Diagnostics and Metrics for Evaluating GCM Simulations of the Asian-Australian Monsoon

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and the

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Diagnostics Task Team

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Gabriel Vecchi	Geophysical Fluid Dynamics Laboratory
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Outline

- Model Validation and Evaluation
  - AR4: Projections of climate change highly uncertain over the Asian-Australian monsoon region
  - CMIP5 vs. CMIP3: Are Revised Models Better Models?
  - First evaluate the Climate of the 20th Century simulations, then evaluate the climate change simulations
- Coordinated approach to model evaluation
  - Previous model intercomparison efforts that panel members have contributed to (e.g., Kang et al. 2002; Wang et al. 2004, Annamalai et al. 2007; Sperber and Annamalai 2008; Turner et al. 2010; Kim et al. 2011; …)
  - Diurnal though interdecadal time scales
  - Skill metric(s) for every diagnostic
- Closing Remarks

CLIVAR AAMP: Asian Monsoon

- Climatological mean performance (boreal summer)
  - Rainfall, 850hPa winds, SST patterns
  - Skill comparison: pattern correlations with observations-CMIP5 vs. CMIP3
- Climatological Annual Cycle
  - Monsoon Precipitation Domain (MPD) and Intensity (MPI)
  - Skill assessed via threat score for MPD and pattern correlation for MPI
  - Candidate diagnostic/metric for the WGNE/WGCM Metrics Panel
- Climatological Monsoon Onset, Peak, Withdrawal, and Duration
  - Pentad rainfall
- ENSO-monsoon relationship
  - Lead-lag of all-India rainfall with Nino3.4 SST
  - Nino3.4 regressions with local rainfall (Do models get the pattern correct?)
  - Lead-lag correlations of Nino3.4 SST with regional monsoon circulation indexes (ISMI, WNPSMI)
- Intraseasonal Variability
  - 20-100 day variance pattern, northward propagation, BSISV life-cycle
- Diurnal Cycle of Rainfall
  - Two leading EOF's

Observations vs. CMIP3 (20c3m; 1961-1999)
JJAS Rainfall Climatology

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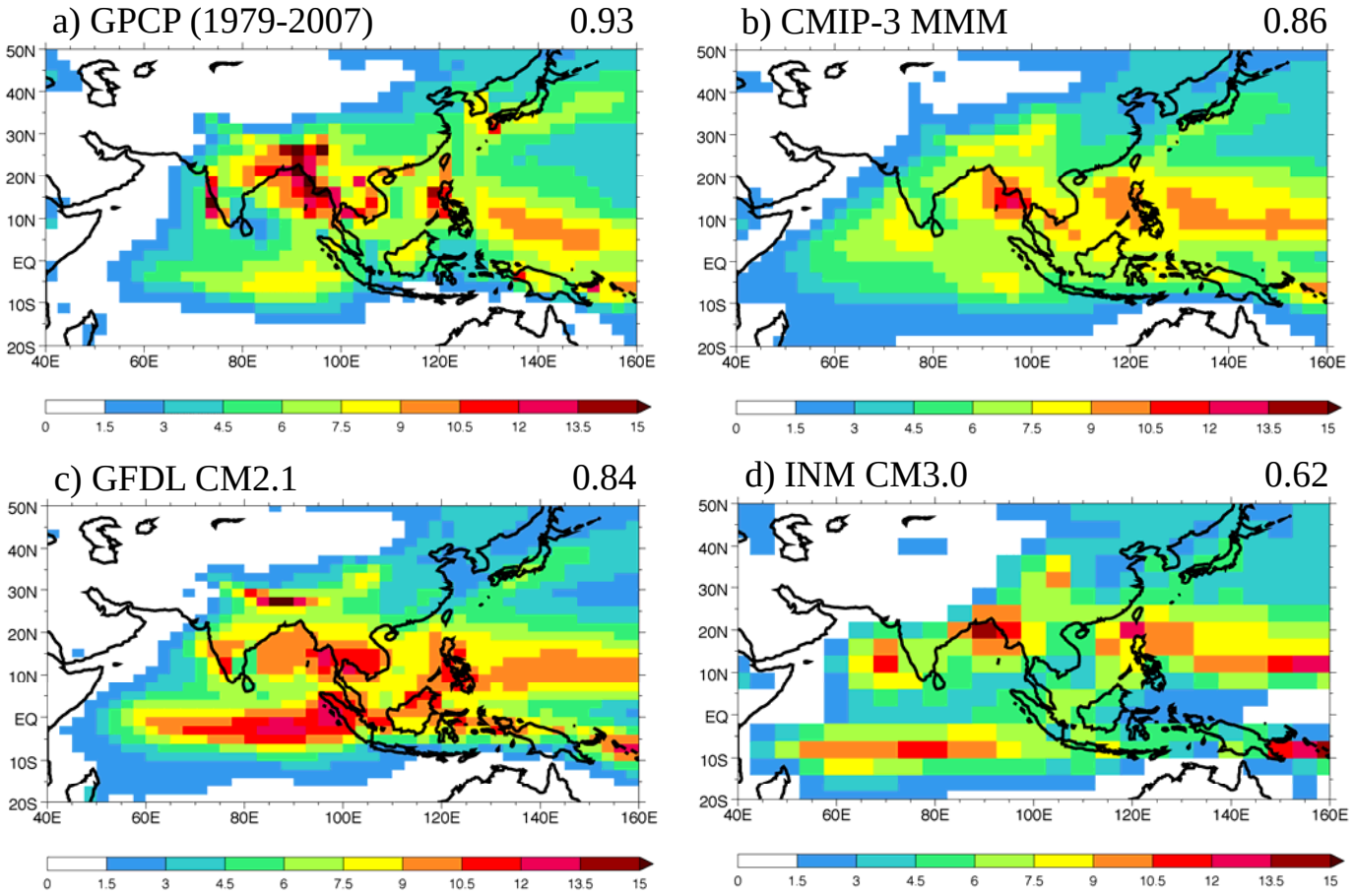
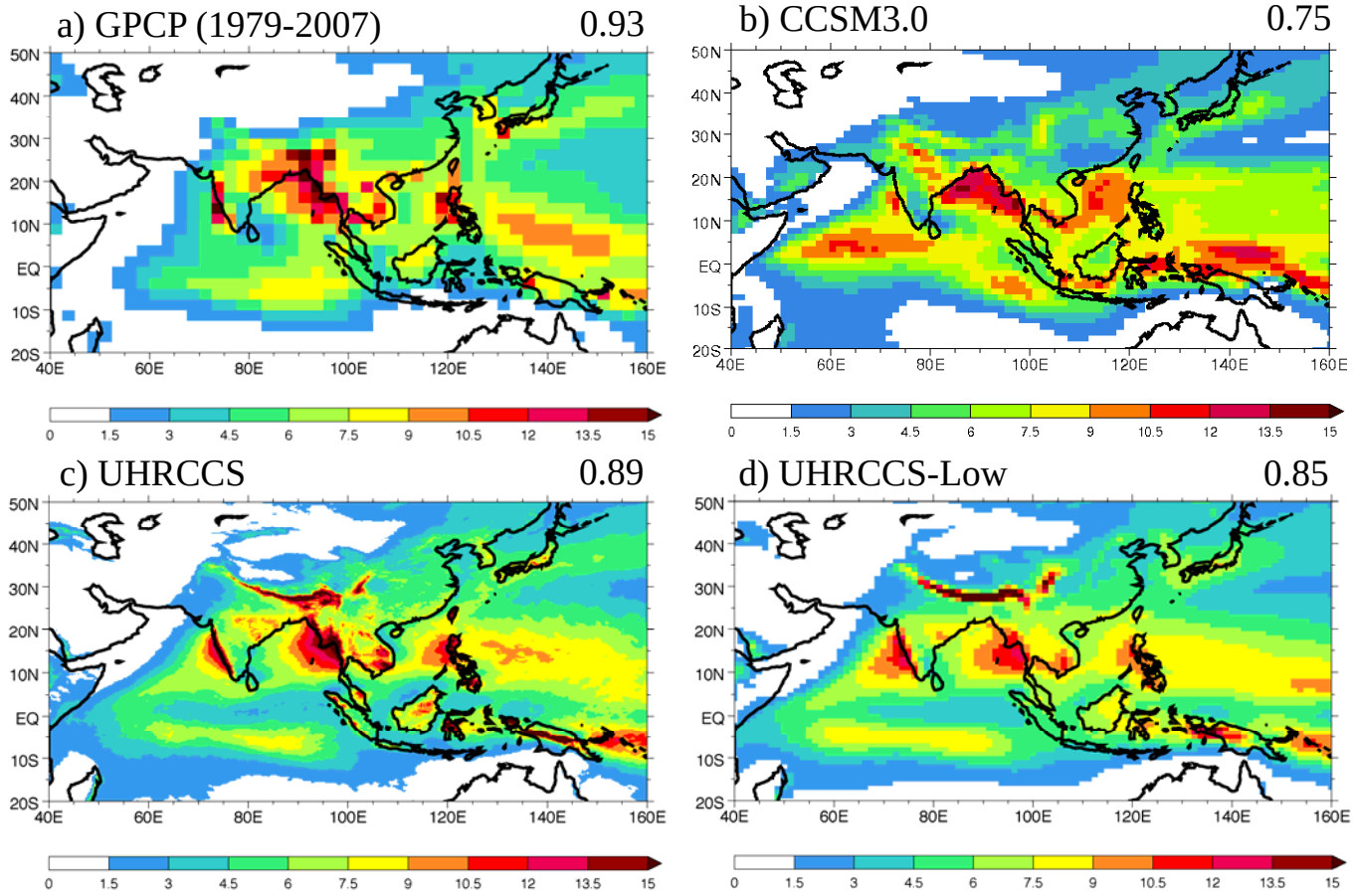
- Observed and simulated results include data from the CMIP3 multi-model mean, and the two models that show the range of performance
  - The CMIP-3 multi-model mean outperforms all of the individual CMIP-3 models



Observations vs. Development Version of CCSM4: JJAS Rainfall Climatology

- The development version of CCSM4 has skill nearly the same or better skill than the CMIP3 multi-model mean, and has larger skill than CCSM3
- High resolution (0.25^o atmos. x 0.1^o ocean) outperforms low-resolution (~1.25^o atmos. x ~1^o Ocean)



Observations vs. CMIP3 (20c3m; 1961-1999)
JJAS 850hPa Wind Climatology: Anomalies

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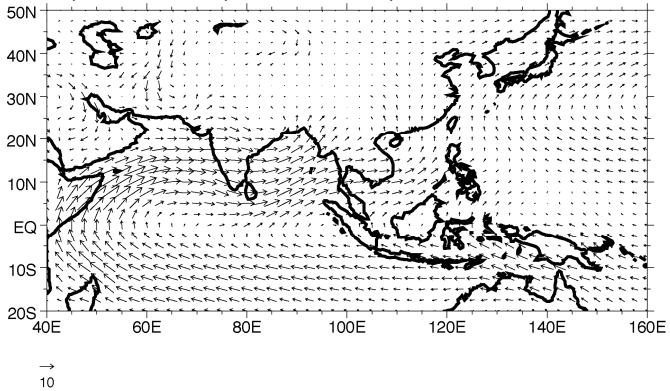
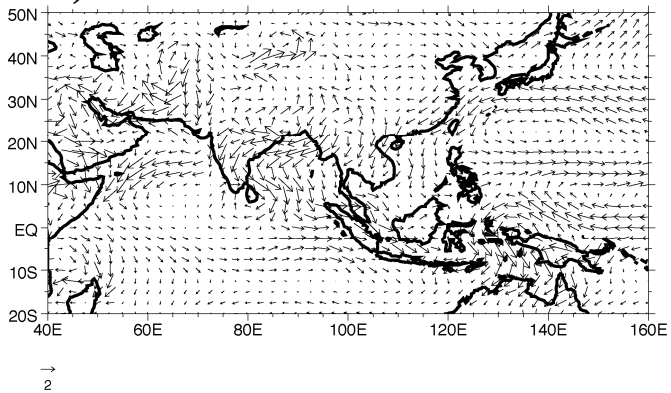
- Observed and simulated results include data from the CMIP3 multi-model mean, and the two models that show the range of performance
  - Errors in the wind consistent with errors in the precipitation climatology

a) ERA40 (1961-1999) 0.99



b) CMIP-3 MMM 0.97



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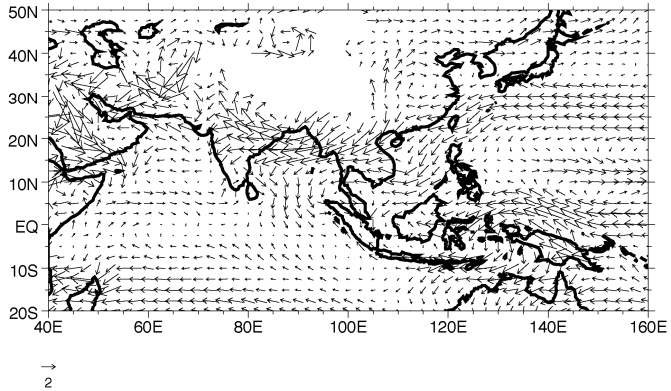
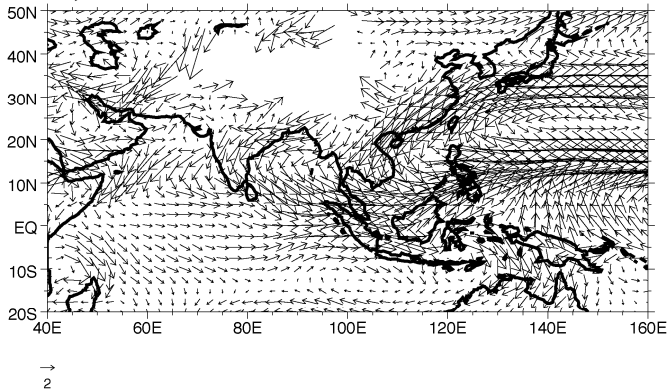
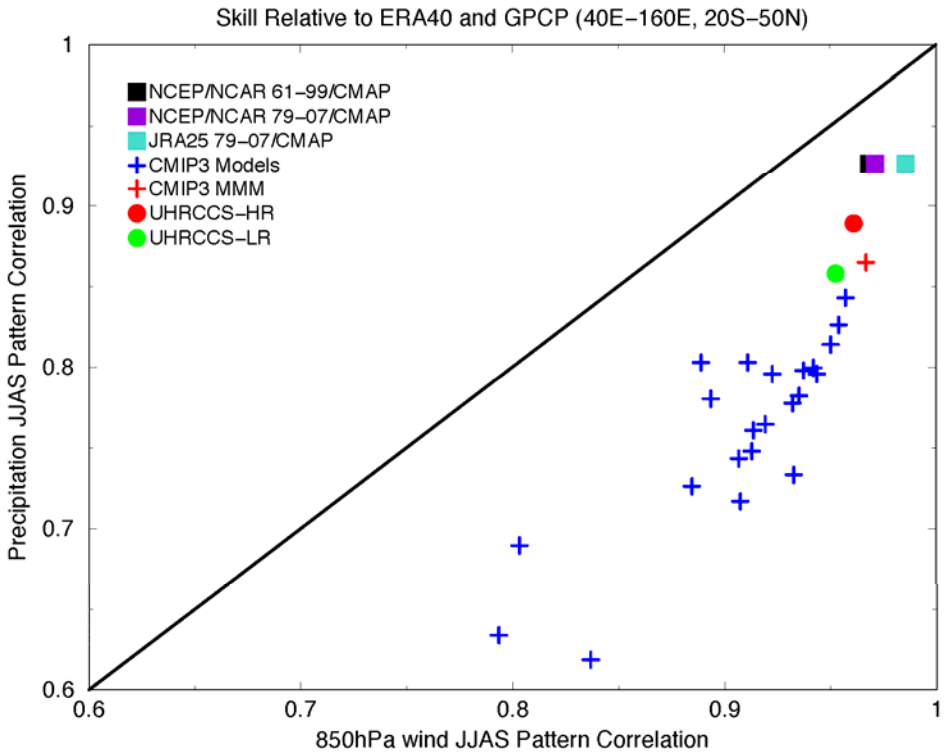


d) NCAR PCM1 0.79



Observations vs. CMIP3 (20c3m; 1961-1999)
JJAS 850hPa Wind vs. Rainfall: Skill

- 850hPa wind climatology pattern correlation vs. ERA40 (1961-1999)
- Rainfall climatology vs. GPCP (1979-2007)
  - Wind is better simulated than rainfall
  - High-resolution development version of CCSM4 outperforms CMIP3 models
  - Models are beginning to approach observational uncertainty in the simulation of the 850hPa wind climatology



Climatological Annual Cycle: MPI and MPD

- Designed by Wang and Ding (2008) and used in Wang et al. (2010) and Kim et al. (2011)
  - Candidate diagnostic/metric for the WGNE/WGCM Metrics Panel

Monsoon Precipitation Intensity = Annual Range/Annual Mean

where,

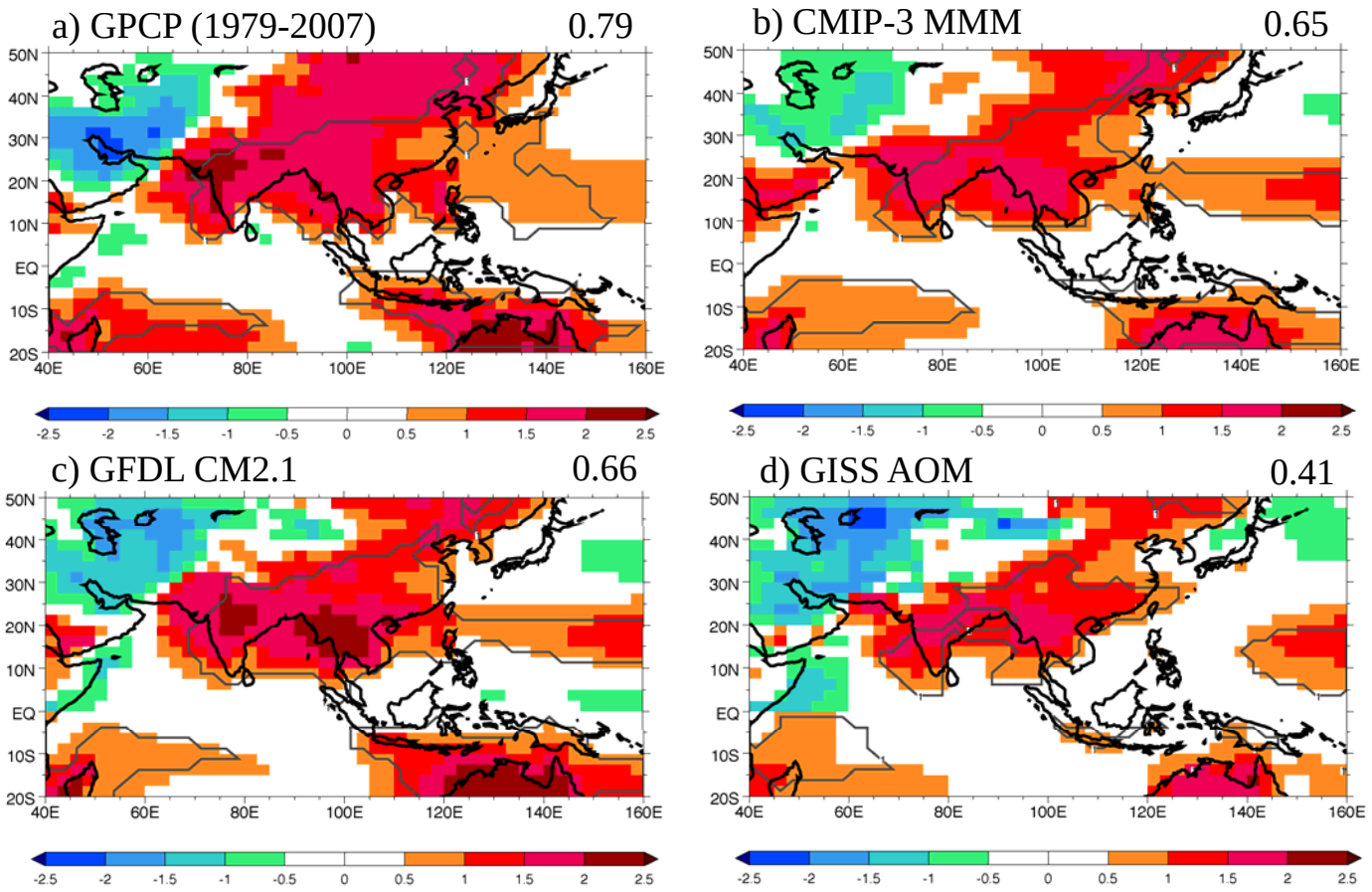
Annual Range = $Precip_{MJJAS} - Precip_{NDJFM}$ (Northern Hemisphere)

Annual Range = $Precip_{NDJFM} - Precip_{MJJAS}$ (Southern Hemisphere)

Monsoon Precipitation Domain defined where Annual Range > 2.5mm day^{-1}

Observations vs. CMIP3 (20c3m; 1961-1999)
MPI and MPD

- Observed and simulated MPD and MPI including the CMIP3 multi-model mean, and the two models that show the range of performance as indicated by the MPD threat score (categorical skill score: 0-bad, 1-good)
  - Monsoon Precipitation Domain: Isoline; Monsoon Precipitation Intensity: Shading



Observations vs. Development Version of CCSM4: MPI and MPD

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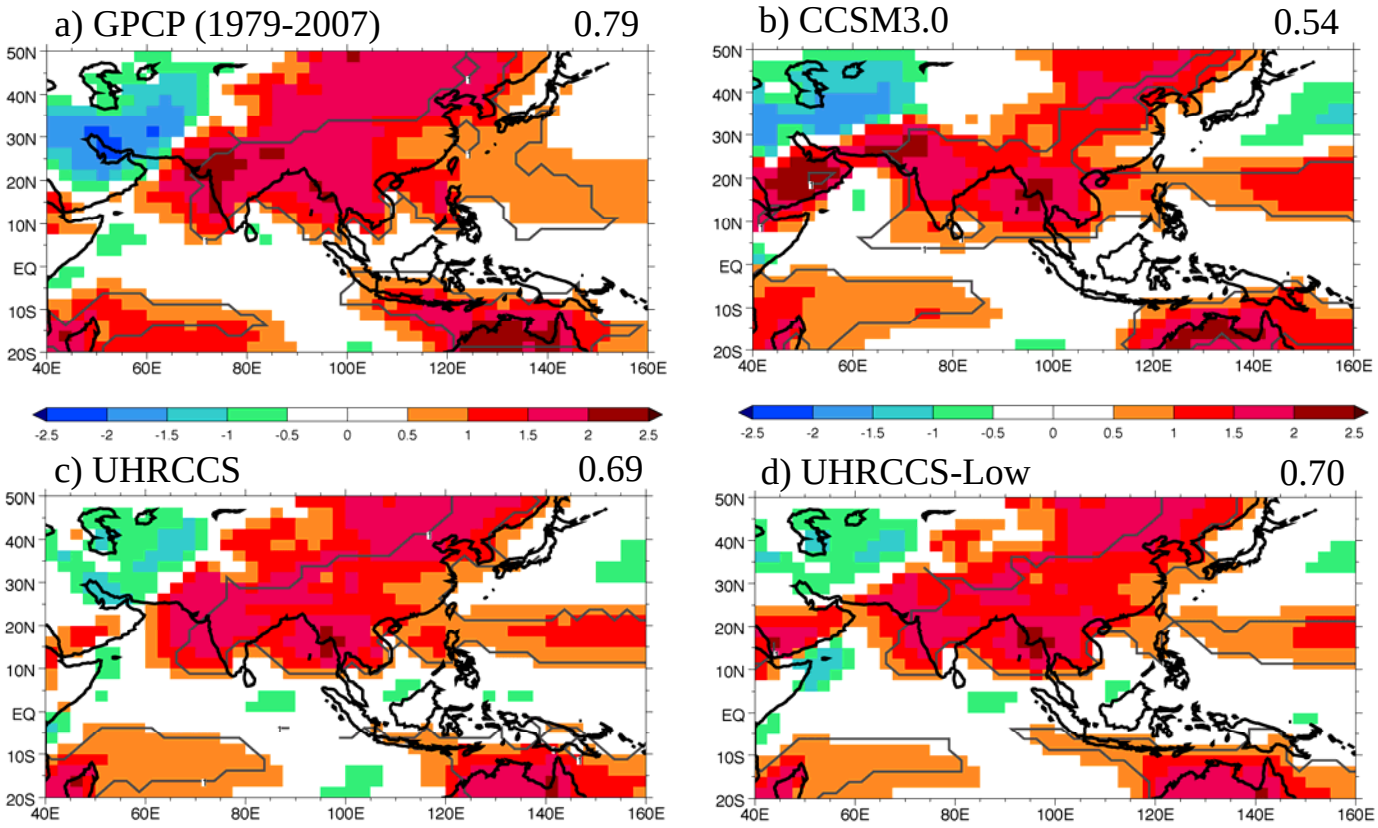
The development version of CCSM4 has better skill than the CMIP3 multi-model mean, and any of the CMIP3 models

– Monsoon Precipitation Domain: Isoline; Monsoon Precipitation Intensity: Shading



Observations vs. CMIP3 (20c3m; 1961-1999)
MPI and MPD Skill

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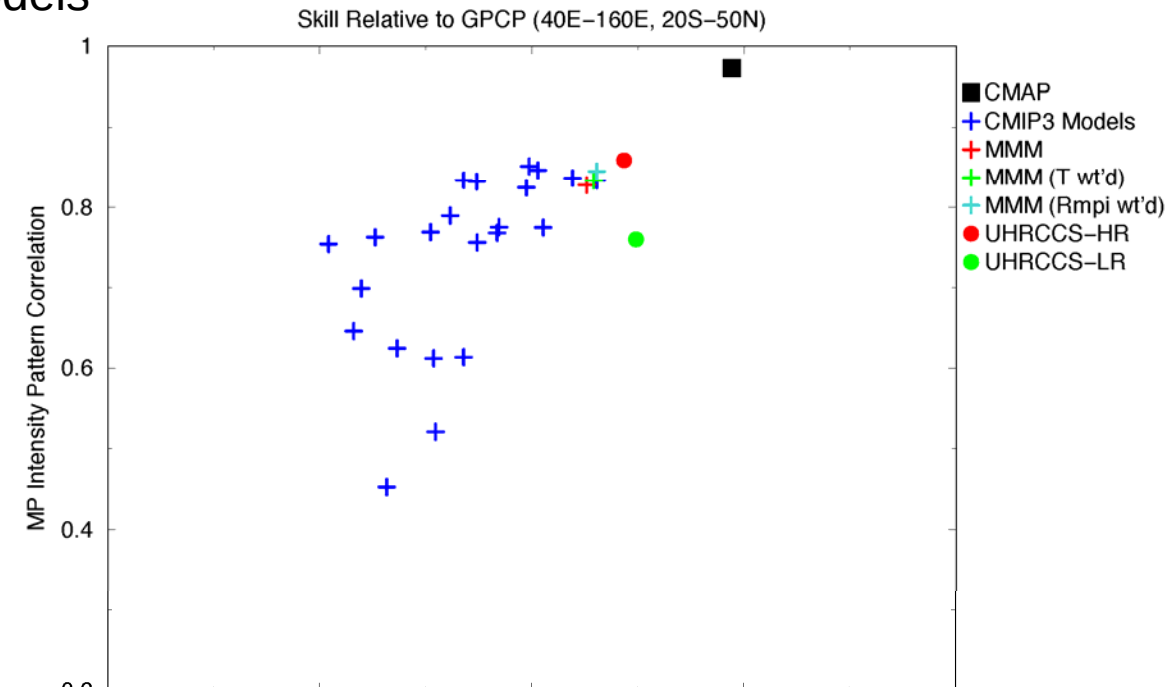
- Skill score assessment relative to GPCP indicates that the multi-model mean performs nearly as well as the best model
- Weighting the models by their threat score or MPI pattern correlation does not result in substantial improvement over the uniformly weighted multi-model mean
- The high-resolution development version of CCSM4 outperforms all of the CMIP3 models



Closing Remarks

- CMIP5 will be a substantial database that will provide and unprecedented opportunity for evaluating climate models in terms of their ability
  - To simulate past, present, and potential future effects due to anthropogenic climate change
  - To evaluate the forcing sensitivities that give rise uncertainty in future change
  - Understanding of processes the are important for simulating modes of variability
  - The potential for making decadal predictions
- CLIVAR AAMP and the YOTC MJOTF are developing diagnostics and metrics
  - To evaluate and understand how well the current generation of models perform with respect to earlier models
  - For evaluating the impact of anthropogenic climate change

Observations vs. CMIP3 (20c3m; 1961-1999)
JJAS Rainfall Climatology: Anomalies

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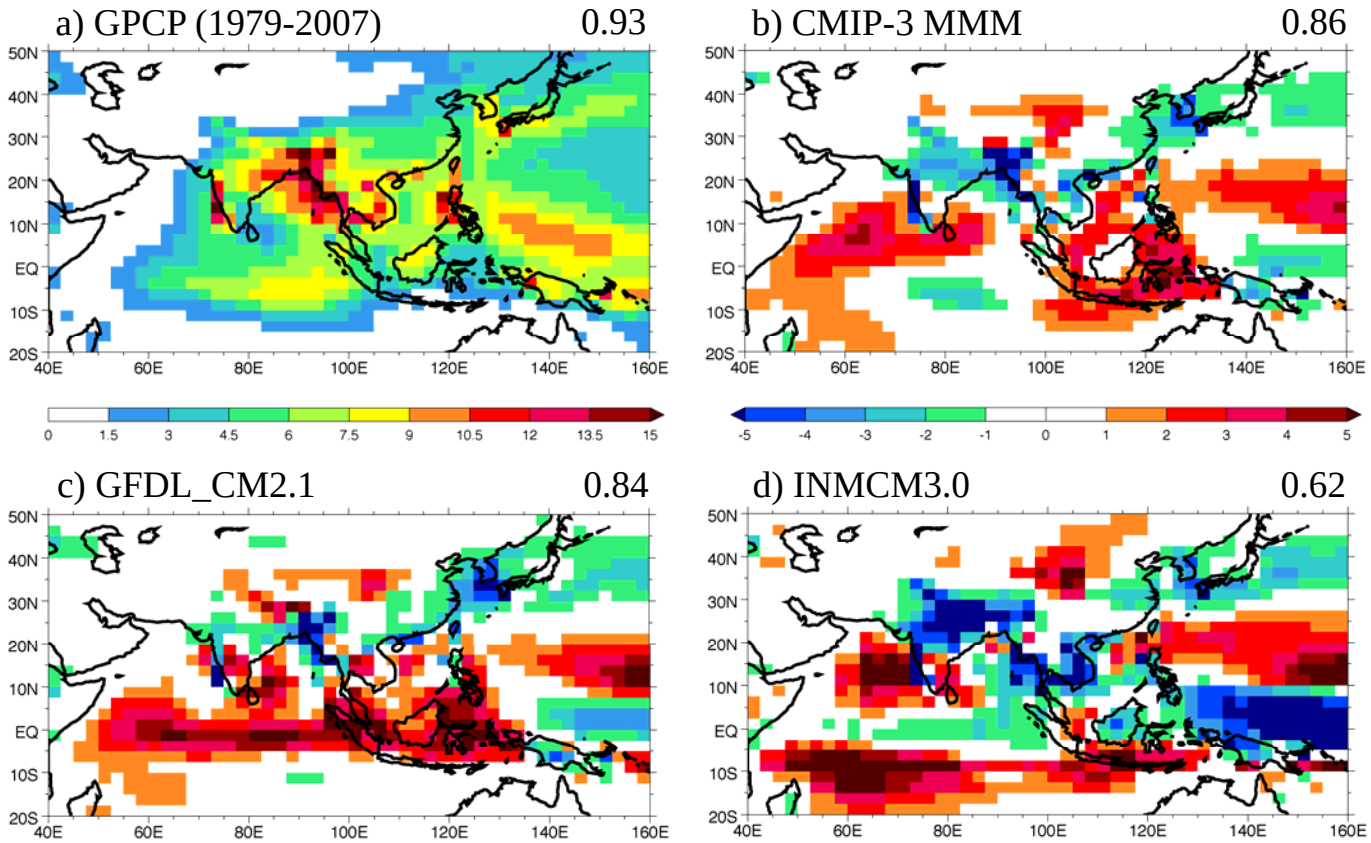
Observed and simulated results include data from the CMIP3 multi-model mean, and the two models that show the range of performance

– Common errors: dry over portions of India and Southeast Asia; tripole pattern over the Pacific Ocean



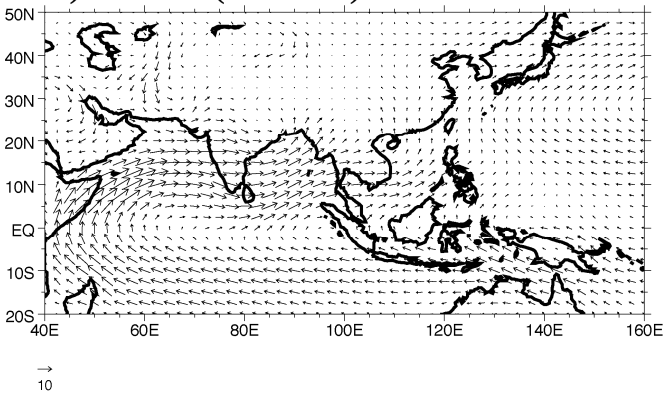
Observations vs. CMIP3 (20c3m; 1961-1999)
JJAS 850hPa Wind Climatology

Program for Climate Model Diagnosis and Intercomparison

Observed and simulated results include data from the CMIP3 multi-model mean, and the two models that show the range of performance

– The wind pattern correlations are larger than those of precipitation

a) ERA40 (1961-99) 0.99



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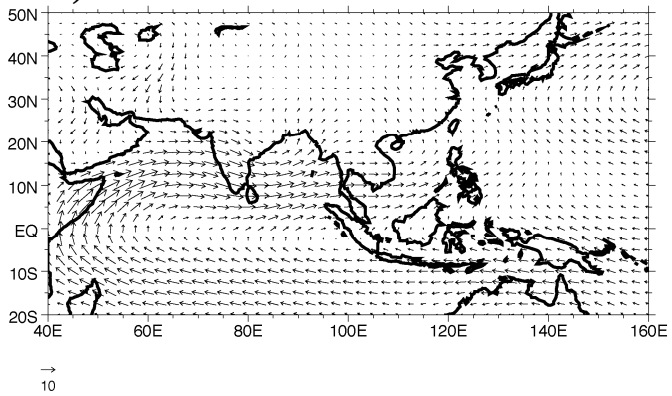

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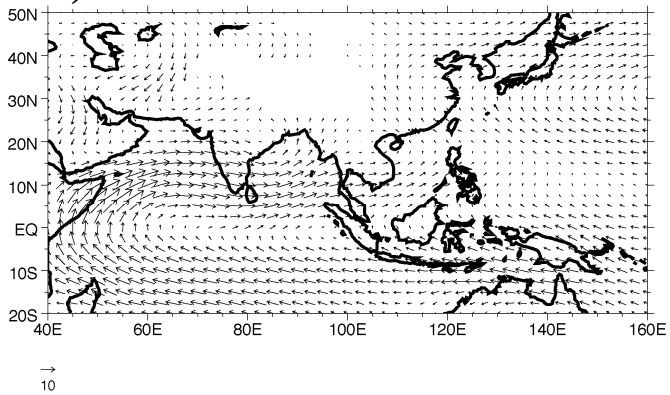

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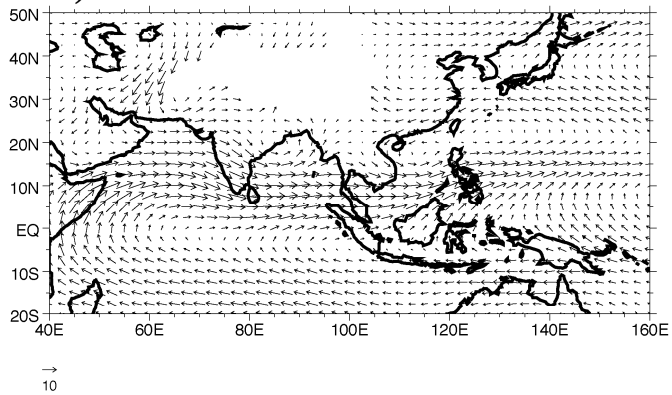

Boreal Summer Intraseasonal Variability: CMIP3 (20c3m; 1961-1999) + ECHAM4/OPYC

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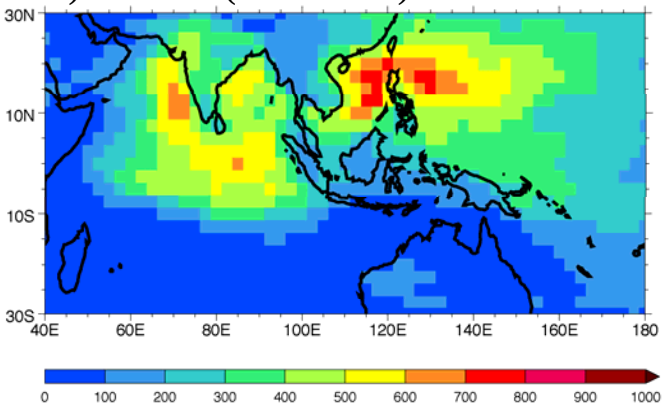
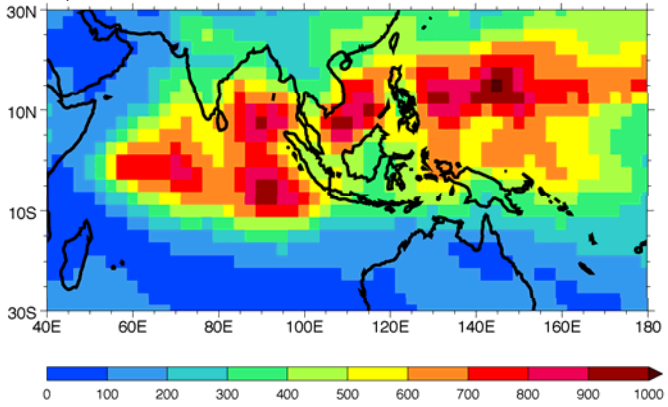
Variance of 20-100 day bandpass filtered OLR (JJAS)

- Pattern correlation relative to AVHRR OLR
- ECHAM4/OPYC, the predecessor to ECHAM5-OM, also has a large pattern correlation

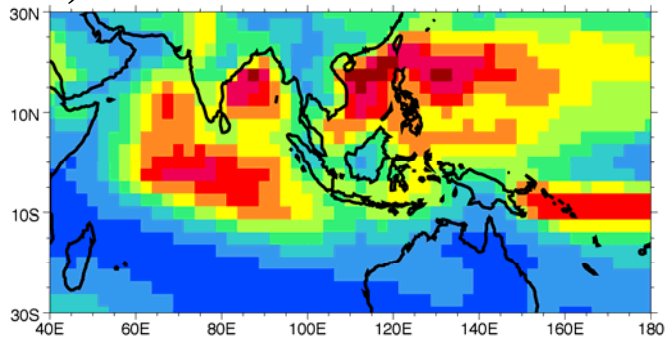
a) AVHRR (1979-2006)



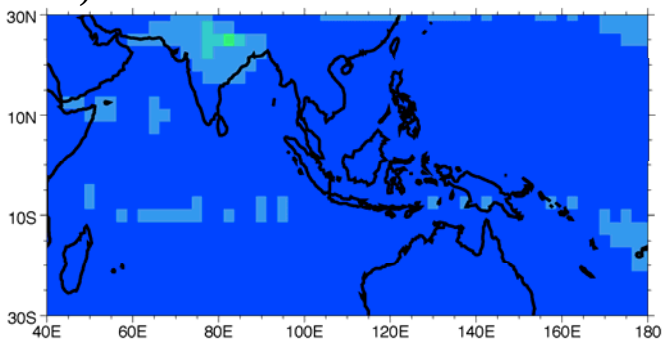
b) ECHAM4/OPYC 0.83



c) ECHAM5-OM 0.87

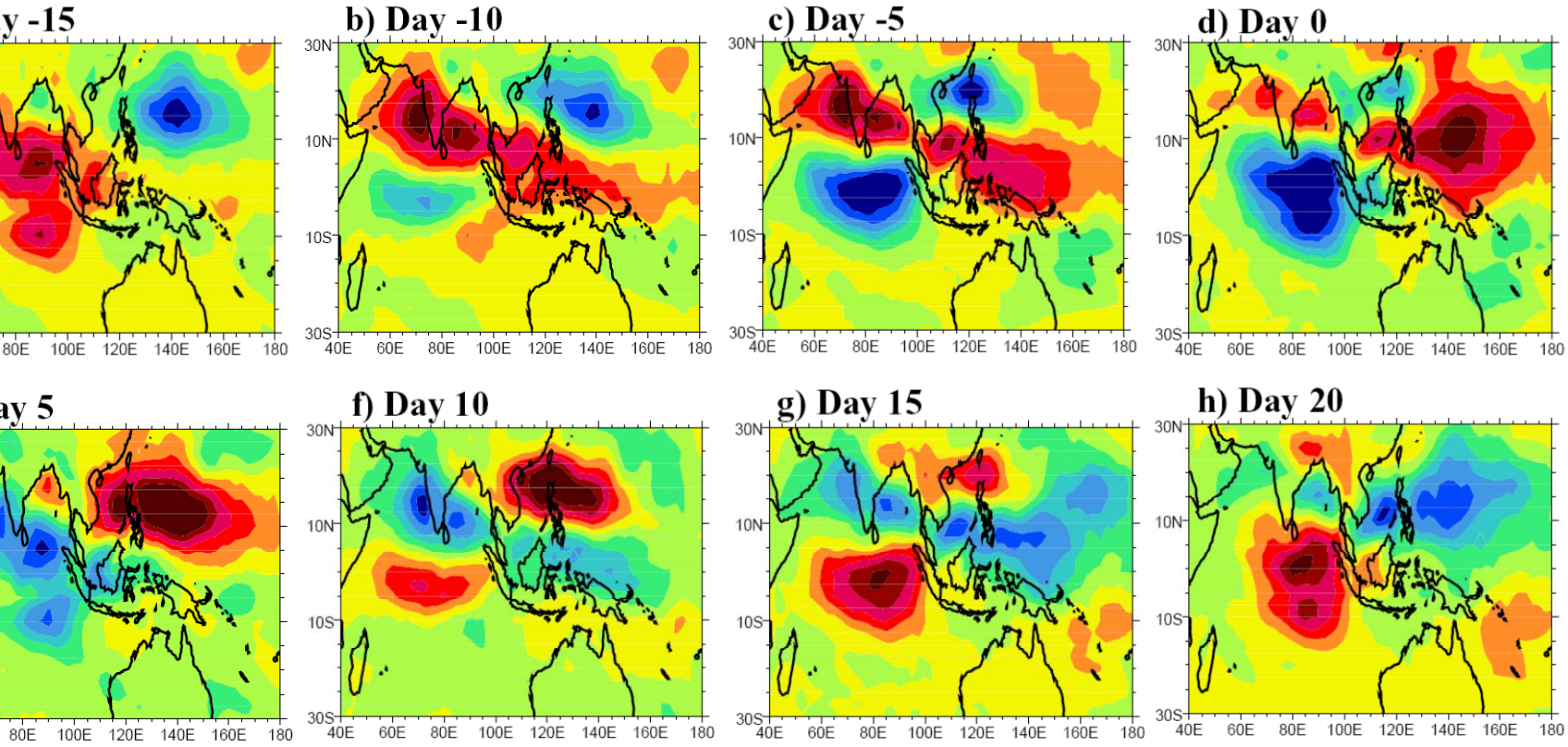


d) GISS AOM -0.07



BSISV: Cyclostationary EOF (CsEOF) using 20-100 day filtered AVHRR OLR (Wm^{-2})

- Eastward and northward propagating OLR anomalies (Annamalai and Sperber 2005, *JAS*, 2726-2748)



Boreal Summer Intraseasonal Variability: CMIP3 (20c3m; 1961-1999) + ECHAM4/OPYC

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Evaluate the skill of simulating the life-cycle of the BSISV vs. the skill at simulating the 20-100 day filtered variance

- For the CMIP3 models the life-cycle of the BSISV is better simulated in models that have a better pattern correlation in their simulation of the 20-100 day filtered variance (the linear regression fit is significant at better than the 1% level)
- Though the ECHAM4/OPYC model has a slightly smaller life-cycle pattern correlation than 2 of the other models, examination indicates that it is actually the most realistic (see Sperber and Annamalai 2008, Clim. Dynam., 31, 345–372)