Observational constraints on the water vapor feedback: A search for the "Hall Effect"

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Workshop on Water Vapor Feedbacks

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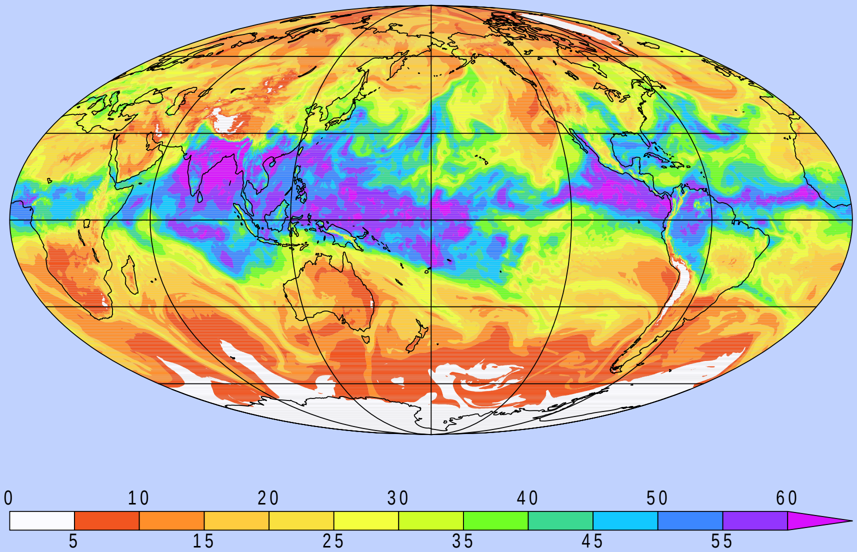

Structure

- Brief review of Santer *et al*. (2007) water vapor detection and attribution ("D&A") paper
- Brief review of Santer *et al.* (2009) water vapor paper on the intersection between model quality and D&A
- Can we constrain uncertainties in the water vapor feedback?
- Conclusions

Scientific questions of interest

- Are scientific claims made by Santer *et al*. (2007) (positive identification of an anthropogenic water vapor fingerprint in observations) robust to current uncertainties in climate models?
- In climate model data, is there evidence that the water vapor feedback is timescale-invariant?
- If such evidence exists, can we use “short-term” (seasonal to interannual) observational data to constrain uncertainties in the “long-term” (decadal to century) behavior of the water vapor feedback?
- Do different properties of the observations (mean state, variability) yield different constraints on the “long-term” water vapor feedback?

What were the primary findings of the Santer *et al.* (2007) water vapor paper?

PNAS

Identification of human-induced changes in atmospheric moisture content

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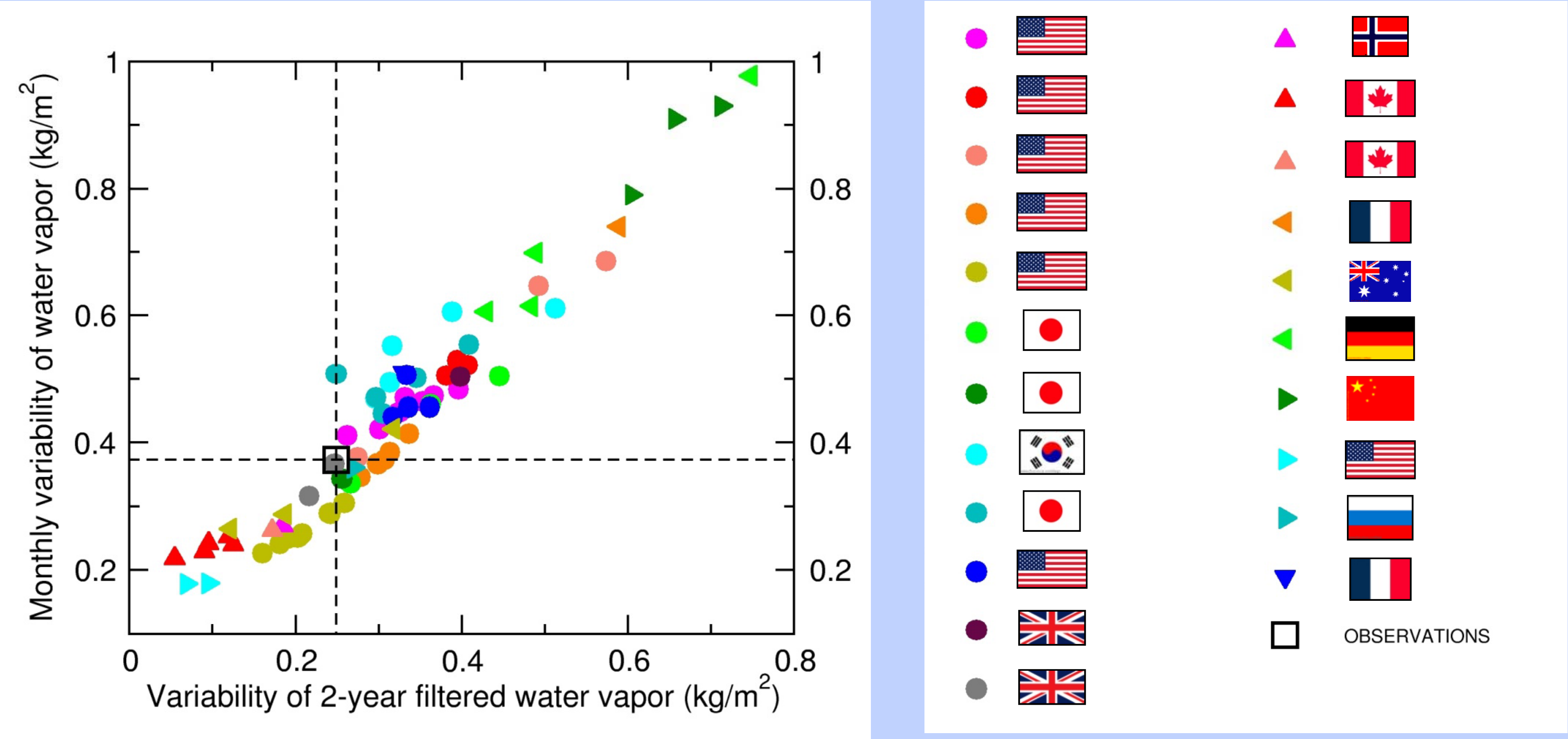
We found that:

- There is an emerging human-caused signal in the increasing moisture content of Earth's atmosphere
- This signal is primarily due to human-caused increases in well-mixed greenhouse gases

Although the models showed important differences in their performance, they had equal weight in the D&A study



Santer *et al.*, *Proceedings of U.S. National Academy of Sciences* (2007)

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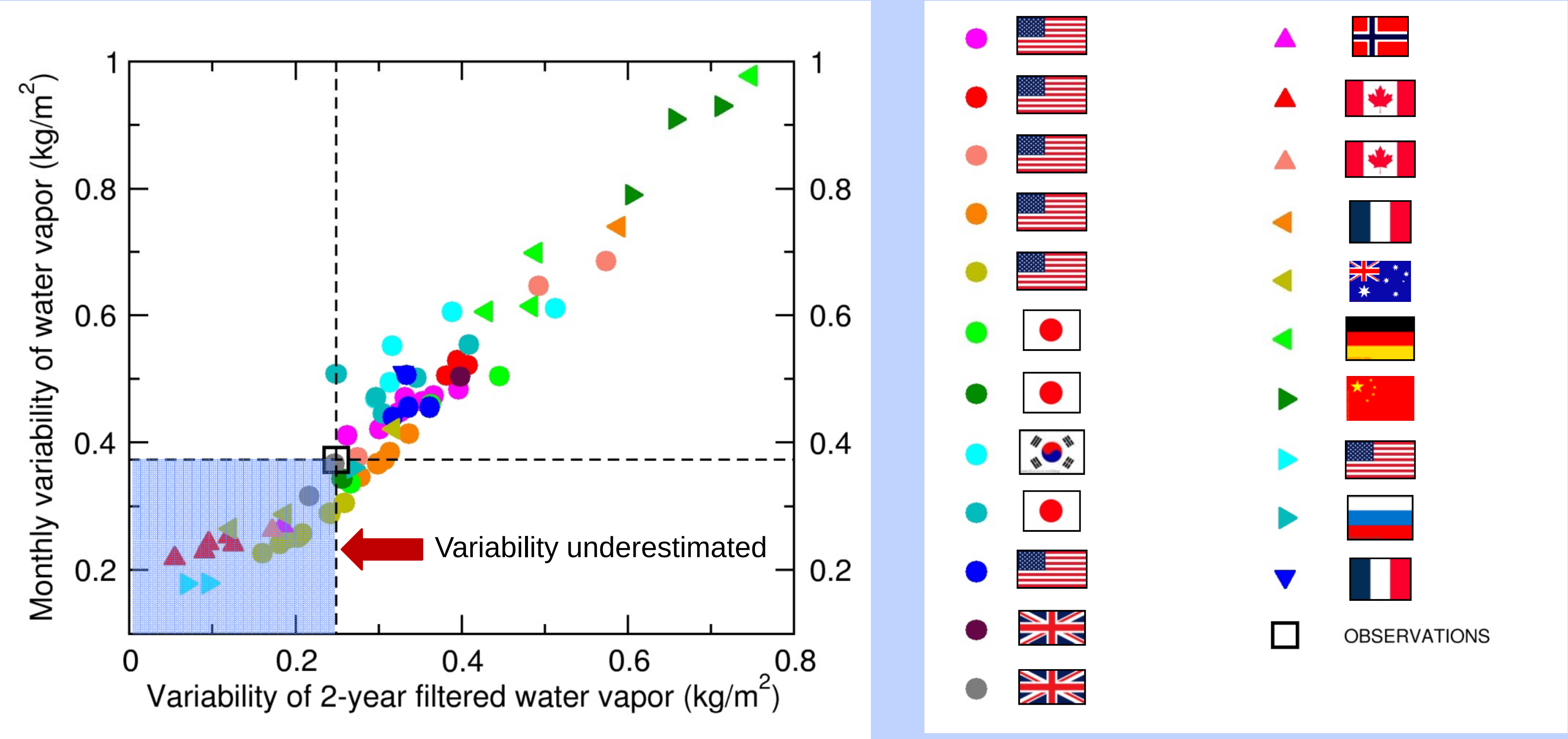

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What were the key findings of the Santer *et al.* (2009) water vapor paper?

Incorporating model quality information in climate change detection and attribution studies

B. D. Santer[a,1], K. E. Taylor[a], P. J. Gleckler[a], C. Bonfils[a], T. P. Barnett[b], D. W. Pierce[b], T. M. L. Wigley[c], C. Mears[d], F. J. Wentz[d], W. Brüggemann[e], N. P. Gillett[f], S. A. Klein[a], S. Solomon[g], P. A. Stott[h], and M. F. Wehner[i]

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We found that:

- Our ability to identify an anthropogenic fingerprint in satellite-based estimates of water vapor changes is not affected by screening based on model quality
- Model water vapor errors are very complex in space and time

What model data did we use in Santer *et al.* (2007)?

- We used water vapor data from 22 different climate models
- Data were from the CMIP-3 archive at PCMDI
- We used model 20th century ("20CEN") simulations to define the fingerprint that we searched for in observations
- We used water vapor data from model control runs (with no forcing changes) to estimate the noise of natural climate variability

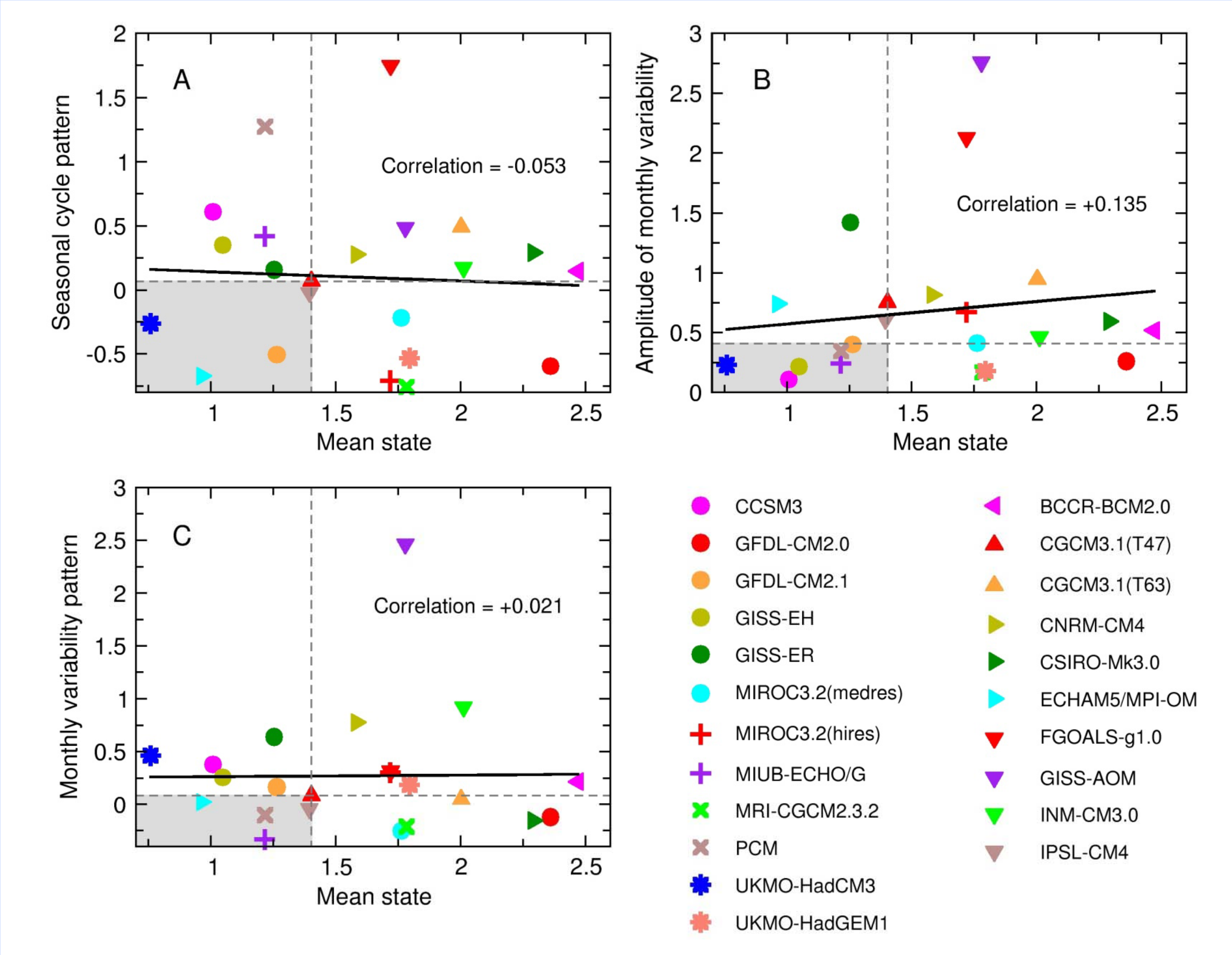
If we use only the “top ten” models, can we still identify a human fingerprint in observed water vapor changes?

- We identified the “top ten” models (out of 22 in the CMIP-3 archive) in three different ways, using measures of model performance in simulating:
  - The climatological mean state and seasonal cycle pattern (“M+SC”)
  - The amplitude and pattern of variability on different timescales (monthly, 2-year, 10-year; “VA+VP”)
  - Mean state, seasonal cycle, and variability (“ALL”)
- This was done for:
  - Two different variables: Water vapor and sea-surface temperature (SST)
  - Five different geographical regions: AMO, PDO, Niño 3.4, tropical oceans (30°N-30°S), and near-global oceans (50°N-50°S)

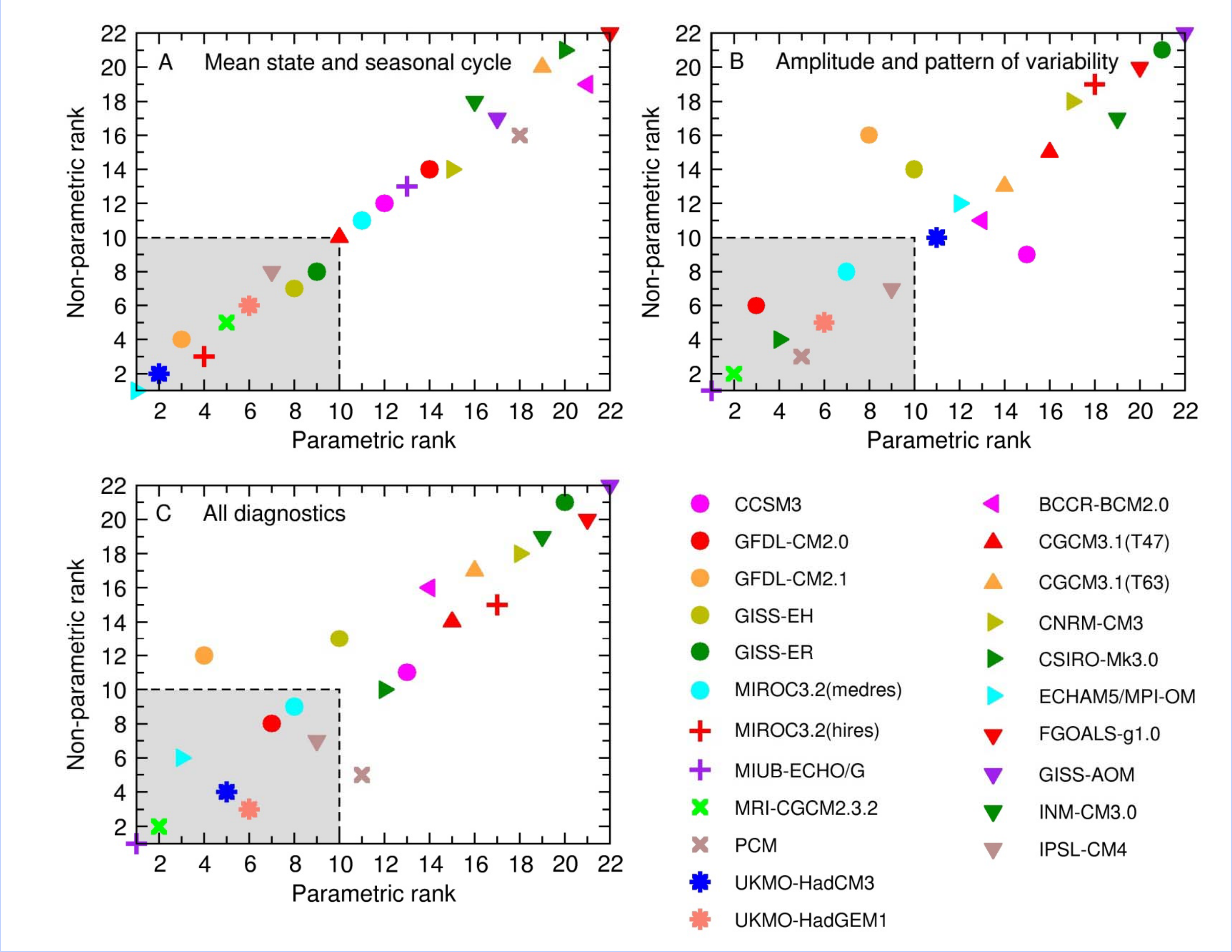
How did we do the model ranking?

- M+SC: 20 model performance metrics
- VA+VP: 50 model performance metrics
- ALL: 70 model performance metrics
- For each set of metrics, model ranking was done in two different ways:
  - Parametrically: Rank is average of normalized values of individual metrics (“P”)
  - Non-parametrically: Average of the ranks for each individual metric (“NP”)
- In each case, identified “top ten” and “bottom ten” models
  - 12 cases: 3 groups of metrics (M+SC, VA+VP, ALL) × 2 ranking schemes (P, NP) × 2 groups of models (Top ten, Bottom ten)

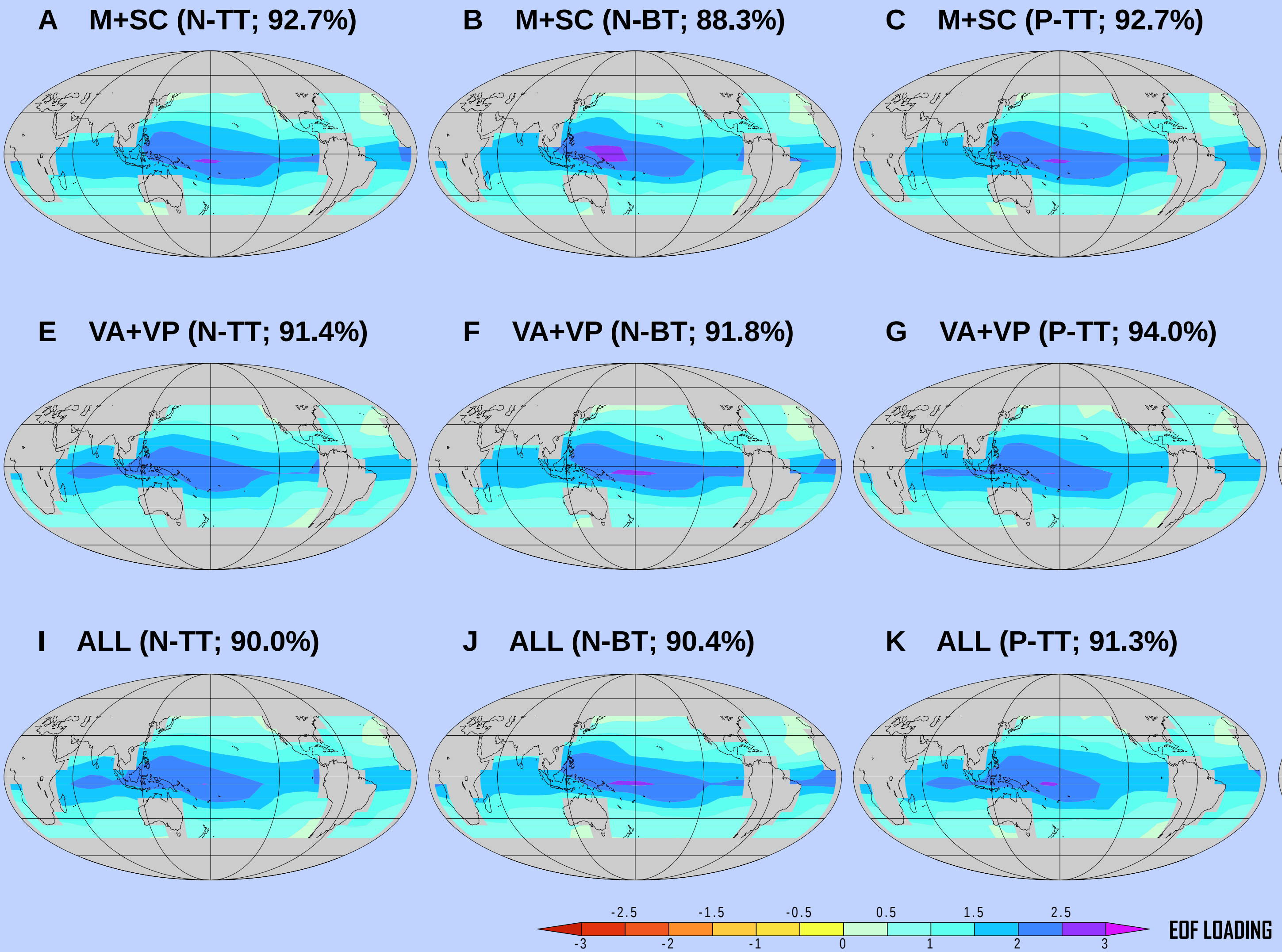
Relationship between different measures of model skill



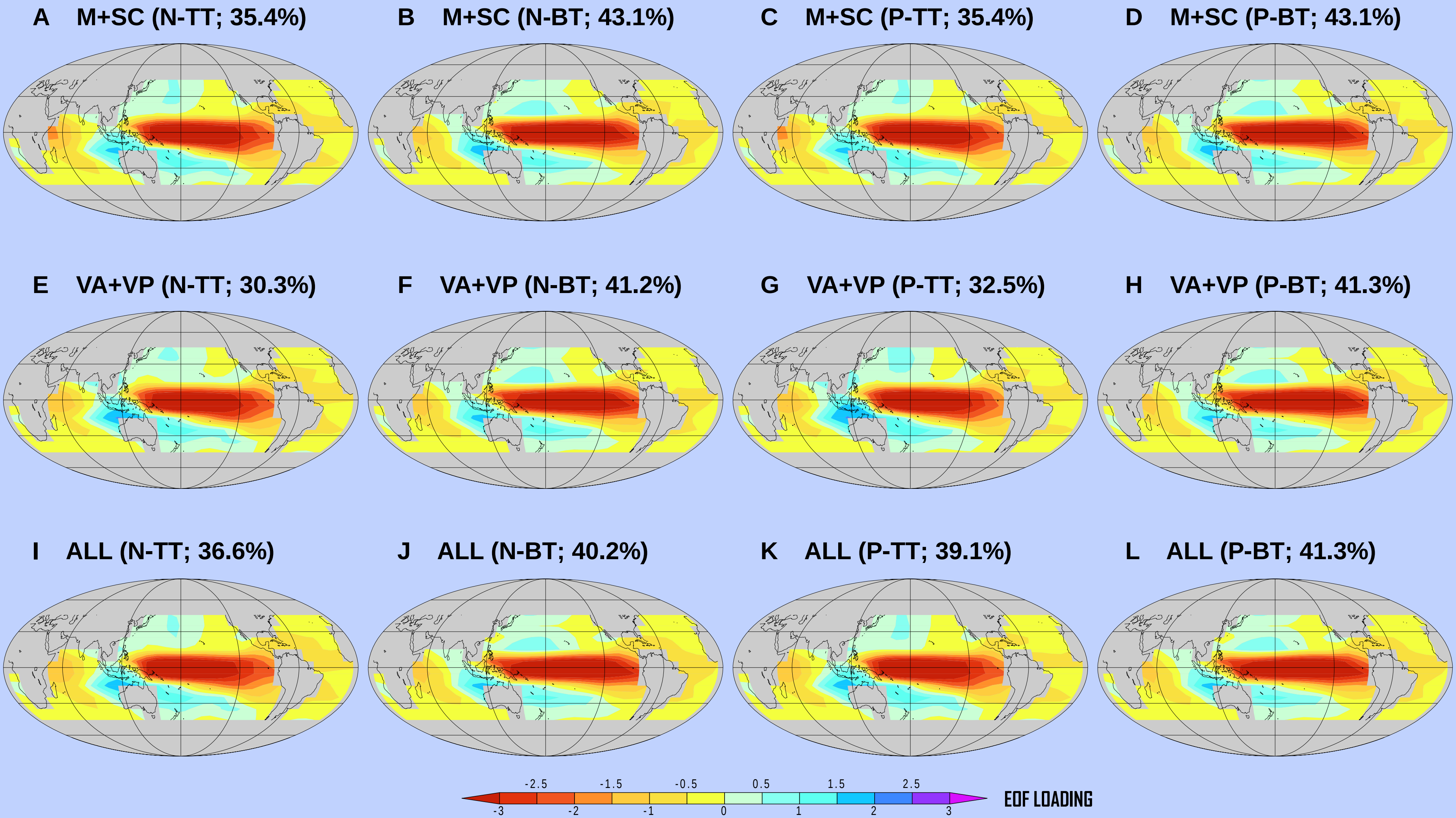
Overall ranking of model performance



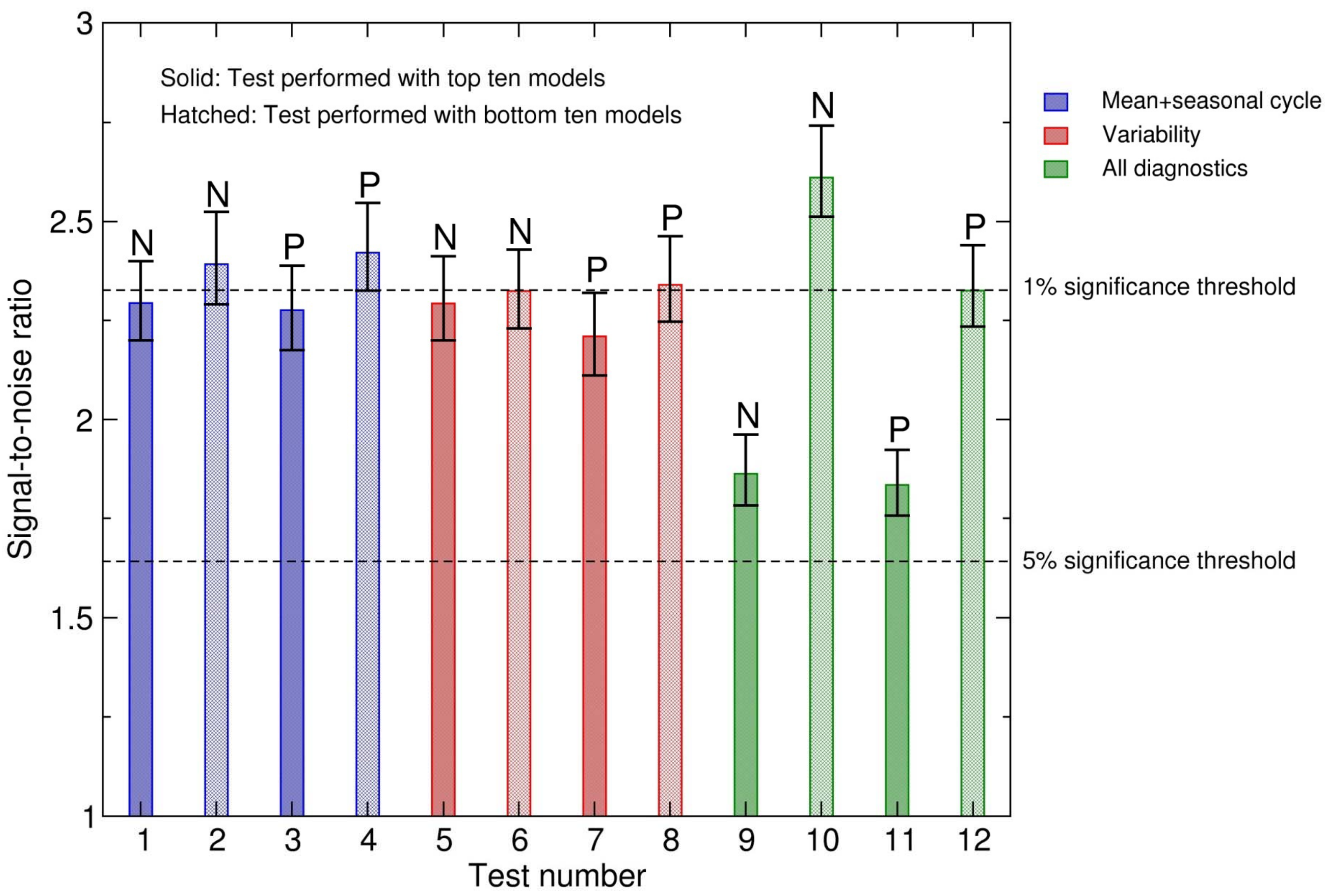
Is the “fingerprint” pattern of externally-forced water vapor changes sensitive to model quality information?



Is the pattern of internally-generated variability of water vapor sensitive to model quality information?



Is the identification of a human "fingerprint" in water vapor changes sensitive to model quality information?



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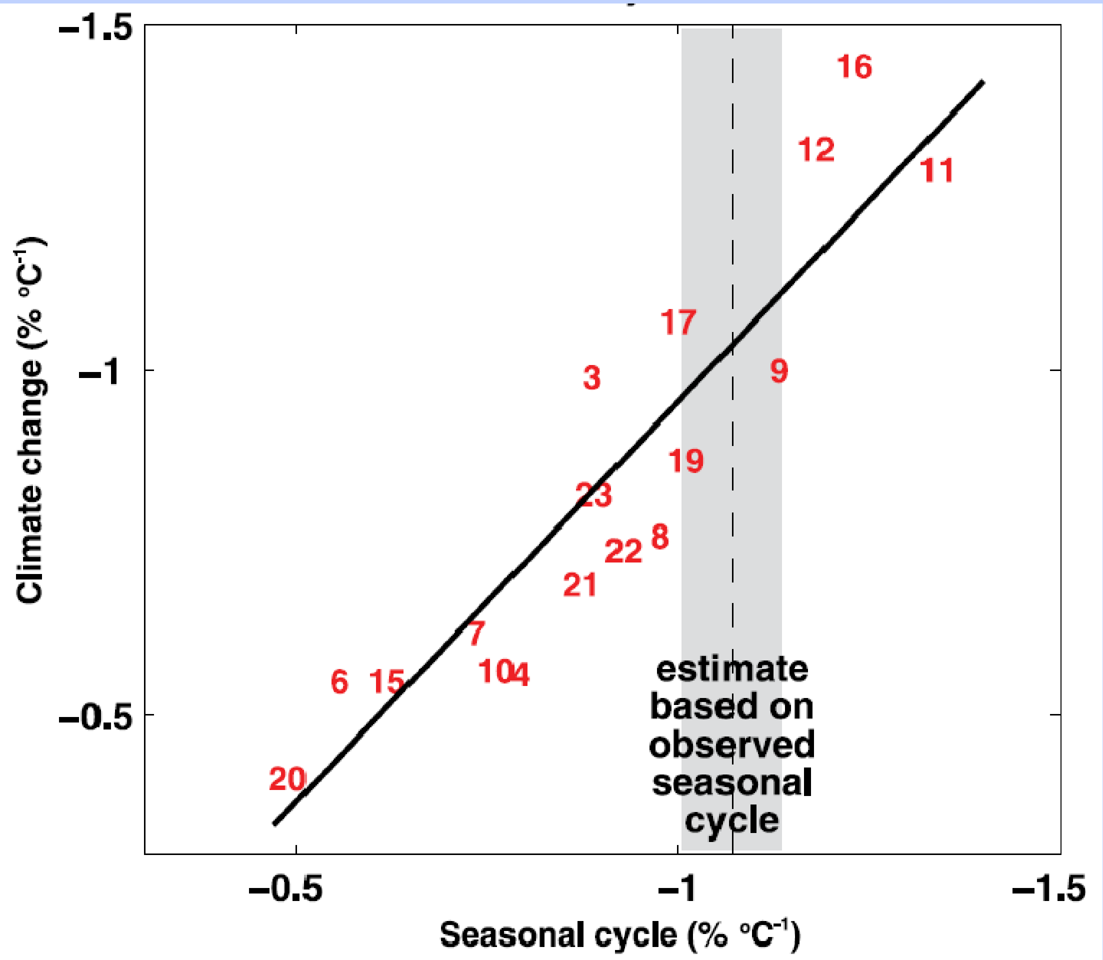
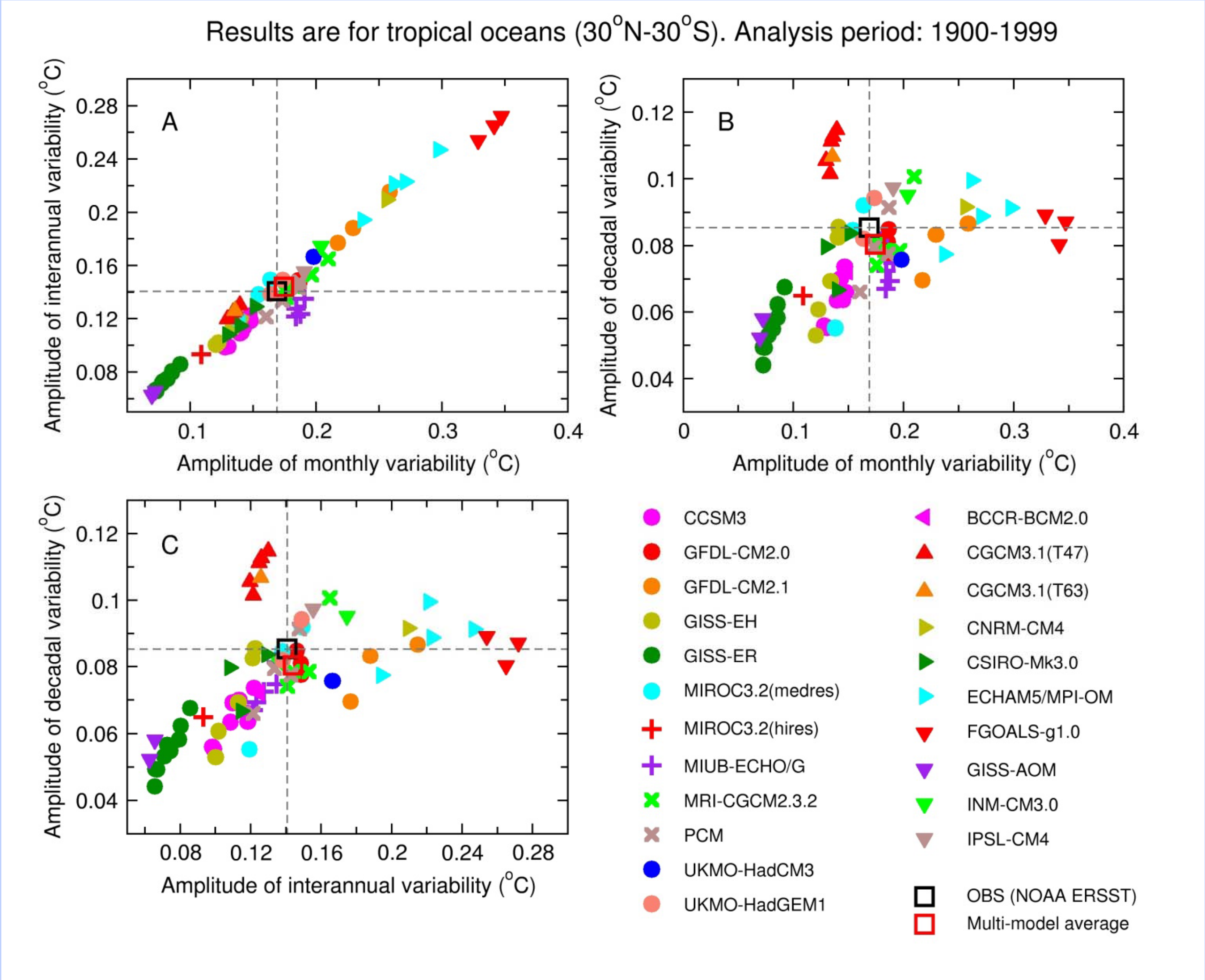
The quest for the Holy Grail: Uncovering relationships between present-day observables and future changes

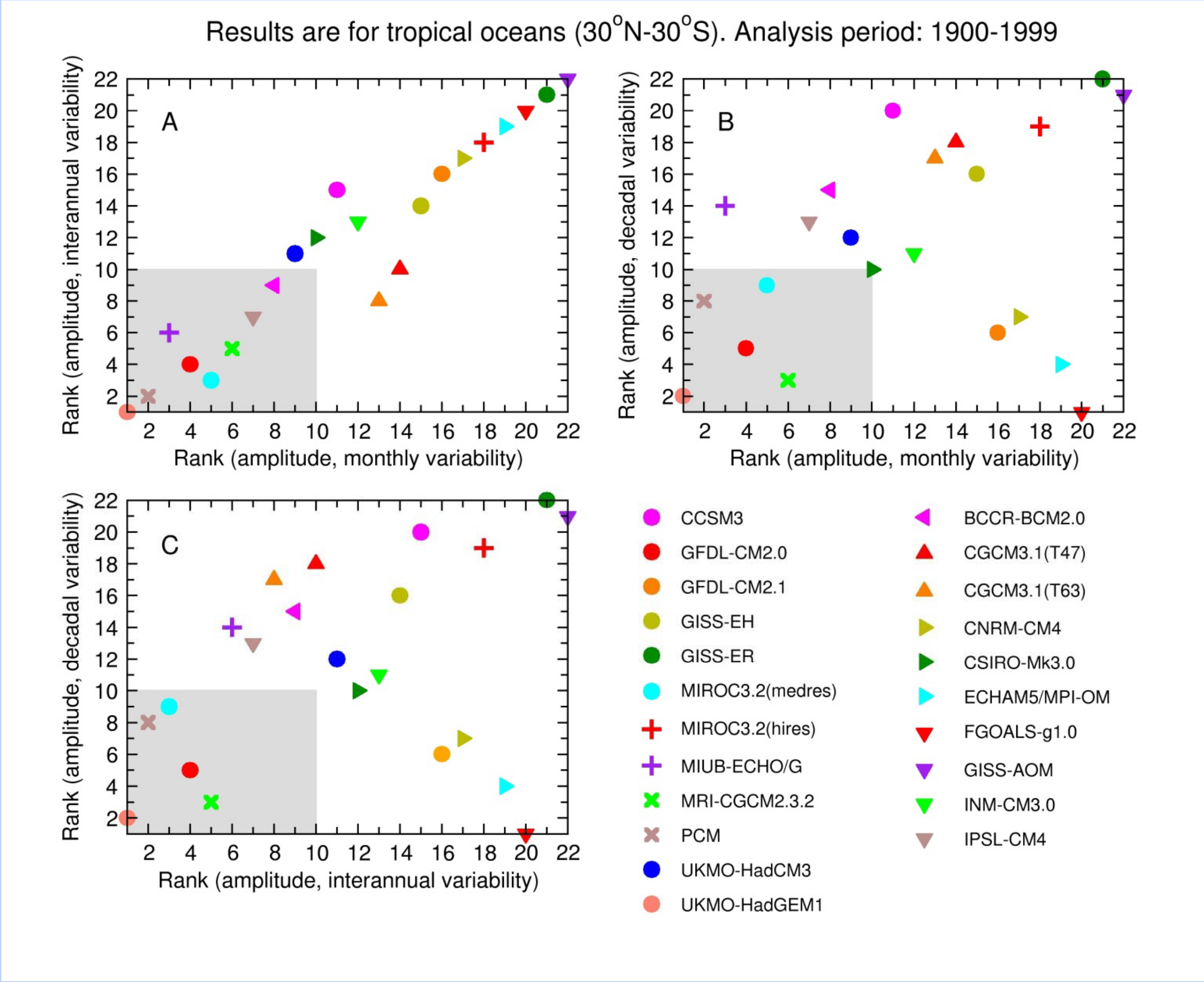


Response of snow cover to global warming in models is related to their snow response to spring warming (Hall and Xu, *GRL*, 2006)

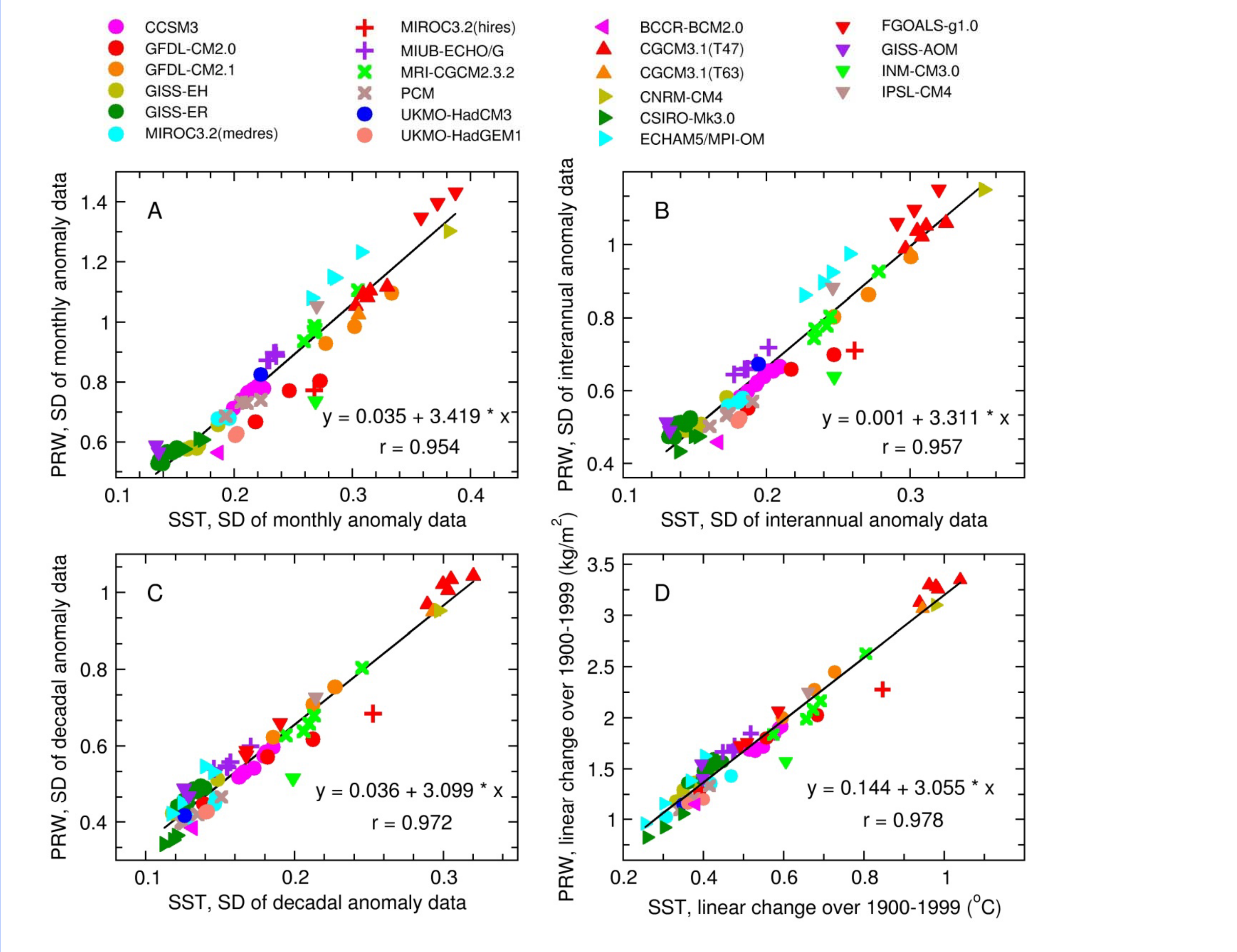
Amplitude of simulated and observed SST variability on three different timescales



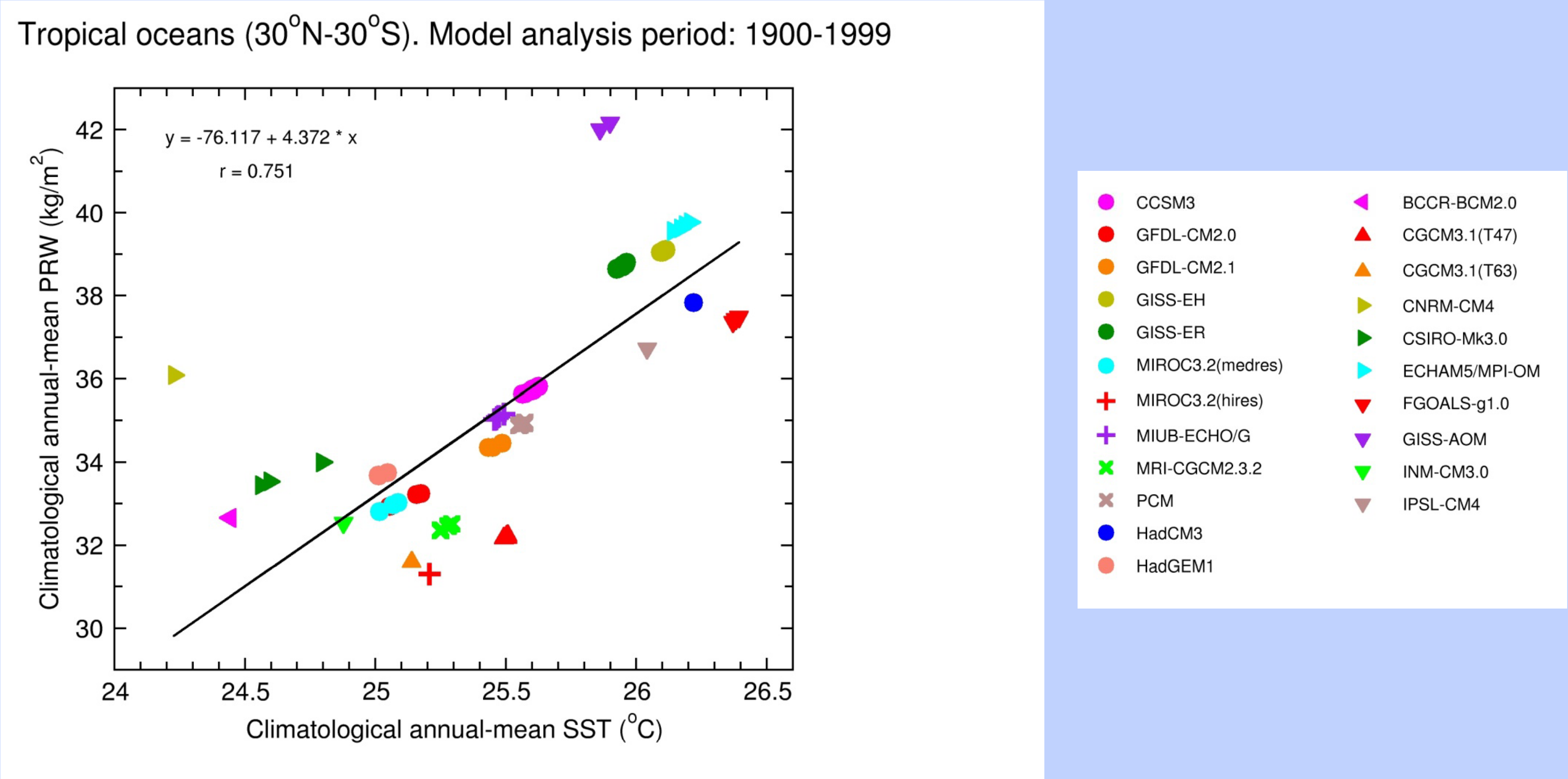
Ranking of CMIP3 models based on amplitude of SST variability on three different timescales



Ratio of water vapor/SST variability on four different timescales (model data only)



Relationship between water vapor and SST mean states



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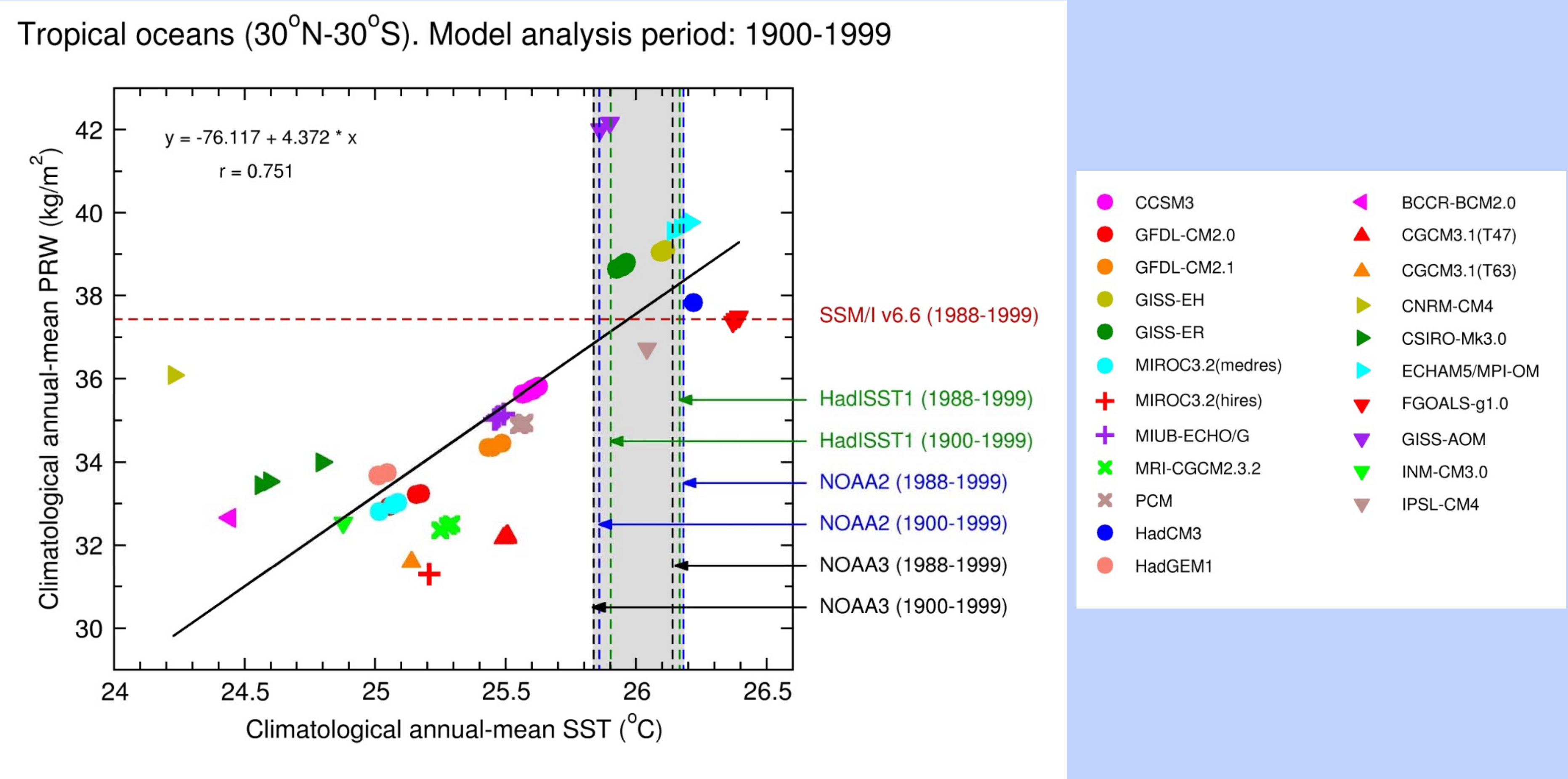
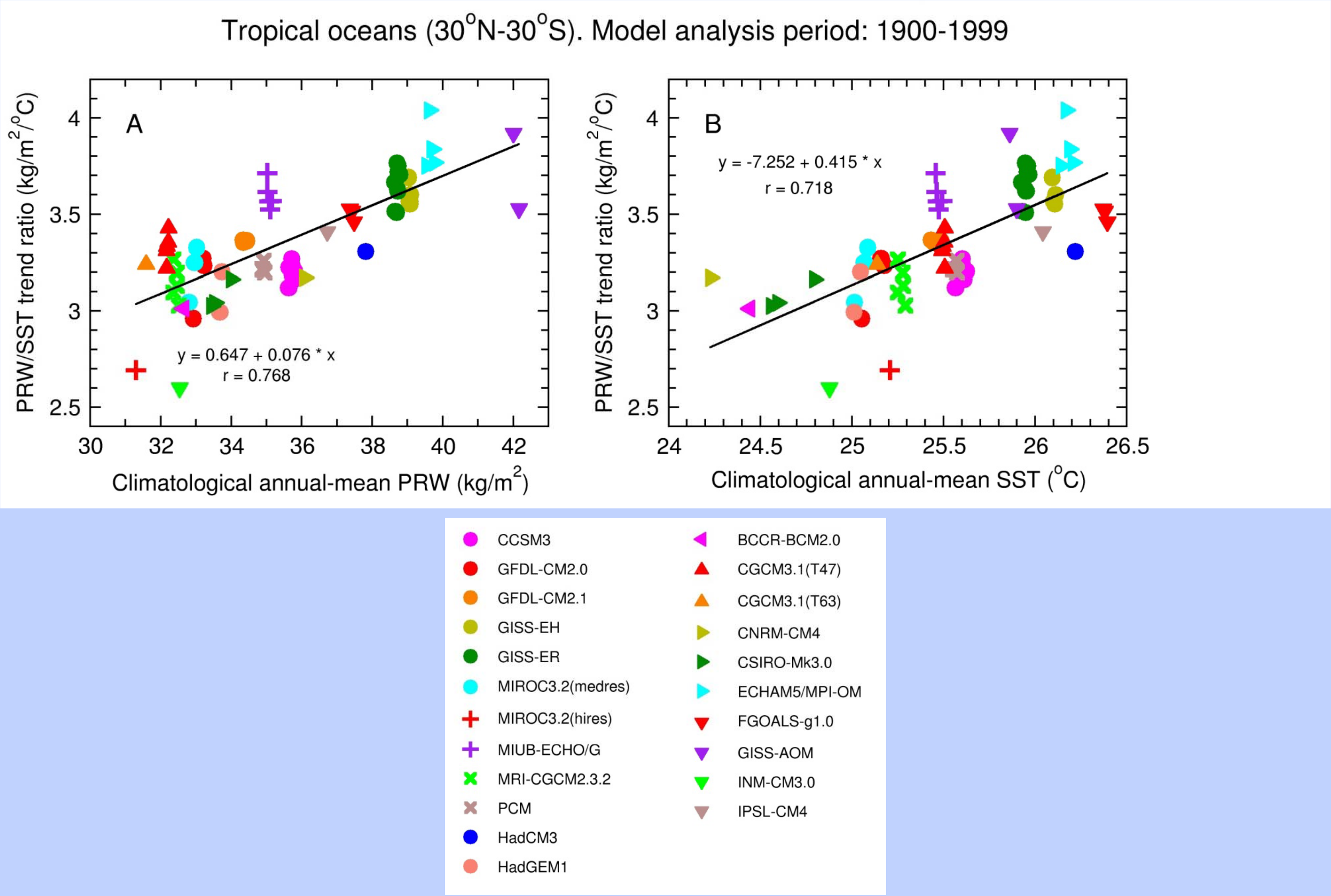


Relationship between water vapor and SST mean states and water vapor feedback



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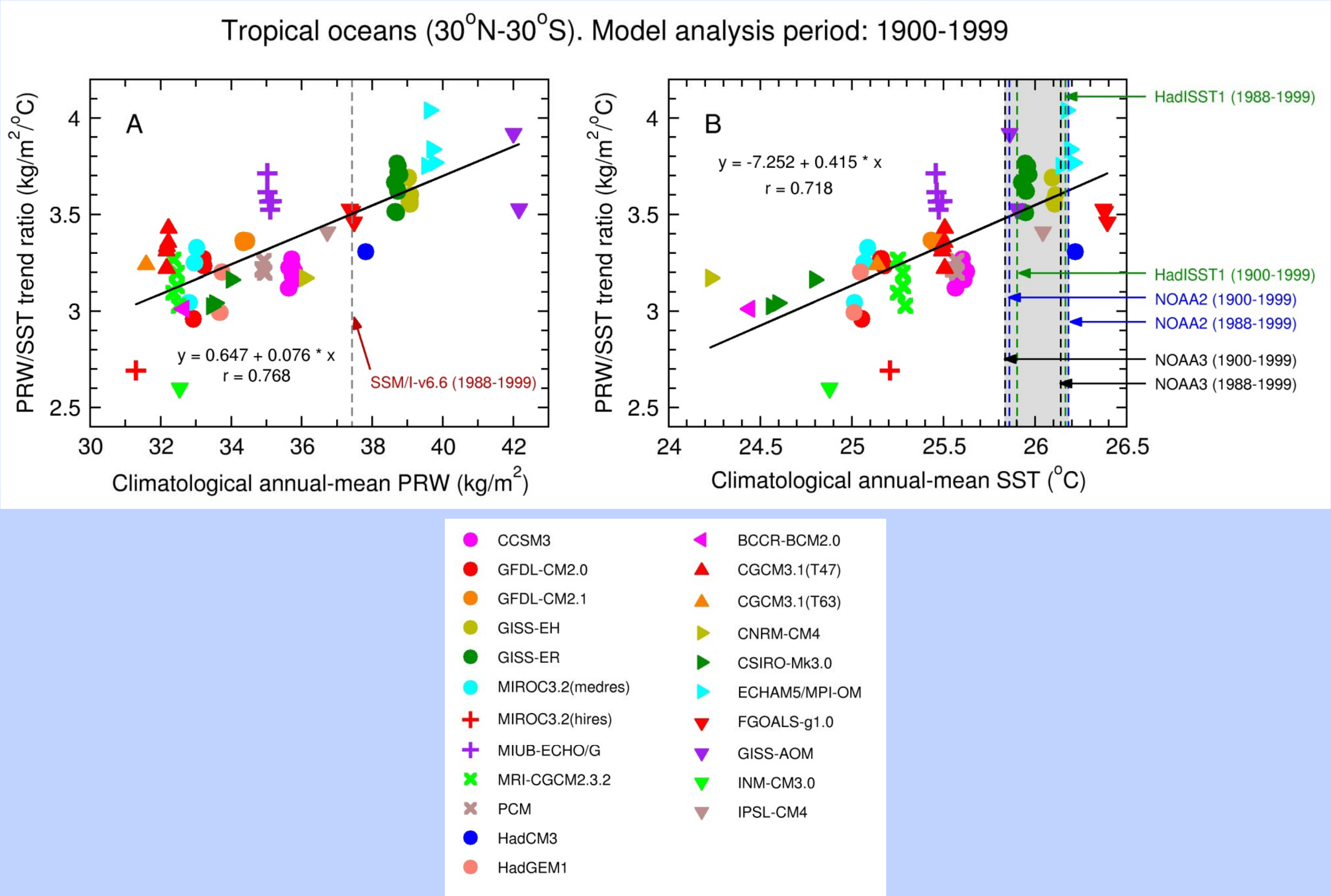

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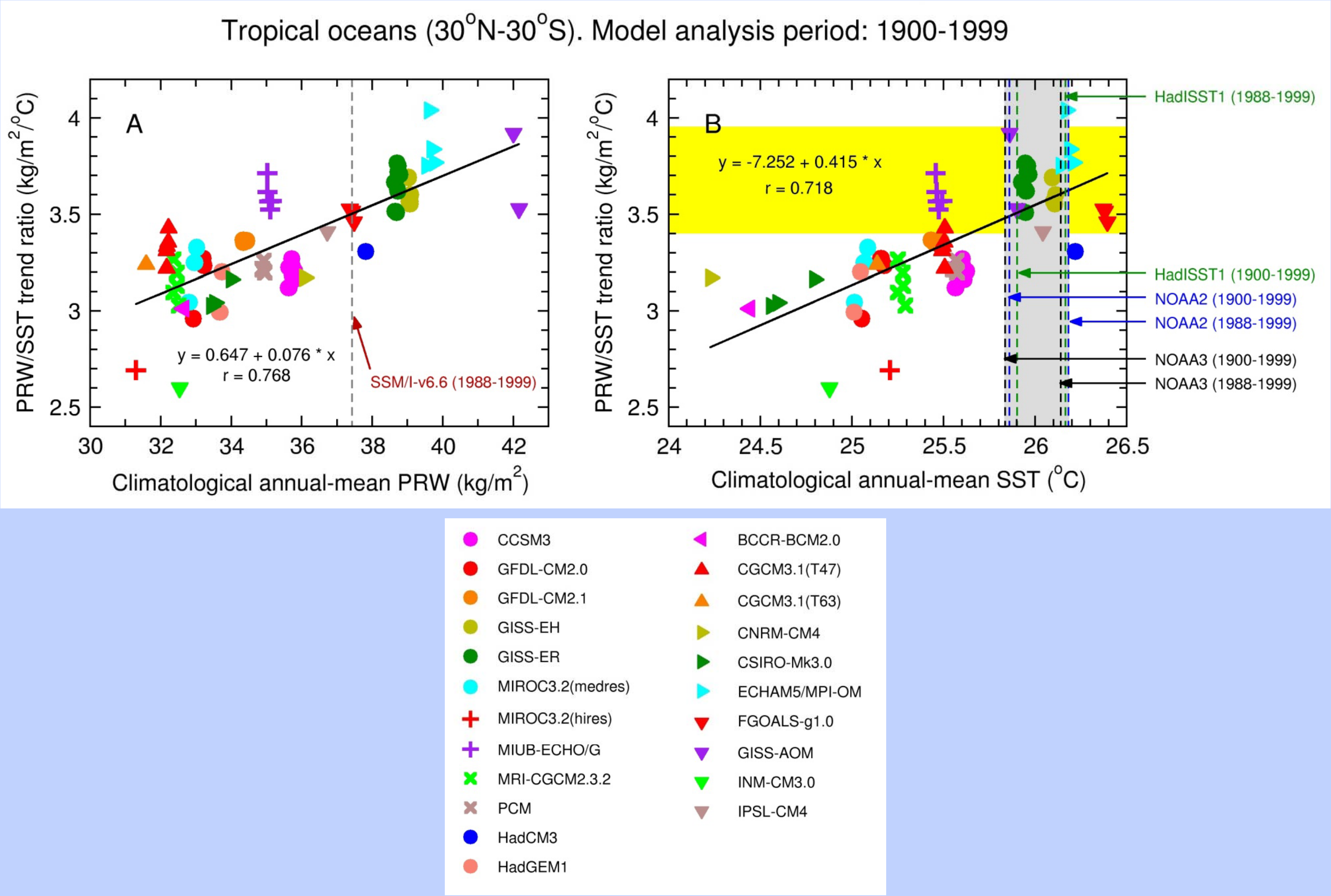
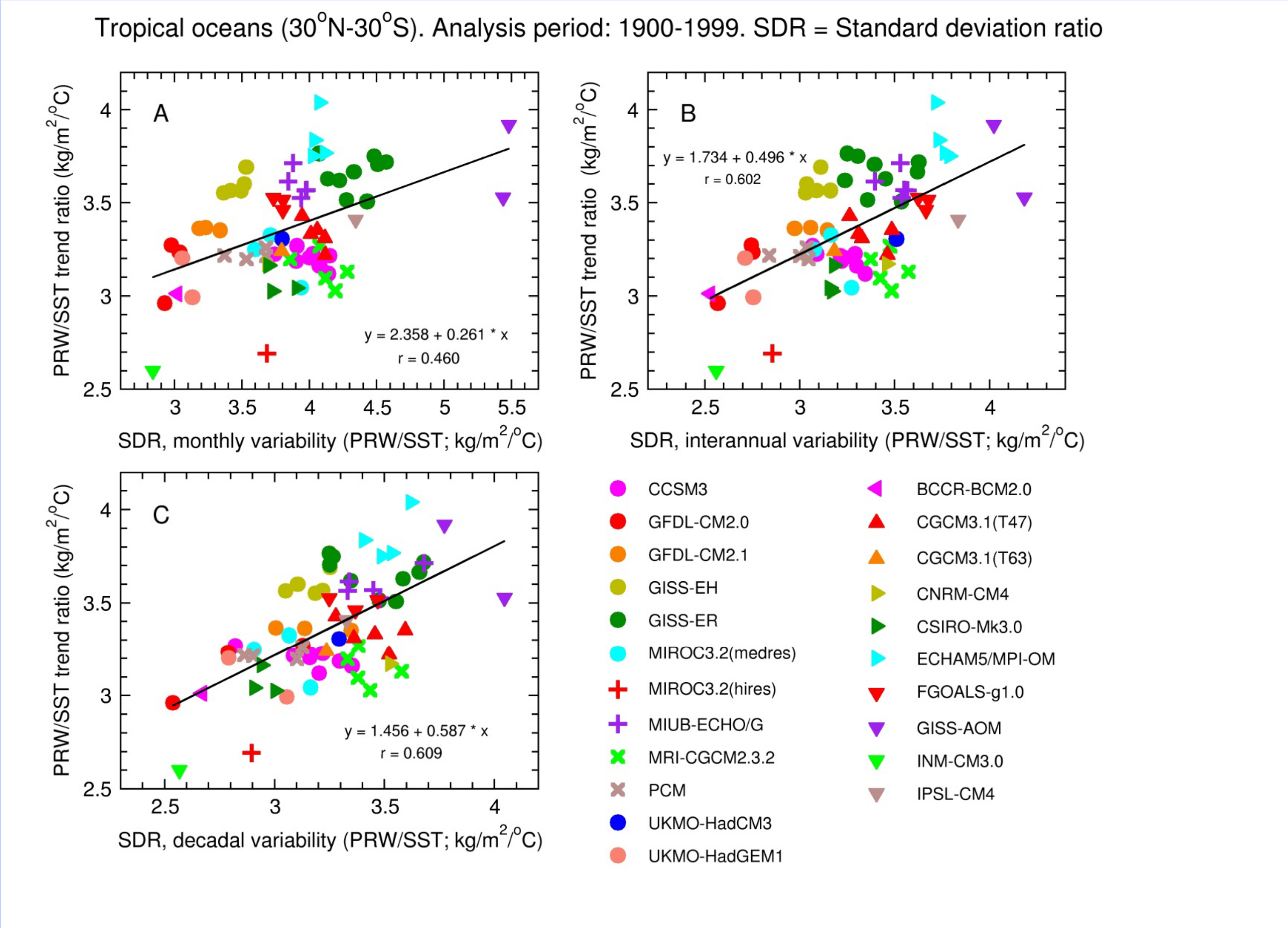


Relationship between water vapor and SST temporal variability and water vapor feedback



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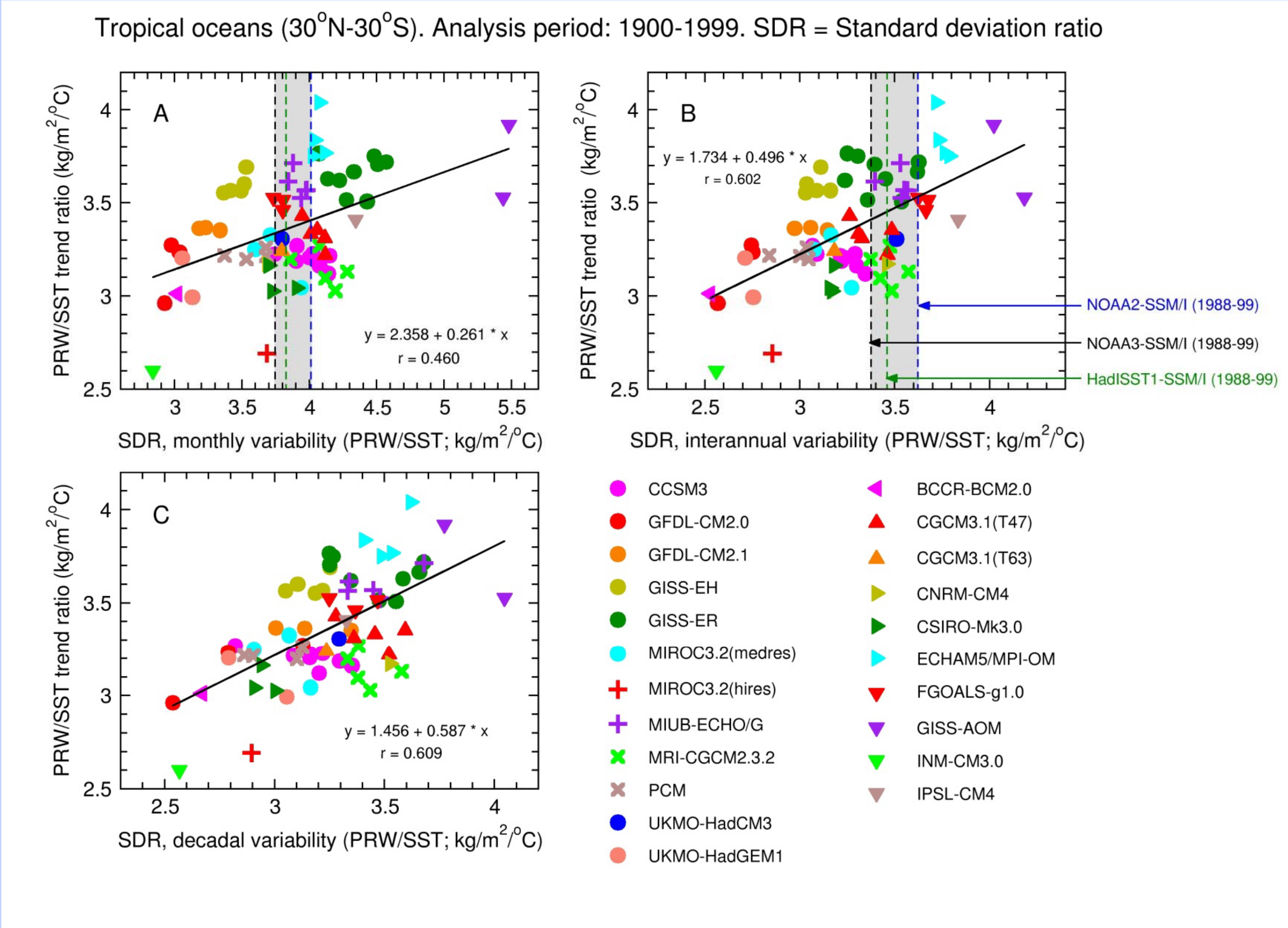

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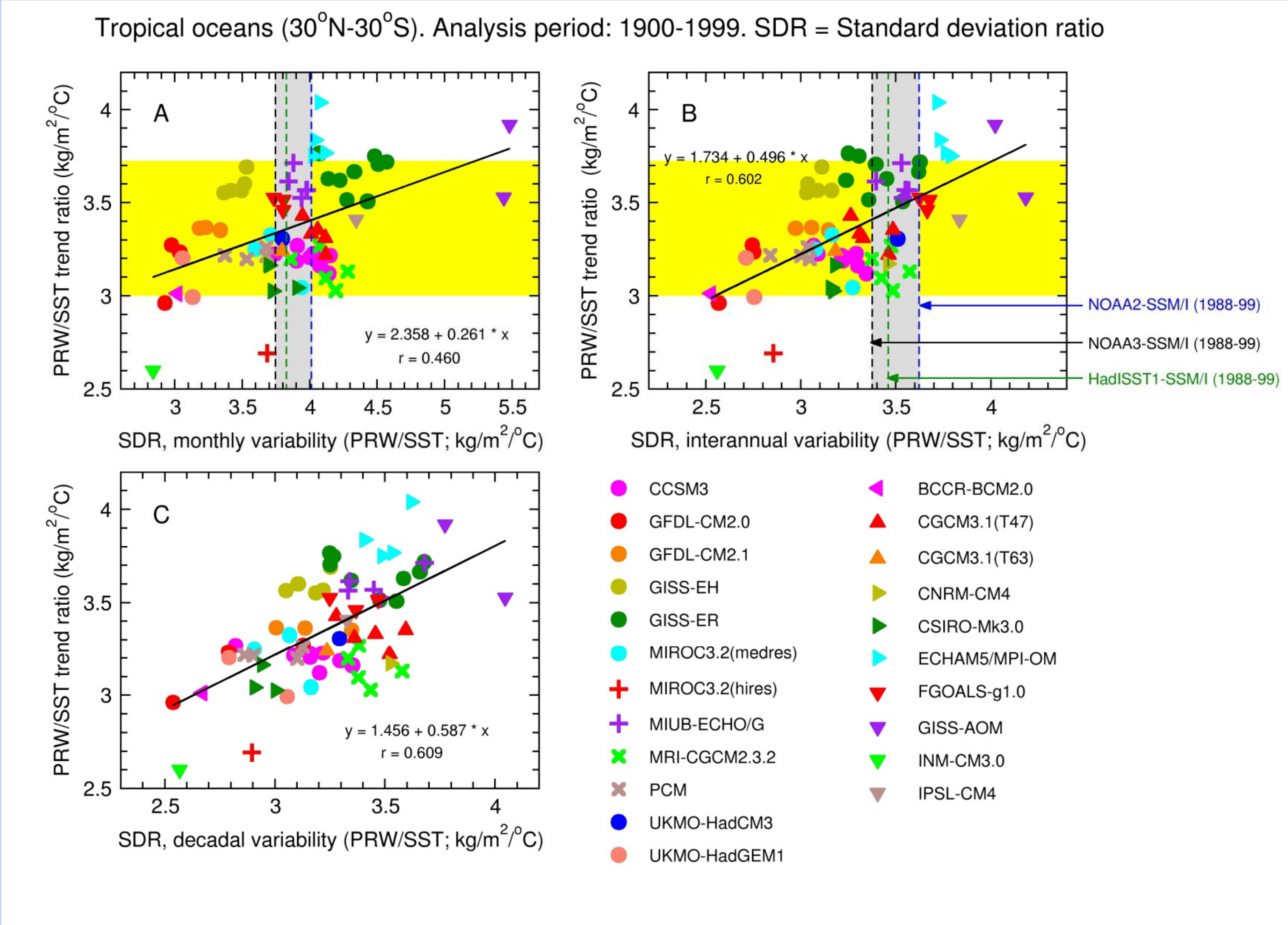

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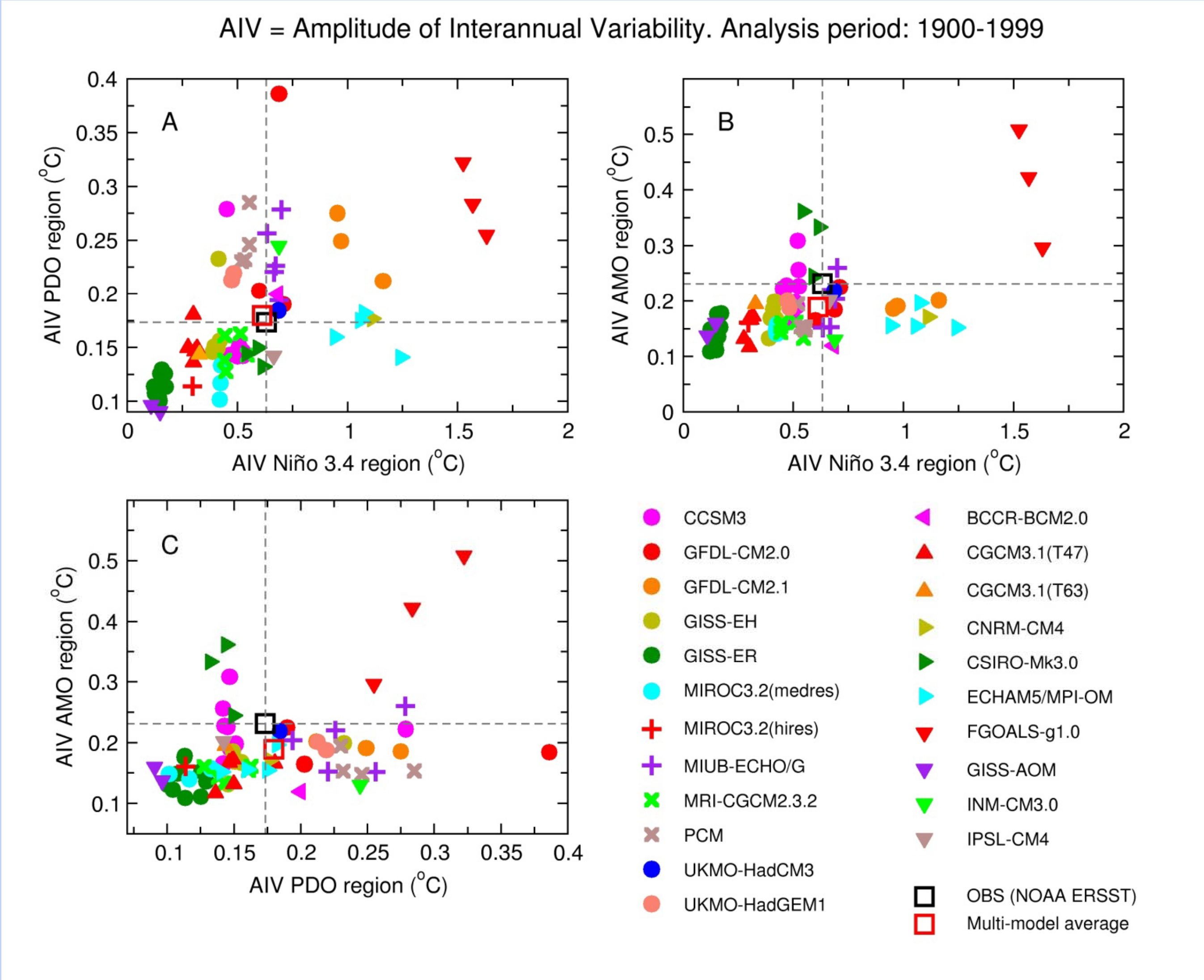
Conclusions

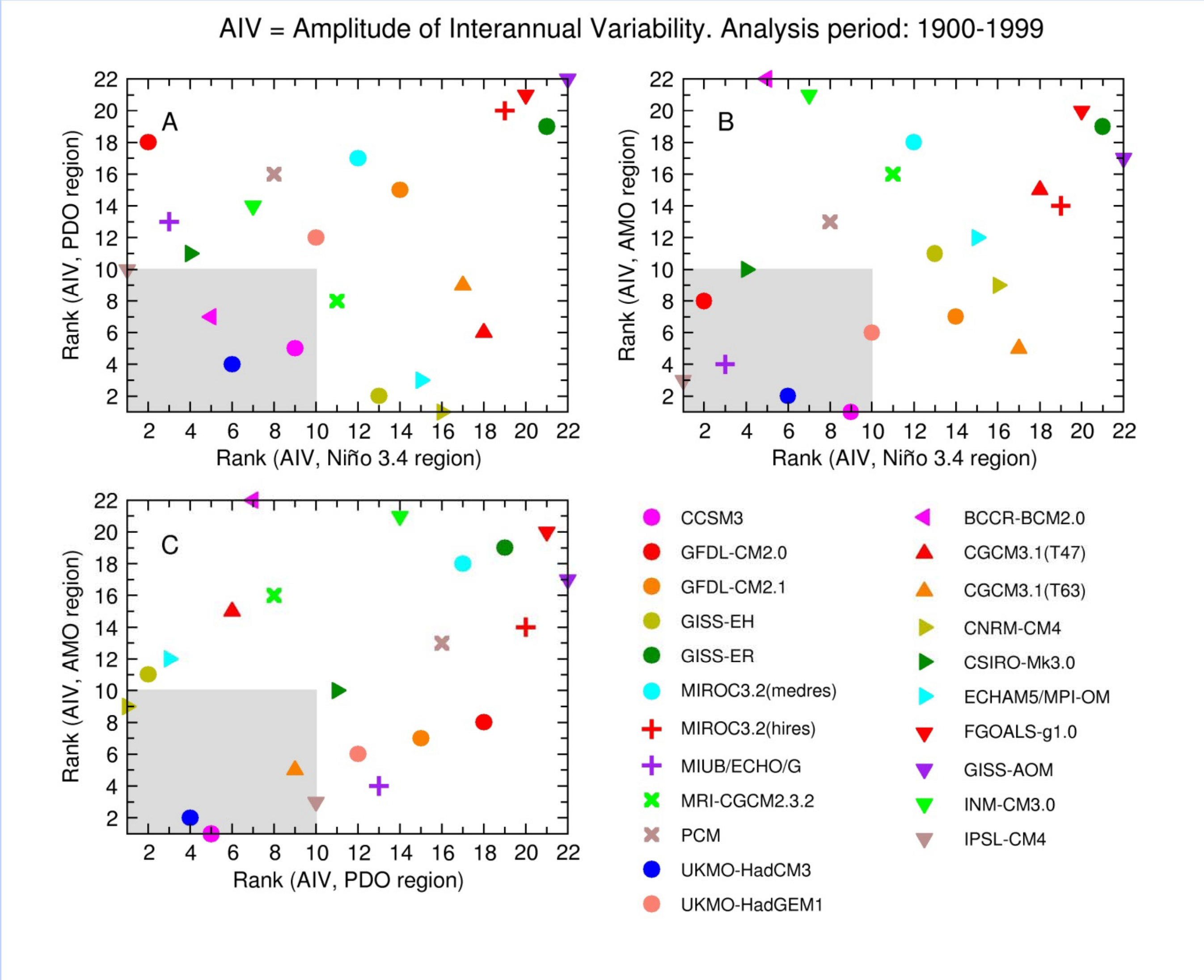
- Findings of Santer *et al*. (2009) are robust to current model uncertainties
- In climate model data, there is evidence that the behavior of the water vapor feedback over tropical oceans (30˚N-30˚S) varies by <10% from seasonal to century timescales
- SSM/I data can help to constrain uncertainties in model estimates of the water vapor feedback
  - ➡ Constraint is weaker than in Hall and Xu (for snow cover feedback)
- Observations appear to rule out “low range” of model water vapor feedback estimates
- Mean and variability data yield different constraints on feedback

- **EXTRA SLIDES**

Amplitude of simulated and observed SST variability in three different regions



Ranking of CMIP3 models based on amplitude of SST variability in three different regions



Relationship between water vapor and SST temporal variability and water vapor feedback