How Linear is Orographic Precipitation?
Insights from Nahuelbulta Mountains in Southern Chile

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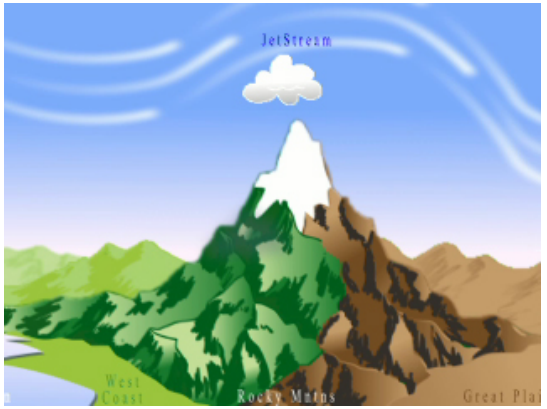
Orographic Precipitation



Upstream precipitation enhancement/downstream rain shadow is a very **consistent meteorological pattern** produced by seemingly simple atmospheric physics.

The **quantitative distribution** of **precipitation** over **mountainous** terrain is, however, a significant **challenge in meteorology**, especially as one considers shorter time scales (e.g., daily or hourly accumulations). On the other hand, precipitation distribution is a critical input for water resource and risk management over complex terrain.

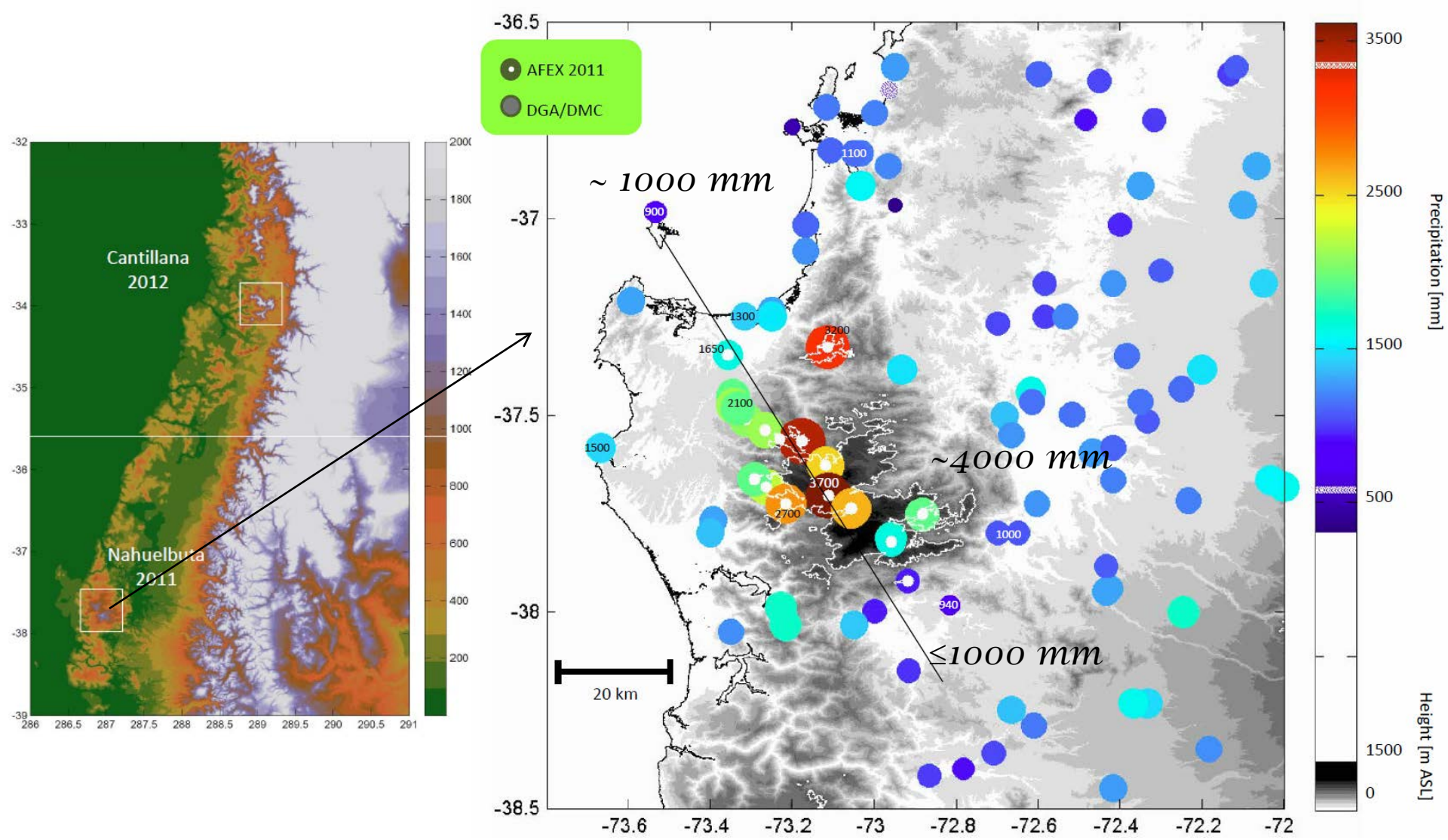
Several methods have been used to obtain the precipitation distribution over mountains:

- **Geo-statistical methods (e.g., PRISM) (need lot of obs.)**
- **Full meteorological models (e.g., WRF) (expensive to run at high resolution)**
- **Linear precipitation models (need to tune a few parameters, fast to run)**

Widely used to force other models…but is it realistic?

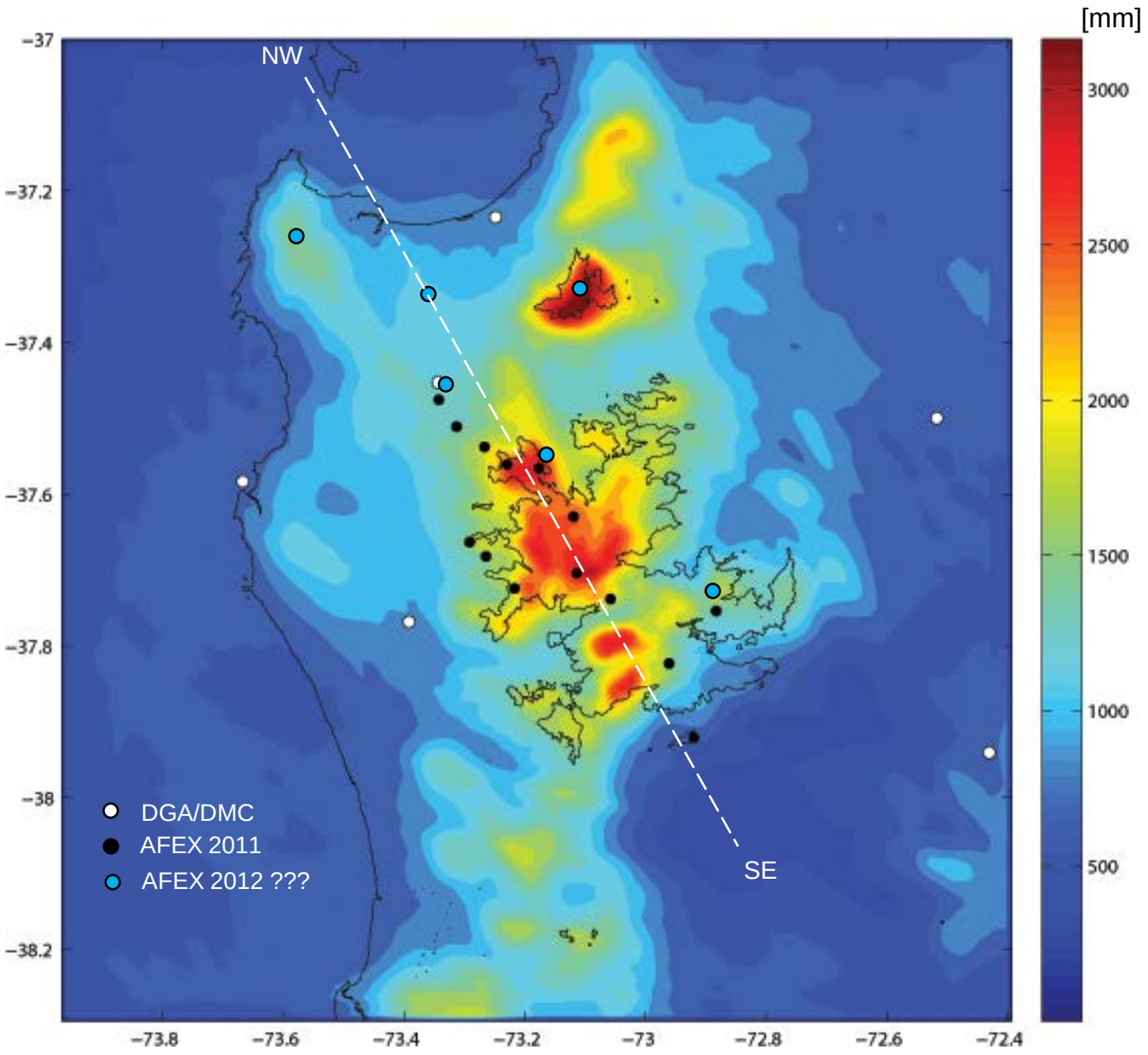
Results from AFEX: Andean frontal Experiment

15 raingauges. 2011-2013. Estimated annual mean precipitation [mm]

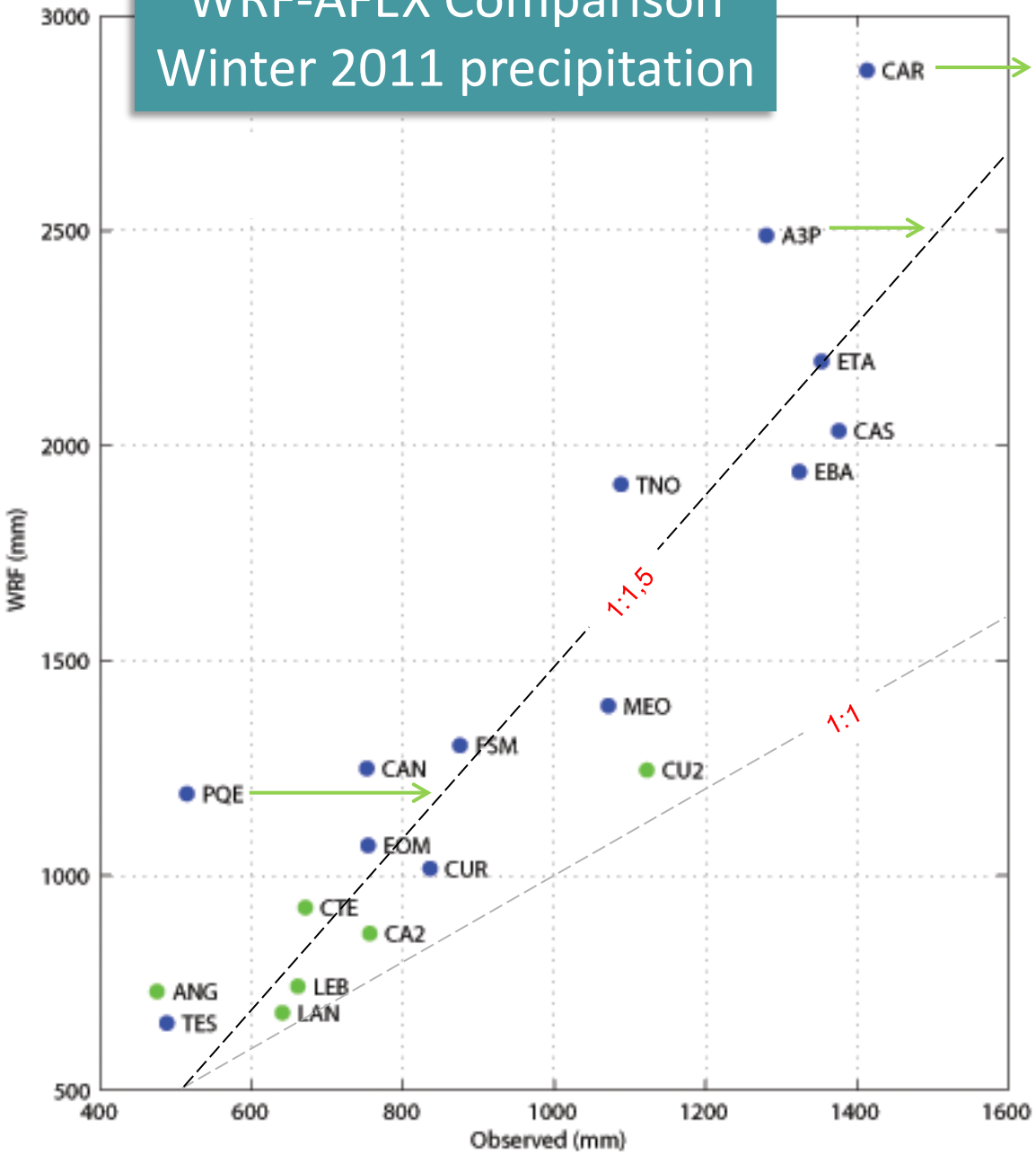


WRF (1 km) continuous run during winter 2011 (May-Sep) forced by GFS

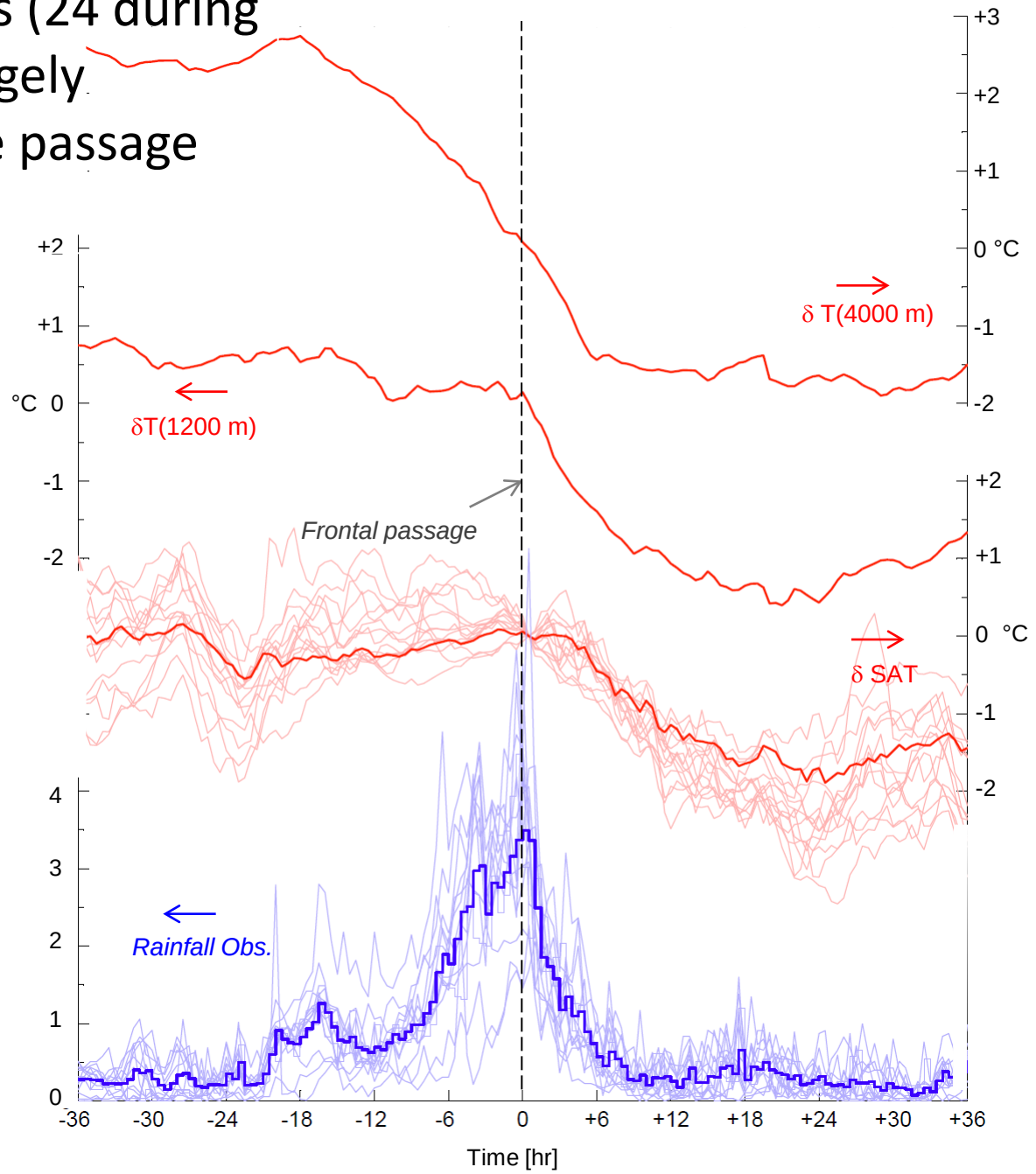
Several weeks of computation in high performace computer…and a lot of pain.

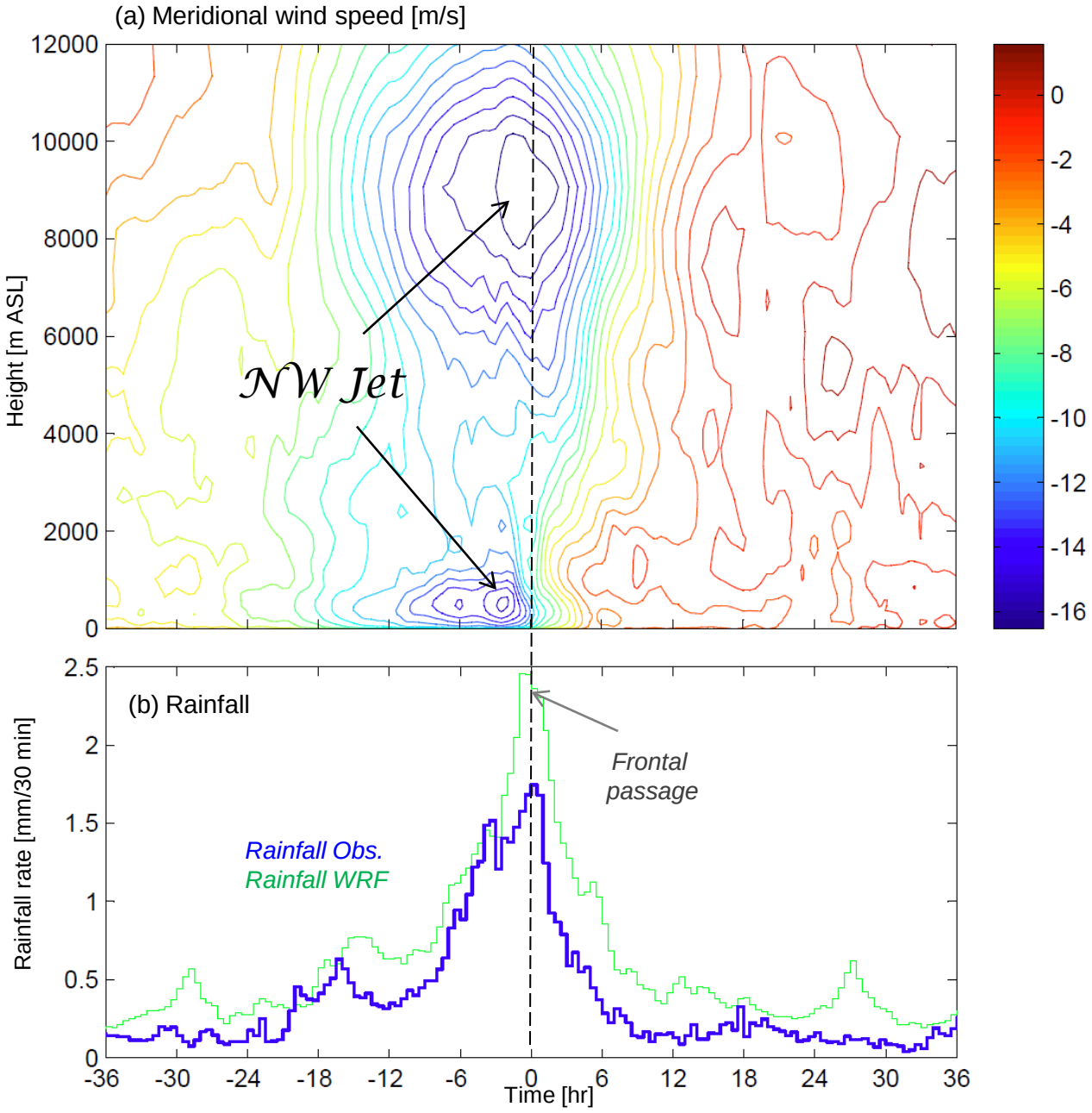


WRF-AFEX Comparison
Winter 2011 precipitation

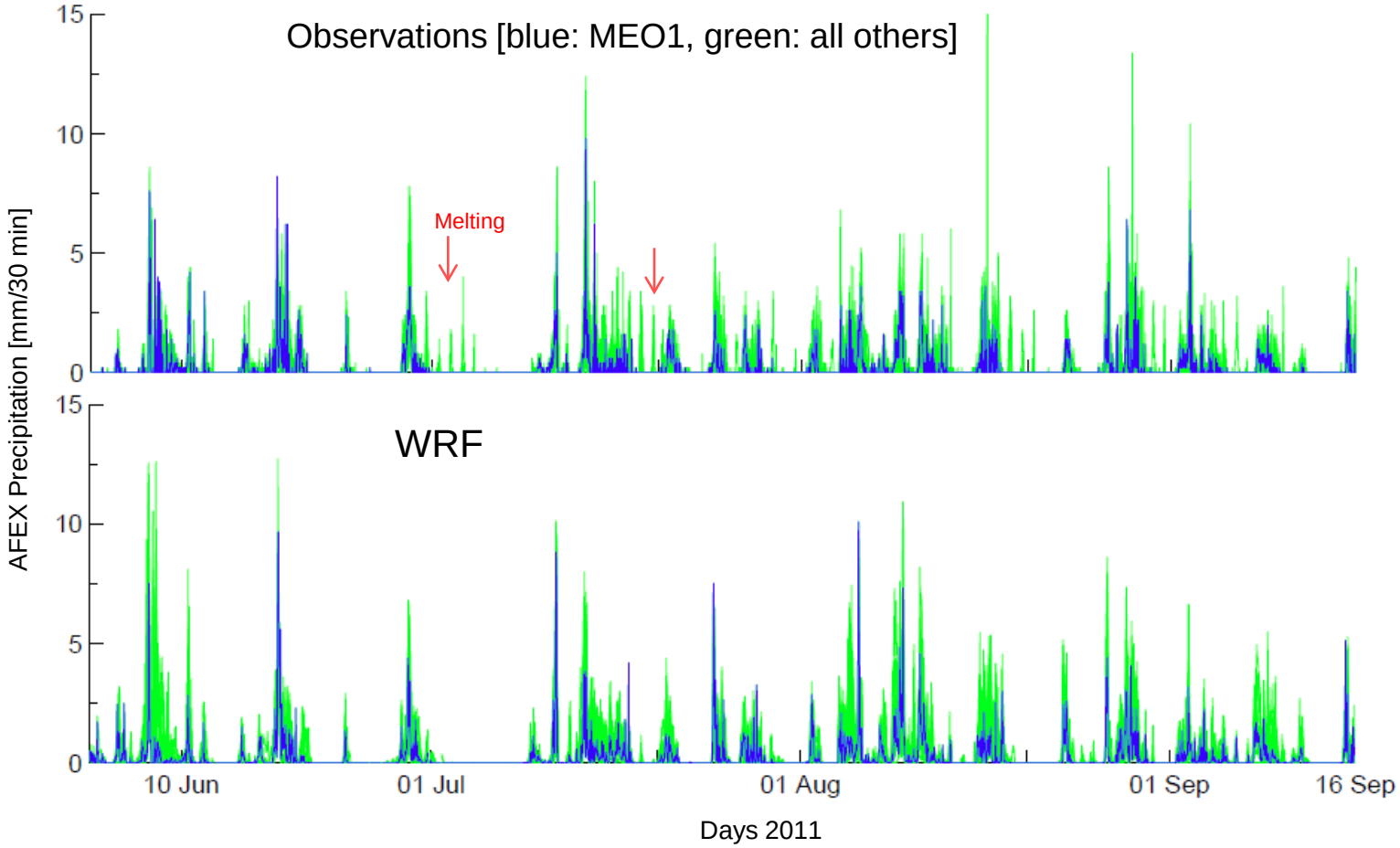


Rainfall episodes (24 during winter 2011) largely produced by the passage of cold fronts



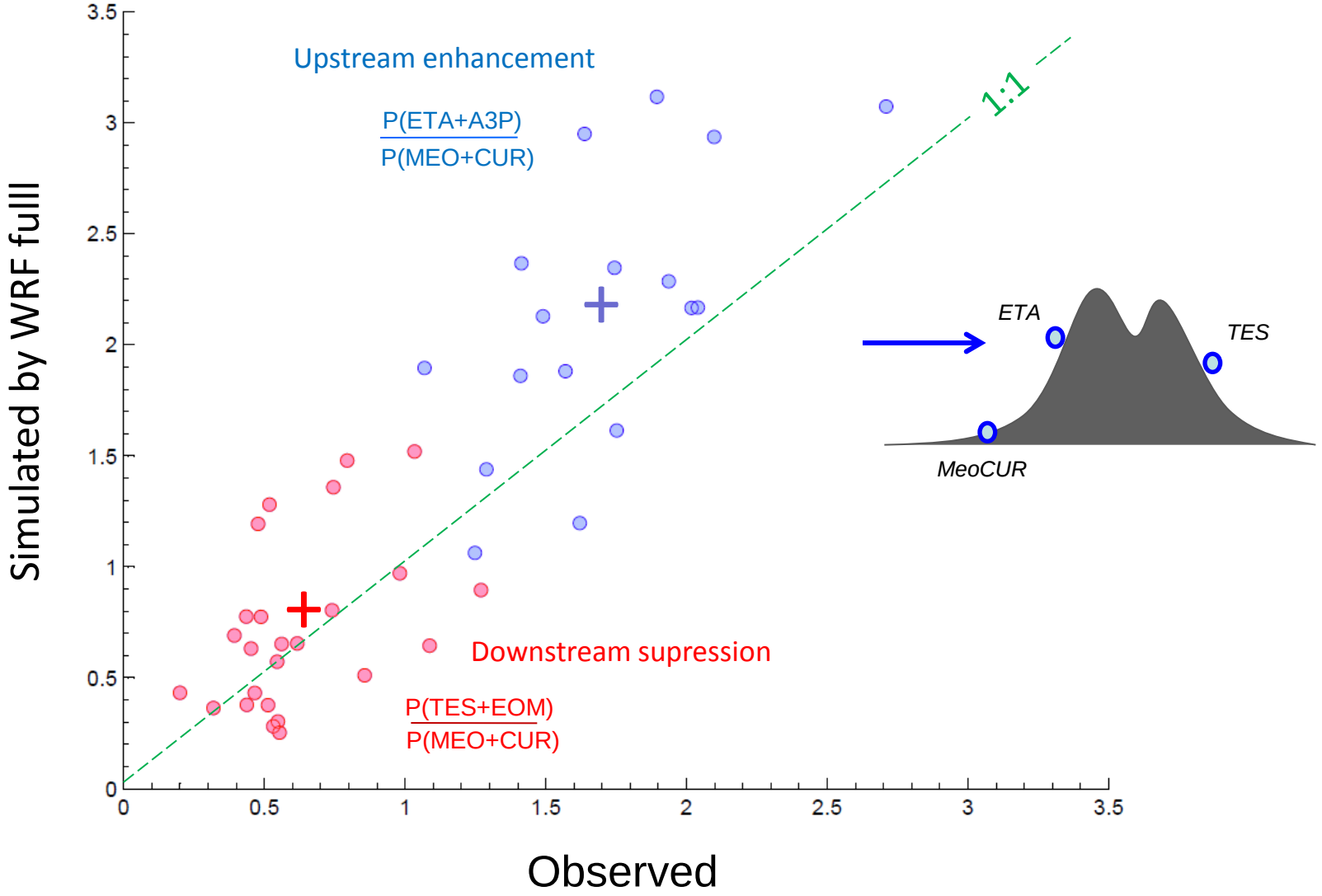

(a) Meridional wind speed [m/s]
Height [m ASL]
12000
10000
8000
6000
4000
2000
0
NW Jet
0
-2
-4
-6
-8
-10
-12
-14
-16
(b) Rainfall
Rainfall rate [mm/30 min]
2.5
2
1.5
1
0.5
0
Frontal passage
Rainfall Obs.
Rainfall WRF
-36
-30
-24
-18
-12
-6
0
6
12
18
24
30
36
Time [hr]

WRF-AFEX Comparison - Winter 2011 precipitation: 24 events



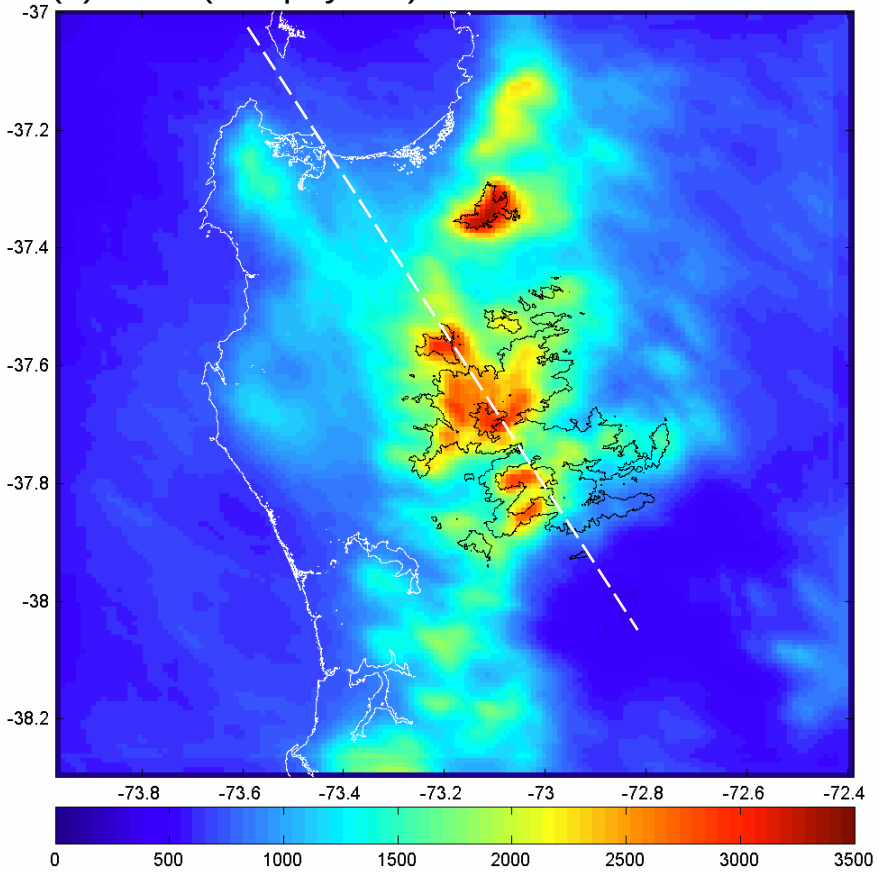
Orographic modification ratios

For each of the 27 events….

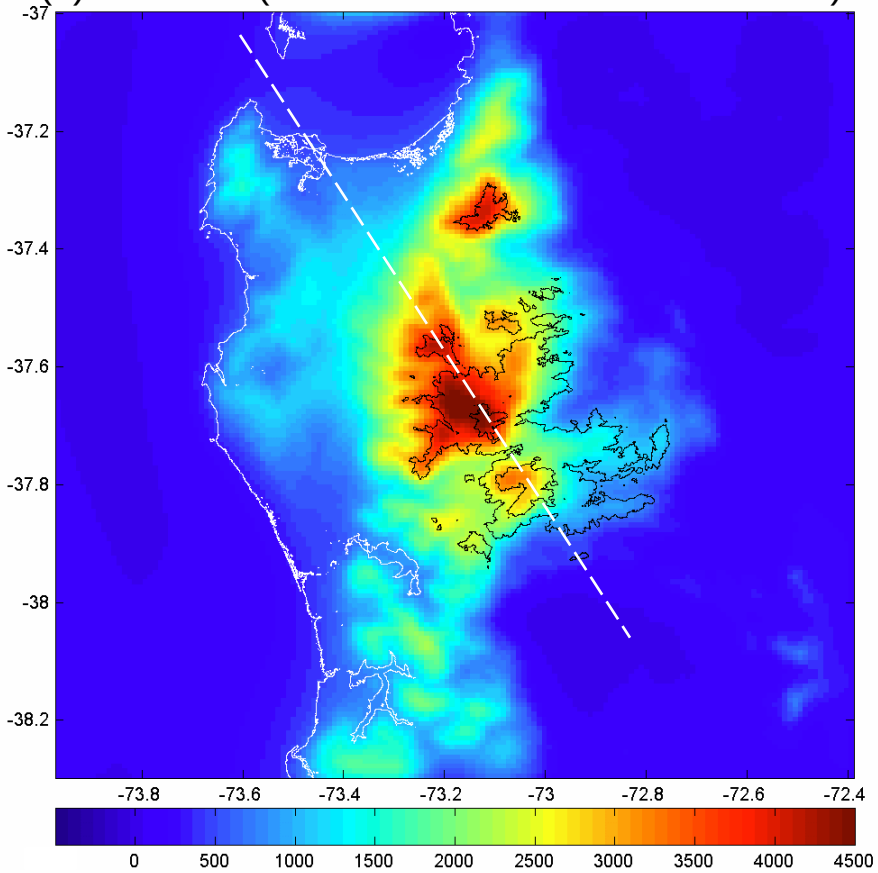


Simulated 2011 winter (May-Sep) Precipitation [mm]

(a) WRF (Full physics)



(b) LT Model (var. Wind and moisture from WRF)

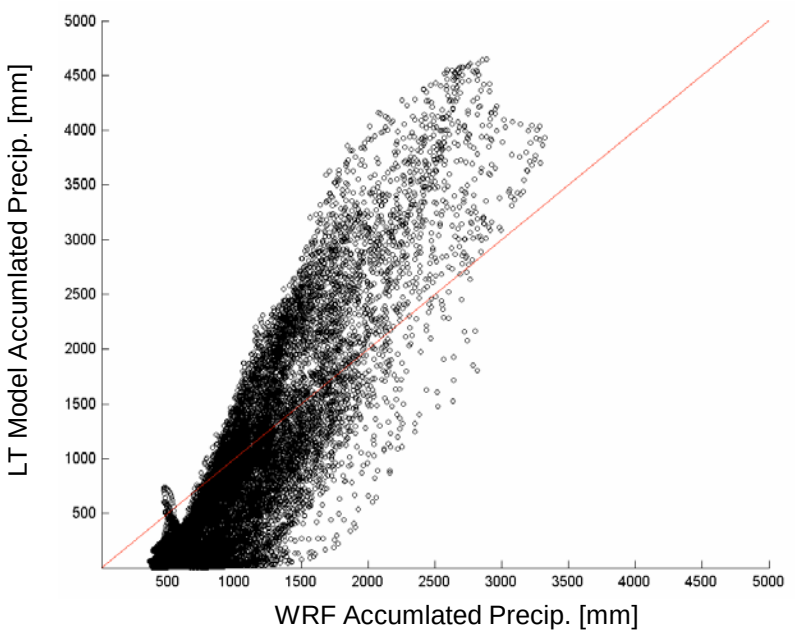


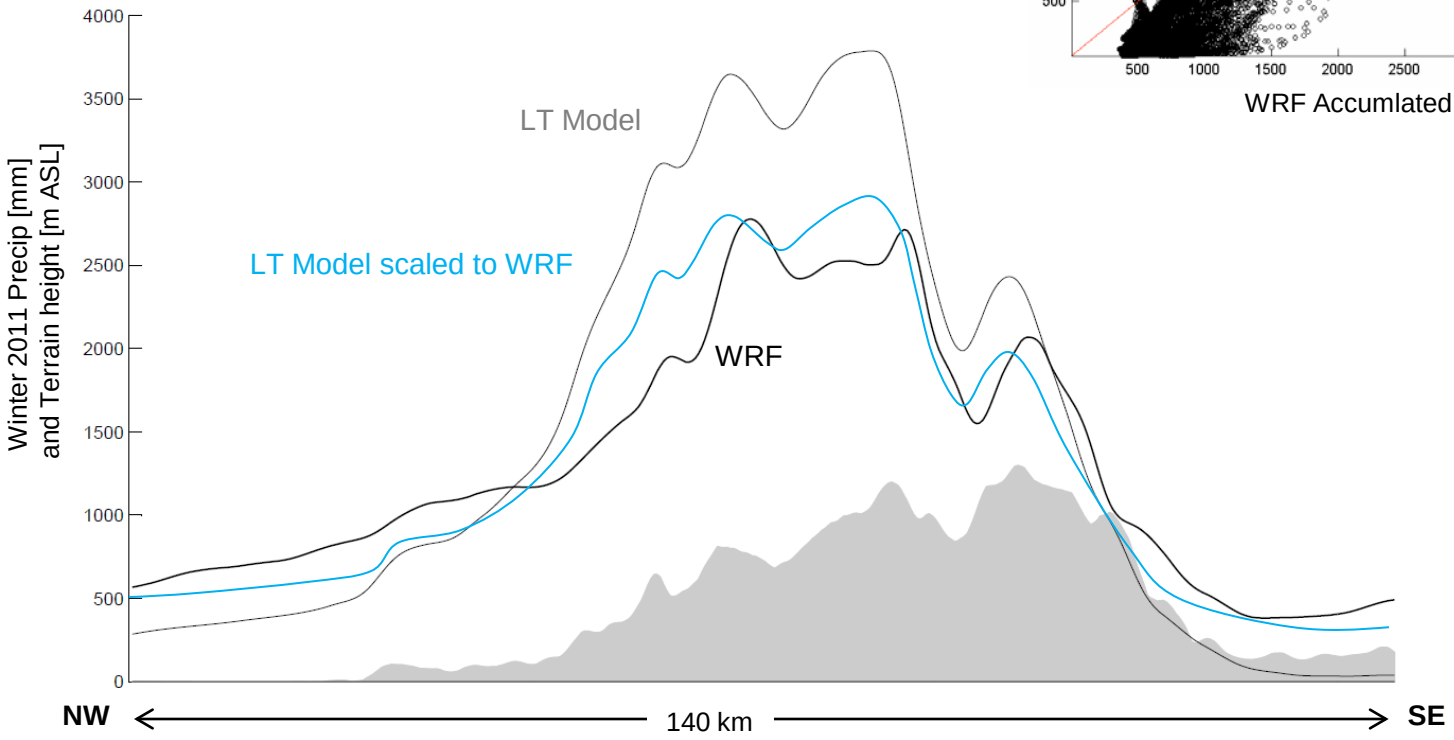
(*) Linear Theory Model by Smith and Barstad (2004)

$\tau_c = \tau_f = 1000$ s, $P_\infty = 0$

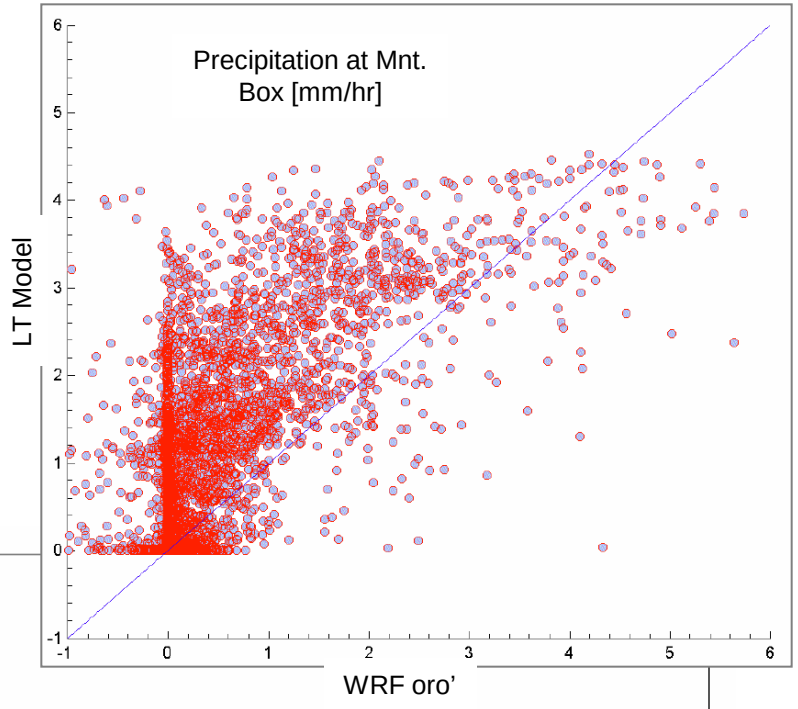
30 min of calculation in domestic PC

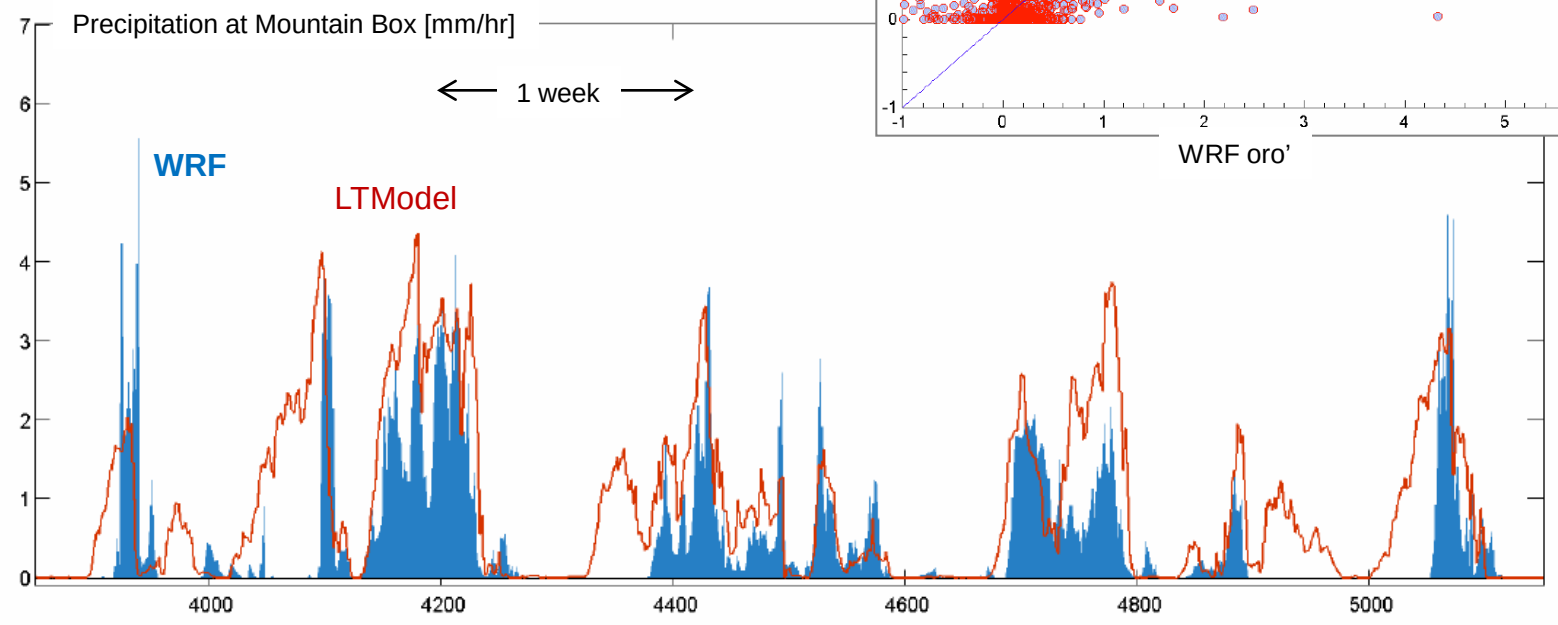
Simulated 2011 winter (May-Sep) Precipitation [mm]





How similar are the WRF and LT-Model precipitation pattern at individual events?





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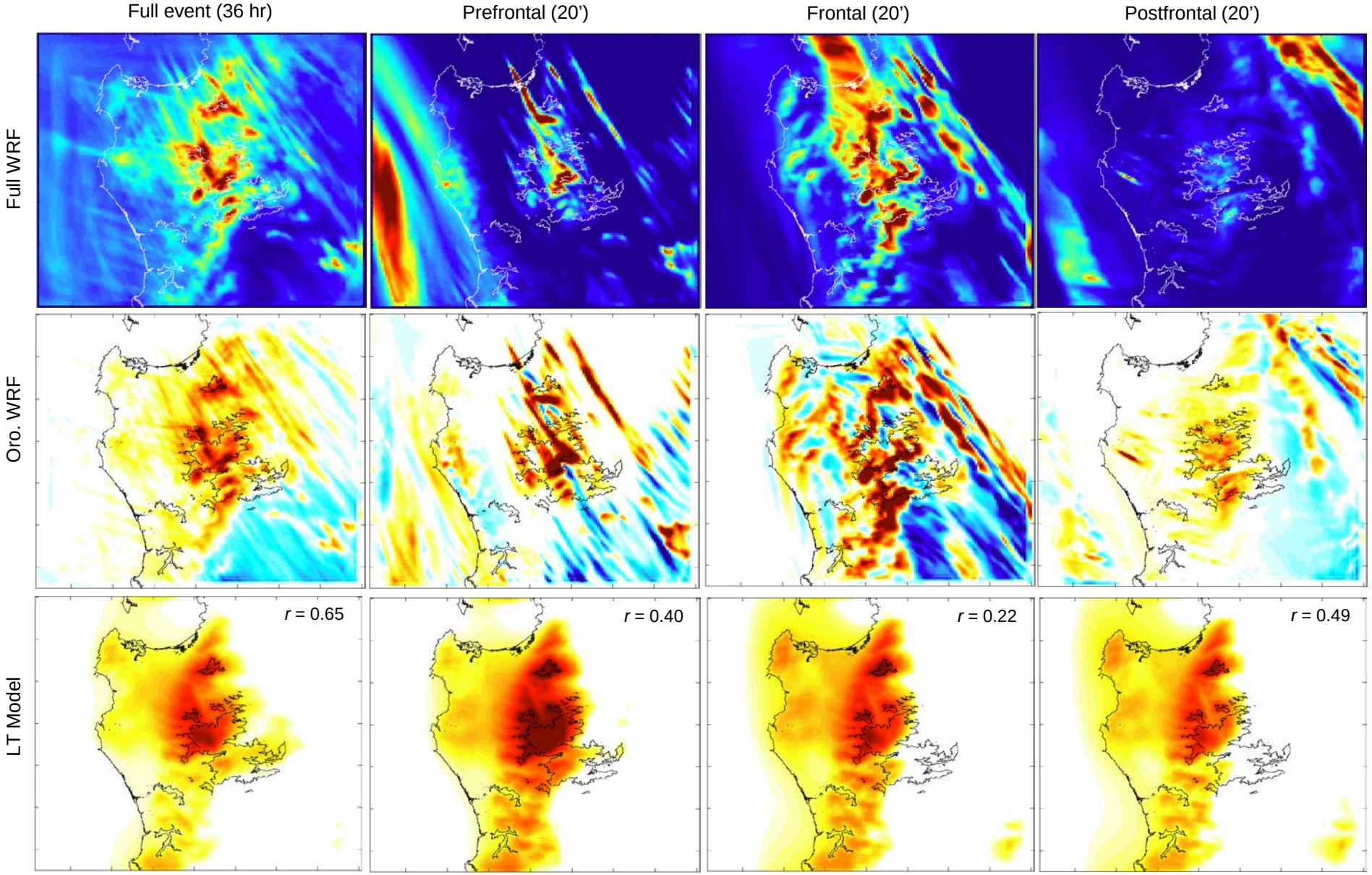
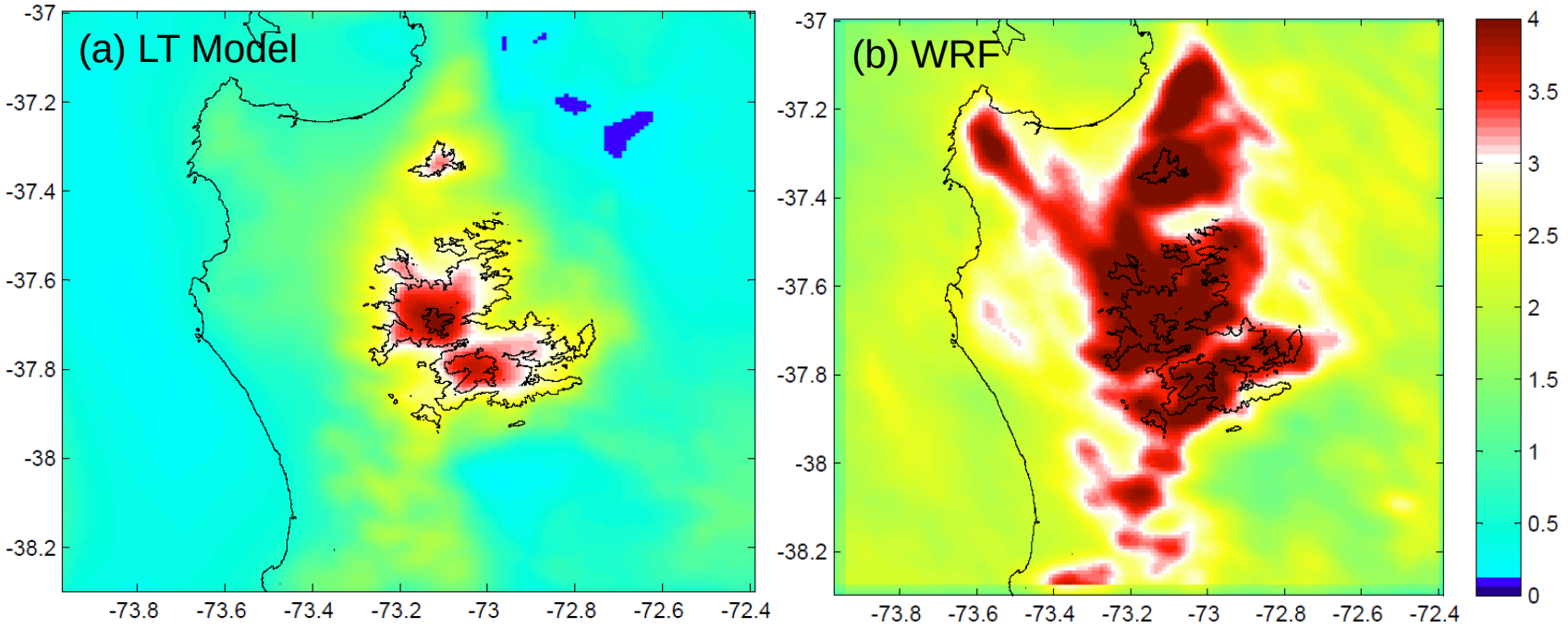


Orographic WRF: Full topo – No topo

How similar are WRF and LT precipitation extremes?

Intense precipitation (>10 mm/hr) restricted to mnt. top in LT Model but widespread in WRF and observations

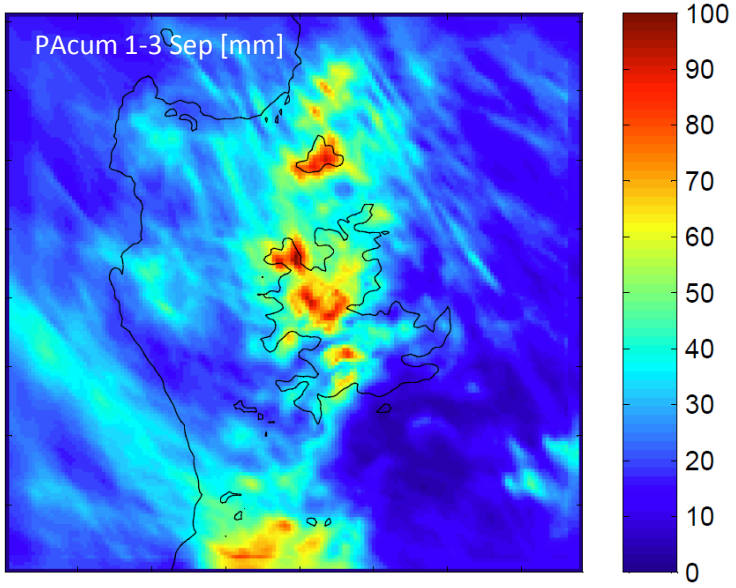


High precipitation events (97.5%)
mm/30 min, same color scale

Another way to look linearity using WRF

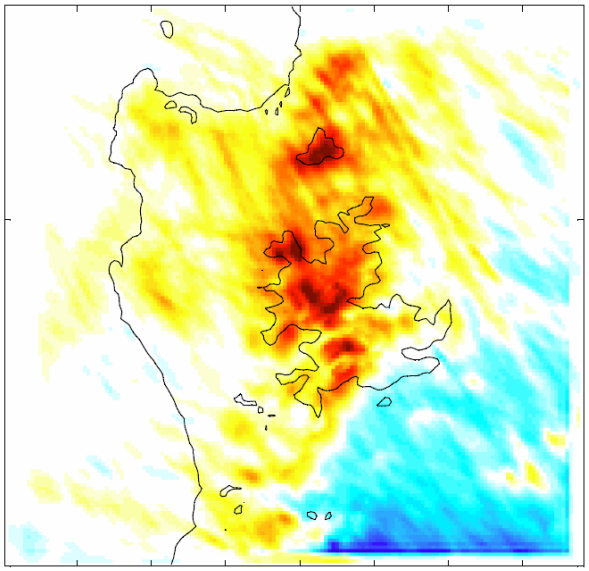
100% topo Run
75% topo Run
50% topo Run
20% topo Run
10% topo Run
0% topo Run

WRF-Oro = $(1-\beta)^{-1}$ [β.TopoRun – 0TopoRun]

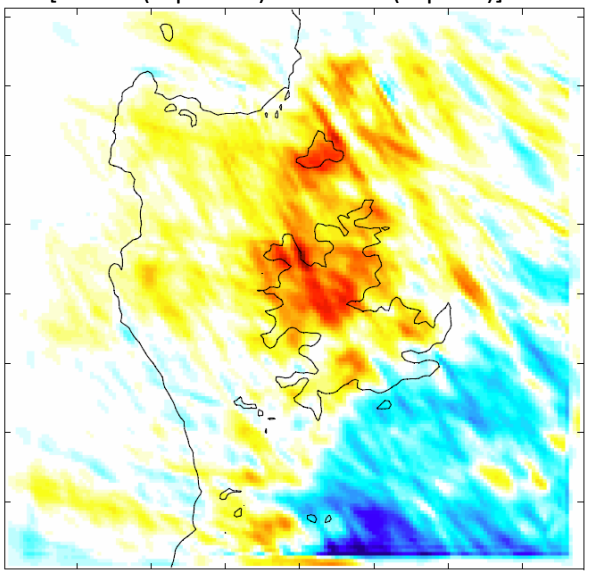


WRF Topographic Effect

PAcum(topo*1) – PAcum(topo*0)



2*[PAcum(topo*0.5) – PAacum(topo*0)]



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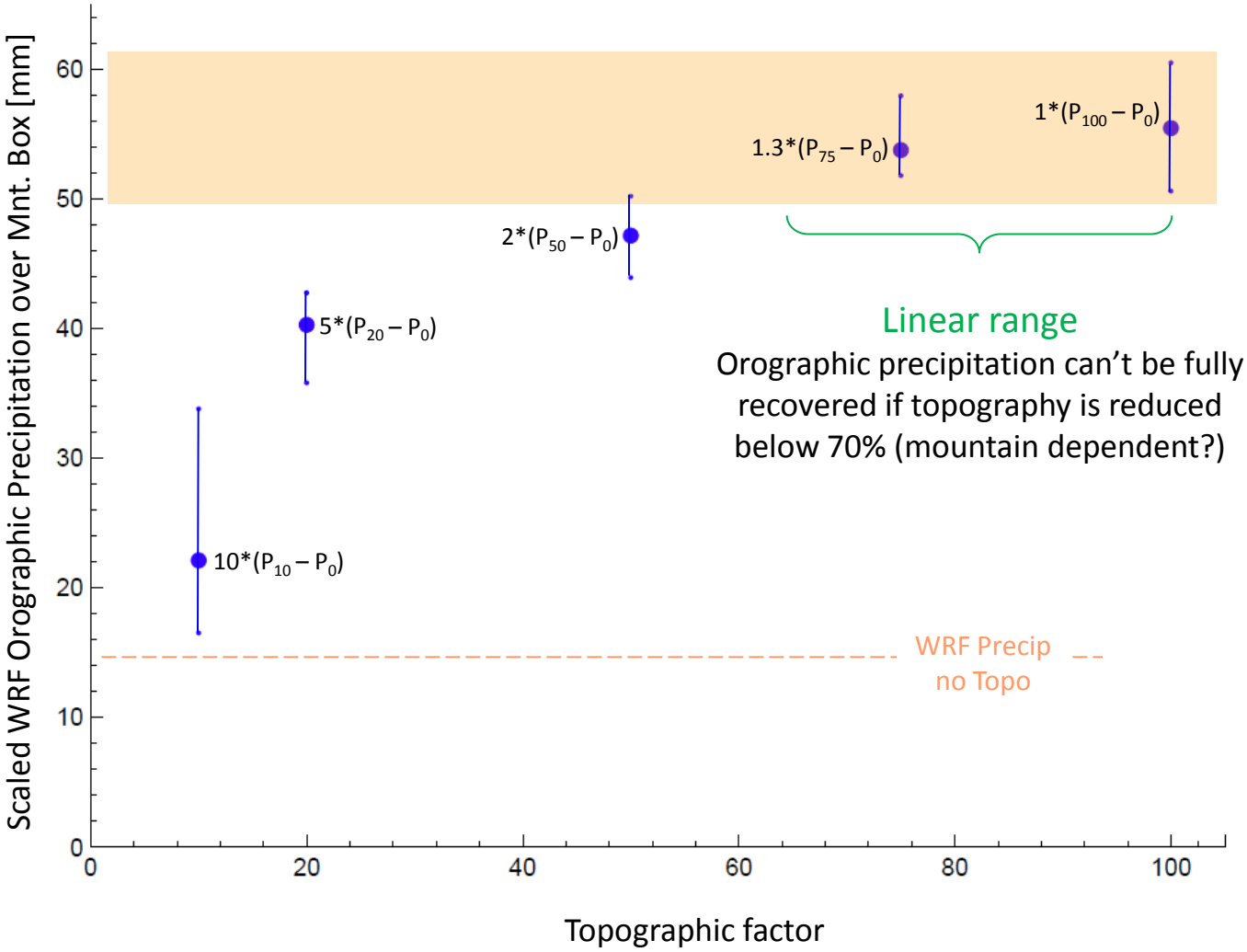

Conclusions

✓WRF model does a good job in simulating the seasonal mean and event rainfall accumulation. WRF itself partially linear.

✓ Linear model does capture the seasonal rainfall distribution of precipitation over the Nahuelbuta mountains, although it overestimate accumulation in the windward side and produce a too strong rain shadow effect.

✘ Over/under estimations in the LT model can be reduced by tuning their parameters and filtering out many periods of light precipitation that the model produce before actual rainfall began.

✘ LT model can't resolve intense, short-lived (less than an hour) rainfall episodes that are associated with non-linear effects during frontal passage. This episodes are highly variable in time and space, so they smooth when considering daily or longer periods.