

# Variational bias correction of GNSS ZTD in the HARMONIE modeling system

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## OUTLINE

1. Motivation
2. GNSS ZTD HARMONIE observation processing
3. Parallel data assimilation experiments
  - **Experimental design**
  - **Verification scores of parallel experiments**
  - **Case studies**
4. Conclusions and future work

# 1 Motivation

- The HARMONIE km-scale system is currently assimilating conventional observations, ATOVS, IASI, radar, Mode-S scatterometer...**BUT** the only direct humidity measurements are: vertical profiles of RS and 2m RH measurements from surface (SYNOP).
- GNSS (Global Navigation Satellite System ) delays appear like a **new source of such mesoscale atmospheric humidity information** and can fill this gap.
- Assimilation tests of Zenith (and Slant) delays from GNSS observations have been performed with HIRLAM model with encouraging results, and so has been done with HARMONIE model.

I explain here an HARMONIE configuration with which a good impact has been found, mainly on humidity and precipitation..

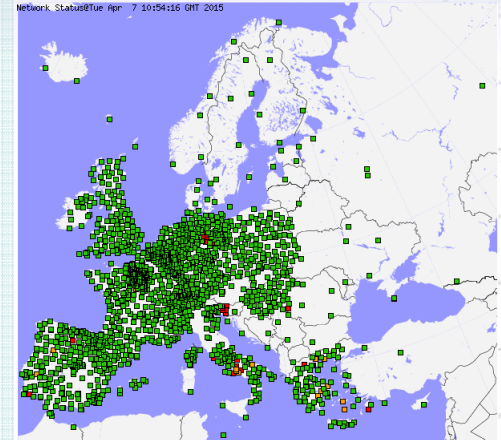
## 2 GNSS ZTD HARMONIE observation processing

### ✓ ZTD GNSS observations:

**E-GVAP** (*EUMETNET EIG GNSS water vapour programme*)

<http://egvap.dmi.dk/>

AIM: to provide its EUMETNET members with European GNSS delay and water vapour estimates for operational meteorology in near real-time.



### ✓ HARMONIE observation processing components:

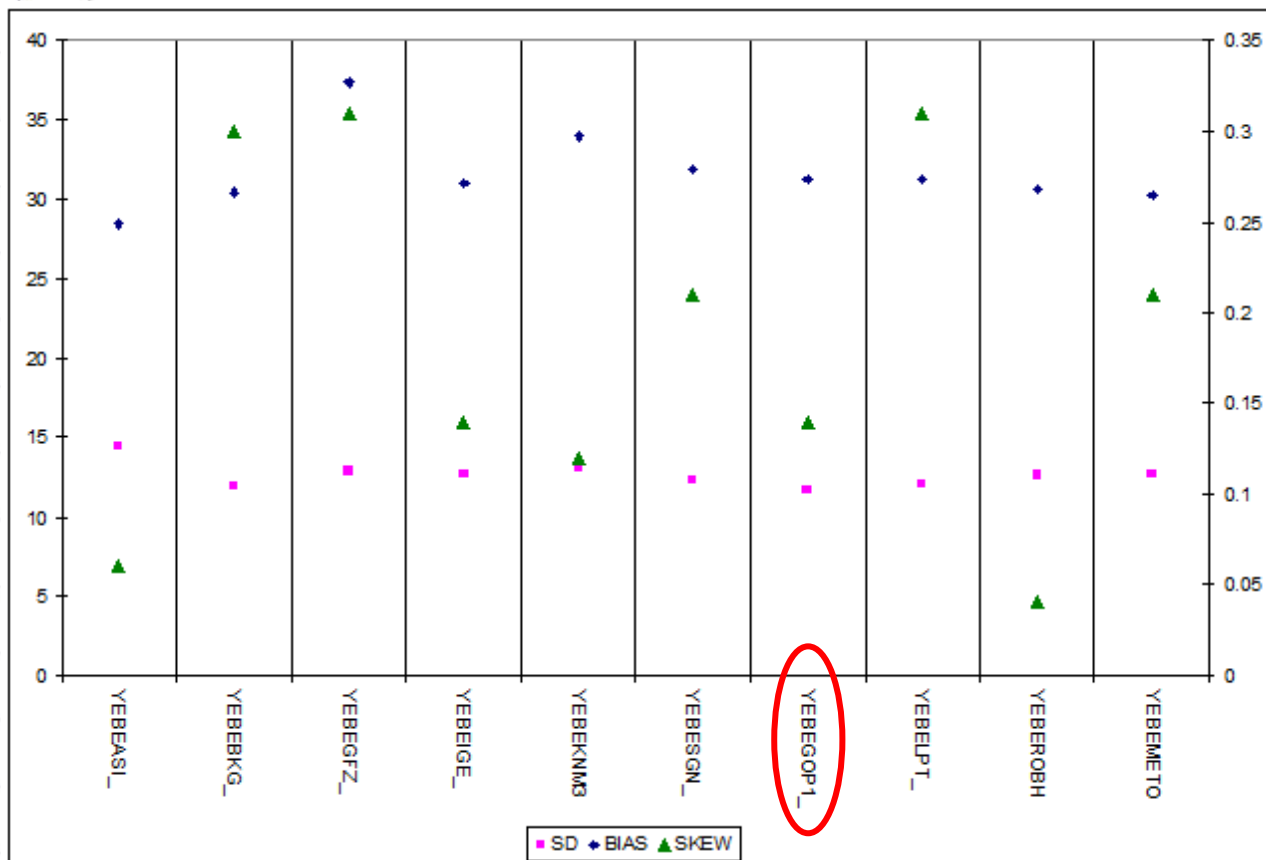
- Handling of redundant information
- Handling of observation error correlations
- Handling of observation biases
- Specification of observation errors
- Observation operator to produce model equivalents of GNSS ZTD observations
- Quality control and handling of observations affected by Gross errors

## 2 GNSS ZTD HARMONIE observation processing

### Handling of redundant information I

✓ A **WHITE LIST** has been created with o-b dep statistics from the passive run for the month previous to the period of study.

*CRITERIA: the smallest SD and little skewness*



YEBE station:

10 possible Analysis Centres

JUST one selected:

YEBEGOP1

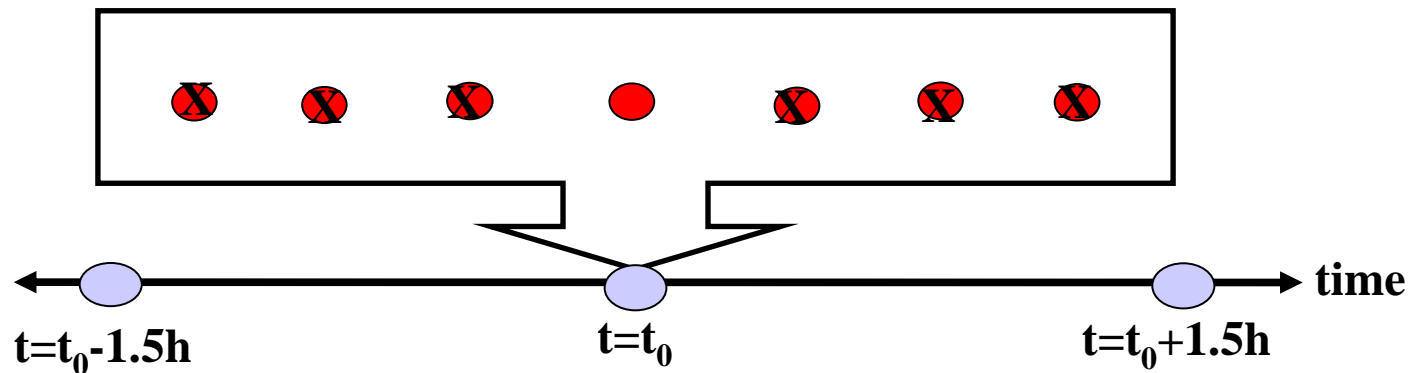
THEN, a list of 213 station&AC can be assimilated

## 2 GNSS ZTD HARMONIE observation processing

### Handling of redundant information II

✓ A **TEMPORAL THINNING** has been applied

The obs closest to the nominal time  
(keep one obs. each 3 h)



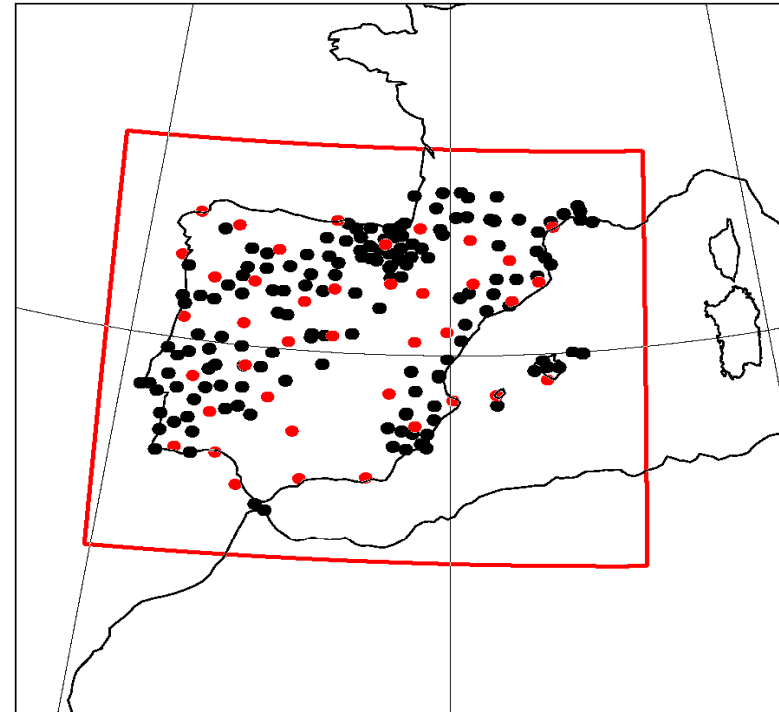
## 2 GNSS ZTD HARMONIE observation processing

### Handling of observation error correlations

✓ A **SPATIAL THINNING** has been applied to treat the correlated observation errors.  
80km thinning distance

**before: 213 sites**  
**after: 46 sites**

*Less severe thinning had a detrimental effect on the quality of the short-range forecast.*



## 2 GNSS ZTD HARMONIE observation processing

### Handling of observation biases I

GNSS ZTD have a BIAS!!! Due to systematic errors in model fields and ZTD obs operator/data processing algorithms..

#### ✓ STATIC Bias Correction

$ob = ob - bias$ , *bias = cte*, calculated from o-b from the passive run of the month before

#### ✓ VARIATIONAL Bias Correction (VBC)

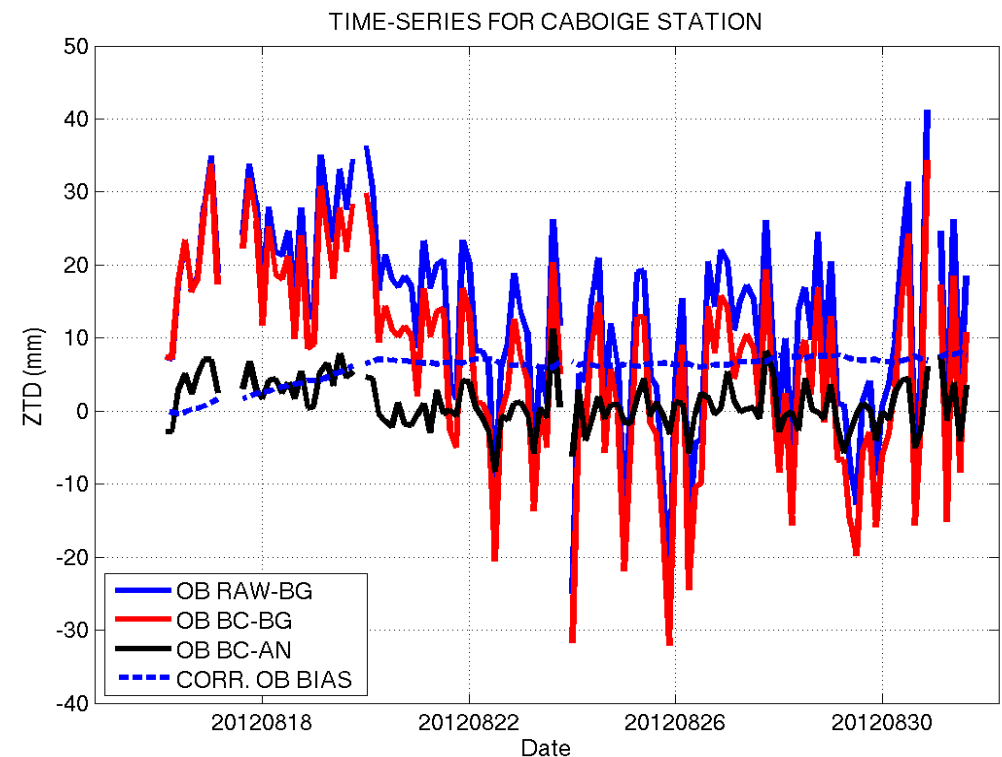
-One single predictor: offset value

Time-serie from GNSS ZTD at CABOIGE\_ :

ob-bg departure **before** and **after** VBC

--- Estimated ob bias to be corrected

**Bias corrected ob-an departure**





## 2 GNSS ZTD HARMONIE observation processing

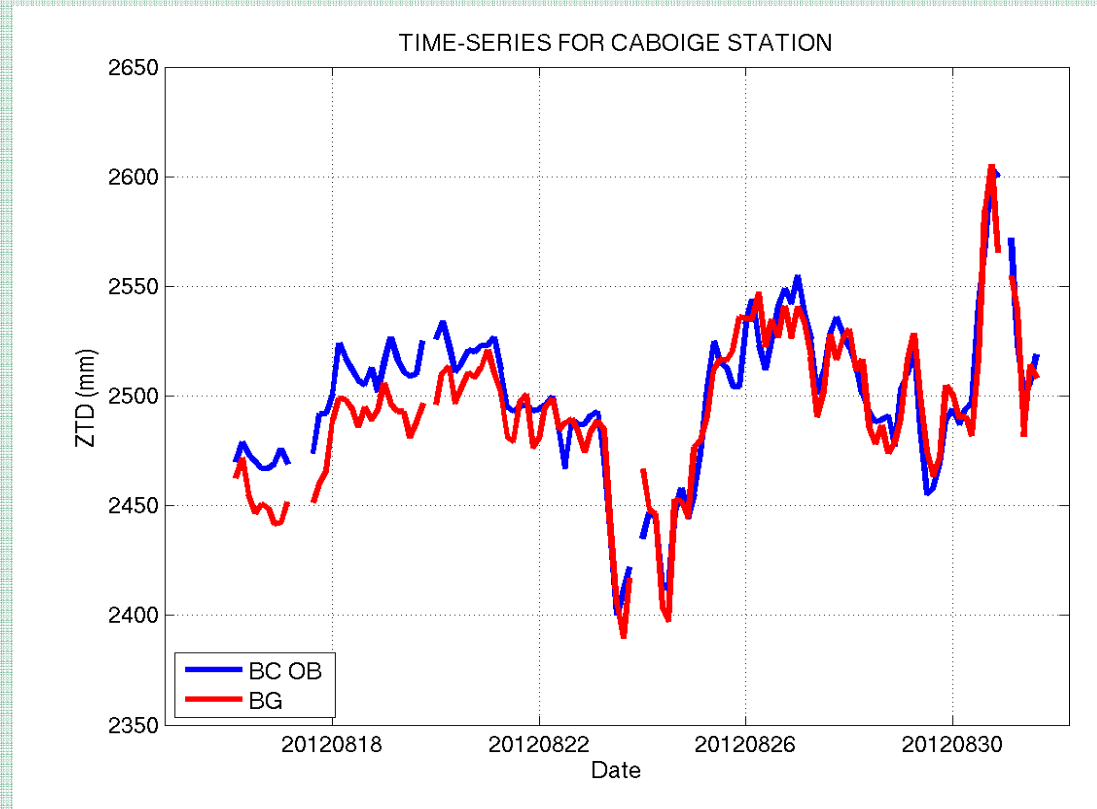
### Handling of observation biases II

#### ✓ VARIATIONAL Bias Correction (VBC)

Time-serie from GNSS ZTD at CABOIGE\_ :

Bias corrected observation

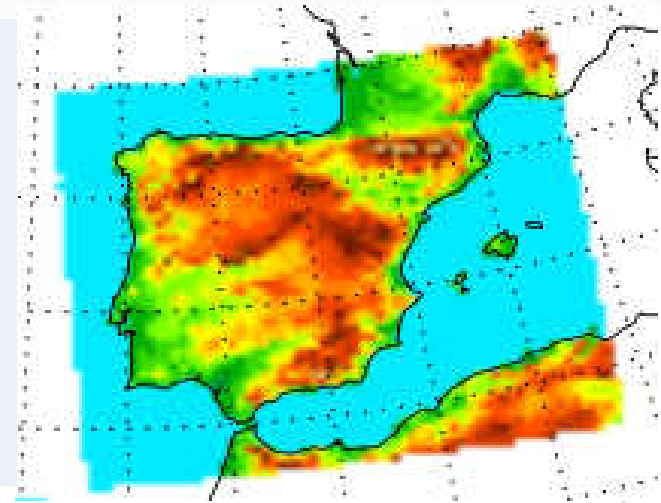
BG equivalent



### 3 Parallel data assimilation experiments

#### Experimental design

- Cy38h1beta3, LSMIX=yes, 3DVar, with 3h cycle: conventional obs +GNSS ZTD
- Period of study: 1-30 September 2012, with a two-week spin-up period before.
- Domain: **IBERIA\_2.5**, 2.5 km horizontal resolution and 65 vertical levels.

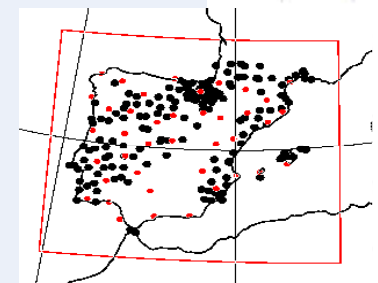


3 parallel experiment are being compared:

**CRL:** conventional observations (*RS,PILOT,SYNOP,SHIP and aircraft*)

**STA:** conv obs + GNSS ZTD with STATIC Bias Correction

**VBC:** conv obs + GNSS ZTD with VARIATIONAL Bias Correction



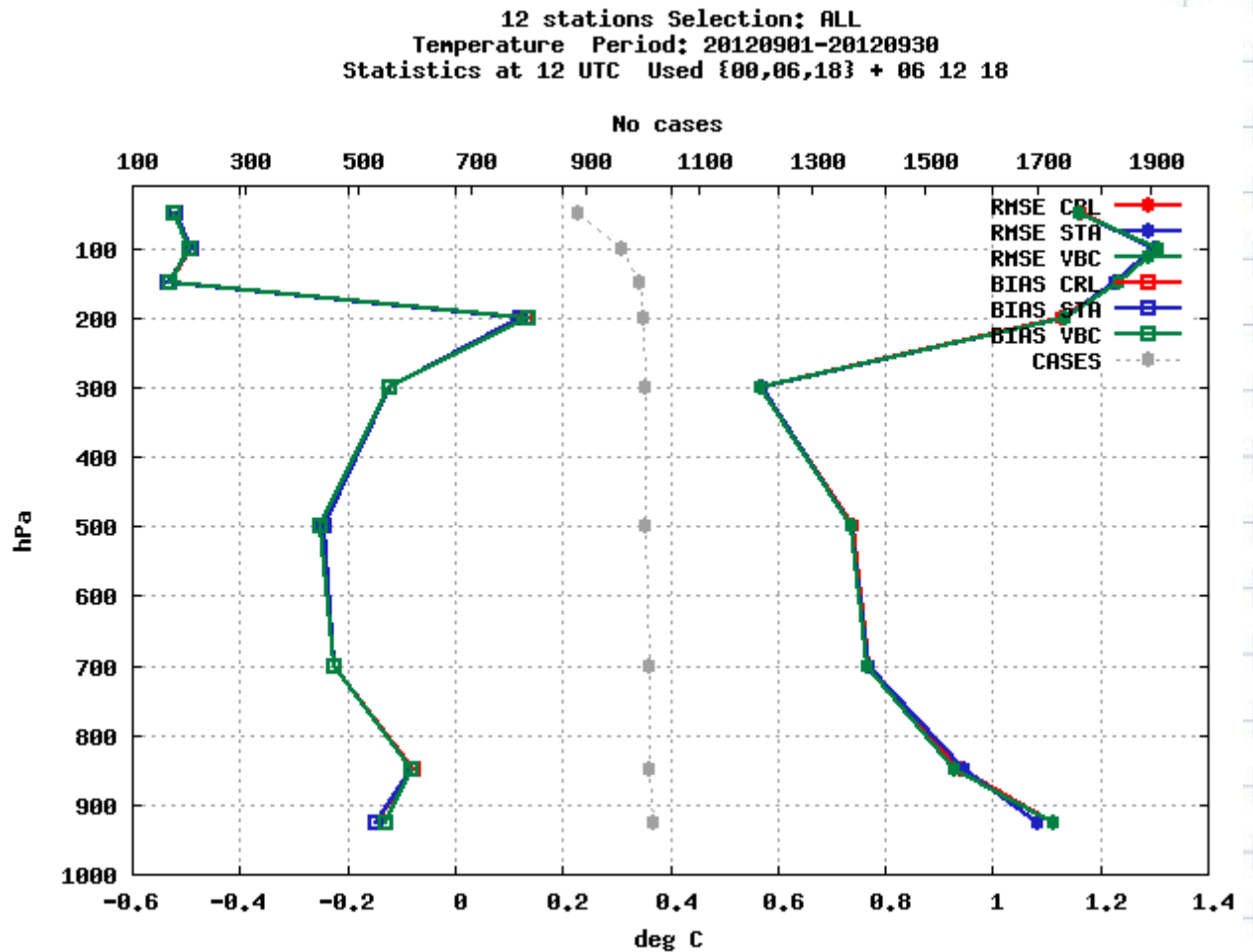
# 3 Parallel data assimilation experiments

## Verification scores of parallel experiments

BIAS and RMSE of +6,+12 and +18 h  
 Period: Sept 2012 Valid Time: 12UTC

*TEMPERATURE*

T neutral



### 3 Parallel data assimilation experiments

## Verification scores of parallel experiments

BIAS and RMSE of +6,+12 and +18 h

*WIND*

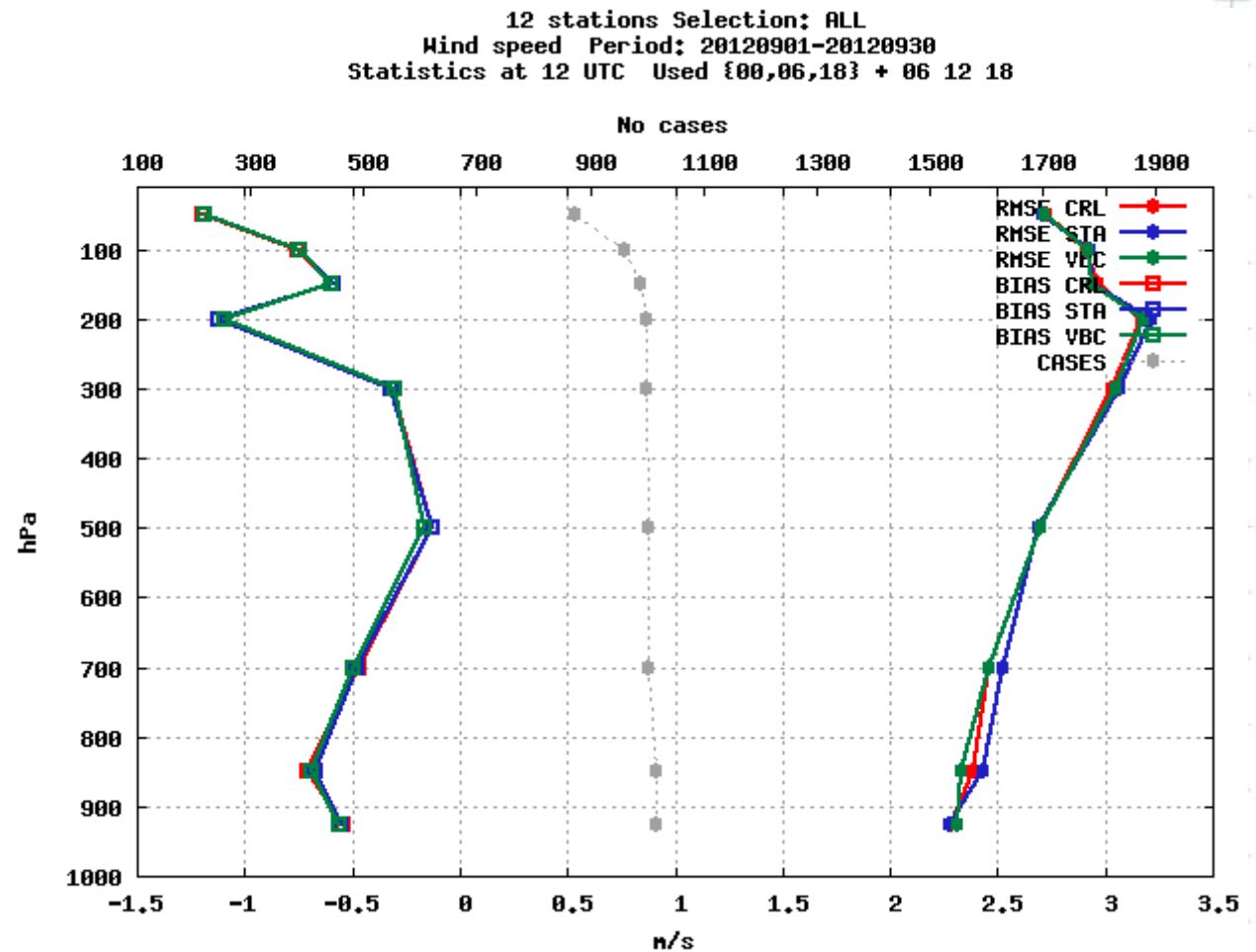
Period: Sept 2012   Valid Time: 12UTC

Wind

Below 500hPa::

STA higher RMSE

VBC lower RMSE



### 3 Parallel data assimilation experiments

## Verification scores of parallel experiments

BIAS and RMSE of +6,+12 and +18 h

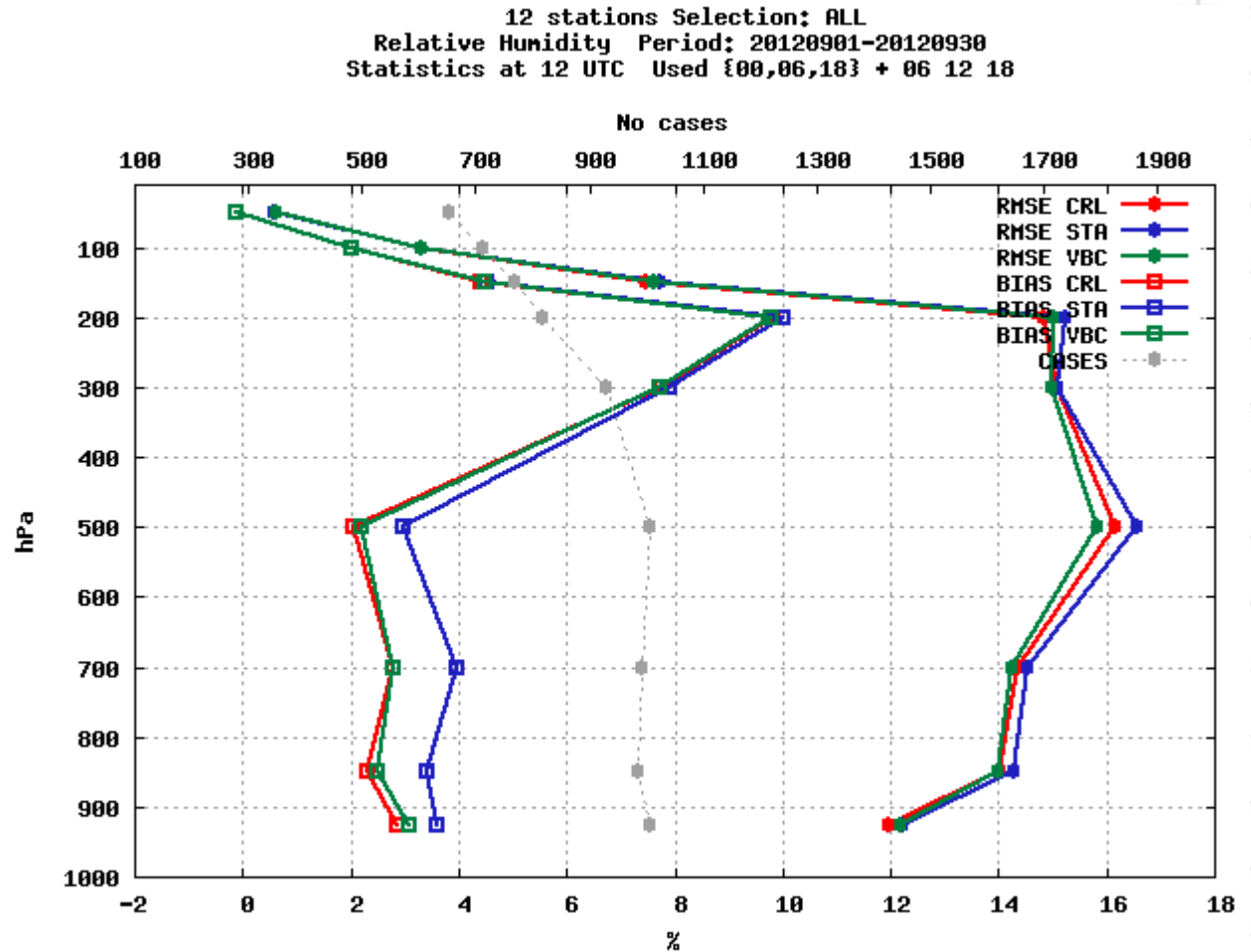
Period: Sept 2012 Valid Time: 12UTC

*RELATIVE HUMIDITY*

RH

**STA** higher bias and RMSE

**VBC** lowest RMSE

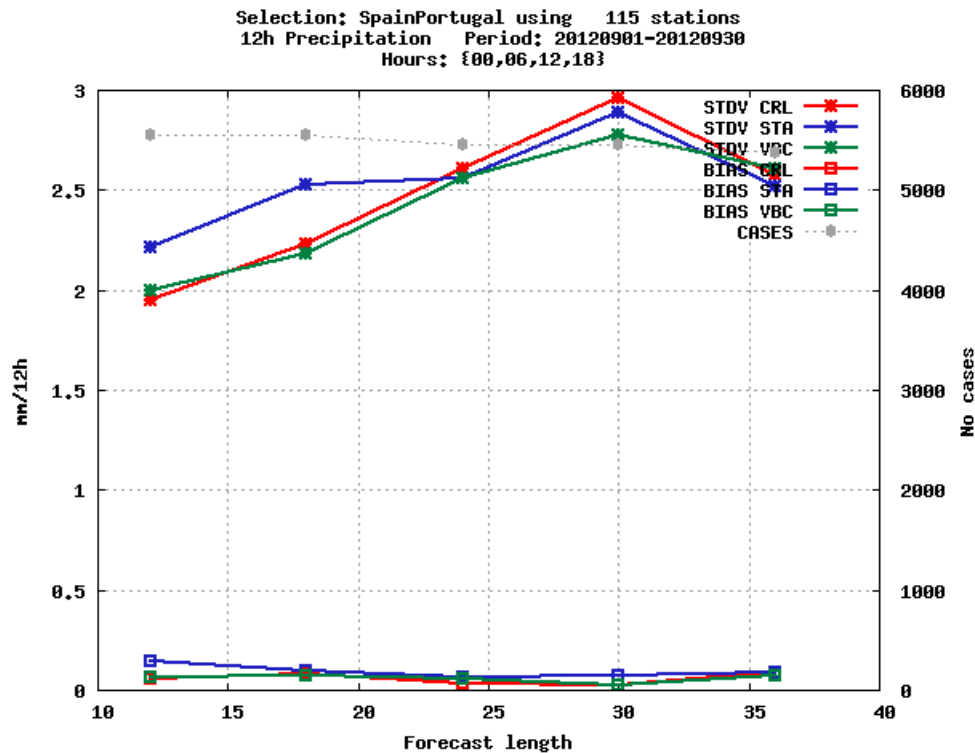


# 3 Parallel data assimilation experiments

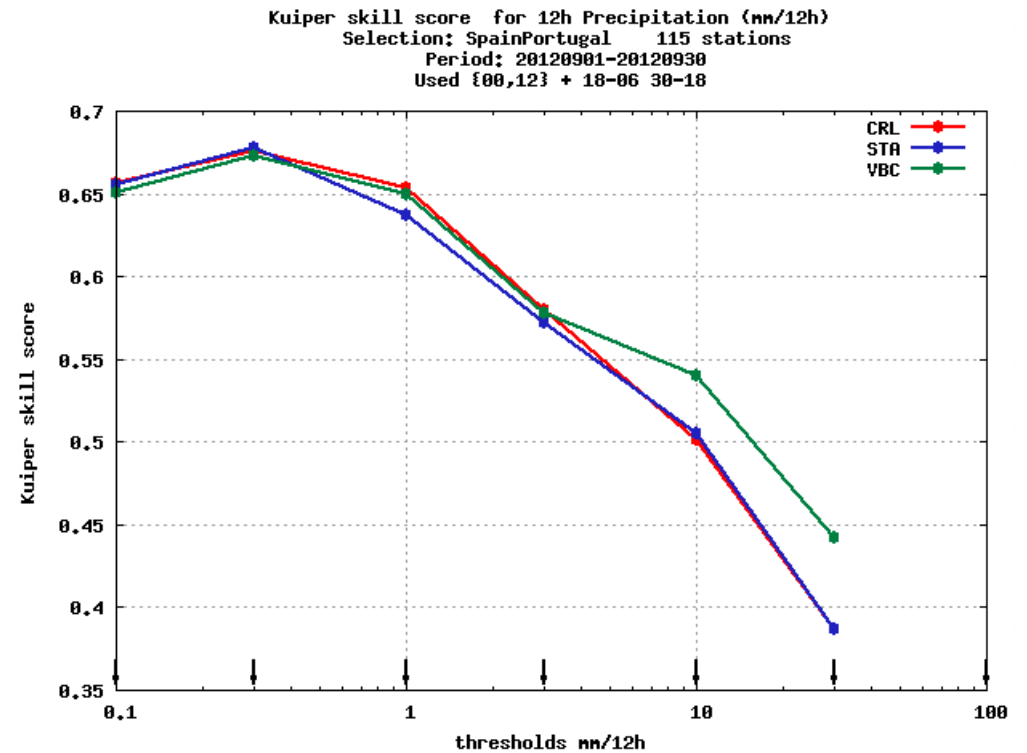
## Verification scores of parallel experiments

Improvement of the forecast skill of **12h accum. precipitation** when assimilating ZTD GNSS observations with VarBC scheme, mainly for high precipitation rates.

### BIAS and RMSE of +6,+12 and +18 h



### Kuiper Skill Score



### 3 Parallel data assimilation experiments

Case study I: 8 september 2012, 12 UTC

Rainy band  
north of Lisbon

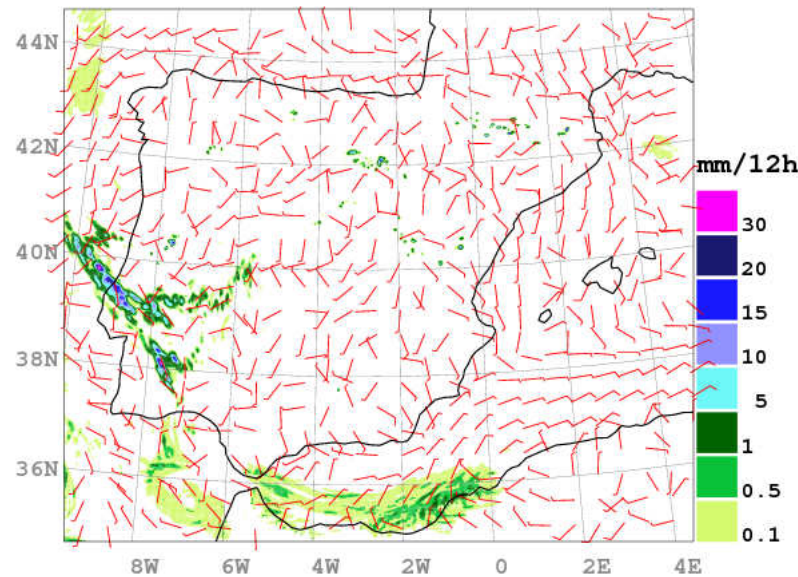
•CRL and STA: overprediction pcp and q

Simulations of acc  
12 h precipitation  
forecasts in mm at  
12 UTC

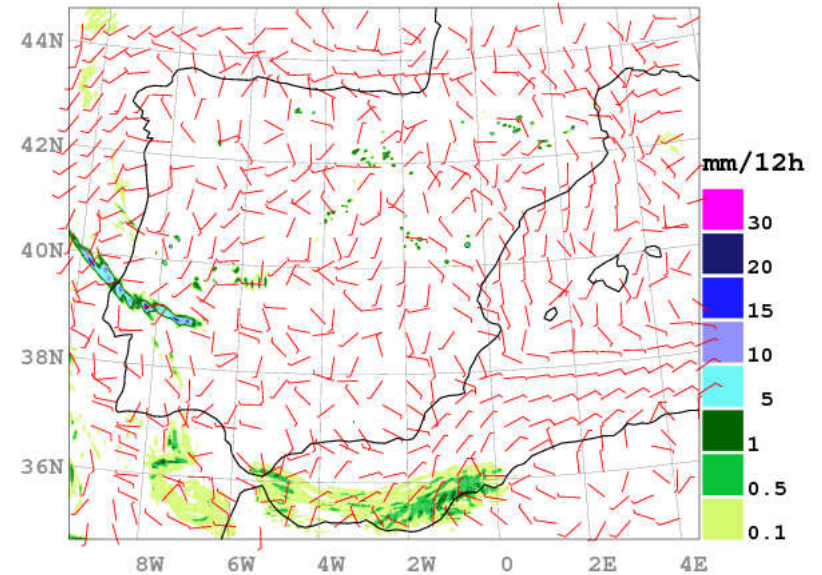
8 September 2012  
12h

. Wind barbs  
represent 10 m wind  
forecasts.

CRL



VBC



### 3 Parallel data assimilation experiments

Case study I: 8 september 2012, 12 UTC

Rainy band  
north of Lisbon

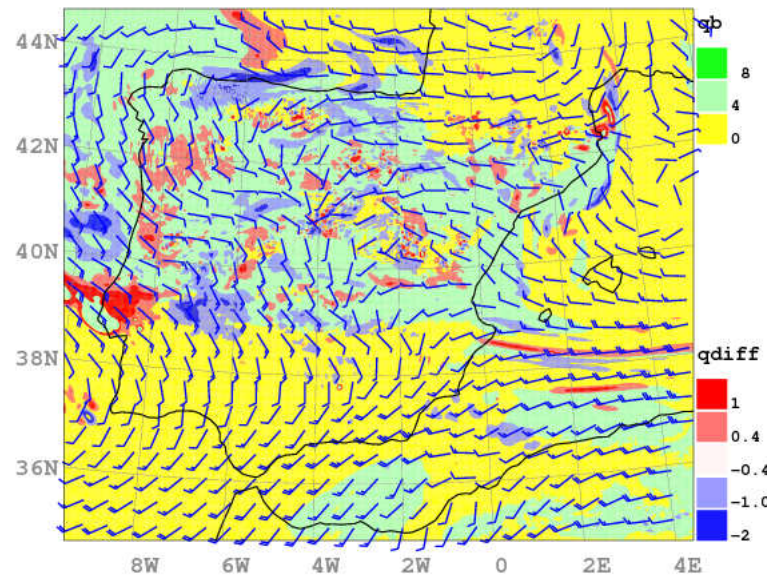
24 h forecast , specific humidity  $q$  and temperature  $T$  CRL- VBC differences

CRL forecasted higher  $q$  and lower  $T$  than VARBC on the western area

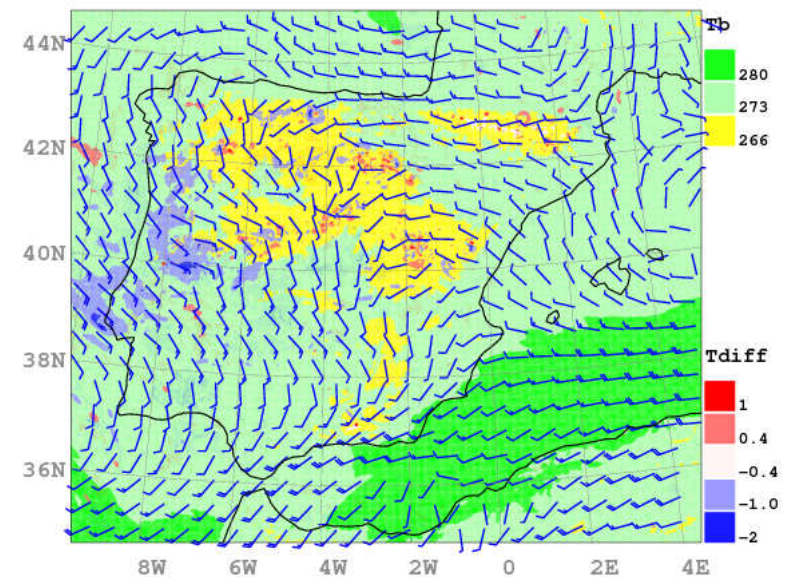
Simulations of 24h  
 $q$  and  $T$  forecasts

8 Sep 2012 12h

$q$  (g/kg)diff



$T$  (K)diff





### 3 Parallel data assimilation experiments

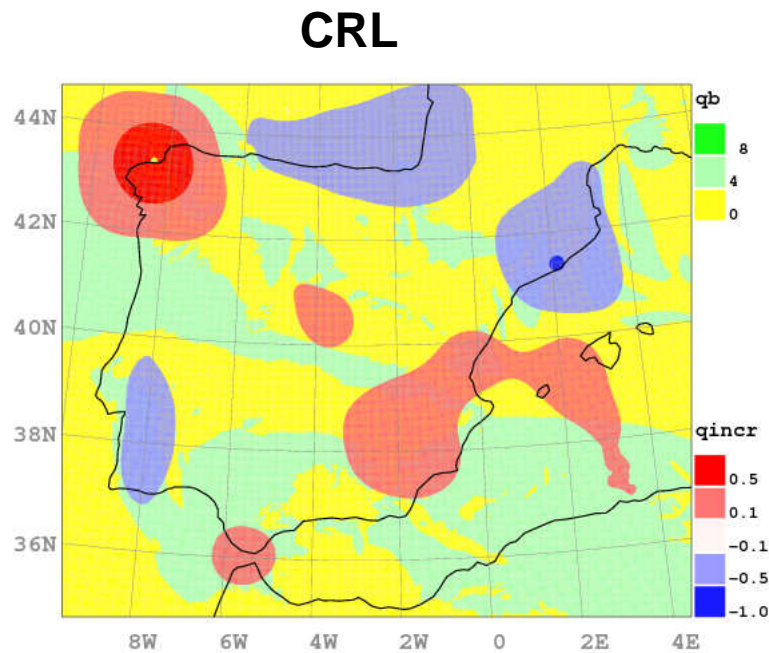
Case study I: 8 september 2012, 12 UTC

Rainy band  
north of Lisbon

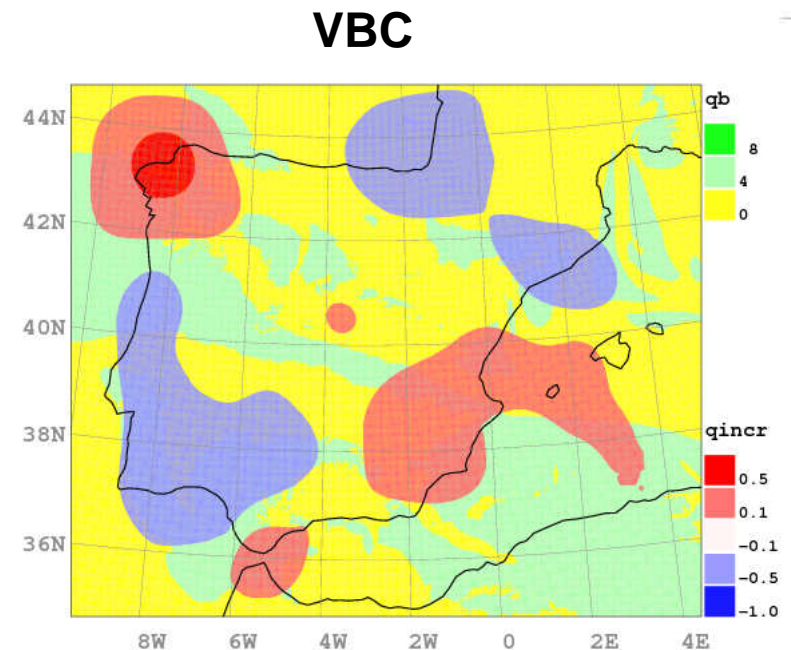
24 h before... analysis increments

Specific humidity analysis increments at model level 33 (~700 hPa). Unit: g/kg.

7 September, 2012, 12UTC



*Because RS*



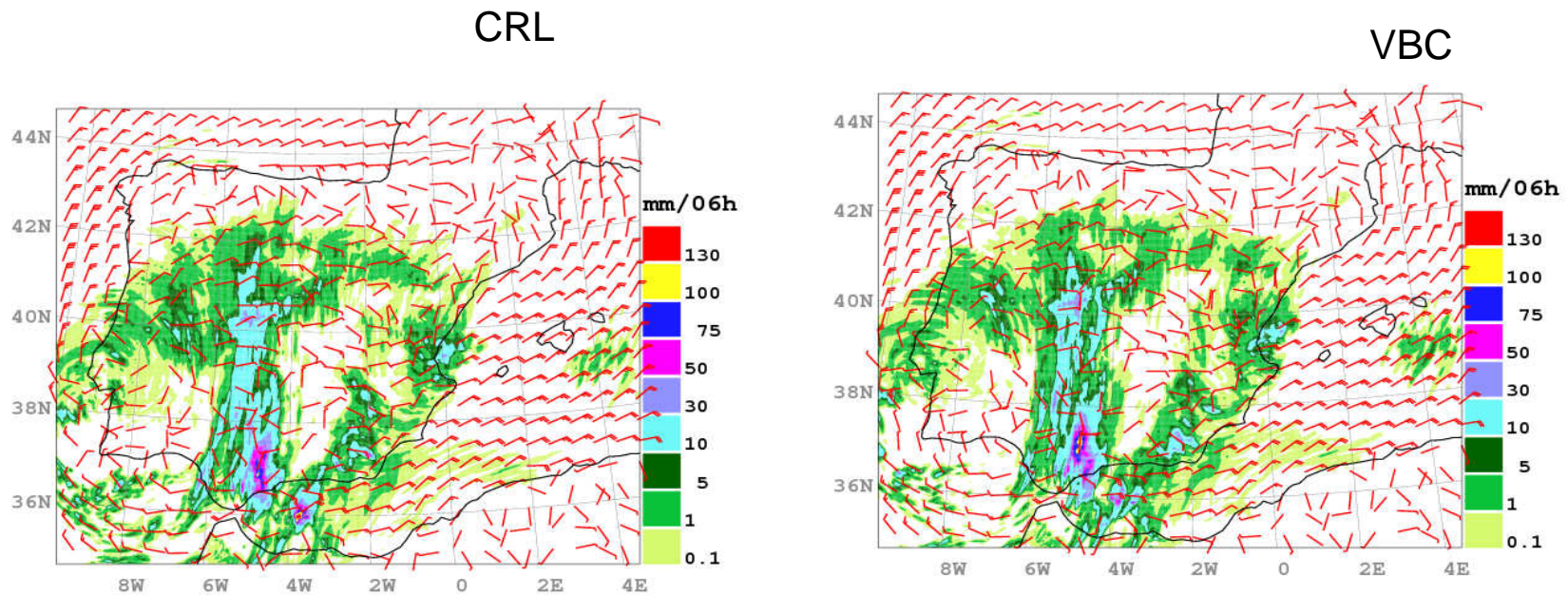
*Because RS+ GNSS ZTD*

### 3 Parallel data assimilation experiments

#### Case study II: 28 september 2012, 06UTC

Simulated 6 h accumulated precipitation (unit: mm),  
between 28 September 2012, 00 UTC and 28 September 2012, 06 UTC.

Overprediction of pcp for CRL: north and south-east.



# 3 Parallel data assimilation experiments

## Case study II: 28 september 2012, 06UTC

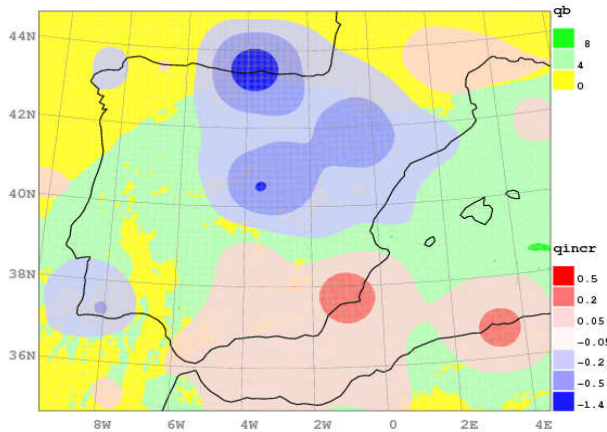
**Analysis: 6 h before..**

Specific humidity analysis increments at model level 33 (~700 hPa). Unit: g/kg. Time 28 September, 2012, 00UTC

Specific humidity analysis and CRL-VBC specific humidity analysis differences at model level 33.

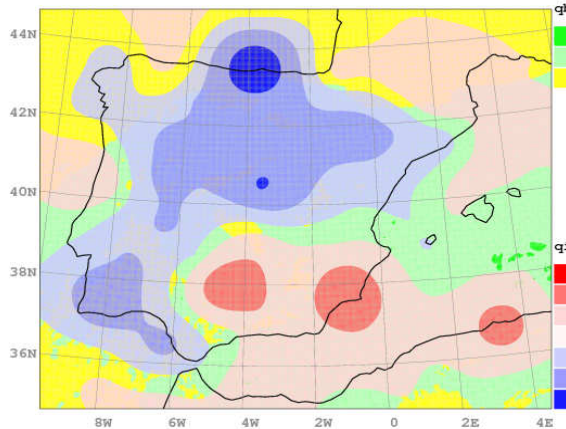
Wind barbs represent the CRL level 33 winds

**CRL**

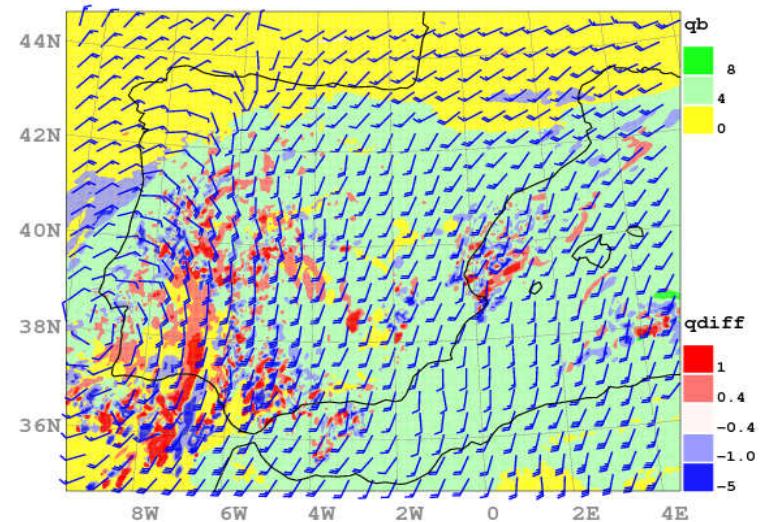


**Because RS**

**VBC**



**Because RS and ZTD**



**CRL-VBC**

**SW and Northern:** VBC q an incr more negative and wider area : an dried the bg more in VBC than in CTL, what lead to a better prediction of 6h acc pc



GOBIERNO  
DE ESPAÑA

MINISTERIO  
DE MEDIO AMBIENTE  
Y MEDIO RURAL Y MARINO

**AEMet**  
Agencia Estatal de Meteorología

## 4 Conclusions and future work

- The HARMONIE km-scale short-range numerical weather forecasting system is prepared for assimilation of GNSS ZTD observations.
- Use of GNSS ZTD observations together with a variational bias correction is shown to improve the short range weather forecasts, both in a statistical sense and in individual case studies.
- The improvement has been due to the ability of the GNSS ZTD observations to dry a too wet model state and therefore improve the precipitation scores.



GOBIERNO  
DE ESPAÑA

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Y MEDIO RURAL Y MARINO

**AEMet**  
Agencia Estatal de Meteorología

## 4 Conclusions and future work

- Further investigation to **reduce the 80 km thinning distance** between GNSS sites.
- Combination of conventional observations, GNSS ZTD and AMSU-A MHS humidity measurements. Study the combined impact and interactions.
- The possibility to further enhance the variational bias correction for GNSS ZTD by introducing **more predictors**, such as layer-thickness, should be investigated.

Thank you for your attention..

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