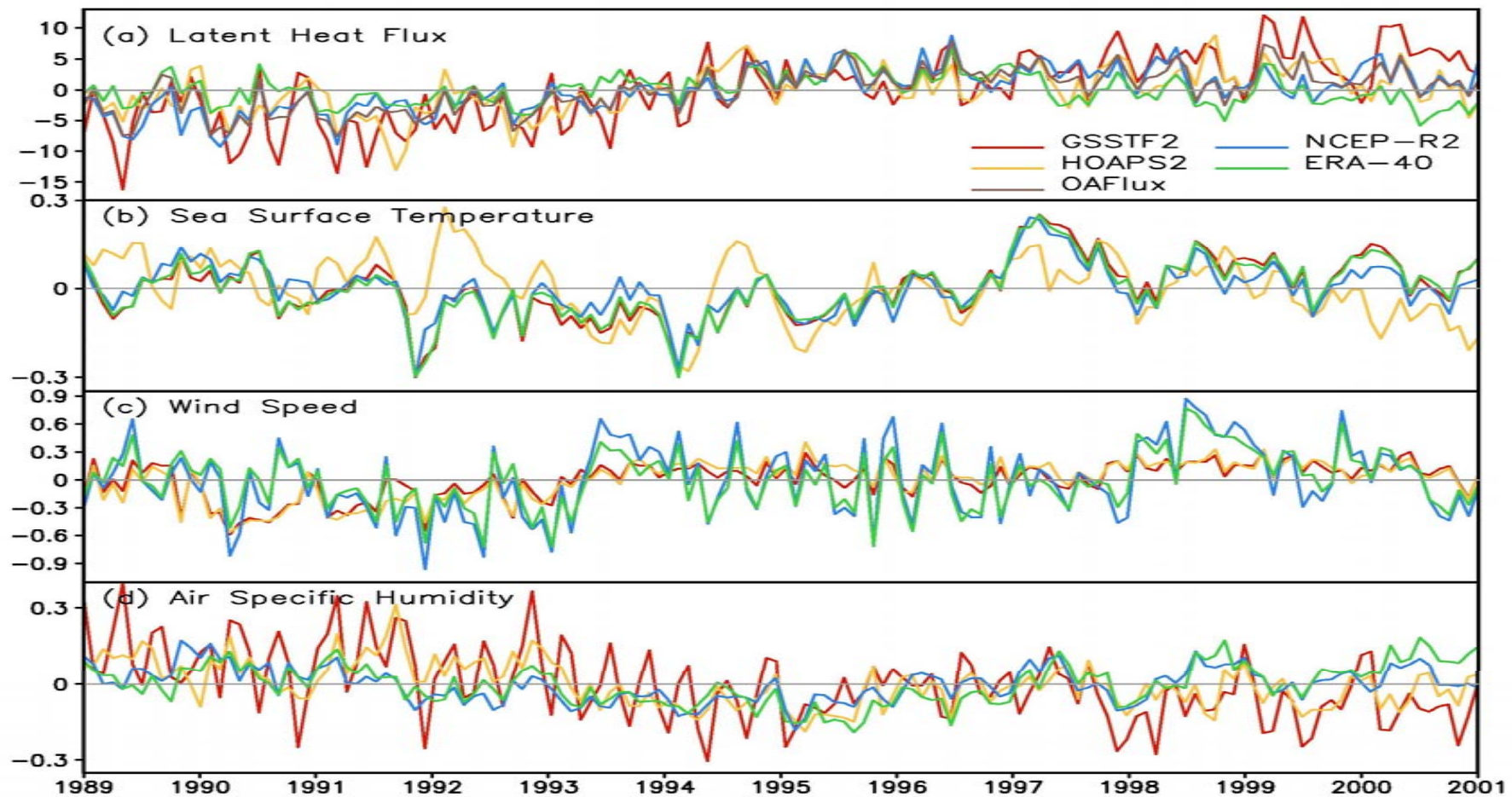
Trends of LHF and input meteorological state variables (60S-30S)
(Trends exceeding 95% confidence level are in red)

Trend (Per Decade)	Satellite			Reanalysis	
	GSSTF2	HOAPS2	OAFlux	NCEP-R2	ERA-40
LHF (W/m²)	11.65	5.39	6.35	6.54	-0.02
SST (°C)	0.11	-0.09		0.03	0.1
U (m/s)	0.29	0.35		0.23	0.18
q (kg/kg)	-0.21	-0.11		-0.01	0.03

Paul R. Houser, Page 40

Impacts of Irrigation on Regional Climate and Hydrology Variability

Proposal Goal: Investigate 1) influences of irrigation on regional hydroclimate, 2) capability of satellite remote sensing of irrigation-induced atmospheric and land surface changes and availability, and 3) sustainability of water resources in relation to irrigation.

Model Study Examining the Influences of Irrigation on Regional Hydroclimate

Model Study Region

Large Scale Irrigation Central-Eastern China
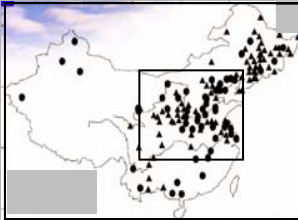
Local Scale Irrigation Central Valley California

Differences (Irrigation Minus No-Irrigation Runs) on Key Variables

Sea Level Pressure — After Irrigation

Surface Air Temp. (2 m) — After Irrigation

Precipitation — After Irrigation
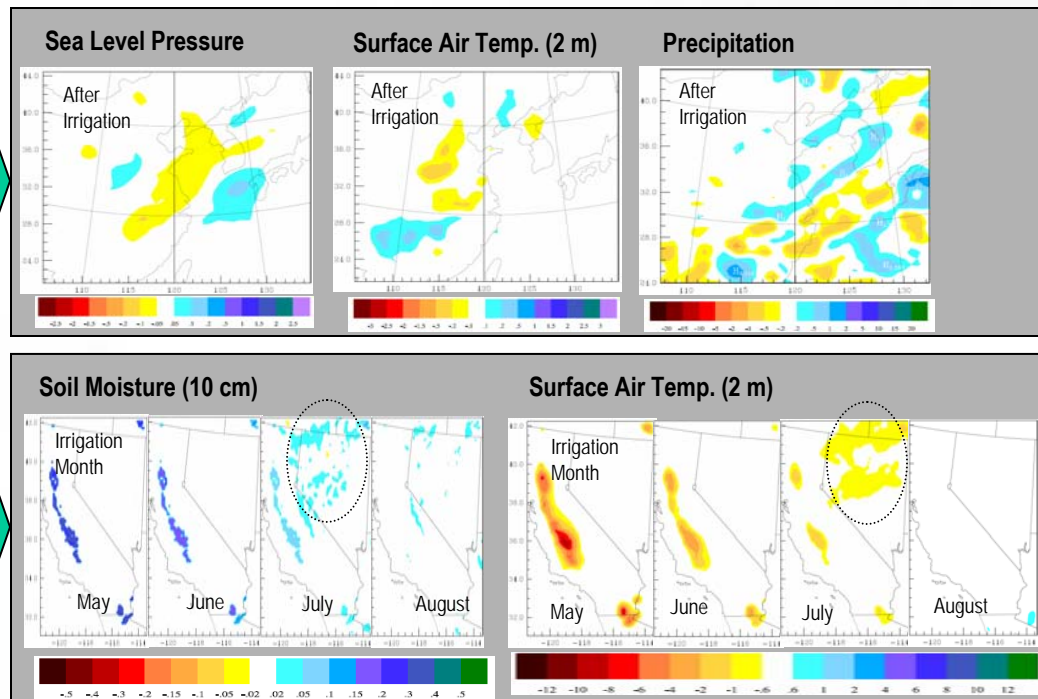
Results show the propagation of irrigation influences towards the Ocean.

Soil Moisture (10 cm) — Irrigation Month — May, June, July, August

Surface Air Temp. (2 m) — Irrigation Month — May, June, July, August

Results show the irrigation influences lasting two months.

Change in (P-E) for 2100 minus 2000
"Dry regions get drier, wet regions get wetter"
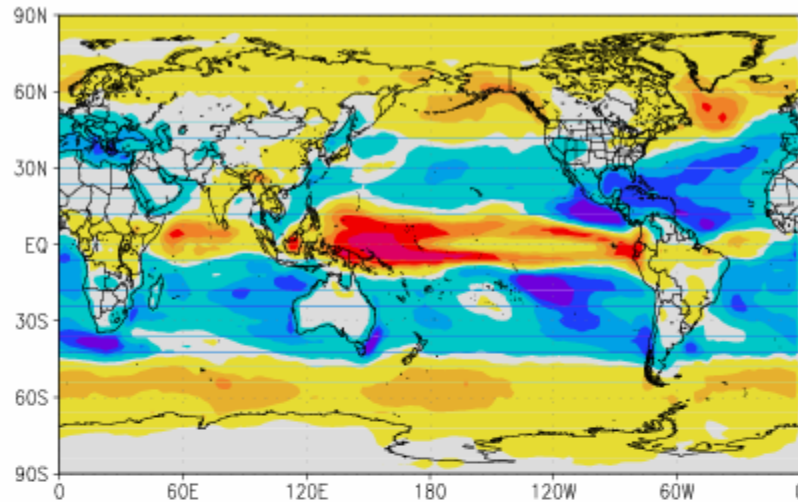
Multi-model ensemble mean change from IPCC GCMs
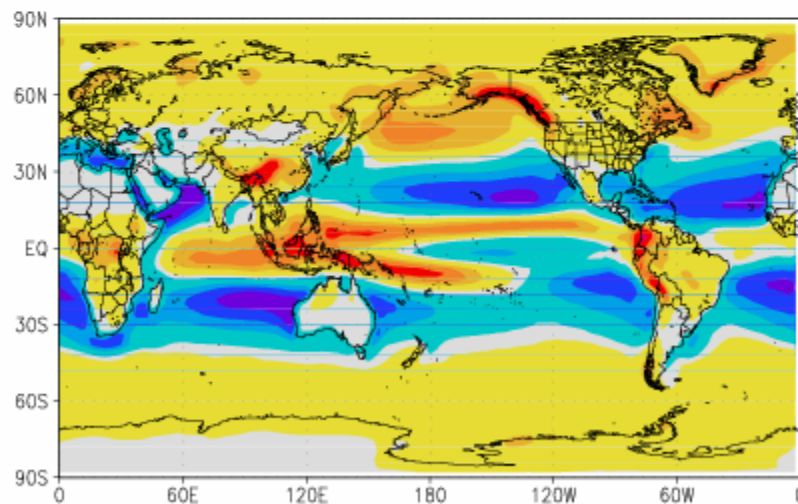
"Thermodynamic" component

−0.3 −0.2 −0.15 −0.1 −0.02 0.02 0.1 0.15 0.2 0.3

Δ(P-E) mm/day

Paul R. Houser, Page 42
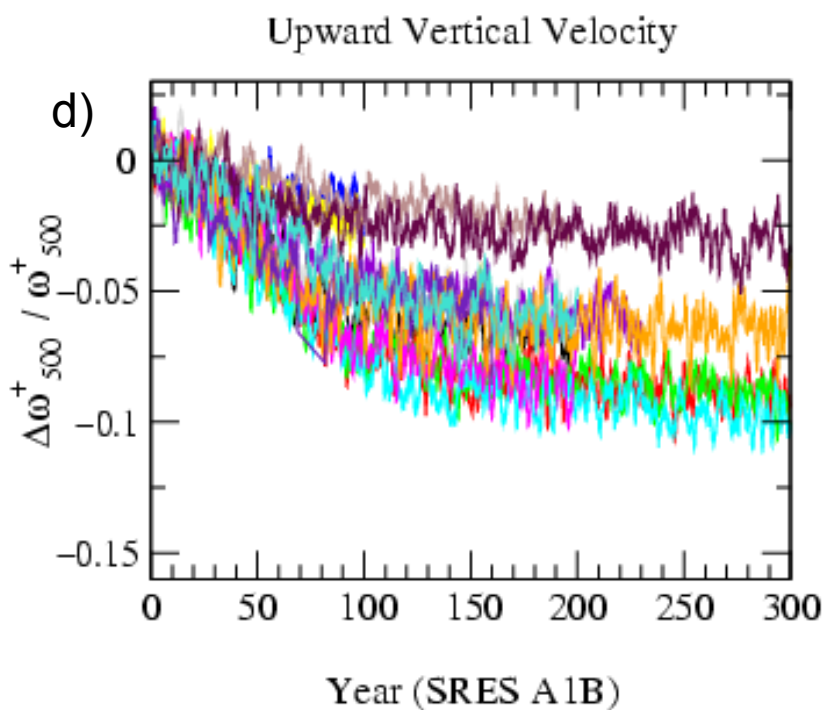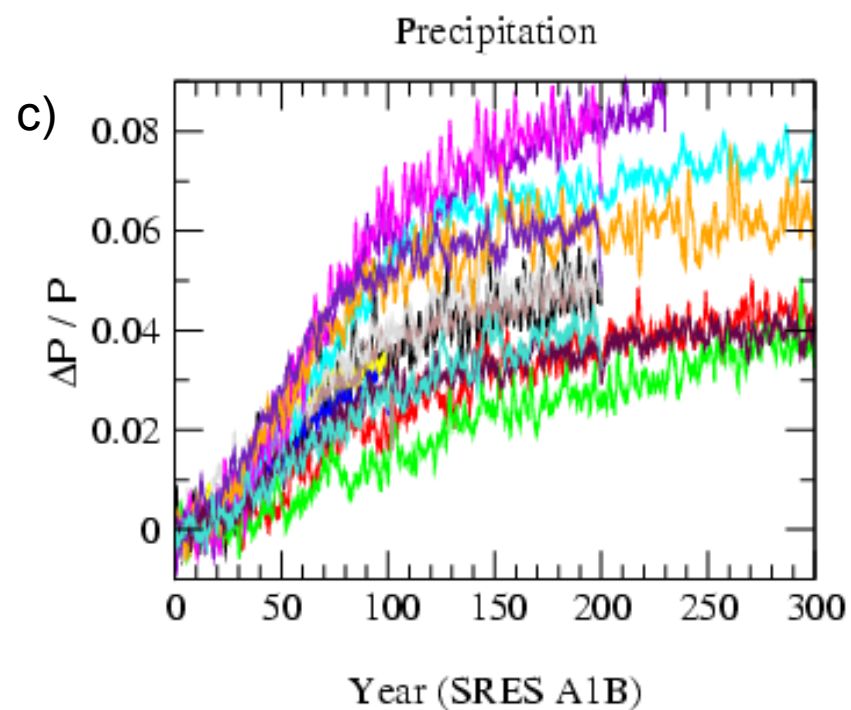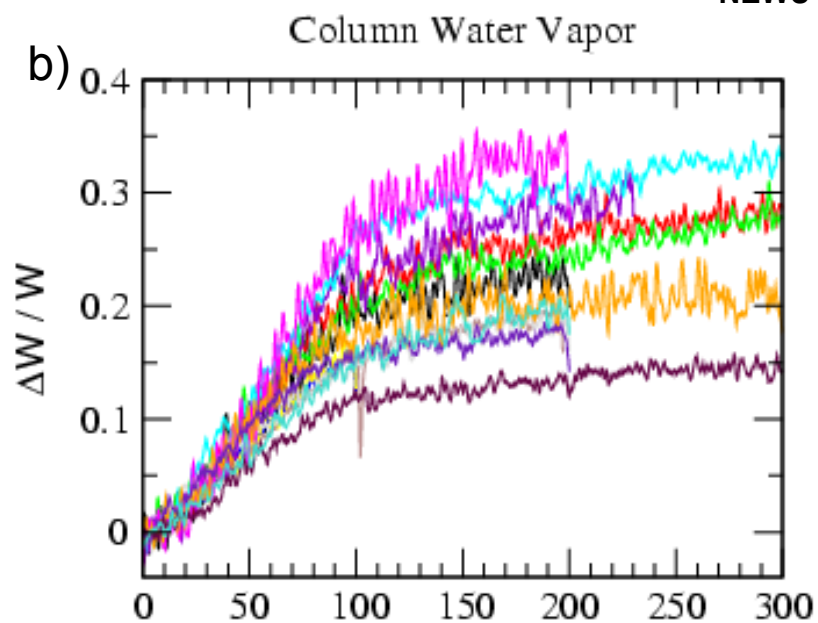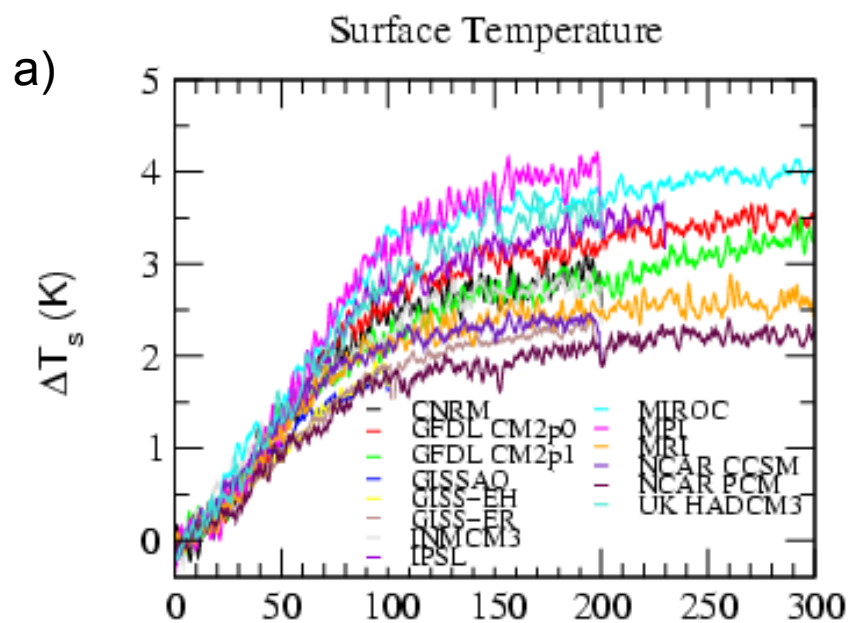
Held and Soden (2006)

a) Surface Temperature

b) Column Water Vapor

c) Precipitation

d) Upward Vertical Velocity

Vecchi and Soden (2007)

NEWS (Bosilovich)

- Biases in assimilation models and changes in observing systems can cause **discontinuities in global and regional time series, adding uncertainty to the investigation of long-term climate variation.**

- This slide shows one case of the impacts of the changes of observation system: The **onset of SSM/I availability (June 1987) significantly alters precipitable water content and precipitation in the Japanese Reanalysis (JRA-25).**

- The impact could have different weight in different parameters, at different heights and in different regions (Fig 1-3).

- Diagnostics in probability domain are important (Fig 4).

Fig 1. Zonal mean precipitable water
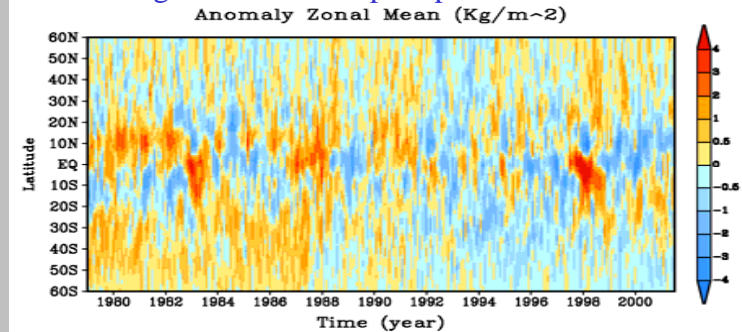
Fig 2. Zonal mean crosssection of specific humidity field (g/Kg)
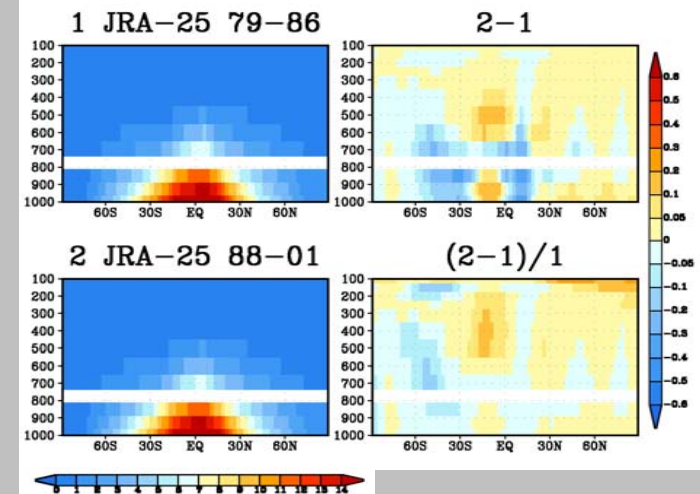
Fig 3. Zonal mean precipitation anomaly

Fig 4. The differentiated change of precipitation weighted by associated TPW-Omega Probability
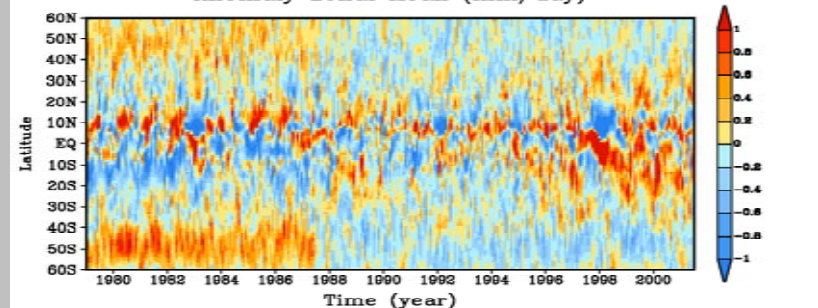
Global and Regional Precipitation Metrics

Using spatial correlations to assess reanalyses and merged products

- While models and observations have uncertainties and biases in P, the spatial distribution should be robust

- Introduction of SSMI in reanalyses has helped oceanic precipitation patterns

- Correlation of observed data sets provides a maximum expected values
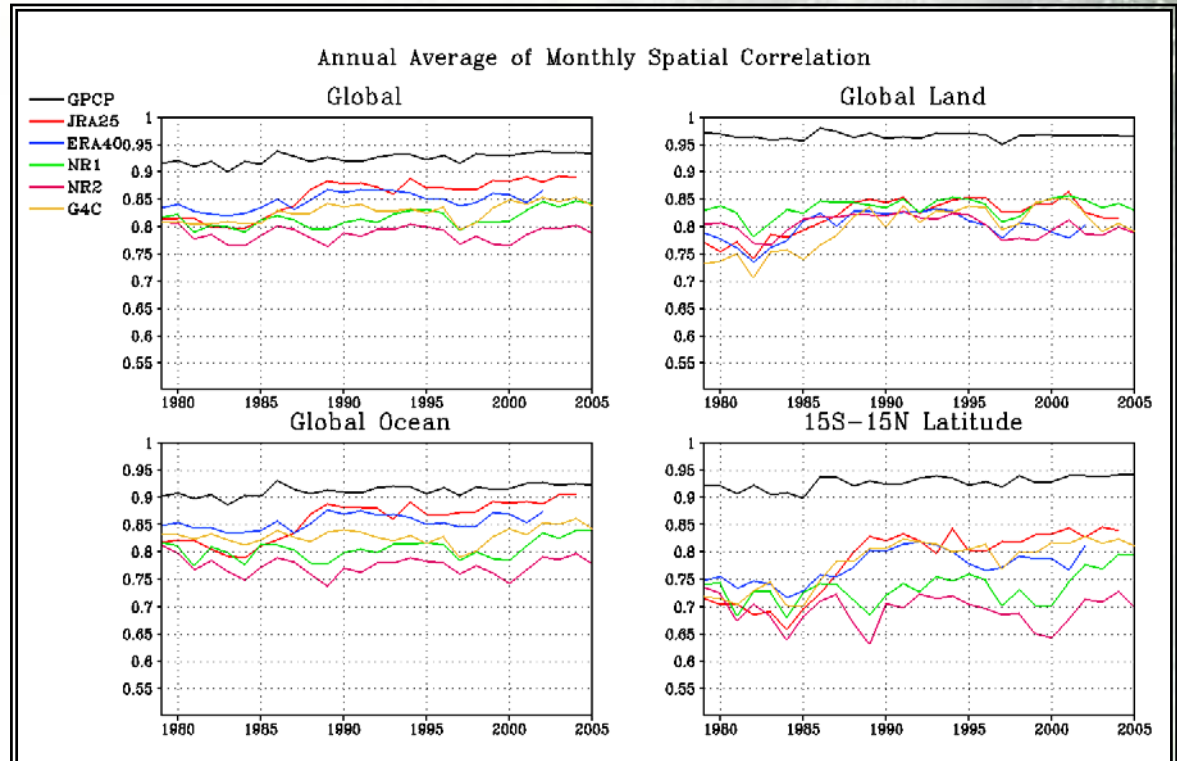
▲ **Annual means of monthly spatial correlation of existing reanalyses and GPCP precipitation to CMAP**

- Can emphasize the strengths and weaknesses in precipitation distribution
- Correlation of unmatched monthly means of observations can provide a minimum of reasonable values (0.7 for the Global Precipitation)

Paul R. Houser, Page 45

Mature Phase El Nino Composite Latent Heat Flux Anomalies from SSM/I and Reanalyses

(DJF '87/'88, '91/'92, '94/'95 '97/'98, '02/'03 mean departures from 1987-2003 Climatology)

- Significant regional ocean LHF anomalies result from El Nino-induced changes in SST and near surface wind, moisture and temperature, e.g. *(i)* increases in Eq central Pacific, subtropical N and S Pacific, *(ii)* reductions over W Pacific and N subtropical Atlantic.

- Substantial variations exist among data sets due to uncertainties in wind, q_s, q_a anomalies

UCSB Univ Cal Santa Barbara
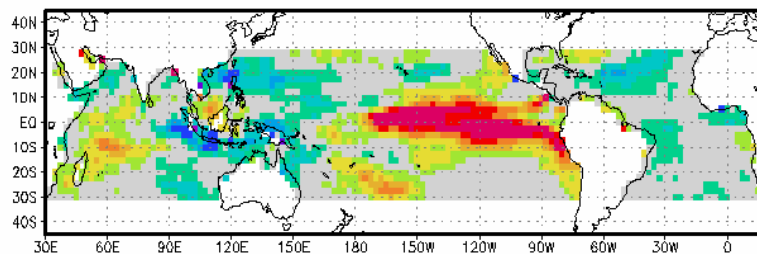
HOAPS Hamburg Ocean Atmosphere
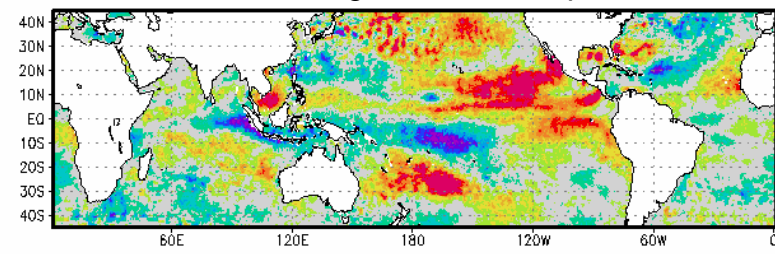
WHOI Woods Hole Ocean Atmosphere
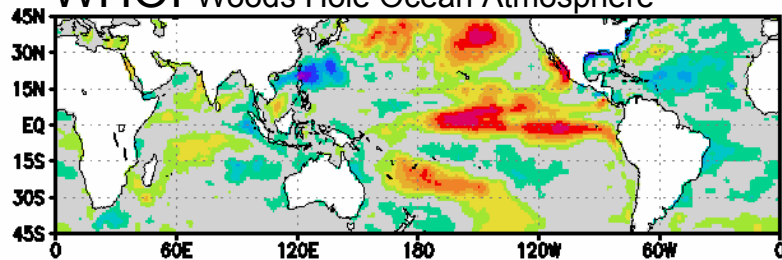
NCEP/NCAR Nat Centers for Environ Pred
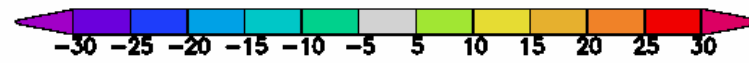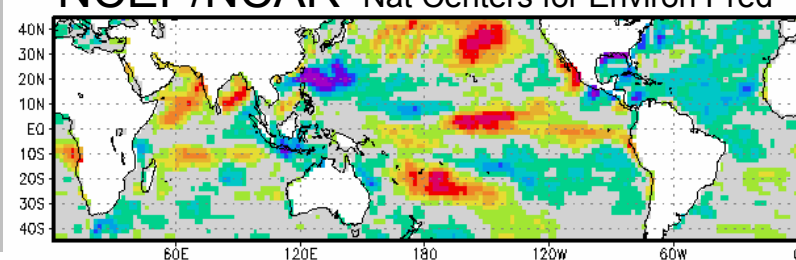
Wm^{-2}

Tropical Sector Latent Heat Flux Anomaly Time Series

30º N/S Averages over E. Pacific and Tropical Atlantic Sectors

5-pt smoothing   Anomalies are from 1988-2002 base climatology

ENSO-related Hadley- Walker Cell dislocations provide teleconnection mechanism *for anti-correlated LHF between Pacific and Atlantic sectors*
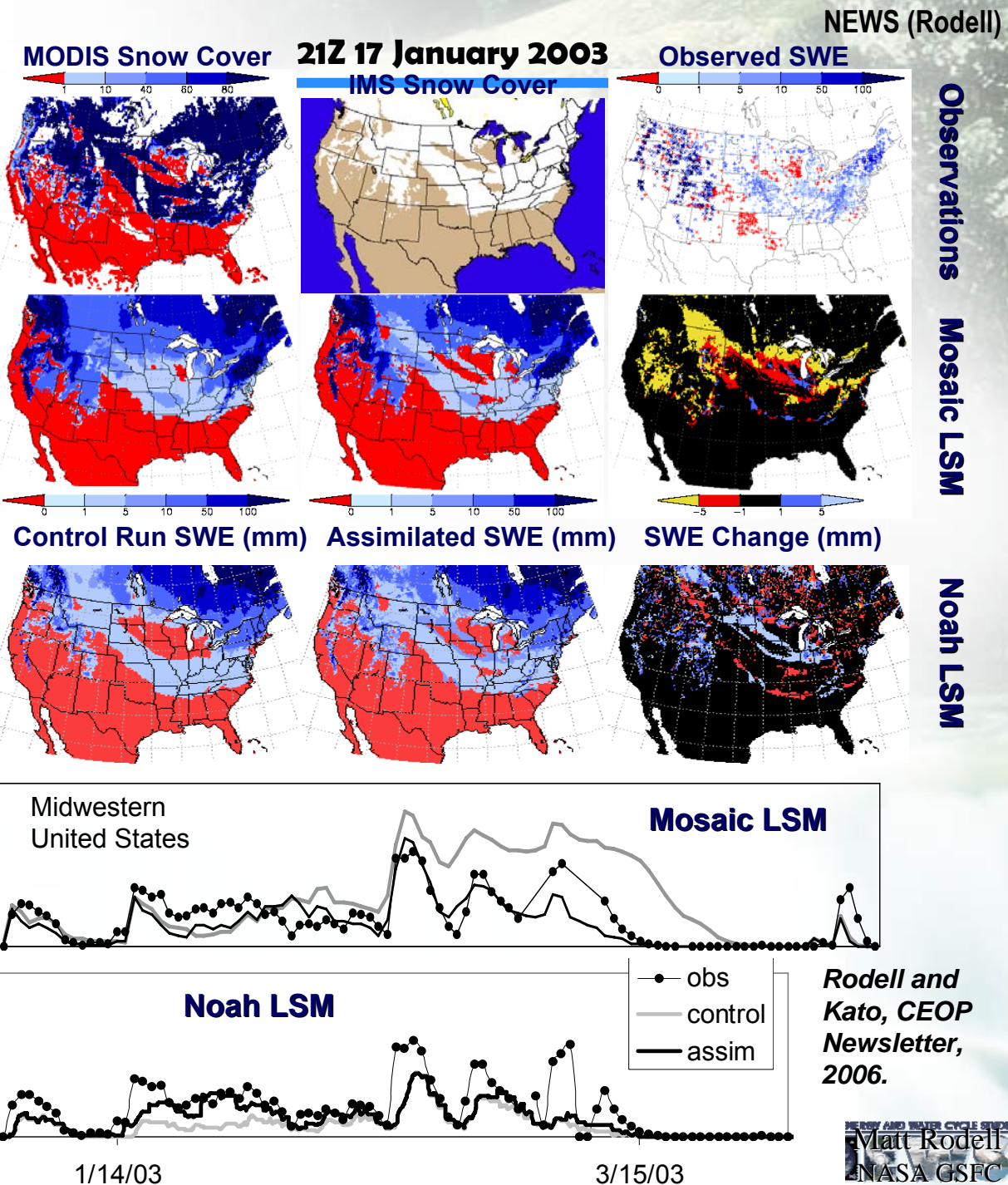
East Pacific 150E-90W

Wm^{-2}

Pac δSST x 30

Atlantic 90W-20E

Wm^{-2}

ATL δSST x 30

Nino 3.4
δSST x 30

NCEP
Rean LHF

WHOI
blended LHF
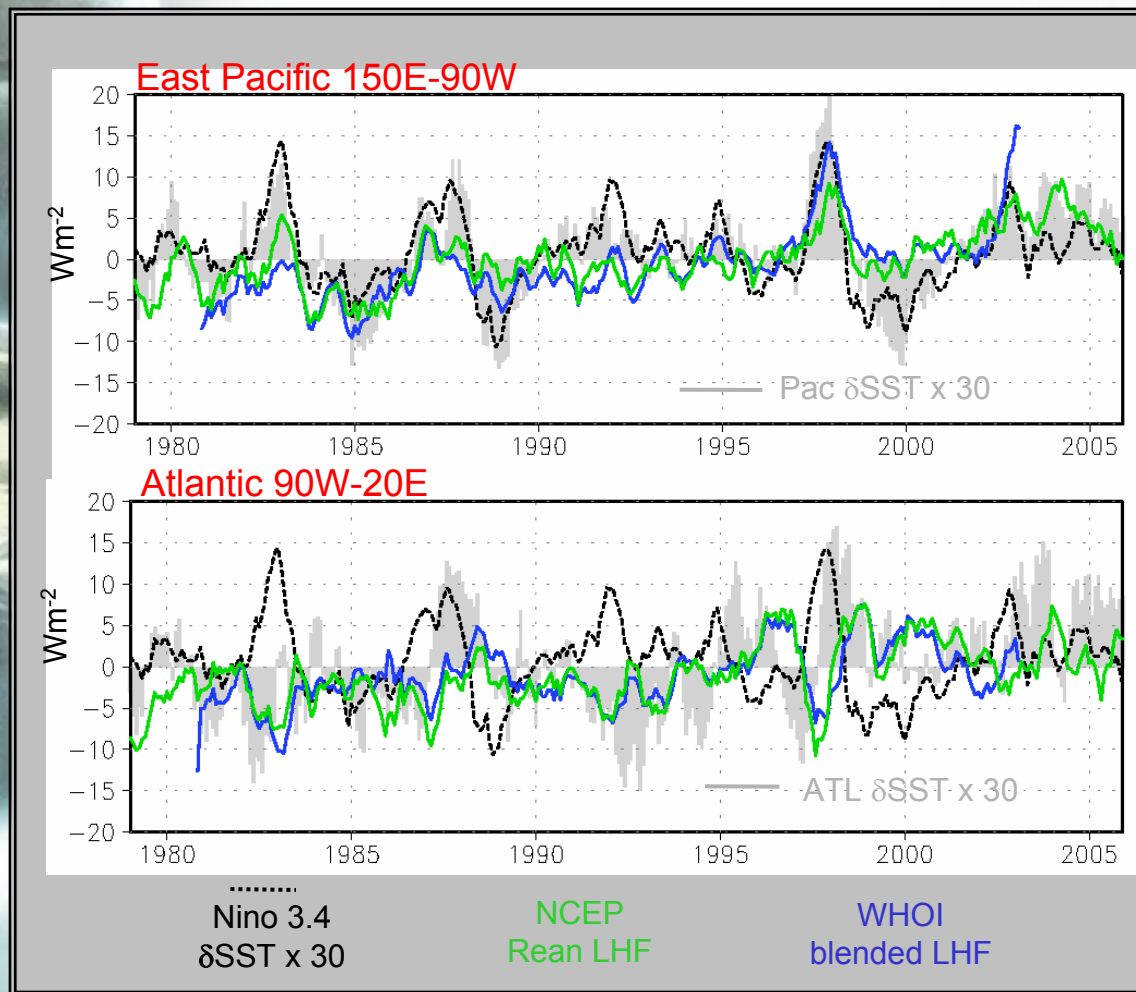
EPAC: LHF correlates with SSTs which are dominated by Nino 3.4 region. SST related q_s-q_a changes dominate wind speed changes in bulk formula.

ATL: LHF is *anti-correlated* with E. Pac LHF and Nino 3.4 SST. Weakened Hadley circulation inflow to Amazonia is primary teleconnection to Pacific. LHF is in phase with ATL $\partial SST/\partial t$ and contributes to tendency for lagged positive correlation between Atlantic and Eastern Pacific SSTs.

GLDAS/LIS
Assimilation of MODIS Snow Cover

MODIS Snow Cover

21Z 17 January 2003

Observed SWE

IMS Snow Cover

Control Run SWE (mm)   **Assimilated SWE (mm)**   **SWE Change (mm)**

Observations

Mosaic LSM

Noah LSM

• MODIS snow cover assimilation technique of Rodell and Houser (2004) installed in LIS/Noah

• 2001-present, global, 1/4° GLDAS/Noah assimilation output is publicly available

• Assimilated output from Mosaic and Noah are better than control in both cases, though biases remain

• Assimilated output is continuous and contains more information (SWE) than MODIS (snow cover) alone

Midwestern United States — **Mosaic LSM**

Midwestern United States — **Noah LSM**

obs
control
assim

11/15/02   1/14/03   3/15/03

Rodell and Kato, CEOP Newsletter, 2006.

Matt Rodell
NASA GSFC

Sensitivity of GLDAS/LIS LSMs to Physics, Land Characteristics, and Forcing

- Control simulations of LIS/Noah, CLM2, and Mosaic forced by CEOP site observations
- Best available global datasets used to test sensitivity of modeled states and fluxes to choice of LSM, precipitation and radiation forcing, elevation, soils, and vegetation
- Choice of LSM has largest impact
- In many cases, observed states and fluxes could not be reproduced no matter which inputs were chosen
- Results emphasize the importance of improving model physics and calibration

Top: Sensitivity of simulated seasonal ET (mm/month) to 6 runtime options

Below: Likely potential ranges of simulated monthly ET (mm/month) compared with CEOP observations
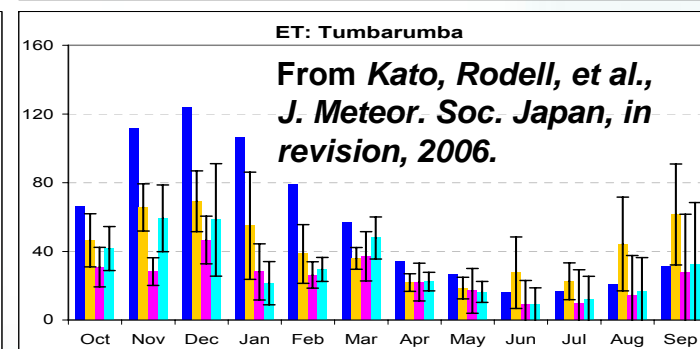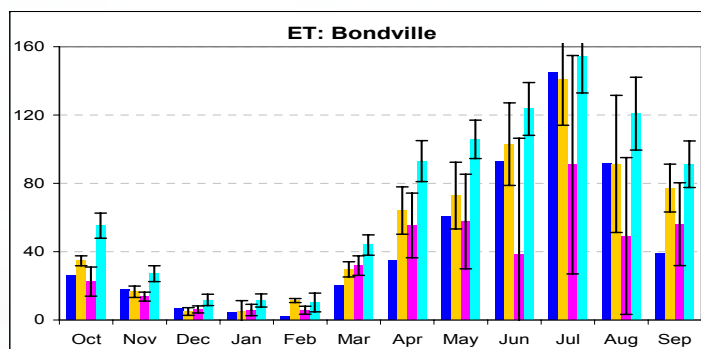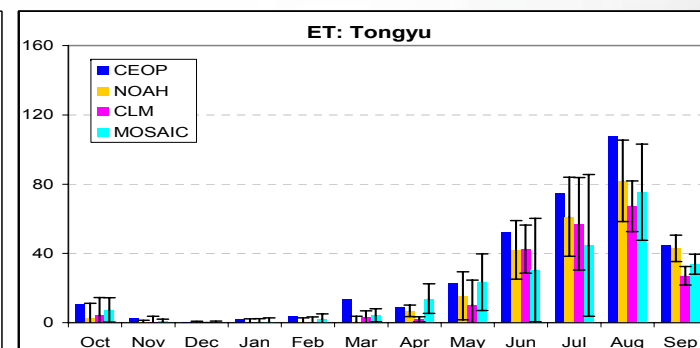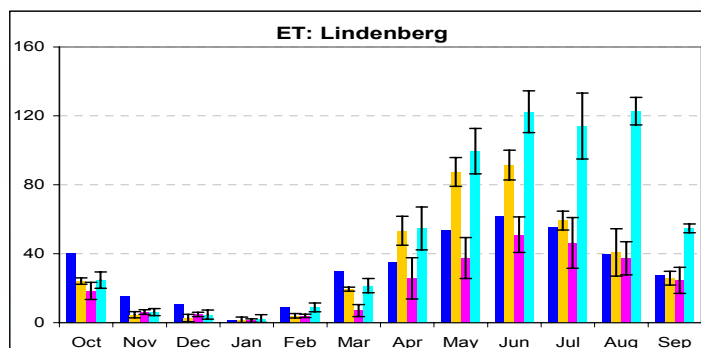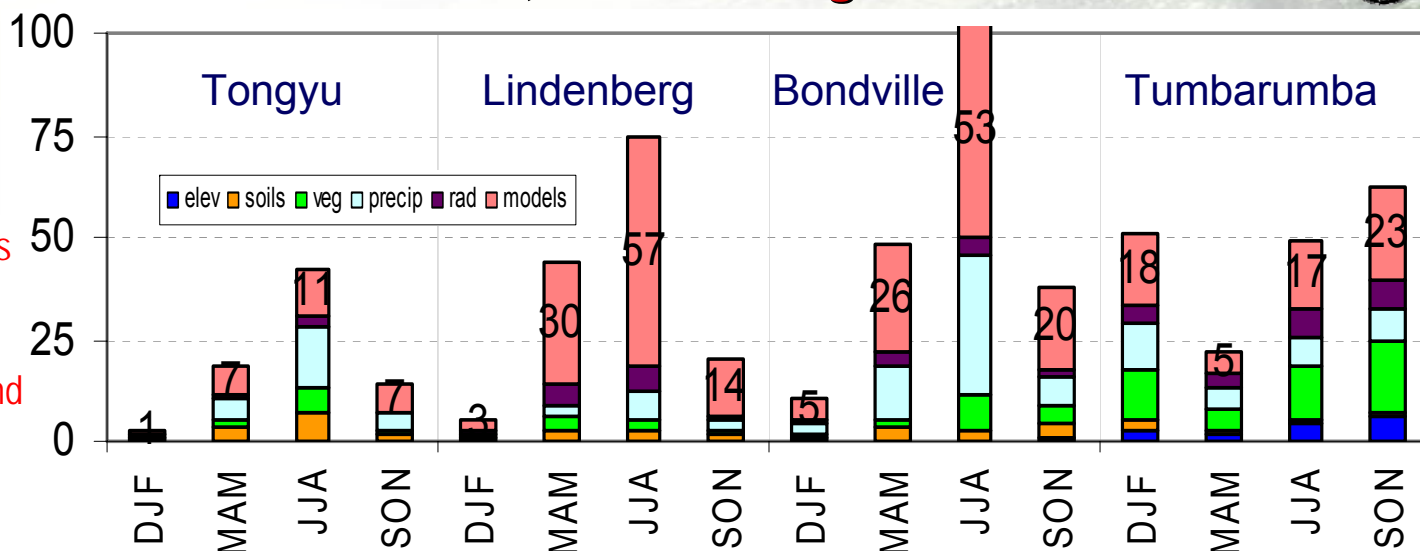
From *Kato, Rodell, et al., J. Meteor. Soc. Japan, in revision, 2006.*

Incorporation of Satellite Derived Irrigation into GLDAS/LIS

· **Extent and intensity of irrigation derived from MODIS satellite observations**

· **Using a rule based approach with crop type data, irrigation is applied within the Noah land surface model, driven by GLDAS/LIS**

· **Preliminary results demonstrate that irrigation significantly effects modeled states and fluxes, including soil moisture, surface temperature, and evapotranspiration**
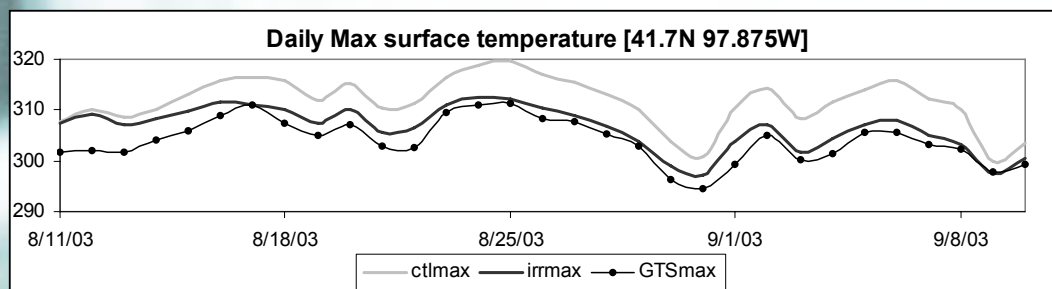
Top right: MODIS derived intensity of irrigation

Right: Percentage difference in evapotranspiration between irrigation and control runs, August-September 2003

Below: Time series of daily maximum surface temperature (K) at an irrigated location from control run (gray line), irrigation run (black line), and observations (dots)
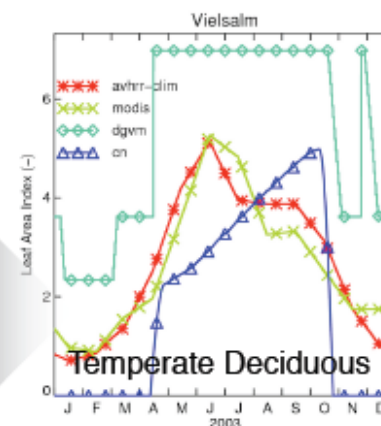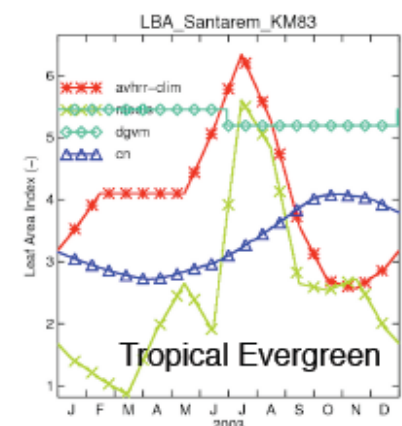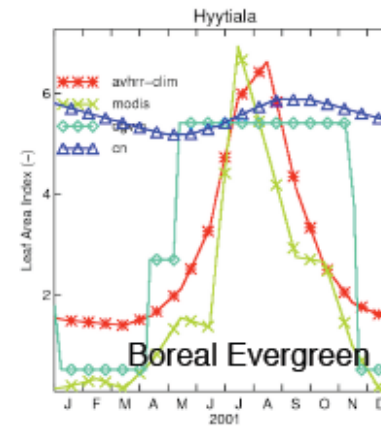

% difference: Aug−Sep
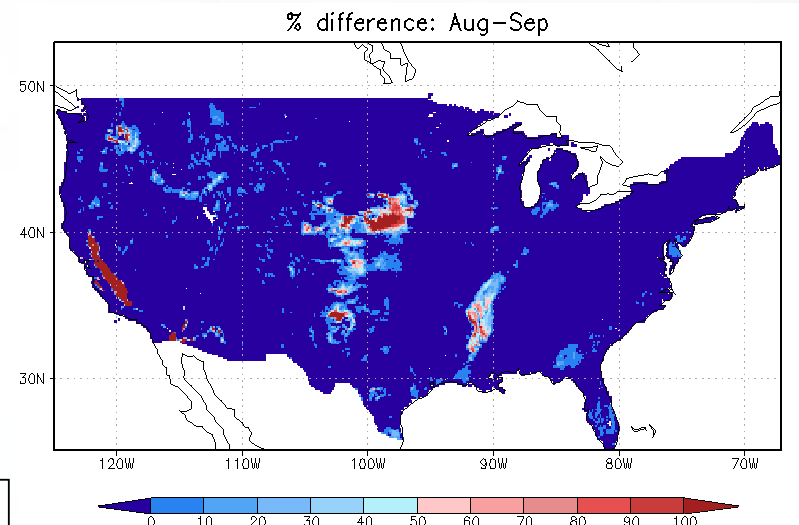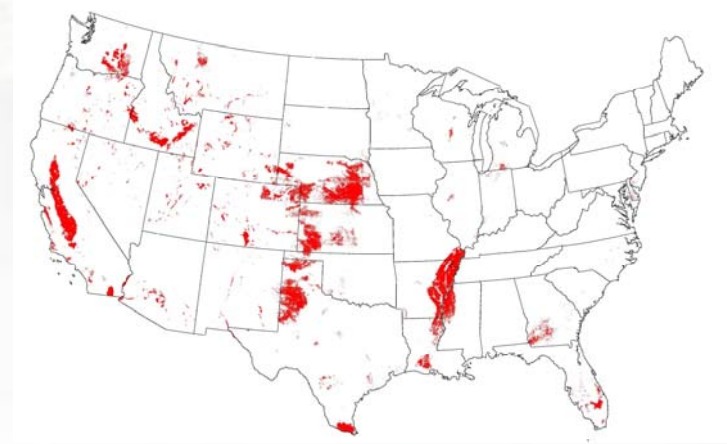
Ozdogan, Rodell, and Kato, in preparation.

Daily Max surface temperature [41.7N 97.875W]

ctlmax — irrmax — GTSmax

Paul R. Houser, Page 50

Matt Rodell
NASA GSFC

A Global Vegetation Modeling System for NEWS

Reto Stöckli, Lixin Lu, Scott Denning (CSU)

Alps Subdomain — Temporal variation of NDVI

Spatial variation of LAI

Hyytiala — Boreal Evergreen

LBA_Santarem_KM83 — Tropical Evergreen

Vielsalm — Temperate Deciduous

CastelPorziano — Mediterranean Evergreen
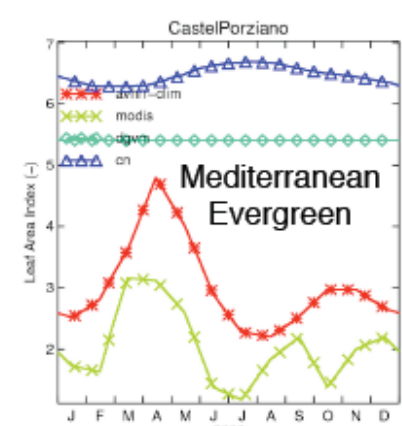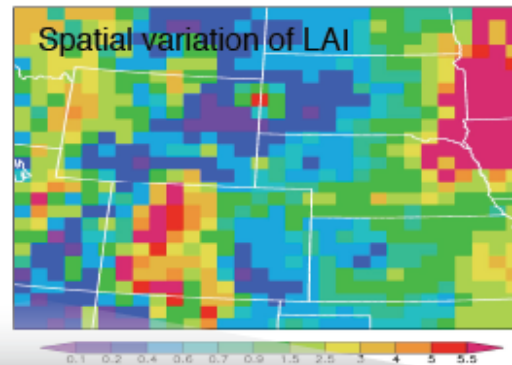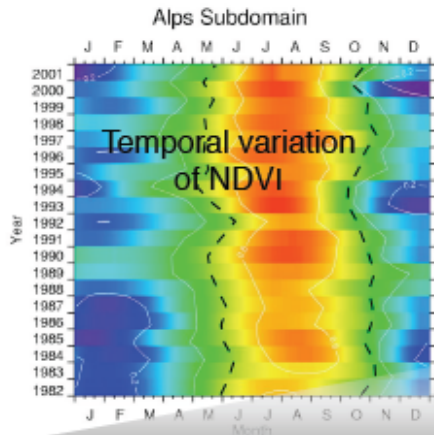
Aim: build a vegetation modeling system which in particular includees capabilities for prognostic vegetation phenology.

Justification: temporal and spatial variability of vegetation phenology is tightly coupled to water and carbon exchanges on the seasonal to interannual scale: needs to be correctly represented in climate models.

Evaluation: the CLM3 prognostic phenology schemes (DGVM/CN) show a good timing in temperate broadleaf forests in comparison to the diagnostic measures from AVHRR and MODIS. Drought-phenology in semi-arid and tropical biomes is more difficult to model. For these climates the satellite VI's also show larger uncertainties.
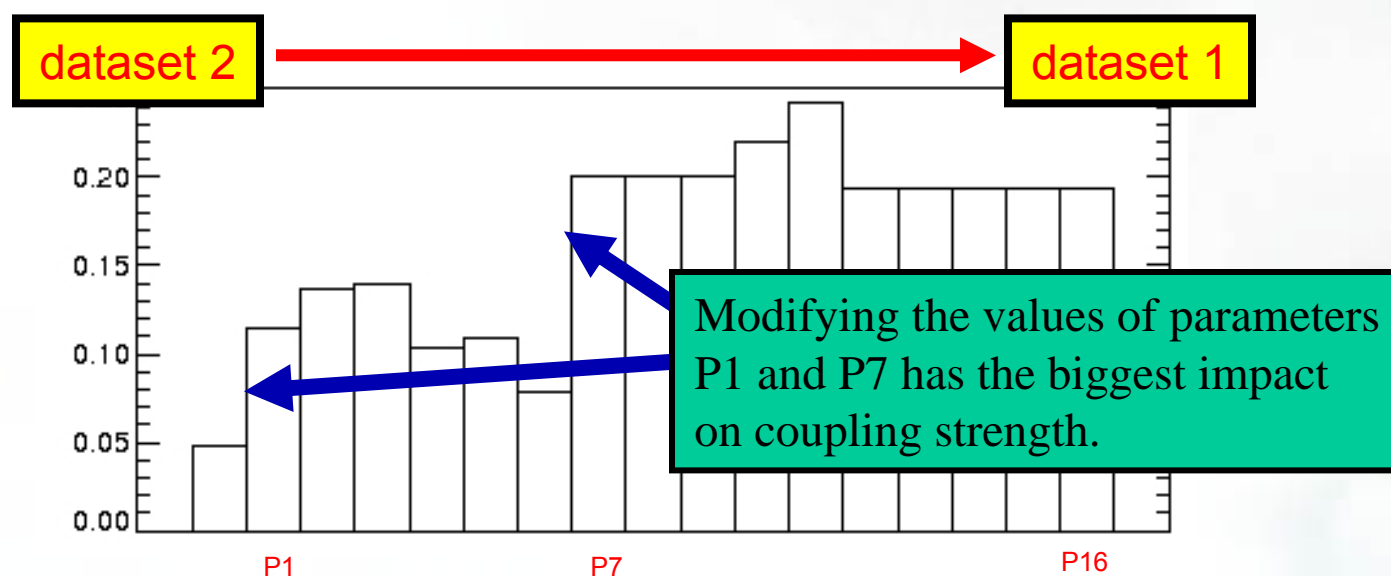

LBA_Santarem_KM83 — Latent Heat Fluxes

LBA_Santarem_KM83 — Sensible Heat Fluxes

LBA_Santarem_KM83 — Net Primary Production
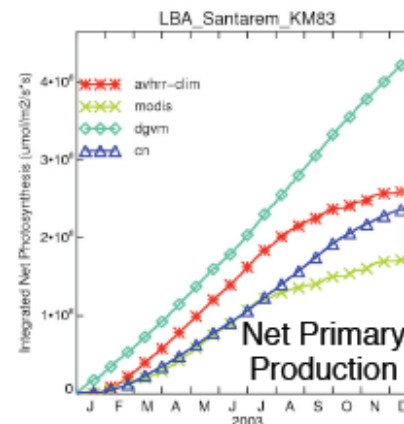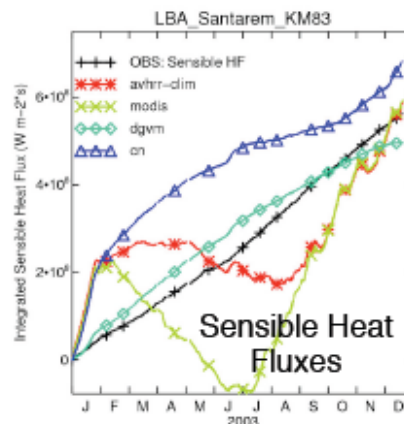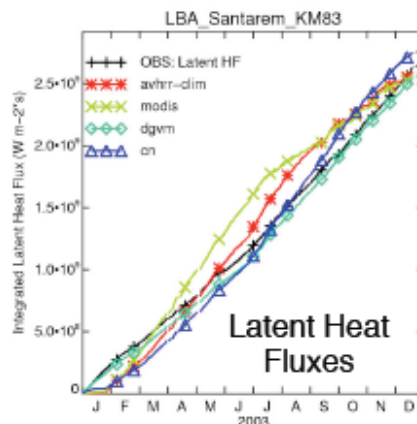
Application: The planned global estimation of generally applicable global phenological model parameters which hold for all vegetation and climate zones will enhance our ability to simulate seasonal and interannual heat, water and carbon exchanges, since these are very sensitive to phenology as our first results show!

Land-Atmosphere Coupling Strength in a Single Column Model Environment

The 16 parameters controlling turbulent and moist processes in the GMAO's GEOS-5 AGCM were modified in sensitivity tests using the single column model (SCM) version of the AGCM. The tests quantified land-atmosphere coupling strength, i.e., **the degree to which soil moisture variations affect rainfall variations.** Sample results:

Ω_P: land-atmosphere coupling strength

dataset 2

dataset 1

Modifying the values of parameters P1 and P7 has the biggest impact on coupling strength.

P1   P7   P16

Thus, in the SCM, coupling strength is controlled mostly by:

P1: *Relative humidity threshold for formation of cloud liquid water.*

P7: *Scale factor describing the treatment of subgrid temperature variability when testing for the onset of convection.*

The control of these parameters on coupling strength is now being tested in the AGCM itself.

Mass Changes in Earth's Global Water Reservoirs from GRACE
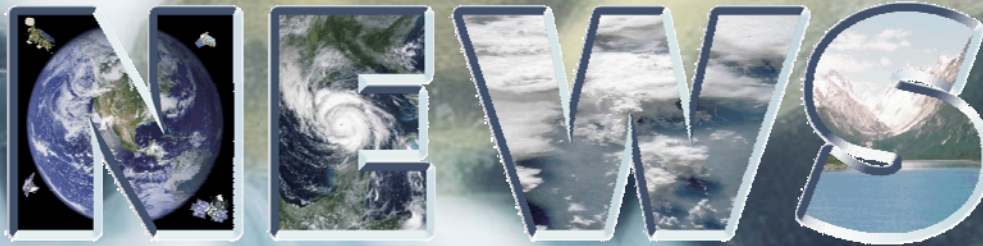
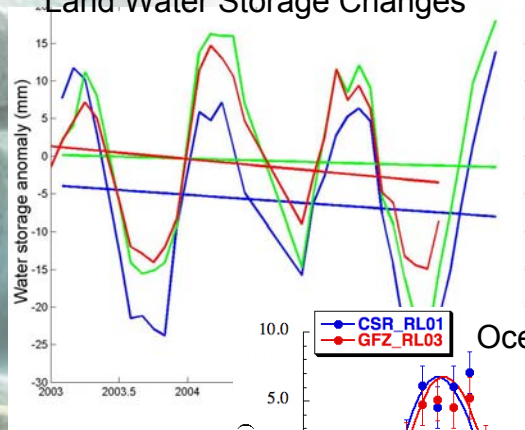J. Famiglietti, University of California, Irvine
D. Chambers, University of Texas at Austin
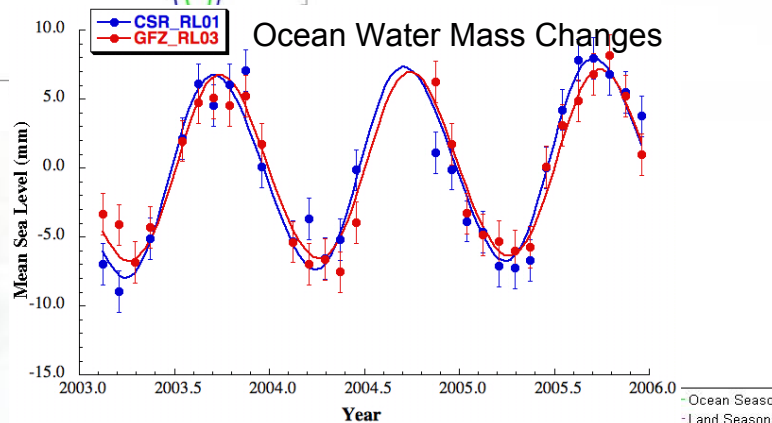S. Nerem, University of Colorado, Boulder
I. Velicogna, Jet Propulsion Laboratory, California Institute of Technology and University of Colorado, Boulder
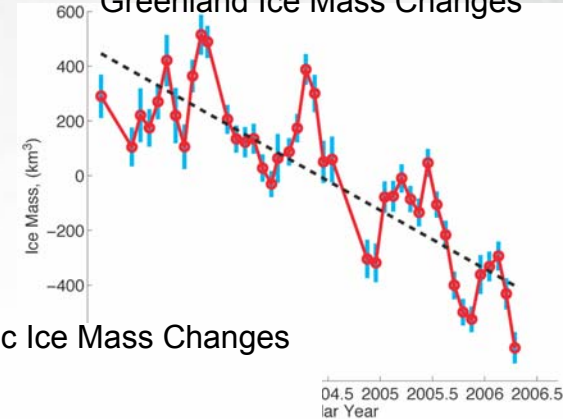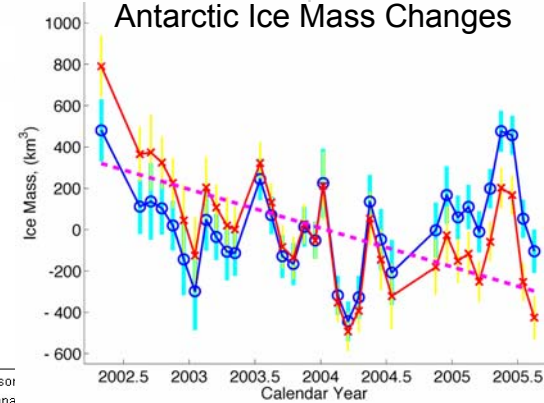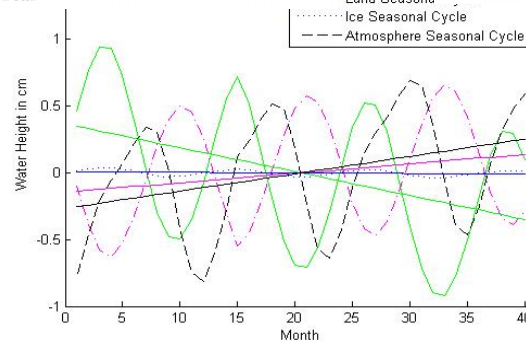F. Frappart, University of California, Irvine

NASA ENERGY AND WATER CYCLE STUDY
NEWS

NEWS Challenge:
Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.

Status:

- Revised Implementation Plan Posted: http://wec.gsfc.nasa.gov
- 2nd annual NEWS PI Meeting
- 20+ Investigations underway, results being produced

- Now it is time to start integrating, and addressing the NEWS implementation steps!