Uncertainties in CMIP3/5 over South Asia

H. Annamalai

INTERNATIONAL PACIFIC RESEARCH CENTER

Annamalai et al. (2007, J. Climate)
Turner and Annamalai (2012,, Nature – Climate Change)
Sperber, Annamalai et al. (2012, Climate Dynamics)
Annamalai, Hafner, Sooraj and Pillai (2012, J. Climate in press)
Annamalai, Mehari and Sperber (2012, submitted)

Climate change and persistent Droughts: Impacts, Vulnerability and adaptation strategies for rice growing sub-basins of India

Tamil Nadu Agricultural University
Coimbatore, TN, India
www.tnau.ac.in

(The Norwegian Institute for Agricultural and Environmental Research)
www.bioforsk.no

INTERNATIONAL PACIFIC RESEARCH CENTER

(2007 – 2012) - Funded by Royal Norwegian Embassy New Delhi, India

http://www.climarice.com

ClimaRice (2007 – 2012) – Two phases (www.climarice.com)

- Technical Briefs

Agriculture/Socio-economic - Dr. Senthilnathan (TNAU)

Hydrology and Water resources - Dr. Balaji (IIT, Chennai)

Maldives, Cauvery basin - Dr. Srinivasan (RIMES, Bangkok)

Pacific Islands (IPRC - lead) - East West Center, USGS

Historical climate simulations ~ 1850 to 2005 (CMIP5)
~ 1861 to 2000 (CMIP3)

best estimates of forcing ~ aerosols, GHG, volcanic, land use change etc
"effectively influence the radiative forcing"

Free climate simulation – observed temporal variability not constrained

- correlations between observed and simulated rainfall are expected to be weak – more so on regional scales

three types of errors (current climate simulation)

- large-scale atmospheric states (across all time scales)
- or unrealistic response to forcing

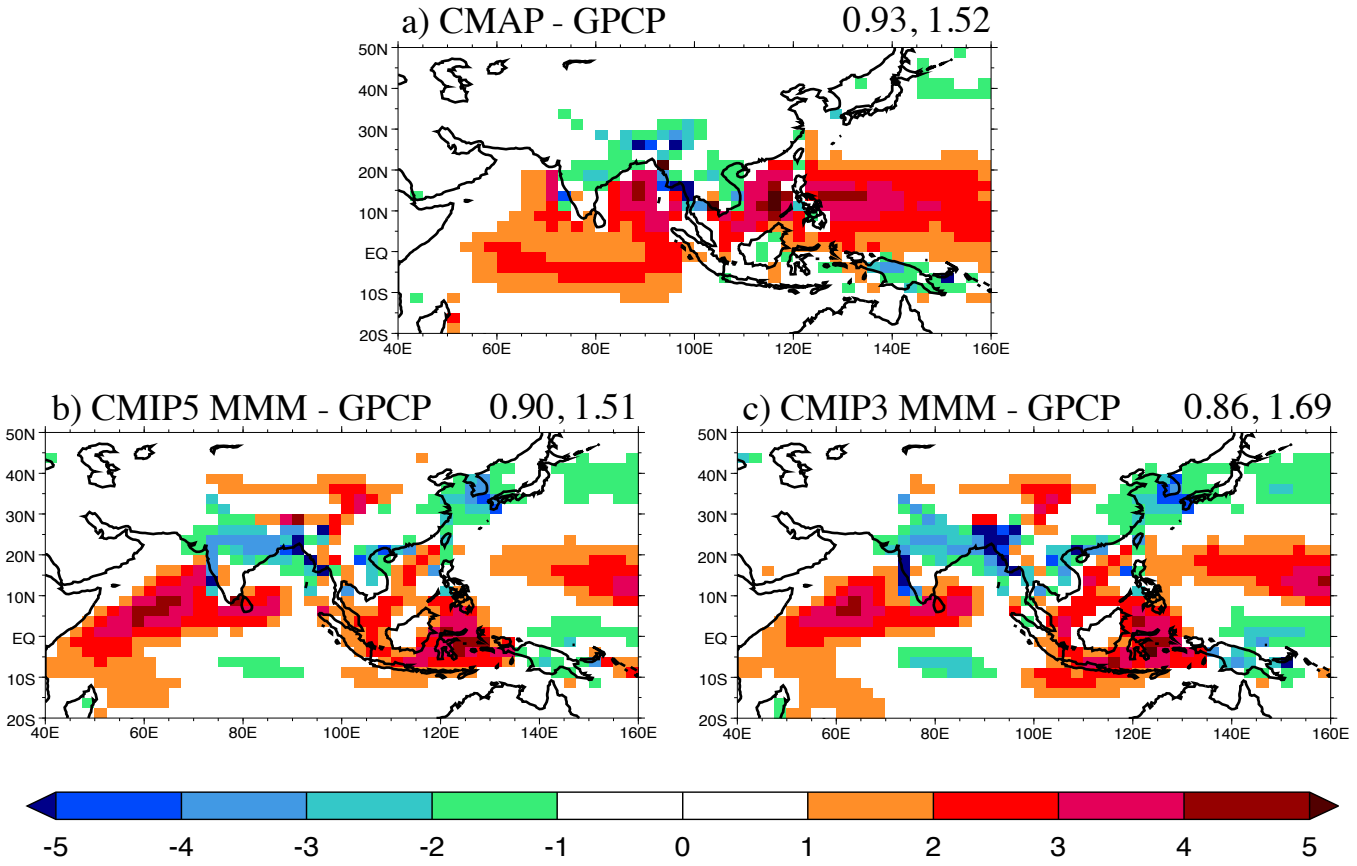
- atmospheric internal variability (across all time scales)

- model physical parameterizations

"assess uncertainties in various aspects of the monsoon – large scale"

JJAS Rainfall Climatology (mm day^{-1}): Systematic Error vs. Observational Spread

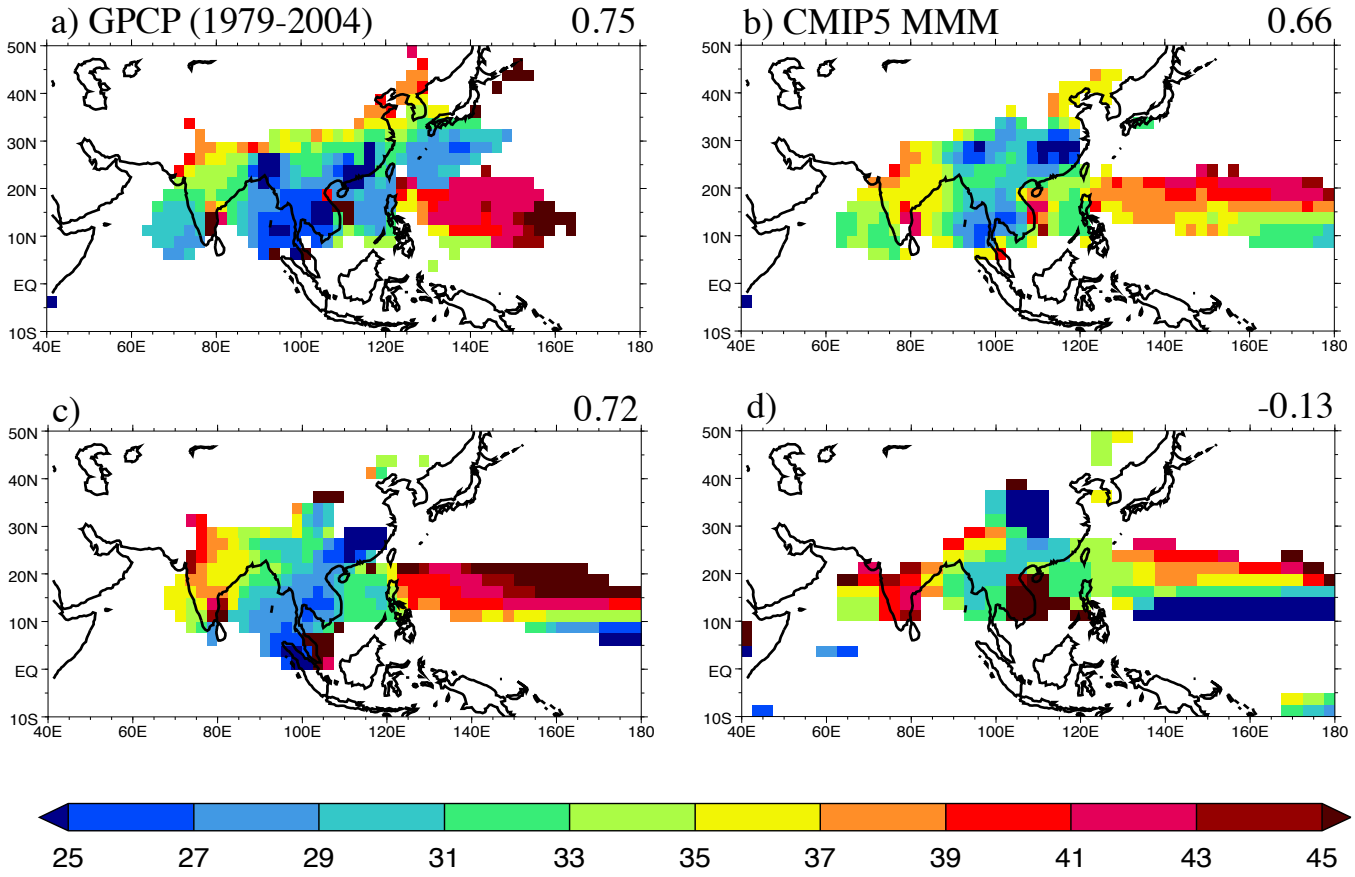
- The systematic error of rainfall is nearly identical in CMIP5 and CMIP3, and their error structure is similar to the difference between CMAP and GPCP
  - Relative to GPCP, the CMIP5 MMM has a larger pattern correlation and a smaller root-mean-square error than the CMIP3 MMM



Sperber, Annamalai et al. (2012, Climate Dynamics)

Climatological Monsoon Onset (Pentad)

- Observed and simulated results include data from the CMIP5 MMM, and the two models that show the range of performance
  - Individual models outperform the multi-model mean
  - Biases: Extent of monsoon domain; timing



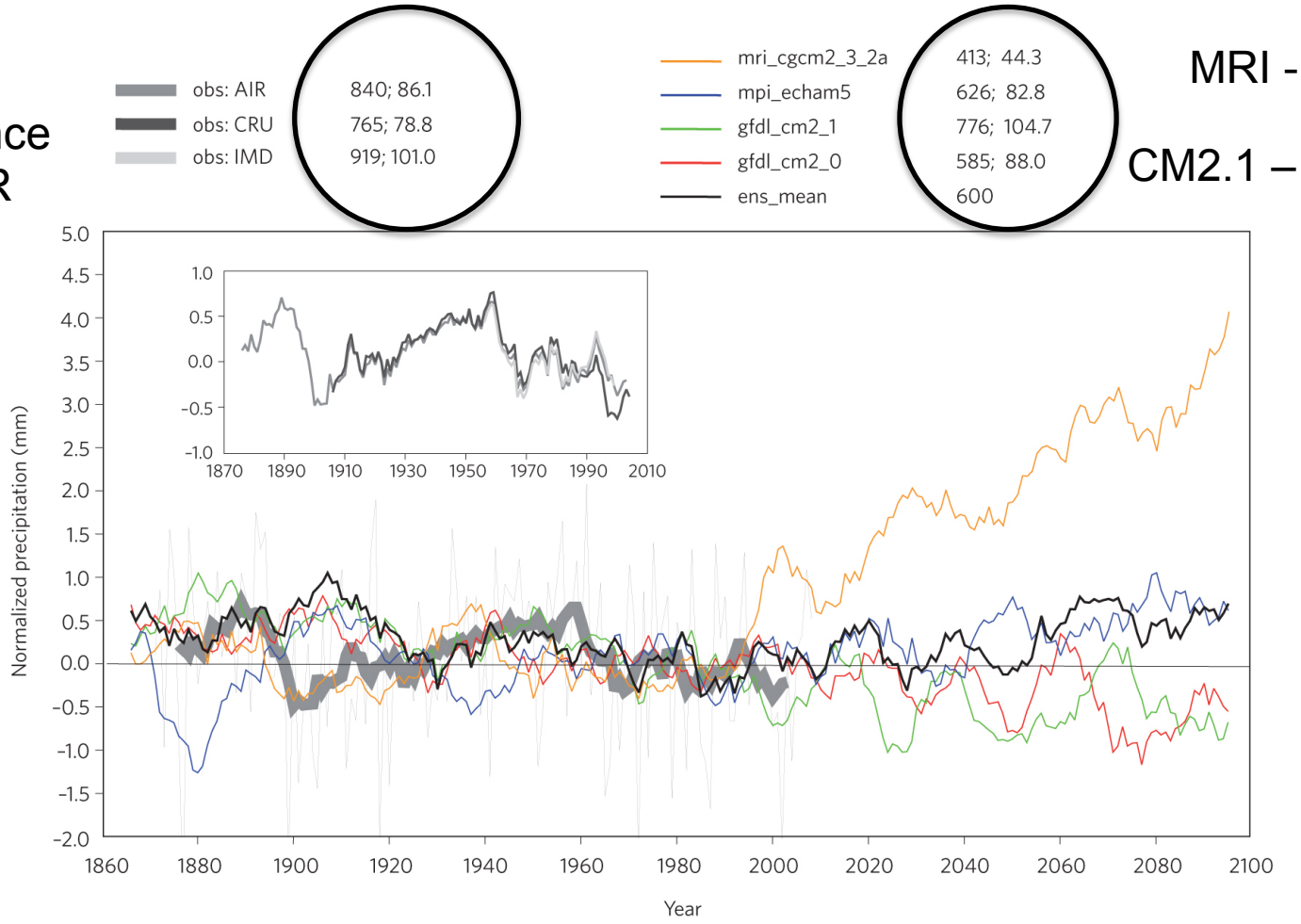
"best"

"worst"

"Onset over South Asia is well delayed"

Uncertainties in observations and models

CRU weak
10% difference
Between AIR



MRI - weak

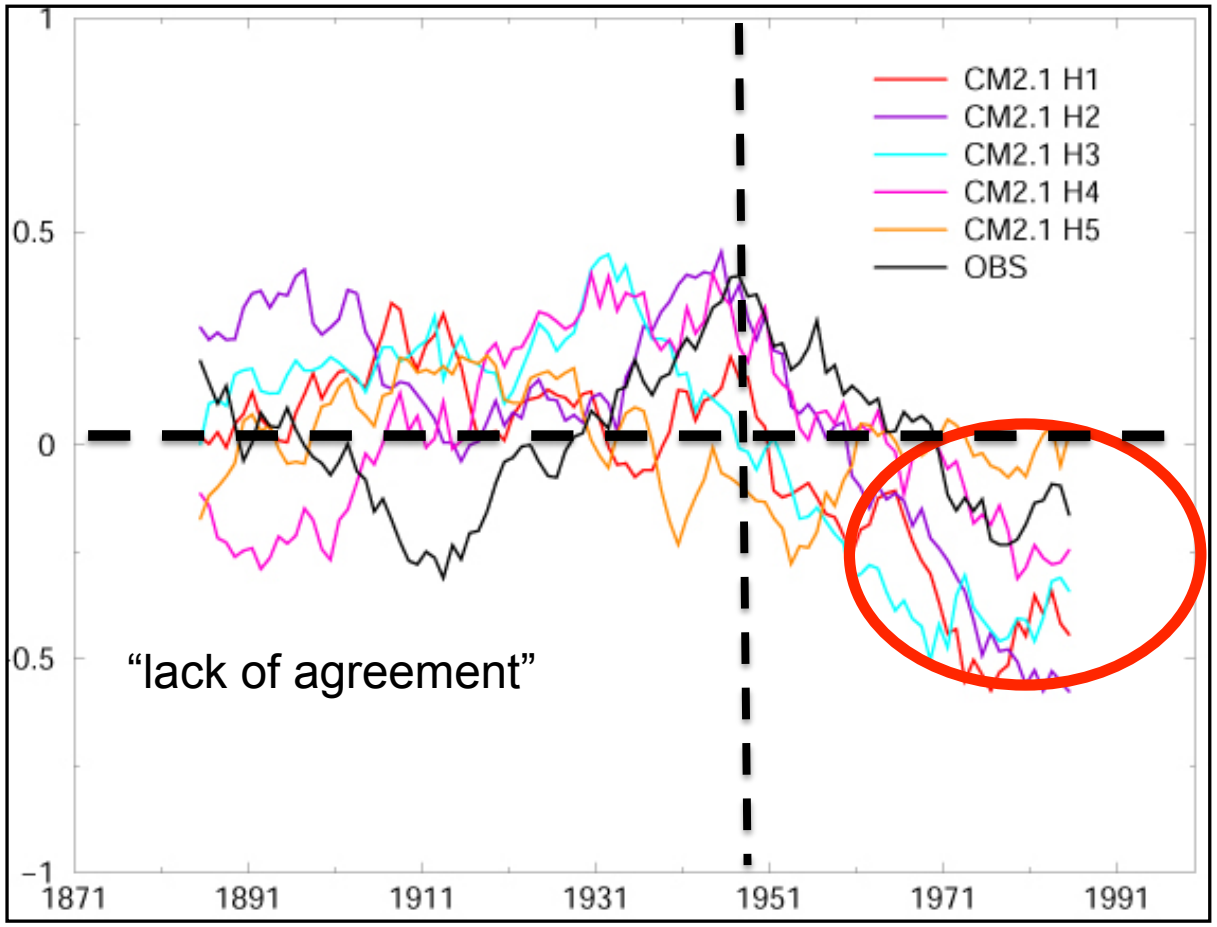
CM2.1 – reasonable

Observational constraints – validate against crop yields, ground water levels

Turner and Annmalai (2012, Nature – Climate Change)

Weakening tendency of monsoon rainfall over India

IC - spread



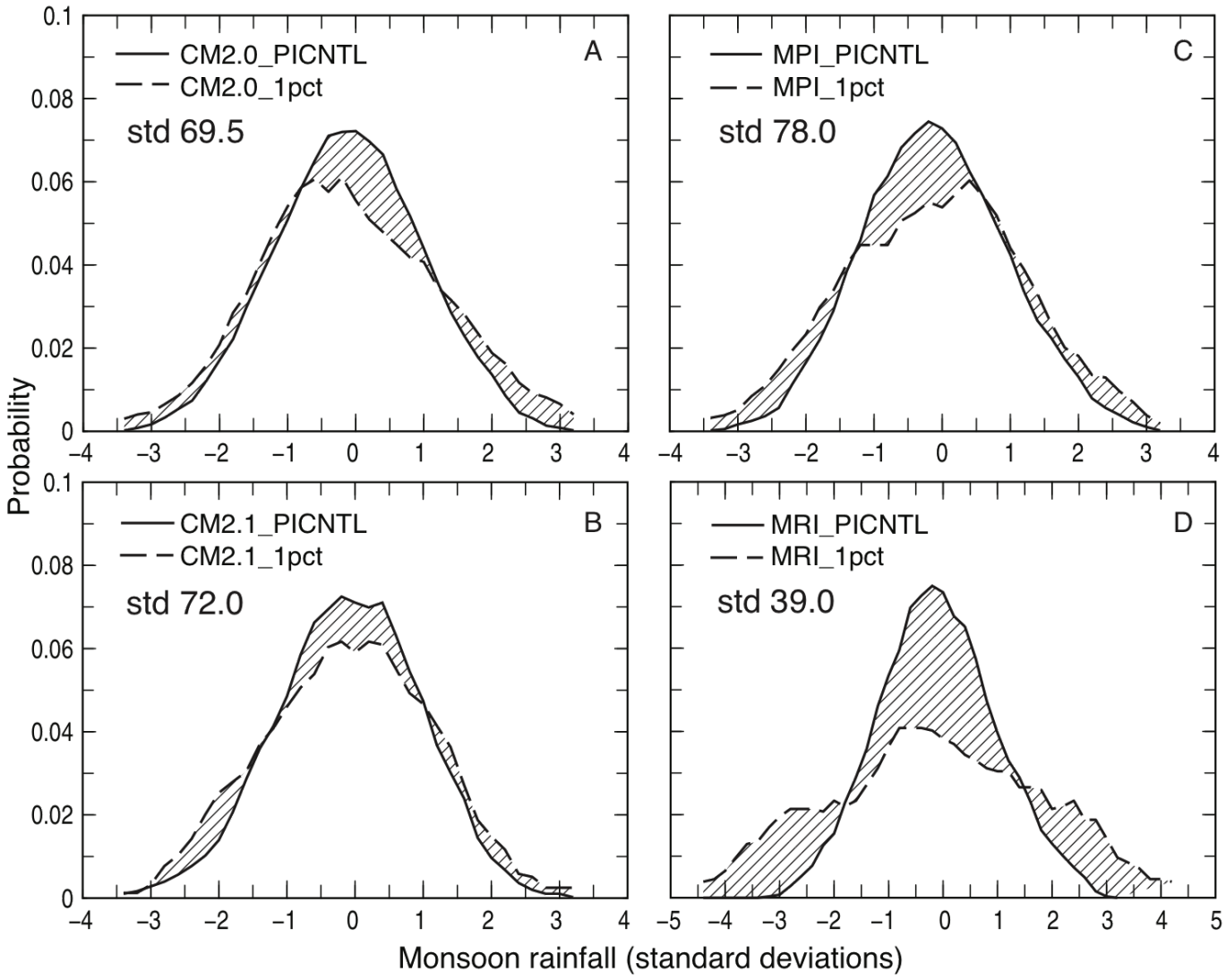
Forcing – spread

Model physics

“amplitude of the initial period spread is similar to end of simulation spread”

Annamalai, Hafner, Sooraj and Pillai (2012, J. Climate in press)

Monsoon – droughts and floods

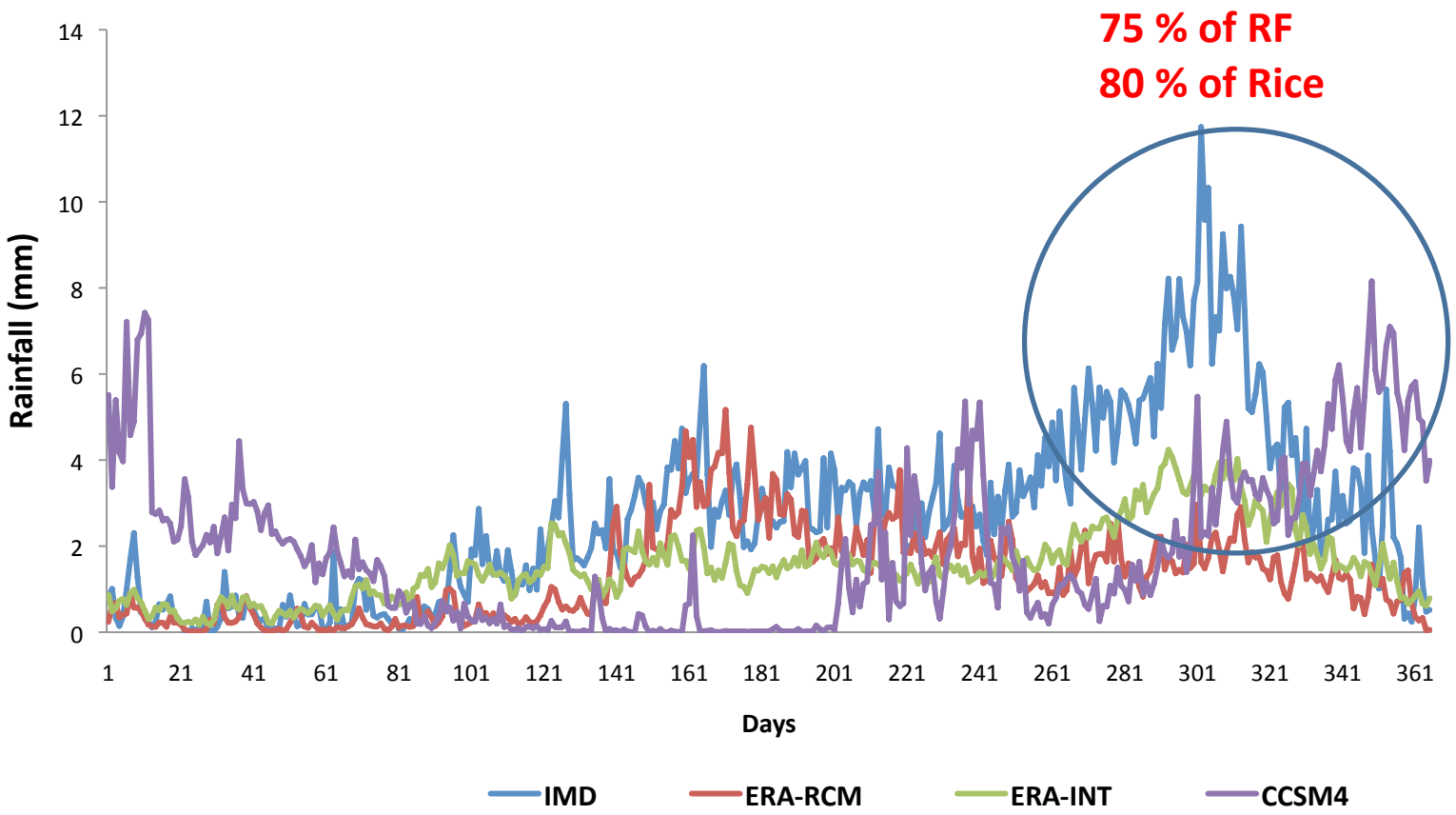


Low mean
Low STD
Stronger response

Science of climate change – is the changes in PDF (normal monsoons – significance)

Turner and Annamalai (2012, Nature – Climate Change)

Observed rainfall climatology compared with IPRC_RegCM over peninsular India



Reanalysis – temporal variability of atmospheric states and internal variability preserved – yet, results are not encouraging

Monsoon region – lack of 3-D moisture observations – severe constraint

Summary

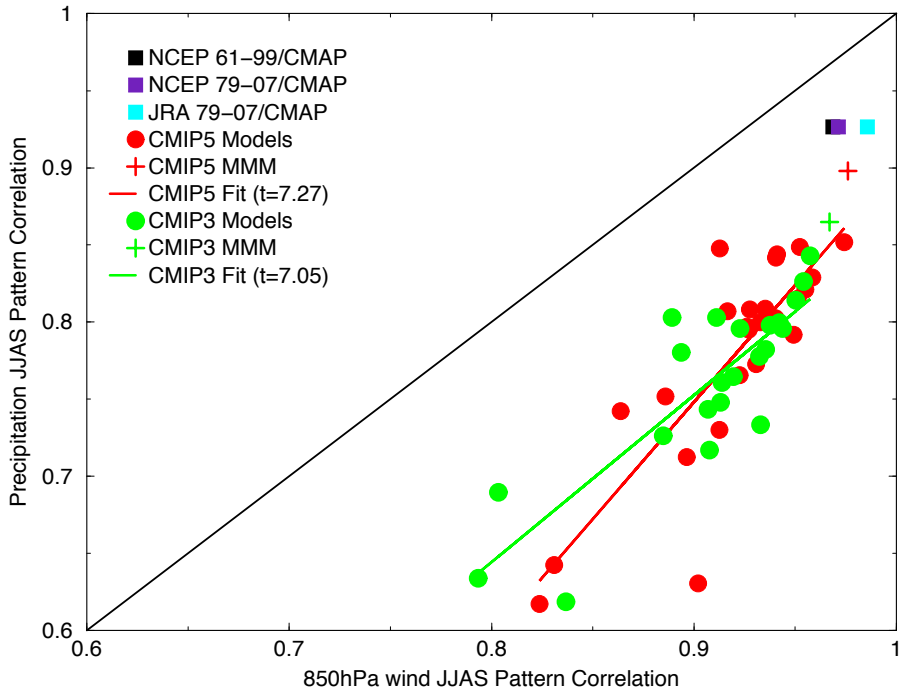
- Uncertainties – both observations and CMIP models
- Historical simulations in CMIP – observed temporal variability not constrained
- Variability assessment in future projections - changes in PDF –

“best” models do not converge

“To reduce uncertainty and gain confidence in monsoon projections – a long way to go”

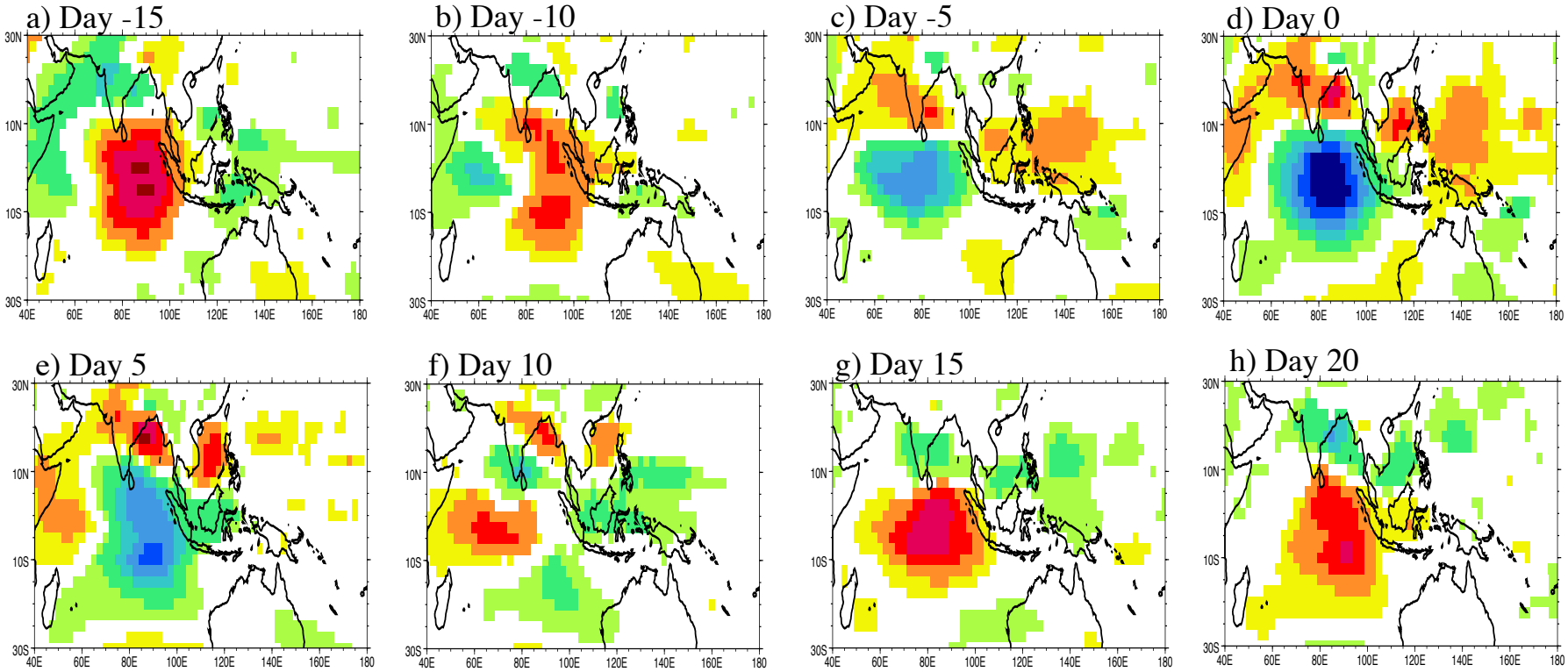
Skill: JJAS Climatology of 850hPa Wind vs. Rainfall

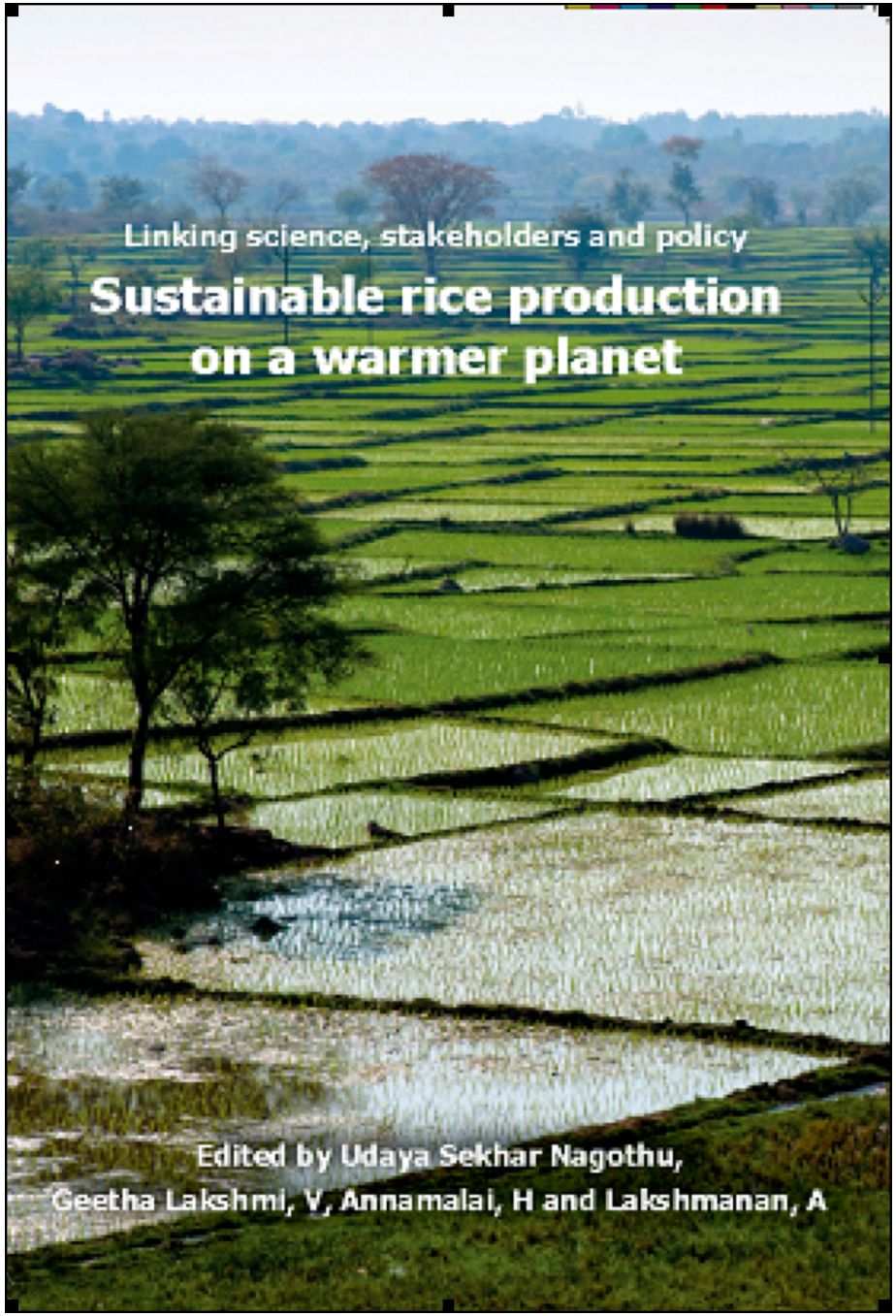
- 850hPa wind climatology pattern correlation vs. ERA40 (1961-1999)
- Rainfall climatology vs. GPCP (1979-2007)
  - Wind is better simulated than rainfall
  - CMIP-5 MMM more skillful than the CMIP-3 MMM
  - For 850hPa wind the models are beginning to be consistent with the spread of observations
  - Statistically significant relationship between the wind skill and the rainfall skill



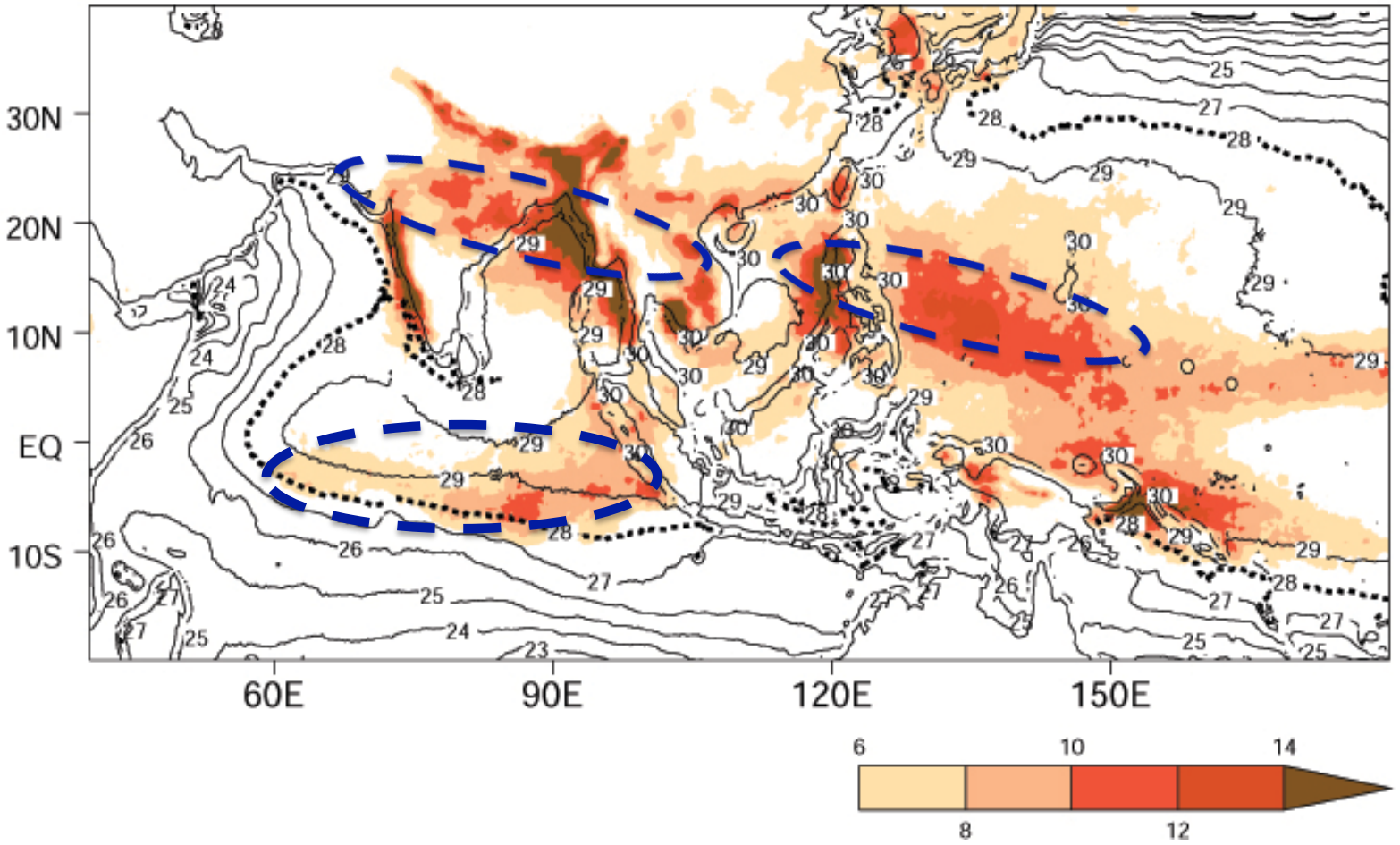
BSISV Life-Cycle: MIROC5 20-100 day Filtered AVHRR OLR (Wm^{-2})

- Similar evolution as observed, but the anomalies are weaker
- Only non-ECHAM-4 based model to “reasonably” simulate BSISV
  - MRI-CGCM3, and to a lesser extent GFDL-ESM2G, have the tilted rainband




Linking science, stakeholders and policy
Sustainable rice production on a warmer planet
Edited by Udaya Sekhar Nagothu,
Geetha Lakshmi, V, Annamalai, H and Lakshmanan, A

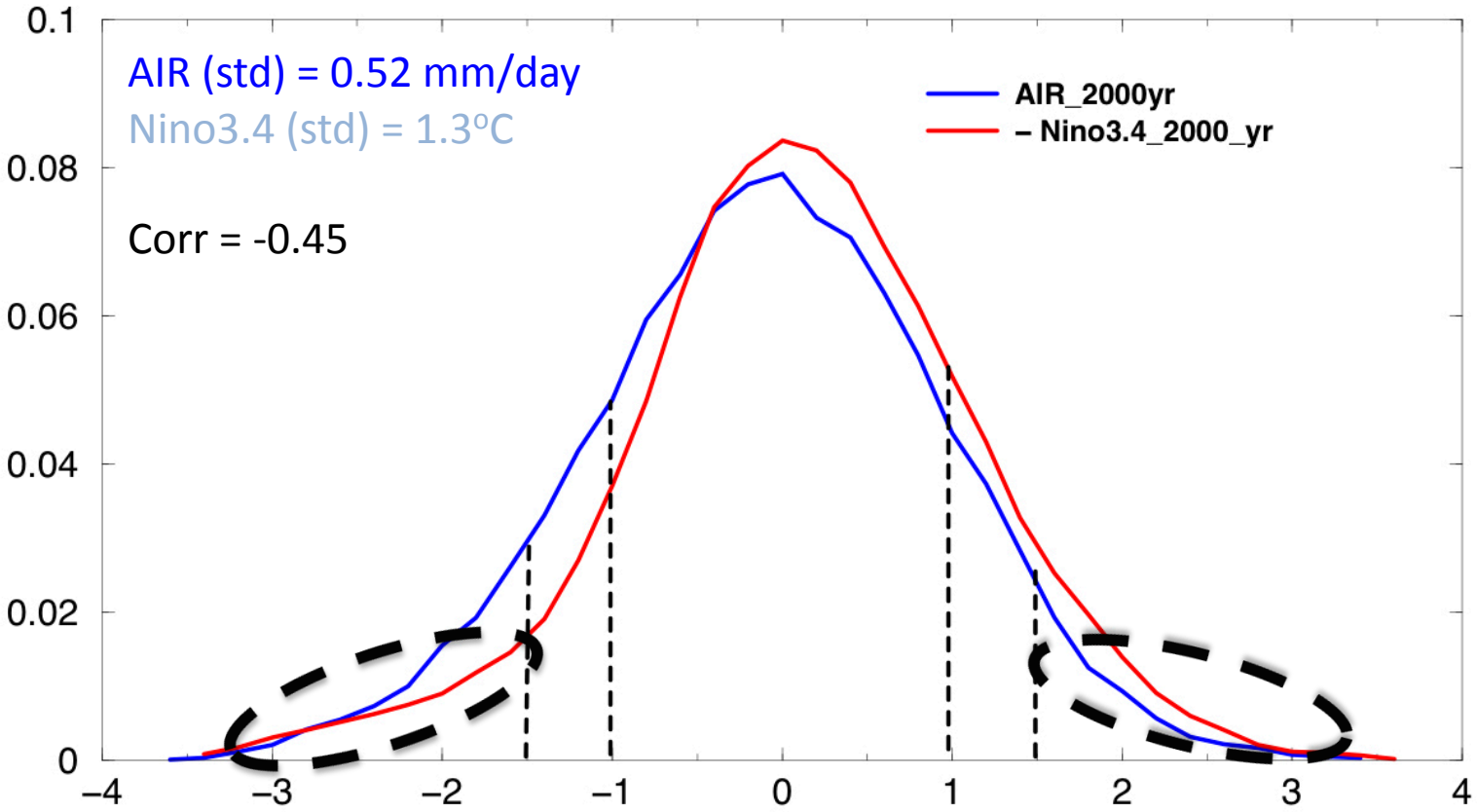
JJAS – Precipitation and SST Climatology



- Multiple regional heat sources -
- EIO and SPCZ – still experience high precipitation (thermal equator at 20^{o}N)
- Central India rainfall – dynamical effects; Rain-shadow regions
- absolute ascent over a large domain

CM2.1 Control simulation (2000-years)

PDF of rainfall over South Asia (7°N-28°N, 65°E-100°E) and Nino3.4 SST



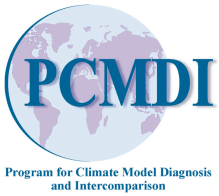
Severe Weak (droughts)

Severe Strong (floods)

How to select models…? That can be used for downscaling

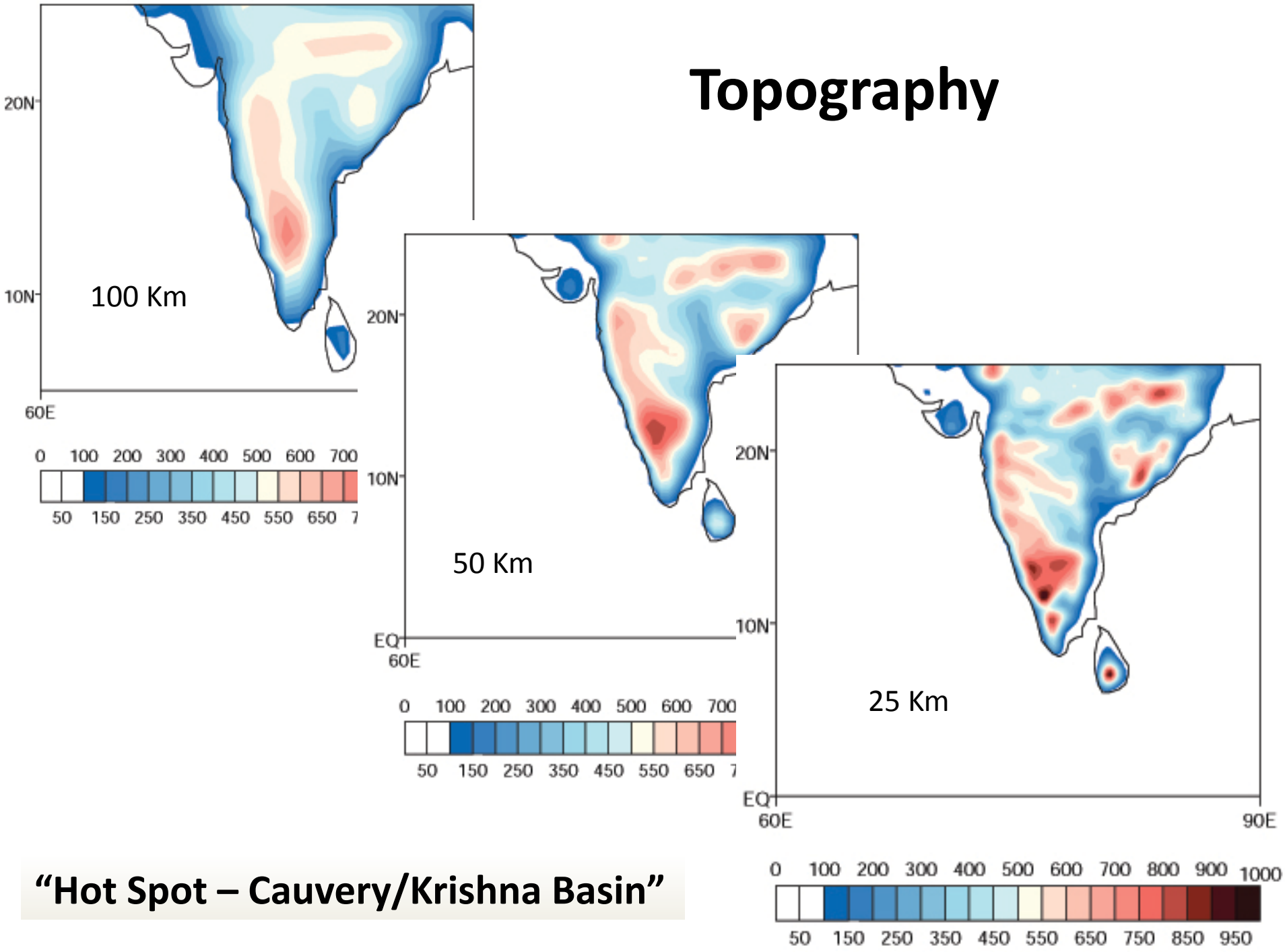
The Asian Summer Monsoon: An Intercomparison of CMIP5 vs. CMIP3 Simulations of the Late 20th Century

K. Sperber, H. Annamalai, I.-S. Kang, A. Kitoh,
A. Moise, A. Turner, B. Wang, T. Zhou



This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Security, LLC, Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

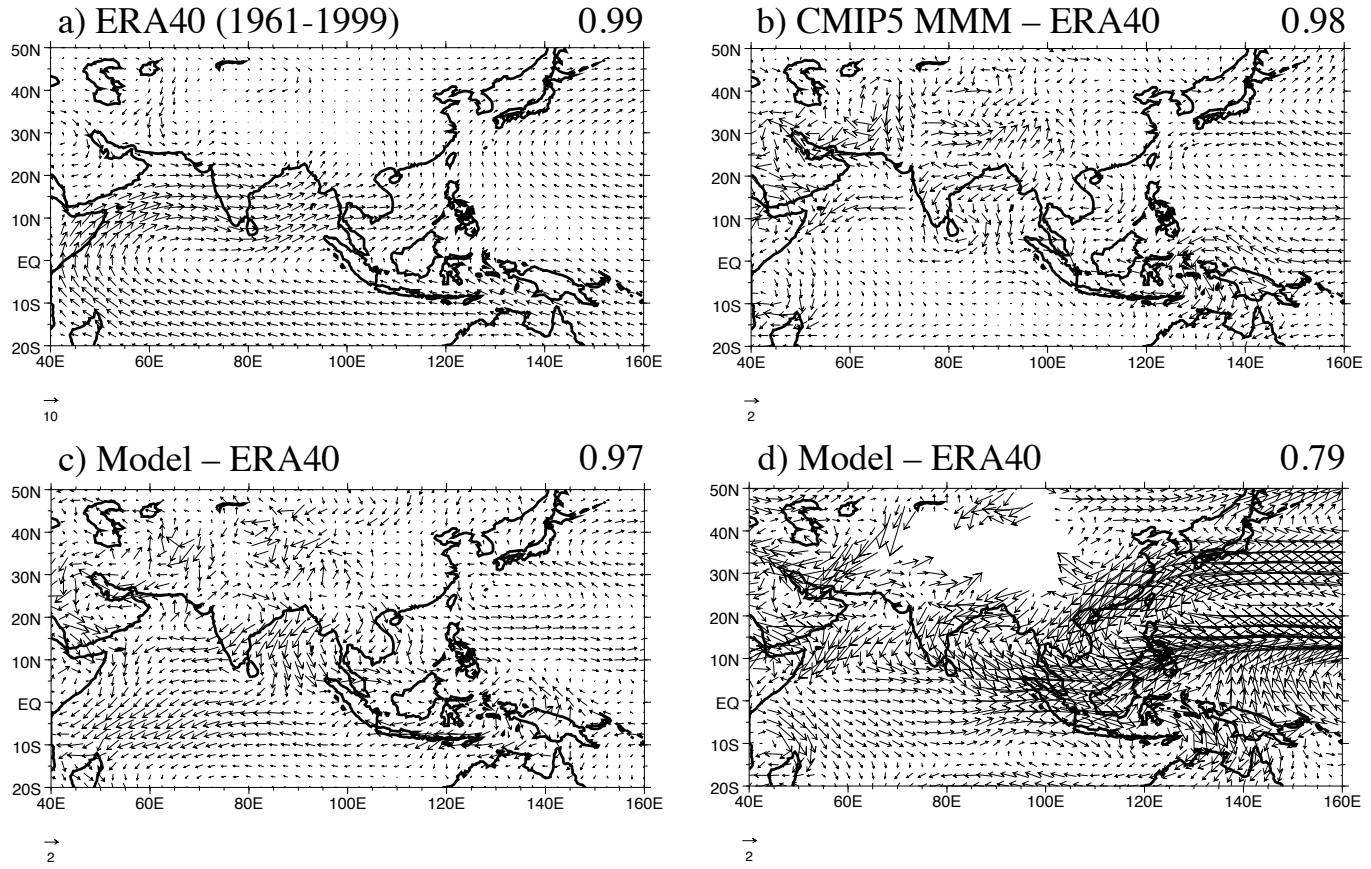
Topography



“Hot Spot – Cauvery/Krishna Basin”

JJAS 850hPa Wind Climatology: Anomalies

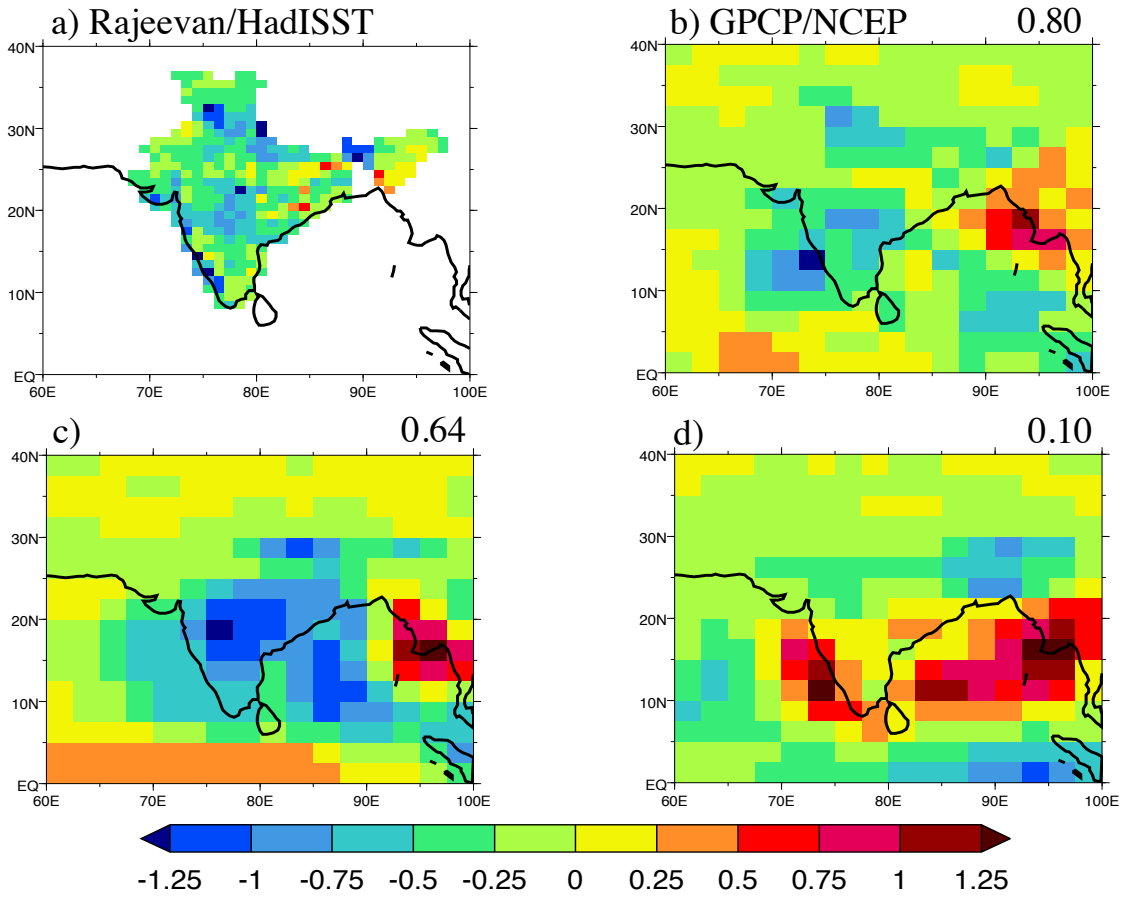
- Observed and simulated results include data from the CMIP5 MMM, and the two models that show the range of performance
  - Errors in the wind consistent with errors in the precipitation climatology



Sperber, Annamalai et al. (2012, Climate Dynamics)

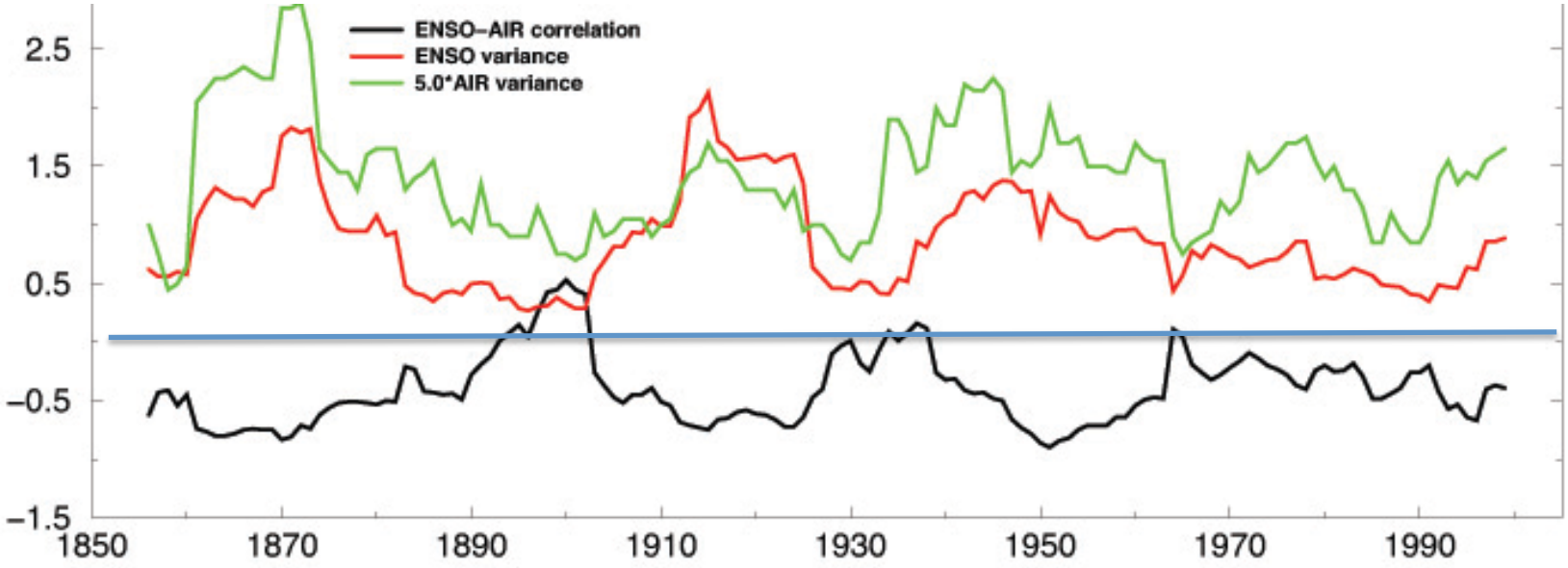
Interannual Variability: Rainfall During El Nino Regression (mm day^{-1}) Relative to NINO3.4 SSTA

- Observed and simulated results that show the range of performance
  - Good agreement between the high-resolution Rajeevan data (1961-1999) with GPCP (1979-2007)
  - Diverse skill in representing the observed rainfall pattern forced by ENSO



“decadal modulation tied to decadal ENSO variance”

CCSM4



Annamalai, Mehari and Sperber (2012 – submitted)