# Data assimilation of Mode-S MRAR over Slovenia

Benedikt Strajnar

# Outline

- Types of Mode-S data
- Preprocessing
- Impact experiments
- Conclusions

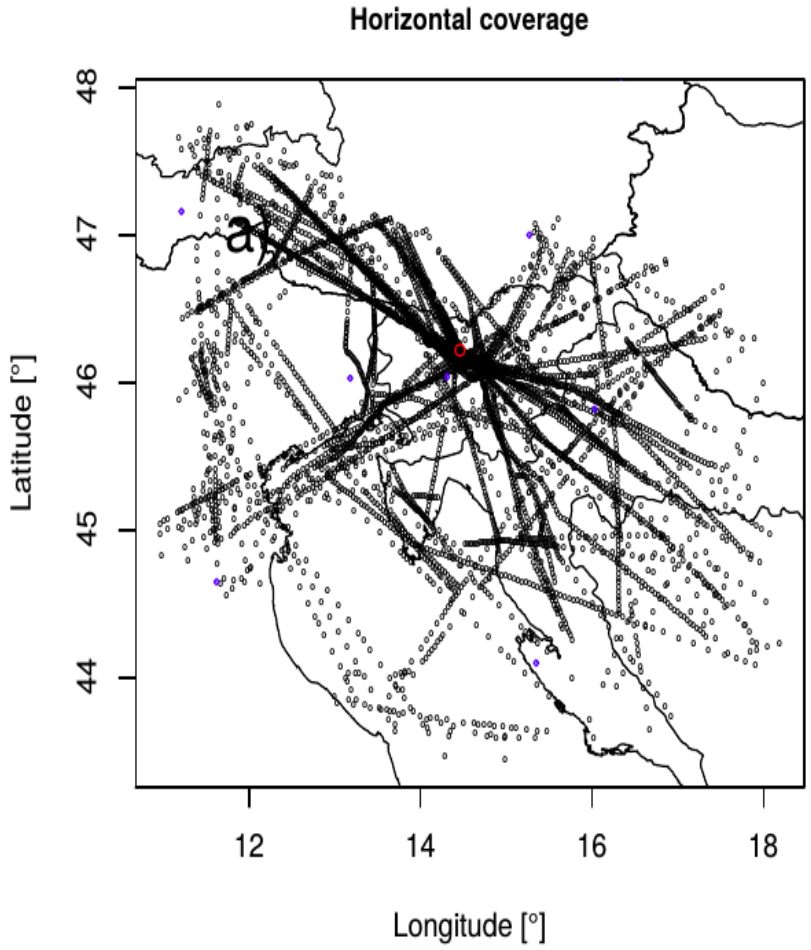
# Mode-S system

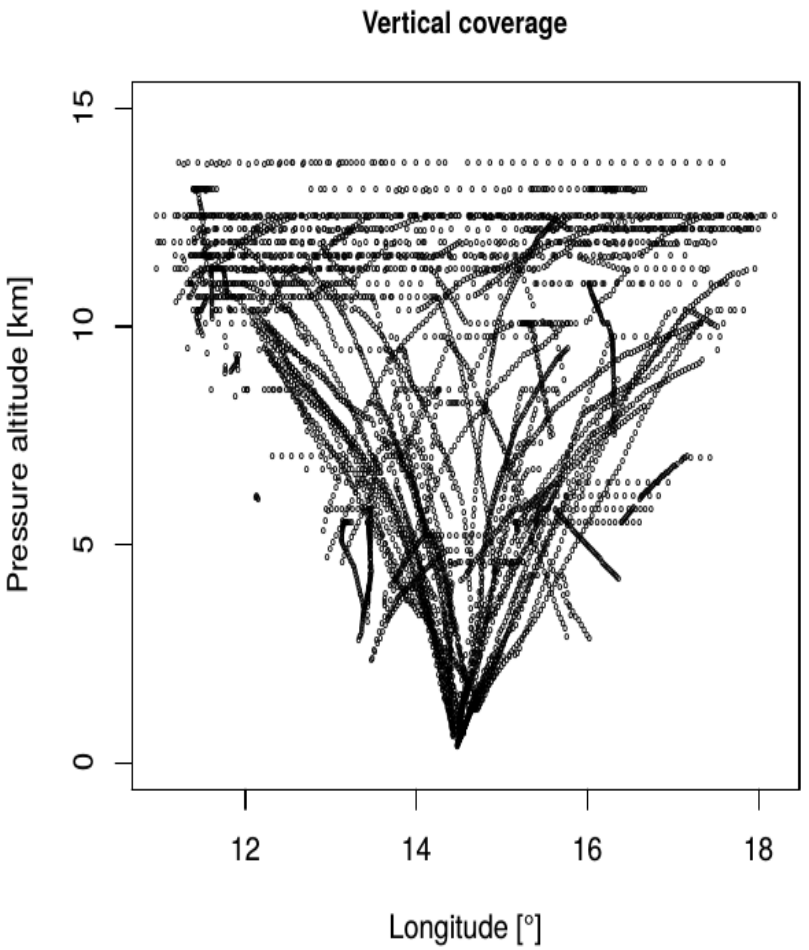
- Primary radars (a pulse is reflected back by the aircraft, enabling its position to be computed)
- Secondary radars (a transponder on board the aircraft transmits its identity, as well as the aircraft's altitude)
- Mode-S: selective communication between airframe and ground station (possibility to transmit data)

# Types of Mode-S met. data

| | MODE-S MRAR<br>*Meteorological routine air report* | MODE-S EHS<br>*Enhanced surveilance (reports)* |
|---|---|---|
| name | | |
| data | ▫ (BDS 4,4) – met. routine air report wind speed, direction, temperature turbulence, humidity<br>▫ (BDS 4,5) – met. hazard report (turbulence, wind shear,microburst,icing) | ▫ (BDS 4,0) selected vertical intent ( selected altitude)<br>▫ (BDS 5,0) track and turn report - roll angle, true track angle and rate, ground speed and true air speed<br>▫ (BDS 6,0) heading and speed report indicated air speed and mach, barometric altitude rate, magnetic heading |
| type | Direct data | Indirect (temperature) data |
| rep. by | around 5 % of all Mode-S equipped aircraft (depends on transponder configuration) | all Mode-S equipped aircraft |
| | *Strajnar 2012, Hrastovec and Solina 2013* | *de Hann 2011, de Haan and Stoffelen 2012* |

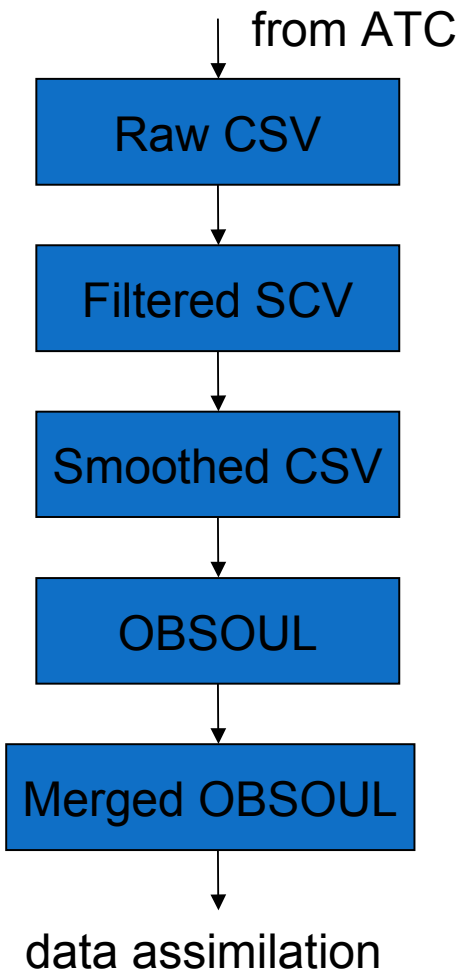
# Example data set



# Preprocessing and quality control

- Temporal smoothing (12s / 60 s)
- Whitelist approach
  - Generated from comparison of Mode-S with operational NWP over a period of 22 months
  - Airplanes with high mean or sd with respect to model flagged
- Coding to OBSOUL format



# Statistics per aircraft type

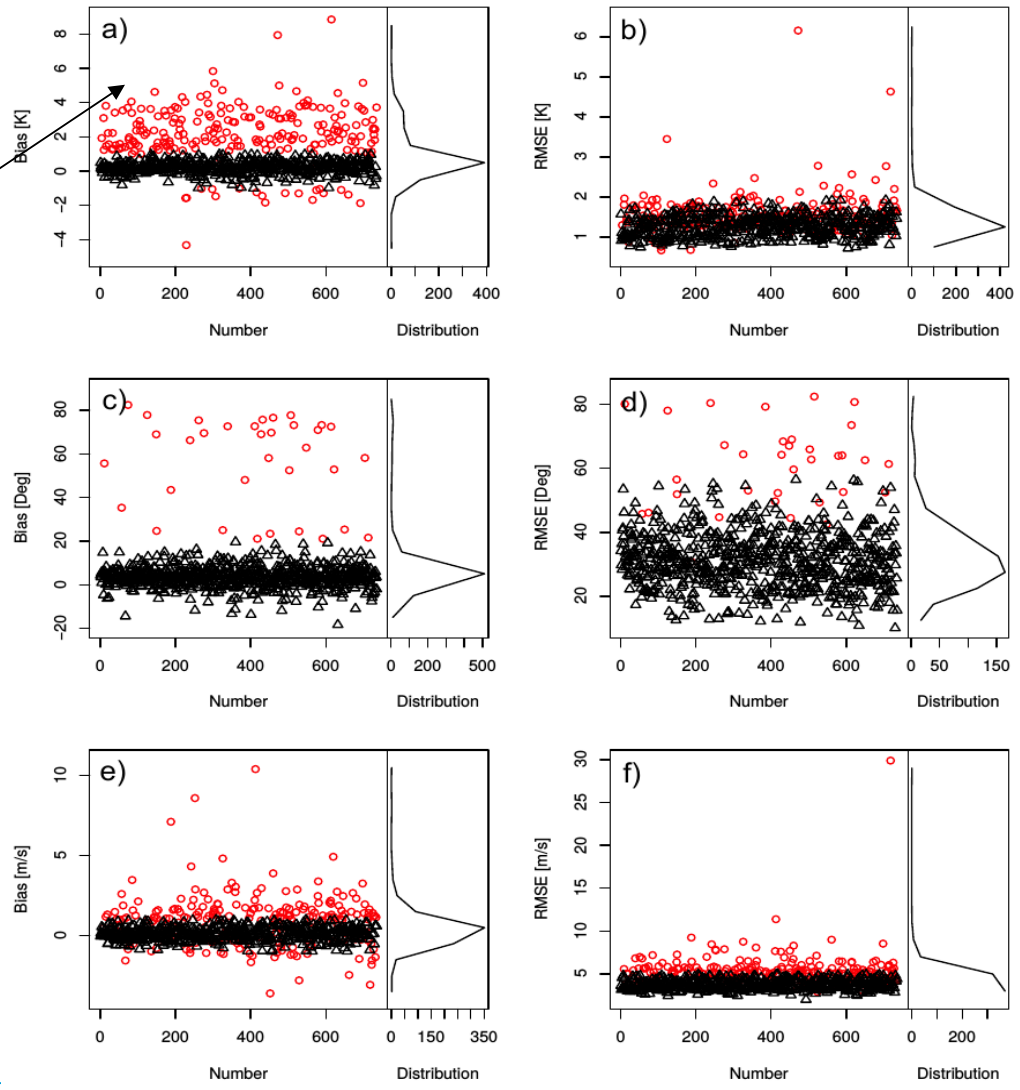
**Table 2.** Statistics of Mode-S - NWP comparison by aircraft types with frequently available observations.

| Aircraft type | Temperature [K] | | | Wind speed [m/s] | | | Wind directio | |
|---|---|---|---|---|---|---|---|---|
| | mean | std | $N_{used}/N_{rej}$ | mean | std | $N_{used}/N_{rej}$ | mean | std |
| AMD-BA Falcon 2000 | -0.061 | 1.400 | 10/0 | -0.415 | 3.739 | 9/1 | 5.821 | 27.269 |
| Bombardier BD100 Challenger 300 | 0.490 | 1.372 | 10/0 | 0.268 | 4.386 | 4/6 | 7.137 | 35.853 |
| Bombardier Challenger 300 | 0.326 | 1.417 | 38/0 | 0.038 | 4.306 | 27/11 | 2.593 | 31.805 |
| Canadair CL604 Challenger | 0.259 | 1.224 | 39/2 | 0.161 | 3.533 | 41/0 | 4.117 | 27.223 |
| Canadair CL605 Challenger | 0.312 | 1.335 | 36/0 | 0.136 | 3.622 | 35/1 | 4.431 | 28.421 |
| Canadair CRJ-200 | 0.057 | 1.028 | 46/0 | 0.145 | 3.378 | 37/9 | 5.721 | 40.302 |
| Canadair CRJ-700 | 0.141 | 1.037 | 20/1 | 0.004 | 3.391 | 20/1 | 3.996 | 29.569 |
| Canadair CRJ-700 Regional Jet | 0.049 | 0.909 | 16/0 | -0.048 | 3.131 | 16/0 | 5.076 | 31.747 |
| Canadair CRJ-900 | 0.100 | 1.041 | 71/0 | 0.107 | 3.266 | 63/8 | 5.085 | 36.678 |
| Cessna 525A CitationJet CJ2+ | 3.428 | 1.713 | 0/7 | 0.396 | 4.095 | 5/2 | 0.809 | 37.204 |
| Cessna 525B CitationJet CJ3 | 3.784 | 1.568 | 0/33 | 0.293 | 4.258 | 23/10 | 3.921 | 34.329 |
| Cessna 560XL Citation XLS+ | -0.580 | 1.431 | 11/0 | 0.214 | 4.158 | 7/4 | 2.959 | 31.760 |
| Dassault Falcon 2000 | 0.022 | 1.375 | 15/0 | 0.182 | 3.535 | 15/0 | 3.557 | 27.588 |
| Dassault Falcon 900EX | -1.002 | 1.359 | 4/7 | 0.048 | 3.316 | 11/0 | 3.796 | 28.209 |
| Gulfstream G150 | 1.326 | 1.342 | 2/6 | 0.109 | 5.184 | 2/6 | -0.783 | 31.649 |
| Gulfstream G200 Galaxy | 0.074 | 1.332 | 24/0 | 0.439 | 5.099 | 8/16 | 1.468 | 35.451 |
| Gulfstream IV | 1.307 | 1.607 | 3/6 | -0.034 | 3.860 | 8/1 | 1.740 | 26.944 |
| Hawker 750 | 2.168 | 1.456 | 1/12 | 0.505 | 4.737 | 9/4 | 3.670 | 31.924 |
| Hawker 800XP | 2.861 | 1.586 | 3/28 | 0.378 | 4.681 | 16/15 | 3.255 | 33.753 |
| Hawker 800XPi | 1.975 | 1.382 | 1/7 | 0.889 | 5.039 | 3/5 | 6.119 | 37.918 |
| Hawker 850XP | 1.882 | 1.484 | 2/11 | 0.170 | 4.459 | 7/6 | 5.240 | 34.553 |
| Hawker 900XP | 3.021 | 1.514 | 0/21 | 0.883 | 4.940 | 7/14 | 2.699 | 31.120 |
| Learjet 60 | 0.548 | 1.379 | 45/0 | 0.425 | 5.023 | 15/30 | 28.093 | 44.253 |
| Raytheon 390 Premier | 0.403 | 1.890 | 12/6 | 1.831 | 5.753 | 3/15 | 5.122 | 39.245 |
| Saab 2000 | 1.529 | 0.883 | 2/7 | -0.263 | 3.593 | 9/0 | 2.101 | 29.730 |
| type not determined | 1.107 | 1.596 | 20/15 | 0.637 | 4.425 | 19/16 | 5.479 | 33.296 |

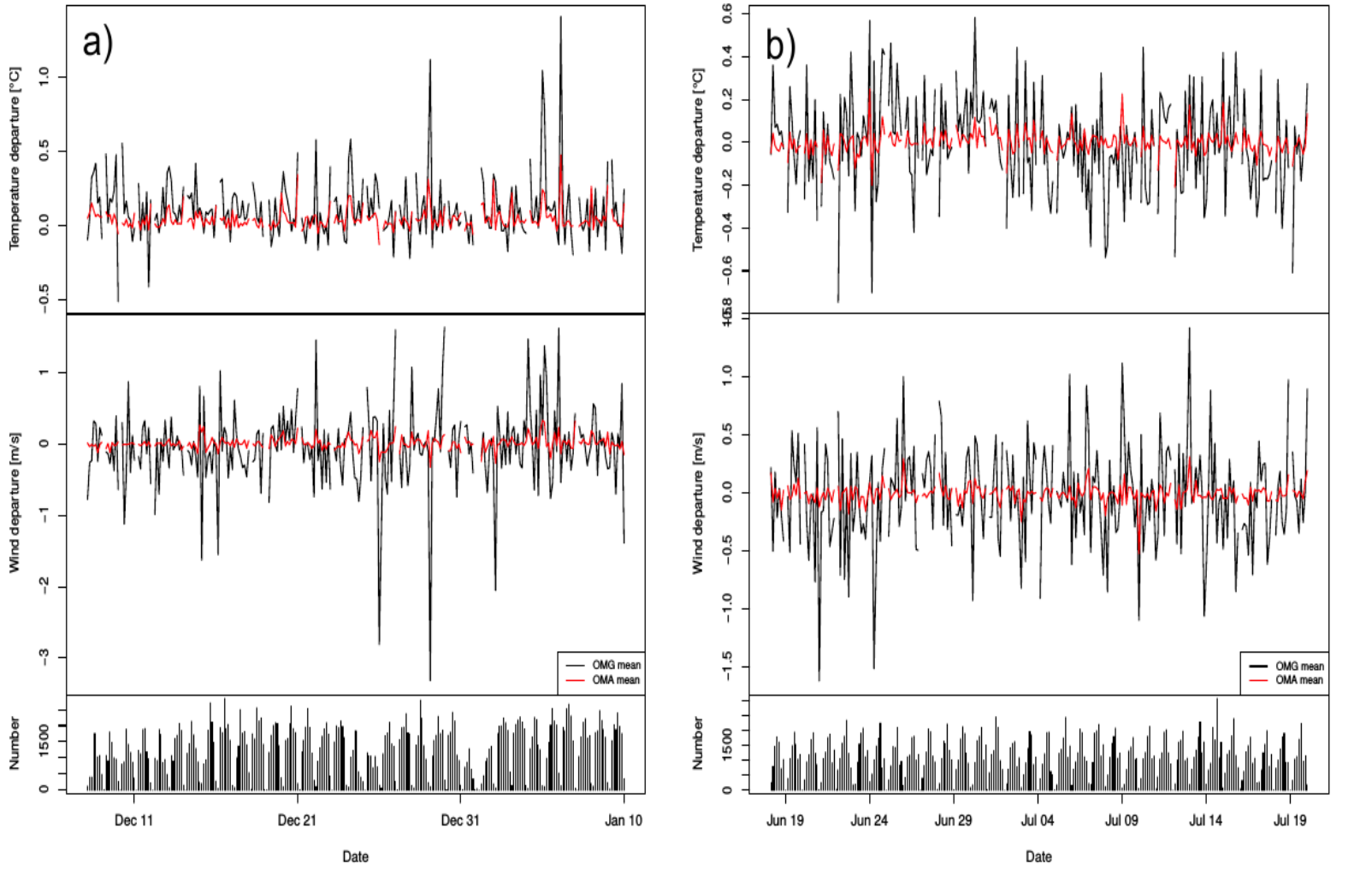
[a] Only aircraft types with at least five different aircraft in the database are shown.

# Quality evaluation

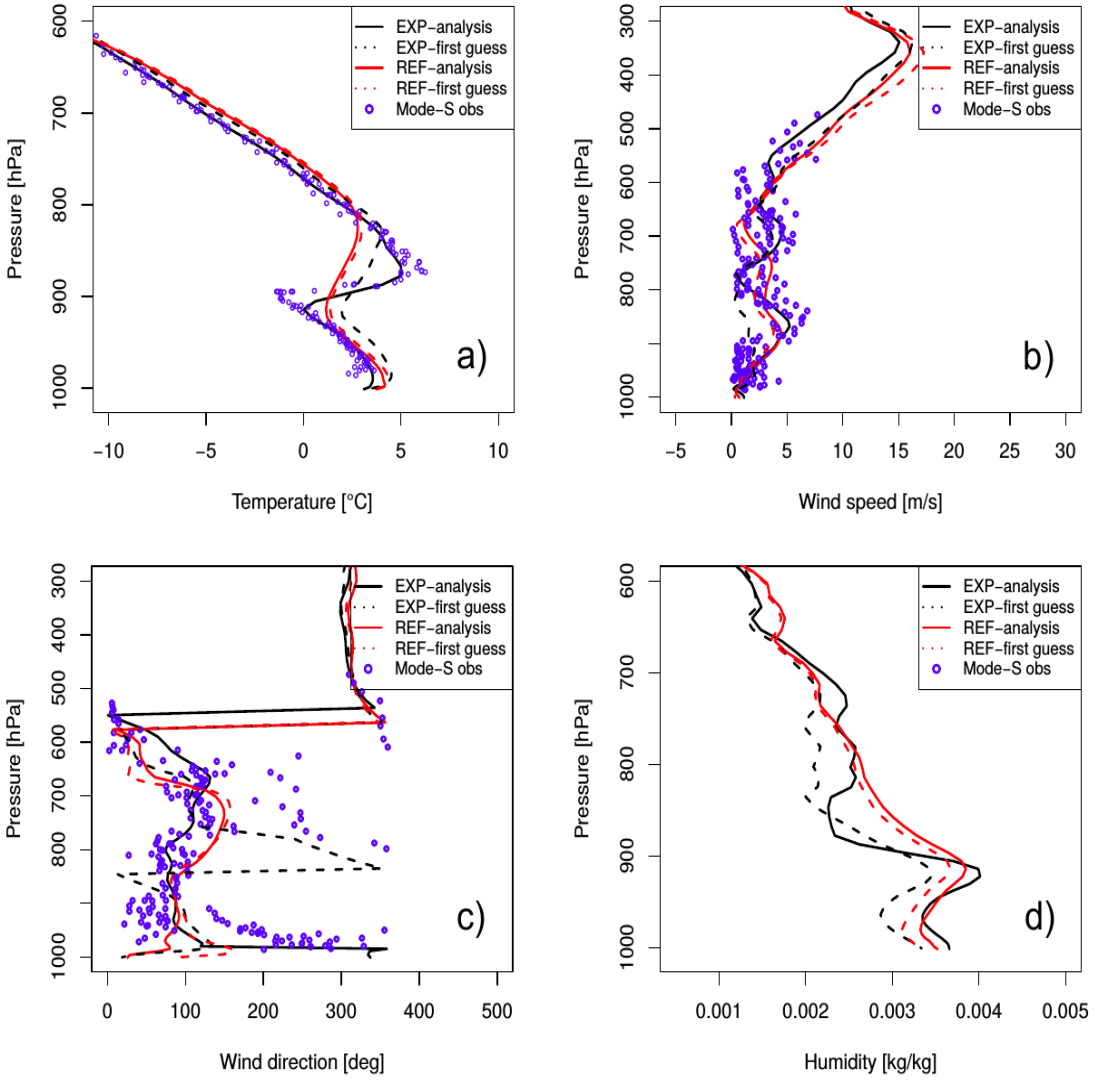
Warm temperature bias



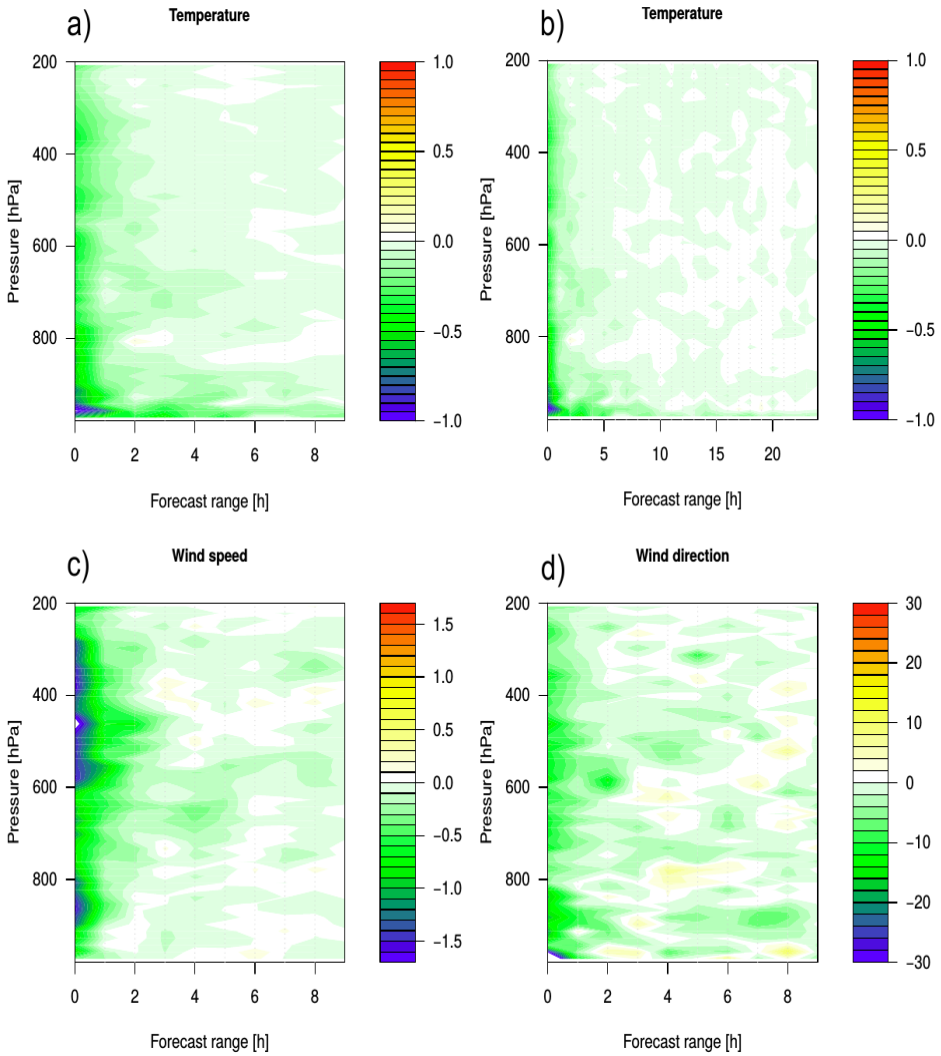
# OMG statistics - mean



# Winter – vertical profiles

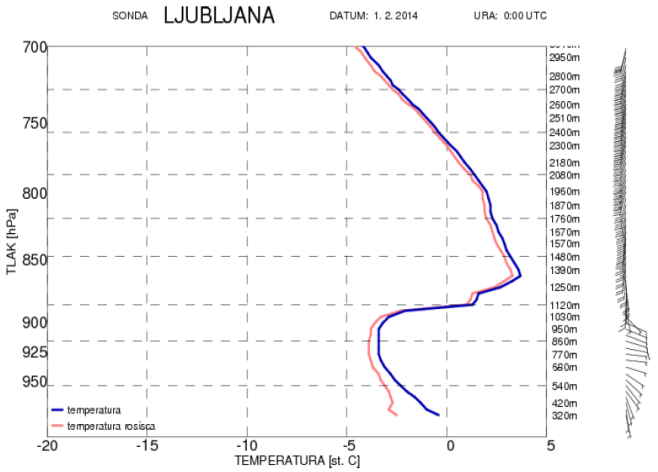


# Winter - scores

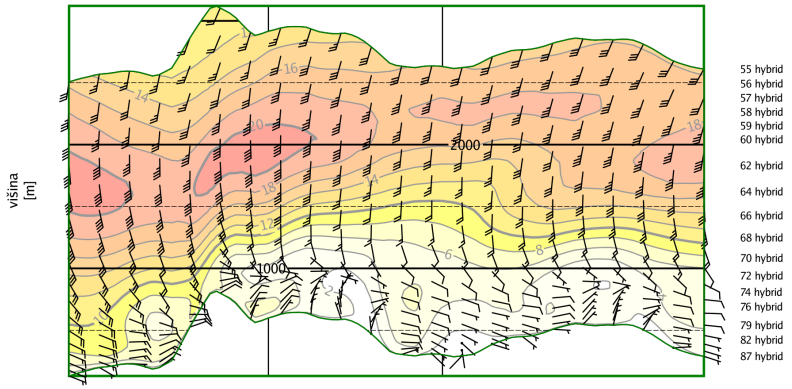


# Severe freezing rain case

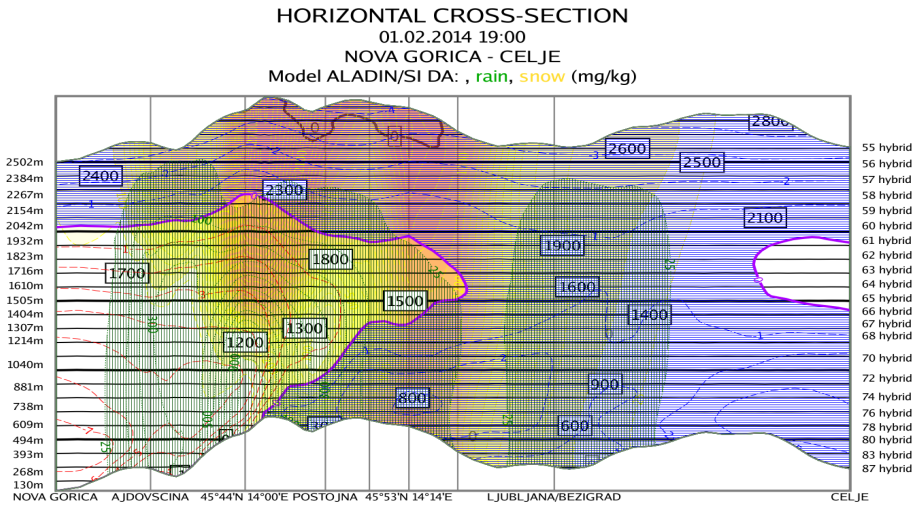
- end of January 2014



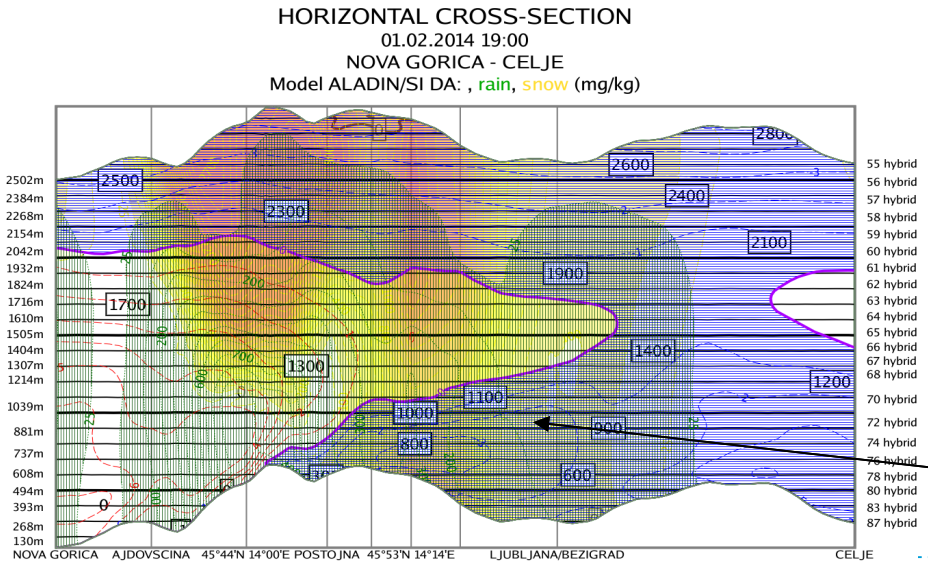

VERTIKALNI KRAJEVNI PRESEK
01.02.2014 06:00
Napoved modela ALADIN/SI DA: hitrost vetra (m/s), horizontalni veter



# Severe freezing rain case




Without Mode-S




With Mode-S

Freezing rain

# Summer front

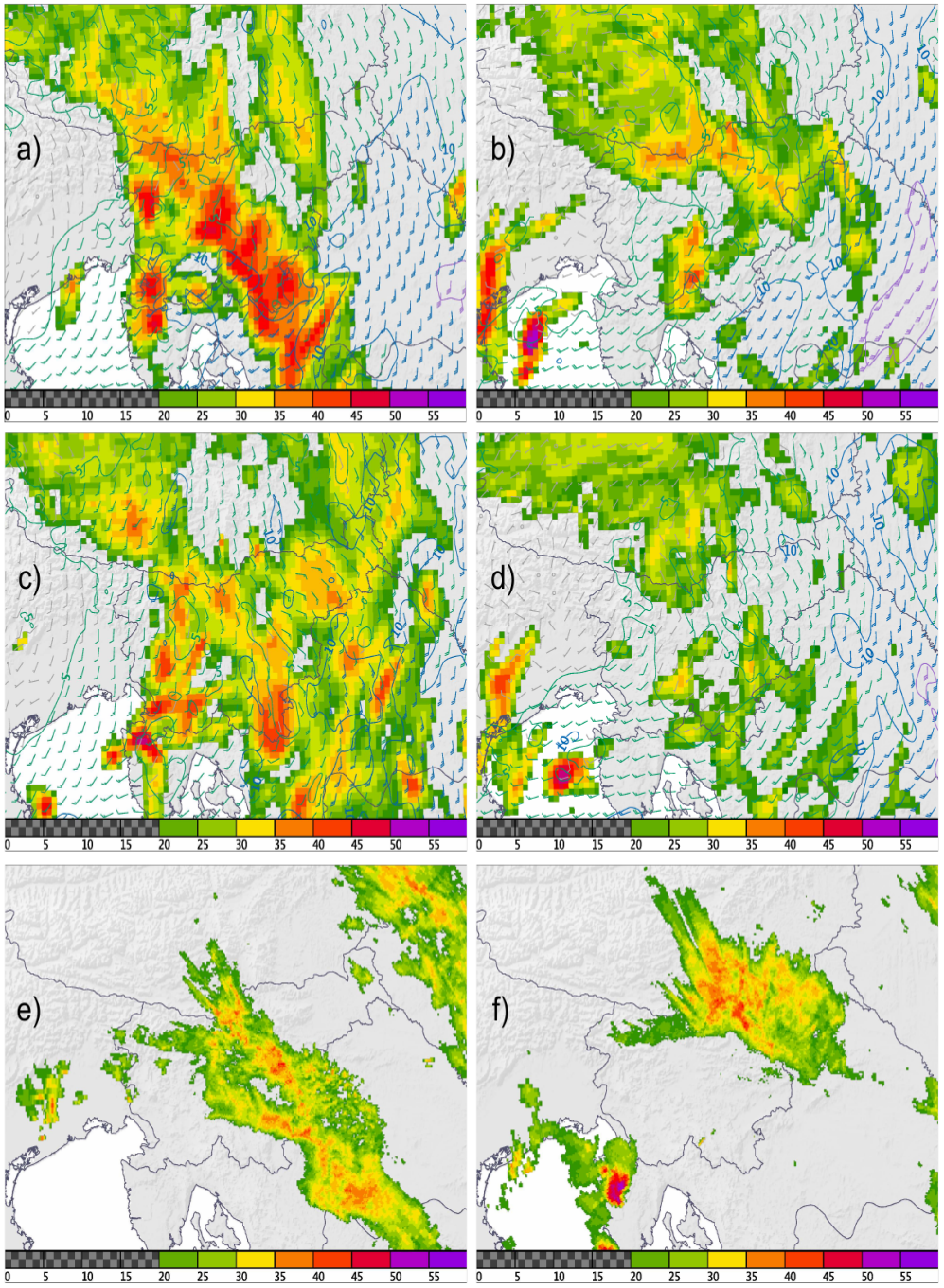
2013-07-24 12 UTC

2013-07-24 15 UTC

With Mode-S

Without Mode-S

Radar

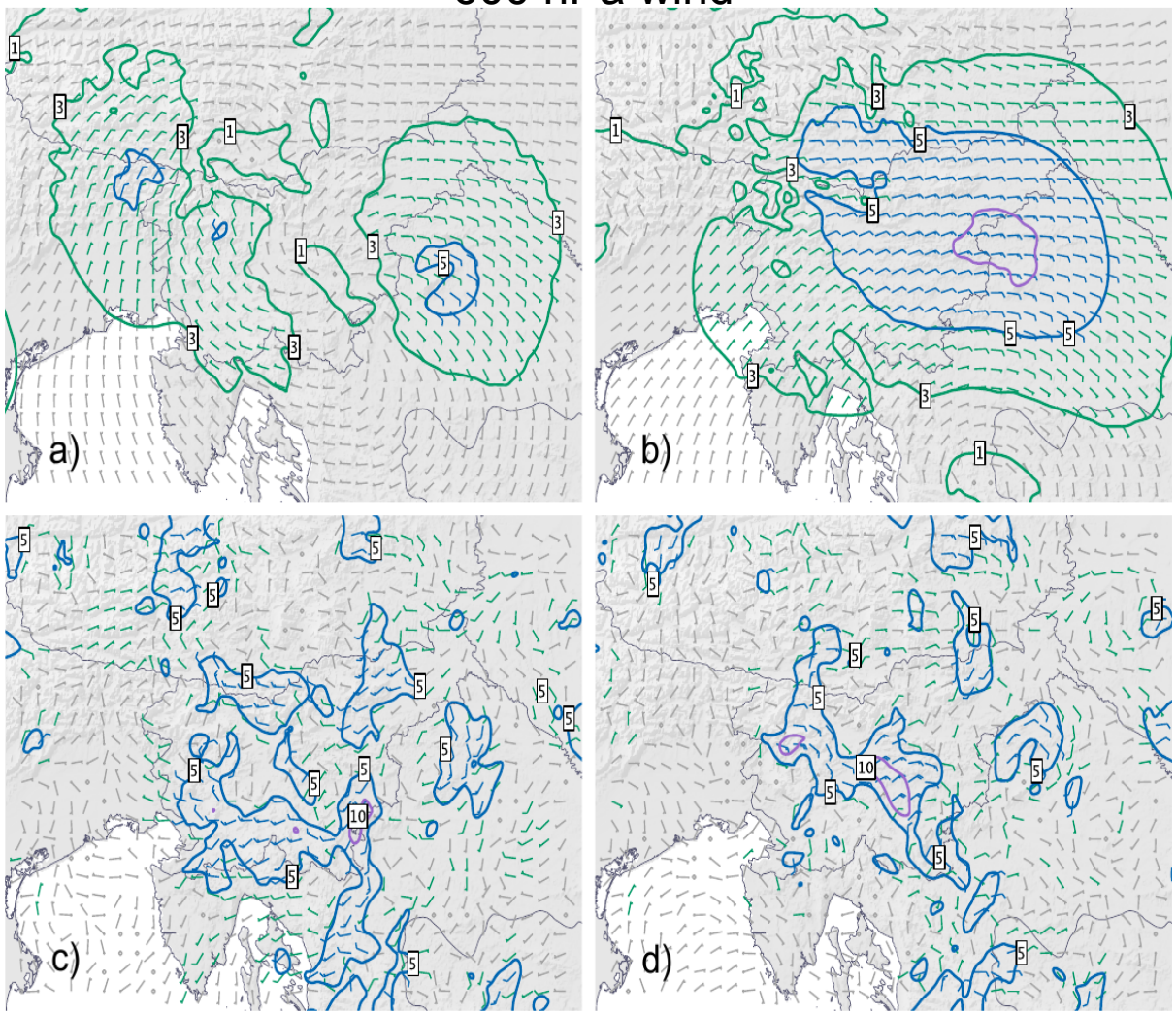


# Summer front (wind)

600 hPa wind

EXP Increment With Mode-S

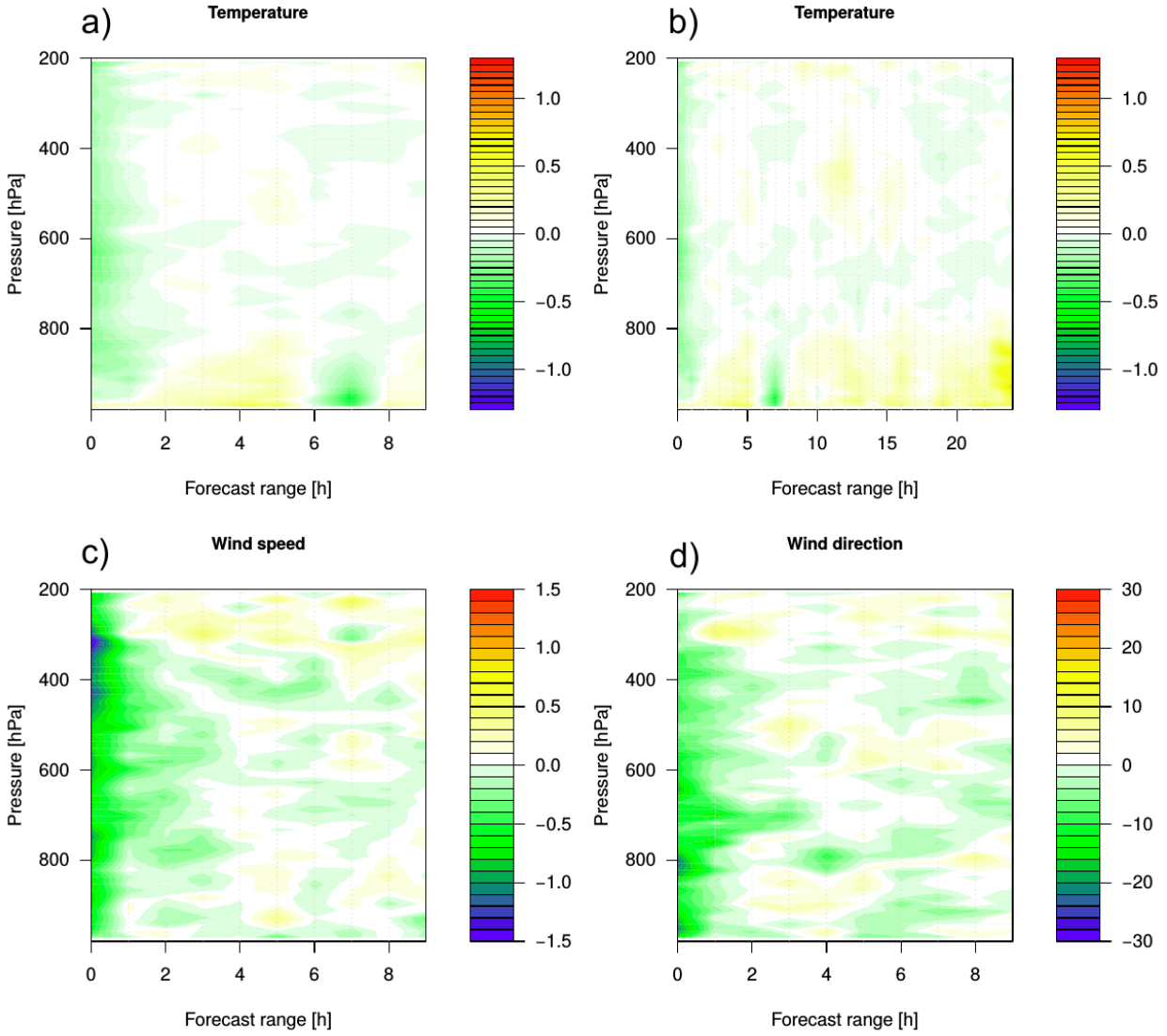
REF Increment Without Mode-S




Difference between analyses

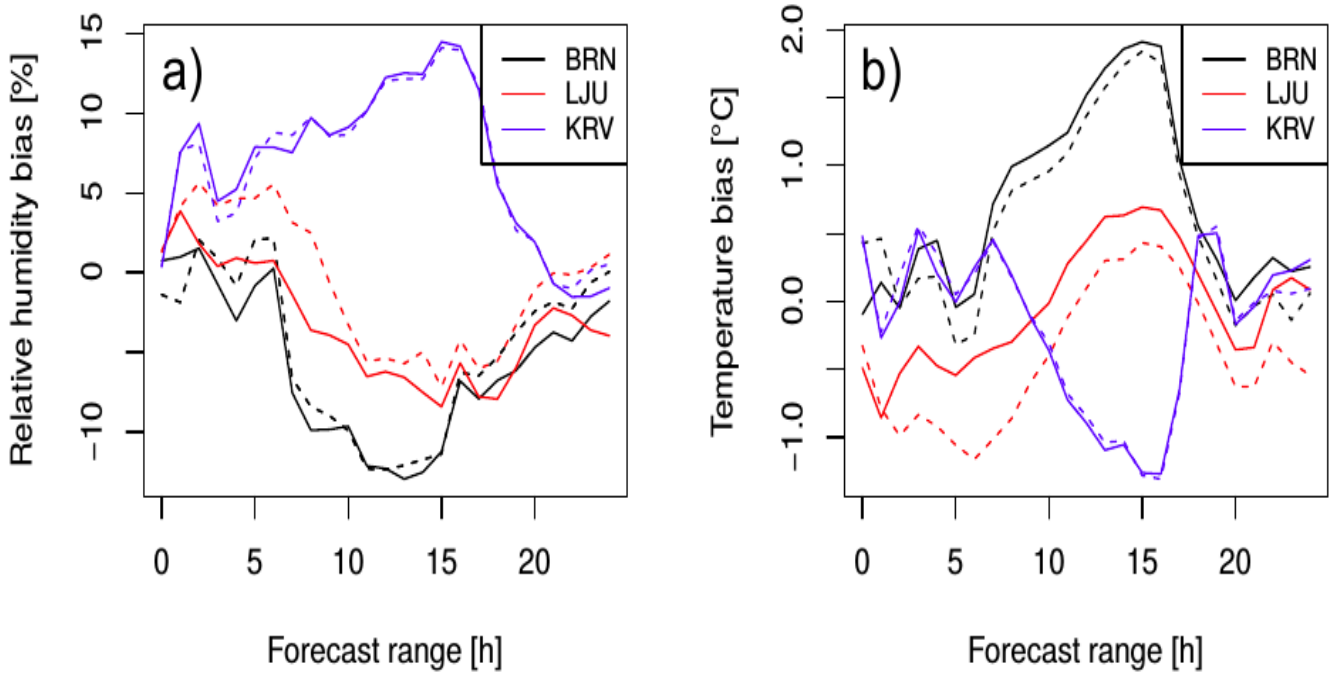
Difference between first guesses

# Summer scores



# PBL biasses

- Biases observed in station in the Ljubljana basin - Mode-S experiment systematically drier and warmer.



# Humidity analysis

- Multivariate links in B-matrix between humidity and other variables

$$\zeta = \zeta$$

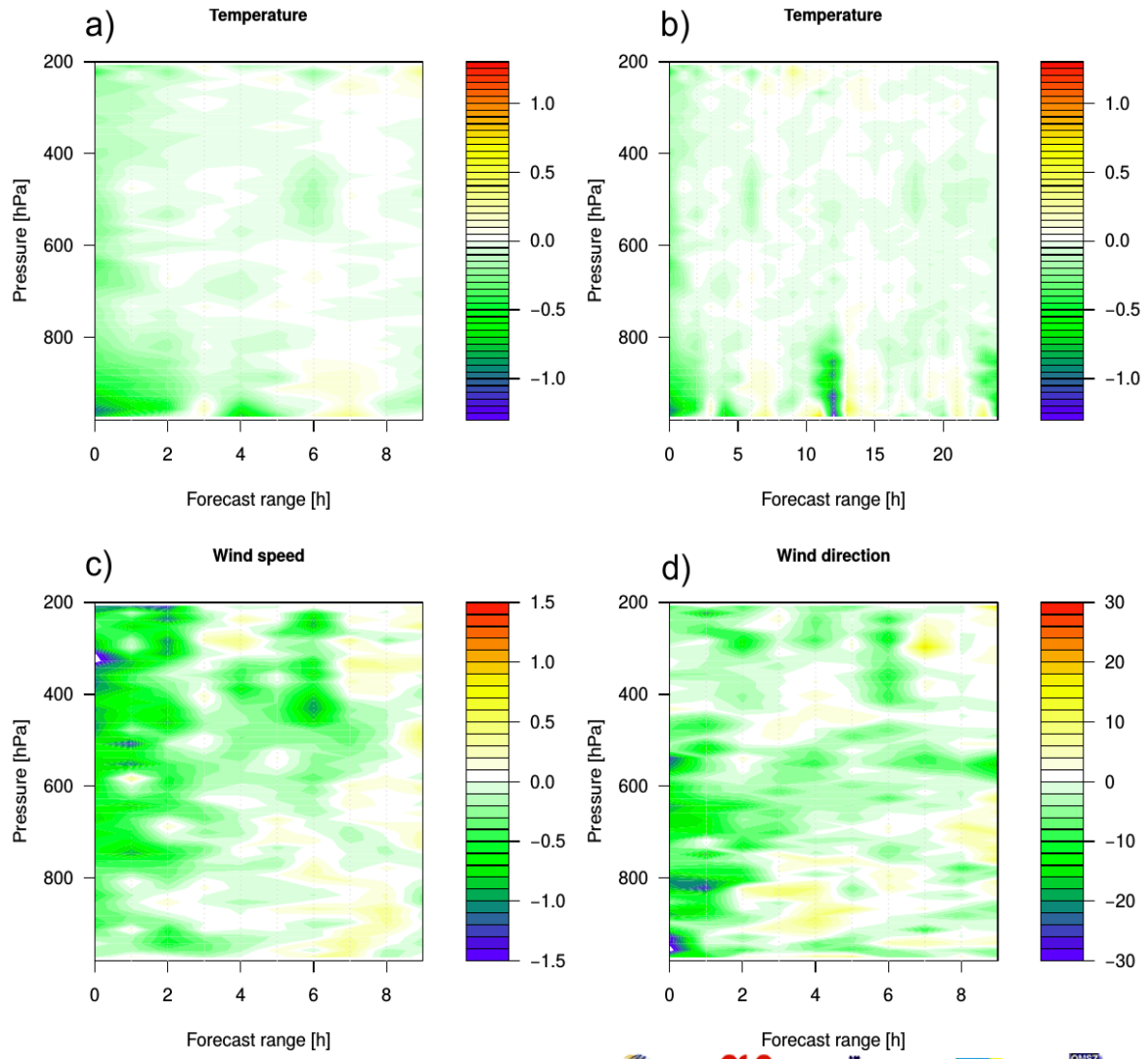
$$\eta = \mathbf{MH}\zeta + \eta_u$$

$$(T, p_s) = \mathbf{NH}\zeta + \mathbf{P}\eta_u + (T, p_s)_u$$

$$q = \mathbf{QH}\zeta + \mathbf{R}\eta_u + \mathbf{S}(T, p_s)_u + q_u$$

Switched off

# Univariate humidity impact



# Conclusions

- Mode-S MRAR are (on average) and after quality-control very good observations
- Clear impact on nowcasting to short range forecasts even with data from a single radar
- Shows challenges with respect to humidity analysis

# Plans – EUMETNET proposal

- New term: Aircraft-Derived Data (ADD)
  - Mode-S EHS; MRAR
  - ADS-B,ADS-C
  - internet
- Expert group gathered information and experience about current ADD activities (KNMI, Met Office, ARSO, …)
- Proposal for additional 1 year activity:
  - To collect information on availability and data policy of ADD over Europe
  - Propose dissemination strategy
  - Propose a new EUMETNET observation project (besides or together with AMDAR)

# Plans – LACE

- Data availability:
  - ARSO: Mode-S MRAR
  - CHMI: Mode-S EHS;MRAR
  - Austria (upgrade postponed to next year)
  - Any other information?
- Data policy to be discussed
- Preprocessing (could be done at ARSO or OMZS?)
- Collection and sharing within OPLACE (till EUMETNET activity)
- Cooperate / exchange data with KNMI