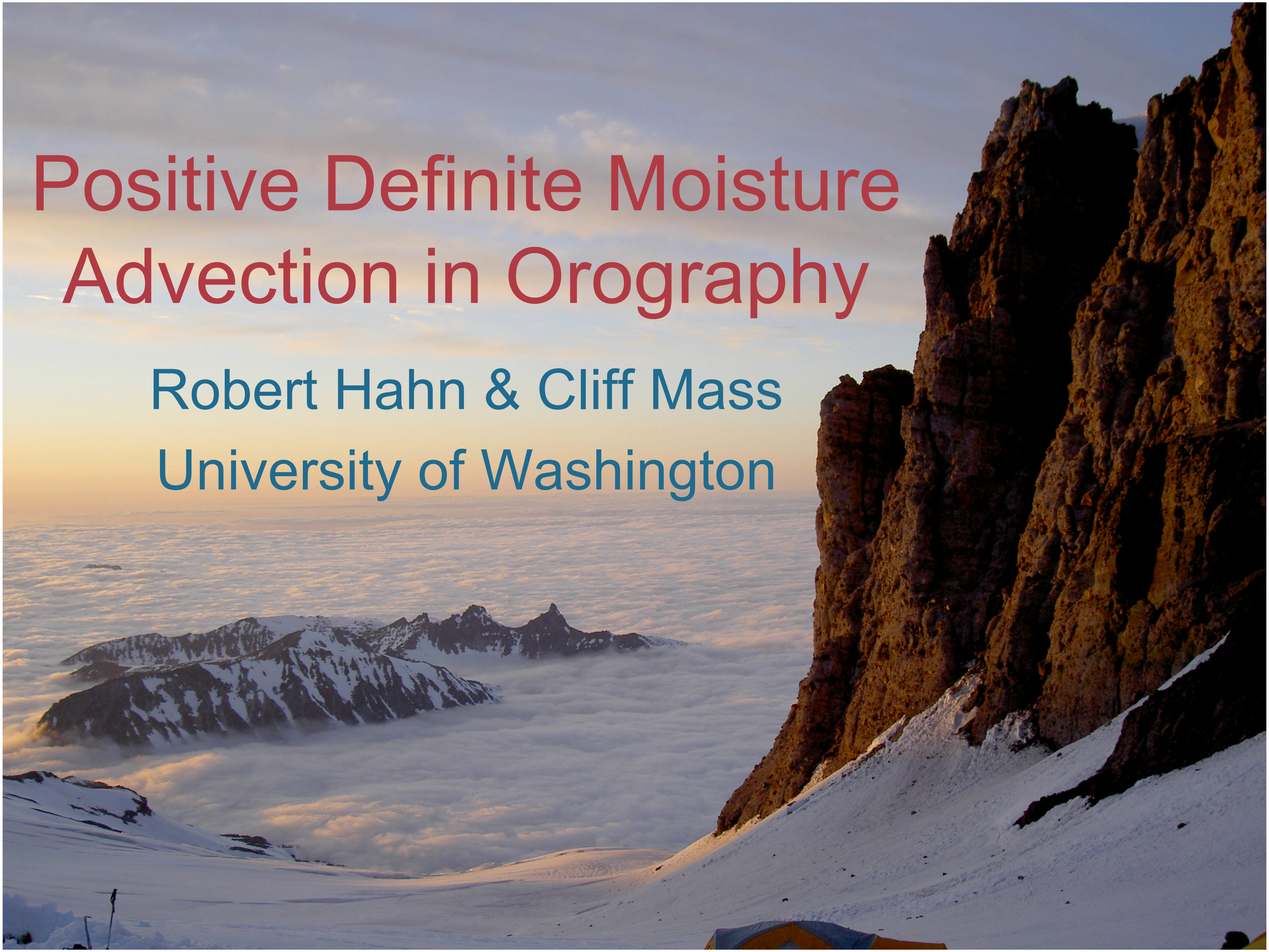
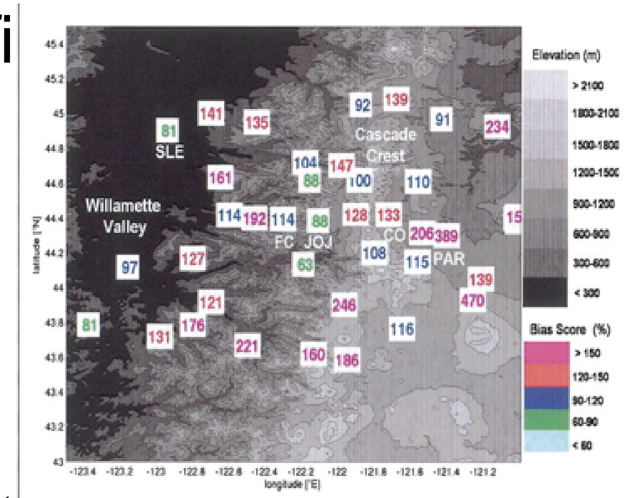

Positive Definite Moisture Advection in Orography
Robert Hahn & Cliff Mass
University of Washington

Why Positive Definite?

- Numerous investigators have found biases in precipitation and mixing ratio fi

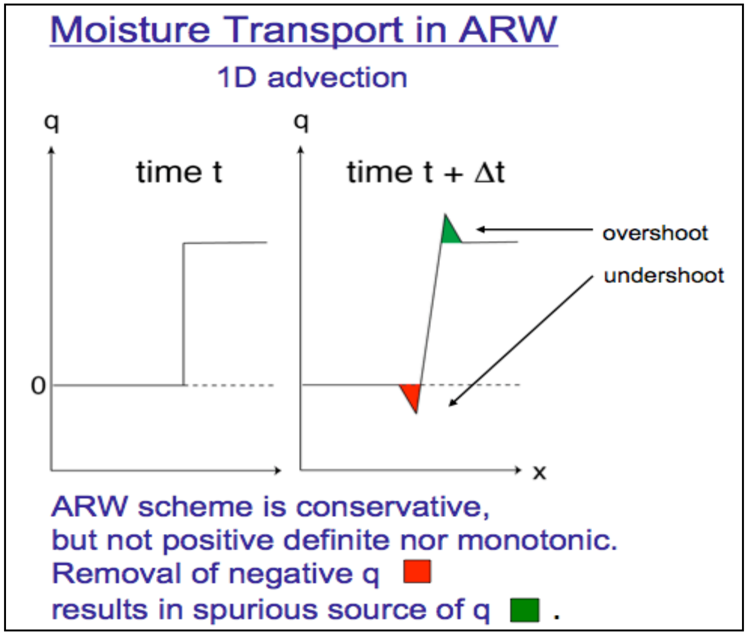


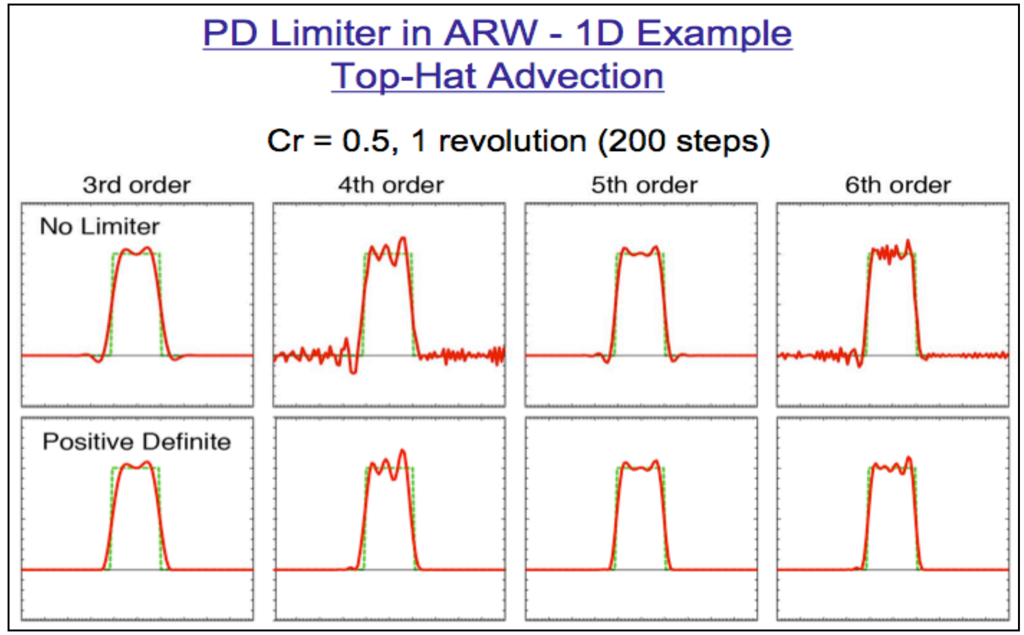
Bias Scores For MM5
1.33-km

$$\text{Bias Score} = \left(\frac{\text{Modeled Precip.}}{\text{Observed Precip.}} \right) \bullet 100$$

- Until recently, mesoscale weather models did not conserve moisture because of overlooked numerical challenges in advection schemes.
- This presentation illustrates the effects of the recently-introduced positive definite moisture advection scheme in WRF at high spatial and temporal resolution.
- With an understanding of changes in model numerics, we will renew investigation of the microphysics schemes themselves.

Advection Schemes





- Advection schemes can introduce both positive and negative errors, particularly when there are sharp gradients.
- This becomes significant when dealing with microphysical quantities because some moisture values can have sharp edges where the quantity goes to zero.
- When negative mass values are generated, models often reset or ‘clip’ these values to zero and moisture is added to the model, artificially.
- Positive Definite (PD) Advection schemes eliminate non-physical generation of negative values, while conserving mass (see figure).

*graphics from a presentation by Morris Weisman

Previous Studies

- Numerical errors in a 2-km MM5 simulation of Hurricane Bonnie contributed a mass equivalent to 13% of total condensation and 15-20% of the precipitation associated with ‘clipping’ of negative mixing ratios (Braun et al., 1998)
- Skamarock (2005) positive definite limiter in WRF.
- For convective cases, Skamarock & Weisman (2008) found
  - PD scheme reduces precipitation by ~15%.
  - The majority of the spurious water is added in the cloud field.
  - The PD scheme reduces positive bias most effectively for larger rain events (>1/2 inch).
- Lin & Colle (2008) investigated the aggregate effects of the PD scheme for the 4-5 December 2008 event.
  - The Non-PD run generated 25-45% more precipitation over the coast range and 10% more precipitation over the cascades. Mixing ratios for non-PD runs are increased by ~10-20%.
  - The non-PD run also generates more precipitation than there are available water sources. PD corrects this problem.

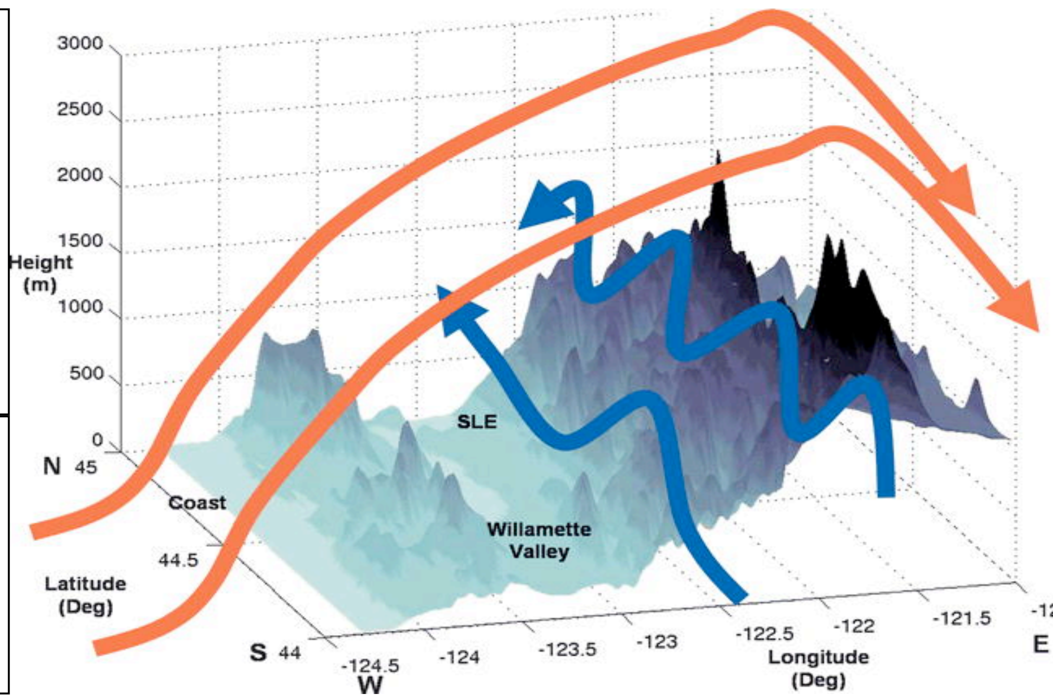
Why Orography?

- Theory indicates that PD should have it's greatest effect where large gradients in moisture species are present.
- Both convection and orography induce such large gradients in many microphysical fields.
- Orography also provides temporal stability of the flow pattern and associated microphysical fields, making it ideal for examining the generation of spurious sources of mass in a real-time simulation.

December 13-14 Case

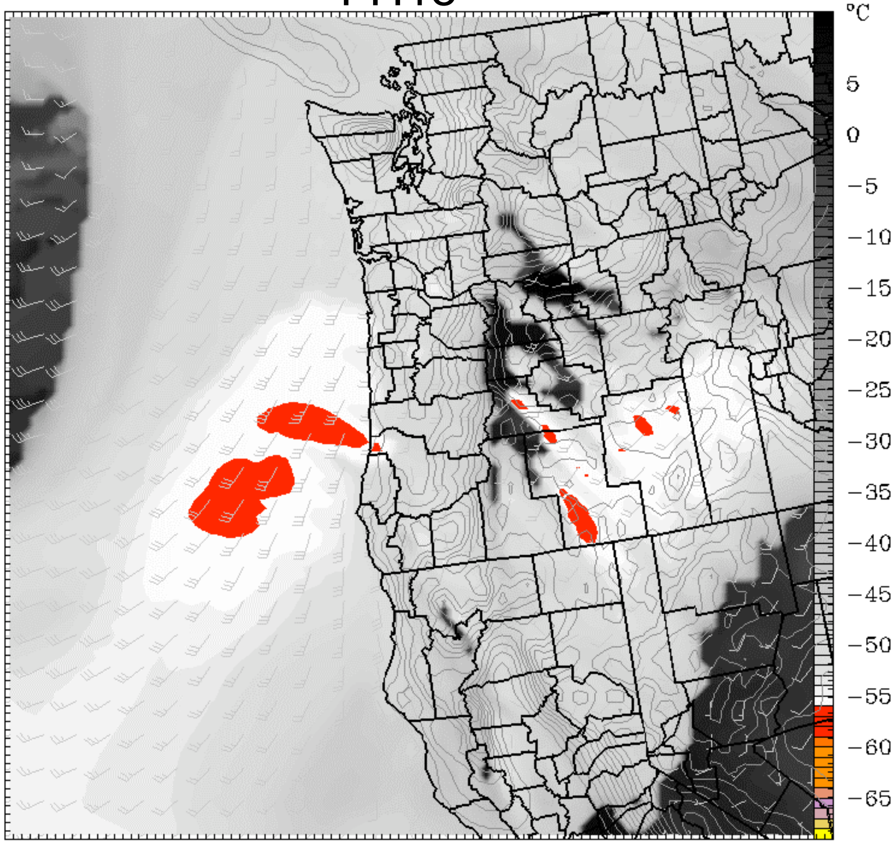
- A unique data assets from the IMPROVE-II field campaign has permitted microphysical investigation since 2001 by Garvert, Colle, Woods and others.
- Vigorous synoptic and orographic forcing combine to make this case ideal for the study of PD advection.

Garvert et al. (2007) found that while broad upward motion is associated with the orographic barrier, alternating upward and downward motions are prevalent as well.
Microphysical quantities responded to the induced vertical motions, creating sharp gradients in moisture.

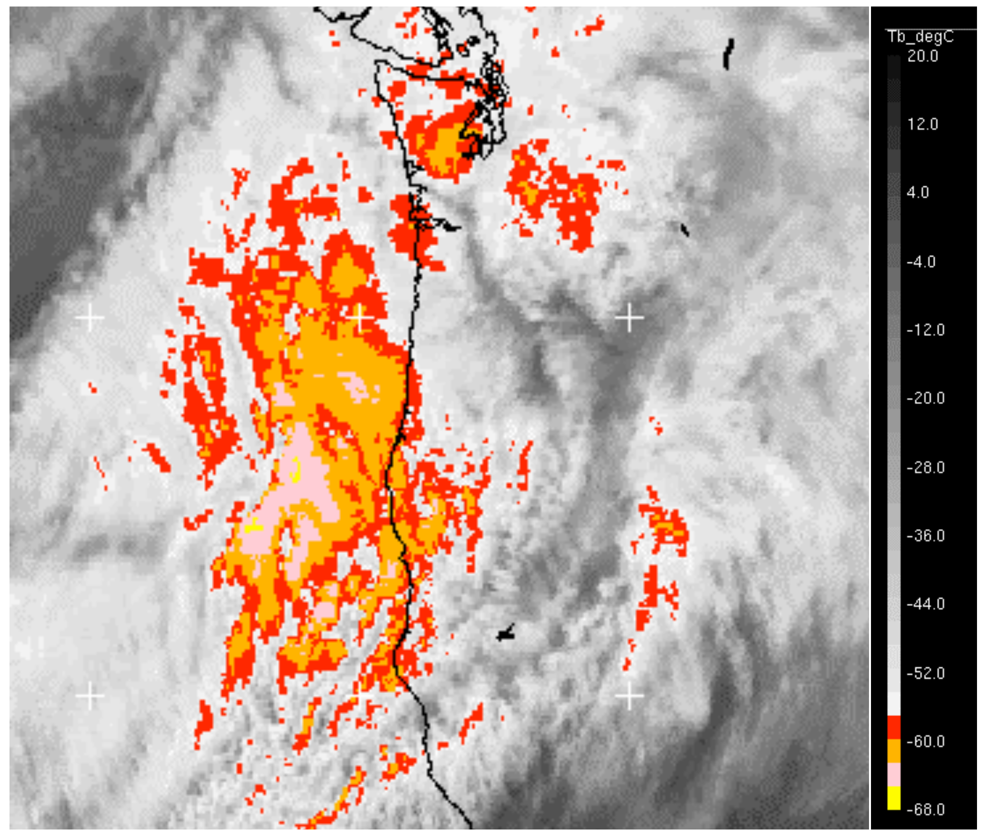


Synoptics: 13-14 December 2001

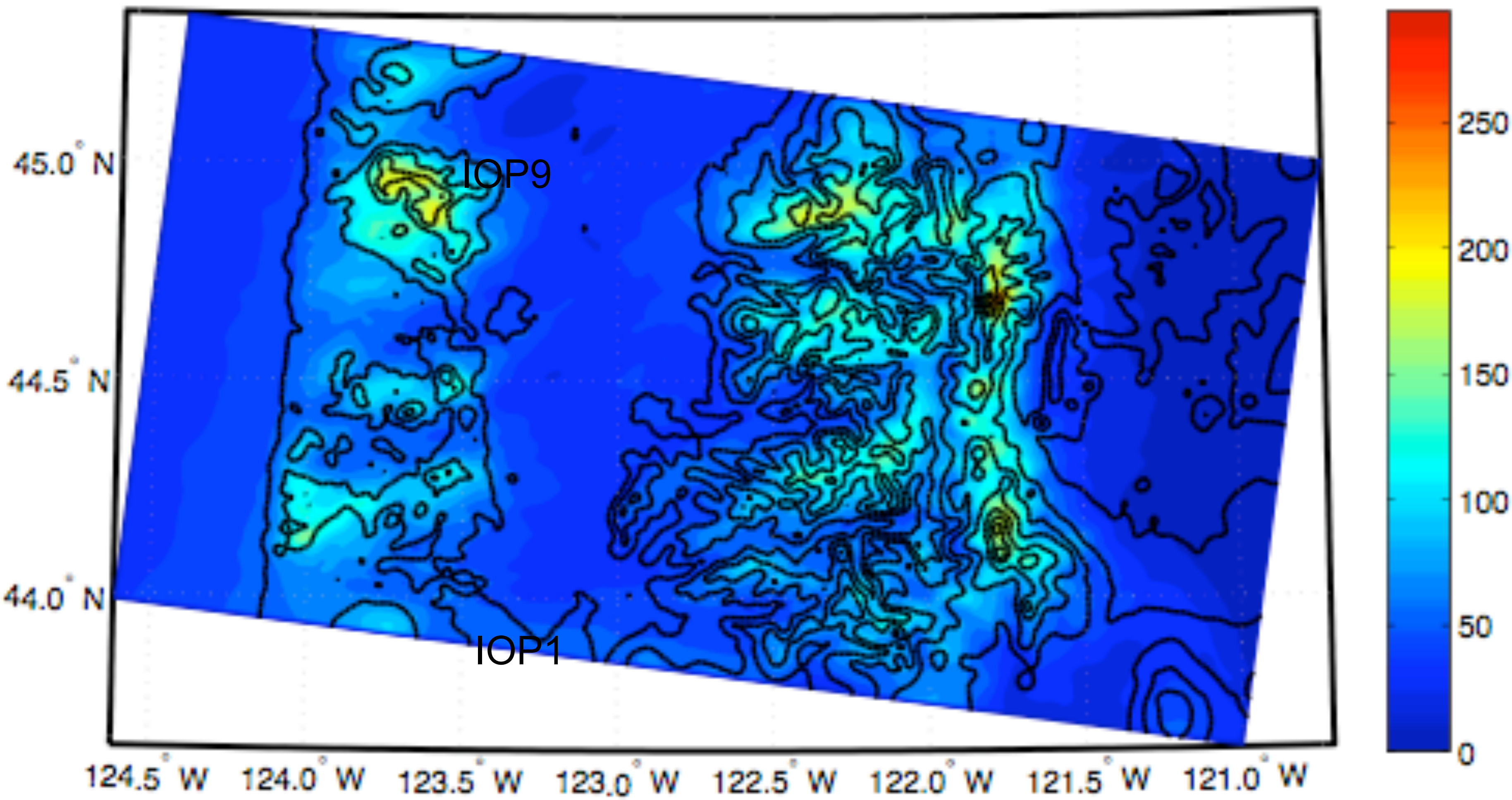
WRF (NOPD) CLOUD TOP TEMPERATURE: FH18



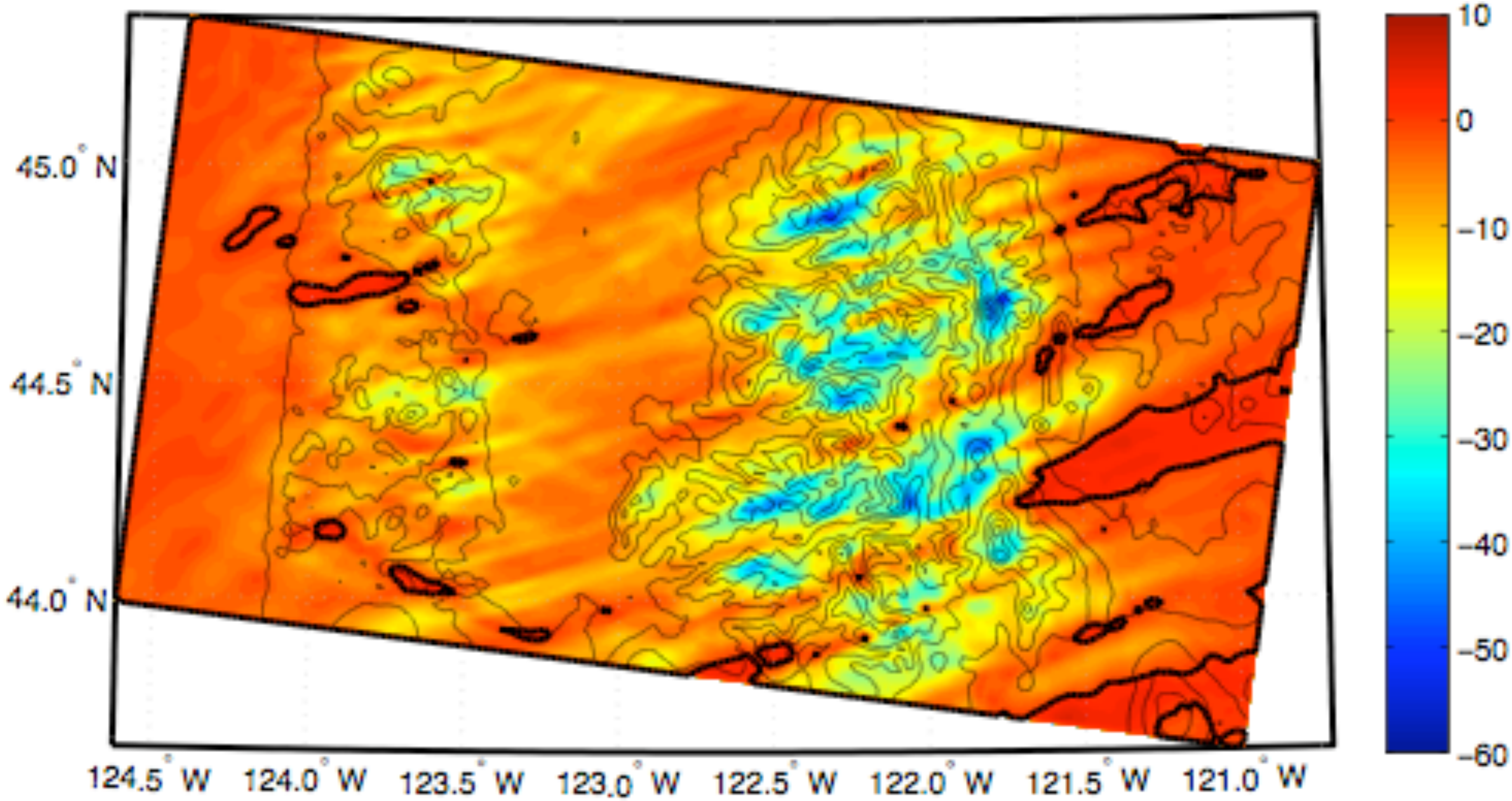
SATELLITE CLOUD TOP TEMPERATURE: FH18



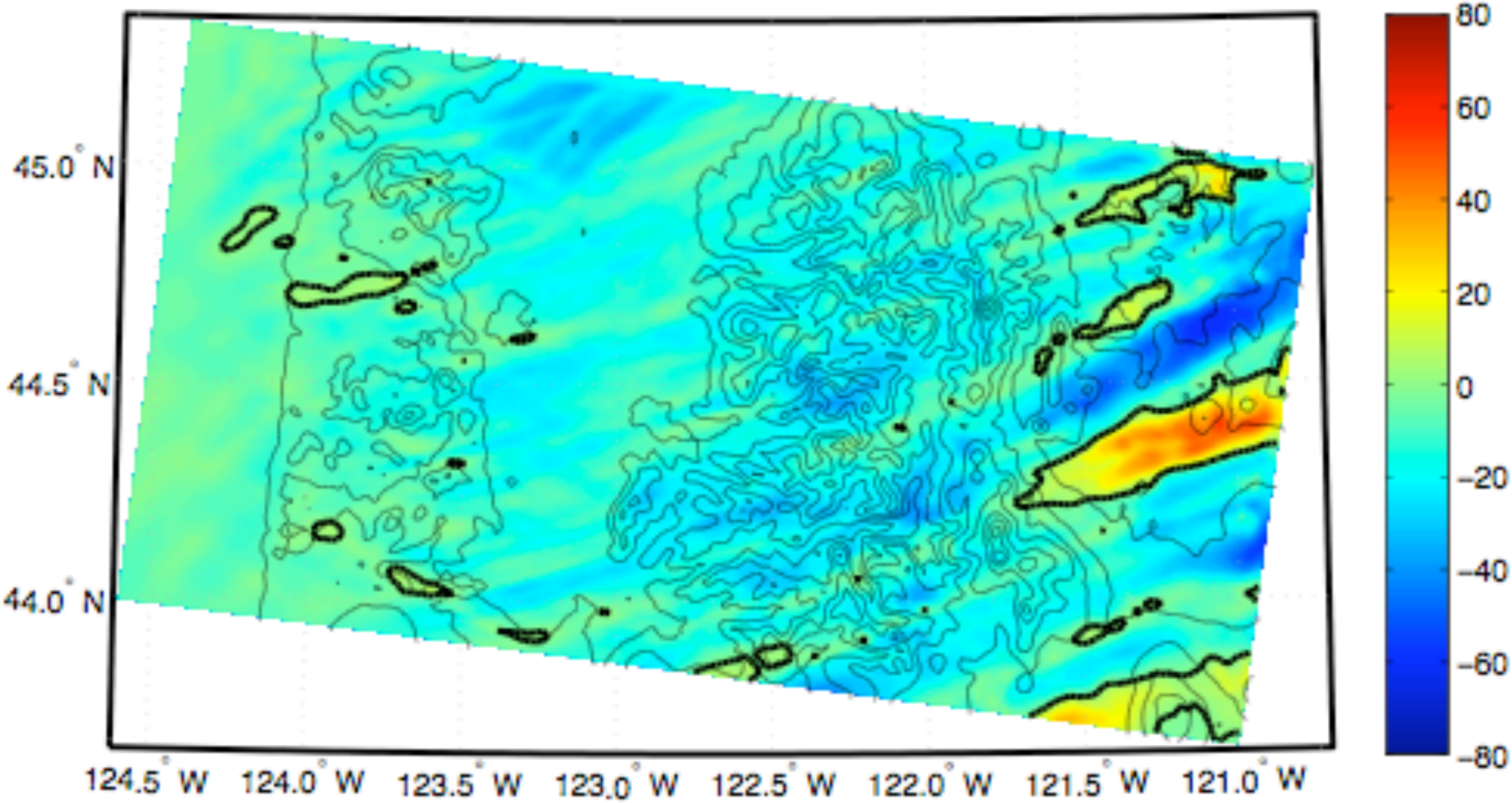
36-hr Accumulated Precip: 1.33-km Grid (PD applied)



36-hr Accumulated Precip (mm): PD-NOPD 1.33-km Grid

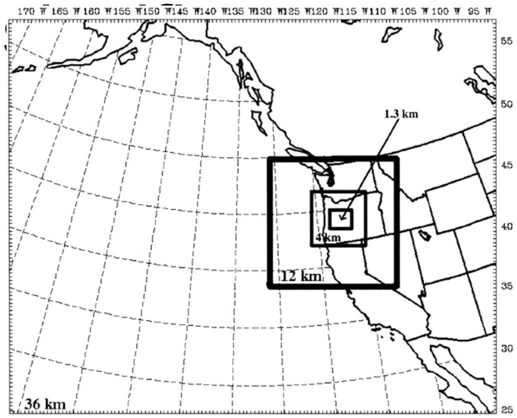


36-hr Accumulated Precip: %Diff PD-NOPD 1.33-km Grid

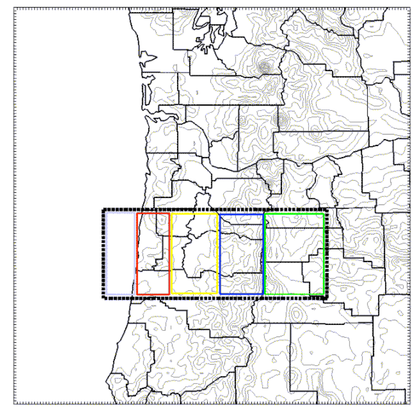


Statistics: Percentage Difference

- Areas with orography tend to be affected more at coarser grid resolution.
- Grid spacing increases % Difference.
- Even at the lowest resolutions, the effects are



36-,12-,4-,1.33-km WRF domains for this case study (from Garvert et. al, 2005)

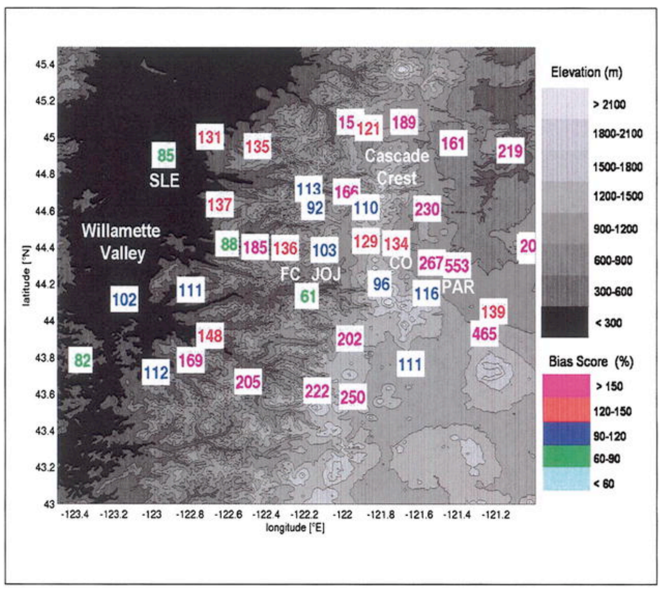


	Coastal Water	Coast Mountain	Willamette Valley	Windward Slopes	Leeward Slopes	TOTAL
36km DOM	-3.4%	-3.8%	-4.0%	-4.9%	-12.6%	-5.9%
12km DOM	-2.5%	-4.5%	-4.1%	-7.2%	-13.6%	-6.1%
4km DOM	-8.4%	-8.9%	-15.4%	-18.7%	-16.1%	-14.6%
1.33km	-14.1%	-11.3%	-16.7%	-20.5%	-16.5%	-17.2%

Model Grid Spacing

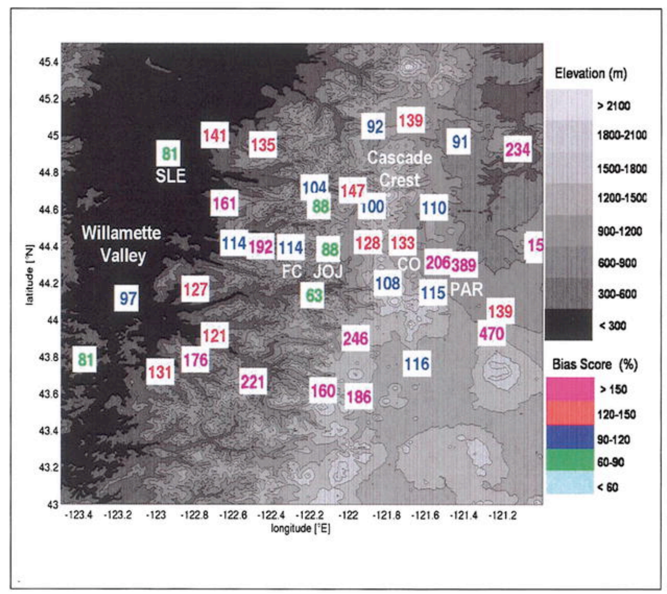
- This is an important point…the problem gets worse at smaller grid spacing.
- This explains some of the problems seen by Garvert et al. (2005) and others.
- Fig. 17. Bias scores for the (a) 1.33- and (b) 4-km model simulations for 1400 UTC 13 Dec 2001 through 0800 UTC 14 Dec 2001.

1.33km



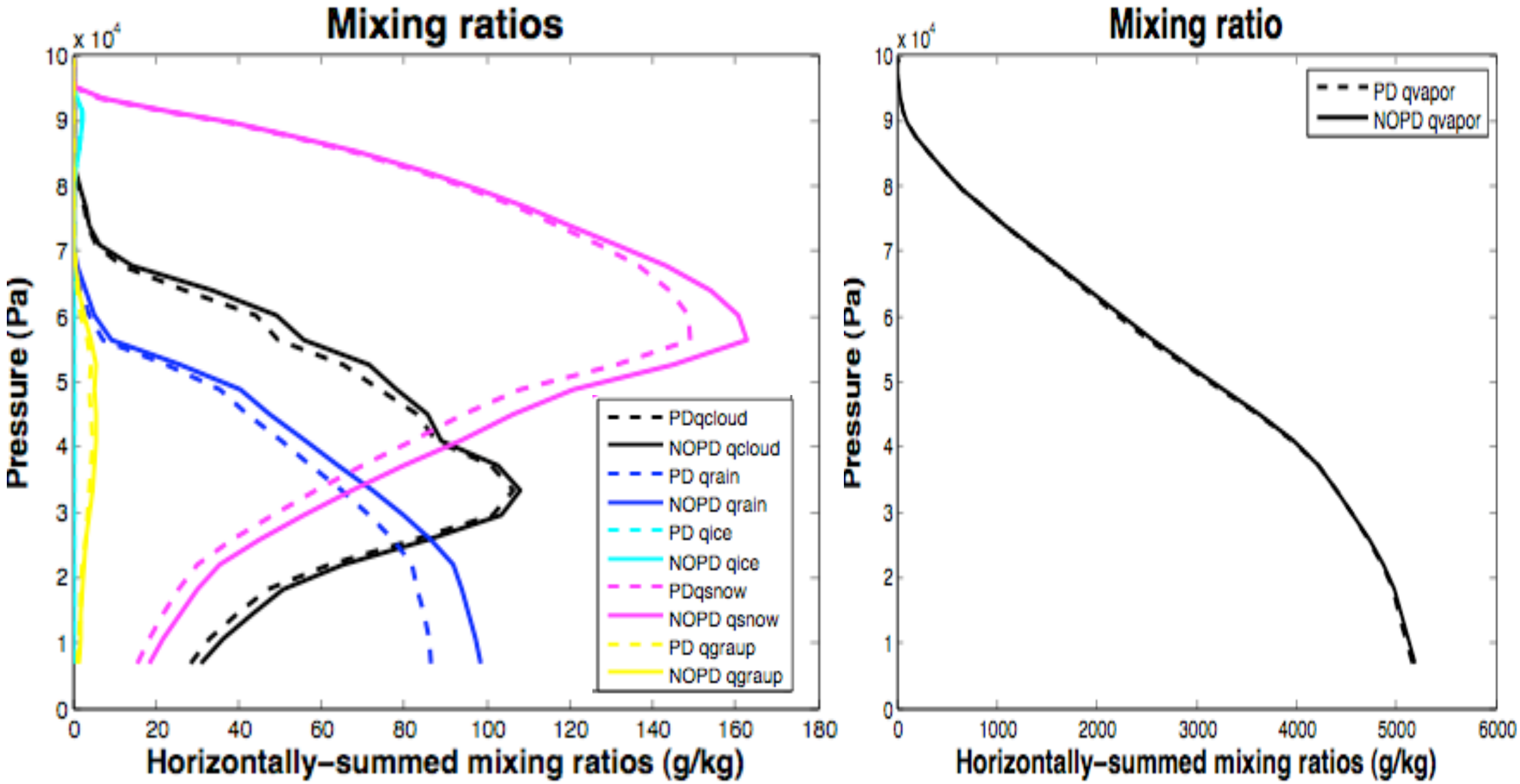
(a)

4km

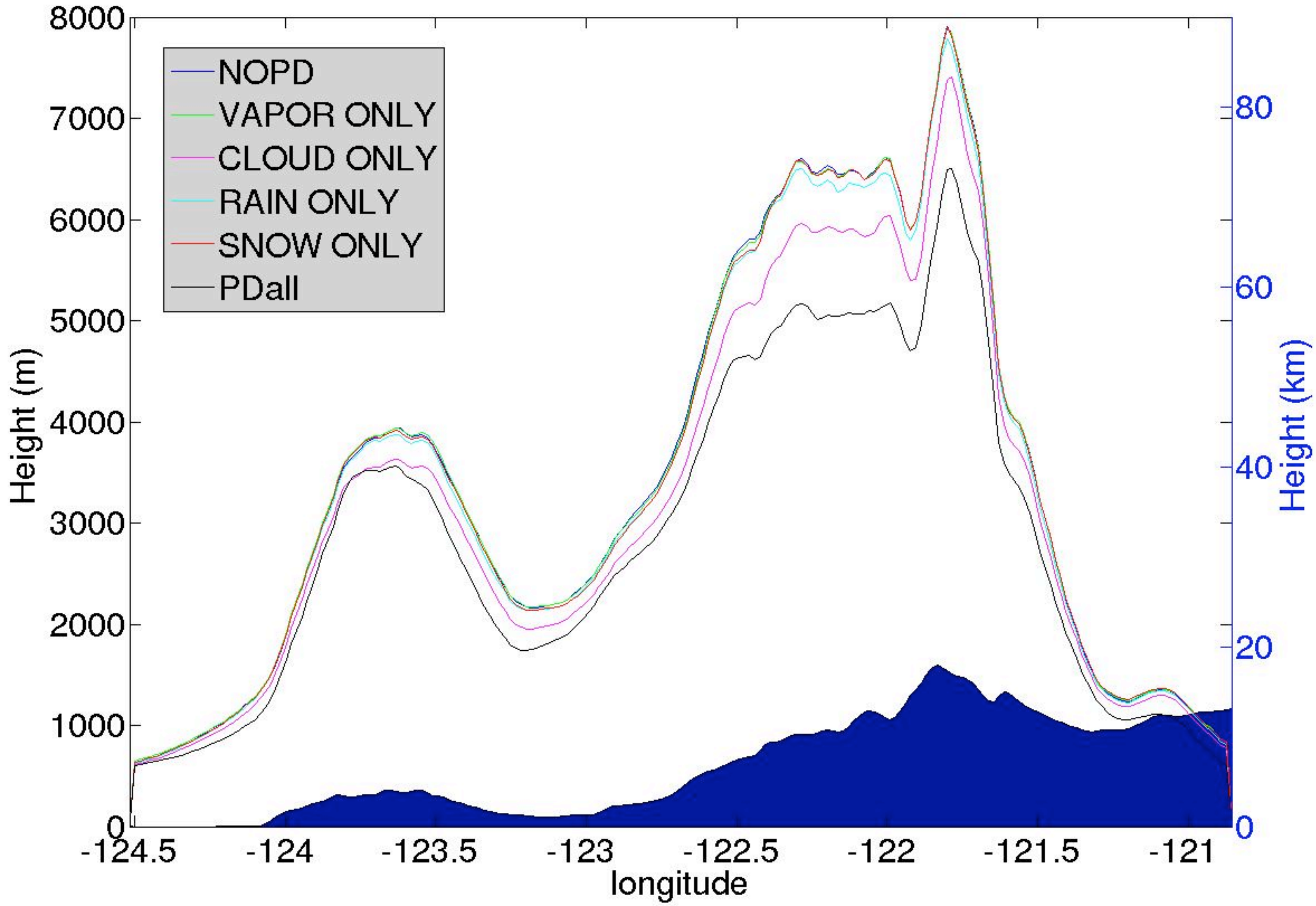


(b)

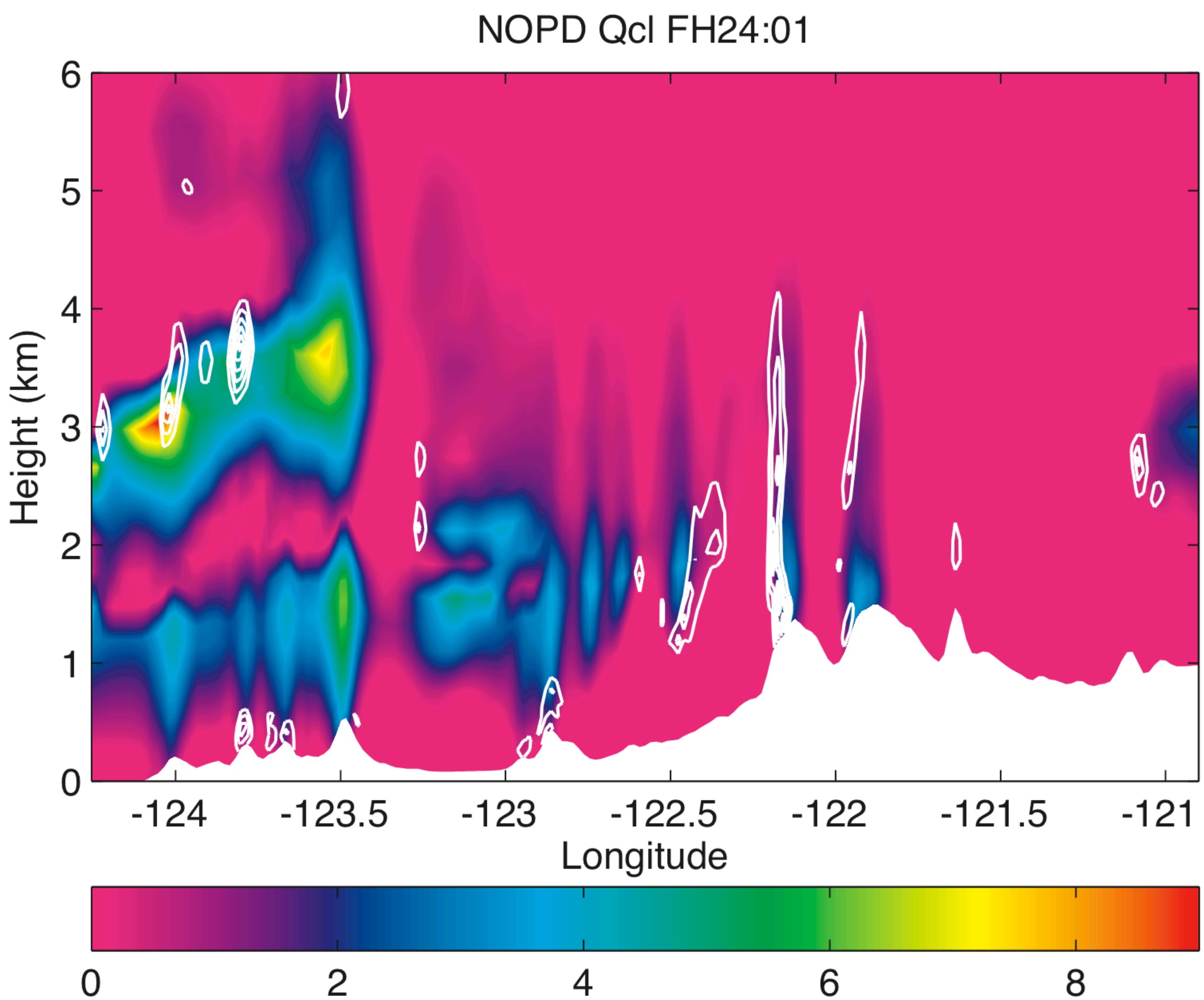
Horizontally Summed Mixing Ratios

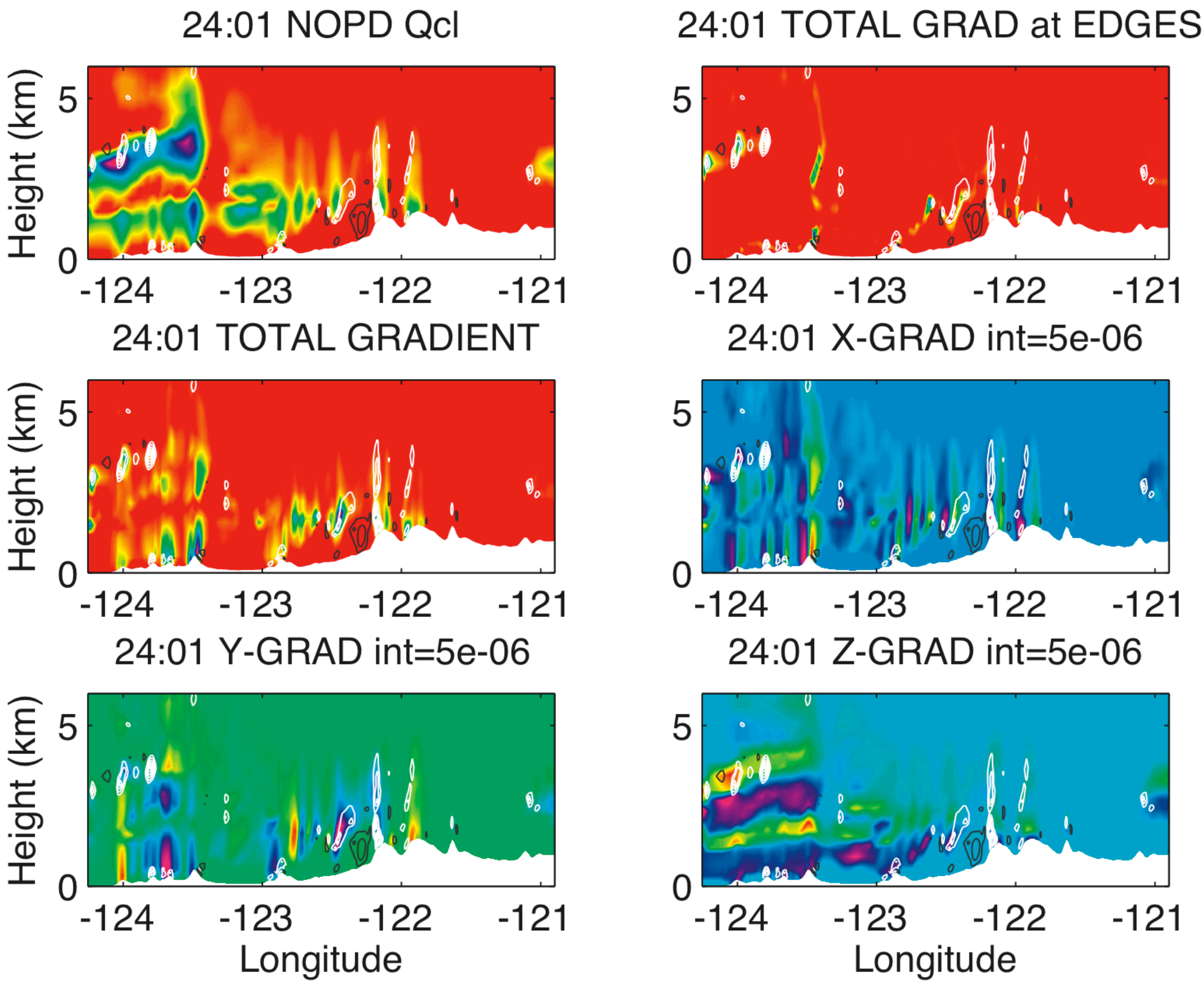


PD applied to individual Hydrometeor Variables

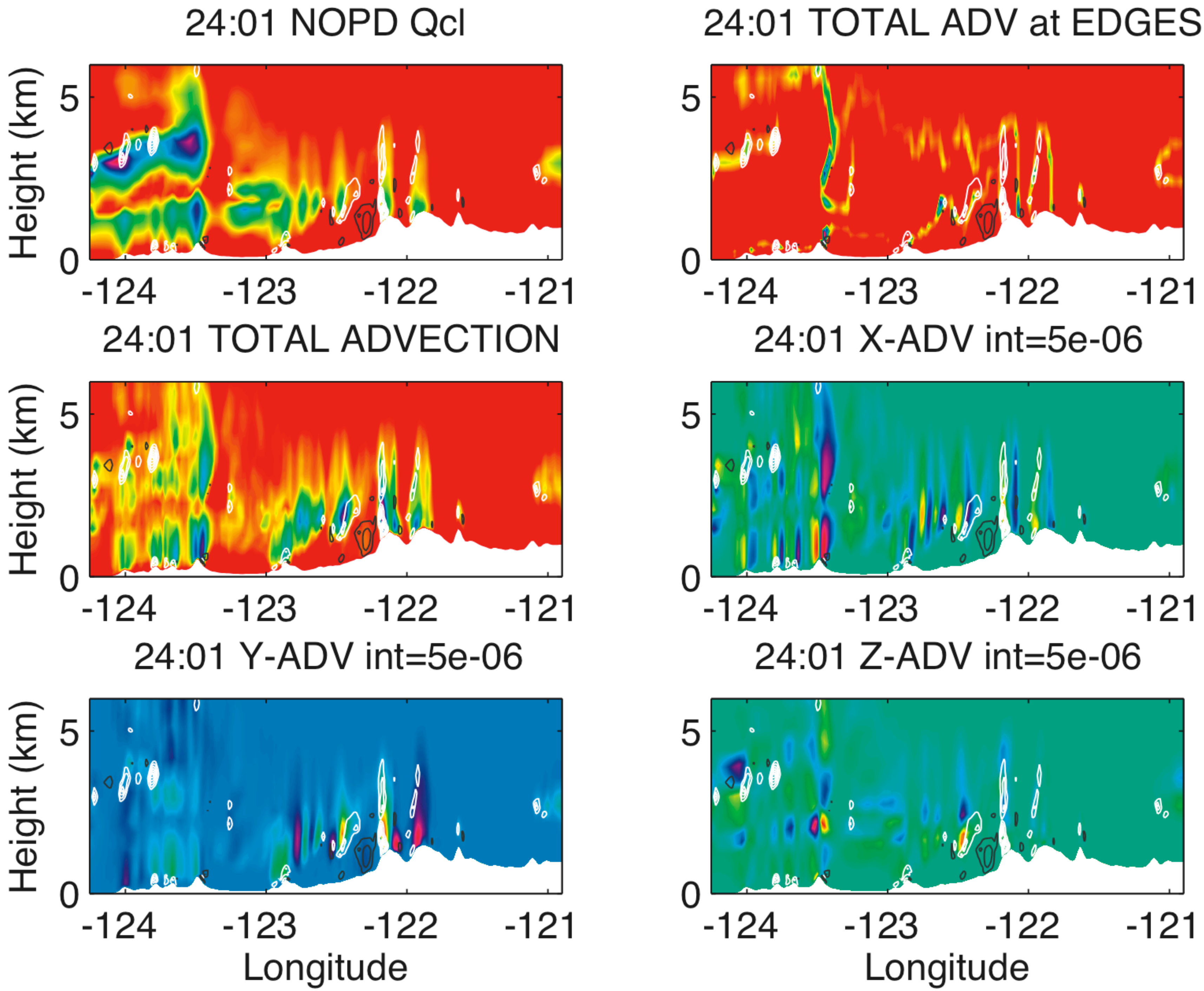


CLOUD X-SECTIONS: PD CLOUD ONLY





24:01 NOPD Qcl
24:01 TOTAL GRAD at EDGES
24:01 TOTAL GRADIENT
24:01 X-GRAD int=5e-06
24:01 Y-GRAD int=5e-06
24:01 Z-GRAD int=5e-06
Height (km)
0
5
-124
-123
-122
-121
Longitude


24:01 NOPD Qcl
24:01 TOTAL ADV at EDGES
24:01 TOTAL ADVECTION
24:01 X-ADV int=5e-06
24:01 Y-ADV int=5e-06
24:01 Z-ADV int=5e-06
Height (km)
0
5
-124
-123
-122
-121
Longitude

Conclusions

- The PD moisture advection scheme removes a significant bias to the model and should be used in all mesoscale modeling applications where moist physics is involved.
- The effect of the PD scheme is significant at all resolutions modeled (36-->1.33km), but greater at higher resolution, where the largest effects were found over the Cascade Range.
- PD when applied to all variables significantly reduces moisture in all hydrometeor fields.
- The cloud field illustrates how the PD scheme removes spurious moisture generation near the edges of individual hydrometeor fields, where sharp gradients exist.
- PD paper coming soon…


The end!
Any Questions?

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