The Impacts of Convection-Permitting Resolution on Tropical Convection and Extended Global Prediction Skill: Preliminary Results with MPAS

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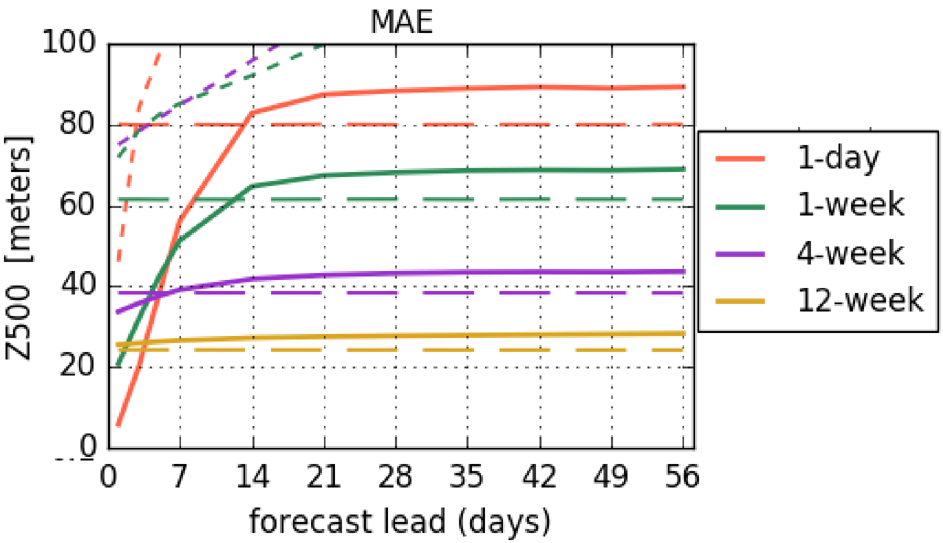
September 6, 2018
2nd GEWEX Convection-Permitting Climate Modeling Workshop
Boulder, CO

Motivation

- Subseasonal predictive skill is limited to just the first 2-4 weeks (depending on the time scale)[1-4]
- Tropical convection, an important driver of extratropical circulation, is poorly simulated in global models[4-8]
- Convection-permitting resolution can improve many aspects of tropical convection, and thus might also increase global subseasonal predictive skill[9-17]



[1]Kumar et al. 2011; [2]Yuan et al. 2011; [3]Li and Robertson 2015; [4]Weber and Mass 2017; [5]Lin 2007, [6]Silva et al. 2014; [7]Gonzalez and Jiang 2017; [8]Kim 2017; [9]Holloway et al. 2012; [10]Inoue et al. 2008; [11]Sato et al. 2009; [12]Davis et al. 2003; [13]Miura et al. 2007; [14]Miyakawa et al. 2014; [15]Wang et al. 2015; [16]Pilon et al. 2016; [17]Prein et al. 2015

Questions for today:

By going to convection-permitting resolution can we…

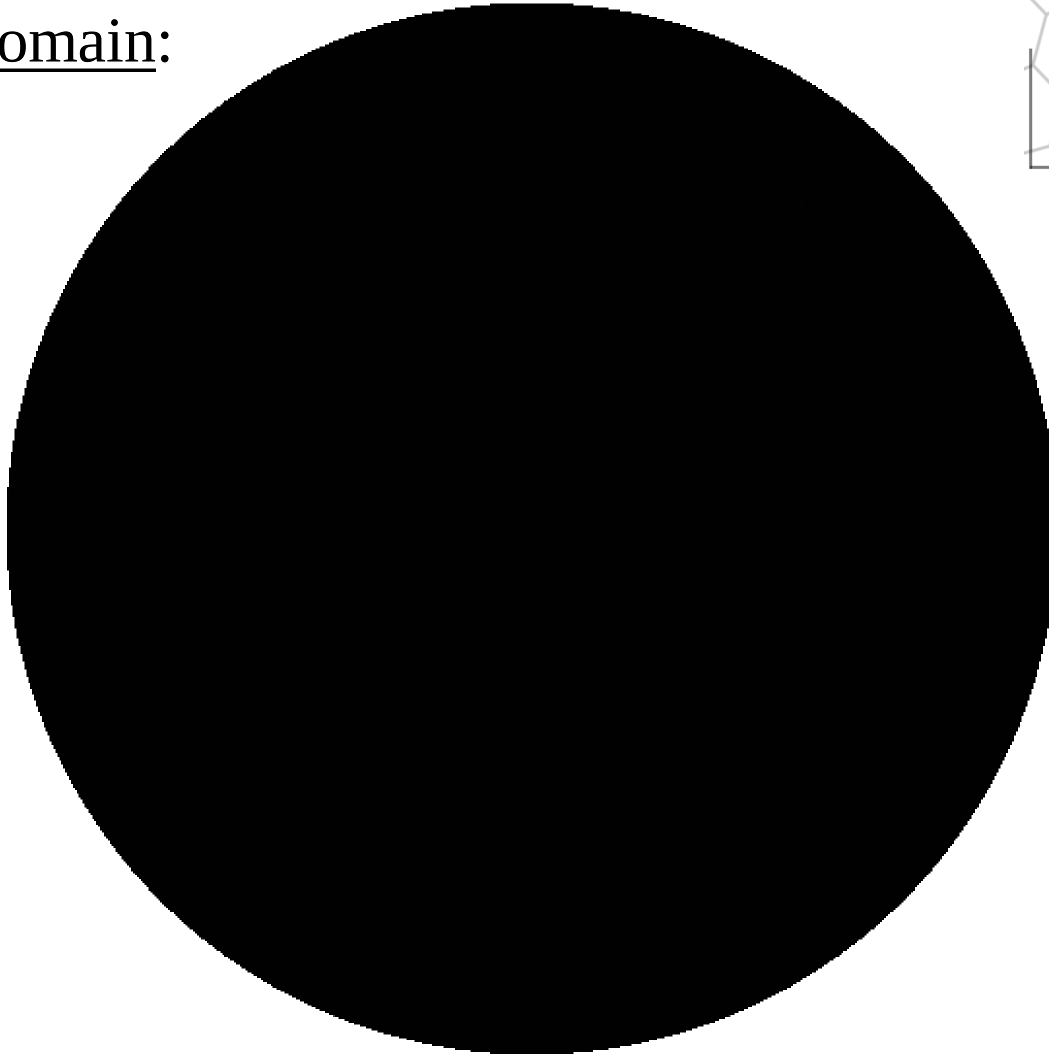
1. Improve the tropical “mean state”?

2. Better predict large-scale convective phenomena (i.e., the MJO)?

3. Increase subseasonal extratropical forecast skill?

Our tool: MPAS

- Version: MPAS v5.1 – “out of the box”
- Domain:



MPAS
Model for Prediction Across Scales

- Resolution:
  120-km
  65+ million cells
- Integration length:
  28 days
- Physics:
  ‘convection_permitting’ suite – ***no*** Cu scheme

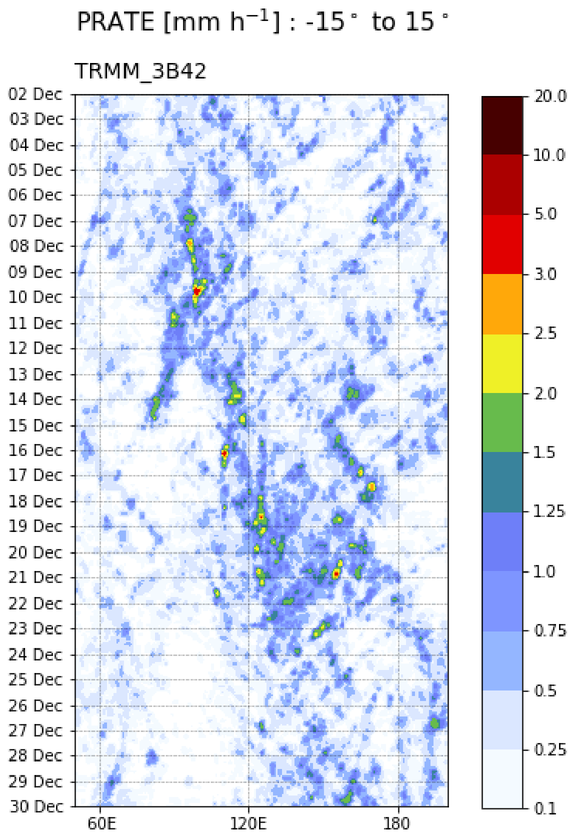
Computer resources per run

- Supercomputer: Cheyenne (5.34 petaflops)
- Run on 512 nodes → 18,432 cores
- Core hours: 2.7 million
- Output: ~80TB

Three case studies

All feature strong MJO events that propagate through the Maritime Continent:

1. Init: November 22, 2011
   – DYNAMO MJO-2 case
2. Init: February 8, 2013
   – MJO associated with strong extratropical pattern[1]
3. Init: December 2, 2003

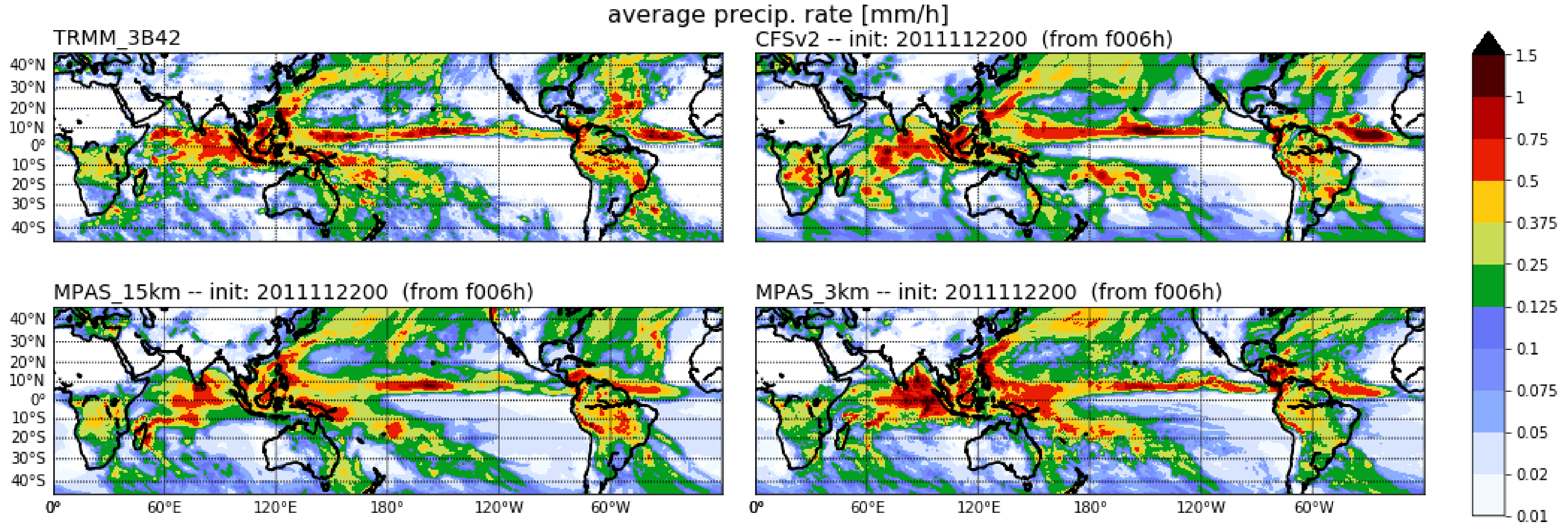


- 15-km counterparts with nTiedtke cumulus scheme
- FNL analyses for ICs and BCs (***SSTs <u>fixed</u> at initial value)***

[1]Vitart and Robinson 2018

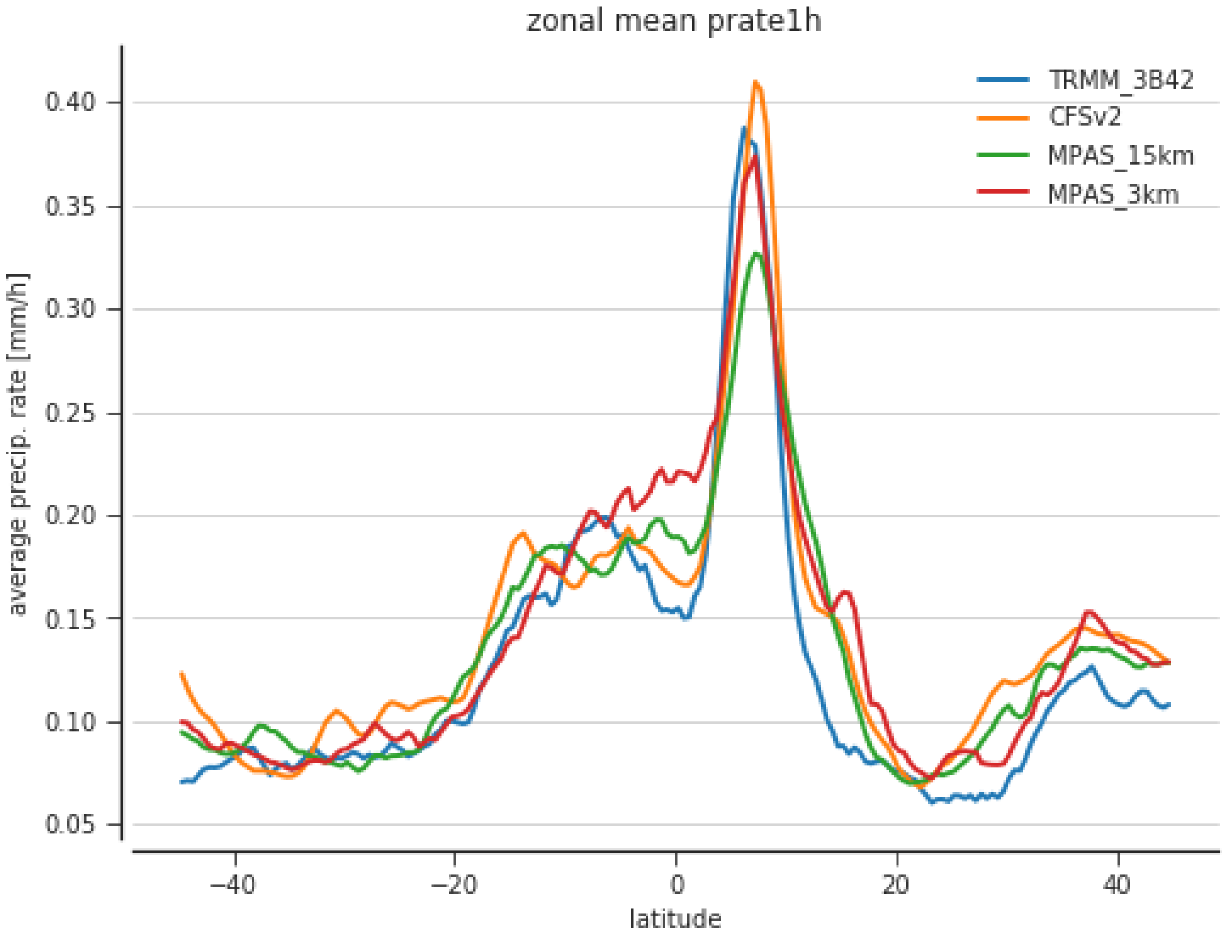
1. Tropical “mean state”: total precipitation

Case 1



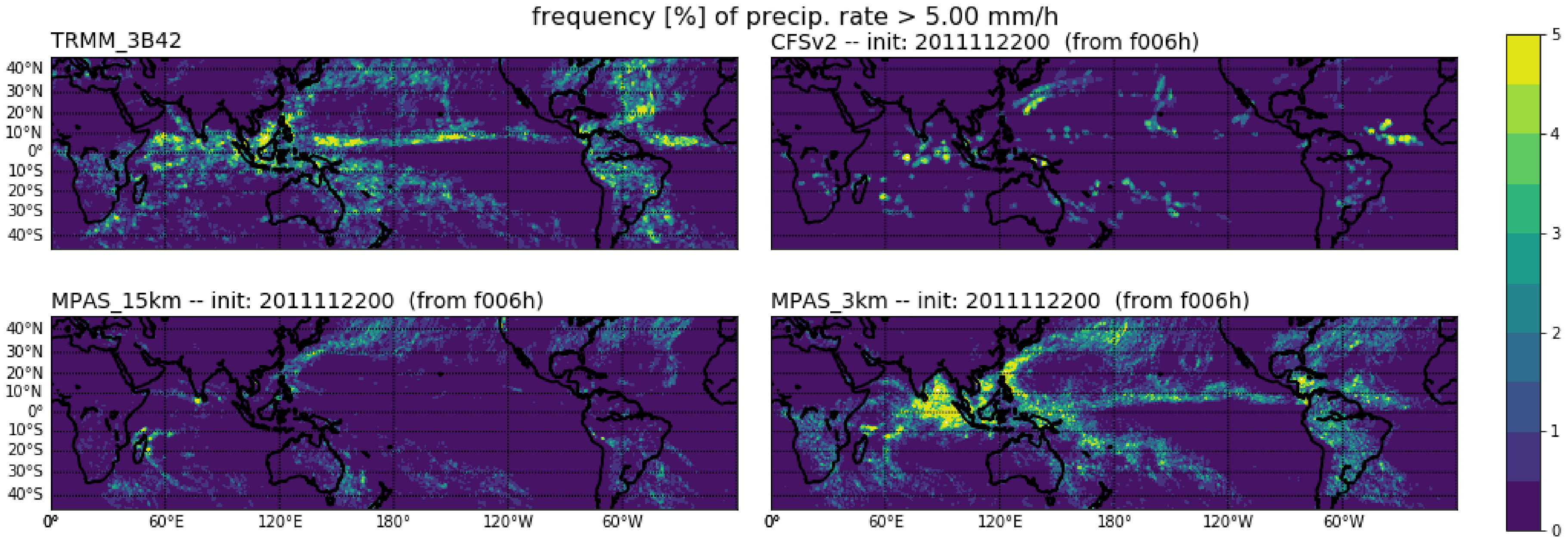
1. Tropical "mean state": total precipitation

- Too much tropical precipitation in 3-km run
- ~10% too much precip.
- Similar for all three cases



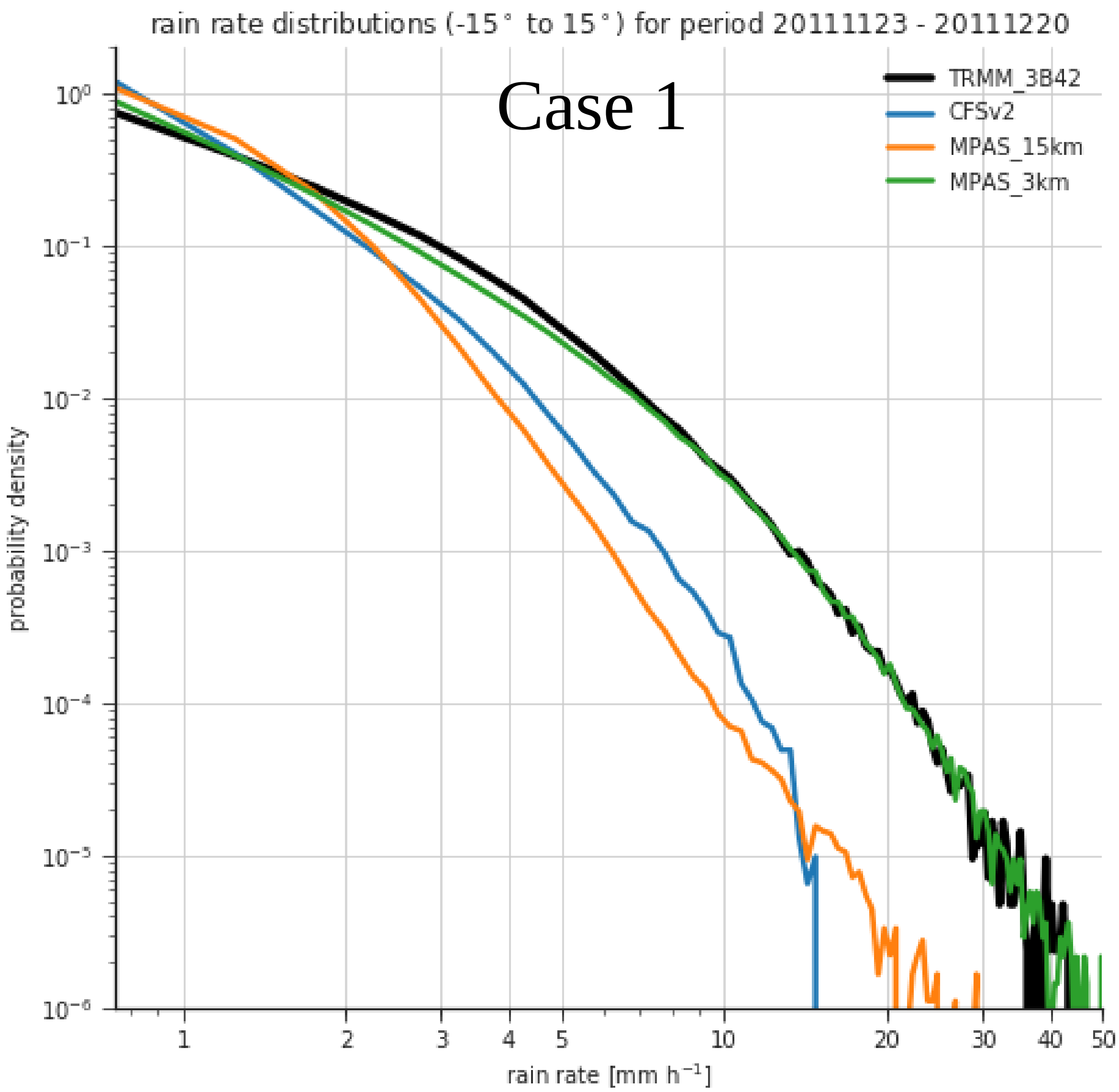
1. Tropical "mean state": precipitation frequency

Case 1



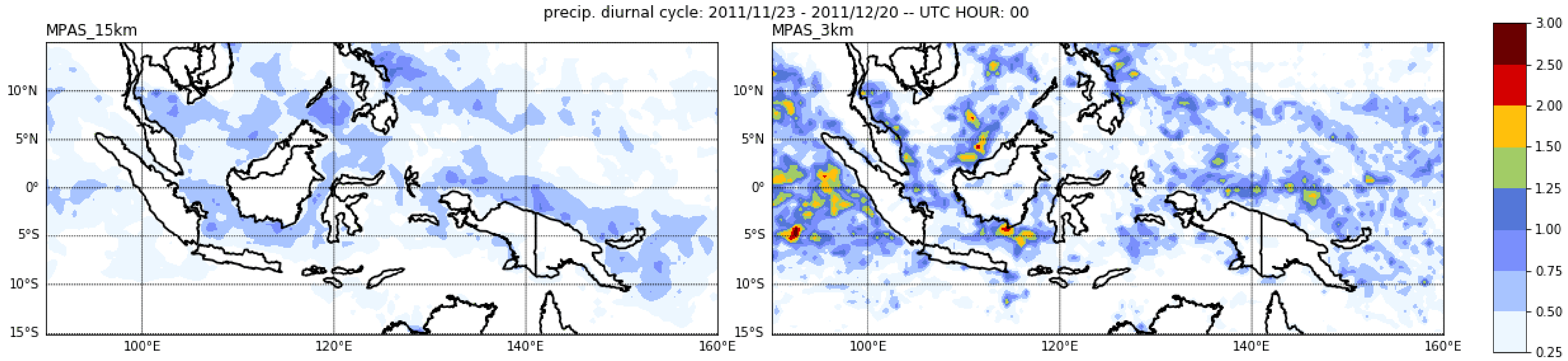
- <u>All precipitation</u>: 3-km simulation reduces the frequency of precipitation, though still overly active
- <u>Heavy precipitation</u>: 3-km simulation captures the strong convection entirely absent in the parameterized runs

1. Tropical "mean state": distribution of precip. rates



- 3-km simulation almost perfectly matches the TRMM distribution
- Parameterized convection runs exhibit too much (little) light (heavy) precipitation
- Looks the same for Case-2 and Case-3

1. Tropical “mean state”: diurnal cycle

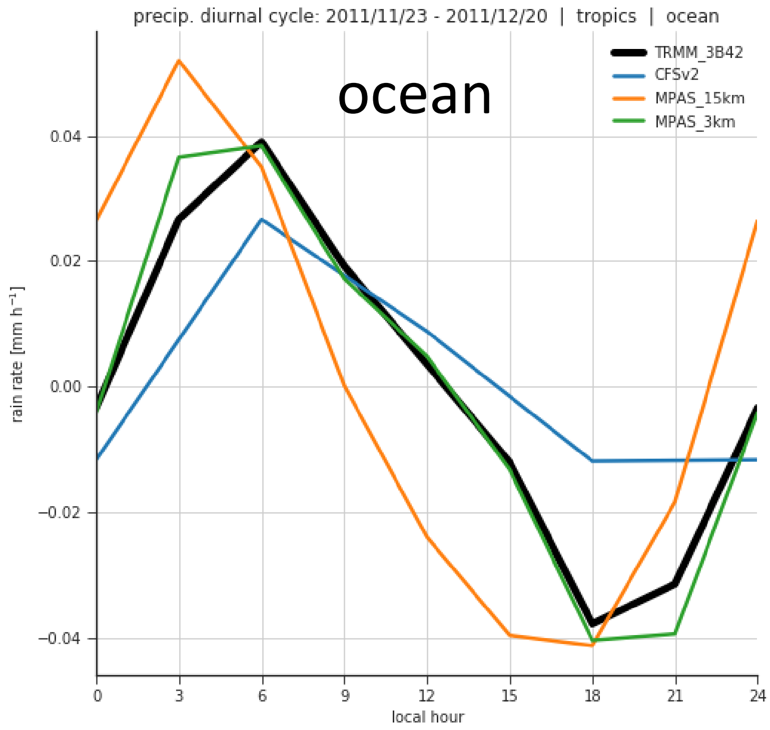


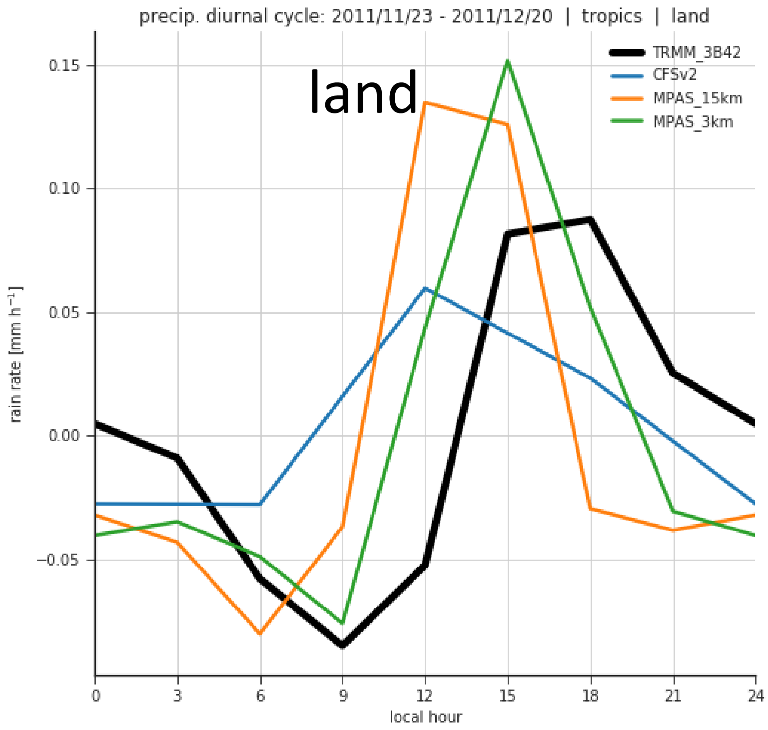
- Does the 3-km simulation improve the intensity and/or timing of the ocean/land diurnal cycle in the tropics?
  - Could be very important for the simulation of, e.g., the MJO[1]

[1]Zhang 2005

1. Tropical "mean state": diurnal cycle

Case 1

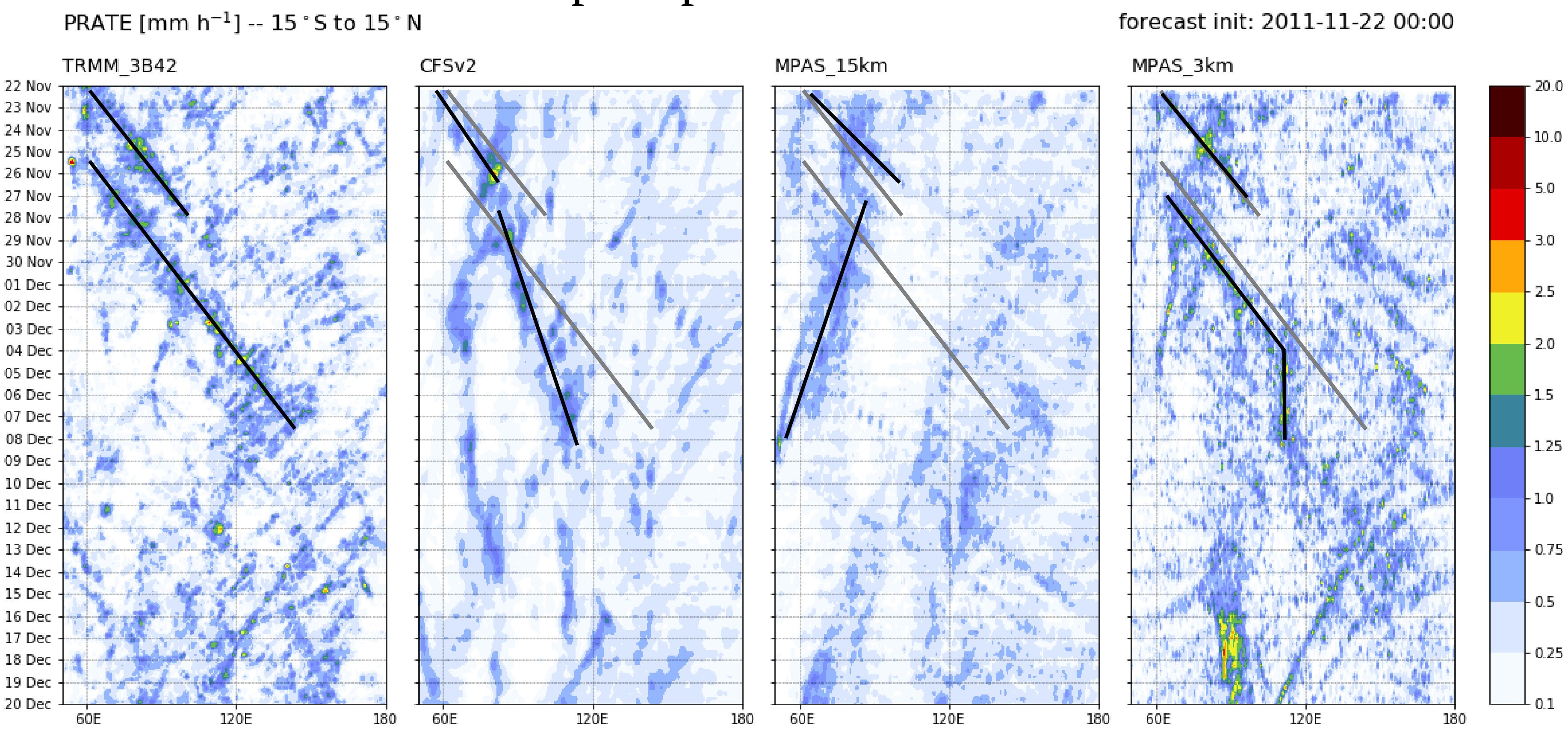




- Significantly improved diurnal timing/amplitude over ocean
- Diurnal timing is somewhat improved over land
- Similar results for just the M.C. region

2. Improved MJO? -- Case 1

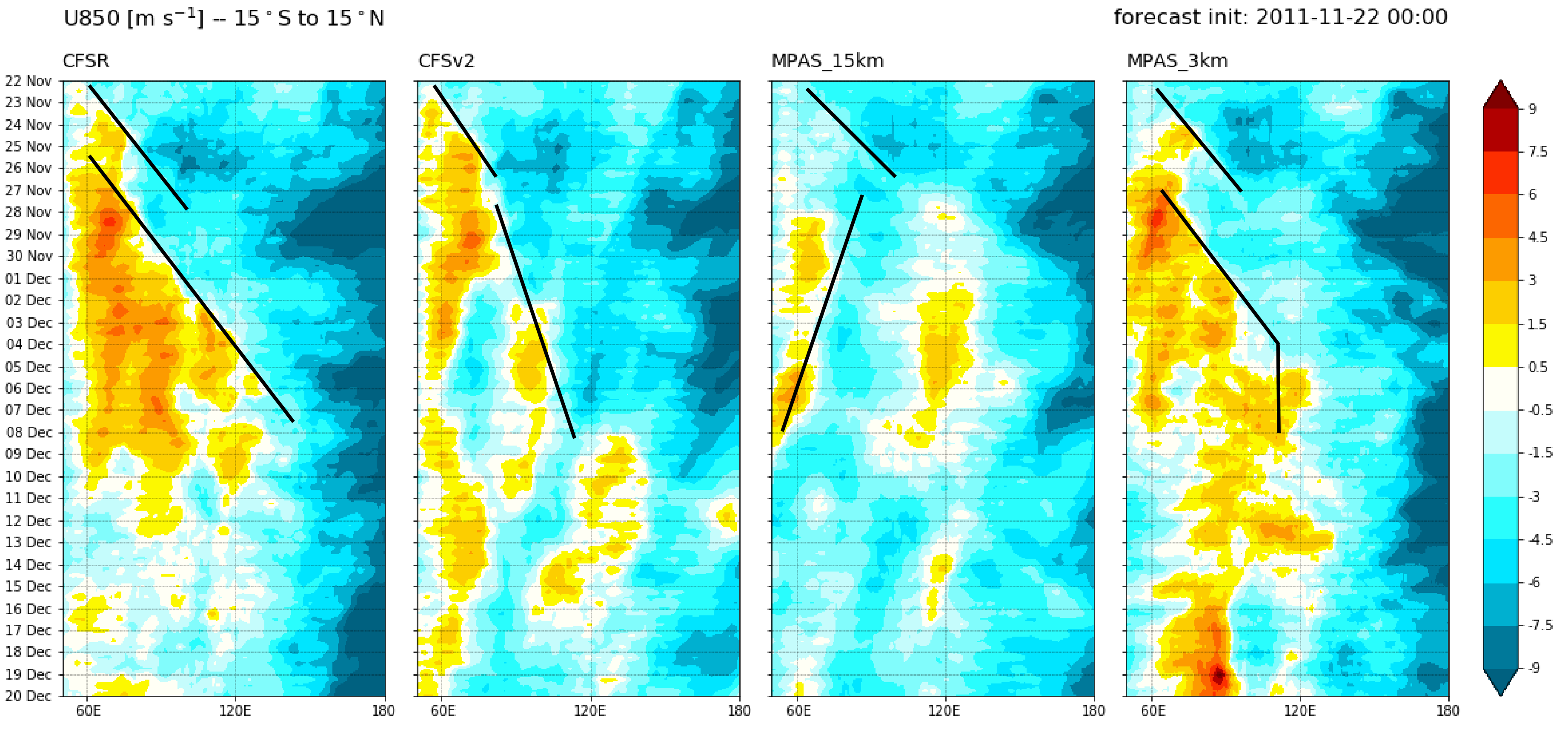
precipitation rate



- Substantial improvement of precipitation propagation

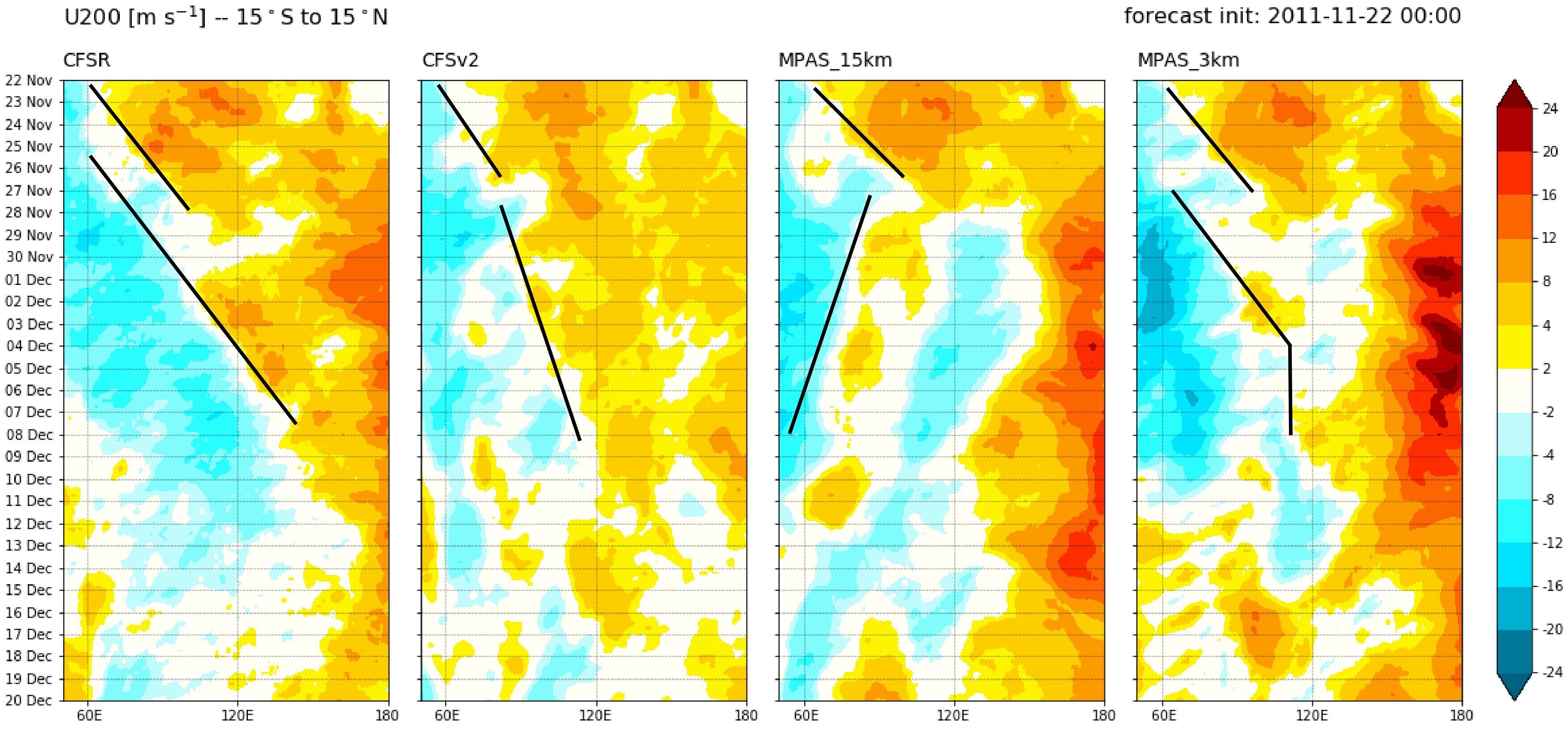
2. Improved MJO? -- Case 1

zonal wind – 850 hPa



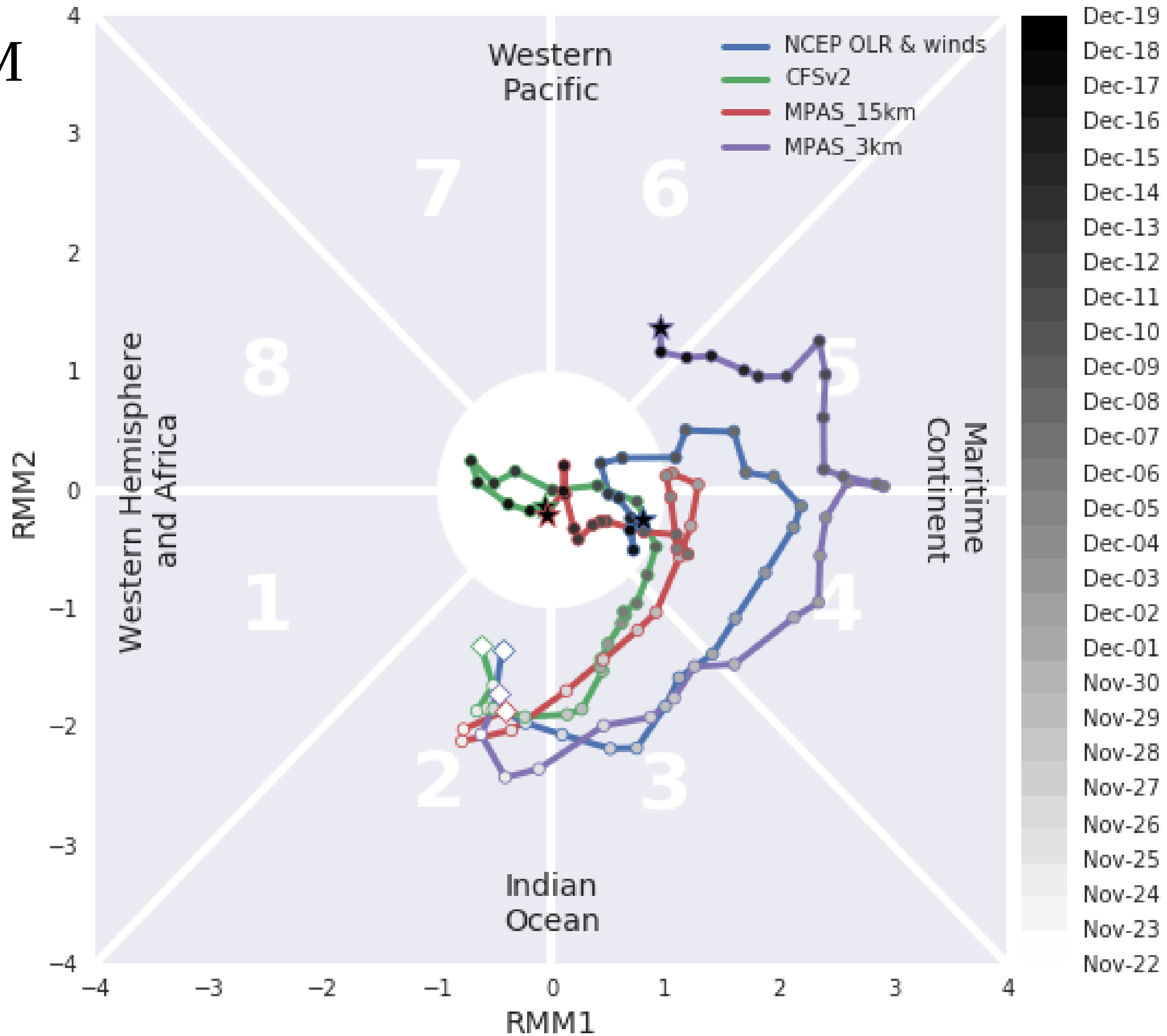
2. Improved MJO? -- Case 1

zonal wind – 200 hPa



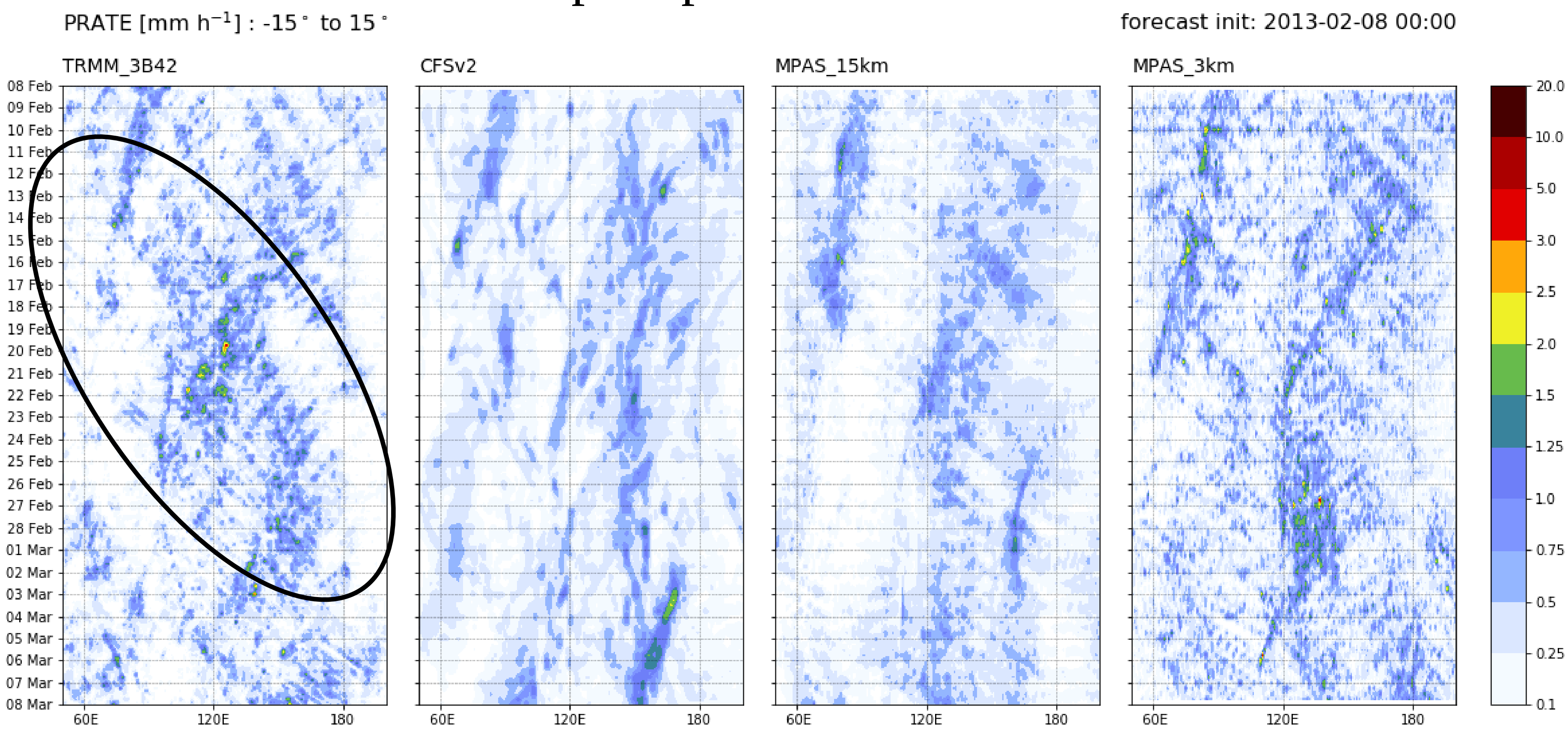
2. Improved MJO? -- Case 1

MJO RMM indices:



2. Improved MJO? -- Case 2

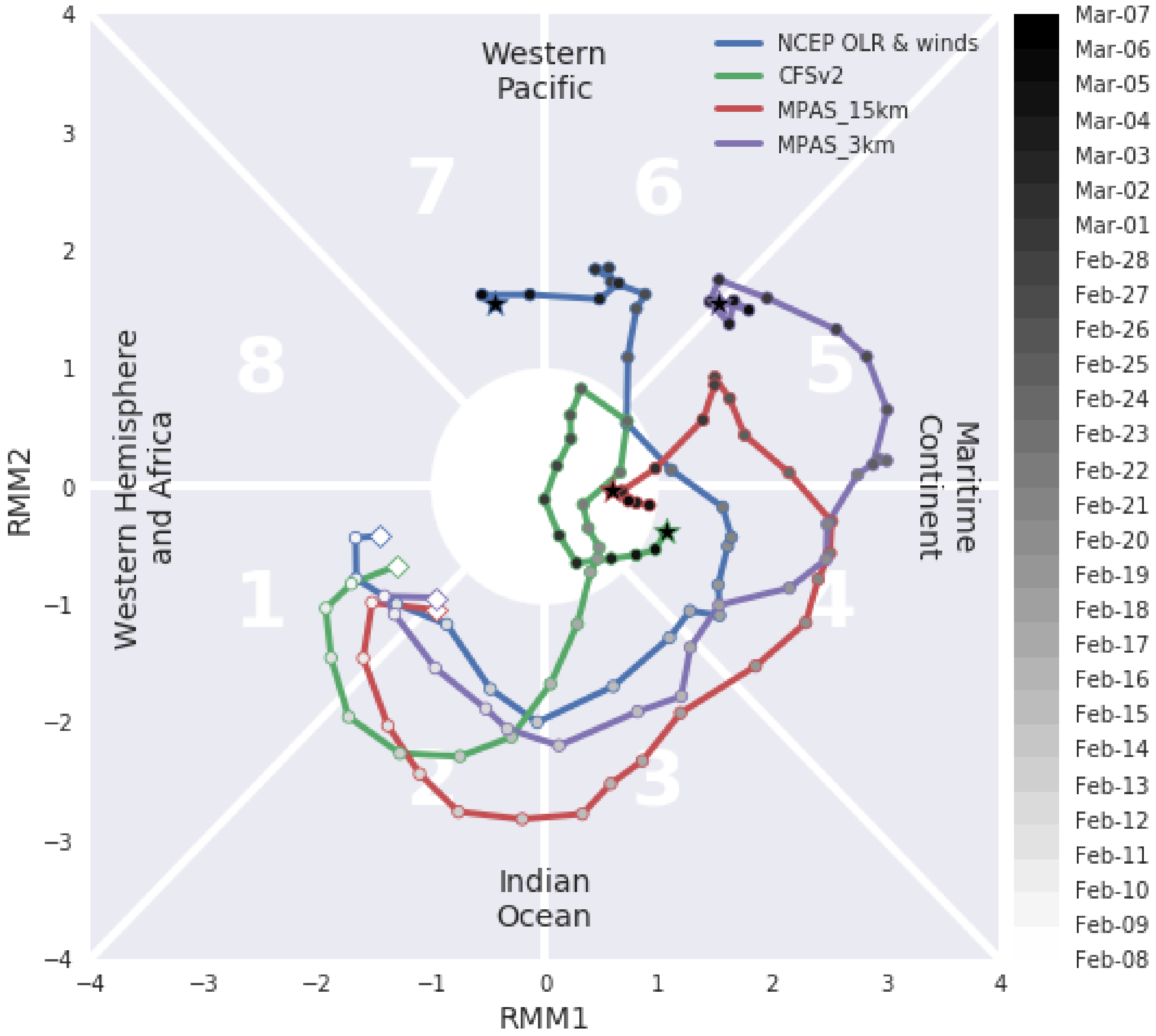
precipitation rate



- Eastward propagation missed by all simulations

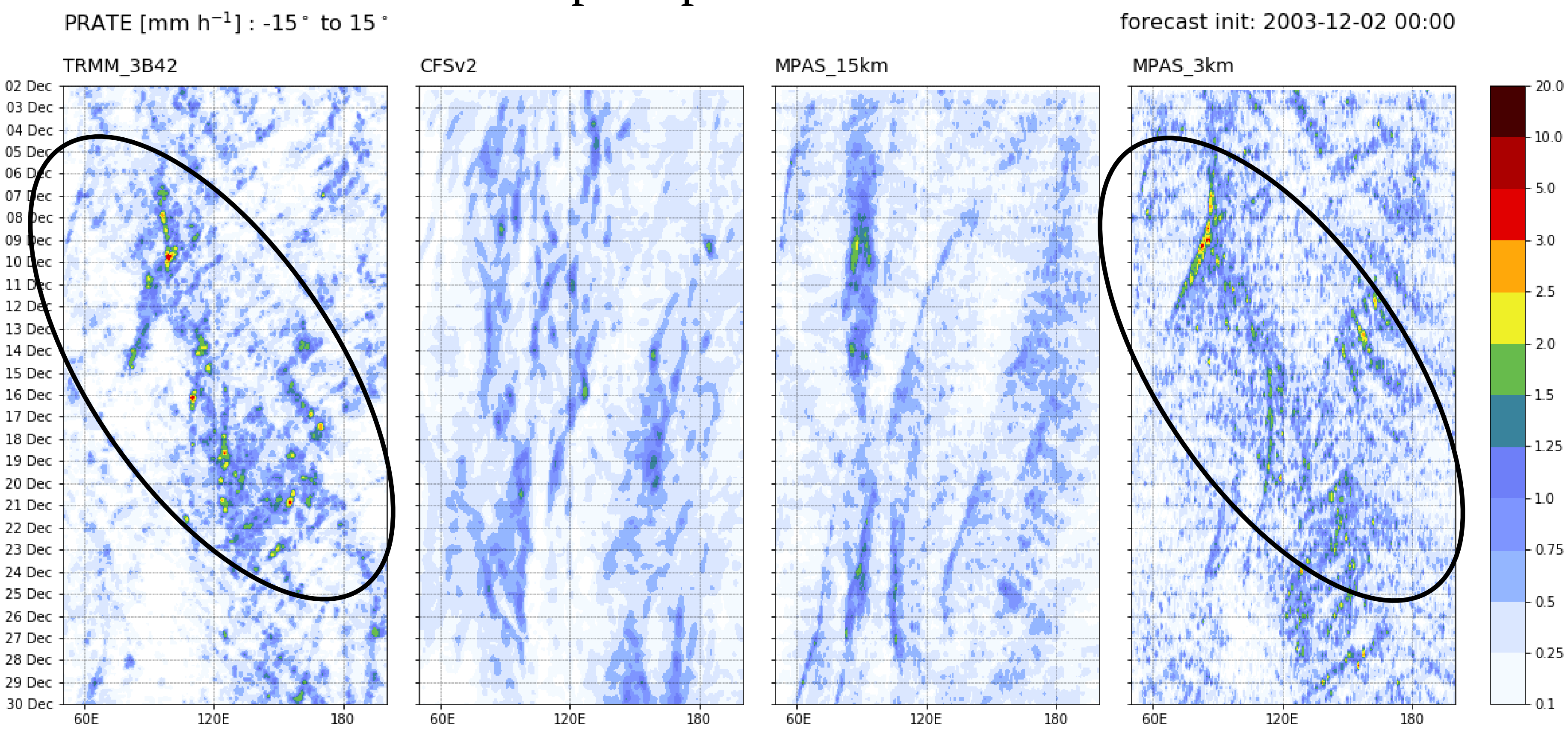
2. Improved MJO? -- Case 2

MJO RMM indices:



2. Improved MJO? -- Case 3

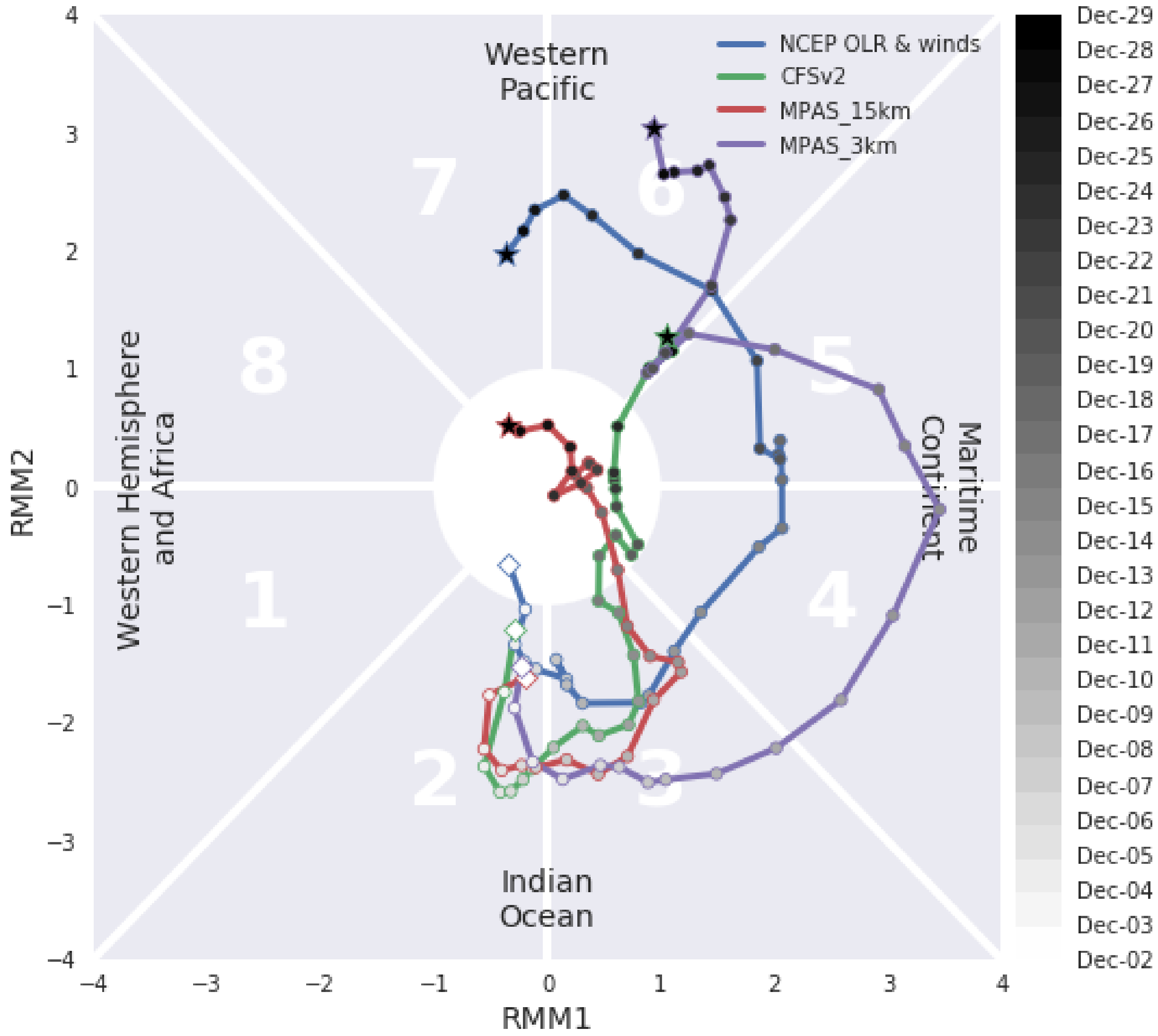
precipitation rate



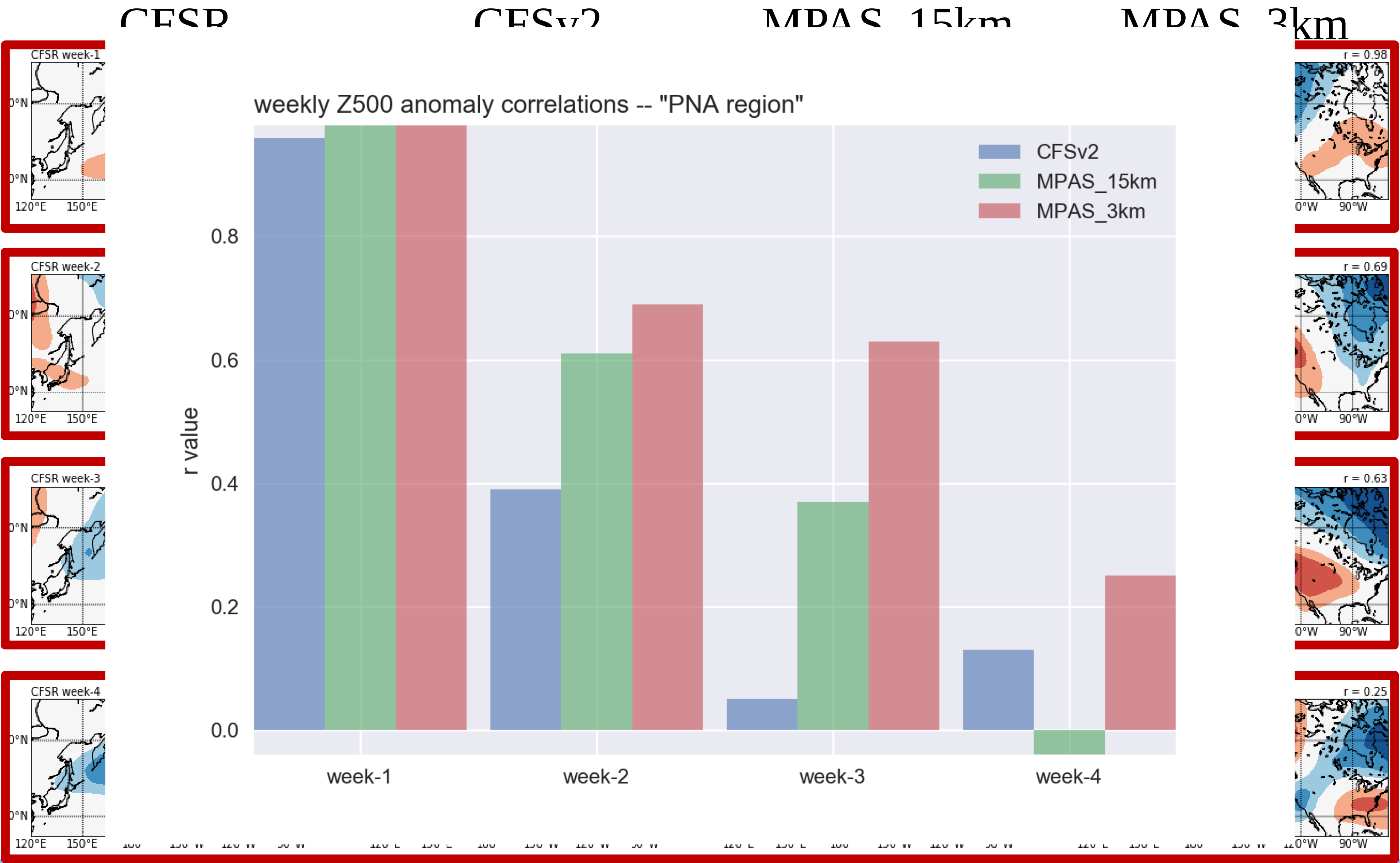
- Eastward propagation only captured by 3-km simulation

2. Improved MJO? -- Case 3

MJO RMM indices:

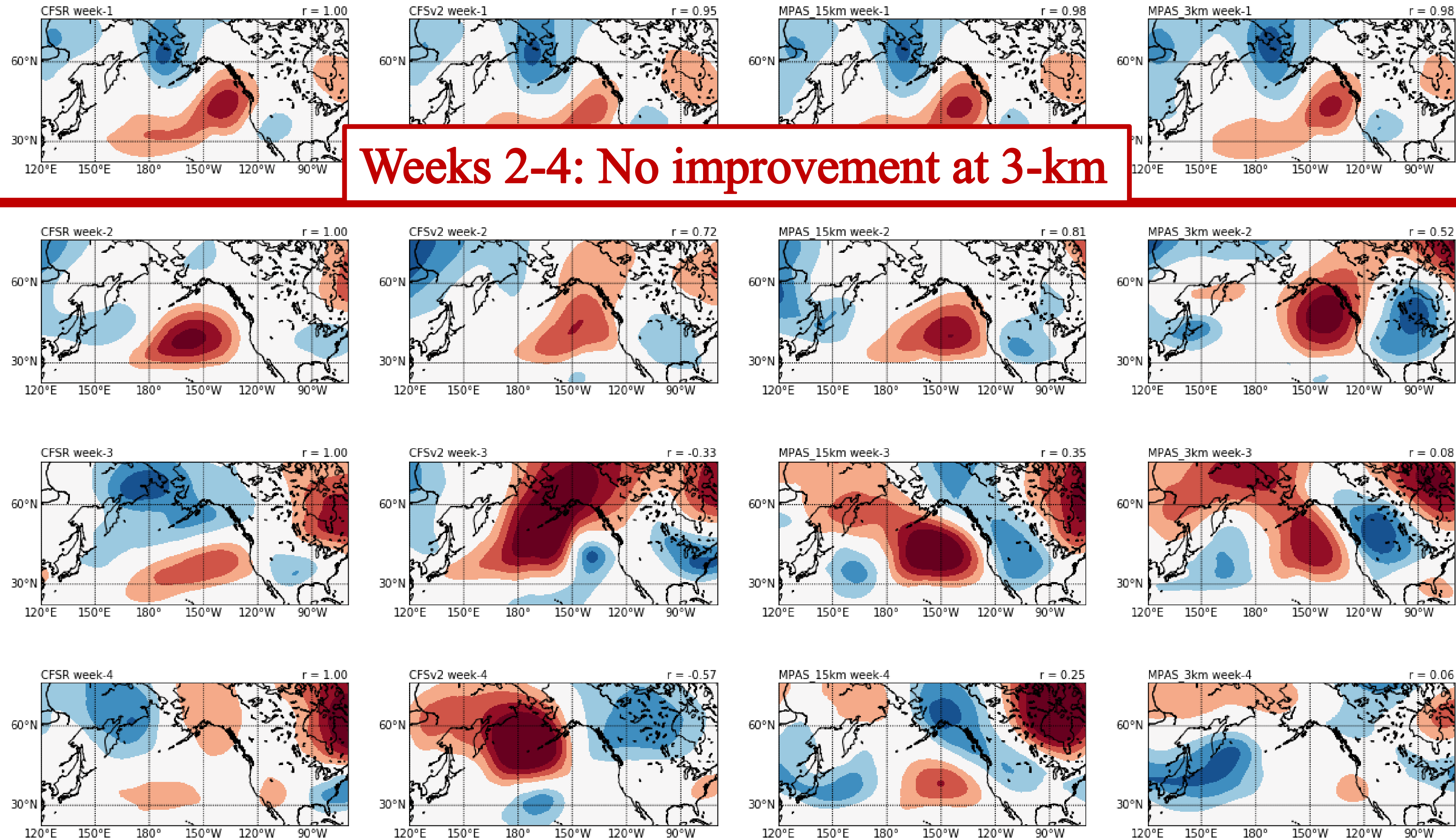


3. Improved extratropics? -- Case 1



3. Improved extratropics? -- Case 2

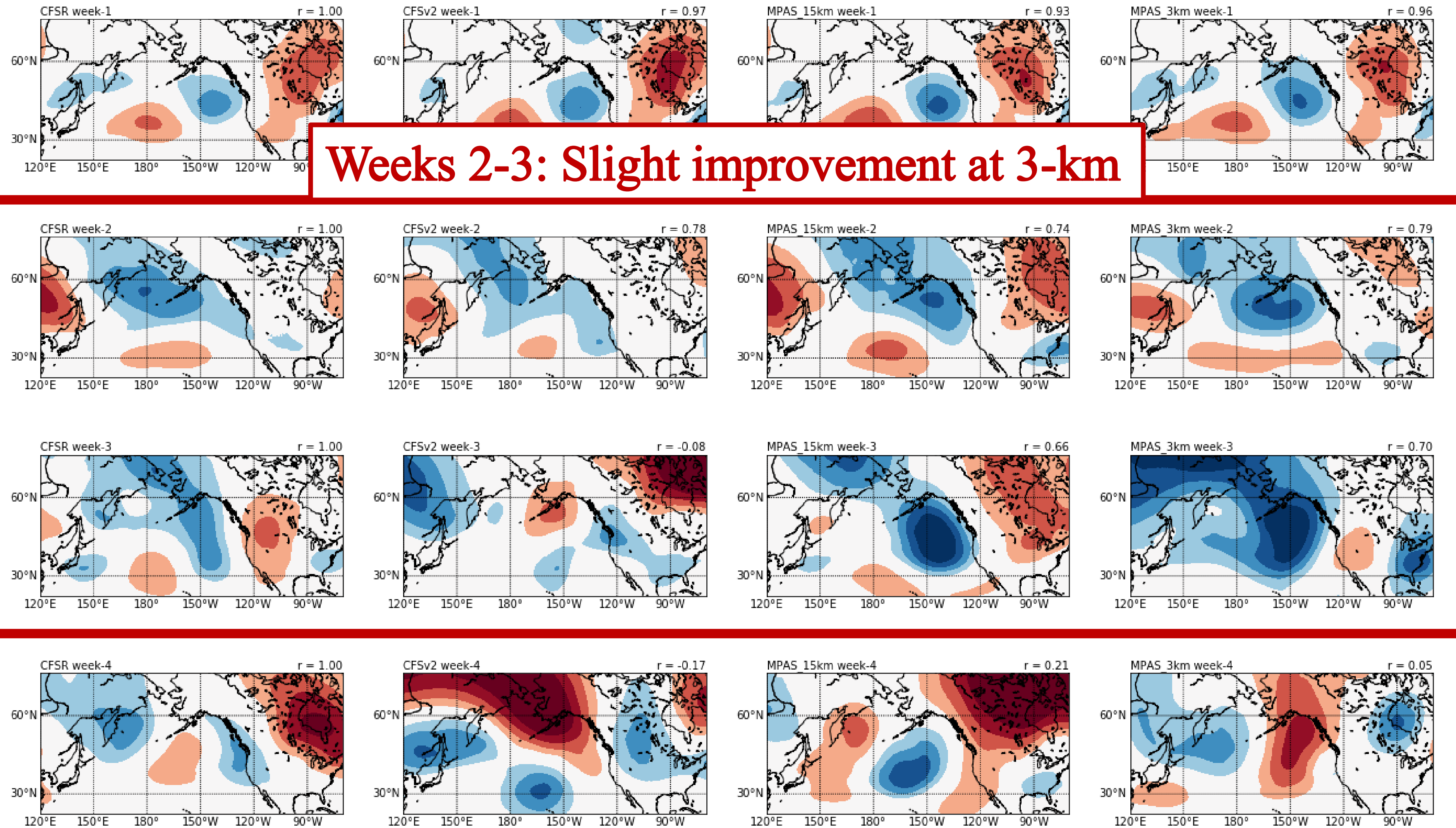
CFSR | CFSv2 | MPAS_15km | MPAS_3km



Weeks 2-4: No improvement at 3-km

3. Improved extratropics? -- Case 3

CFSR | CFSv2 | MPAS_15km | MPAS_3km



Weeks 2-3: Slight improvement at 3-km

Wrap-up:

By going to convection-permitting resolution can we…

1. Improve the tropical "mean state"?

   Case 1: ✓ Case 2: ✓ Case 3: ✓

2. Better predict large-scale convective phenomena (i.e., the MJO)?

   Case 1: ✓ Case 2: ✗ Case 3: ✓

3. Increase subseasonal extratropical forecast skill?

   Case 1: ✓ Case 2: ✗ Case 3: ✓

Conclusions

- Convection-permitting resolution can improve important aspects of the tropical mean state, but can introduce a positive precipitation bias
- In agreement with other studies, foregoing convective parameterization can improve the simulation of the MJO
- Global subseasonal forecast skill improvement is less clearly associated with convection-permitting resolution, but seems to be related to MJO simulation fidelity

Ongoing work

- Investigating the MPAS_3km wet bias: a product of the lack of ocean coupling?
- Implementing a more rigorous MJO tracking methodology (LPT).
- Verification against more observational datasets (e.g., SSMI)
- Why does the DYNAMO MJO stall over the Maritime Continent? Why are some MJOs simulated better than others?
- Is the improved PNA circulation tied to the MJO? – Look at Rossby Wave Source.
- Vertical latent heating/vertical motion profiles.
- Look into moisture/convection coupling.

Questions?

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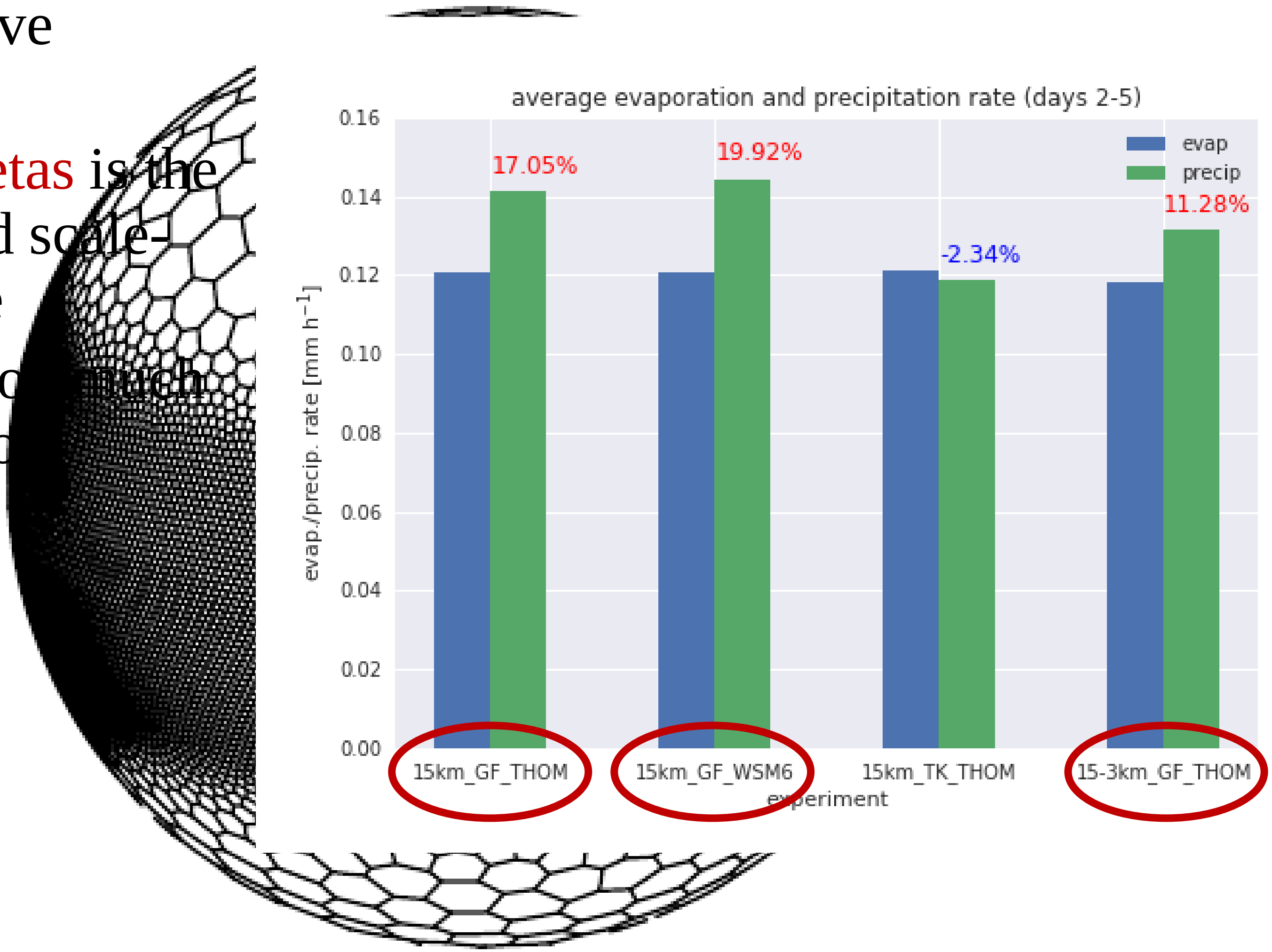
Extra

Slides

Why not use a "tropical channel" mesh?

- Would conserve resources!
- But Grell-Frietas is the only packaged scale-aware scheme
  - Produces too much precipitation



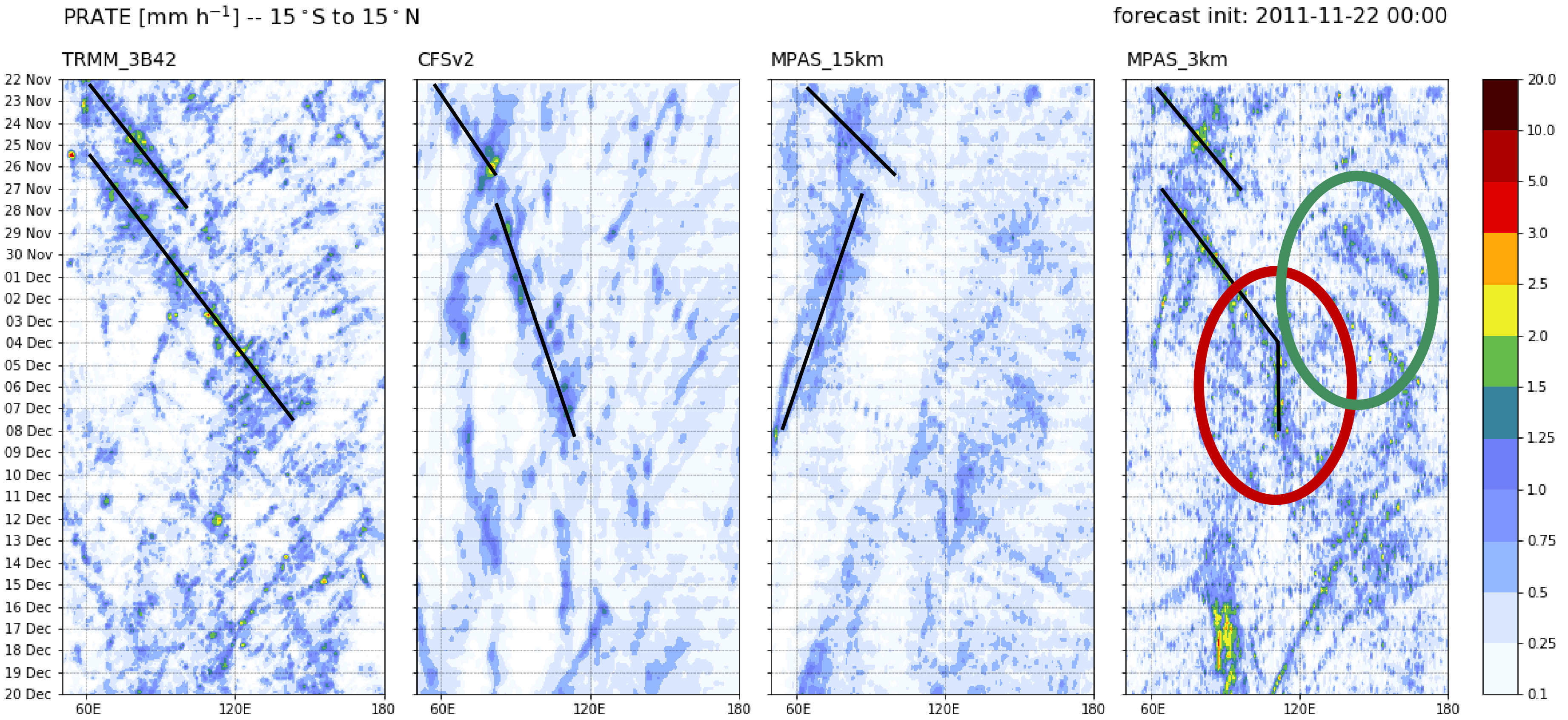
Physics parameterizations

- ***No*** convection scheme
- Thompson* microphysics
- RRTMG radiation
- MYNN* surface layer & PBL schemes
- Noah land surface
- 2D-Smagorinsky subgrid mixing scheme

*Sensitivity tests were done to compare with other schemes

M.C. barrier in MPAS_3km – Case 1

precipitation rate

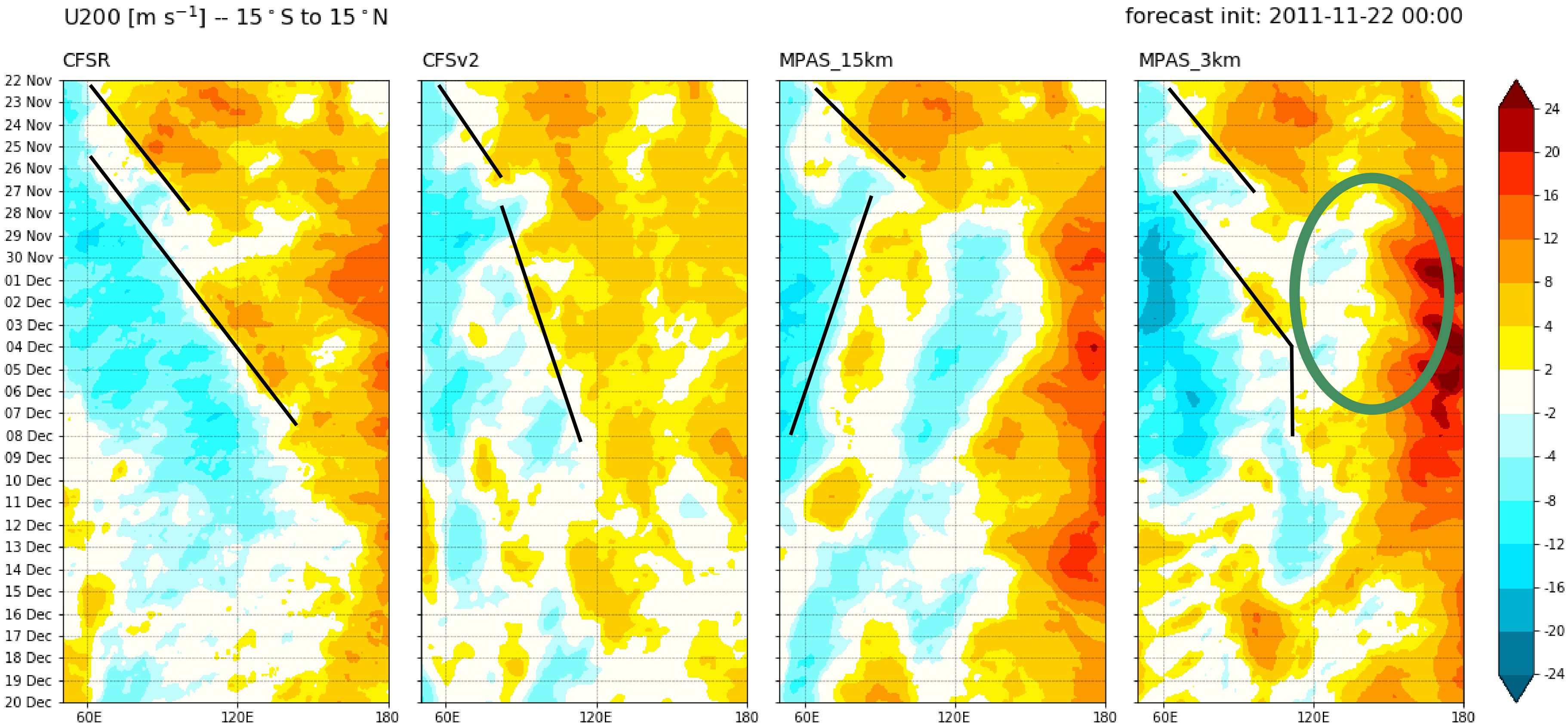


Propagation halts over M.C. – Why?

Theory #1: Preceding convection over M.C./W. Pacific

M.C. barrier in MPAS_3km – Case 1

zonal wind – 200 hPa

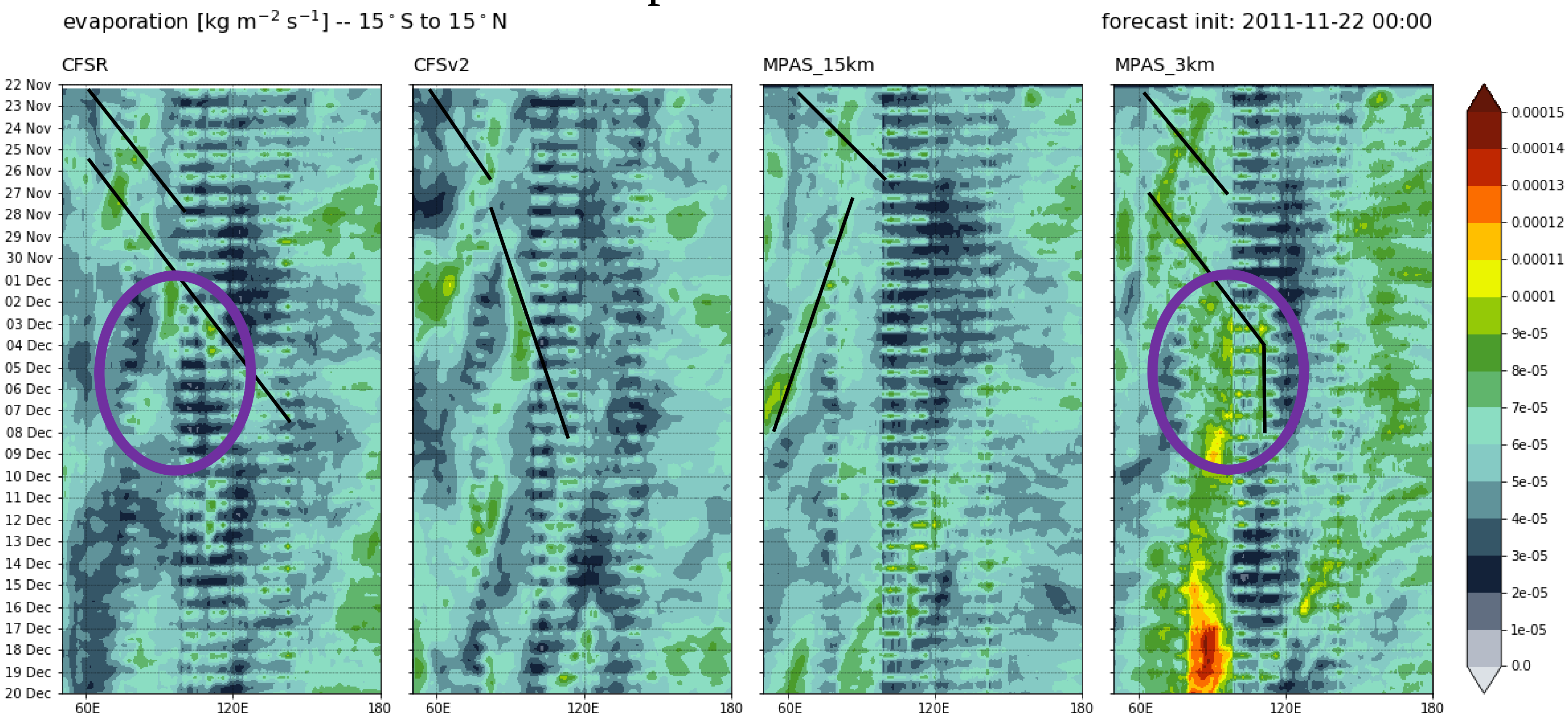


<u>Theory #1</u>: Preceding convection over M.C./W. Pacfic

M.C. divergence disrupts MJO outflow

M.C. barrier in MPAS_3km – Case 1

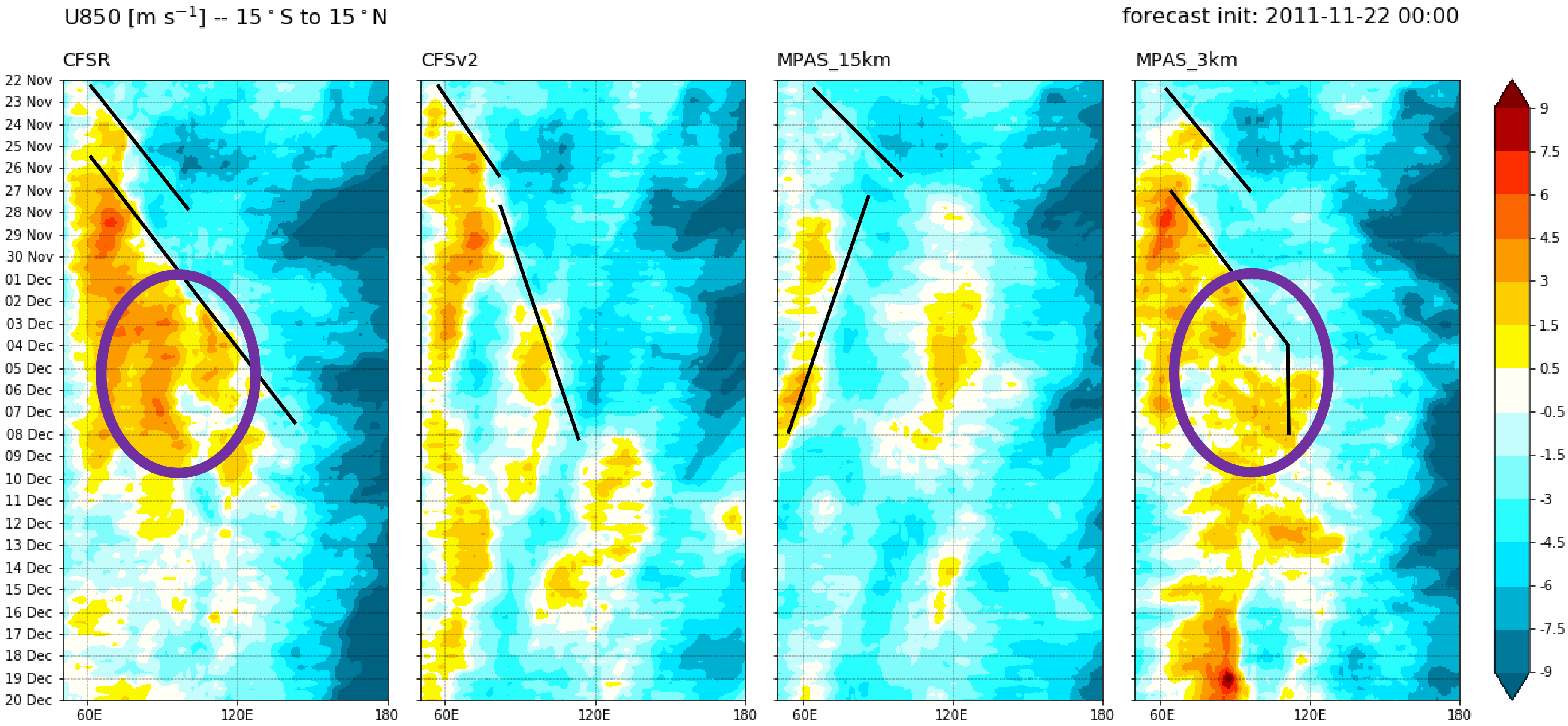
evaporation rate



Theory #2: Stronger evap. W. of convection → more low-level moisture

M.C. barrier in MPAS_3km – Case 1

zonal wind – 850 hPa



<u>Theory #2</u>: Stronger evap. W. of convection → more low-level moisture

Low-level winds are not stronger. Fixed SSTs maybe be removing the negative moisture (cooling) feedback of the winds.