Update from the NOAA MAPP Model Diagnostics Task Force (MDTF)

J David Neelin (UCLA)

- Task Force consists of collaborators on proposals funded by NOAA Climate Program Office MAPP program as a result of FY15 competition in the area of process oriented metrics
- Chair, Eric Maloney (Colorado State), co-leads Aiguo Dai (University at Albany), Andrew Gettelman (NCAR), and Yi Ming (GFDL).
- Program Manager Dan Barrie
- Type 1 Team grant: E. Maloney, A. Gettelman, Y. Ming, D. Neelin

MAPP
Modeling, Analysis, Predictions, and Projections

Model Diagnostics Task Force— Projects (*3 examples presented)

* **Development of a Framework for Process-Oriented Diagnosis of Global Models**
Eric Maloney (Colorado State University), Yi Ming (NOAA GFDL), Andrew Gettelman (NCAR), David Neelin (UCLA)

* **Evaluation of Warm Cloud Microphysical Processes in Global Climate Models with Multi-Sensor Satellite Observations** Kentaroh Suzuki (University of Tokyo), Jean-Christophe Golaz (NOAA GFDL), Huan Guo (NOAA GFDL), Peter Bogenschutz (NCAR)

Process Oriented Diagnostics of Tropical Cyclones in Climate Models Suzana Camargo (Columbia University), Adam Sobel (Columbia University), Daehyun Kim (U Washington), Anthony D. Del Genio (NASA GISS)

Metrics for general circulation model biases in extratropical cyclone clouds and precipitation: evaluating their skill and identifying processes to be improved James Booth (City University of New York, City College), Catherine Naud (Columbia University), Zhengzhao Luo (City University of New York, City College), Jean-Christophe Golaz (NOAA GFDL)

Development of process-oriented metrics for ENSO- induced teleconnection over North America and U.S. Affiliated Pacific Islands in Climate Models H. Annamalai (U Hawaii), Arun Kumar (NOAA CPC)

Process oriented metrics of land-surface-atmospheric interactions for diagnosing coupled model simulations of land surface hydro-meteorological extremes Justin Sheffield (Princeton University)

* **Process-oriented Diagnosis and Metrics Development for the Madden-Julian Oscillation Based on Climate Simulations** Xianan Jiang (UCLA); Eric Maloney (CSU), Ming Zhao (GFDL), Shian-Jiann Lin (GFDL)

Diurnal Metrics for Evaluating GFDL and Other Climate Models
Aiguo Dai (University at Albany), Jean-Christophe Golaz (NOAA GFDL), Junhong Wang (University at Albany), Ming Zhao (NOAA GFDL)

Evaluation and Diagnosis of the Atlantic Meridional Overturning Circulation 3D Structure in Climate Models Xiaobiao Xu (Florida State University), Eric Chassignet (Florida State University), Molly Baringer (NOAA AOML), Shenfu Dong (NOAA AOML)

MDTF diagnostics package

- "Process-oriented diagnostic" characterizes a physical process hypothesized to be related to the ability to simulate an observed phenomenon (Eyring et al. 2005, *BAMS*; Sperber & Waliser 2008, *BAMS;* Maloney et al. 2014, *J. Clim*.; Kim et al. 2014, *J. Clim*.)
- diagnostics to be repeatable in modeling center workflow, focused on model improvement

Applications Programming Interface

- python script:
  1. Set up paths, variable names,..
  2. Call diagnostics **contributed by various groups*** >plots
  3. Compose plots into a web page
- *open source, observational comparisons supplied; user can test a diagnostic to submit, contributed to library of diagnostics
- Currently being developed with NCAR, GFDL

API Set up by the Type 1 Team, PIs: Eric Maloney (CSU), Andrew Gettelman, Yi Ming (GFDL), David Neelin (UCLA); + Jack Chen (NCAR), Yi-Hung Kuo (UCLA) + others….

Implementation status of MDTF diagnostics in the software framework (as of 6/27/2017; at 1.9 y of 3y project):

Successfully implemented

- Overall framework—including feedback from initial implementations (Type 1 Team)
- * David Neelin (fast timescale diagnostics for tropical convection)
- * Kenta Suzuki (diagnosis of warm rain processes using MODIS and CloudSAT and particle size analysis)

Ready to be implemented

- * Xianan Jiang (Diagnostics on MJO amplitude and propagation [convective timescale and mean moisture distribution])
- * Eric Maloney (diagnostics on MJO tropical-extratropical teleconnections)
- Annamalai (vertical-integrated MSE budget diagnostics for ENSO)
- Aiguo Dai and Junghong Wang (Diurnal cycle, 2 meter temperature and surface energy budget diagnostics)
- Suzana Camargo et al (vertically-integrated MSE budget diagnostics for tropical cyclones)

Diagnostics Still in Development

- Jimmy Booth (precipitation partitioning and vertical velocity in extratropical cyclones)
- Alexis Berg and Justin Sheffield (diagnostics on land-atmosphere coupling)
- Xiaobiao Xu (Atlantic MOC and ocean mixing)

* Examples presented

Model Diagnostics Task Force Time-slice experiment

Time-slice experiment (GFDL and NCAR model versions):

- allows special output protocol for diagnostics
- intervals with high-frequency 3-D output, incl. 5-yr (2008-2012) with 6-hourly, 2-yr with hourly (2009-2010)
- moist static energy budget terms (GFDL model by Ming Zhao)

Also analyzed: MJO Task Force experiments

Most recent task force meeting in conjunction with Working Group on Numerical Experimentation workshop, Montréal, June 2017: talks included D. Neelin, J. Booth, A. Berg, H. Annamalai, D. Barrie, J. Wang, X. Xu, D. Kim, X. Jiang, E. Maloney, K. Suzuki, …

Examples from 3 groups here

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Evaluation of Warm Cloud Microphysical Processes in Global Climate Models with Multi-Sensor Satellite Observations

K. Suzuki (University of Tokyo), JC Golaz (GFDL), H. Guo (GFDL), P. Bogenschutz (NCAR)

Suzuki *et al*. (JAS 2015): biases in warm rain formation traced to microphysics process representations

Test with GFDL AM3 data

A new diagnostic tool has been implemented into the MDTF software.

The added codes include:

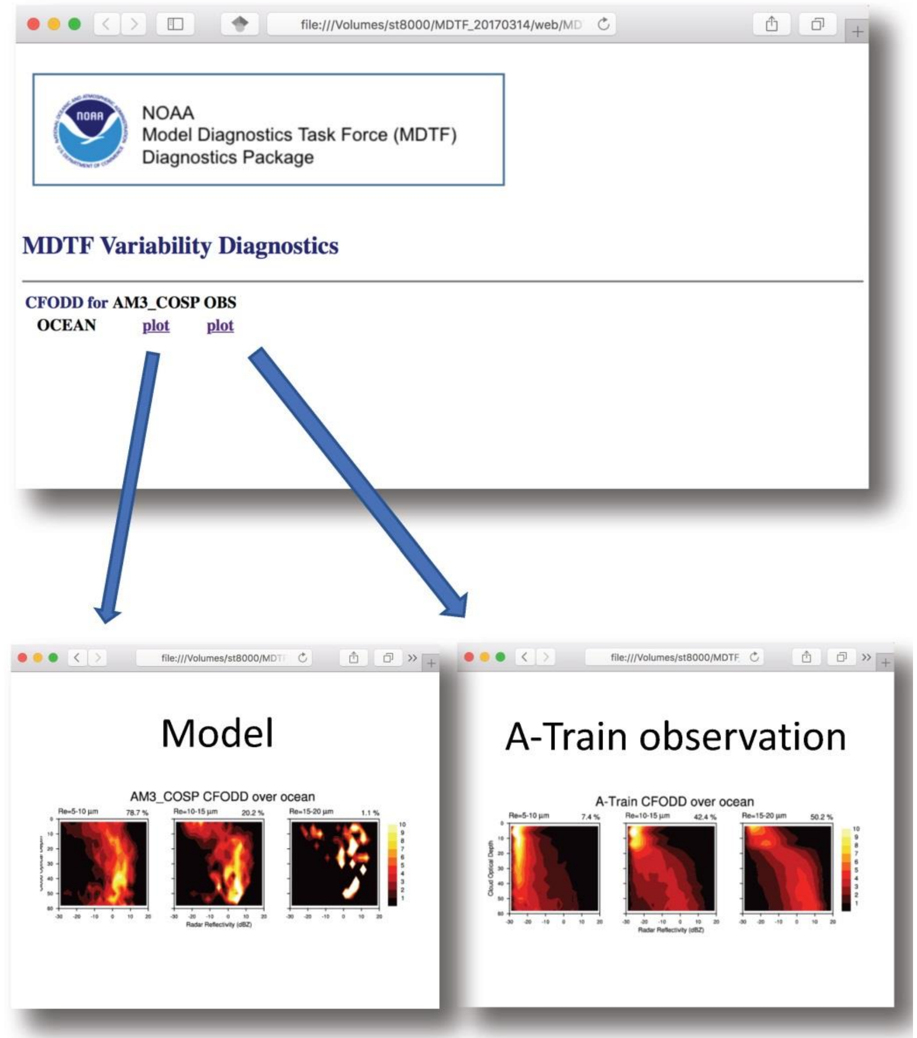
- **cfodd_plots.py**: interface to the main python code.
- **compute_cfodd.ncl**: NCL code to calculate CFODD for model output.
- **cfodd_plot.ncl**: NCL code to plot CFODD for model results.

Peculiar model output required:

1. sub-column radar reflectivity and cloud type (COSP)
2. cloud top temperature, cloud-top particle size and cloud optical depth at each model layer.

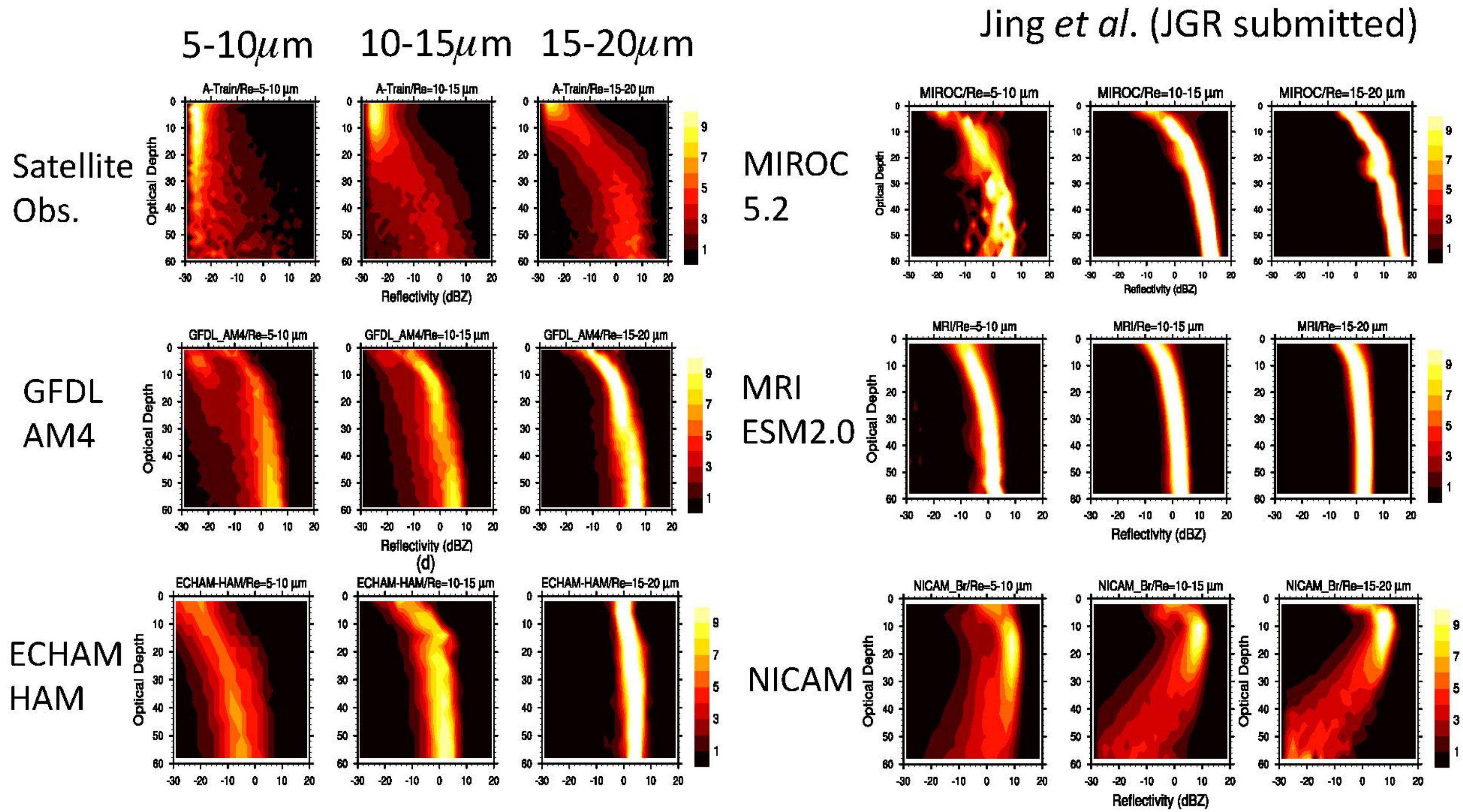
(at 6-hourly instantaneous for 3months)

(By Xianwen Jing)



Evaluation of Warm Cloud Microphysical Processes in Global Climate Models with Multi-Sensor Satellite Observations K. Suzuki (University of Tokyo), JC Golaz (GFDL), H. Guo (GFDL), P. Bogenschutz (NCAR)

Multi-model diagnostics for up-to-date models



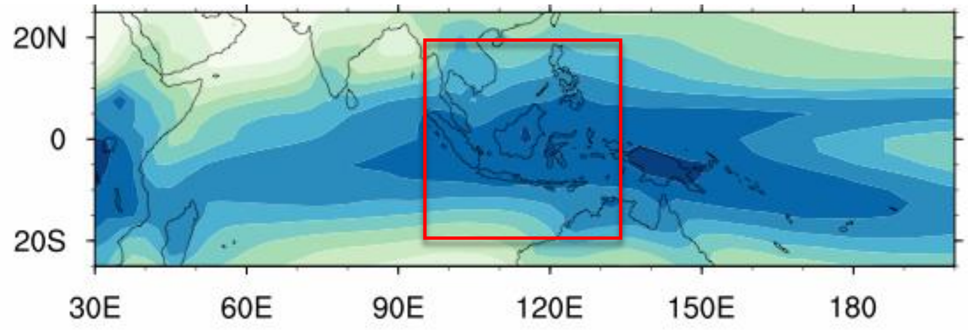
- Models share a common bias of “too-fast” rain formation
- The issue still remains in CMIP6 version of some models

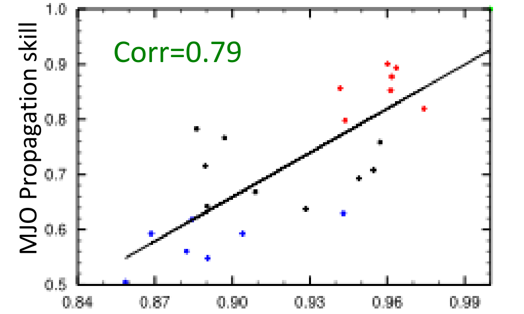
Process-oriented Diagnosis and Metrics Development for the Madden-Julian Oscillation…

Xianan Jiang (UCLA); Eric Maloney (CSU), Ming Zhao (GFDL), Shian-Jiann Lin (GFDL)

Model Winter MJO Eastward Propagation and Low-Level Mean Moisture over the Maritime Continent

Winter mean 650-900hPa moisture

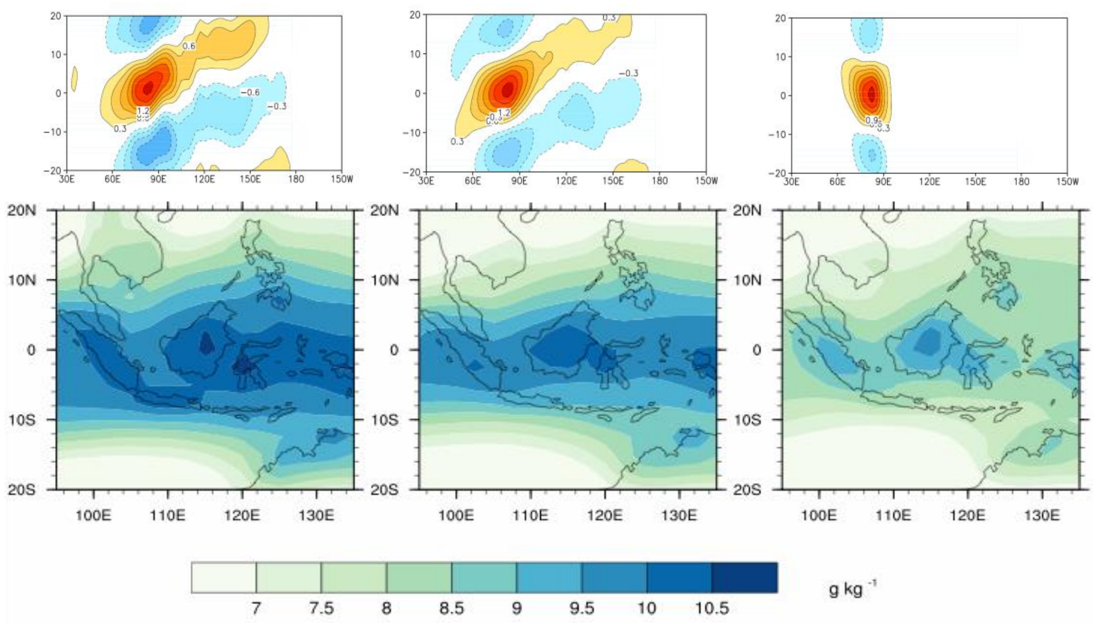




OBS

Good MJO models

Poor MJO models

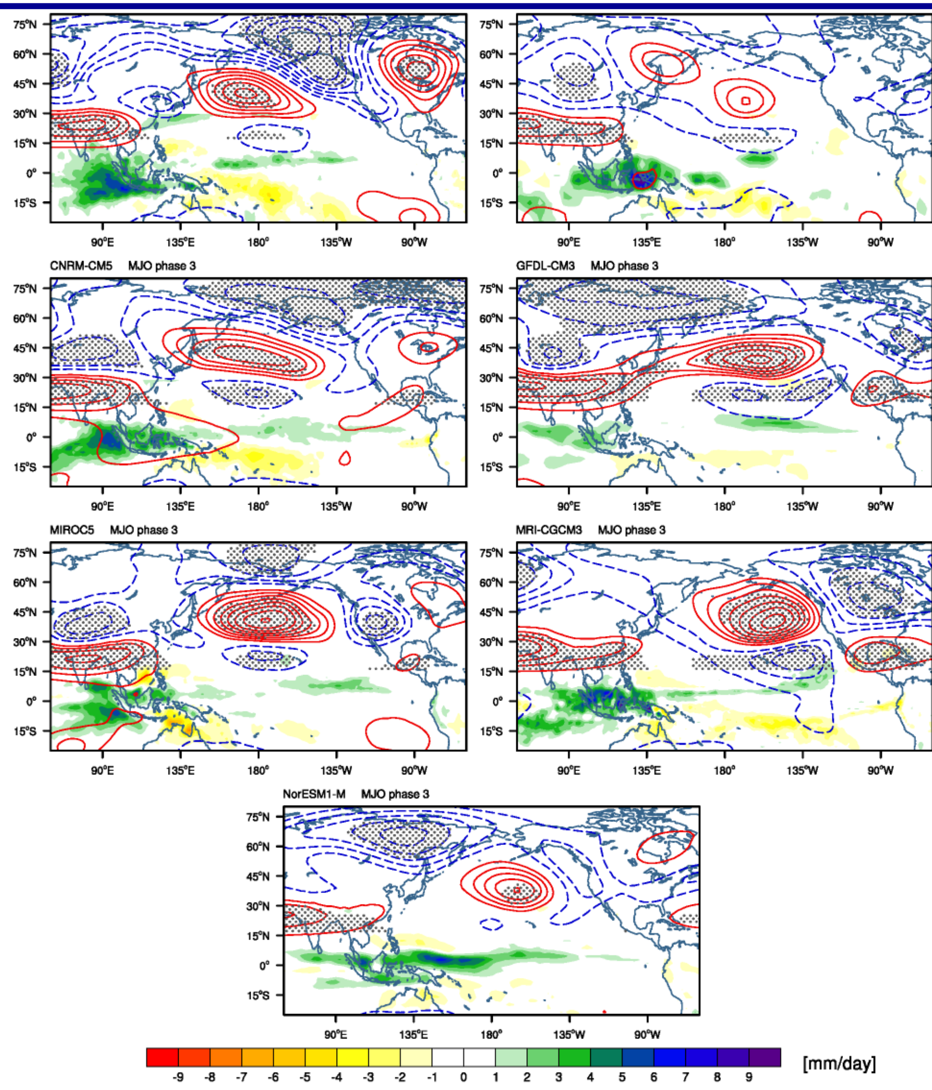


Gonzalez & Jiang 2017

Jiang 2017;
see also Jiang et al. 2015; Maloney et al. 2014; Kim et al. 2014

*also connects with MJO task force & with analysis below

Diagnostics for MJO Teleconnections



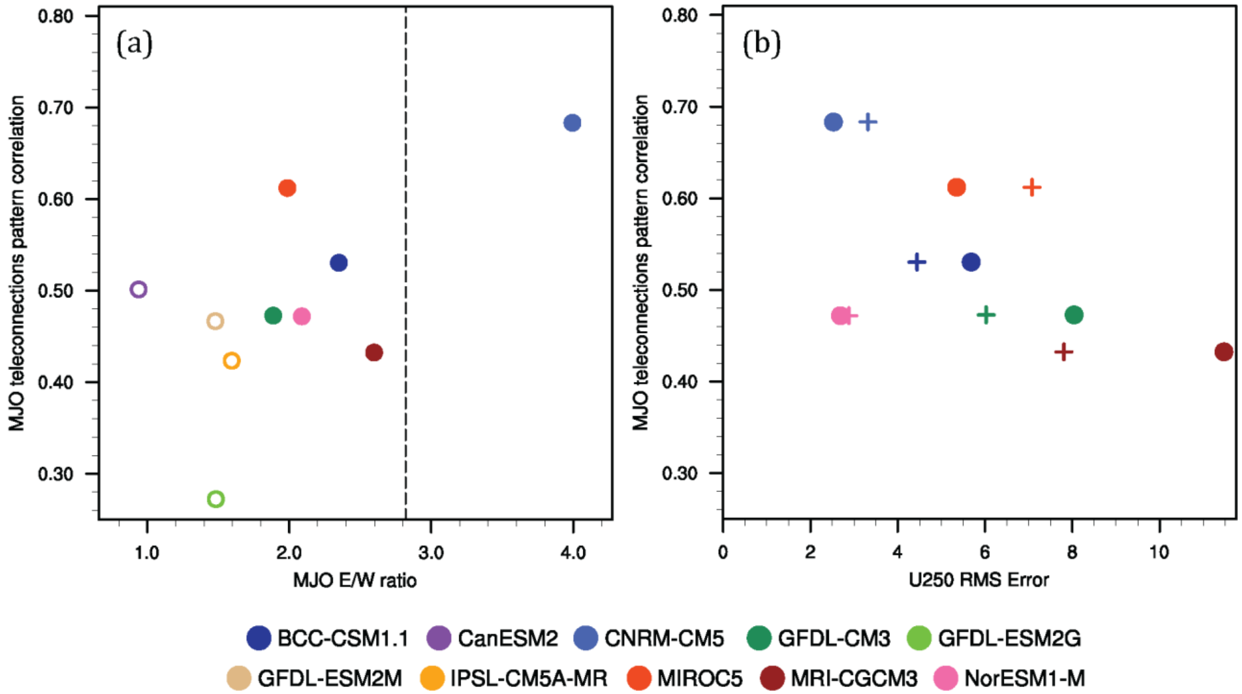
- 250hPa geopotential height and precip. anomalies for six CMIP5 models assessed to have "good" MJOs through various metrics vs. MJO phase 3 reanalysis
- As can be seen, ability to simulate a "good" MJO does not necessarily correspond to a good teleconnection
- Why is this?

Henderson et al. (2017)

Process-oriented Diagnosis and Metrics Development for the Madden-Julian Oscillation…

Xianan Jiang (UCLA); Eric Maloney (CSU), Ming Zhao (GFDL), Shian-Jiann Lin (GFDL)

Diagnostics for MJO Teleconnections



Henderson et al. (2017)

- **Left:** Model pattern correlation with reanalysis Z250 anomalies in Pacific and N. American region: 15N - 80N, 130E – 60W versus MJO E/W wavenumber-frequency precip. ratio across all phases.
  Good MJO models do not necessarily produce good teleconnections, consistent with previous plot, although a positive correlation of 0.61.
- **Right:** Same pattern correlation versus RMS error in longitude span of Pacific jet over the Pacific domain: 15°N – 60°N, 110°E – 120°W (filled circles) for the good MJO models. *r*=-0.64.
  Model teleconnection performance relates to ability to simulate zonal extent of the jet

Xianan Jiang (UCLA); Eric Maloney (CSU), Ming Zhao (GFDL), Shian-Jiann Lin (GFDL)

Weak temperature gradient moistening diagnostics for MJO performance

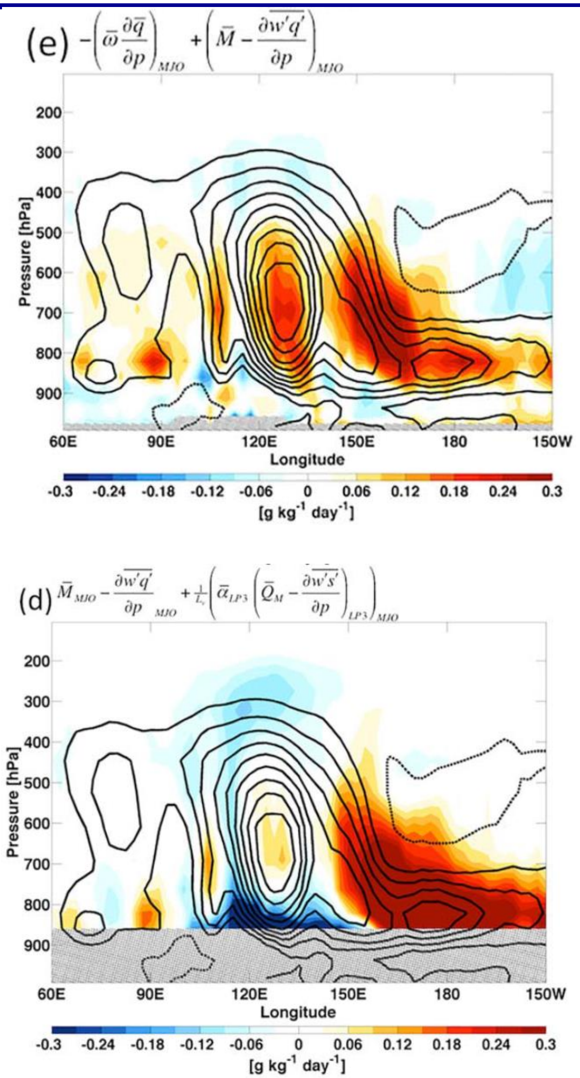
Using WTG balance, $\omega \frac{\partial s}{\partial p} = Q$

vertical advective moistening by a diabatic heating anomaly can be diagnosed as:

$$Moistening = -Q\left(\frac{\partial s}{\partial p}\right)^{-1} \cdot \frac{\partial Lq}{\partial p} = \alpha Q$$

e.g of use: **top panel** total moistening anomaly due to convection for a composite MJO event in the SP-CCSM;
bottom panel same, but with the moistening due to the radiative heating anomaly under WTG *removed*. Contours show specific humidity anomalies.

This example shows the essential role of radiative feedbacks for destabilizing the MJO, and can be compared to observational estimates.



Wolding et al. (2017)

Development of a Framework for Process-Oriented Diagnosis of Global Models

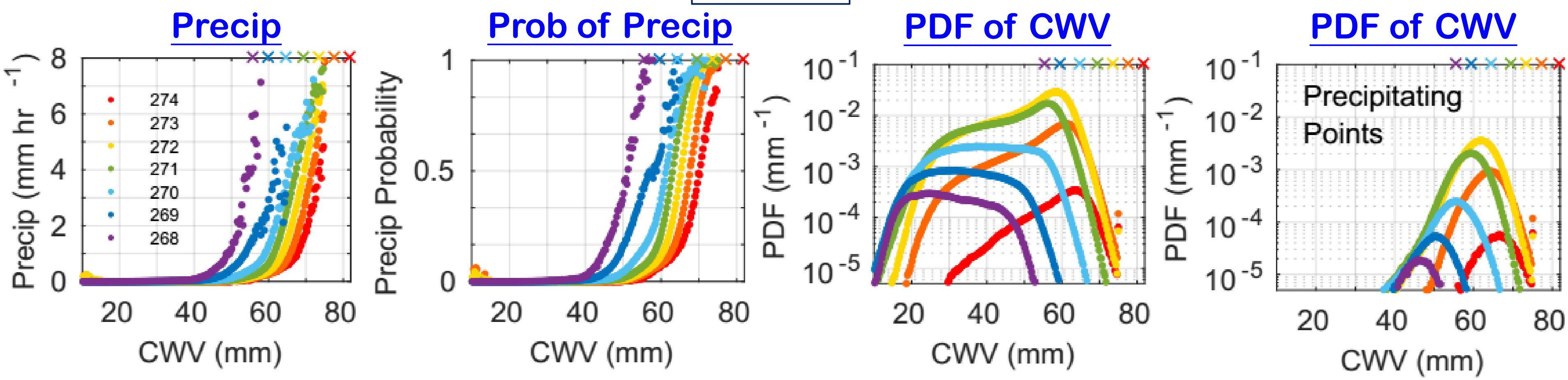
Eric Maloney (CSU), Yi Ming (GFDL), Andrew Gettelman (NCAR), David Neelin (UCLA);
Yi-Hung Kuo (UCLA); Kathleen Schiro (UCLA)

Convective Transition Statistics

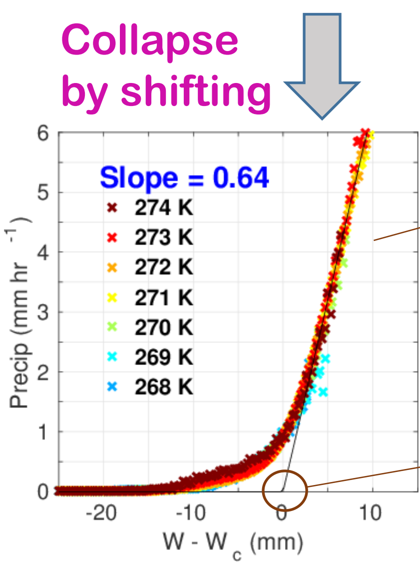
RSS TMIv7 CWV & Precip (0.25° snapshot)
20°S-20°N 2002/6-2014/5
NCEP-DOE Reanalysis-2 Temperature (2° 6-hourly)
T: 1000-200 mb mass-weighted column average temperature

Condensing stats for Precip(CWV,*T*)

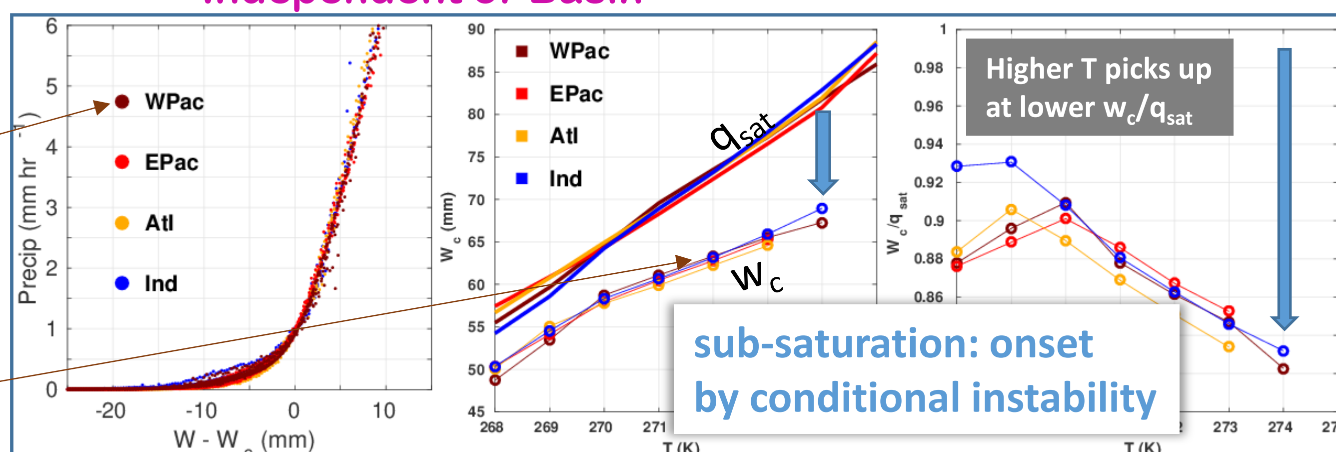
W. Pacific



Collapse by shifting



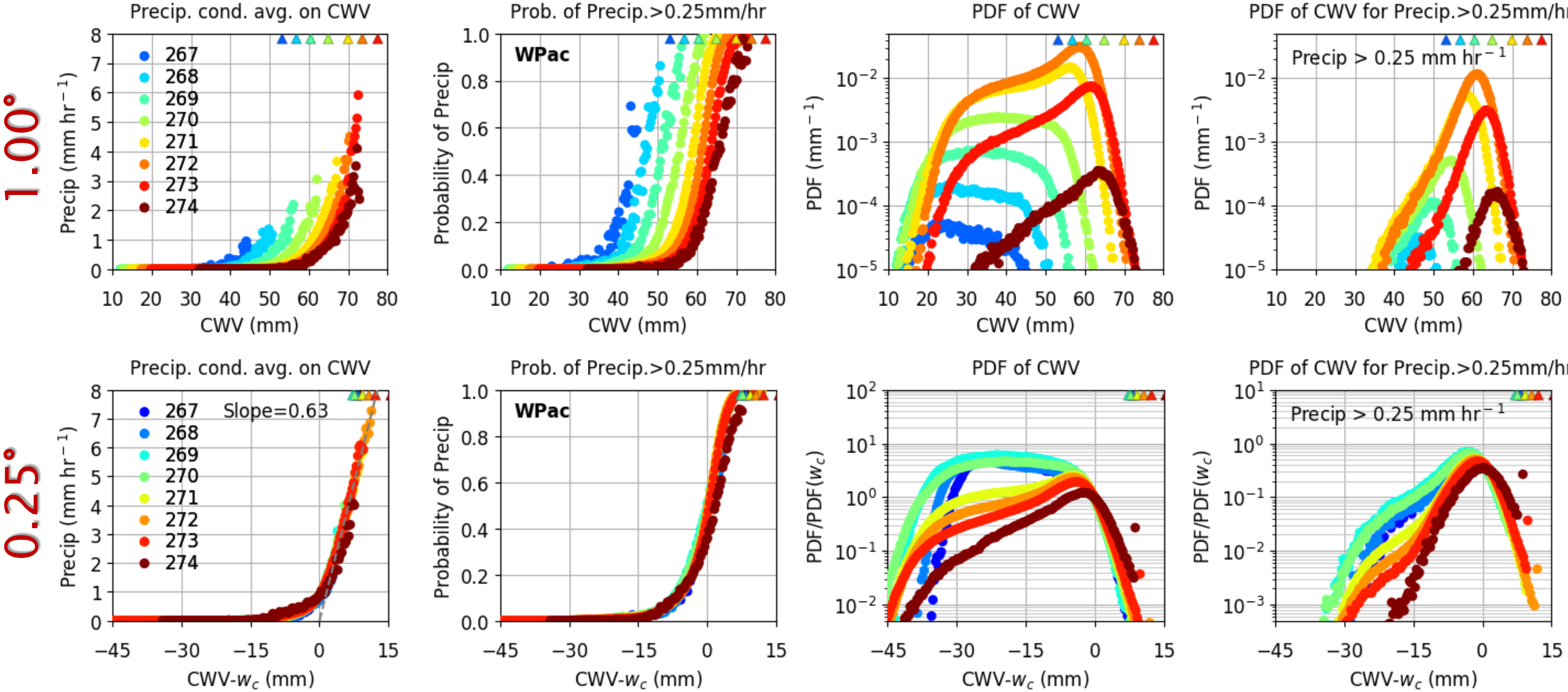
Independent of Basin



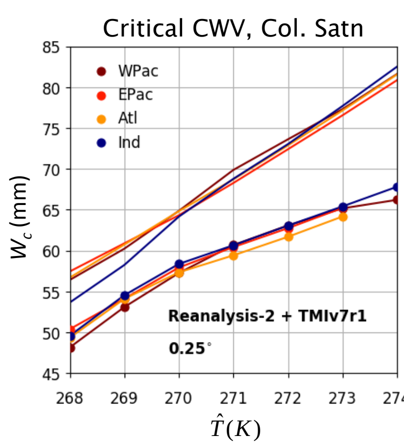
Kuo et al., in prep.

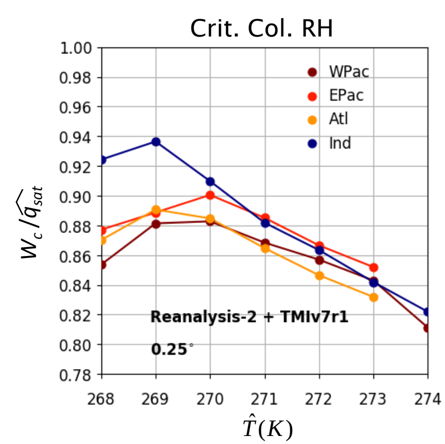
Convective Transition Statistics

UCLA contribution* to Type 1 team



Observations (TMIv7r1 CWV & Precip; Reanalysis-2 Temp.) **dependence on column water vapor** (orig. & collapsed)

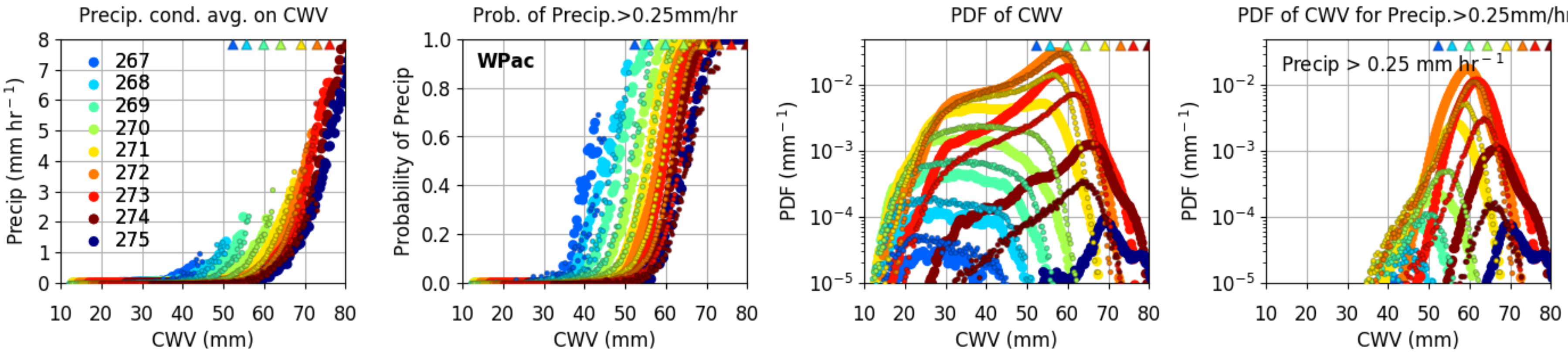




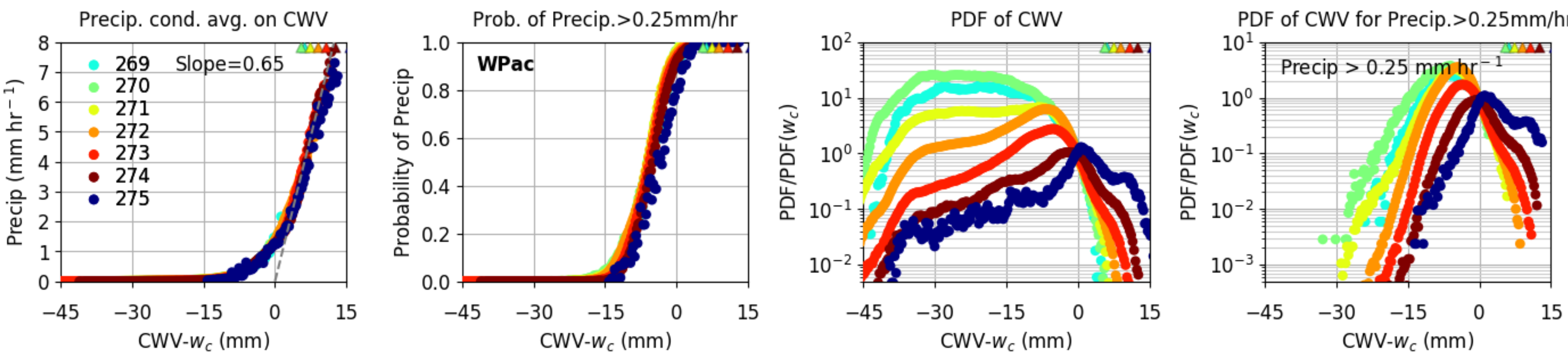
Critical CWV, Col. Satn, & Critical Col. RH

* Yi-Hung Kuo, K. Schiro, ... 2017a, in prep.

Convective transition: Basic statistics

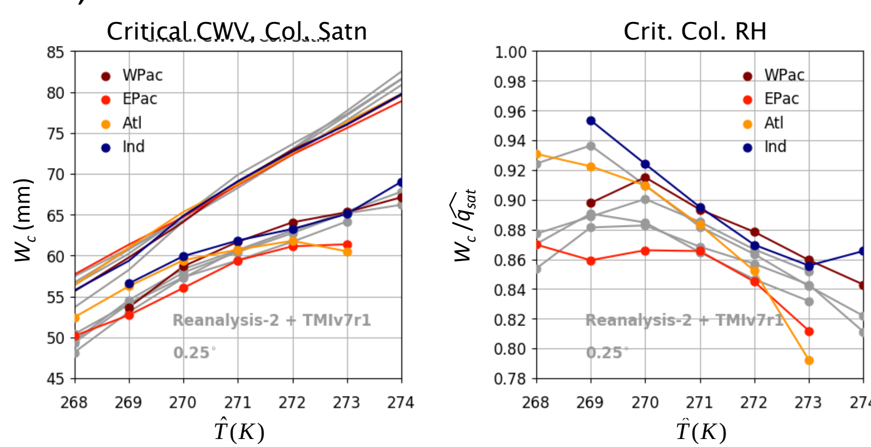


Convective transition: Collapsed statistics



Critical CWV, Column saturation & Critical column relative humidity

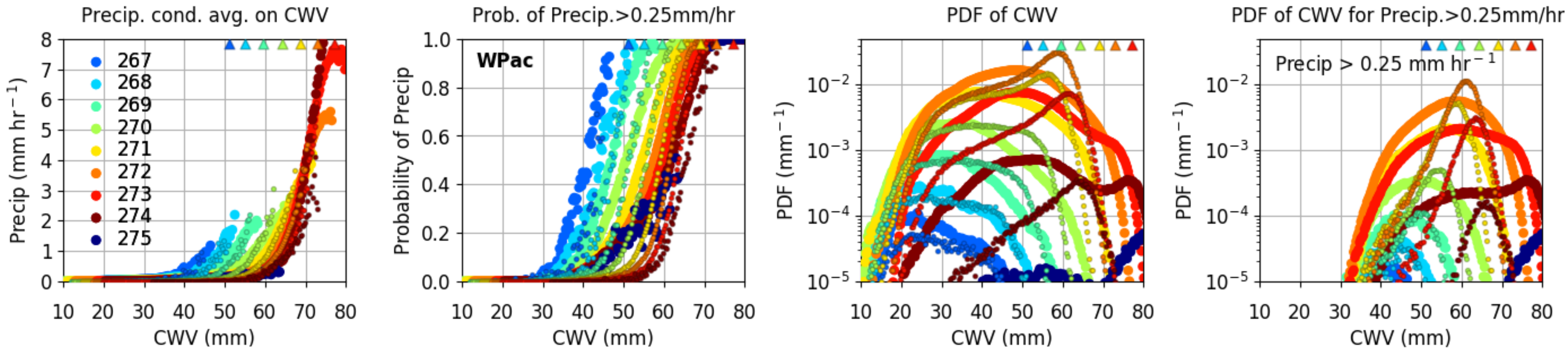
MDTF Timeslice Exp. Hourly,1° GFDL AM4 2-plume



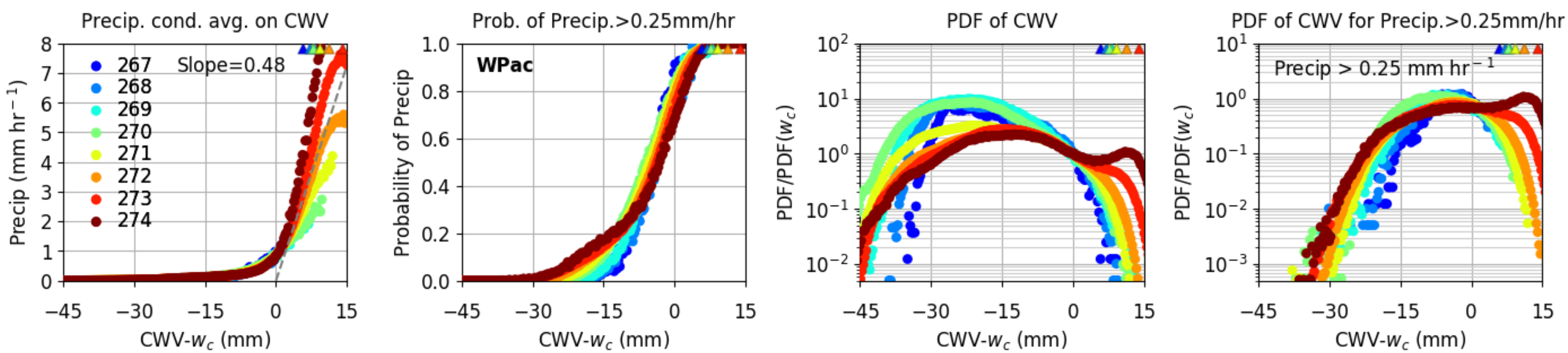
Quant. match with obs; higher PDF for high CWV & T

Kuo et al., 2017b, in prep.

Convective transition: Basic statistics

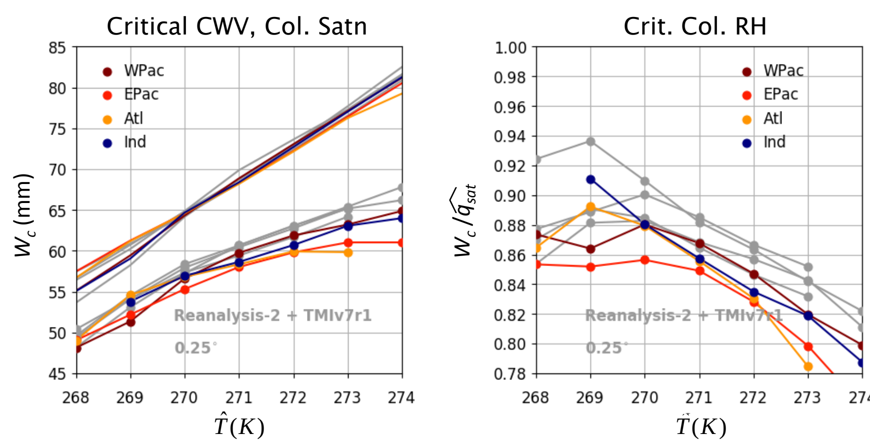


Convective transition: Collapsed statistics



Critical CWV, Column saturation & Critical column relative humidity

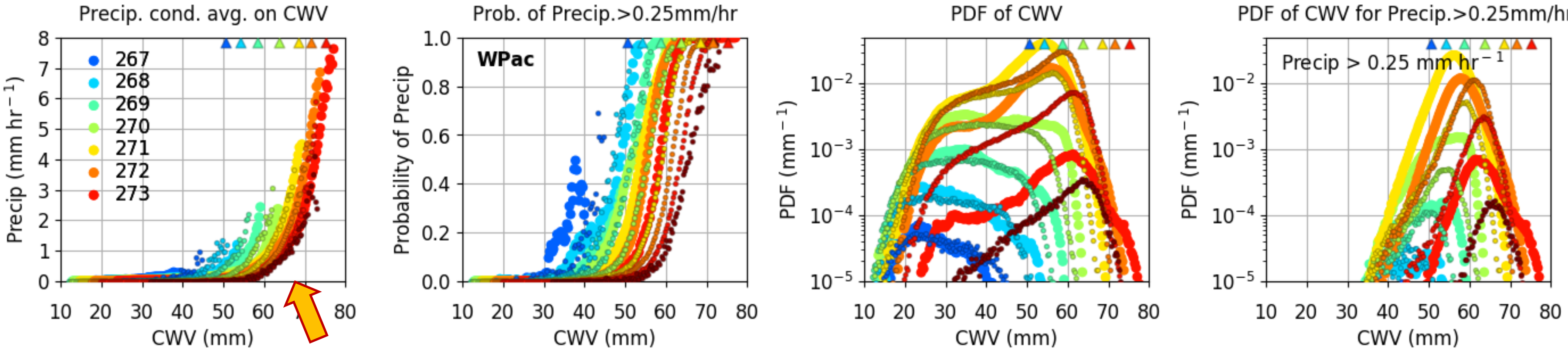
MDTF Timeslice Exp. Hourly,1° GFDL AM4 Donner



Pickup good; but PDFs too wide

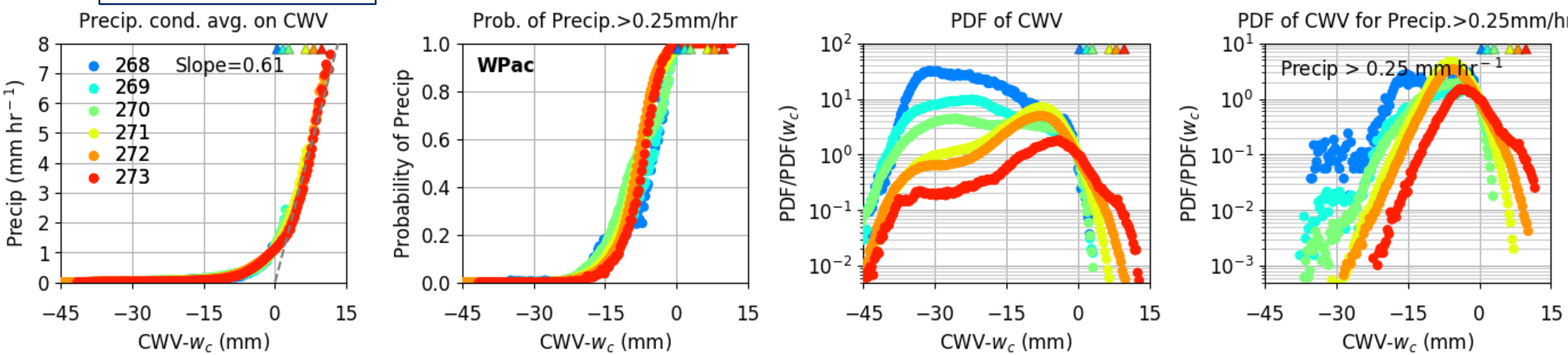
Kuo et al., 2017b, in prep.

Convective transition: Basic statistics



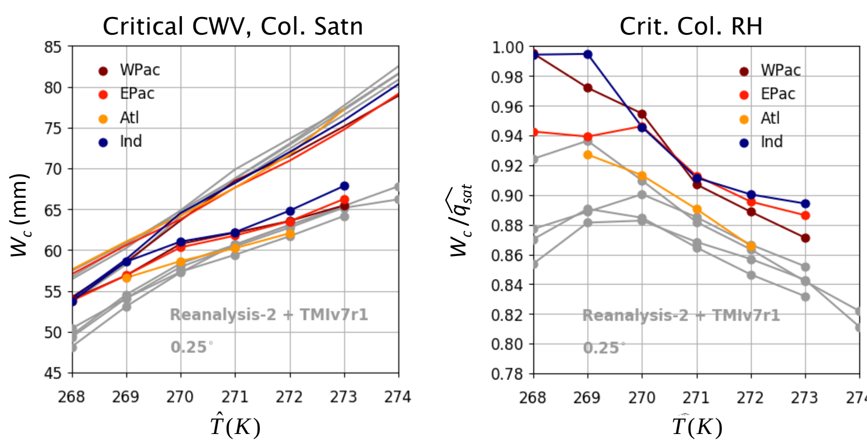
Small dots: obs

Convective transition: Collapsed statistics



Critical CWV, Column saturation & Critical column relative humidity

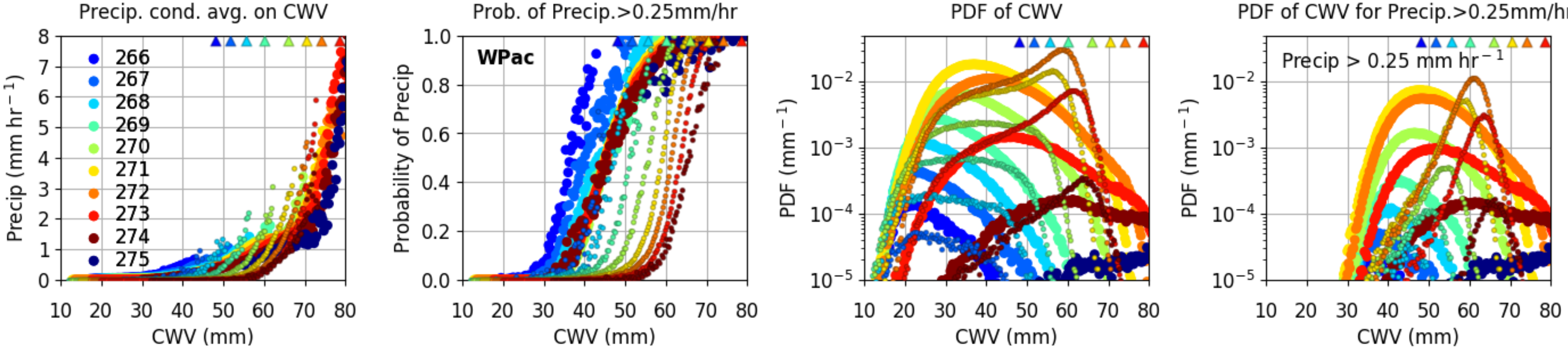
MDTF Timeslice Exp. Hourly,1° NCAR CAM5.3



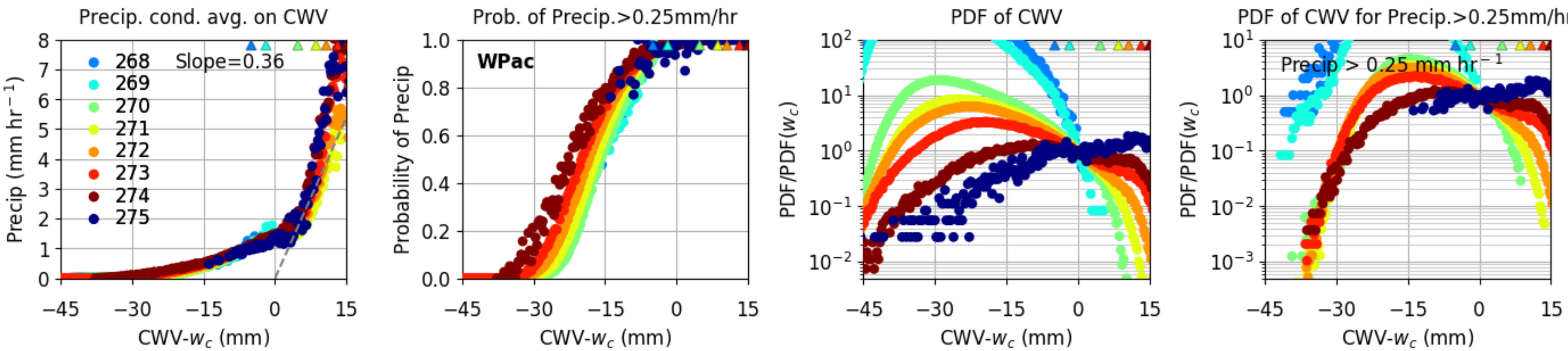
Pickup good, slightly high critical CWV; good PDFs

Kuo et al., 2017b, in prep.

Convective transition: Basic statistics

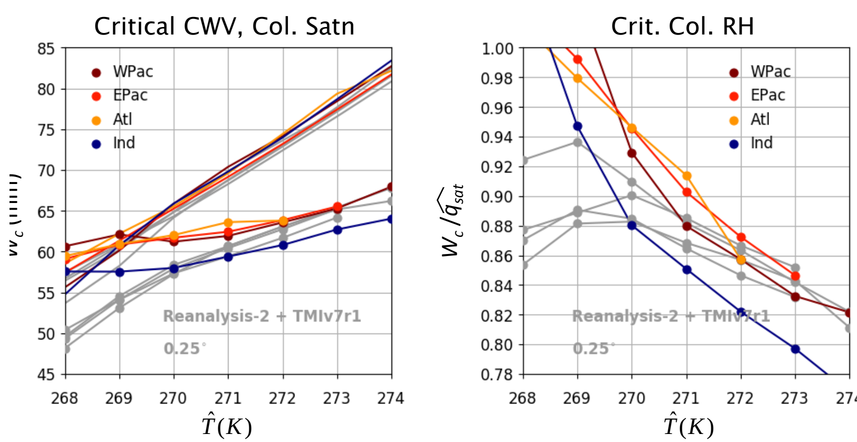


Convective transition: Collapsed statistics



Critical CWV, Column saturation & Critical column relative humidity

Compare to MJOTF runs –2 examples (6-Hourly,2.5°) CWB Taiwan GFS

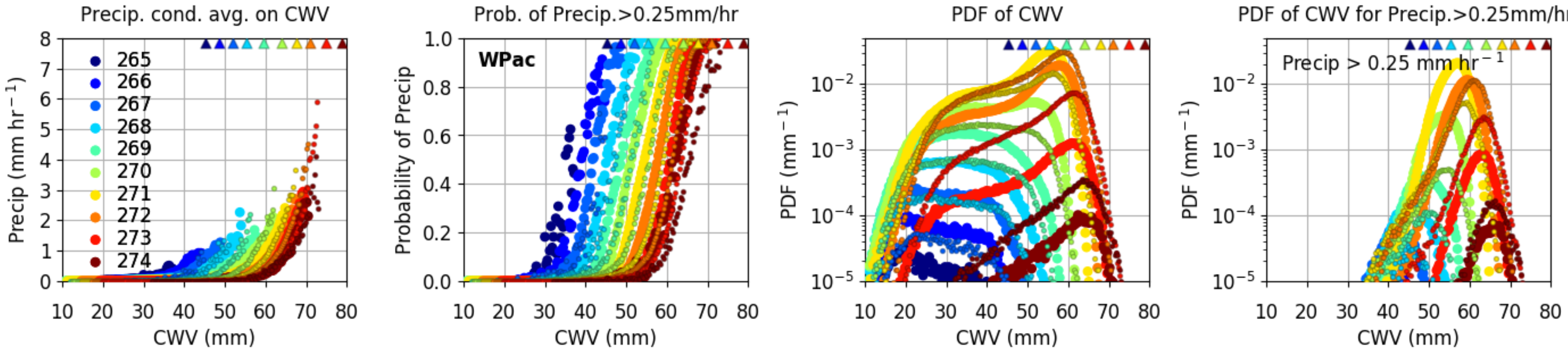


Bad: 2-step pickup pb.; poor PDFs & PDFs$|_{P>.25}$

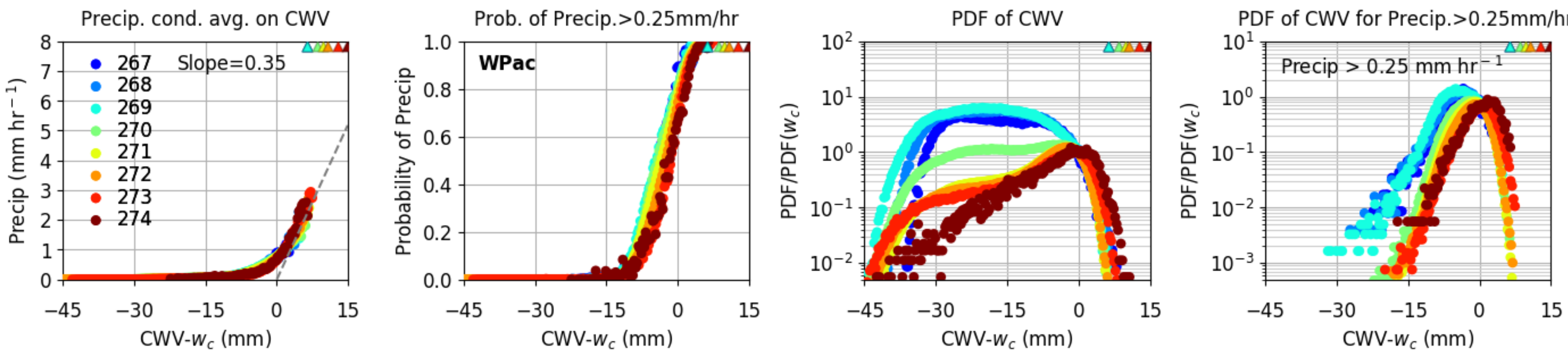
Bad MJO (Gonzalez & Jiang 2017)

Kuo et al., 2017b, in prep.

Convective transition: Basic statistics

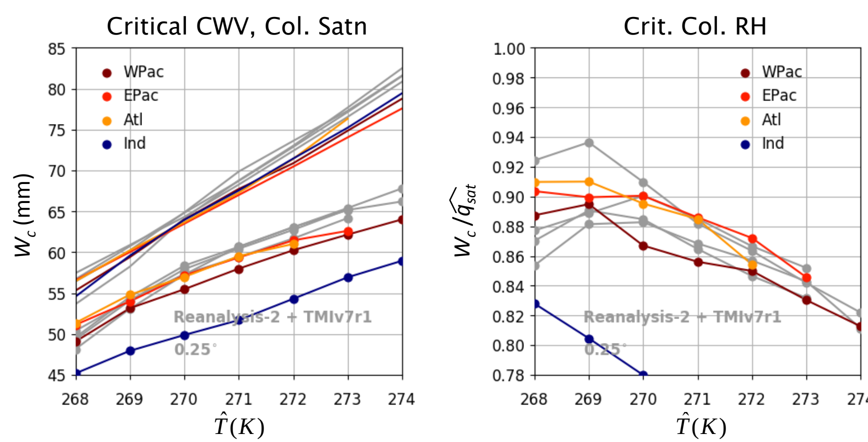


Convective transition: Collapsed statistics



Critical CWV, Column saturation & Critical column relative humidity

MJOTF
6-Hourly,2.5°
EC-Earth



Pickup good; good PDFs & PDFs|$_{P>.25}$

Good MJO (Gonzalez & Jiang 2017)

Kuo et al., 2017b, in prep.

Task Force Vision for 2018

- Have a finalized software framework to efficiently incorporate diagnostics into GFDL and NCAR diagnostics packages
- Incorporation of diagnostics from the 9 diagnostic development teams funded under the NOAA MAPP program into these evaluation packages
- Expansion to other U.S. and international models, aided by the highly adaptable nature of framework
- Documentation of our effort in both detailed papers on individual diagnostics, and an overview study outlining the optimal path forward for collaborations among modeling centers and the outside community to aid model development in an ***AMS journal special collection***