Evaluation of the WRF hybrid coordinate for an air turbulence simulation

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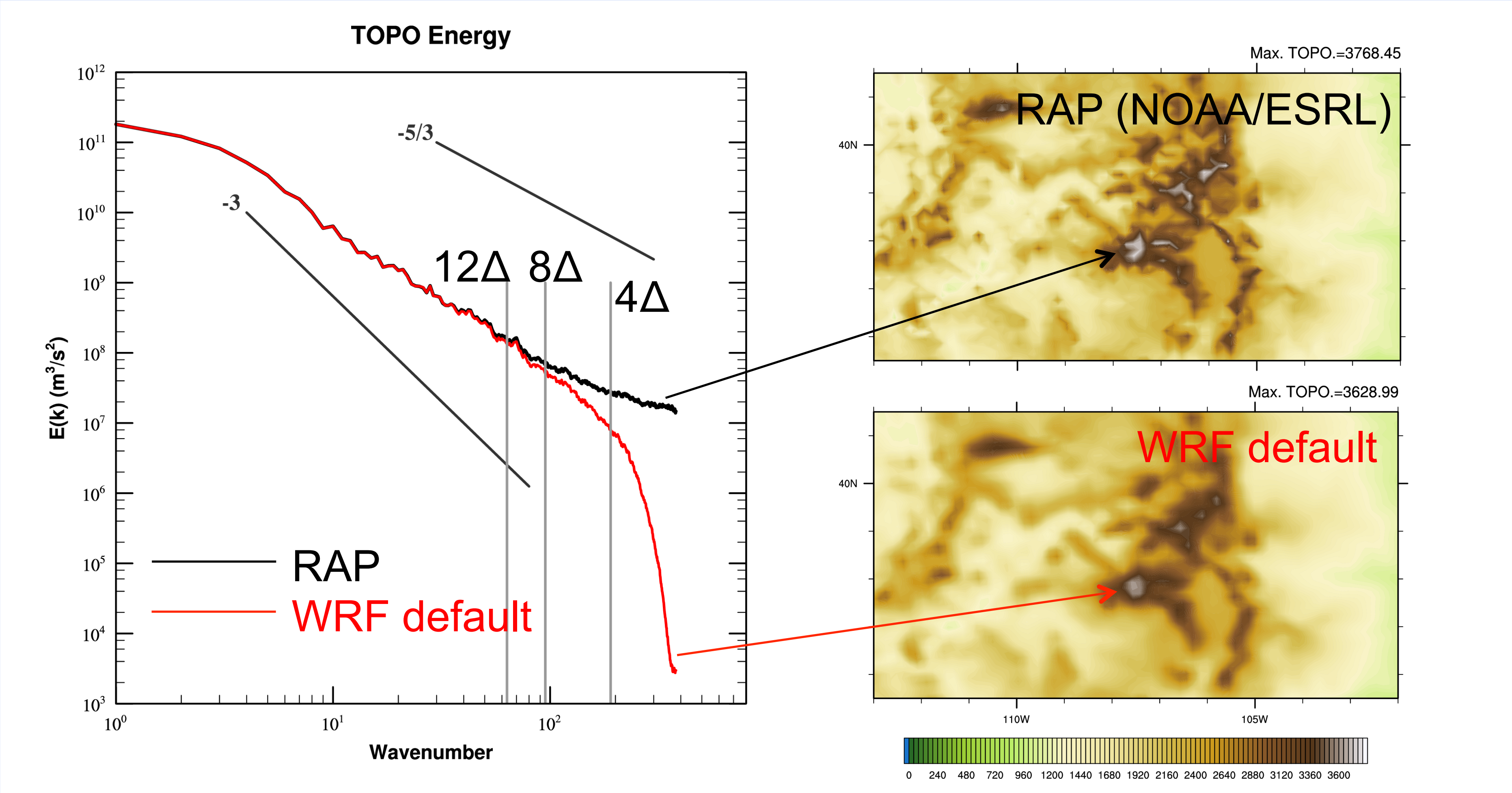
Contents

- False Alarm of air turbulence or mountain waves from RAP
- Hi-frequent Topography in RAP and smoothed topography

  (from 2016 WRF workshop)
- Hybrid coordinate
- Hybrid coordinate with smoothed terrain
- KE spectra from testing with hybrid coordinate

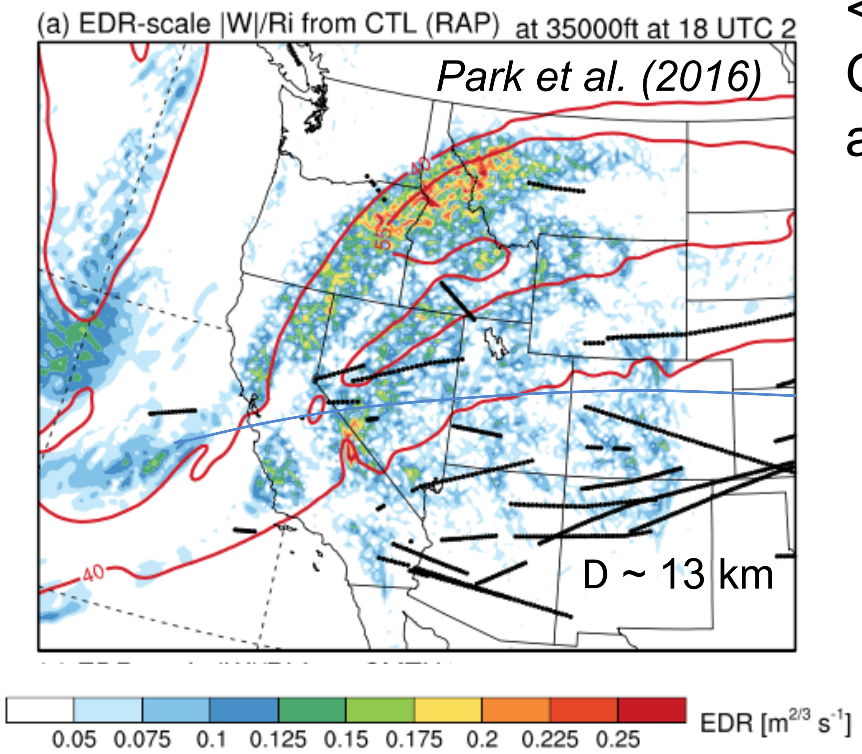
Power Spectra of Topography



- WRF default averages 30s terrain data within a grid cell and runs one pass of a 4th order filter (set to remove 2D)
- RAP interpolates terrain 2m TOPO data directly to model grid -> **It includes high-frequent topo!**

Analysis of terrain influences as motivated by persistent overprediction of air turbulence in the NOAA/ESRL operational Rapid Refresh (RAP) Model (based on the WRF-ARW)*

Eddy Dissipation Rate (EDR)

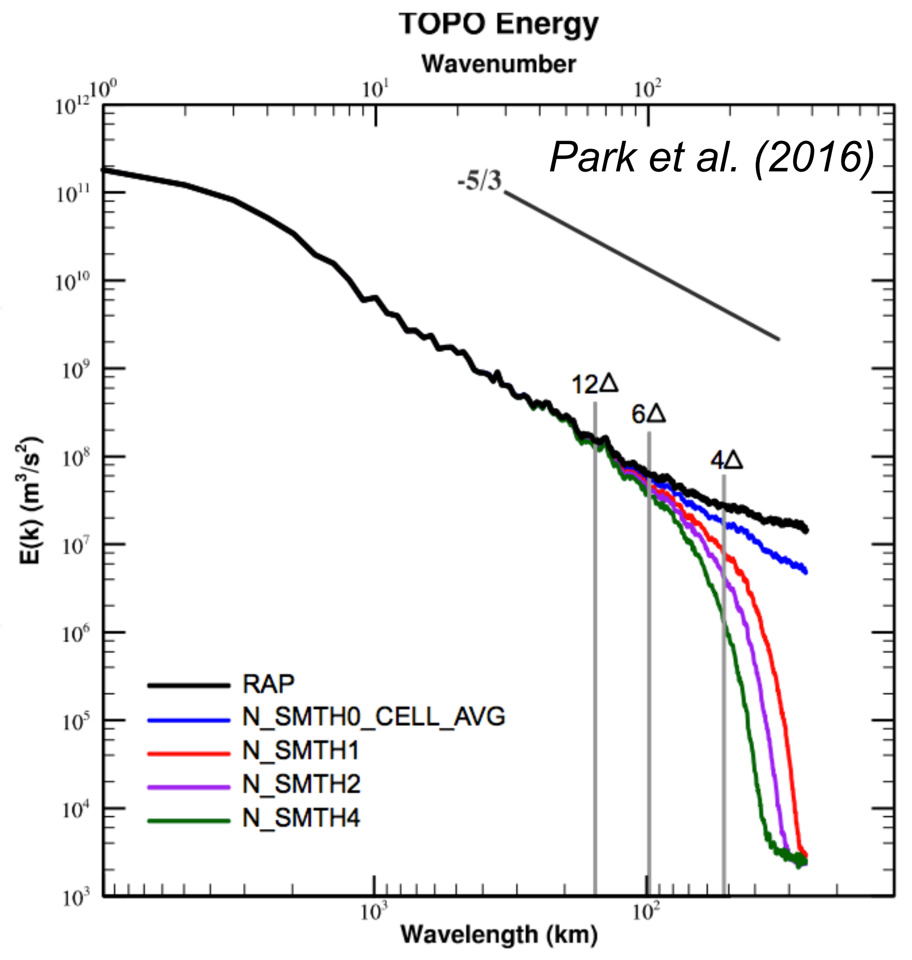


<0.05 EDR Obs. From aircraft

WSPD. contours (40, 55 m/s)

- Graphical Turbulence Guidance 2015.11.02 at 18 UTC
- EDR turbulence diagnostic (shading, based on $|w|/Ri$)
- Horizontal wind speed (40 and 55 m/s, red contours)

Dependency of Terrain Power Spectra on Filtering



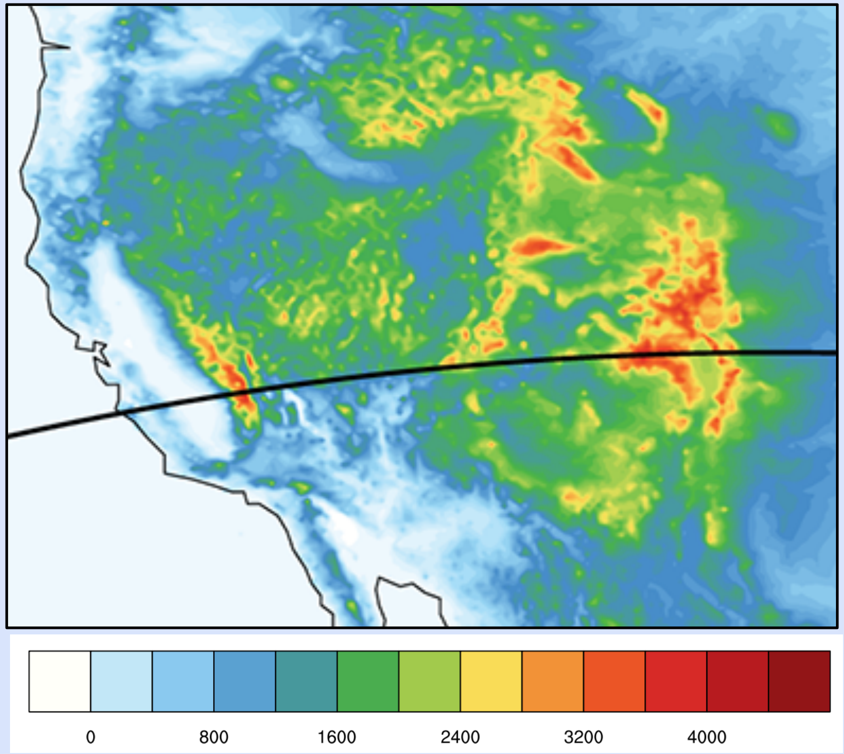
$$\phi^n = \phi^{n-1} + \alpha \nabla^4 \phi^{n-1}$$

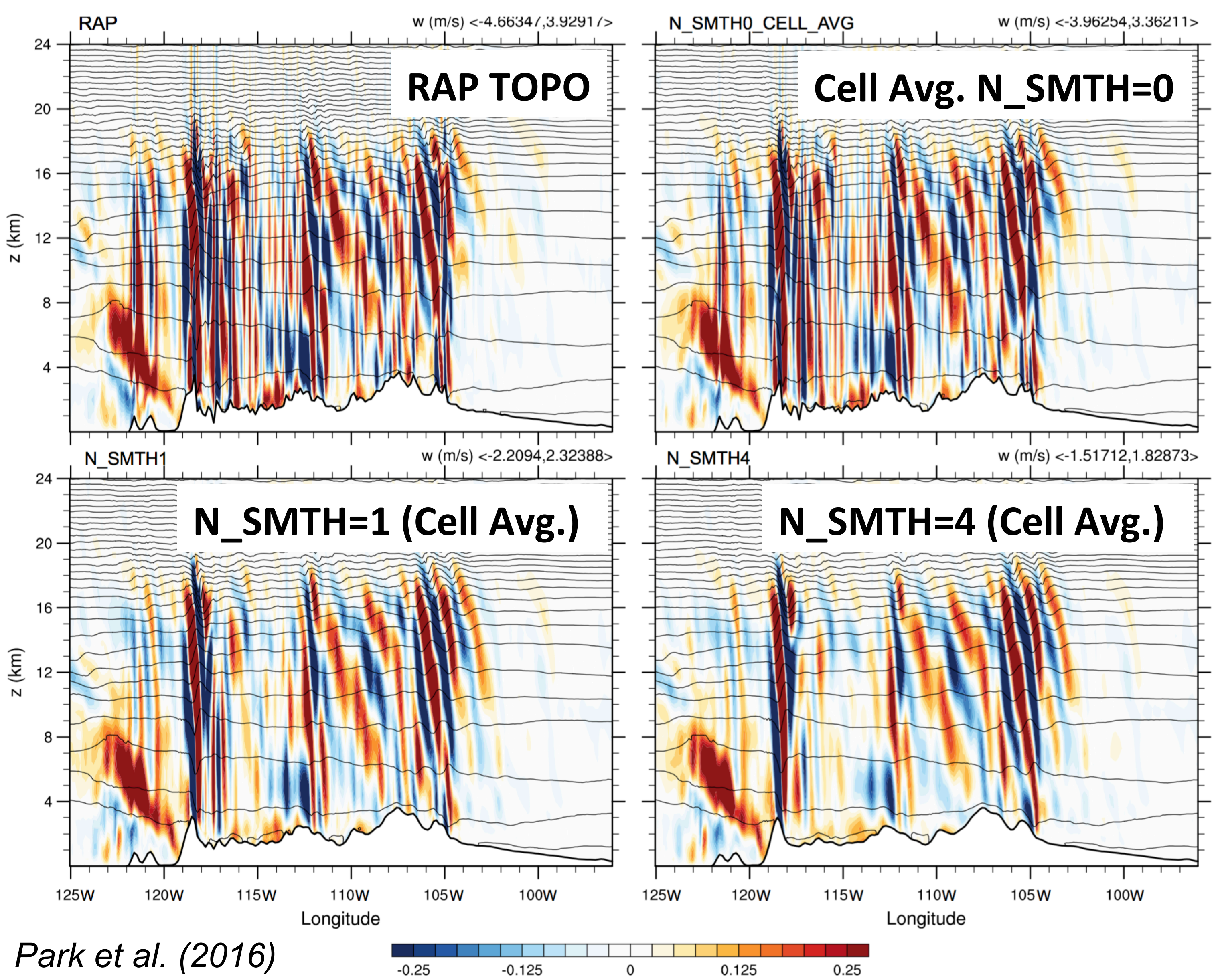
TOPO. Source	INTERP . method	num_ smoothness (n)	Max. TOPO.
2m	4pt. Interp.	0	3768.4
30s	cell avg	0	3643.7
30s	cell avg.	1	3629.0
30s	cell avg.	2	3625.5
30s	cell avg.	4	3618.2

With no terrain smoothing (*num_smoothness=0*), $2\triangle$ modes are not removed regardless of interpolation method and source data of TOPO.

Sensitivity of Mountain Waves (w) to terrain smoothing

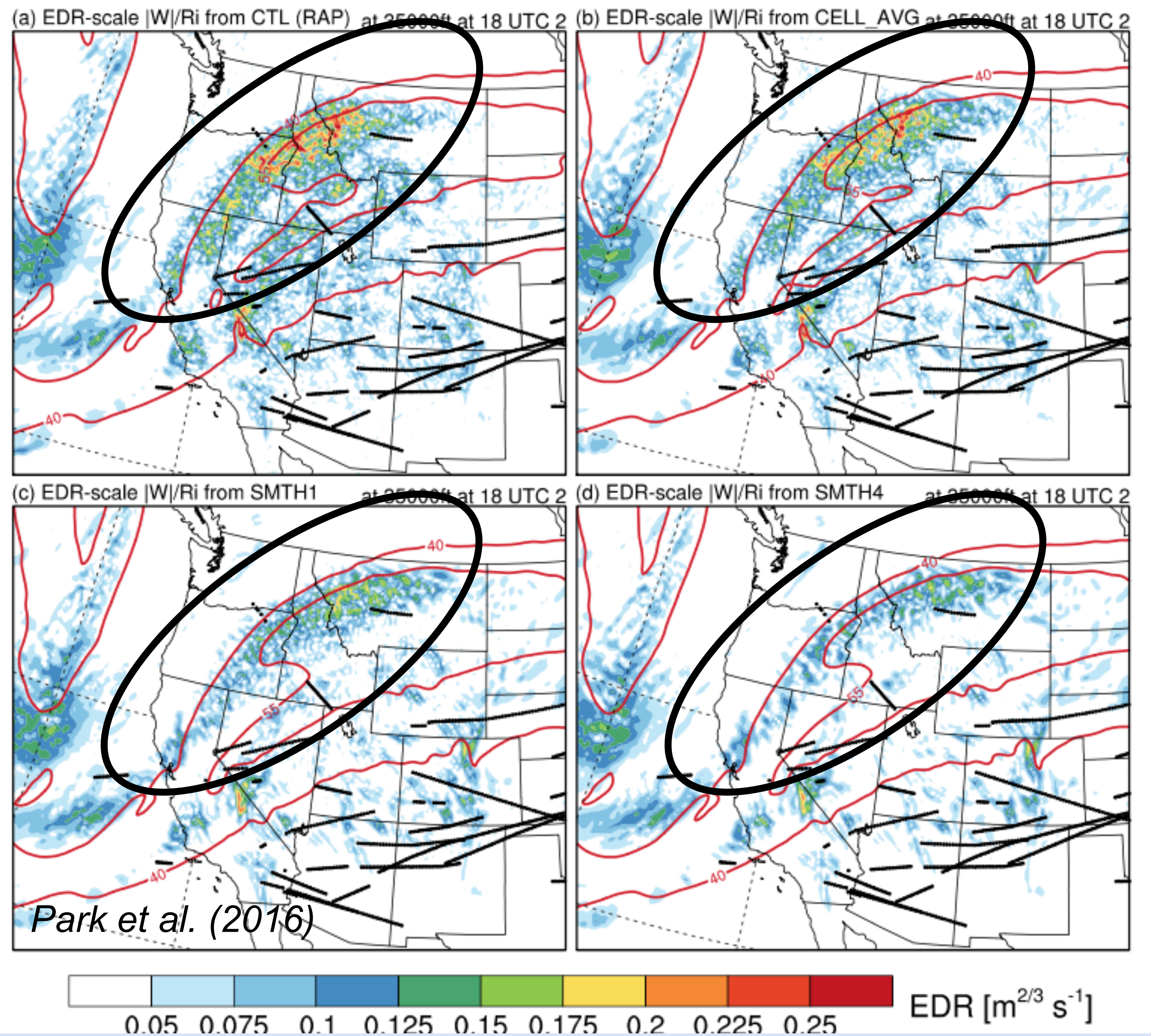
topography





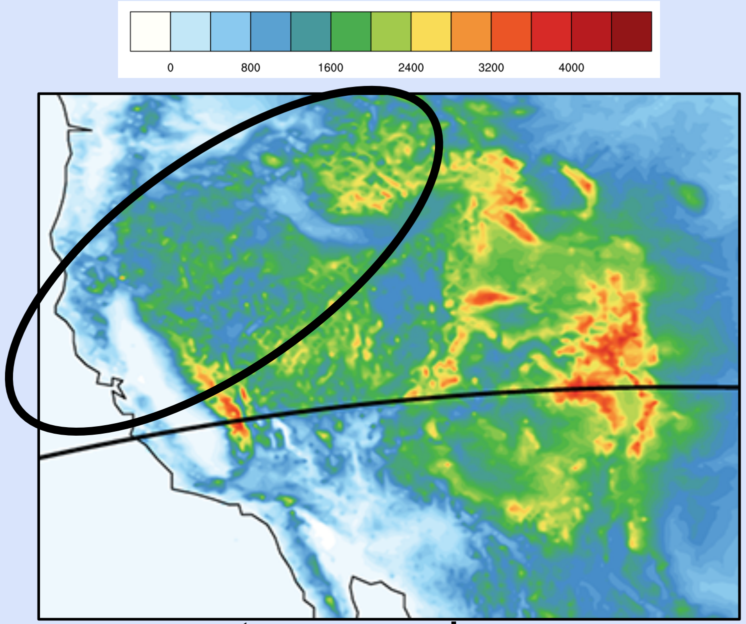
Park et al. (2016)

Sensitivity of Air Turbulence (EDR) to Terrain Smoothing



<0.05 EDR Obs. From aircraft

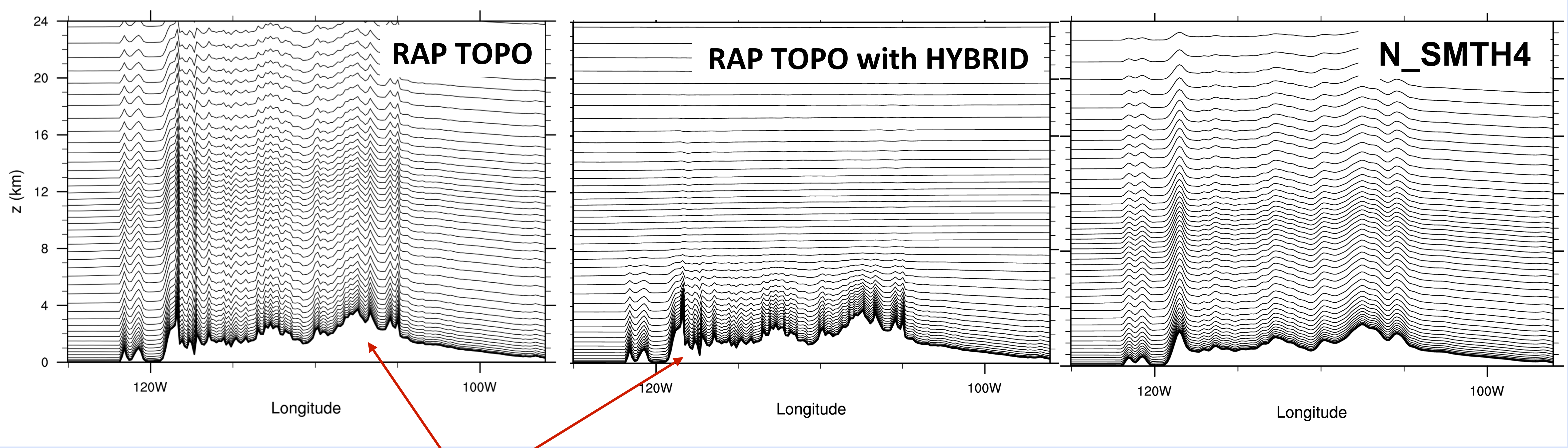
WSPD. contours (40, 55 m/s)



topography

Other Possibilities to reduce False Alarm

- *vertical coordinate (need smoothed coordinate?)*



- Both of TOPO. include $2\triangle$ mode (*num_smoothness=0*), but new a option HYBRID vertical coordinate (see Park et al (2013) *or* Dave Gill Talk in WRF2016) is applied in the middle panel.

WRF Hybrid Pressure Vertical Coordinate

Basic sigma (BTF) coordinate

$$p_d = \eta(p_s - p_t) + p_t$$

$$\eta = \frac{p_d - p_t}{p_s - p_t}$$

Coordinate metric:

$$\mu_d(x, y, t) = \frac{\partial p_d}{\partial \eta} = \Delta p_c$$

Hybrid sigma (HTF) coordinate

$$p_d = B(\eta)(p_s - p_t) + [\eta - B(\eta)](p_0 - p_t) + p_t$$

$B(\eta)$: Relative weighting between terrain-following and pure dry hydrostatic pressure coordinate:

$$\eta = \frac{p_d - p_t}{p_s - p_t} \quad \text{for } B(\eta) = \eta$$ (basic sigma)

$$\eta = \frac{p_d - p_t}{p_0 - p_t} \quad \text{for } B(\eta) = 0$$ (pure pressure)

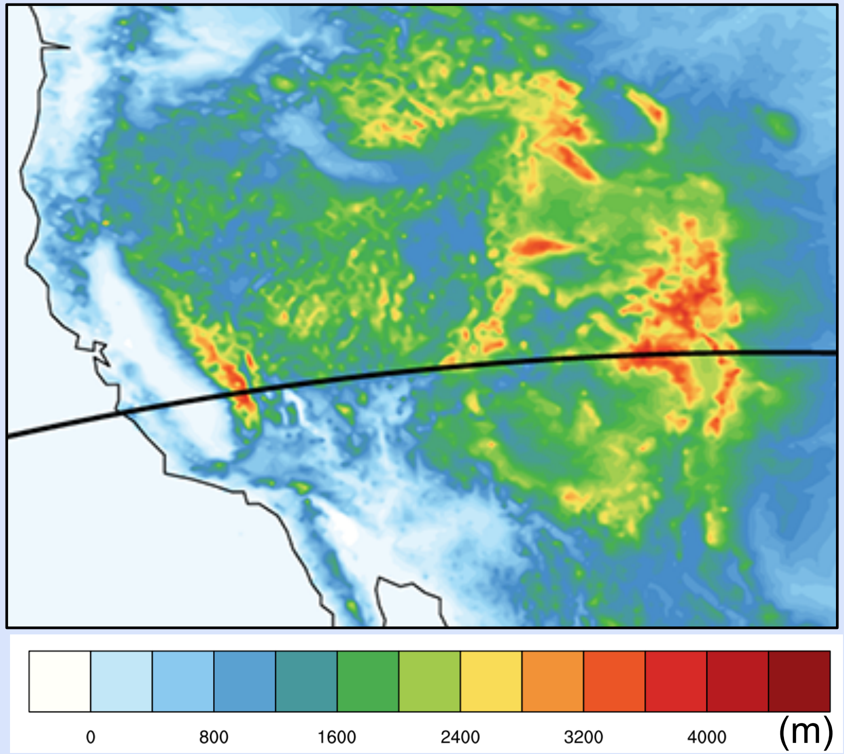
$$\mu_d(x, y, \eta, t) = \frac{\partial p_d}{\partial \eta} = B_\eta \Delta p_c + (1 - B_\eta)(p_0 - p_t)$$

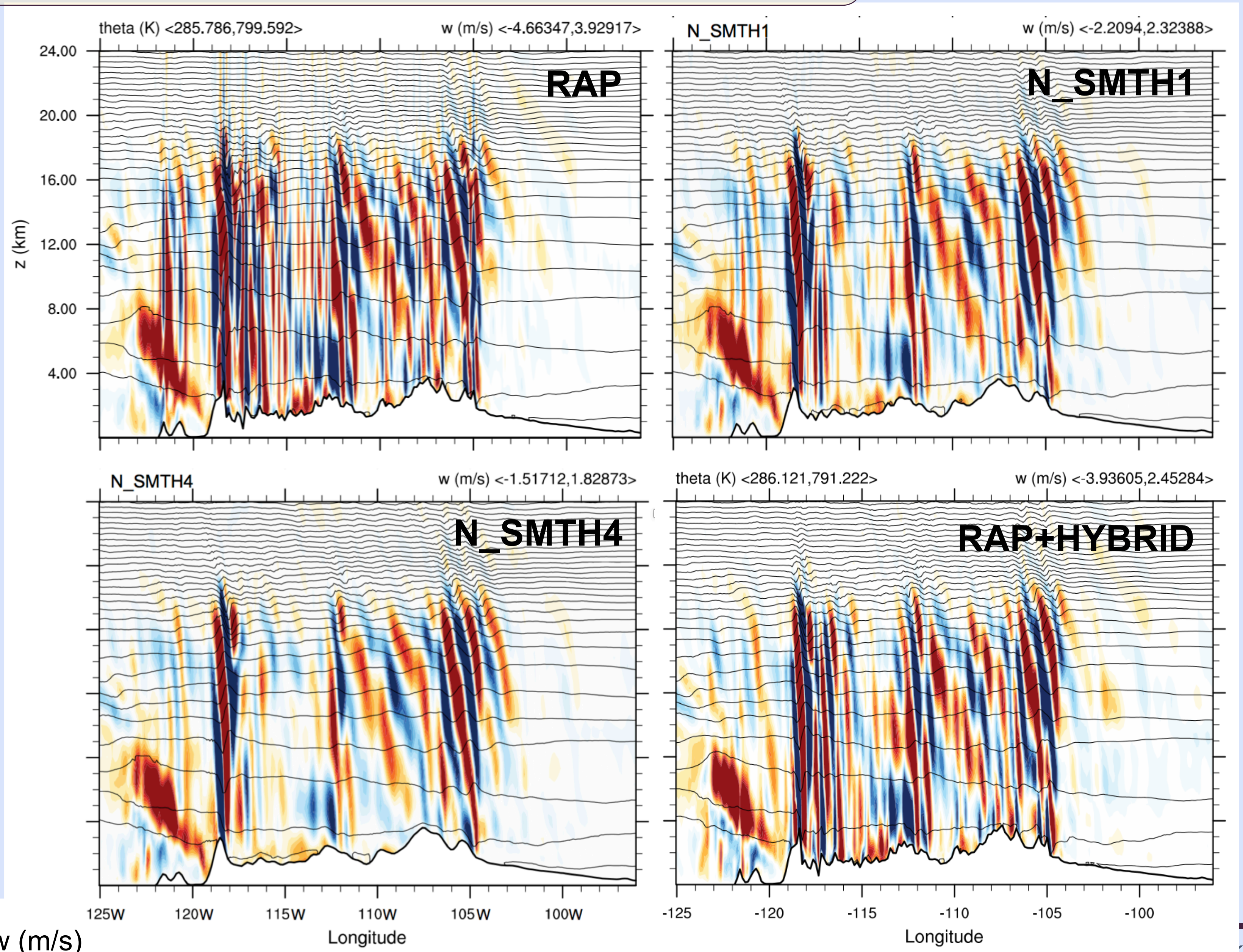
$$\Delta p_c = p_s - p_t$$ ~ mass in each vertical column

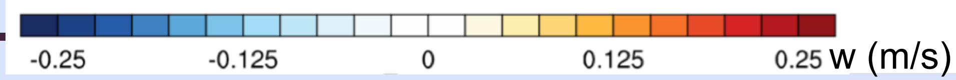
See Lecture in *WRF2016 (from Dave Gill)* or *Park et al. (2013)*

Sensitivity of Mountain Waves (*w*)

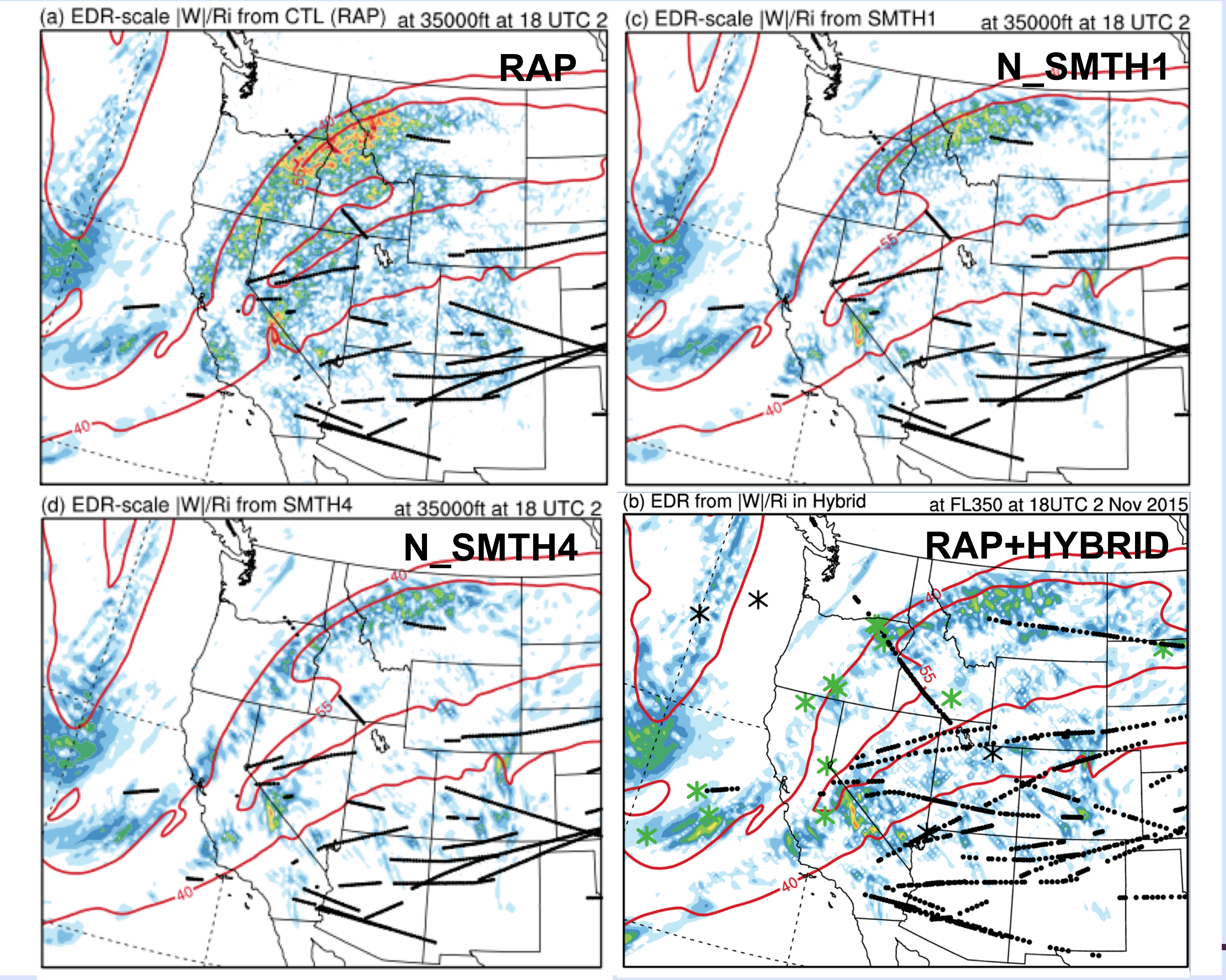
topography







Sensitivity of Air Turbulence (EDR) to Hybrid Coordinate

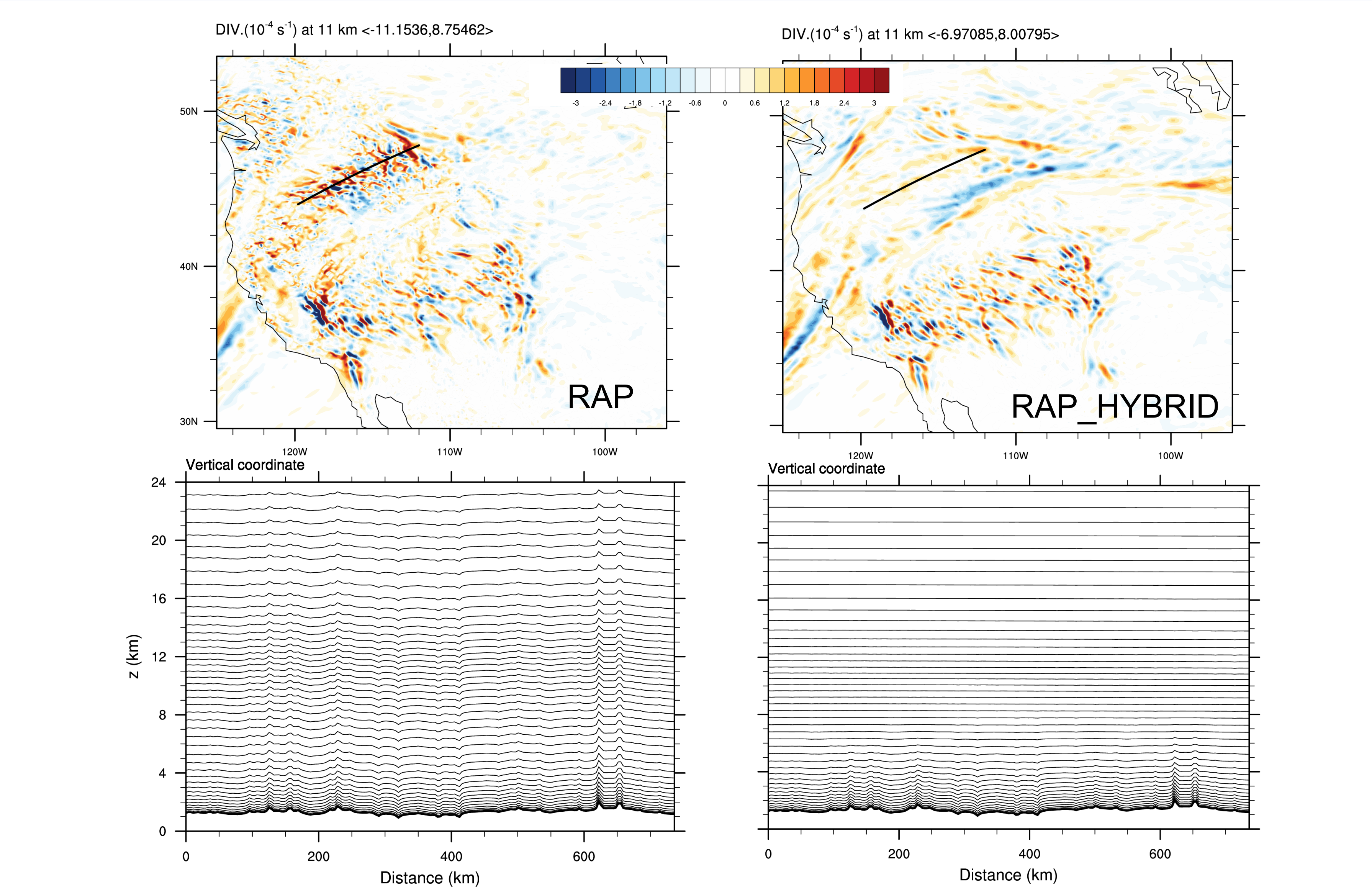


z ~ 11 km

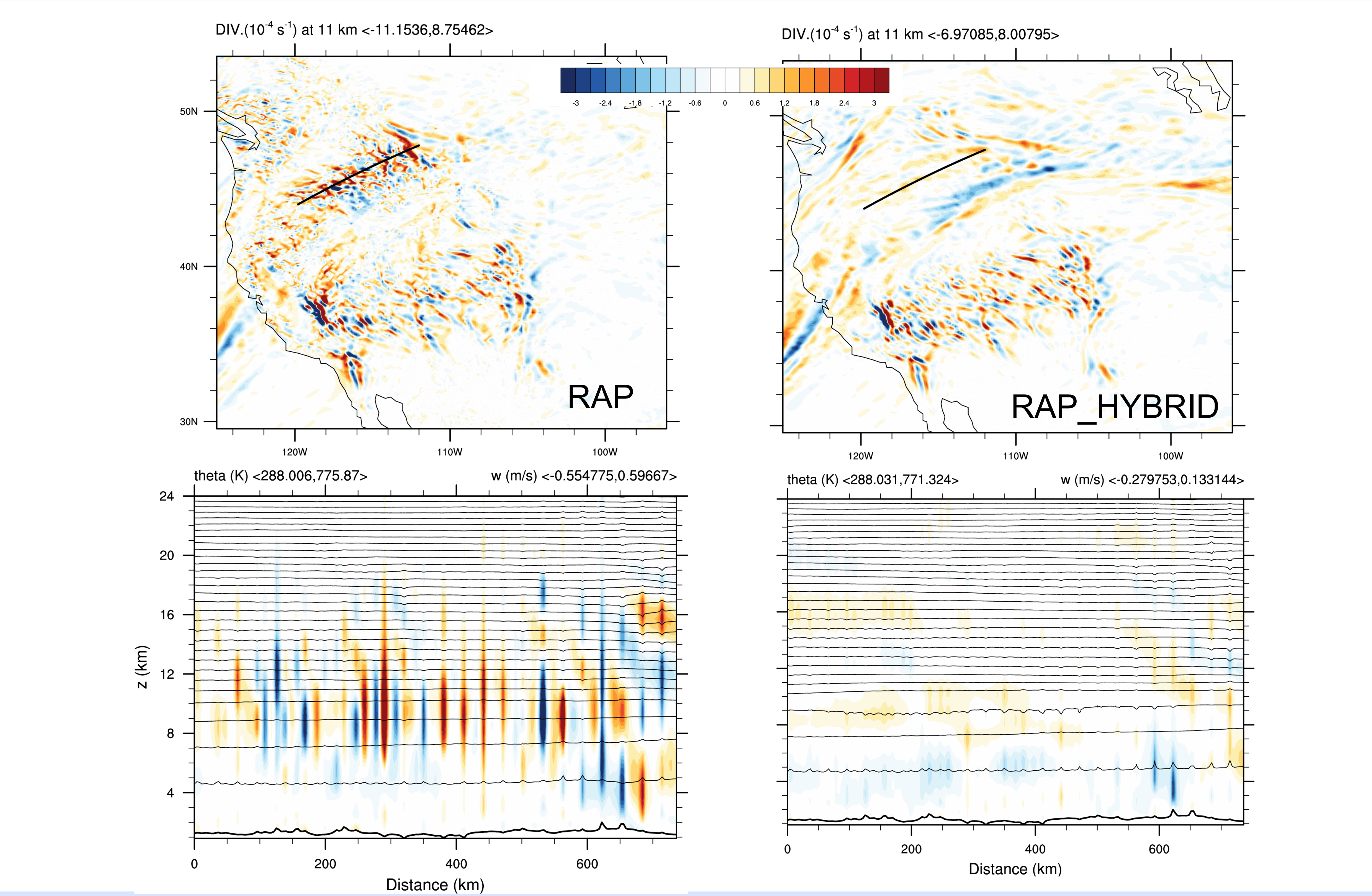
<0.05 EDR Obs. From aircraft

WSPD. contours (40, 55 m/s)

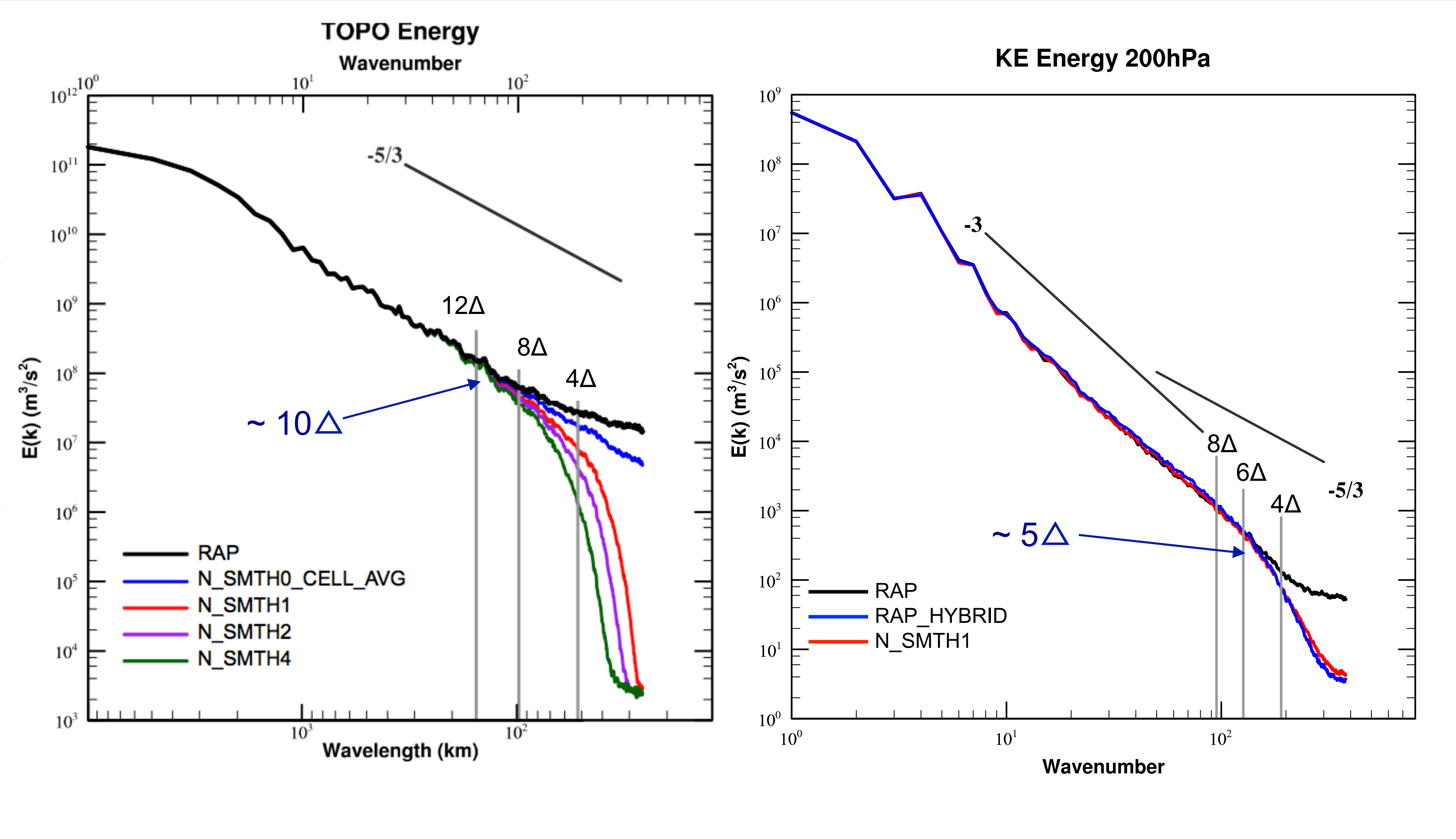
Vertical Cross Section in Vicinity of Upper Level Jet



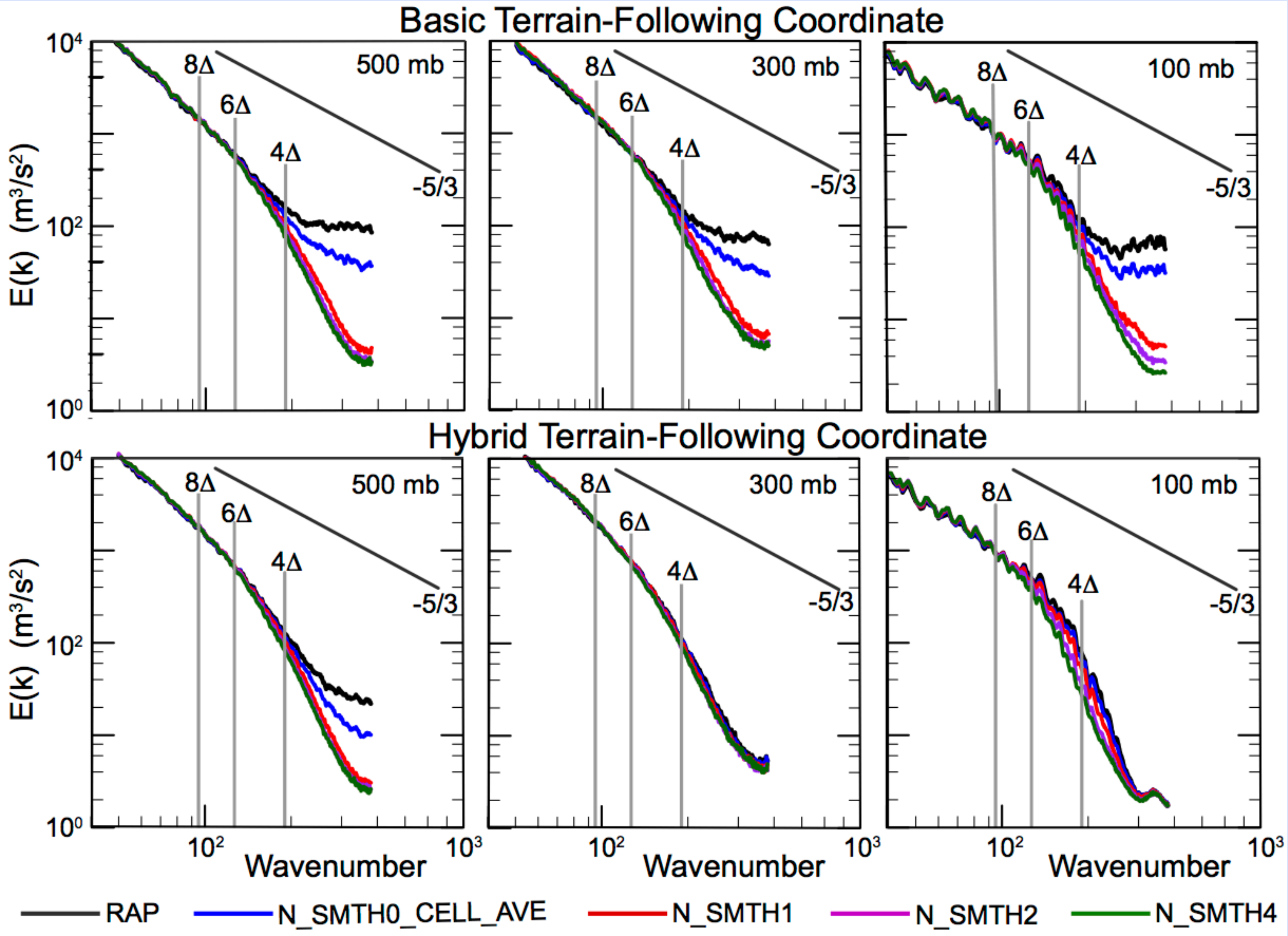
Vertical Cross Section in Vicinity of Upper Level Jet



Kinetic Energy Spectra and Treatment of Terrain



Kinetic Energy Spectra and Treatment of Terrain



Conclusion

- Disturbances appear to result from numerical errors in representing strong advection along irregular coordinate surfaces

- Errors from irregular coordinate surfaces can be amplified where strong winds are existed

- Terrain smoothing and/or a hybrid vertical coordinate may be effective in reducing the overestimation of upper-level waves that contribute to false alarm predictions of air turbulence.

  - With the HTF coordinate, upper-level flow is not sensitive to small-scale terrain features

  - (With the BTF coordinate, terrain smoothing is required to remove upper-level noise)

- Model kinetic energy spectra and terrain power spectra provide useful diagnostics in assessing this balance.

- Ideally, we believe terrain filtering should be implemented such that the effective resolution of the topography is similar to that of the model numerics.