Subseasonal prediction in a global convection-permitting model: insights and challenges in simulating tropical convection and extratropical teleconnections

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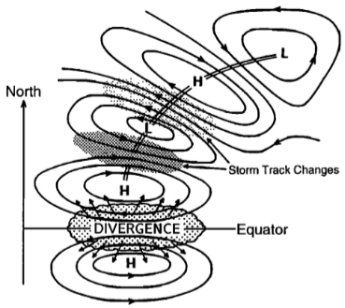
Section 1

Introduction

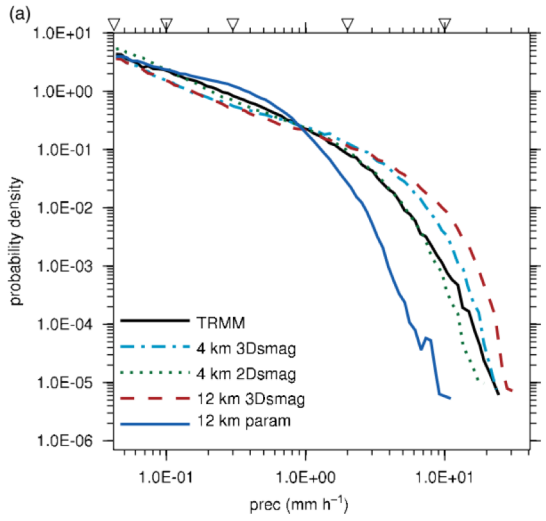
Why go to convection-permitting resolution?

Convection significantly impacts global circulation on many timescales (via teleconnections)[1-3]

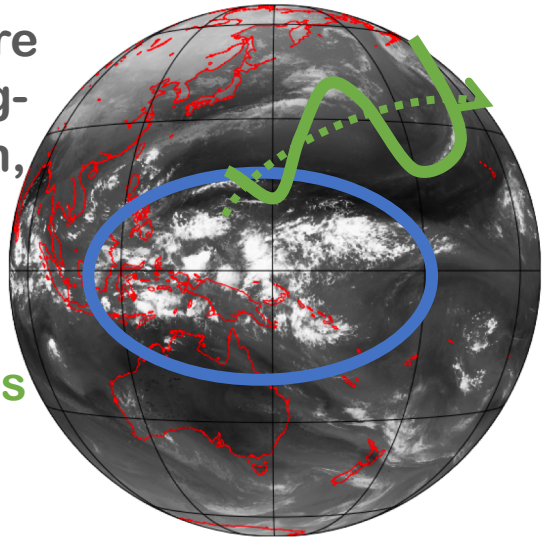


GCMs exhibit many issues associated with their parameterization of convection (e.g., diurnal cycle, frequent light precipitation, biases, and poor MJO propagation)[4-7]

Convection-permitting models (CPMs) mitigate many of these issues[8-11]



Global CPMs are perfect for long-term prediction, capturing both the convection *and* its teleconnections



[1]Trenberth et al. 1998; [2]Alexander et al. 2002; [3]Zhang 2013; [4]Dai and Trenberth 2003; [5]Holloway et al. 2012; [6]Pilon et al. 2016; [7]Weber and Mass 2017; [8]Prein et al. 2015; [9]Holloway et al. 2012; [10]Sato et al. 2009; [11]Miyakawa et al. 2014

Our simulations

- **The model: MPAS v5.1 (global)[1]**
- **Physics: 'convection_permitting' suite**
- **Four cases (all integrated 28 days):**
  - **November 22, 2011 (DYNAMO)**
  - **February 8, 2013**
  - **December 2, 2003**
  - **December 8, 2013**
- **Configurations:**
  - **15-km resolution, nTiedke Cu scheme**
  - **3-km resolution, no Cu scheme (Section 2)**
  - **15-km resolution, no Cu scheme (Section 3)**
  - **15-to-3-km tropical channel, Grell-Freitas (Section 4)**
- **FNL analyses used for ICs and BCs; SSTs fixed at initial value**

MPAS
Model for Prediction Across Scales

[1]Skamarock et al. (2012)

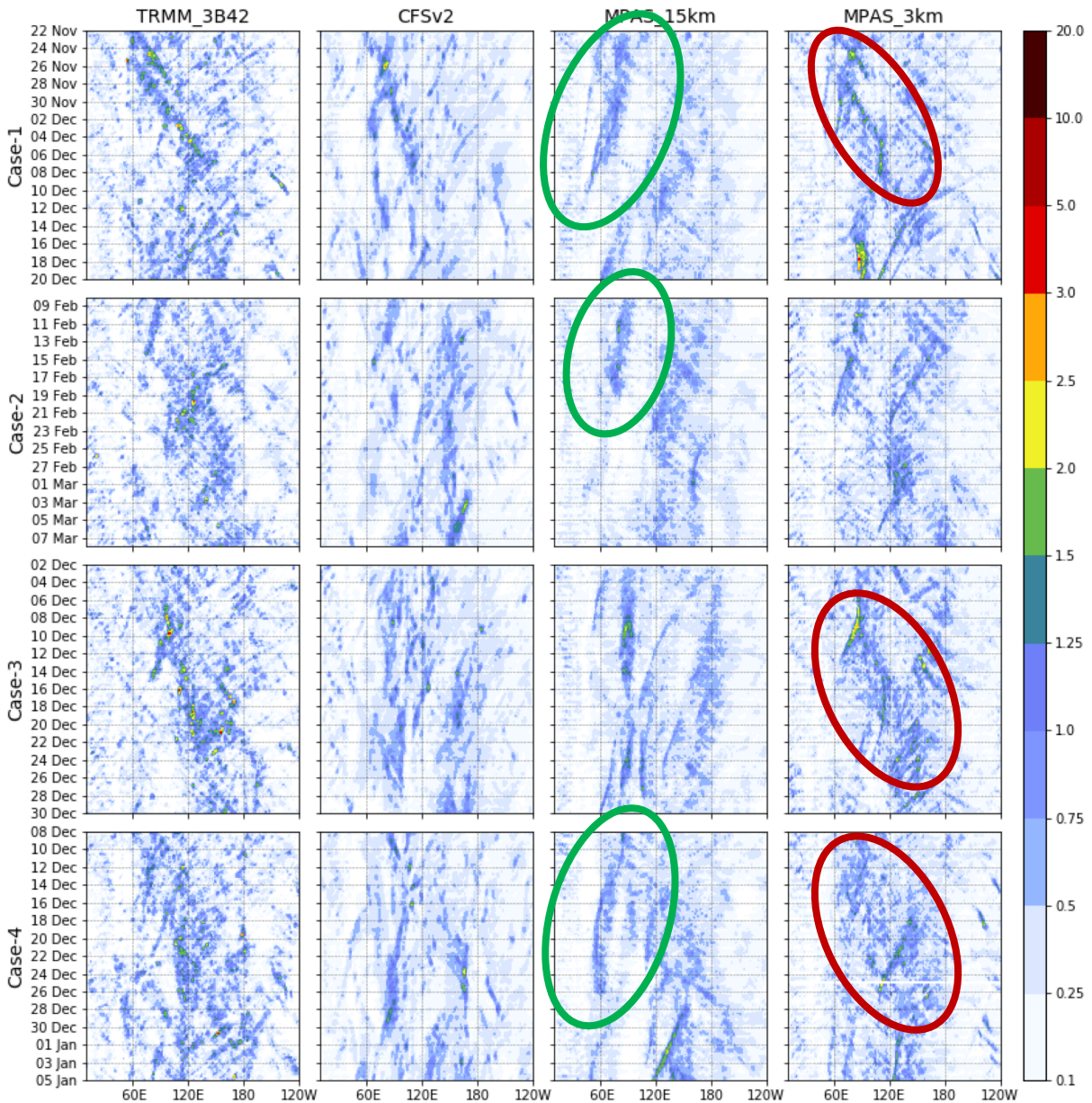
Section 2

Verifying the 3km and 15km MPAS

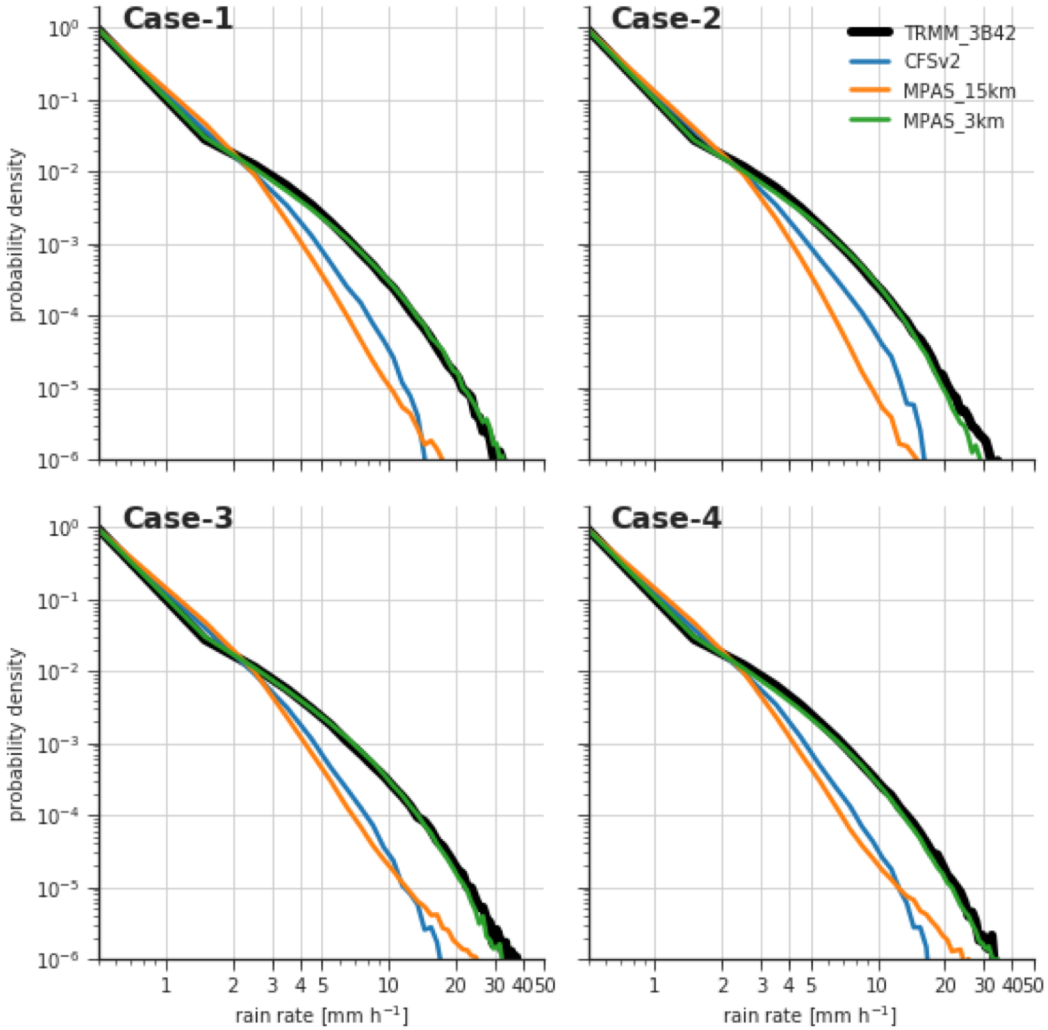
MJO simulation

Precipitation (mm/h) Hovmöllers (15S-15N) reveal:

- **Weaker, more widespread rain in models with parameterized convection**
- **Improved eastward MJO propagation in 3km model for three cases**
- **Favored westward propagation in 15km simulations**

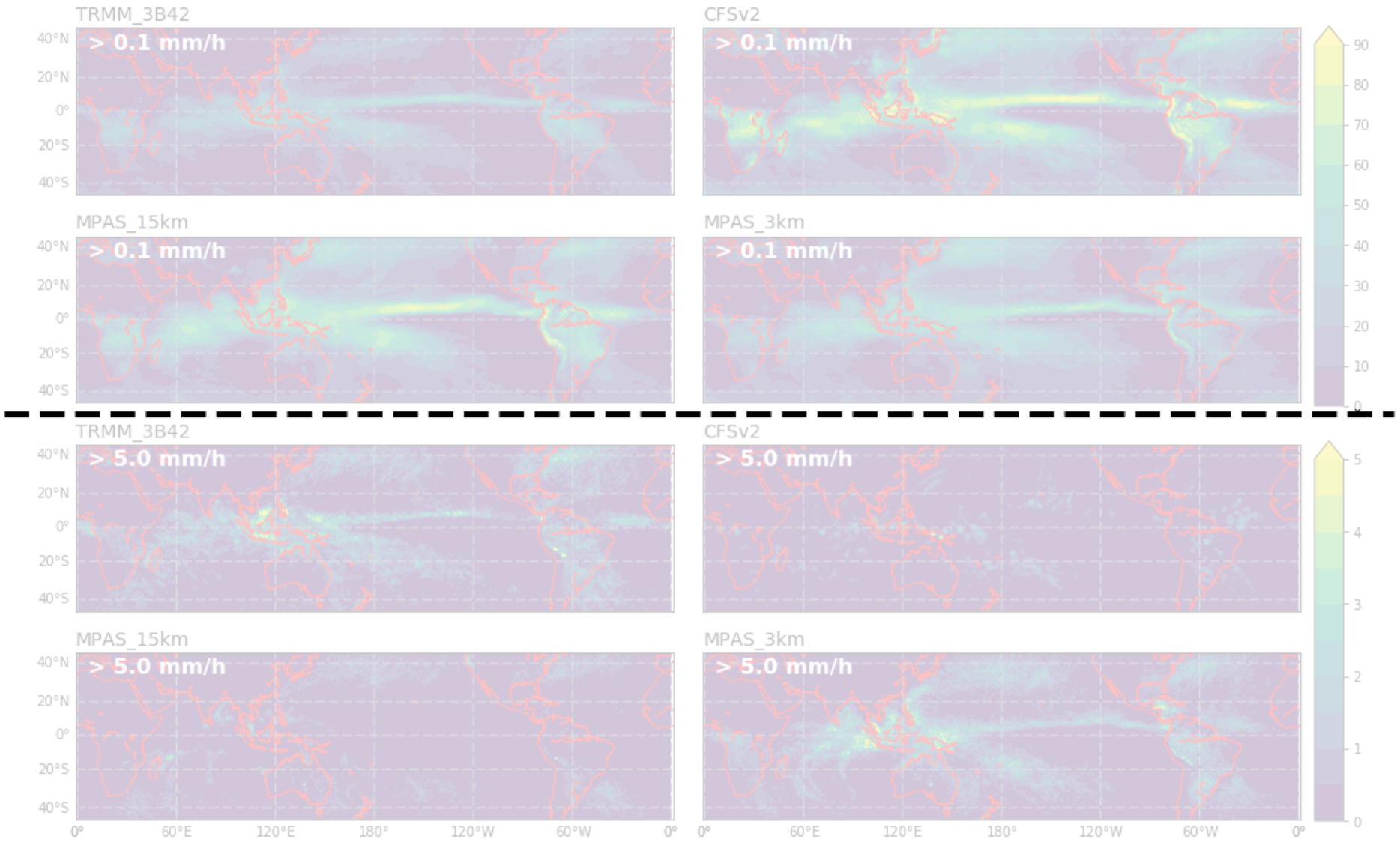


Precip. statistics: Rain rate distribution

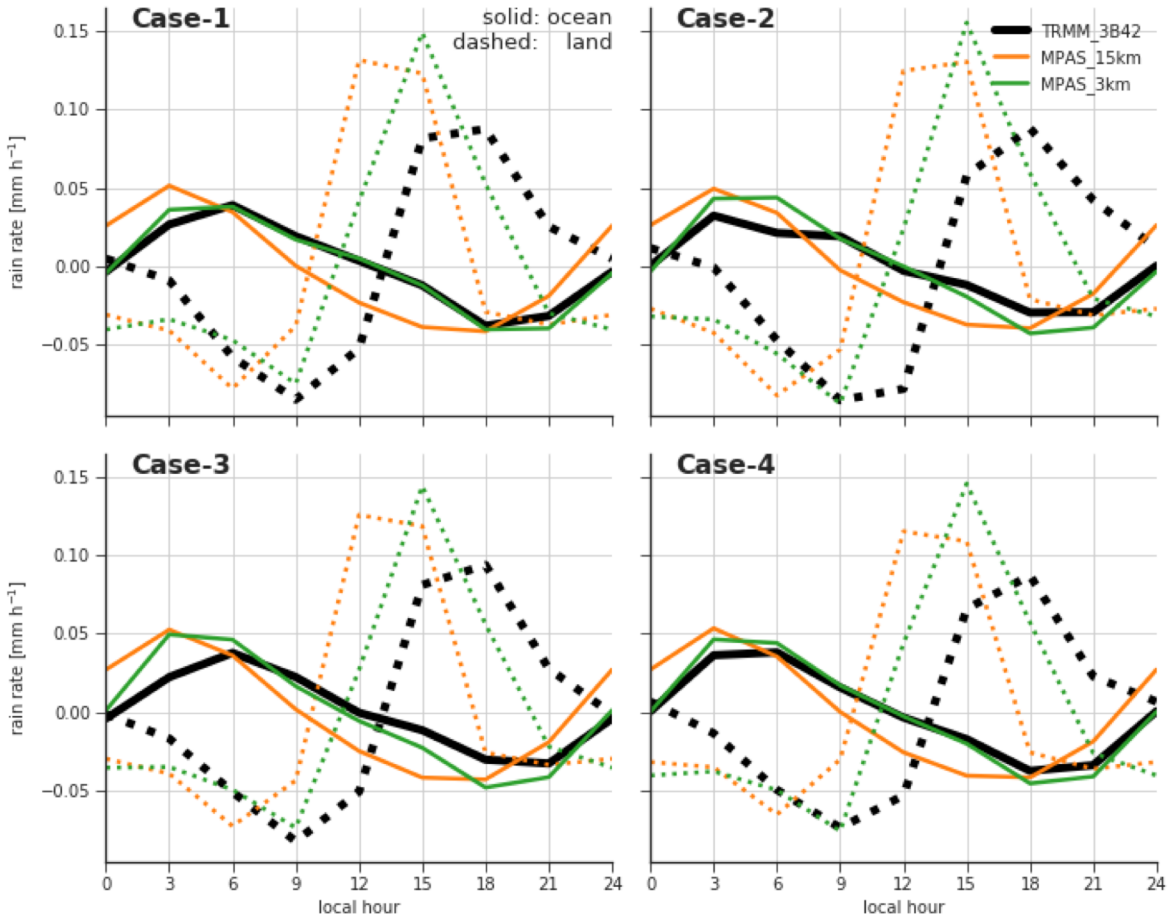


- **CFS and 15km MPAS produce too much (little) light (heavy) precipitation**
- **3km MPAS closely matches TRMM estimates**

Precip. statistics: Rain frequency (%)



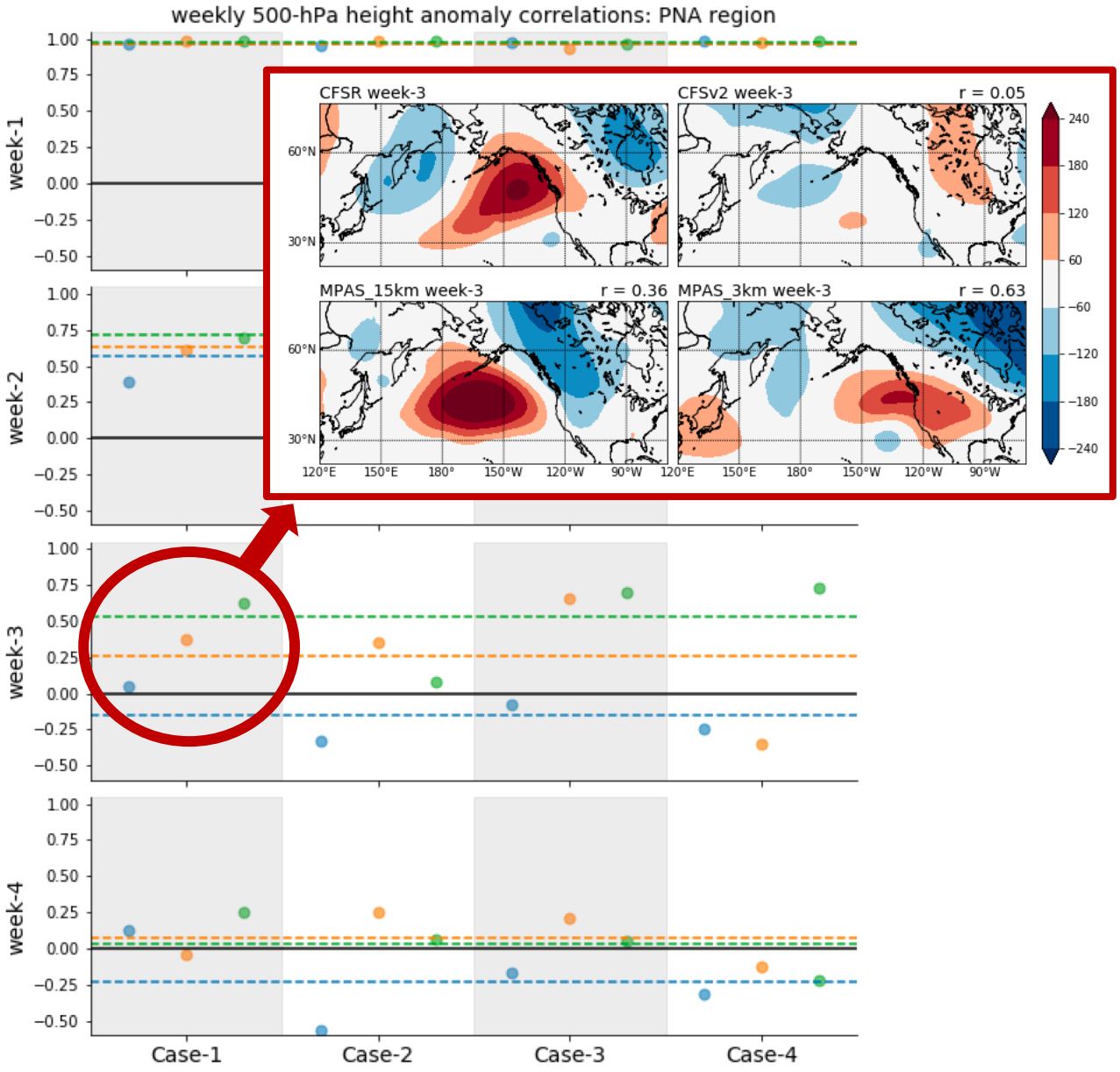
Precip. statistics: Diurnal cycle



- **Improvement in diurnal timing over both land and water**
- **Amplitude over land is still overestimated**

Extratropical skill: weekly Z500 scores

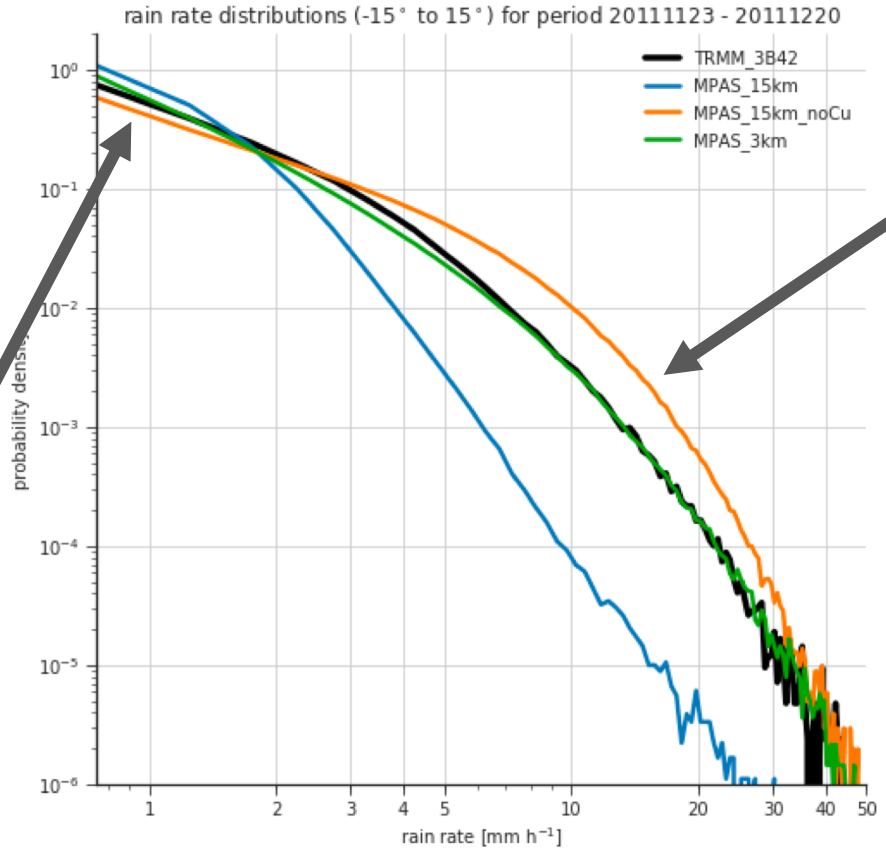
- The bulk of the improvement is in week-3
- Similar results over the entire Northern Hemisphere



Section 3

What happens in a coarse-resolution, convection-allowing run?

Precipitation rates



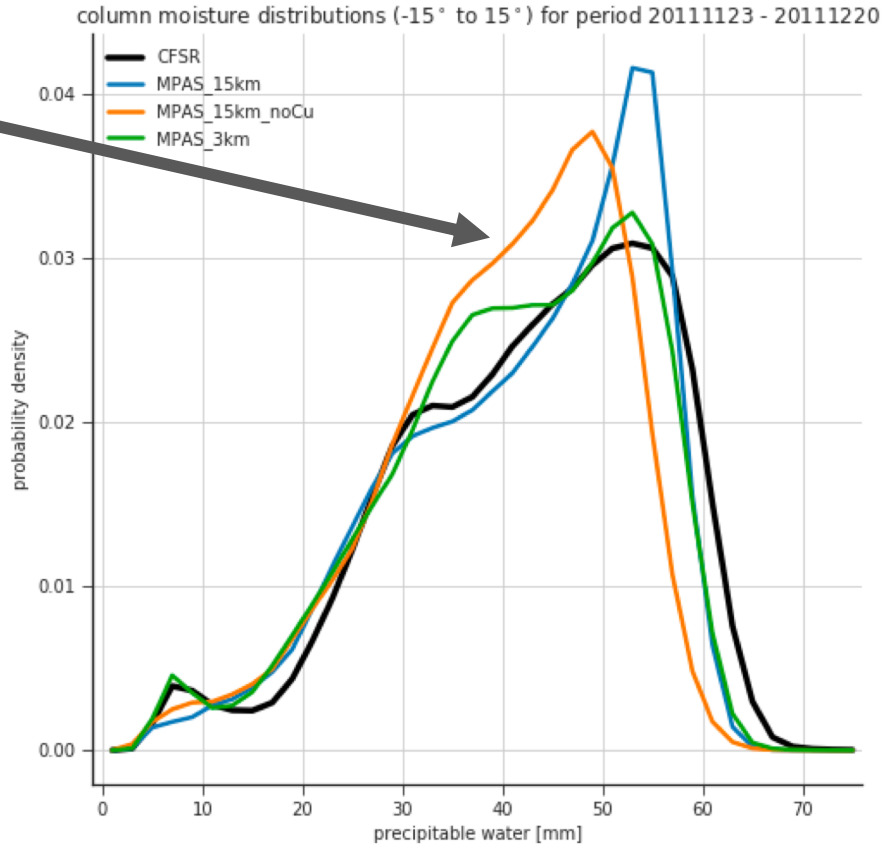
Too much heavy precipitation

Too little light precipitation

***Identical results for all four cases**

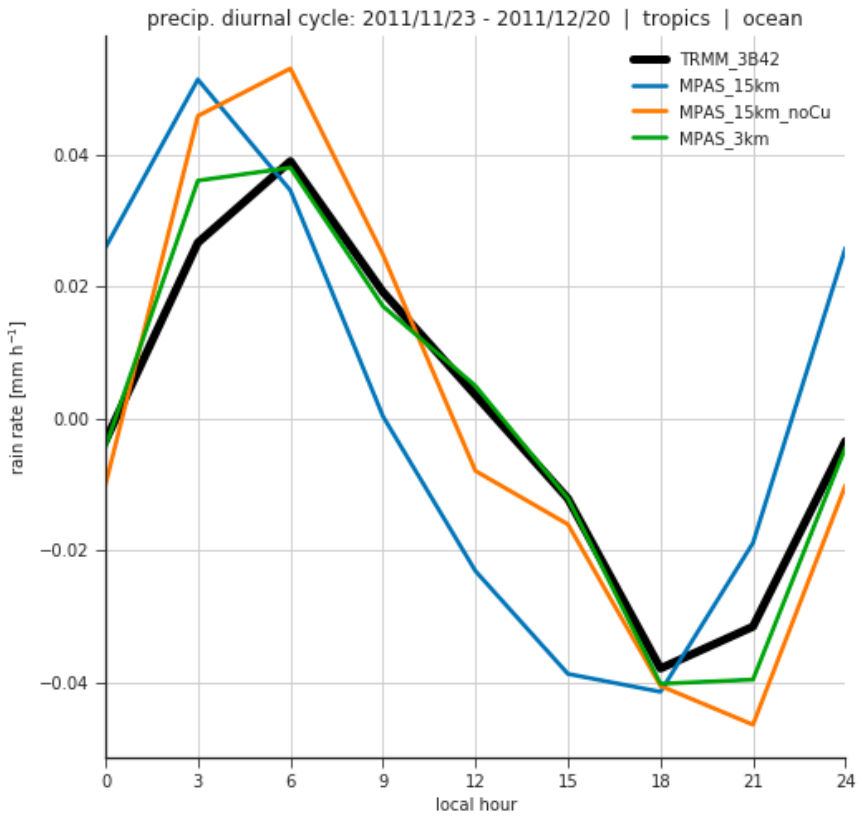
Tropical moisture

Way too dry

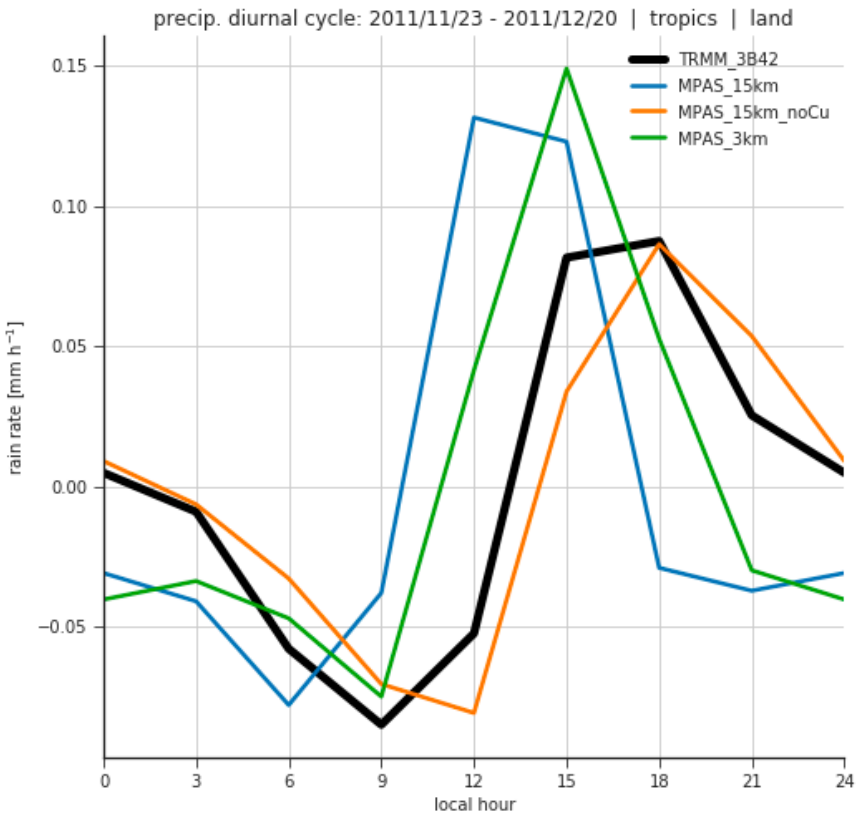


Diurnal cycle

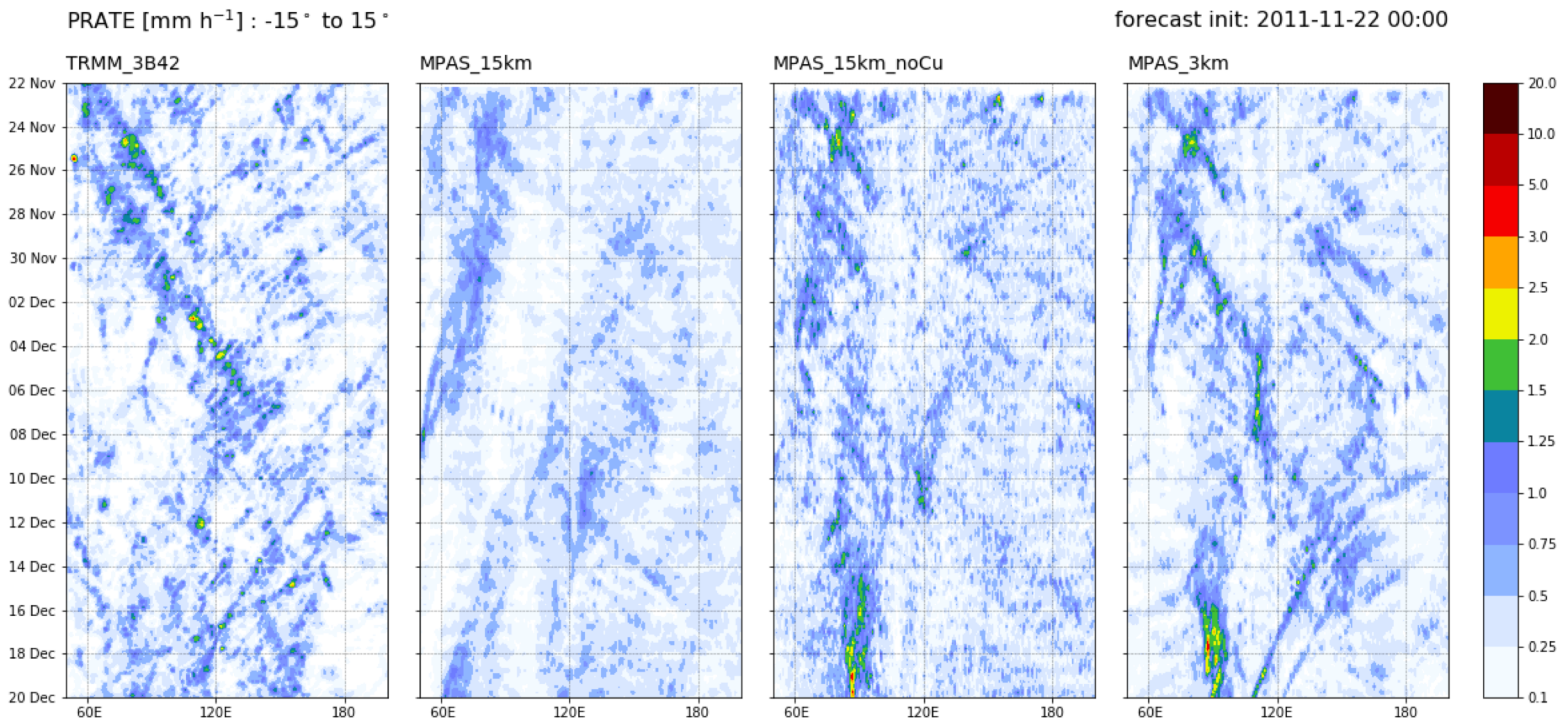
Slight amplitude overestimation over ocean



Significant *improvement* in timing and amplitude over land

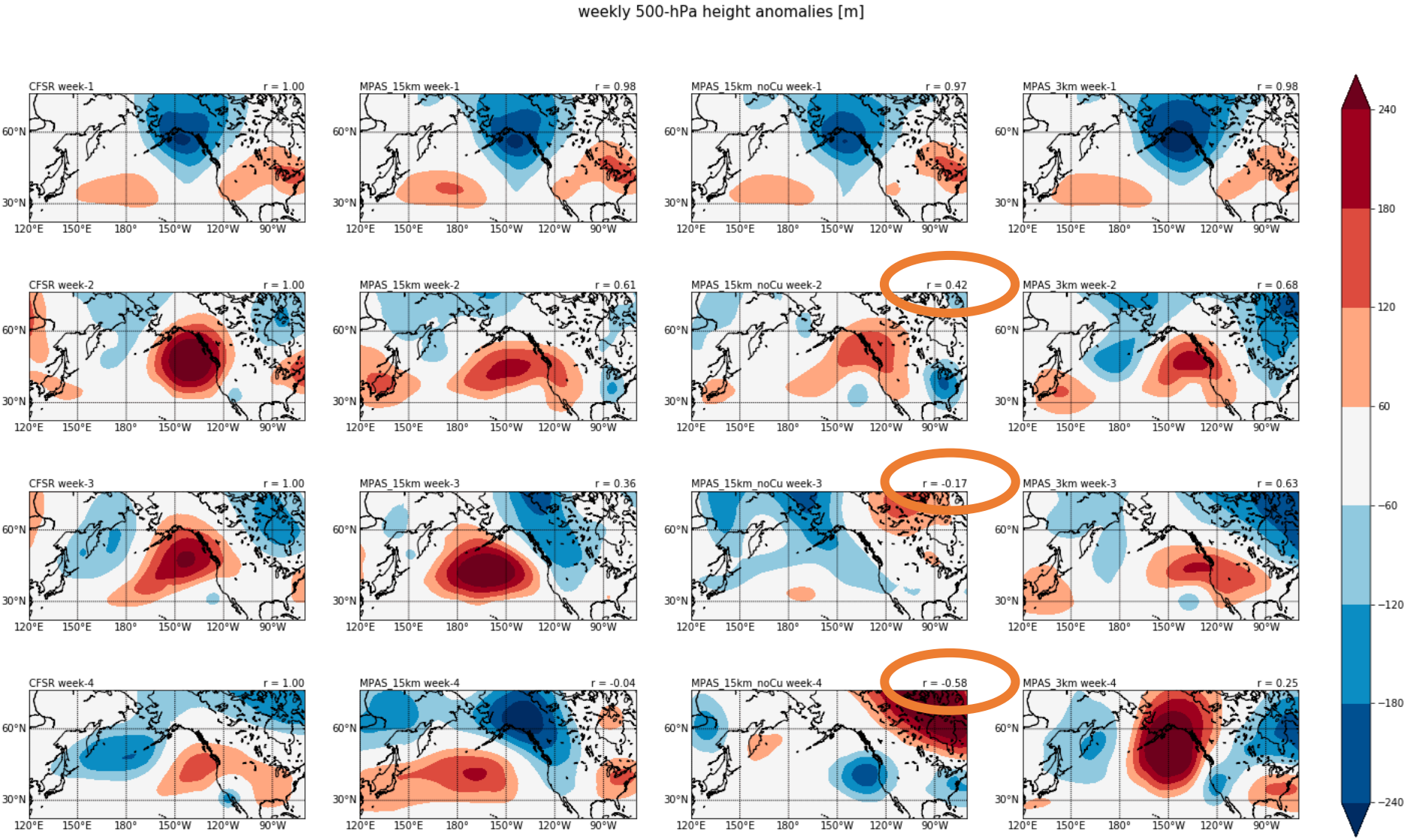


MJO propagation



- **15-km no-Cu-scheme fails to capture the eastward propagation**
- **Similar results for all four cases**

Subseasonal extratropical skill



- **Weak anomaly correlations for the 15-km no-Cu-scheme run**

Section 4

What if we resolve convection only in the tropics?

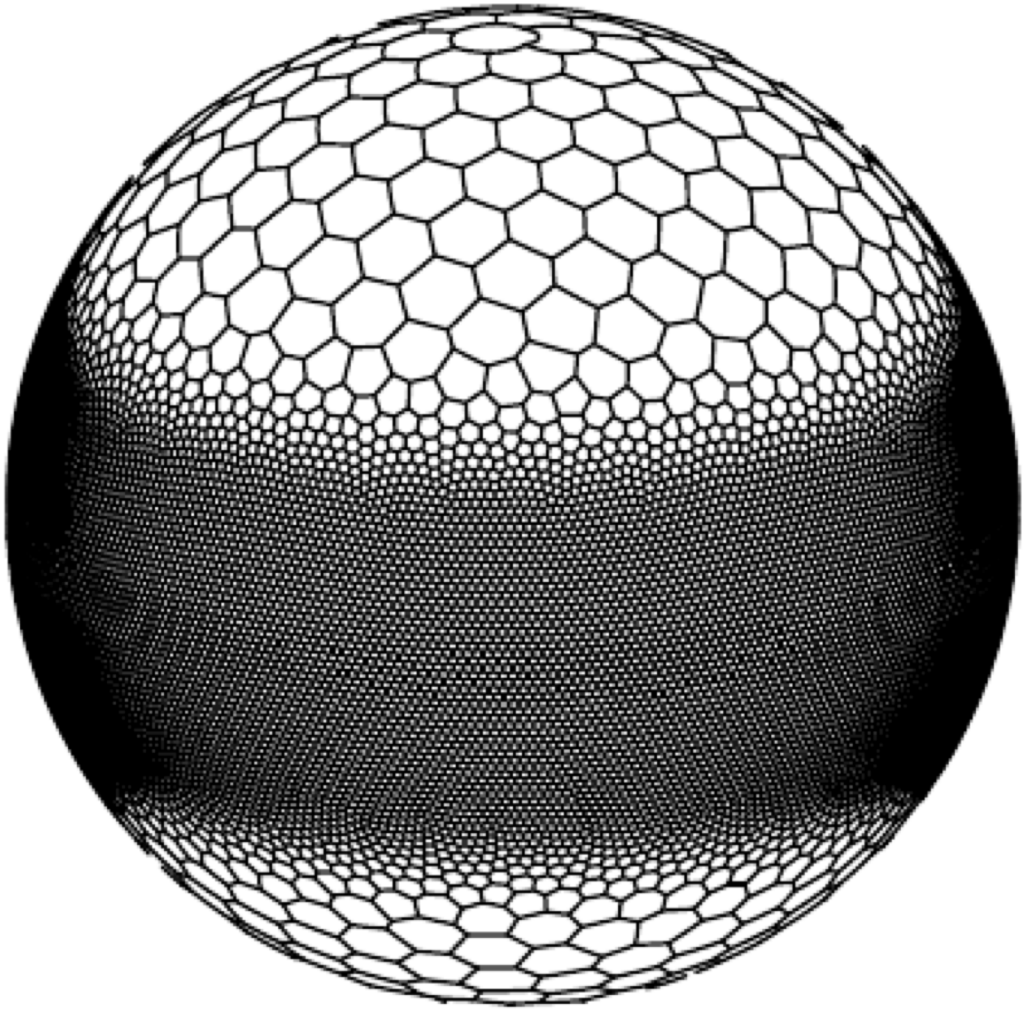
Channel configuration

15-km resolution

20N

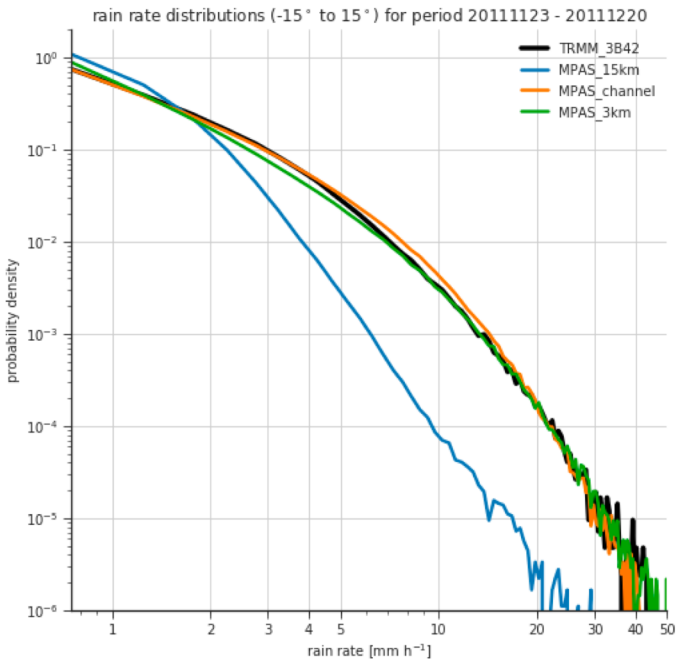
3-km resolution

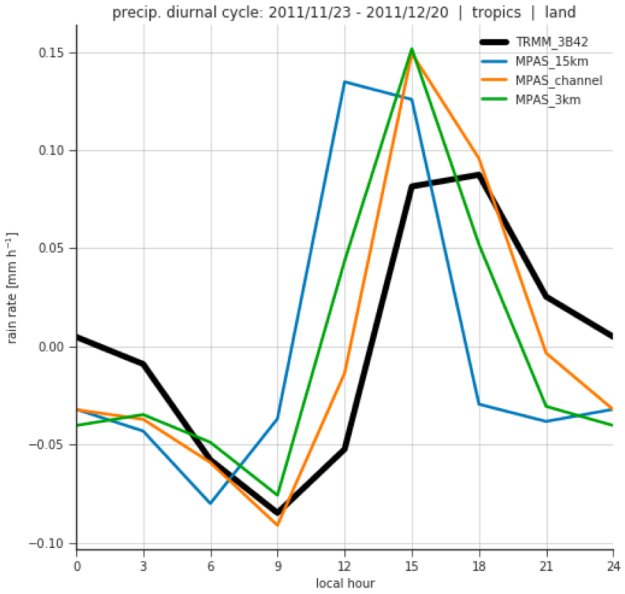
20S

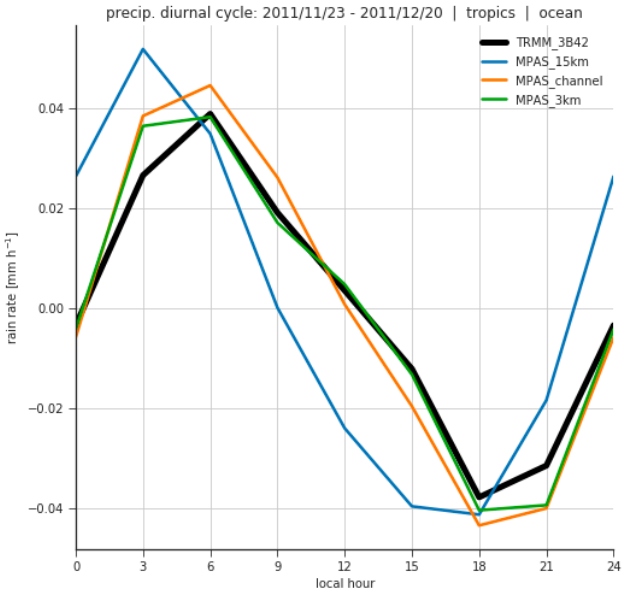


15-km resolution

Precipitation statistics

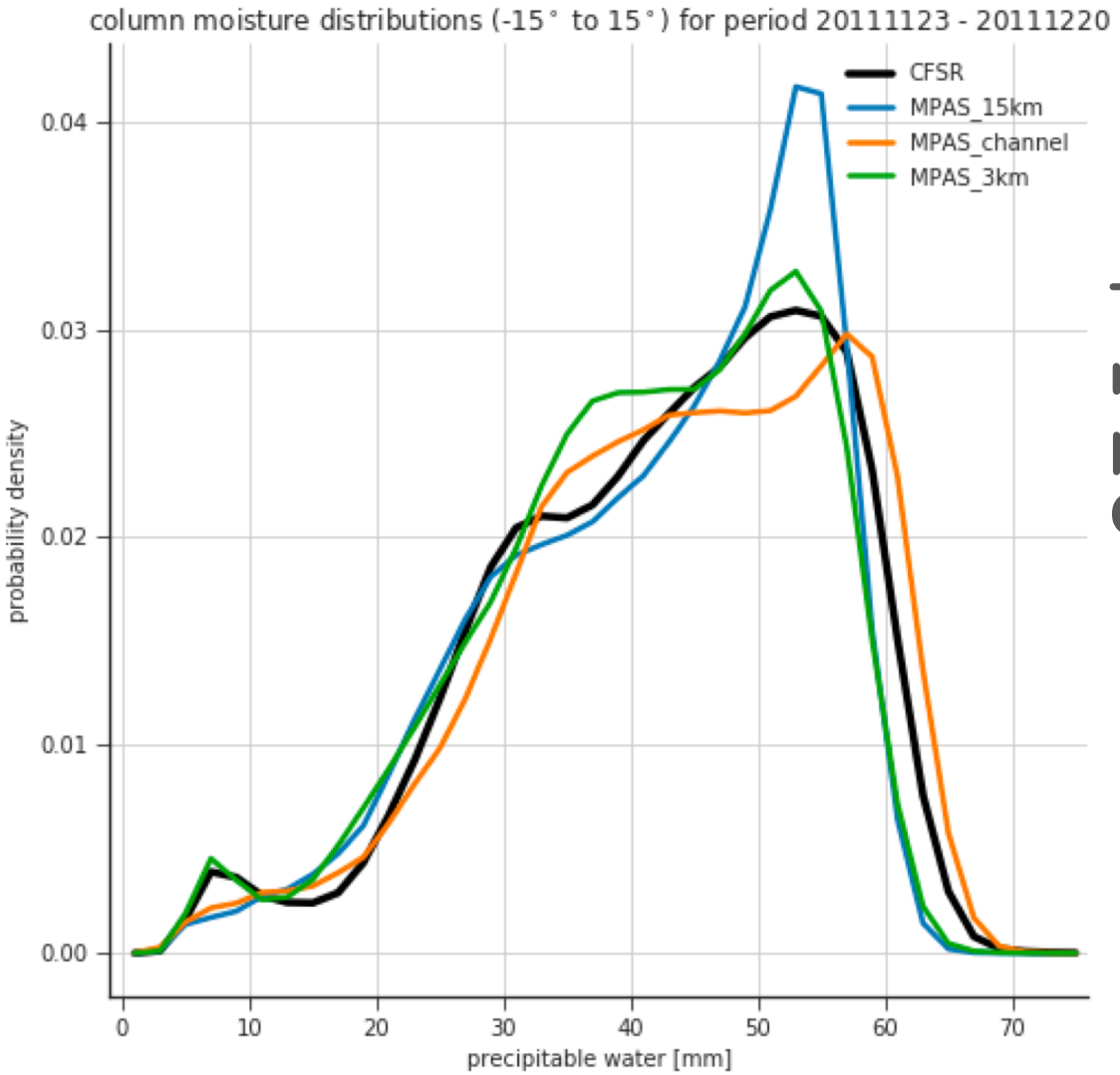






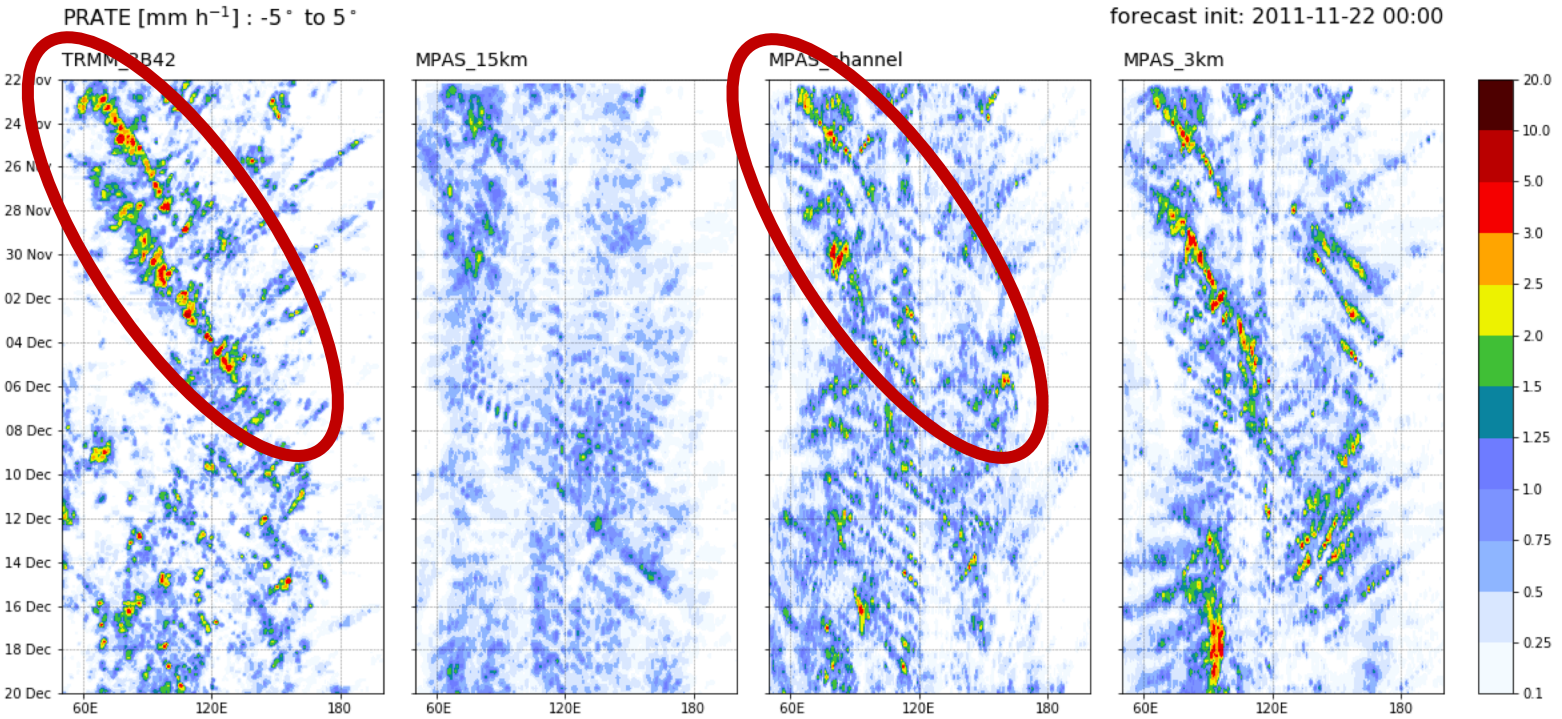
Tropical rain rate distribution, land diurnal cycle, and ocean diurnal cycle are all comparable to the 3-km global simulation

Column moisture

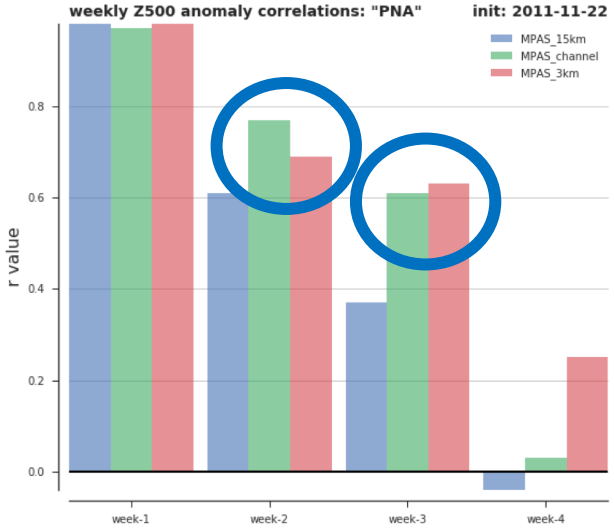


Too much moisture produced by GF scheme

MJO and subseasonal extratropical skill



- MJO propagation **not well-captured** in the channel run
- But **good Z500 prediction** in the PNA region for week-2 and week-3



Section 5

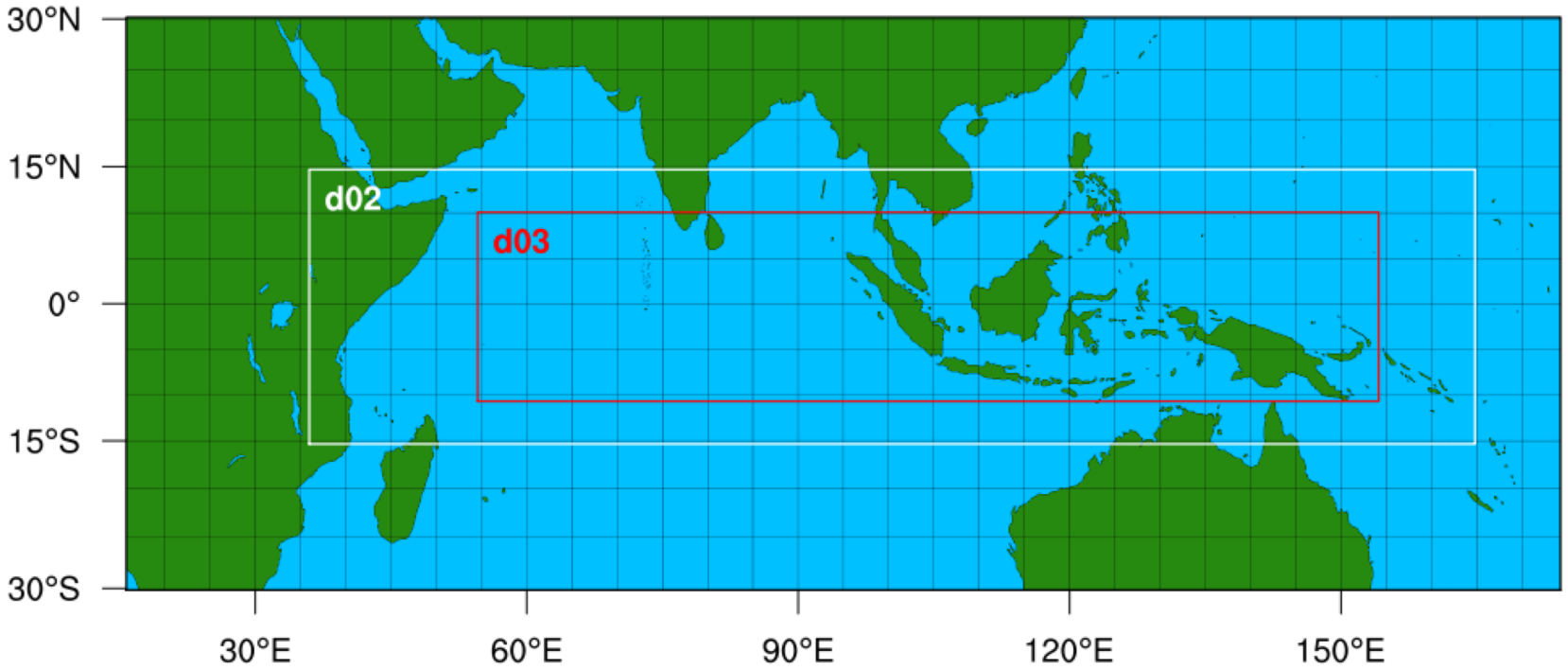
Discussion

Some questions

- **Why does the convection-permitting MPAS configuration produce an MJO while the 15-km runs do not?**
- **Why does excluding the Cu scheme in the 15km runs improve the diurnal cycle, but degrade everything else?**
- **In the channel simulation, is the MJO more affected by the inclusion of shallow Cu from the G-F scheme, or by the lower-resolution subtropics and extratropics?**
- **What is the relationship between MJO fidelity and extratropical forecast skill in these simulations?**

How important are lateral BCs?

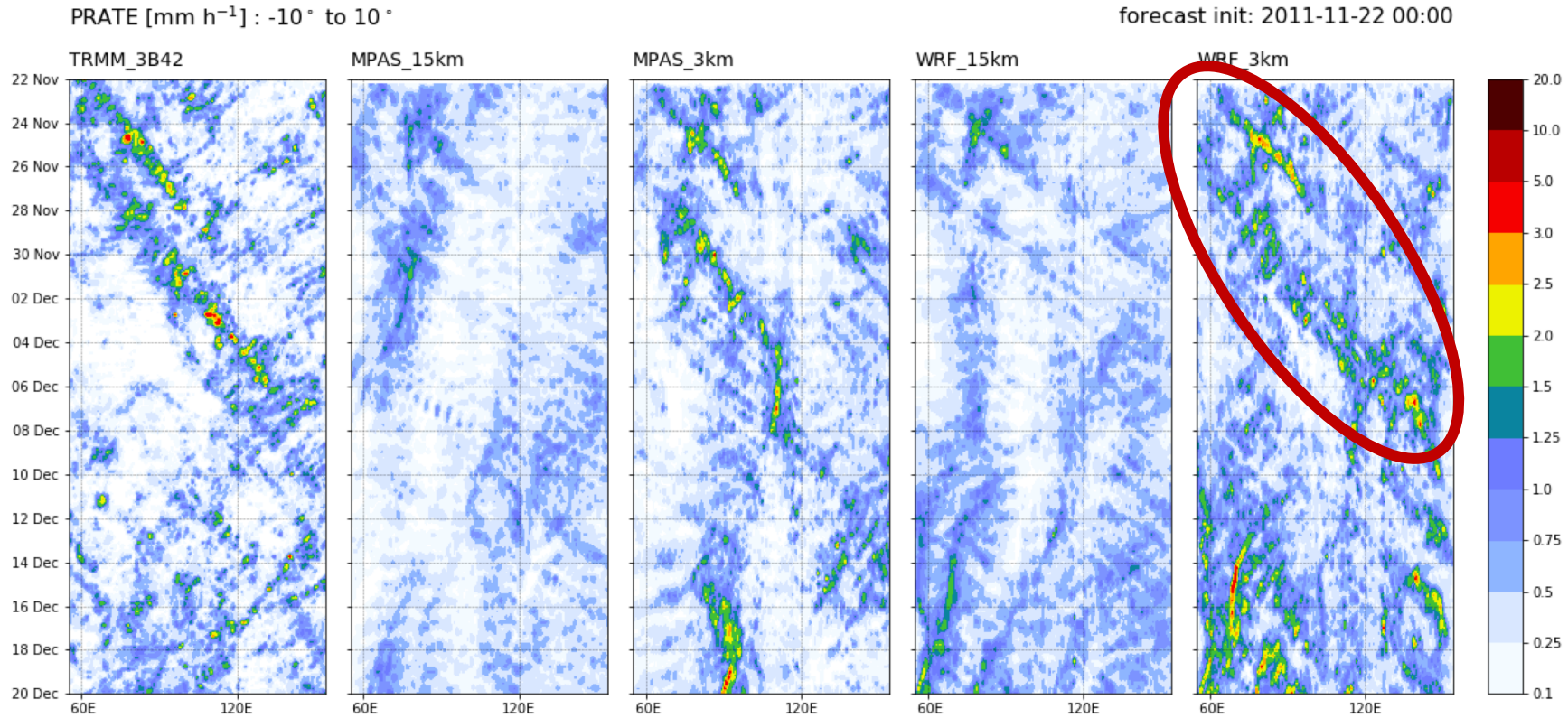
WRF simulation was run for Case-1 with 60km-15km-3km nested domains.



Same physics parameterizations as MPAS simulations Using WRFv3.9.1

How important are lateral BCs?

The 3-km WRF simulation actually propagates the MJO through the Maritime Continent!



The physics are the same… so is this because of the lateral BCs from the extratropics? Is this also why the channel run did not produce a propagating MJO?

Conclusions

- **Global convection-permitting MPAS boasts improved precipitation statistics, better MJO propagation, and higher subseasonal extratropical circulation skill compared to the 15-km runs**

- **Omitting the convection scheme at coarse (15-km) resolution has *some* benefits, but also creates a handful deficiencies**

- **A tropical channel configuration capitalizes on most of the benefits of convection-permitting resolution in the tropics, but still somehow fails to produce MJO propagation**

References

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Extra slides

Computer resources per 3-km run

E X T R A

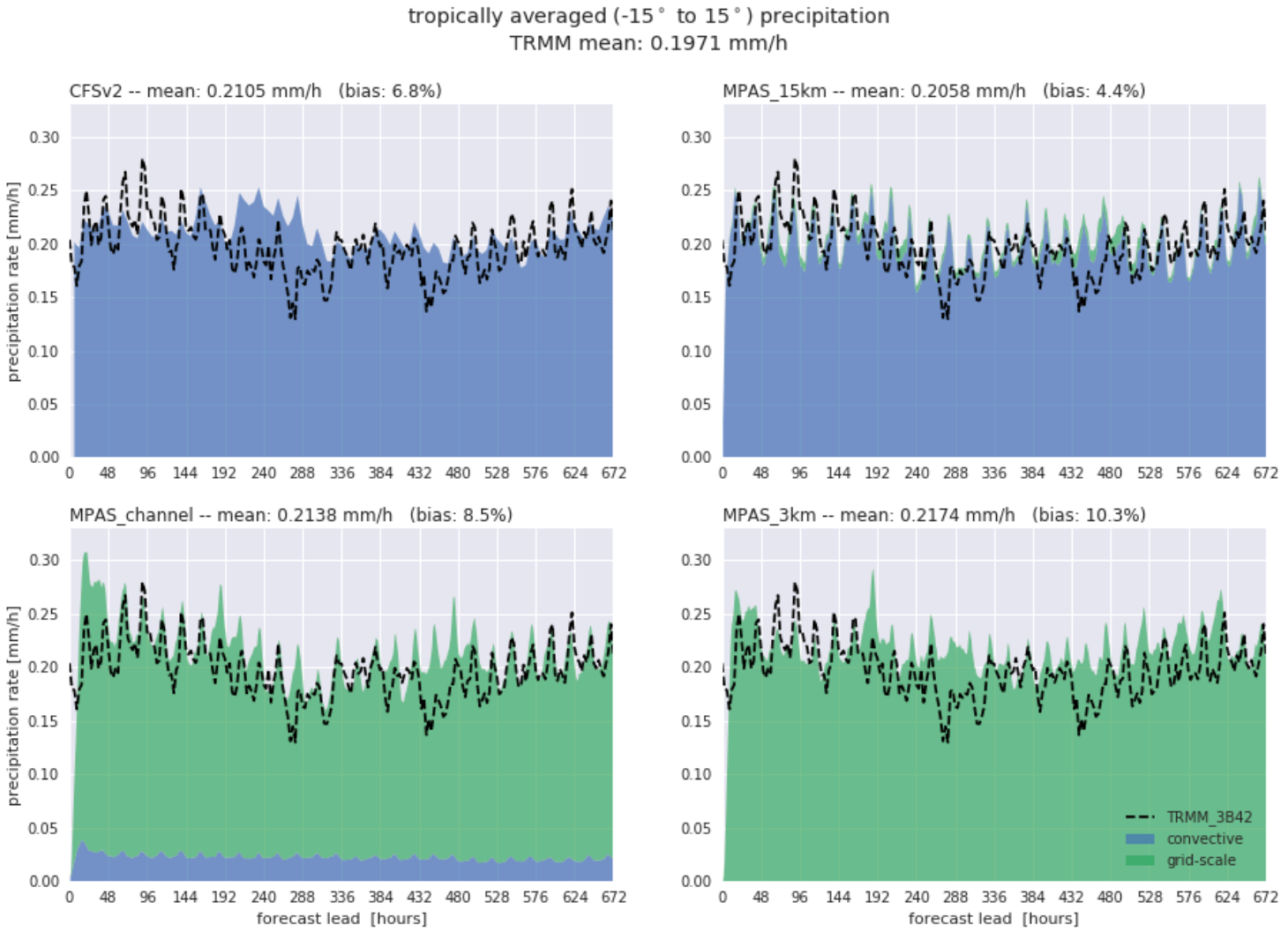
- **Supercomputer: Cheyenne (5.34 petaflops)**
- **Run on 1024 nodes → 36,864 cores**
- **Core hours: 2.7 million**
- **Wall clock: 74 hours**
- **Output: ~80TB**

Total precipitation: grid-scale vs Cu scheme

E X T R A

~10% of channel run precipitation is produced by G-F scheme

All MPAS runs exhibit a positive bias in tropical precipitation

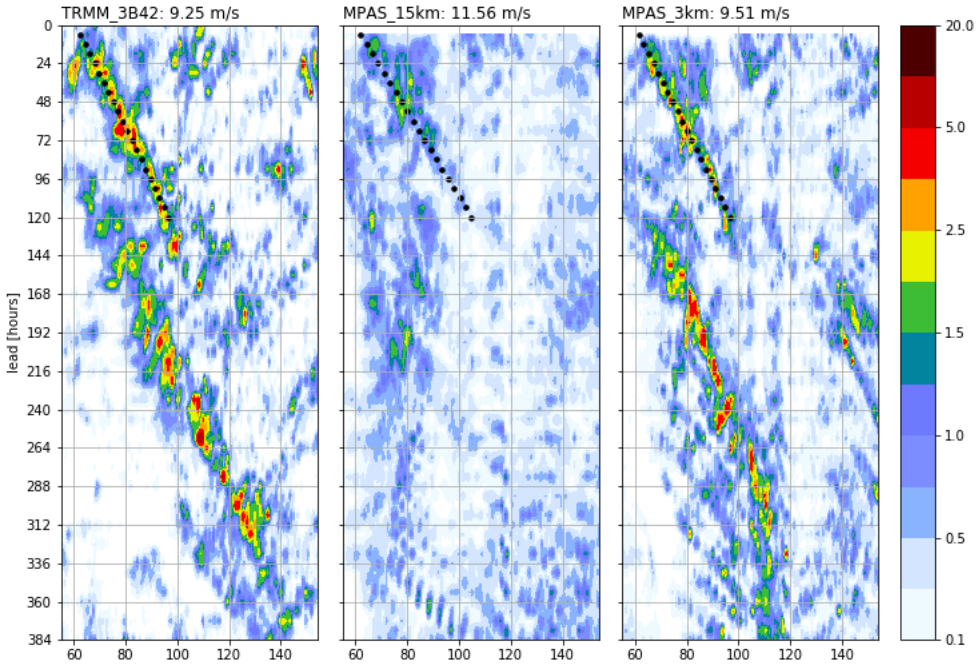


Structure of organized convection

E X T R A

Composite meridionally averaged 3D fields about the “Kelvin” wave in Case-1

The 15-km simulation:



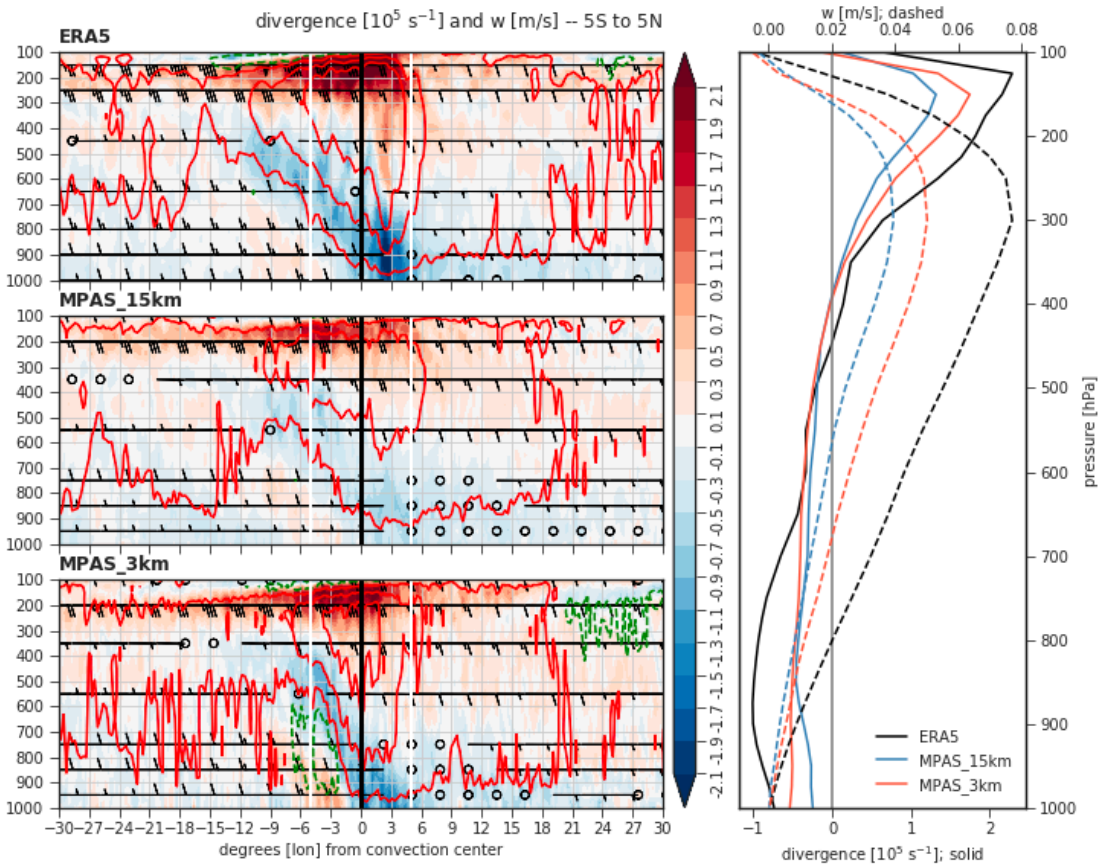
Structure of organized convection

E X T R A

Composite meridionally averaged 3D fields about the “Kelvin” wave in Case-1

The 15-km simulation:

- **Exhibits weaker vertical motion & less of a second baroclinic (stratiform) mode**



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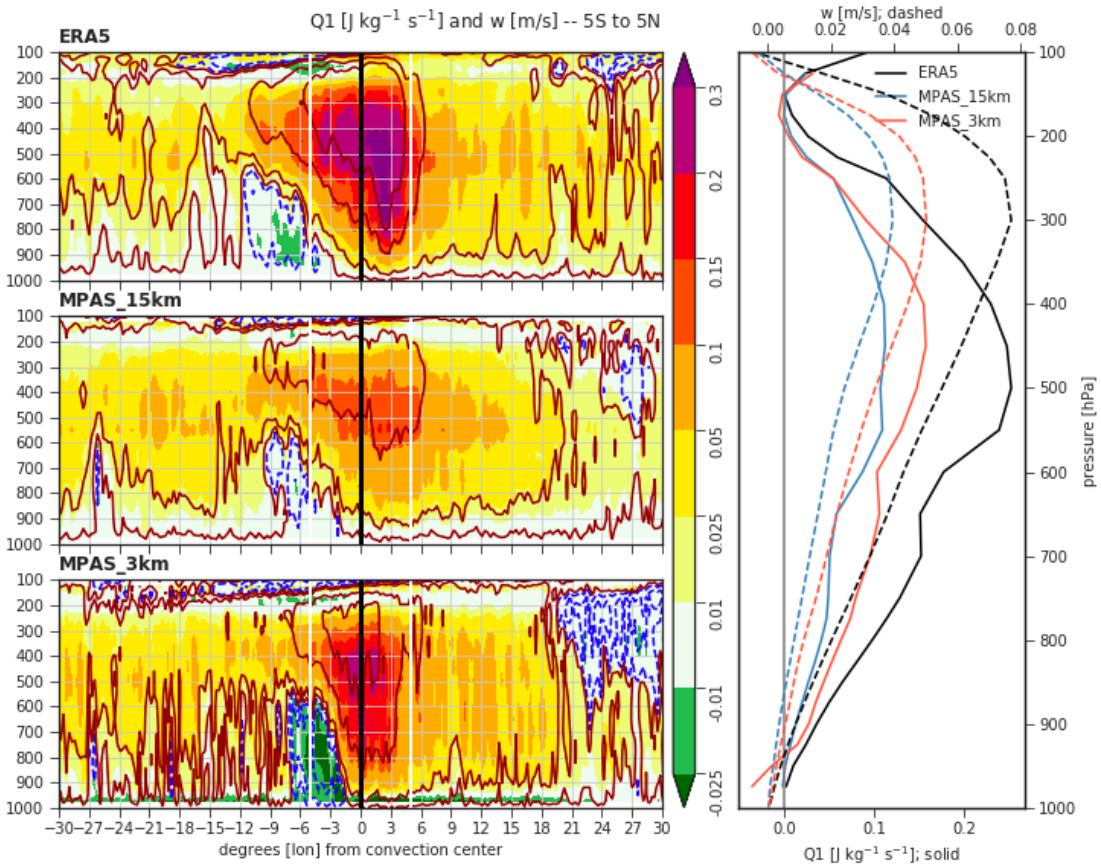

Structure of organized convection

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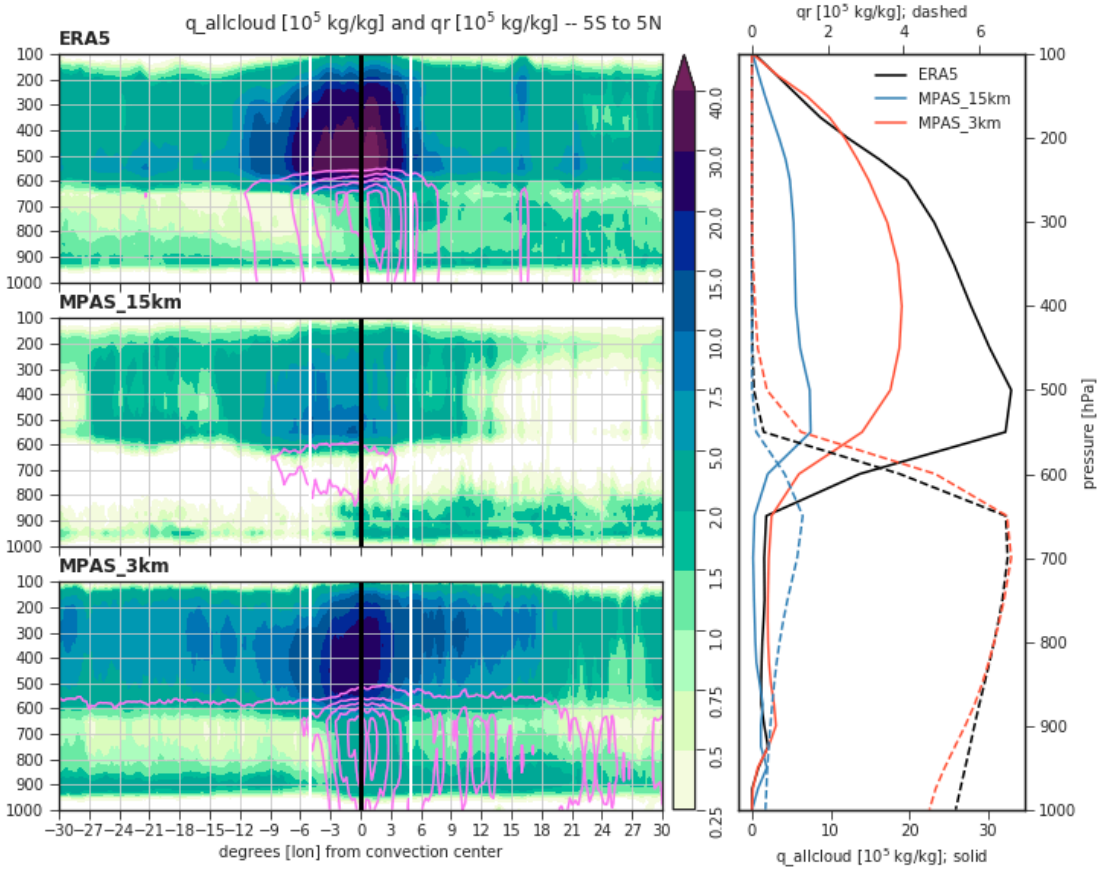
Composite meridionally averaged 3D fields about the “Kelvin” wave in Case-1

The 15-km simulation:

- **Exhibits weaker vertical motion & less of a second baroclinic (stratiform) mode**
- **Releases less latent heat in convection**
- **Produces much less cloud ice and precipitation**



Precip. statistics in WRF runs

E X T R A