MJO and Intraseasonal Activity in Climate Prediction GCMs at GFDL

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Take Home: Significantly improved MJO In GFDL coupled GCMs (CGCMs) with high atmospheric resolution. Further improvement in CM4 development CGCM using new convective scheme.

Key Issues and Questions

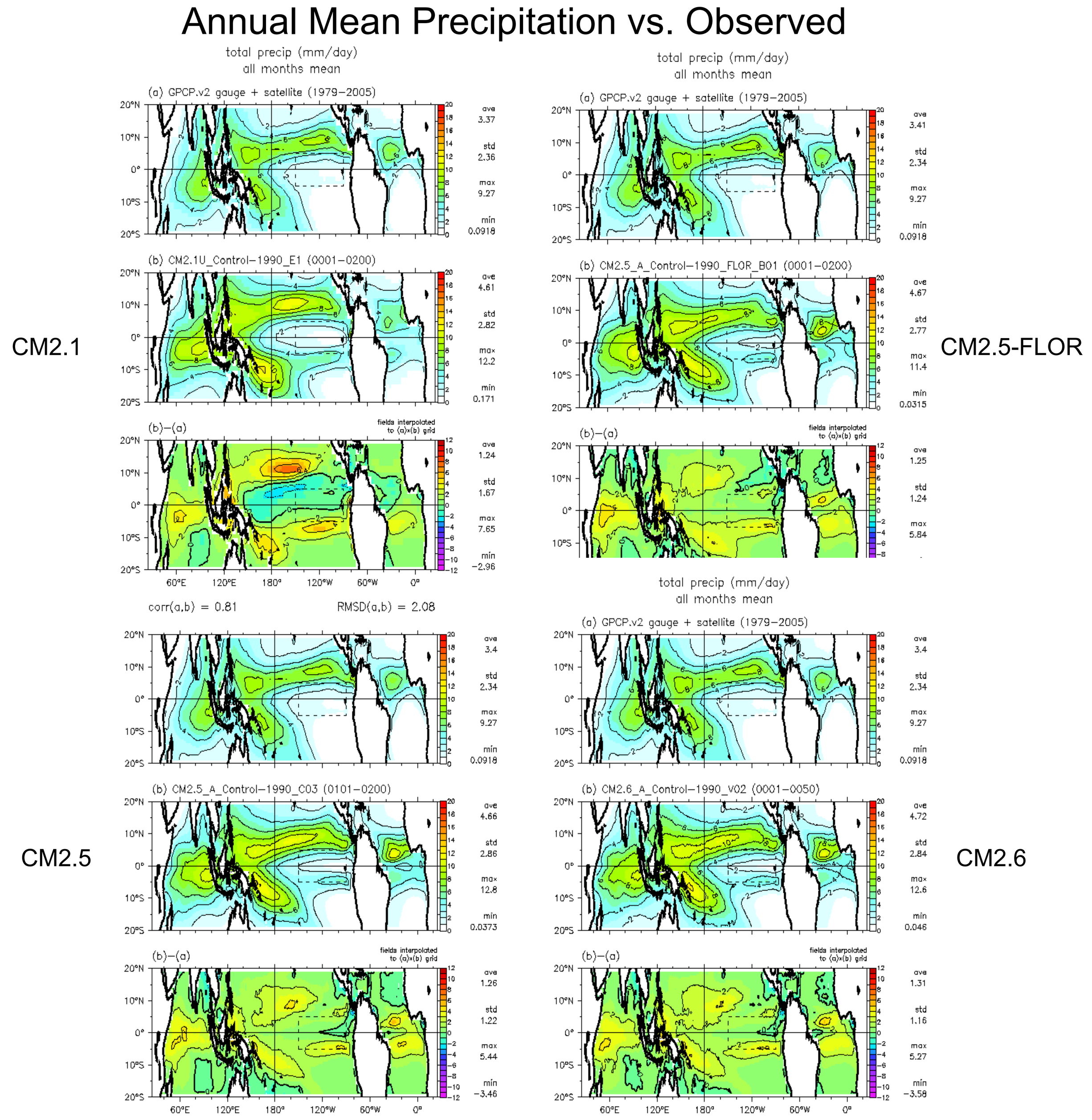
- Intraseasonal variability (ISV), particularly the Madden-Julian Oscillation (MJO), significantly influences tropical weather and climate with indications of impact on ENSO and some extratropical extreme weather. Yet representation of the MJO and other tropical waves has not been very good in many GCMs used for climate prediction.
- GCMs with increased resolution and appropriate physical parameterizations improve the representation of climate features including ENSO, tropical cyclone statistics and seasonal to interannual (SI) variability.
- Can enhanced atmospheric and oceanic resolution in GCMs lead to improvements in representing the MJO? What is the impact of coupling? Is there an impact of SI initialization?
- Behaviour of the MJO is sensitive to convective parameterizations. Can convective schemes be designed/implemented so that the representation of key features of the model climate are not degraded, while improving the GCMs' MJO and ISV characteristics?

High Resolution Model Development GFDL

- **Scientific Goals:**
- **Developing improved models (higher resolution, improved physics) is crucial for studies of variability and predictability on seasonal to decadal time scales.**
- **Explore impact of atmosphere and ocean resolution on climate / climate variability**
- **New atmospheric physics development streams. Improve MJO/ISV? Reduce bias? -> HiRAM+D -> CM4**

GCMs	Ocean (MOM4)	Atmos	Numerics (Atmos)	Computational Resources
AM2.1	NA	250 Km	FV lat-lon	~2.5hrs/yr; ~32 PEs
AM2.5	NA	50 Km	Cubed Sphere	~4hrs/yr; ~1944 PEs
CM2.1	100 Km	250 Km	FV lat-lon	~2.75hrs/yr; ~64 PEs
CM2.5FLOR	100 Km	50 Km	Cubed Sphere	~8.25hrs/yr; ~520 PEs
CM2.5	10-25 Km	50 Km	Cubed Sphere	~5hrs/yr; ~6496 PEs
CM2.6	4-10 Km	50 Km	Cubed Sphere	~12hrs/yr; ~12000 PEs

Annual Mean Precipitation vs. Observed



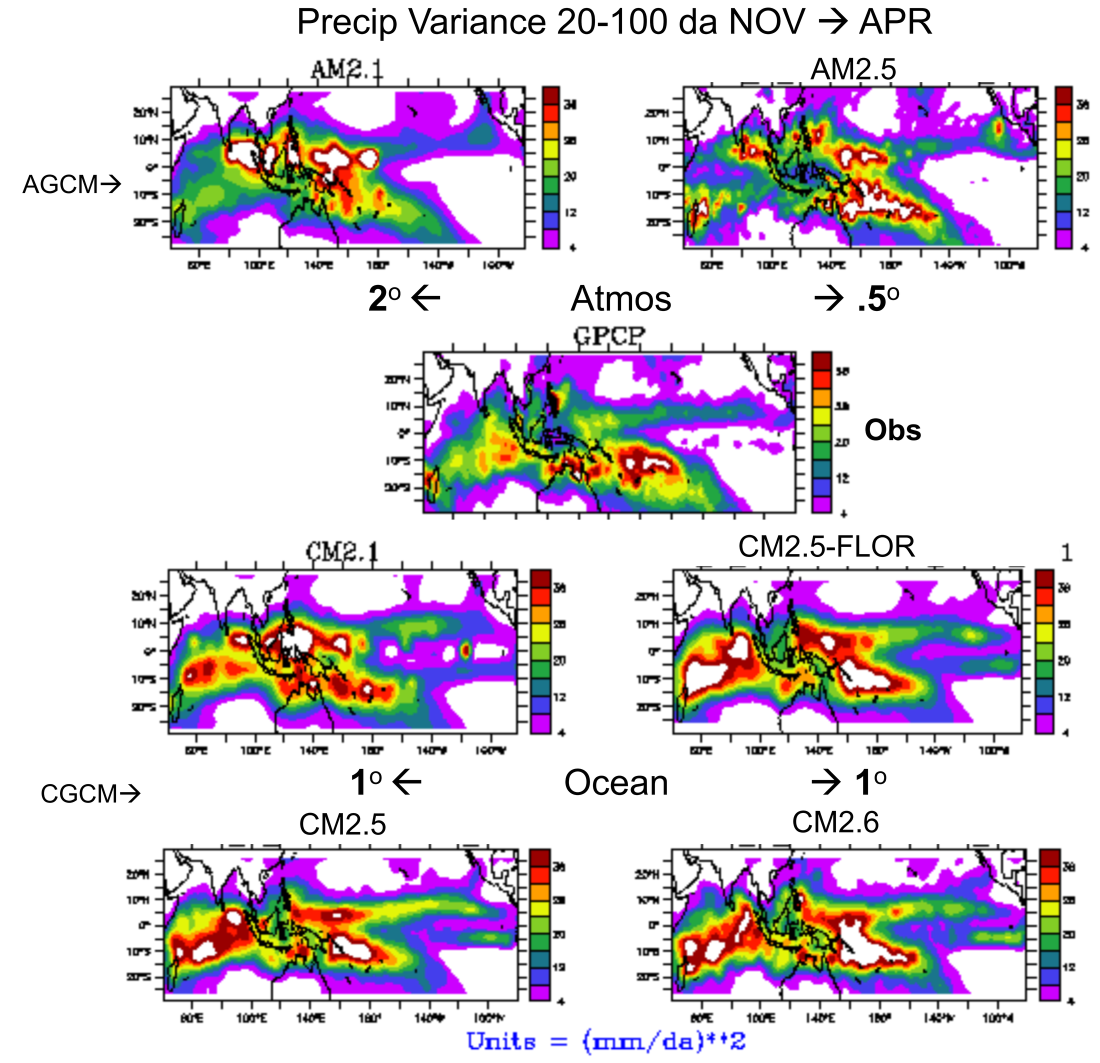
GFDL "CM2.1 Physics" GCMs – atmospheric (AGCM); coupled (CGCM)

*(GFDL Global Atm. Development Team, 2004; Delworth et al., 2006)

Impact of resolution and coupling on ISV and MJO

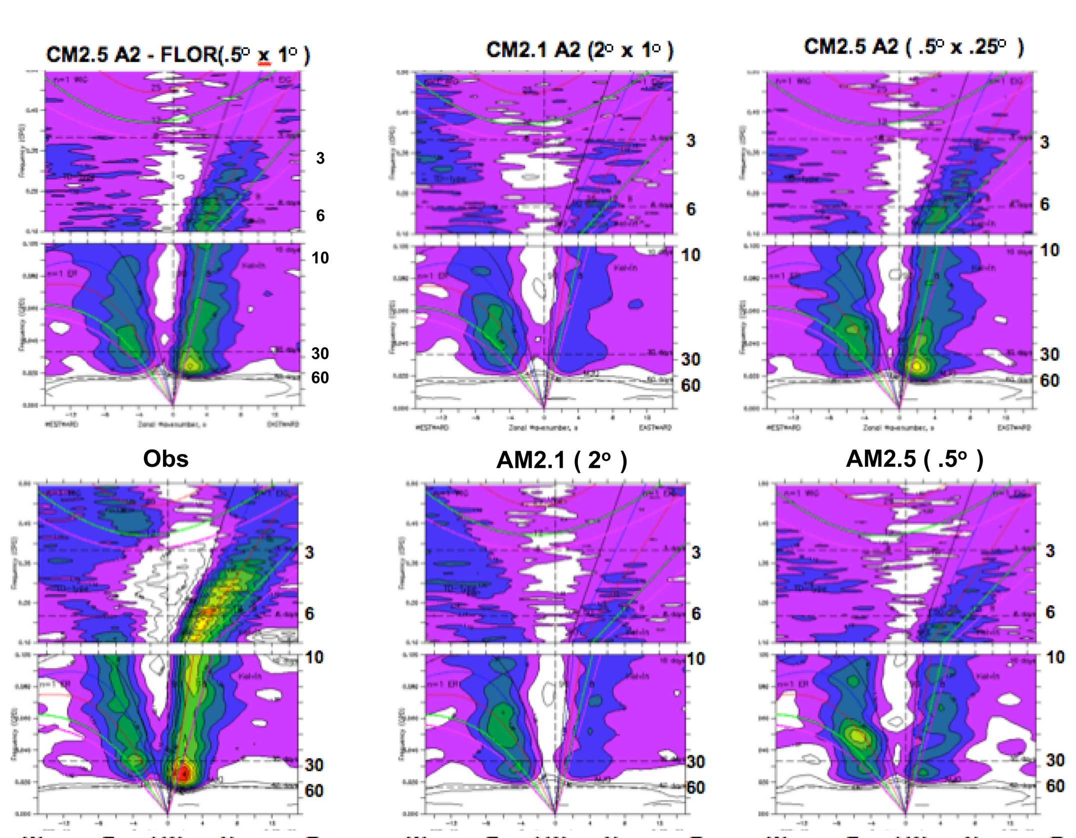
MJO/ISV metrics for "CM2.1 physics" simulations

Precip Variance 20-100 da NOV → APR

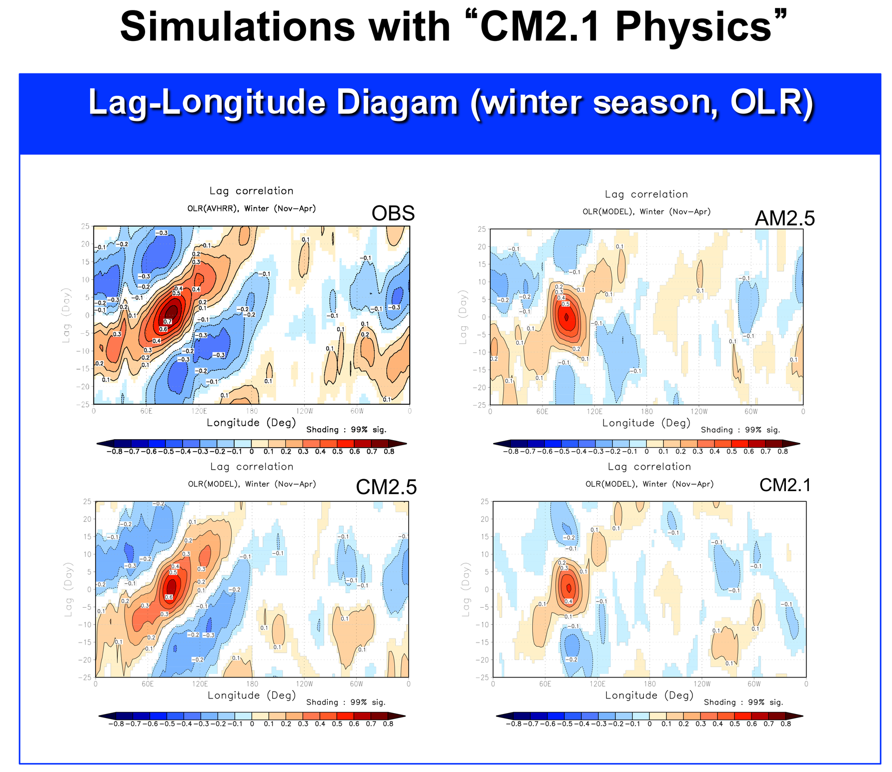


Wheeler-Kiladis Tropical Wave Analyses (1999)

Equatorial zone (15s-15n) analyses of OLR in a wavenumber frequency domain are performed. By normalizing relative to background (red) spectra, shaded regions indicate spectral power exceeding the background . (Symmetric modes shown)



Simulations with "CM2.1 Physics"

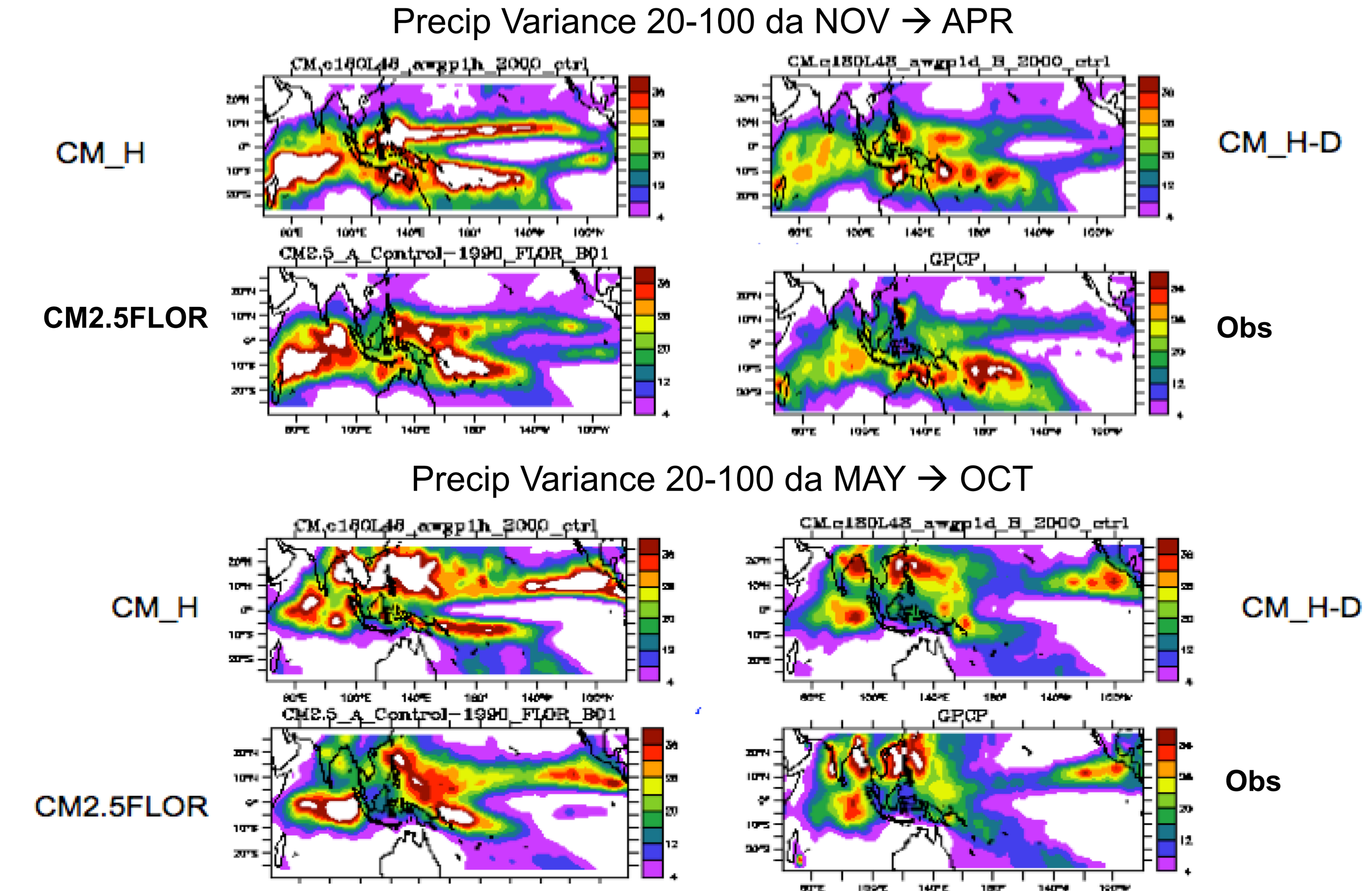


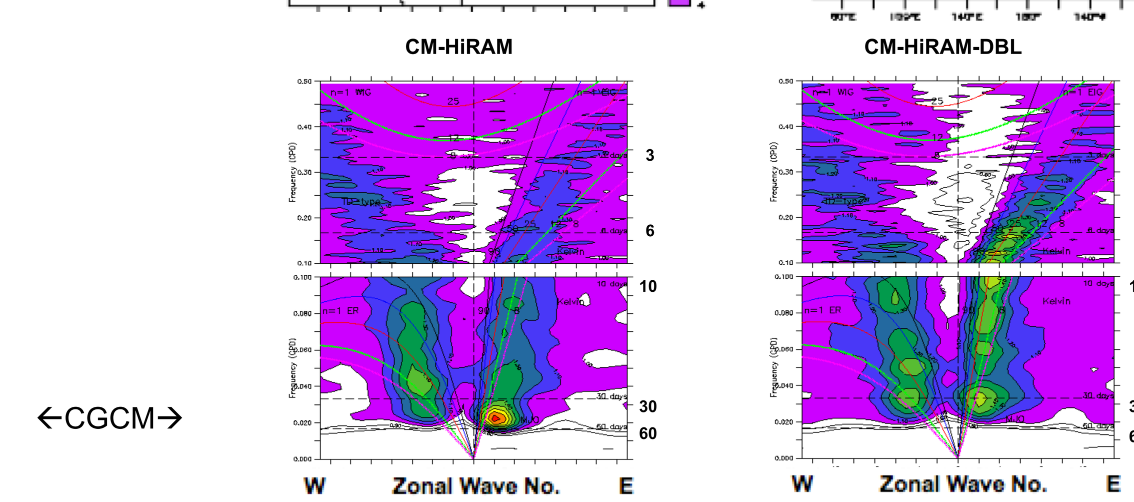
New model development (*Zhao et al., 2012; 2009*); HiRAM → CM4 – Impact of new convection on ISV and MJO

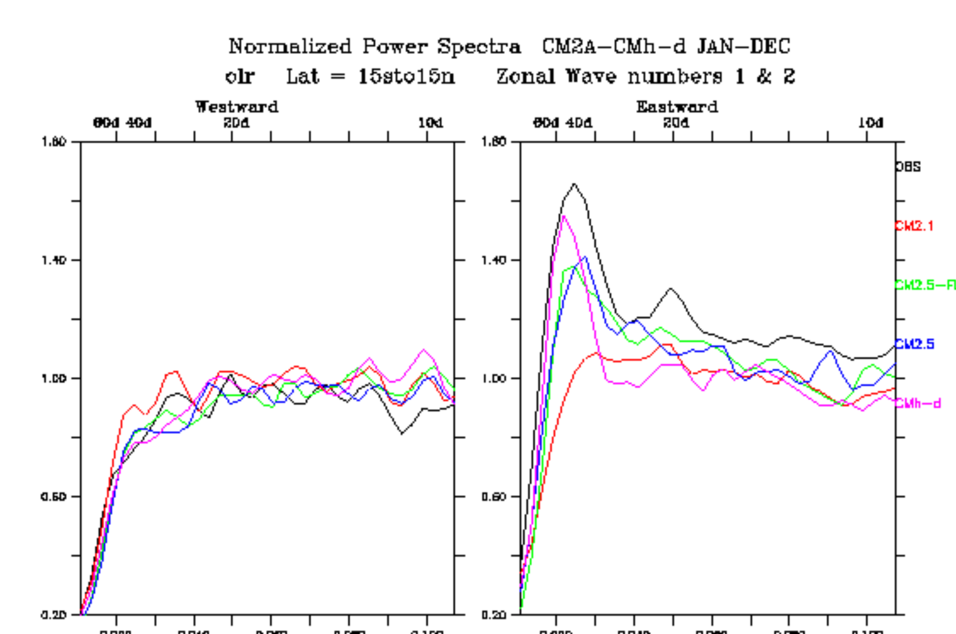
HiRAM - TCs and some aspects of ISV well simulated, but coupling introduces significant biases in tropical precipitation; MJO not particularly well represented.
HiRAM+DBL – Modified HiRAM model's convective parameterization to allow for deep convection by adding a 2[nd] plume that interacts with environmental RH.

MJO/ISV metrics for simulations using "HiRAM→CM4" physics

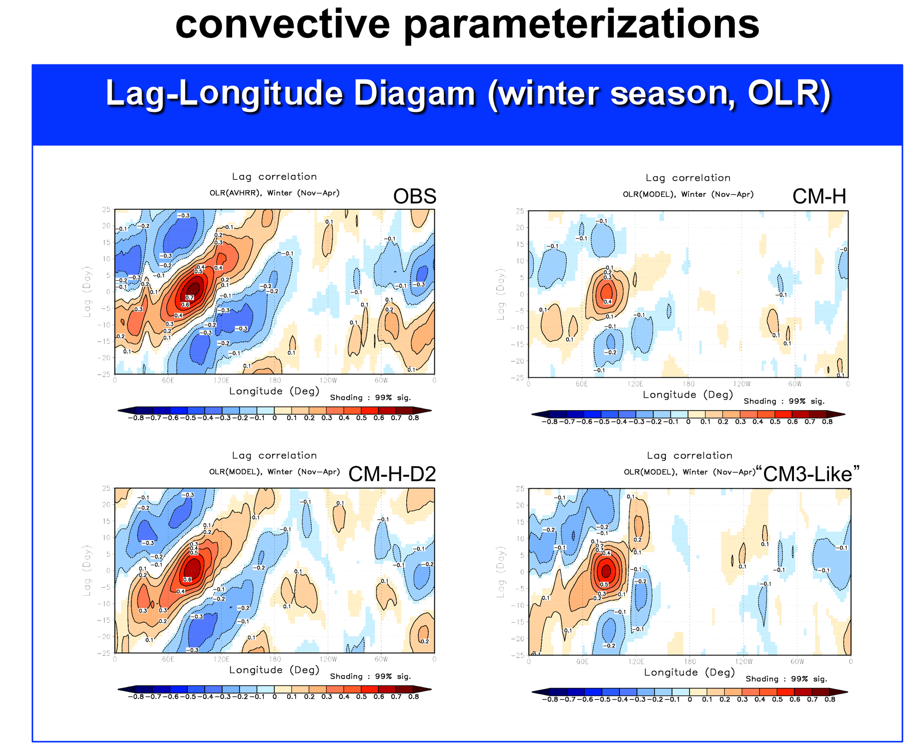
Precip Variance 20-100 da NOV → APR







Coupled simulations (.5° x 1°) with new convective parameterizations

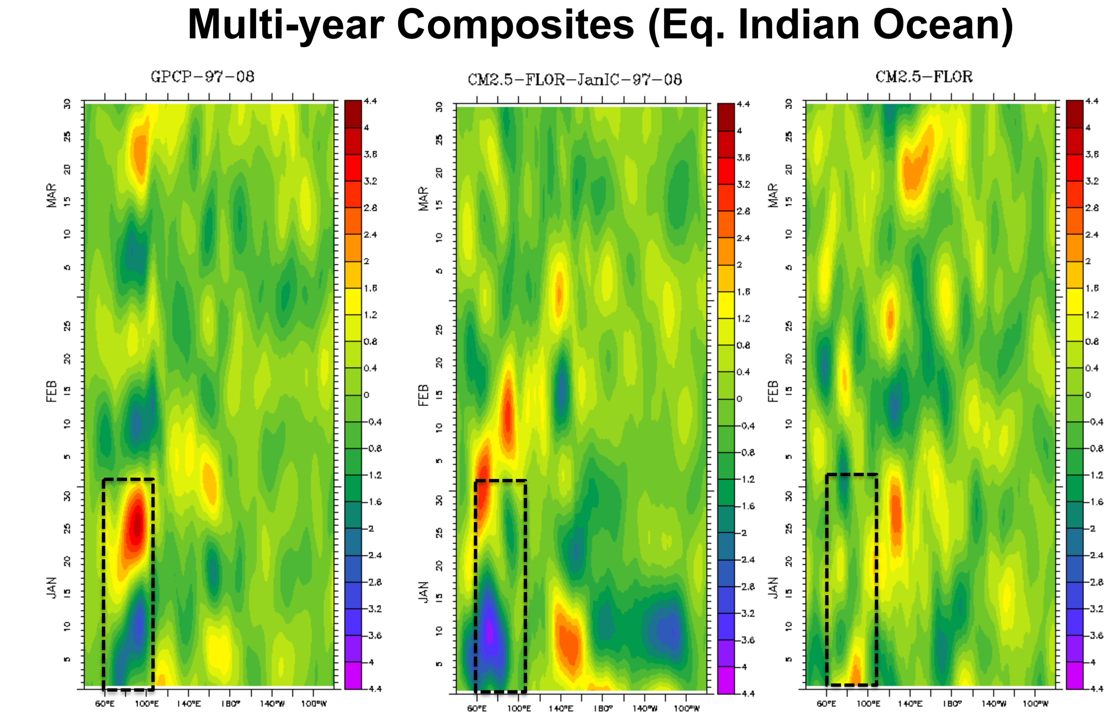


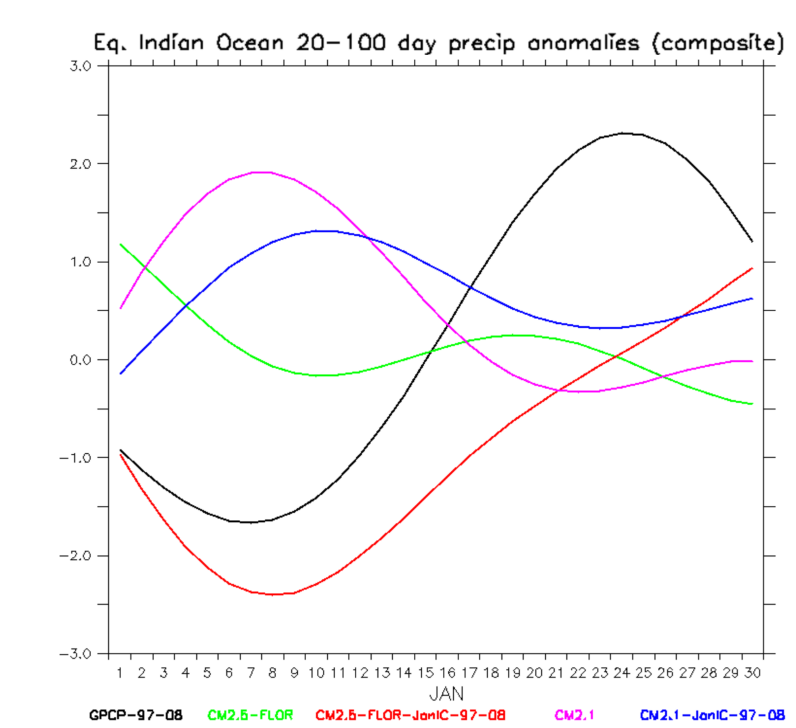
CM2.5FLOR Experiments and Initialization

12 month hindcasts from IC vs. long free runs

Ocean IC from ECDA (*S. Zhang, M. J. Harrison, A. Rosati, and A. Wittenberg; MWR 2007*)
Atmosphere from AM2.5 AMIP runs

Lon vs Time 20-100 da Precip Anomalies – Multi-year Composites (Eq. Indian Ocean)





Summary

- **Increasing resolution in GFDL coupled GCMs clearly improves representation of intraseasonal activity**
  Intraseasonal daily precip variance – Improved geographic distribution in tropical Indian – Pacific for finer atmospheric resolution. Nov-Apr activity shifts from north of equator to ~10S. Significant impact of coupling with higher resolution atmosphere, particularly over Indian Ocean.
  MJO and tropical convective waves – WK analyses show improved symmetric wave spectra in high resolution, especially when coupled. Improved speed (slows down) and enhanced amplitude of MJO, with somewhat better representation of the Kelvin mode.
  MJO propagation – Lag-Lon. plots => more robust propagation in CM2.5 vs AM2.5 and CM2.1.
- **Coupling can have a positive impact on MJO**
  In GFDL GCMs an AGCM configuration that does not produce an MJO will not likely produce one when coupled, but if the AGCM is able to simulate some MJO, coupling improves it.
- **HiRAM enhances some intraseasonal activity, but coupling produces significant biases and degrades the model climate**
  Tropical features – Coupled HiRAM has excessive high frequency precipitation in SPCZ and across the Indian Ocean, with spuriously strong double ITCZ – associated with an extended warm bias along the SPCZ and an equatorial cold bias seen in the mean SSTs.
- **HiRAM + Double Plume improves MJO while matching A2 physics CGCM model climate features**
  Tropical features – Coupled HiRAM – Double Plume reduces biases in tropical precip seen in HiRAM. Double ITCZ extent and ENSO structure now comparable to CM2.5FLOR.
  MJO and tropical convective waves – WK analyses indicate an MJO with improved amplitude and speed in Double Plume vs HiRAM. Although HiRAM does capture the asymmetric mixed Rossby Gravity mode.
  MJO propagation – Lag-Lon. Plots => more robust propagation in Dbl. Plume vs. HiRAM.
- **Initialization – CM2.5FLOR-IC shows correspondence with Obs, but CM2.1-IC => IC may not be important when GCM is not capable of producing an MJO**