

# Impact of the variational assimilation of ground-based GNSS Zenith Total Delay into AROME-Morocco model

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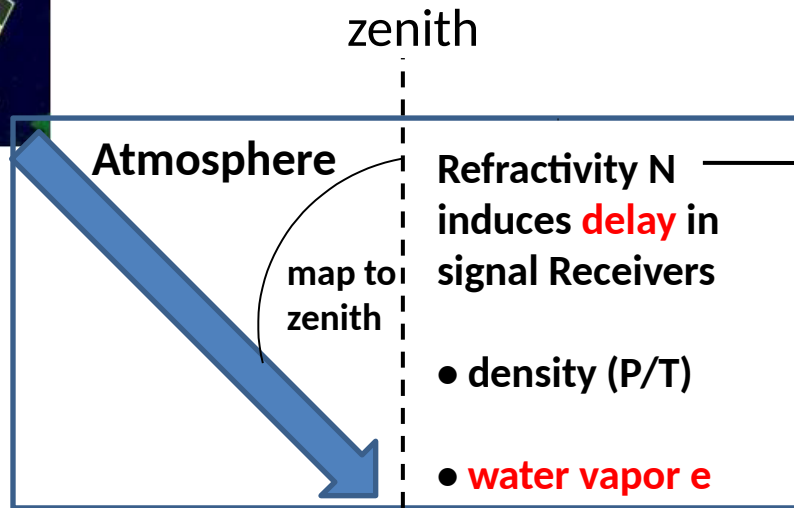
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CNRMSI/SMN - Maroc Météo - Morocco

# Outline

- Introduction
- Moroccan GNSS network
- Methodology of assimilating GNSS ZTD data in Arome-Morocco model
- Impact of the ground-based GNSS ZTD in Arome-Morocco
- Case study
- Conclusion and future work

# Zenith total delay (ZTD)



$$N = k_1 \frac{P}{T} + (k_2 - k_1) \frac{e}{T} + k_3 \frac{e}{T^2}$$

( $k_1, k_2$  et  $k_3 = \text{cste}$ )

[Thayer, 1974]



Zenith Total Delay (ZTD)

$$ZTD = 10^{-6} \int_0^{\infty} N(z) dz$$

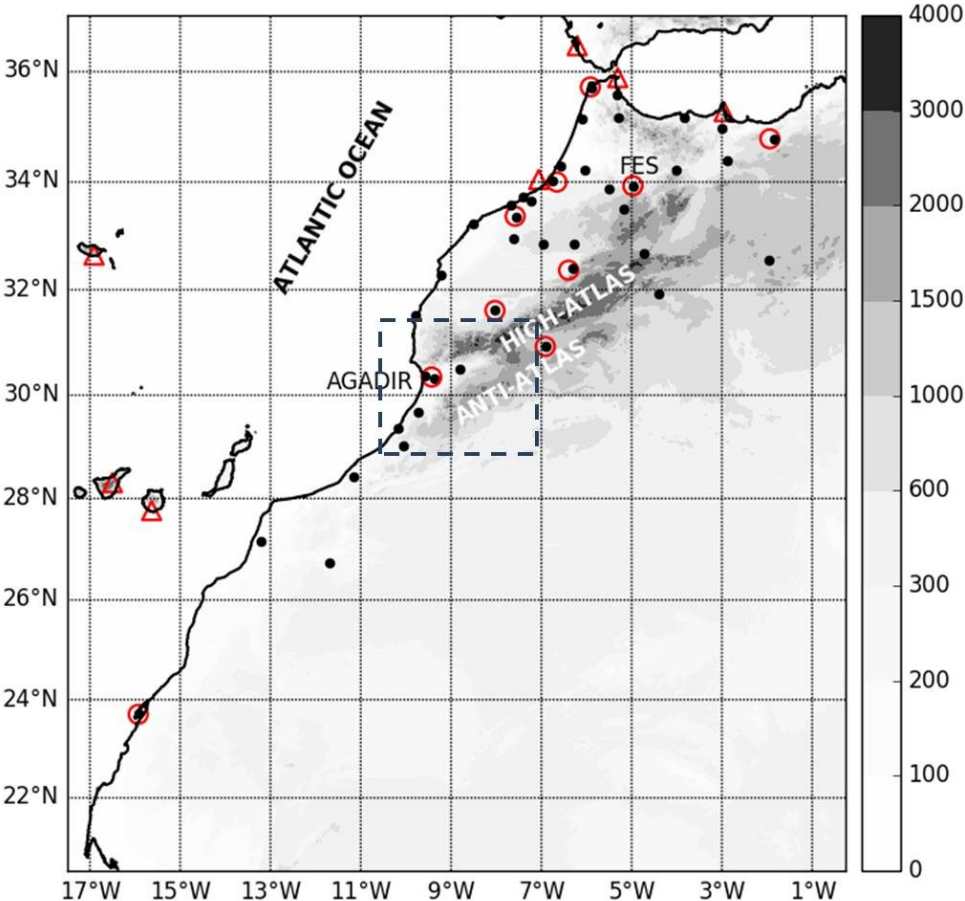
ZTD is the delay one would observe if there was a GNSS satellite at zenith



ZTD is estimated from raw GNSS receiver data with geodetic processing software (e.g. Bernese) designed for precise positioning applications



# Moroccan GNSS network

# Moroccan ground-based GNSS network

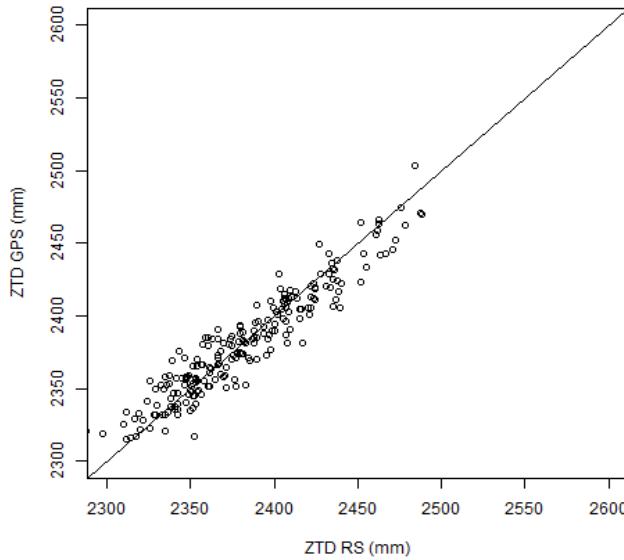


-  GNSS Moroccan stations
-  GNSS IGS stations

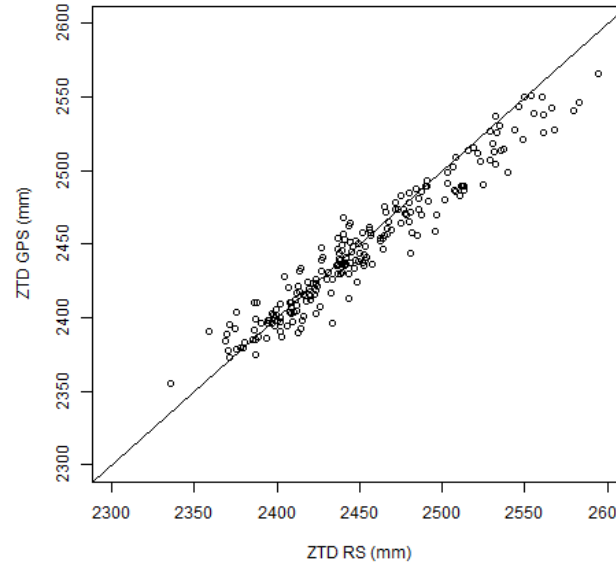
- Network started in 2012 by Maroc-Météo for NWP purpose
- IGS (International GNSS Service) stations are also added
- Raw observations processed locally by Bernese software
- GNSS ZTD available every 15 minutes
- Good data reliability and accuracy

# Near-real-time ZTD GNSS quality assessment

Casablanca

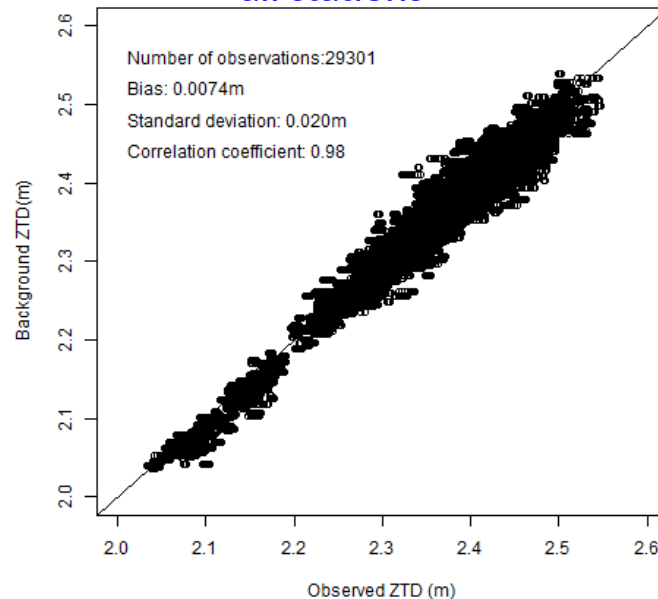


Dakhla



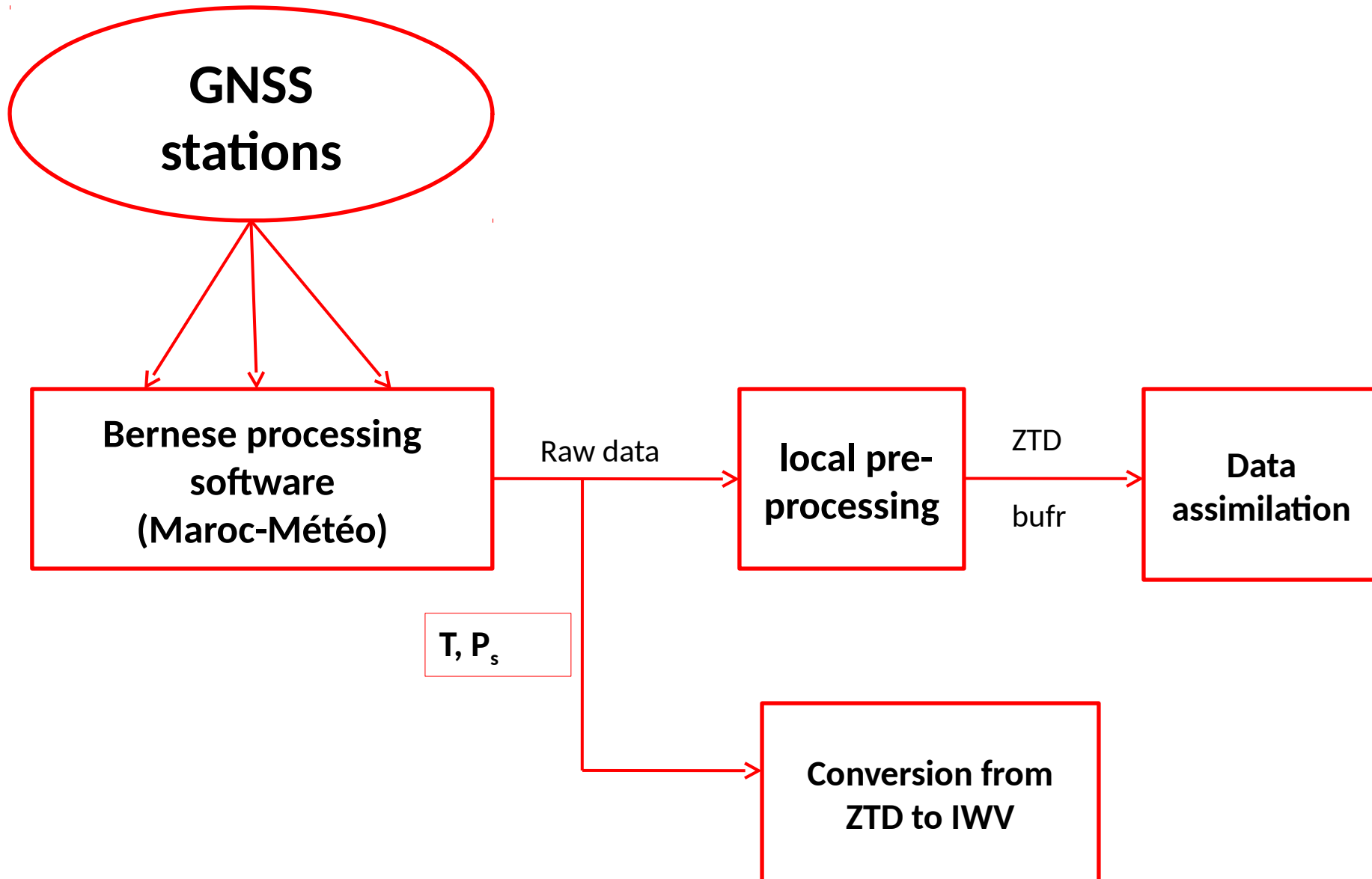
➤ Comparison of GNSS ZTD observations with ZTD derived from radiosondes for CASA and DAKH (Hdidou et al., 2018)

all stations



➤ Comparison of GNSS ZTD Observations with NWP 3h forecasts (fg)

## Analysis/production data flow

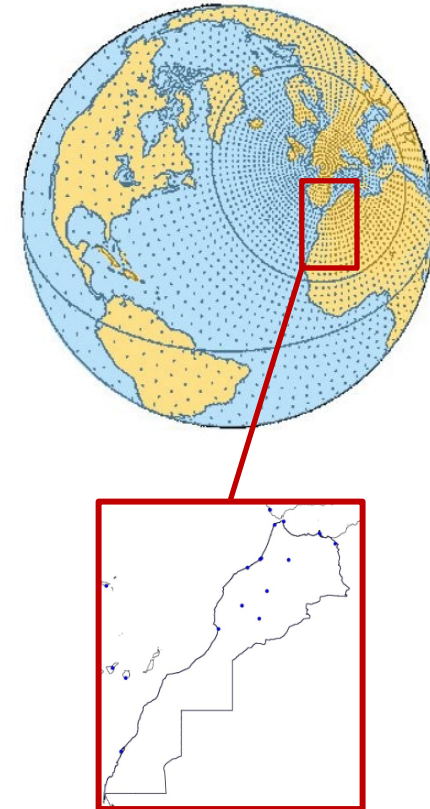


# Methodology of assimilating GNSS ZTD data in AROME-Morocco



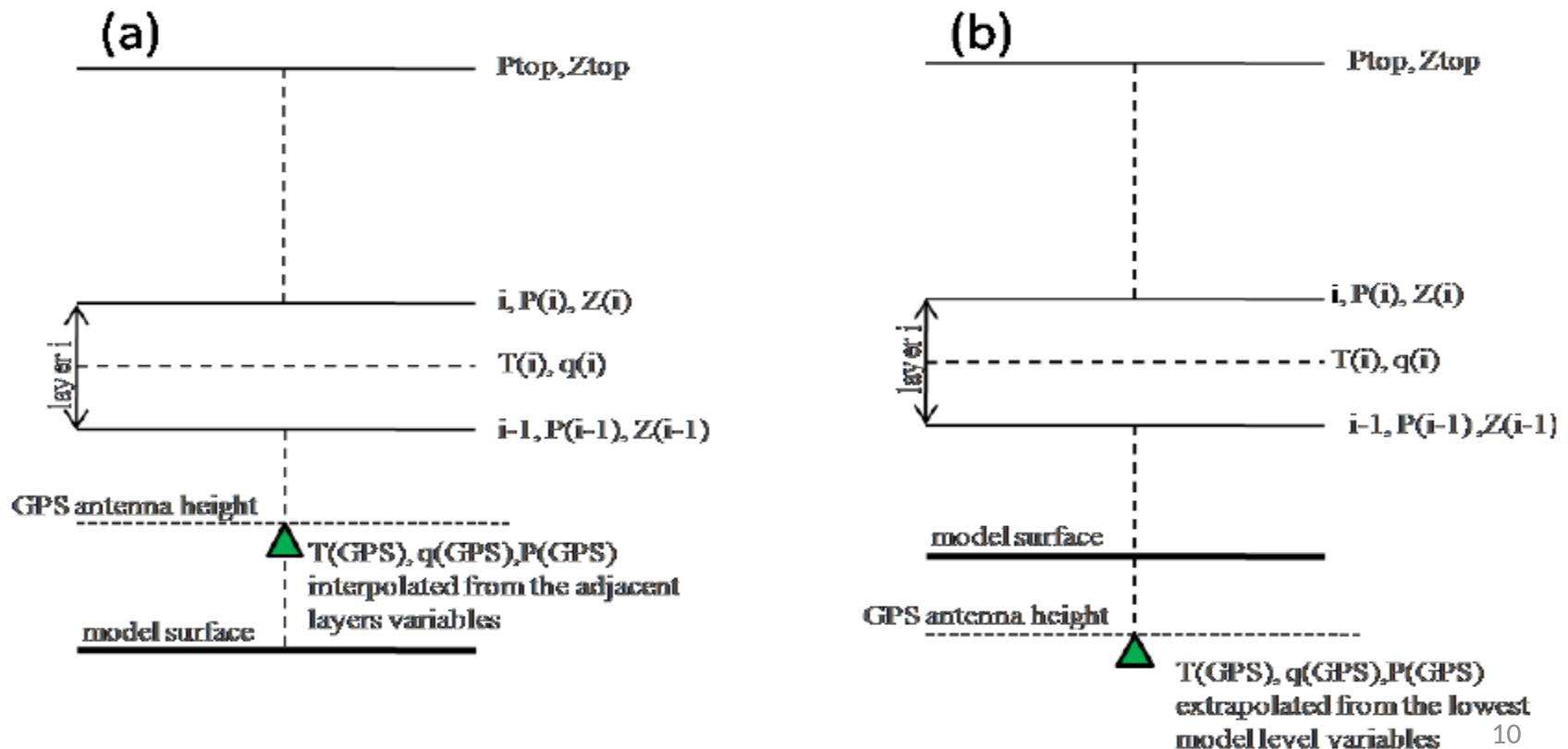
## AROME-Morocco model

- horizontal resolution: 2.5 km,
- vertical resolution : 90 levels,
- runs twice a day ( $t_0 = 00h$  and  $t_0 = 12h$ ) to produce forecasts up to 48h forecast range,
- lateral boundaries: ALADIN-Morocco model (7.5 km)
- initial conditions: 3D-Var data assimilation (3h cycling)



## Computing ZTD from NWP fields (Obs. operator)

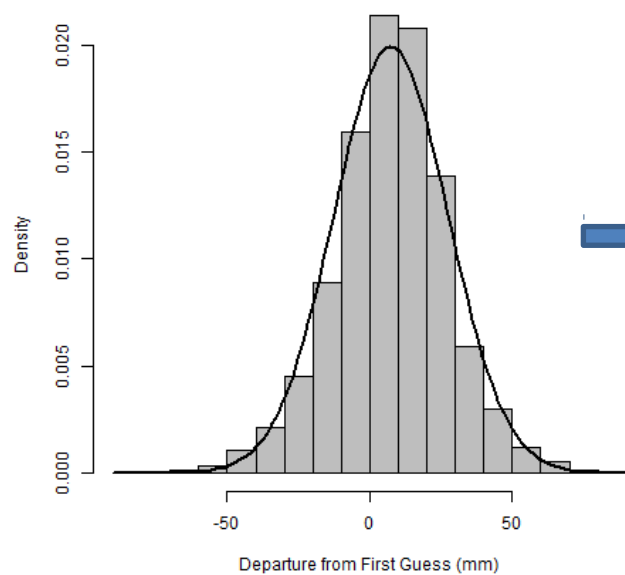
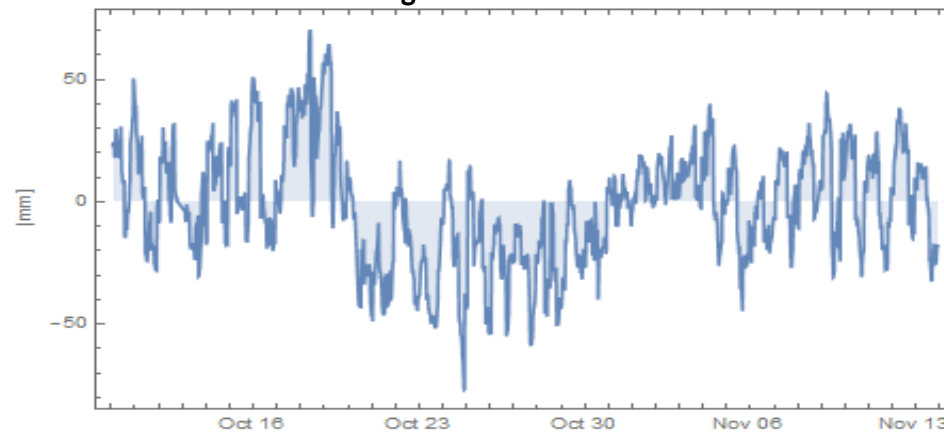
- (1) Interpolation of specific temperature and humidity profiles from model to observation point
- (2) Computation of  $N(z)$  at the observation point (**Thayer formulation**)
- (3) Vertical integration from GNSS antenna height to  $Z_{\text{top}}$  to obtain ZTD



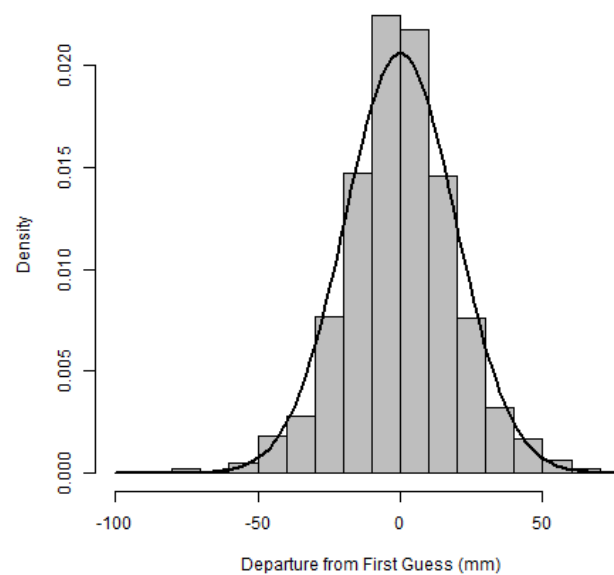
## Pre-processing and bias correction

- Mean of departure “obs-fg” ZTD statistics reveal site-specific biases that are removed before assimilation using a **static bias correction system**
- Observations errors** are estimated from the standard deviations of background departures

Time series of « obs - fg » over 1-month for Casablanca station



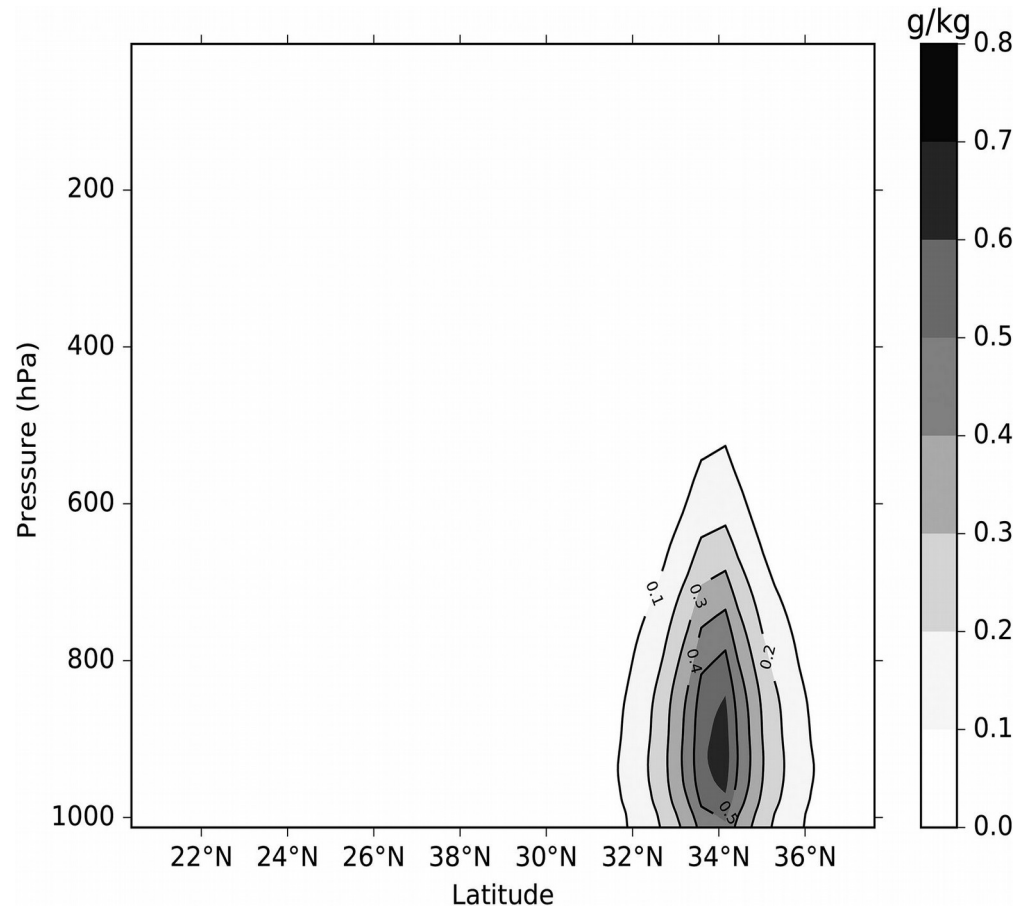
before BC



after BC

# Impact of the ground-based GNSS ZTD in Arome-Morocco

## Single observation experiment



- **Vertical cross-section of the analysis increment of specific humidity for the Fes station (02/26/2018 at 12 UTC):**  
Assimilation of GNSS ZTD produces increments in the low troposphere (below 500 hPa), with max impact around 900 hPa level.
- neutral impact on temperature parameter

## Assimilation experiment design (OSE experiment)

➤ Two experiments have been run over 1-month period (from 10 October to 10 November 2017): **EXP-CRL & EXP-GNSS**

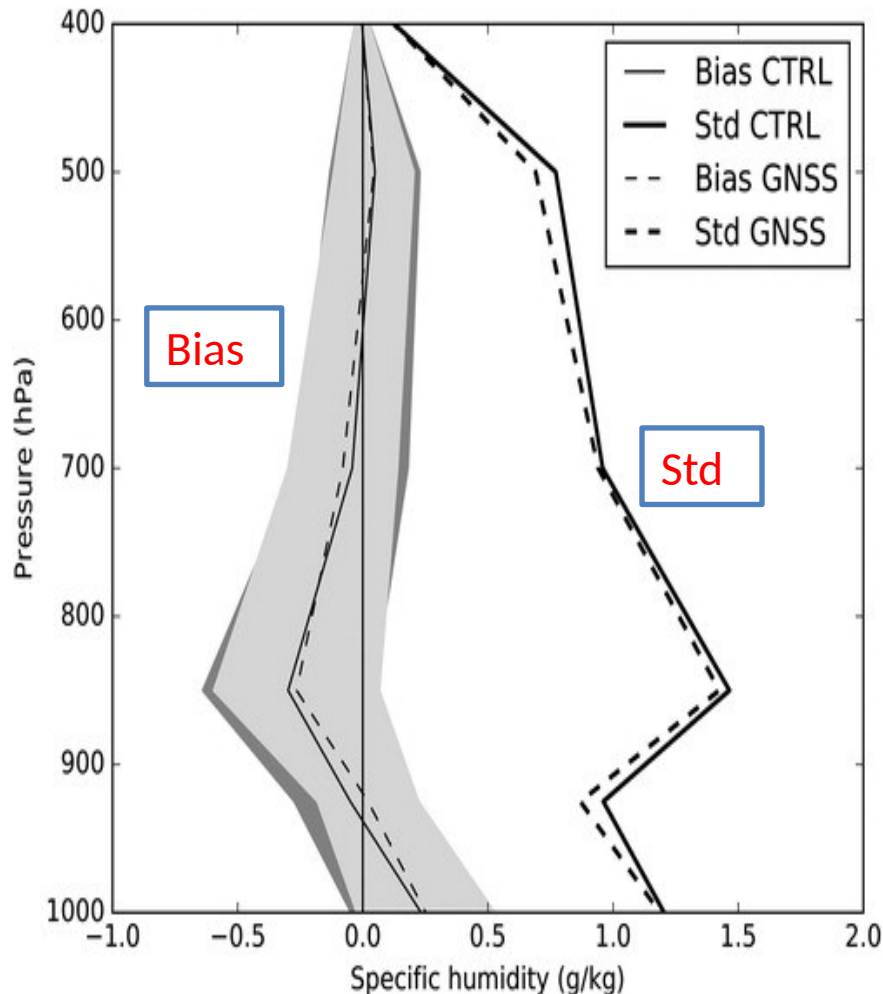
Type of observations	EXP-CTRL	EXP-GNSS
Conventional	SYNOP AIREP DRIBU TEMP	SYNOP AIREP DRIBU TEMP
Satellite	ATOVS	ATOVS <b>GNSS</b>

➤ forecast verifications done :

- verification of specific humidity with radiosonde observations
- verification of 2m relative humidity with surface weather observations
- verification of 24h precipitation accumulations with rain gauge observations

## Assimilation Experiment results

### ➤ verification of specific humidity with radiosonde observations



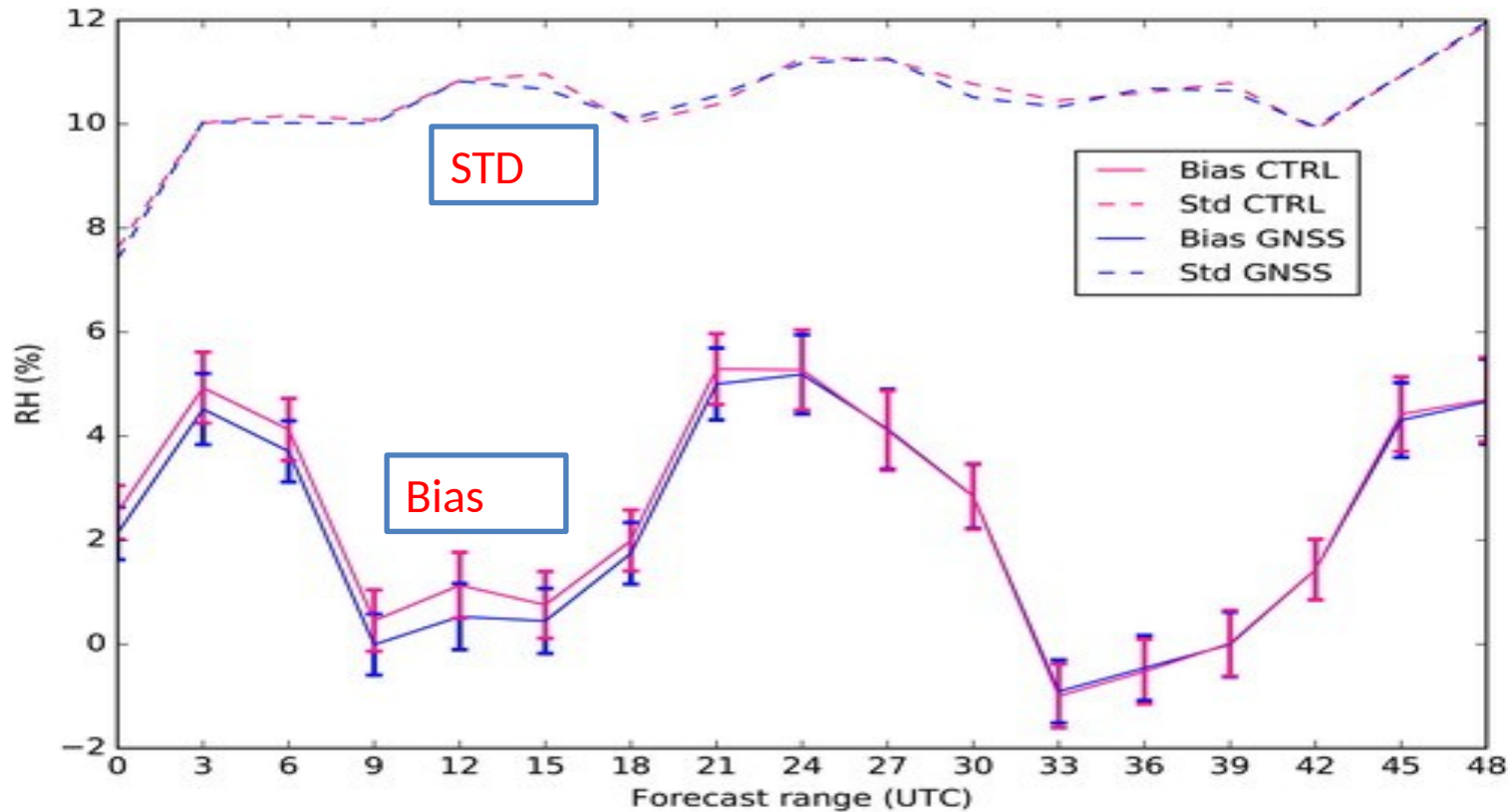
- Statistics (Bias and STD) of background departures for specific humidity from radiosonde observations (in g/kg) for CTRL and GNSS

- Small positive impact on standard deviation between 1000 hPa and 400 hPa levels

- mixed impact on bias

## Assimilation Experiment results

- verification of 2m relative humidity forecast with surface weather observations

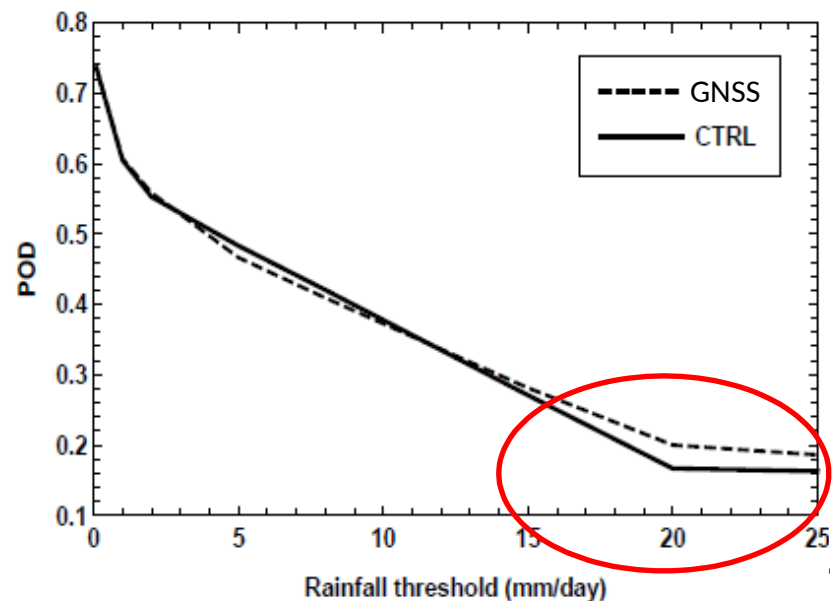
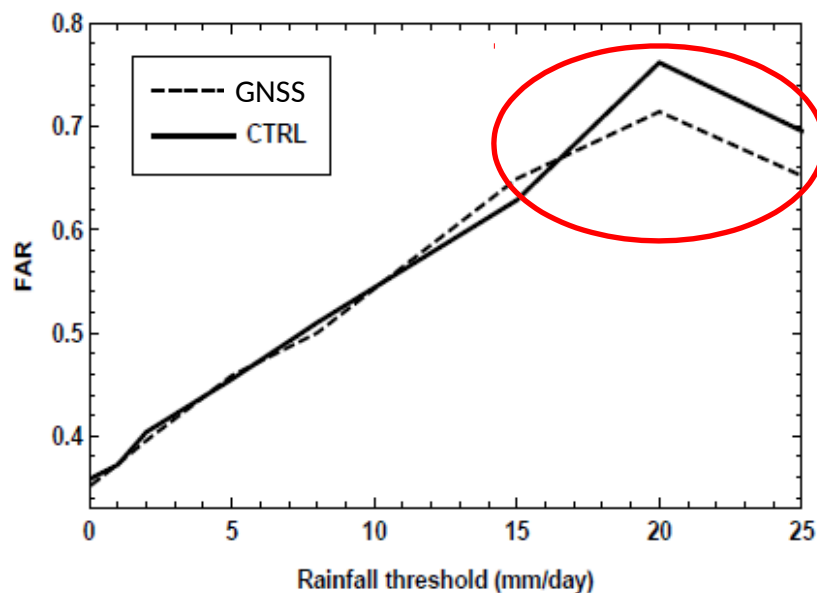


- positive impact on bias up to 24-hour forecast range
- neutral impact on standard deviation



## Assimilation Experiment results

- verification of 24-h precipitation accumulations (6h-36h) against rain gauge observations



- False Alarm Ratio (FAR) and Probability of Detection (POD)

- positive impact for high precipitation (>15 mm).

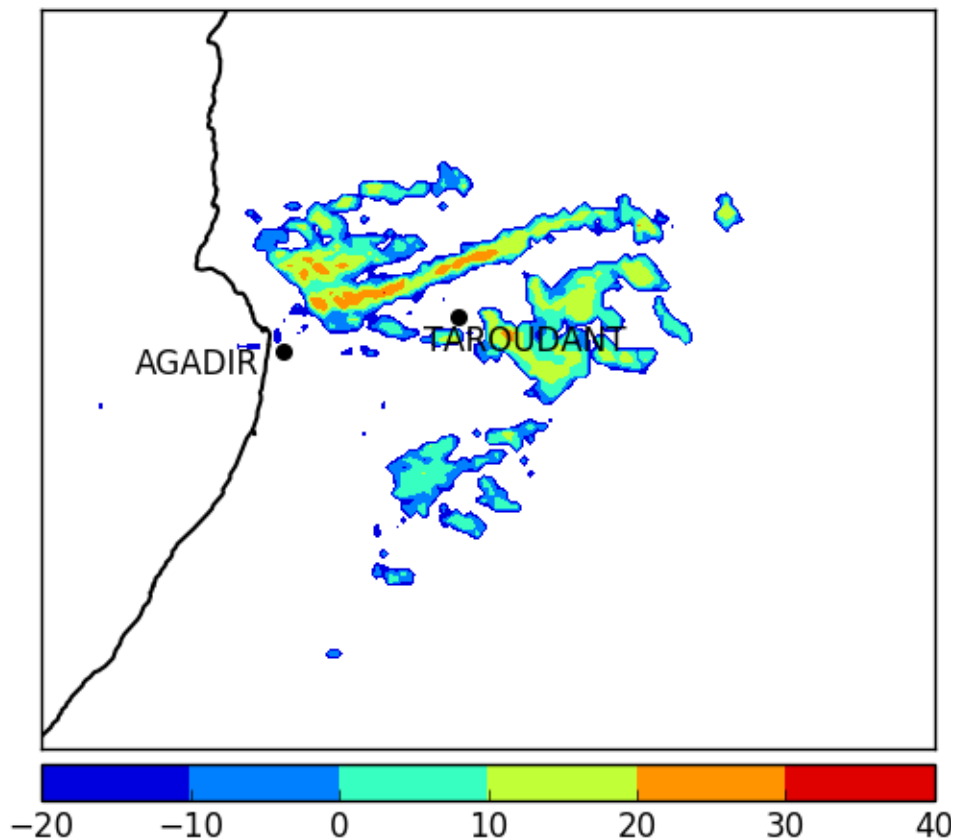
- neutral impact for the lowest thresholds



# Case study

## Case study: HPE of 1 March 2018

Reflectivity from the Agadir radar in dBZ on  
1/03/2018 between 07 UTC and 12 UTC

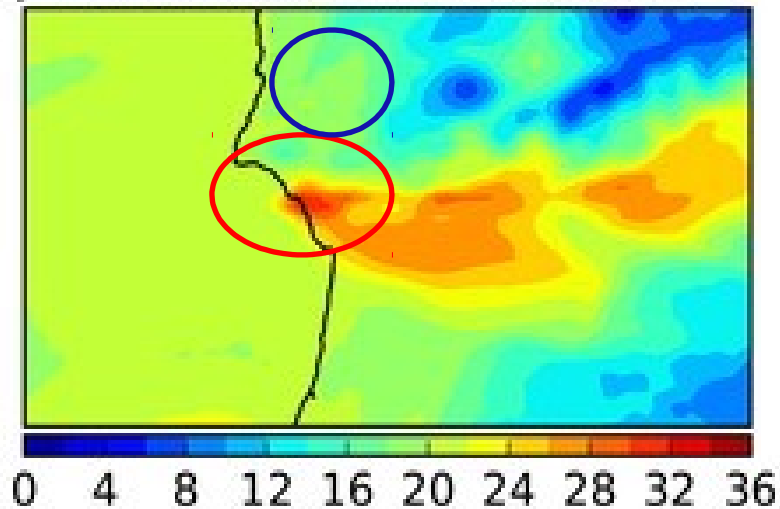


- Case study over Souss-Massa region (South of Morocco)
- Daily accumulated precipitation reached 91 mm in the East of Agadir city

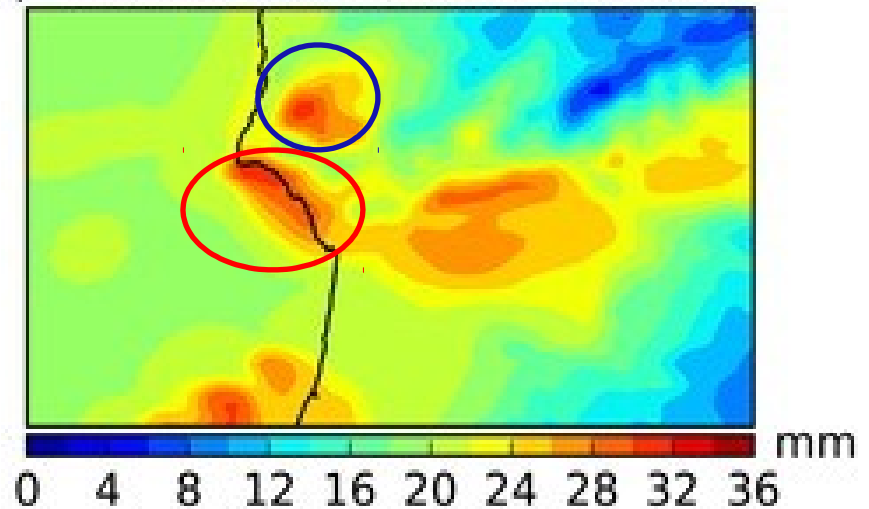
## Case study: HPE of 1 March 2018

- AROME-Morocco 8-hour forecast range valid at 08 UTC, 1 March 2018 for:  
integrated water vapour (in mm) from (a) CTRL experiment (b) GNSS experiment

(a) Integrated Water Vapour (CTRL)



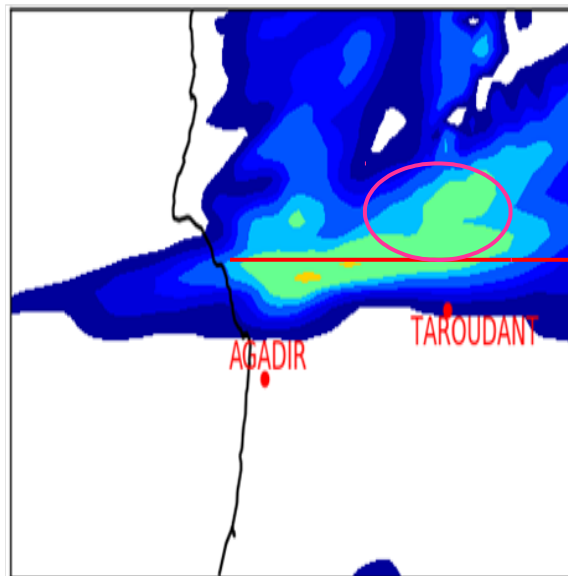
(b) Integrated Water Vapour (GNSS)



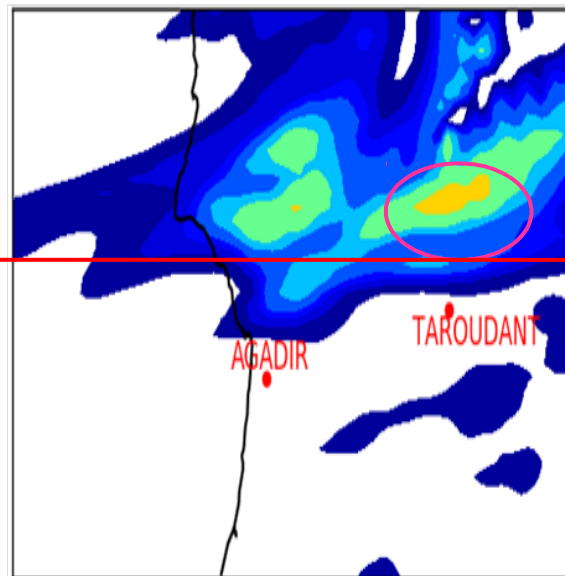
## Case study: HPE of 1 March 2018

➤ 24-h accumulated rainfall from 1 March 2018 06 UTC to 2 March 2018 06 UTC

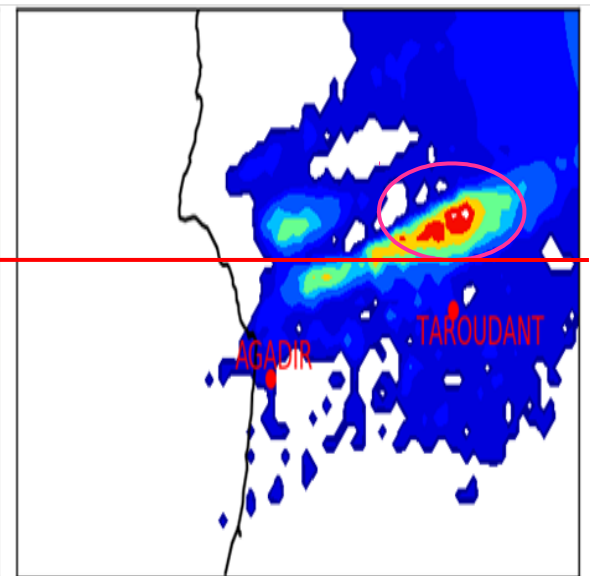
**EXP-CTRL**



**EXP-GNSS**



**Radar QPE**





# Conclusions and Future work

## Conclusions

- ✓ Ground-based GNSS data from the Moroccan GNSS network have been assimilated into AROME-Morocco model.
- ✓ The assimilation of GNSS ZTD data modifies the moisture field in the low troposphere with a maximum around 900 hPa level.
- ✓ Diagnostic of the impact of GNSS ZTD assimilation into AROME-Morocco:
  - small positive impact on 3h forecast of specific humidity in low troposphere
  - positive impact on 0-24h forecast range of 2m relative humidity (RH2m)
  - mixed impact on precipitation : positive for high accumulations and neutral for small threshold accumulations
  - positive impacts in both location and intensity were evident when examining a case study.

## Futur work

- Add more existing GNSS sites in Morocco (e.g. ANCFCC GNSS receiver networks)
- Conduct more experiments to investigate the impact of assimilating GNSS observations for different weather types and for other seasons
- Examine ZTD bias correction strategy: dynamic instead of static scheme (VarBC).
- Test the assimilation of other GNSS observation :
  - tropospheric gradients that can provide additional information on the horizontal variations of water vapour (work in progress/collaboration with MF).





Thank you for your attention