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Assimilation of Raman Lidar observations and the impact of specified observation error.

Bas Crezee & Daniel Leuenberger

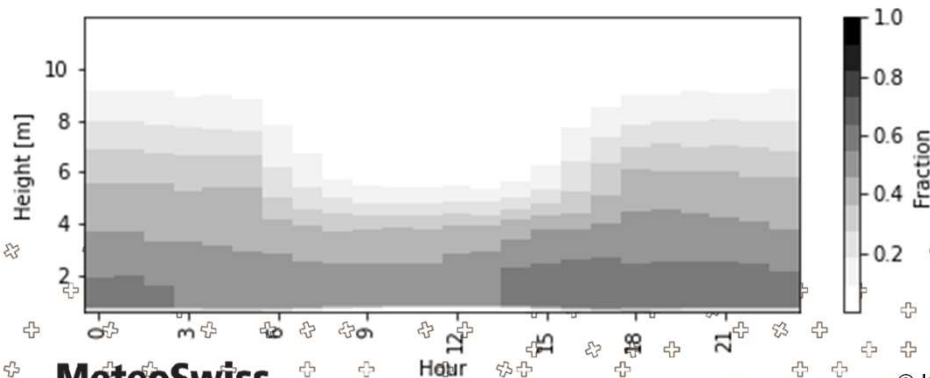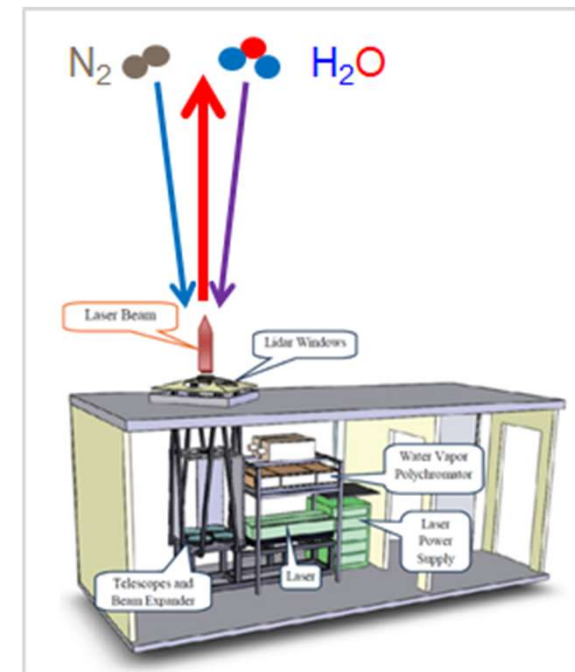Thanks to: Giovanni Martucci, Alexander Haefele, Marco Arpagaus

Raman Lidar (RALMO)

- Vertical profiles of Temperature and WV Mixing Ratio at 30 min temporal resolution
- Coverage of about 60% below 2000m (see below)

Diurnal data coverage as a fraction for RALMO (T)

Raman lidar for meteorological observations (RALMO), one instrument in PAY

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Recap COSMO GM

- Developed a new observation operator in MEC-light for RALMO
- First experiments show **reduction of dry-bias** in the model and **improvement in precipitation forecast** verified against surface stations for RALMO compared to REF (see below) over a 10-day summer convective period.

6h precip > 5 mm
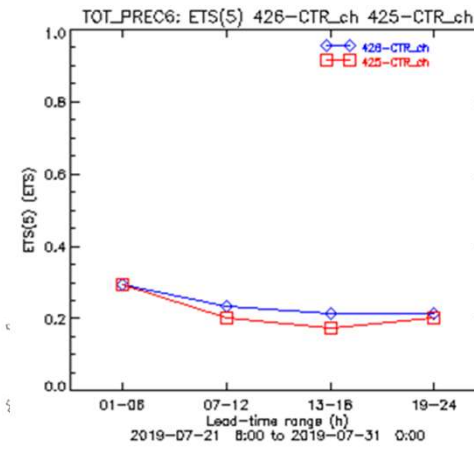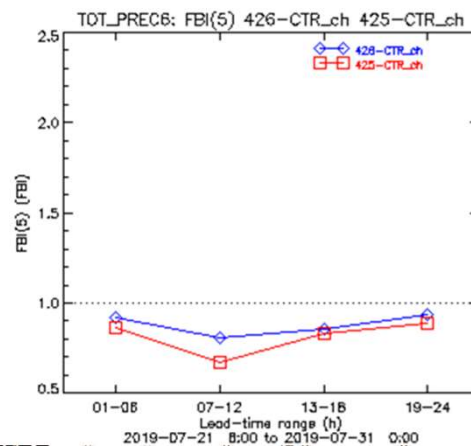
Setup & Outline

Setup: KENDA 2.2 km 10-day convective period 20-30 July 2019.

A) Which specification of observation error for RALMO provides us the best results?
   → Verification based on comparison of first-guess difference against sounding (relative humidity and temperature)

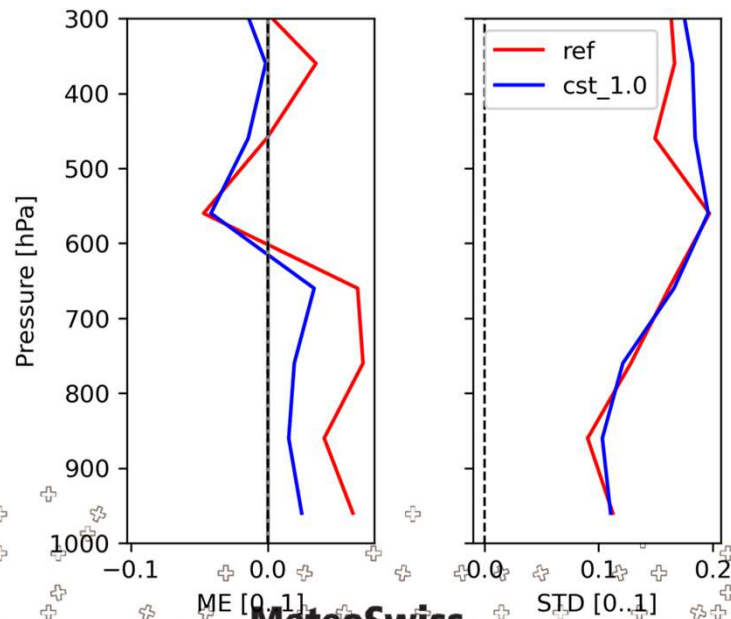A) Does the assimilation of RALMO lead to better forecasts?
   → Verification against surface stations / satellite / combiprecip
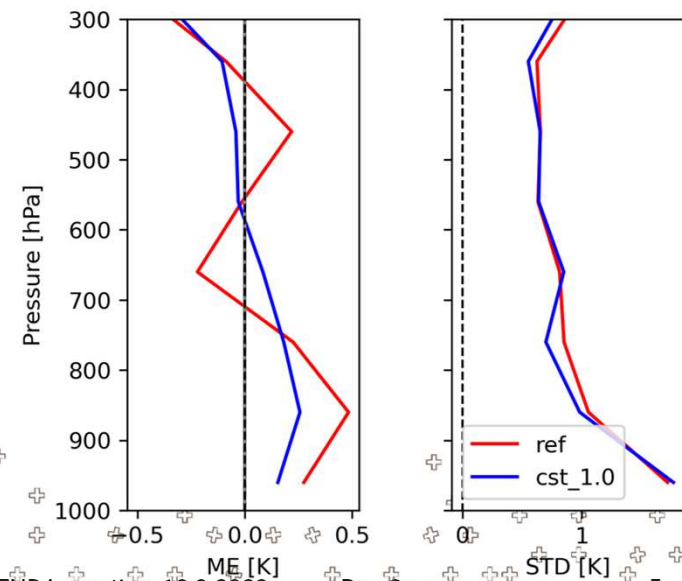
Impact of RALMO for constant obs error [1 g/kg ; 1 K]

- Reduction of dry-bias.
- RH STD neutral below 500 hPa and gets worse above.

- Temperature bias improved
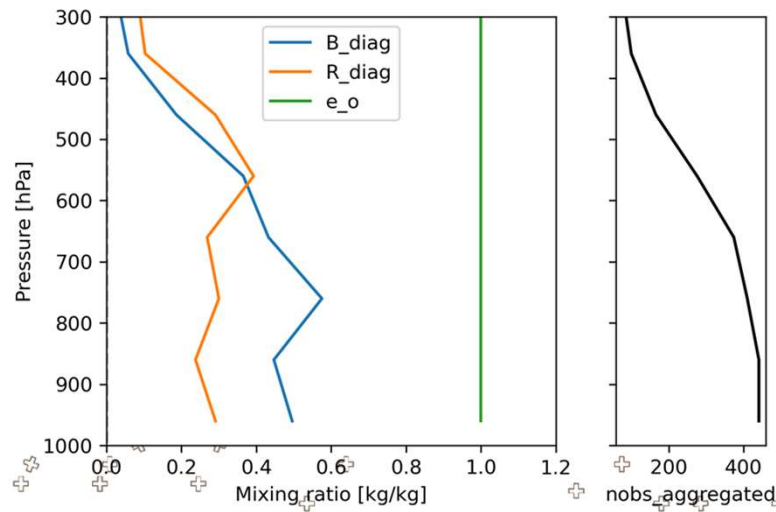- T STD slightly improved between 900-700 hPa.
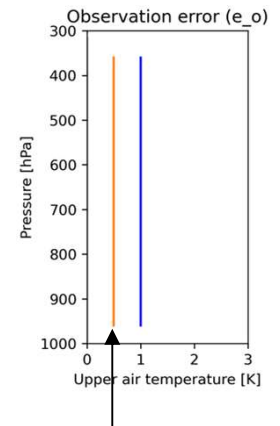
# Desroziers suggests we can lower observation error

MIXR

T
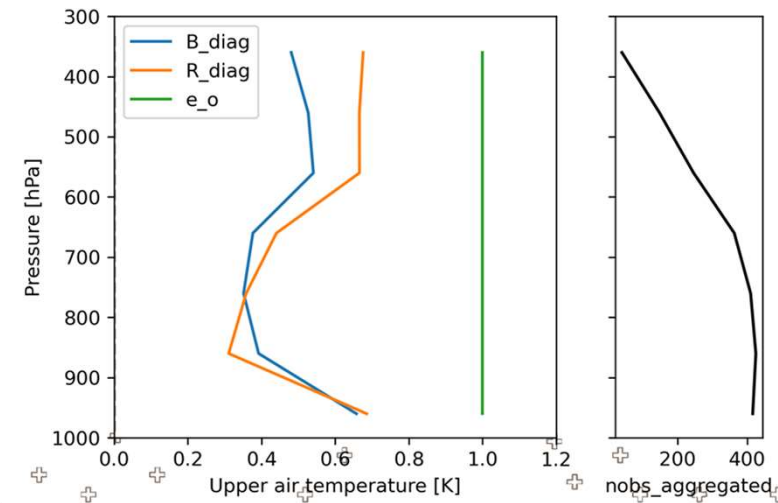
Can we indeed further *lower* the observation error?

- Dry-bias is further reduced!
- However, STD increases, especially for upper levels.

- Temperature bias overall neutral
- STD increases as well.

It is likely that e_o is correlated with height and therefore Desroziers method gives a too low estimate... How about increasing obs_error ?
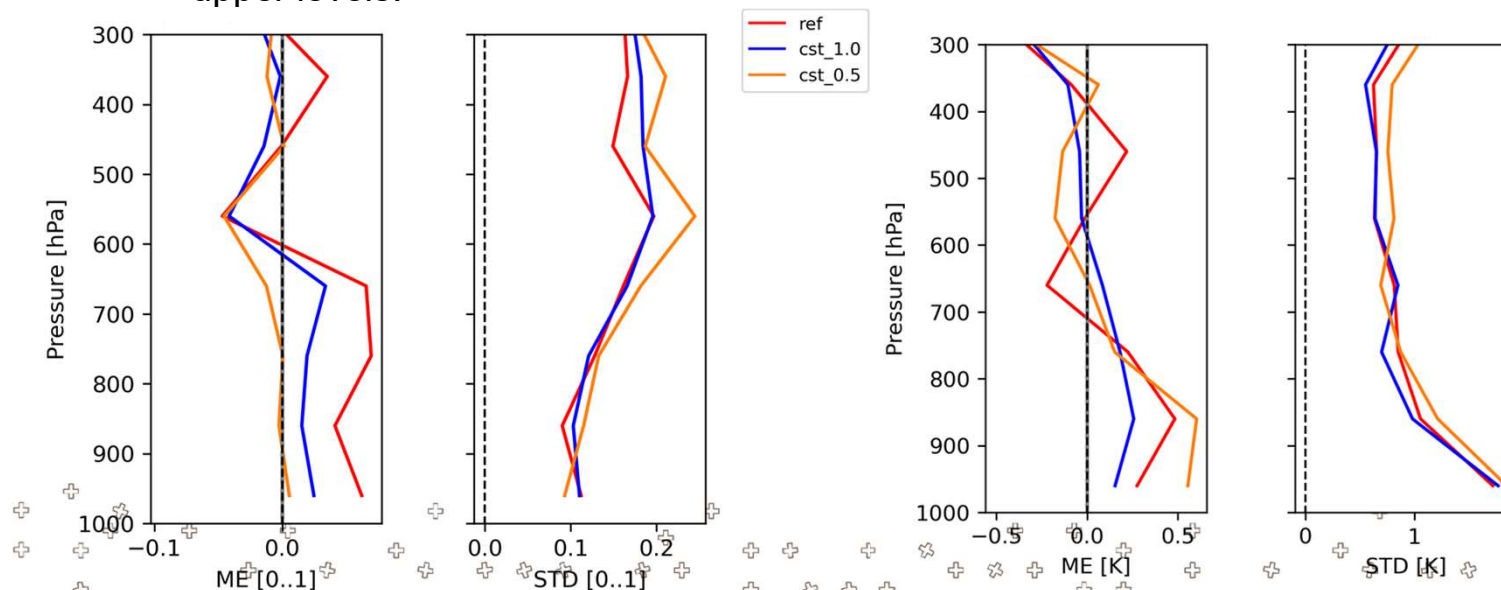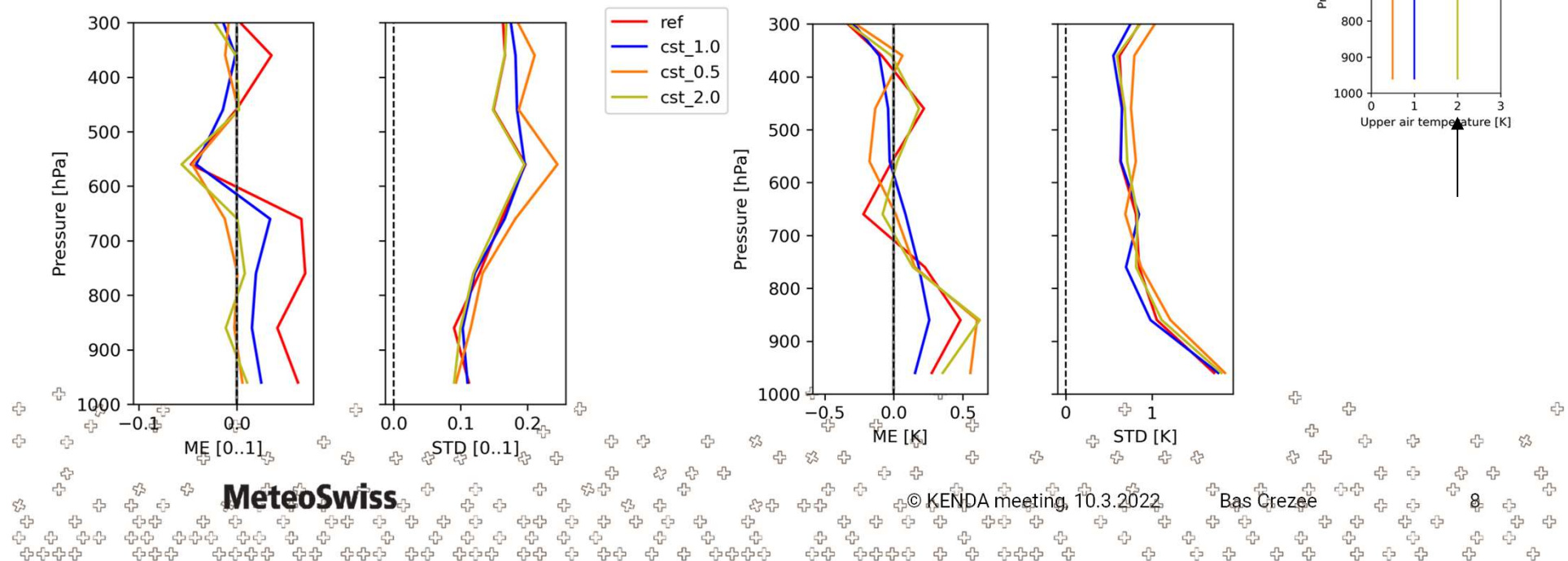
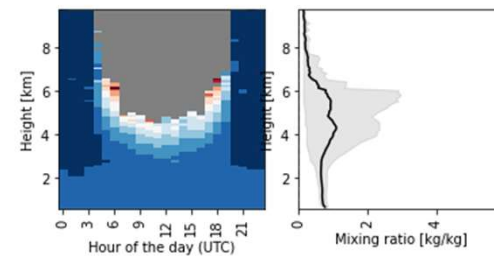MeteoSwiss

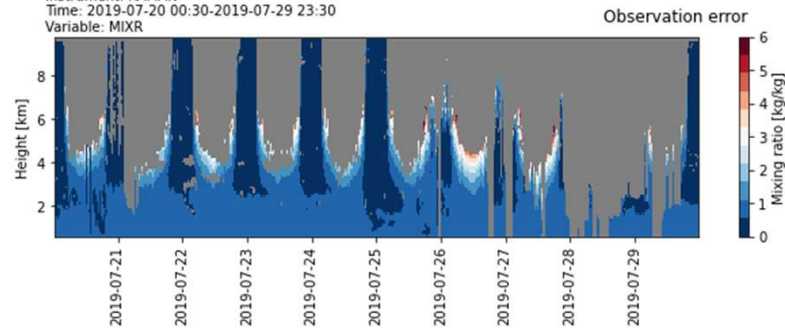# How about *increasing* the observation error?

- Also improved RH bias compared to REF
- STD rather neutral compared to REF

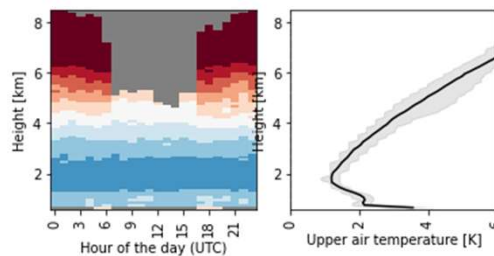- Temperature bias rather neutral
- STD very similar

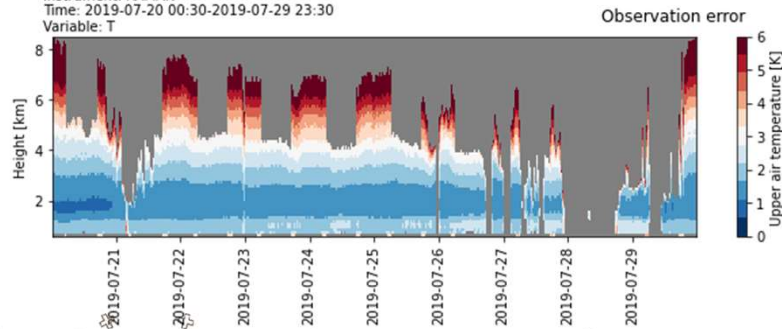# Time-varying observation error from RALMO

Can we further improve using time-varying obs error?

Observation error (e_o)

Relative Humidity

- Bias reduced, except for ~650 hPa level (--> likely due to T bias!)
- STD improved below 650 hPa, above it gets worse

Legend:
- ref (red)
- cst_1.0 (blue)
- cst_0.5 (orange)
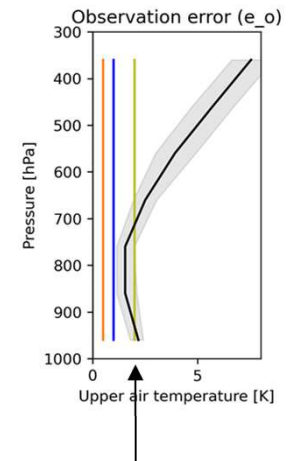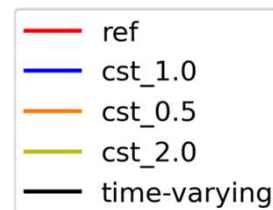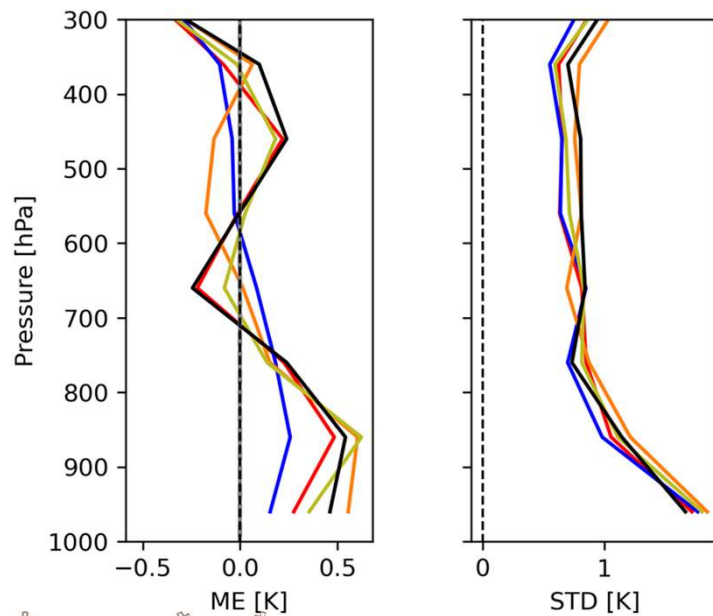- cst_2.0 (olive)
- time-varying (black)
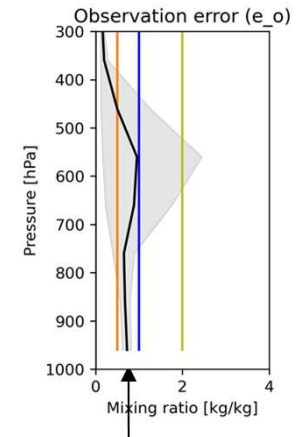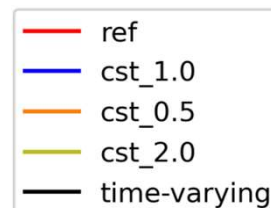
Can we further improve using time-varying obs error?

Temperature

- No clear positive impact can be identified.

Time-varying over extended time period (31 days)

Legend:
- ref (red)
- cst_1.0 (blue)
- time-varying (black)
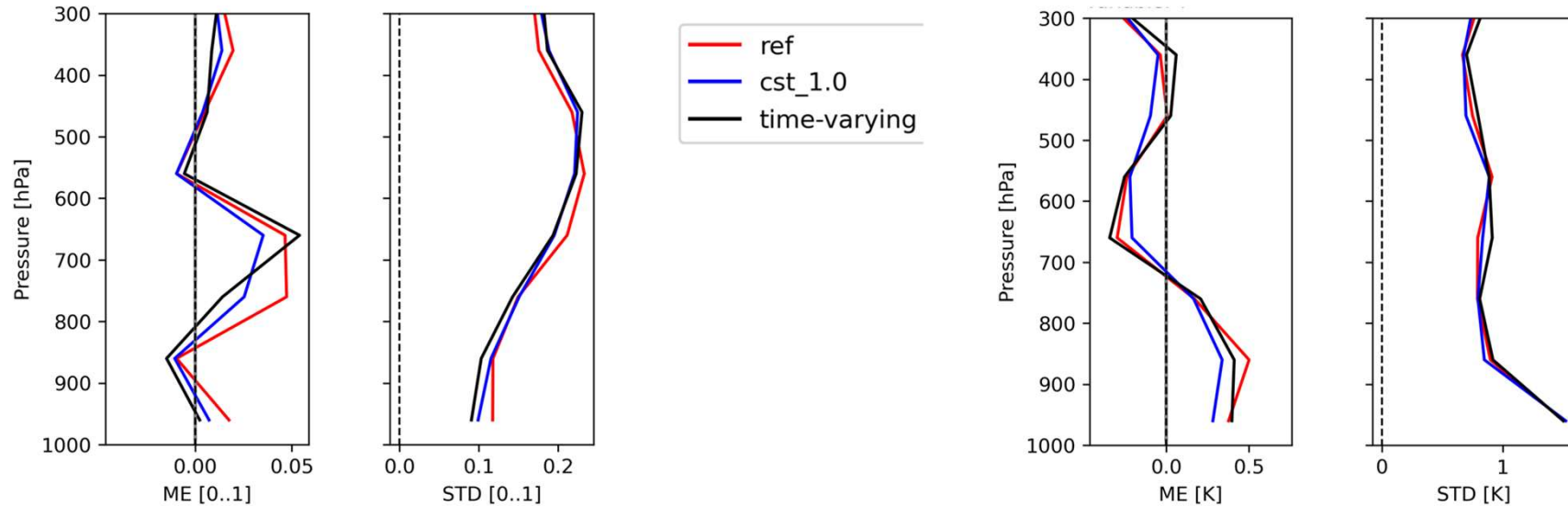
Relative Humidity
- Robust improvement in STD for RH below ~500 hPa
- BIAS in RH improved at most levels except 650 hPa → potentially related to T assimilation

Temperature
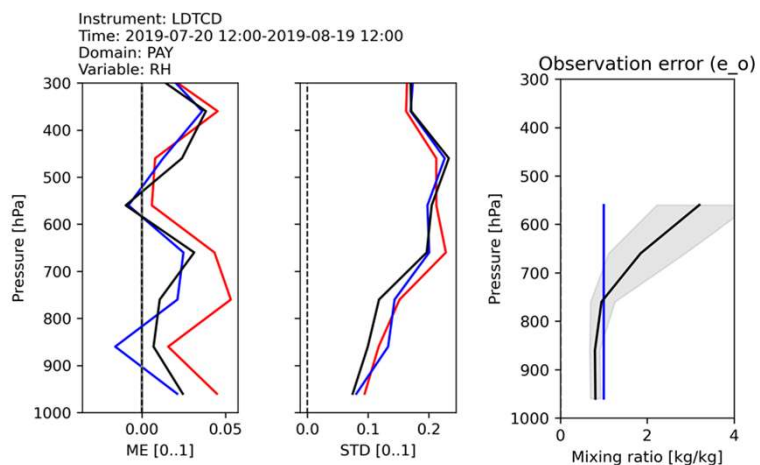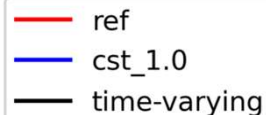- BIAS rather neutral
- STD gets slightly worse (→ data quality?)

Daytime only

Instrument: LDTCD
Time: 2019-07-20 12:00-2019-08-19 12:00
Domain: PAY
Variable: RH

Instrument: LDTCD
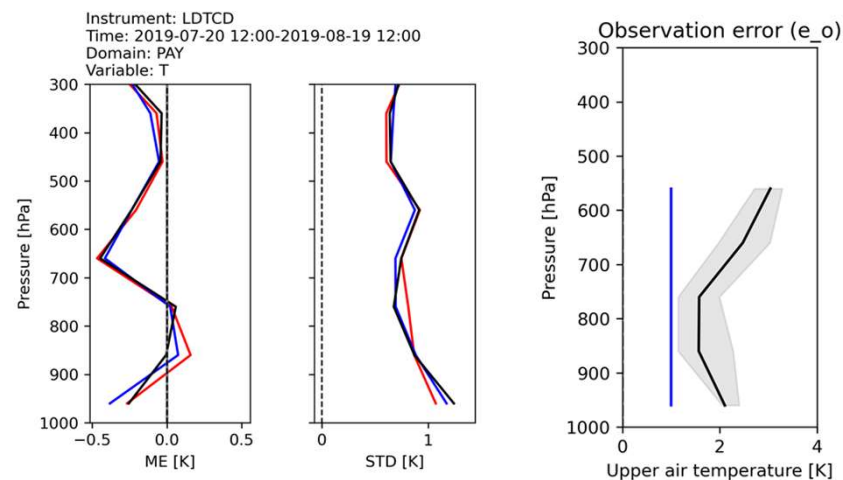Time: 2019-07-20 12:00-2019-08-19 12:00
Domain: PAY
Variable: T

Relative Humidity
- Robust improvement in STD for RH
- BIAS in RH also improved

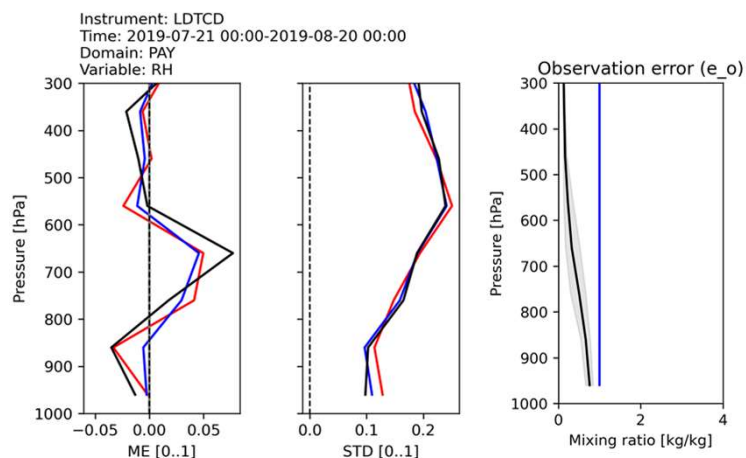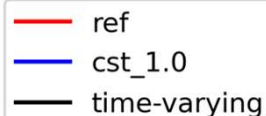Temperature
- Both BIAS and STD rather neutral

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Nighttime only

ref
cst_1.0
time-varying

Instrument: LDTCD
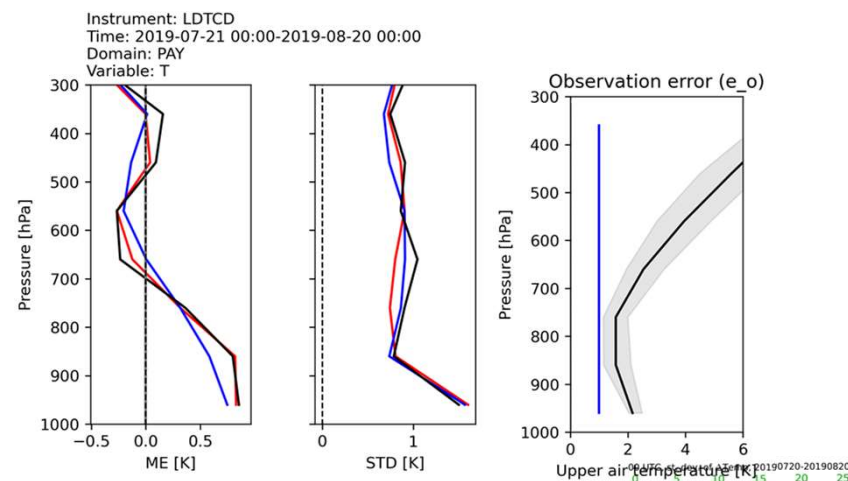Time: 2019-07-21 00:00-2019-08-20 00:00
Domain: PAY
Variable: RH

Relative Humidity
- Improvement in STD less pronounced compared to daytime
- BIAS in RH improved at most levels except 650 hPa → potentially related to T assimilation
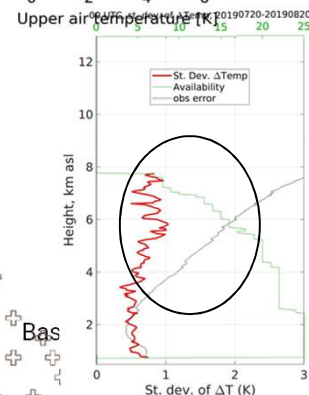
Instrument: LDTCD
Time: 2019-07-21 00:00-2019-08-20 00:00
Domain: PAY
Variable: T

Temperature
- BIAS neutral
- STD gets worse between 850-600 hPa.

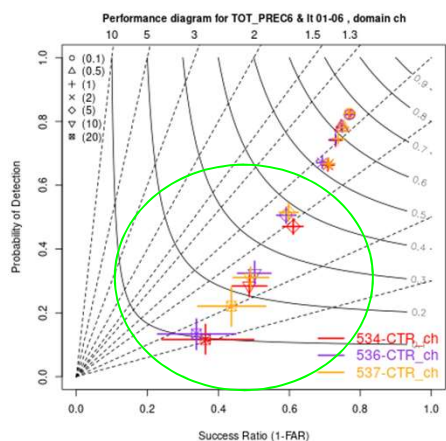Mismatch between specified Temperature observation error and comparison to radiosounding →

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© KENDA meeting, 10.3.2022

Bas

4

Does the assimilation of RALMO lead to better forecasts?
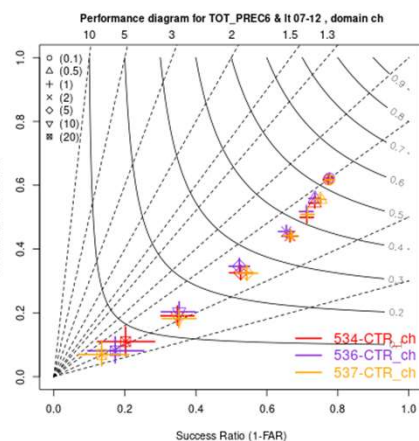
Verification of precipitation against surface stations.
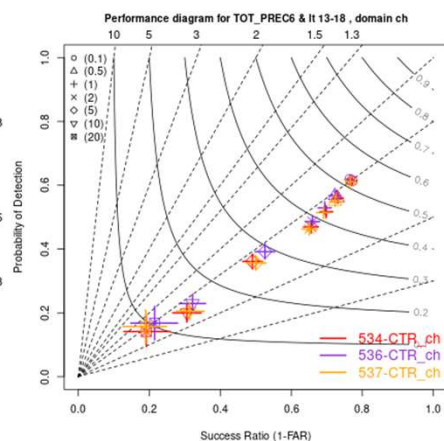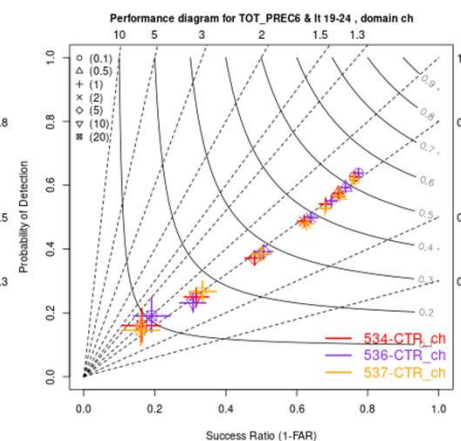
1-6 hours   **7-12 hours**   **13-18 hours**   **19-24 hours**

- Moderate to large improvement for short leadtimes (1-6h) at larger thresholds (5,10,20 mm in 6 hours)
- Some positive impact can be seen also into the longer leadtimes

ref
cst_1.0
time-varying

Spatial verification

Precipitation 1h against combiprecip
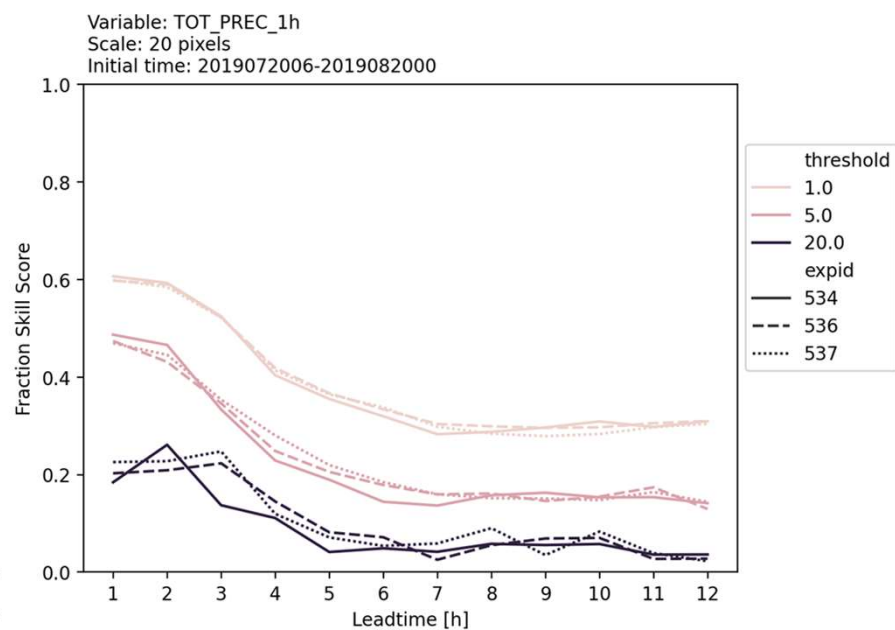
Synthetic satellite images against MSG

Summary

Assimilation of RALMO data

- Reduces dry bias and improves STD of RH up to ~600 hPa

- Leads to better precipitation forecasts with significant impact up to +8 h leadtime and potentially positive impact up to +36 h

- Has a neutral impact on temperature profiles

- There is a positive impact for time-varying compared to constant obs_error, this vanishes above 500 hPa likely due to misspecification of obs_error

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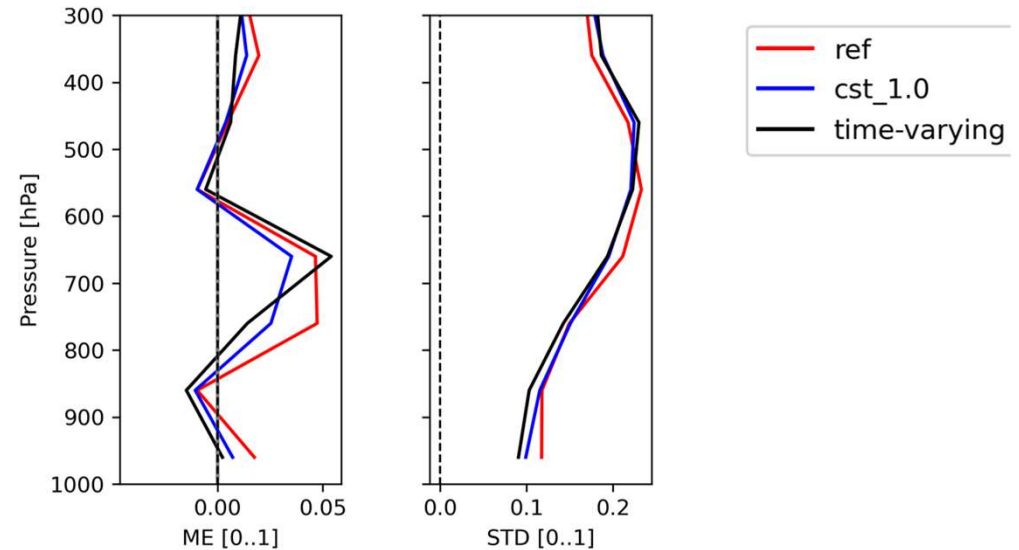
Discussion

- Disentangling MIXR and T effects is hard → separate experiments

- Observation thinning was tested and updated Desroziers estimate is much closer to RALMO error → see figures.

- Not confident in obs_error of T above 600 hPa at night.
    - → Colleagues in PAY are looking into this

Ideas for future experiments
1. Only assimilate MIXR time-varying. Aim: see if worse RH verification above 600 hPa is due to T assim
2. "Extreme" thinning experiment with just 3 points in the vertical with time-varying obs_error. Aim: compare updated Desroziers estimate with obs_errors from RALMO
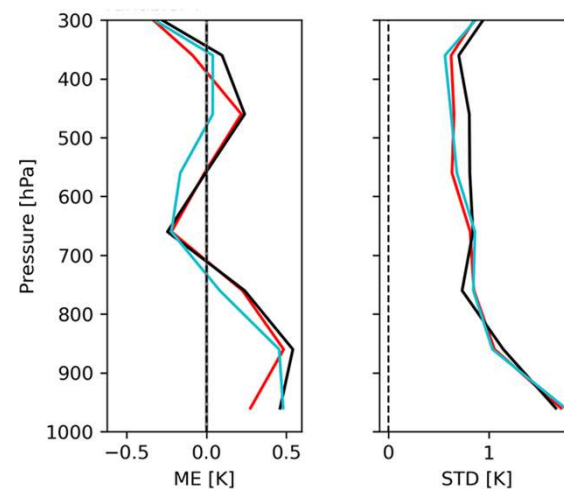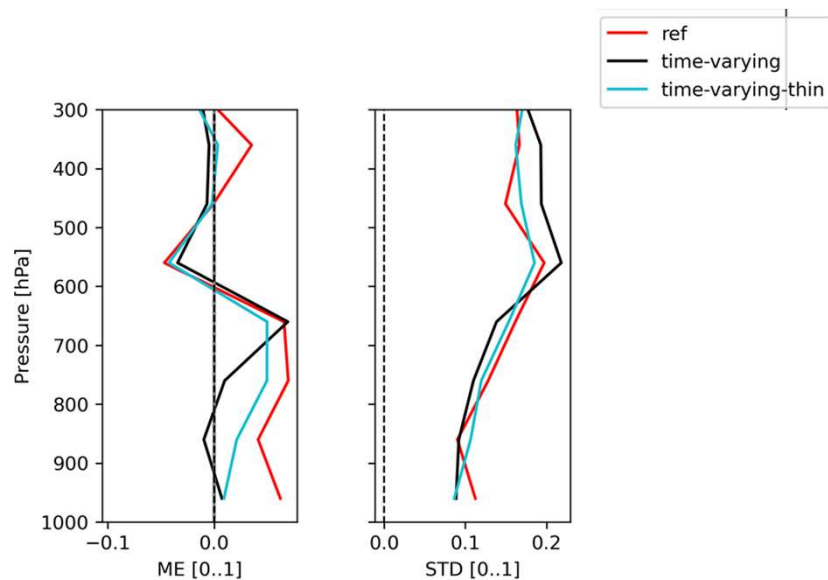3. Outcome of 1. and 2. helps us design an optimal observation error (multiplicative or additive) experiment.

Clarify:
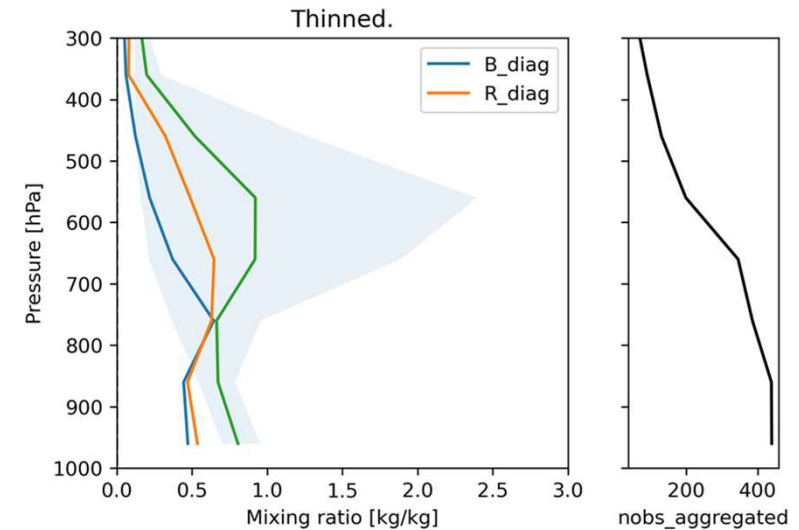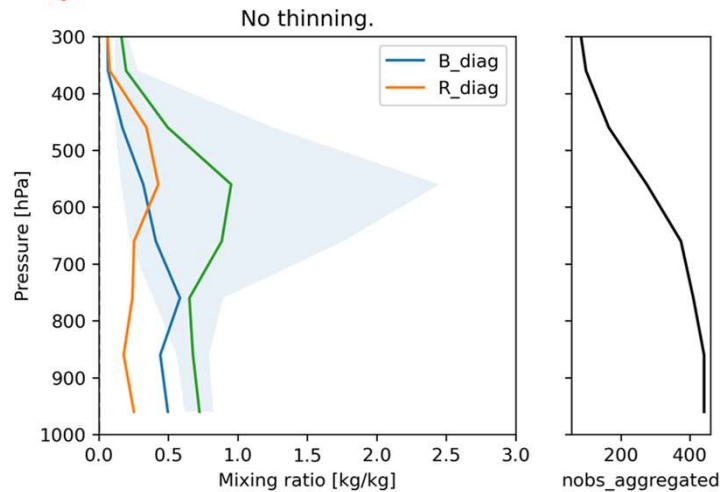- Use time-varying observation error but specify variance instead of STD (?)

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Thinning

Thinning: From one measurement every 30m to one measurement every 600m in vertical.

New Desroziers estimate for thinned experiment.

- R_diag much closer to obs_error
- Outlook:
  - Same for Temperature
  - Split out to Day/Night
  - Another "extreme" THINNING experiment with e.g. only three points assimilated at 850 hPa; 650 hPa and 450 hPa?
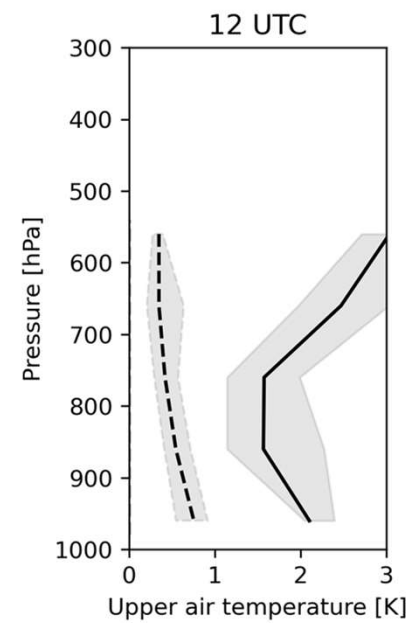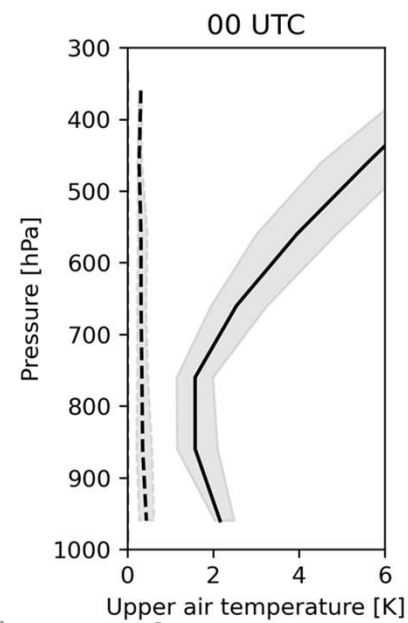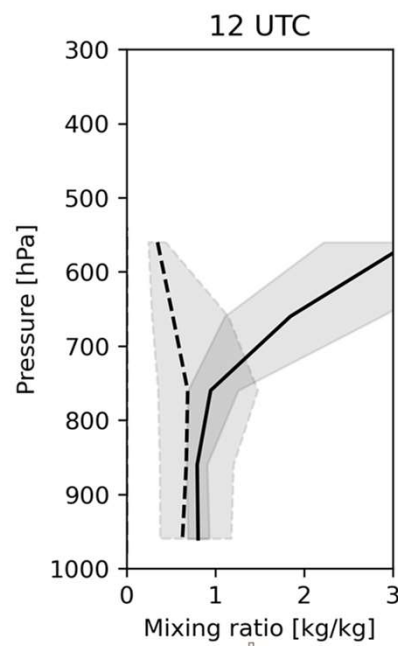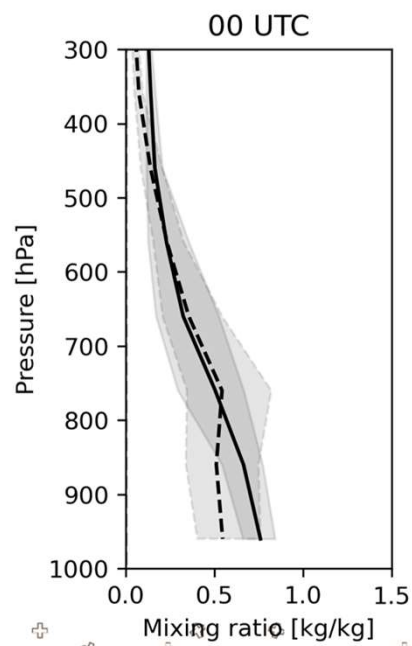
Comparison obs_error (solid) vs fgspread (dashed)

Verification of forecasts (6-hourly up to +36h)
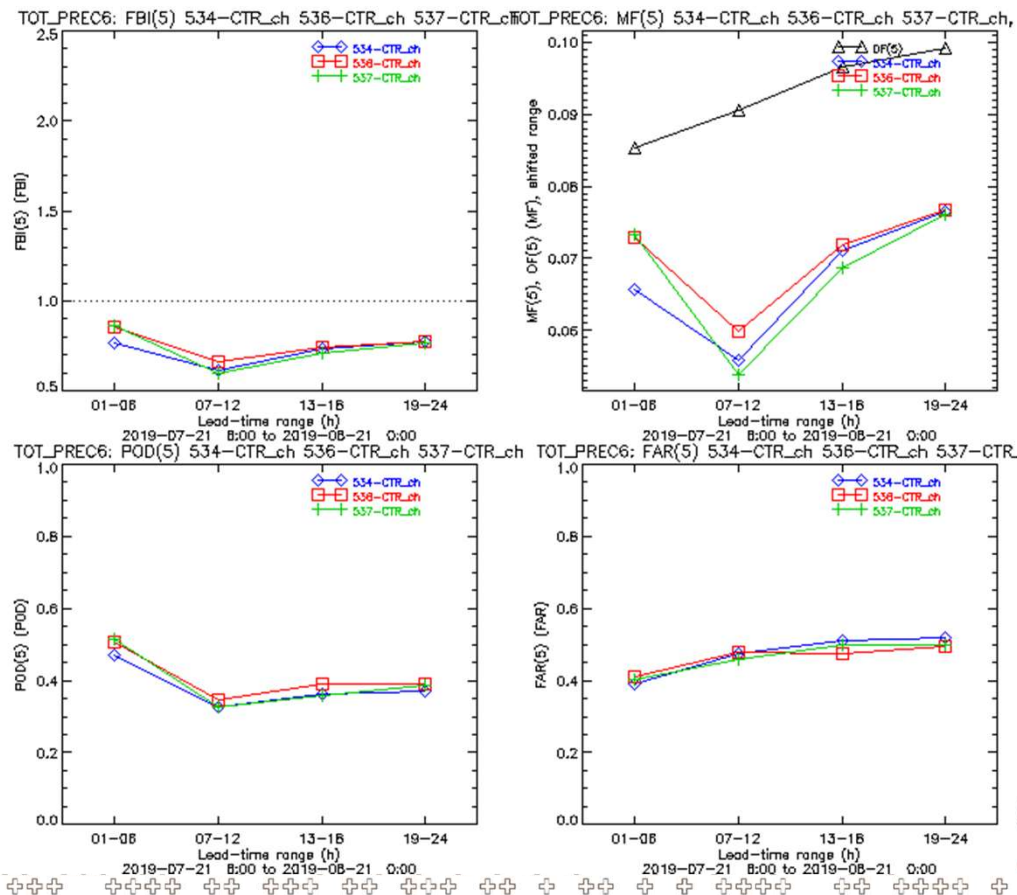
Plots RALMO vs RS for Temperature

Plots RALMO vs RS for MIXR