Assimilation of Mode-S aircraft observations in COSMO-DE-KENDA

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LMU Munich and DWD Offenbach

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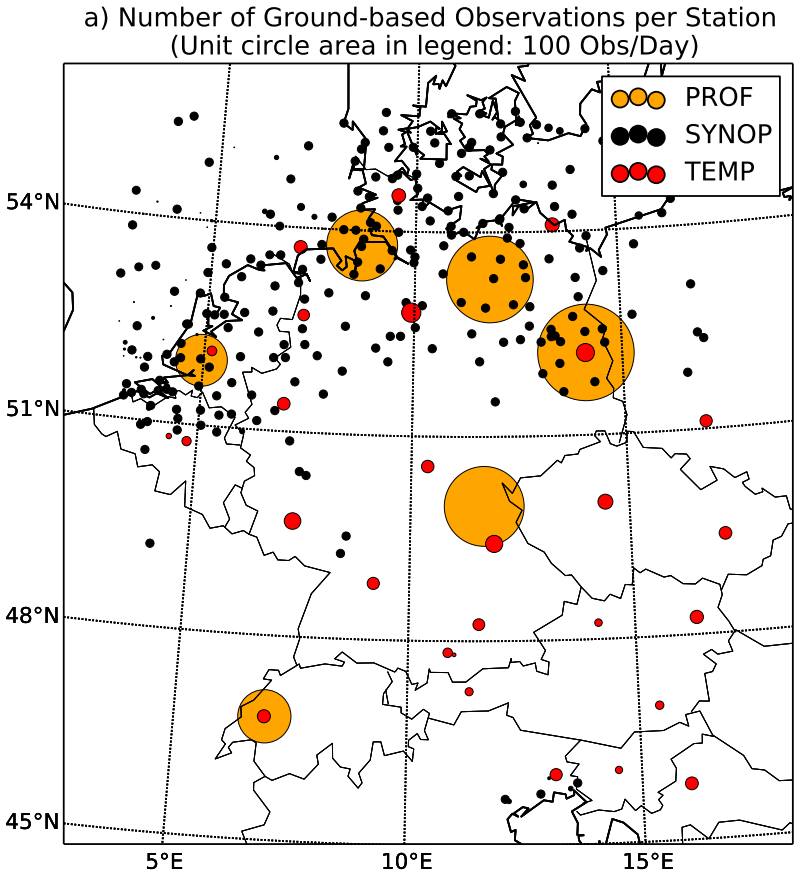
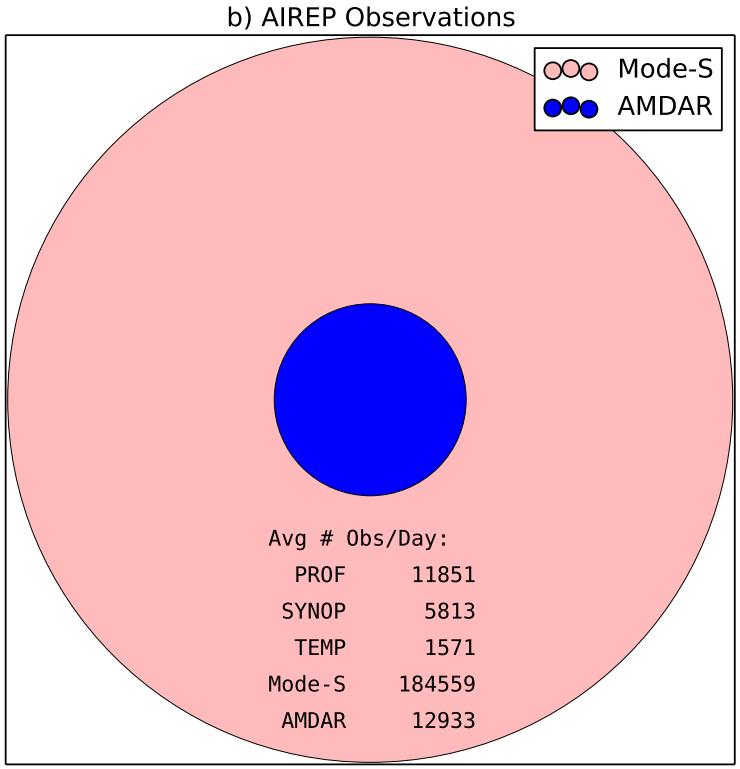
03.03.2015

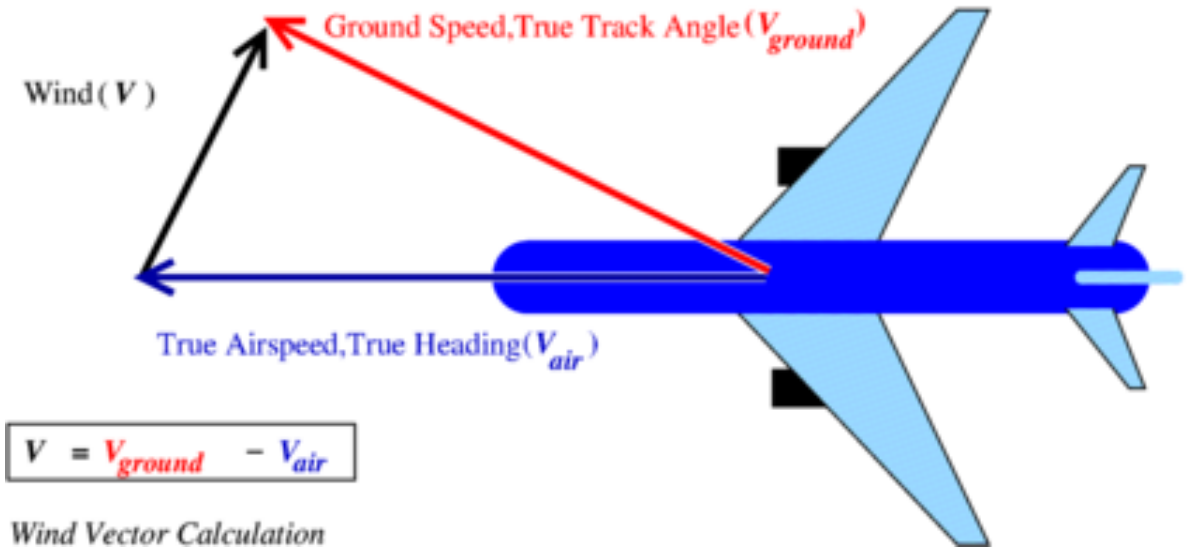
Conventional observations and AIREP



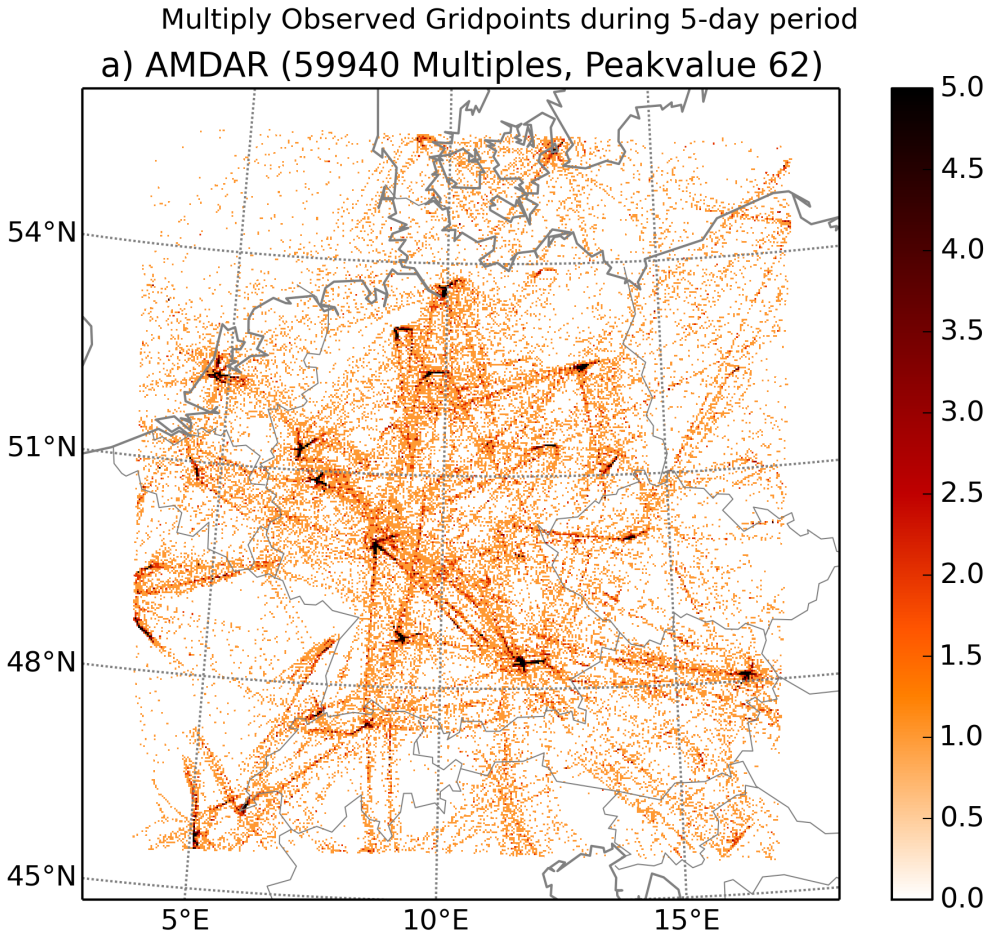


Aircraft Observations

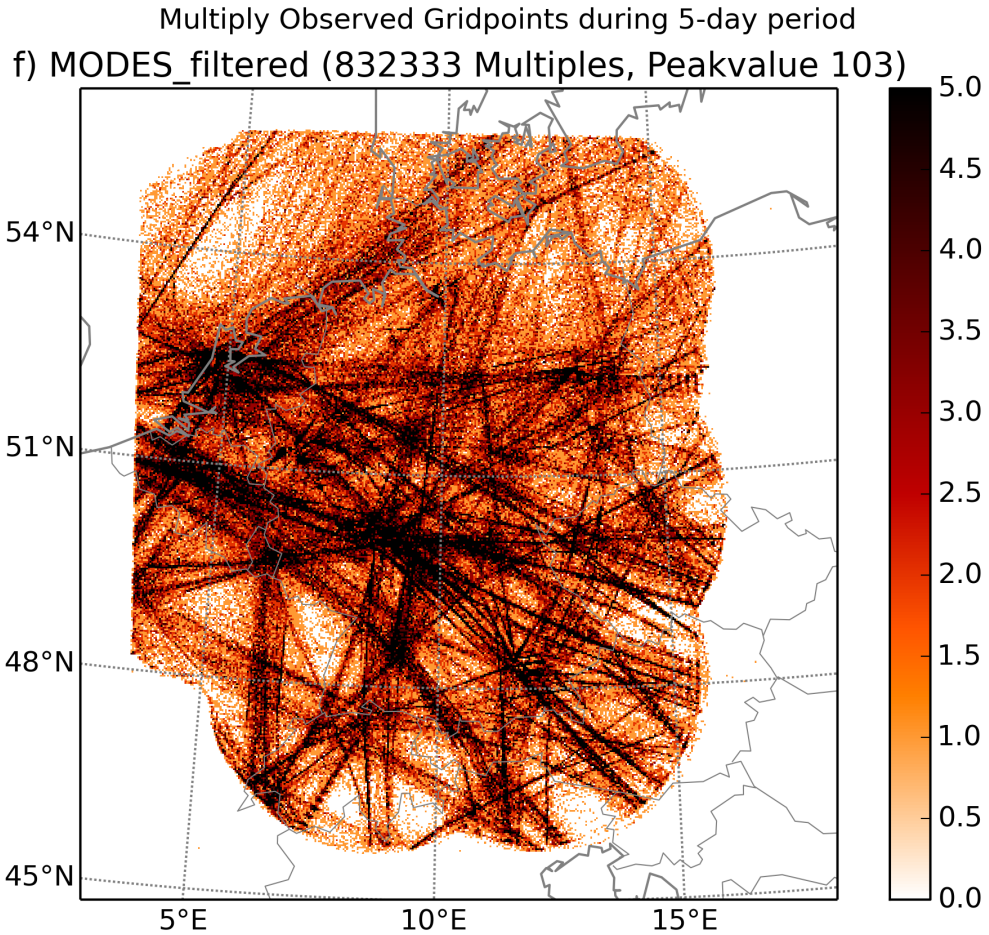
Mode-S observations collected and preprocessed at KNMI by Siebren de Haan (http://mode-s.knmi.nl)



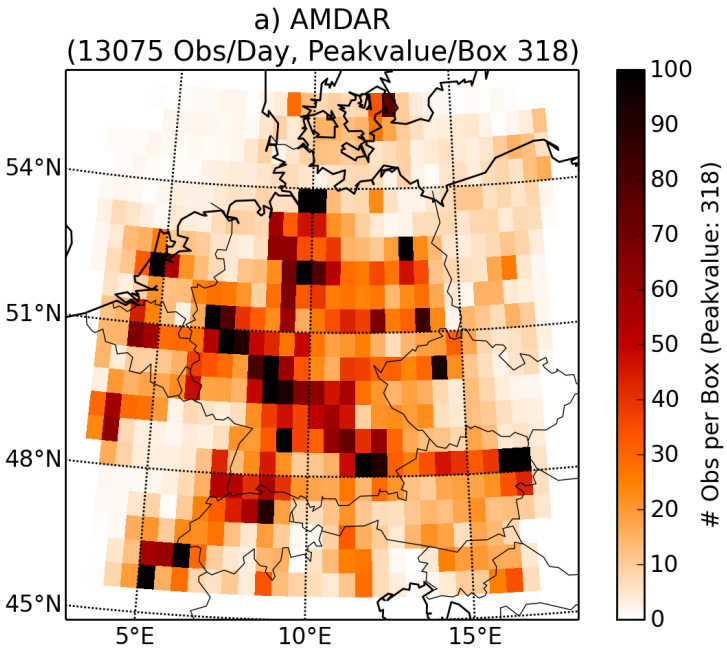
AMDAR observation space

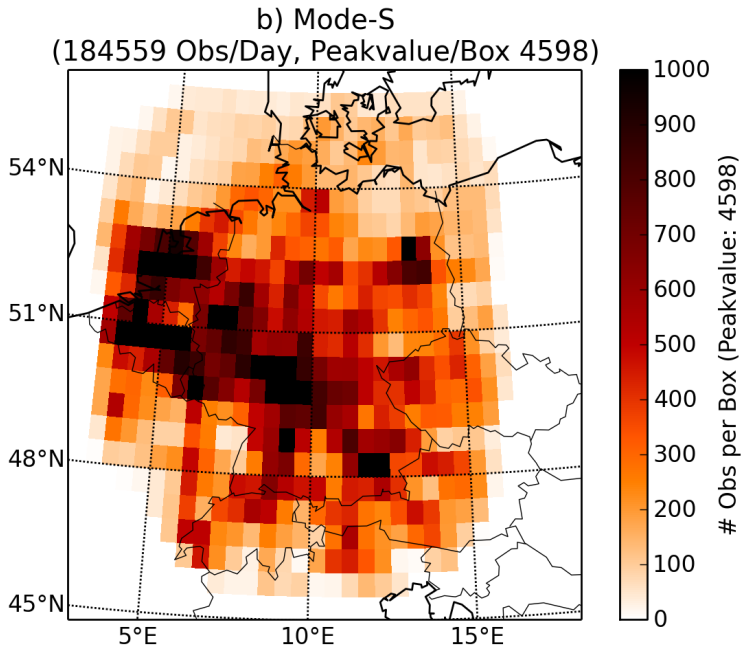


Mode-S observation space

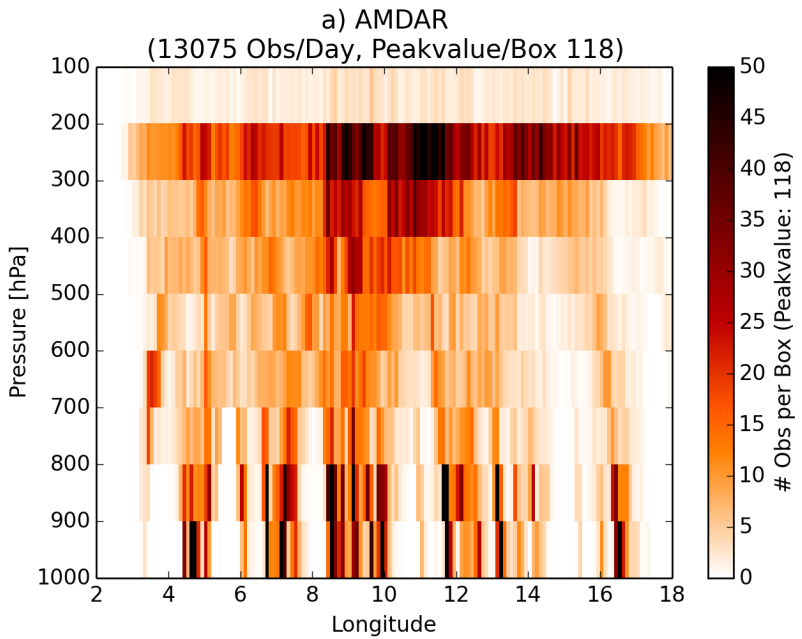


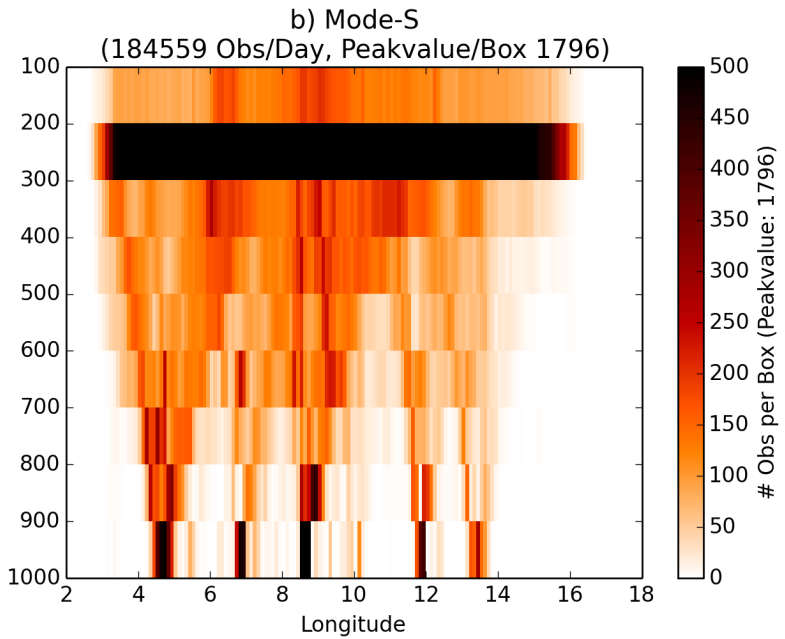
AMDAR and Mode-S horizontal density





AMDAR and Mode-S vertical density

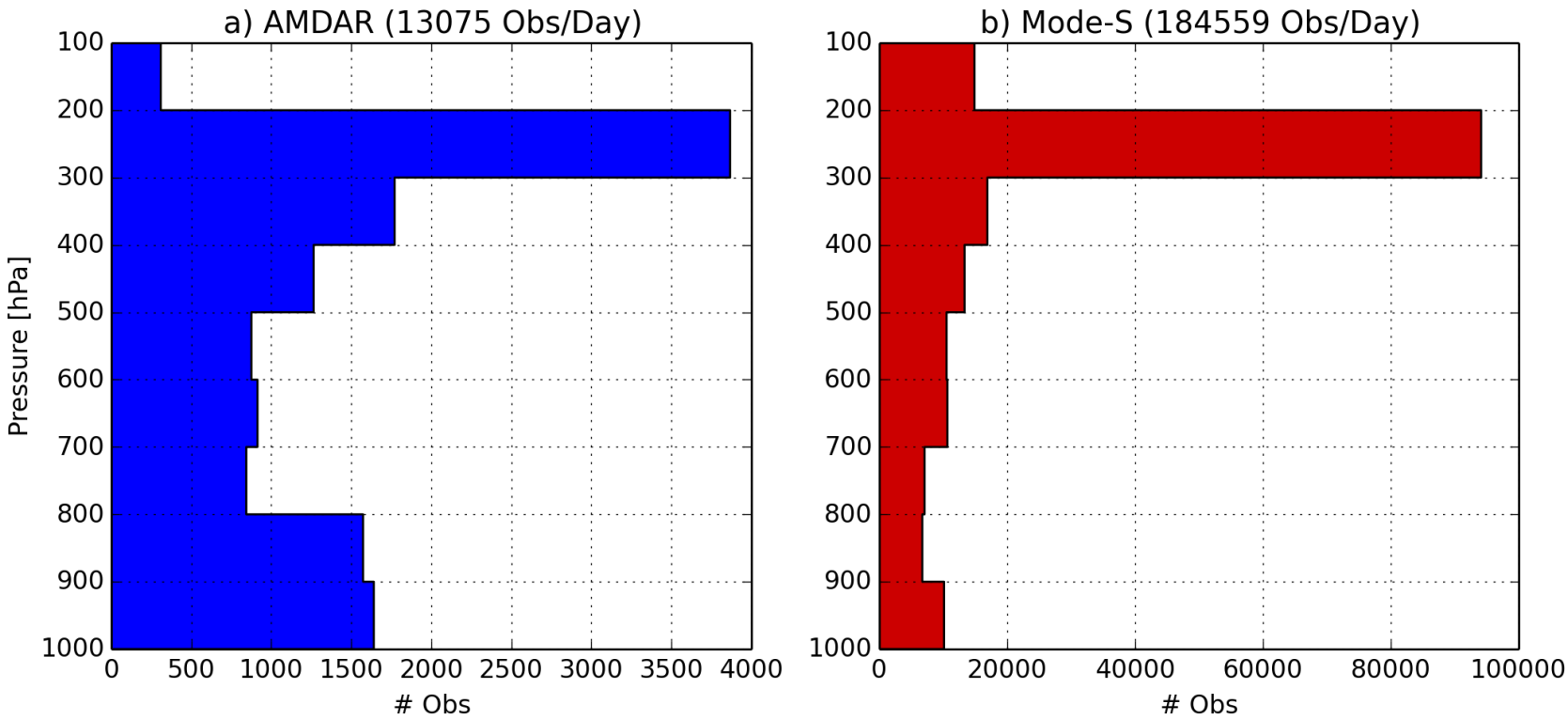




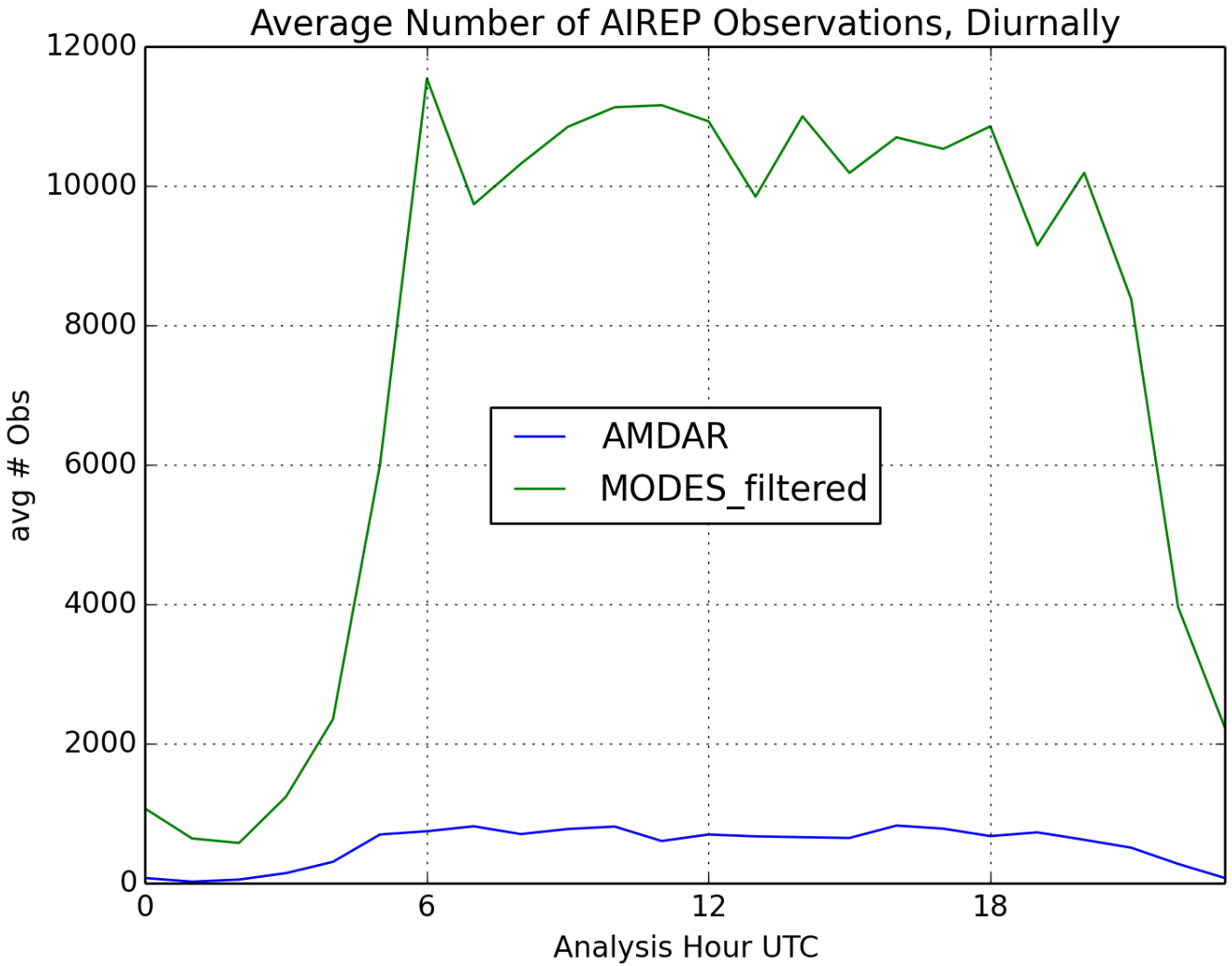
AMDAR and Mode-S flight track density

- Mode-S original resolution: **every** aircraft **every** 4 sec
- Mode-S averaged along flight tracks in AMDAR-fashion
- Average distance between consecutive observations: 15 km
- 15 x times more flights in Mode-S than in AMDAR

AMDAR and Mode-S observation density



Temporal density



COSMO-DE-KENDA Setup

Basic Cycling (BaCy) setup:

- 40 Member Ensemble of COSMO-DE
- Initial and boundary data:
  - 40 global ICON Members
  - Period: 06.05.2014 – 12.05.2014
- LETKF:
  - 1-hourly cycling
  - RTPP-factor 0.75 for background ensemble
  - Adaptive Inflation and Adaptive Localization
  - Observations sets:
    - SYNOP
    - PILOT
    - AIREP (AMDAR **or** Mode-S)
    - TEMP Radiosondes (monitored)

Goals/Experiments

1. Combinations of AMDAR and Mode-S
2. Monitor quality of Mode-S vs. AMDAR
3. Thinning of Mode-S (3 hour forecasts)

Experiments table

	TEMP	SYNOP	PROF	AMDAR	Mode-S
NoDA	mon.	mon.	mon.	mon.	mon.
Aconv	mon.	•	•	•	mon.
Mconv	mon.	•	•	mon.	•
MAconv	mon.	•	•	•	•
MAconvTh10	mon.	•	•	•	• 10%
MAconvTh50	mon.	•	•	•	• 50%

RMS, and Spread

$$\mathrm{RMS}(\mathbf{d}) = \sqrt{\frac{1}{m}\sum_{j=0}^{m} d_j^2} \tag{1}$$

where

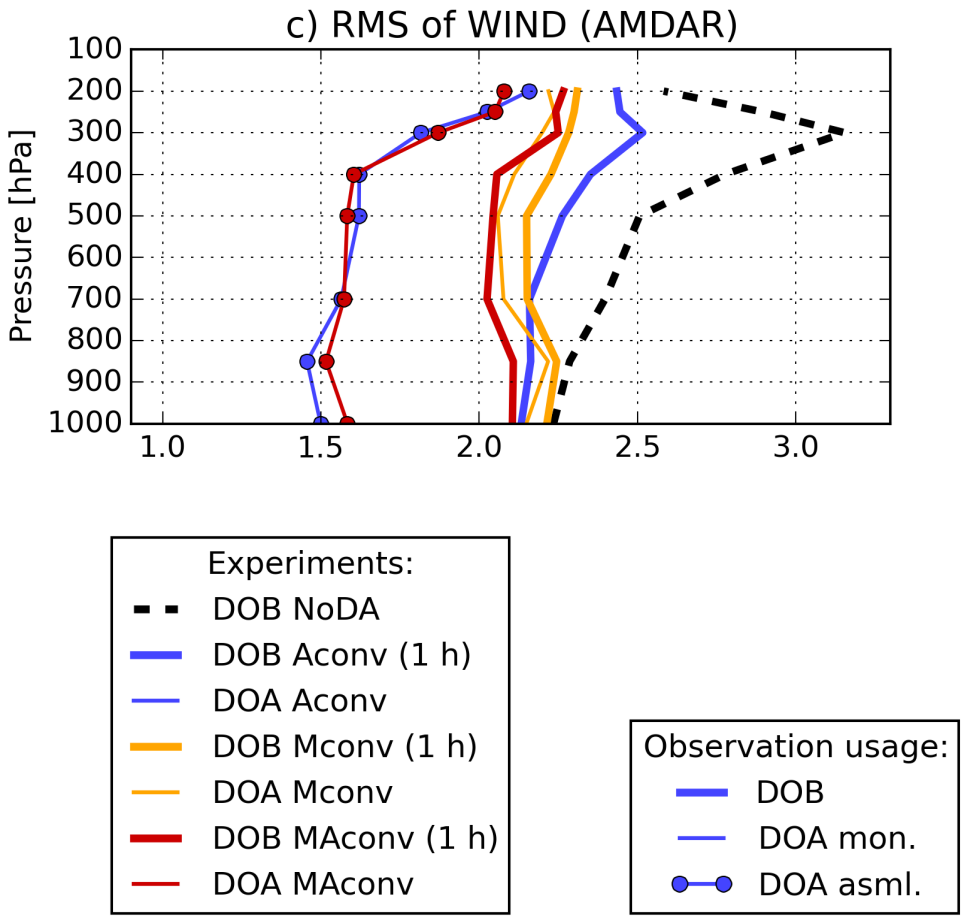
$$d_j = \left(y_j^o - \overline{H(\mathbf{x}_i)_j}\right) \tag{2}$$

Analyis: $\mathbf{d}_{o-a}$ (DOA)
Background: $\mathbf{d}_{o-b}$ (DOB)

$$\mathrm{spread} = \sqrt{\frac{1}{n}\sum_{j=0}^{n}\left\{\frac{1}{k-1}\sum_{i=1}^{k}[H(\mathbf{x}_i^b) - \overline{H(\mathbf{x}_i^b)}]^2\right\}} \tag{3}$$

AMDAR and Mode-S Assimilation Result

	TEMP	SYNOP	PROF	AMDAR	Mode-S
NoDA	mon.	mon.	mon.	mon.	mon.
Aconv	mon.	●	●	●	mon.
Mconv	mon.	●	●	mon.	●
MAconv	mon.	●	●	●	●
MAconvTh10	mon.	●	●	●	● 10%
MAconvTh50	mon.	●	●	●	● 50%



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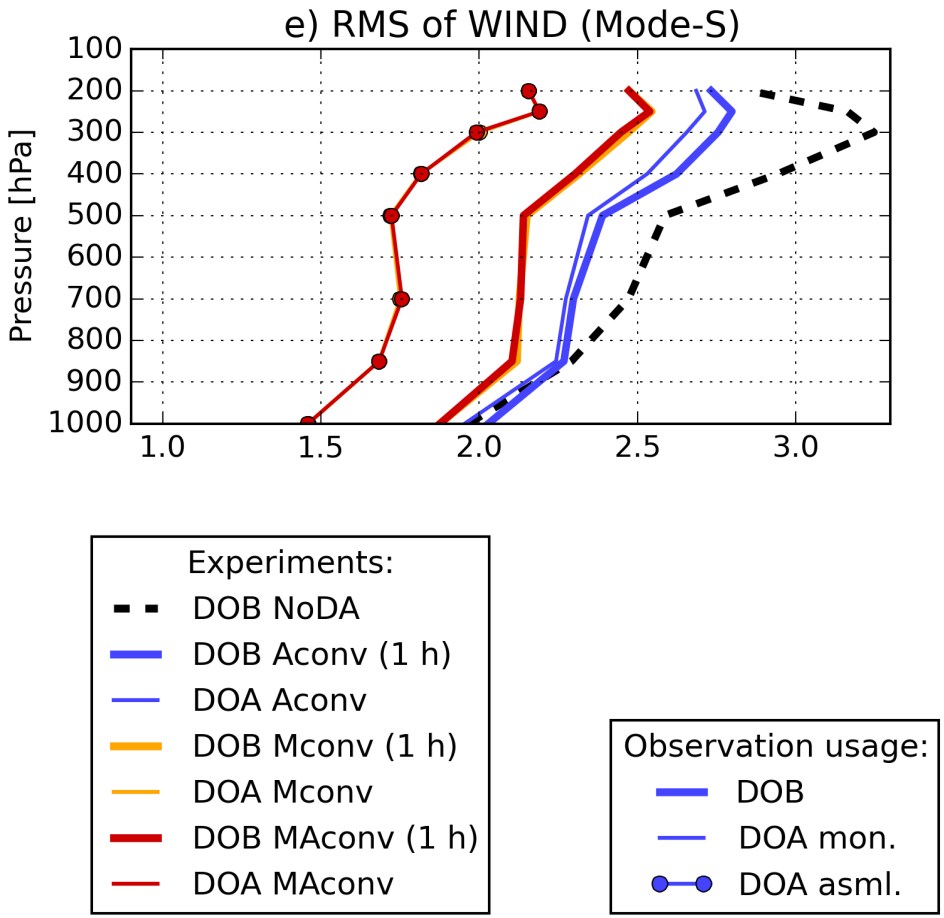

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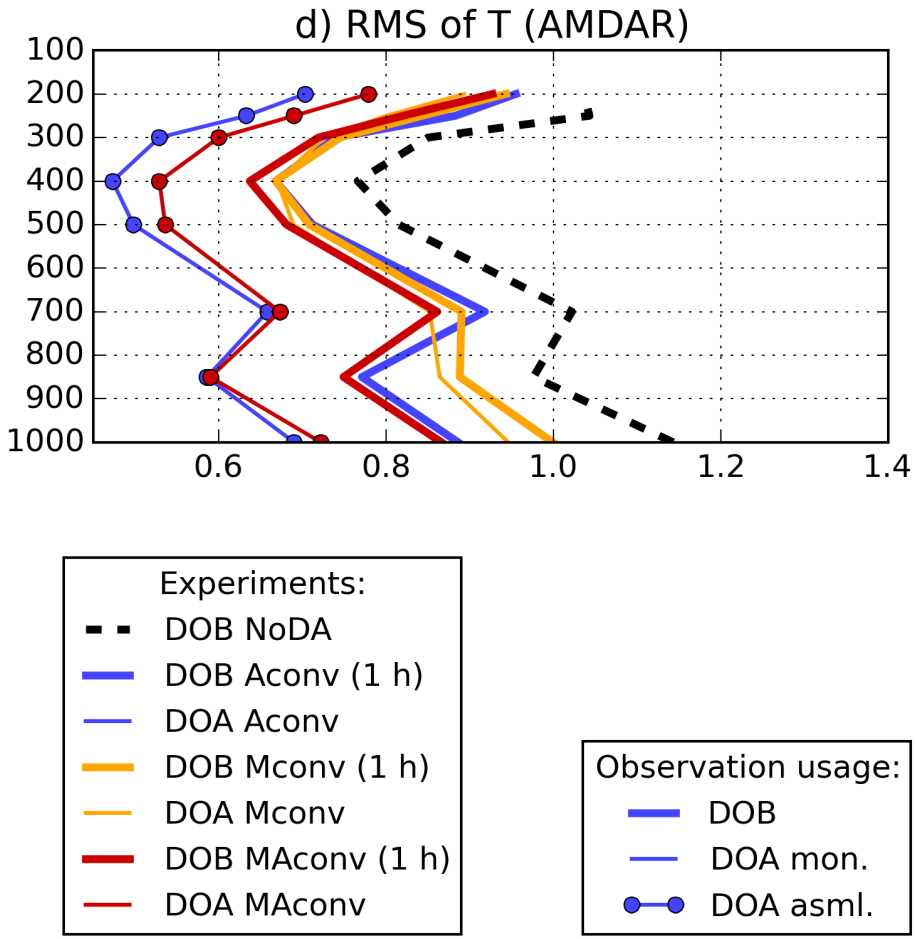

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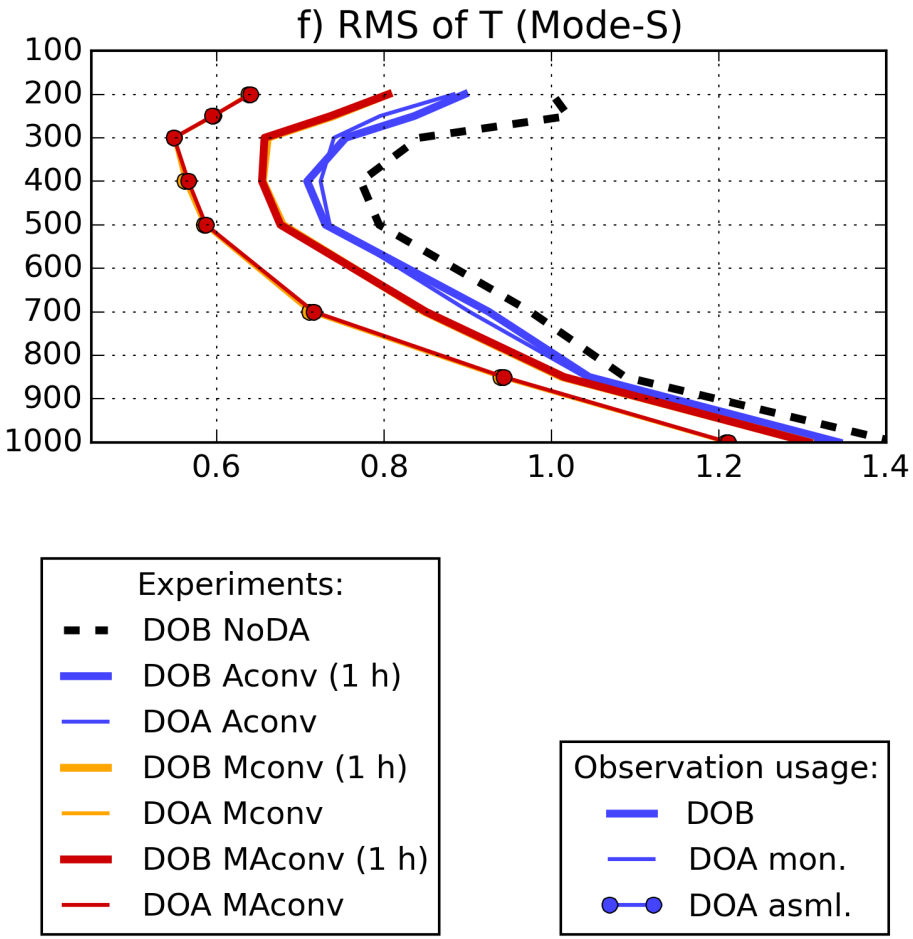

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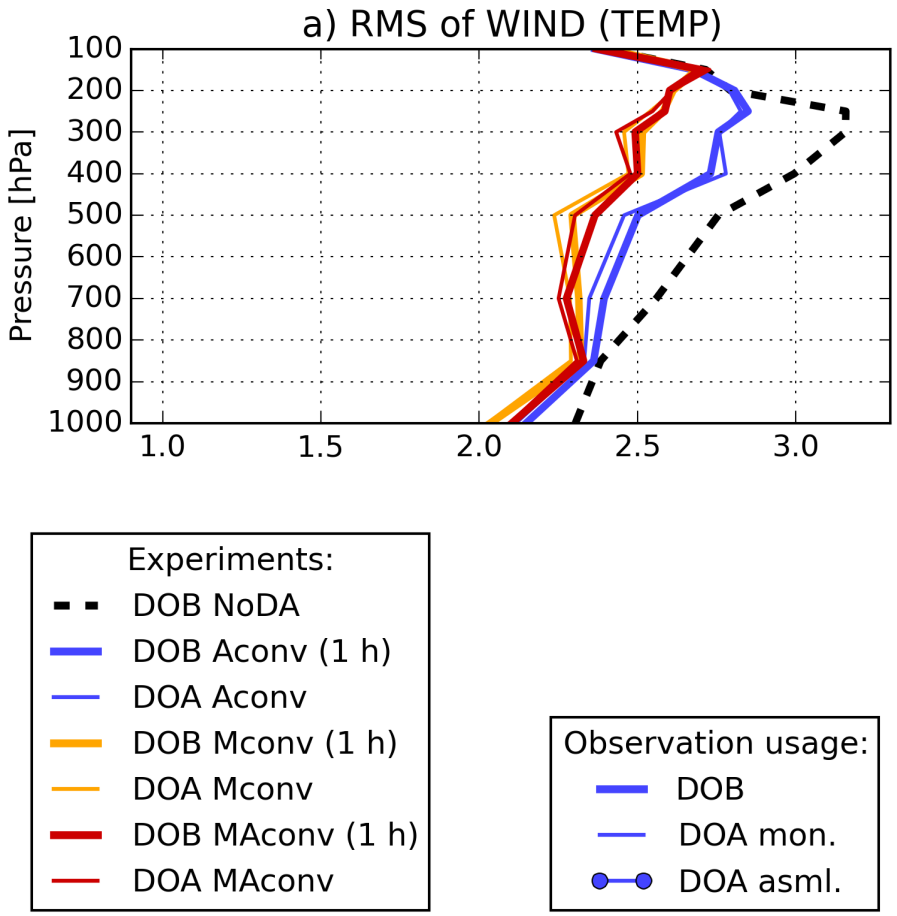
MAconv	mon.	●	●	●	●
MAconvTh10	mon.	●	●	●	● 10%
MAconvTh50	mon.	●	●	●	● 50%



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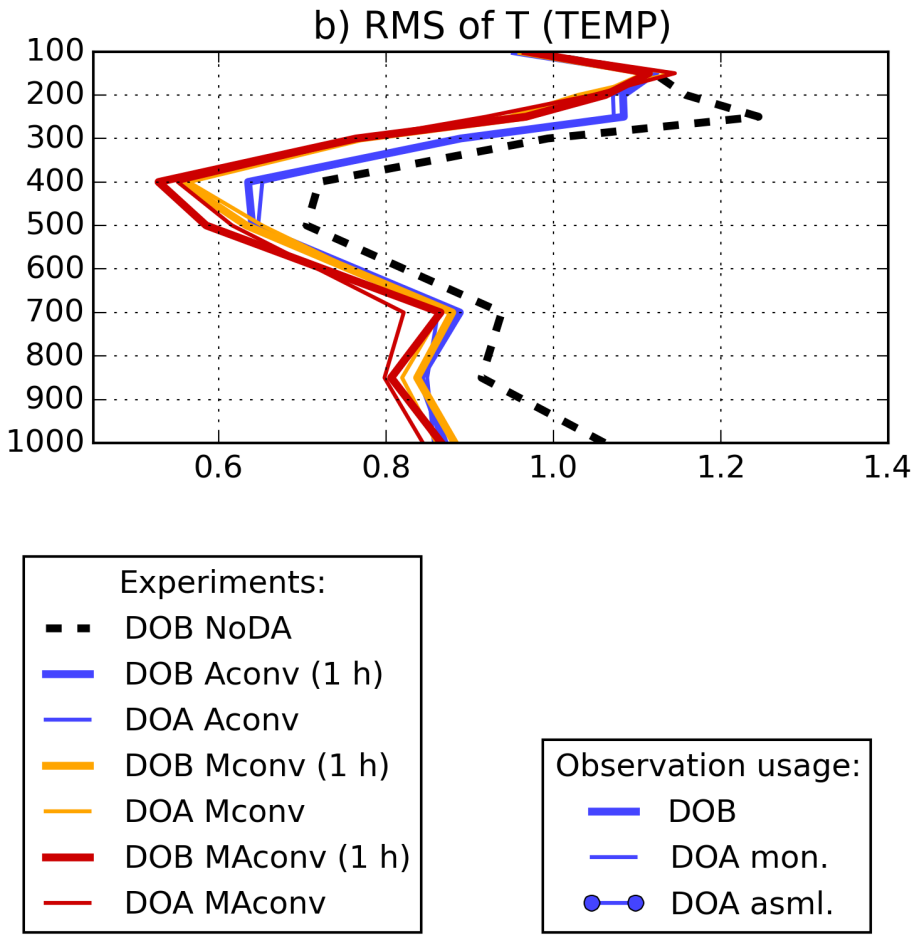

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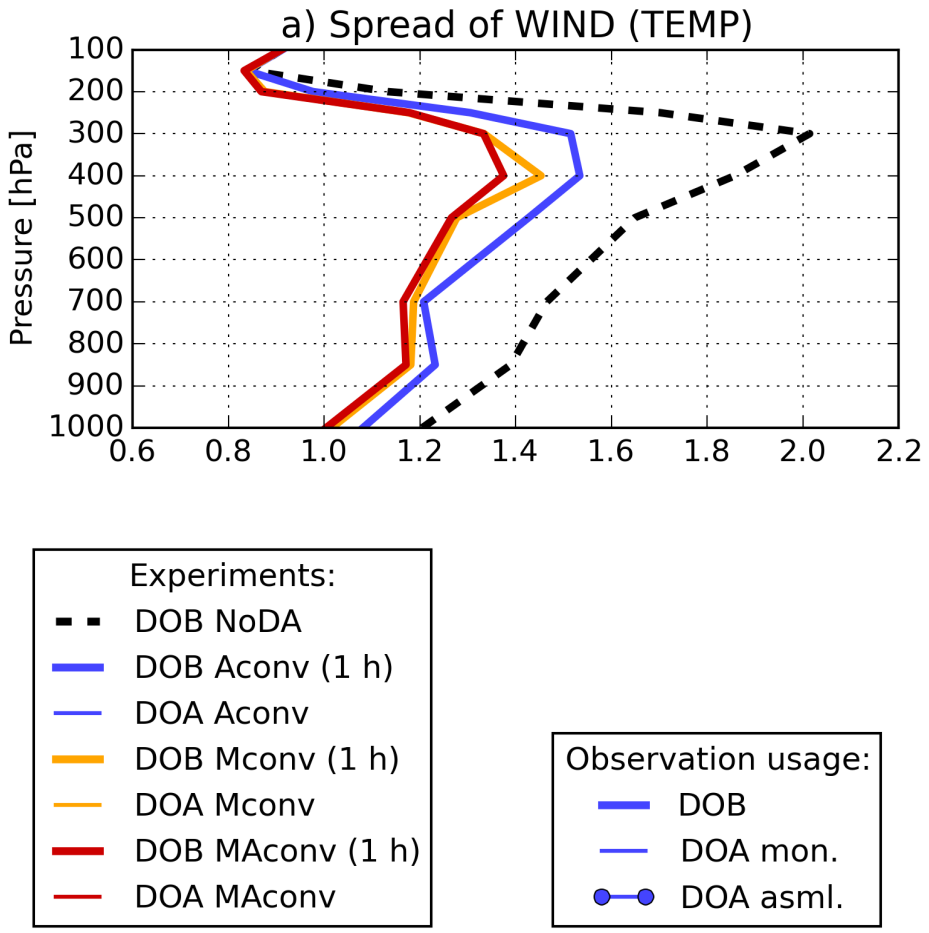
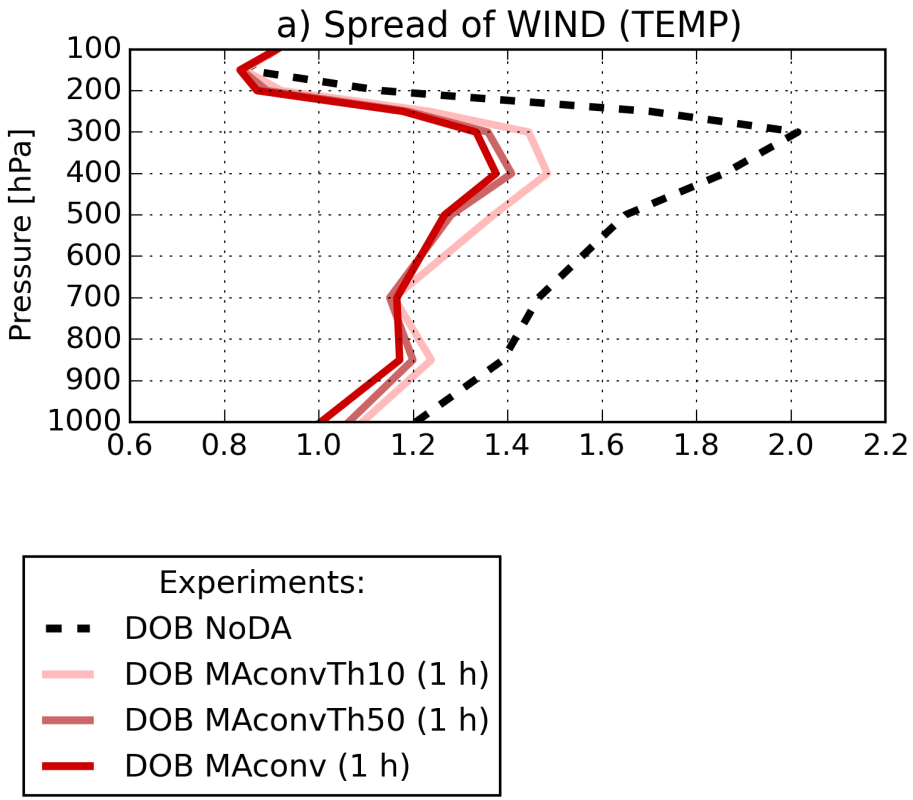
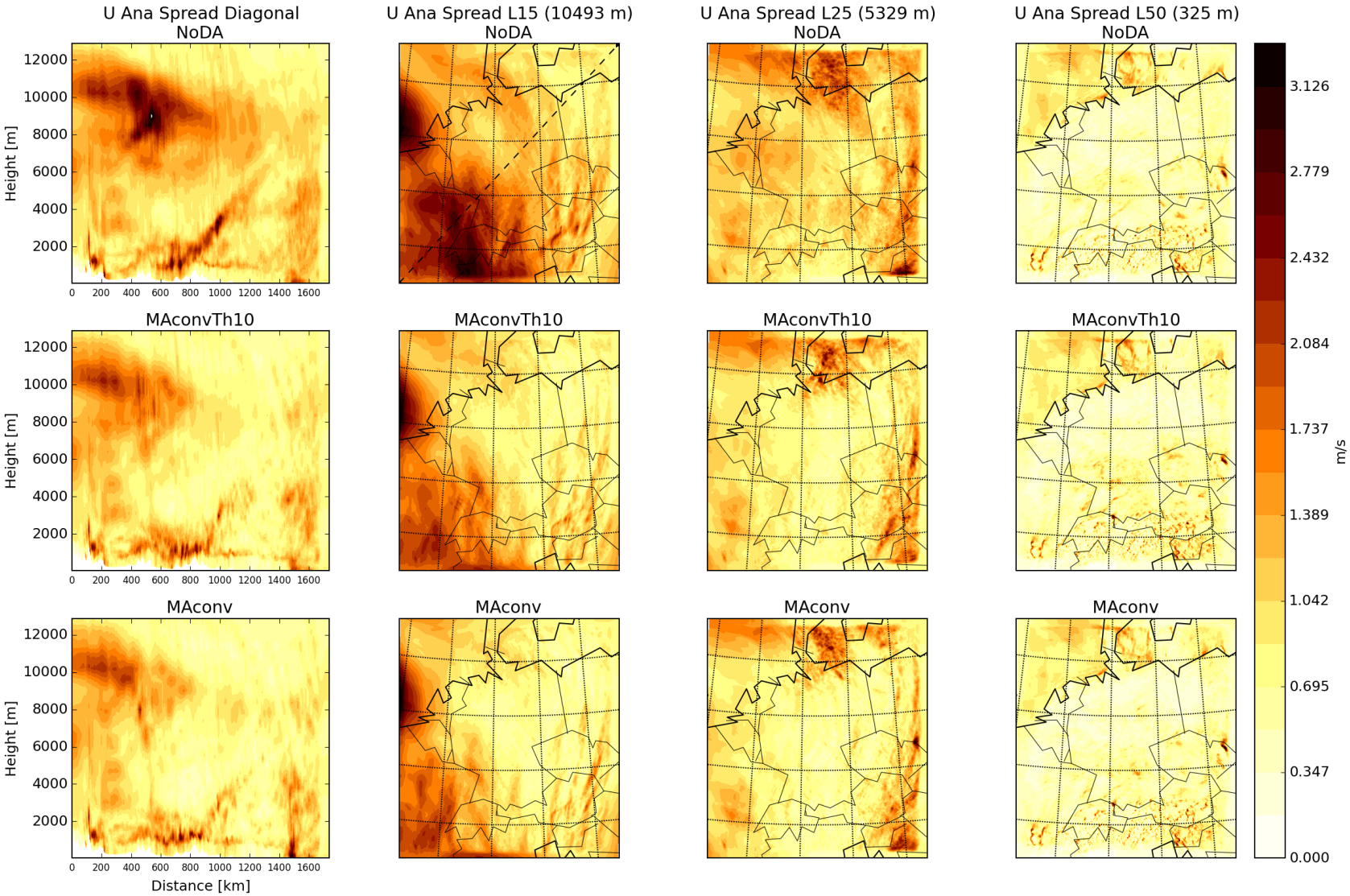


Mode-S Thinning Results

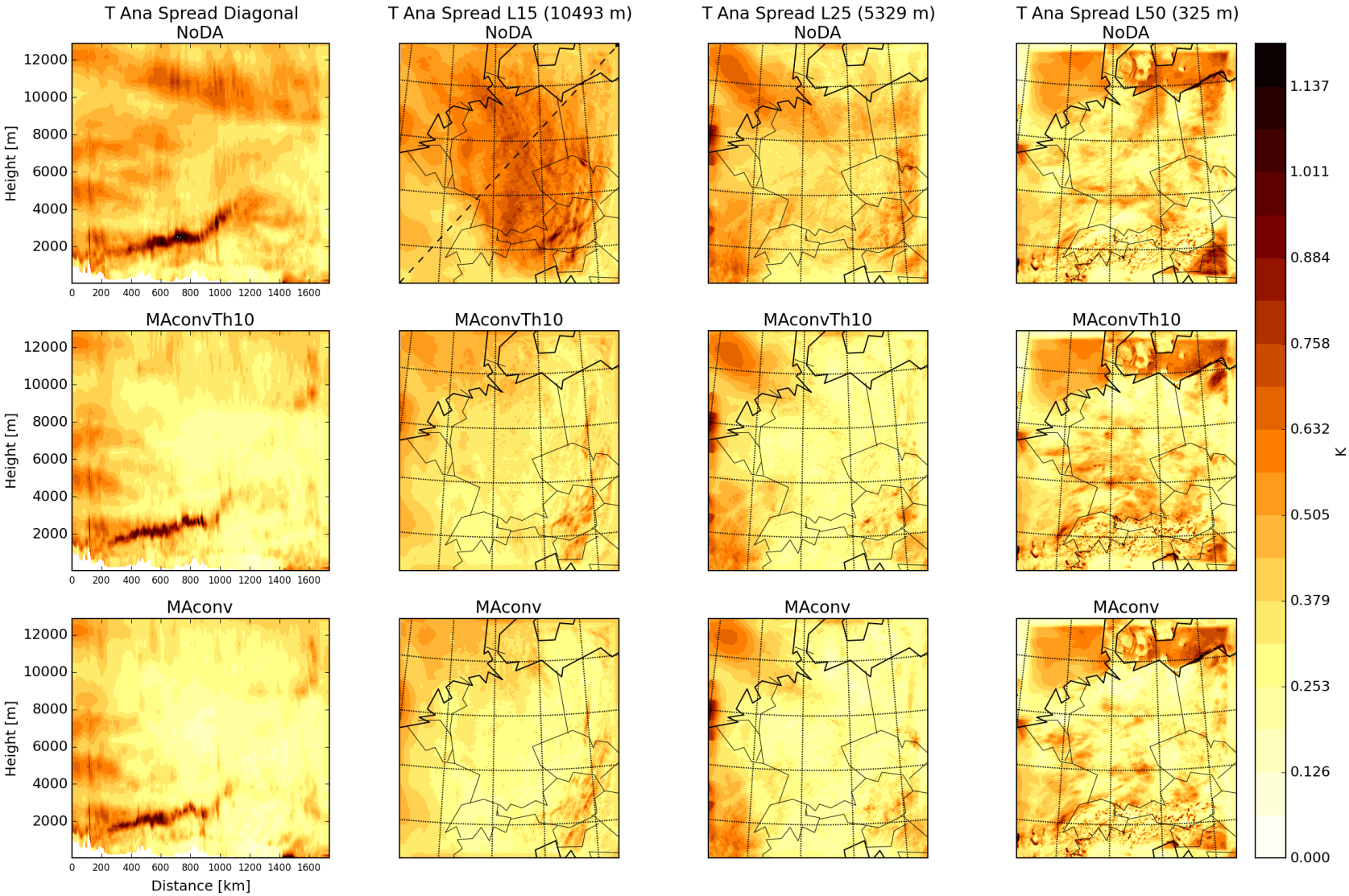
	TEMP	SYNOP	PROF	AMDAR	Mode-S
NoDA	**mon.**	**mon.**	**mon.**	**mon.**	**mon.**
Aconv	mon.	●	●	●	mon.
Mconv	mon.	●	●	mon.	●
MAconv	**mon.**	●	●	●	●
MAconvTh10	mon.	●	●	●	● 10%
MAconvTh50	mon.	●	●	●	● 50%



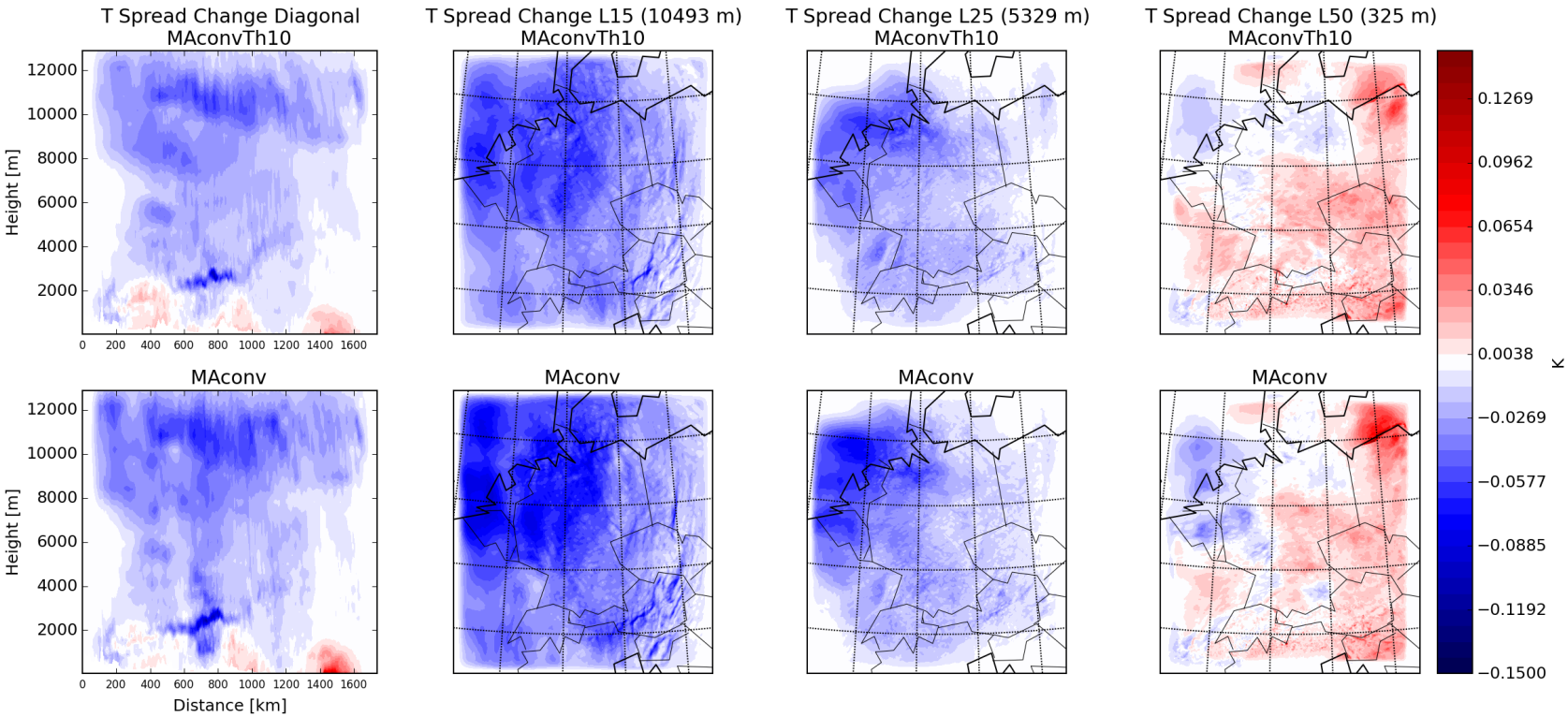
Mode-S: Thinning Analysis Spread (Zonal Wind U)



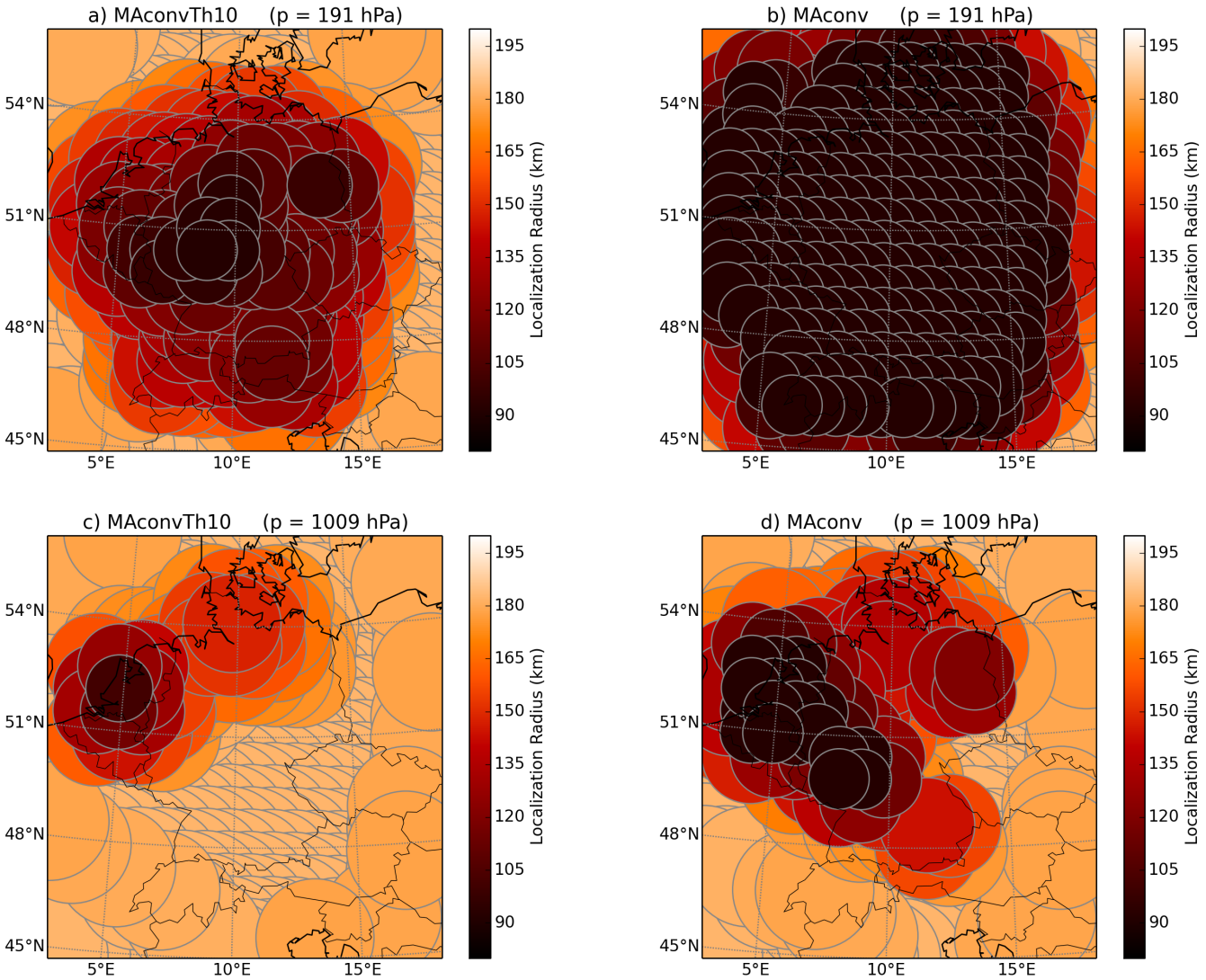
Mode-S: Thinning Analysis Spread (Temperature T)



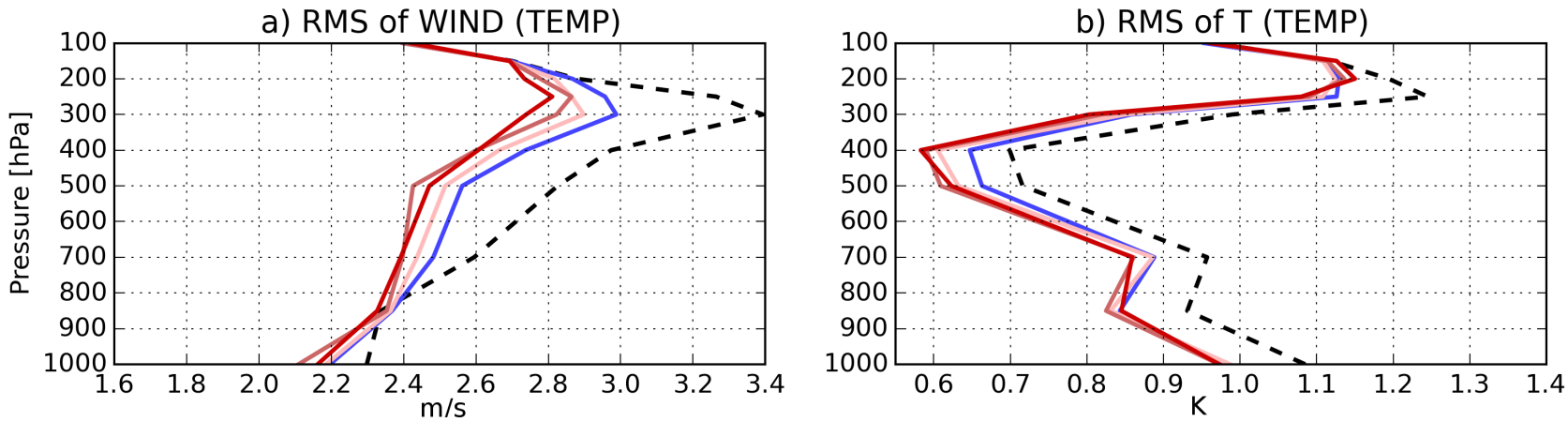
Mode-S: Thinning Spread Change (Temperature T)



Mode-S: Adaptive Localization Radius

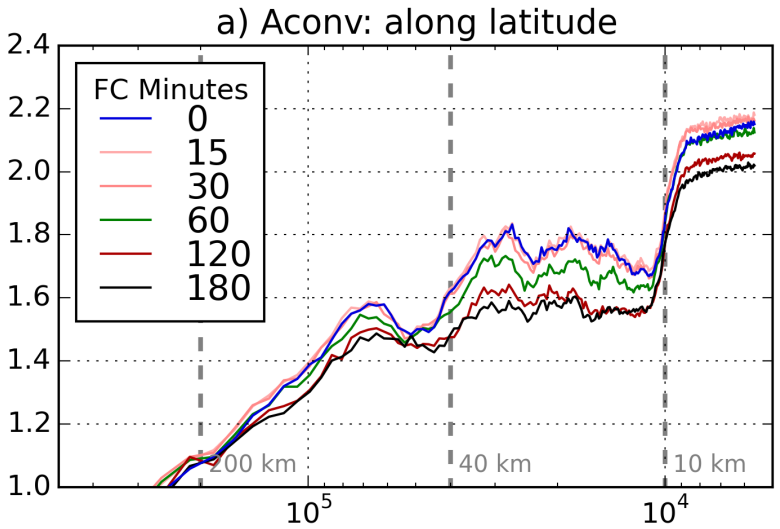


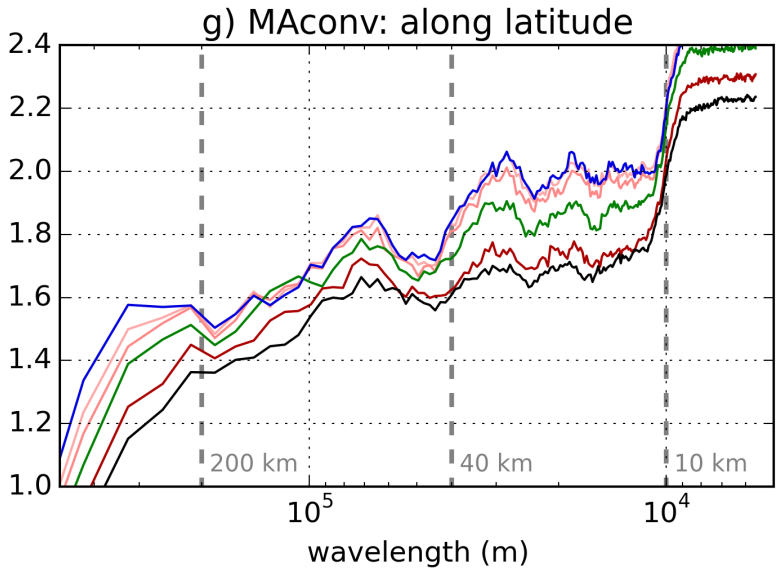
3 Hour Forecast Window



Forecast Spectra

Relative Difference Energy from NoDA within 3 hours of ensemble forecast (scaled by absolute energy of NoDA)





Conclusions

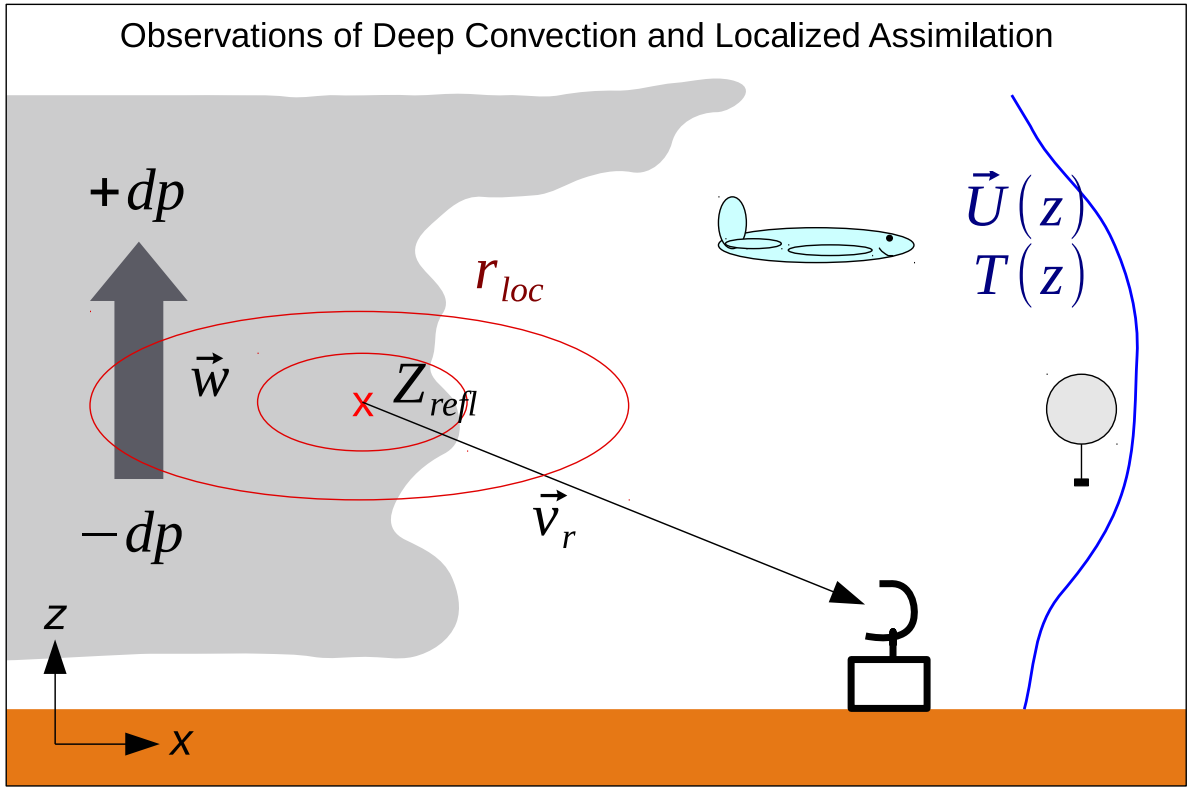
Data Quality of Mode-S:

- Wind error comparable to AMDAR
- Temperature error larger than AMDAR for low levels
- No considerable biases

Ensemble Data Assimilation:

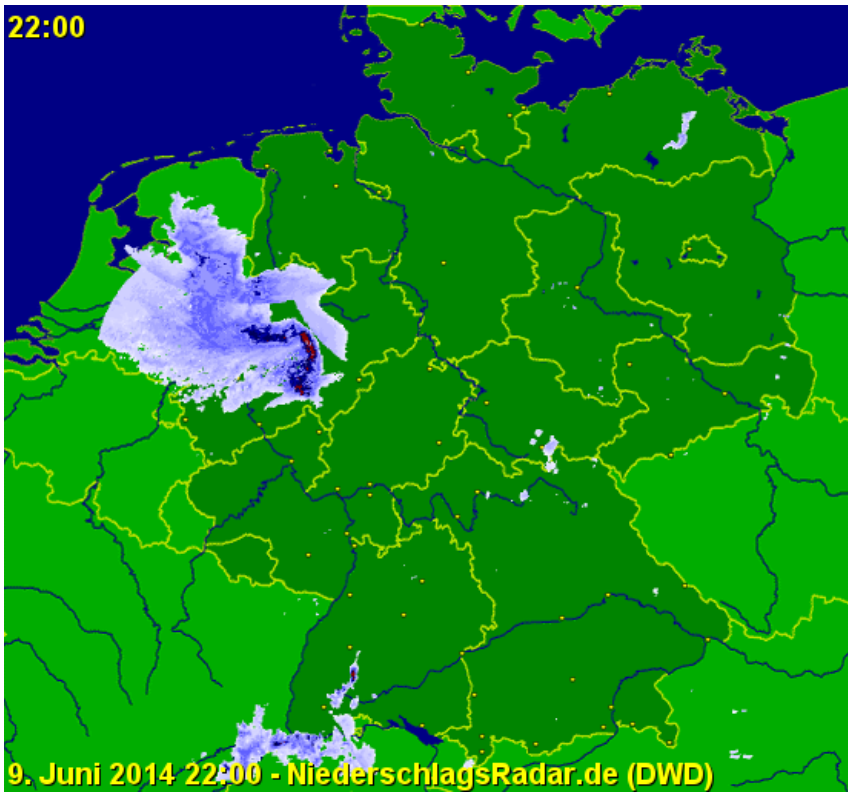
- Mode-S data strongly improves analyses and forecasts of 1 and 3 hours, but mainly in flight levels
- COSMO-KENDA can handle the full Mode-S data
- Ensemble Spread conserved by Relaxation-to-Prior, Adaptive Inflation and Adaptive Localization
- Saturation of benefit at 50 % Mode-S data **in current setup**

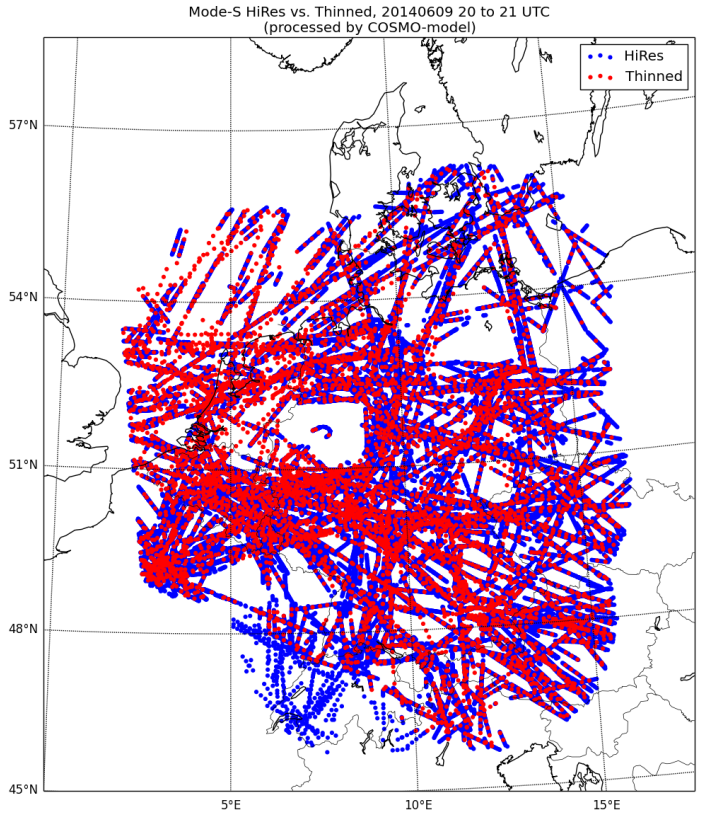
Outlook: Combination of volume observations



Cloud and Radar observation operators developed and tested at DWD, HErZ Munich (Poster: Michael Würsch, Talk: Tobias Necker), HErZ Bonn (Talk: Theresa Bick)

Outlook: Combination of volume observations





LETKF-Settings

Namelist-Paramter	Value	Effect
`k_enkf`	40	Number of ensemble members
`det_run`	1	Compute deterministic analysis
`excl_bnd` (deg)	0.67	Distance: Obs excluded if too close to lateral boundaries
`height_t` (hpa)	100.	Top pressure: Obs excluded if close to model top
`rho`	1.1	Covariance inflation factor
`adap_loc, nobs_gp`	True, 100	Adaptive horizontal localization, # Obs/Gridpoint
`lh_min, lh_max,`	50., 100.	Min/Max Horizontal localization length scale
`lv_surf, lv_top`	0.075, 0.5	Bottom/Top Vertical localization length scale
`apply_rtpp, rtpp_alpha`	True, 0.75	Relax to prior perturbation, relaxation factor
`rf, nzr`	3, 30	Horizontal coarse grid factor, vertical analysis levels
`adap_rho (_u,_l)`	True, 0.5, 3.	Adaptive background covariance inflation (upper/lower bound)
`q_bound, sat_ad`	True, True	Positive analysis humidity, saturation adjustment
`hyd_bal, bal_var`	True, PP	Hydrostatic balancing, balanced variable (pressure perturbation)

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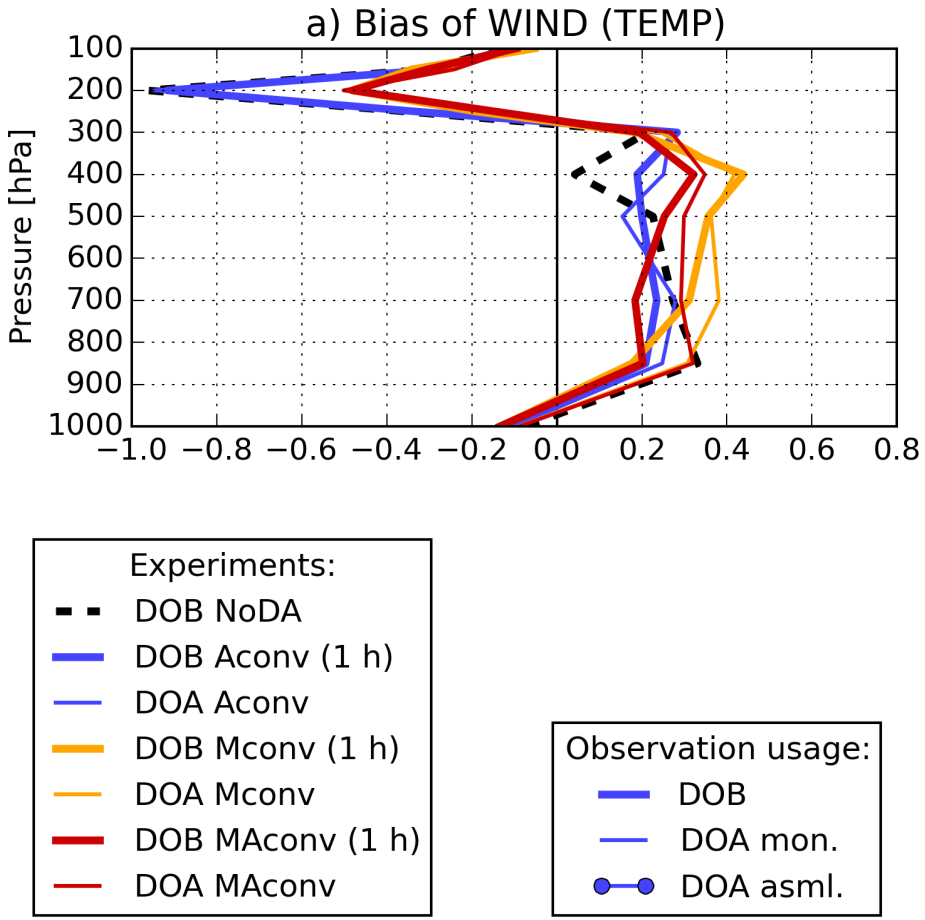

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MAconv	mon.	●	●	●	●
MAconvTh10	mon.	●	●	●	● 10%
MAconvTh50	mon.	●	●	●	● 50%