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

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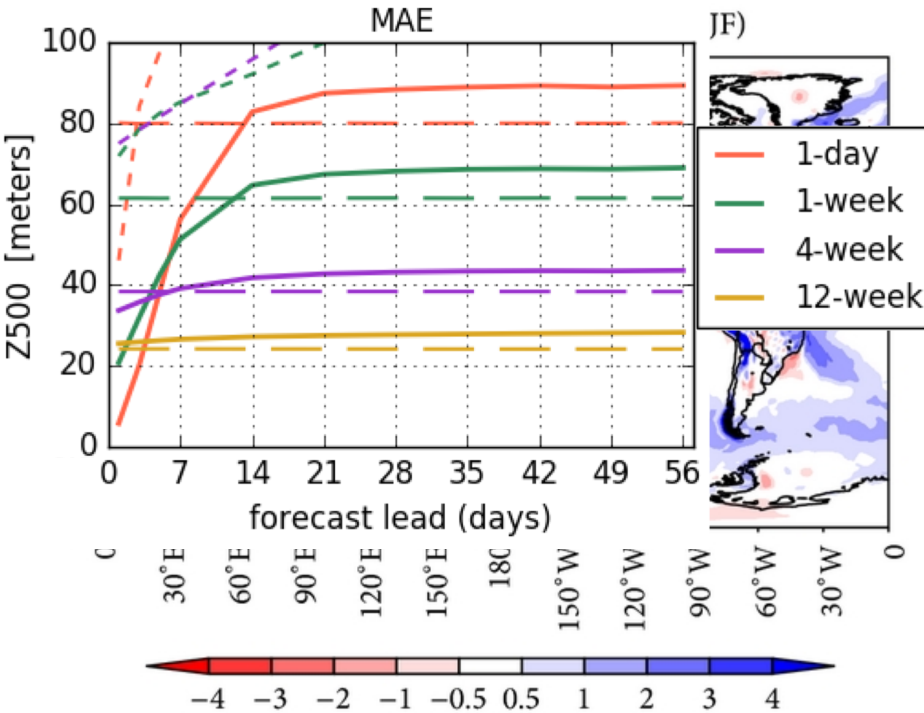
The current state of extended/subseasonal forecasting

- Subseasonal predictability is limited to just the first 2-4 weeks (depending on the time scale)[1,2,3,4]
- Tropical convection, an important driver of extratropical circulation, is poorly simulated in global models[4,5]
- Biases in convection, moisture, and circulation may poorly impact other aspects of the forecast (e.g., the MJO)[4,6,7,8]

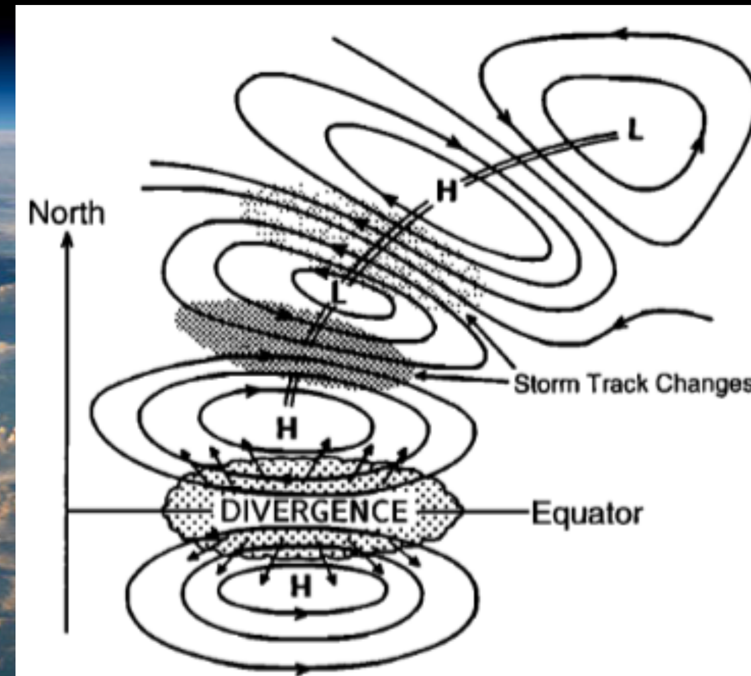


[1]Kumar et al. 2011; [2]Yuan et al. 2011; [3]Li and Robertson 2015; [4]Weber and Mass 2017; [5]Lin 2007, [6]Silva et al. 2014; [7]Gonzalez and Jiang 2017; [8]Kim 2017

Why convection-permitting resolution?

- **Explicit convection *can* improve:**
  - **Precipitation distribution[1,2]**
  - **Diurnal cycle[3]**
  - **Propagating convection/MJO[4-8]**
  - **Mean state?[9]**

- **Thus, we expect improved extratropical prediction**



[1]Holloway et al. 2012; [2]Inoue et al. 2008; [3]Sato et al. 2009; [4]Davis et al. 2003; [5]Miura et al. 2007; [6]Miyakawa et al. 2014; [7]Wang et al. 2015; [8]Pilon et al. 2016; [9]Prein et al. 2015

Questions for today:

By going to convection-permitting resolution can we…

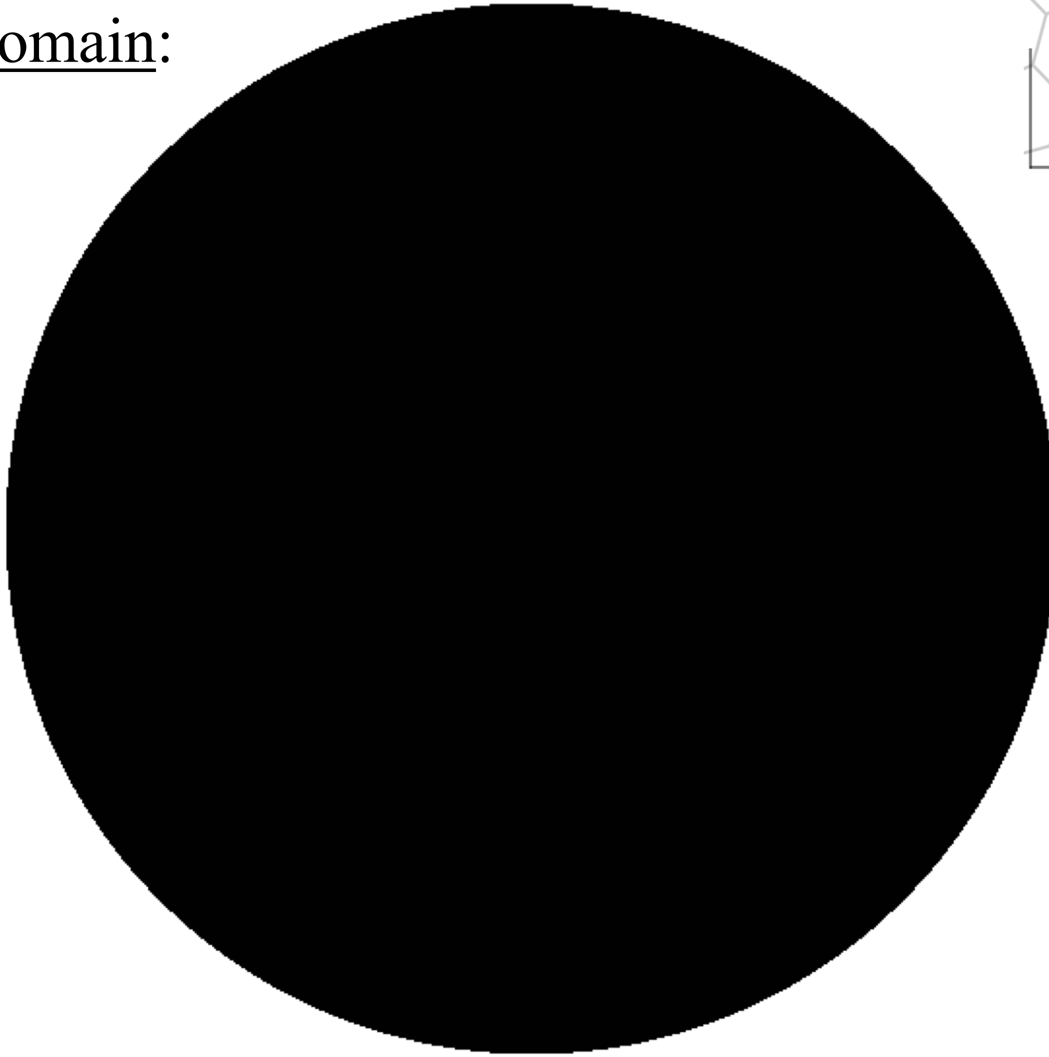
1. Improve the tropical mean state?

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

3. Increase subseasonal extratropical forecast skill?

Our tool: MPAS

- <u>Version</u>: MPAS v5.1 – “out of the box”
- <u>Domain</u>:



MPAS
Model for Prediction Across Scales

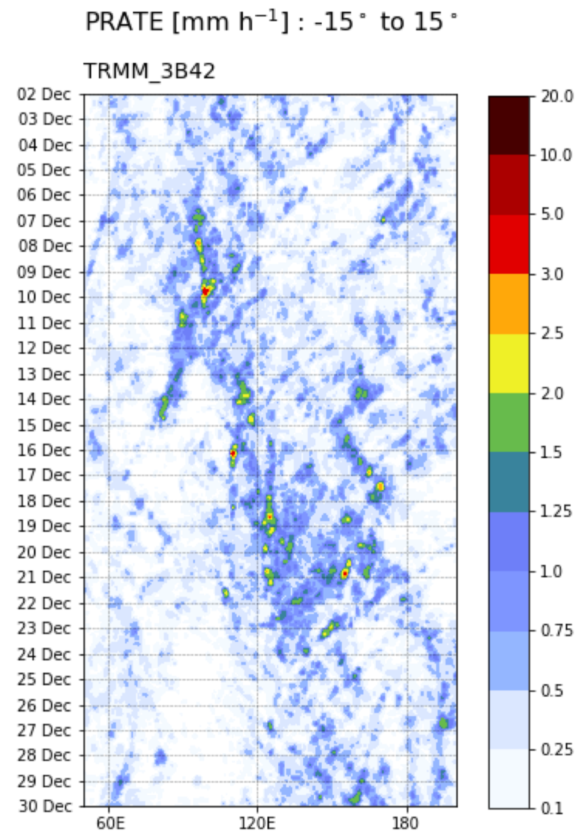
- <u>Resolution</u>:
  120-km
  65+ million cells

- <u>Physics</u>:
  ‘convection_permitting’ suite – ***no*** Cu scheme

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

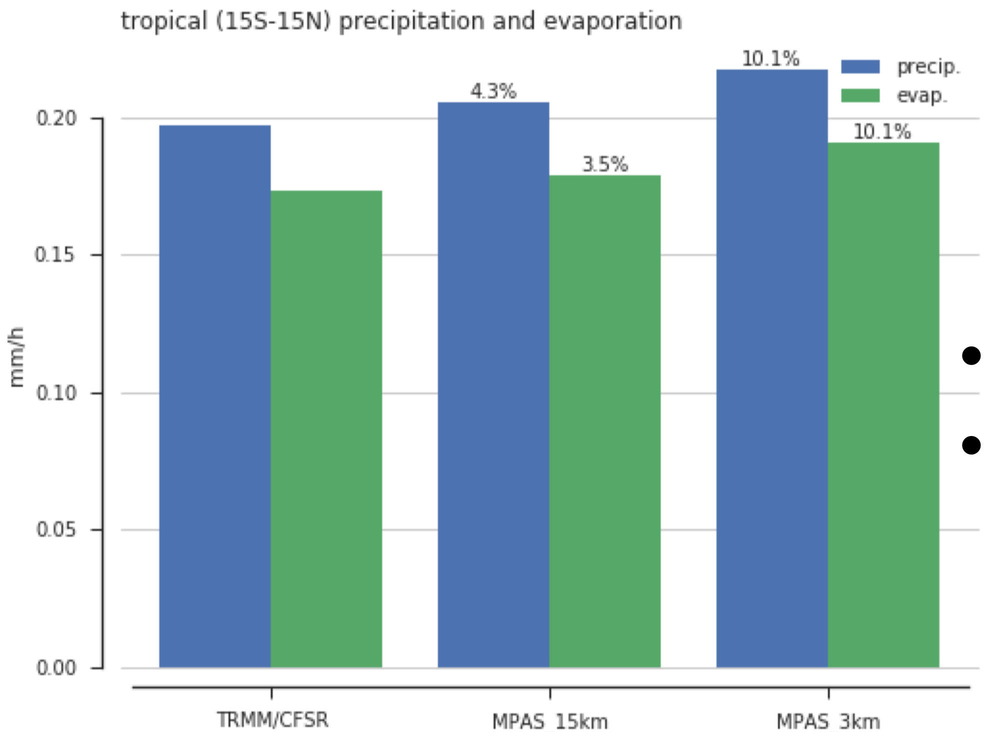


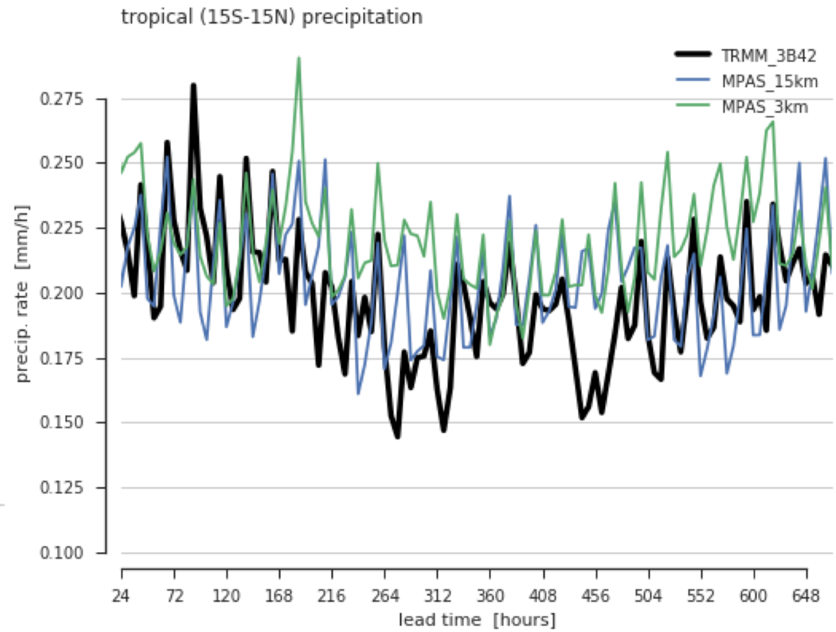
- All integrated for 28 days
- FNL analyses for ICs and BCs (***SSTs <u>fixed</u> at initial value)***

[1]Vitart and Robinson 2018

1. Tropical mean state: volumetric precipitation

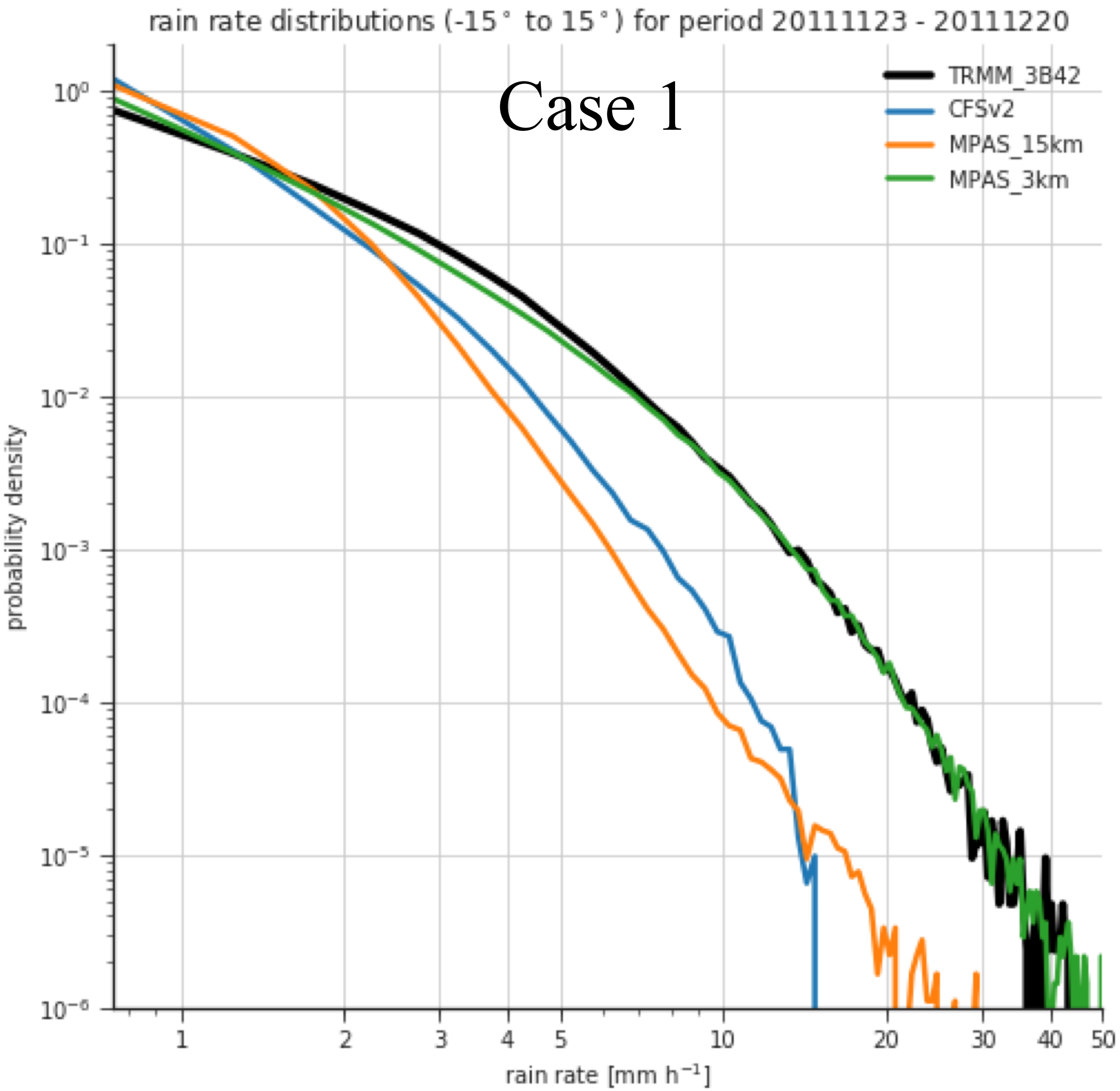
- Too much tropical precipitation in 3-km run
- ~10% too much precip. and evaporation





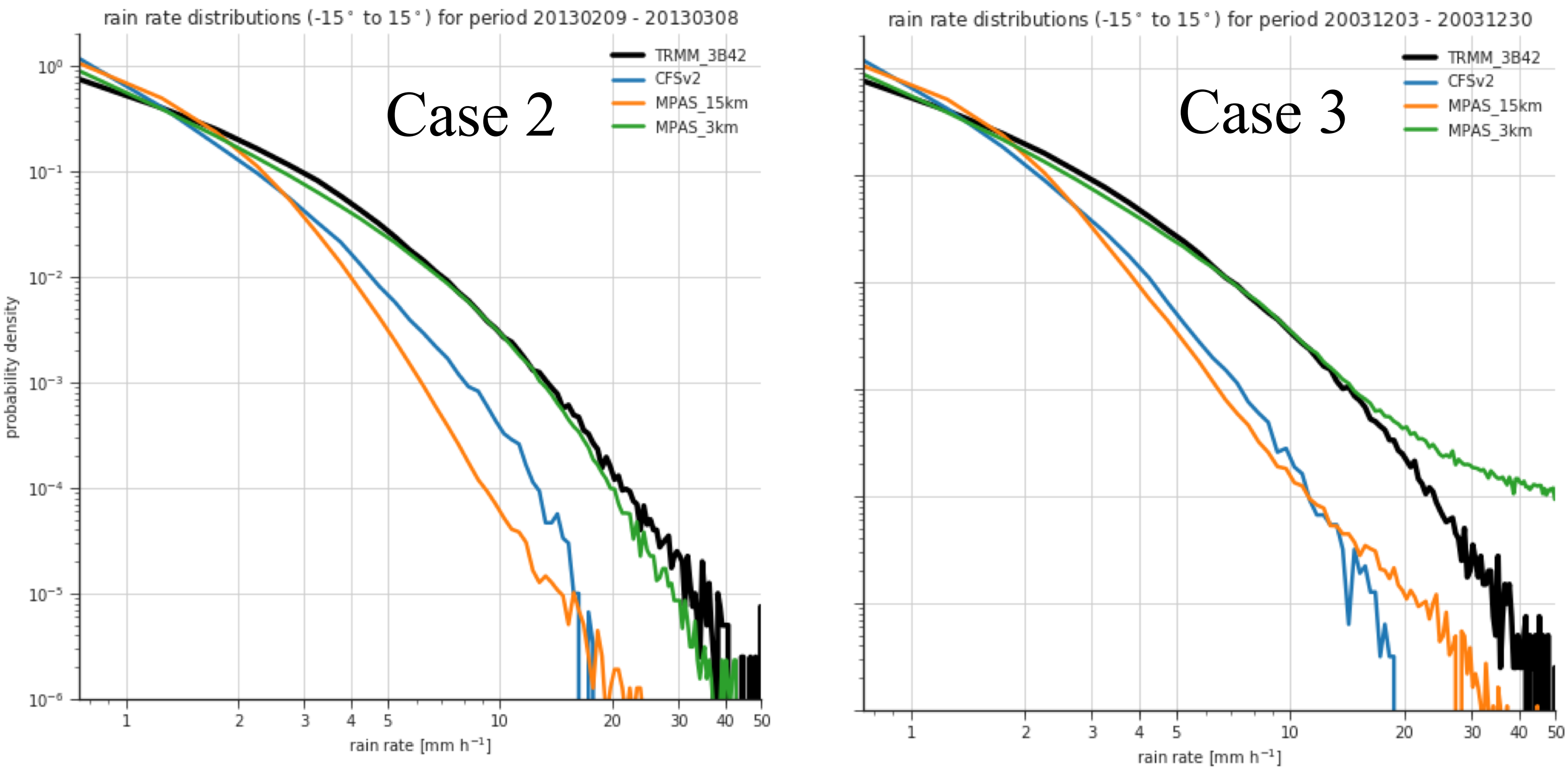
- Similar for all three cases
- No bias in *global* values

1. Tropical mean state: distribution of precip. rates



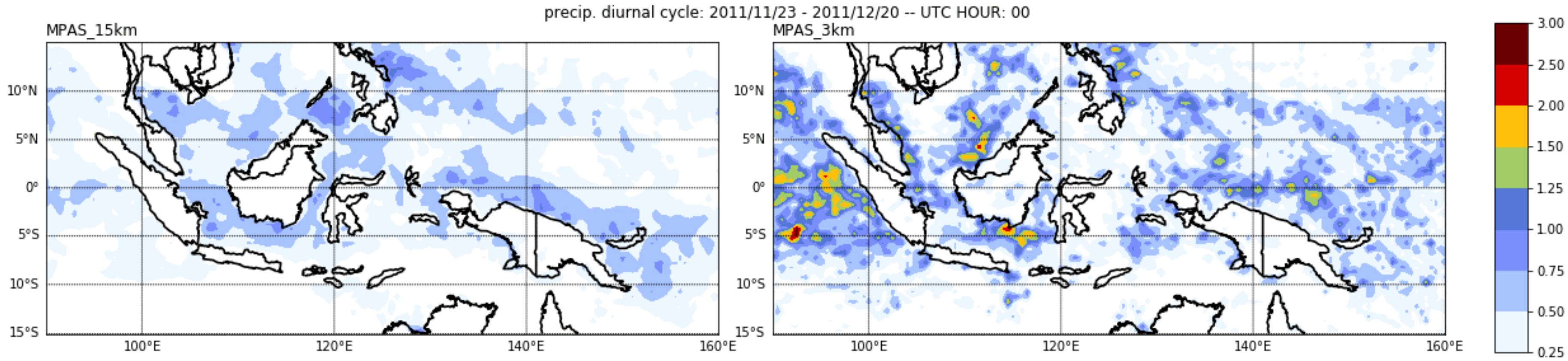
- 3-km simulation almost perfectly matches the TRMM distribution
- Parameterized convection runs exhibit too much (little) light (heavy) precipitation

1. Tropical mean state: distribution of precip. rates



- Similar improvement for the other two cases

1. Tropical mean state: diurnal cycle

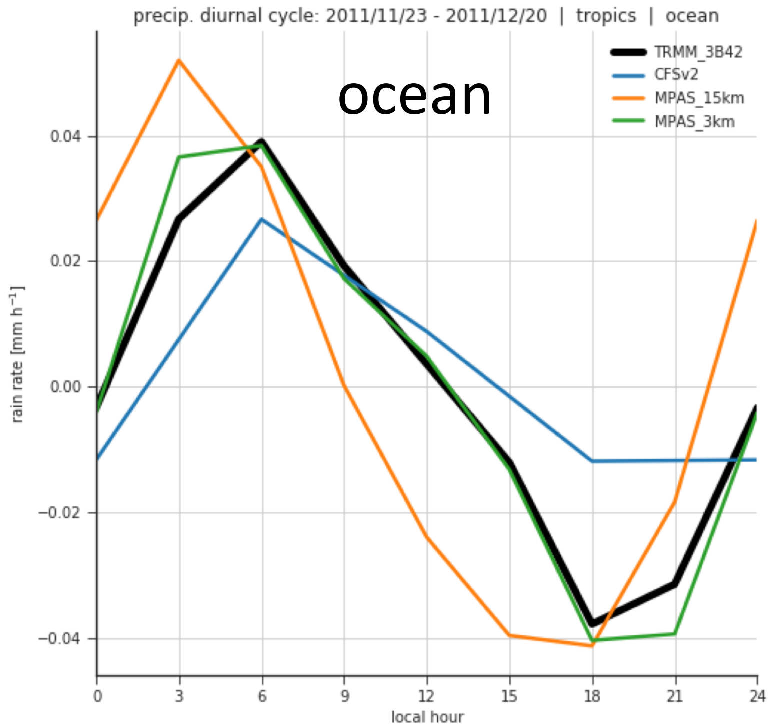


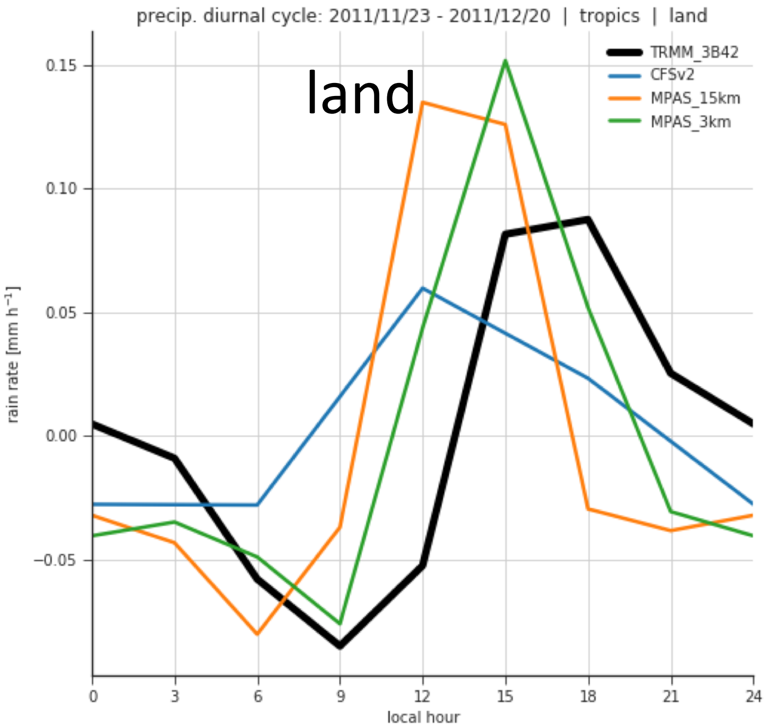
- Does the 3-km simulation improve the intensity and/or timing of the ocean/land diurnal cycle in the tropics?
  - Could be very important for the simulation of, e.g., the MJO[1]

[1]Zhang 2005

1. Tropical mean state: diurnal cycle

Case 1

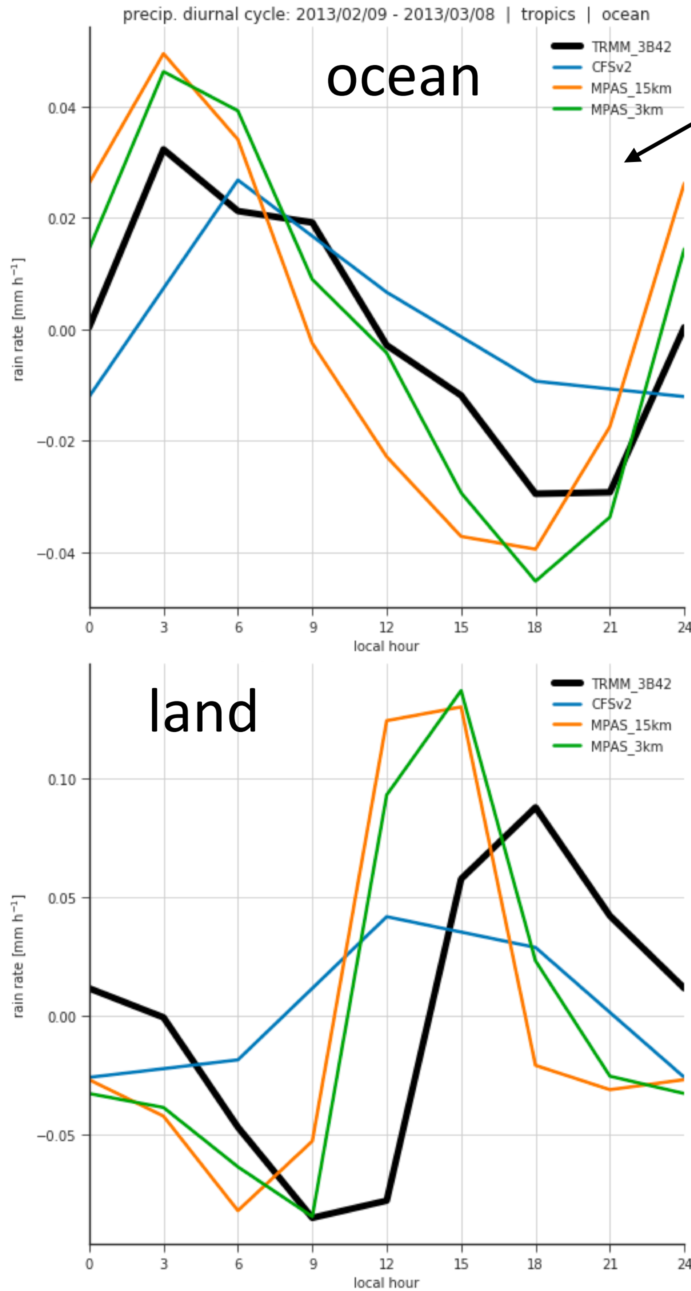




- Significantly improved diurnal timing/amplitude over ocean
- Diurnal timing is somewhat improved over land
- Similar results for just the M.C. region

[1]Zhang 2005

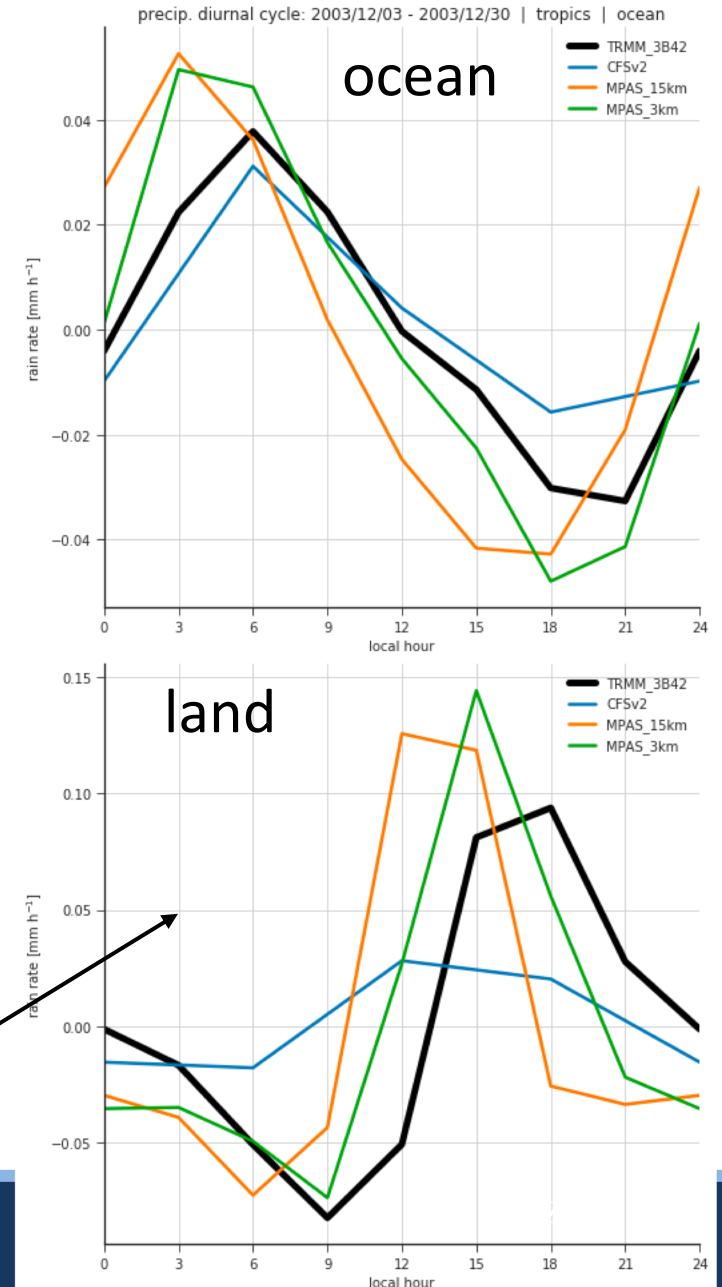
1. Tropical mean state: diurnal cycle



Case 2

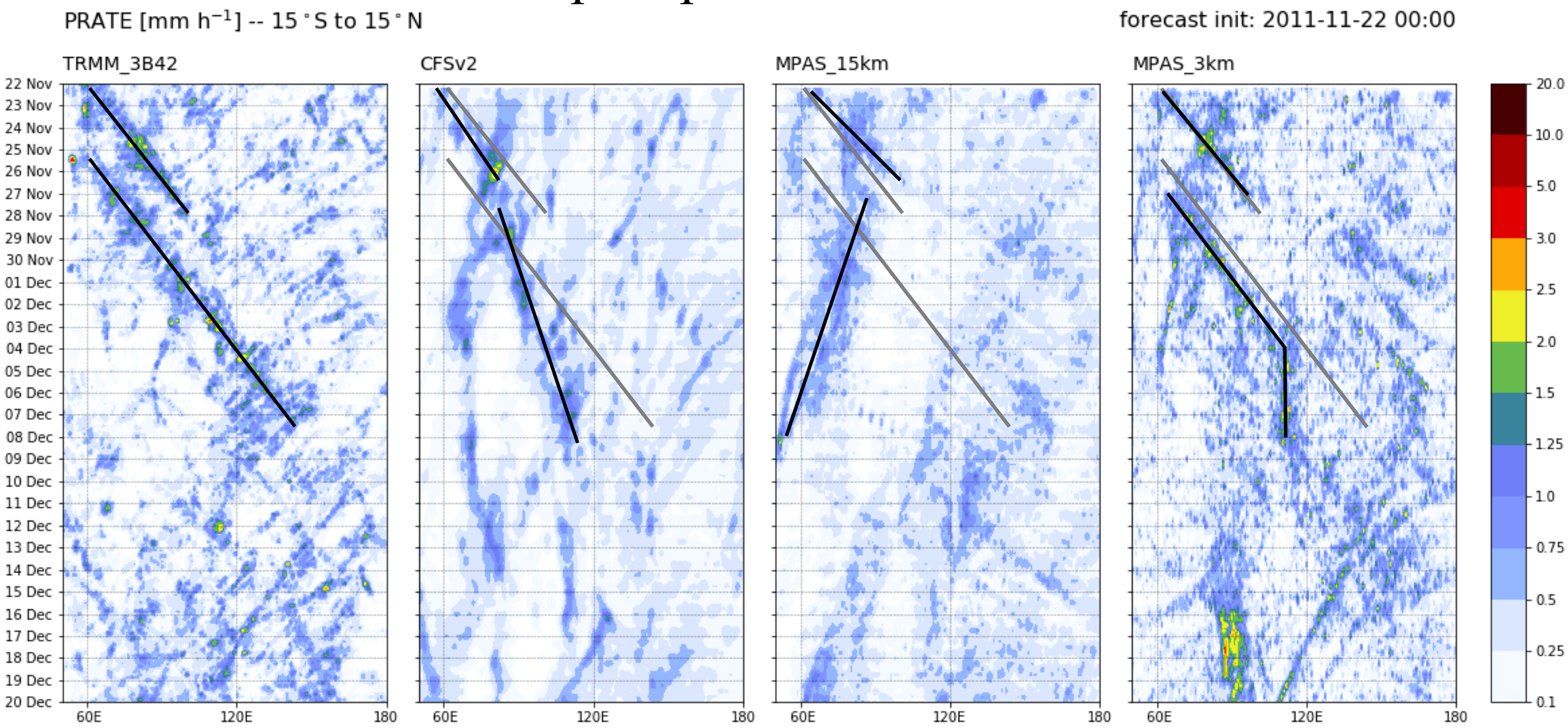
- Diurnal improvement is less for Case 2, but similar for Case 3

Case 3



2. Improved MJO? -- Case 1

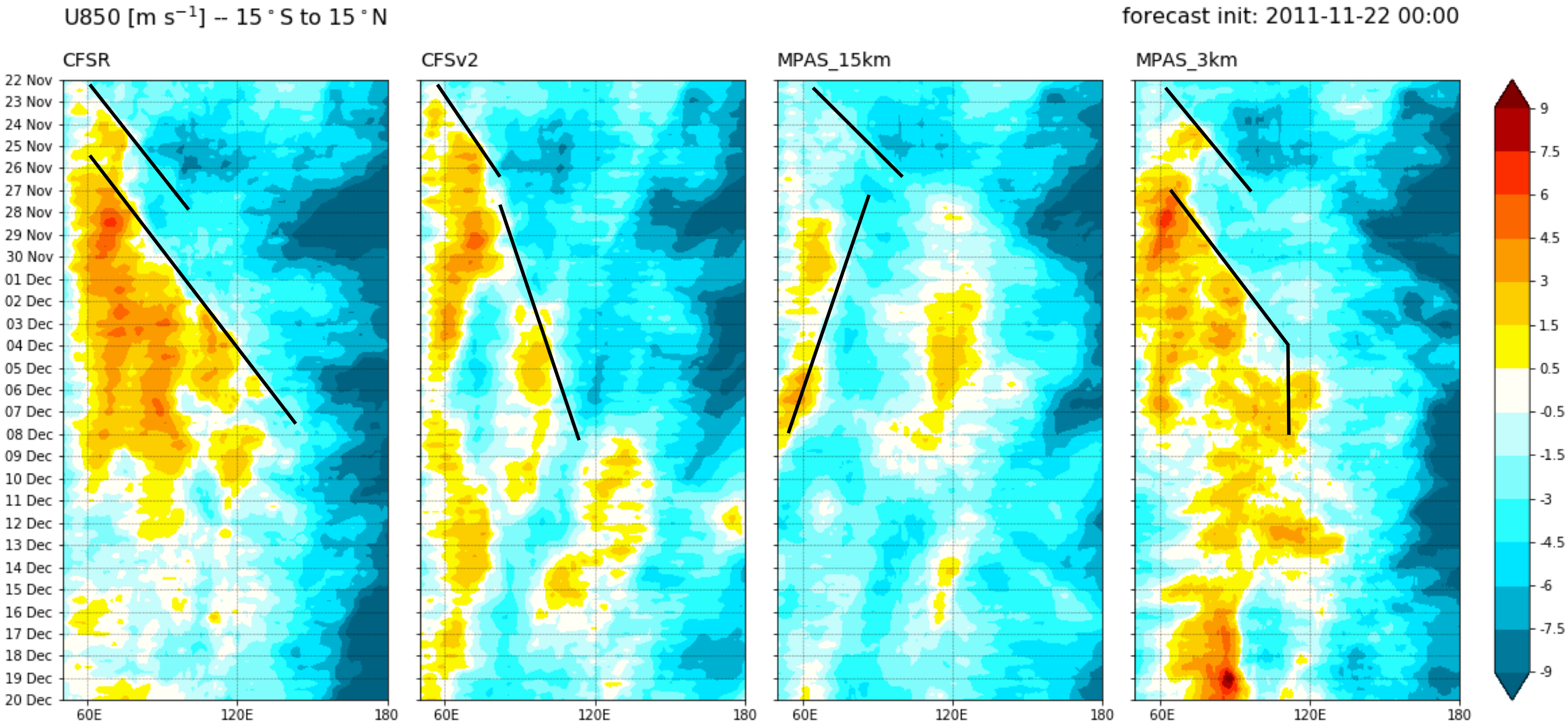
precipitation rate



- Substantial improvement of precipitation propagation

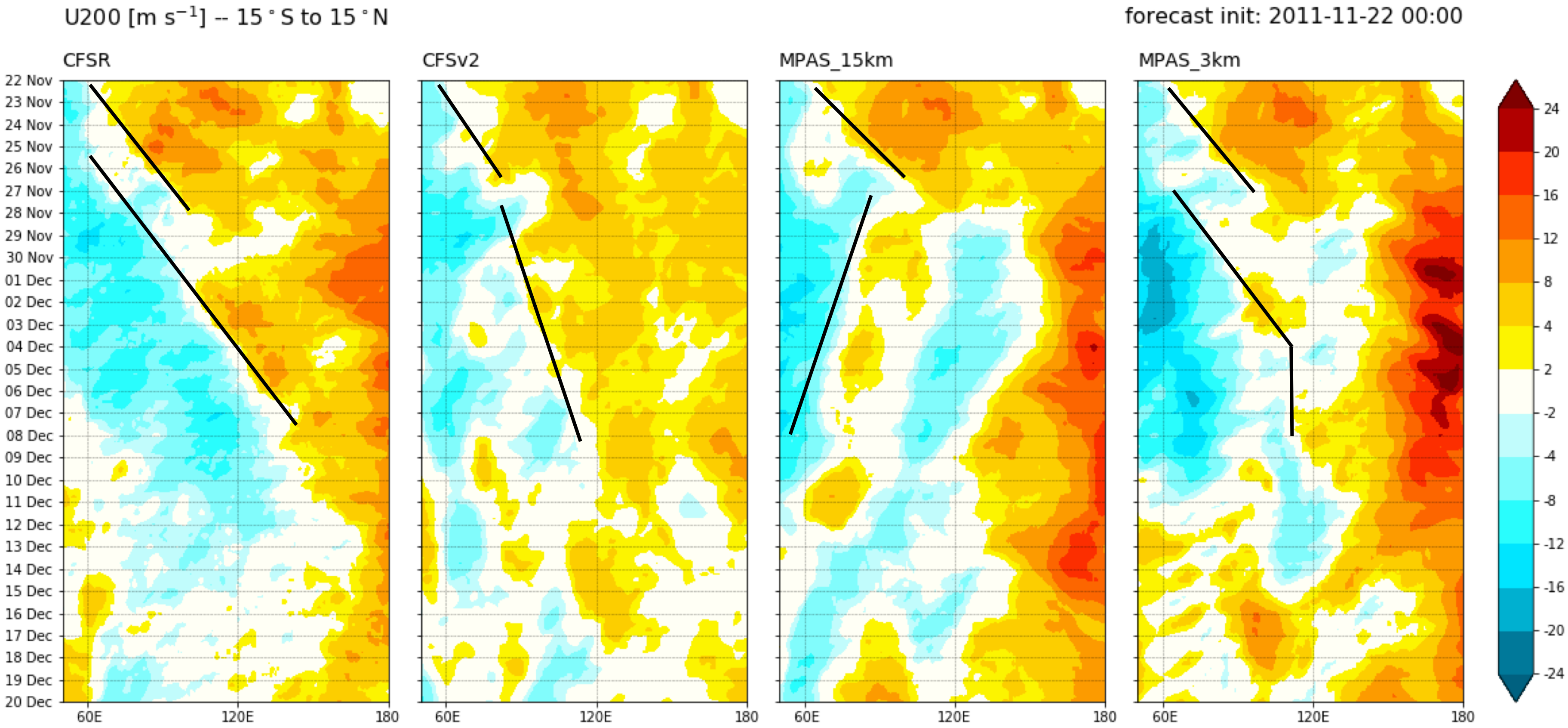
2. Improved MJO? -- Case 1

zonal wind – 850 hPa



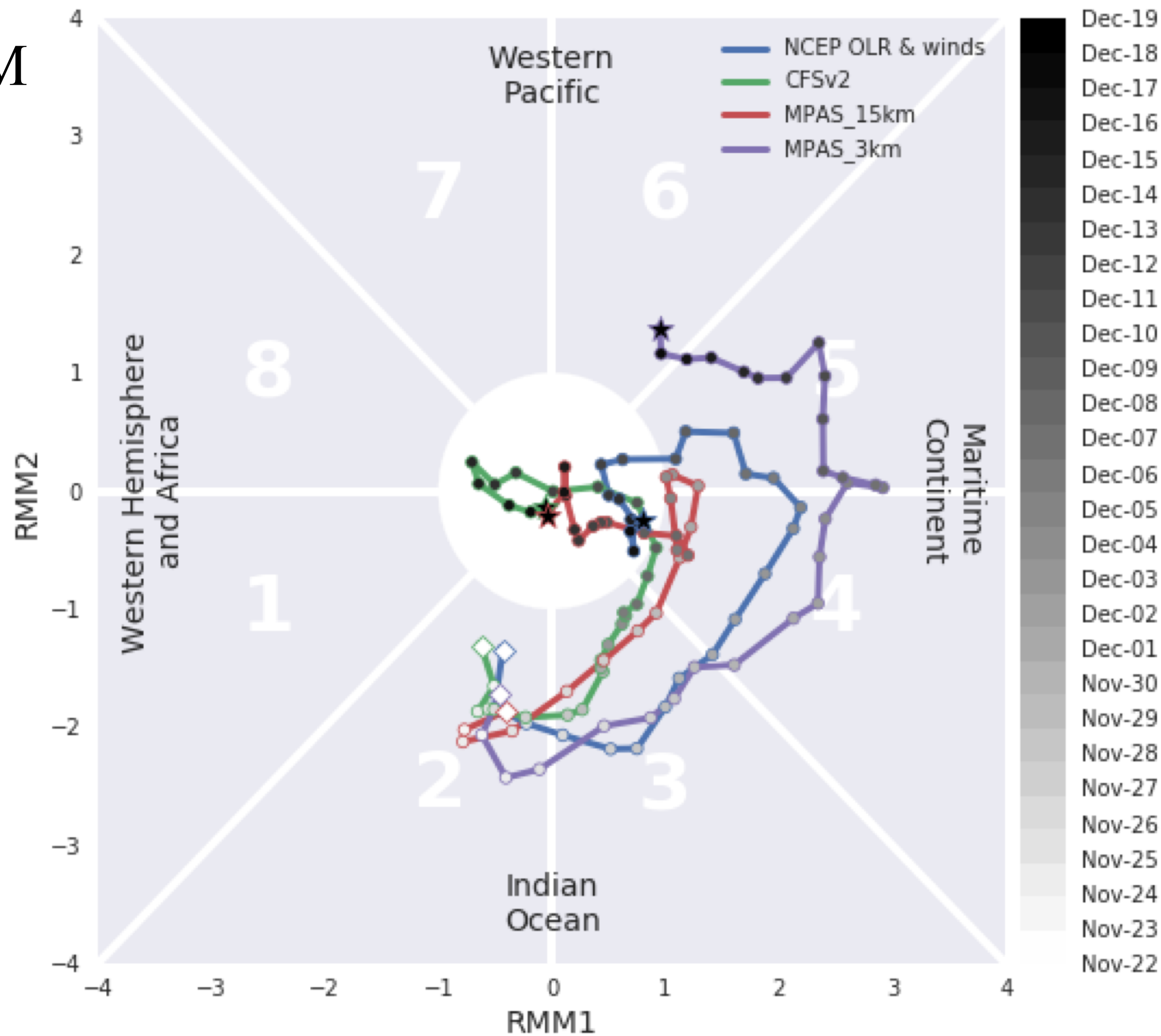
2. Improved MJO? -- Case 1

zonal wind – 200 hPa



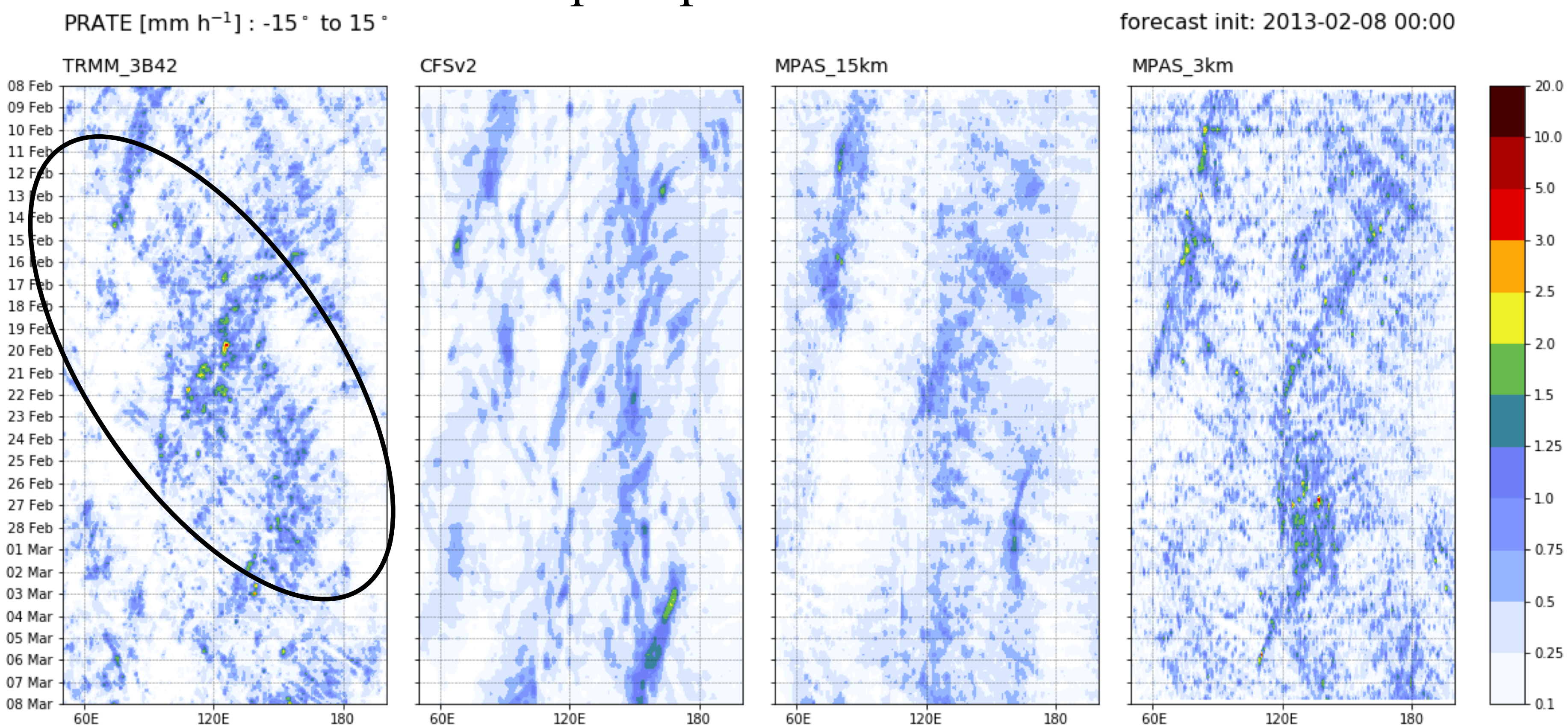
2. Improved MJO? -- Case 1

MJO RMM indices:



2. Improved MJO? -- Case 2

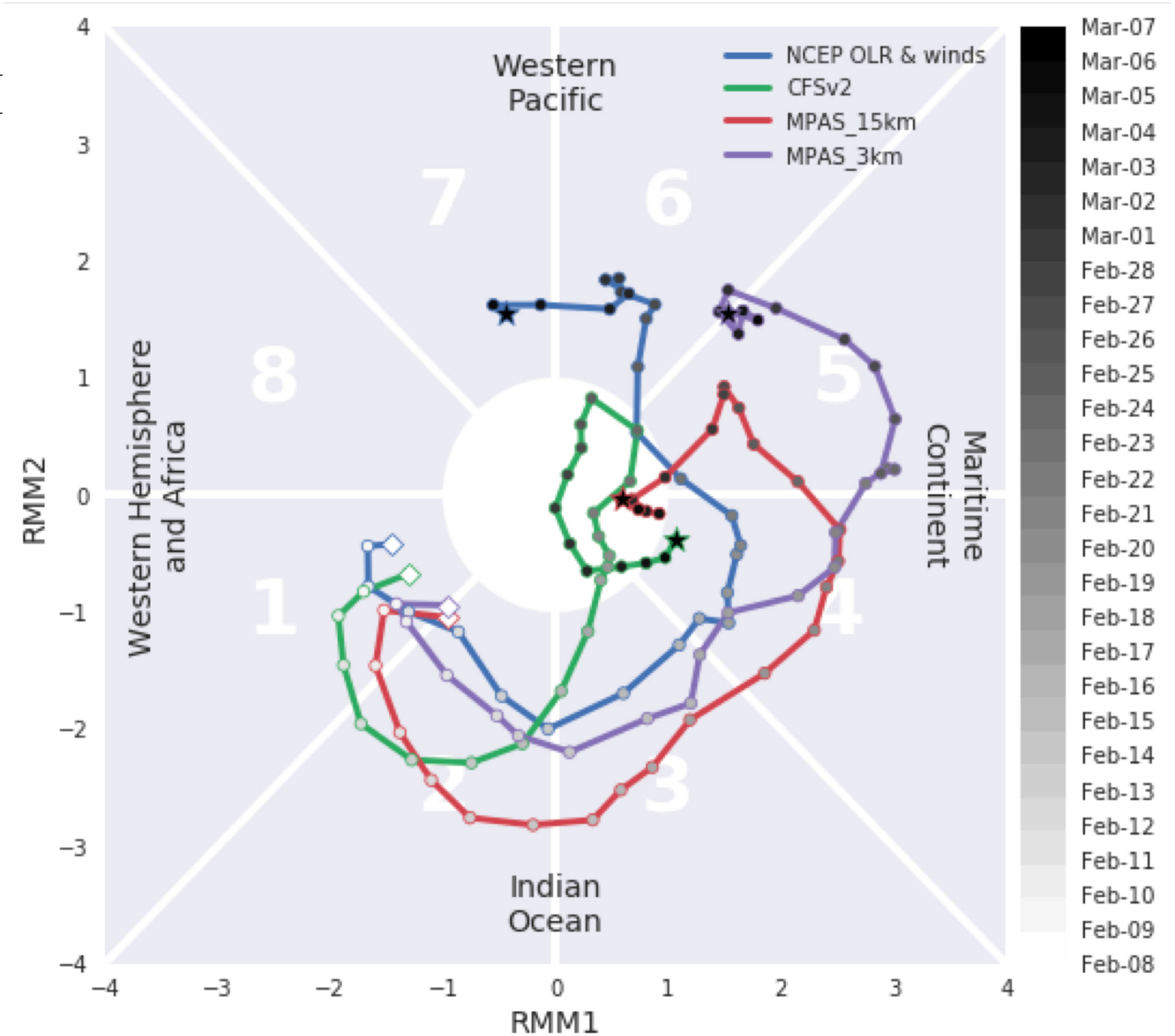
precipitation rate



- Eastward propagation missed by all simulations

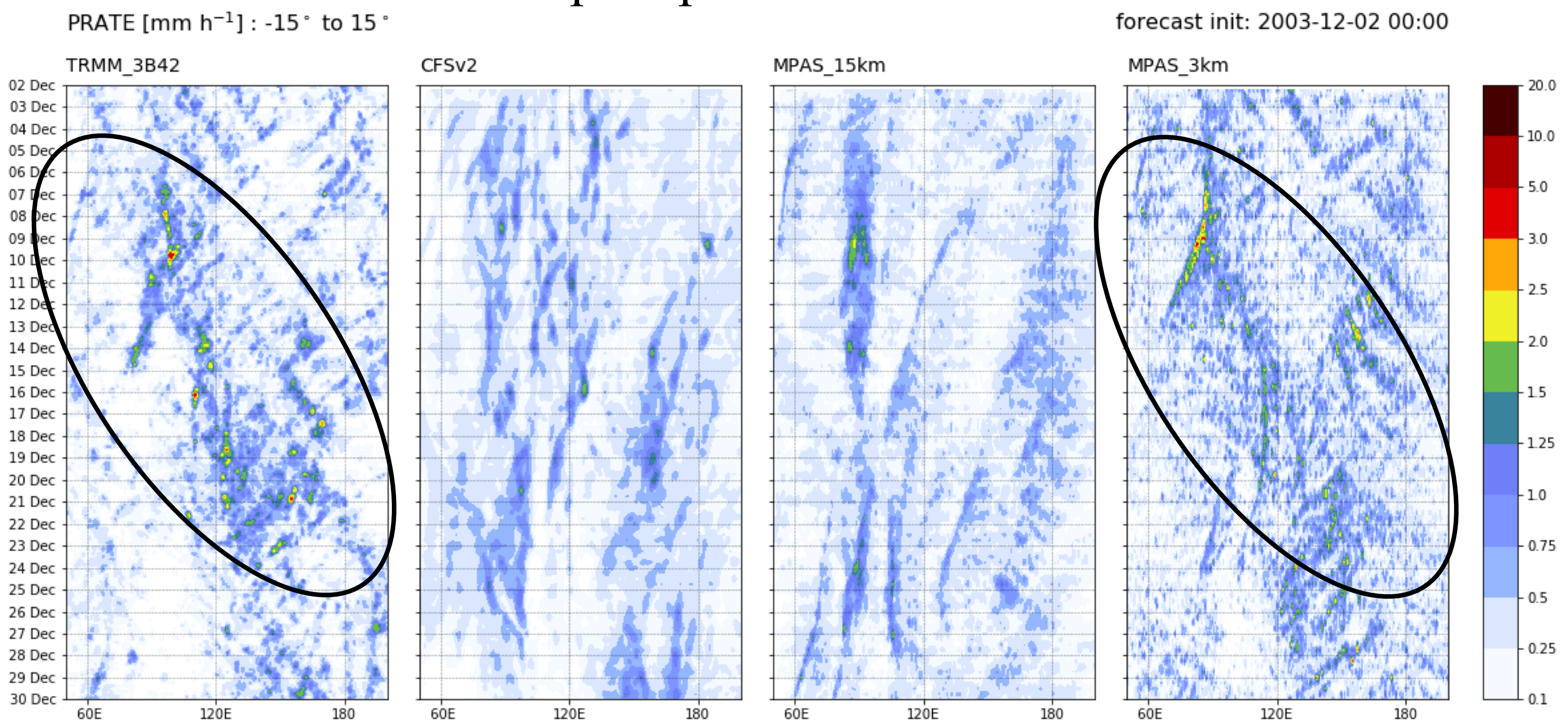
2. Improved MJO? -- Case 2

MJO RMM indices:



2. Improved MJO? -- Case 3

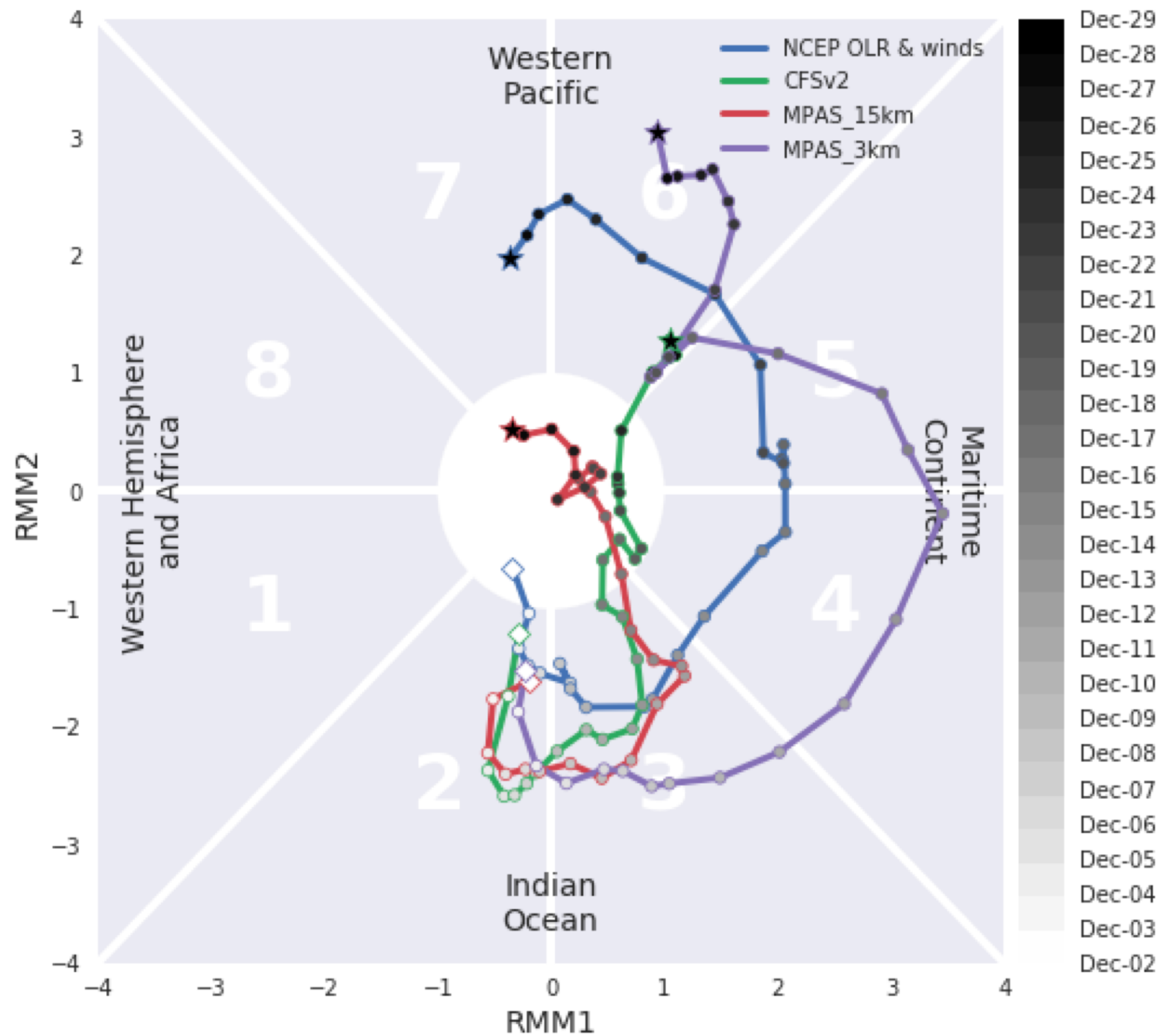
precipitation rate



- Eastward propagation only captured by 3-km simulation

2. Improved MJO? -- Case 3

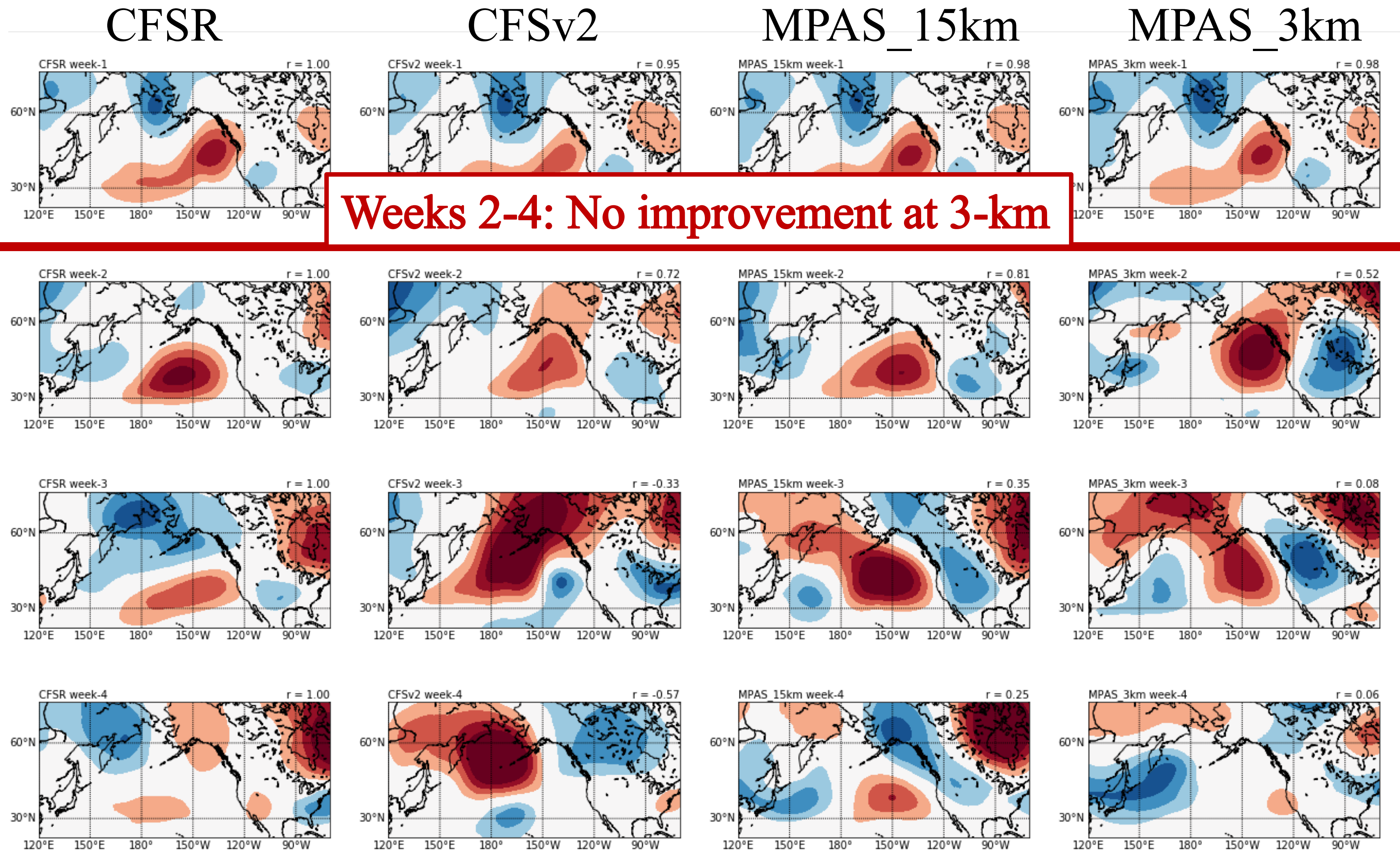
MJO RMM indices:



3. Improved extratropics? -- Case 1

CFSR CFSv2 MPAS 15km MPAS 3km

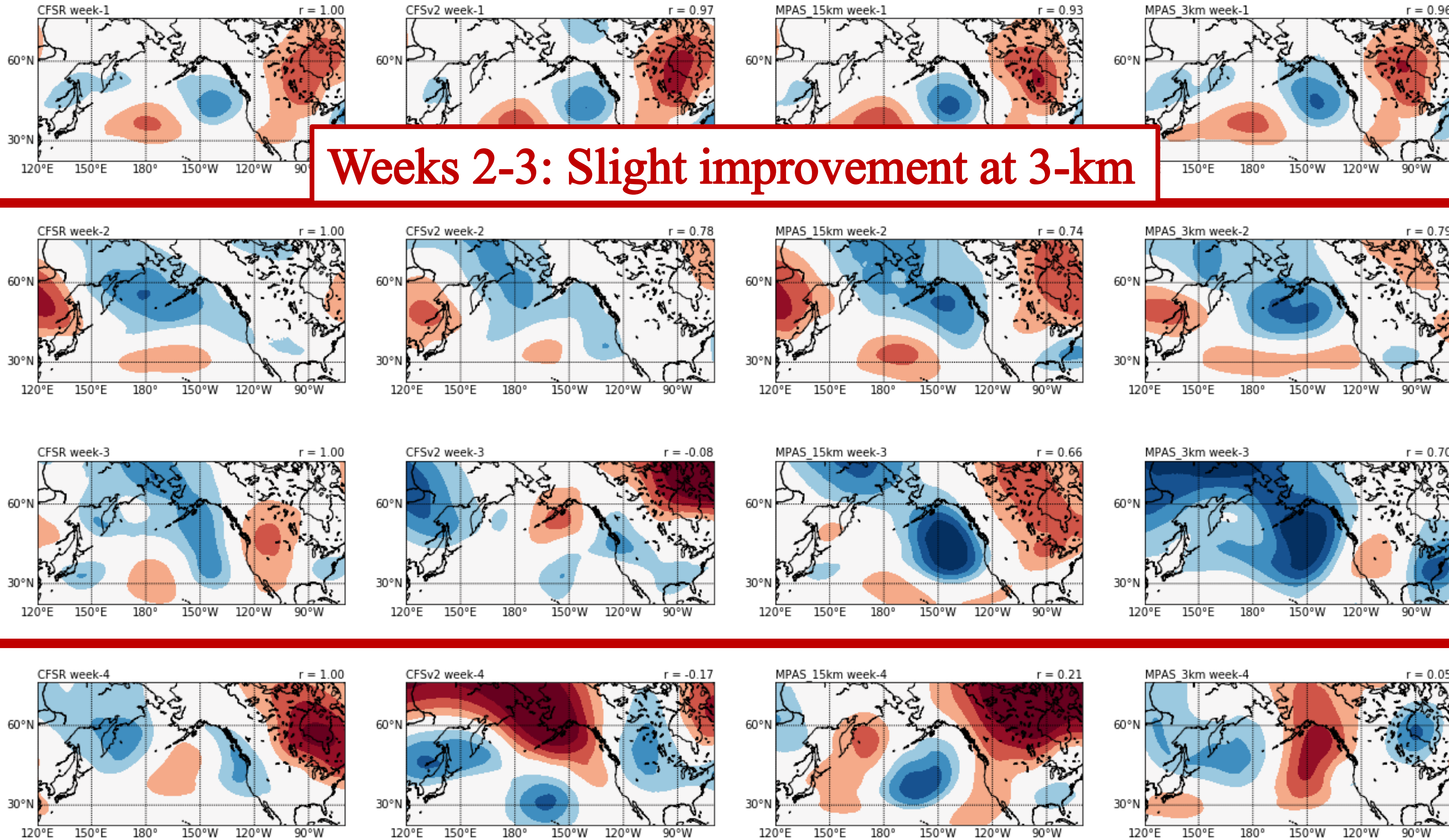
3. Improved extratropics? -- Case 2



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

Questions?

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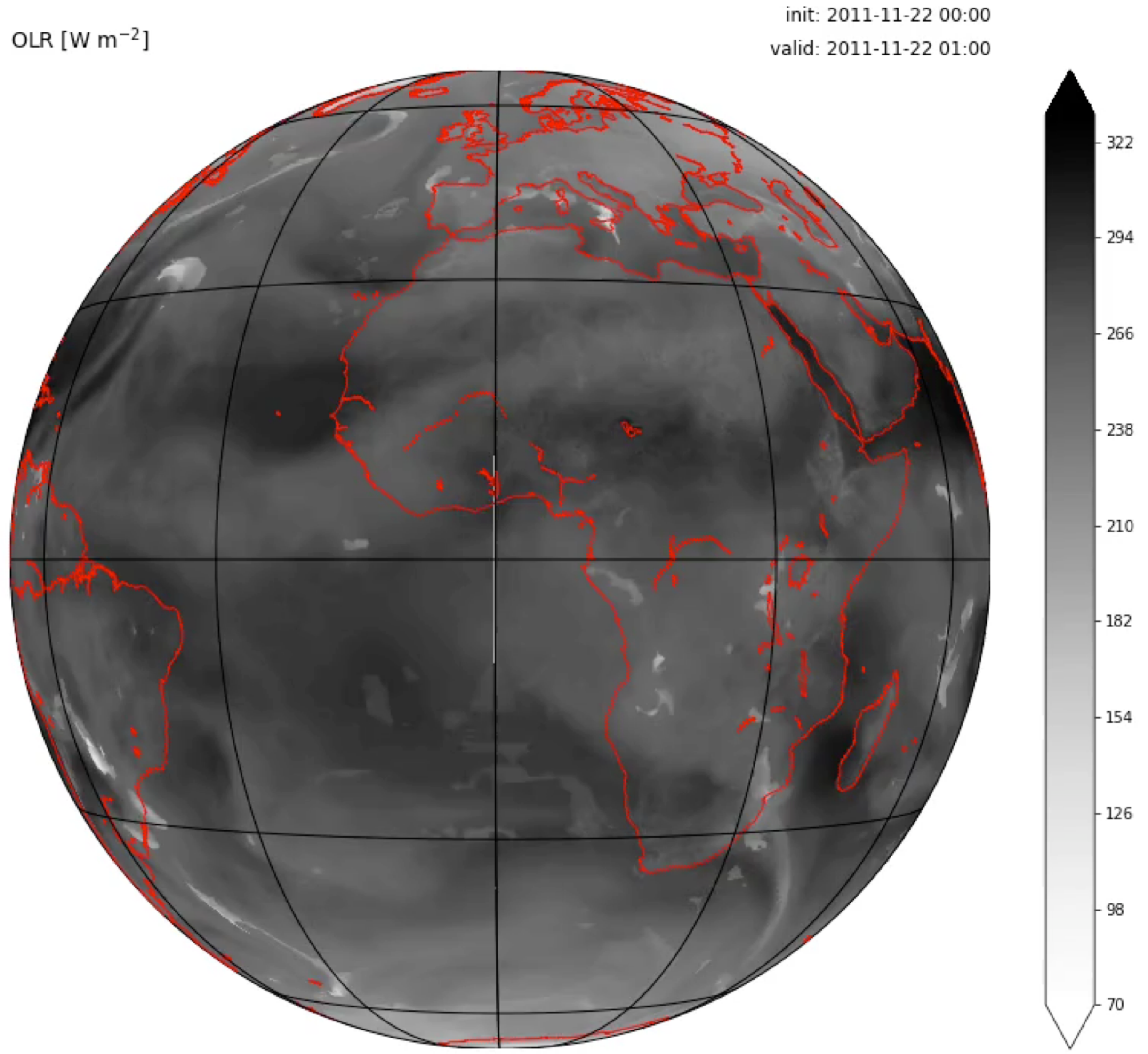
Extra

Slides

MPAS OLR

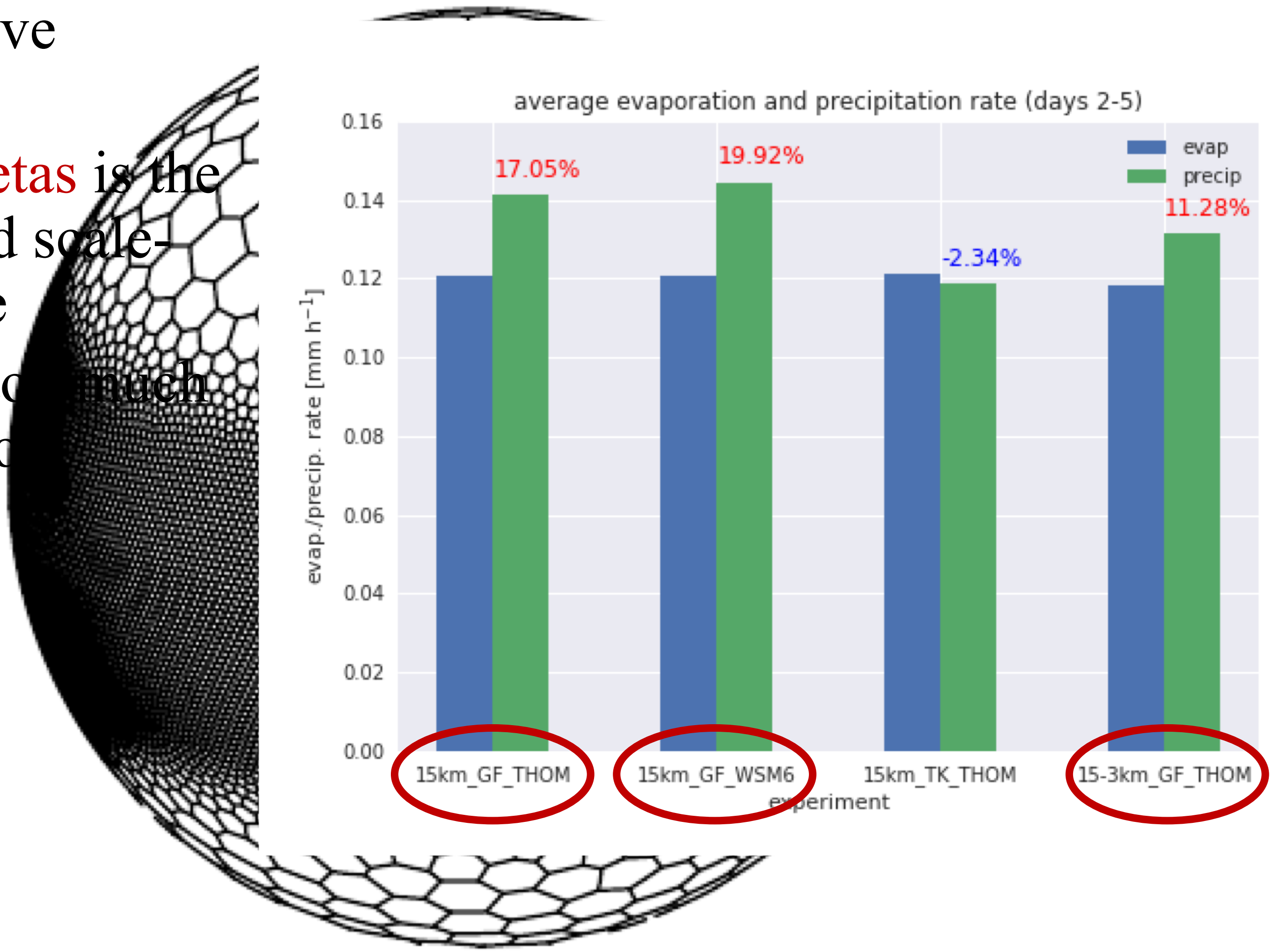

OLR [W m^{-2}]
init: 2011-11-22 00:00
valid: 2011-11-22 01:00
322
294
266
238
210
182
154
126
98
70

Computer resources per run

- Supercomputer: Cheyenne (5.34 petaflops)
- Run on 1024 nodes → 36,864 cores
- Core hours: 2.7 million
- Wall clock: 74 hours
- Output: ~80TB

Why not use a "tropical channel" mesh?

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



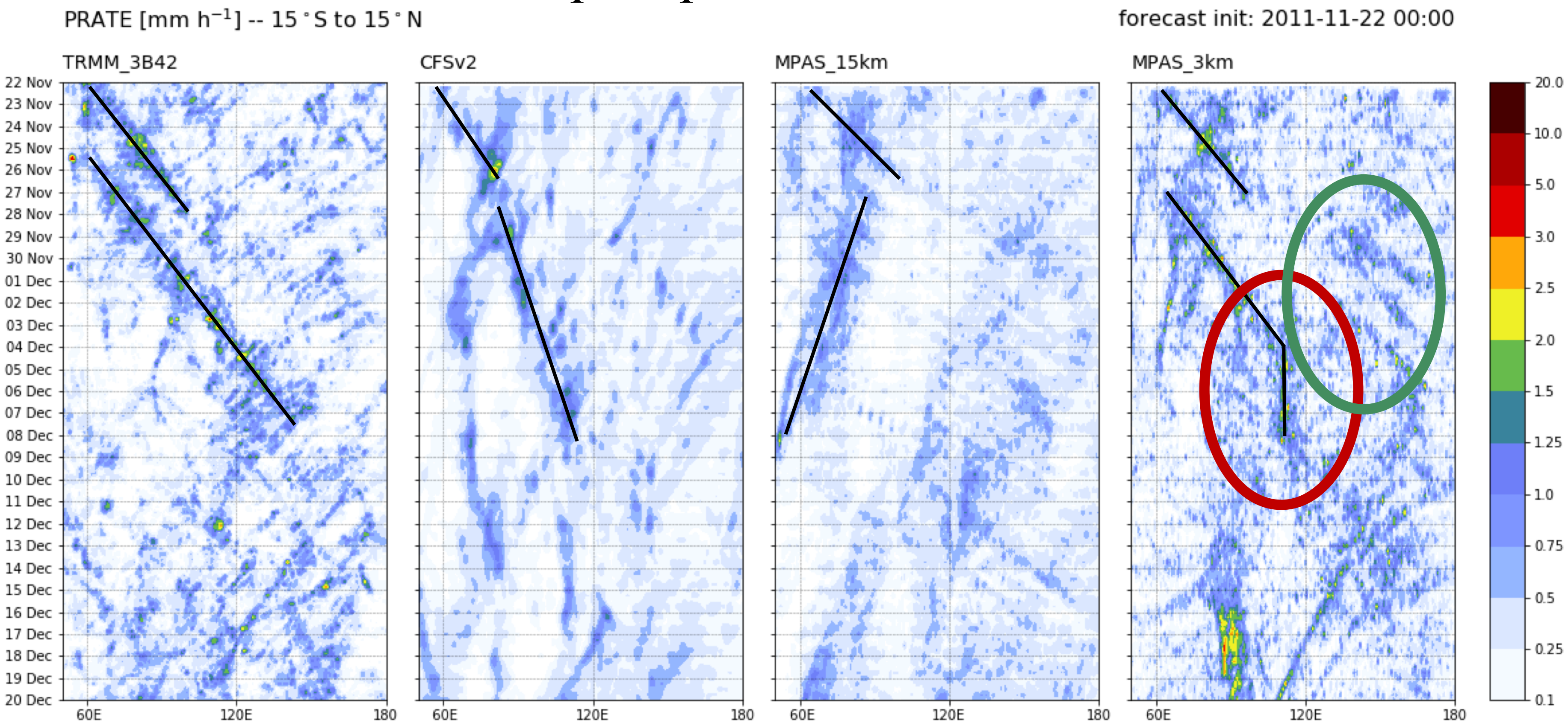
Physics parameterizations

- ***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

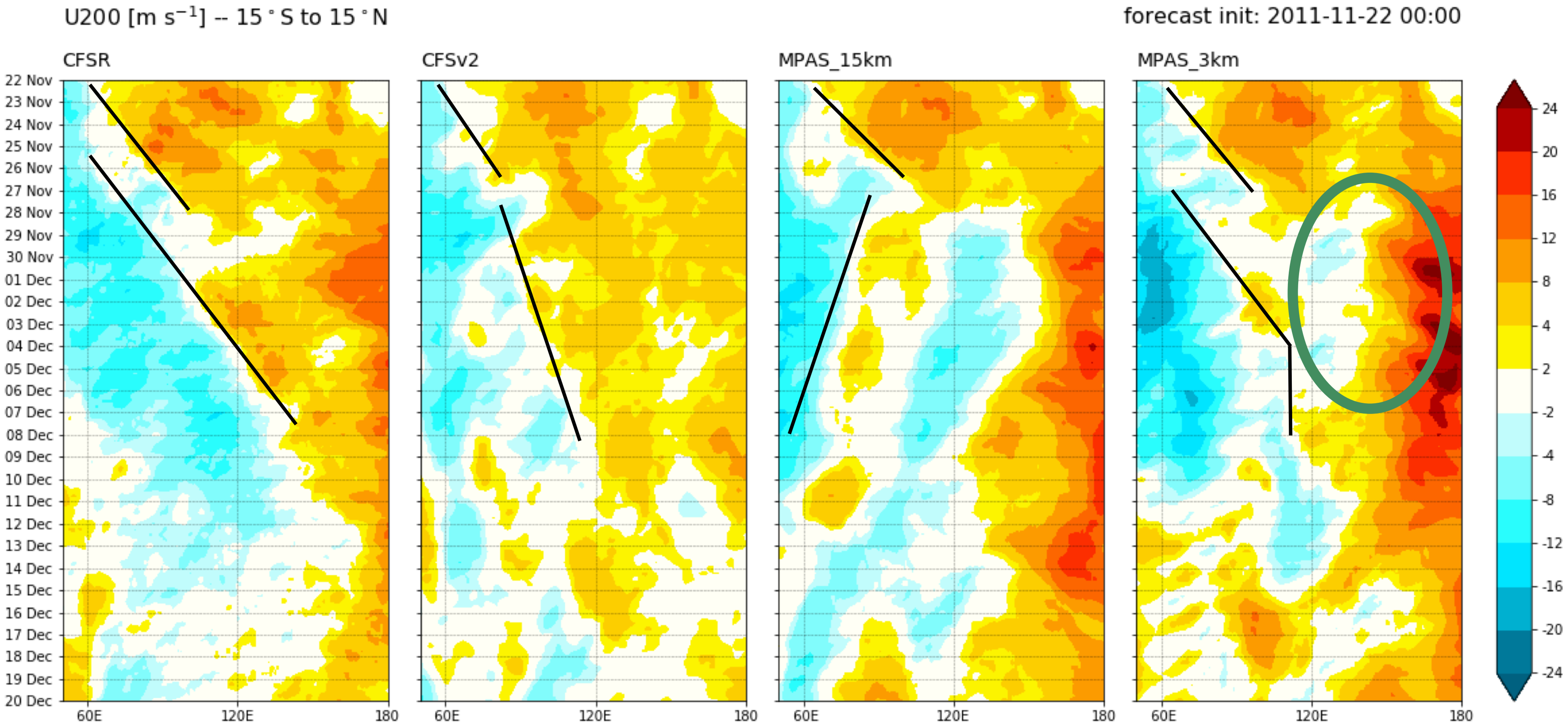


Propagation halts over M.C. – Why?

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

M.C. barrier in MPAS_3km – Case 1

zonal wind – 200 hPa

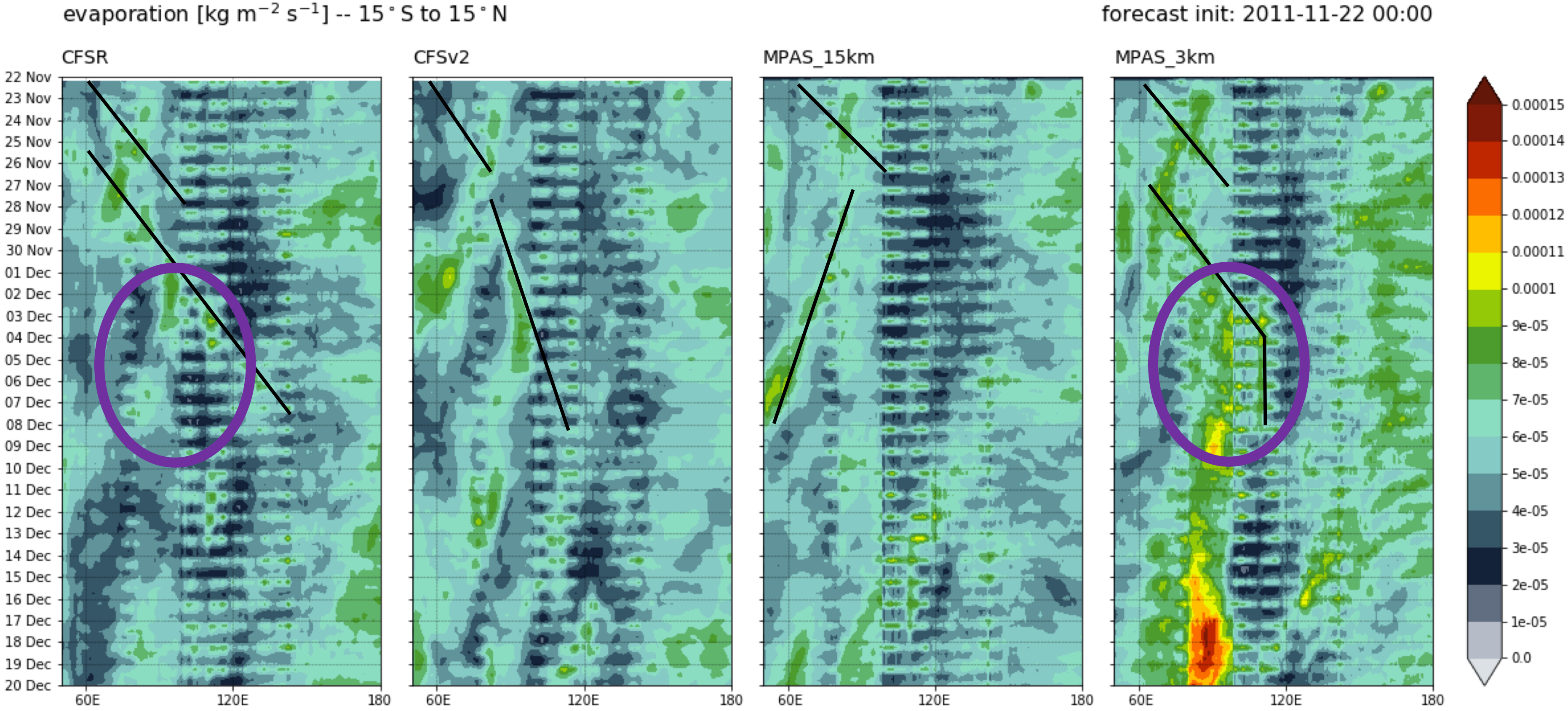


Theory #1: Preceding convection over M.C./W. Pacfic

M.C. divergence disrupts MJO outflow

M.C. barrier in MPAS_3km – Case 1

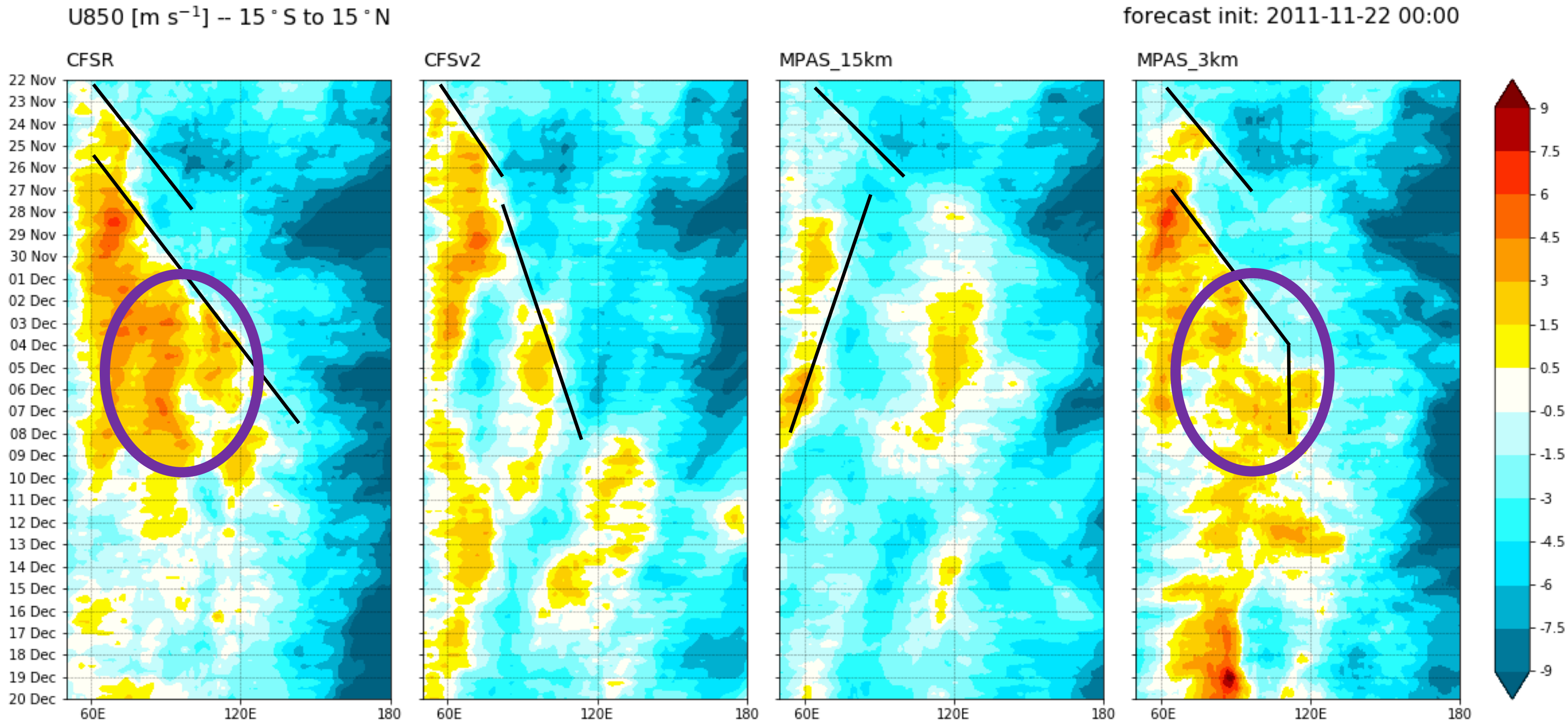
evaporation rate



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.

Currently being investigated:

- "Why does the 15-km simulation fail to produce the eastward-propagating Kelvin waves (and thus an MJO)?"
- "Why does the 3-km MJO stall over the M.C.?"
- "What component(s) of the overall moisture tendency is/are captured better in the 3-km simulation?"
- "Will prescribed SSTs improve surface fluxes and thus MJO propagation?"
- "Is the improved PNA circulation tied to the MJO?" – Look at Rossby Wave Source
- Vertical latent heating/vertical motion profiles
- Moisture/convection coupling