An updated view of global water cycling

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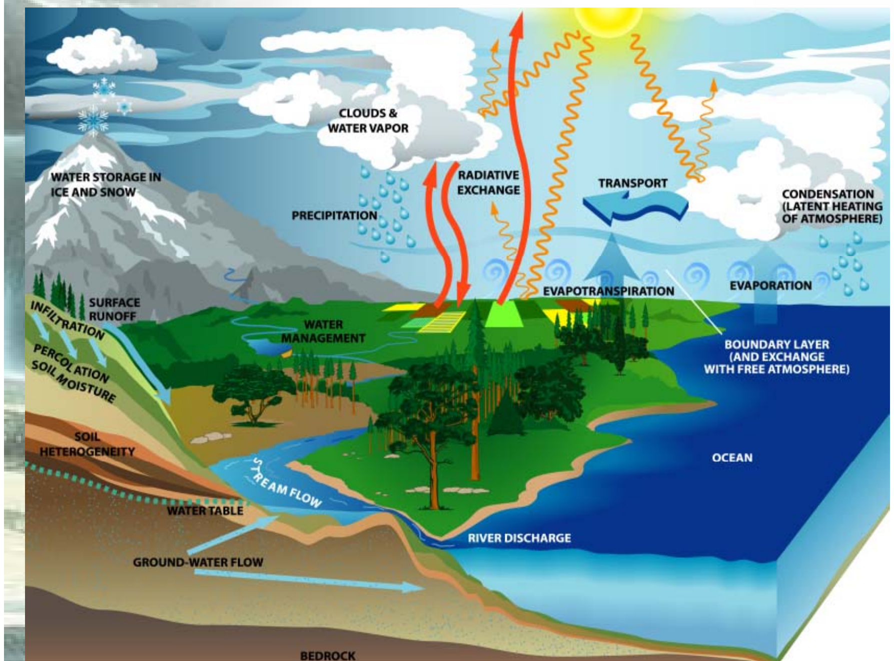
http://crew.iges.org

The Water and Energy Cycle



Water in the climate system functions on <u>all</u> time scales: From hours to centuries

Why study the water & Energy cycle?

1. *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*
2. *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*
3. *Water is the ultimate solvent and global biogeochemical and element cycles are mediated by the dynamics of the water cycle*
4. *Water is the element of the Earth system that most directly impacts and constraint human society and its well-being.*

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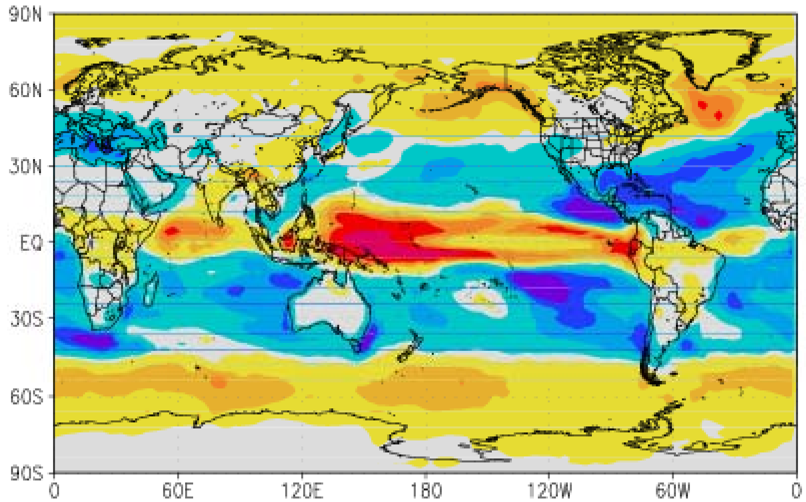
Multi-model ensemble mean change from IPCC GCMs

NEWS (Soden)

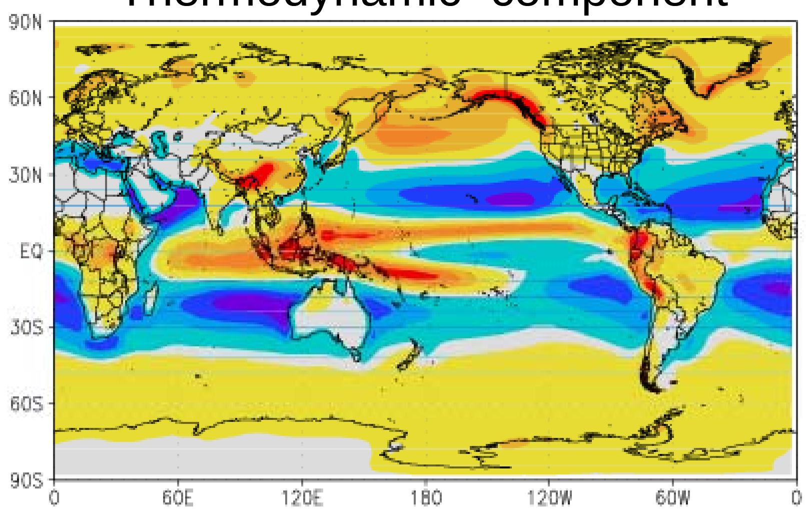
Change in (P-E) for 2100 minus 2000

"Dry regions get drier, wet regions get wetter"

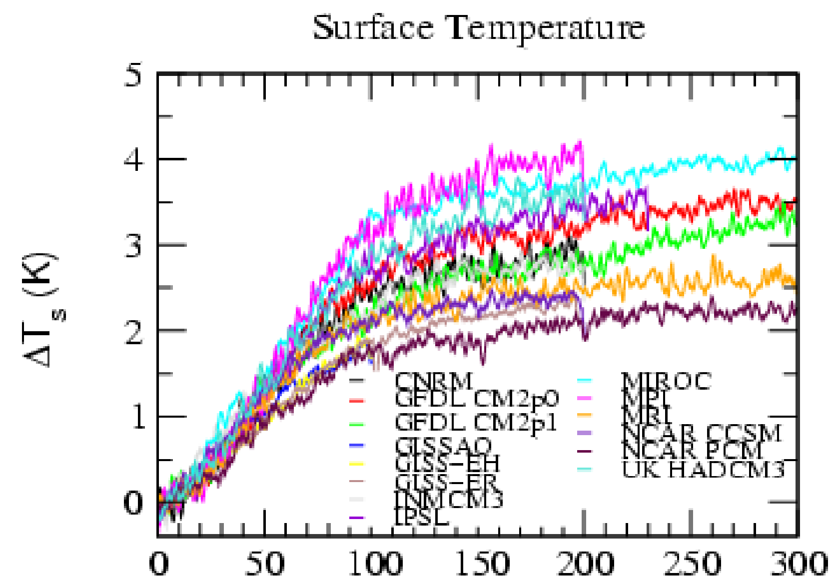


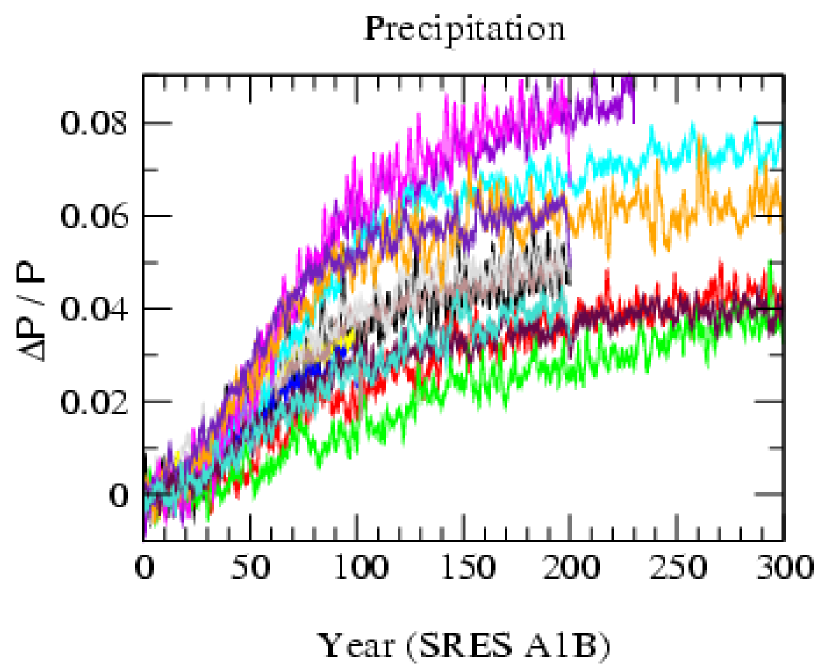
Held and Soden (2006)

"Thermodynamic" component



Δ(P-E) mm/day



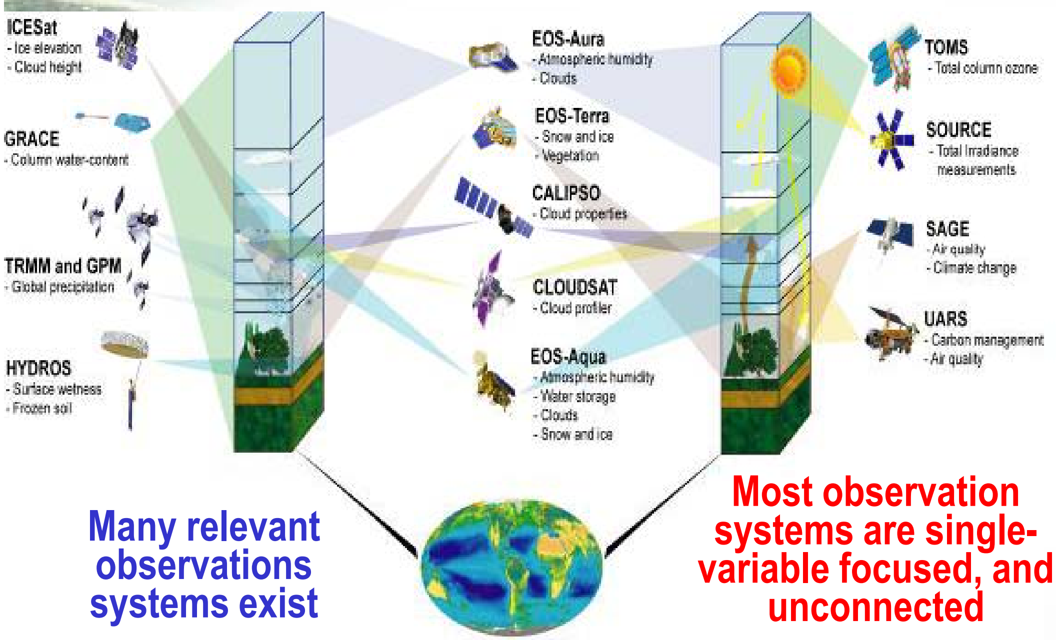


Vecchi and Soden (2007)

Objective

Summary: Integrate legacy global water and energy (W&E) cycle data sets and construct/splice the state-of-the-art W&E climatology; understand the global W&E variations at annual and longer time scales.

Hypothesis: Observationally-based estimates water and energy fluxes can be balanced and provide useful characterizations and evaluation data for climate studies and modeling.



Science Questions:

- Do observations provide a consistent depiction of global energy and water cycling?
- What are the observational uncertainties, and are they “useful” for evaluation?
- What basic processes can be resolved and characterized by the integrated data sets?
- How do we test weather/climate models using these integrated W&E observations?
- Why do the water and energy budget terms not balance? Are there algorithms and/or assumptions at play?

Data and Methods

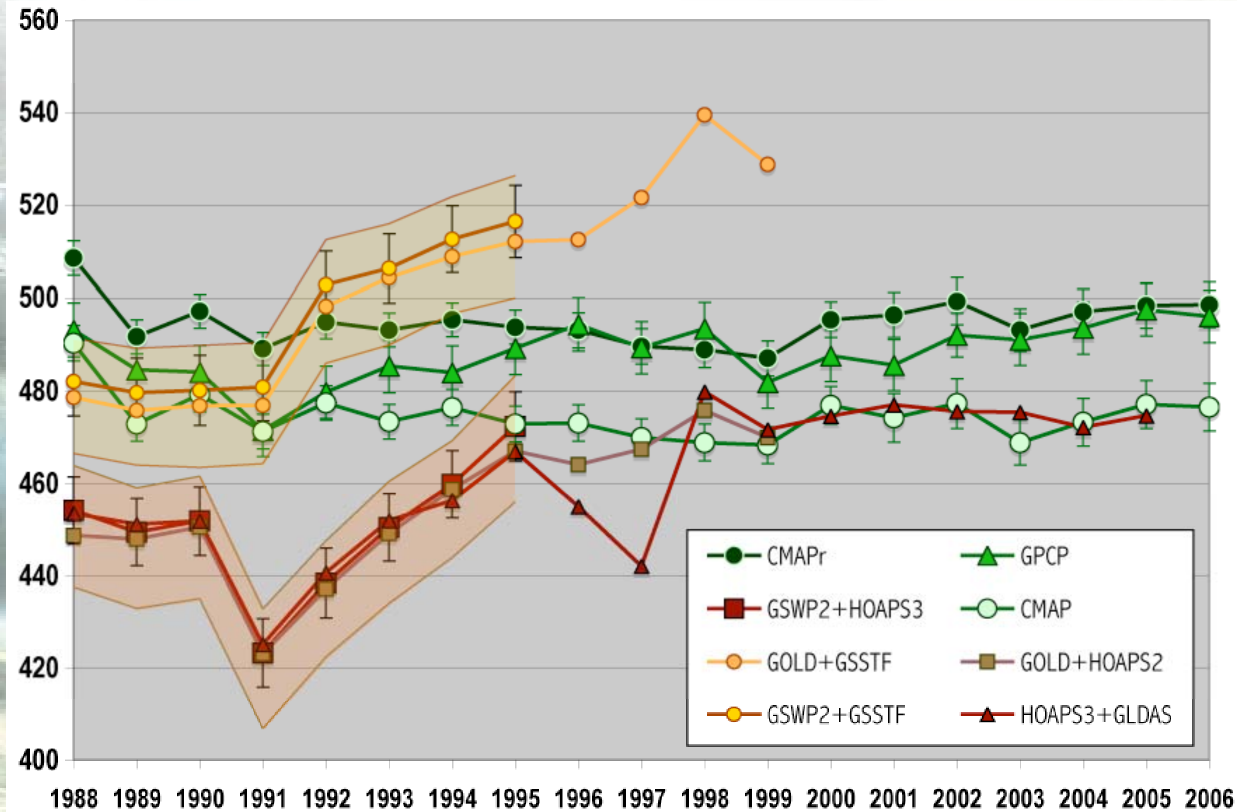
Extended Analyses (of Schlosser and Houser, J. Climate, 2007)

Fluxes	Product	Spatial	Temporal	Source & Primary Contact(s)
Precipitation	TMPA	60S ~ 60N; 180W ~ 180E (0.25°)	12Z29Jan2002 ~ present (3hr)	trmmopen.gsfc.nasa.gov (George J. Huffman)
	CMORPH	60S ~ 60N; 180W ~ 180E (0.25°)	00Z07Dec2002 ~ present (3hr)	ftp.cpc.ncep.noaa.gov (Robert Joyce & John Janowiak)
	PERSIANN	50S ~ 50N; 180W ~ 180E (0.25°)	00Z01Mar2000 ~ present (6hr)	hydis8.eng.uci.edu (Kuolin Hsu & Dan Braithwaite)
Evaporation	GLDAS (Land)	60S ~90N; 180W ~ 180E (1°)	Jan1979 ~ Aug2006 (Monthly)	hsbserv.gsfc.nasa.gov (Matthew Rodell)
	HOAPS (Ocean)	80S ~ 80N; 180W ~ 180E (1°)	00Z01Jan1987 ~ 12Z31Dec2005 (12hr)	www.hoaps.zmaw.de (Axel Andersson)
Storage	AIRS-AMSRE (Atmosphere)	90S ~ 90N; 180W ~ 180E (1°)	00Z01Jan2005 ~ 21Z31Dec2005 (3hr)	JPL (Eric Fetzer and Van Dang)
	GRACE (Terrestrial)	90S ~ 90N; 180W ~ 180E (1°)	CSR: Aug2002 ~ Dec2006 GFZ&JPL: Feb 2003 ~ Nov 2006 (Monthly)	podaac.jpl.nasa.gov (Don Chambers and Jay Famiglietti)
Moisture Transport	MOIS_TRANS	30S-30N; 180W-180E (0.5°)	07Jul1999 ~ 31Dec2005 (daily)	airsea.jpl.nasa.gov (Timothy Liu & Xiaosu Xie)

Atmospheric Budget: $dQ/dt = E - P - div(Q_t)$

Terrestrial Budget: $dS/dt = P - E - R$

Global Results: 1988-2001

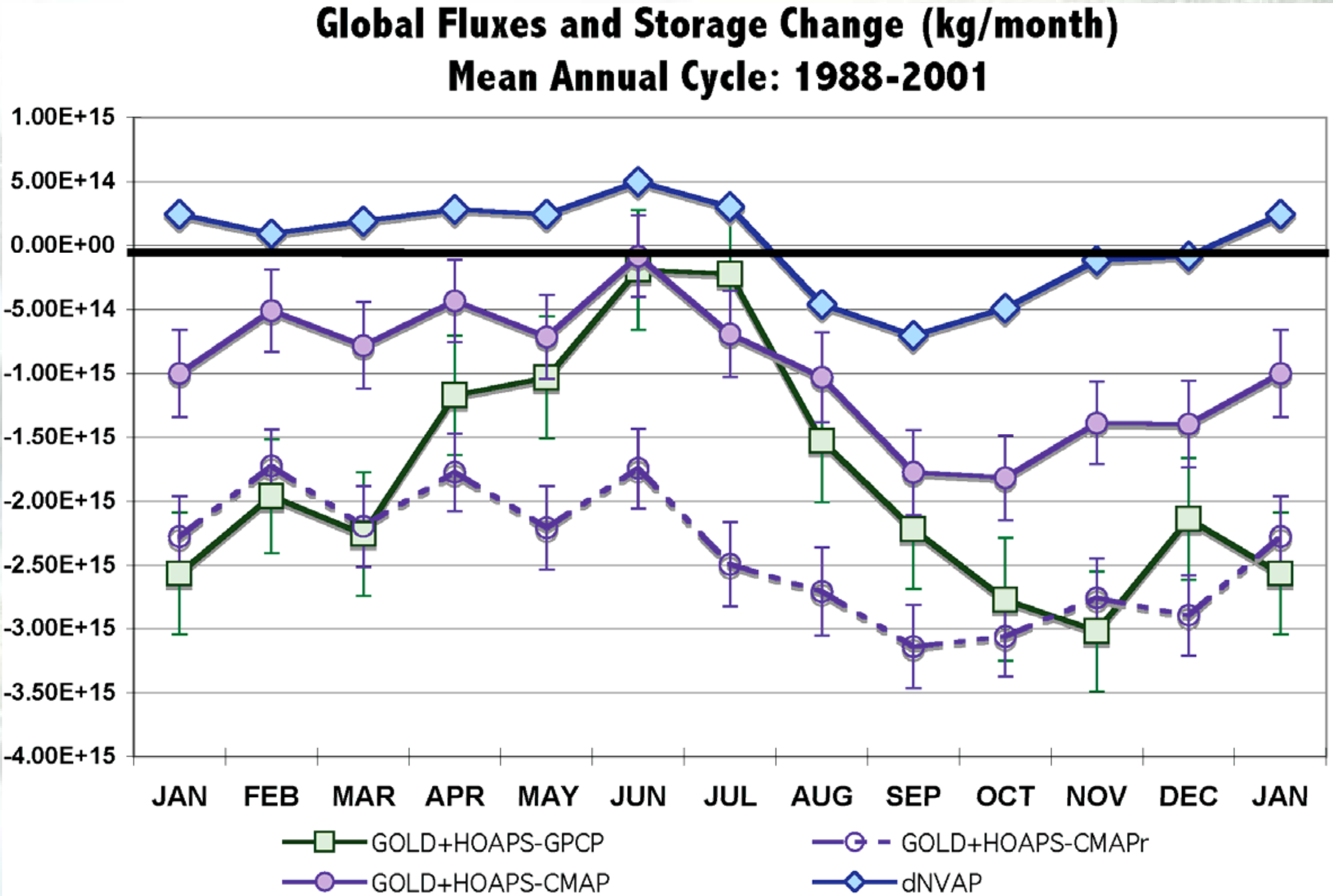


	GPCP	CMAP	CMAPr	HOAPS & GOLD
Land	1.07±0.02	9.98±0.01	1.00±0.01	0.684
Ocean	3.79±0.06	3.74±0.04	3.94±0.04	3.95
Global	4.86±0.06	4.75±0.04	4.94±0.04	4.63

Table 1. Global annual mean results of water budget terms for the period 1988-2001. Values are given in units of 10^{17} kg/yr.

- HOAPS (still) shows trend and Pinatubo plunge.
- GPCP/CMAP(r): The good, the bad, and the "split"
- Latter half of period, fluxes converging, really?
- Trend detection - need long monotic trend to verify GCMs (for low-risk detection).

Global Mean Annual Cycles of Atmospheric Budget



- Most regions - land evaporation peaks in summer, ocean evaporation in winter.
- Annual cycle of global water vapor storage reflects the Northern Hemisphere signal.

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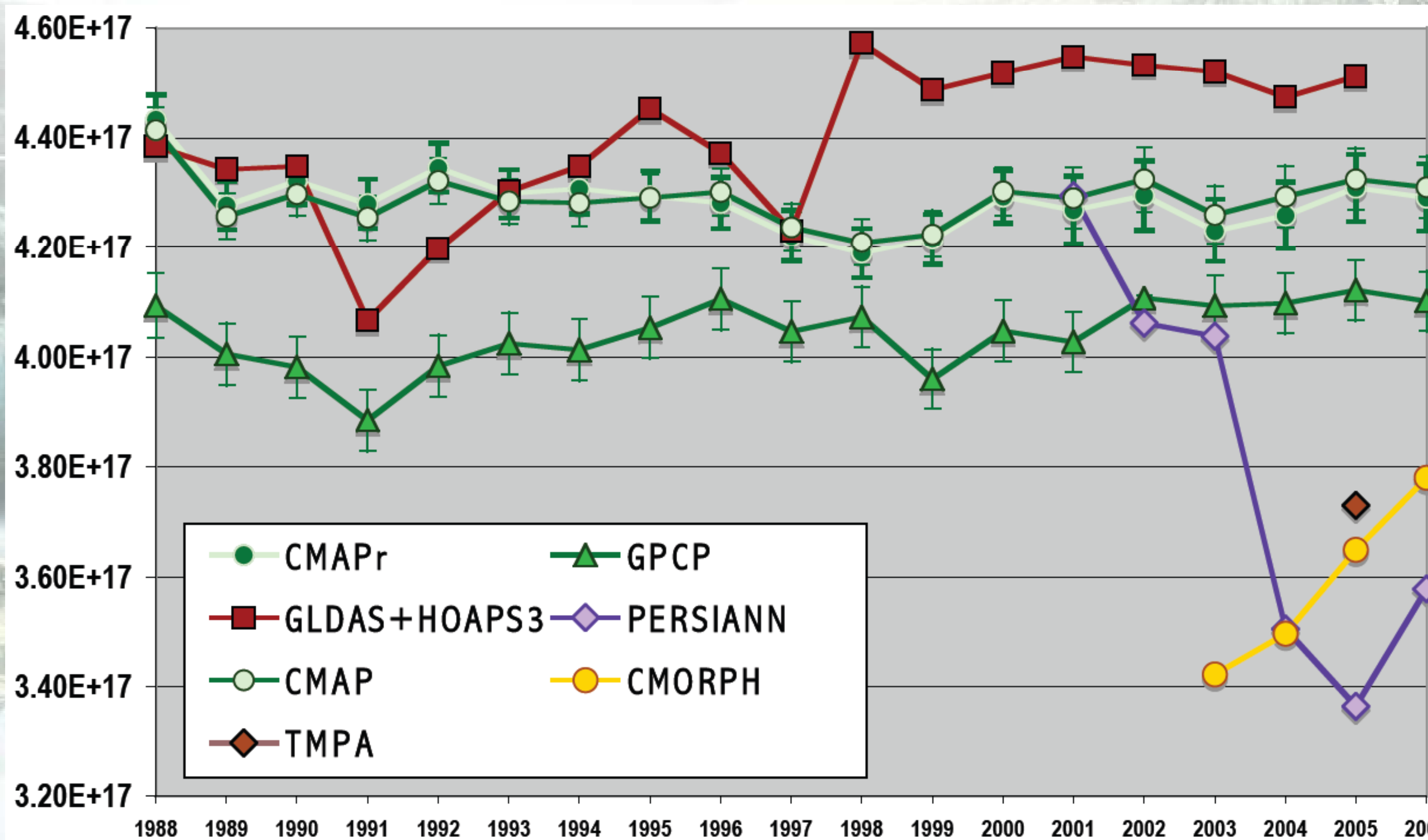
"Global" (50S-50N) Annual Timeseries of Legacy and Next-Generation Precipitation



Not much consistency seen between legacy and next-generation estimates at the global scale... for now.

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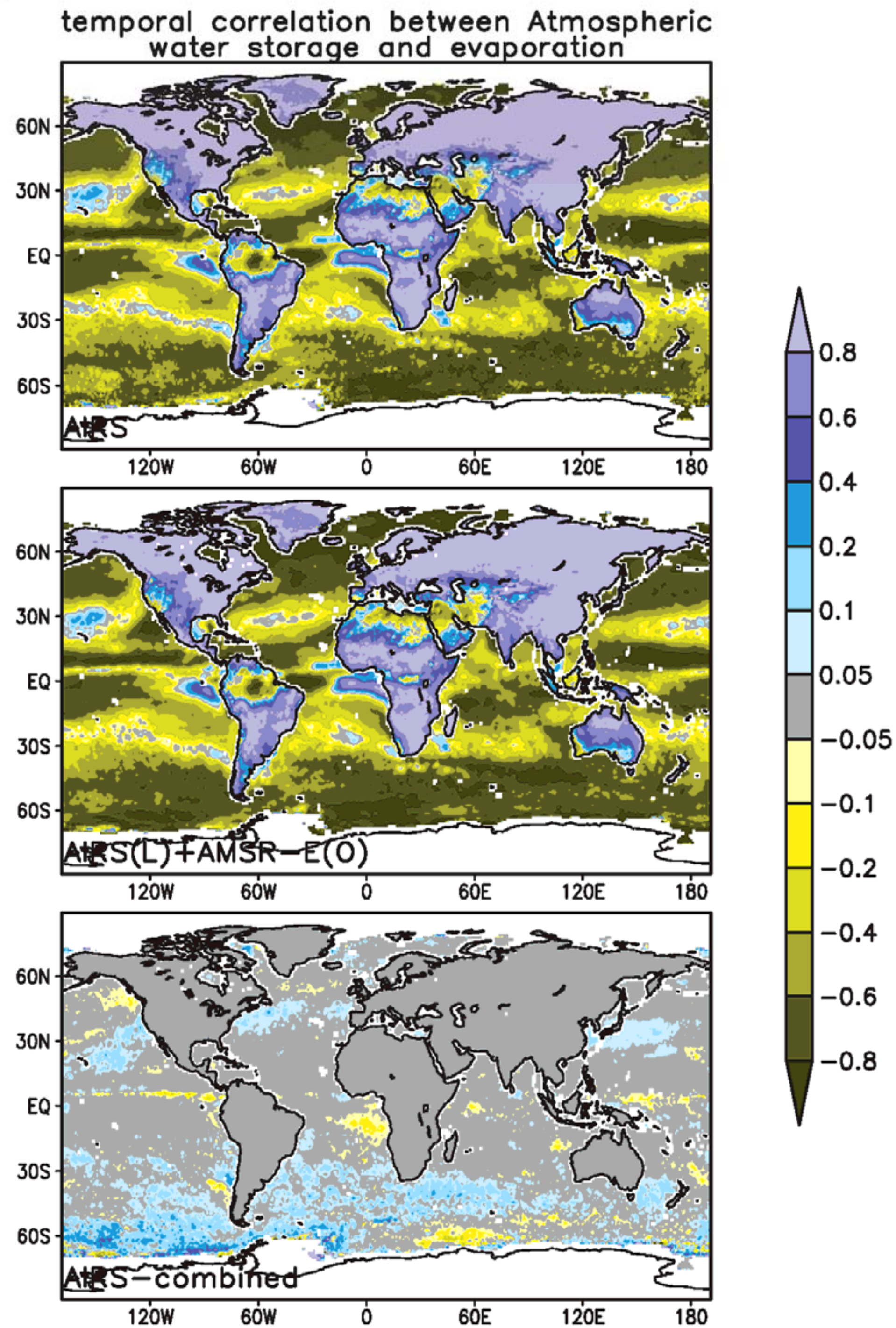
Atmospheric Water Storage

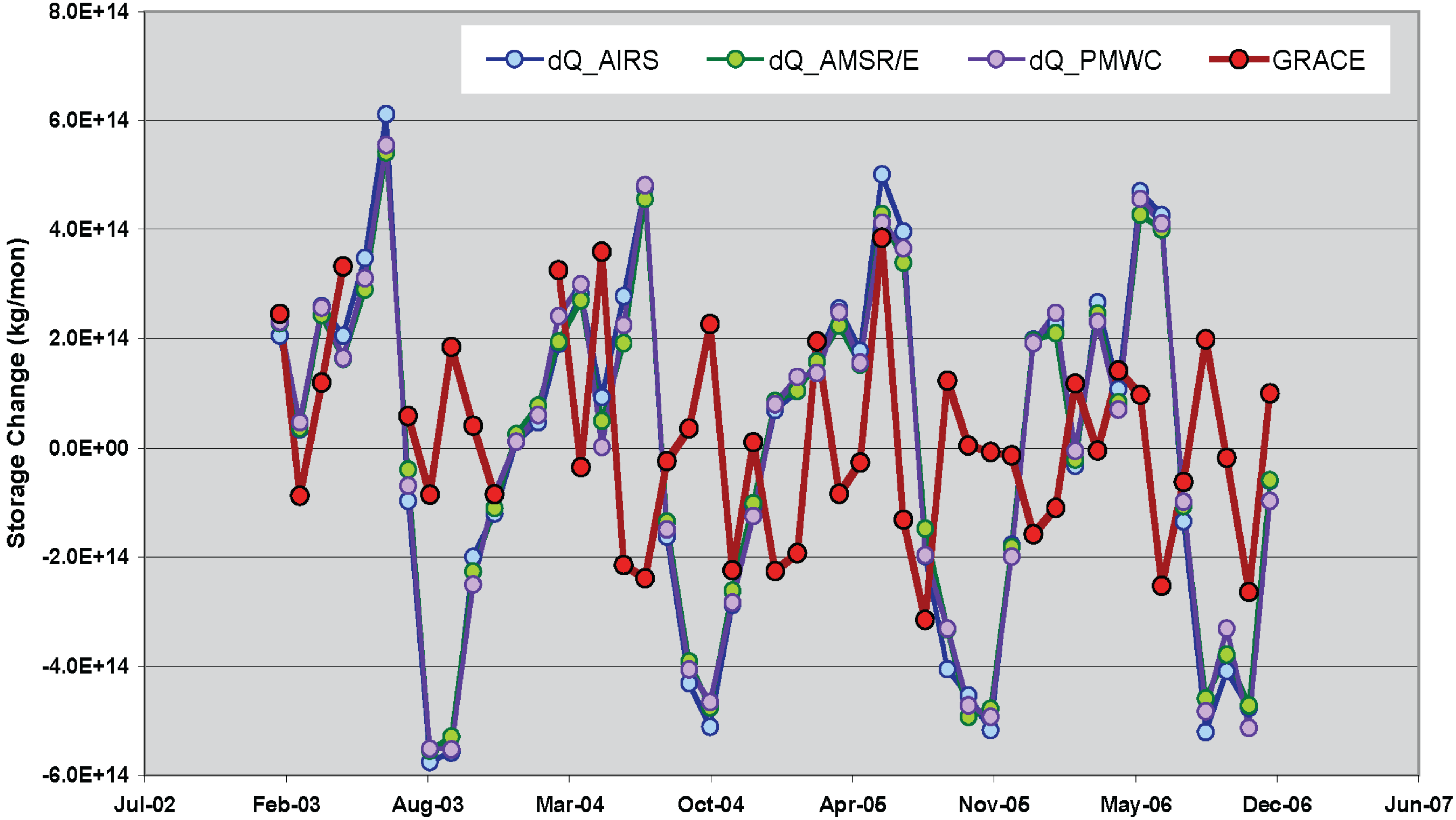


Most land regions - evaporation positively correlated with atmospheric vapor.

Most ocean regions - correlation is largely negative. Due to bulk evaporation formula driven by winds, which are high in winter.

These characterizations, although weakened somewhat, also hold if "annual cycle" of period removed.

Consistency between Atmospheric Storage and Surface (Land+Ocean) Storage?



$$\Delta Q_{LAND} + \Delta Q_{OCEAN} + \Delta Q_{ATMOS} = 0$$

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Terrestrial Water Storage Change

A: GRACE

$$\Delta \overline{S} = d_{mn} - d_{mc}$$

d = anomaly of monthly mean equivalent water thickness

B: GLDAS_der

$$\Delta \overline{S} = \overline{S}_{mn} - \overline{S}_{mc} = \frac{1}{N}\sum_{i=1}^{N}(S_{mn,i} - S_{mc,i})$$
$$= \frac{1}{N}\sum_{i=1}^{N}\sum_{j=i}^{N+i-1}(P_j - E_j - R_j)$$

C: GLDAS_dW

$$\Delta \overline{S} = \overline{W}_{mn} - \overline{W}_{mc}$$

W = monthly mean of sum of soil moisture in all soil layers, accumulated snow water equivalent, and plant canopy surface water.

D: GLDAS_dW01

$$\Delta \overline{S} = W_{mn\ 01} - W_{mc\ 01}$$

W = Sum of soil moisture in all soil layers, accu-mulated snow water equivalent, and plant canopy surface water at 1st day of each month .

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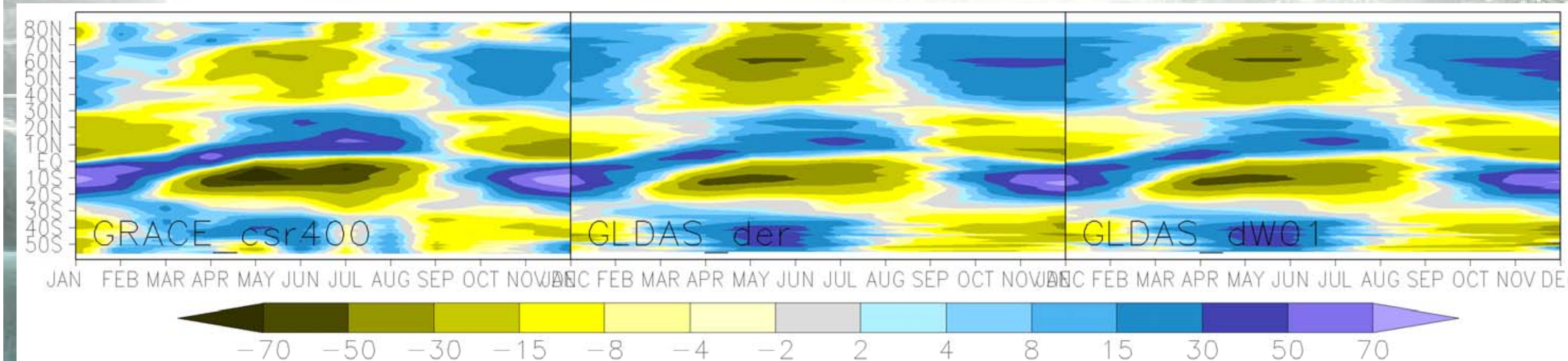
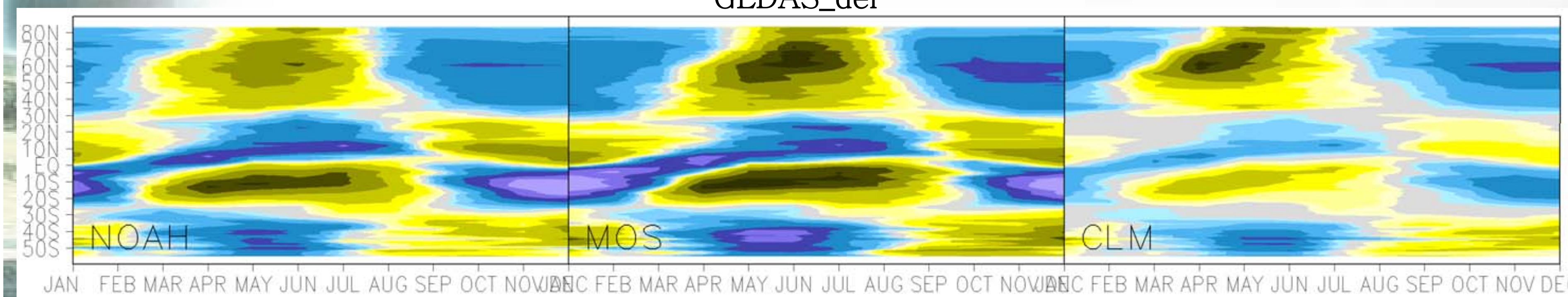
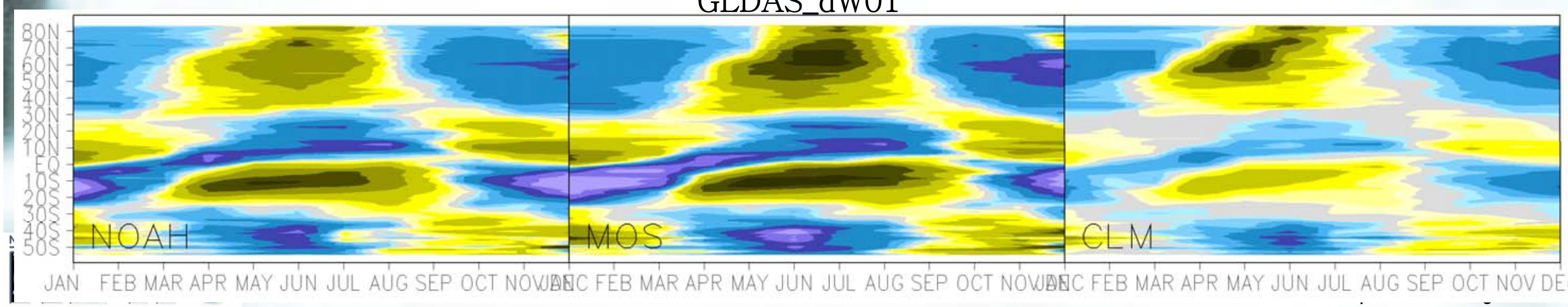
terrestrial water storage change (mm/mon)



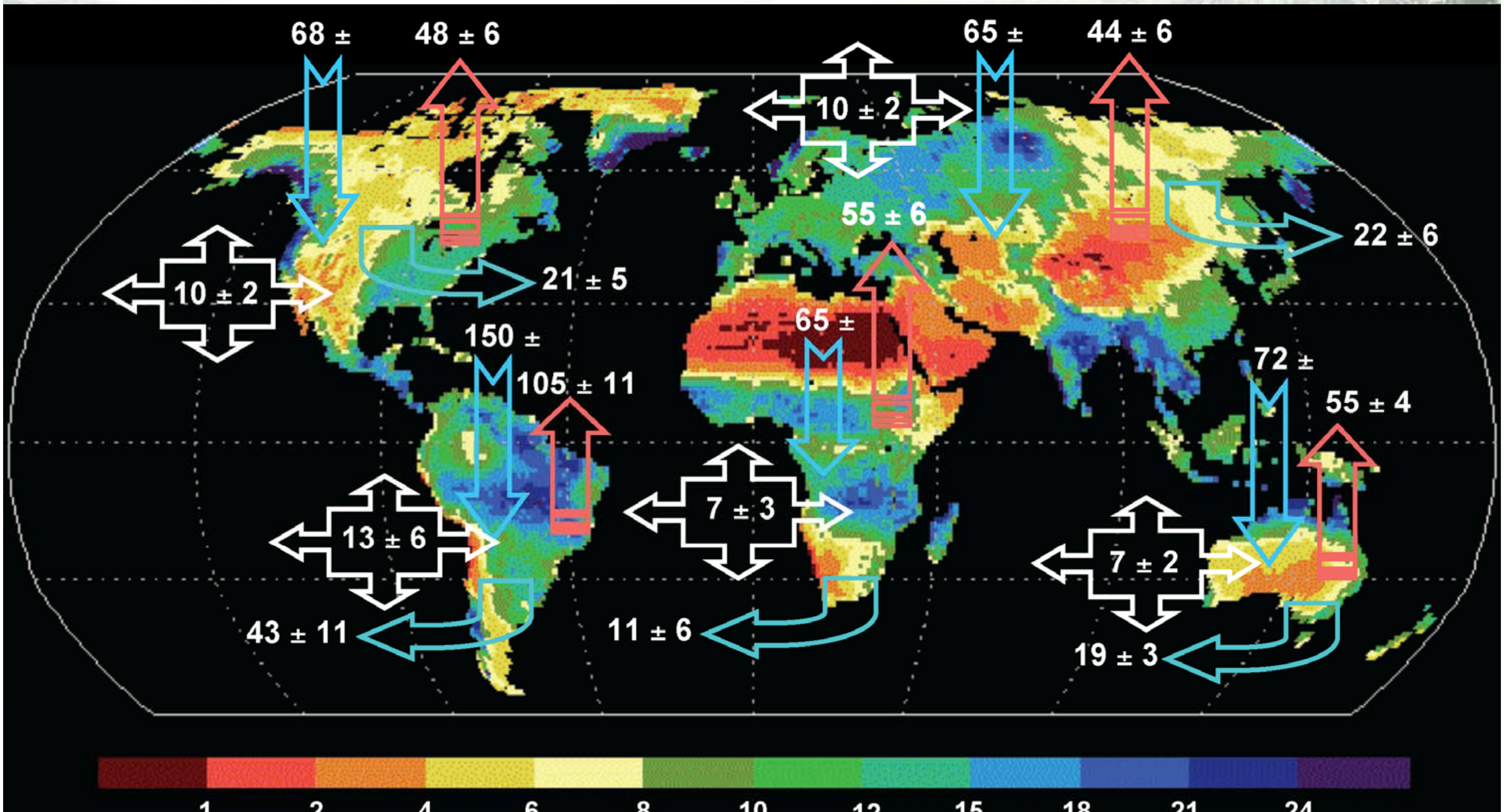
GLDAS_der



GLDAS_dW01



GLDAS-based continental water balance



Annual mean precipitation (GPCP/CMAP), evapotranspiration, runoff, and terrestrial water storage amplitude (range/2) by continent, as equivalent heights of water (cm = 10 kg/m2) based on 1979-2007 output from four GLDAS-driven models: Noah, VIC, CLM2, and Mosaic. Map shows terrestrial water storage amplitude (cm).

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Rodell et al., 2008

Summary

- Annual global precipitation and evaporation are close to balance - with uncertainty.
- Ocean evaporation estimates still show unconfirmed trend.
- Next generation, high resolution precipitation data need work.
- The derived water vapor convergence from AIRS and AMSR-E demonstrates strong spatiotemporal consistency with each other.
- The terrestrial water storage change derived from GLDAS compares quite well with GRACE observations in terms of spatial pattern and seasonal variations, but their magnitudes show notable differences.
- Energy balance estimates are mature, and need integration with water balance analysis.

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