The NASA Energy and Water Cycle Climatology (NEWCC) Integration Project

C. Adam Schlosser, Bing Lin, and the NEWCC Team*

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Scientific Impetus

Under the integrating auspice of NEWS...

- ***Global water and energy cycle/system***:
  - If we say we measure “globally” we should be held accountable.
  - Do “all datasets” show ***consistency*** across fluxes, storages/states, and spatiotemporal scales?
- ***Document uncertainties and refine irregularities***:
  - Bias/error: No gold standard - must leverage off balance and ***consistency*** assessments.
- Observations and models evaluated accordingly.
- Can observations and models faithfully depict extremes and trends?...that’s for another NEWS integration project.

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NEWCC Strategic Framework

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:

To what extent do our global observations provide a *consistent depiction* of the inter-seasonal to inter-annual variations of global energy and water cycling?

What are the *errors/uncertainties* associated with these integrated observations, and do these characterizations therefore provide "useful" information for evaluation?

What basic *processes* of atmospheric and oceanic general circulations can be *resolved and characterized* by the integrated data sets?

How do we test weather/climate models using these integrated W&E data sets (i.e. *metrics*)?

Why do the water and energy budget terms not balance? Are there algorithms and/or assumptions at play?

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NEWCC "Phase 0" Plan

Data:

- Assemble data for the 2003-05 time period (at least).
- Provide zonal averaged profiles at (minimum) resolution of 2.5 degrees.

Metrics:

- 3-year annual mean
- Mean annual cycle (at least monthly)
- Provide error estimates

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

$$\frac{dQ}{dt} = E - P - div(Q_T)$$

Results from could/should support and lead to:

- Consistency check of heat/moisture divergence
- Cross-evaluation of surface evaporation, precipitation, and storage
- Radiation, heat storage and other heat terms for energy conservation

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Data Compilation for NEWCC Phase "0" (2003-2005 at least)

Precipitation: GPCP product; with help from CMAP and PMWC (from RSS)

Evaporation:

- HOAPS Version 3: ocean evaporation estimates; with help from estimates from RSS (Wentz and Hilburn)
- GLDAS: Global Land Data Assimilation System; with a little help from Global Soil Wetness Project Phase 2 (GSWP2)

Water Storage:

- AIRS/AMSR-E: Infrared and microwave retrievals; with help from PMWC (RSS).
- GRACE: Land and ocean water storage changes based on gravity observations.

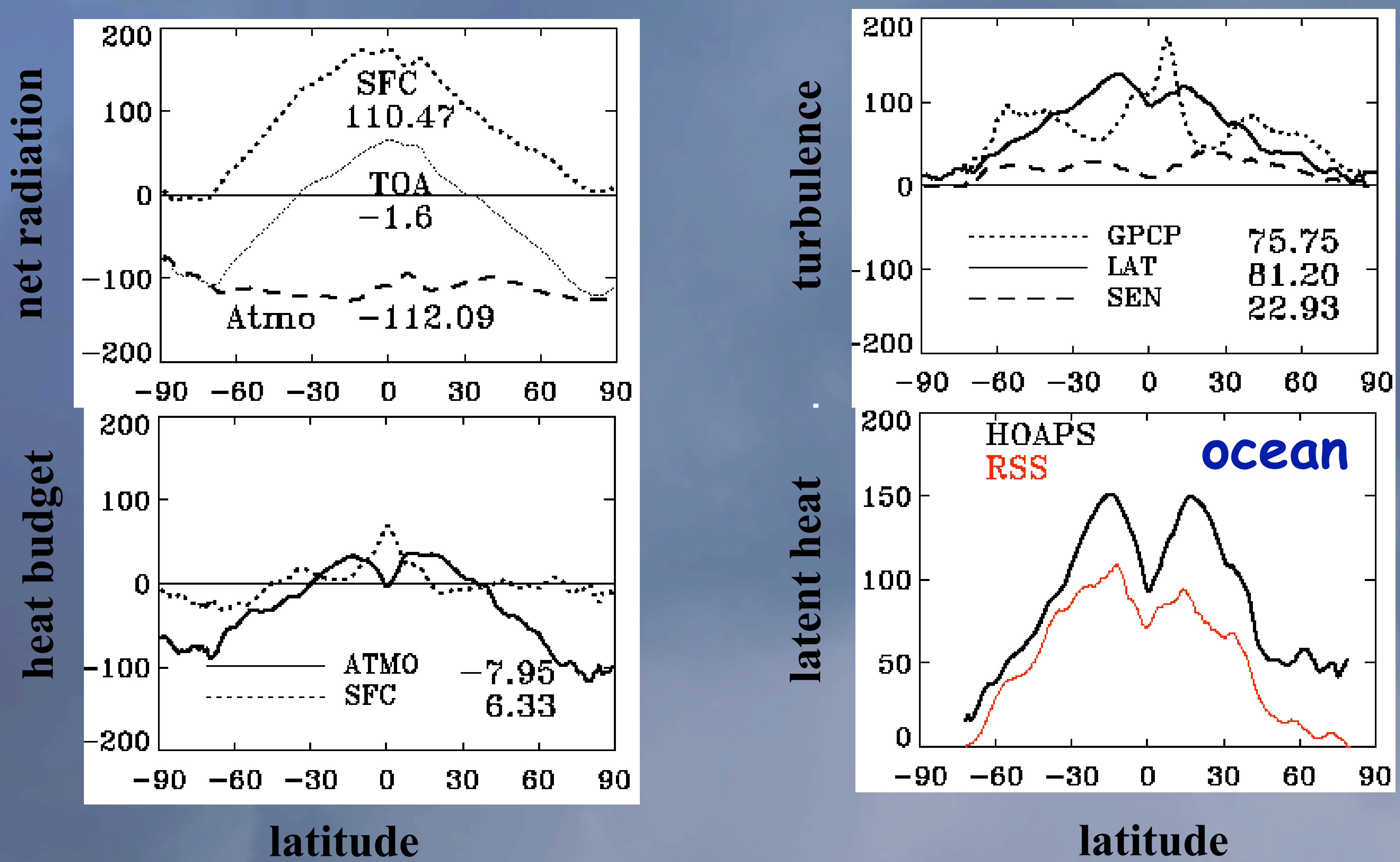
Surface Radiation: Surface Radiation Budget (SRB)

TOA Radiation: ERBS, CERES and ISCCP-FD

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)

Energy/Heat Budget Assessments

Atmos. heat budget (2003)

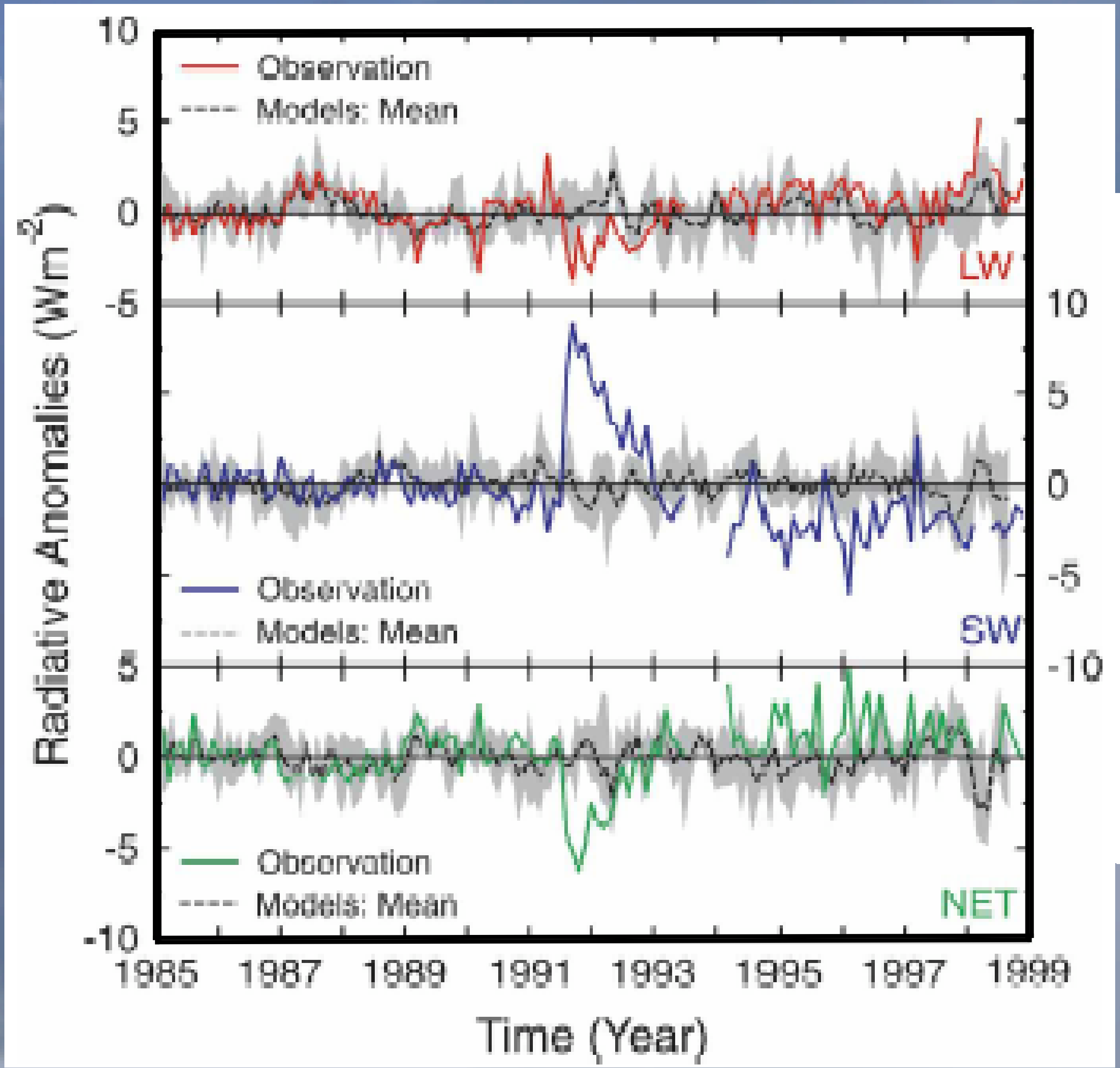


unit: W/m² HOAPS, MOSAIC & SRB used in balance

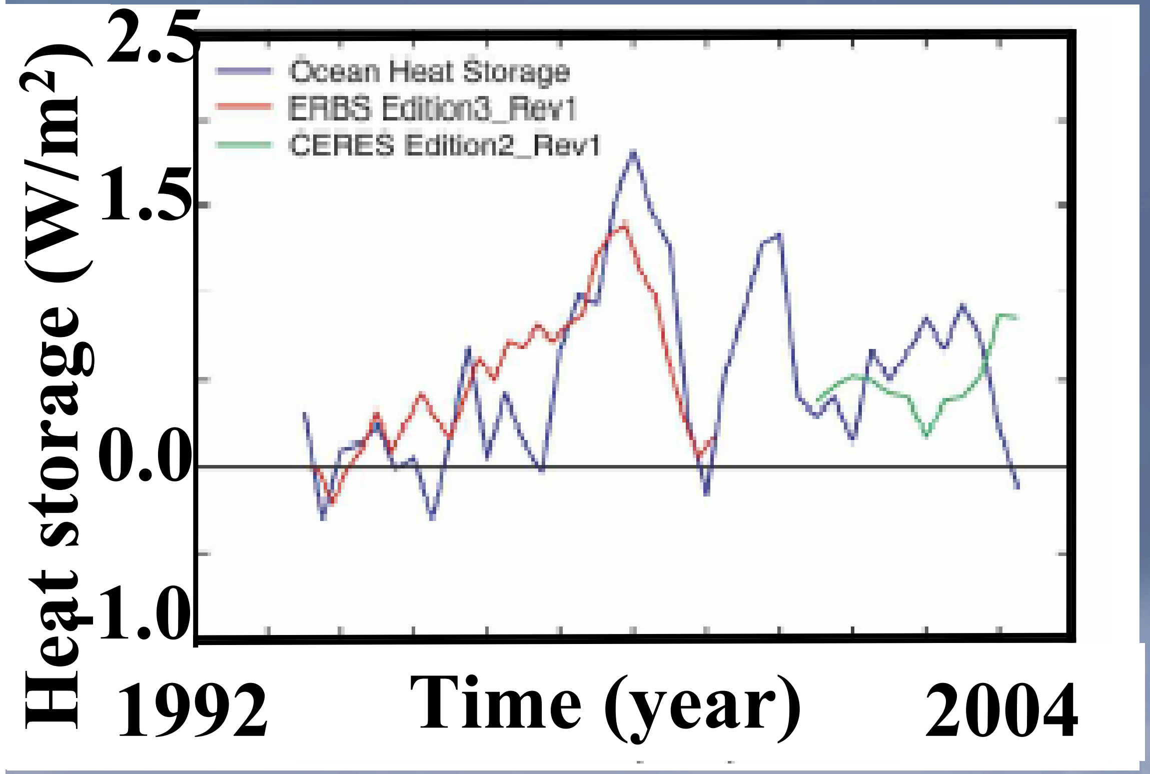
Energy/Heat Assessments

Satellite data records

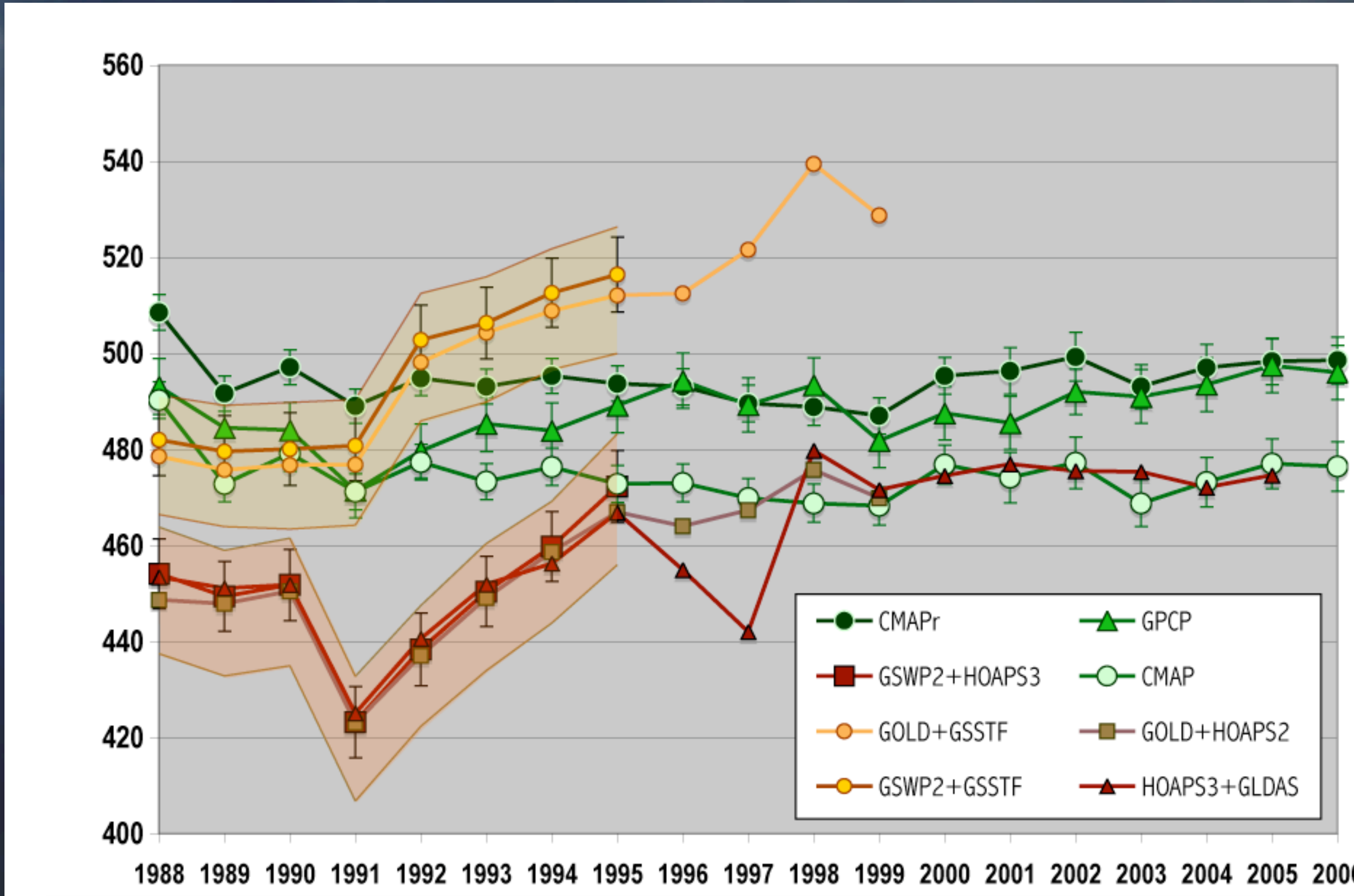
shaded: model range



Ocean heat storage vs Radiation ERBS & CERES



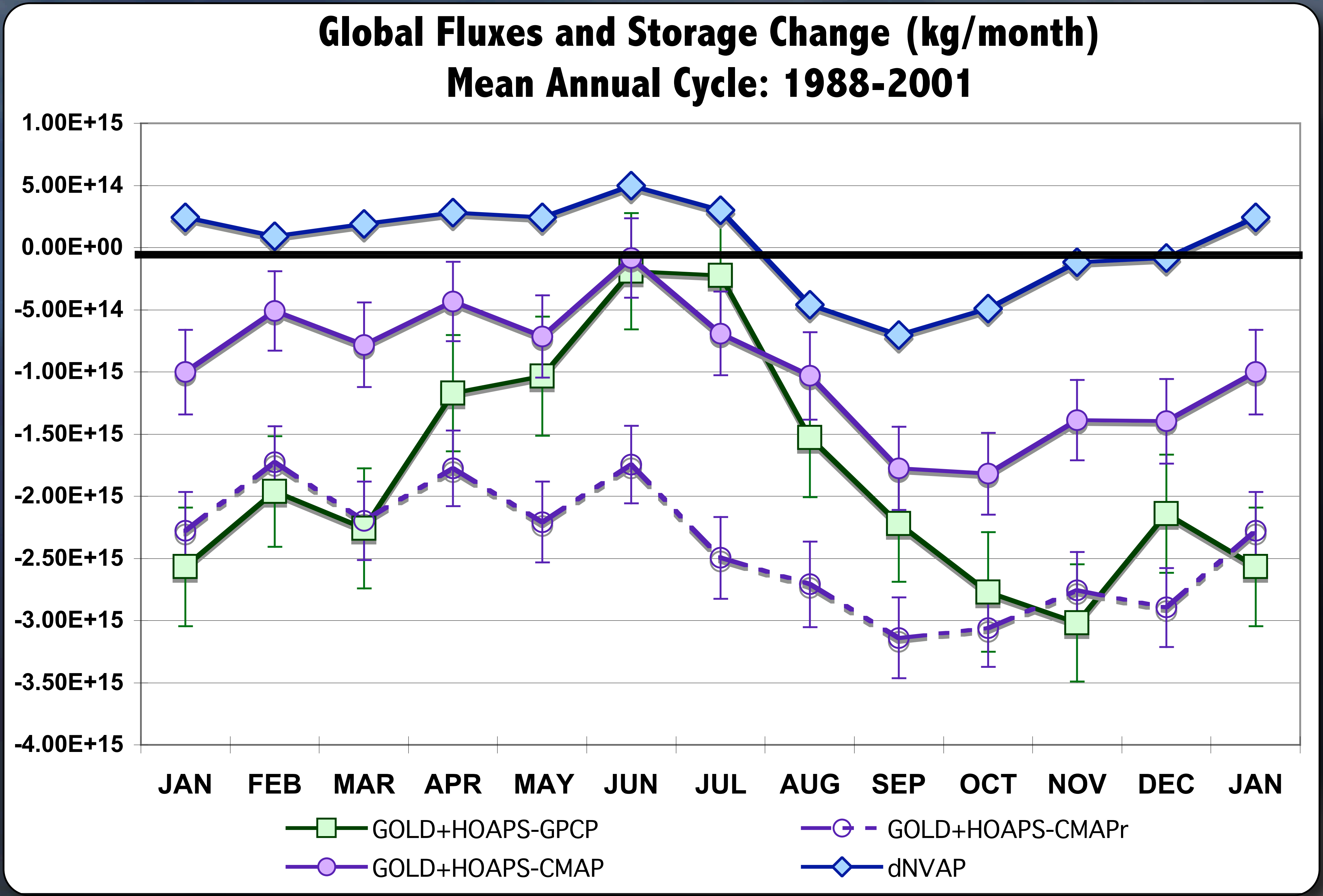
Annual Timeseries of Global Water Budget



	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. Values are given in units of 10^{17} kg/yr.

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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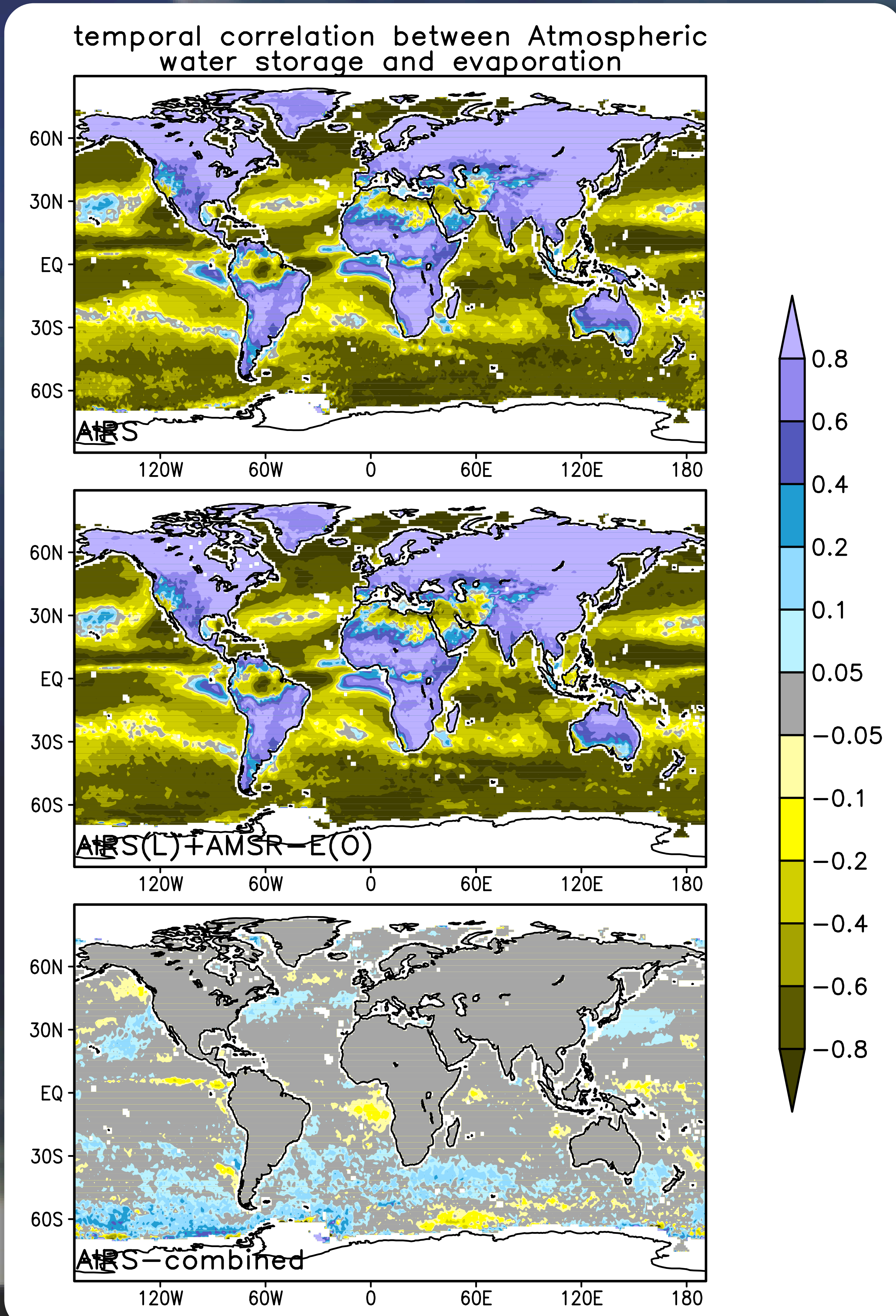
Evaporation and Atmospheric Water Storage Correlation



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.

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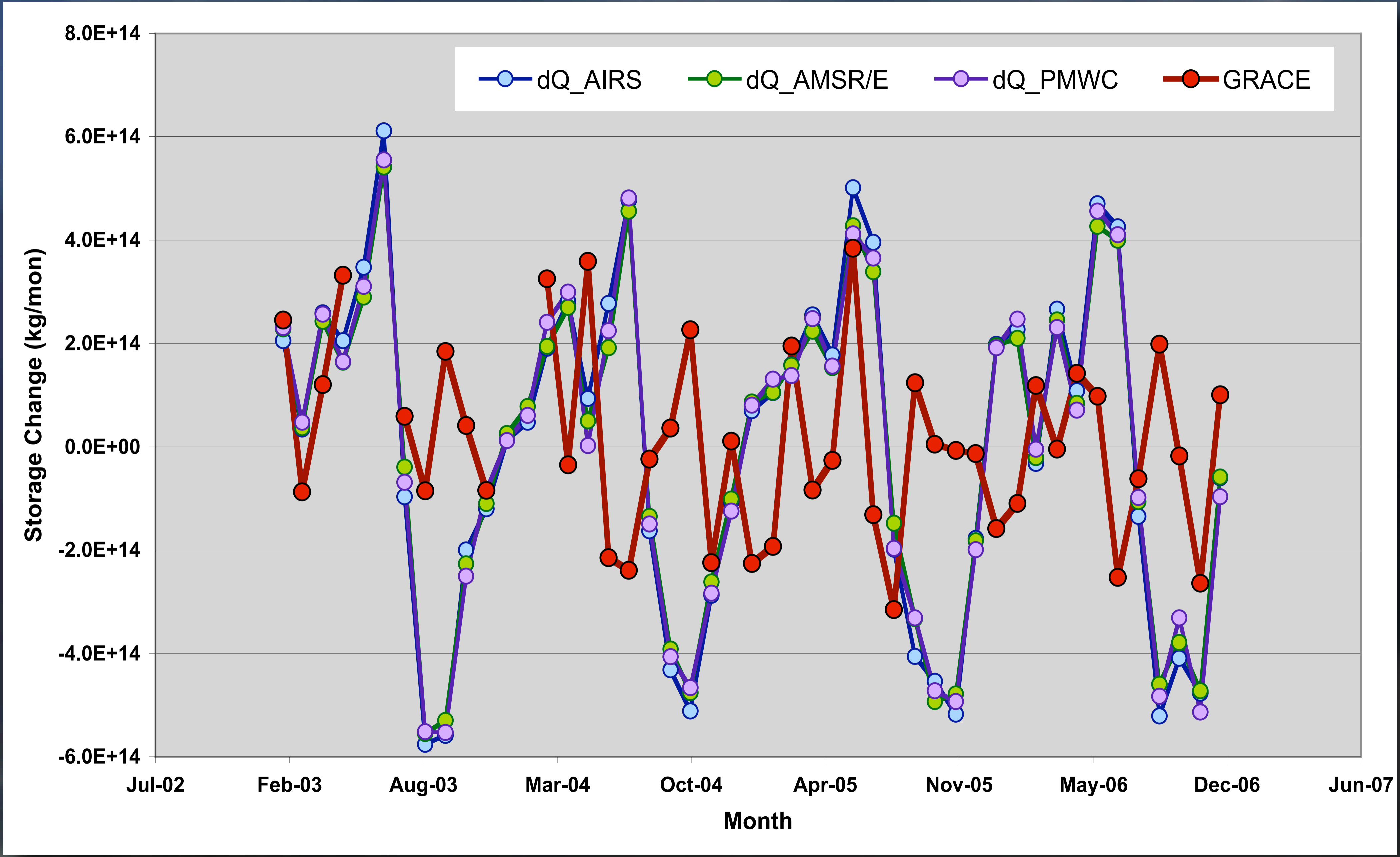
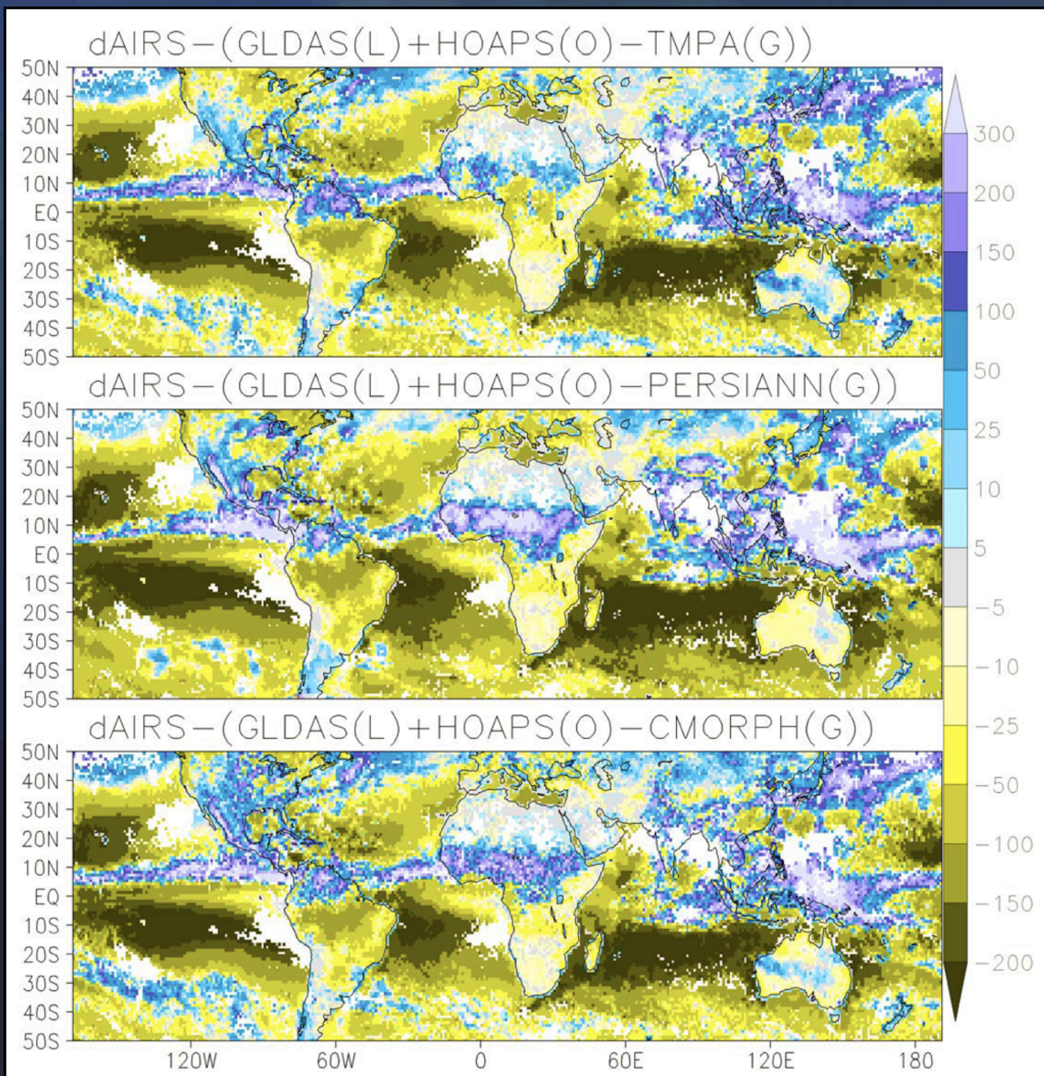
Consistency between Atmospheric Storage and Surface (Land+Ocean) Storage or lack thereof?...



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

Consistency of Atmospheric Vapor Convergence Estimates

Residual Estimates

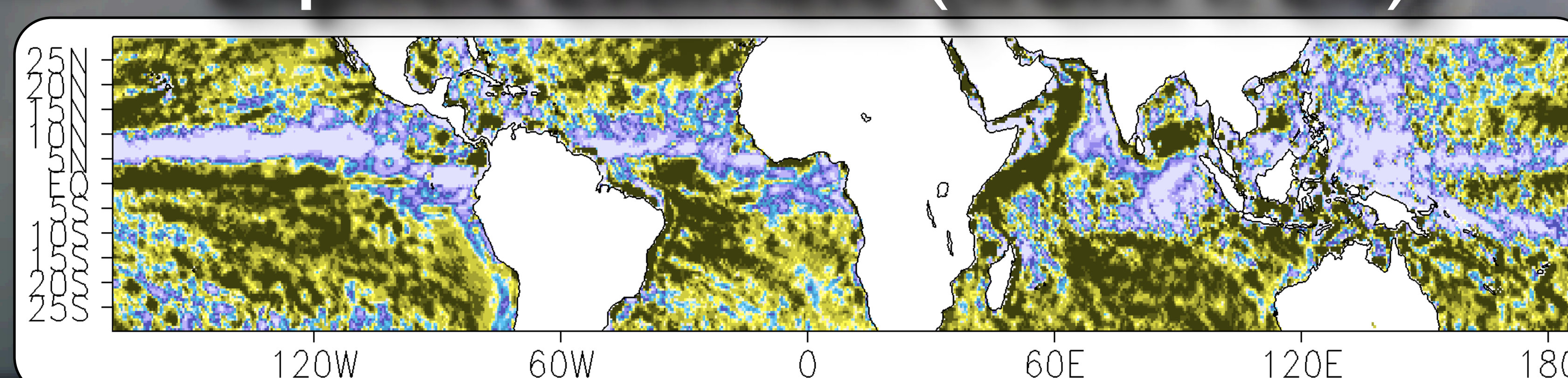


$$\frac{dQ}{dt} = E - P - div(Q_T)$$

Results for June 2003-5 (mm/month)

- Choice of water vapor data largely insensitive in convergence fields' results. Choice of precipitation has more notable impact.
- Consistency in large-scale features amongst the residual and explicit (i.e. Liu product) estimates evident. Regional inconsistencies (i.e. equatorial regions) also notable.
- Small scale features of the explicit estimate absent in residual estimate.

Explicit Estimate (from T. Liu)



The Road Ahead: Data

Short term goal: (by fall of 2008) Transition from zonal to global gridded data – assign spatial (e.g., 2.5* 2.5 or 1*1) and temporal resolutions (e.g. monthly).

Middle term goals:

a) Within next year, extend the monthly data to daily.
b) Within 1.5 year, extend data "backward" to 2000.
c) Perform integrated assessment of global water andenergy budgets.

Long-term goals: (at the end of phase 1 of NEWS program)

a) Extend monthly analysis forward/backward to longest term possible.
b) From global gridded monthly means to global gridded daily means.
c) Obtain 3hourly, full time period, gridded data sets.

Middle and long term goals:

a) Identify critical gaps for pending/potential mission (i.e. SMAP, Surface water mission, cold lands, etc.).
b) Model/Reanalysis comparisons, assessments and metrics.

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The Road Ahead: Data and Metrics

1. What we can do with the observational/model data we have?
   1.1. Land and ocean budgets can be considered.
   1.2. Bring models into the picture (e.g. Soden - AR4/extremes and Waliser AR4/MJO)

2. What we would really like to do if we had "new" data?

"New":

Not just new missions.

What we can do with the data we already have? (i.e. and can augment/enhance via reprocessing or combined processing), but for whatever reason hasn't been done

What we can derive from both observations and models?

3. What metrics are needed to evaluate a CLIMATOLOGY?
   Consider only the mean and/or median, and sigmas of a distribution?
   Co-variability?

4. Do the metrics target our ability to predict climate variations (i.e. seasonal to inter-annual, SI, prediction), and/or do they resonate more with our ability to project/detect CHANGES in climate (i.e. under anthropogenic forcing)?
   4.1. Could very well be two suites of metrics that cater more to either the SI prediction or climate-change projections.

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Metrics: Contributions from NEWCC Team

From George Huffman:

1) Word-smithing issue - the NEWCC as currently posed isn't a sufficiently long period to qualify as a "climatology"; nonetheless the exercise is extremely helpful for providing an end-to-end look at trying to close the water and energy cycles.

2) For long-term datasets the big hole continues to be decent schemes for assessing bias. Hope in the "Bob Adler approach" for global precipitation.

3) I have some hope that creative intercomparison of datasets representing the various water and energy cycle components will at least uncover the most egregious errors in the individual data sets. This happened in Version 1 of the GPCP monthly, when modelers told us that there was no reasonable heat balance possible in the Southern Ocean with our then-current precipitation estimates.

4) For evaluating climate variations, it seems as though we need to know the variability of both the observational and the model datasets so that we can assess the significance of each dataset's apparent systematic changes.

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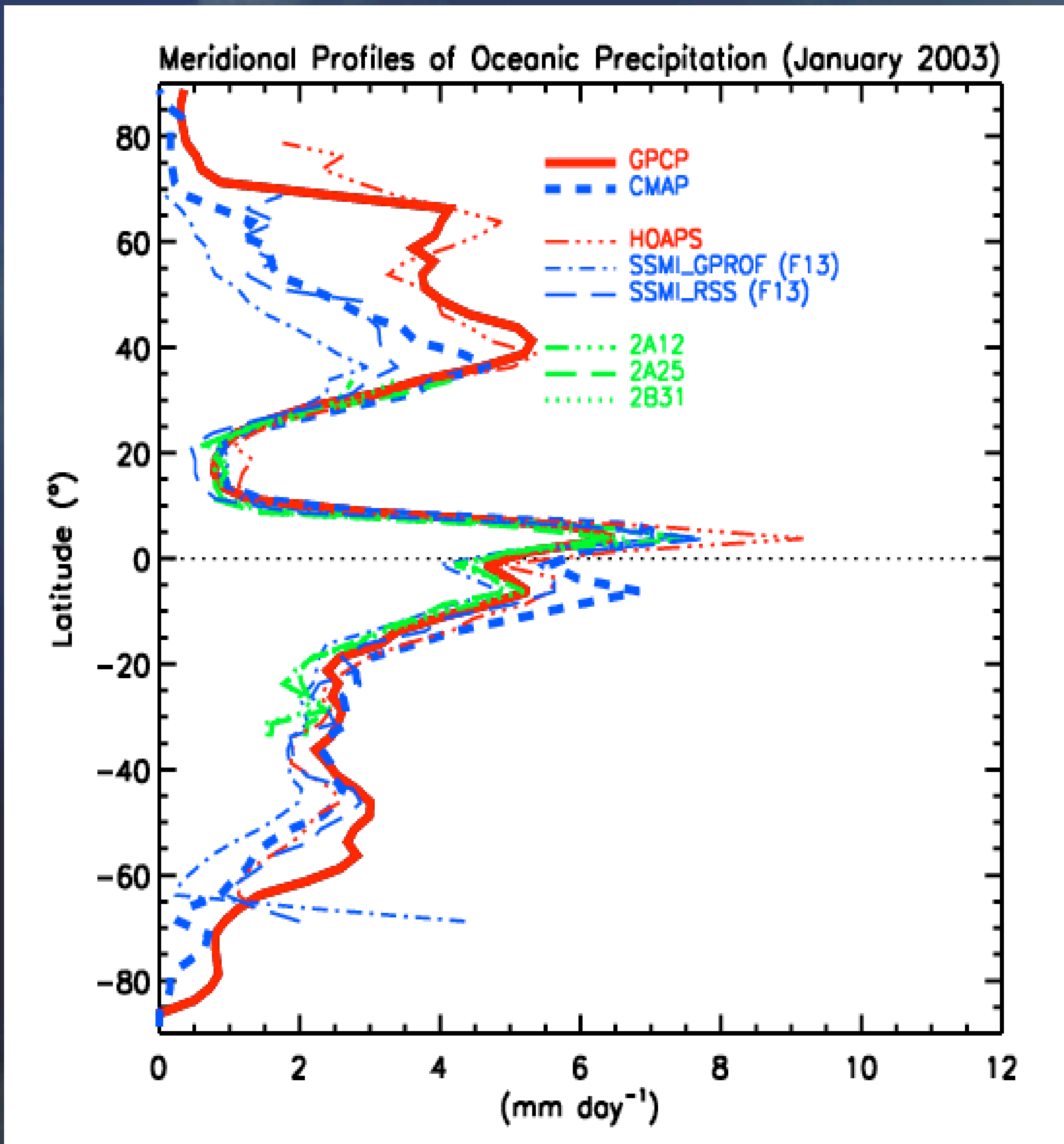

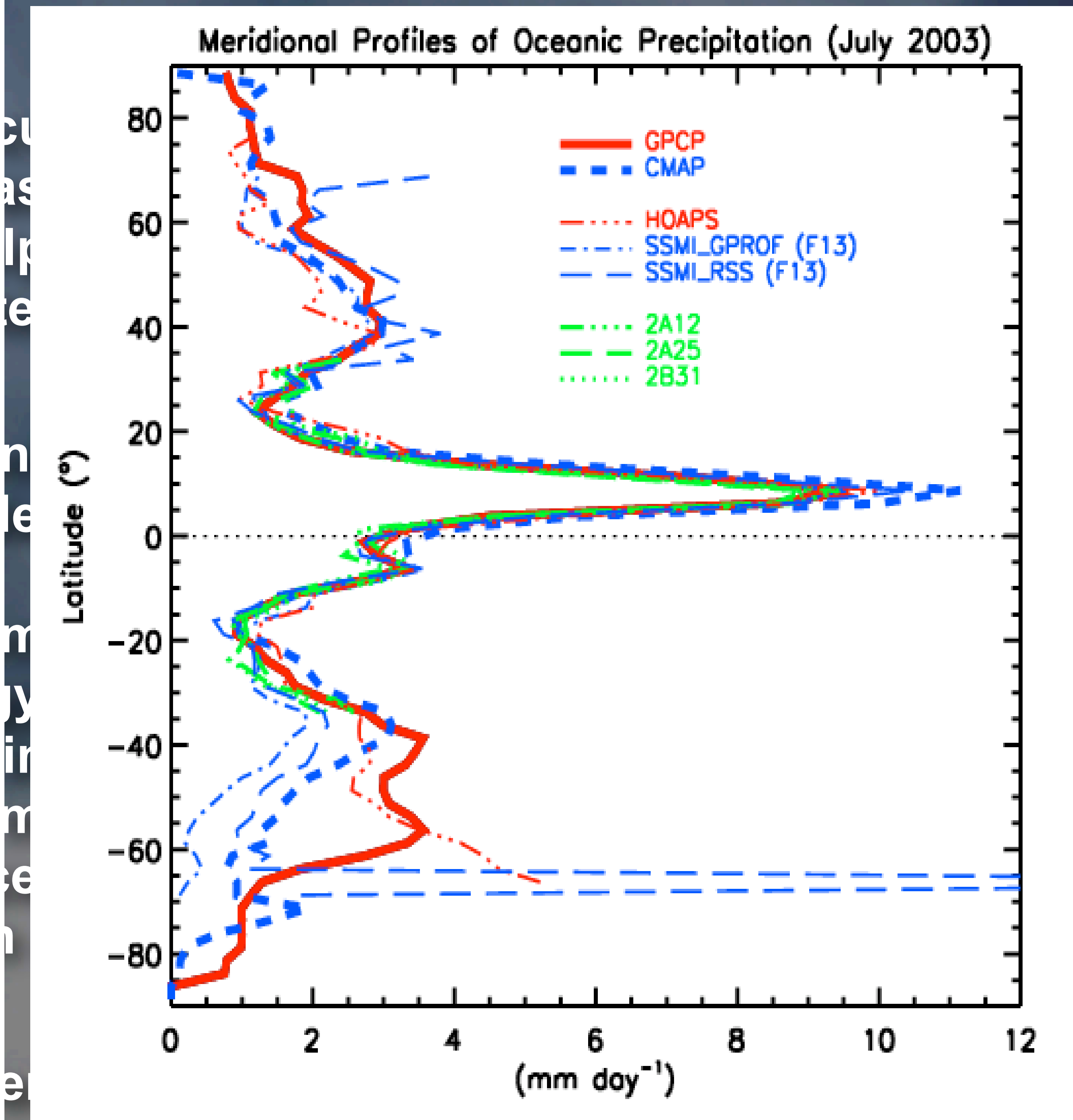

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Metrics: Contributions from NEWCC Team

From Reto Stockli:
1. use of local H, LE, R measurements to improve modeled hydrological processes in a land model

2. use of satellite RS to constrain empirical phenology parameters in a land model

Both parts focus on improving seasonal-interannual H+LE fluxes, and ultimately carbon fluxes in those models, have shown the use of data from the earth observing system makes the difference when applied to process-based models.

Relevant publications:

Stöckli, R., Lawrence, D. M., Niu, G.-Y., Oleson, K. W., Thornton, P. E., Yang, Z.-L., Bonan, G. B., Denning, A. S., and Running, S. W. (2008). The use of FLUXNET in the community land model development. J. Geophysical Research-Biogeosciences, 113(G01025):doi: 10.1029/2007JG000562.

Oleson, K. W., Niu, G.-Y., Yang, Z.-L., Lawrence, D. M., Thornton, P. E., Lawrence, P. J., Stöckli, R., Dickinson, R. E., Bonan, G. B., and Levis, S. (2008). Improvements to the community land model and their impact on the hydrological cycle. J. Geophysical Research-Biogeosciences, 113(G01021):doi:10.1029/2007JG000563.

Stöckli, R., Rutishauser, T., Dragoni, D., Keefe, J. O., Thornton, P. E., Jolly, M., Lu, L., and Denning, A. S. (submitted). Remote sensing data assimilation for a prognostic phenology model. J. Geophys. Res. - Biogeochemistry.

Stöckli, R., Vidale, P. L., Boone, A., and Schär, C. (2007). Impact of scale and aggregation on the terrestrial water exchange: integrating land surface models and rhone catchment observations. J. Hydrometeorol., 8(5):1002–1015.

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Metrics: Contributions from NEWCC Team

From John Roads:

1. Need more comparisons among the many possible data and model sources to provide realist estimates of current observational and model uncertainties.

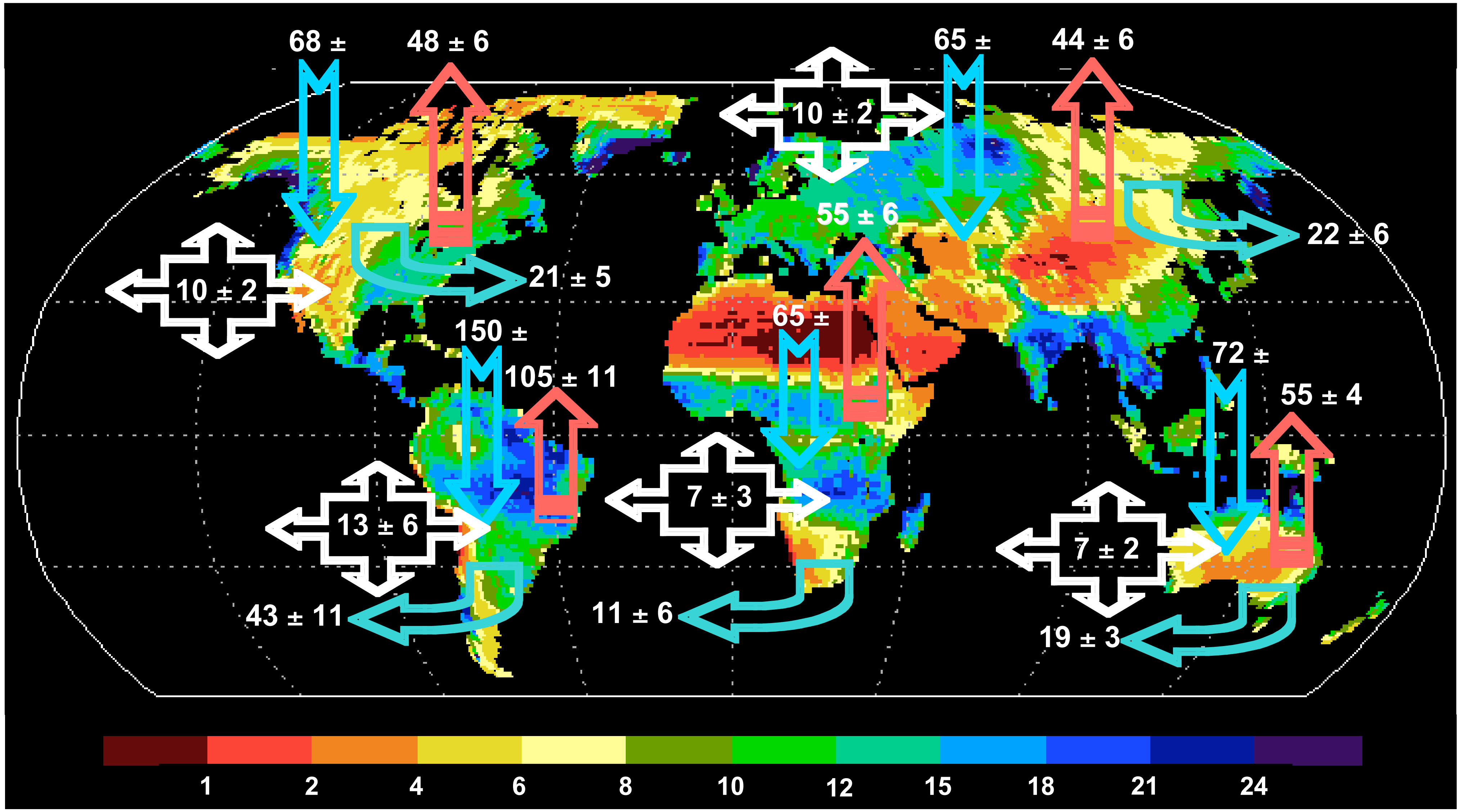
2. We may want to try for a longer time period so we have more data for this comparison. A longer time period would also provide some measure of the temporal uncertainties.

3. We need to compare many different measures of the water cycle states and fluxes and then advocate for additional missions to get at poorly observed variables. The soil moisture, salinity mission is a start but we also need better measures of surface and atmospheric water and energy fluxes, streamflow, etc. The comparisons should probably include global, zonal. land, ocean, and regional means and variations. It might be useful to ask for volunteers to lead a comparison of specific NEWS variables. It might then be useful to try to summarize each comparison in a NEWS summary document.

4. The metrics should include mean as well as RMS differences for different regions and times.

Metrics: Contributions from NEWCC Team

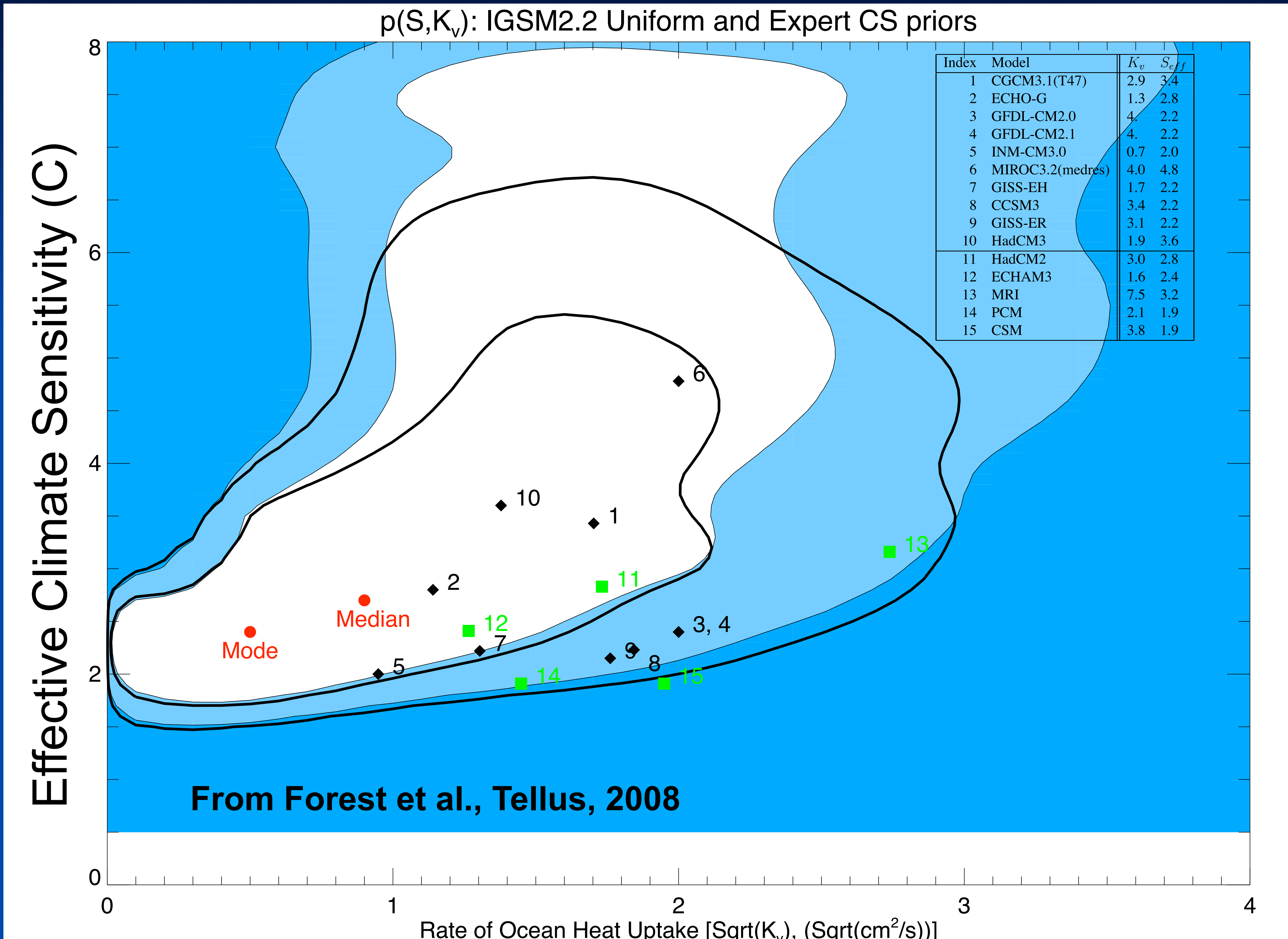
GLDAS Continental Water Balance



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

Matt Rodell
NASA GSFC

Climate Change Metrics



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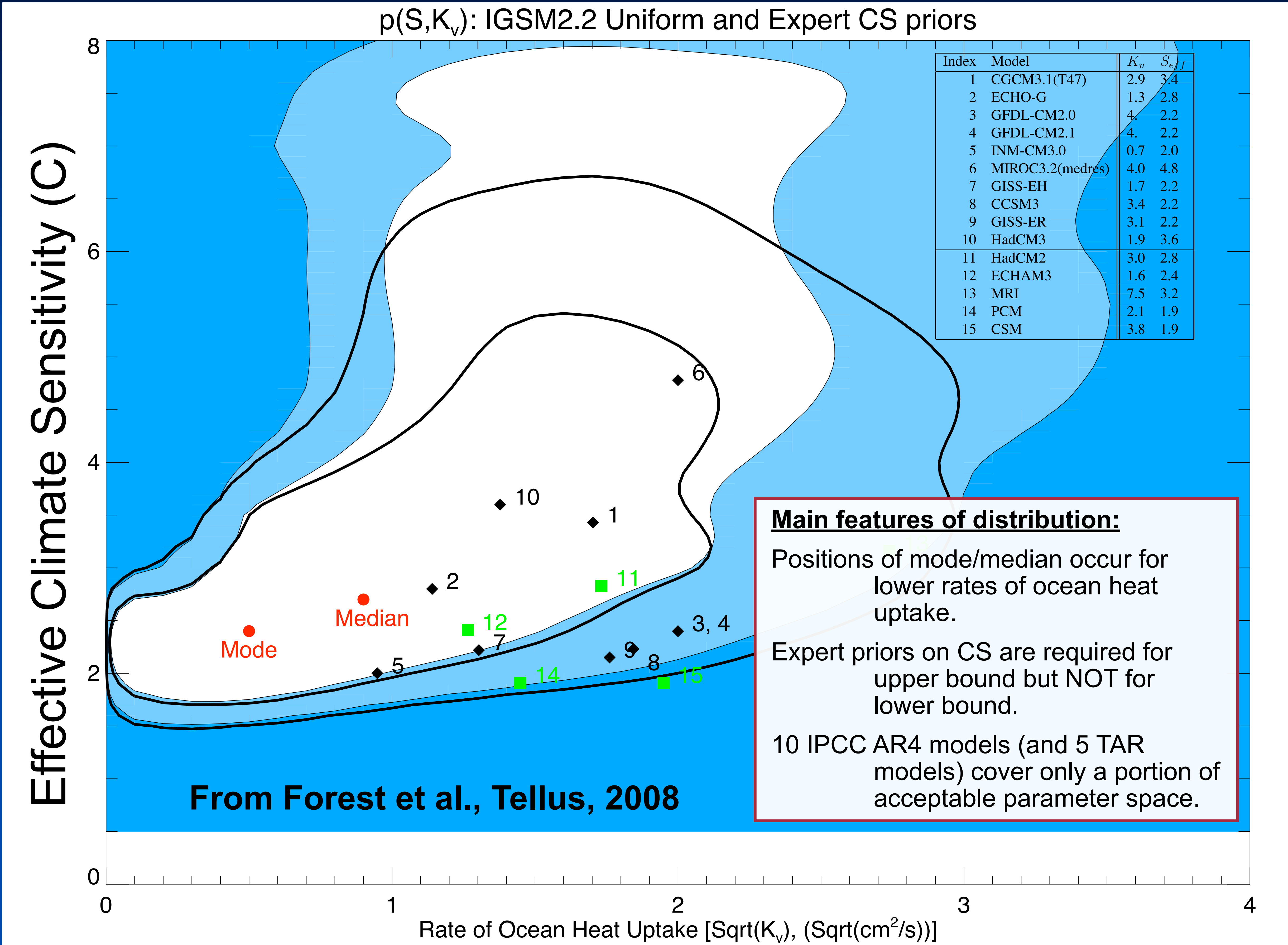
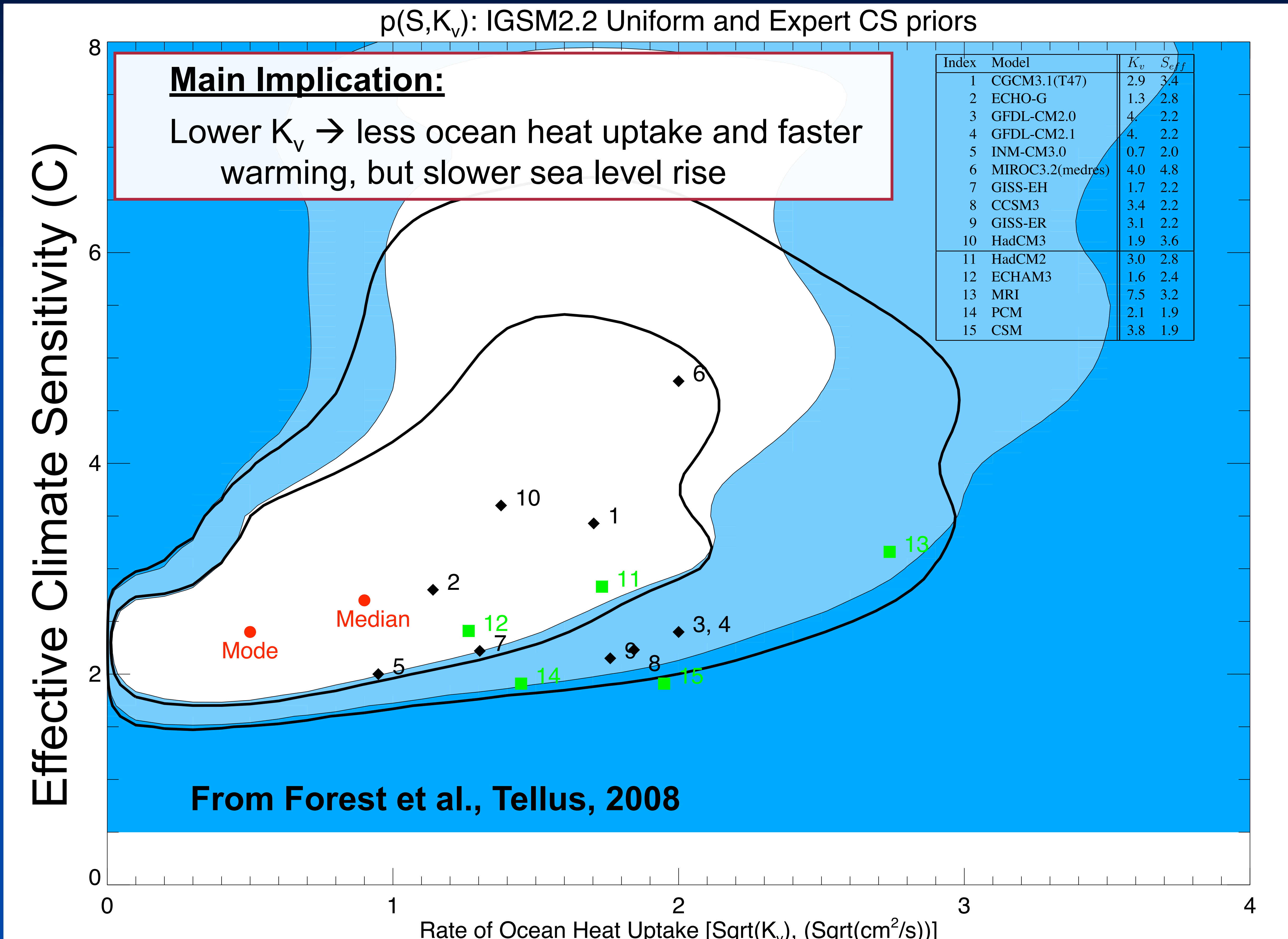


Index	Model	K_v	S_{eff}
1	CGCM3.1(T47)	2.9	3.4
2	ECHO-G	1.3	2.8
3	GFDL-CM2.0	4.	2.2
4	GFDL-CM2.1	4.	2.2
5	INM-CM3.0	0.7	2.0
6	MIROC3.2(medres)	4.0	4.8
7	GISS-EH	1.7	2.2
8	CCSM3	3.4	2.2
9	GISS-ER	3.1	2.2
10	HadCM3	1.9	3.6
11	HadCM2	3.0	2.8
12	ECHAM3	1.6	2.4
13	MRI	7.5	3.2
14	PCM	2.1	1.9
15	CSM	3.8	1.9

Climate Change Metrics



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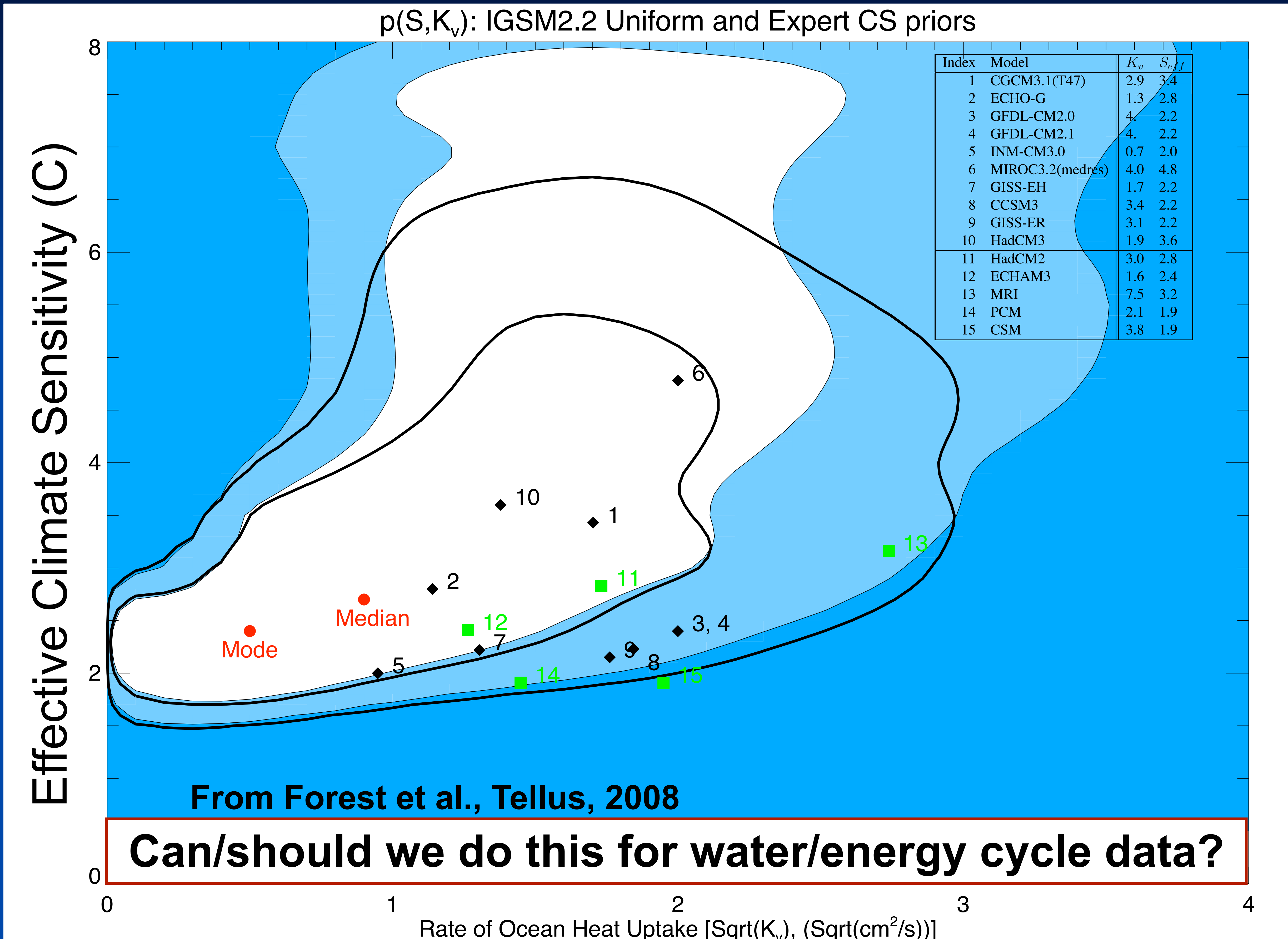

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15	CSM	3.8	1.9

Can/should we do this for water/energy cycle data?

Climate Prediction/Predictability Metrics

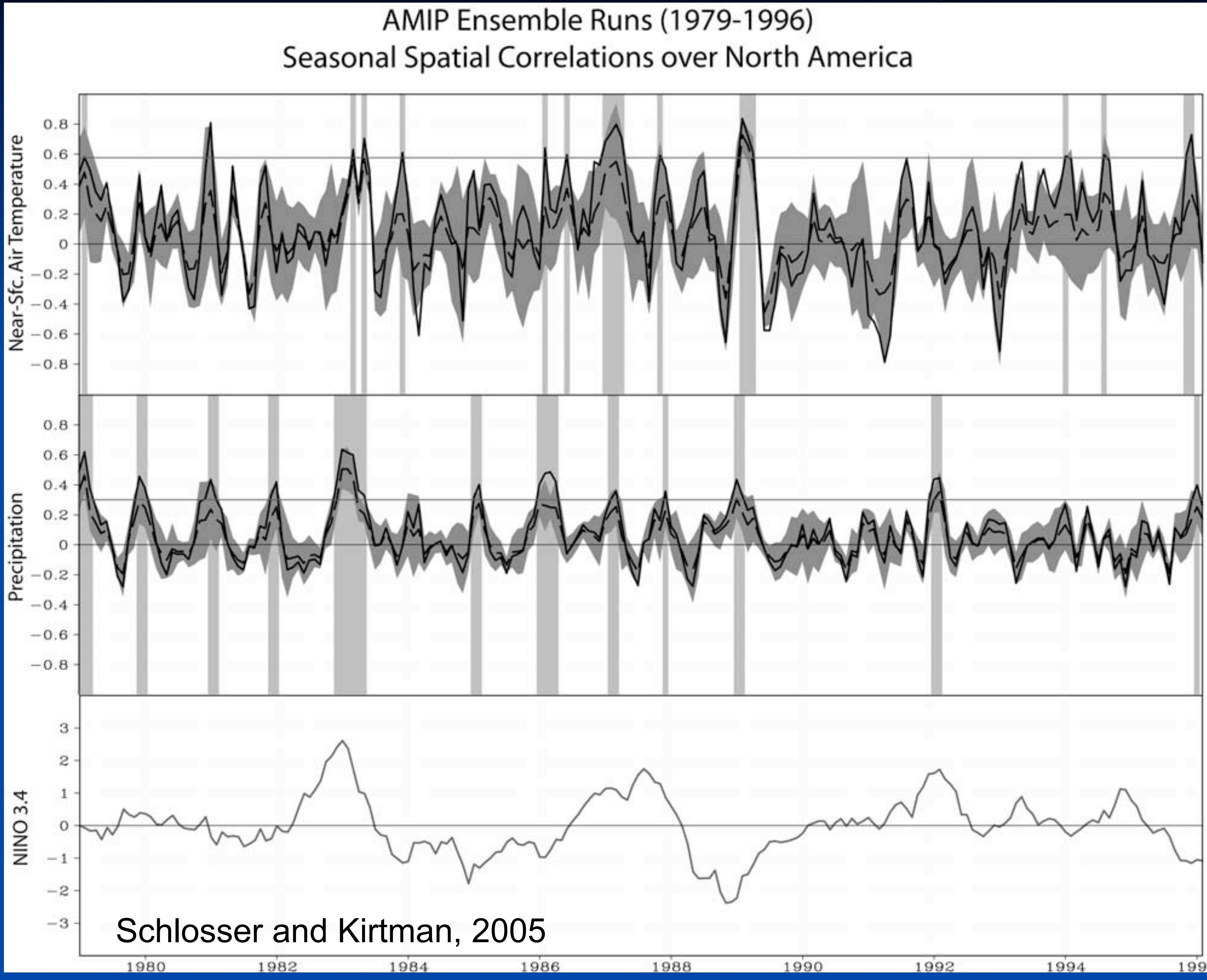
What is predictable and skillfull?

- Initial value problem (1st kind): SI issue, persistence and coupling
- Exogenous forcing (2nd kind): Forced climate response/change issue
- Scale (3rd kind): How does the representation across scales affect?

Difficulty arises for metric that applies to both models and nature.

- Legacy of most model-based assessments revolve around ensemble clustering... but there are ways to do both... For example:

Climate Prediction/Predictability Metrics



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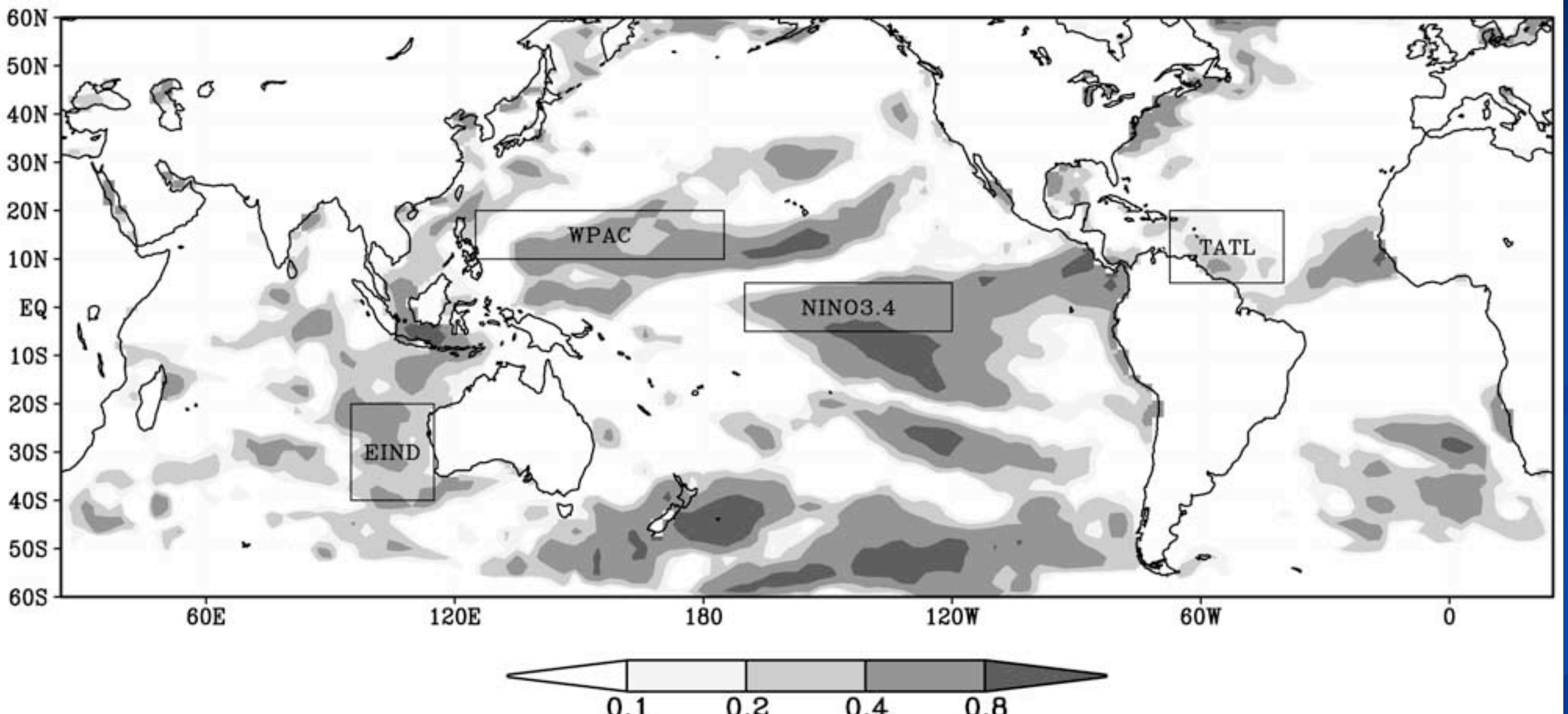

Figure 5. Point-wise contemporaneous multiple correlation coefficient (described in text) of seasonal (i.e., 3-month running mean) sea surface temperature (SST) anomalies to the North American predictable skill periods of precipitation.

Climate Prediction/Predictability Metrics