Improvement in the simulation of convection through humidity Data Assimilation and sub-kilometre grid refinement

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Bundesministerium für Bildung und Forschung

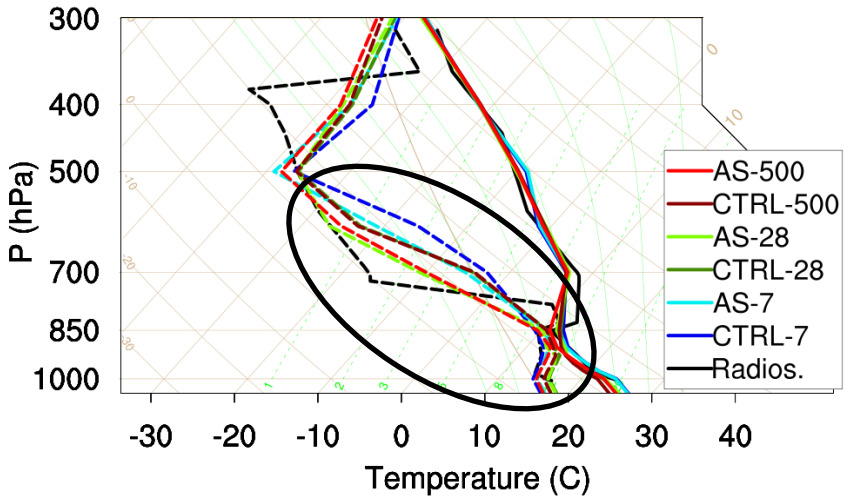
- Even small variations (~1g/kg) of atmospheric moisture in an hourly temporal scale can impact strongly Deep Moist Convection (DMC; *Sherwood et al., 2010; Li and Shen, 2010*)

  → *How is the representation of DMC during a western Mediterranean Heavy Precipitation event affected by the assimilation of highly-sampled humidity observations?*

- Open questions remain regarding the effect of reaching simulation resolutions in the "gray zone" (~1km) on DMC representation *(Barthlott et al., 2015; Verrelle et al., 2015)*

  → *How will the assimilation of humidity observations impact simulations at the limit of the micro-scale?*

- Correction of Integrated Water Vapour (IWV) by a continuous GPS Data Assimilation. However, errors in the order of 1g/kg persist below 700hPa *(Caldas-Alvarez and Khodayar, 2017)*



2. Methodology

- COSMO (v5.1) simulations of 22-Sep to 25-Sep 2012 (HyMeX-IOP6)
- Modelling experiments

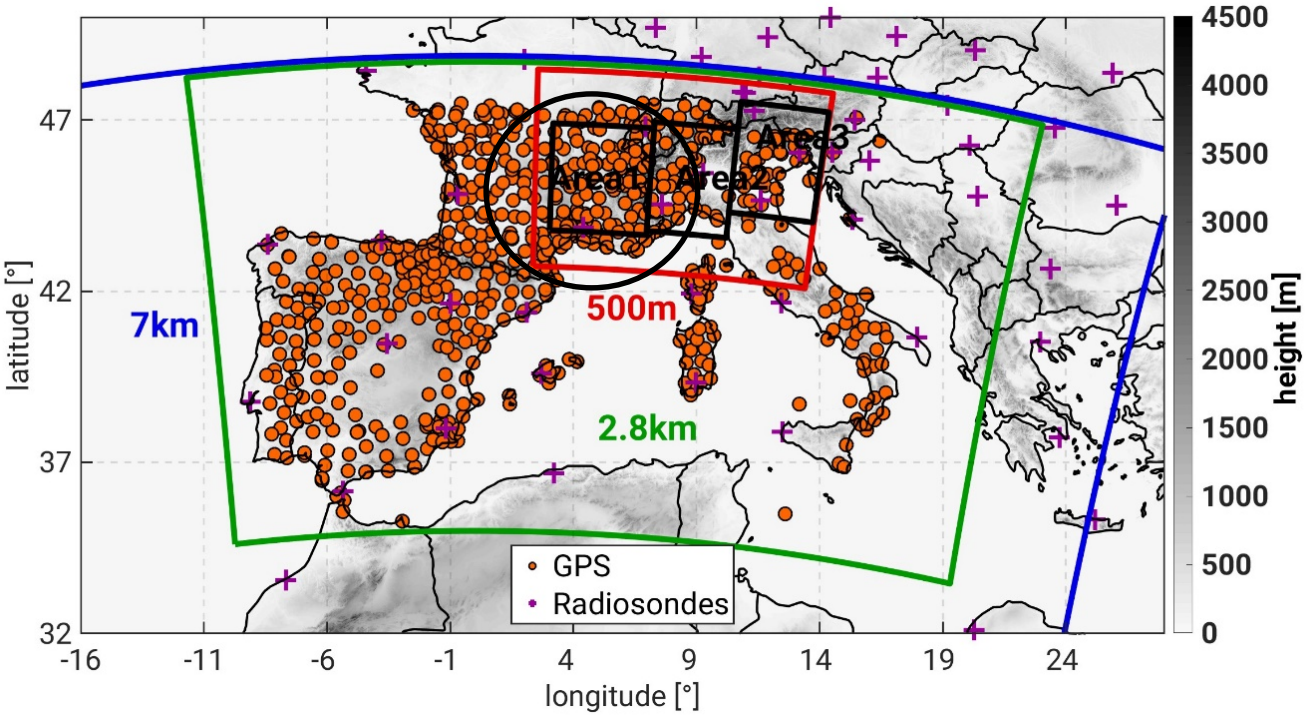
Grid refinement	Atmospheric moisture Data Assimilation
7km, 2.8km and 500m	GPS-IWV and Radiosondes

→ 12 simulations: CTRL-7, AS-GPS-7, AS-RAD-7, AS-GPS-RAD-7, CTRL-2.8, AS-GPS-2.8 …

- Dynamic downscaling: IFS analyses (~28km) → 7km → 2.8km → 500m

7km	Tiedtke deep & 1D turb.
2.8km	Tiedtke shallow & 1D turb.
500m	3D Turb

- Validation data sets
  - Radiosondes *(HyMeX)*
  - GPS-IWV *(Bock et al., 2015)*
  - Rain Gauges *(HyMeX)*
  - CMORPH *(Joyce, 2004)*

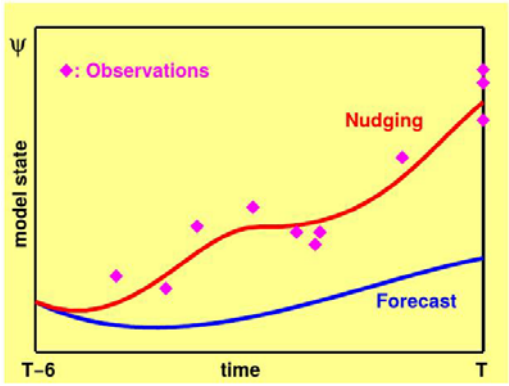


Humidity Observations Data Assimilation

The Nudging Scheme *(Schraff et al., 2013)*

$$\frac{\partial}{\partial t}\varphi(\boldsymbol{x},t) = F(\boldsymbol{\varphi},\boldsymbol{x},t) + G_{\varphi}\cdot\sum_{k_{obs}} W_k(\boldsymbol{x},t)\cdot\left[\varphi_k^{obs} - \varphi(\boldsymbol{x}_k,t)\right]$$

Prognostic variable	*Numerics & Physics*	*Nudging coefficient*	*weights*	*Obs. increments*



GPS-IWV assimilation

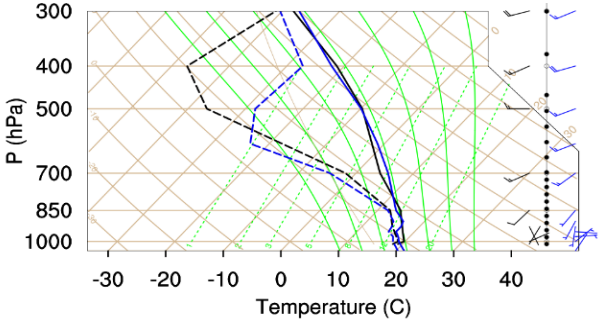
- Provided by LAREG *(Bock et al., 2015)*
- Continuous assimilation (10 min)
- IWV conversion to q_v profile

$$QV_{obs} = QV_{mod}\cdot\frac{IWV_{obs}}{IWV_{mod}}$$

- Rejection of reports if BIAS surpasses threshold

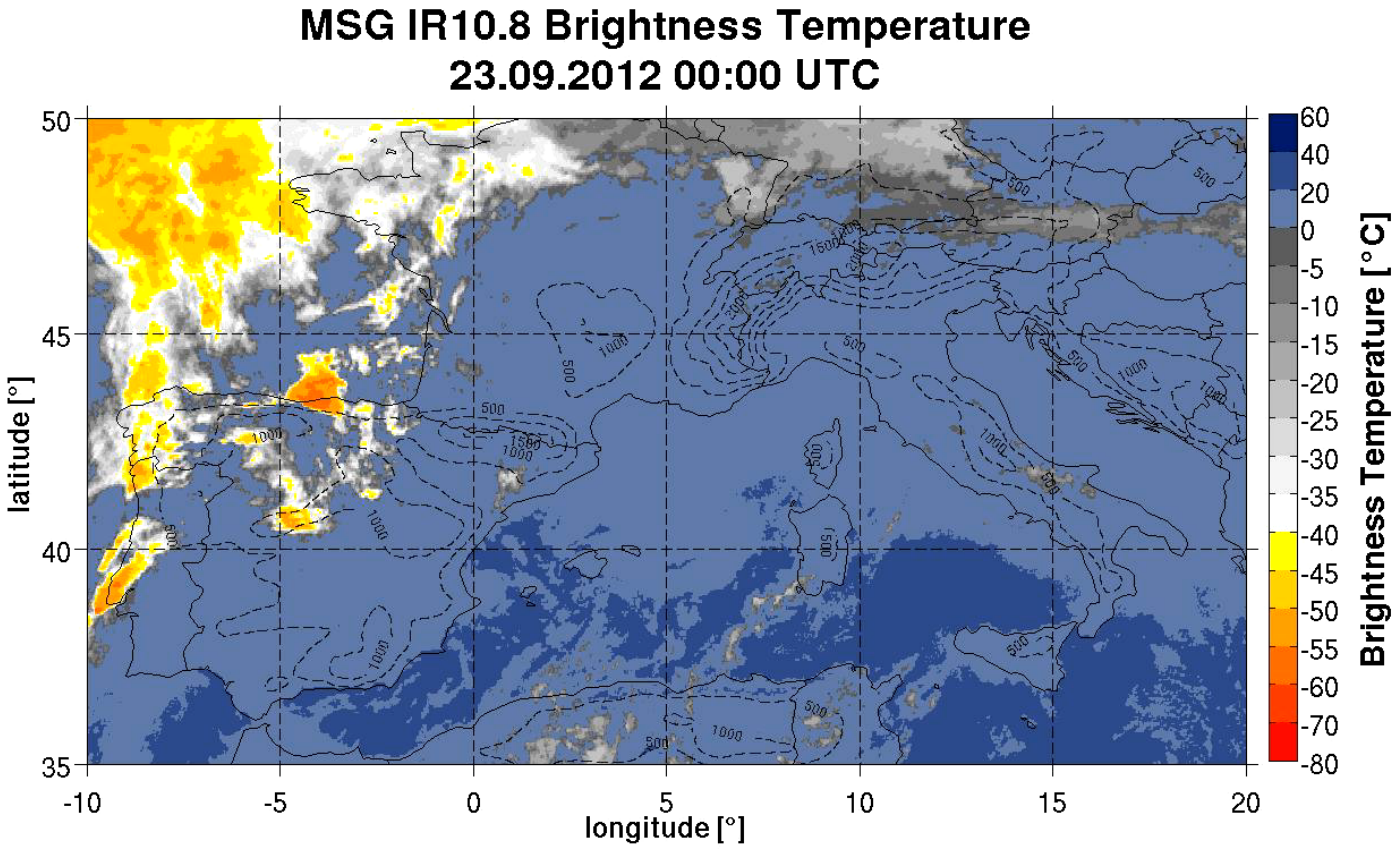
Radiosondes

- Every ~6h
- Provided by HyMEX
- Humidity BIAS correction



Case Overview

- >100mm/6h over southern France, the Alps and northern Italy
- Earlier southwesterly moist inflow favouring CAPE build up at low-terrain
- Deep Moist Convection triggered at the arrival of an upper-level trough

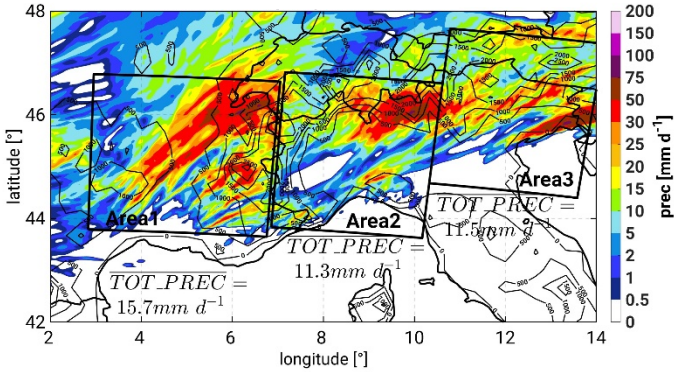


4. Impact of DA and grid refinement

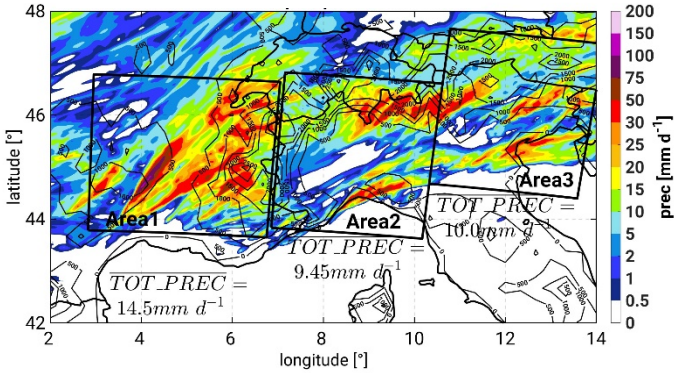
24h accumulated precipitation (24-Sep-2012)

2.8km

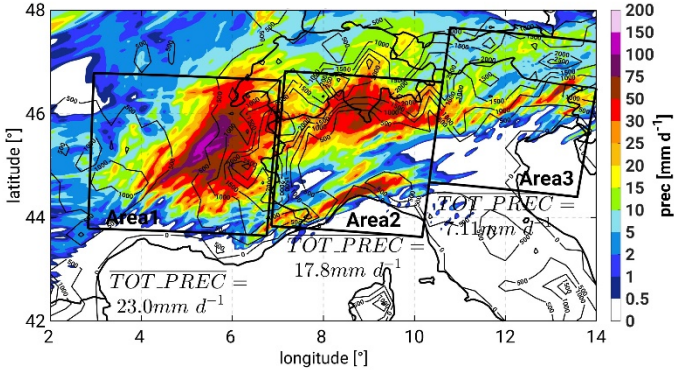
CTRL



AS-GPS



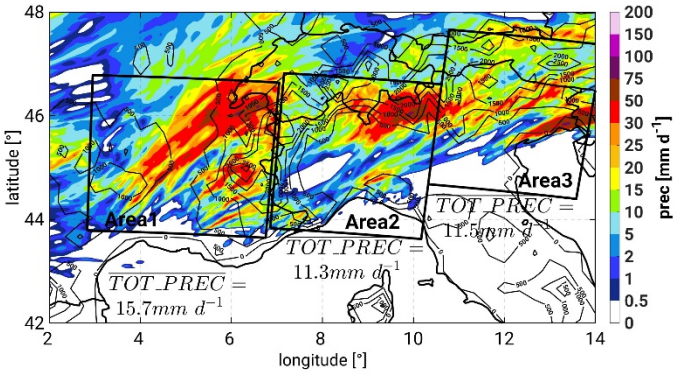
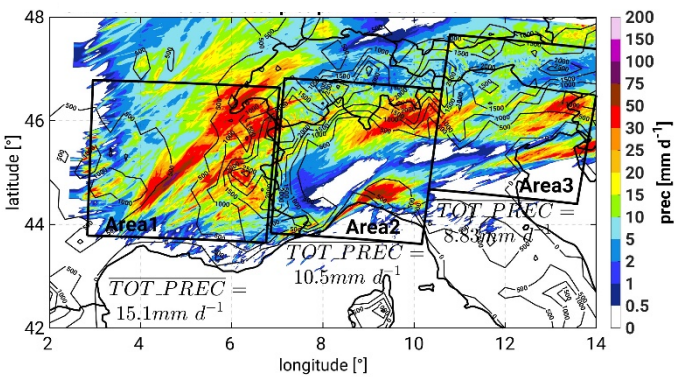
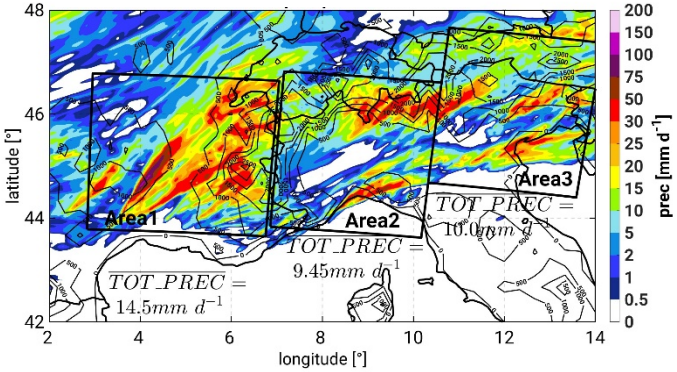
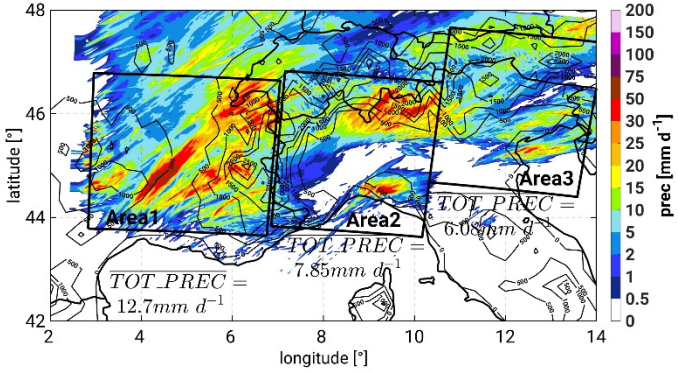
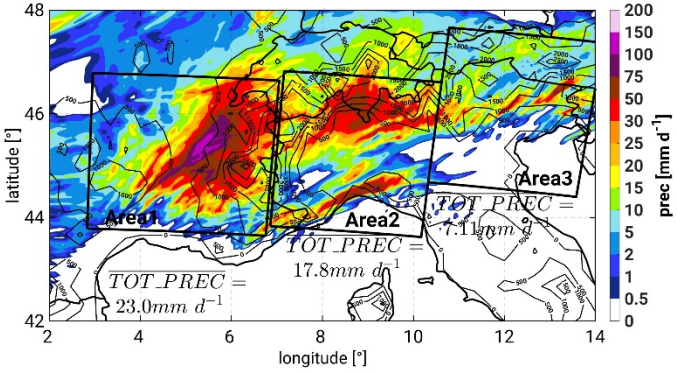
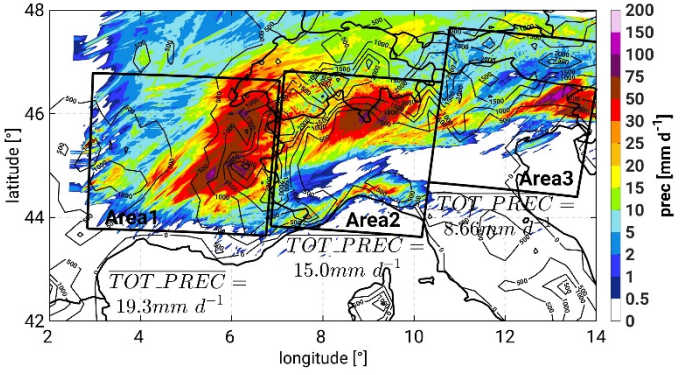
AS-RAD



4. Impact of DA and grid refinement

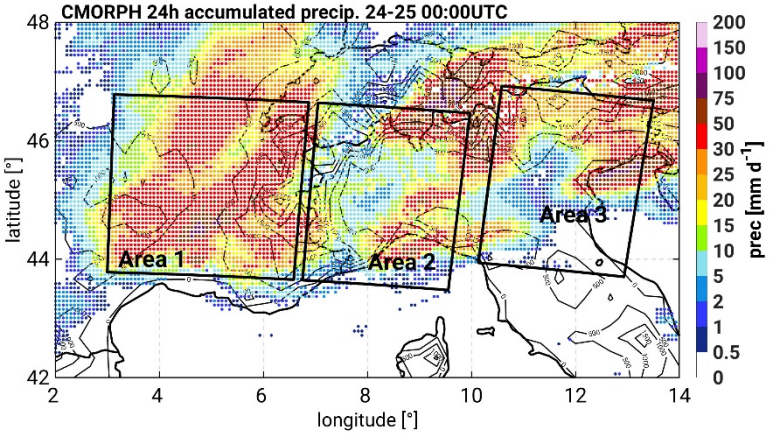
24h accumulated precipitation (24-Sep-2012)

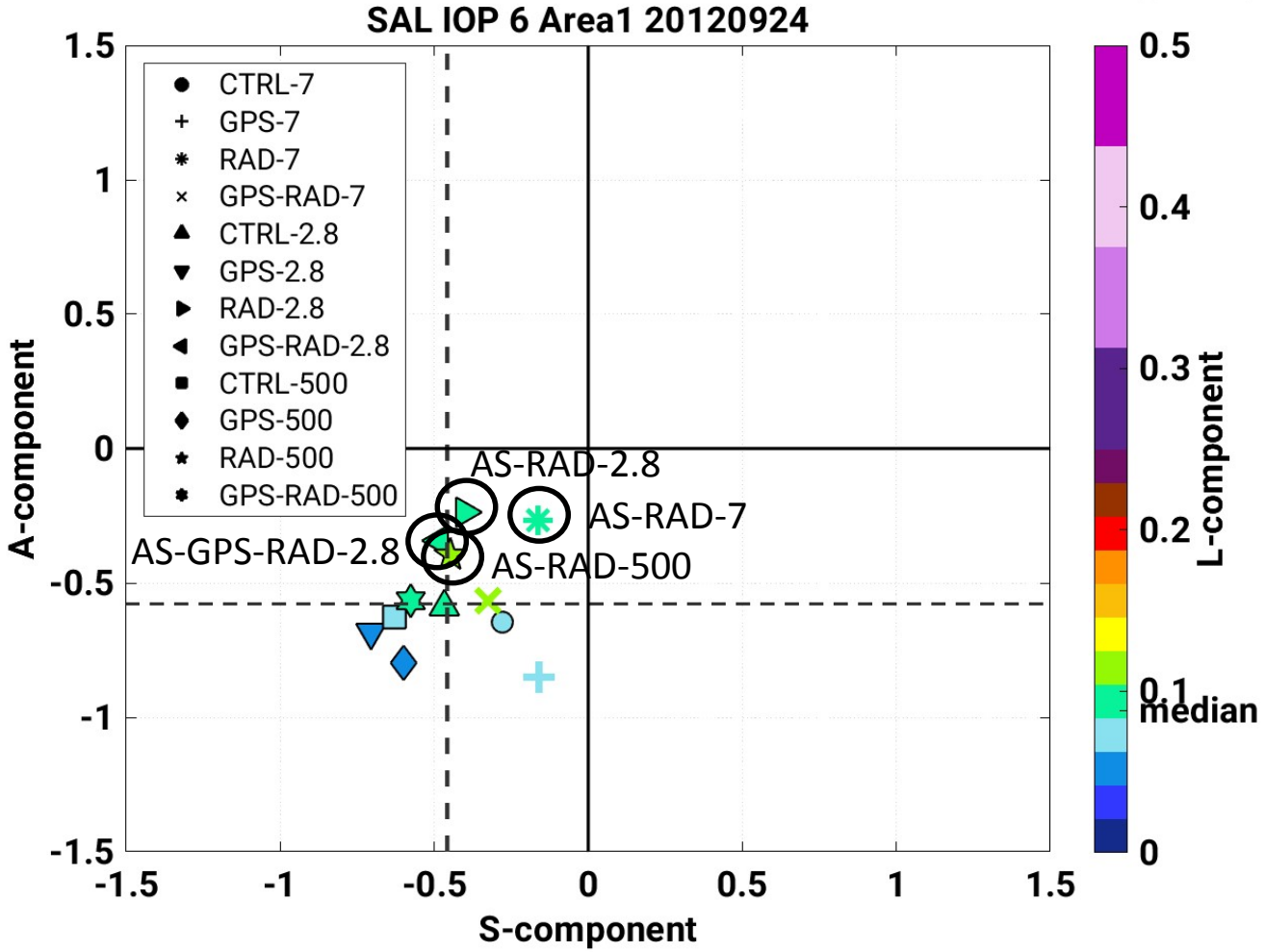
Karlsruhe Institute of Technology

	2.8km	500m
CTRL		
AS-GPS		
AS-RAD		

4. Impact of DA and grid refinement

SAL metrics comparison against CMORPH

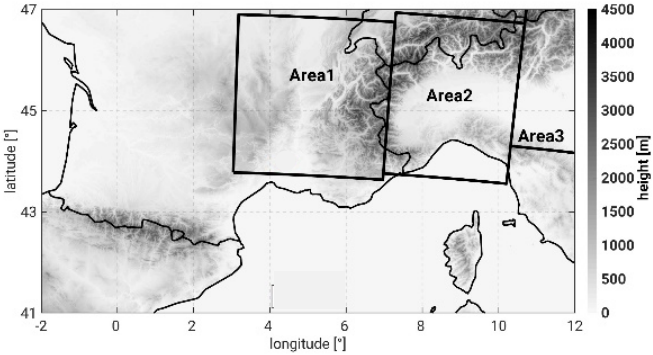


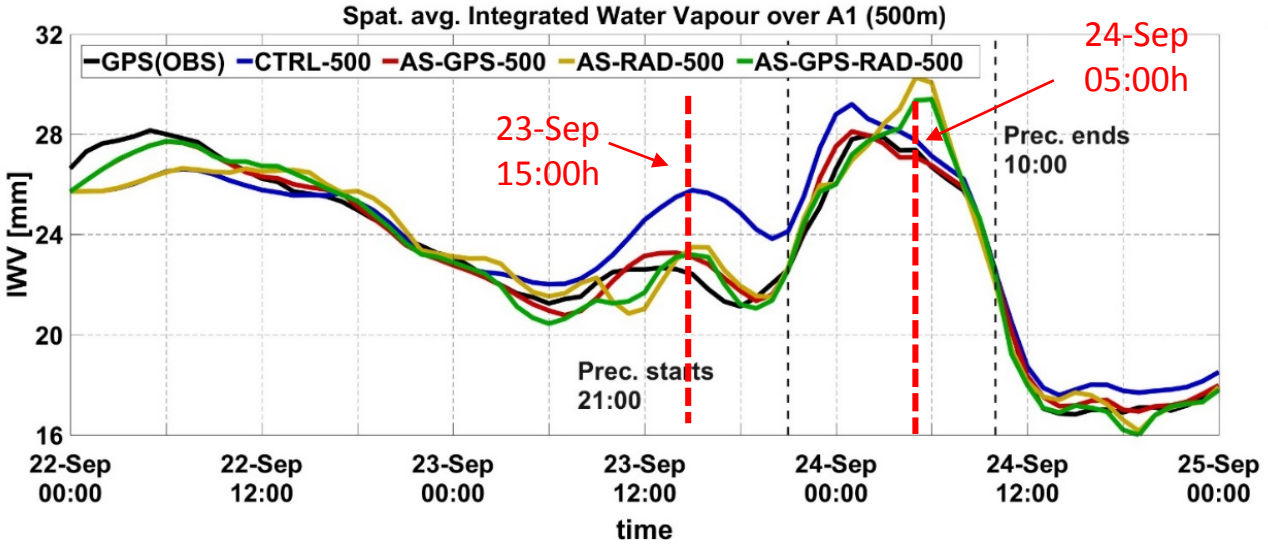


Best results by simulations including RAD assimilations alone, or combined with GPS

4. Impact of DA and grid refinement

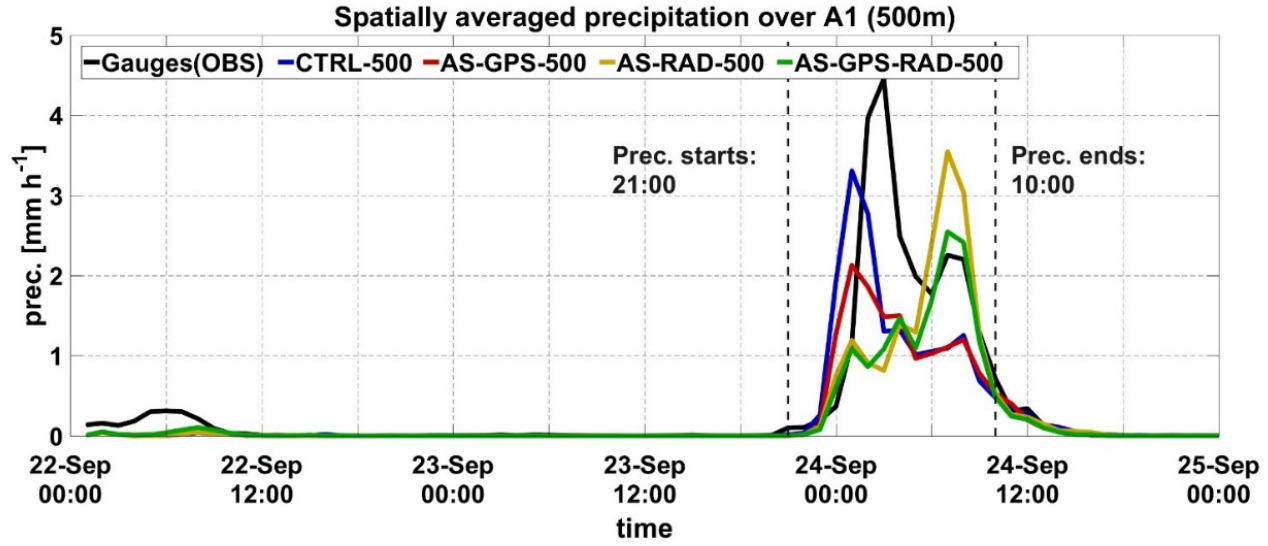
IWV and Precipitation temporal evolution





The AS runs represent less humidity and instability together with more CIN

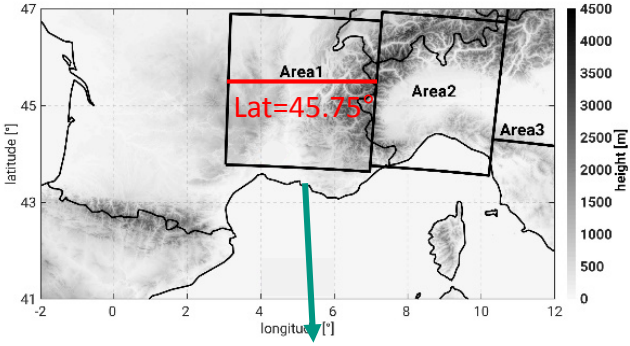
→ *Precipitation is reduced during the first 4 hours*

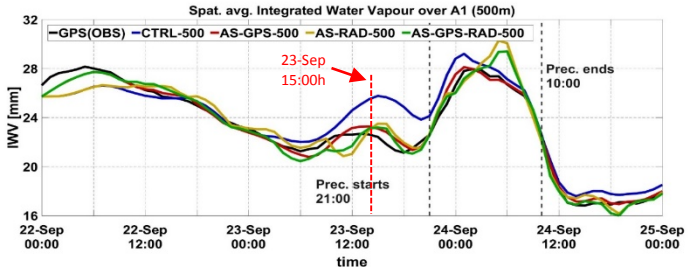


The AS-RAD and AS-GPS-RAD assimilations show an abrupt and spread precipitation increase at 06:00h with AS-GPS-RAD-500 showing the best results

4. Impact of DA and grid refinement

Vertical profile during preconditioning

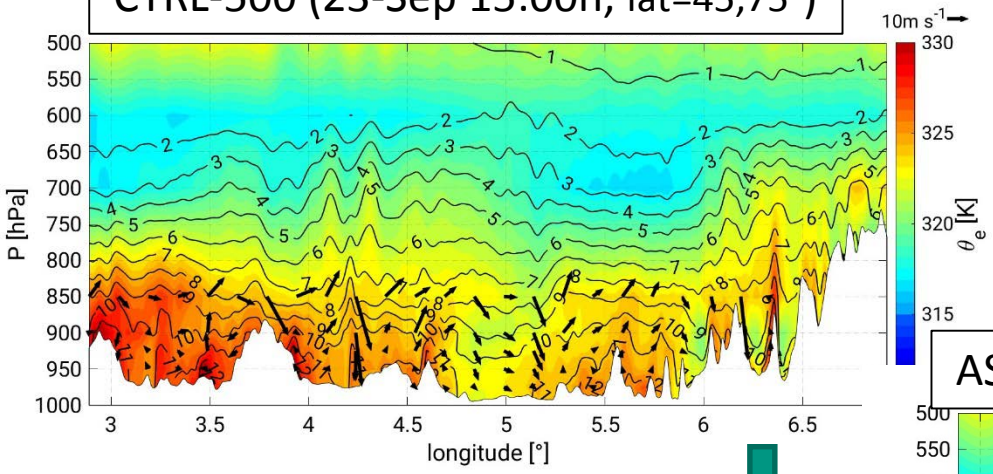




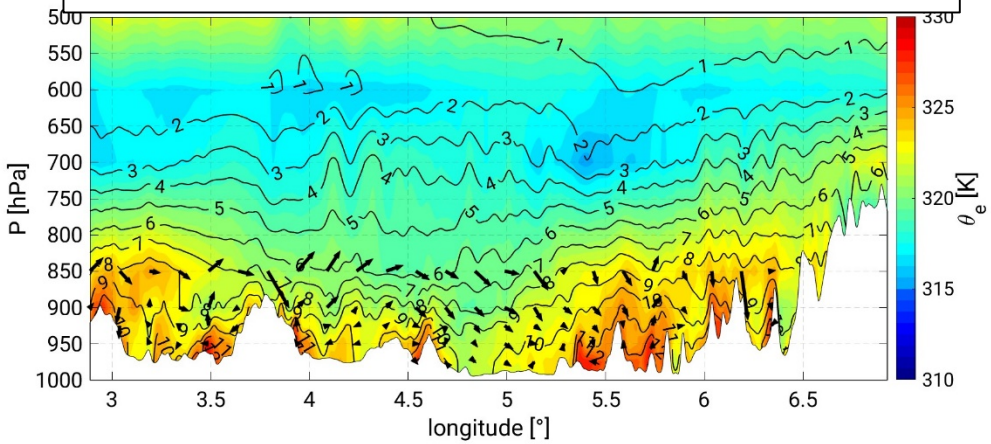
23-Sep 15:00h

500	IWV [mm]	CAPE [J/kg]	CIN [J/kg]
CTRL	23.9	61.5	50.6
AS-GPS	21.4	32	101
AS-RAD	21.7	55.9	110
AS-GPS-RAD	21.4	54.4	247

CTRL-500 (23-Sep 15:00h, lat=45,75°)

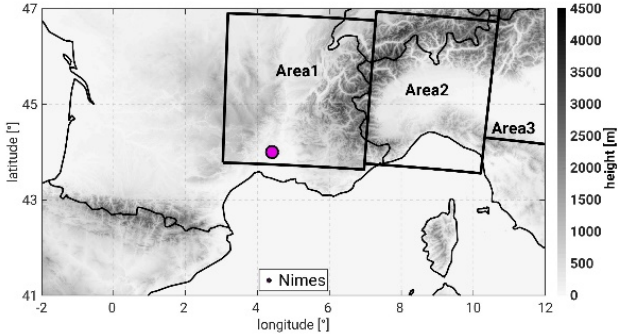


AS-GPS-RAD-500 (23-Sep 15:00h, lat=45,75°)

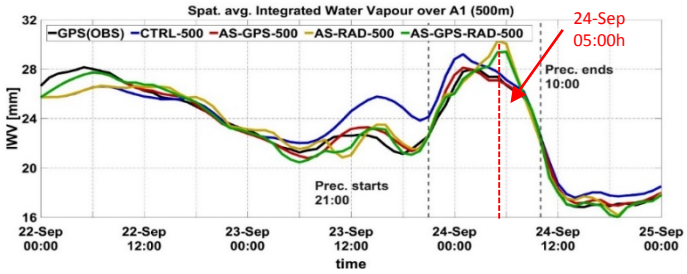


Higher θ_e at the PBL and deeper in the lower-free troposphere is found for the CTRL-500

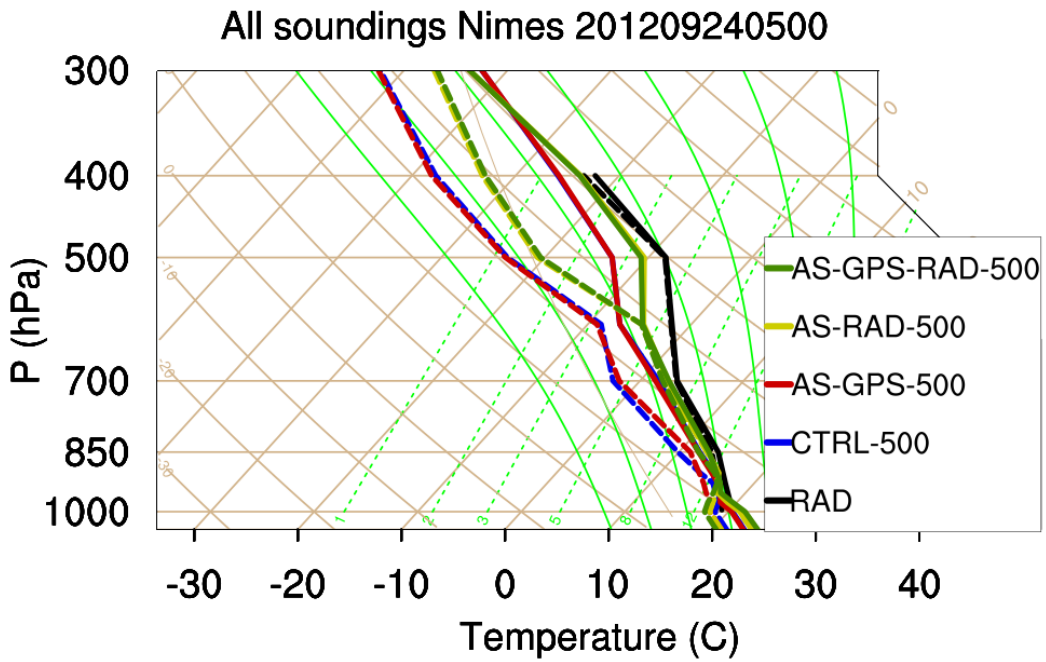
4. Impact of DA and grid refinement



Vertical profile during the Heavy Precipitation Event



The assimilation of the 05:15h Nimes radiosonde forces the AS-RAD and AS-GPS-RAD runs toward saturation up to 600hPa



The radiosonde assimilation improves the vertical distribution of humidity and the GPS regulates the extent bringing a better representation of the second precipitation maxima

5. Conclusions

- The GPS and Radiosondes assimilation improves the representation of the spatio-temporal distribution of humidity for the shown event in COSMO, specially on the 500m grid

- The radiosonde assimilation spread the structure of precipitation increasing the amount and shifting the location of the maxima. The GPS regulated the precipitation amount

- The best results in precipitation representation as given by the SAL metrics are shown by the simulations using radiosondes alone or together with GPS reports. This holds for all investigation areas

- Over Area1 the decrease in instability and larger inhibition induced by the different assimilations explains the lower precipitation during the first 4 hours of the event. Once precipitation has started, the assimilation of new radiosondes forces the model profile toward saturation bringing abrupt precipitation increases in the AS-RAD and AS-GPS-RAD simulations

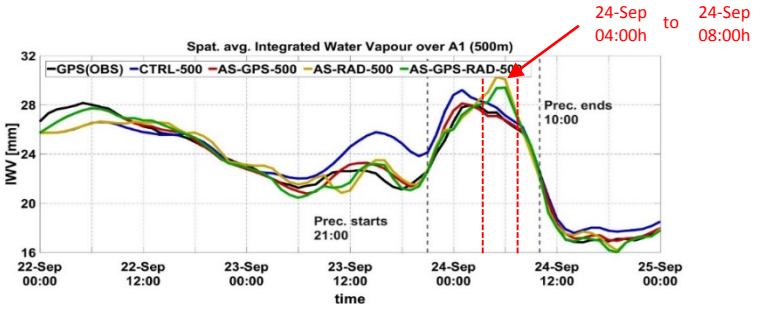
Thank you for your attention

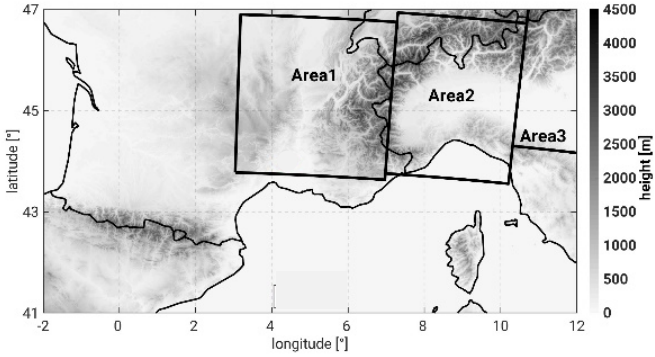
COSMO in a 7km, 2.8km and 500m configuration

7km	2.8km	500m
40 lev	50 lev	80 lev
Tiedtke Deep	Tiedtke Shallow	Explicit
1D TKE closure	1D TKE closure	3D TKE closure
2-moment with basic species + cloud water + cloud ice + graupel	2-moment with basic species + cloud water + cloud ice + graupel	2-moment with basic species + cloud water + cloud ice + graupel
TERRA land model	TERRA land model	TERRA land model

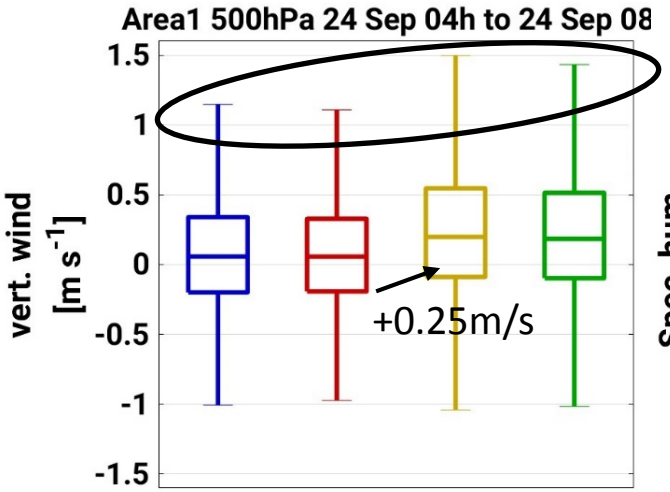
4. Impact of DA and grid refinement

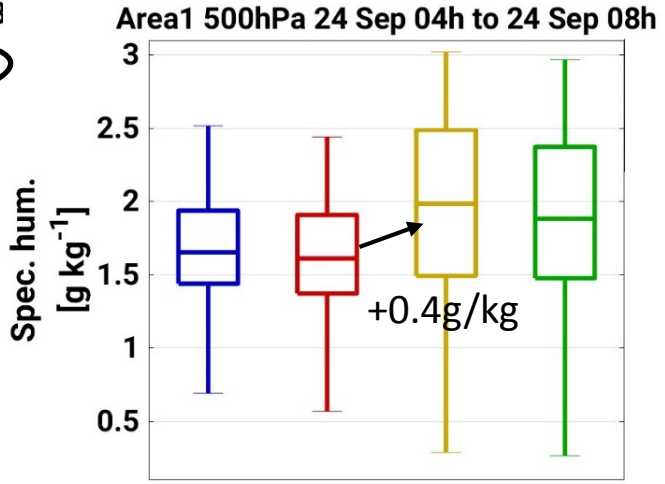
Vertical profile during the Heavy Precipitation Event





Very large humidity corrections between 850 and 500hPa enhance convective updrafts





The radiosonde assimilation improves the vertical distribution of humidity and the GPS regulates the extent bringing a better representation of the second precipitation maxima

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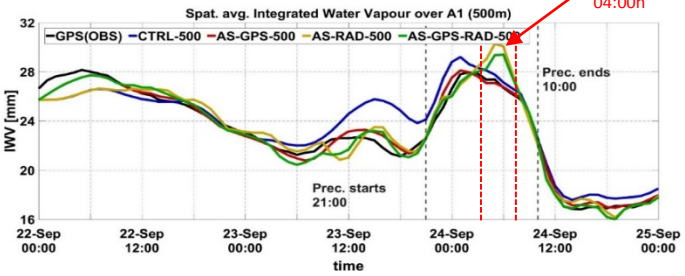
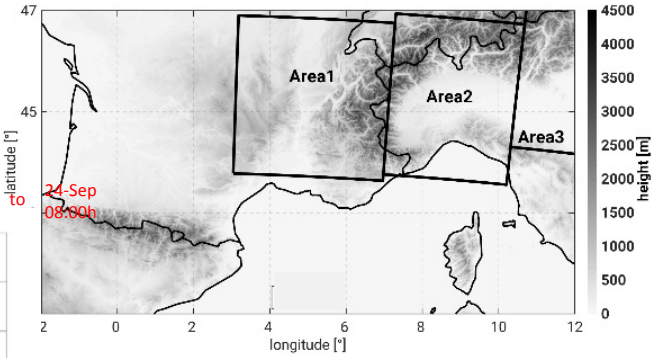
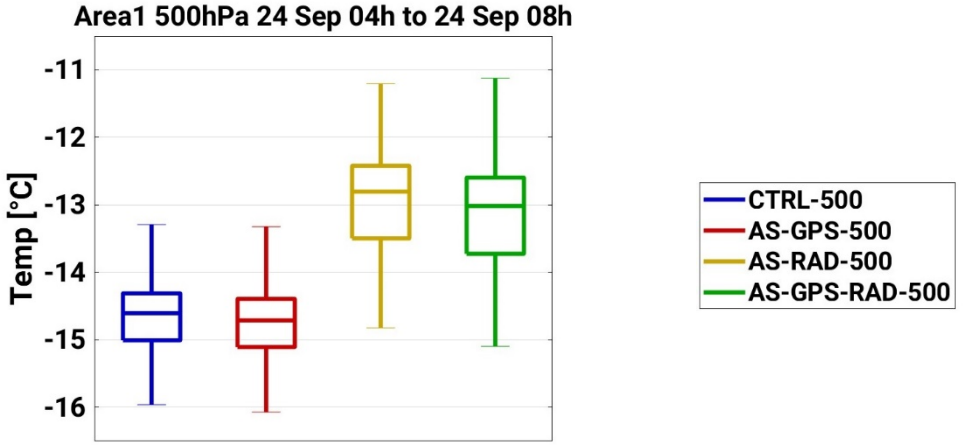
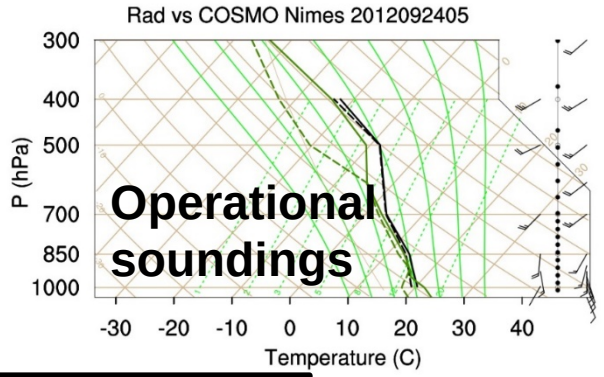
Vertical profile during the Heavy Precipitation Event







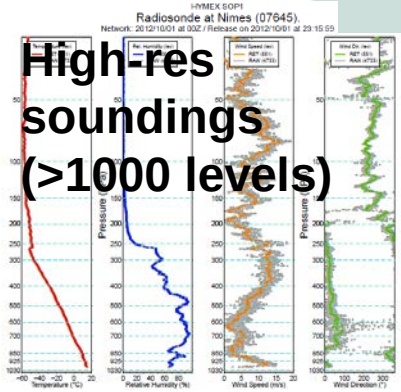
Deeper convection and saturation is represented in the assimilated runs with radiosondes after 05:00h. Humidity, vertical winds and temperature are largely impacted up to 500hPa

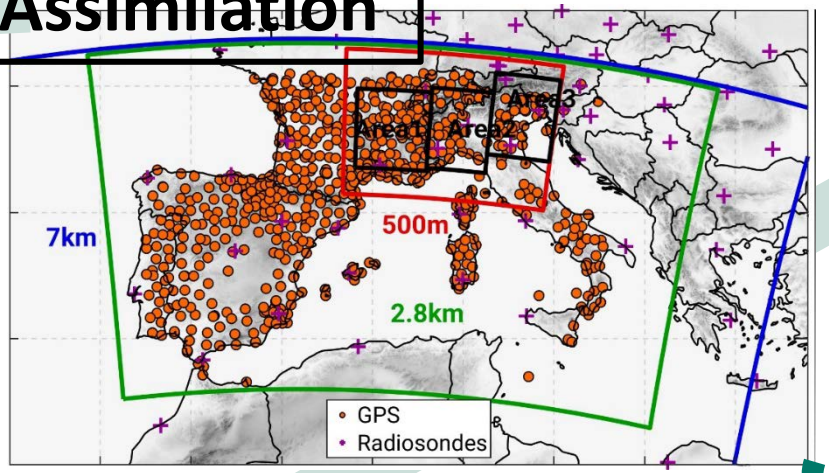


Grid refinement

7km, **2.8km** and **500m**

Humidity obs.
Data Assimilation





IOP6 (24-Sep)

- NWP simulations
- 500m simulations
- High-res sounding

Process-understading

HyMeX

HyMeX-SOP1

- 7km and 2.8km
- CTRL vs AS

2012

Sep | Oct | Nov

IOP6

IOP16

Continous GPS-IWV Data Assimilation (10 min)