ROM SAF – IROWG 2019
Helsingør, Denmark

Observing Water Vapor with GNSS Radio Occultation Data:
Genoa Lows and Atmospheric Rivers

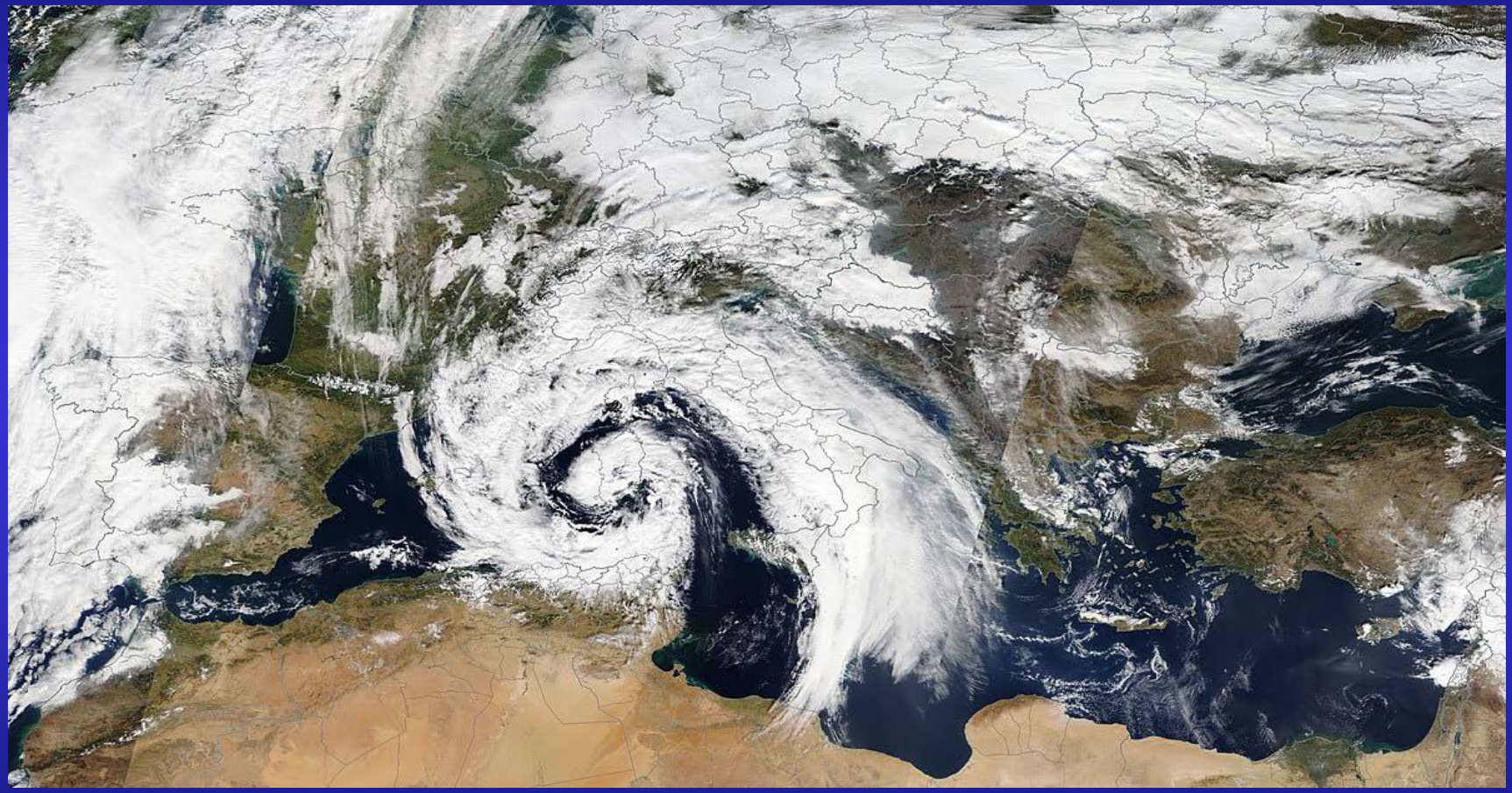
Ulrich Foelsche, Julia Danzer, Lucas Oppeneiger, and Stephanie Haas

Institute for Geophysics, Astrophysics, and Meteorology/Institute of Physics (IGAM/IP), and Wegener Center (WEGC), University of Graz, Austria

ulrich.foelsche@uni-graz.at

Partly funded by the Austrian Science Fund
Project: NEWCLIM T 757

Genoa Lows



“Vb cyclones”, and in particular “Genoa Lows” advect high amounts of moisture from the Mediterranean Sea to Central Europe (example: “Xena”, Nov. 4, 2018, NASA).

Genoa Lows

They constitute only a few % of all Central European Cyclones, but are responsible for many **extreme large-scale precip. events**, leading to intense flooding (Gail Valley, Austria, Nov. 2018, credit: BMNT).

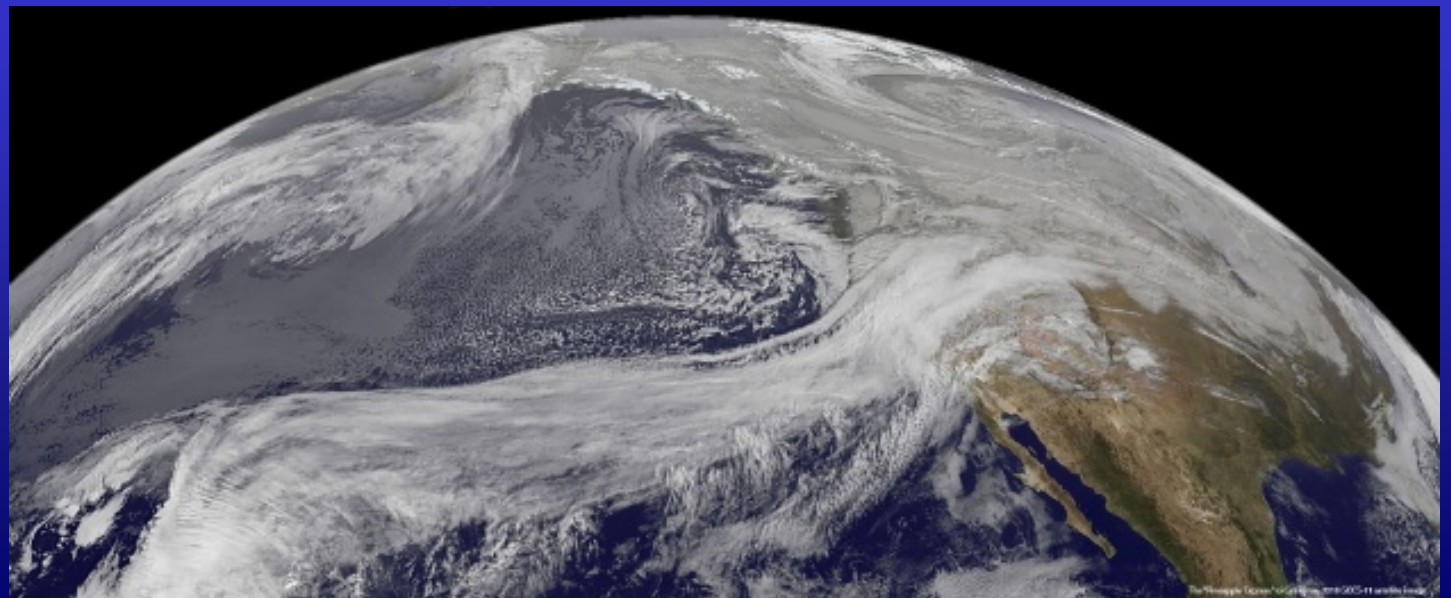
My usual bike-path to UoG

Tram Line (!) – not this day

Graz, Andritz, 21. 8. 2005;
127 mm in 24 h at UoG

Atmospheric Rivers

Atmospheric Rivers (AR) are comparatively narrow regions in the **lower troposphere** that are responsible for **most** of the horizontal transport of water vapor in the extratropics. ARs are responsible for many **extreme precipitation events** and floodings at mid-latitudes, including Europe and the US. A famous example is the "Pineapple Express" (credit: NOAA).



Precipitable Water

ARs are often represented as precipitable water (vapor):

Integrated Water Vapor [kg/m^2]

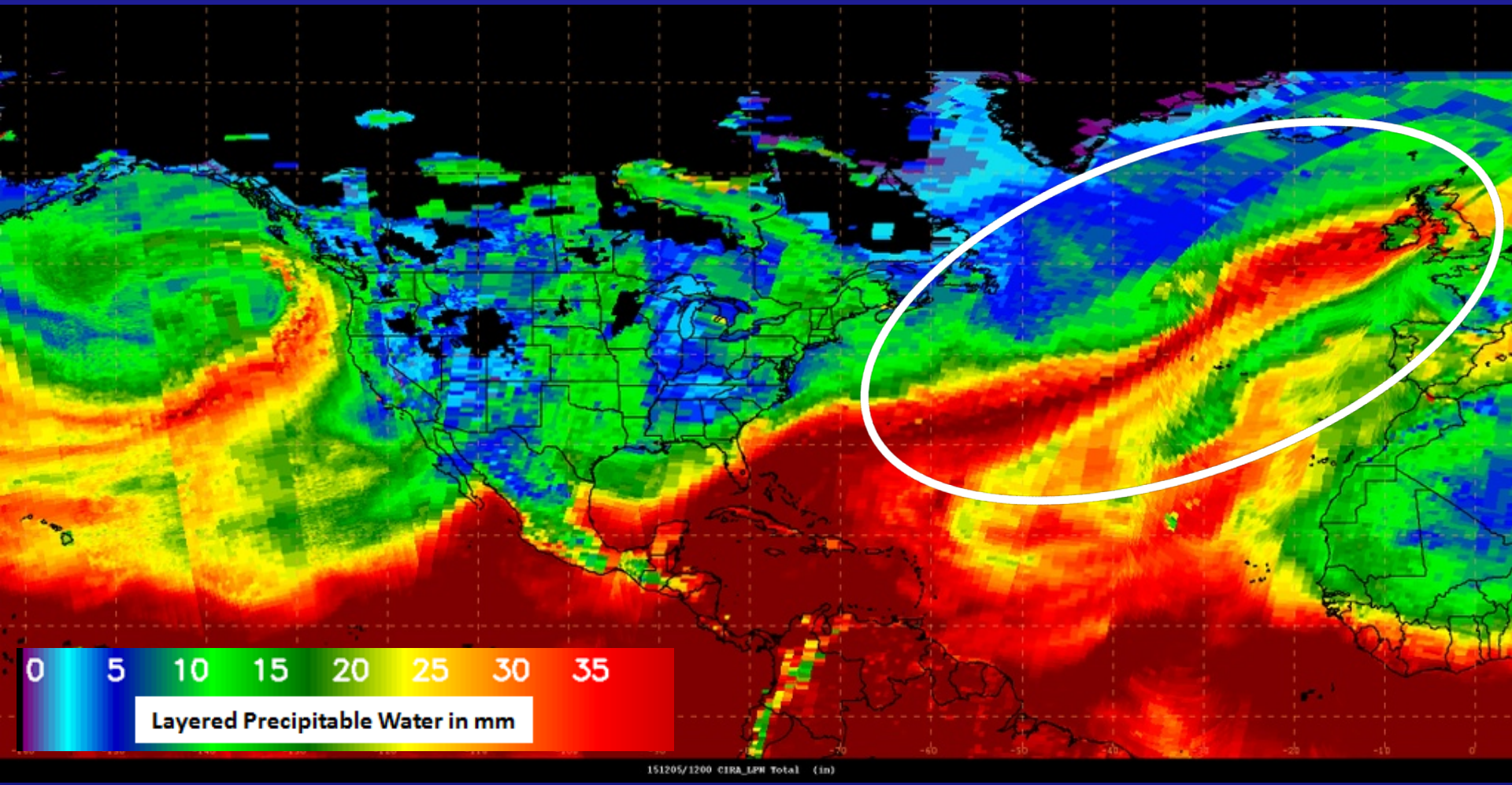
$$IWV = \int_0^{\infty} \rho_w(z)\,dz$$

asks for data down to the surface, ρ_w is the water vapor density in [kg/m^3].

Precipitable water (vapor), usually expressed [mm], where ρ_l is the density of liquid water.

$$PW = \frac{IWV}{\rho_l}$$

Atmospheric Rivers



Precipitable water, Dec. 5, 2015 (NOAA), resulting in …

Extreme Precipitation

Storm Desmond in UK/Ireland (Synne in Norway) with rainfall totals exceeding 200 mm (Rolling News, Getty Images).

Observing ARs with RO

Due to their modest horizontal resolution, RO data might not be the first choice to observe narrow features in the atmosphere – but they provide good vertical resolution.

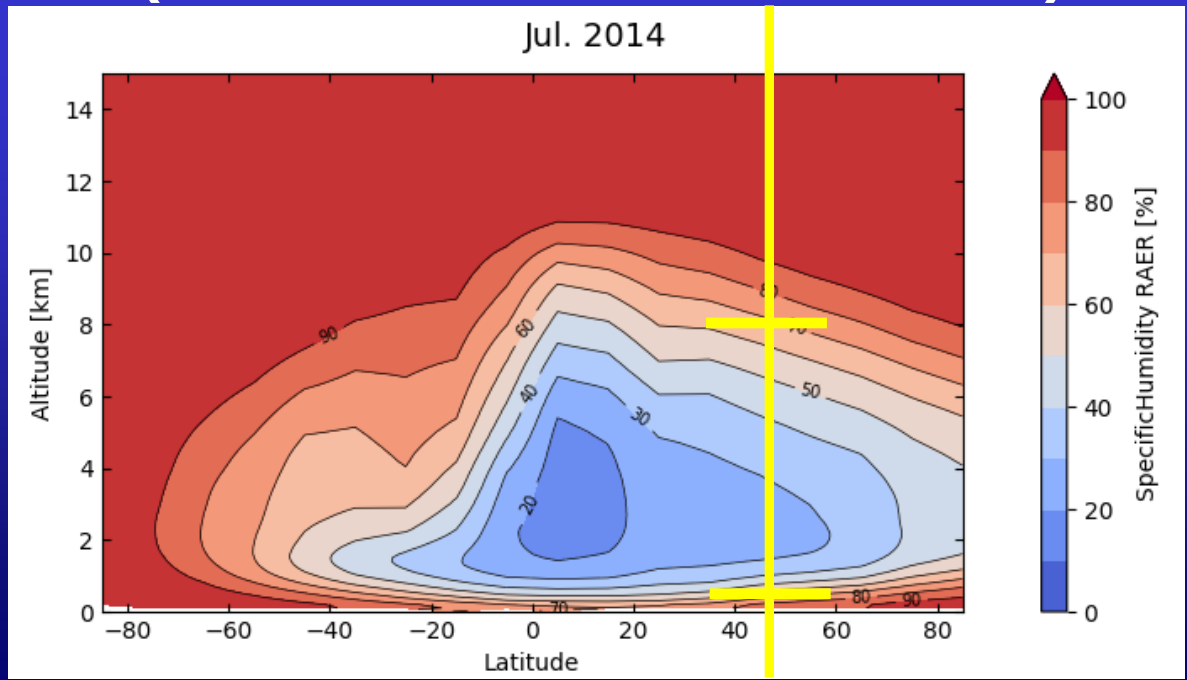
We used 2.5° x 2.5° gridded data (see *Brunner et al.*, ACP, 2017) using WEGC OPSv5.6 profiles.

We have to expect a systematic **underrepresentation** of the total precipitable water, since we miss some of the water vapor in the lowest kilometer.

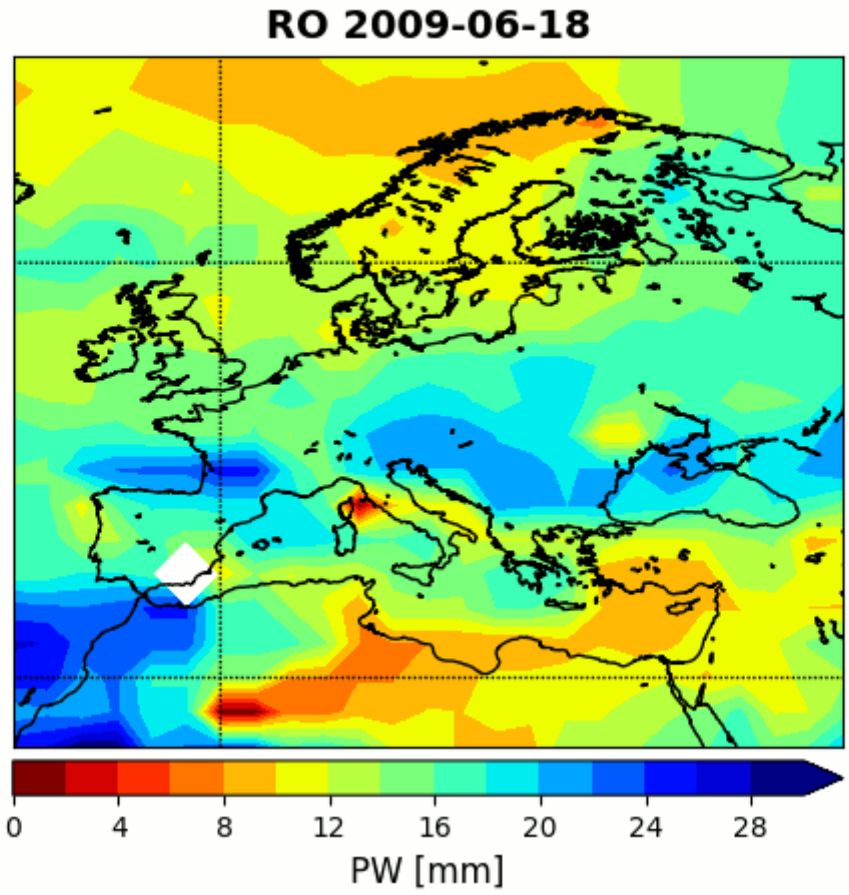
Water Vapor from RO

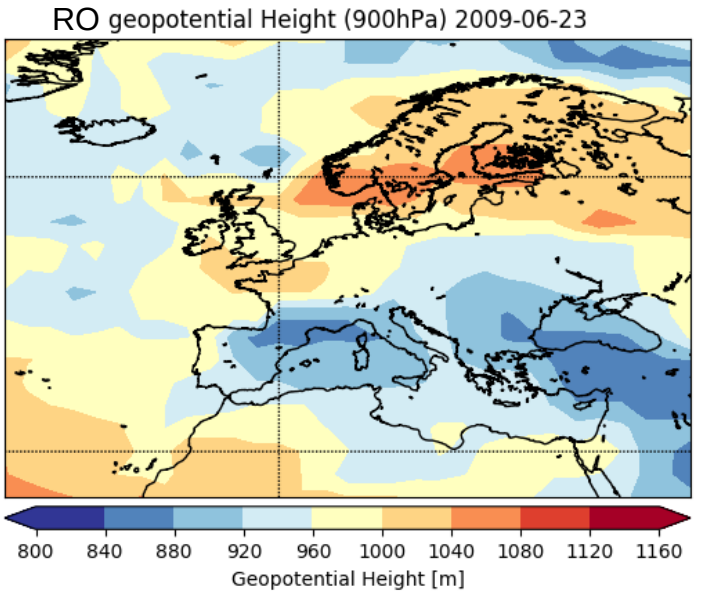
WegCenter **OPSv5.6** moist air retrieval, quasi 1DVar: Below 14 km: retrieval of T and p using **ECMWF** short-range **forecast** specific humidity q_B; q and p using ECMWF SR-FC temperature T_B; statistical optimization of T and q with q_B and T_B, background error from ROPPv6.0 45 (*Culverwell and Healy*, 2011), RO obs. error (*Scherllin-Pirscher et al.*, 2011).

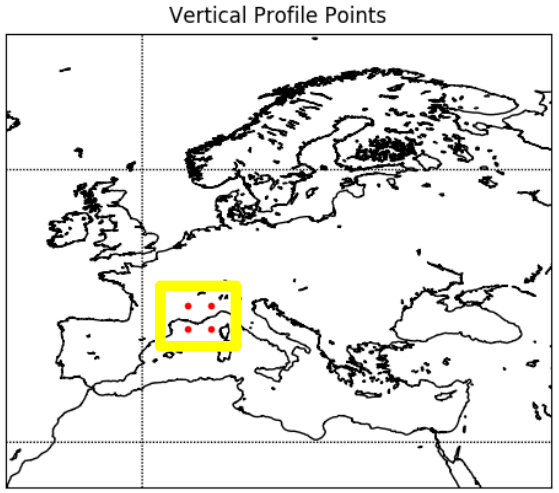
Zonal mean **Specific Humidity Retrieval-to-a priori error ratio** (RAER), **July** (Marc Schwärz, WEGC). RAER < ~70 % Obs. dominate.



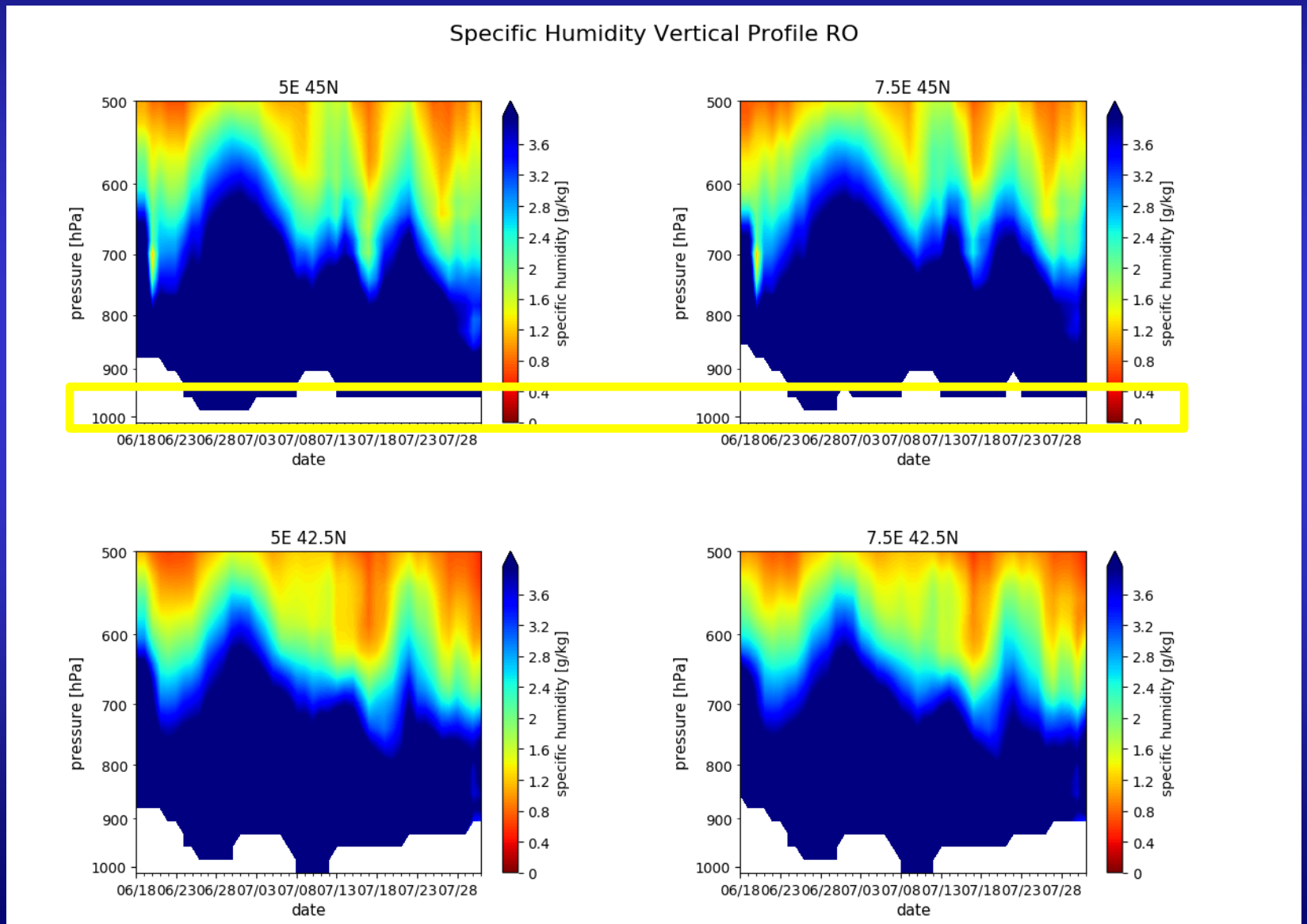
Genoa Lows 06/07 2009



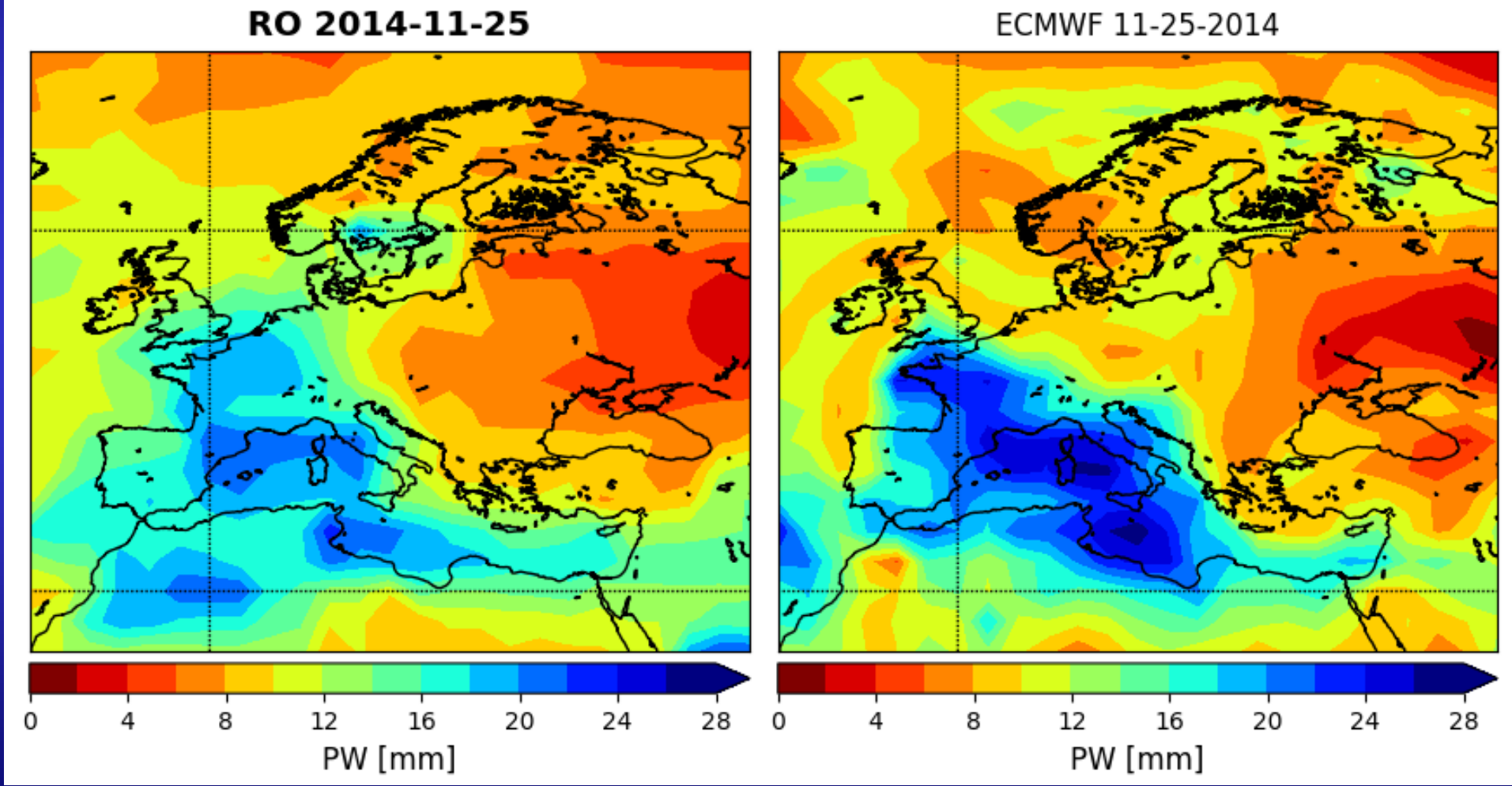




Genoa Lows 06/07 2009

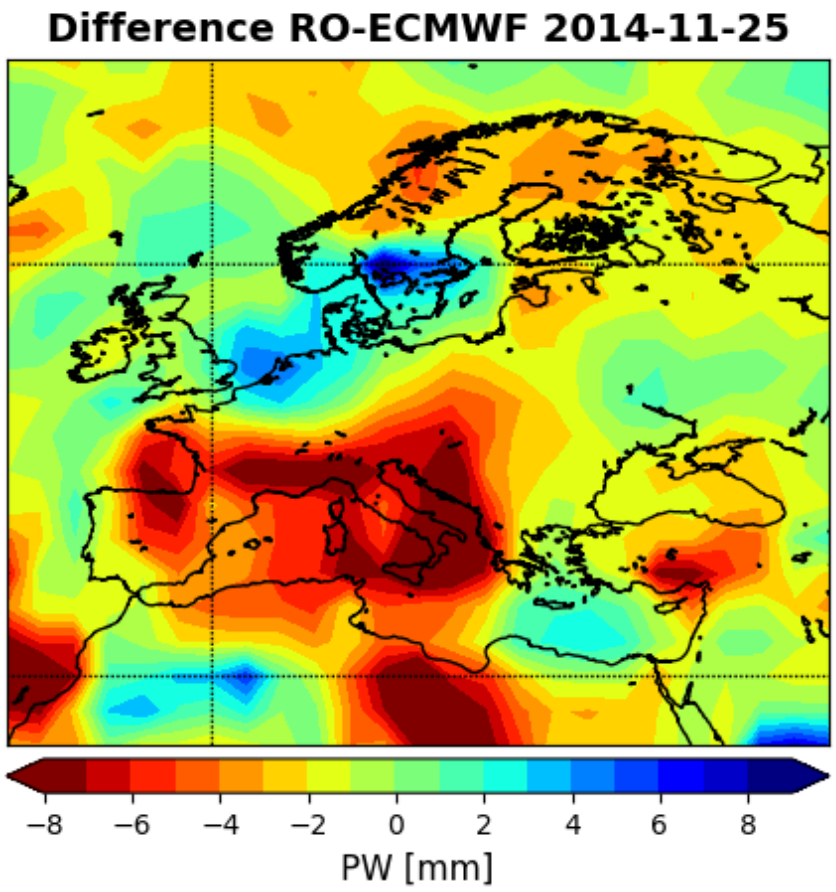


Genoa Lows Nov 2014



Precipitable water from RO and ECMWF Analyses.

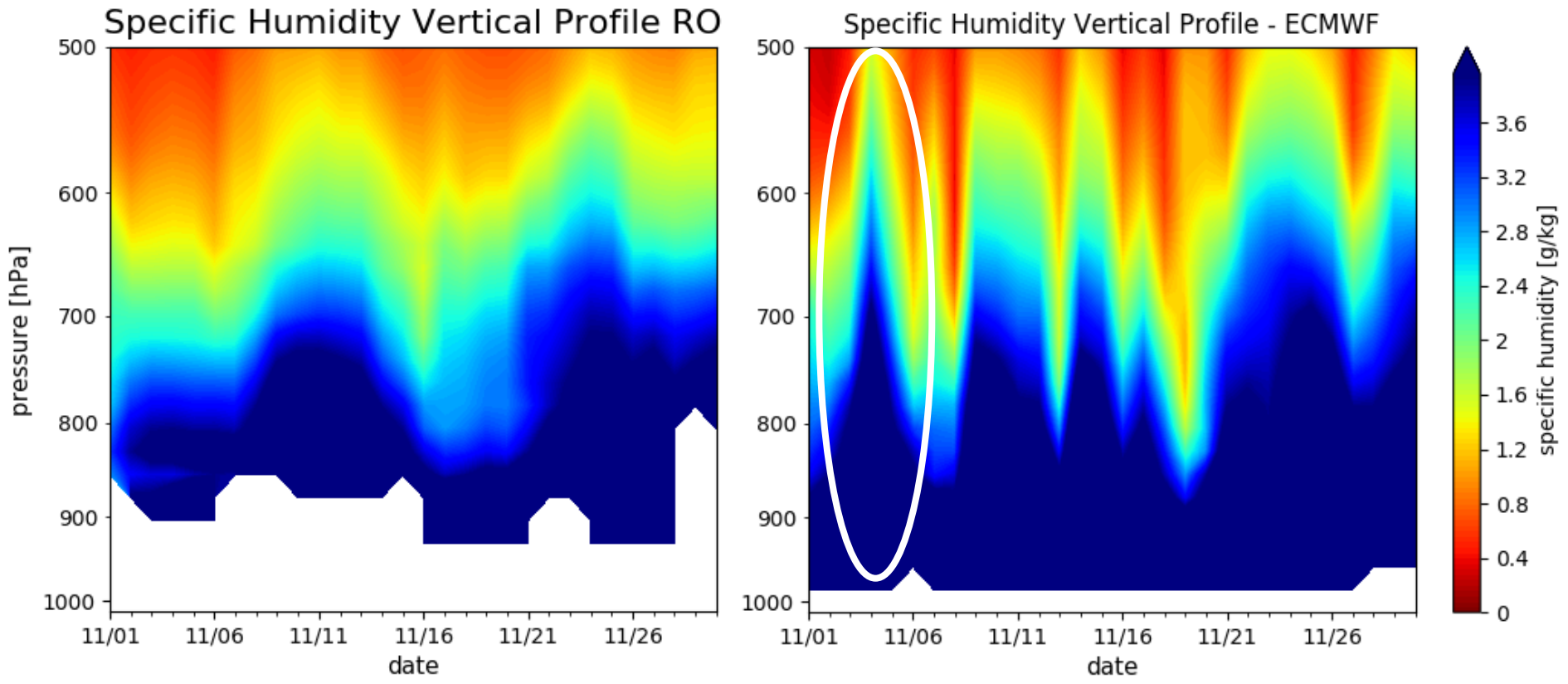
Genoa Lows Nov 2014



Difference between PW from RO and ECMWF Analyses.

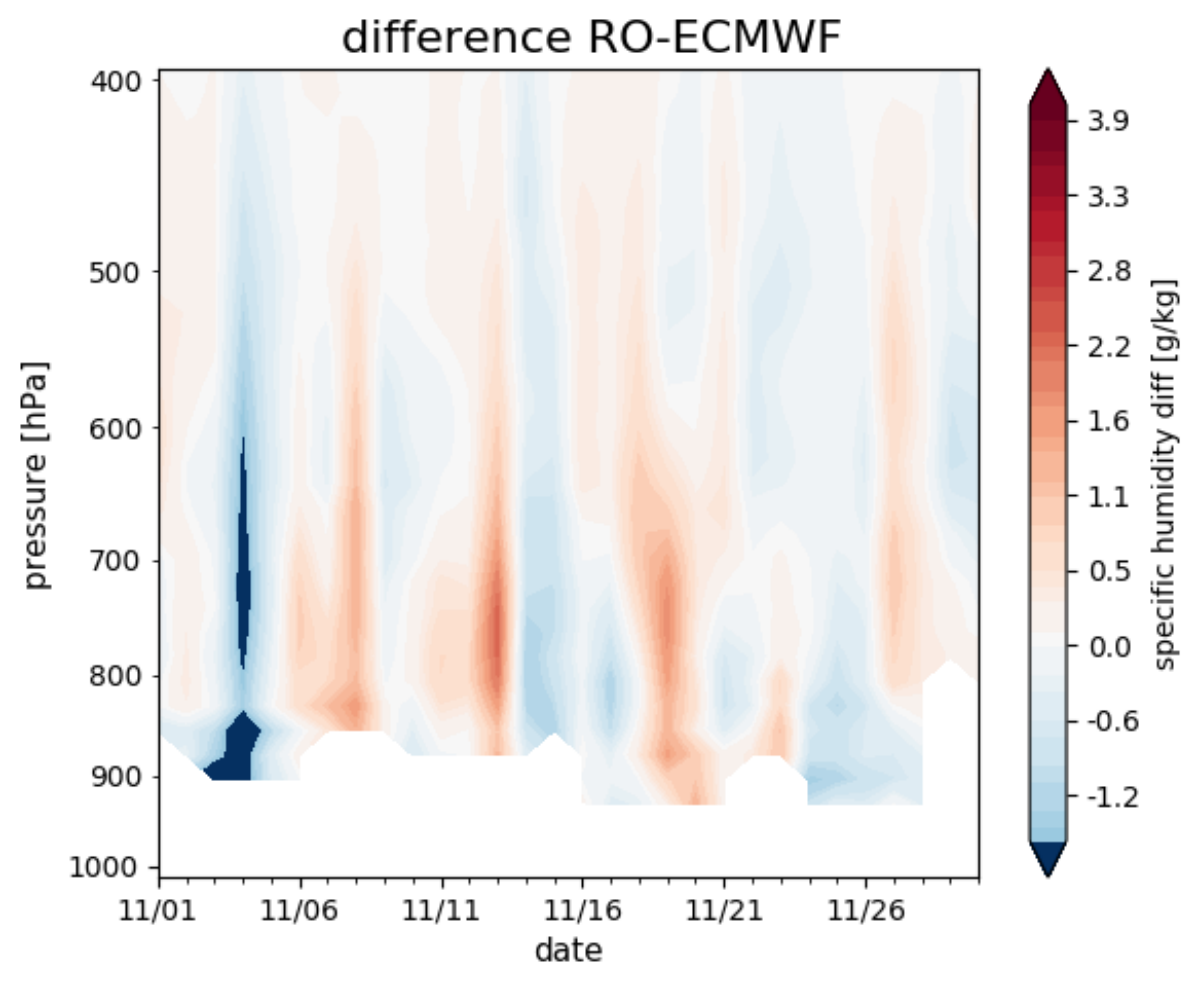
We expected to see a positive bias ~ through-out, since RO is missing an important fraction of the total water vapor in the lowest km, but there are also regions, where RO observes more PW.

Genoa Lows Nov 2014



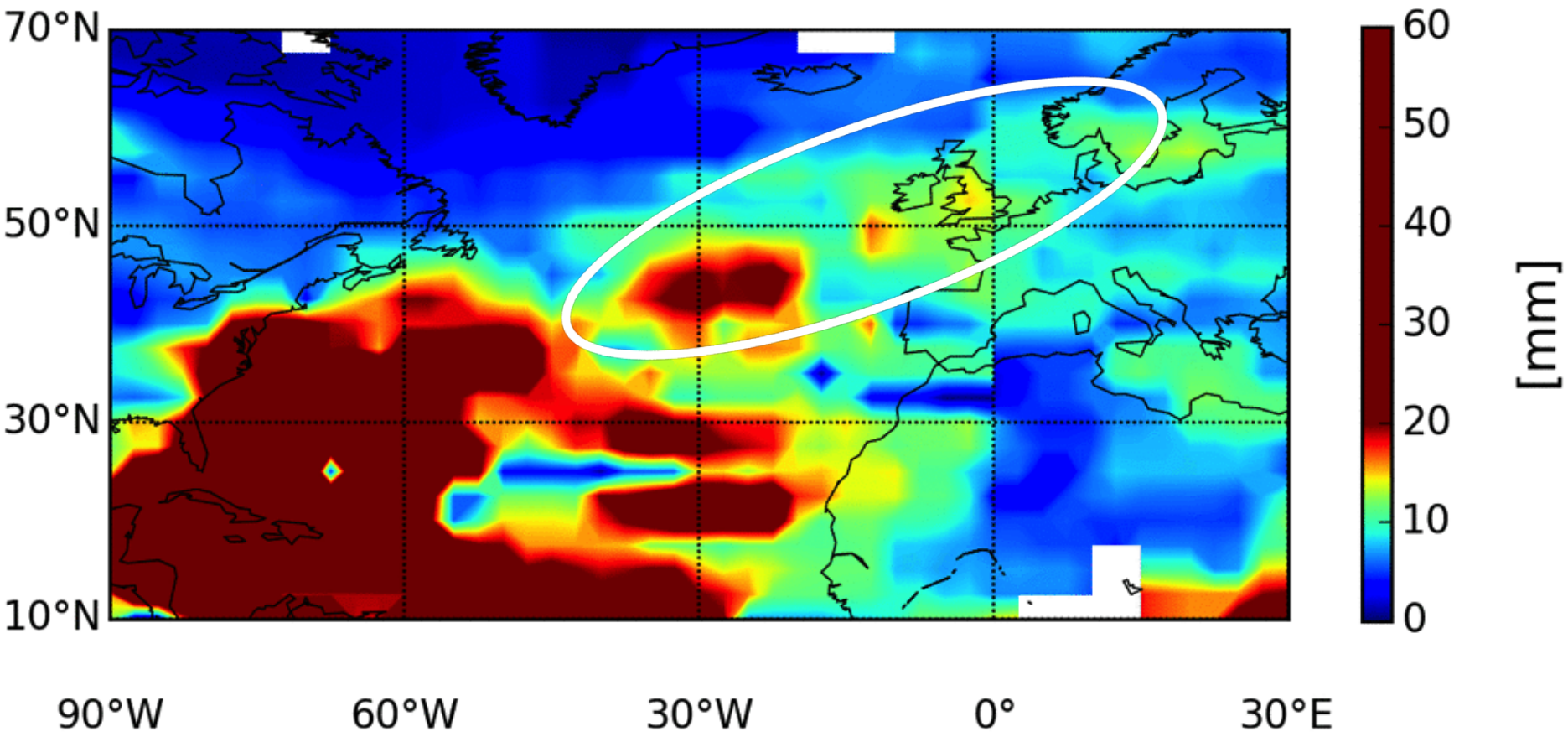
Vertically resolved specific humidity from RO and ECMWF Analyses, average over the four grid points in slide 11 (Note that ECMWF Forecasts have been used as background).

Genoa Lows Nov 2014



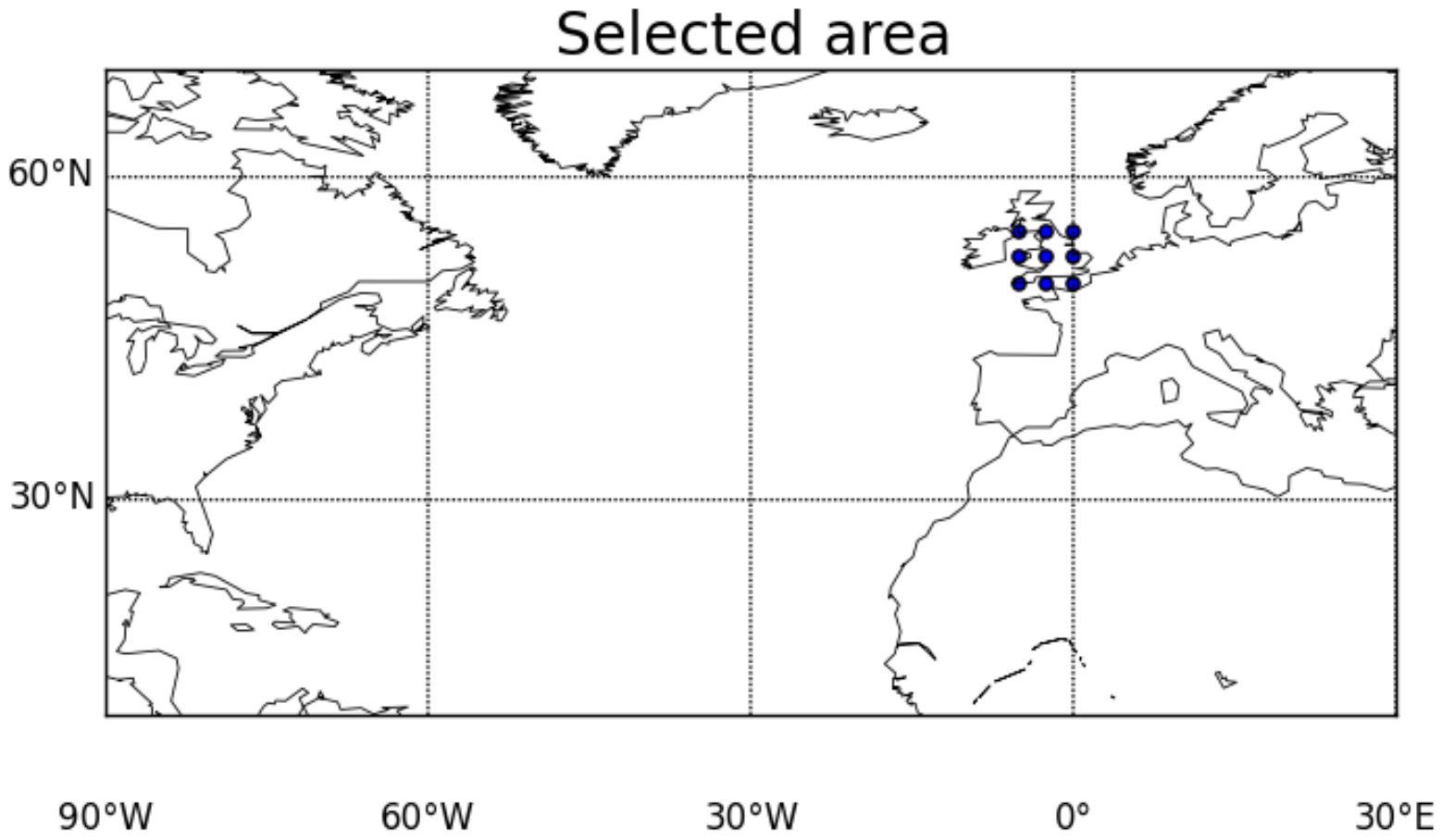
Differences between specific humidity from RO and ECMWF **Analyses**, are more dynamic than we would have expected. RO seems to see more than "just the back-ground".

Atmospheric Rivers



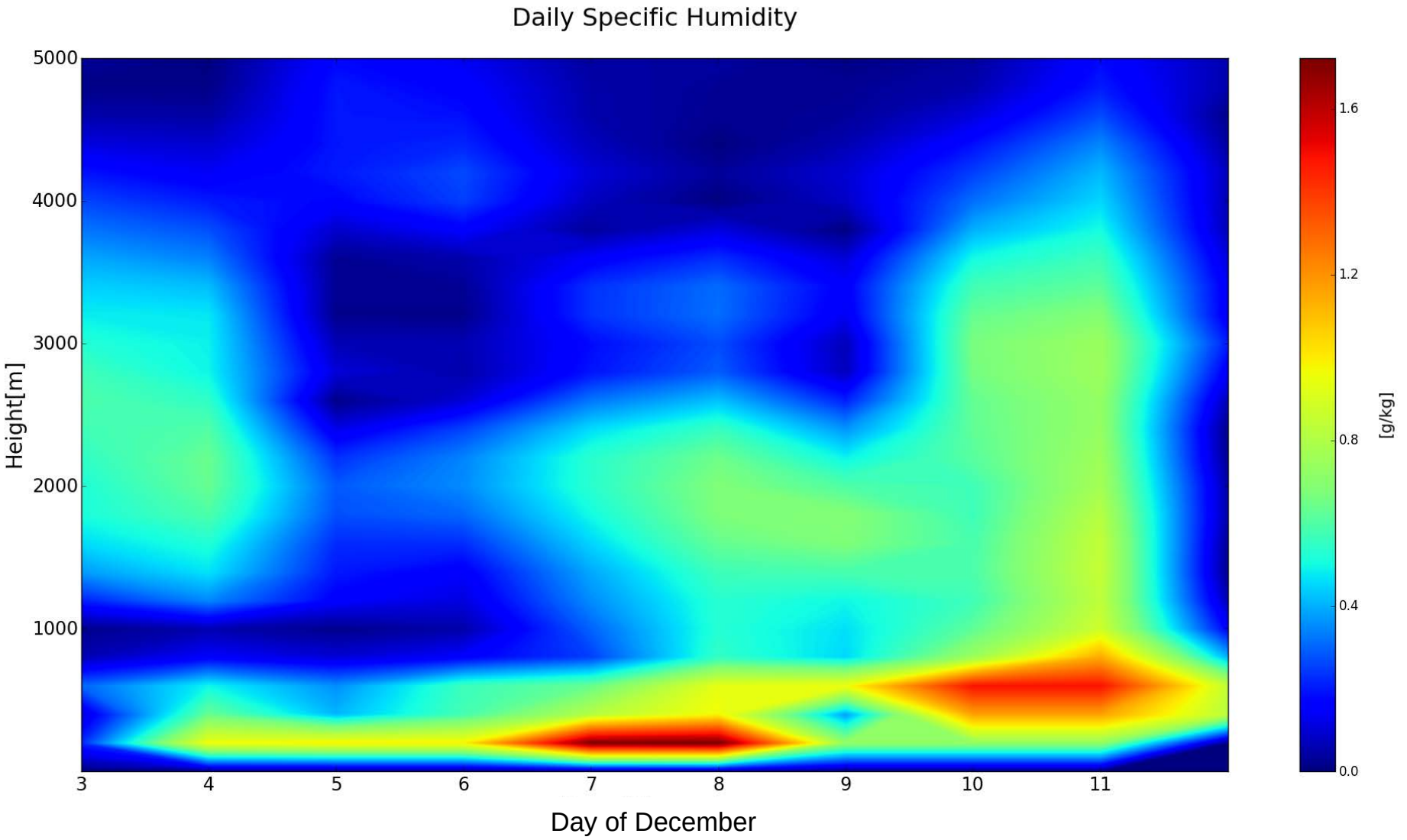
"Desmond" and "Synne", December 2015

Selected Region, Dec. 2015

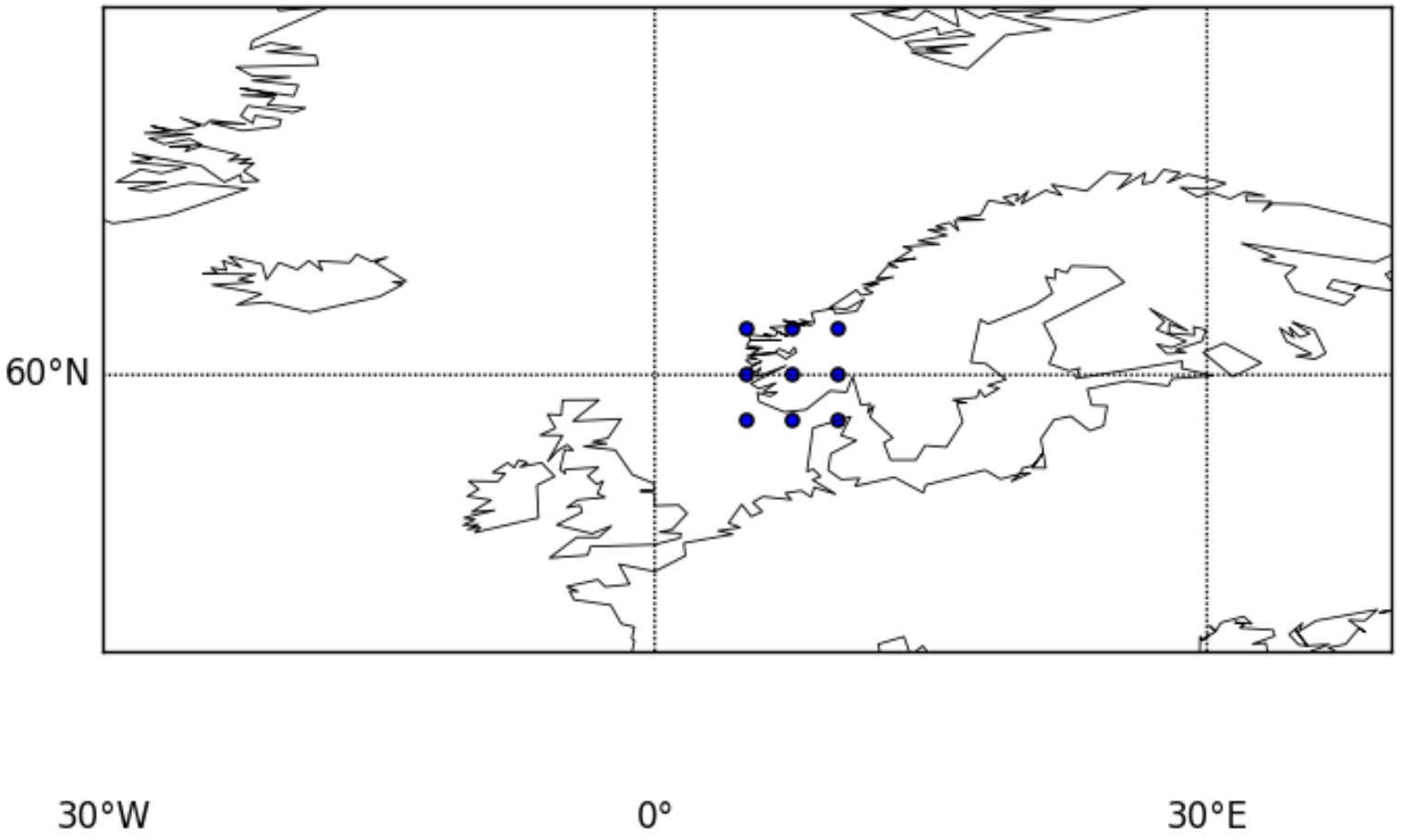


Focus on UK – “Desmond”, average over 9 grid-points

Spec. Hum., Dec. 2015

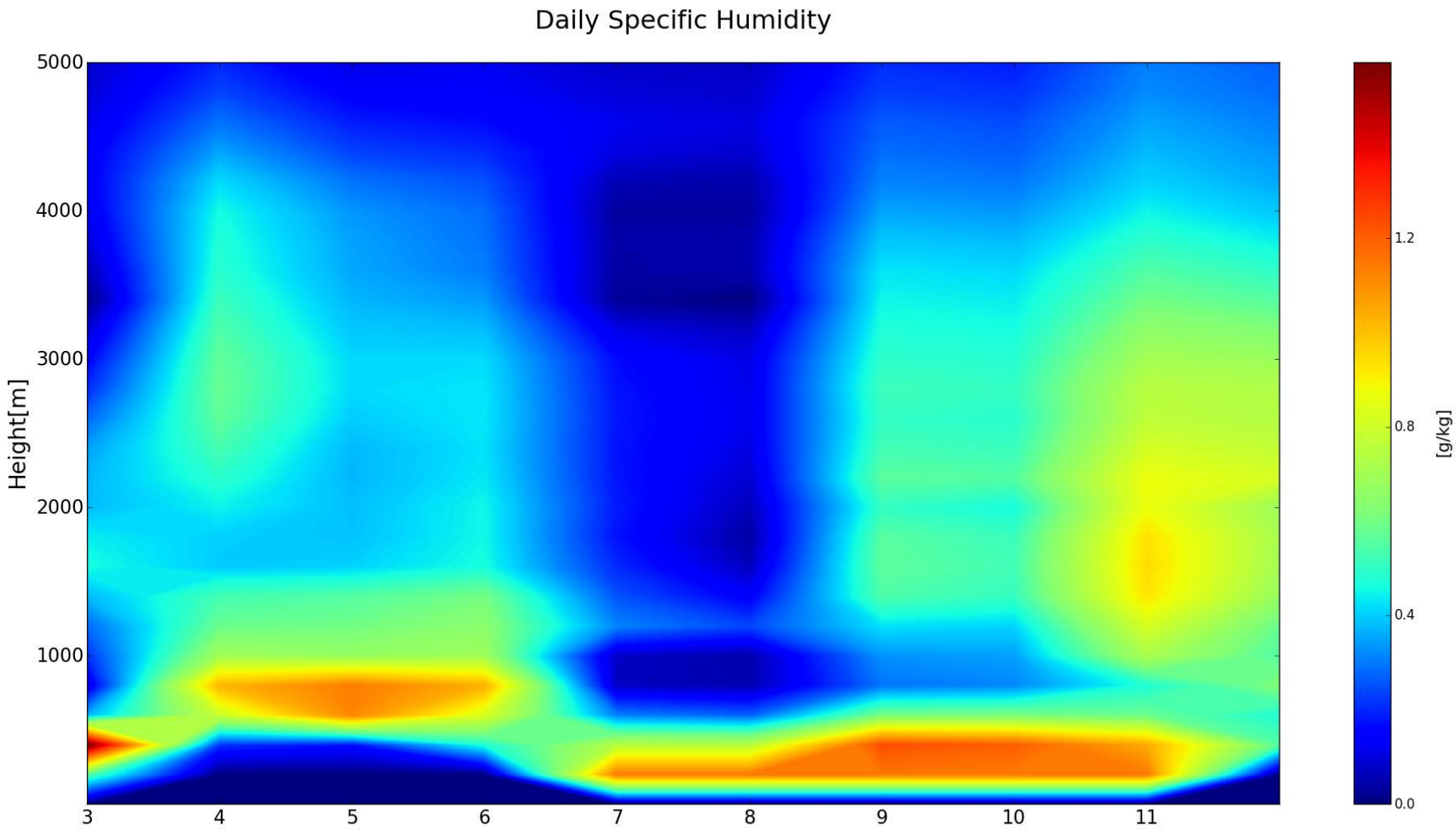


Same Period, Dec. 2015

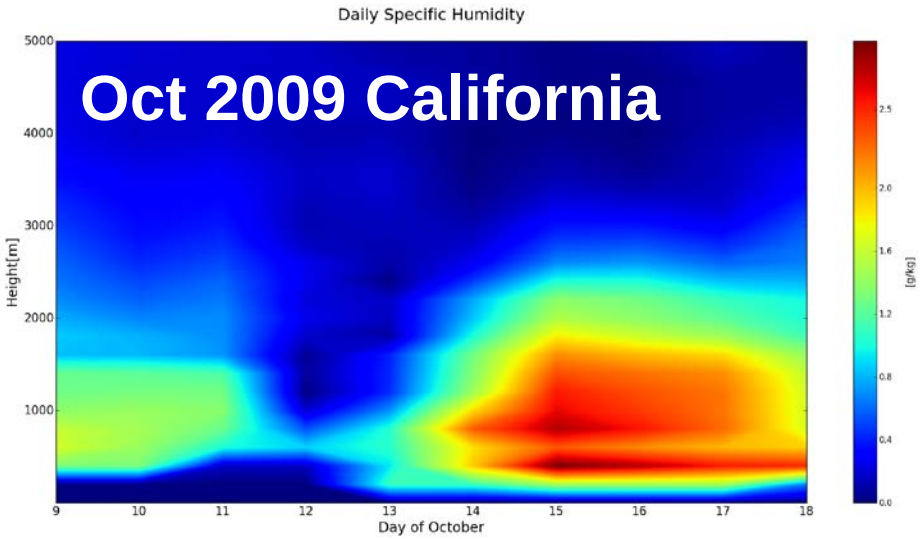


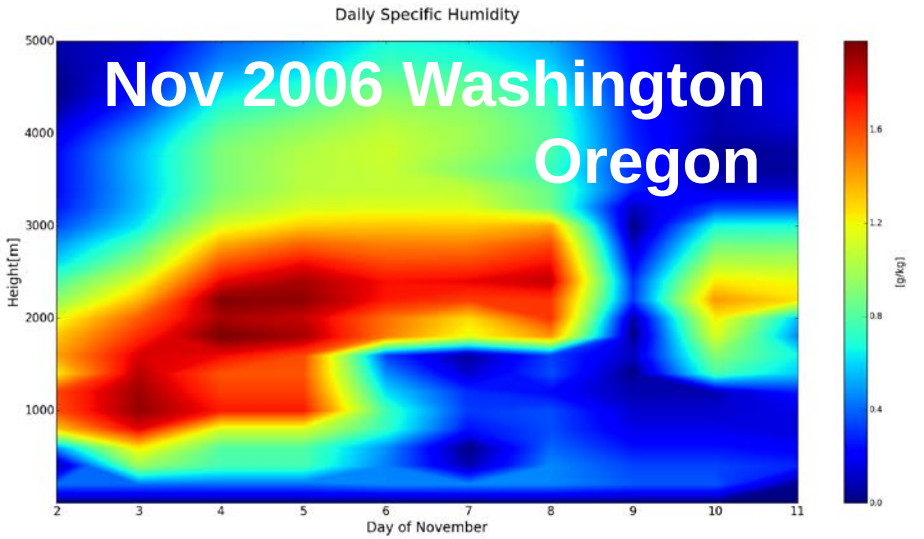
Focus on Norway – “Synne”

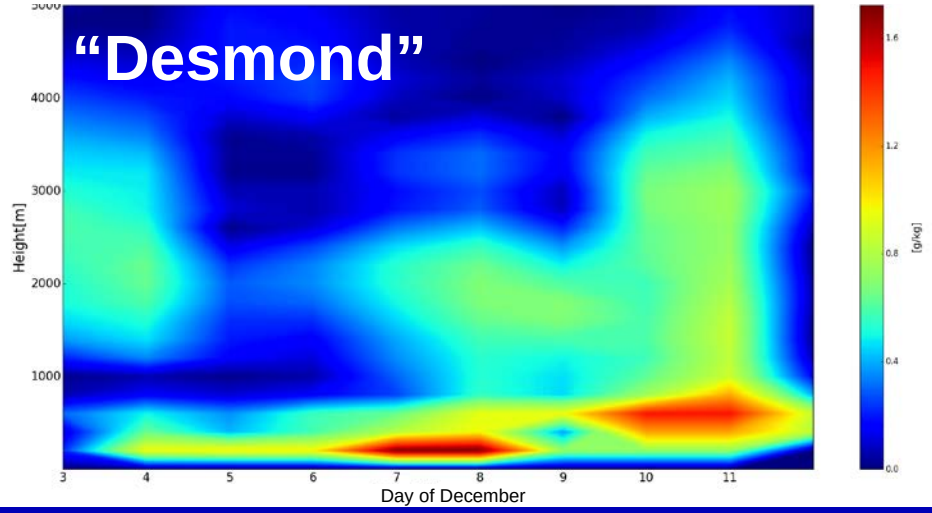
Spec. Hum., Dec. 2015

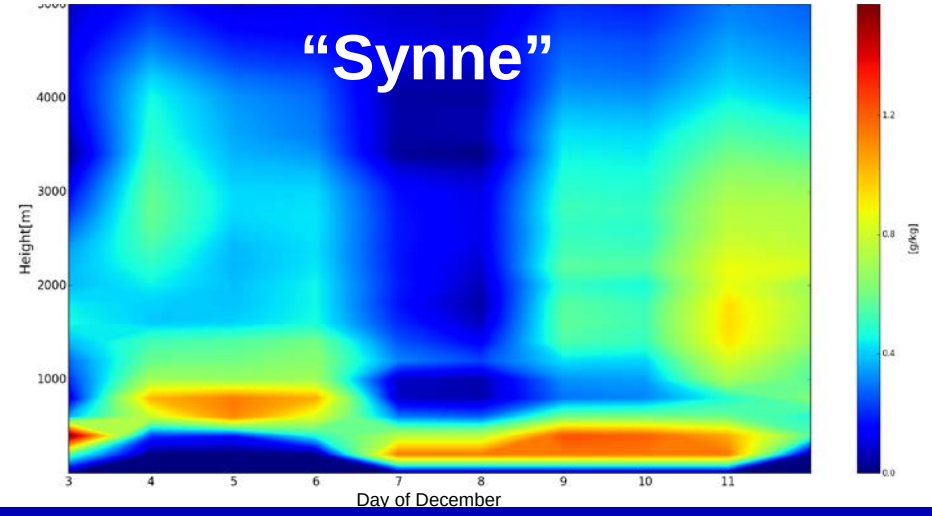


Different Cases









Note different structures (and SpecHum ranges)

Summary

Atmospheric rivers are usually characterized using IWV or PW, e.g. based on data from satellite passive microwave radiometers – providing a good picture of the horizontal extend, but little information about the vertical variation.

GNSS RO can provide this vertical information – if the profiles penetrate deep enough.

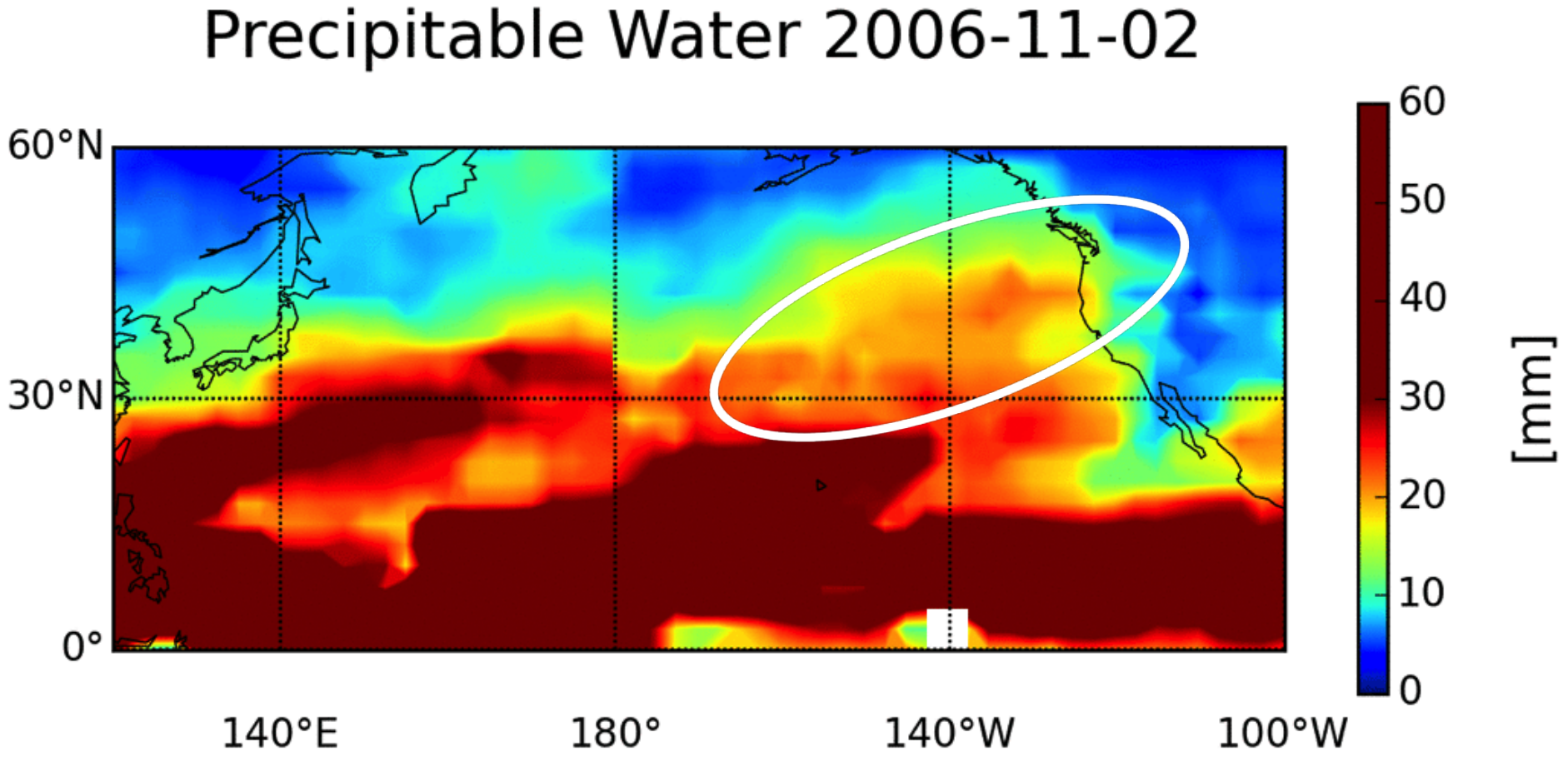
A combination of both data should provide good results.

There seems to be water vapor information in RO data beyond that, what is already contained in analyses.

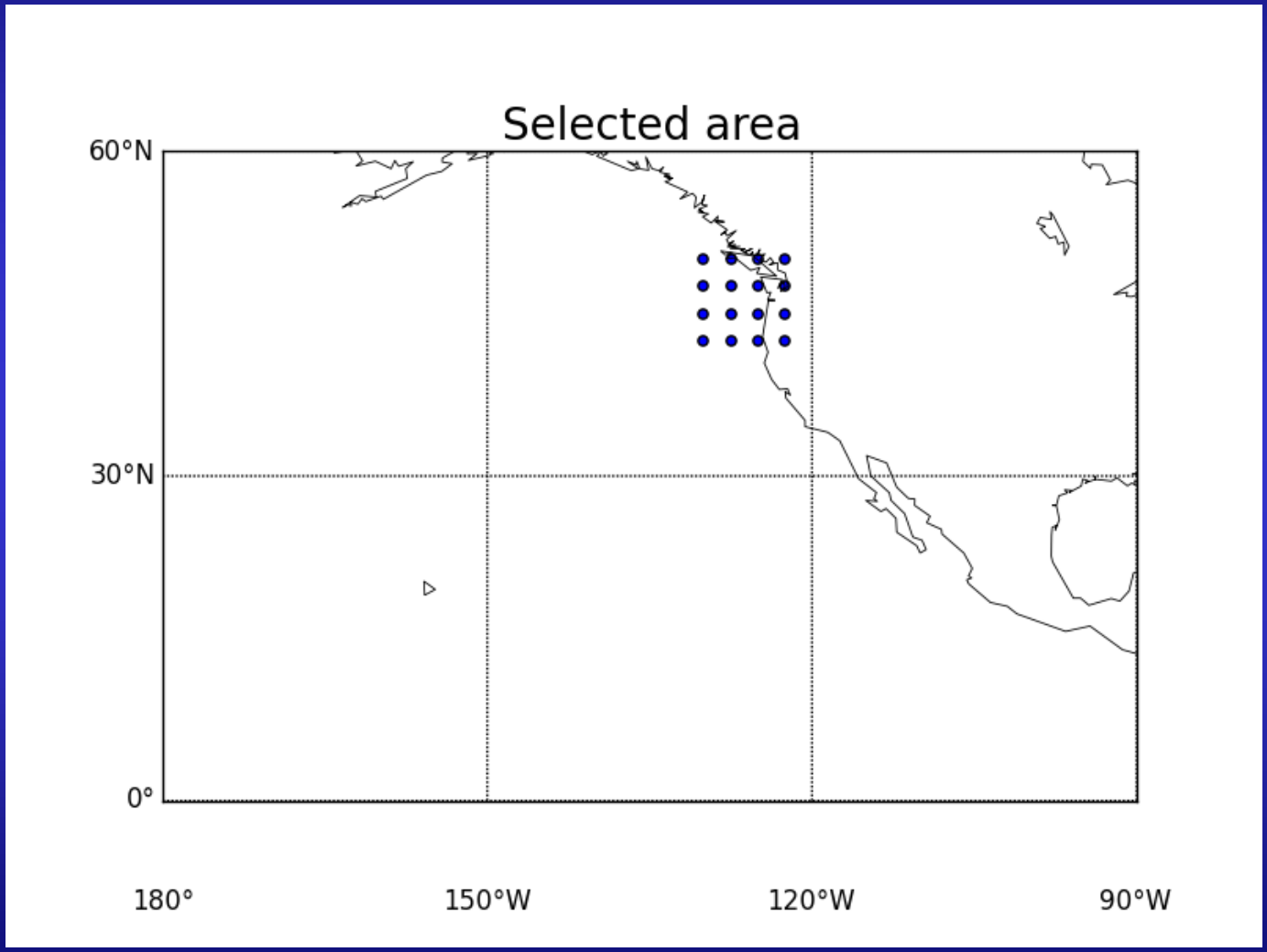
The progress of this work shows some similarities with the fate of Holger the Dane, but I hope that there will be an awakening.

Thank you very much!

Atmospheric River, 2006



Selected Region, Nov. 2006



Focus region, average over 16 grid-points

Spec. Hum., Nov. 2006