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A data assimilation experiment of temperature and humidity profiles from an international network of ground-based microwave radiometers

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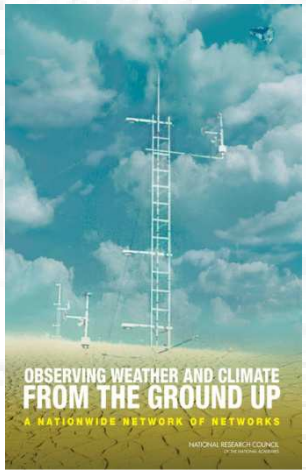
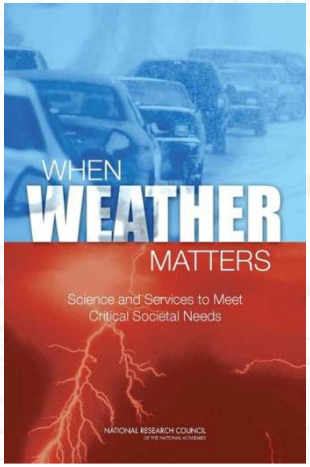
Motivations (1/2)

U.S. National Research Council Reports*:

- The planetary boundary layer (PBL) is the single most important under-sampled part of the atmosphere
- The vertical structure of the PBL is not systematically observed
  - Surface → met data
  - PBL → gap
  - Upper air → satellite
- Particularly important in nowcasting and severe weather initiation

• **Observing Weather and Climate from the Ground Up;** A Nationwide Network of Networks (2009)
• **When Weather Matters:** Science and Service to Meet Critical Societal Needs (2010)





Motivations (2/2)

WMO guidance on observations for NWP:

- four critical atmospheric variables are not adequately measured
  - wind profiles
  - **temperature and humidity profiles (in cloudy areas)**
  - precipitation
  - snow mass

- Ground-based microwave radiometers (MWR) provide T and H profiles
  - High temporal resolution (~1 min)
  - Low-to-moderate vertical resolution
  - Information mostly residing in the PBL

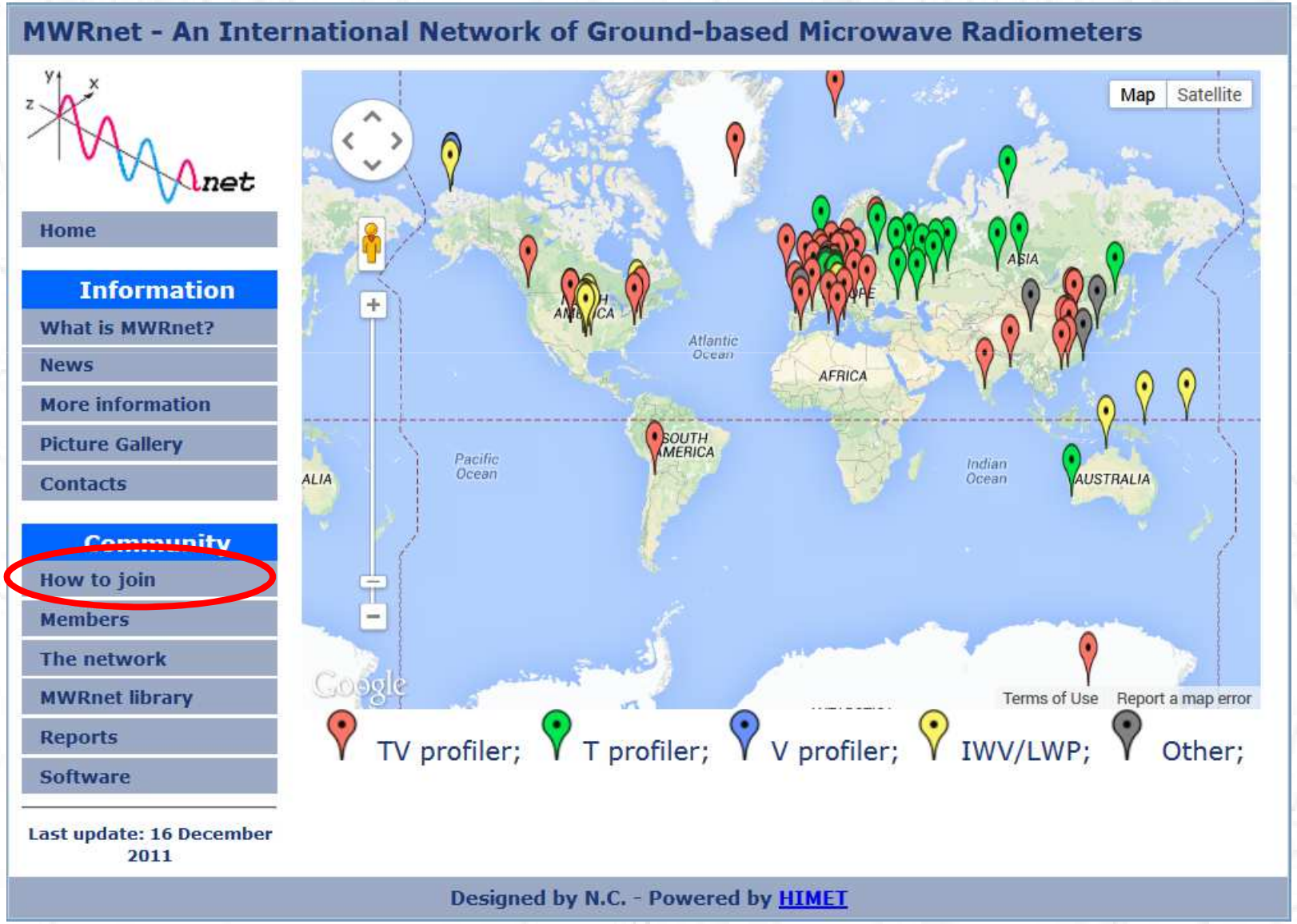
*https://www.wmo.int/pages/prog/www/OSY/GOS-RRR.html

Approach

- A ground-based MWR network could provide continuous T and H profiling to feed NWP DA ☺
- In the current financial scenario, the deployment of a new dedicated MWR network is not likely ☹
- Several MWR are currently operational:
  - But different organizations and purposes 😐
  - Data uder-used 😐
  - No coordination… 😐 **...until MWRnet!** ☺ ☺ ☺

What's MWRnet?

http://cetemps.aquila.infn.it/mwrnet



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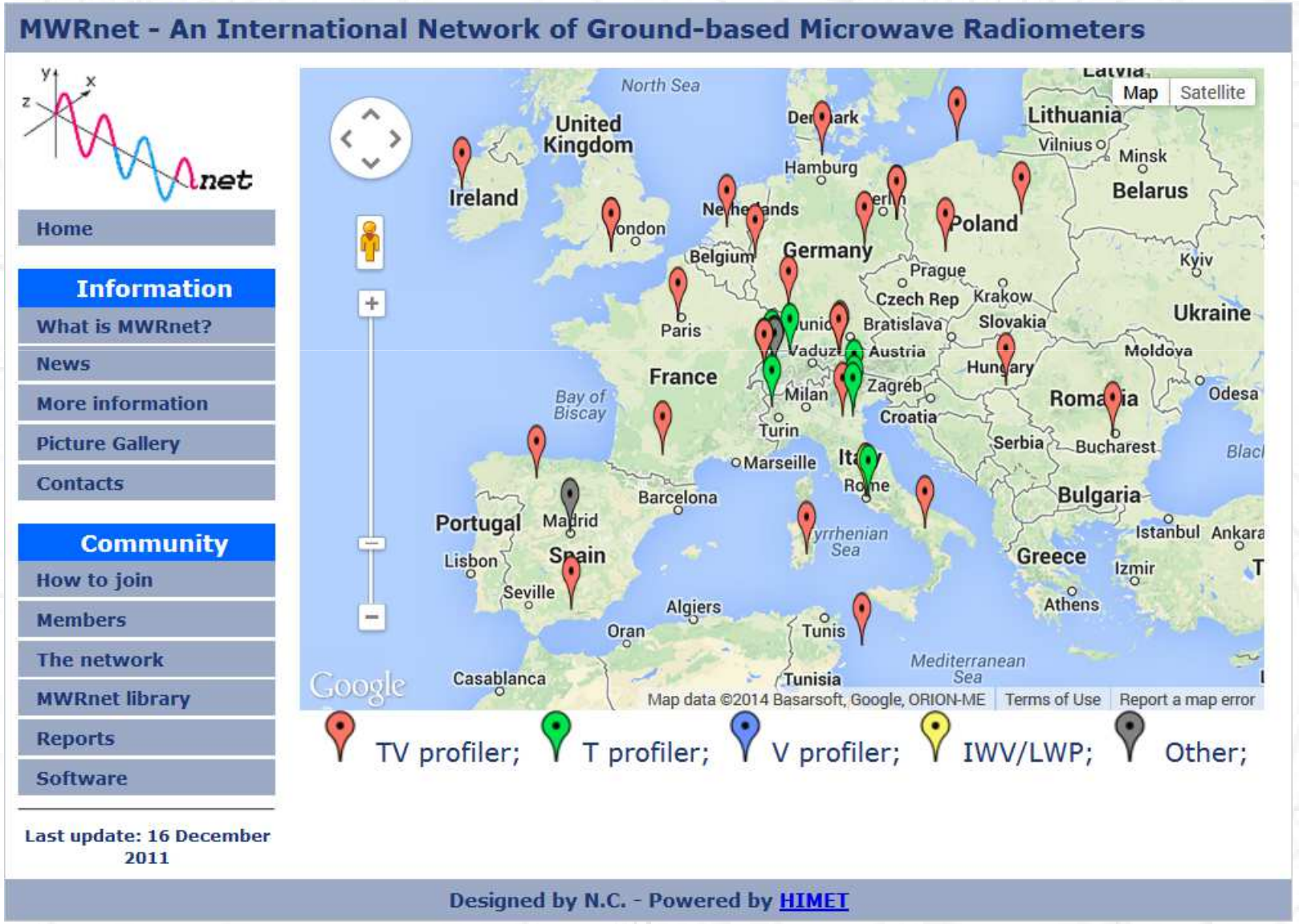


Previous MWR DA experiments (1/2)

Vandenberghe and Ware (2002)

- **Obs:** One single MWR
- **Model:** MM5 (+4DVAR)
- **Period**: One case study (3-hour data assimilation)
  - winter fog event at Denver Airport (**missed by NWP**)
- **Conclusions**: 4DVAR DA assimilation was able to generate fog, though benefits were rapidly lost in the free forecast

Previous MWR DA experiments (2/2)

Otkin et al. (2011); Hartung et al. (2011)

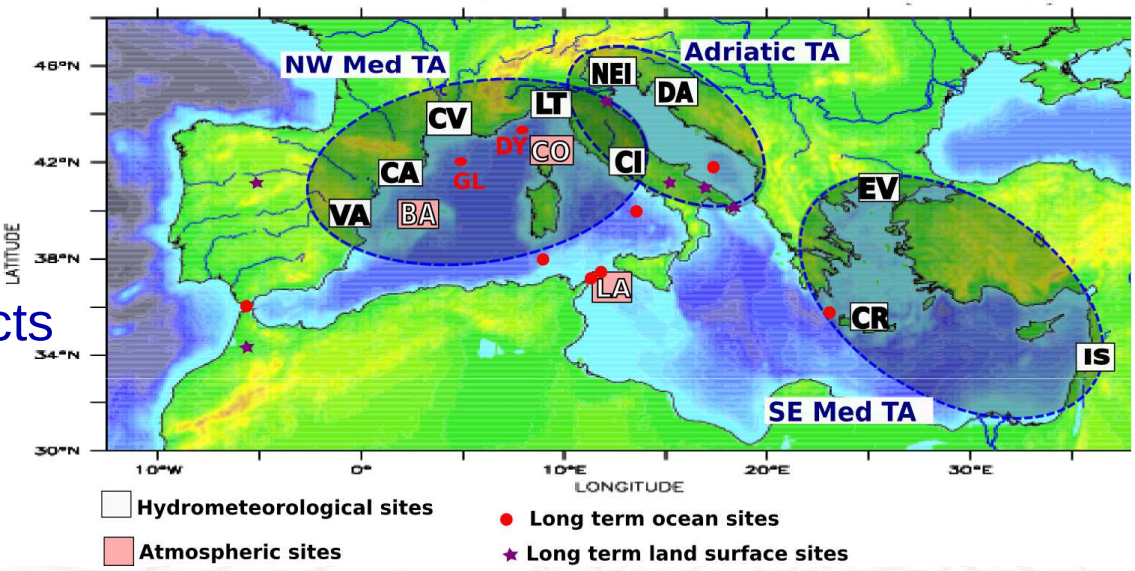
- **Obs:** ~140 MWR (+other instr.)
  - OSSE: Observing System **Simulation** Experiment
- **Model:** WRF (+EnKF)
- **Period:** One case study in continental U.S.
  - winter storm case
- **Conclusions**: reduced errors in the intensity and location of the mesoscale structure, but not in prediction of heaviest precipitation

DA of a real network of ground-based MWR has never been attempted before

Context: HyMeX (1/2)

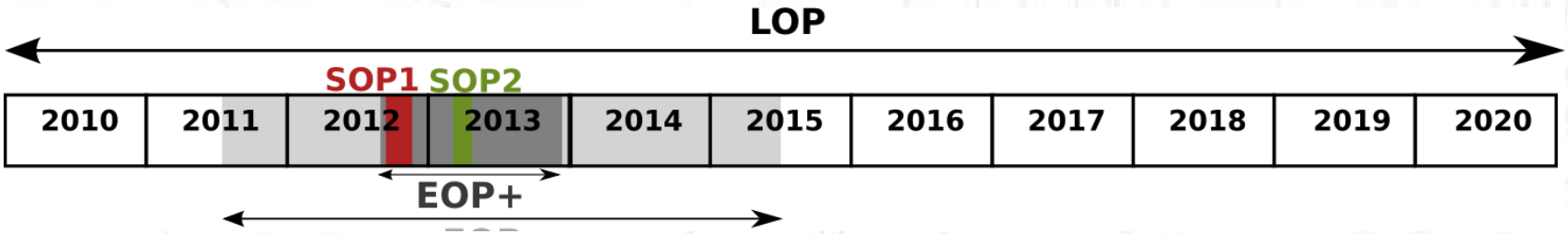
HyMeX: Hydrological cycle in the Mediterranean Experiment

- Water budget
- Hydrological cycle
- Air-Sea interactions
- Heavy rainfalls, floods
- Socio-economic impacts



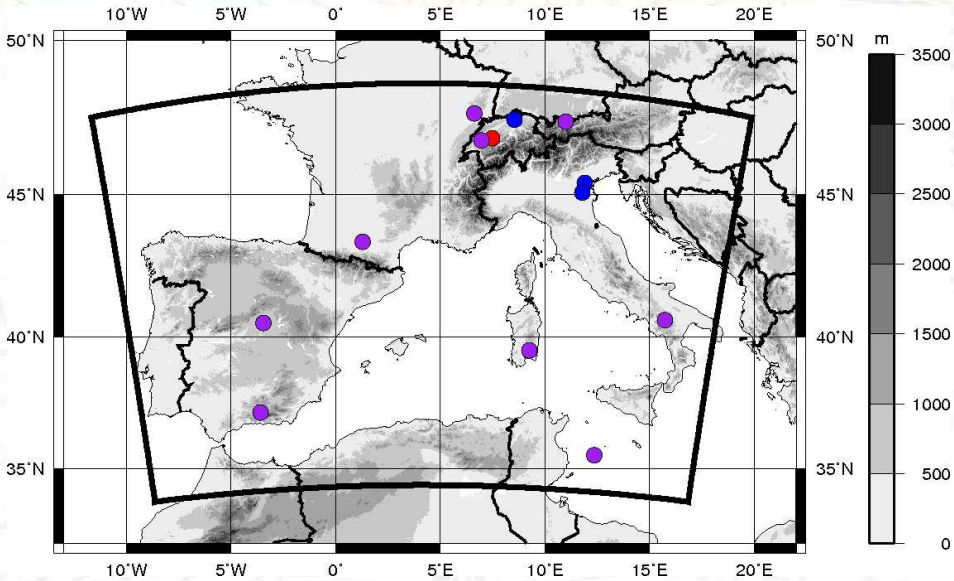
Observation Strategy:

- 10-year Long-term Observation Period (**LOP**)
- 4-year Extended Observation Period (**EOP**)
- Short-term Special Observation Periods (**SOP**)



Context: HyMeX (2/2)

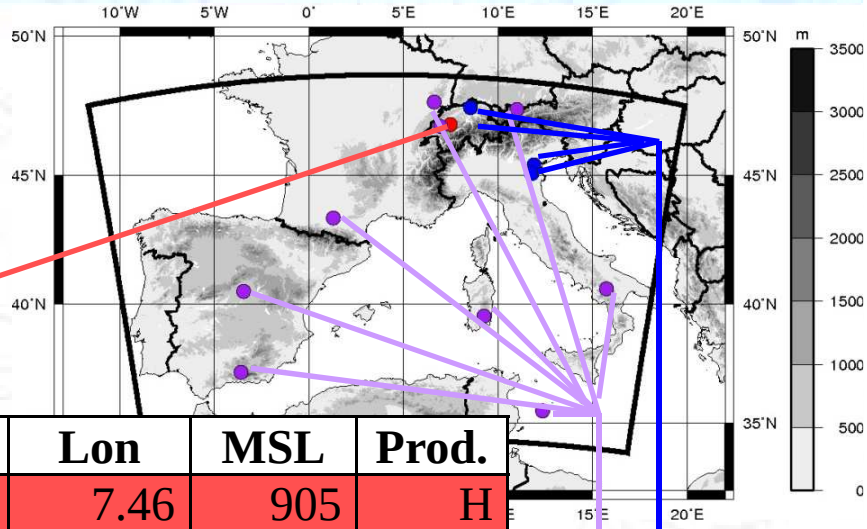
- Work done in preparation to the HyMeX SOP1
  - Sep-Nov 2012
- HyMeX West Mediterranean (WMed) target area



- Arome-WMed NWP system (Météo-France)
  - 2.5 km horizontal resolution
  - non-hydrostatic, detailed physics
  - coupled with global NWP system Arpege (Météo-France)

Ground-based MWR network

- A network of 13 MWR:
  - H profilers (1)
  - T profilers (4)
  - T&H profilers (8)



Station	Institution	Lat	Lon	MSL	Prod.
Bern	IAP	46.88	7.46	905	H
Cagliari	INAF/OAC	39.5	9.24	623	T, H
Granada	CEAMA-UGR	37.16	-3.6	683	T, H
Kloten	MeteoSwiss	47.48	8.53	436	T
Lampedusa	ENEA	35.51	12.34	50	T, H
Madrid	UniLeon	40.49	-3.46	620	T, H
Padova	ARPAV	45.4	11.89	30	T
Payerne	MeteoSwiss	46.82	6.95	491	T, H
Potenza	IMAA/CNR	40.6	15.72	760	T, H
Rovigo	ARPAV	45.07	11.78	23	T
Schaffhausen	MeteoSwiss	47.68	6.62	437	T
Schneefernerhaus	UniCologne	47.42	10.98	2650	T, H
Toulouse	ONERA	43.38	1.29	144	T, H

MWR DA Experiment

- Observations:
  - 13 MWR
  - ~2 months (October-November, 2011)
    - including several heavy precipitation events
      - Over Spain, France, Italy
  - T & H retrievals
    - Retrieval method depending upon site

- Model and Data Assimilation:
  - Arome WMed
  - 3DVAR assimilation of T&H profiles every 3 h

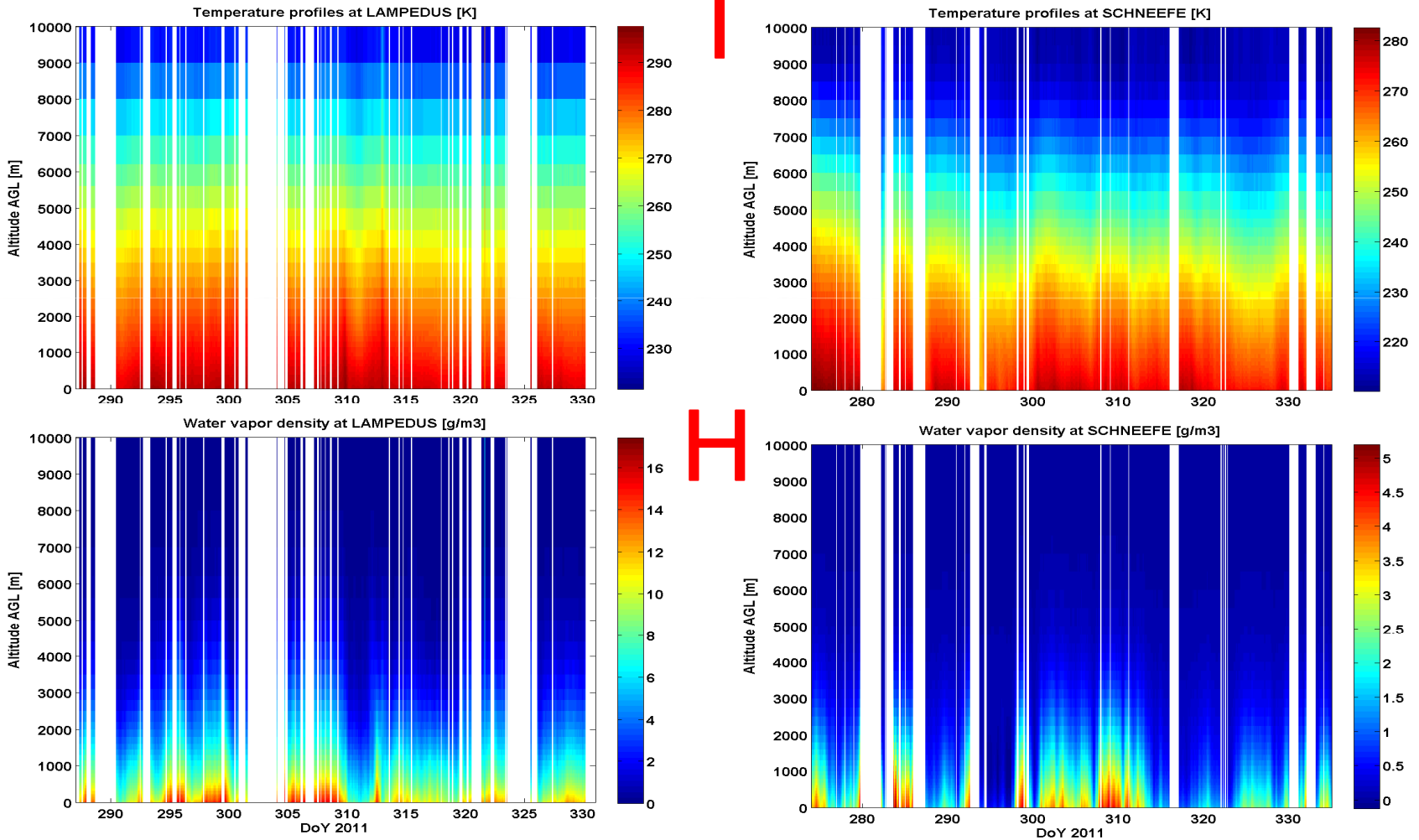
MWR Data Assimilation Experiment

Lampedusa
(Italy, 50 m asl)

Schneeferner glacier
(Germany, 2969 m asl)

T

H



October-November, 2011

MWR Data Assimilation Experiment

- Other assimilated data in the Control (CTRL) run include:
  - radiosondes
  - wind profilers
  - aircrafts
  - ships
  - buoys
  - automatic weather stations
  - satellite radiometers
  - weather radars
  - ground-based GPS
  - GPS radio-occultation

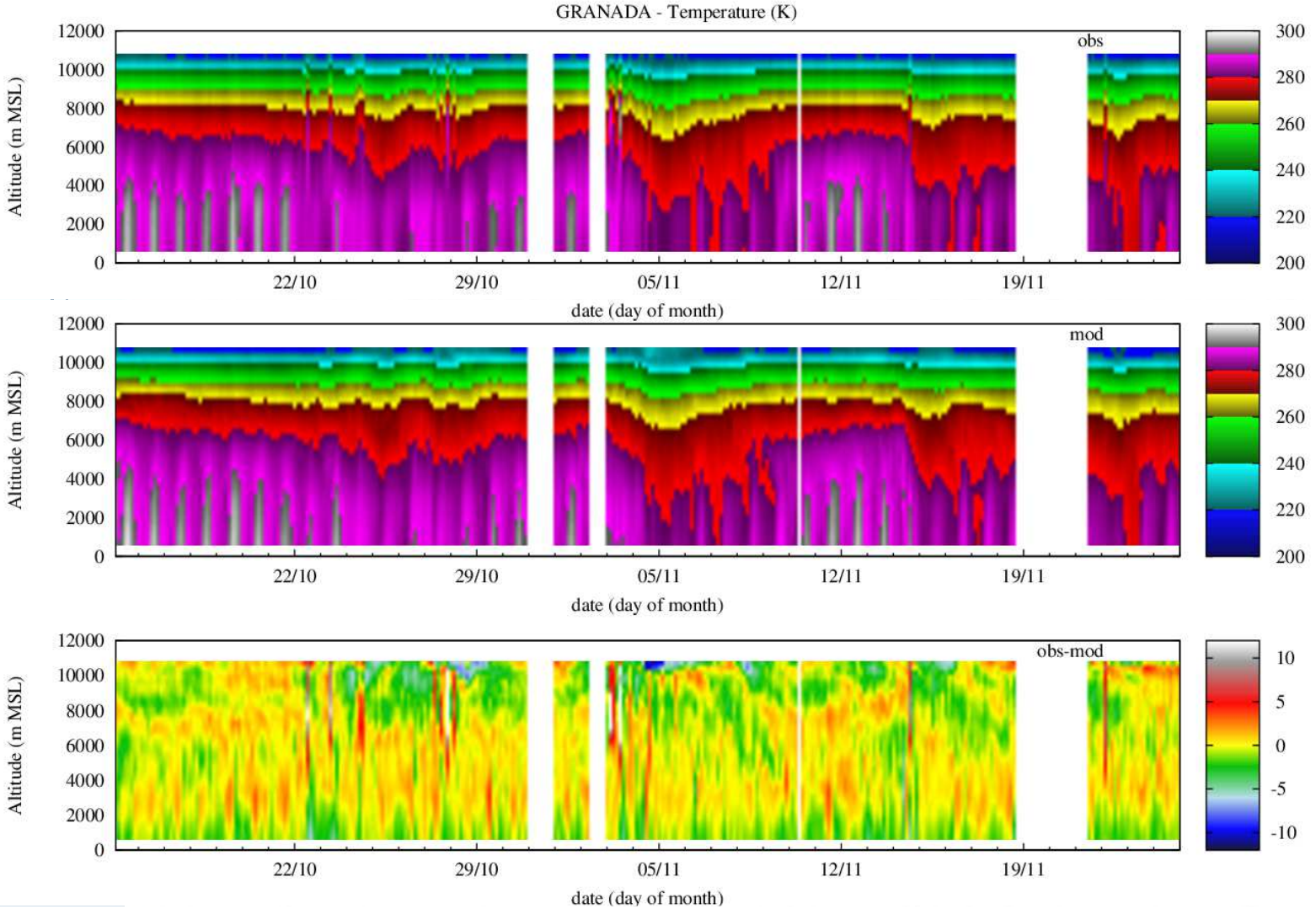
….very little room to make an impact!

MWR Data Assimilation Experiment

- Results:
  - Observation-minus-background (O-B) statistics
    - MWR retrievals minus control run (CTRL) profiles
  - Data assimilation impact:
    - precipitation (ground truth: rain gauges)
    - other surface fields (on going)
    - upper air fields (on going)

O-B Time series

TEMPERATURE - GRANADA



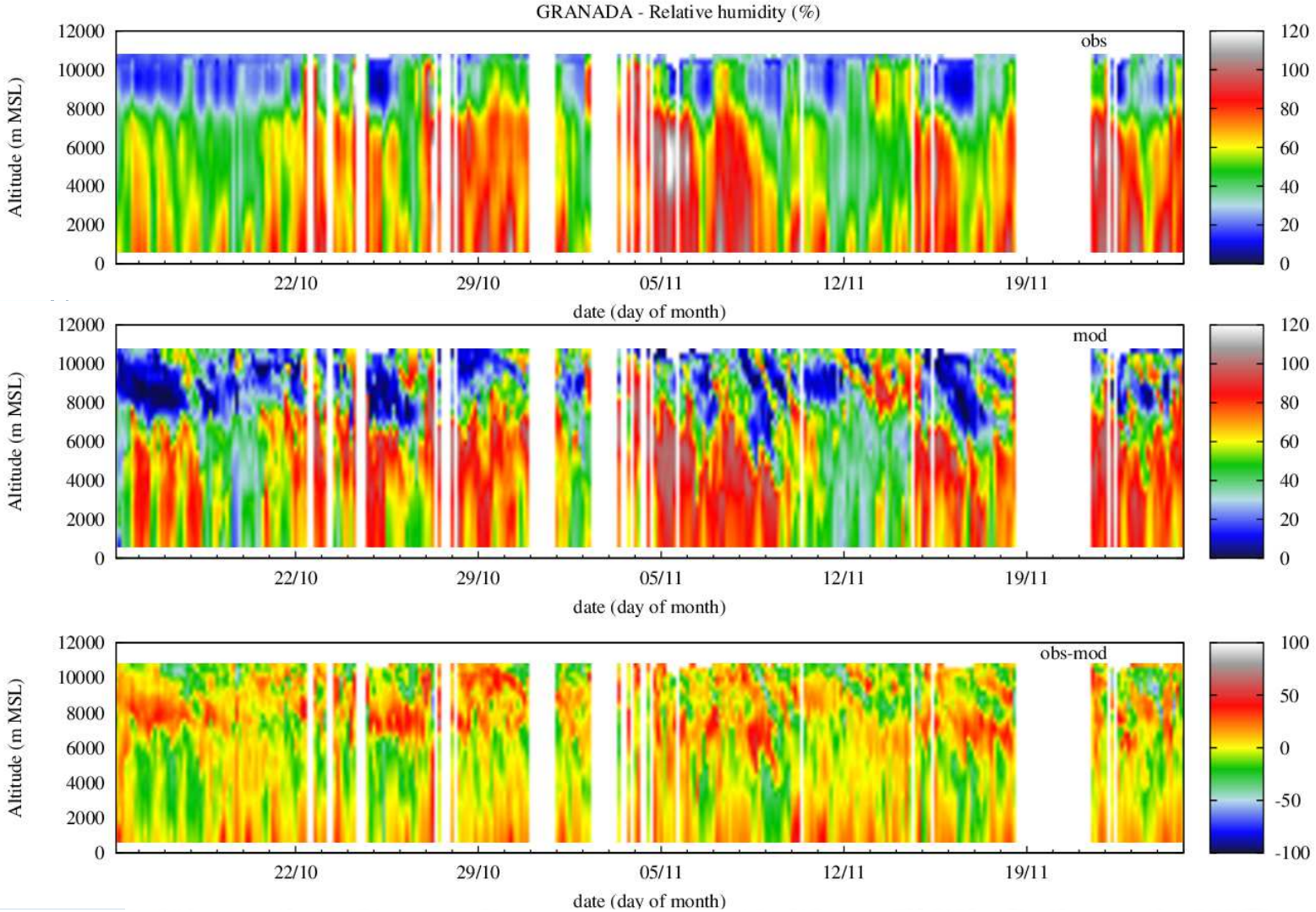
OBS

MOD

OBS-MOD

O-B Time series

HUMIDITY - GRANADA



OBS

MOD

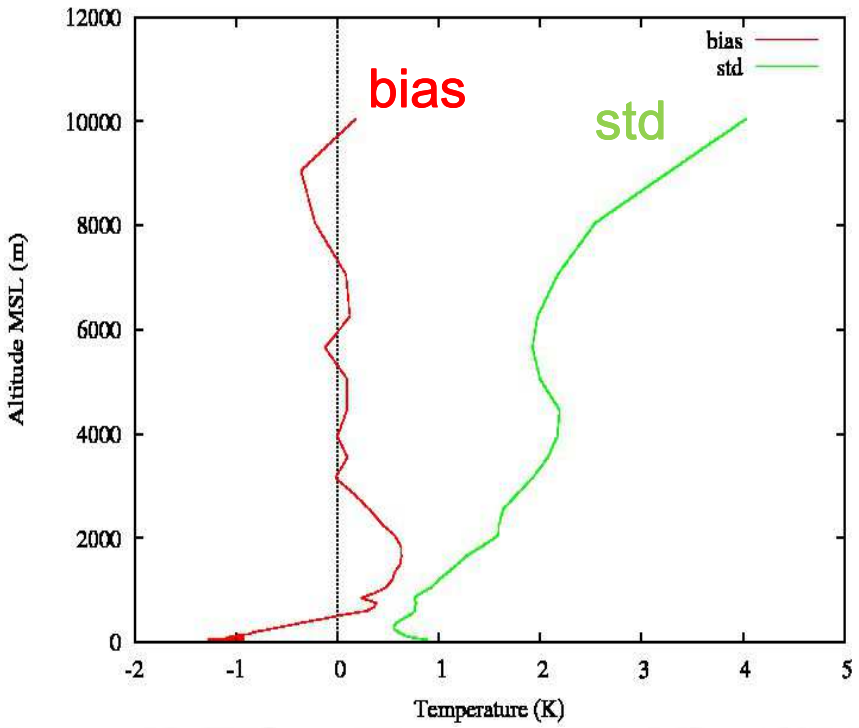
OBS-MOD

O-B statistics

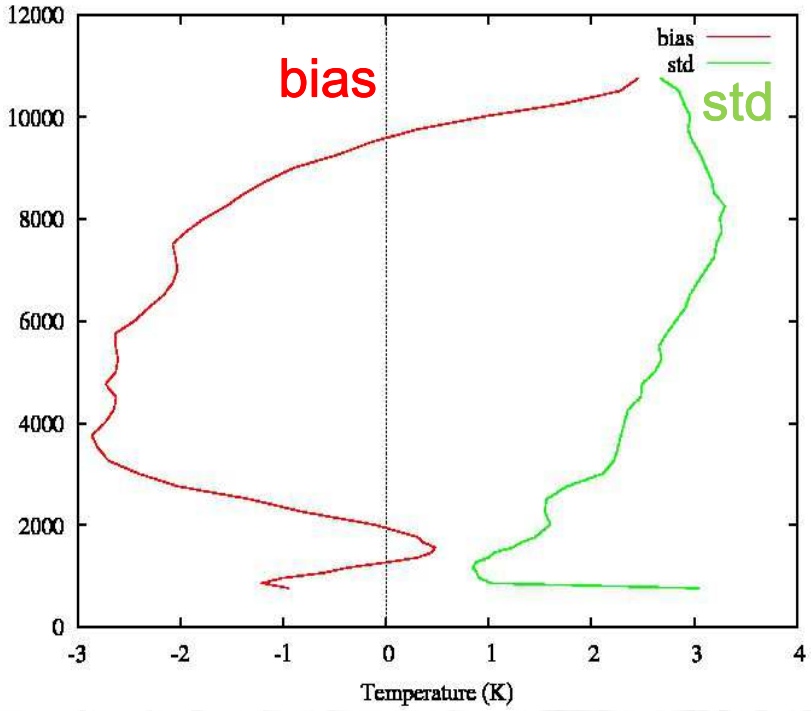
Check consistency between MWR products and original CTRL forecast

TEMPERATURE

Lampedusa (Italy)



Potenza (Italy)

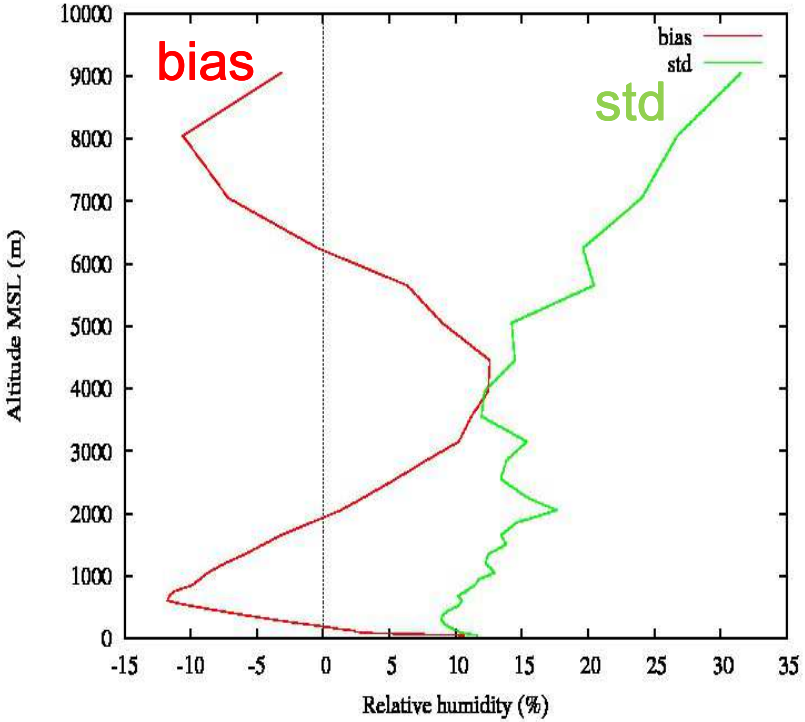


O-B statistics

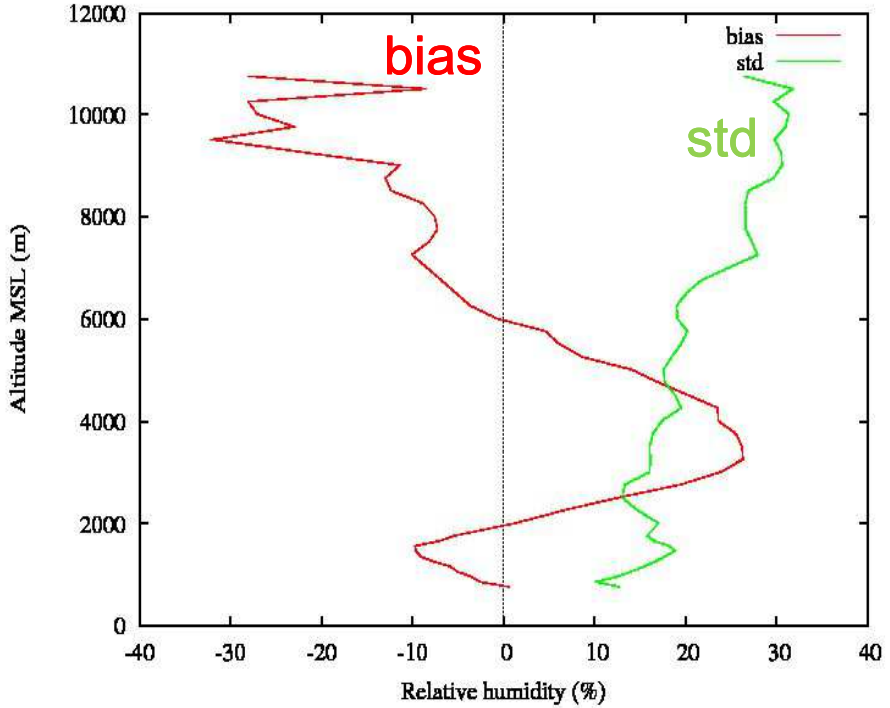
Check consistency between MWR products and original CTRL forecast

HUMIDITY

Lampedusa (Italy)



Potenza (Italy)



O-B statistics

Conclusions

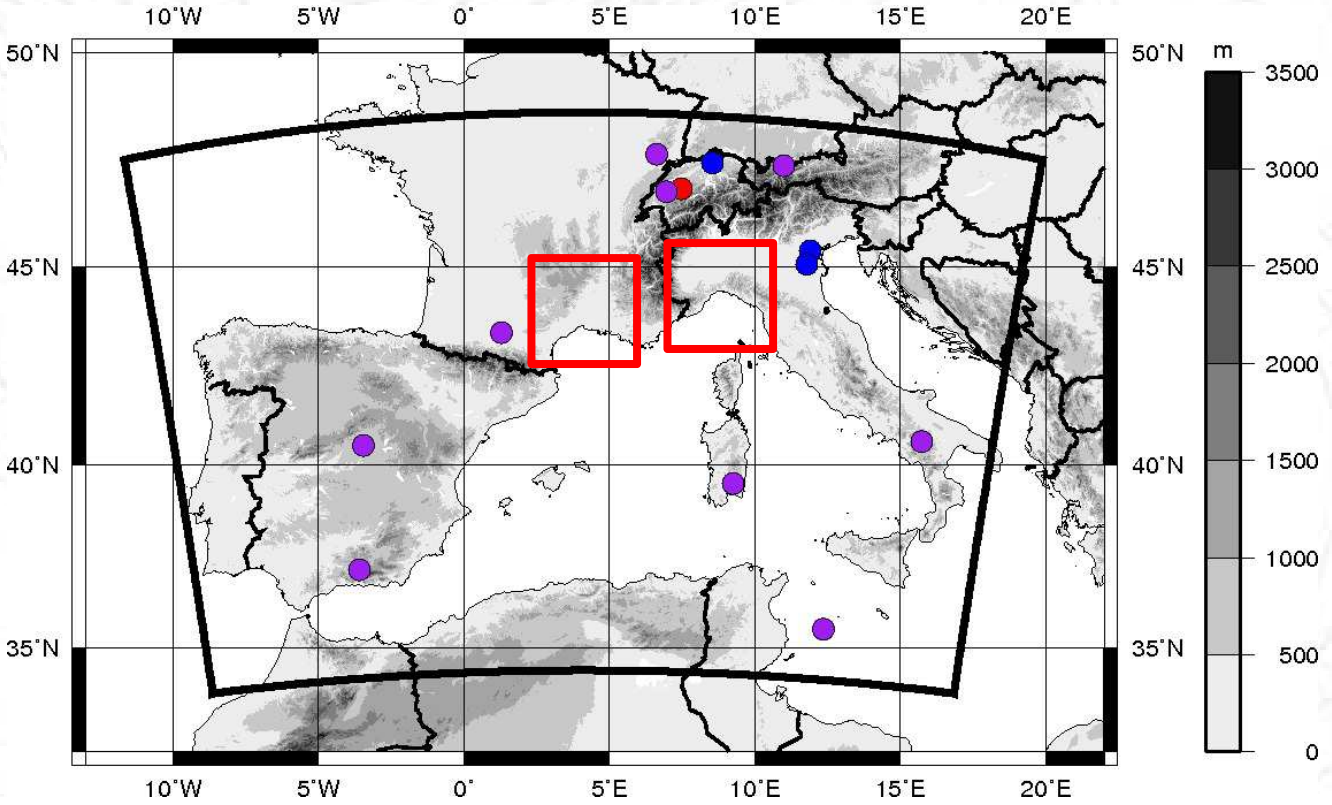
- Std similar to radiosondes
- Bias much larger than radiosondes
- The large biases are due to a combination of:
  - model bias
  - instrument bias
  - retrieval bias

This needs further investigation

Data assimilation impact

4 runs

- CTRL : assimilation of operational data only
- DA_T : as CTRL + MWR-derived T
- DA_U : as CTRL + MWR-derived U
- DA_TU : as CTRL + MWR-derived T&U

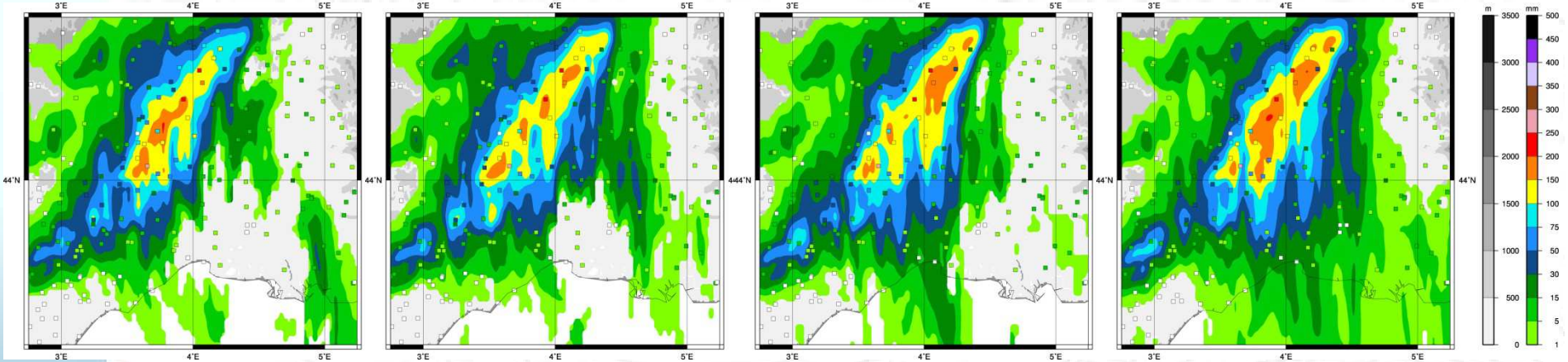


Data assimilation impact

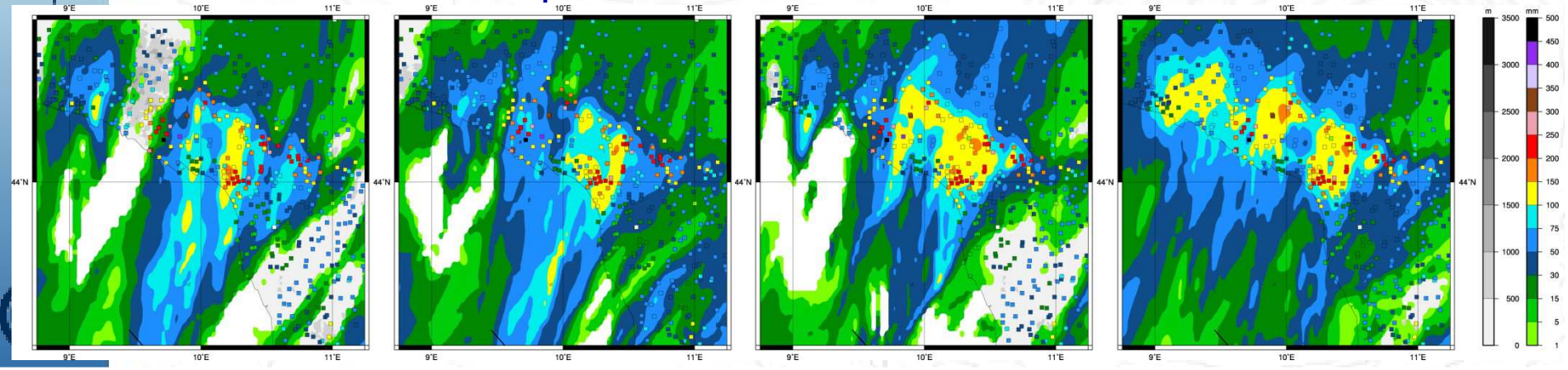
Verification w.r.t. **24-h accumulated precipitation** (‘truth’: rain gauges)

CTRL **DA_U** **DA_T** **DA_TU**

2-3 November, Cévennes



26-26 October, Cinque Terre

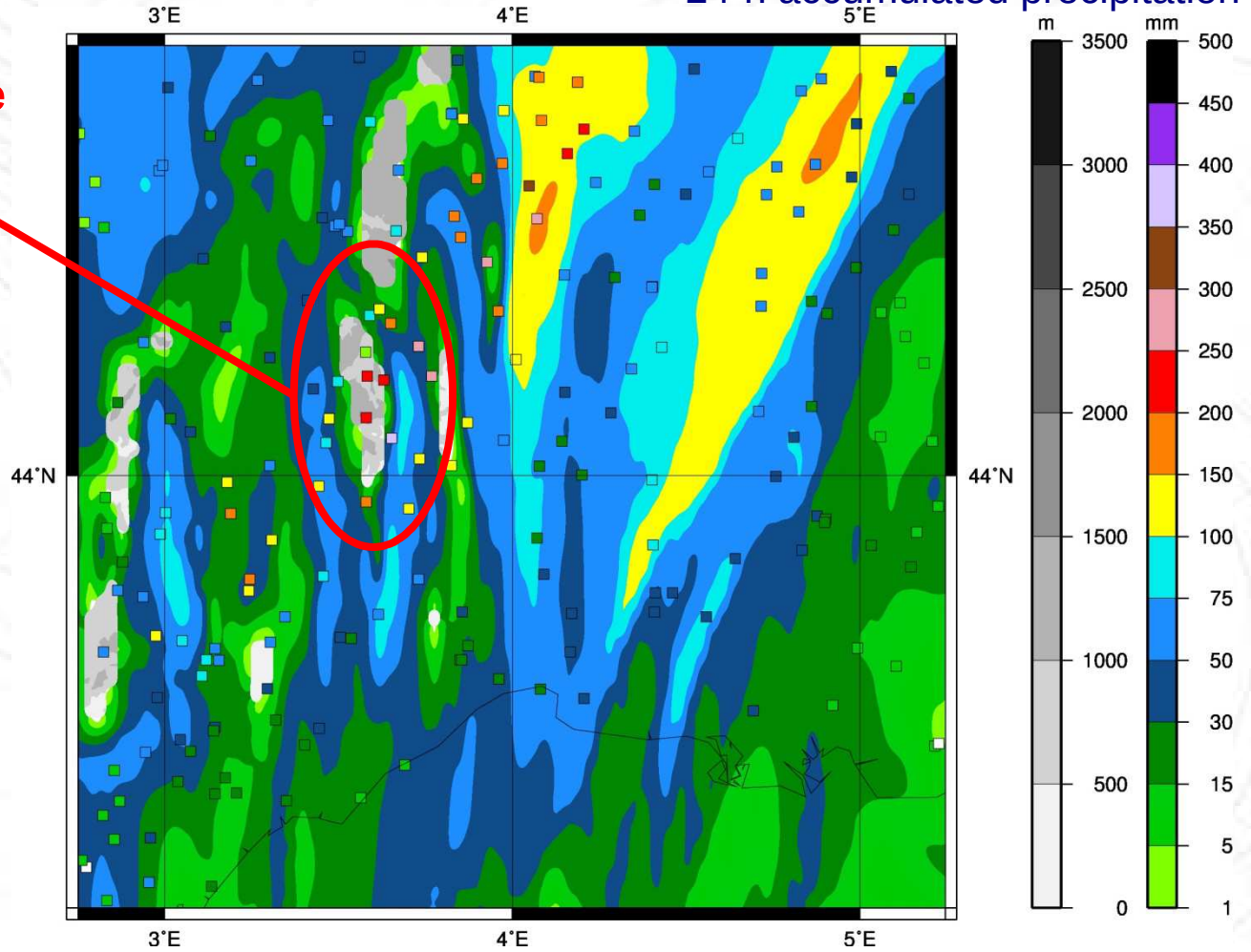


Data assimilation impact

- **Case #1**: 3-4 Nov, Cévennes (France)
- **CTRL**: precipitation patterns are misplaced and too weak

24-h accumulated precipitation

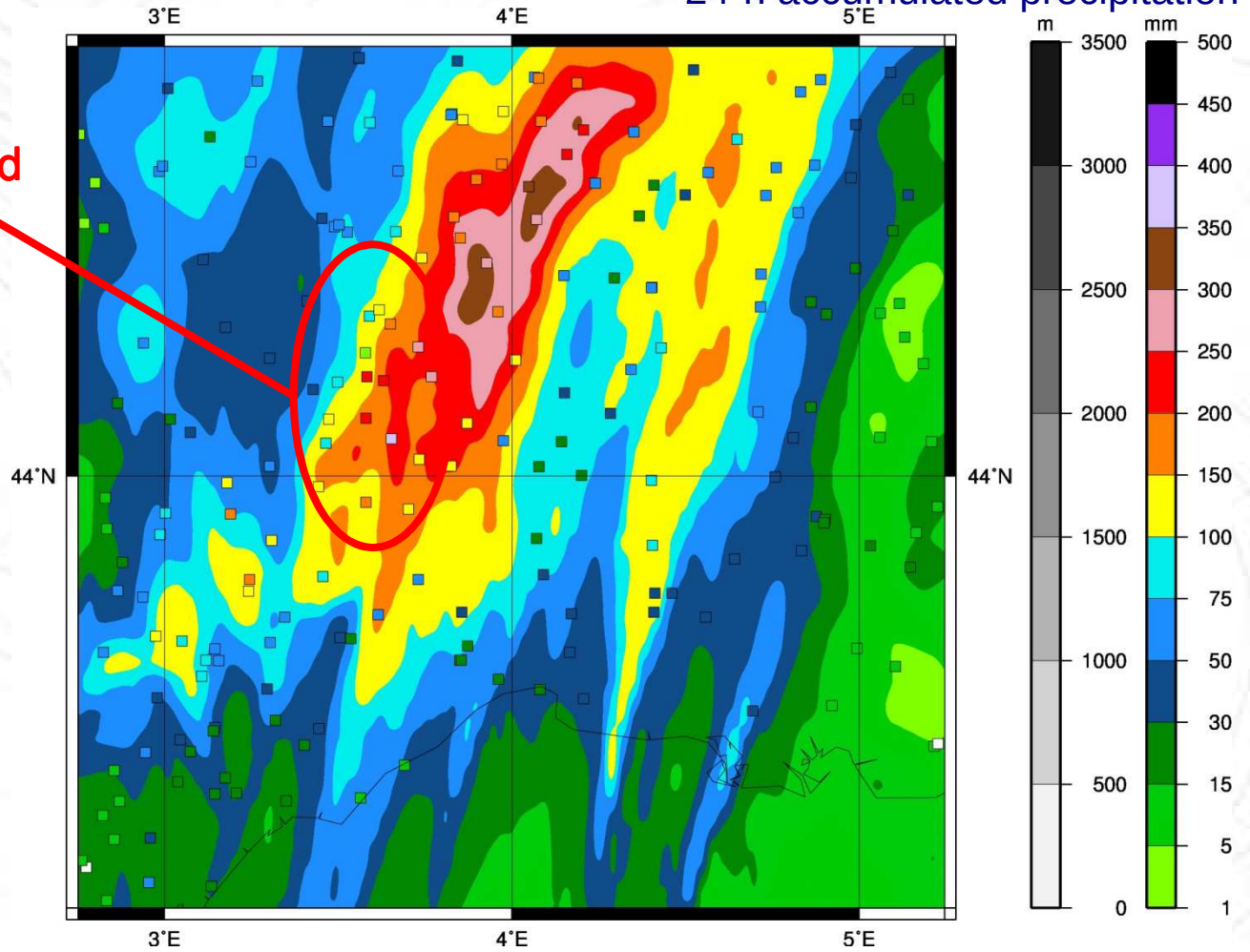
0 mm where the maximum of observed precipitation is located



Data assimilation impact

- **Case #1**: 3-4 November, Cévennes
- **DA_TU**: more precipitation, good location

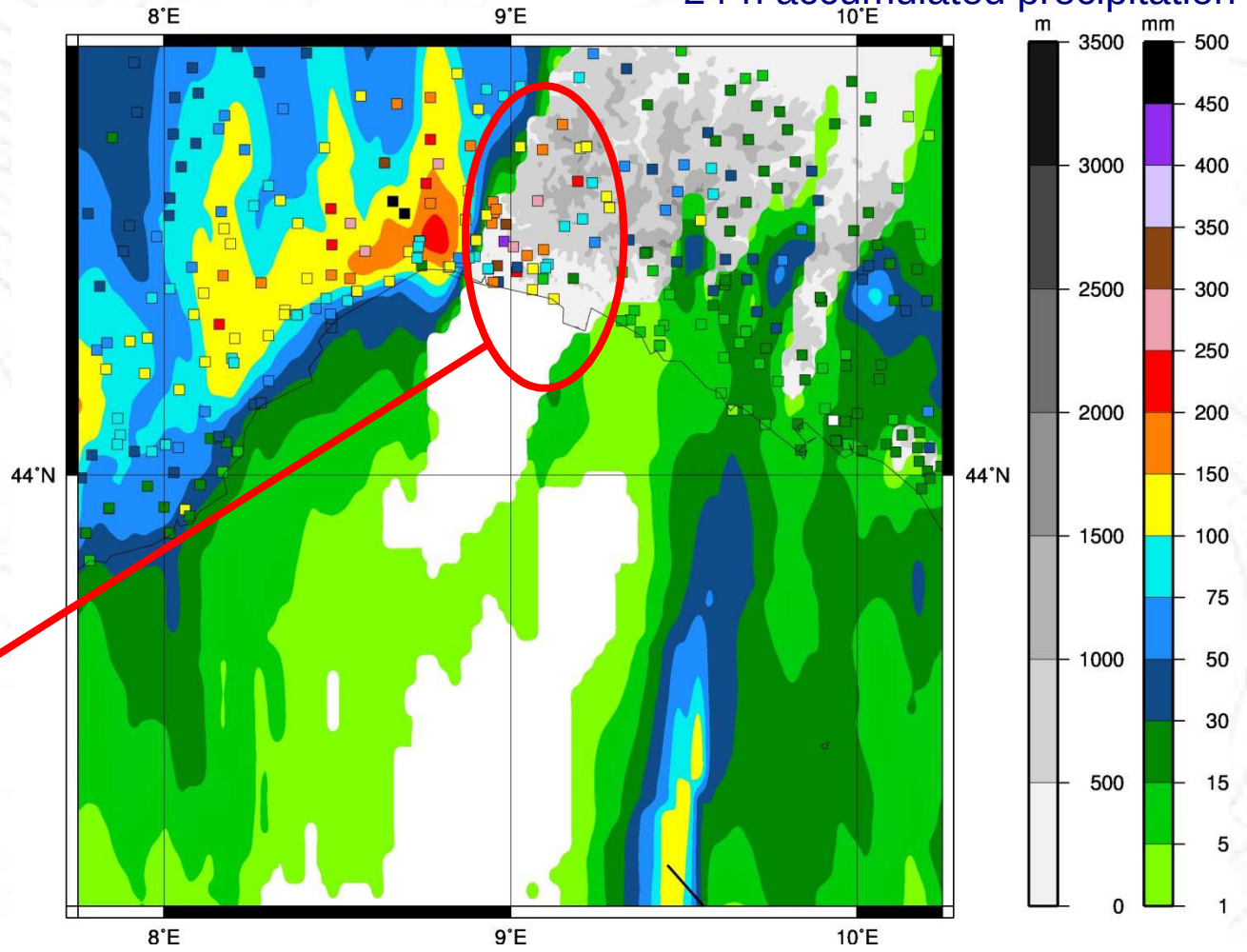
24-h accumulated precipitation



Data assimilation impact

- **Case #2**: 4-5 Nov, Genoa (Italy)
- **CTRL**: No precipitation forecast over Genoa

24-h accumulated precipitation

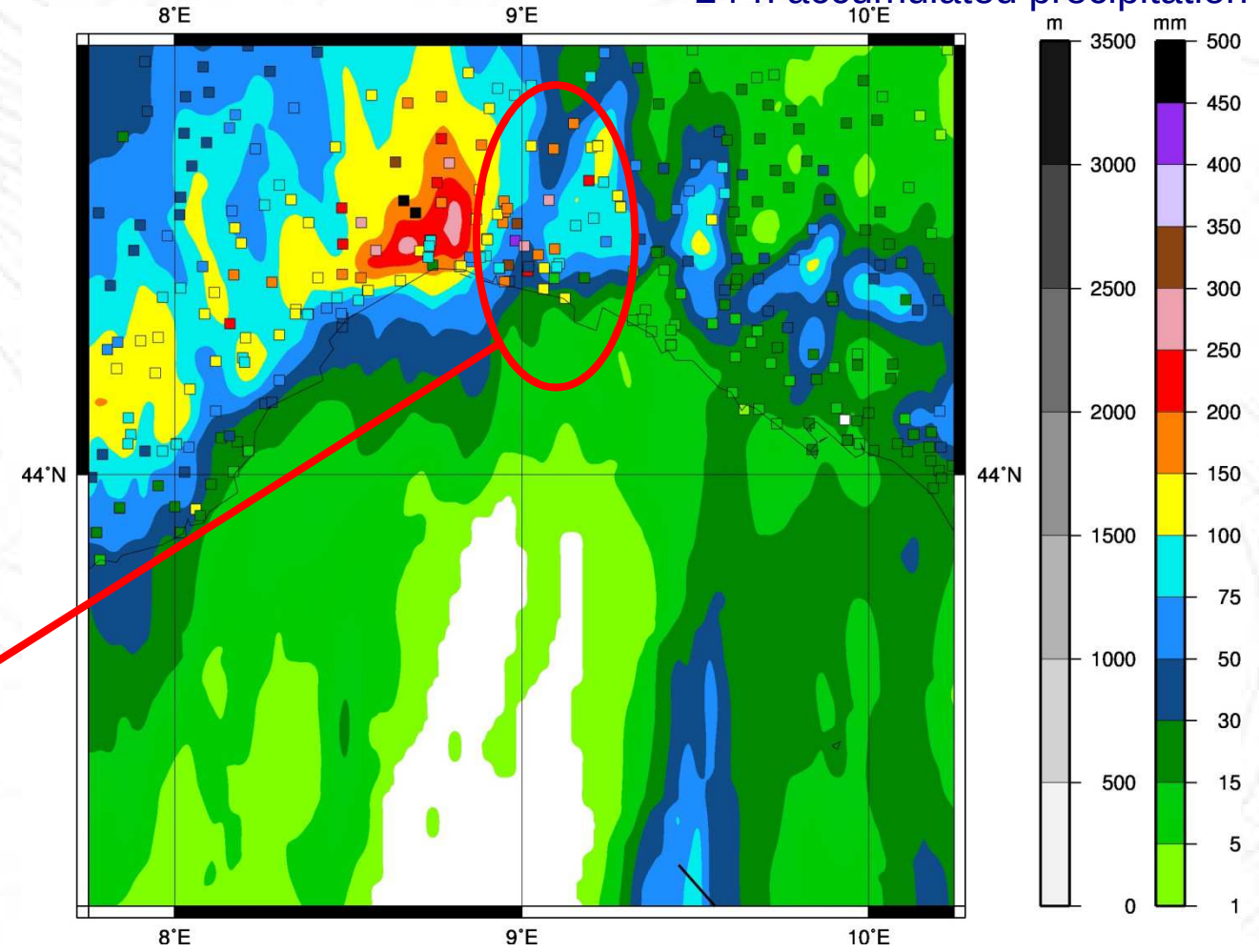


0 mm where the maximum of observed precipitation is located

Data assimilation impact

- **Case #2**: 4-5 Nov, Genoa (Italy)
- **DA_TU**: Better location and intensity, but still drier than gauges

24-h accumulated precipitation



Better location and intensity

Data assimilation impact

Skill scores for 24-h precipitation accumulation (over 2-month period):

	Bias (mm)	Rmse (mm)	CorrCoef
CTRL	-0.23	6.58	0.62
DA_T	-0.22	6.71	0.64
DA_U	-0.24	6.61	0.64
DA_TU	-0.22	6.62	0.64

- MWR DA shows neutral (-to-positive) impact:
  - data are such that can be safely assimilated
  - to be confirmed (w.r.t. surface and radiosonde T&H data)

- More benefit is expected by:
  - improving the data quality (QC + retrieval bias)
  - assimilating brightness temperature (Tb) directly

Results summary

- Results from the first MWR Data Assimilation experiments show neutral (-to-positive) impact

- Possible reasons include:
  - Relatively scarce data (w.r.t. other assimilated sources)
  - Retrieval biases
  - Assimilation of retrievals instead of Tb

Ongoing activities

- Validation with respect to other references:
  - Surface data (T, H)
  - Upper air (radiosonde)
- Towards direct Tb assimilation:
  - TOPROF (EU COST Action)
    - Assessing MWR Tb uncertainties
    - Adaptating fast RTM for ground-based obs
      - Satellite heritage

Summary, conclusions and future plans

- Feasibility demonstration of pseudo-operational DA of a real network of ground-based MWR
- First results show neutral (-to-positive) impact
  - Not great, but encouraging
- Possible reasons:
  - Only few network nodes (13)
  - Retrieval bias
  - Data quality
- On going activities:
  - Complete validation
  - Move towards direct Tb evaluation

Thank you very much for your attention!

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