Use of Regional Climate Models for Seasonal Prediction Lessons for Climate Change Application

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with inputs from
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Workshop on Evaluating and Improving Regional Climate Projections
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Seasonal Climate Prediction Using RCMs

- IRI since 1997
- NR&M (Queensland)/IRI 1998
- FUNCEME/IRI since 2001
- CWB/IRI since 2003
- ICPAC/IRI since 2004
- SAWS/IRI 2006, 2007
- ZCC/IRI 2007
- CMC/IRI 2009
- ECPC/NTU,HKO, BIU since 2003
- NCEP since 2002

Challenges

- Scientific issues related to predictability at smaller scales
- Technical issues for regional climate modeling
- Computational constrains

OUTLINE

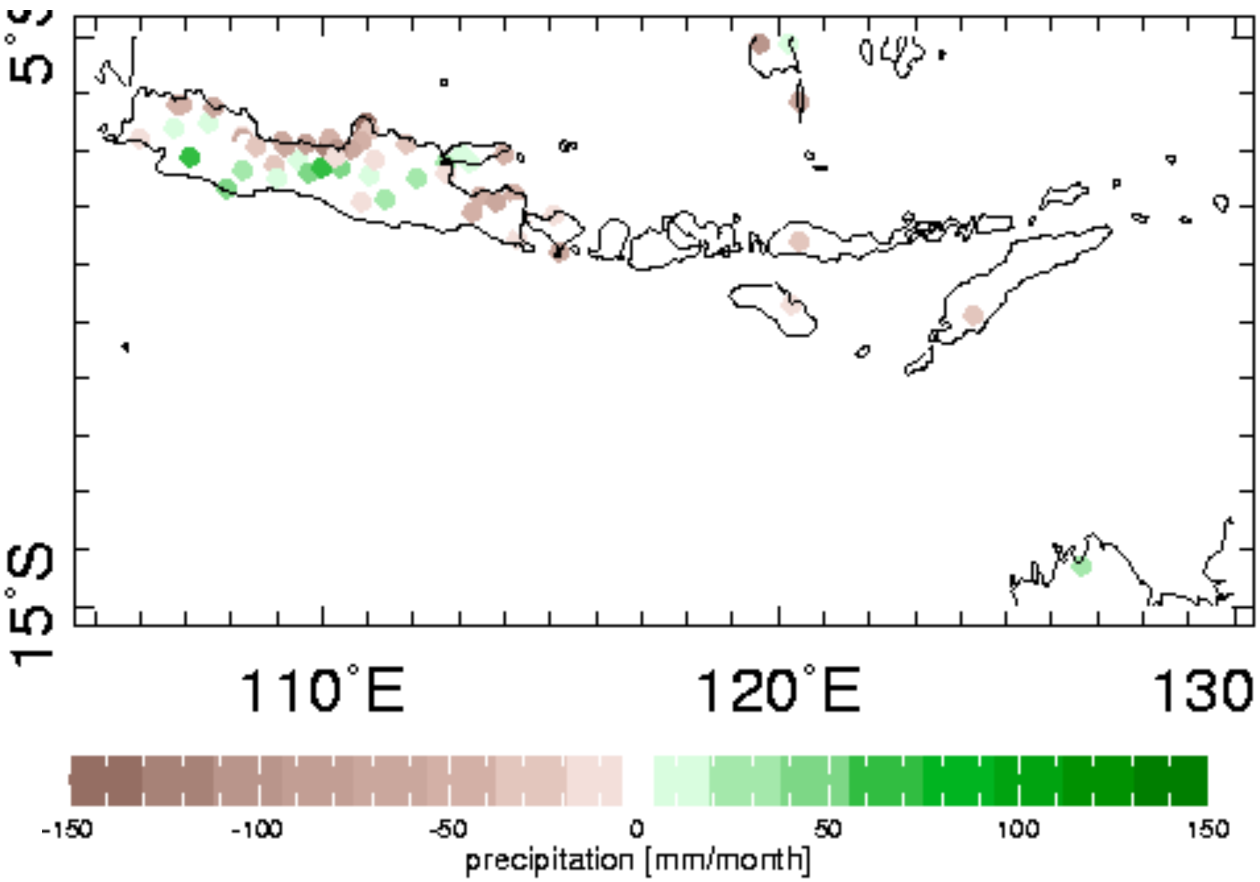
- Capacity building
- Predictability of sub-GCM spatial scale climate
- Challenges in dynamical downscaling of seasonal prediction and implications for climate projection downscaling
- Managing climate variability
- Recommendations

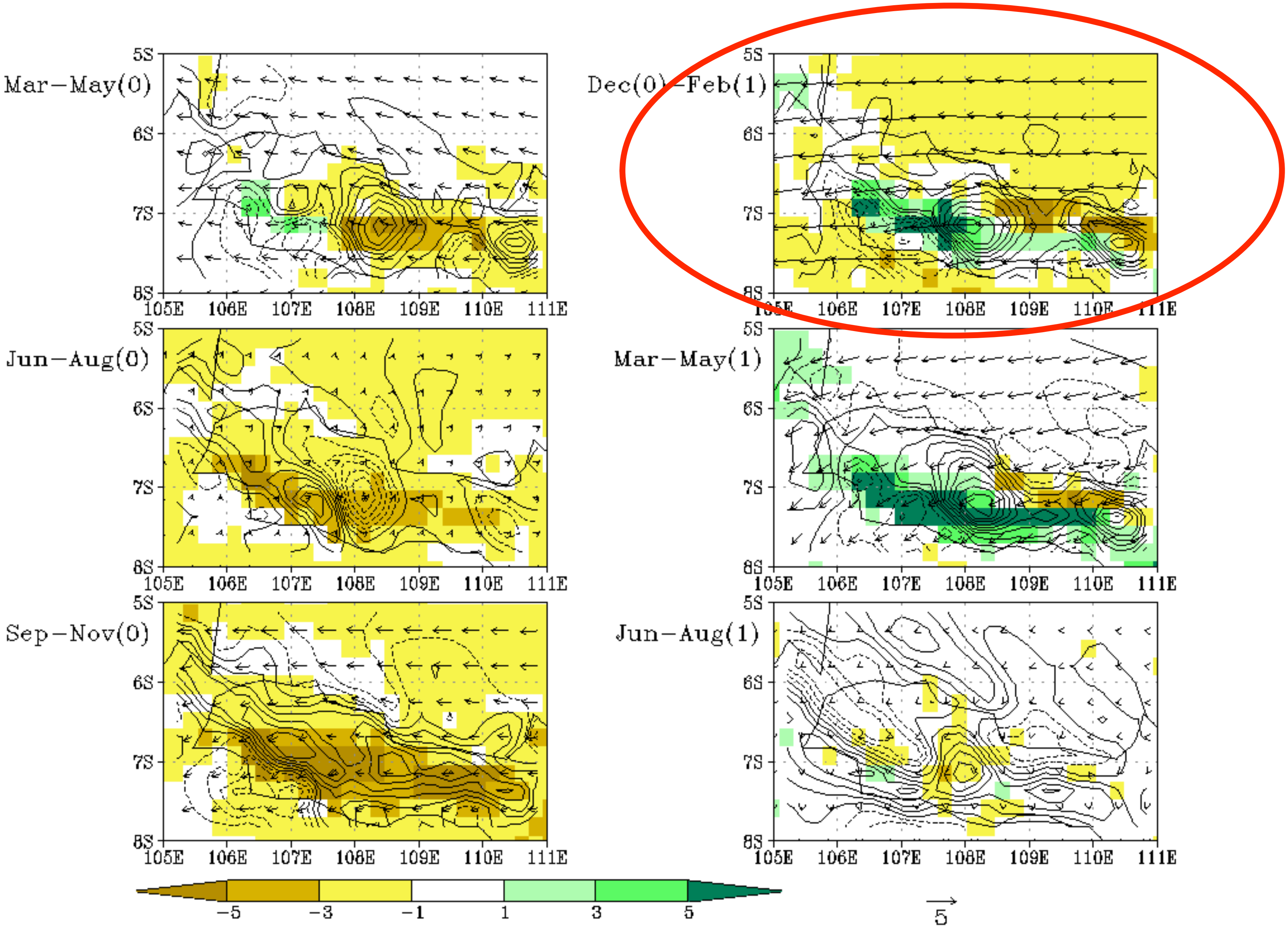
Manual for Climate Downscaling Using RCMs

1. Introduction (motivation, history ...)
2. Nesting strategy (one-way nesting, two-way nesting, variable resolution, multi-nesting, anomaly nesting, nesting strength, nudging, lateral buffer zone, GCM bias correction, validation of the nesting methodology, ...)
3. Domain (physics consideration, computational constrain, location of the lateral boundary, ...)
4. Resolution (vertical and horizontal, model physics, application need, computational constrain, ...)
5. Spin-up (atmosphere, land, ocean, ...)
6. Quality of driving large-scale data & interpolation error (vertical, coast line, mountain, ...)
7. Update frequency of driving data
8. Model physics (physics adequacy and compatibility, transferability, air-sea coupling, large-scale bias correction, ...)
9. Land surface process (initialization, vegetation, soil, topography, ...)
10. climate drift
11. Model output diagnosis (quality of observations, regional scale, noise, signal, seasonal mean, weather within climate, ...)
12. Downscaling forecast (predictability, system design, probability forecasts, products, forecast skill and reliability, verification, ...)
13. Using downscaling forecast in decision making
14. Overview of dynamical downscaling: current status and future direction

*Sub-GCM spatial scale climate is **POTENTIALLY** predictable over many regions*

Observed DJF rainfall: ENSO composite



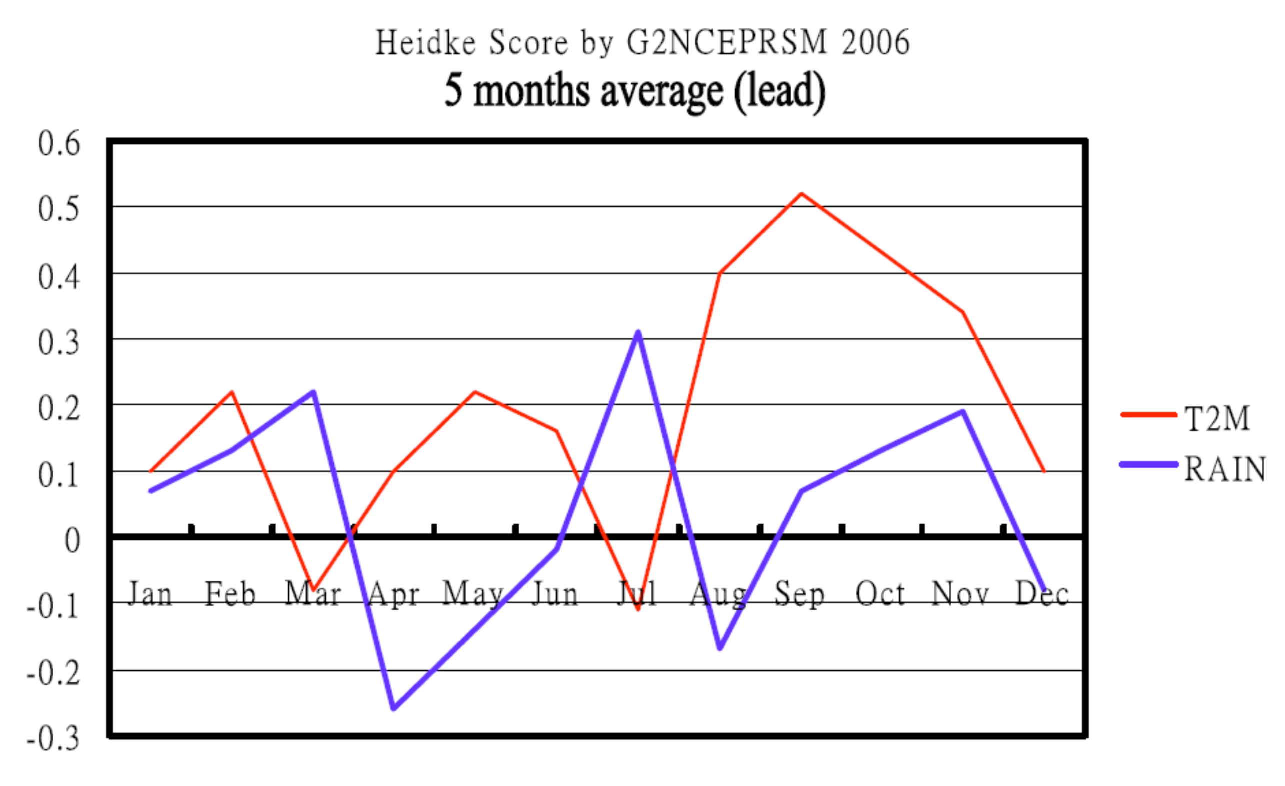


(El Nino – La Nina) Composite of ECHAM–driving RegCM3 Seasonal Precipitation (mm/day; shaded), Winds (m/s, vector) and Divergence (contour) at σ=0.865. (Res: 25km; El Nino years: 72/73, 82/83, 86/87, 91/92, 94/95, 97/98) (La Nina years: 73/74, 75/76, 84/85, 88/89, 98/99, 99/00)

Qian *et al.* (2006)

Is Sub-GCM spatial scale climate ***ACTUALLY*** *predictable?*

Dynamical Downscaling



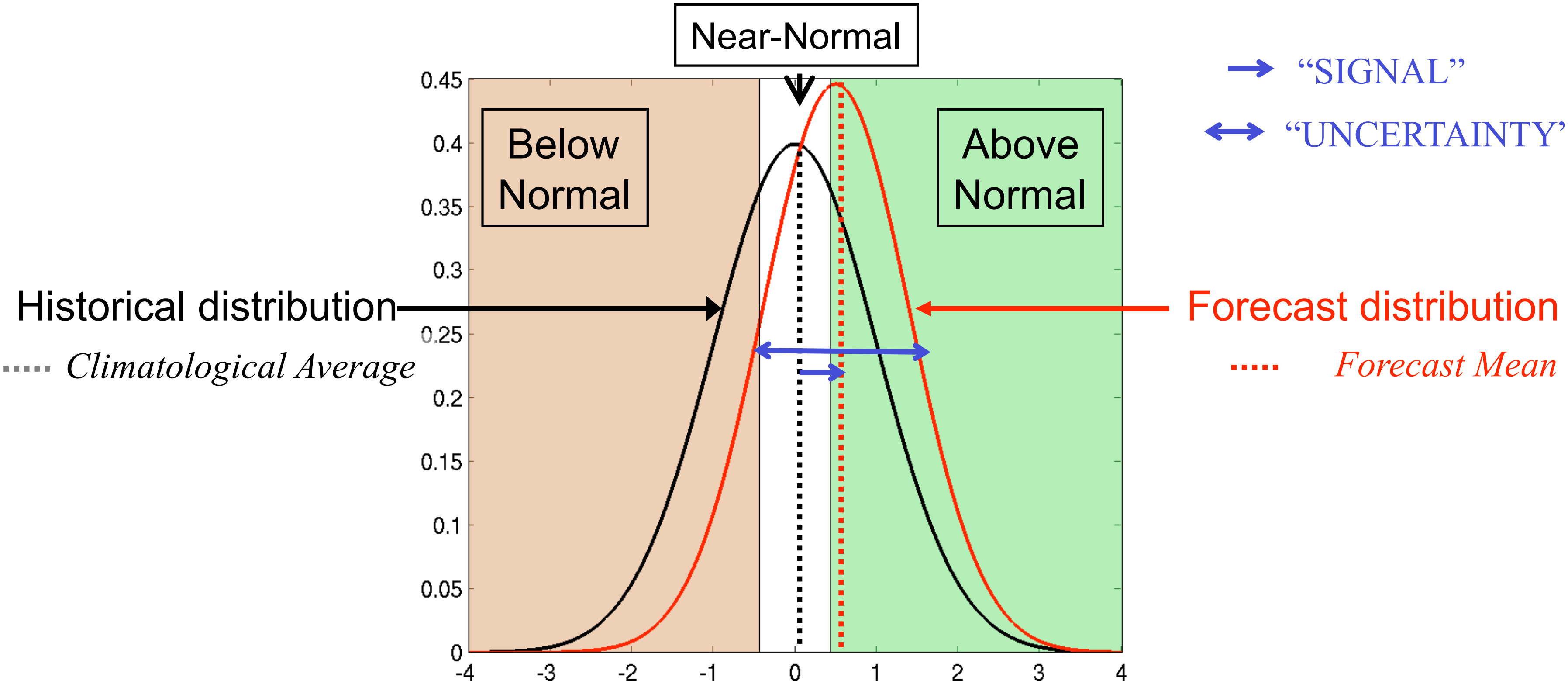
Skill comparison between the driving ECHAM forecasts and the nested RSM forecasts. The RPSS (%) was aggregated for the whole Nordeste region.

	JFM		**FMA**		**MAM**		**AMJ**	
	ECHAM	*RSM*	*ECHAM*	*RSM*	*ECHAM*	*RSM*	*ECHAM*	*RSM*
2002	7.1	4.5	5.2	10.1	14.9	23.5	1.2	14.1
2003	-6.1	-3.2	-2.6	7.2	9.4	15.3	5.4	12.1
2004	25.7	-7.4	0.8	0.4	-5.7	28.6	5.8	16.4

Challenges in dynamical downscaling of seasonal prediction

- **Signal & Uncertainty**
- **GCM & RCM Biases**
- **Land Process**
- **Air-Sea Interaction**

Climate Forecast: Signal + Uncertainty



The **SIGNAL** represents the 'most likely' outcome.

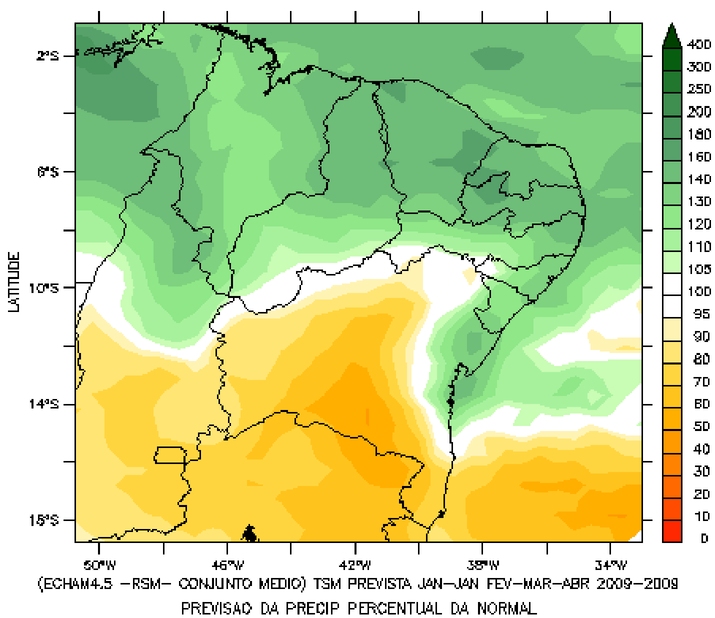
The **UNCERTAINTY** represents internal atmospheric chaos, uncertainties in the boundary conditions, and errors in the models.

Optimizing probabilistic information – multi-model ensemble approach

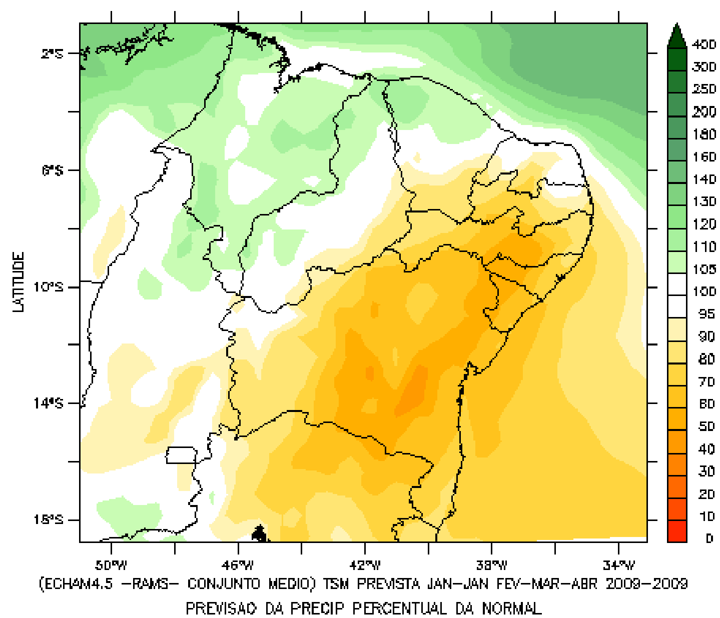
- Reliably estimate the uncertainty (for both forcing & response)
- Minimize the random model errors

Downscaling of ECHAM4.5 AGCM Forecast for FMA 2009

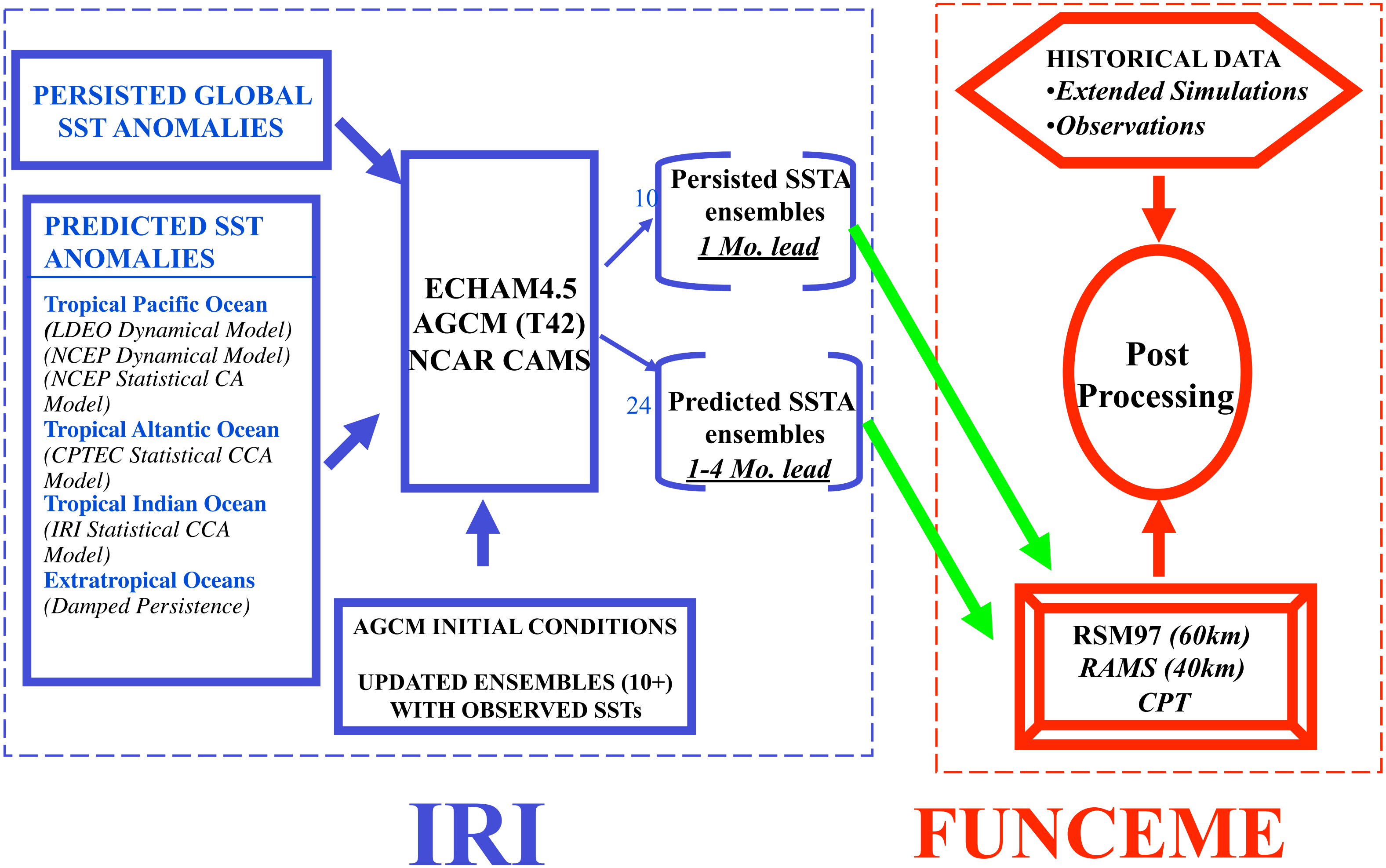
RSM



RAMS



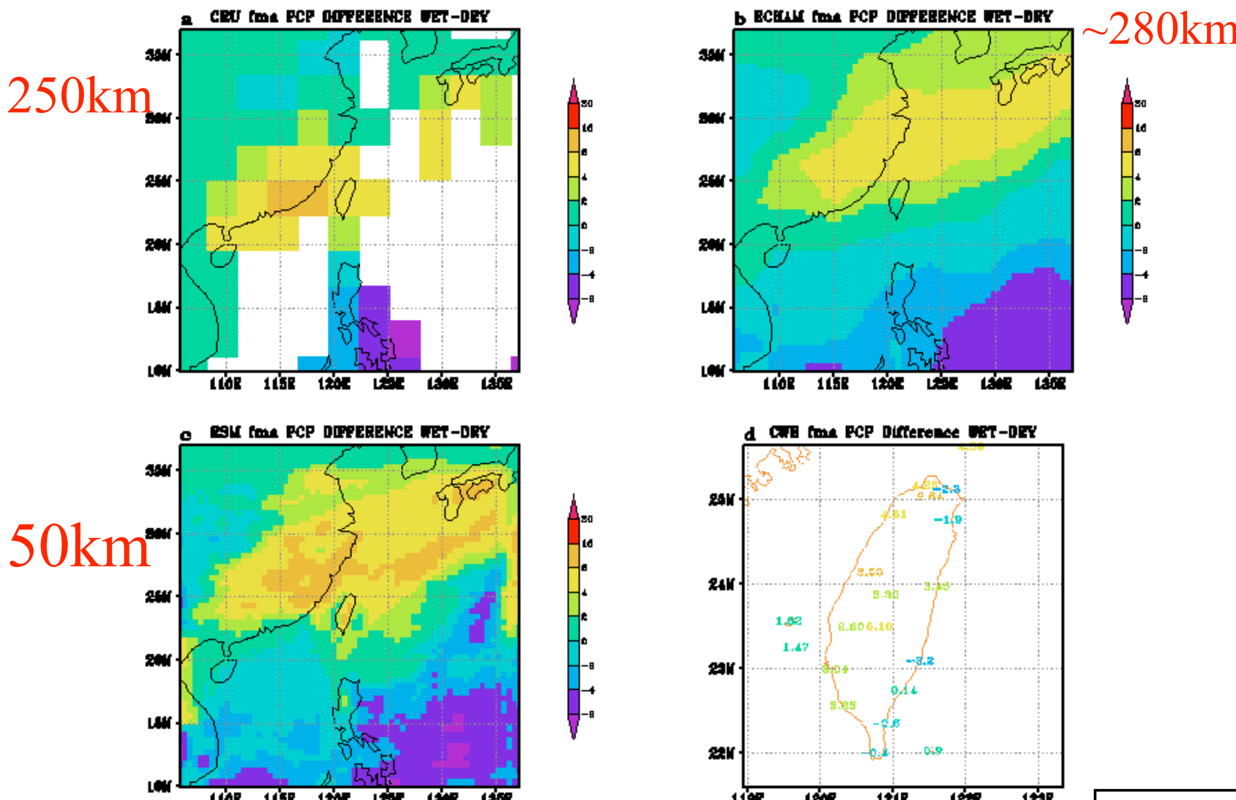
CLIMATE DYNAMICAL DOWNSCALING FORECAST SYSTEM FOR NORDESTE



Sun *et al.* (2006)

GCM Bias

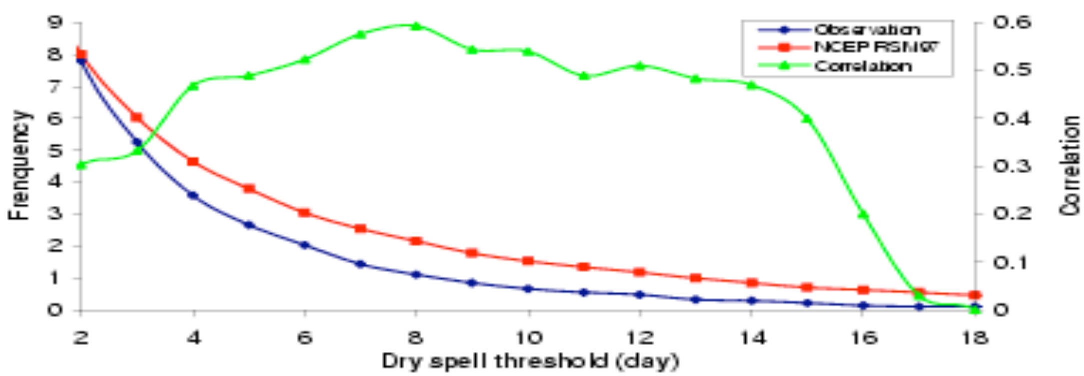
FMA Precipitation: 1983-1971



Sun and Hu (2002)

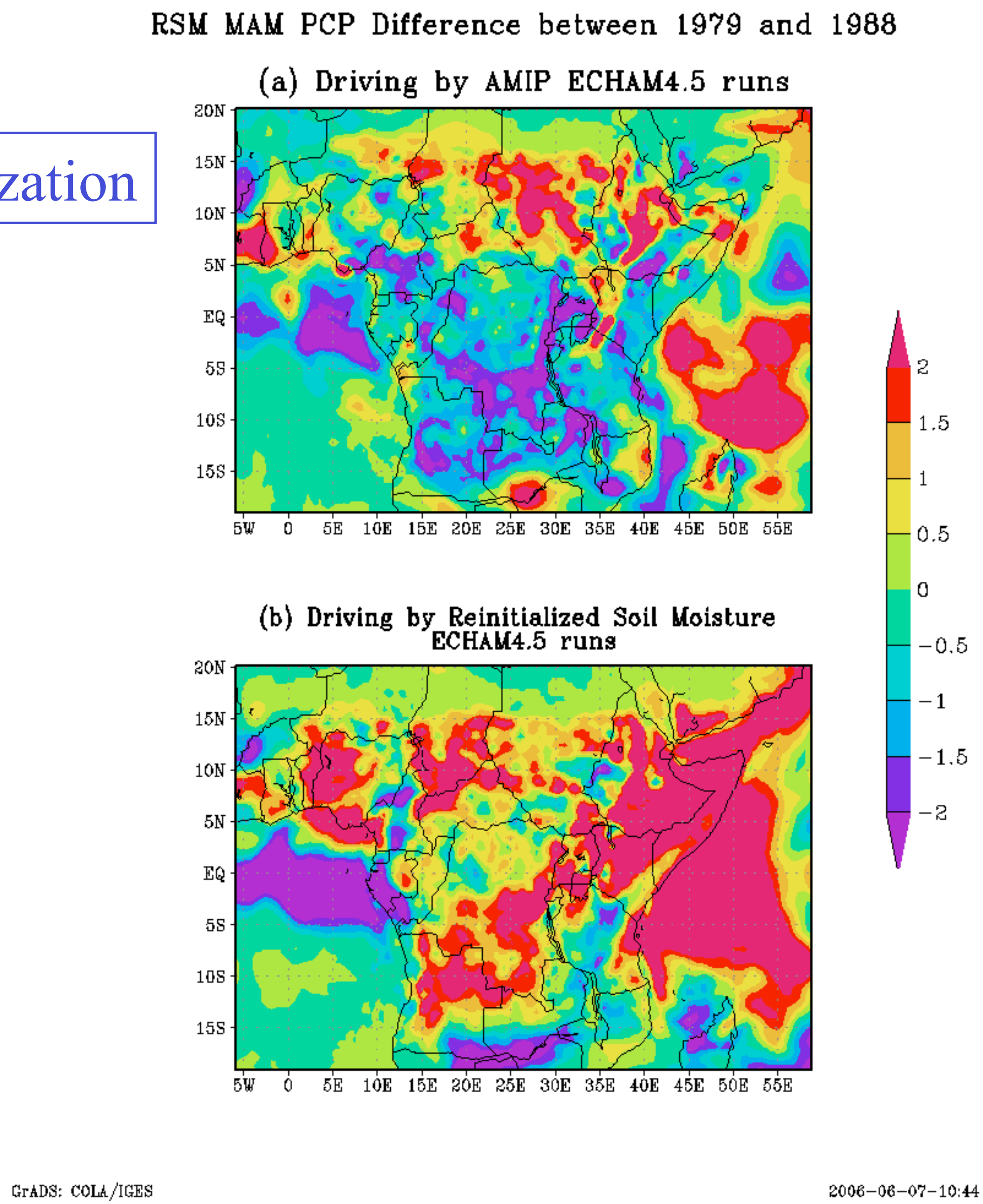
RCM Bias

Fig. 15. Climatology of the occurrene of dry spells with different thresholds (frequency on left axis). Also plotted is the correlation between observed and NCEP RSM97 simulated dry spells with different thresholds (use of right axis). Both are for the period February-March-April 1974-2000 in the rain fed argiculture region of Ceará.



Sun et al. (2005)

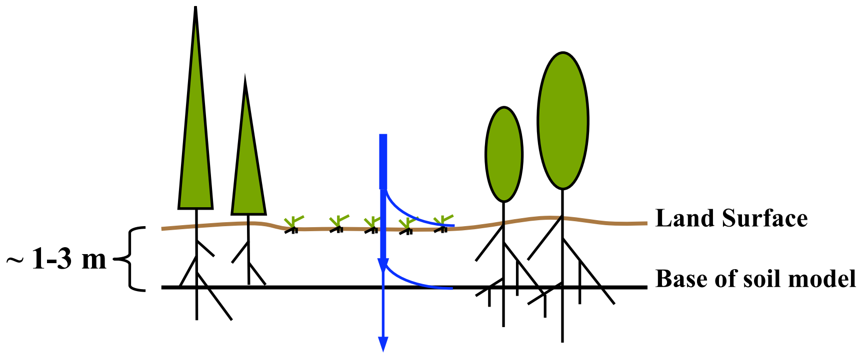
Land initialization

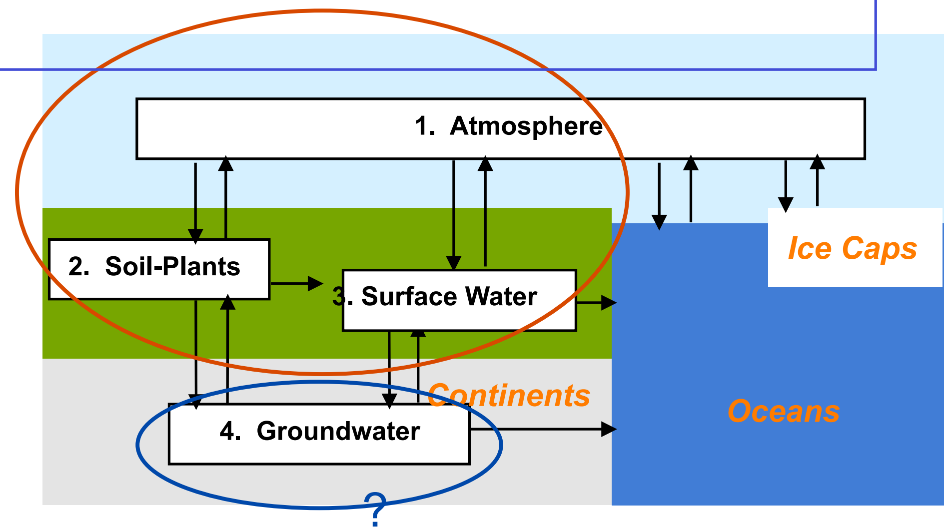


Land Process

Treatment of Groundwater Reservoir in climate models

Present (Regional) climate Models

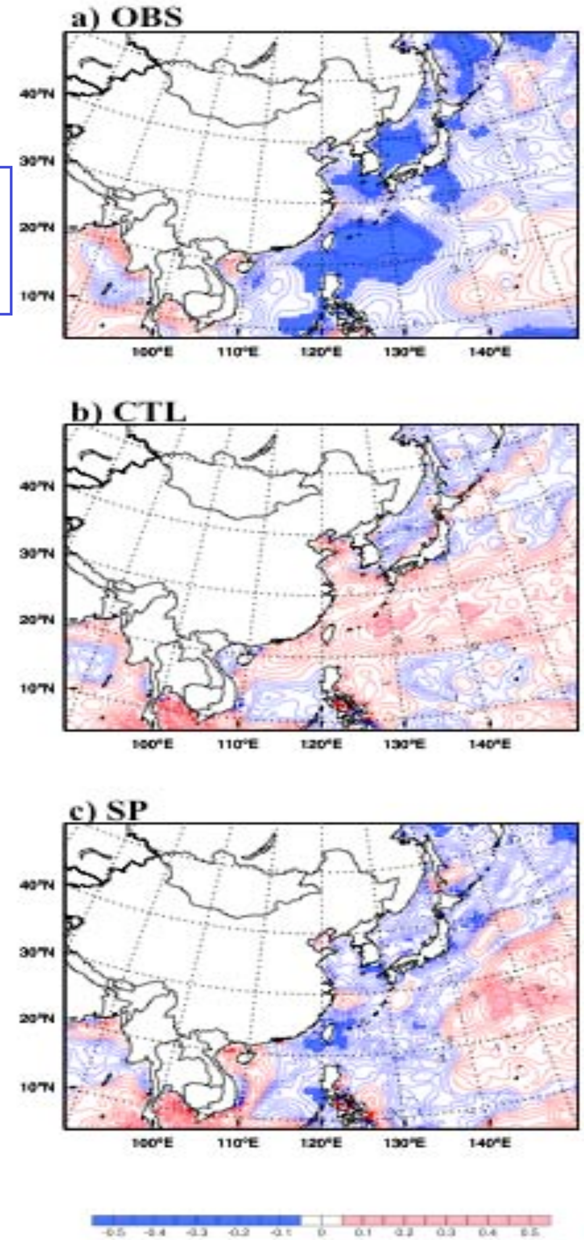




- Soil water reaching the soil-model base through gravitational flow freely drains out
- That water is no longer available for evapotranspiration even during times of water stress

Miguez-Macho *et al.* (2007)

Air-sea Interaction

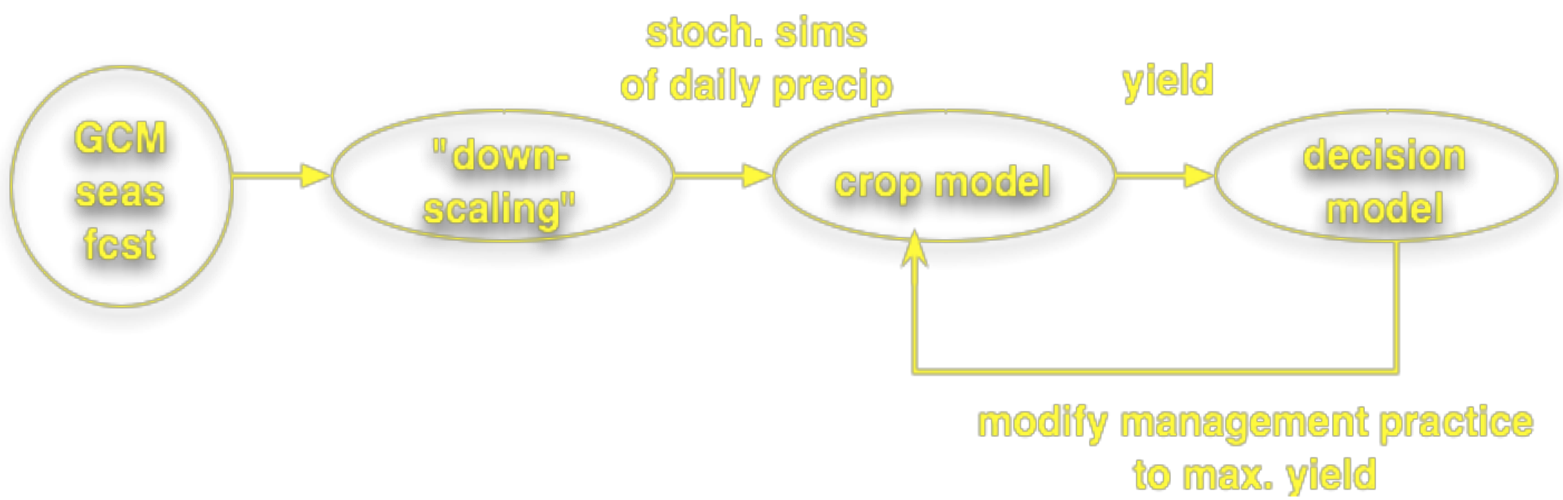


Correlations between SST and precipitation for the period MJJA 1979-2006. The areas exceeding the 95% significance level are shaded. Cha and Lee (2009)

Managing Climate Variability

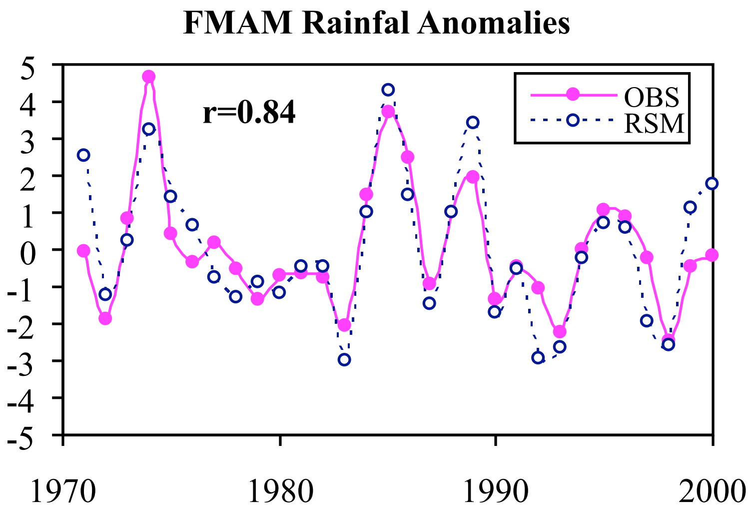
bridging **C**limate into **R**isk **M**anagement

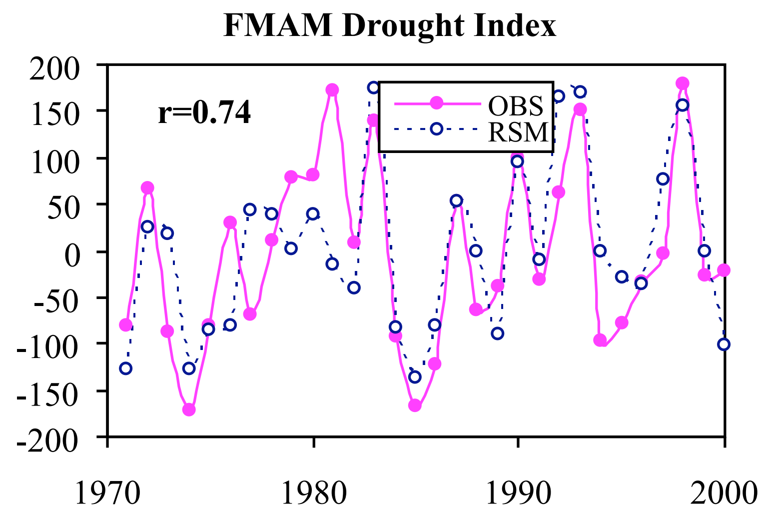
.. crop models need daily time sequences

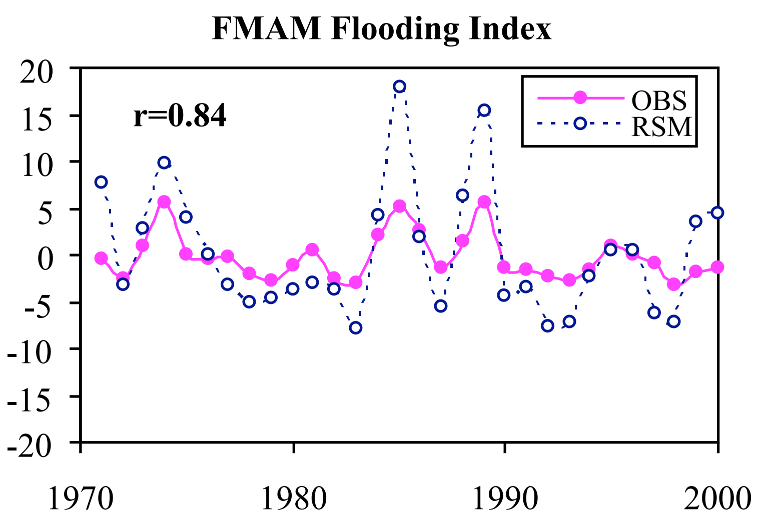


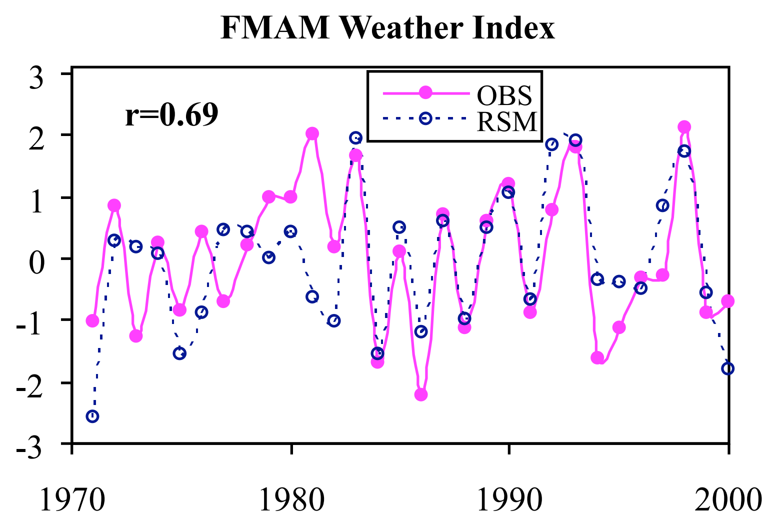
.. as do malaria models and hydrologic models

RSM Hindcast Validation

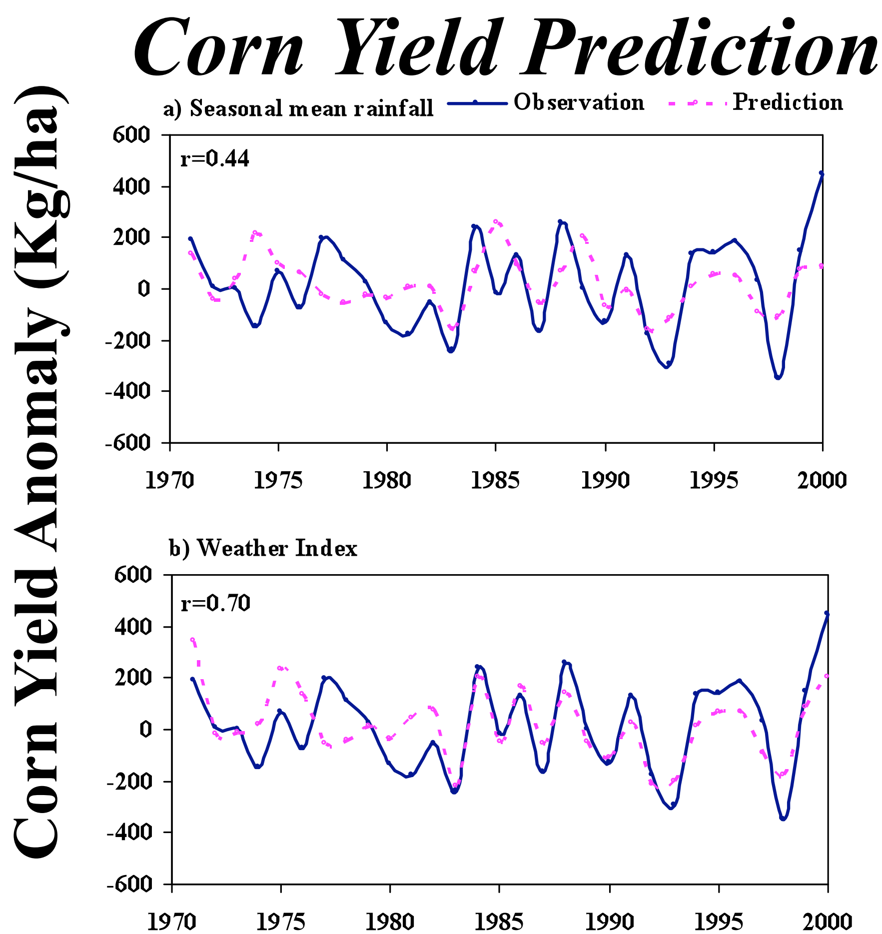








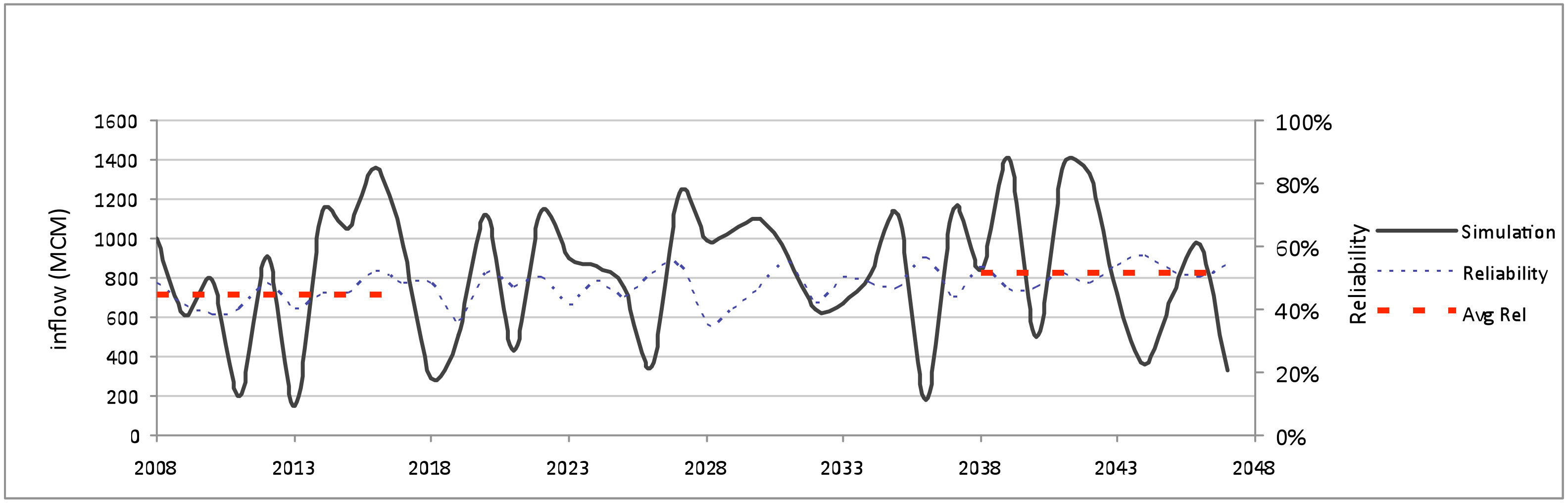
Linking prediction and application



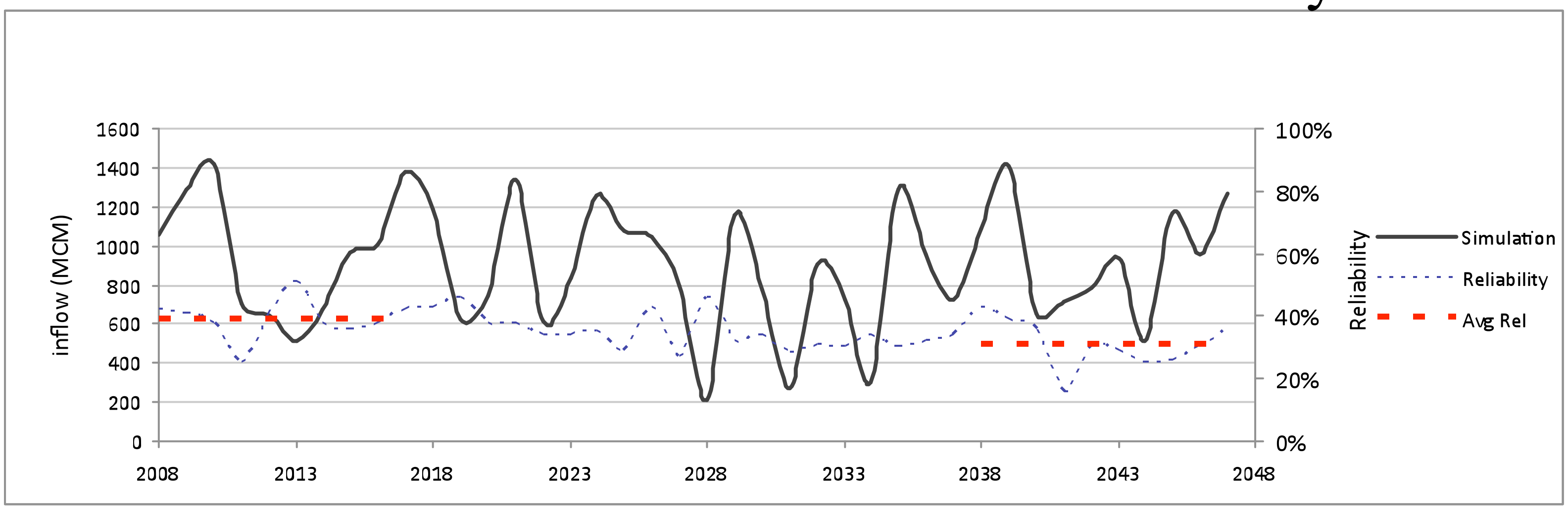
Sun *et al.* (2007)

Reservoir reliability under climate change scenarios

Trend of +10% and **no** multidecadal variability



Trend of -10% and **no** multidecadal variability



Baroang & Kaheil

Simulation: single inflow simulation run *Reliability:* 100 run average
Avg Rel: average Reliability over 10 years

Recommendations for Downscaling Climate Projections

- Use of Multi-model ensemble approach to estimate climate change signal & uncertainty – *projection coordination needed*
- Removal of GCM (systematic) biases to improve RCM performance – *more research needed*
- Application of model output statistics to reduce RCM errors
- Incorporating water table dynamics into RCMs and land initialization to better represent land-atmosphere interaction
- Use of spectral nudging technique to reduce RCM errors
- Focusing on climate variables that are both relevant and predictable/projectable (e.g., dry spells, rainfall frequency, monsoon onset) - *require creativity to address users' needs*