An Overview of NRCM Activities and Lessons Learned

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With the NRCM group

Rationales for an NRCM Effort

The NRCM effort was initiated in 2003 to develop regional climate modeling capability in WRF for:

- Downscaling

  - Address regional climate variability and change

- Process study

  - Understand regional earth system processes

- Upscaling

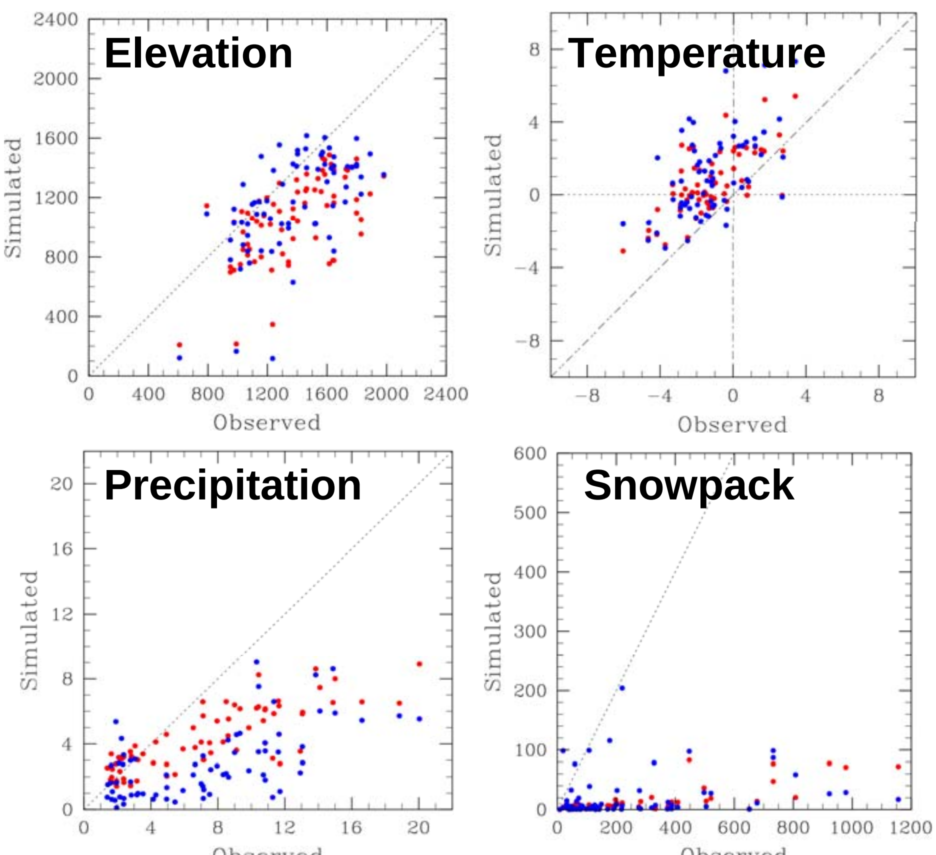
  - Address large scale biases in global models

Model Development

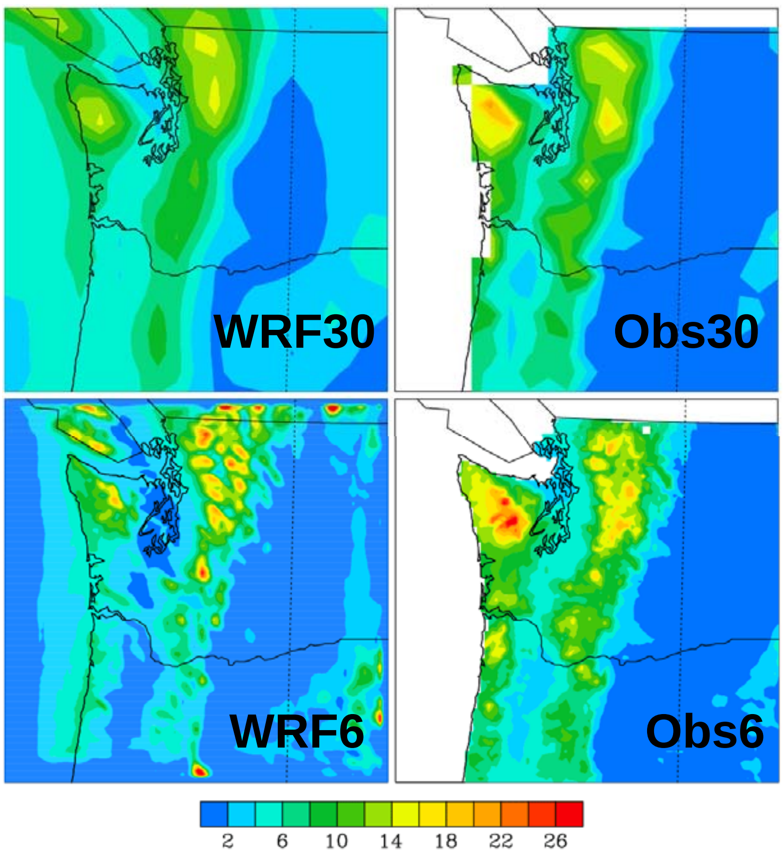
- Implementation of CCSM physics: CAM radiation and CLM land surface model
- Generalize WRF framework for climate simulations:
  - Updating of SST, sea ice, vegetation fraction, surface albedo
  - Diagnostic variables (e.g., ISCCP simulator, total/clear sky radiative fluxes, accumulated fluxes)
  - Cloud fraction based on Xu and Randall used in radiative transfer
  - Sea surface skin temperature based on Zeng and Beljaars
  - Channel configuration (specified N-S, periodic E-W)
- Preprocessor: Generate WRF inputs from GCM outputs
- Community efforts: Coupling WRF and ROMS (UCLA), development of WRF-CHEM (NOAA, PNNL, and others), development of global WRF (Caltech/NCAR)
- Established WRF RCM working group to coordinate community efforts
- Organized a RCM workshop in 2005: Identified three areas for model development and research including regional earth system modeling, high resolution modeling, and upscaling

Downscaling: Western US

- WRF displays precipitation features that are more strongly forced by orography than MM5
- Wet bias that increases with increasing spatial resolution
- Wet bias not very sensitive to cloud microphysics
- Larger negative bias in snowpack than MM5, both using the Noah LSM (dependence on snow emissivity; a value of 0.9 yields good simulation of temperature but low bias in snowpack)

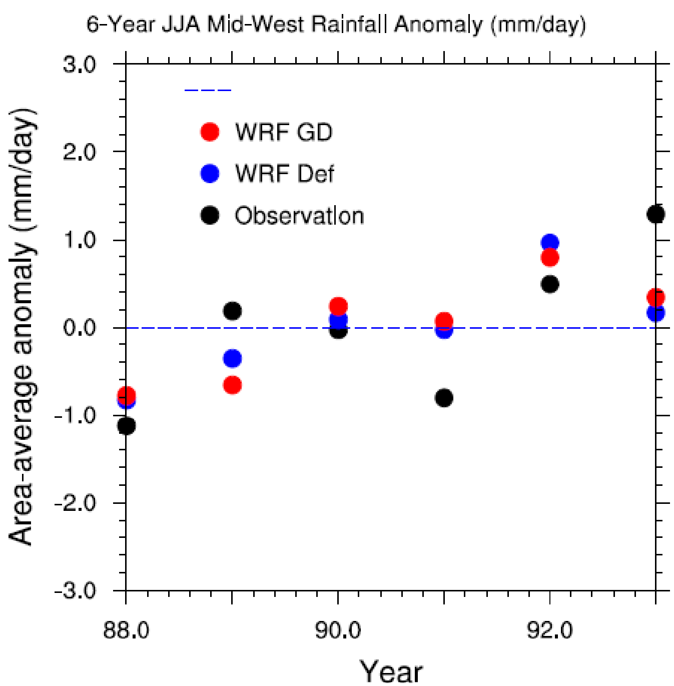


DJF Precipitation



Downscaling: North America

- Investigated biases in warm season precipitation and its interannual variations in the central US
- GD produces more rainfall than KF, but does not improve simulation of interannual variability
- Large scale bias patterns depend more on domain size/location than physics (cumulus and radiation schemes), with little interannual variations
- Impacts of internal model variability (IMV) for the large domain are as large as impacts due to physics or domain sizes

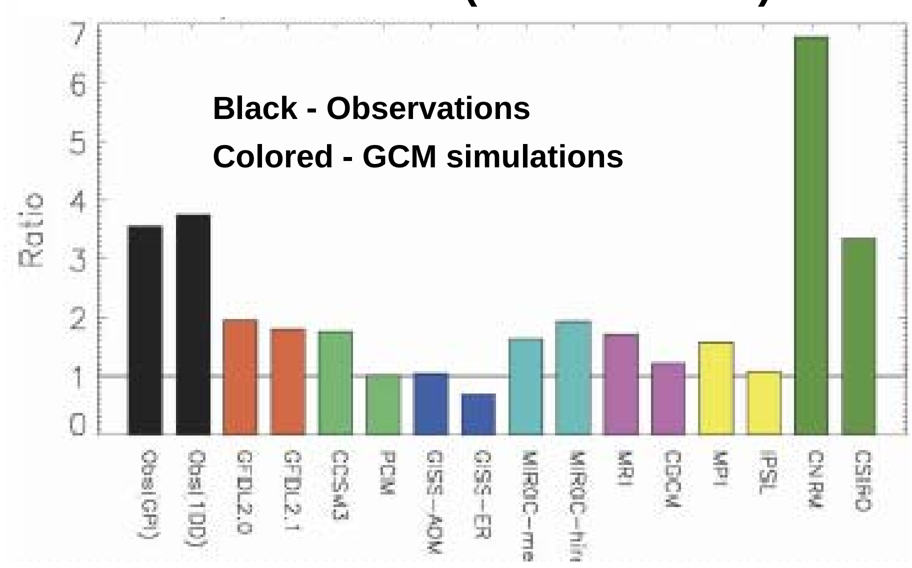


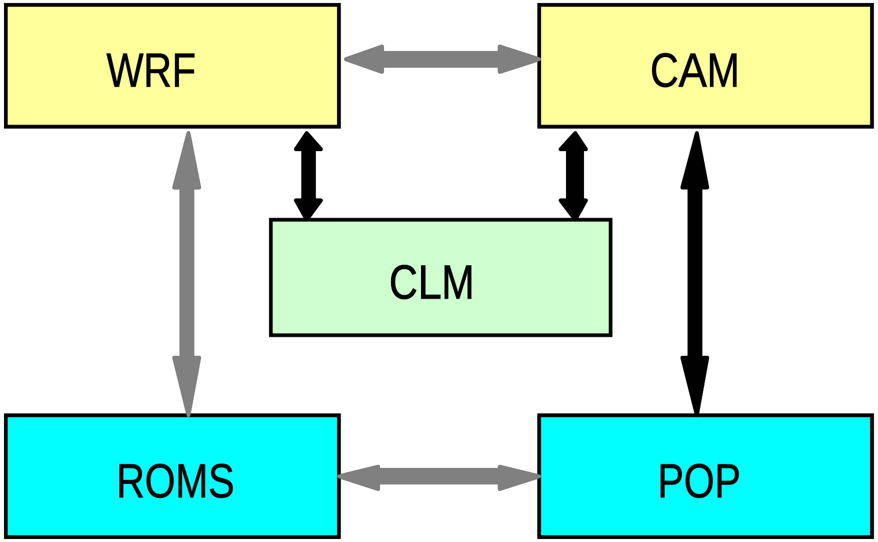
- Error growth: fast adjustment of 2 days and slow adjustment of 14 days before reaching an equilibrium
- Implications for testing physics parameterizations
- Better simulations can be obtained using re-initialization or nudging to constrain the large scale circulation

Upscaling

- Convective latent heat release in the tropics modulates the large-scale circulations and excites tropical modes that influence both the tropical and extra-tropical climates
- Most GCMs exhibit large tropical biases, including simulations of the ITCZ, tropical modes, diurnal cycle, and hurricanes
- The lack of scale interactions in GCMs could be the most critical factor responsible for the tropical biases
- Will two-way coupling of WRF and CAM in “hot spots” help address tropical biases in GCMs?

Eastward vs westward MJO variance in the Indian Ocean (Lin et al. 2006)

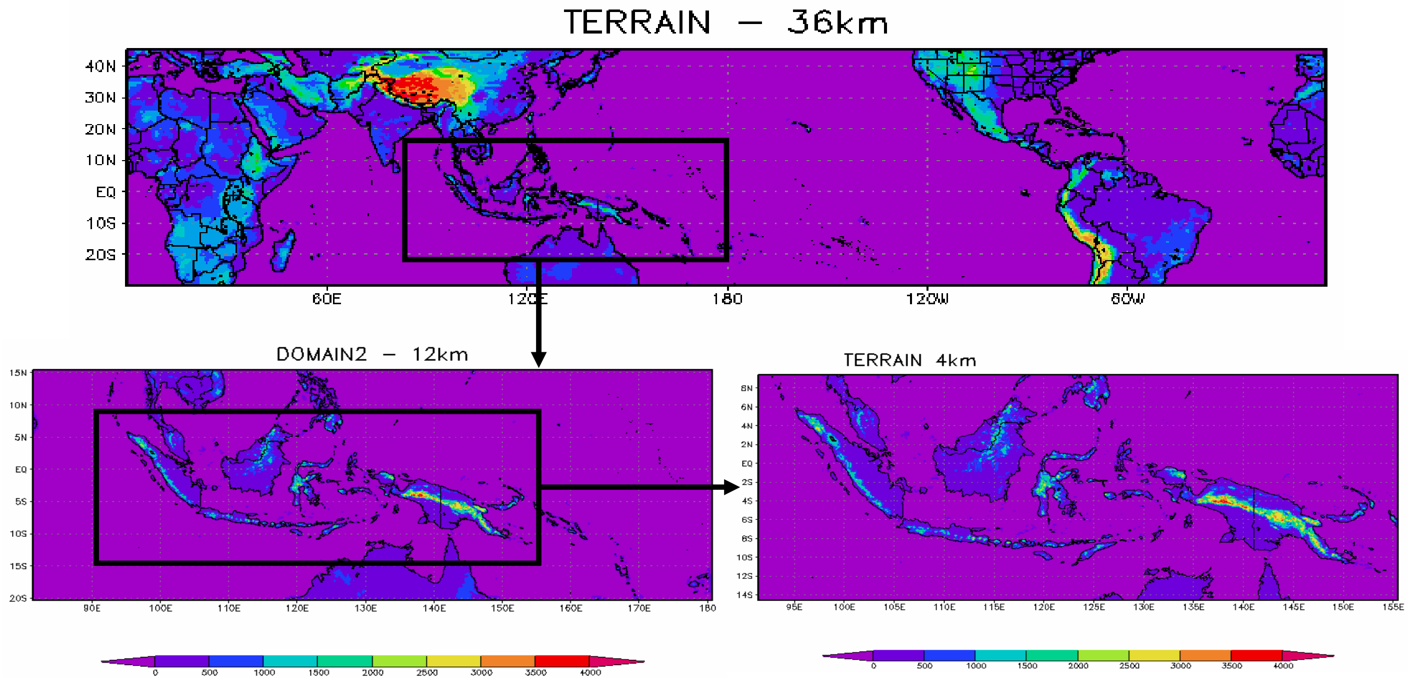




Predictions Across Scales Initiative

- WRF has been configured as a tropical channel at 36 km resolution to simulate tropical phenomena
- A cloud resolving nest at 4 km resolution is embedded over the Pacific warm pool - the heat engine of the tropics - to investigate tropical convection and its upscaled effects
- Simulations were performed on the NCAR Bluevista and NASA LCF Columbia using 132 to 496 processors for 5 years each

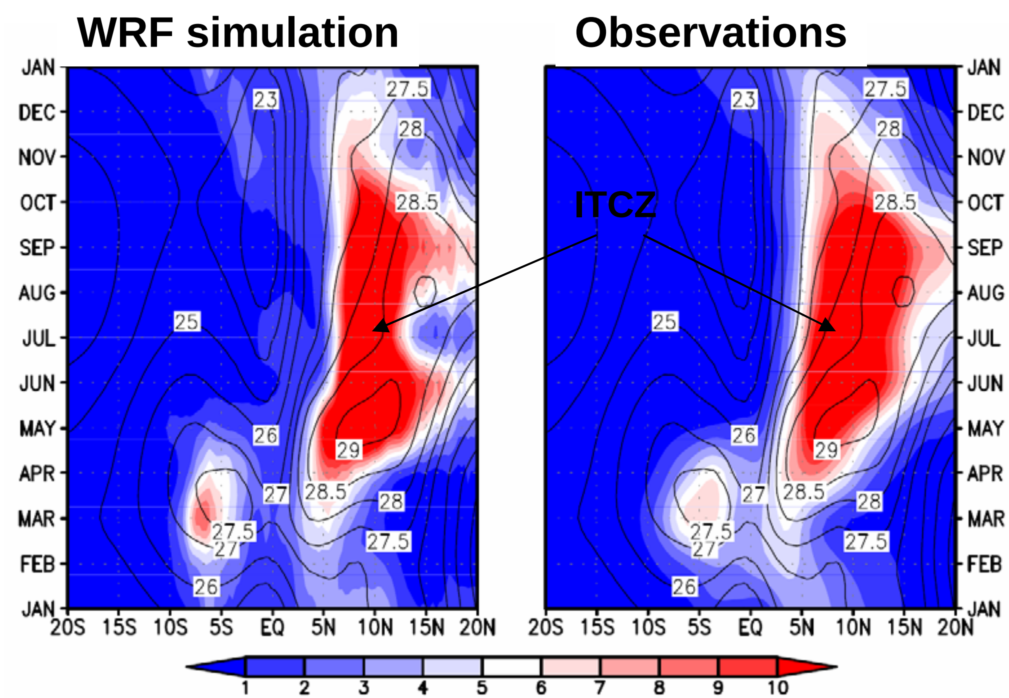
Tropical channel configuration



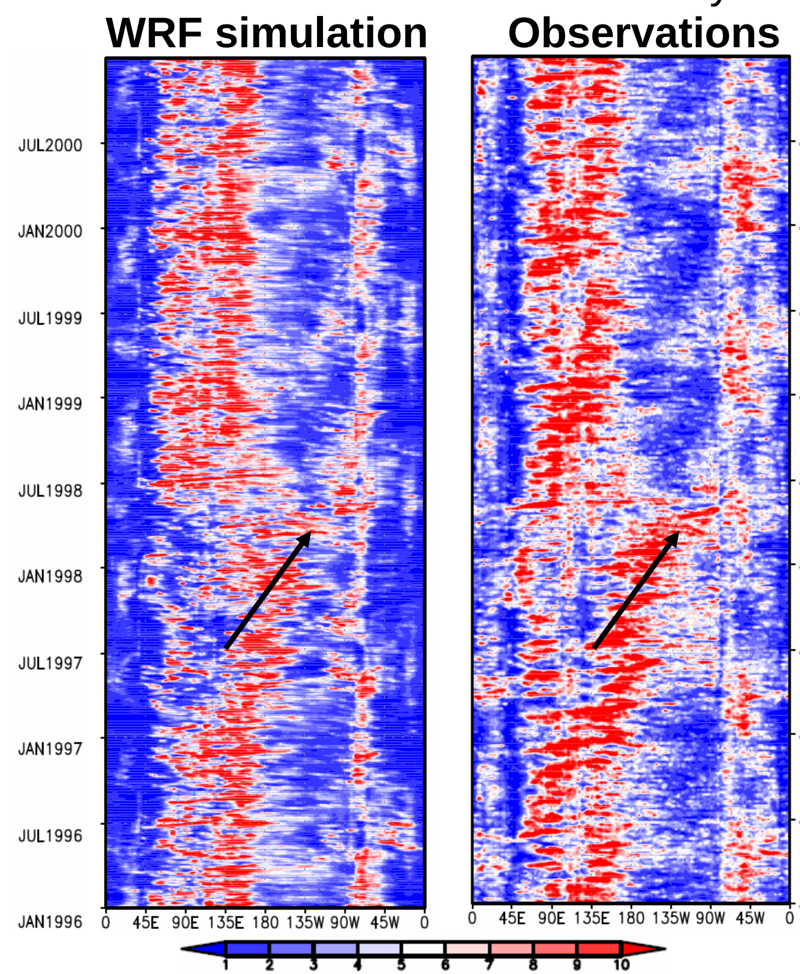
Large Scale Circulation Features

- The simulation shows some realistic climate features of the tropics, including the ITCZ and precipitation response to ENSO forcing

Seasonal evolution of the Inter-tropical Convergence Zone (ITCZ). Some features (red indicates heavy rain) are well simulated over the eastern Pacific (90-120W)



Precipitation averaged over 10S to 10N: Rainfall shifted eastward in response to the 1997 El Nino SST anomaly

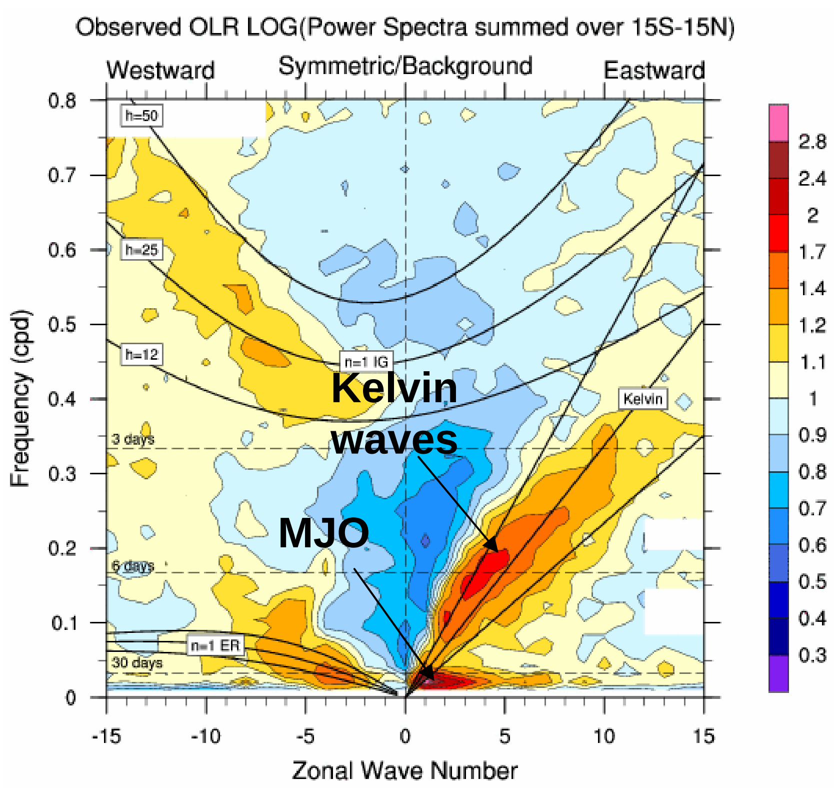


Source: Ray Pallav

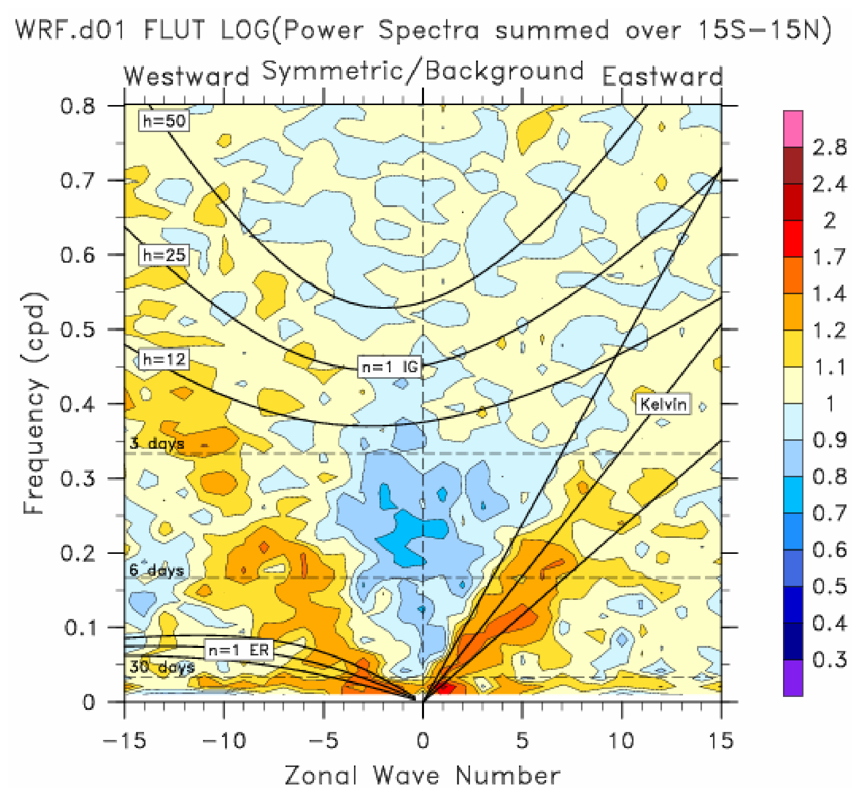
Tropical Modes

- WRF reasonably captured various tropical modes, including the eastward traveling Kelvin waves and MJO

Observed power spectra



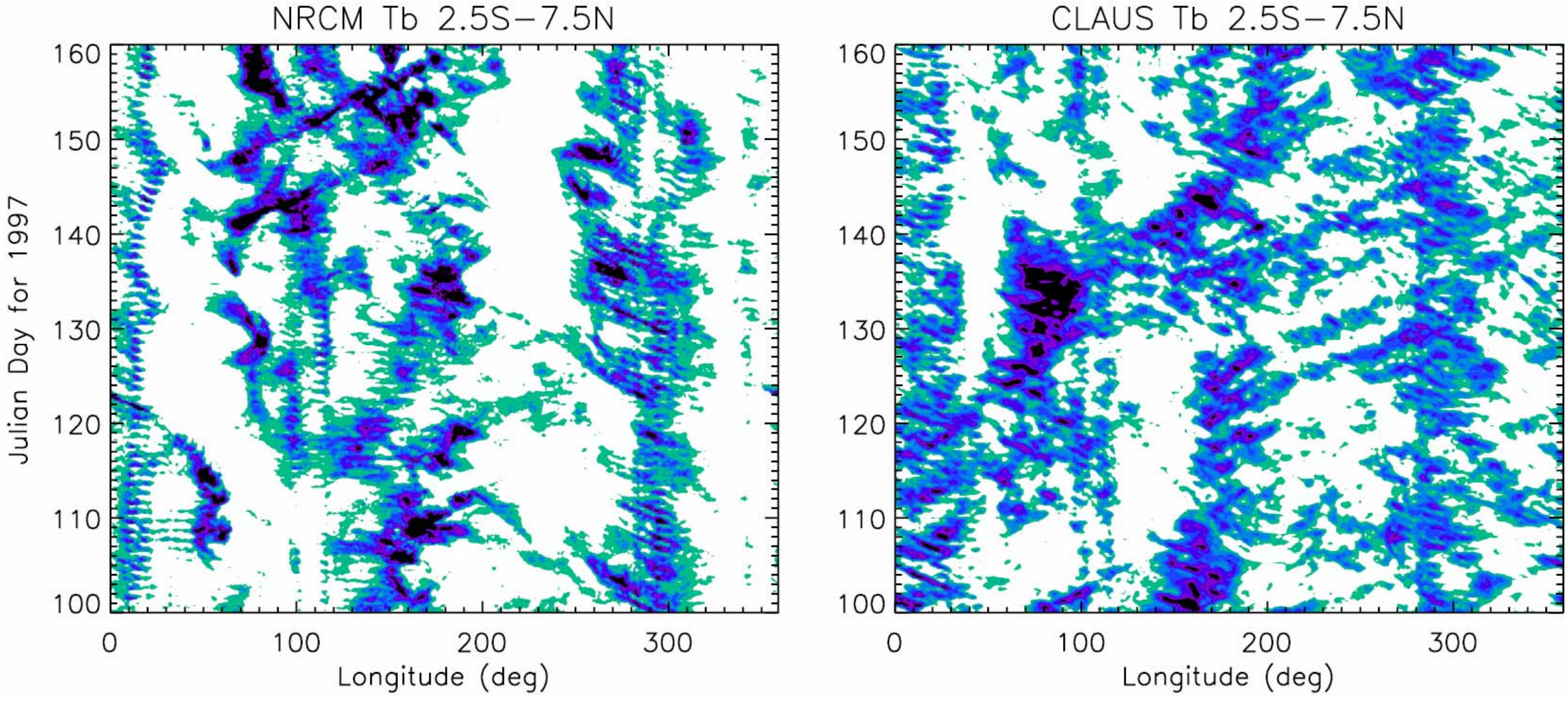
Simulated power spectra



Source: Julie Caron

Tropical Modes

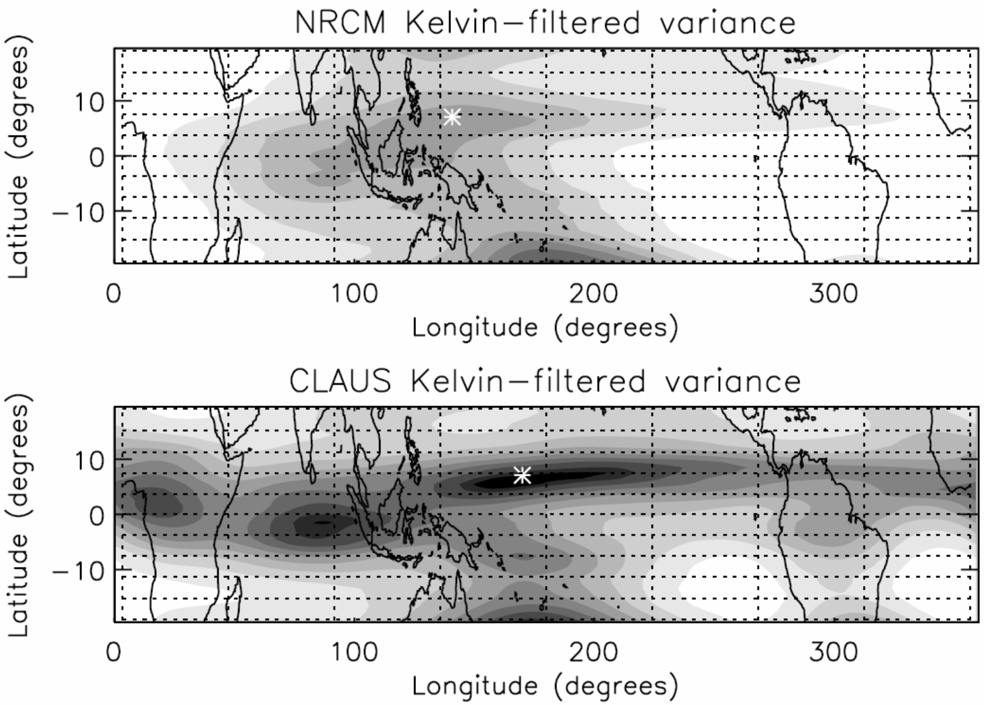
- More organized eastward propagating tropical waves in the observations over the India Ocean, South America, and West Africa

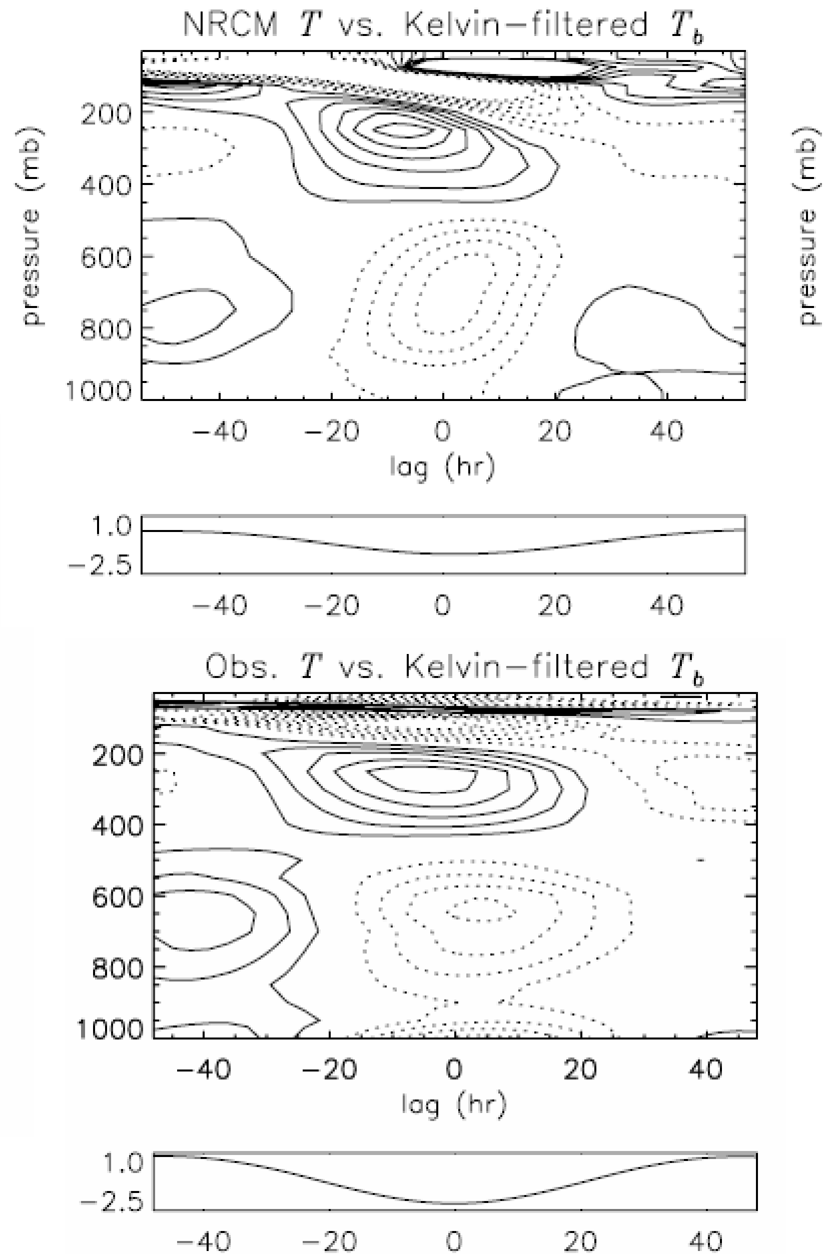


Source: Stefan Tulich

Kelvin Wave Variance and Structure

- Low Kelvin wave variance in the deep tropics
- Simulated realistic structures of Kelvin waves

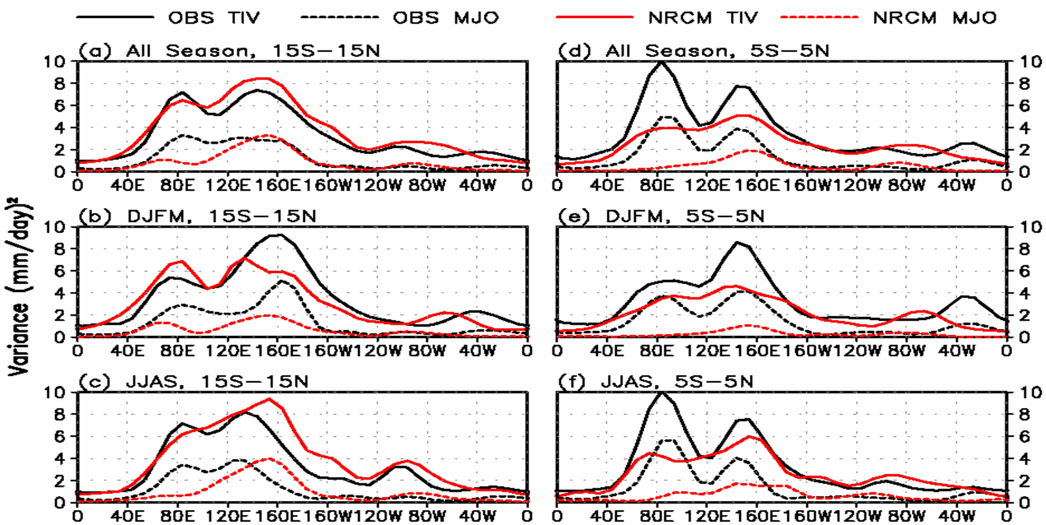




Source: Stefan Tulich

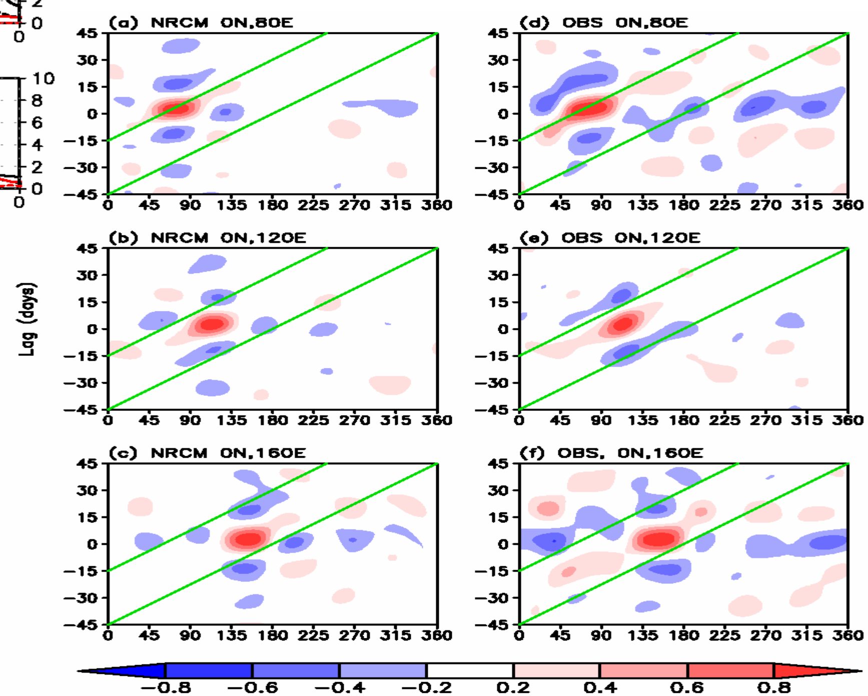
MJO Variance

- Insufficient TIV (total intraseasonal variance) and MJO variance in the deep tropics, particularly over the Indian Ocean
- MJO propagation speed fairly well captured



MJO variance and Total Intraseasonal Variance (TIV) of precipitation

Lag-correlation of 20-90 day precipitation



Source: Ray Pallav

What Have We Learned?

- When applied at horizontal resolution of 10 – 40 km, WRF has similar performance compared to MM5 for both cold season and warm season precipitation in the US

- Interannual variations of precipitation are well captured in the cold season regime (e.g., western US where ACC > 0.9), but less so in the warm season regime (e.g., central US where ACC is between 0.2 – 0.5)

- Need further investigations of the source of large scale biases that limit skill in simulating interannual variability in the summer

- WRF captured some basic large scale circulation features in the tropics such as the seasonal migration of ITCZ, TOA cloud forcing, and transition from stratocumulus to deep convection in the East Pacific transect

- In the large tropical channel, the simulation is more strongly controlled by SST than lateral boundary conditions, though results show some sensitivity to the location of the southern boundary, particularly over the South Indian Ocean

What Have We Learned?

- Some features of MJO and Kelvin waves are well simulated, but the simulation generally lacks intraseasonal variability in the deep tropics, with less organized eastward propagation

- Larger biases are found over the Indian Ocean and western Pacific where convection responds too strongly to warm SST; biases in diabatic heating have negative impacts on the monsoon circulation (see Bill Kuo's presentation for more details)

- In the tropical channel at 36 km spatial resolution, parameterized convection continues to present challenge in simulating tropical convection

- Lack of air-sea interactions could also be an important factor contributing to the biases in tropical convection and tropical modes

- The impacts of the cloud resolving (4 km) nest over the warm pool have not been addressed