Analysis and Evaluation of WRF Tropical Channel Simulations

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Predicting the Earth System Across Scales

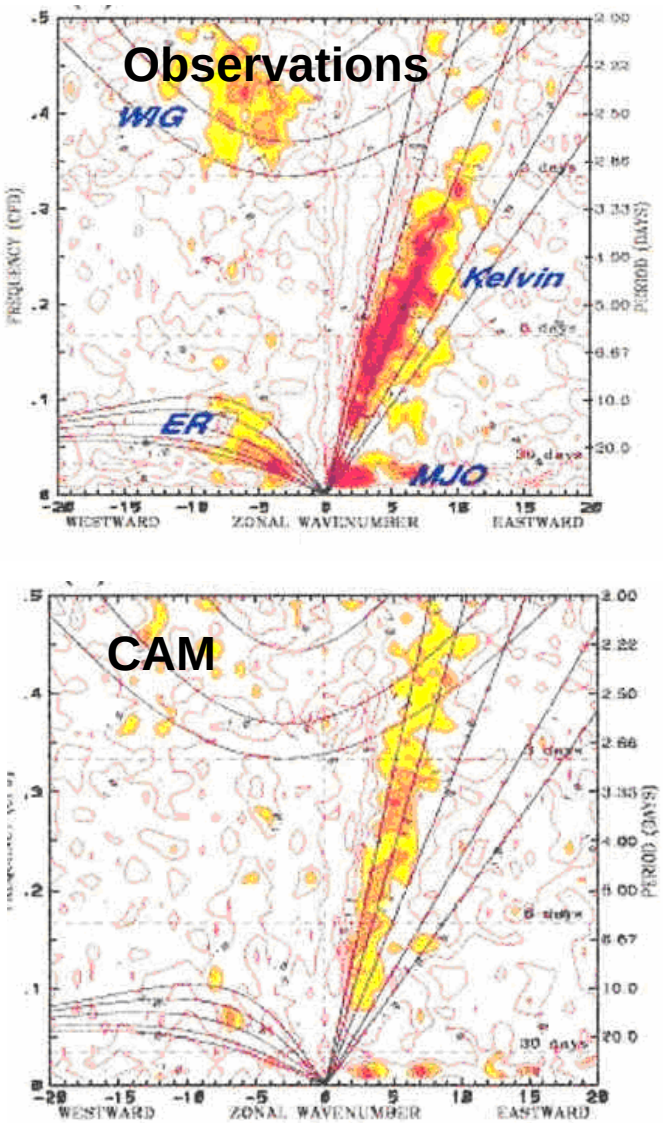
Overarching Goal:

- To improve our understanding and simulation of the complex, 2-way scale interactions that are critical to climate and weather predictions

Objectives:

- To improve *downscaling* from global climate simulations for accurate regional predictions
- To improve *upscaling* of regional processes in global climate simulations;

Getting the Tropical Modes



(Lin et al. 2006)

- Currently CAM and CCSM have difficulty capturing the modes of tropical variability, from equatorial Rossby, through westward inertia gravity and MJO. Even the Kelvin modes are poorly captured.
- This program will focus on understanding and reducing such biases.
- A working hypothesis is that the upscale development from organized tropical convection is a critical factor.
- By utilizing cloud-resolving nested models in critical areas, we plan to both test this hypothesis and develop an approach to improving CAM and CCSM in this important characteristic.
- Taking advantage of Blue Vista during its bedding in period, we performed WRF simulations with cloud resolving nest to investigate the usefulness of the nesting approach

Nested Regional Climate Model

WRFV2.1

Physics:

- CAM radiation: radt = 30min
- WSM-6 microphysics
- Noah LSM
- YSU bounday layer
- Kain Fritsch (new Eta) convection

Code modifications:

- Periodic lateral boundary conditions in East-West.
- Updated lower boundary condition: SST and Vegetation Fraction.
- Wide buffer zone of 10 grid points using a combined linear-exponential relaxation.
- Expanded diagnostic outputs including the ISCCP simulator and accumulated fluxes

Tropical Channel Simulations

Forcing Data:

- NCEP-NCAR reanalyses at north and south boundaries (6 hourly at 2.5°)
- Periodic lateral boundary conditions East-West.
- Lower boundary conditions: AMIP SST (0.5 degree) and mean monthly vegetation fraction

Vertical Levels:

- 35 sigma levels for all domains.
- Terrain following close to surface transitioning to pressure levels at model top.

Model Outputs:

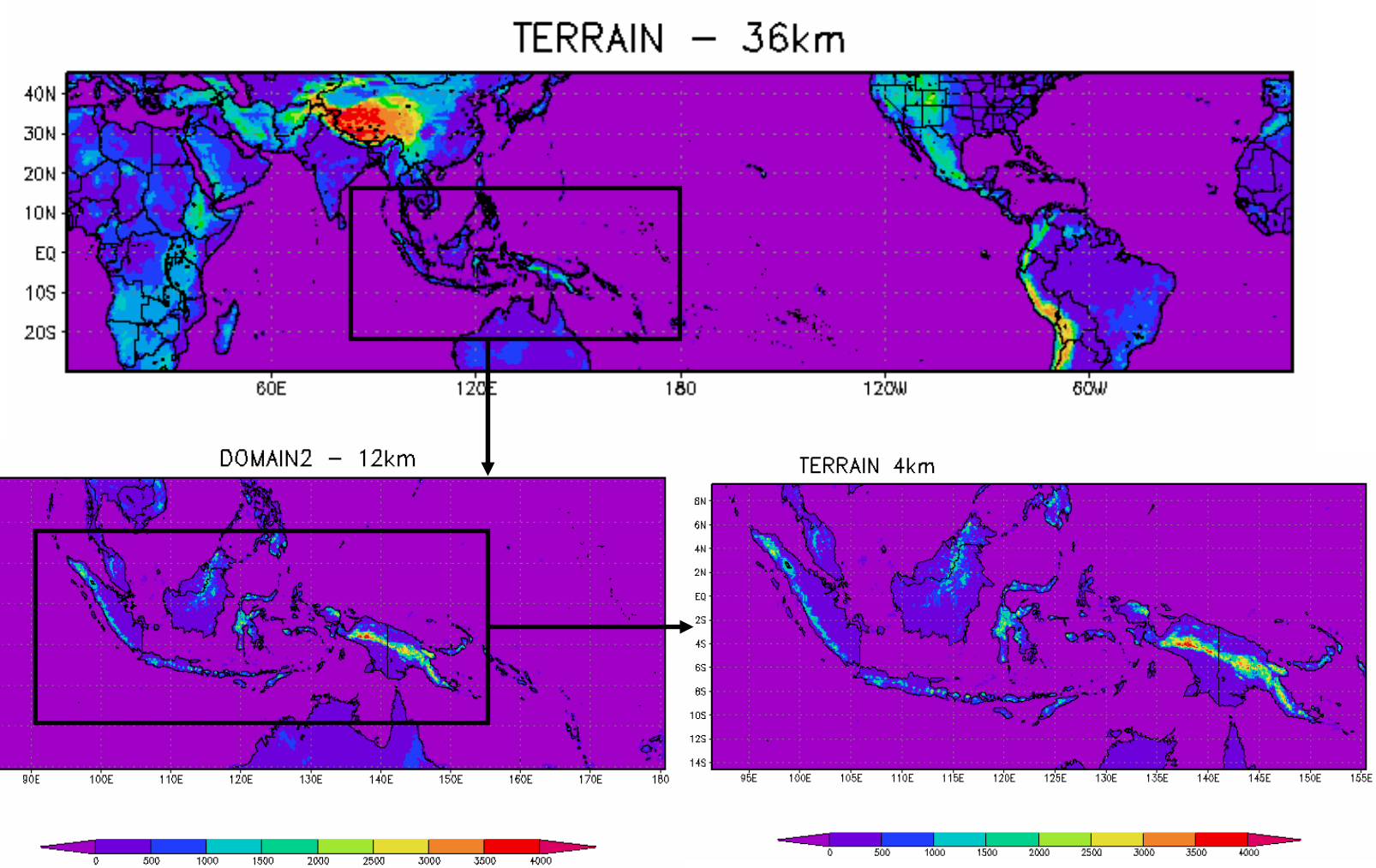
- 3-hourly instantaneous 3D fields
- Hourly surface and TOA fields and averaged fluxes

Analysis and Evaluation:

- Climate diagnostics (Julie Caron and Jim Hack)
- EUROCS transect (Ruby Leung and Roger Marchand)
- Tropical cyclone statistics (Greg Holland)

Model Setup

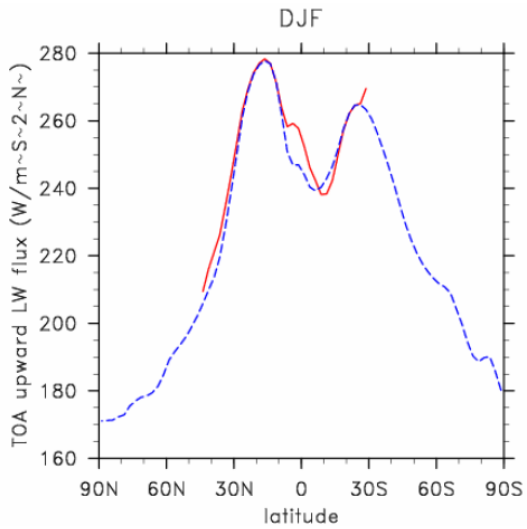
- **Center latitude = 9.5 Center longitude = 180.0 Map projection = Mercator**
- **Domain 1: 1112 x 255 grid points at dx = 36 km (Jan 1, 1996 to Jan 1, 2001)**
- **Domain 2: 922 x 340 grid points at dx = 12 km (Domains 1 + 2: Jan 1, 1996 to Mar 1, 1998)**
- **Domain 3: 1783 x 673 grid points at dx = 4 km (Domains 1 + 2 + 3: Jan 1, 1997 to Jul 1, 1997)**

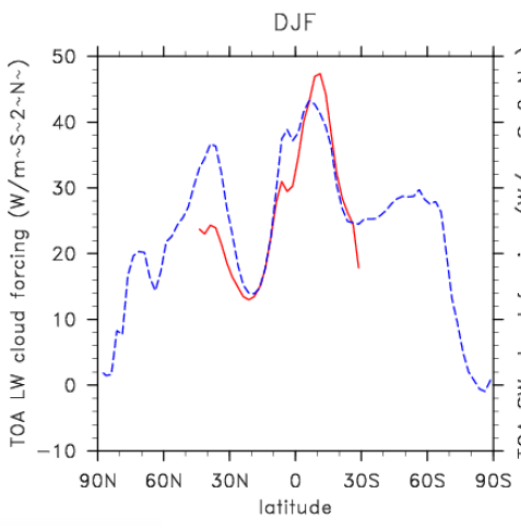


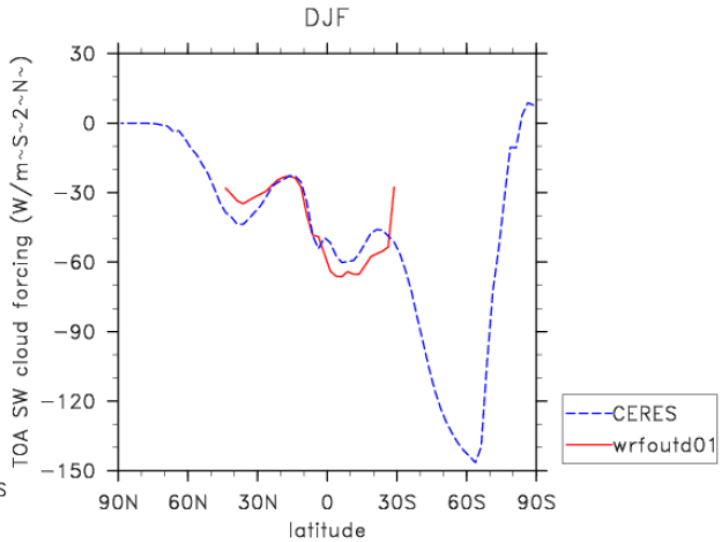
TOA Radiative Fluxes

TOA Upward LW **TOA LW Cloud Forcing** **TOA SW Cloud Forcing**

DJF







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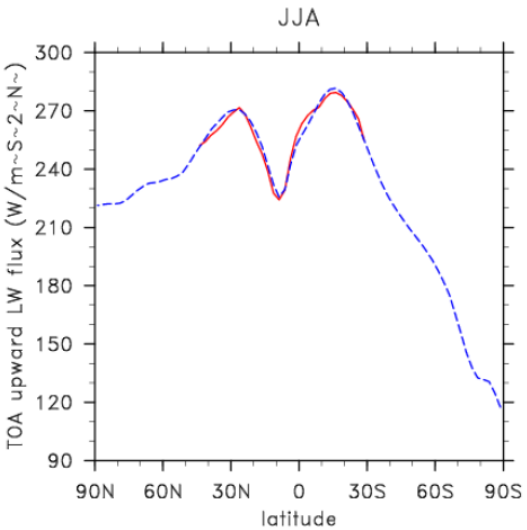
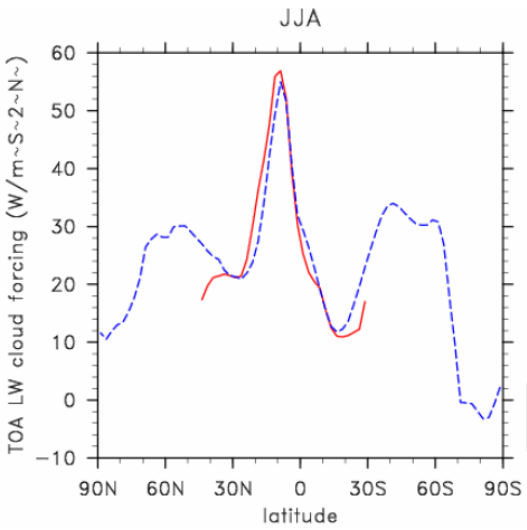
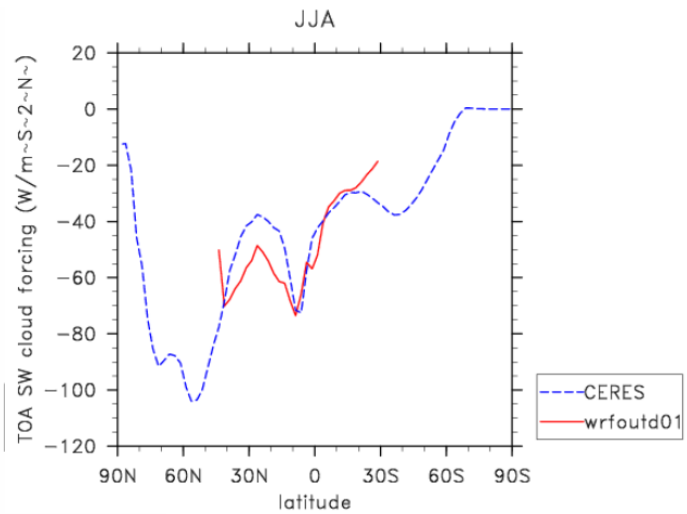




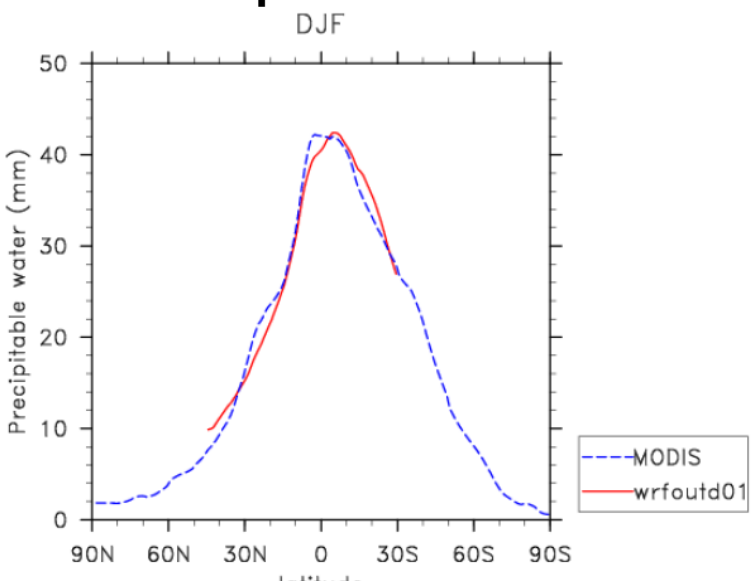


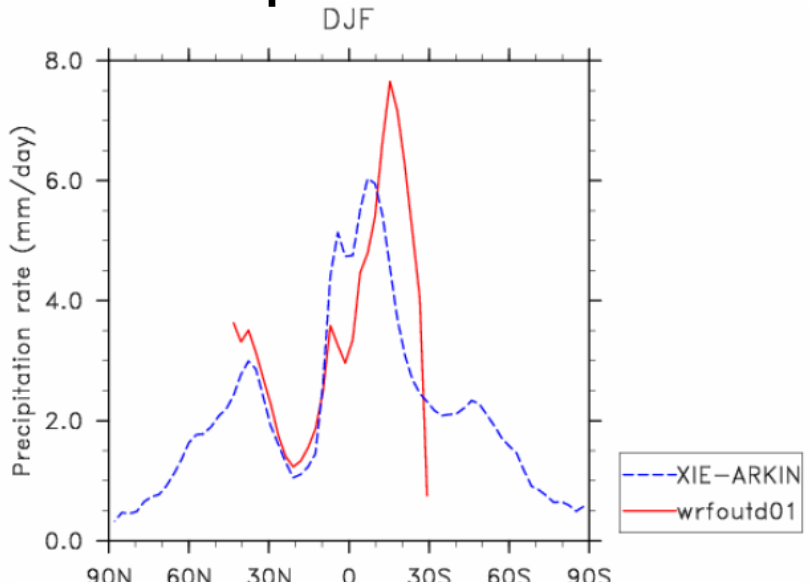
Precipitable Water/Precipitation

Precipitable Water

Precipitation Rate

DJF





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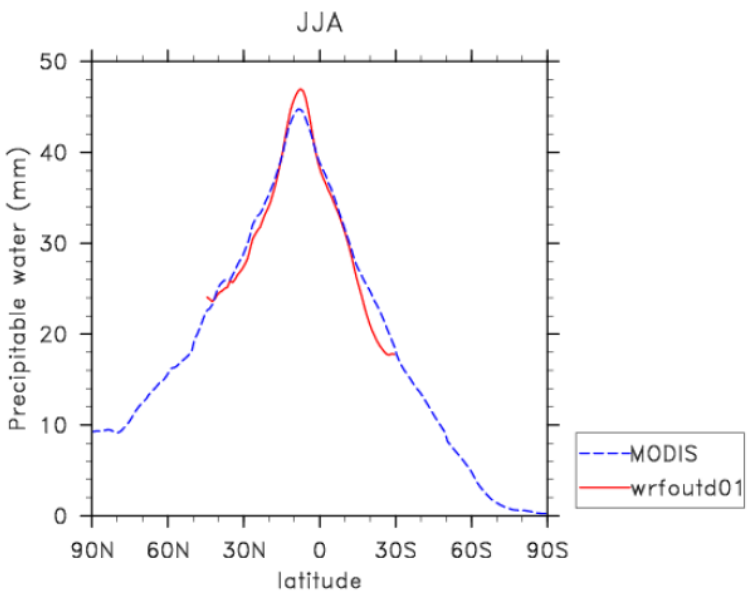
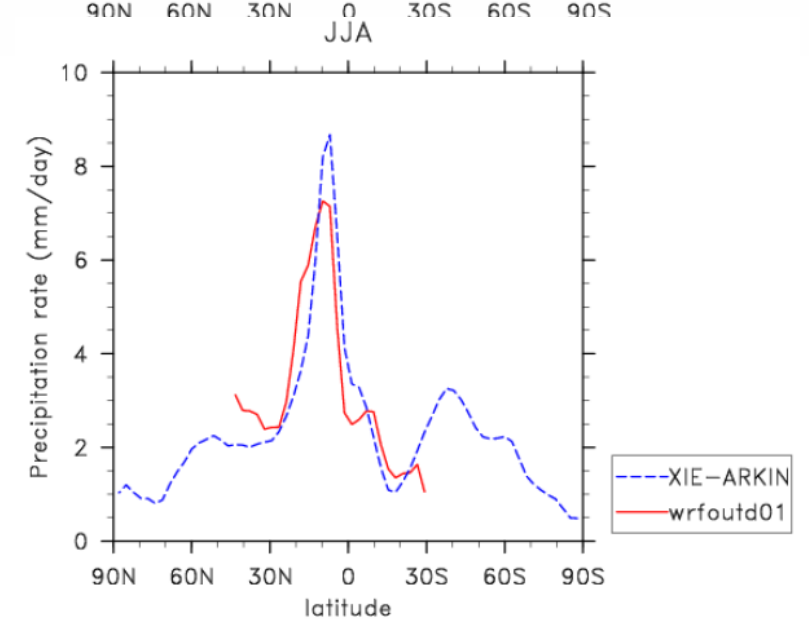
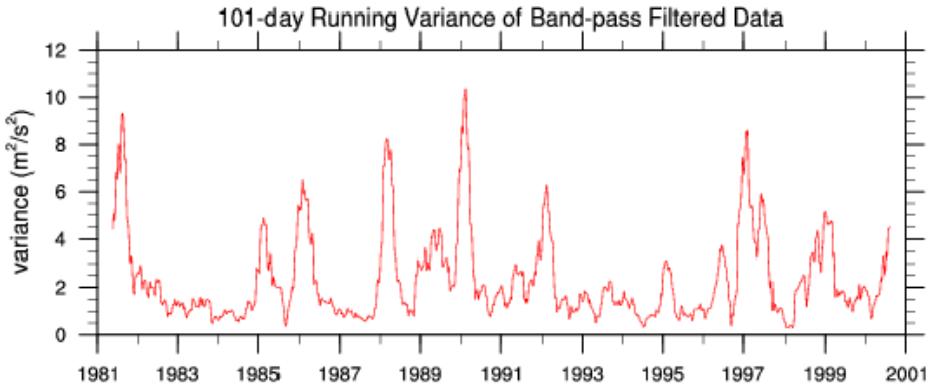


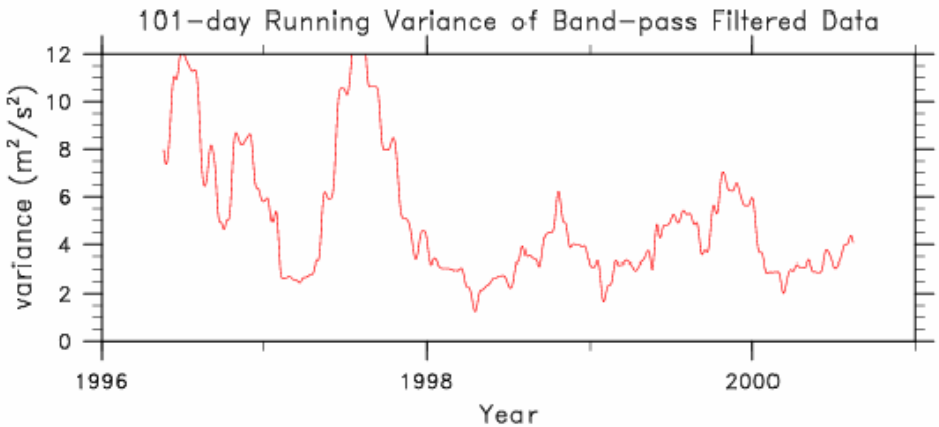


MJO Indices

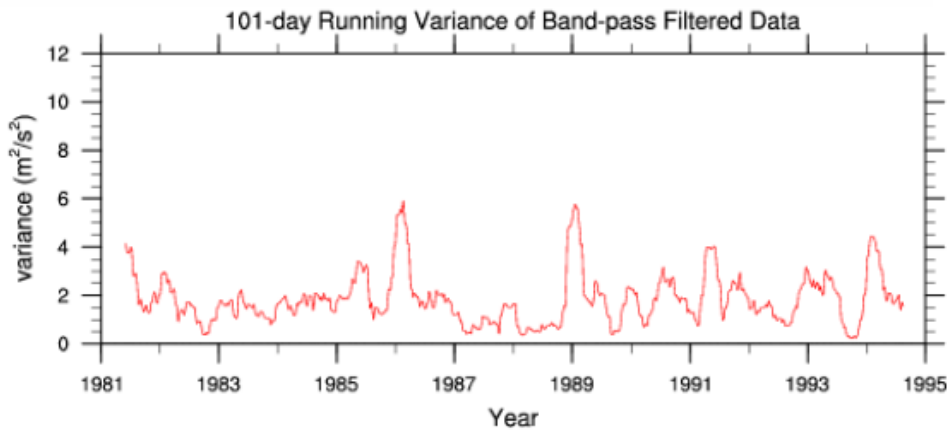
NCEP



WRF

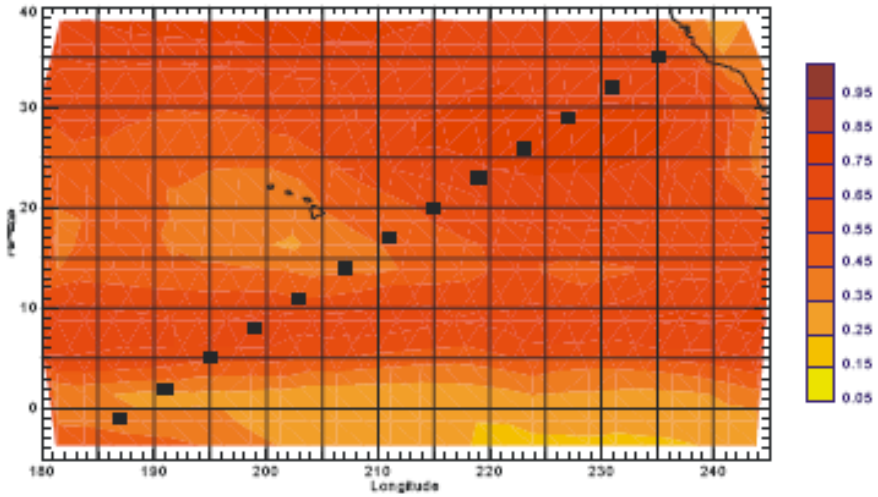


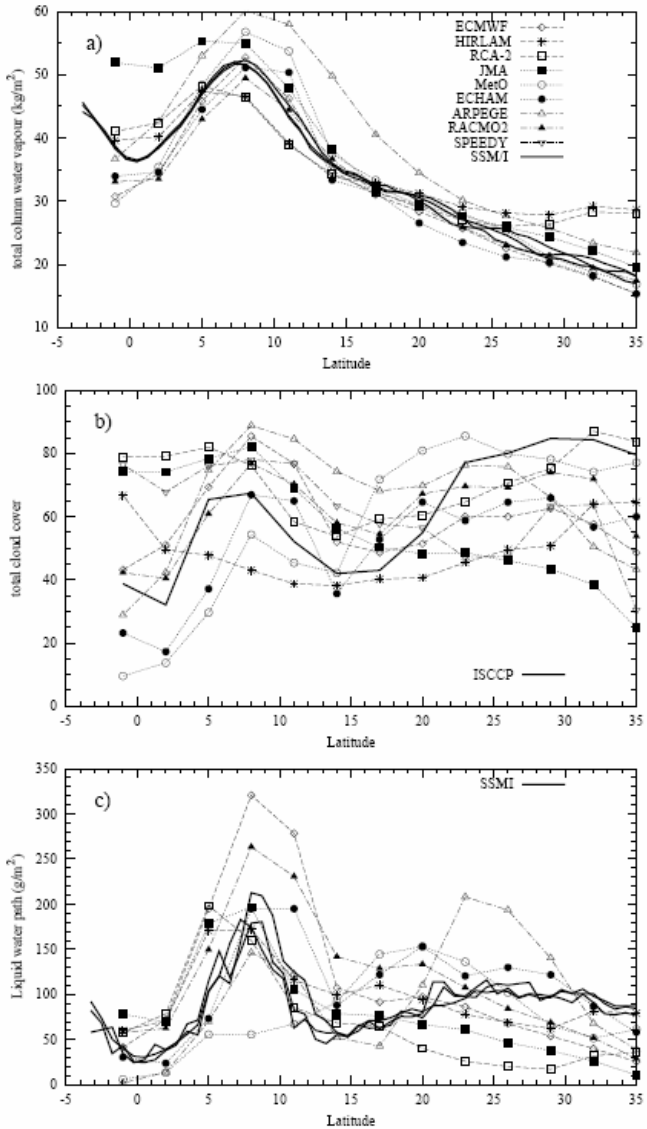
CAM T170



EUROpean Cloud Systems Study (EUROCS)

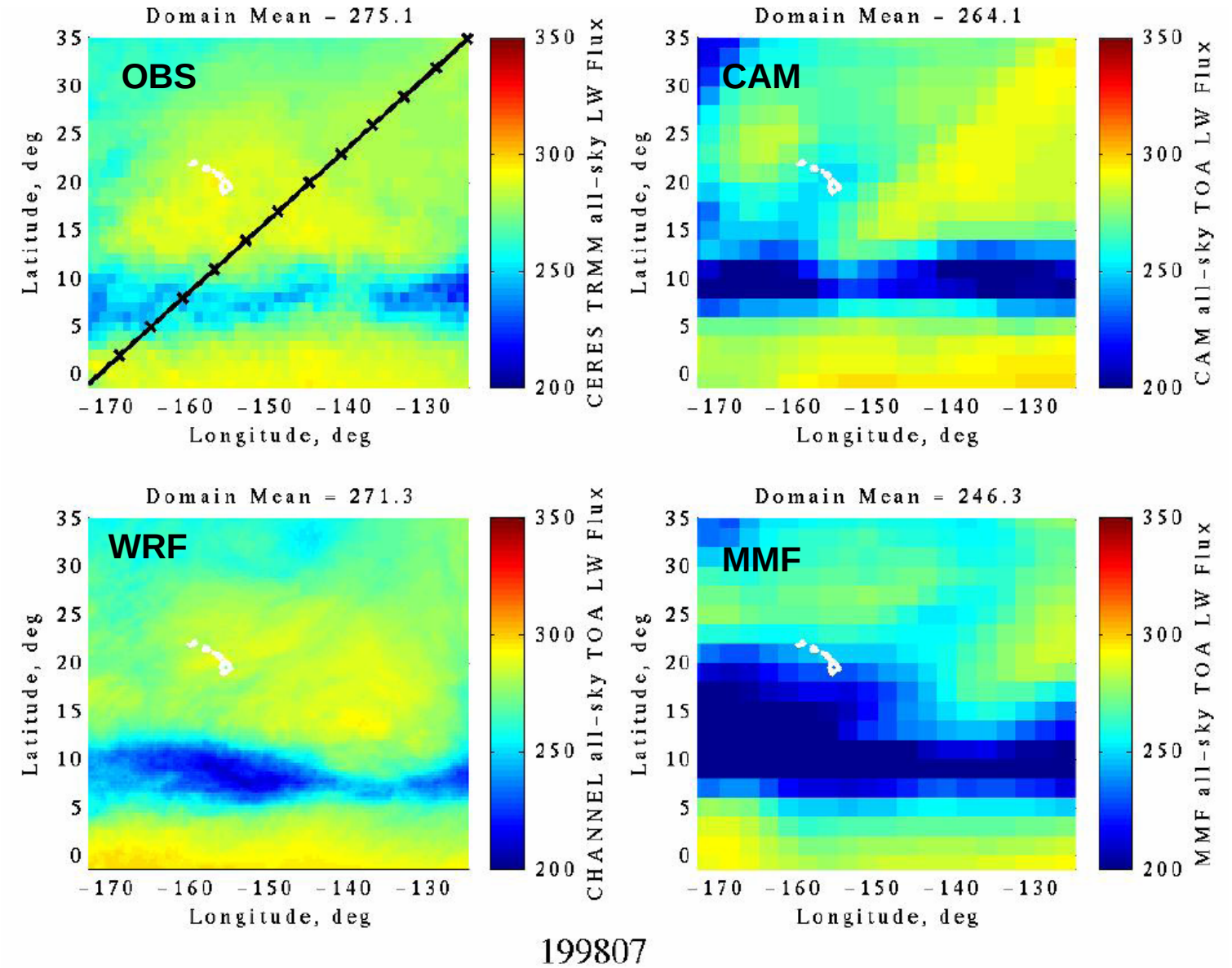
(Siebesma et al. 2002)



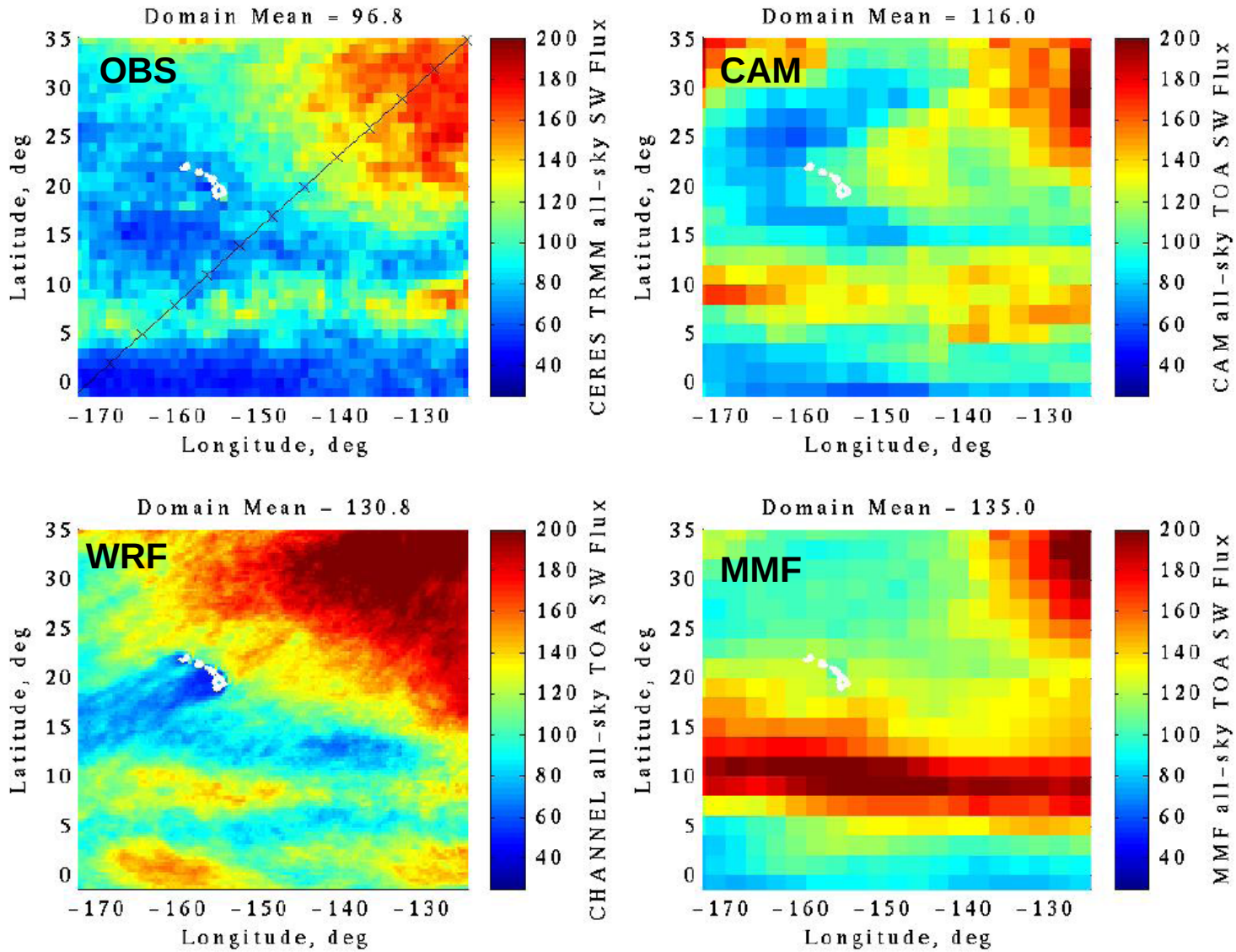


1. June – August 1998
2. Idealized transect along the eastern Pacific representing the transition from stratocumulus, shallow cumulus, and deep cumulus
3. 9 climate and weather models participated
4. Most models underpredict cloud cover in the stratocumulus regime, and vice versa in the trade wind and ITCZ region

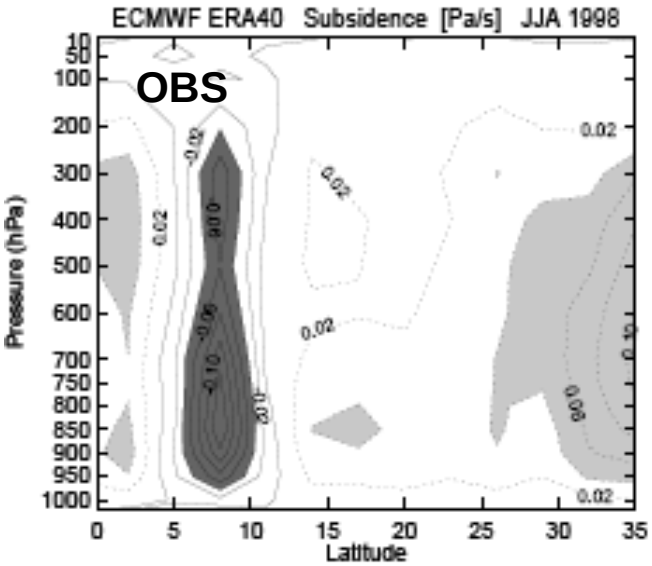
TOA Upward LW Fluxes

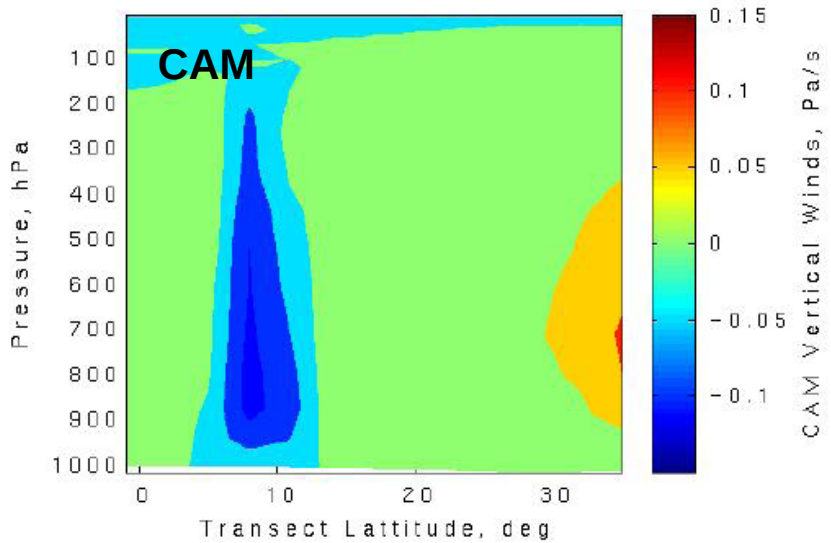


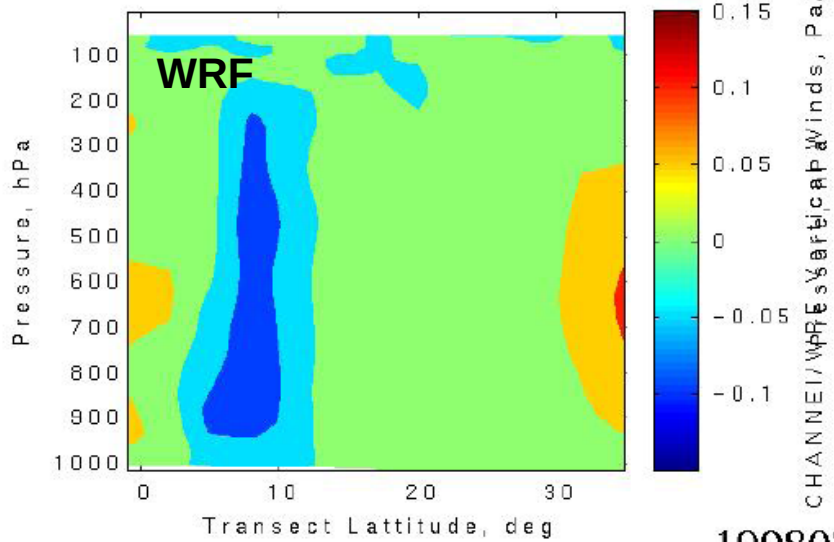
TOA Upward SW Fluxes

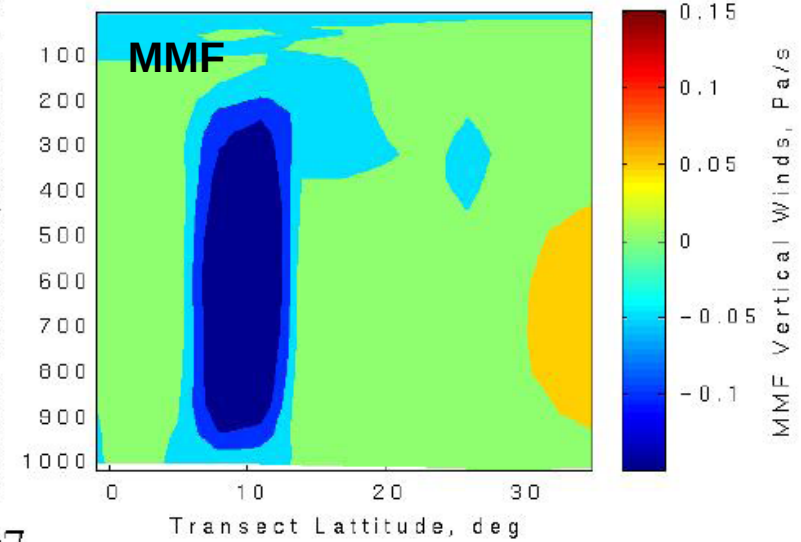


Vertical Velocity









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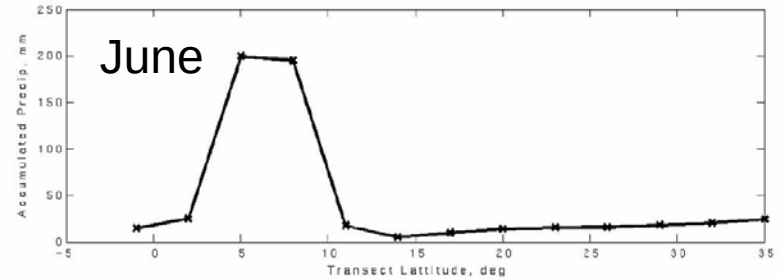
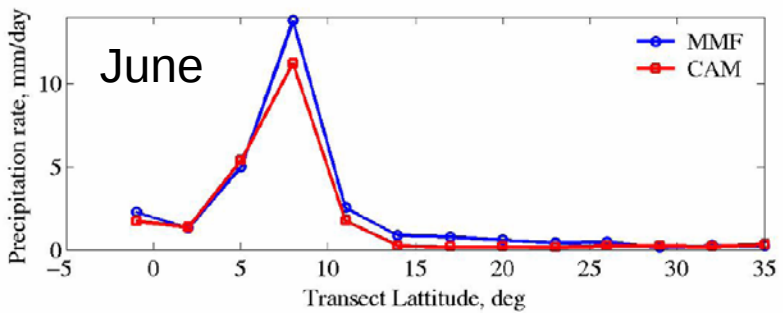
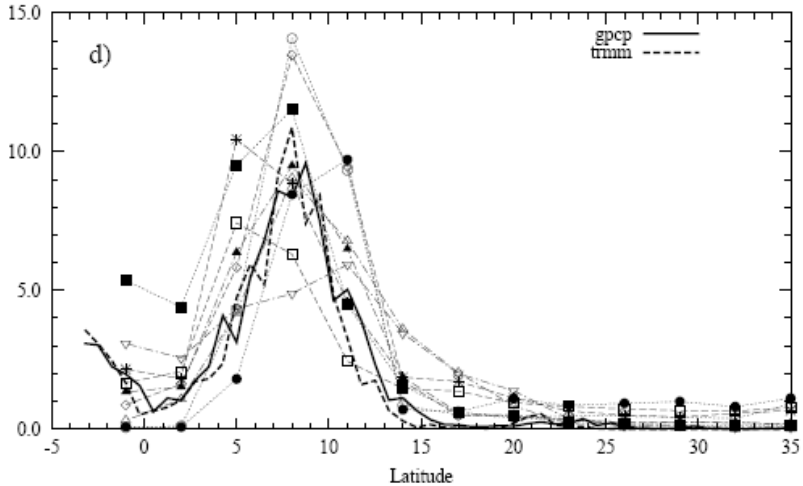
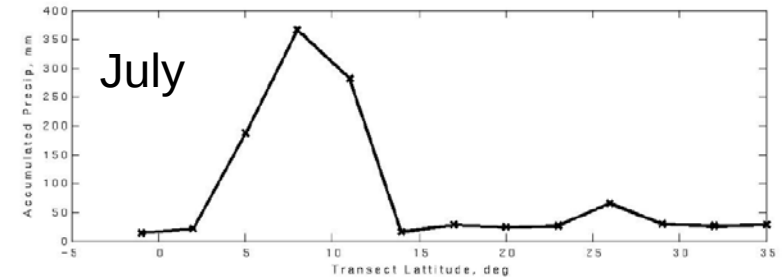
Rainfall Along Transect

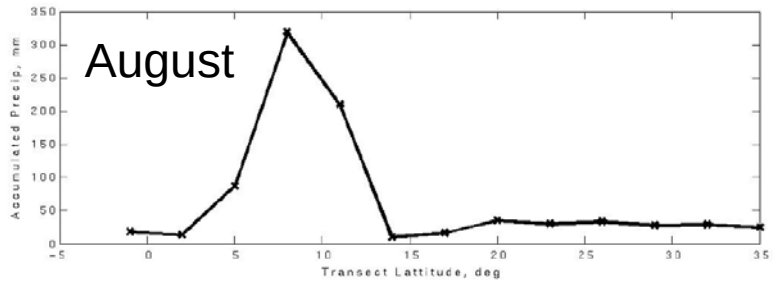


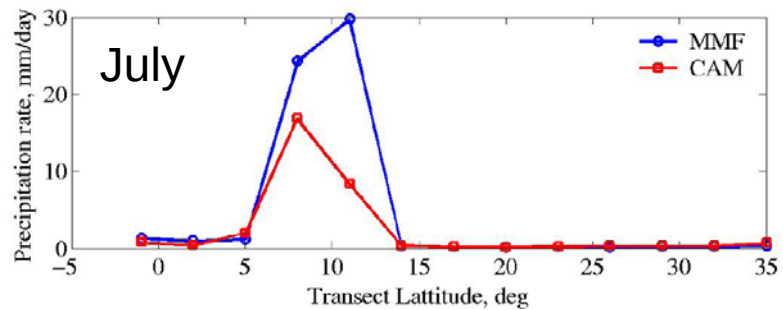


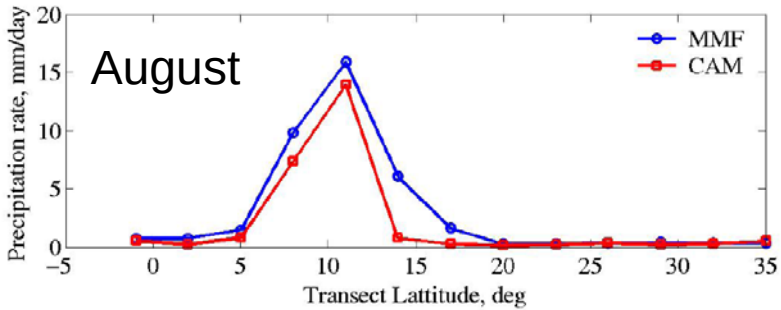
WRF: 10 mm/day CAM: 15 mm/day
MMF: 20 mm/day GPCP: 10 mm/day



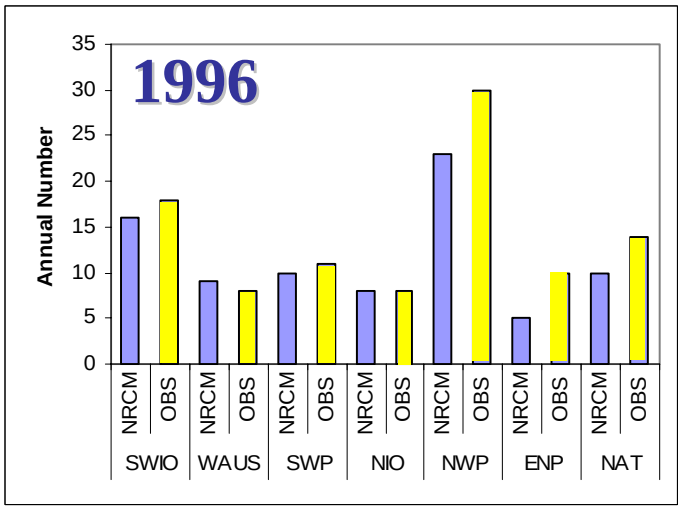


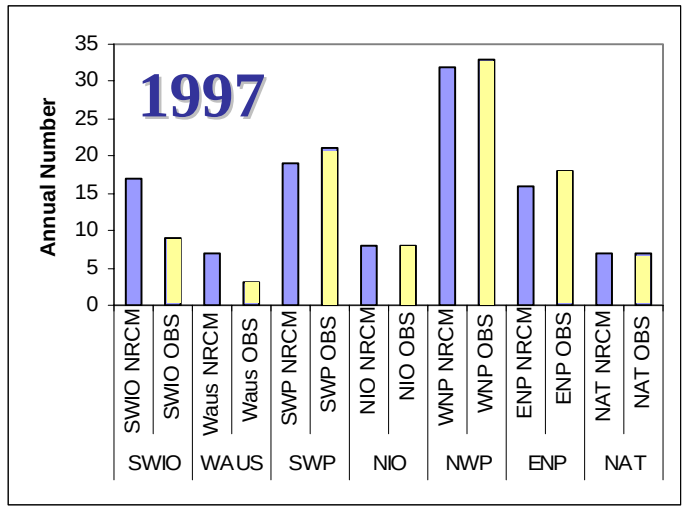


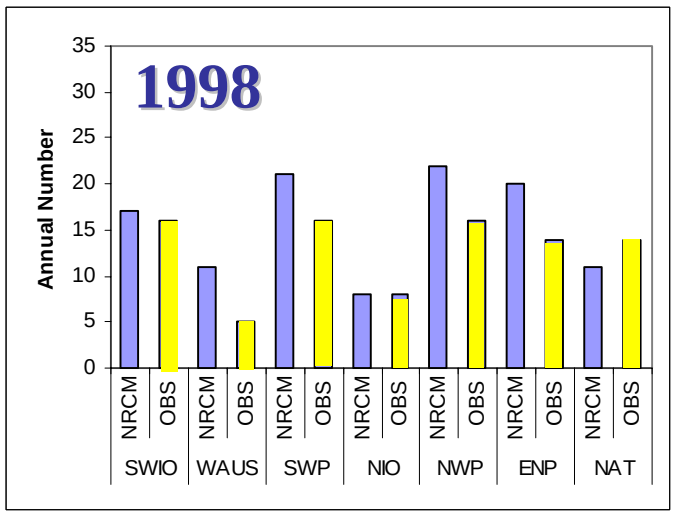




Annual Tropical Cyclone Statistics







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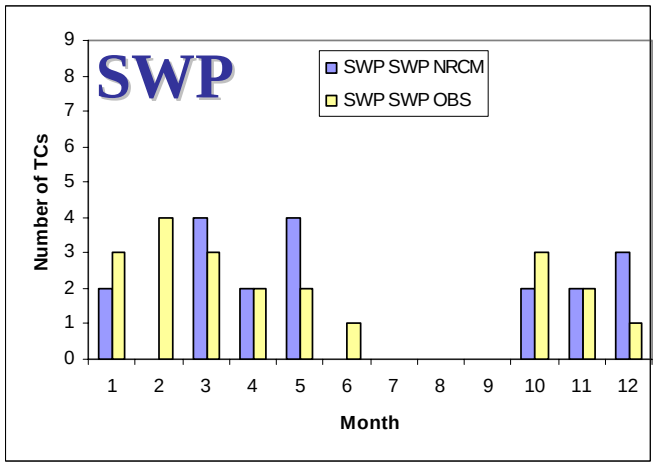
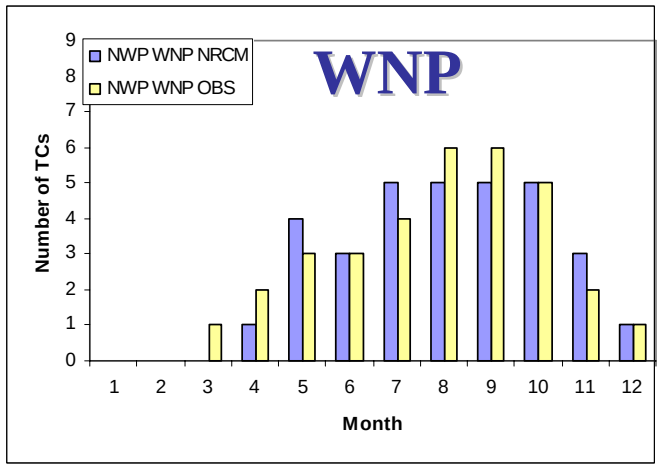
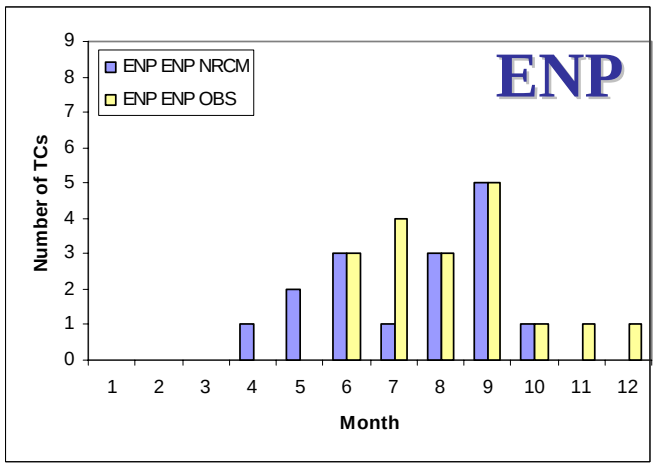
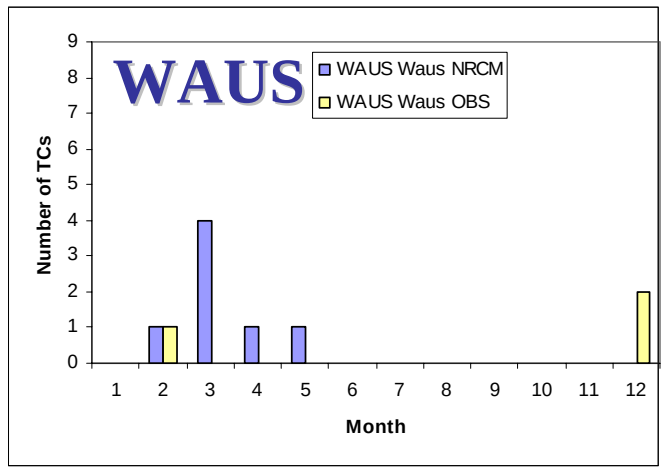
1997 Tropical Cyclone Statistics









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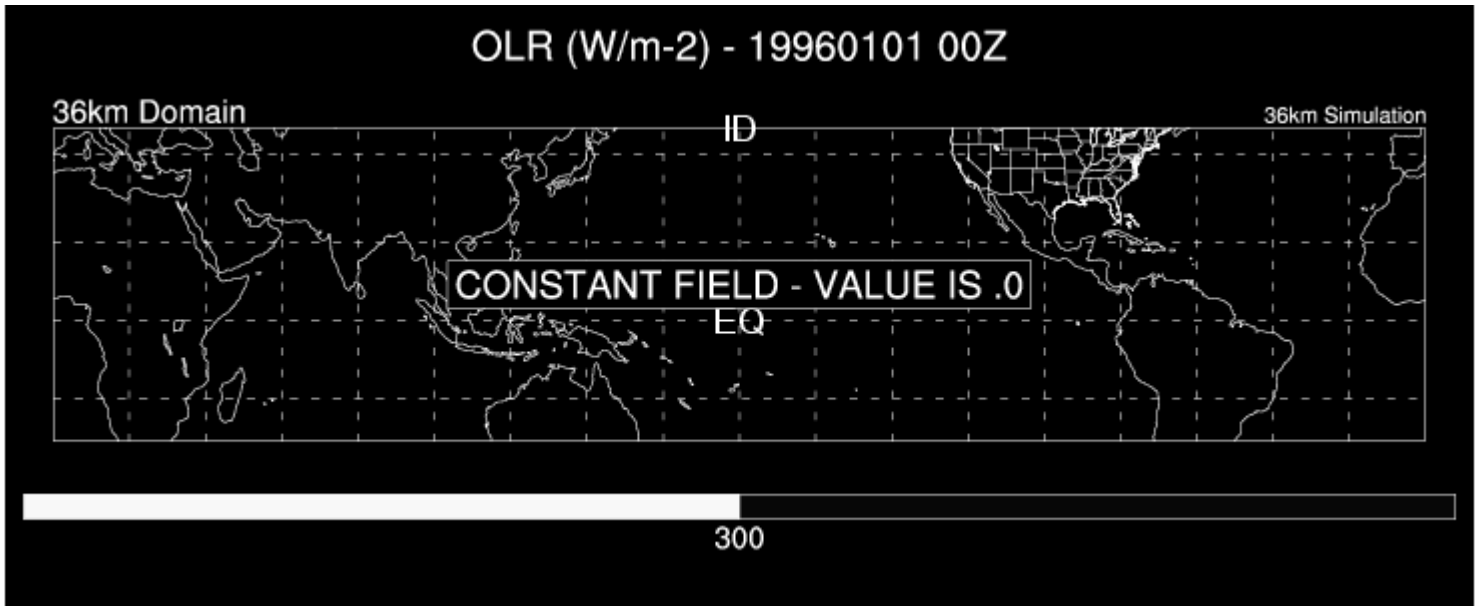
Summary

- The 36-km WRF tropical channel simulation reproduces large scale climatic features reasonably well
- Comparison of WRF, CAM, and MMF simulations over the EUROCS transect shows that WRF simulates more realistic structure of the ITCZ, but more extensive stratocumulus
- The WRF tropical cyclone statistics compare well with observations; this suggests the simulation may be a useful dataset for investigating cyclogenesis and its relationship to large scale circulation
- Future studies will investigate the upscaled effects of tropical convection by comparing the 36 km runs with and without nesting, analysis of tropical modes, and climatic features including the monsoon in different continents
- These simulations will be extended using the Columbia computing resources to provide a unique dataset for studying scale-interactions, tropical modes, and their influence on large scale and regional scale climate
- A two-way coupled CAM-WRF will be developed as an approach to incorporate upscaled effects to address CAM biases


OLR (W/m-2) - 19960101 00Z
36km Domain
ID
36km Simulation
CONSTANT FIELD - VALUE IS .0
EQ
300

Key Areas for Development

- **To Include regional earth system components**
- Ocean and sea ice
- Chemistry/aerosols/clouds
- Land surface and hydrology
- Biogeochemistry
- Address model development, evaluation, computational efficiency, model sensitivity

Key Areas for Development

- **Model numerics and physics for high-resolution applications**
- Evaluate long term cloud resolving simulations to understand limitations
- Develop physics parameterizations for cloud resolving simulations (e.g., microphysics, turbulence and shallow convection, terrain effects on PBL and radiation, urban effects)
- Balance complexity and computational efficiency

Key Areas for Development

- **Nesting RCMs within global models**
- Two-way coupling allows both downscaling and upscaling
- Basic assumption: such coupling is only important in certain regions such as the warm pool and monsoon regions
- Address model compatibility issues
- Maintain conservation in the host GCM

Key Areas for Development

- **Global WRF**

- A global WRF with nesting capability will ensure compatibility of the regional and global domains
- Examine alternative grid structures
- Ensure global conservation
- Must be able to produce realistic TOA and surface energy budgets and large scale circulation