

# Assimilation of AMDAR humidity observations

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## Outline

- 1) E-AMDAR humidity observations
- 2) Impact of E-AMDAR humidity observations in comparison to radiosonde data (IFS-ECMWF)
- 3) Assimilation of E-AMDAR humidity in HARMONIE-AROME

# 1) E-AMDAR humidity observations



Since June 2016 a group of 9 Lufthansa aircrafts equipped with the WVSS-II humidity sensor are serving a number of airports in Europe.

E-AMDAR profiles are obtained for:

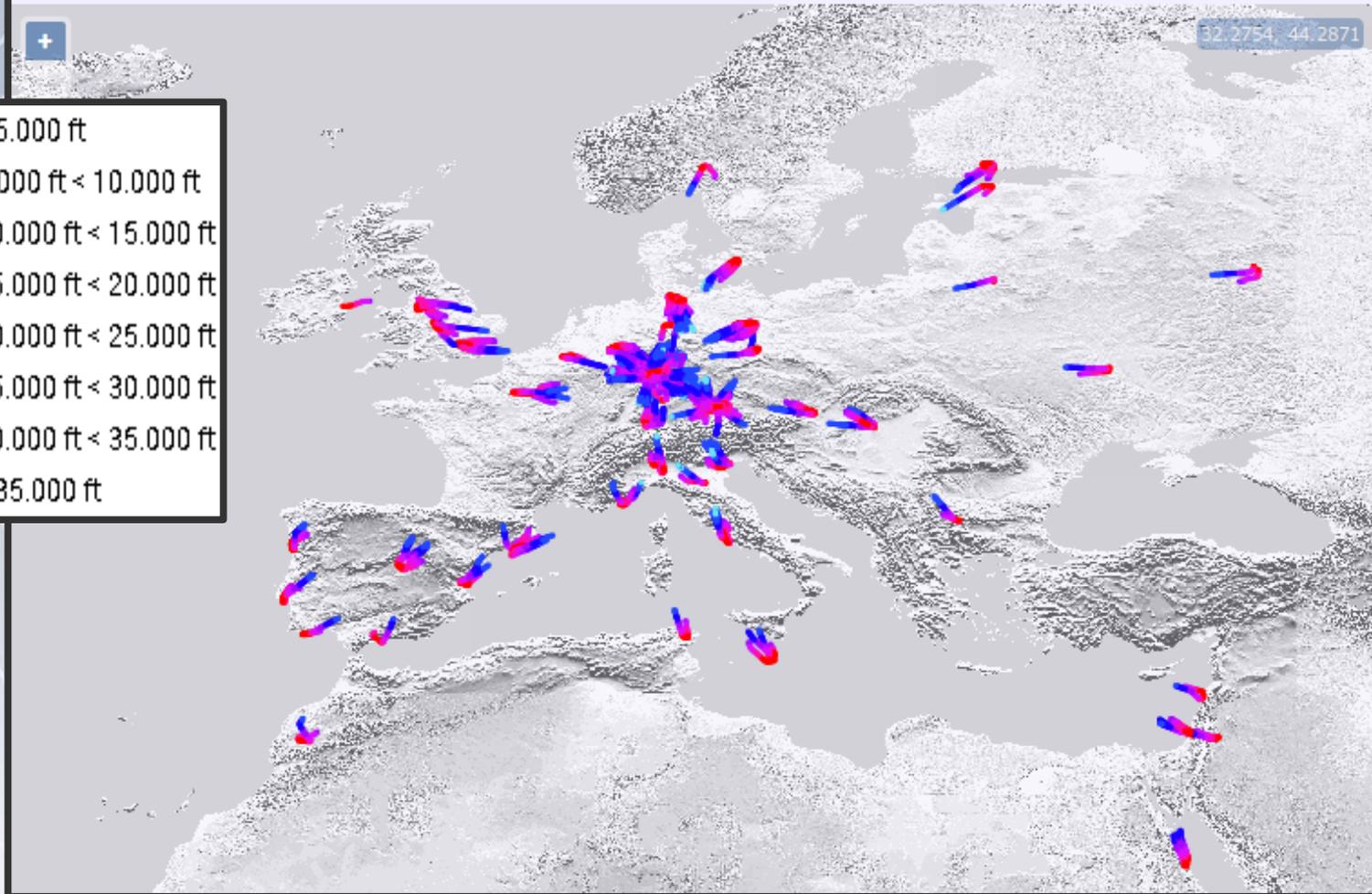
- ascent (samples every 20 seconds from take-off for a period of 900 seconds), and
- descent (samples every 40 seconds from altitude of 18,000 feet).
- Automated aircraft waper vapor reports are at least as accurate as radionsonde observations (Petersen et al., 2016).

26.11.2018 00:00 - 02.12.2018 23:59; Display: Pressure altitude; Airport: None; Display area: None; Humidity equipped aircraft only: true; EU Identifier: All; Airline: All; Flight Phase: ASC, DES; Aircraft type: All



32.2754 - 44.2871

- < 5.000 ft
- 5.000 ft < 10.000 ft
- 10.000 ft < 15.000 ft
- 15.000 ft < 20.000 ft
- 20.000 ft < 25.000 ft
- 25.000 ft < 30.000 ft
- 30.000 ft < 35.000 ft
- $\geq$  35.000 ft



E-AMDAR humidity observations from 26th Nov to 2 Dec 2018.

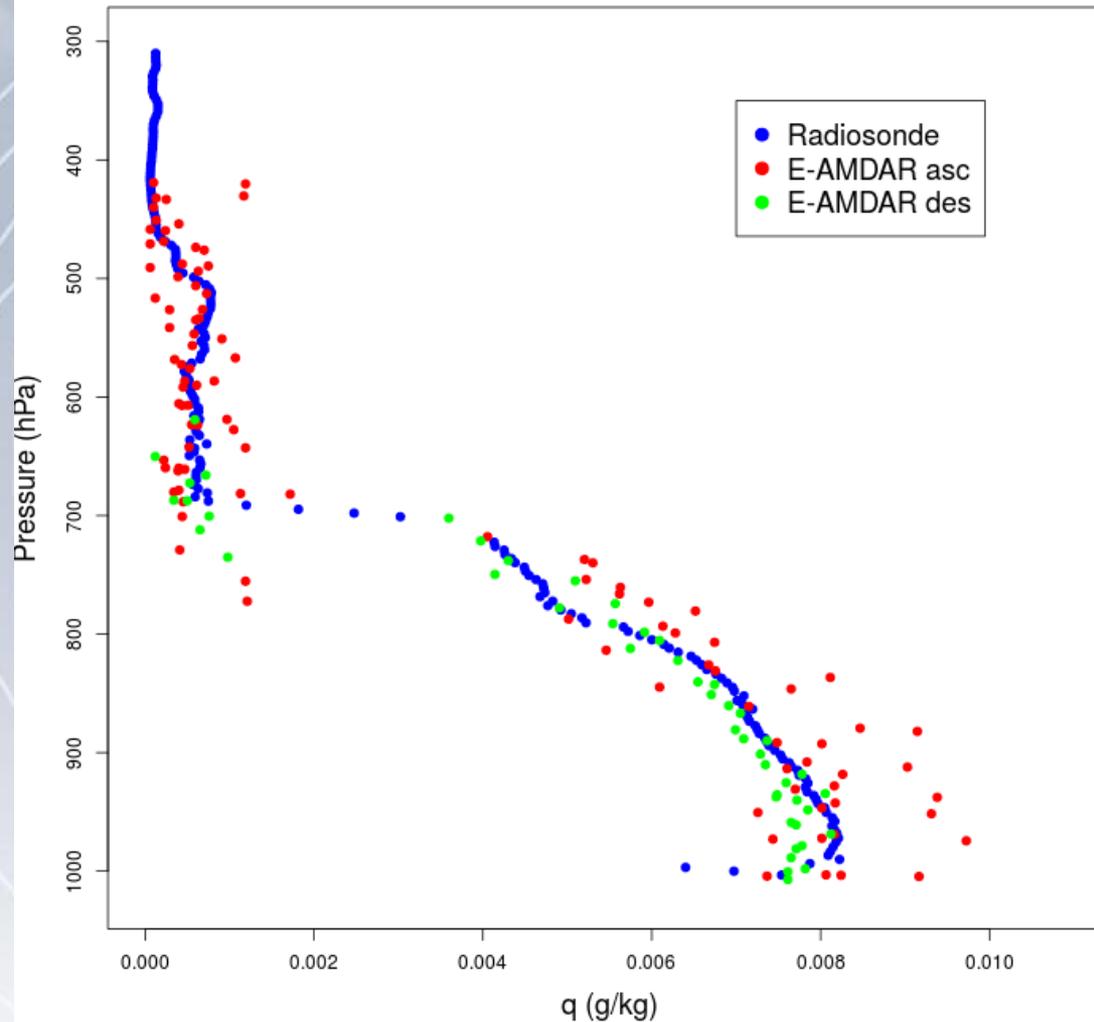
<b>ICAO code</b>	<b>Airport</b>	<b>Gridbox</b>	<b>All profile totals</b>	<b>All profile obs.</b>	<b>[0-3]</b>	<b>[3-6]</b>	<b>[6-9]</b>	<b>[9-12]</b>	<b>[12-15]</b>	<b>[15-18]</b>	<b>[18-21]</b>	<b>[21-24]</b>
EDDT	BERLIN/TEGEL	1540 (WC)	198	6267	-	3	57	29	25	38	42	4
EDDK	COLOGNE/BONN	1511 (WC)	6	199	-	1	-	2	-	-	2	1
EDDC	DRESDEN	1540 (WC)	4	118	-	-	-	-	-	2	2	-
EDDL	DUSSELDORF	1511 (WC)	20	596	-	1	8	2	-	3	5	1
EDDF	FRANKFURT/MAIN	1511 (WC)	1253	44907	-	35	274	256	216	216	234	22
EDDH	HAMBURG	1513 (SS)	162	5441	-	11	40	24	25	30	25	7
EDDV	HANNOVER	1512 (WC)	18	510	-	1	5	3	2	5	1	1
EDDM	MUNICH	1566 (WC)	314	9921	-	3	69	70	40	59	56	17
EDDN	NURNBERG	1539 (WC)	1	32	-	-	-	-	-	-	1	-
EDDS	STUTTGART	1538 (WC)	2	50	-	-	1	-	1	-	-	-

<b>ICAO code</b>	<b>Airport</b>	<b>Gridbox</b>	<b>All profile totals</b>	<b>All profile obs.</b>	<b>[0-3]</b>	<b>[3-6]</b>	<b>[6-9]</b>	<b>[9-12]</b>	<b>[12-15]</b>	<b>[15-18]</b>	<b>[18-21]</b>	<b>[21-24]</b>
LEBL	BARCELONA/EL PRAT	1534 (WM)	69	2576	-	4	7	13	19	13	6	7
LEBB	BILBAO	1479 (FA)	2	65	-	-	-	-	2	-	-	-
LEMD	MADRID/BARAJAS	1478 (IB)	49	1797	-	4	8	8	13	3	7	6
LEMG	MALAGA	1504 (IB)	14	517	-	-	-	5	8	1	-	-
LEPA	PALMA DE MALLORCA	1534 (WM)	6	204	-	-	-	2	-	3	1	-
LEVC	VALENCIA/MANISES	1506 (IB)	12	398	-	-	1	8	2	-	-	1

Number of humidity profiles/observations (ascending and descending) for airports in Germany and Spain at 3-h interval (November 2018)

- The majority of profiles are generated over Germany, but there are a significant number of profiles produced in other countries (e.g. Spain).
- Diurnal and seasonal variability of E-AMDAR data availability.

Barcelona (LEBL and 08190)  
10 - October - 2016 at 12 UTC



Humidity profiles assimilated by the IFS run at 12 UTC on 10 October 2016 over Barcelona: E-AMDAR humidity ascent/descent profiles obtained by Lufthansa aircrafts (in red/green) and TEMP profile (in blue).

## 2) Impact of E-AMDAR humidity observations in comparison to radiosonde data (IFS-ECMWF)

EUMETNET OBS-Programme endorsed AEMET to carry out a study on the “Impact of E-AMDAR humidity observations (‘conditional’ FSOI assessment) in comparison to radiosonde data” (Study 1 – Case 3, EMT\_OBS\_2016\_02).

### **Goal:**

To assess the impact of E-AMDAR and TEMP humidity observations on short-range **IFS-ECMWF** forecasts by using **FSOI** diagnostics.

**FSOI (Forecast Sensitivity Observation Impact)** is the adjoint-based tool used at ECMWF to monitor the impact of observations on the quality of the Integrated Forecasting System (IFS) short-range forecasts (Cardinali, 2009).

- FSOI data for E-AMDAR and TEMP humidity observations from the IFS operational setup, two times a day:

  - 00 UTC run (uses observations from 21 UTC to 09 UTC)

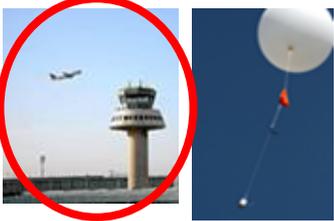
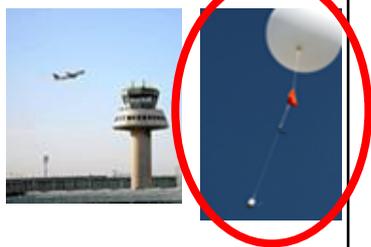
  - 12 UTC run uses observations from 09 UTC to 21 UTC)

- Separate statistics for 00 and 12 UTC

- Period: June 2016 to November 2017 (18 months)

- FSOI Radiosonde data used only  $p \geq 400$  hPa

- The Final Report was delivered to EUMETNET OBS Programme in December 2018.

Group A (AMDAR)	Group B (TEMP)	Group C (AMDAR)	Group D (TEMP)
 <p>dist &lt;50km</p>	 <p>dist &lt;50km</p>	 <p>No nearby RS station</p>	 <p>No nearby airport serving AMDAR-q</p>

**A:** E-AMDAR humidity data for selected airports with a radiosonde station nearby

**B:** TEMP humidity data for selected radiosonde stations with a nearby airport sometimes serving E-AMDAR humidity observations

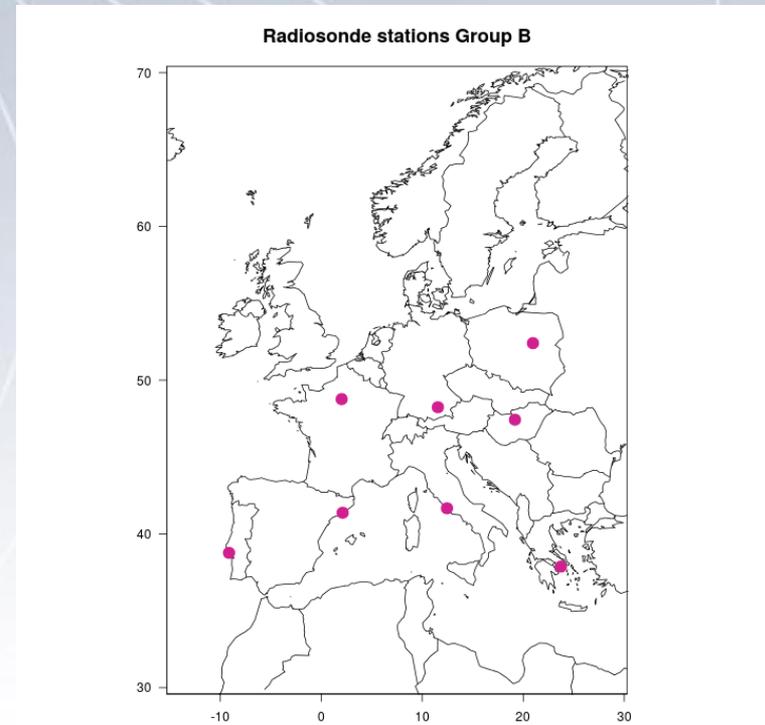
**C:** E-AMDAR humidity data for selected airports without a radiosonde station nearby

**D:** TEMP humidity data by selected radiosonde stations without a nearby airport serving E-AMDAR humidity observations

# Groups A and B

## Selection of close airports (A) and radiosonde stations (B) :

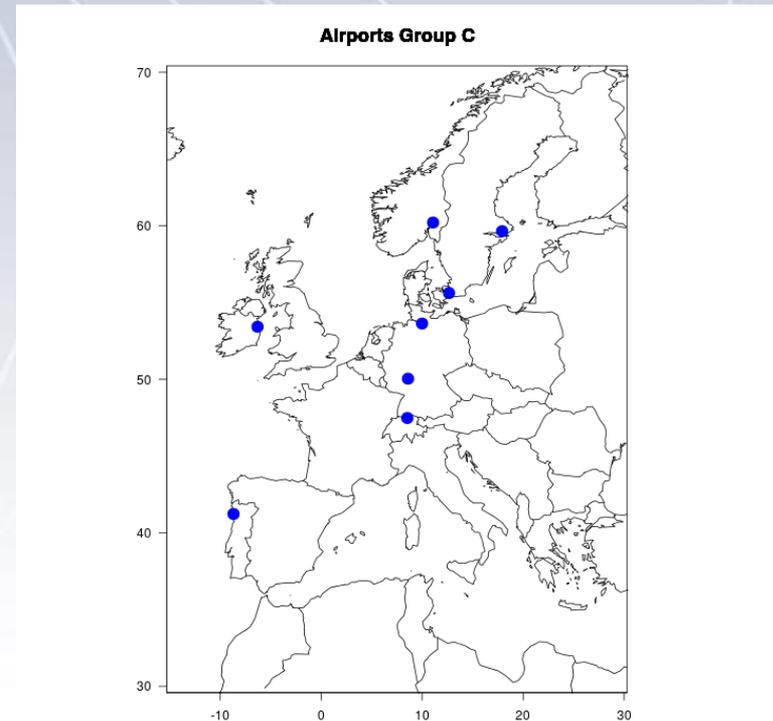
Munich:	EDDM	and	10868
Paris:	LFPG	and	07145
Warsaw:	EPWA	and	12374
Budapest:	LHBP	and	12843
Rome:	LIRF	and	16245
Lisbon:	LPPT	and	08579
Barcelona:	LEBL	and	08190
Athens:	LGAV	and	16716



## Group C

Set of airports where no radiosonde station is nearby:

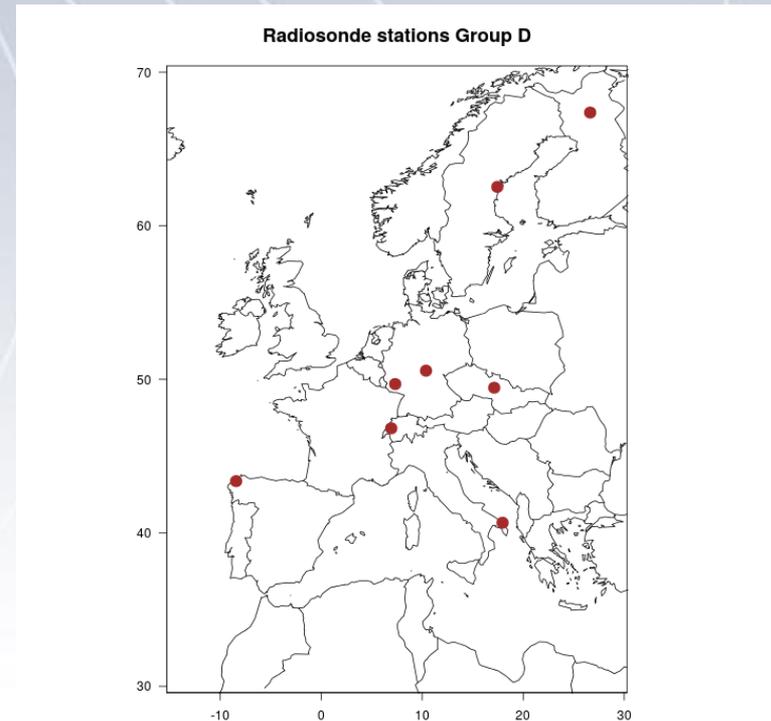
Frankfurt:	EDDF
Dublin:	EIDW
Hamburg:	EDDH
Stockholm:	ESSA
Oslo:	ENGM
Copenhagen:	EKCH
Zurich:	LSZH
Porto:	LPPR



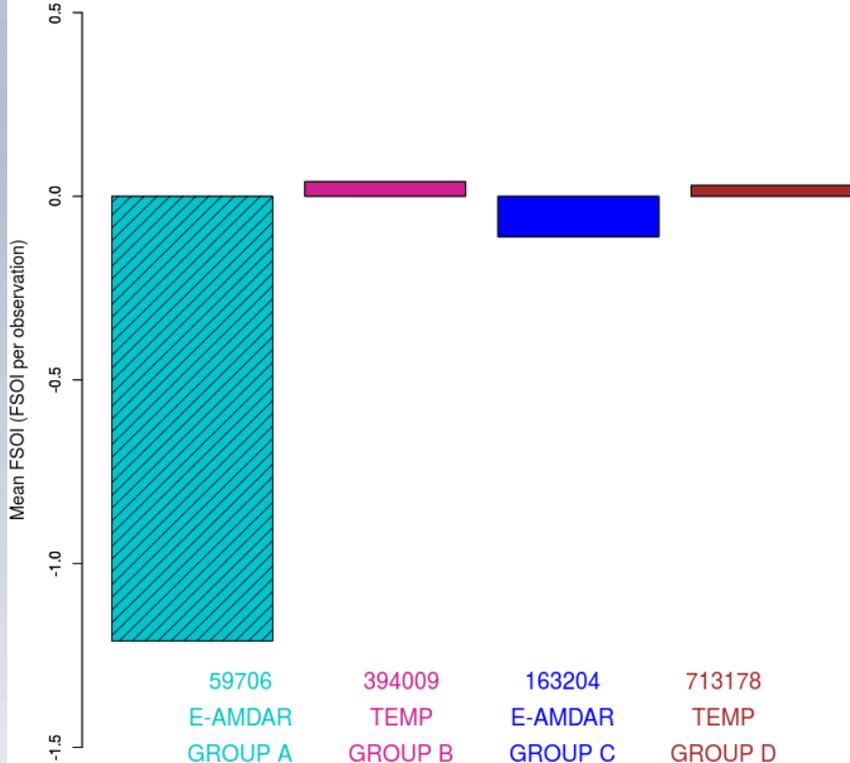
## Group D

Set of radiosonde stations where no airport is nearby:

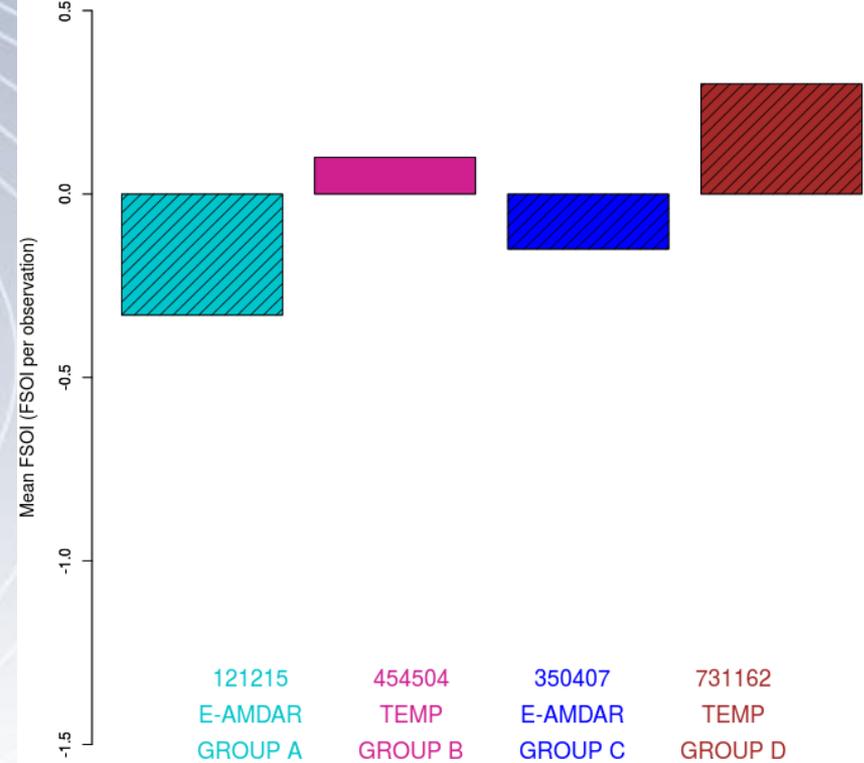
Idar-Oberstein:	10618
Meiningen:	10548
Sundsvall:	02365
Payerne:	06610
Protejow:	11747
Sodankyla:	02836
La Coruña:	08001
Brindisi:	16320



**Airport and radiosonde stations at 00 UTC**



**Airport and radiosonde stations at 12 UTC**



Mean FSOI for groups A, B, C and D at 00 and 12 UTC (when bar striped the result is statistically significant at the 95 % confidence level).

## **Main conclusions (Groups A, B, C and D)**

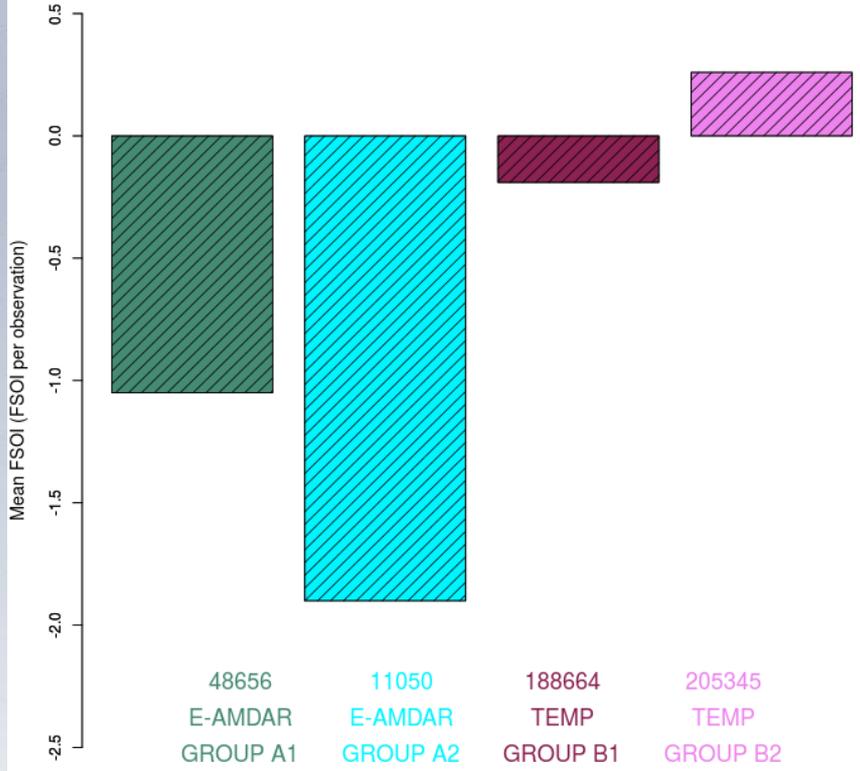
- 1. E-AMDAR humidity have had a clear overall beneficial forecast impact according to IFS FSOI statistics over the analyzed period (June 2016-November 2017)**
- 2. EUMETNET TEMP humidity observations have had an overall detrimental forecast impact over the analyzed period**

## ‘Conditional FSOI statistics’

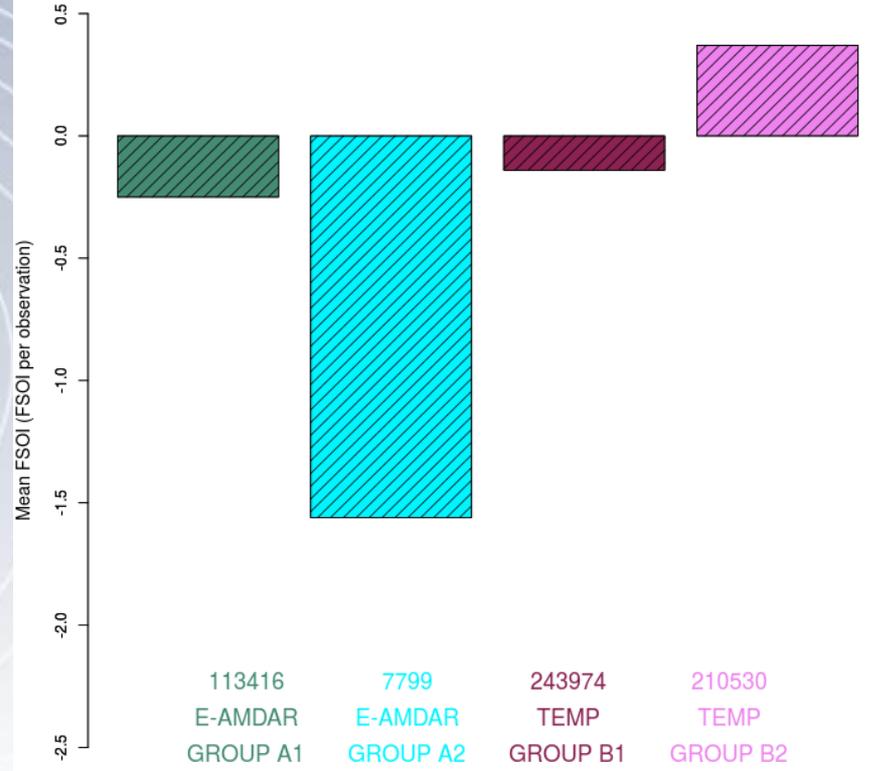
Group A1 (AMDAR)	Group A2 (AMDAR)	Group B1 (TEMP)	Group B2 (TEMP)
 <p data-bbox="255 996 548 1082">When AMDAR-q + TEMP-q assimilated</p>	 <p data-bbox="614 996 923 1082">When only AMDAR-q assimilated</p>	 <p data-bbox="973 996 1263 1082">When AMDAR-q + TEMP-q assimilated</p>	 <p data-bbox="1325 1016 1607 1102">When only TEMP-q assimilated</p>

- A1:** E-AMNDAR-q data for those days when TEMP-q data was also assimilated.
- A2:** E-AMNDAR-q data for those days when **TEMP-q data was NOT assimilated.**
- B1:** TEMP-q data for those days E-AMNDAR-q data was also assimilated.
- B2:** TEMP-q data for those days when **E-AMNDAR-q data was NOT assimilated.**

**Airport and radiosonde stations at 00 UTC**



**Airport and radiosonde stations at 12 UTC**

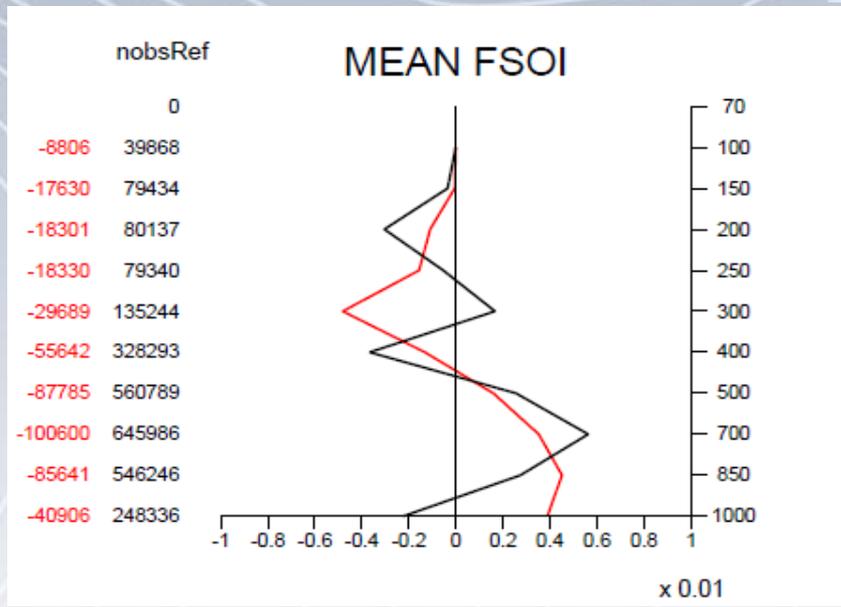
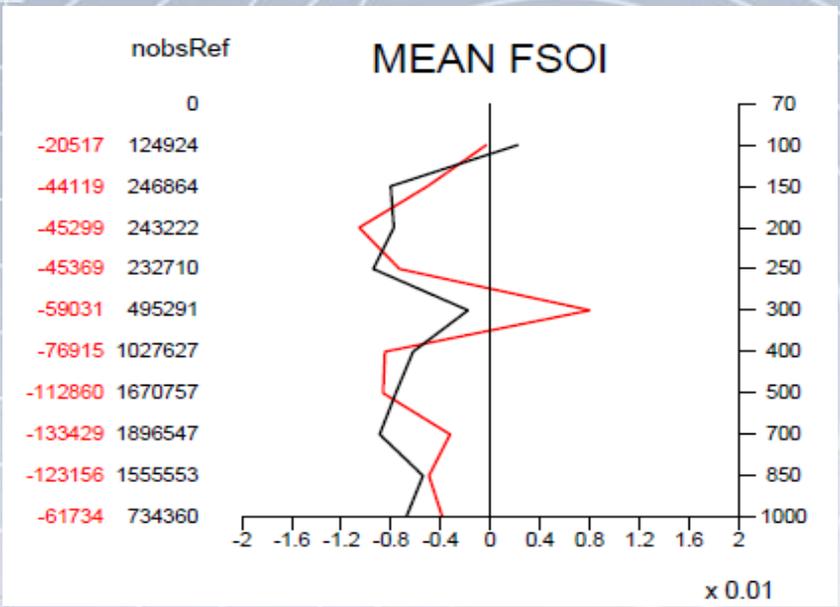


Mean FSOI for groups A1, A2, B1 and B2 at 00 and 12 UTC (when bar striped the result is statistically significant at the 95 % confidence level).

## **Main conclusions ('Conditional FSOI')**

**3. There is a very clear positive synergy of the joint assimilation of TEMP and E-AMDAR humidity observations**

Lars Isaksen (ECMWF) obtained FSOI statistics for Jan-May 2018 for TEMP and AMDAR observations, globally and for Europe



TEMP-q Globe

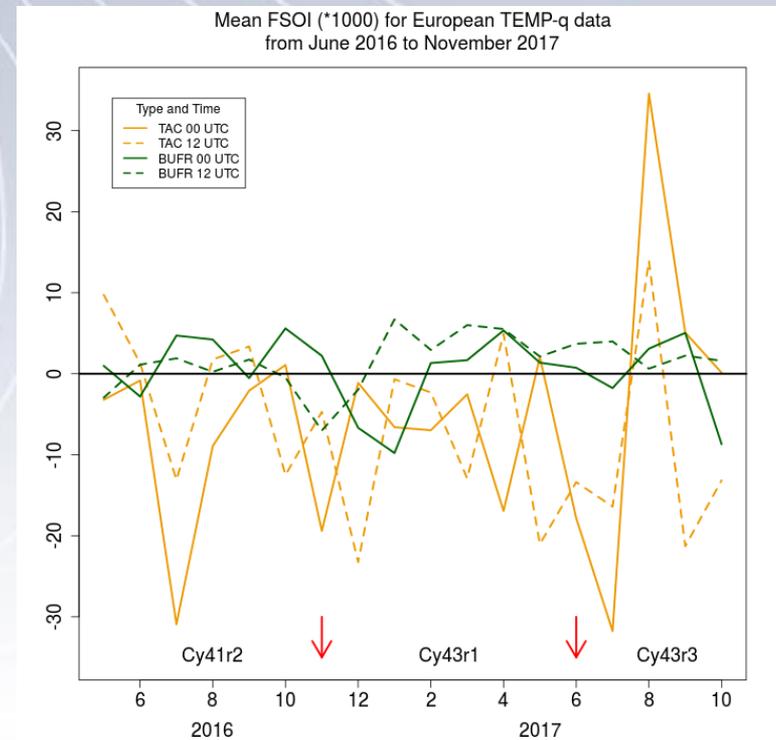
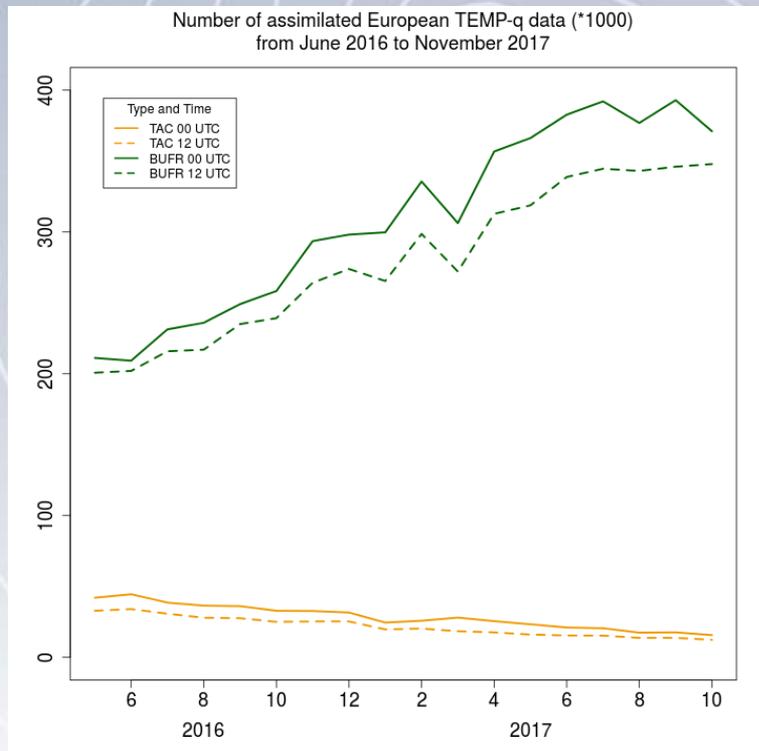
— Fc sensitivity (12UTC)  
 — Fc sensitivity (00UTC)

TEMP-q Europe

Globally radiosonde humidity is beneficial, but detrimental in Europe. Among other reasons, it has to be taken into account that whereas in Europe most TEMP-q data is exchanged encoded in BUFR format, it is very likely that TAC encoding still dominates globally.

# Influence of change of TEMP encoding format (TAC ot BUFR).

The number of assimilated TEMP-q observations encoded in TAC/BUFR has show and steady growth/decrease until July 2017.



**TAC:** Positive impact, larger at 00 UTC (not statistically significant)  
**BUFR:** Negative impact, larger at 12 UTC (statistically significant at 12 UTC).

### **3) Assimilation of E-AMDAR humidity in HARMONIE-AROME**

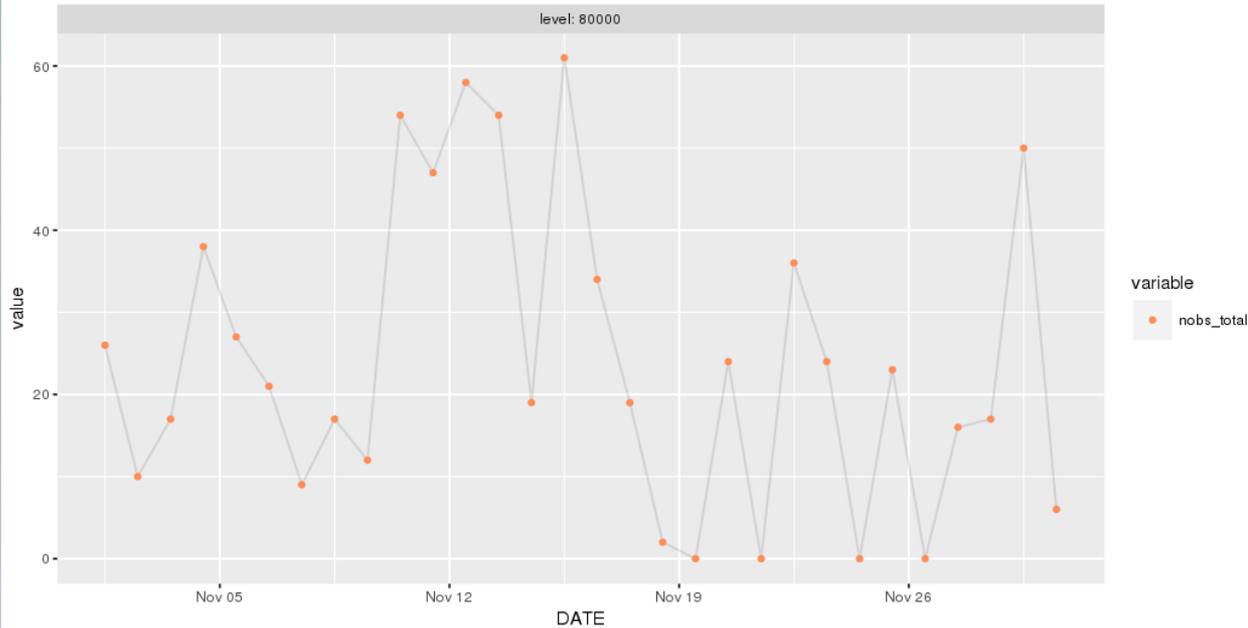
## Control Experiment **AIB\_40h111**

- Model version 40h1.1.1
- Resolution: 2.5 km and 65 levels
- Domain: Iberia
- Boundaries: ECMWF BC every hour
- DA Cycle: 3 hours
- DA upper air: 3D-Var, only conventional obs.
- Forecast length: 12 hours (00, 06, 12 and 18 UTC)

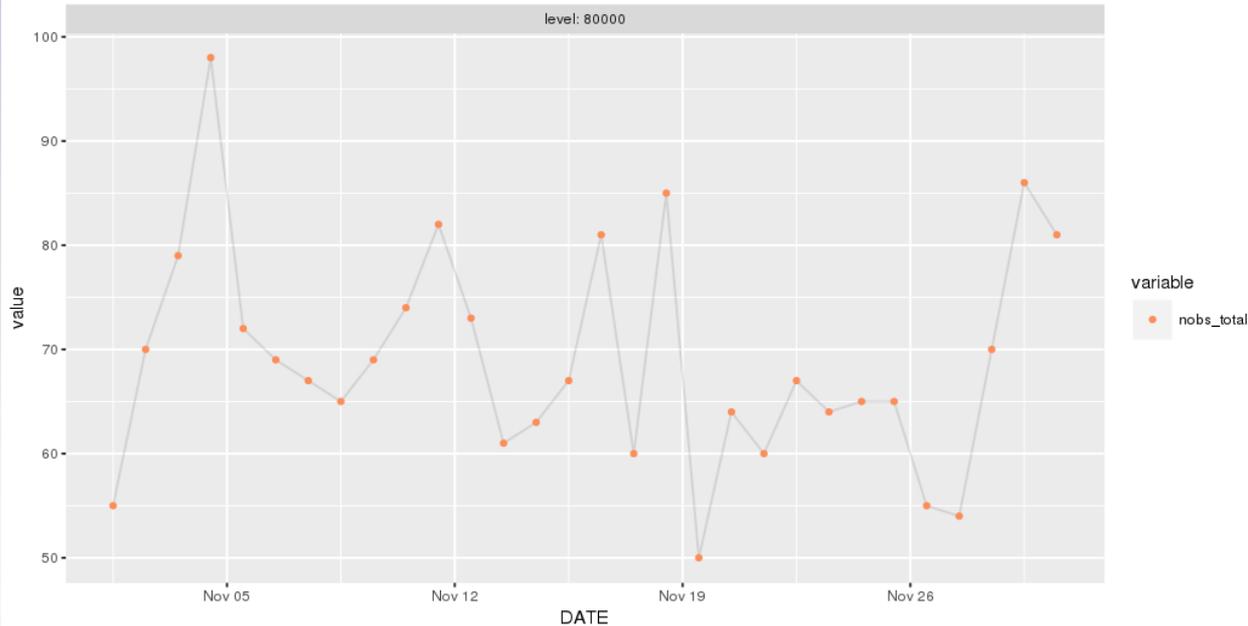
Experiment **AIB\_40h111\_q**: Control + AMDAR-q  
assimilation

Period: 1st to 30th November 2018

AIB\_40h111\_q: Number of Observations aircraft q [2018-11-01–2018-11-30, (12)]

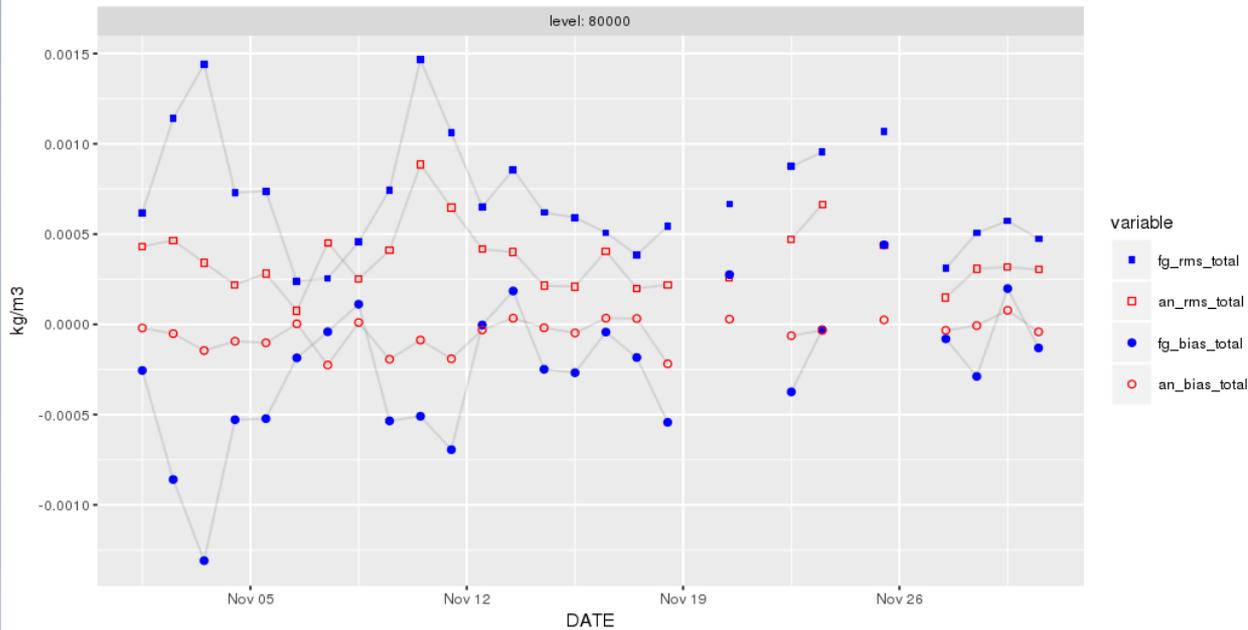


AIB\_40h111\_q: Number of Observations temp q [2018-11-01–2018-11-30, (12)]



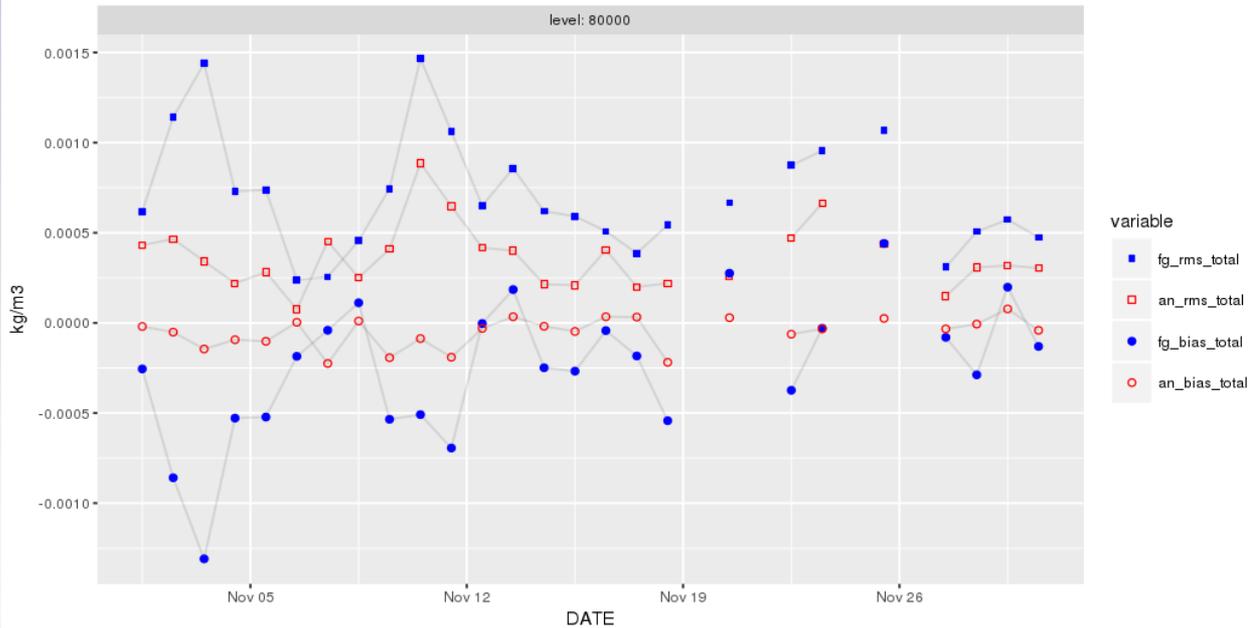
Number of observations for for AMDAR-q (top) and TEMP-q (bottom) observations around 800 hPa at 12 UTC.

AIB\_40h111\_q: ObsFit aircraft q [2018-11-01–2018-11-30, (12)]



Bias (circles) and RMS (squares) FG (blue) and AN (red) departures for AMDAR-q (top) and TEMP-q (bottom) observations around 800 hPa at 12 UTC.

AIB\_40h111\_q: ObsFit aircraft q [2018-11-01–2018-11-30, (12)]

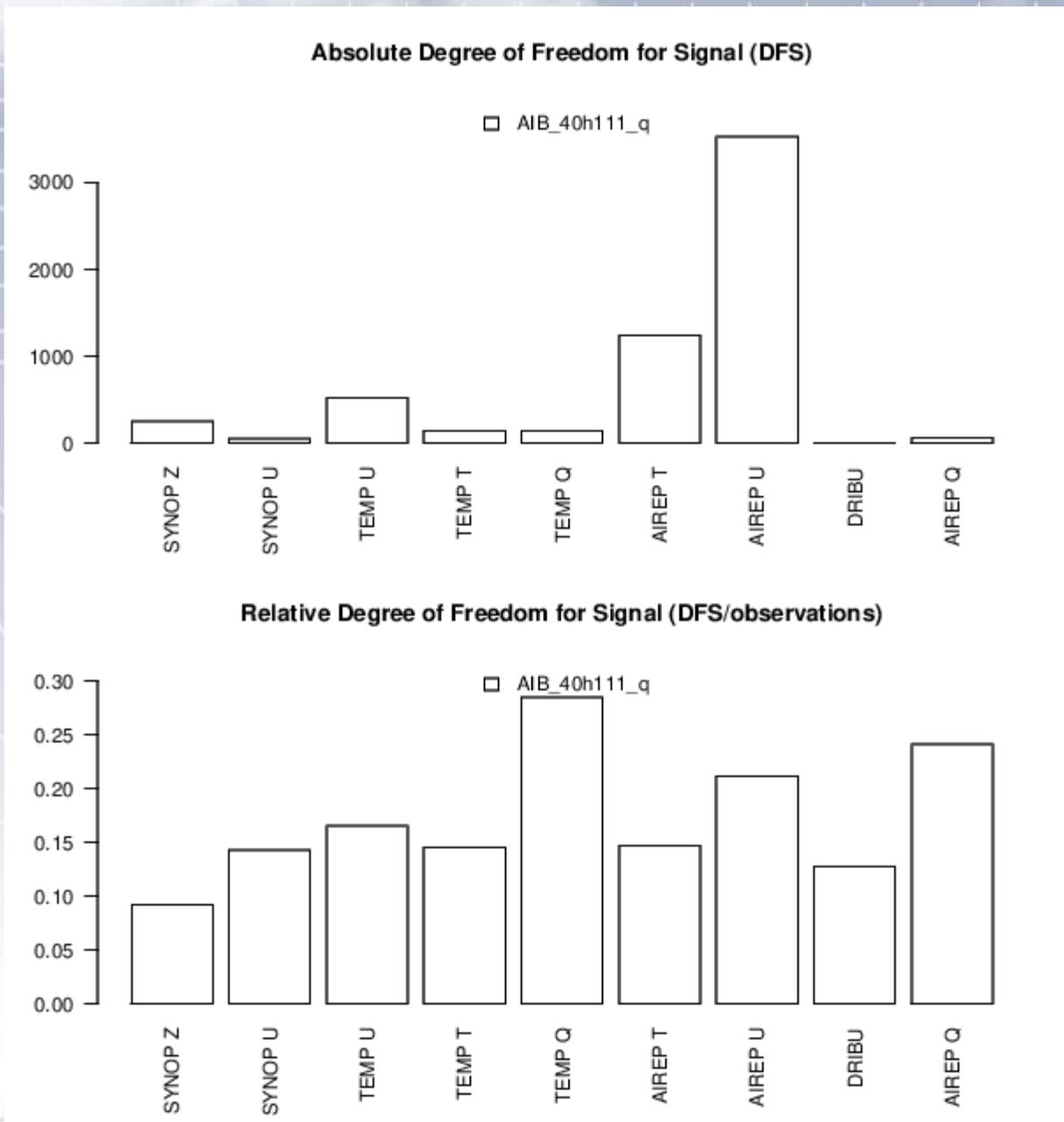




# Degrees of freedom for signals

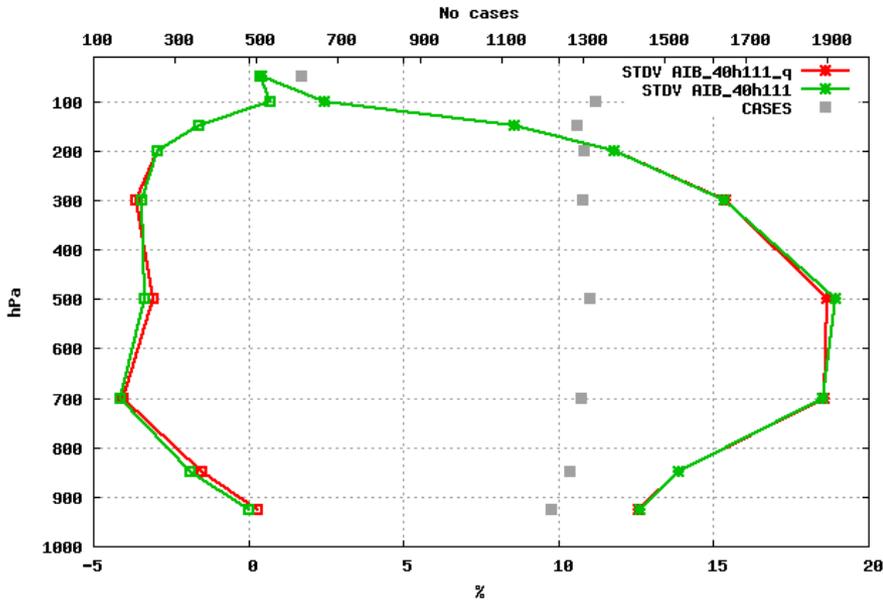
**DFS** is a diagnostic tool to evaluate the impact of observations on the analyses.

15 Nov 2018  
(00 to 21 UTC)

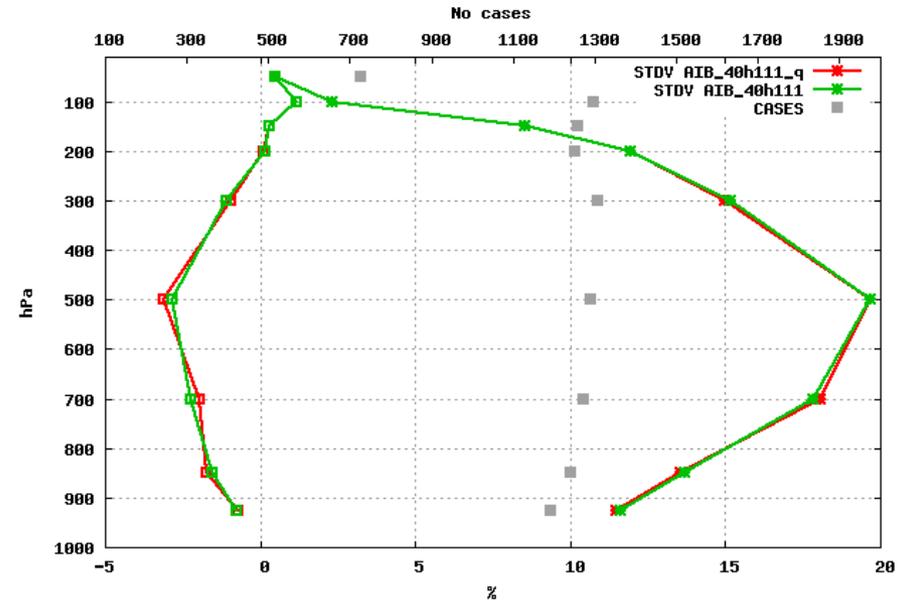


# Verification

15 stations Selection: ALL  
Relative Humidity Period: 20181101-20181127  
Statistics at 00 UTC Used {00,12,18,21} + 00 03 06 12



16 stations Selection: ALL  
Relative Humidity Period: 20181101-20181127  
Statistics at 12 UTC Used {00,06,09,12} + 00 03 06 12



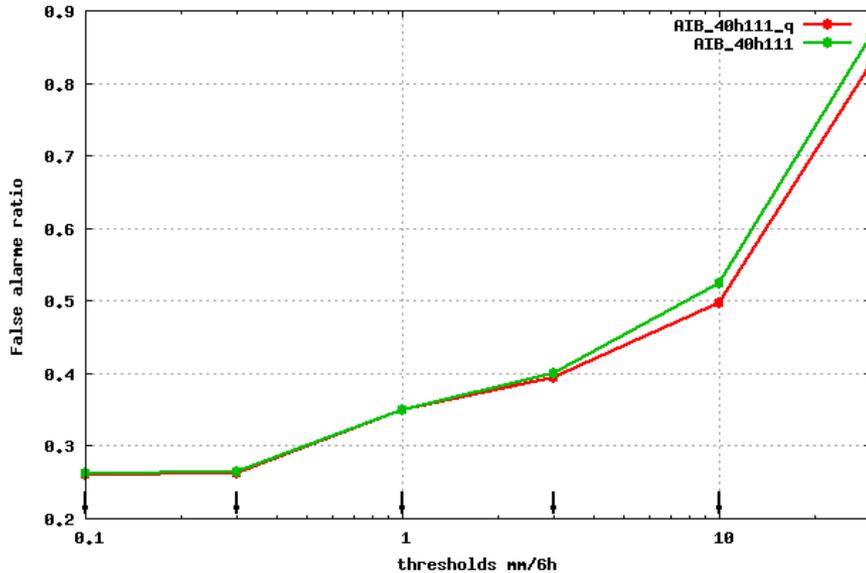
Vertical profiles: Bias and Stdv for RH (%) at 00 UTC (left) and 12 UTC( right).

AMDAR-q exp (AIB\_40h111\_q)

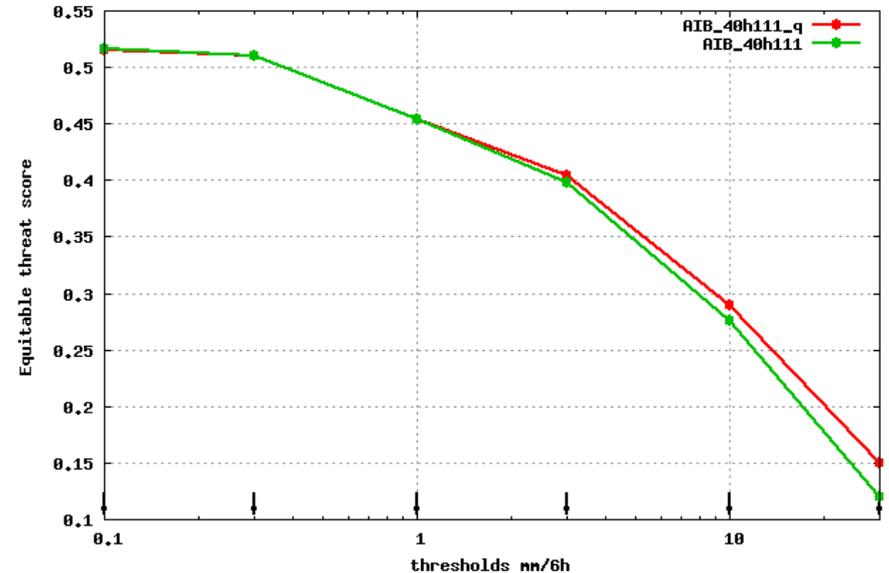
CONTROL (AIB\_40h111)

# Verification

False alarm ratio for 6h Precipitation (mm/6h)  
Selection: ALL 450 stations  
Period: 20181101-20181127  
Used {00,06,12,18} + 06-00 09-03 12-06



Equitable threat score for 6h Precipitation (mm/6h)  
Selection: ALL 450 stations  
Period: 20181101-20181127  
Used {00,06,12,18} + 06-00 09-03 12-06



6h precipitation (mm/6h): False Alarm Ratio (left) and Equitable Threat Score (right).

AMDAR-q exp (AIB\_40h111\_q)

CONTROL (AIB\_40h111)

## Results and further work

- The assimilation of E-AMDAR humidity have had a clear overall beneficial impact on IFS-ECMWF short-range forecasts.
- Preliminary tests in HARMONIE-AROME shows that the assimilation of EMDAR-q has an overall neutral impact.
- A basic HARMONIE-AROME setup was used as Control, where only TEMP-q data as humidity observation was included.

## Results and further work

- The present AEMET operational run assimilates GNSS and ATOVS radiances, and in the very near future radar reflectivities will also be assimilated. New tests with this improved setup are planned.
- E-AMDAR-q might be also usefull as anchoring for other biased humidity observations (as GNSS and ATOVS).

Thank you for your attention!!

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