Observed and Resolved Mountain Waves from the Surface to the Mesosphere Near the Drake Passage

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The ISSI Team

Organized by Joan Alexander

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[10]University of Vigo



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Objective 1:

To provide estimates of middle-atmosphere momentum flux and drag anchored to reality

Objective 2:

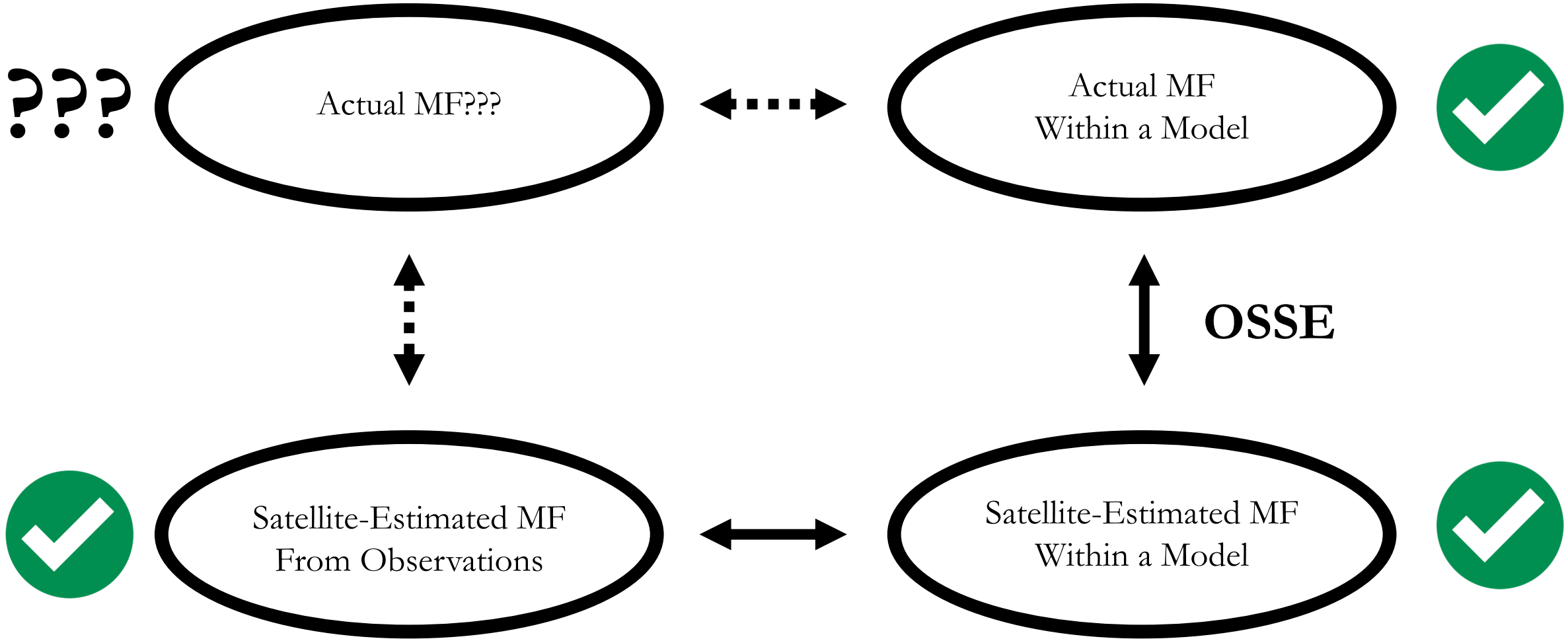
Use these estimates to improve/constrain MW drag parameterizations

Approach:

Use primarily satellite observations and multiple validated MW-resolving models to quantify MW MF and drag



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Model Validation, Comparison

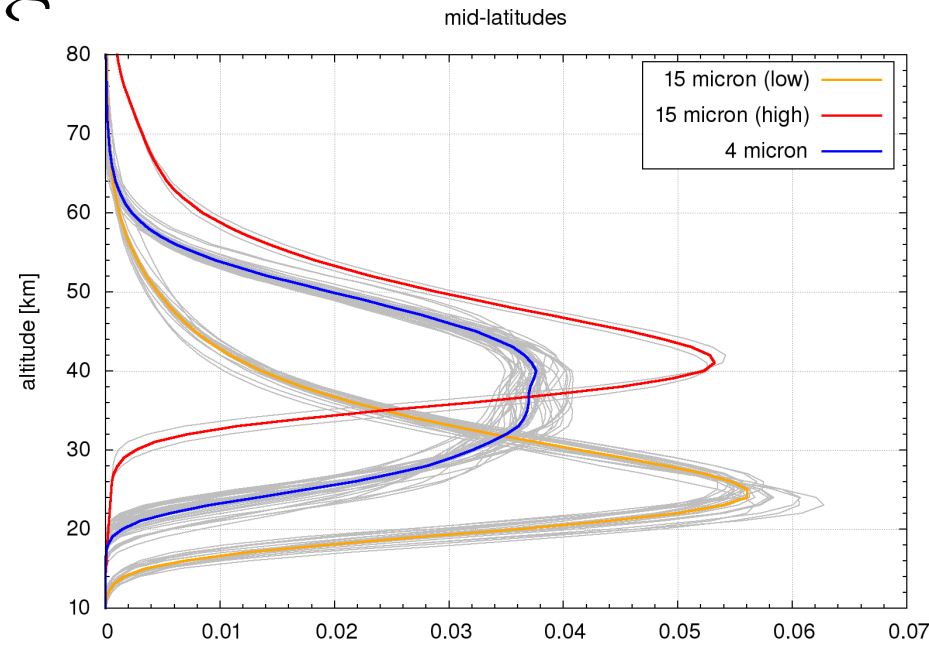
This Talk/Paper

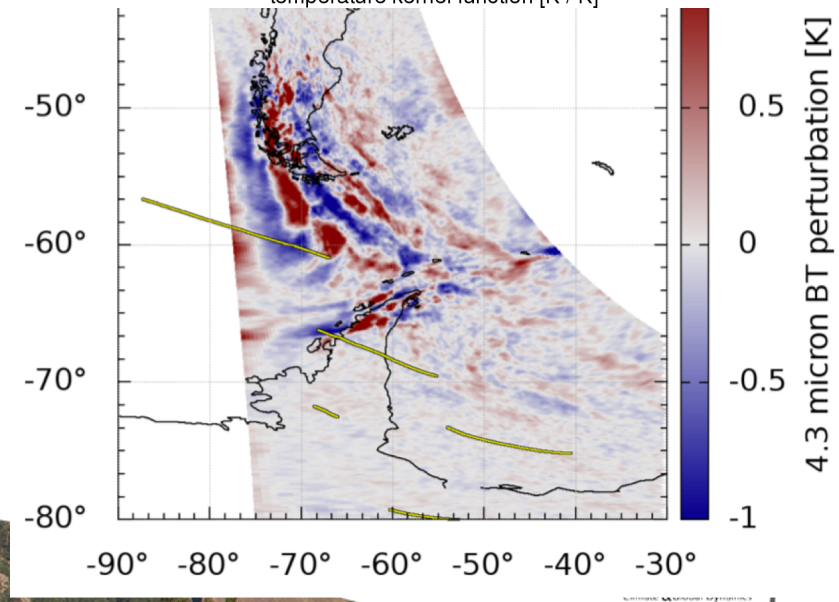
Participating Models, Configurations

- Four MW-resolving models participating (soon five):
  - Limited Area - *__WRF (dx=3km)__, Met Office __UM (dx=3km)__
  - Global – ECMWF __IFS (dx~9km)__, German __ICON (dx~13km)__
  - All forced/initialized with 2010 operational IFS analyses

- 2º WACCM nudged to MERRA-2 with two OGWD params
  - Old param: isotropic, McFarlane type OGWD parameterization
  - New param: anisotropic, better SGS ridge heights
  - Strong nudging: 6 hour nudging time scale

- Performed deep (z = 0 – 80 km) hind-casts of 8-19 Oct 2010 over the Drake Passage
  - Allows AIRS kernels to be contained within domains => model/AIRS comparison possible
  - Deep, realistic simulation a new capability of WRF



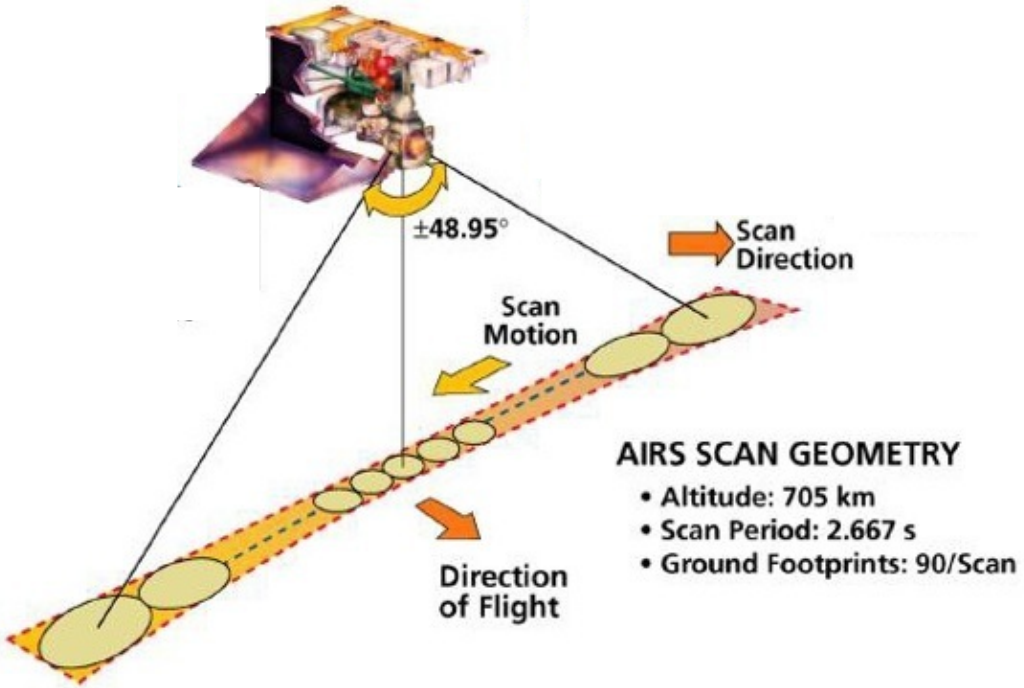


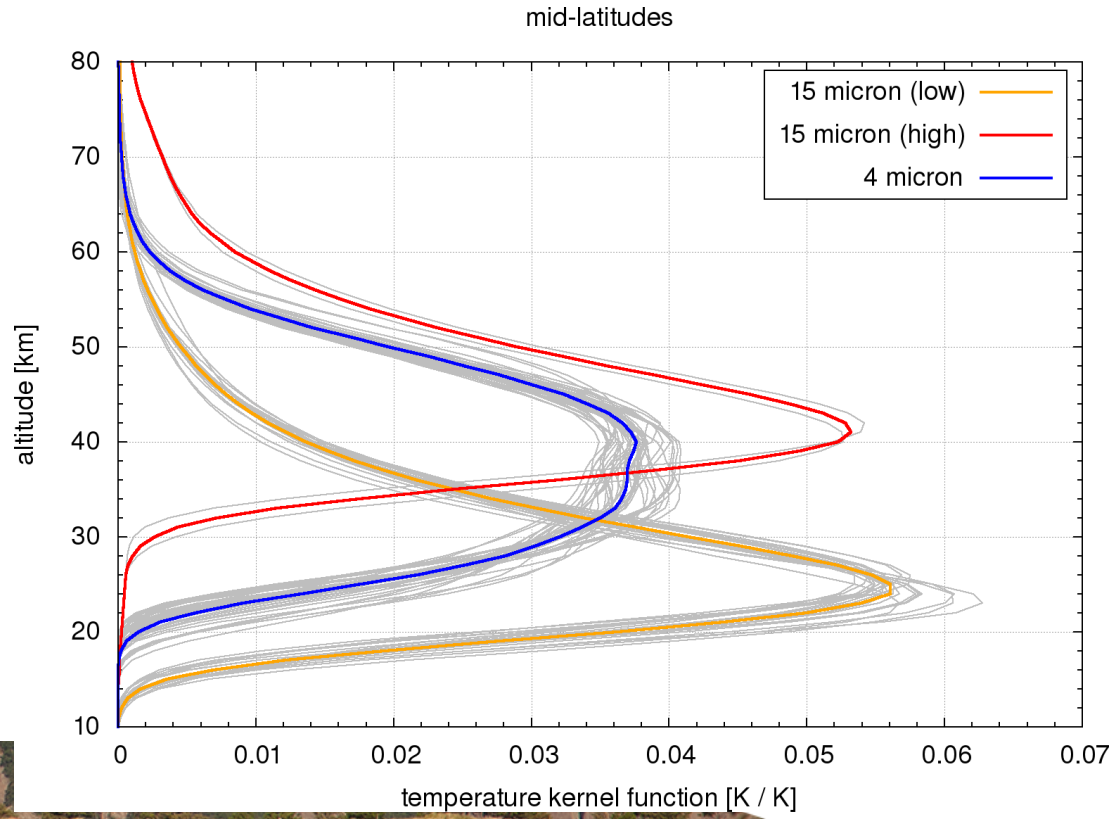
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AIRS/Model Comparison

- Synthetic AIRS "data" generated from 4-D model fields (done by Lars Hoffmann)
  - Quite involved! Take into account:
    - Obs time
    - Viewing geometry
    - Radiative transfer of individual relevant channels to estimate radiation to sensor







AIRS/Model Brightness T' Comparison

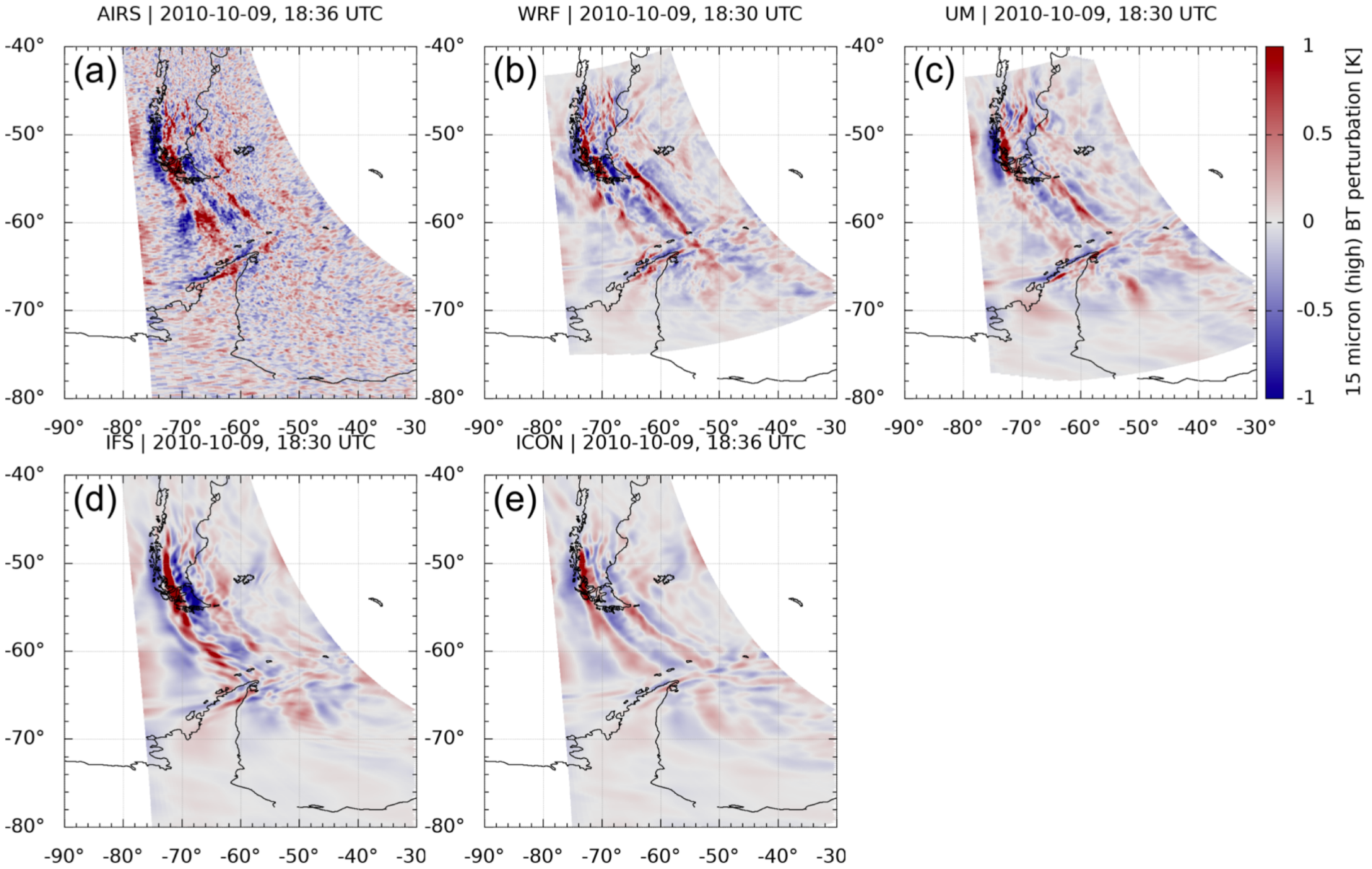


FIG. 4. A good comparison, by eye.

AIRS/Model Brightness T' Comparison

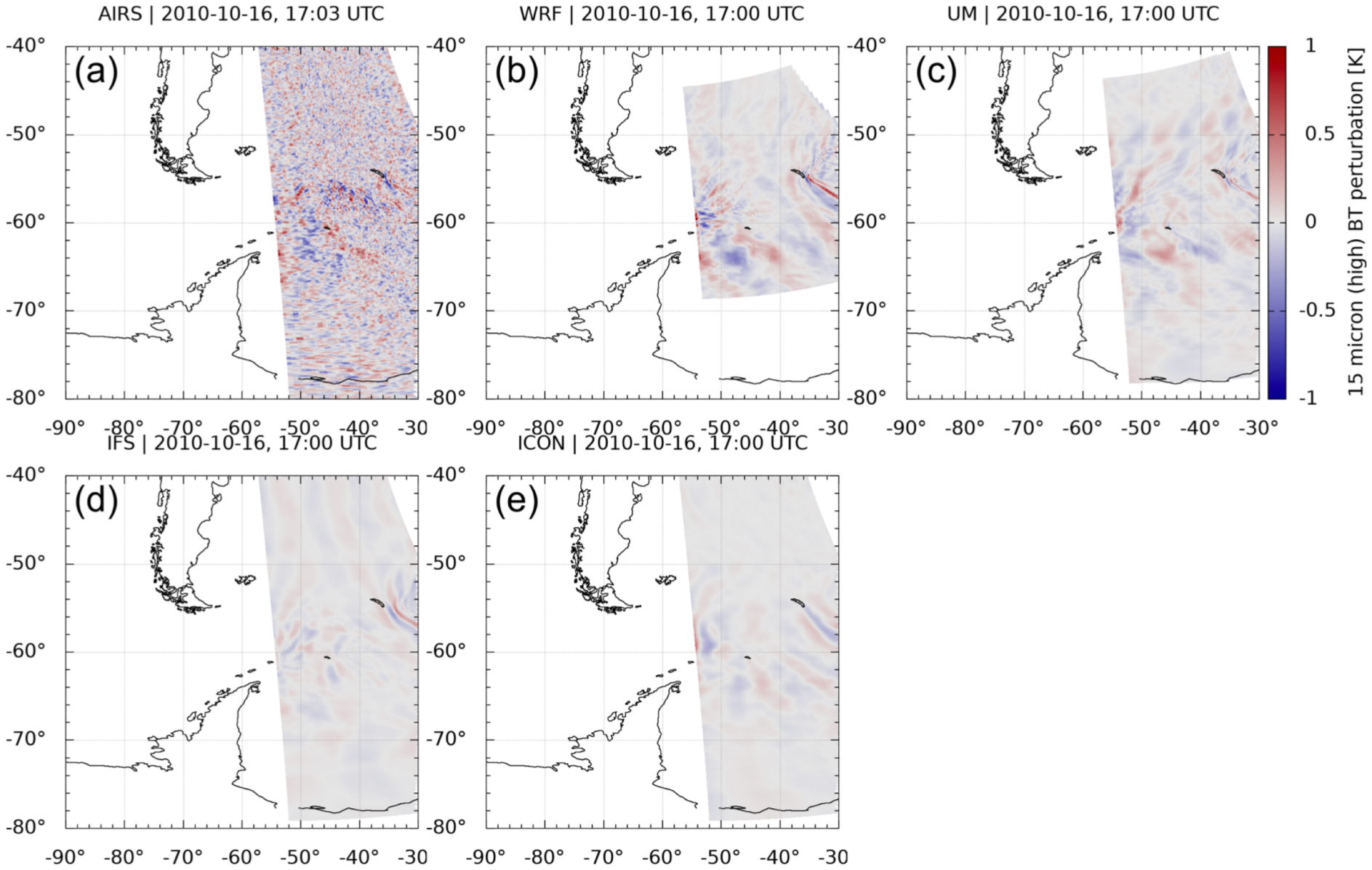
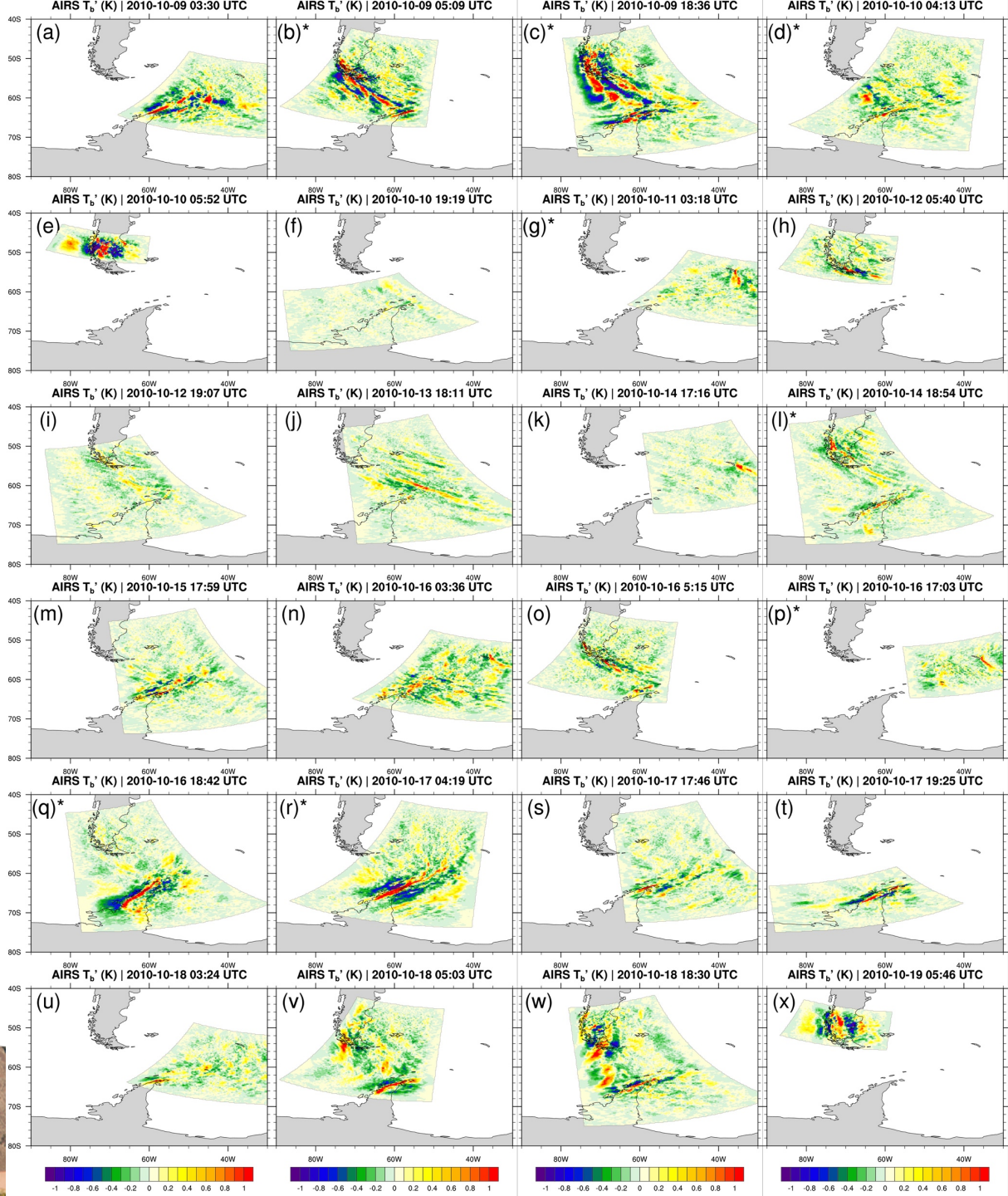


FIG. 5. An ok comparison, by eye. Clear difference in waves as a function of resolution.

AIRS Swaths Used in Model Validation

- Observed T_b' Contoured
- Areas contoured contained within all model domains
- 24 Overpasses used in MIP validation



Observed, Simulated Brightness T' Spectra

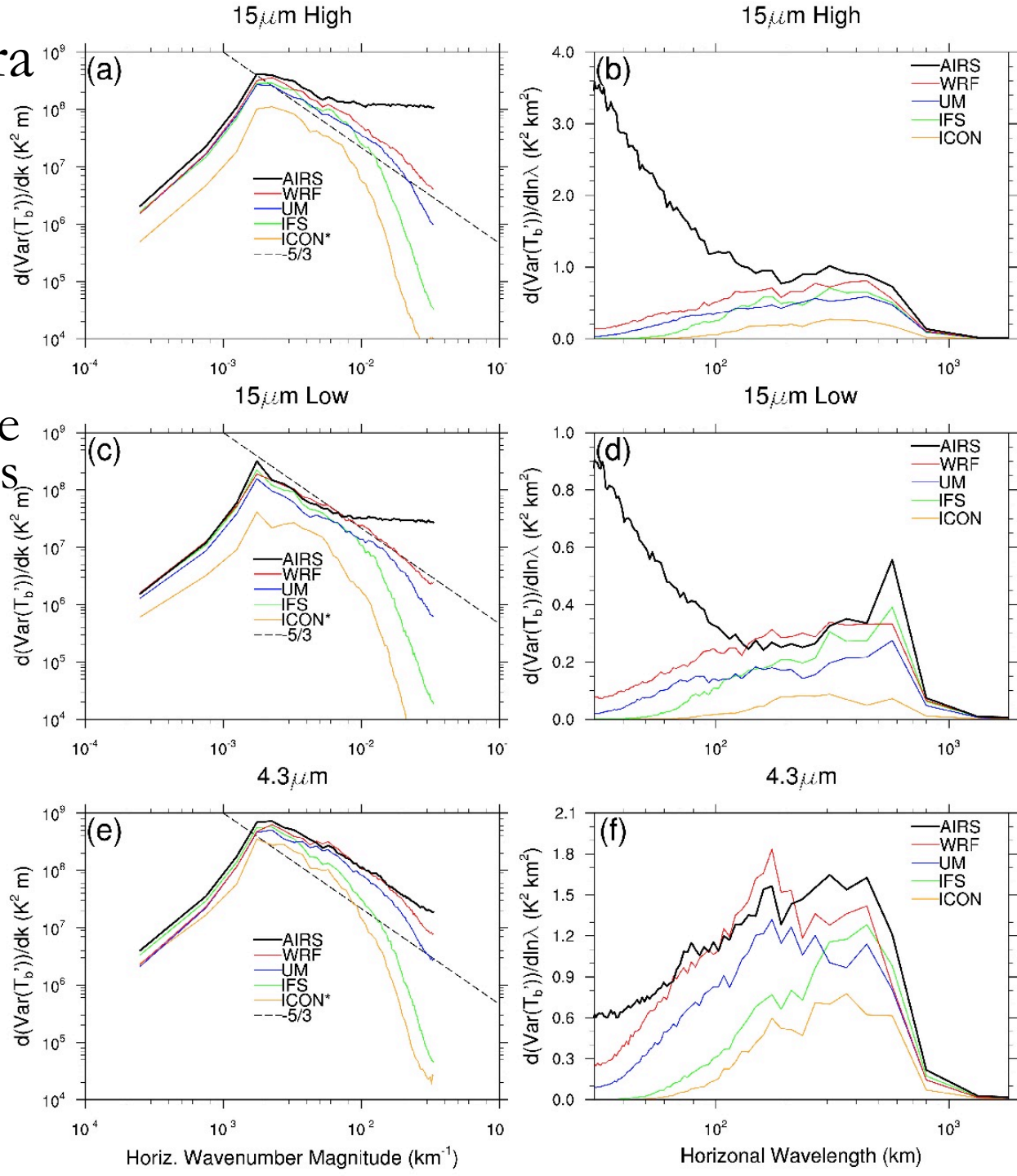
- Averaged over all overpasses (prev. slide)
- All models under-represent observed T_b'
- Modeled, Overpass-Avg T_b' spectra have same shapes as observed, except for observed scales influenced by noise

Amplitude error metrics averaged over all overpasses.

$\sigma_{T_b'}$ = spatial standard deviation of T_b'

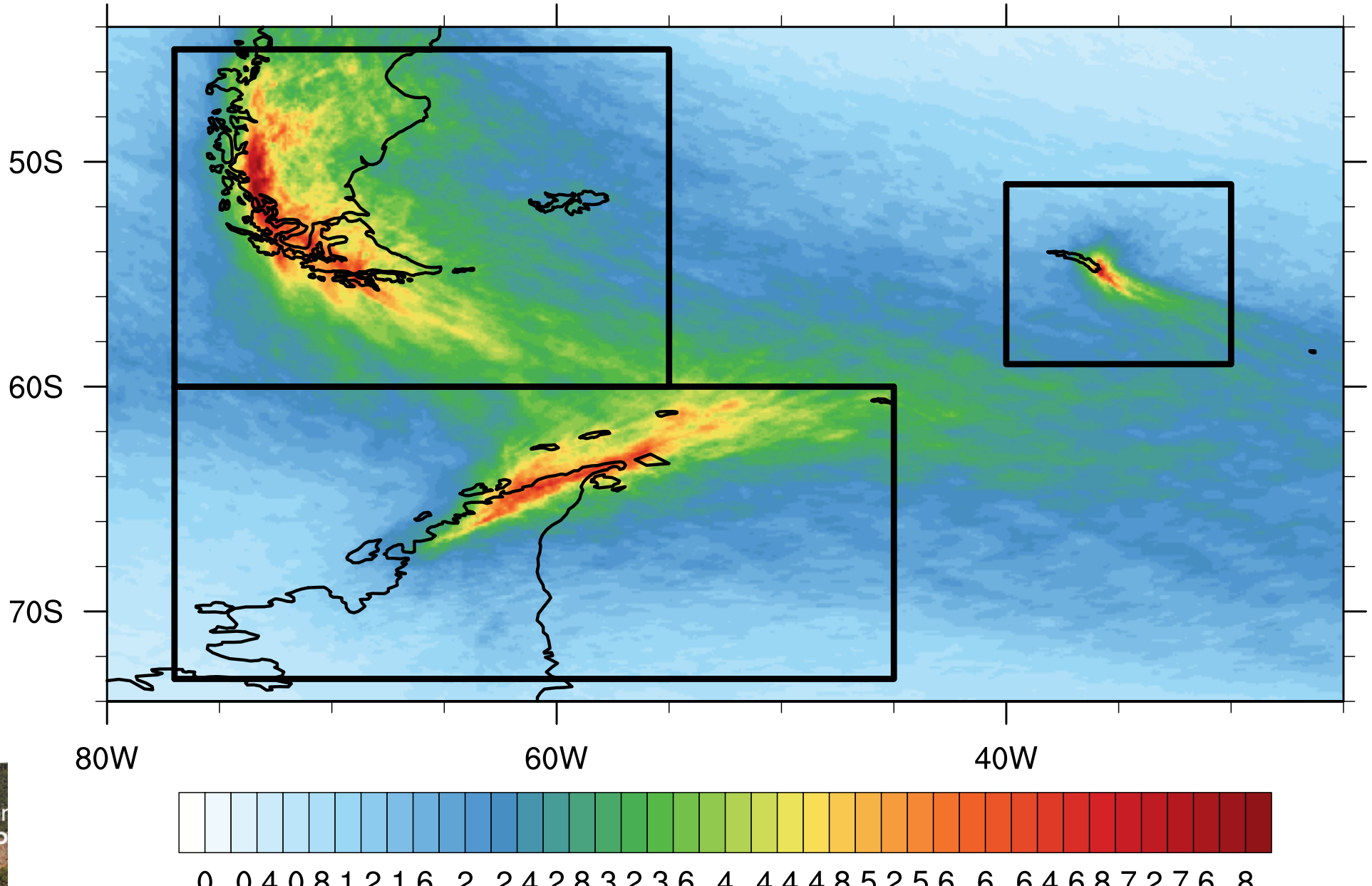
$\Delta\sigma_{T_b'} = \sigma_{T_b',model} - \sigma_{T_b',obs}$

15μm High	WRF	UM	IFS	ICON
$\frac{\Delta\sigma_{T_b'}}{\sigma_{T_b'}}$ (%)	-18.63	-30.41	-32.30	-39.55
$\frac{\lvert\Delta\sigma_{T_b'}\rvert}{\sigma_{T_b'}}$ (%)	19.84	30.41	32.30	39.55
15μm Low	**WRF**	**UM**	**IFS**	**ICON**
$\frac{\Delta\sigma_{T_b'}}{\sigma_{T_b'}}$ (%)	-8.30	-23.06	-21.34	-29.56
$\frac{\lvert\Delta\sigma_{T_b'}\rvert}{\sigma_{T_b'}}$ (%)	28.70	29.99	22.68	30.28
4.3μm	**WRF**	**UM**	**IFS**	**ICON**
$\frac{\Delta\sigma_{T_b'}}{\sigma_{T_b'}}$ (%)	-3.94	-18.54	-39.13	-32.75
$\frac{\lvert\Delta\sigma_{T_b'}\rvert}{\sigma_{T_b'}}$ (%)	16.52	19.75	39.45	36.98



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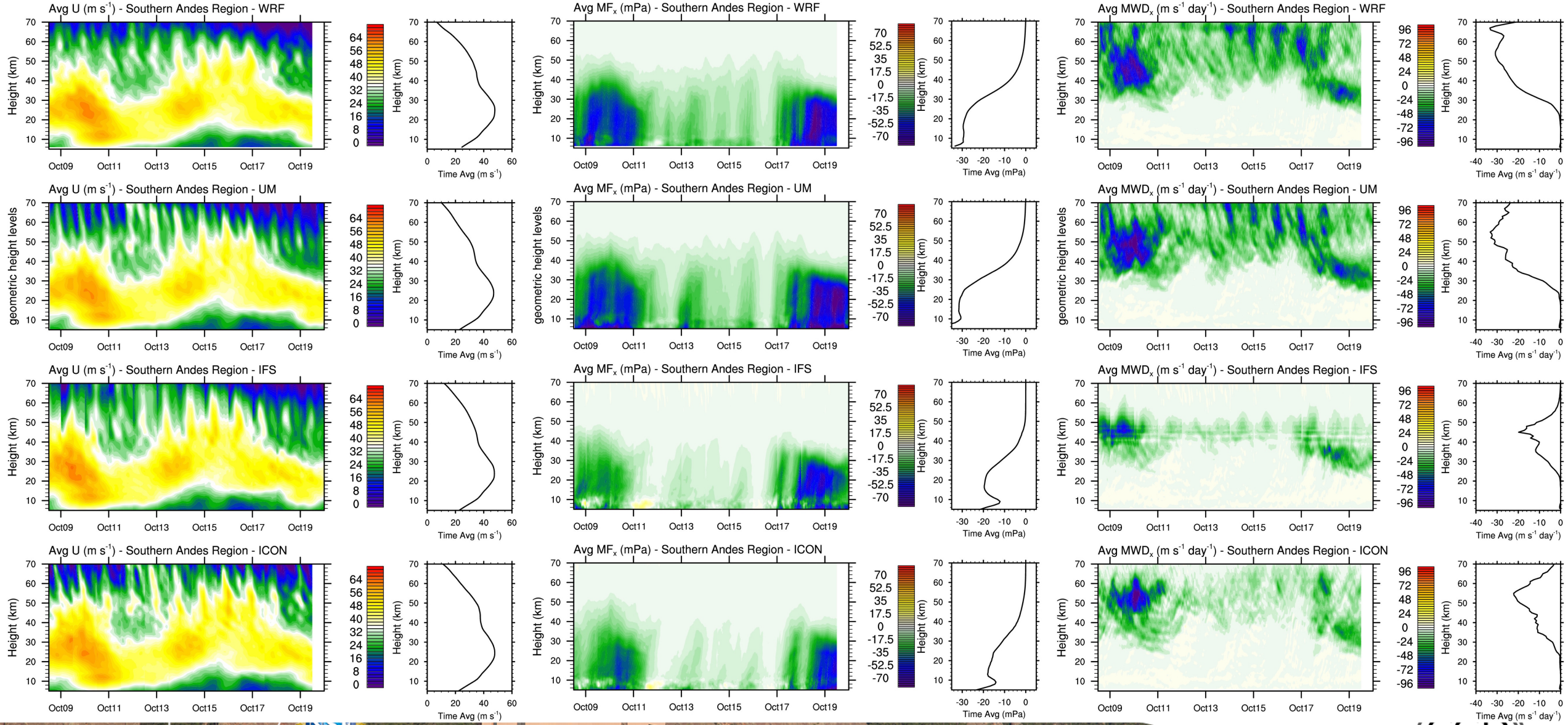
MIP Subdomains



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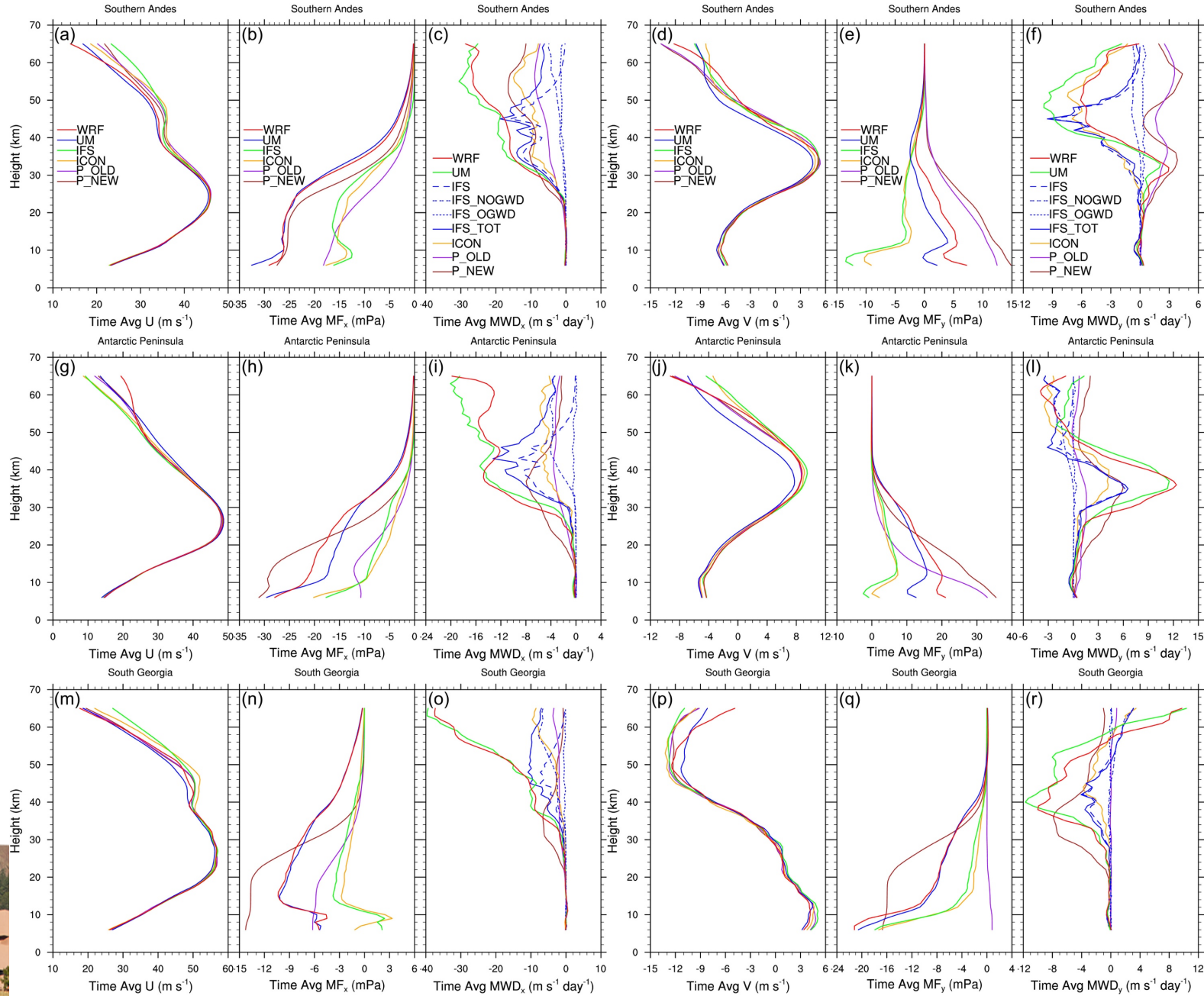
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U, MF_x, and MWD_x Intercomparison



Time Avg Profile Intercomparison

- Global models (IFS,ICON) under-represent middle-atmosphere MFs and GWDs
  - Even with parameterized drags in IFS

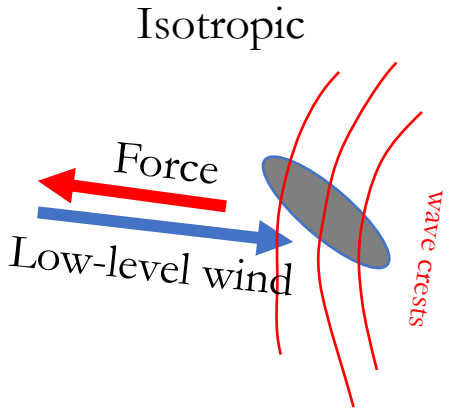


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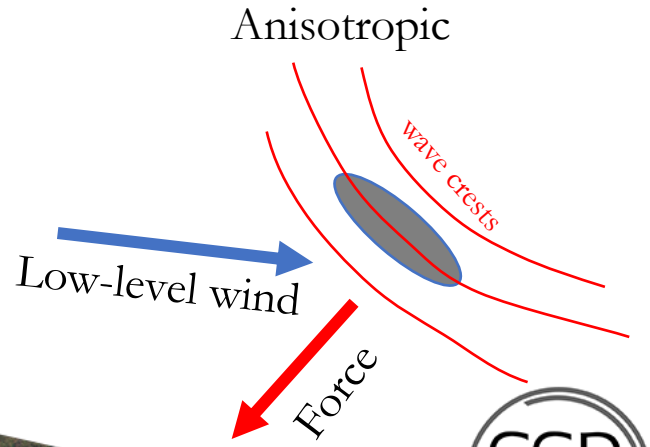
Mini-MIP, Parameterization Comparison

- Previous and new MWD parameterizations evaluated in **2^0** WACCM strongly nudged to MERRA-2

- Previous param:
  - Mountain height from sub-grid-scale (SGS) variance
  - SGS terrain assumed isotropic



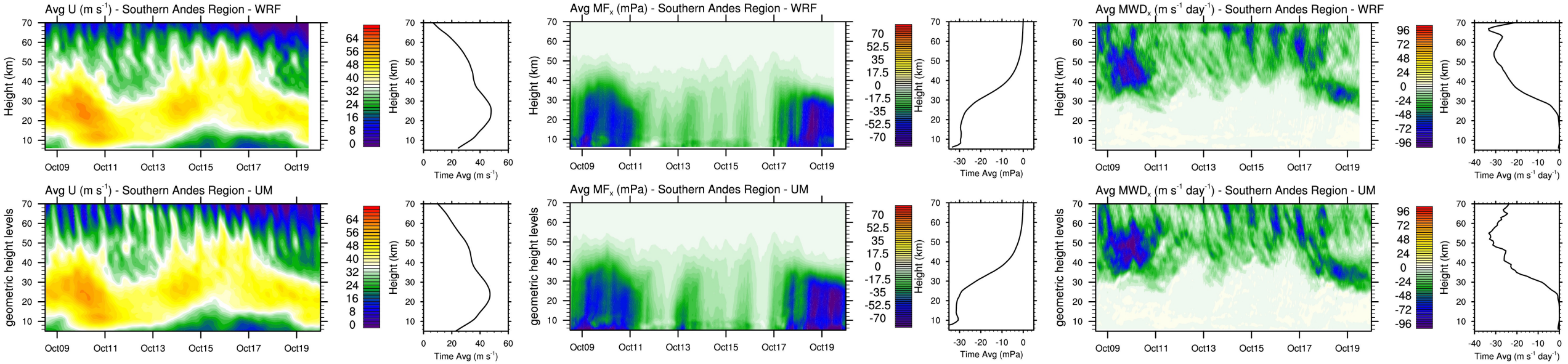
- New Param (Bacmeister et al., in prep):
  - Dominant ridges in SGS determine mountain heights
  - Ridge orientation accounted for
  - In latest version of CESM/CAM



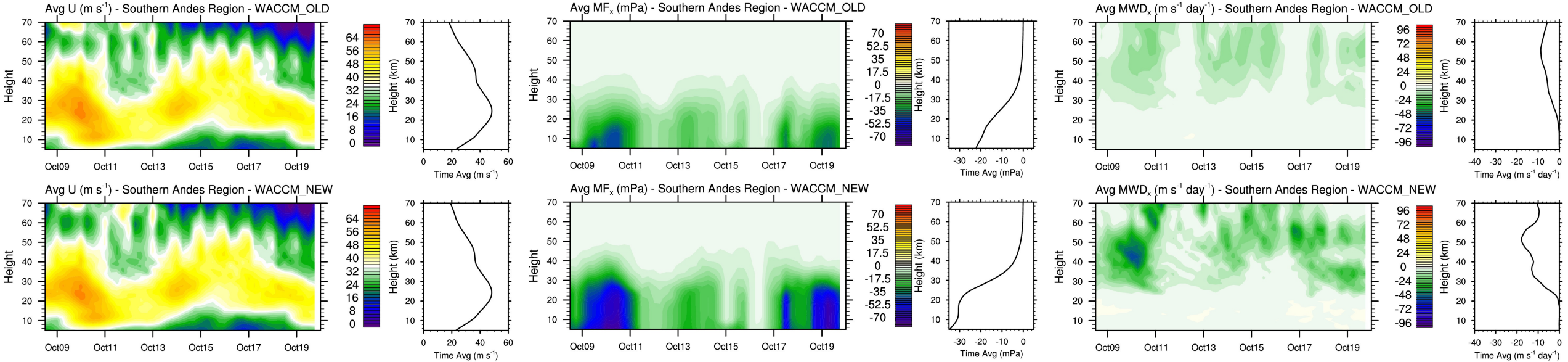
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High-Res Model, Parameterization **x**-Comparison

- WRF, UM dx ~ 3 km U, MF_x, and MWD_x over the **Southern Andes**

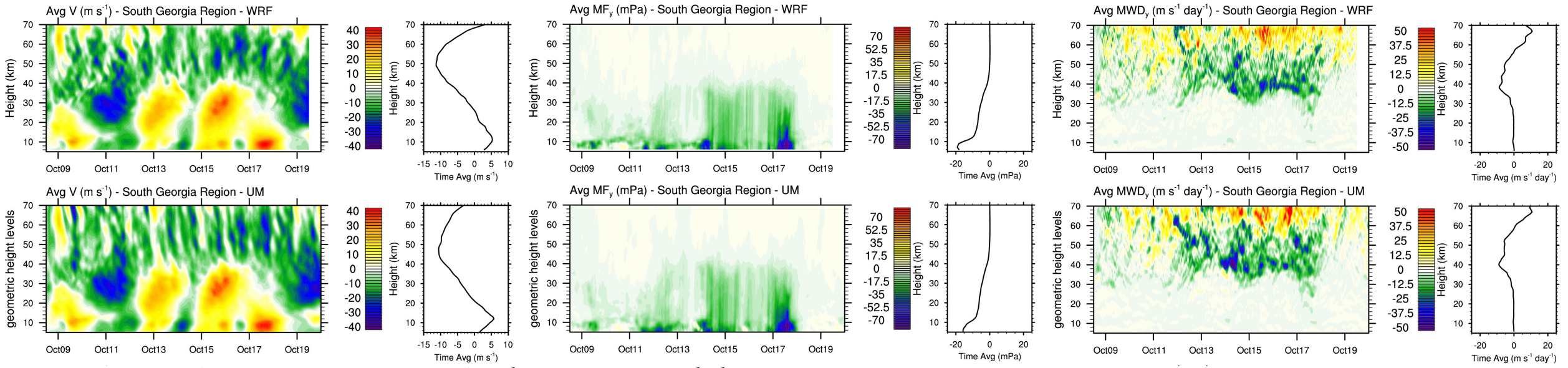


- Previous, New parameterized MW MF_x and drag

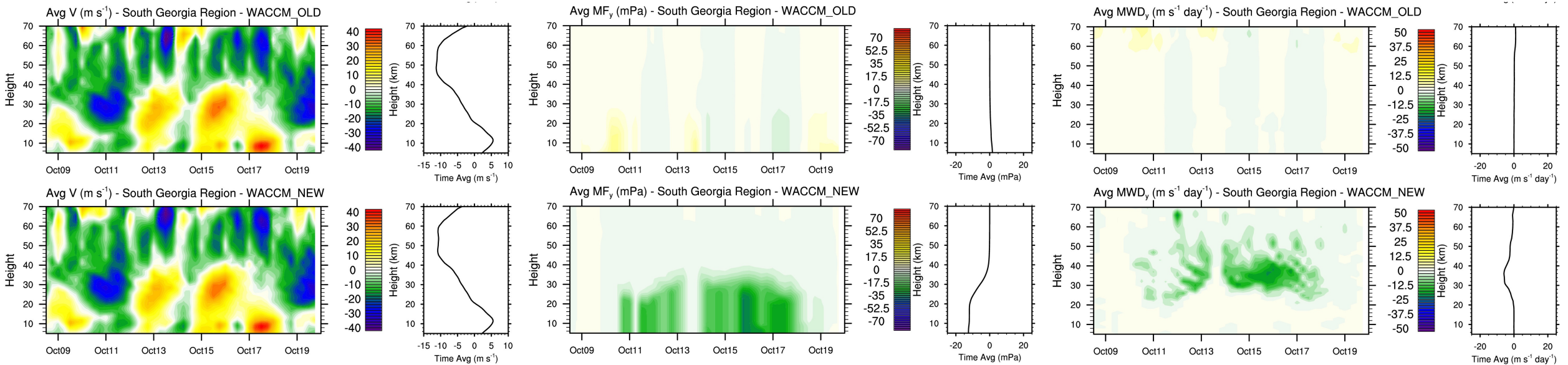


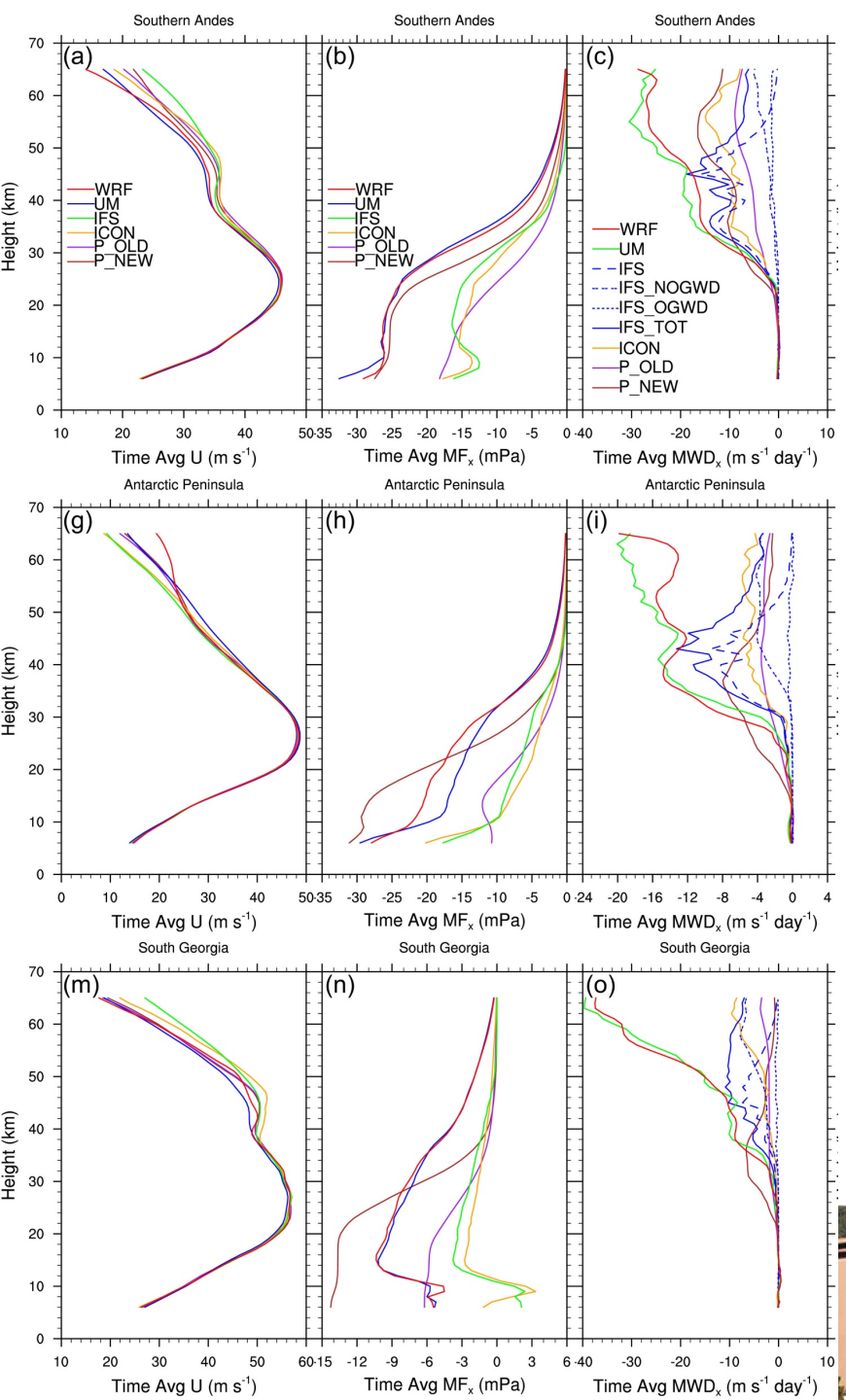
High-Res Model, Parameterization y-Comparison

- WRF, UM dx ~ 3 kmV, MF_y, and MWD_y over NW/SE-oriented **South Georgia**



- Previous, New parameterized MW MF_y and drag





CAM OGWD Param. Summary

- New anisotropic, SGS-ridge-based OGWD parameterization significant improvement over previous parameterization
- Still lots of room for improvement; too much drag at too low an altitude

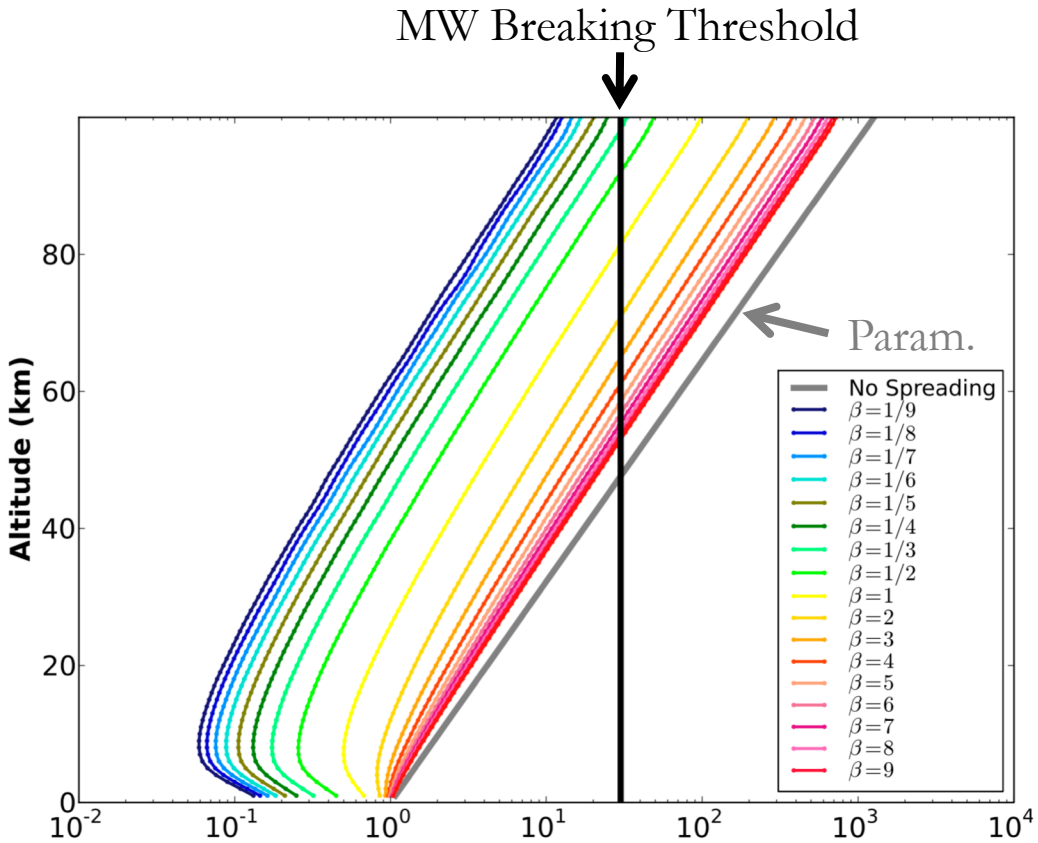
Hypotheses:

- Source MW amplitudes too large?
  - True for Antarctic Peninsula, South Georgia
- Lateral MW propagation, spreading?
  - Eckermann et al. 2015, 2016
- Vertical/Temporal spreading?
  - Kruse and Smith 2018



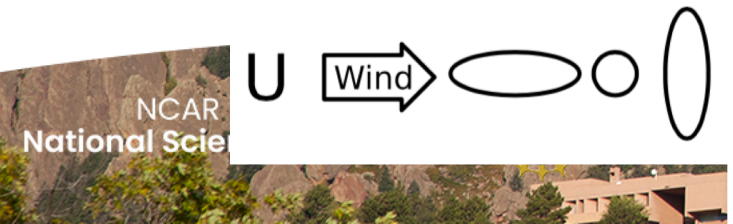
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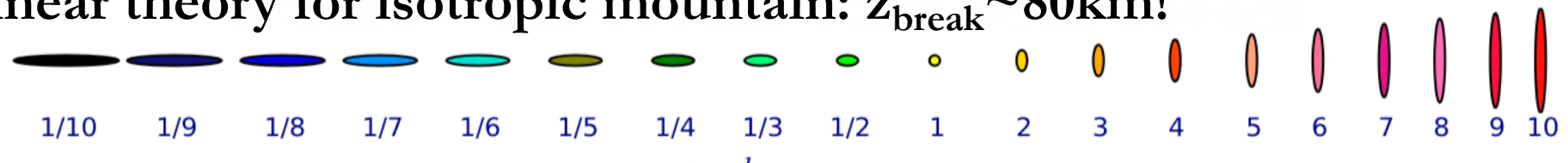
Lateral Spreading Strongly Influences MW Breaking Levels



Param: z_{break}~40km

Linear theory for isotropic mountain: z_{break}~80km!





Eckermann et al. 2015

Summary

- State-of-the-Science models can reproduce observed middle-atmosphere mountain waves surprisingly well

- Mountain wave parameterization still needed in current O(10km) resolution NWP models
  - Resolved drags in dx~9km IFS, dx~13km ICON significantly lower than dx=3km WRF, UM
  - Significant MF, GWD contributions from 10-60 km scales that are poorly resolved/unresolved by O(10km) resolution models (last extra slide)

- New anisotropic, SGS-ridge-based mountain wave drag parameterization in latest version of CESM/CAM a significant improvement over previous isotropic, SGS-variance-based parameterization
  - Still, lots of room for improvement; incorporate lateral spreading to raise drag levels upward?

Thanks!

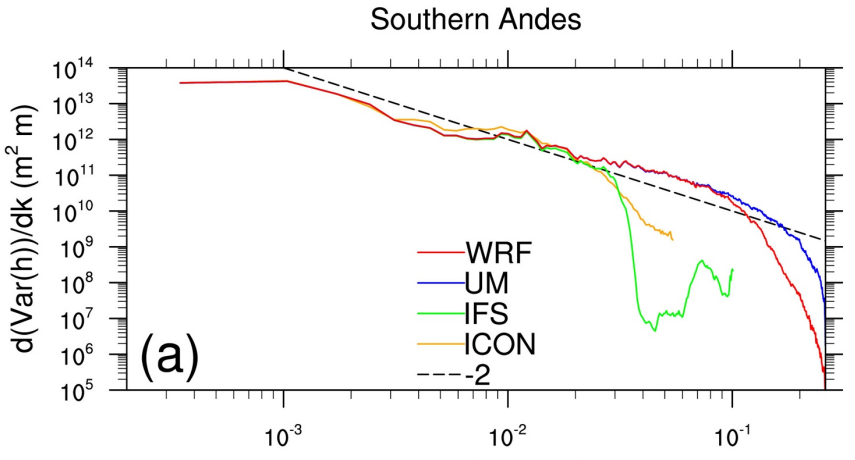
- Apologies for way too many slides

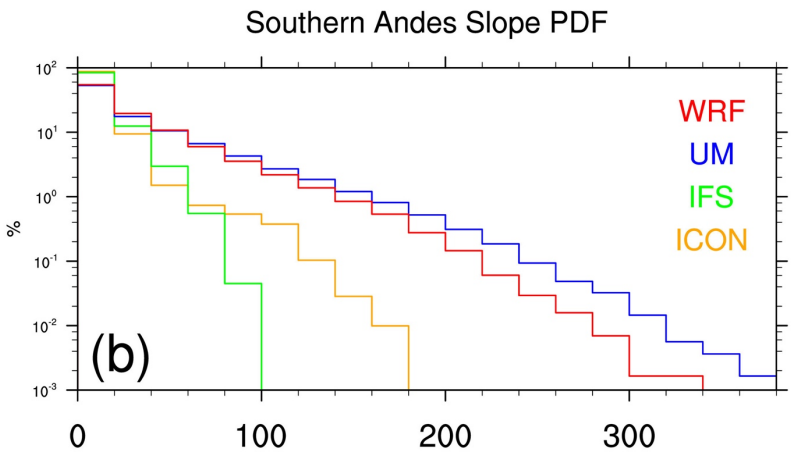
- Any comments/feedback appreciated! ckruse@ucar.edu

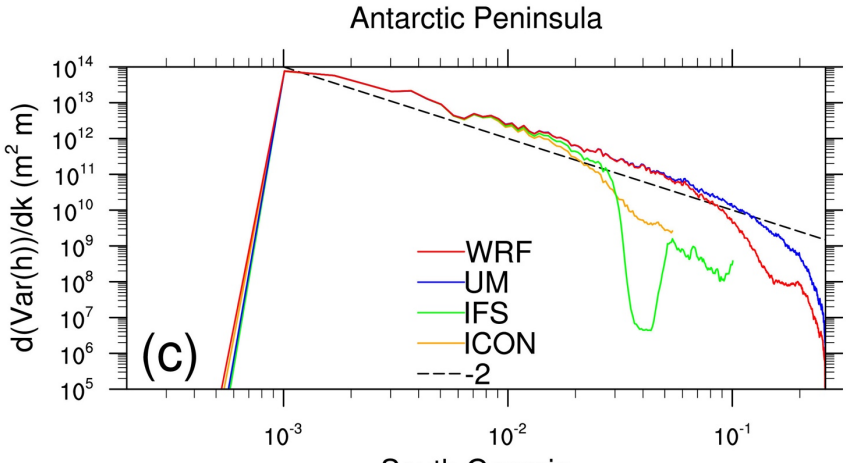


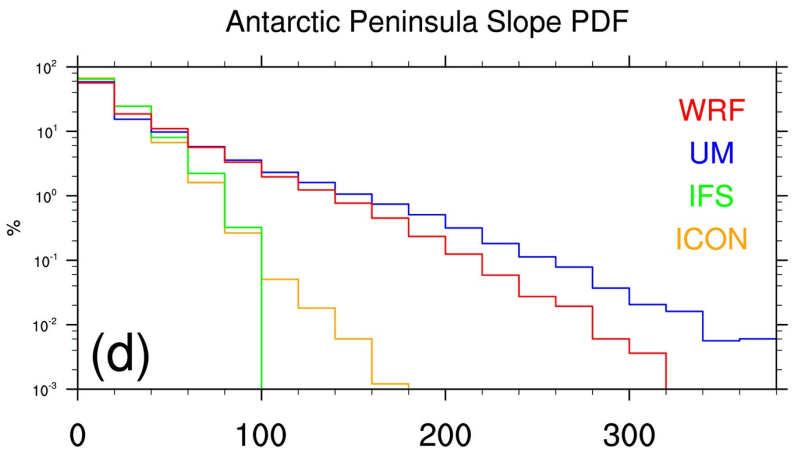
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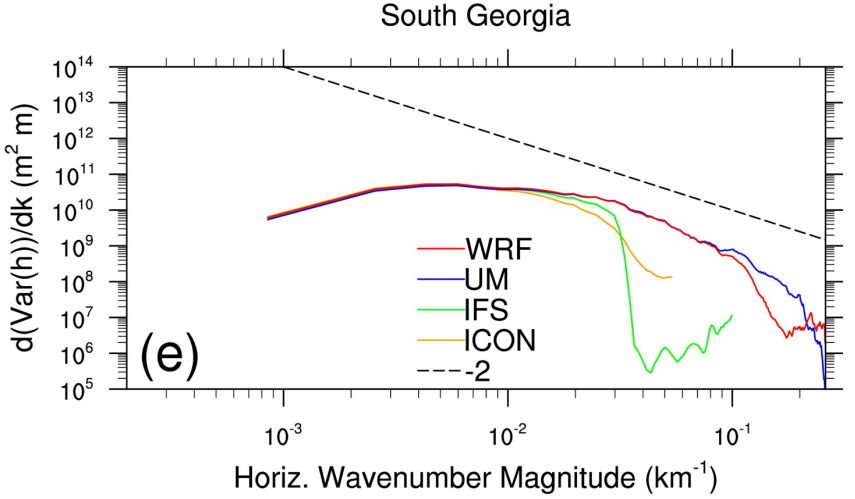
Orog Spectra MIP

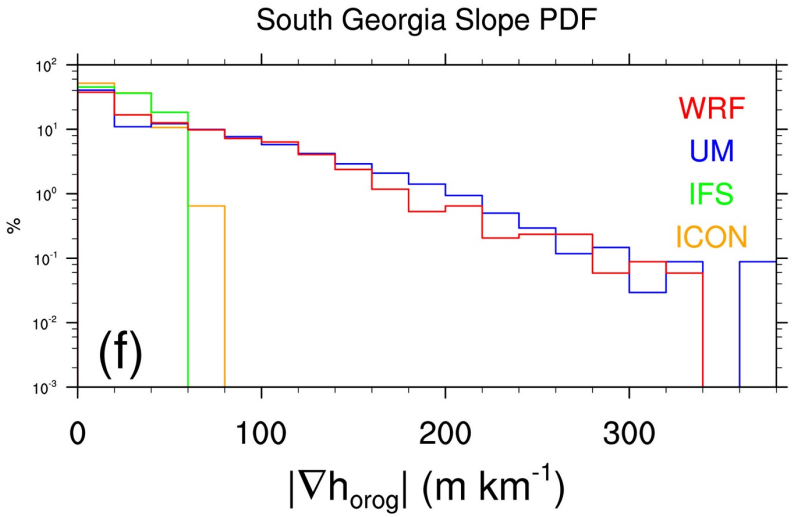






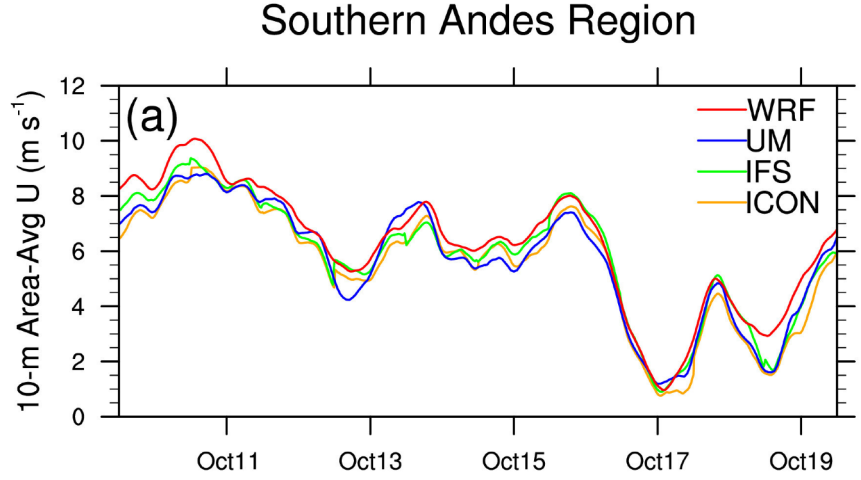


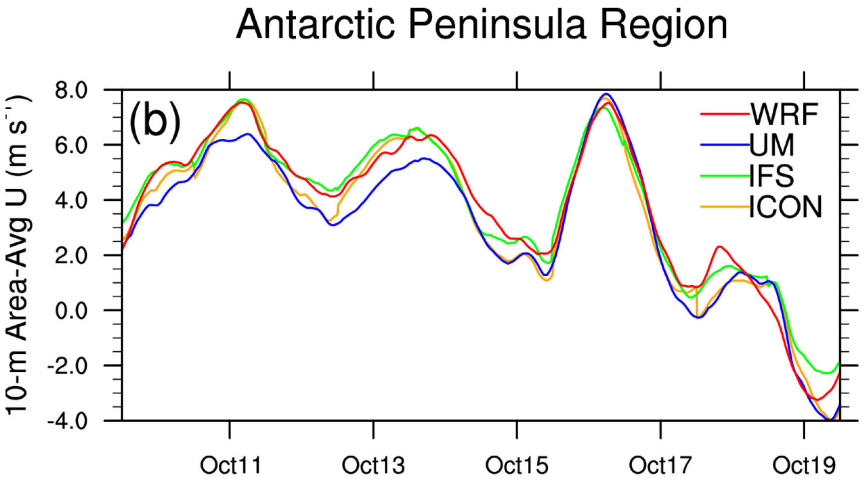


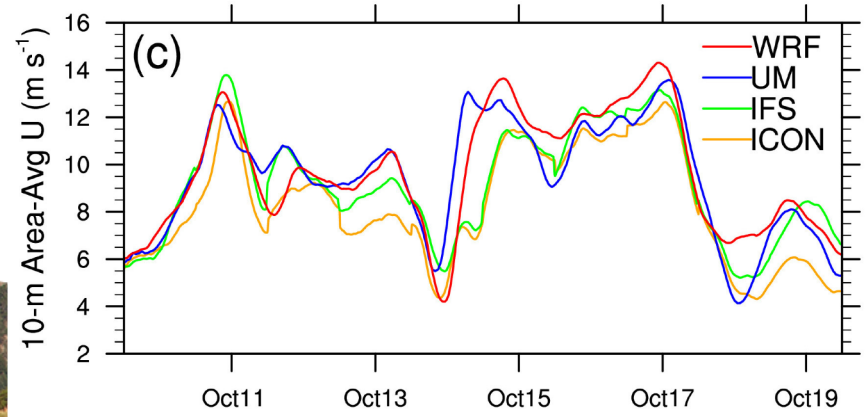




10-m Wind MIP by Sub-Domain

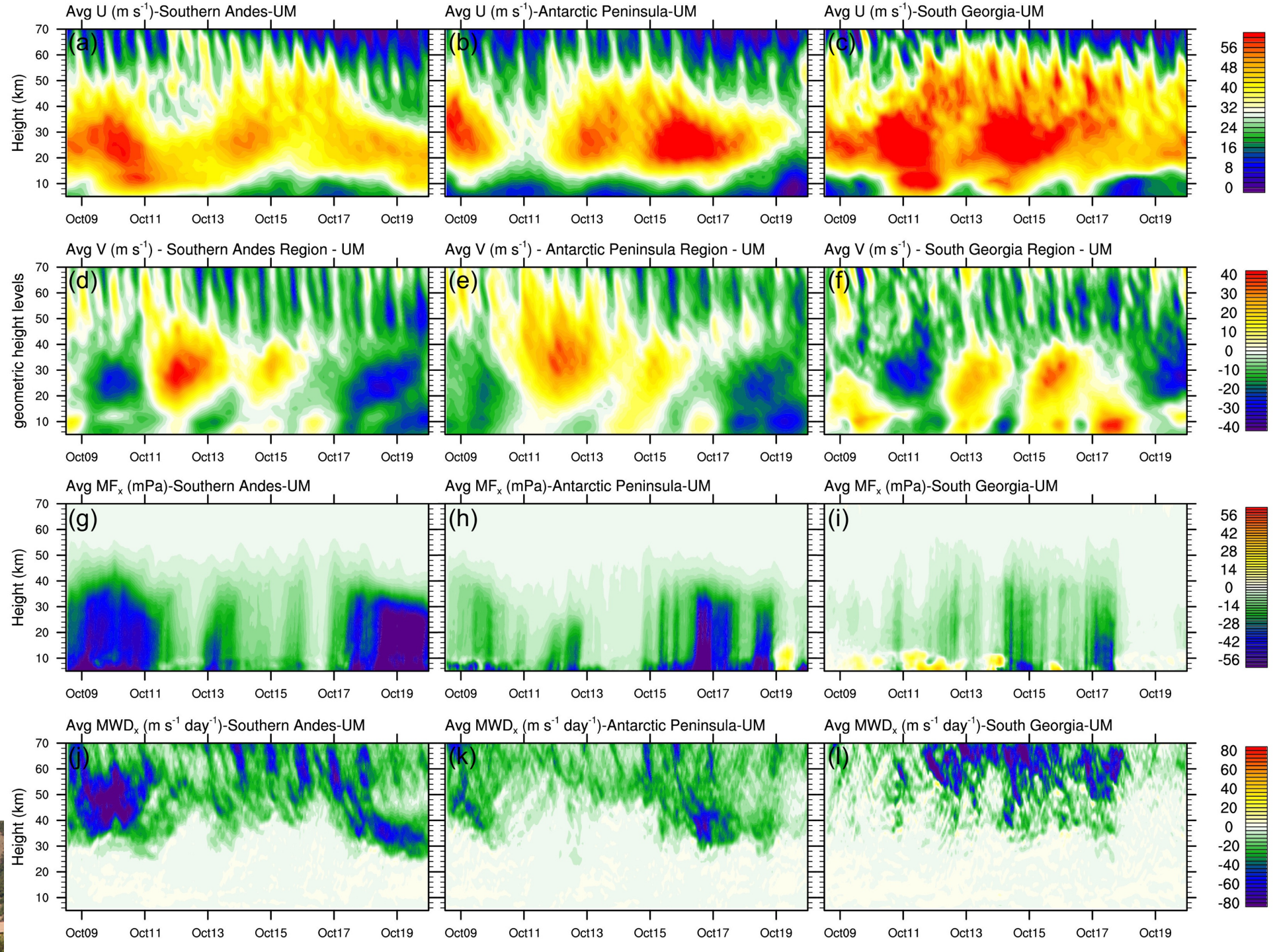






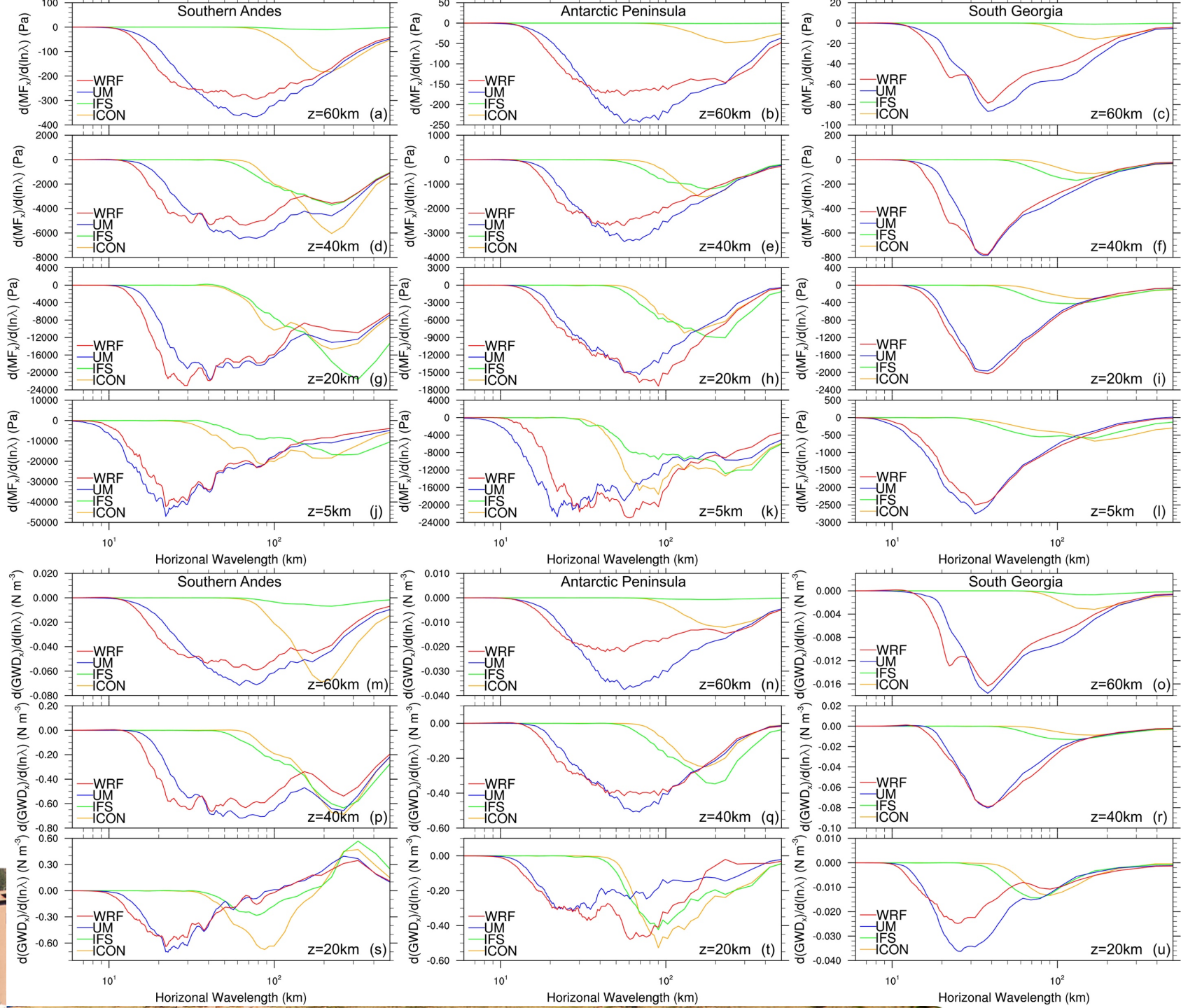


Overview by Sub-Domain



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MF_x, GWD_x Cospectra MIP



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