# Updates on running ROMEX experiments at ECMWF

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Thanks to: Sean Healy

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ECMWF

# Topics

- How impact scales with number of RO observations.
- How cooling is affected from changes in FO.
- What EDA experiments can tell us.

# Review

**Setup**

- Using past operational model cycle of the IFS (48R1)
- Run data assimilation experiments for Sept – Nov 2022

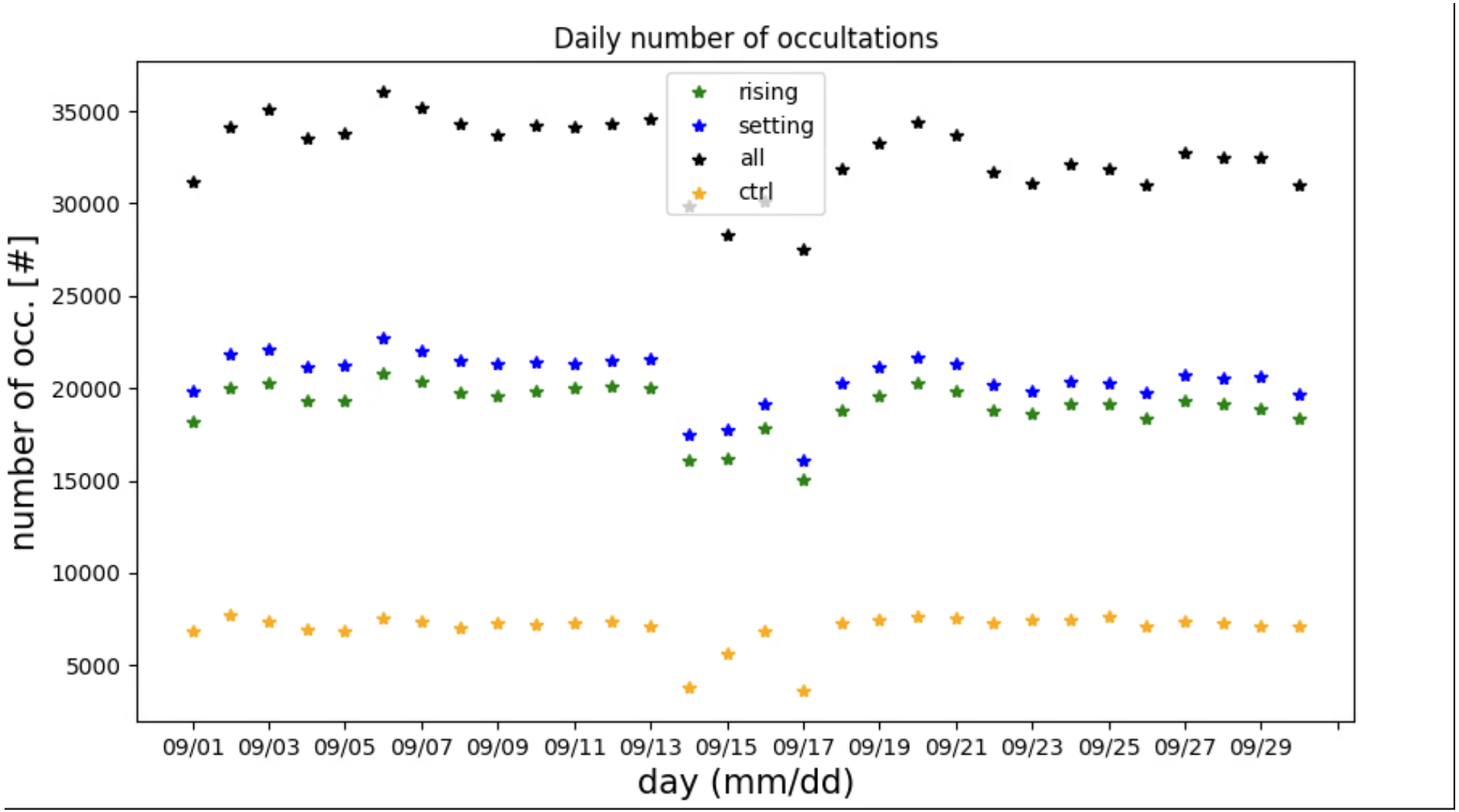
**Verification against operational analysis and observations**

- Fits to independent observations
- Forecast scores (Std dev., RMSE, Anomaly correlation)
- Omit first 9 days in verification statistics to avoid including spinup issues

# Experiments

| id | daily number | description |
|---|---|---|
| **ctrl** | 7000 | Baseline (all GNSS-RO data excl. commercial and Chinese data) |
| **ctrl w/o C2** | 3000 | **Ctrl** w/o COSMIC2 |
| **ROMEX** | 33,000 | **Ctrl** + Commercial and Chinese data = All ROMEX data |
| **noRO** | 0 | No GNSS-RO data |
| **rising** | 19,000 | **Ctrl** + only rising occ. from commercial and Chinese data |
| **setting** | 21,000 | **Ctrl** + only setting occ. from commercial and Chinese data |

# Number of occultations



# Scorecard: Romex vs. Control – against operational analysis

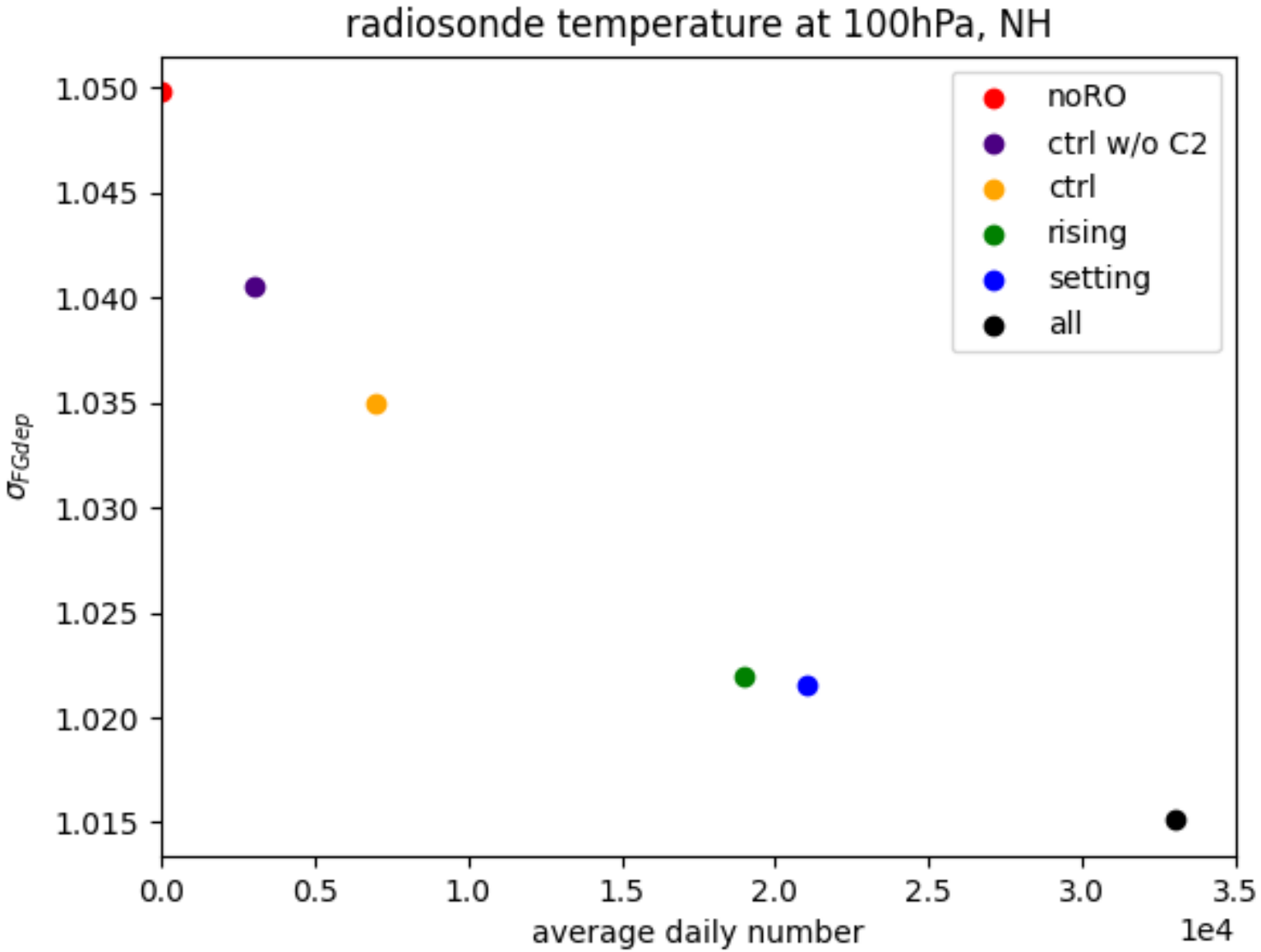

ccaf = Anomaly correlation

rmsef=Root mean square error

sdef = Standard deviation of forecast error

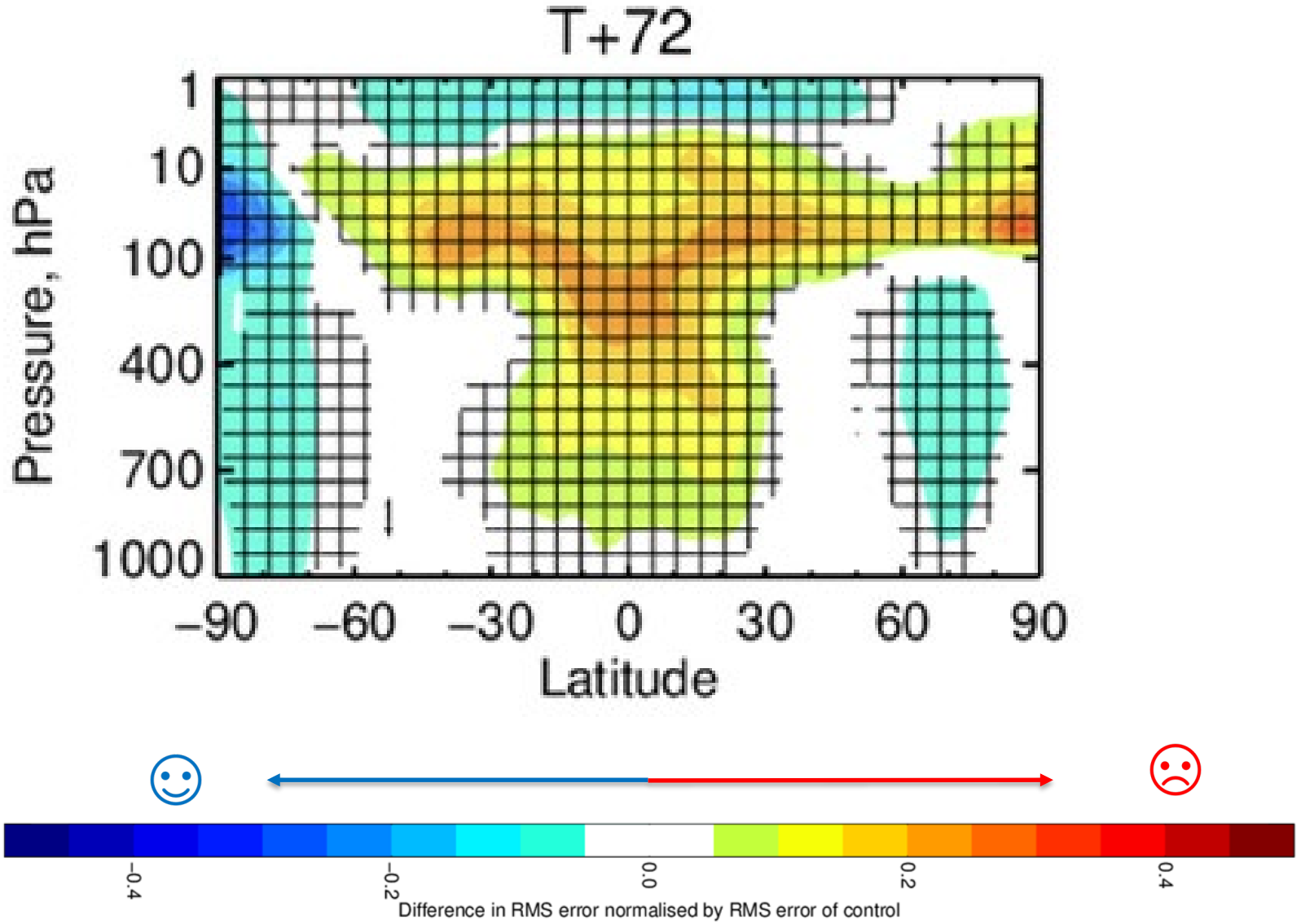
# Scorecard: Romex vs. Control – against observations

# How does impact scale with daily number of RO?



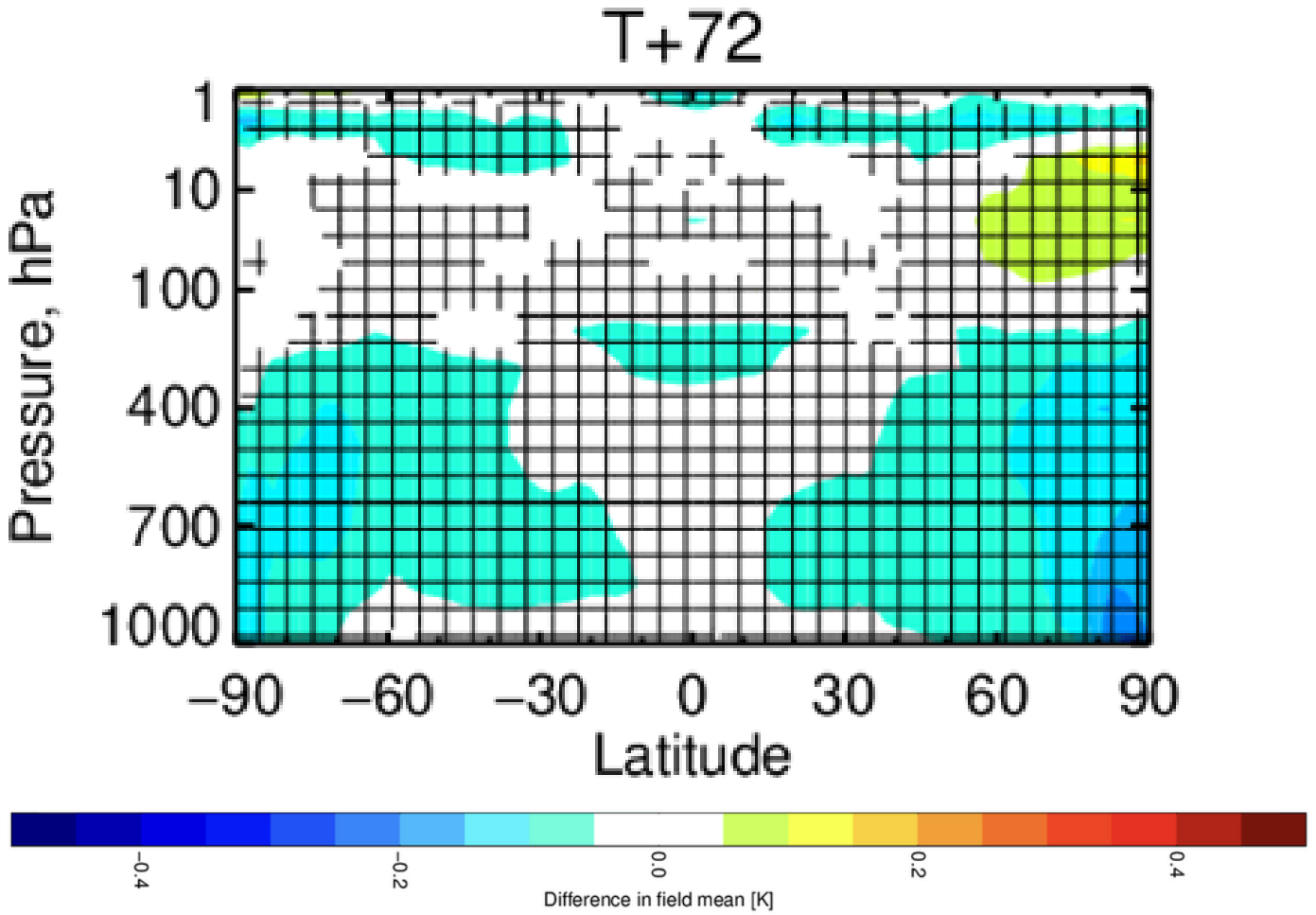
# Increase in RMSE for Geopotential

**ROMEX - control**



# mean change in temperature

**ROMEX - control**




Cooling of atmosphere

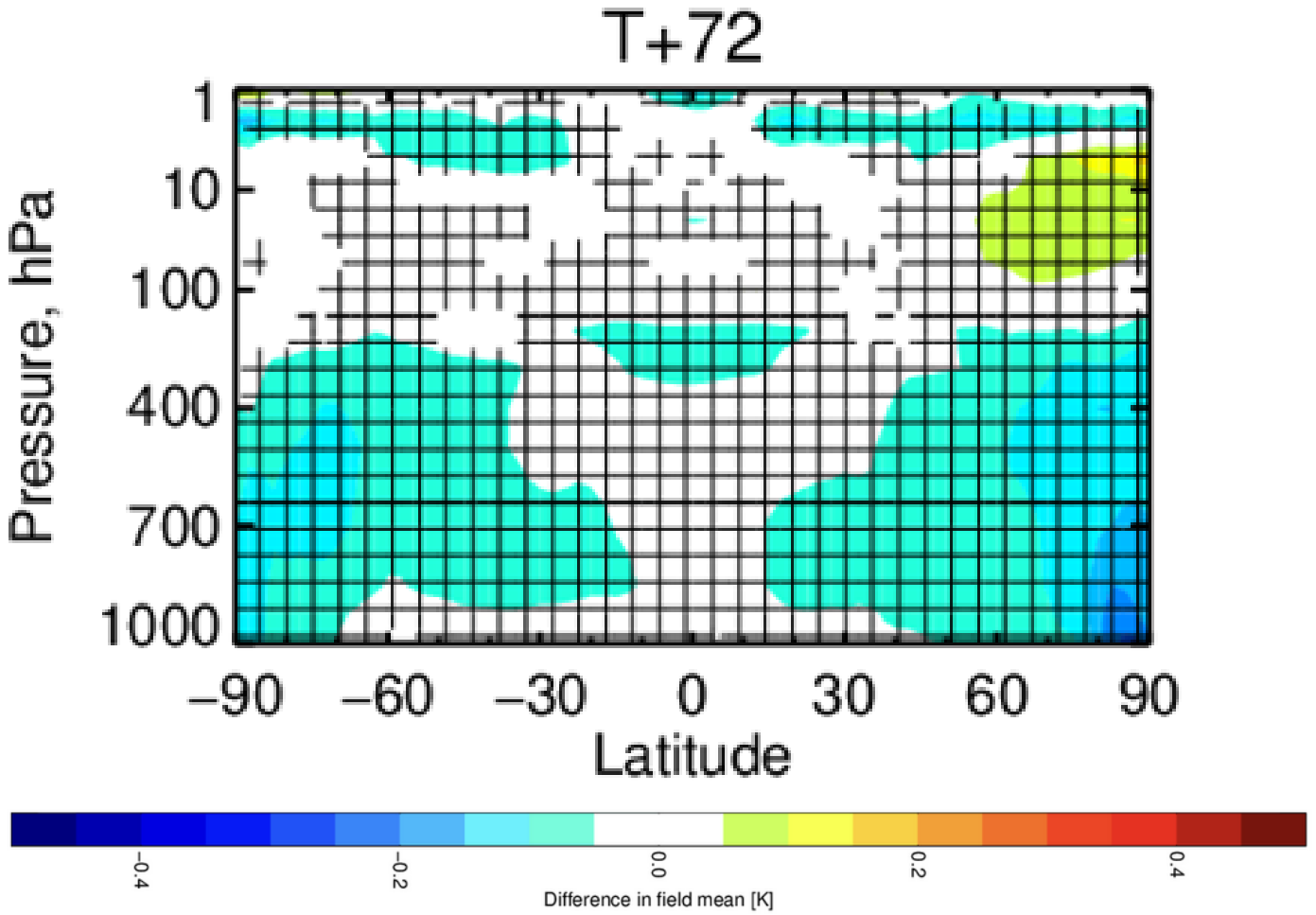
# Sensitivity experiments

- small modifications of the GNSS-RO forward operator -

| id | description |
|---|---|
| control | |
| control w/o C2 | |
| ROMEX | |
| noRO | |
| rising | |
| setting | |
| **ROMEX no 5km** | Exclude GNSS-RO in lowest 5 km |
| **ROMEX no hydro** | Removing hydrostatic tail |
| **- 7m** | Take 7m off from geometric height |
| **0.1% refrac coeff** | Add 0.1% to refractivity coefficient N |

# mean change in temperature

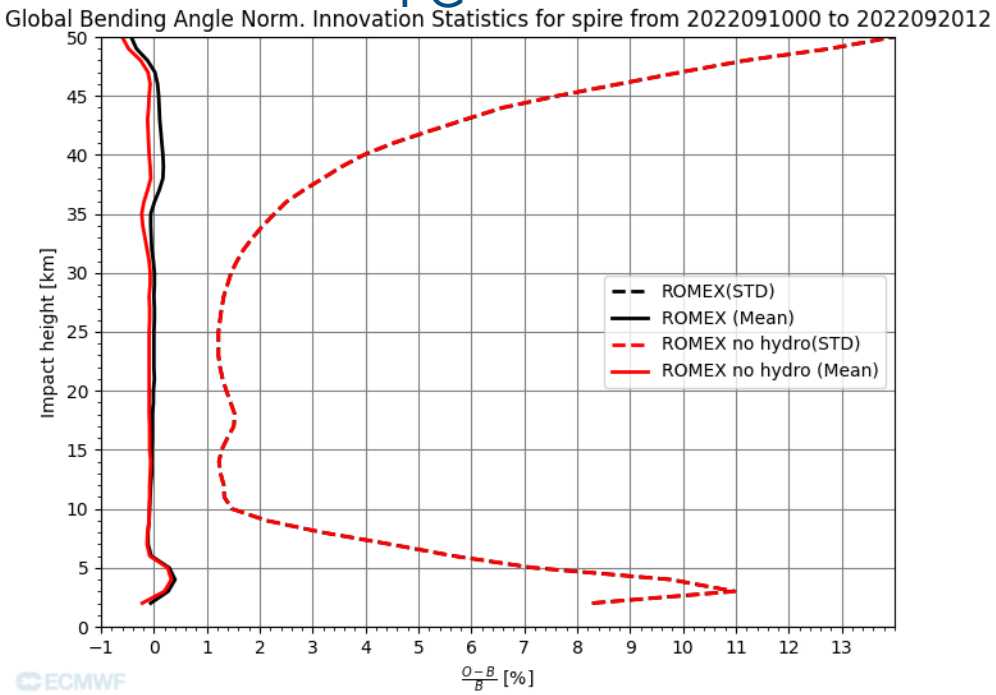
**ROMEX - control**



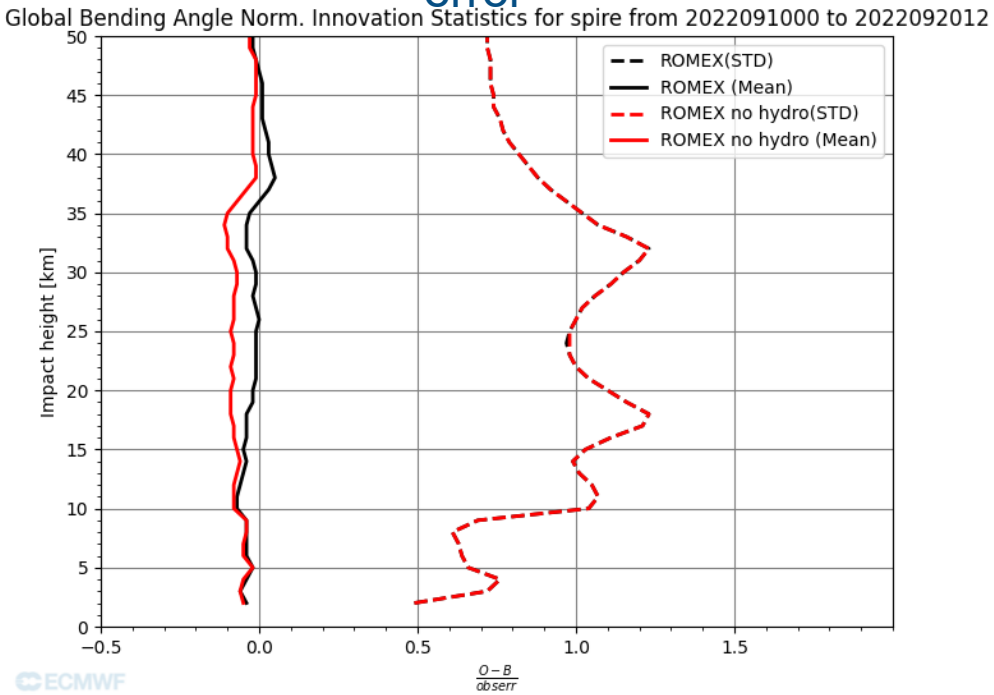
# Normalised FG dep for Spire data

## testing no hydrostatic tail

by FG

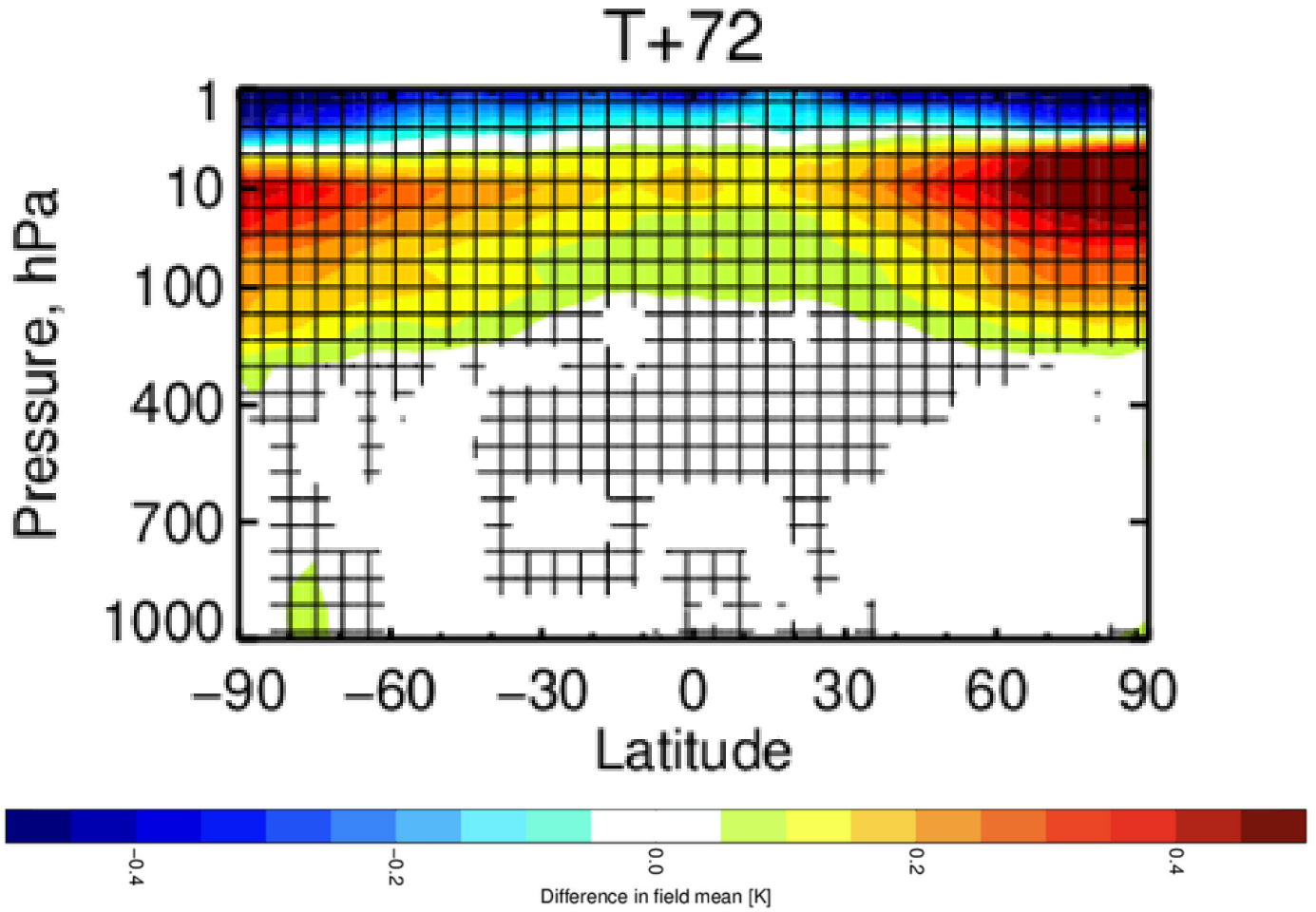



by obs error

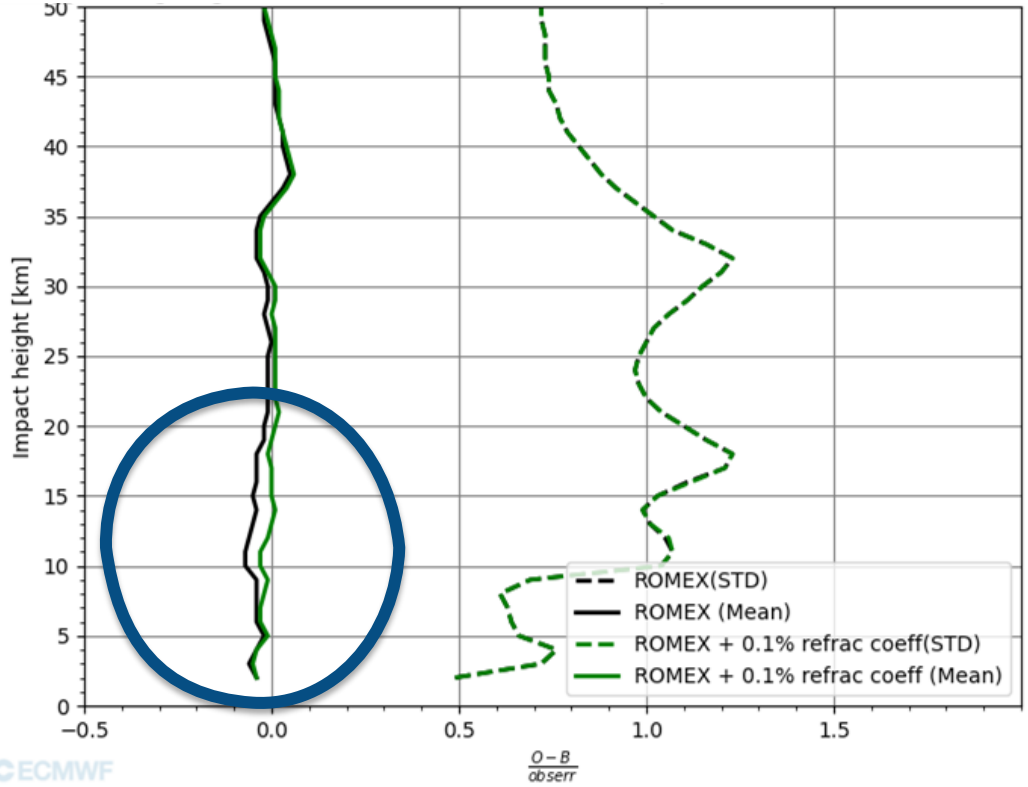


# mean change in temperature

## ROMEX no hydro - control



# normalised FG dep for Spire data
(by obs
error)
testing 0.1 % refrac coefficient in FO

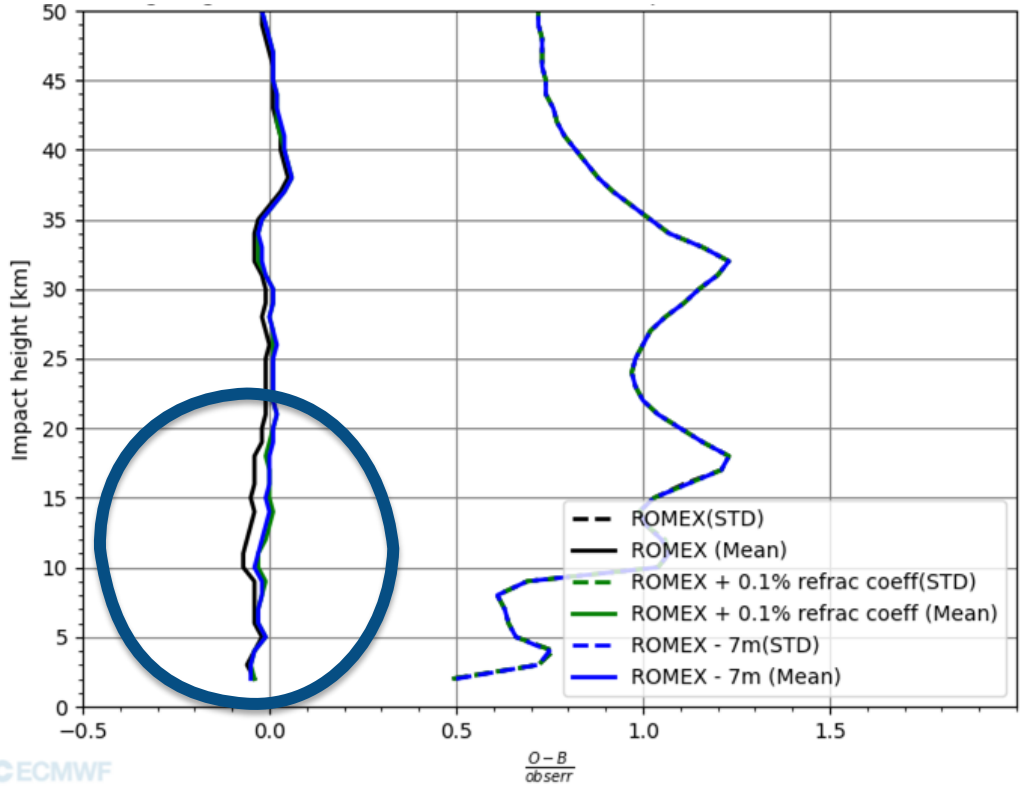


# normalised FG dep for Spire data

(by obs
error)

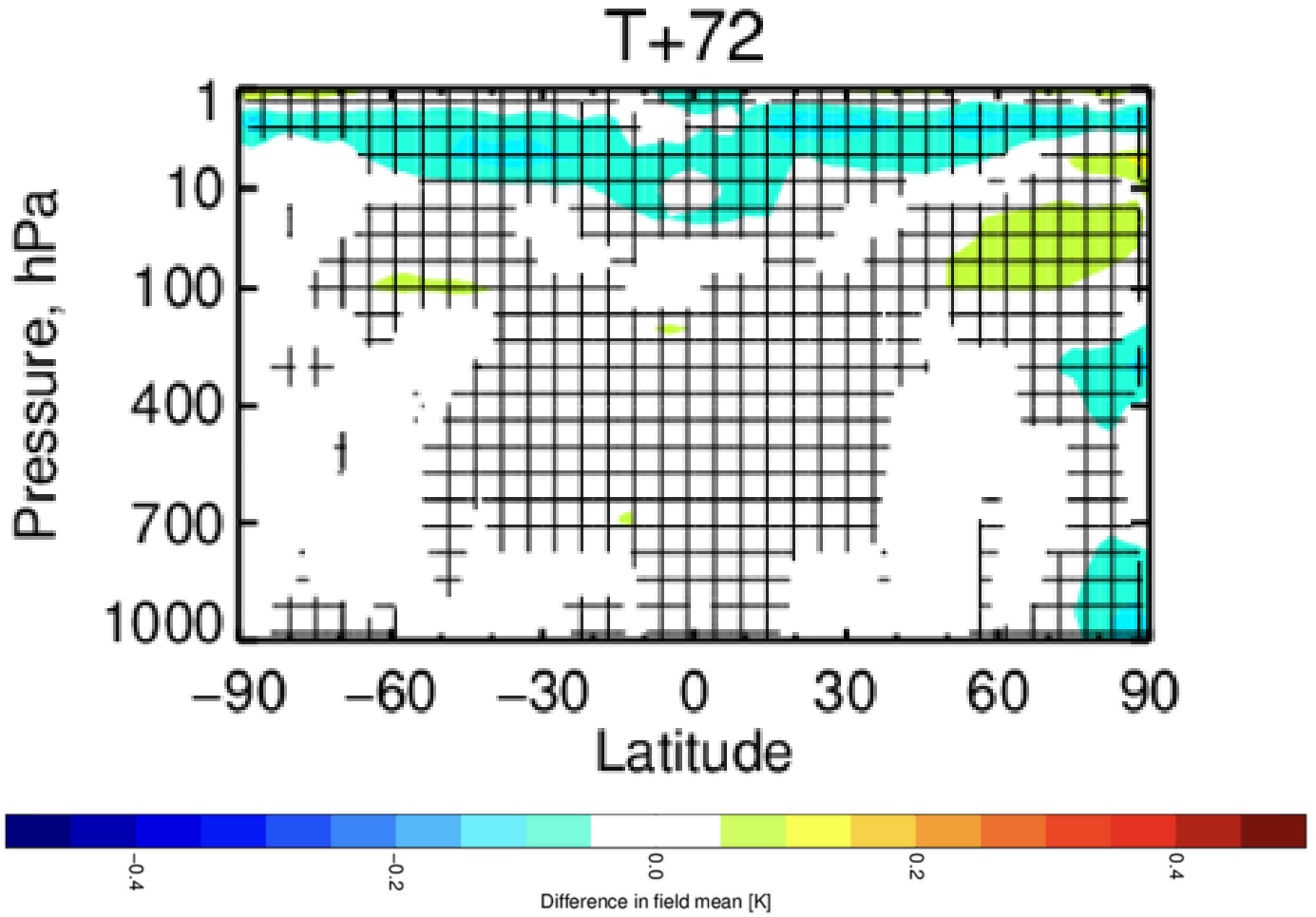
testing 0.1 % refrac coefficient in FO

testing substracting 7m in calculating geometric height in FO



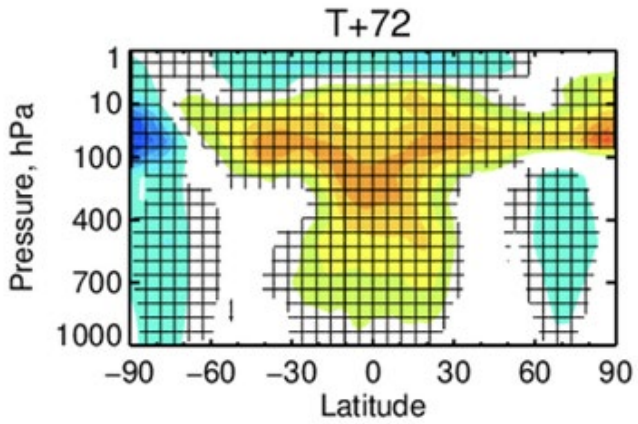
# mean change in temperature

## 0.1% refrac coeff - control

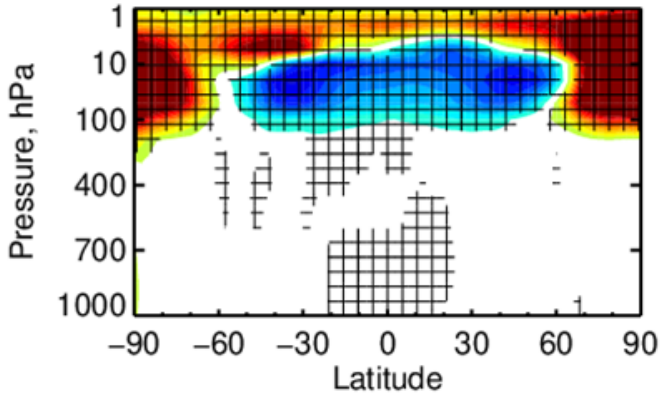


# Change in RMSE for Geopotential

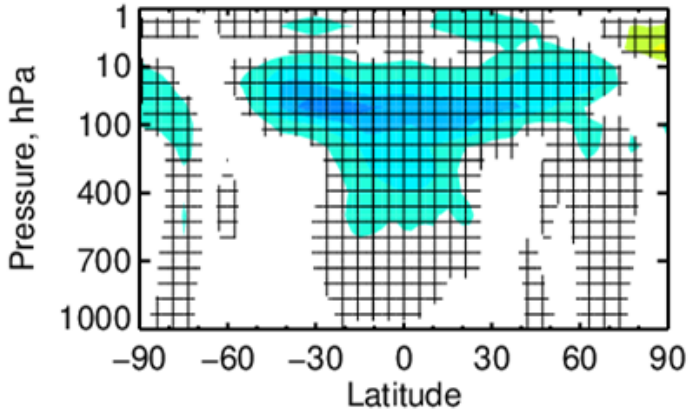
## ROMEX - control



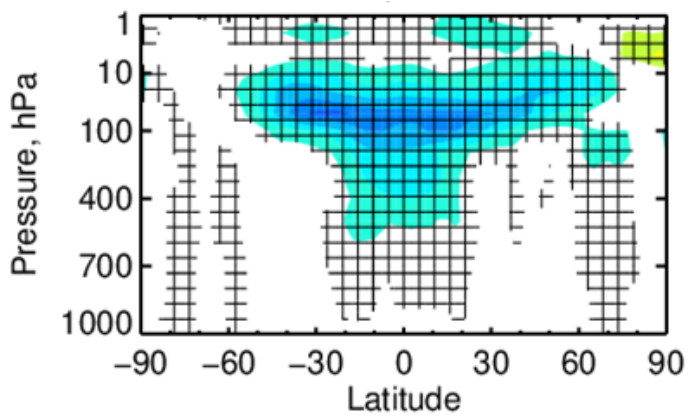

## ROMEX no hydro - control




## 0.1% refrac coeff - control




## Minus 7m - control



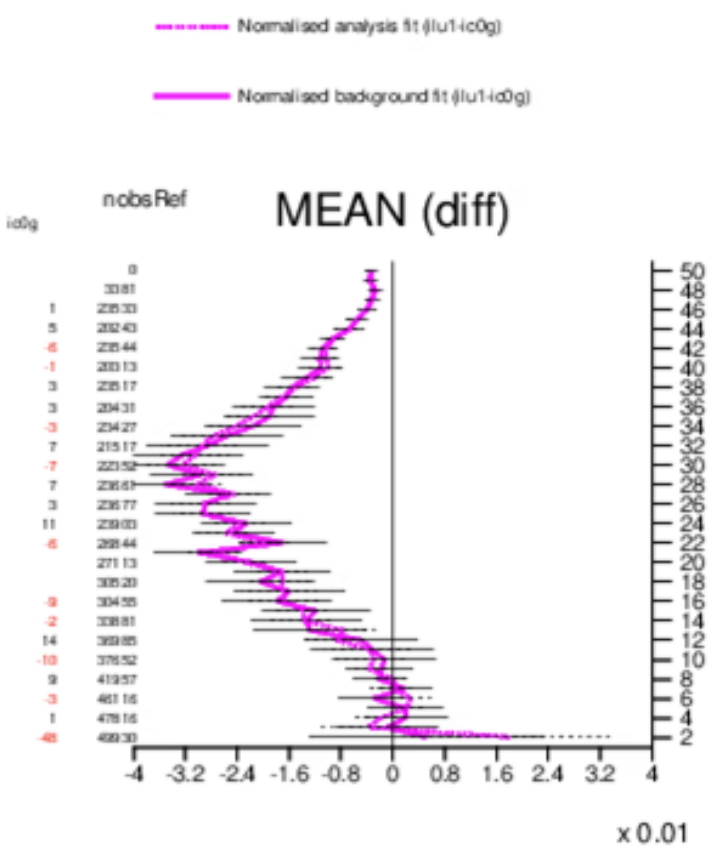

# sensitivity experiments

- small modifications of the GNSS-RO forward operator -

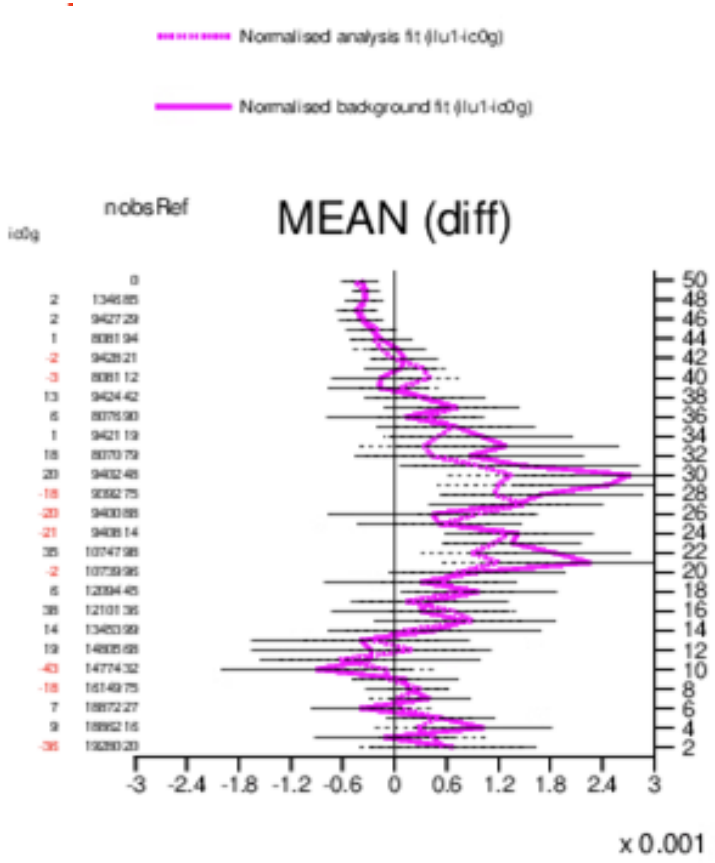
| id | description |
|---|---|
| control | |
| ROMEX | |
| noRO | |
| rising | |
| setting | |
| ROMEX no 5km | |
| ROMEX no hydro | |
| - 7m | |
| 0.1% refrac coeff | |
| **dR** | add correction dR as suggested by Josep A. |

# Difference in normalised mean BA (ROMEX_dR –ROMEX)

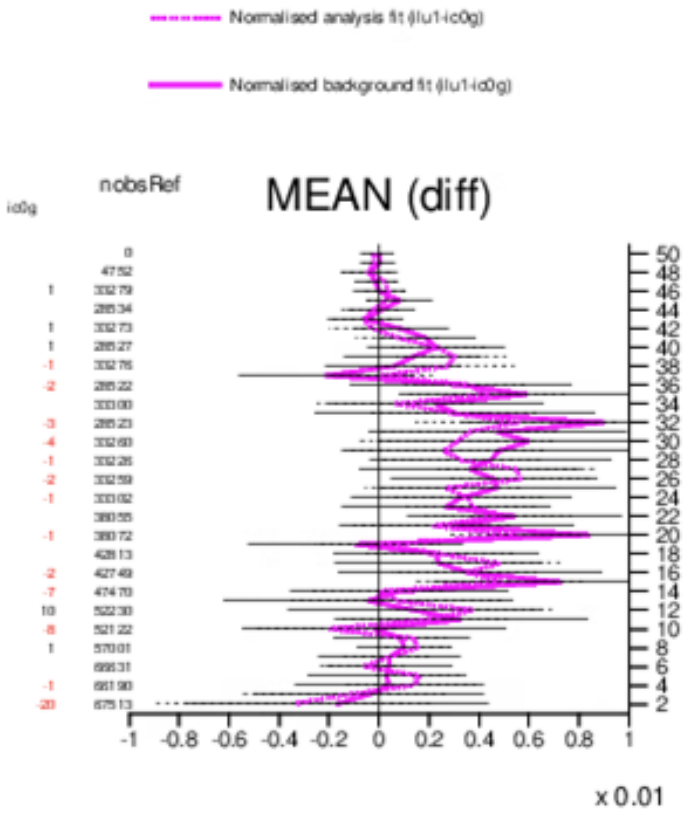
## COSMIC-2 E6, R




## SPIRE 3U, R

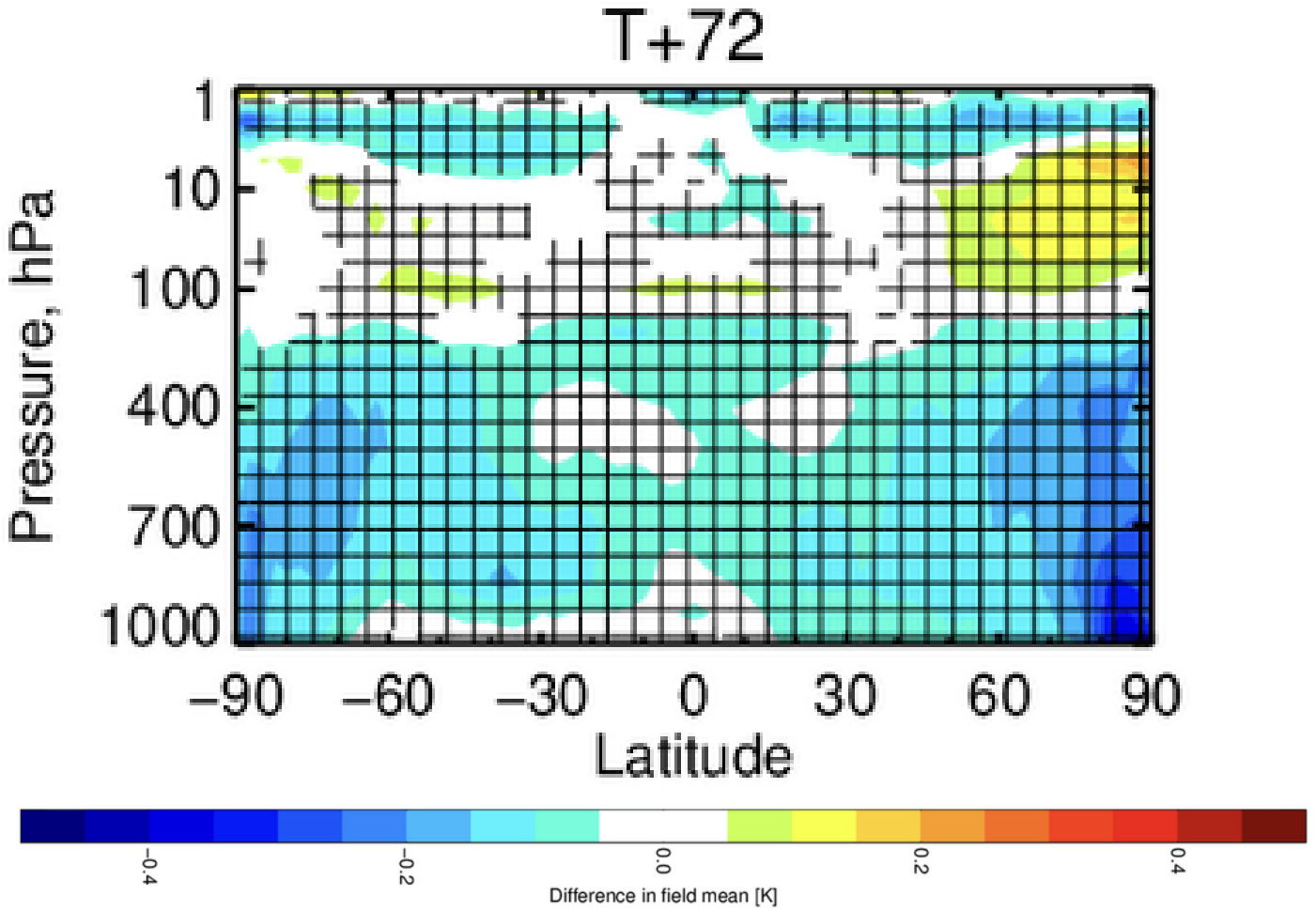



## METOP-C, GRAS, R



# mean change in temperature

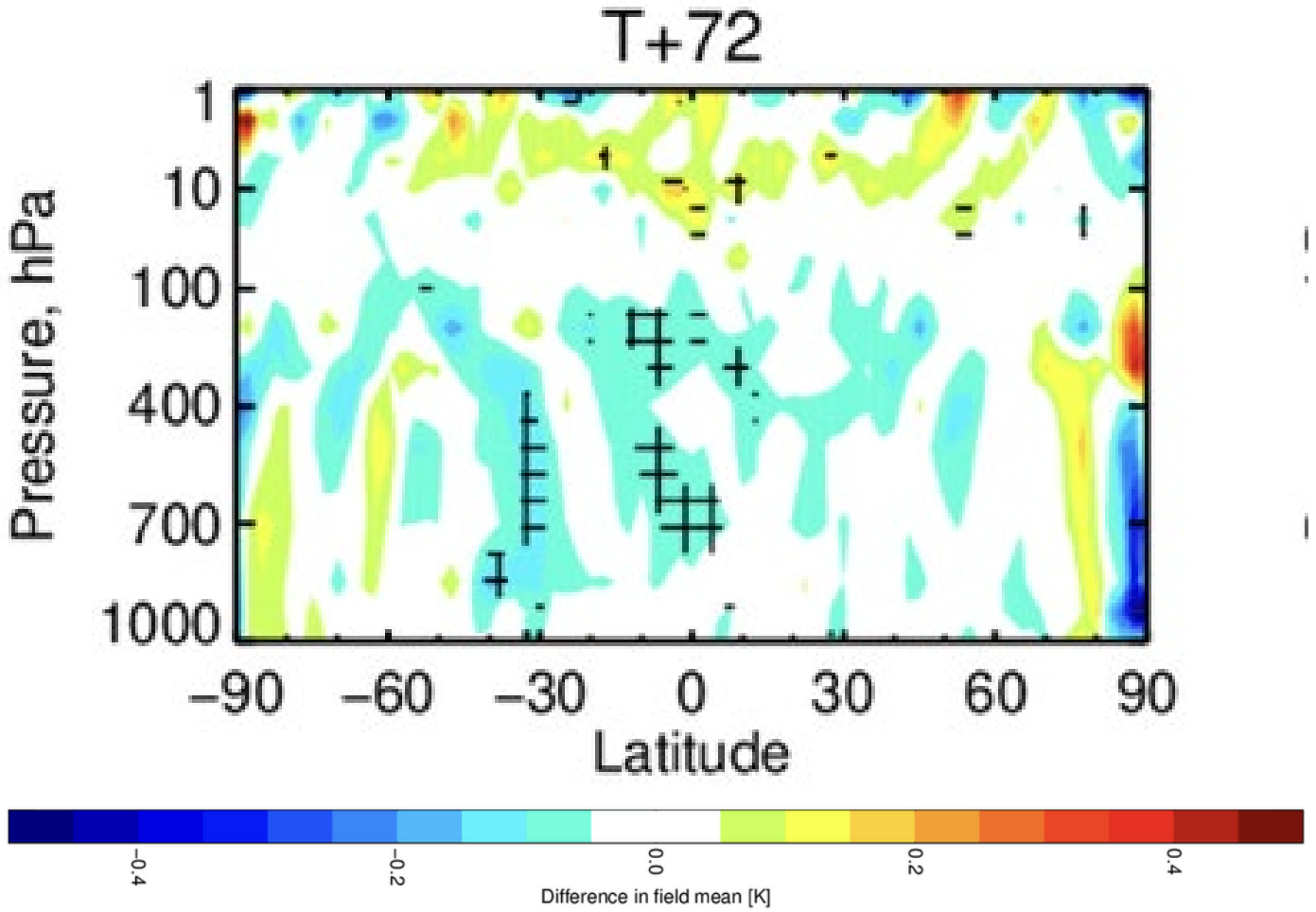
**ROMEX - control**




Cooling of atmosphere

# mean change in temperature

**ROMEX dR - ROMEX**

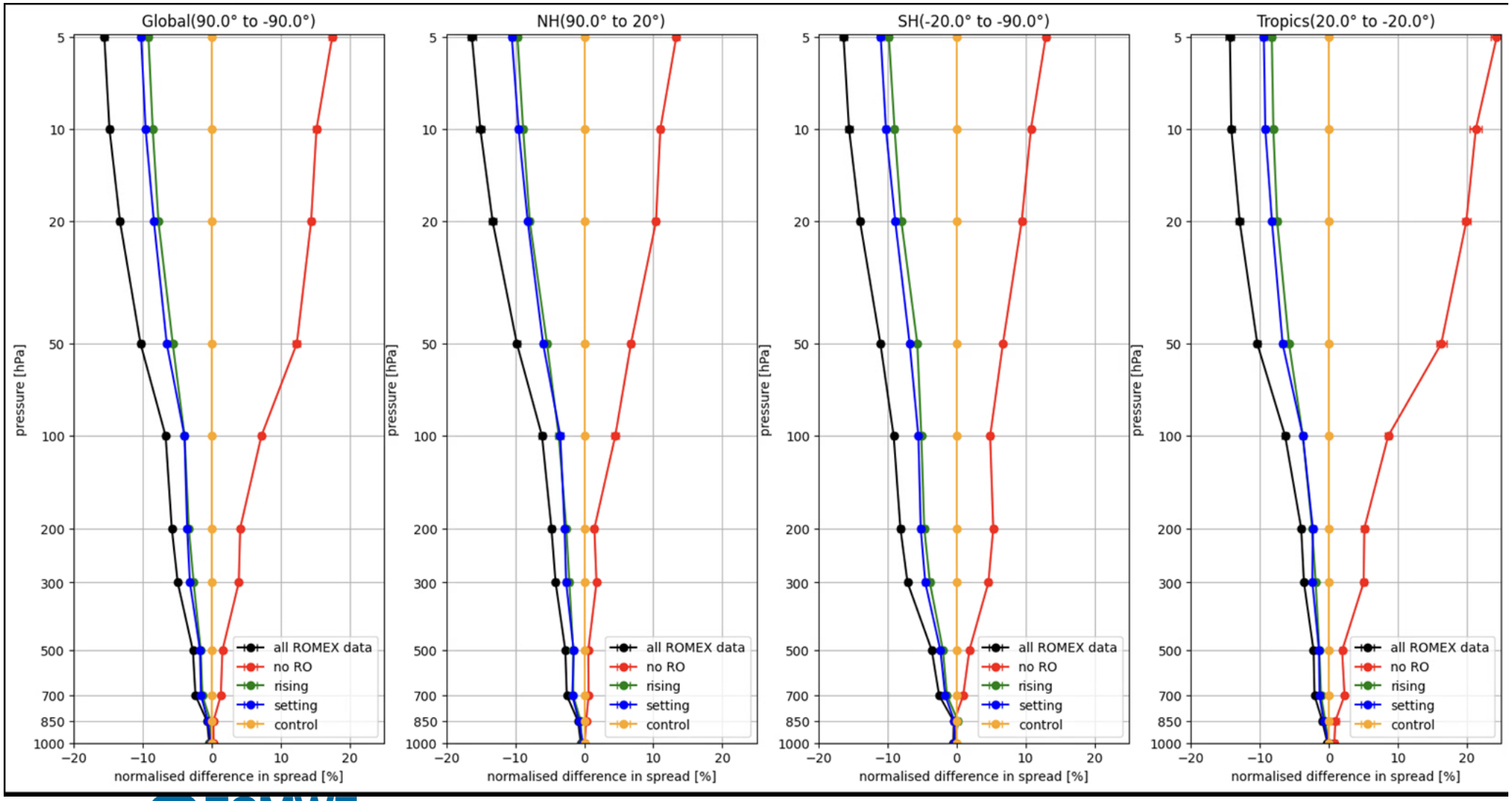



additional
cooling of atmosphere

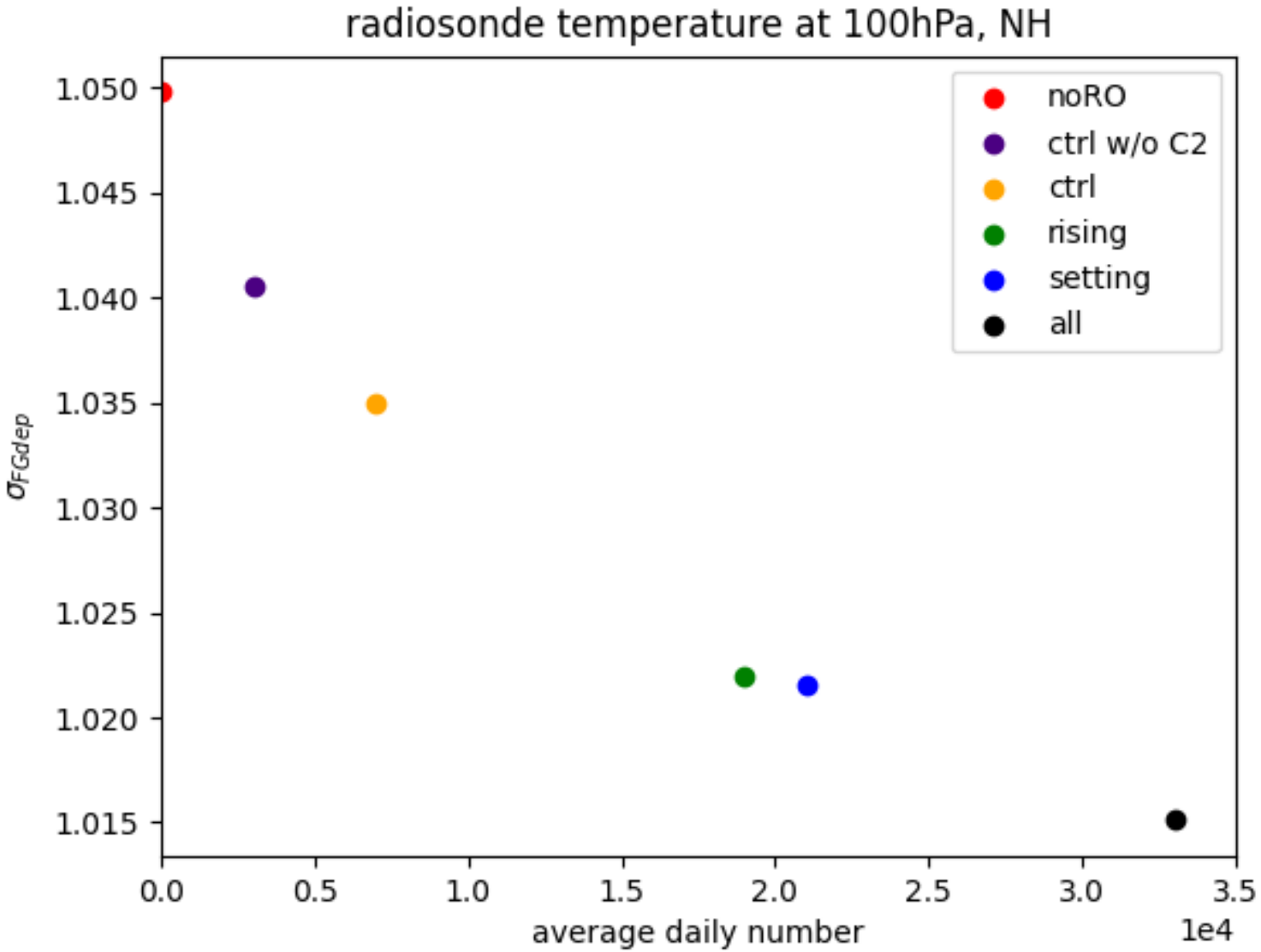
# Running Ensemble of Data Assimilation (EDA) experiments

- Compute std dev of e.g. temperature using ensemble members
- Compare this spread to Control run
- Reduction = good

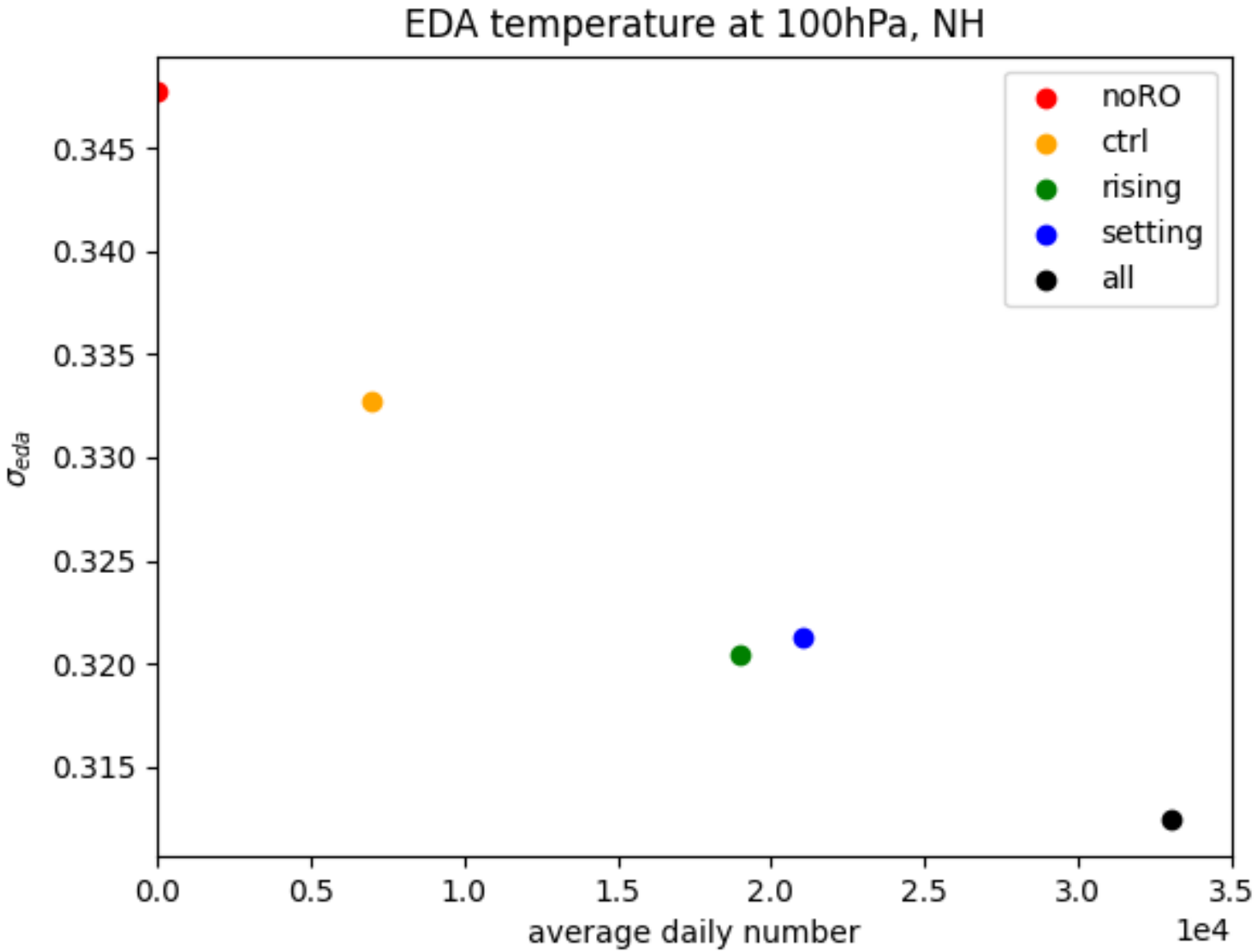
# Change in EDA spread in temperature



# How does impact scale with daily number of RO?

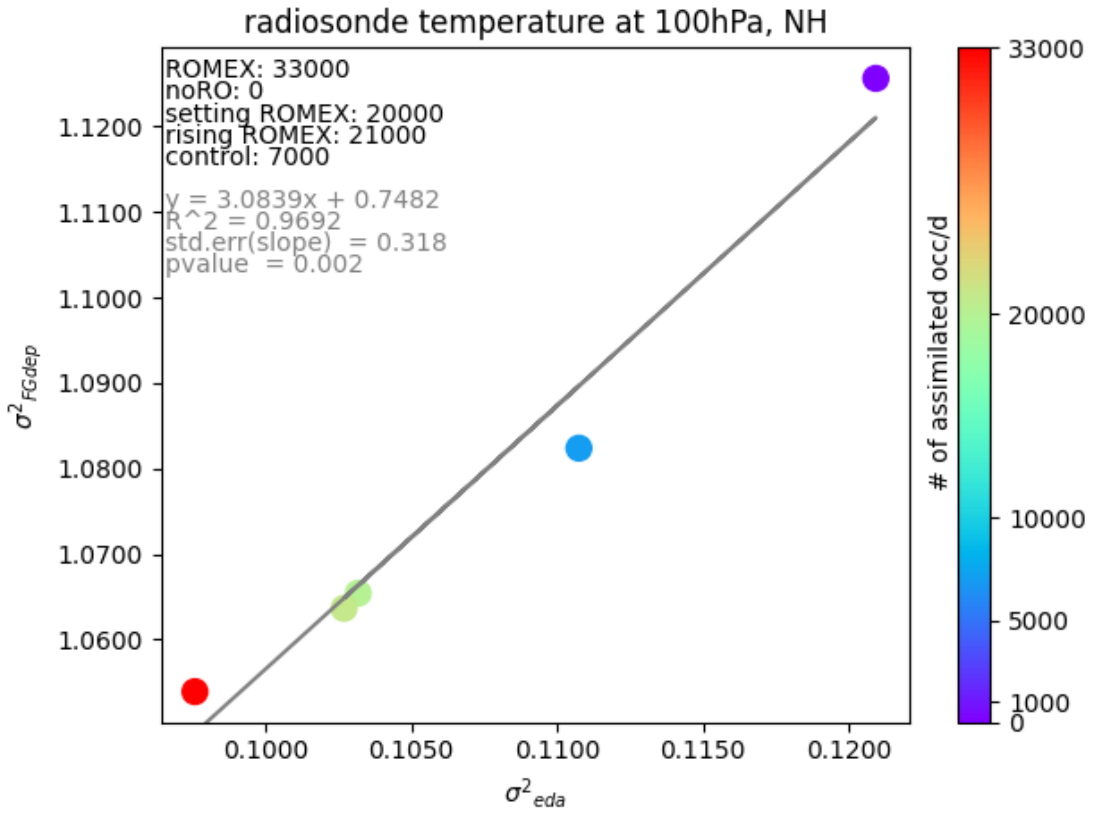


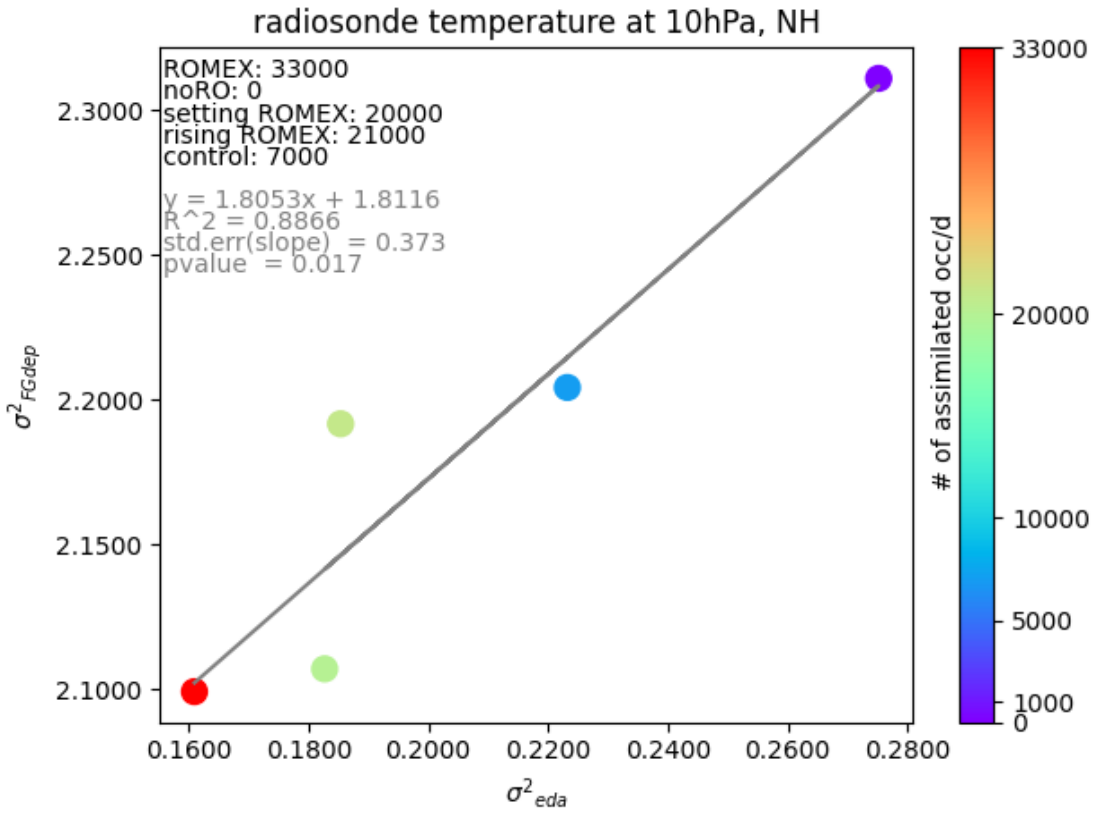
# How does impact scale with daily number of RO?



# Change in EDA spread compared with change in FG dep

- temperature at 100 and 10 hPa, NH



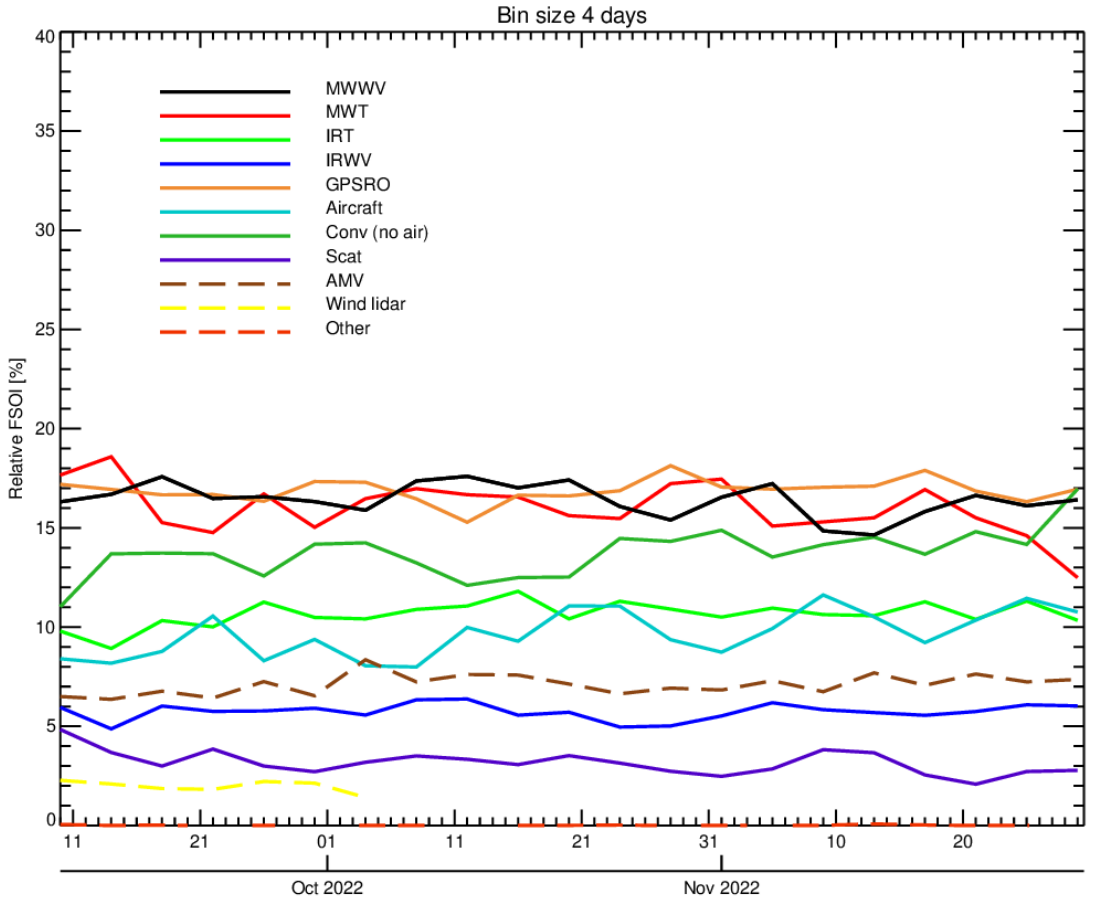



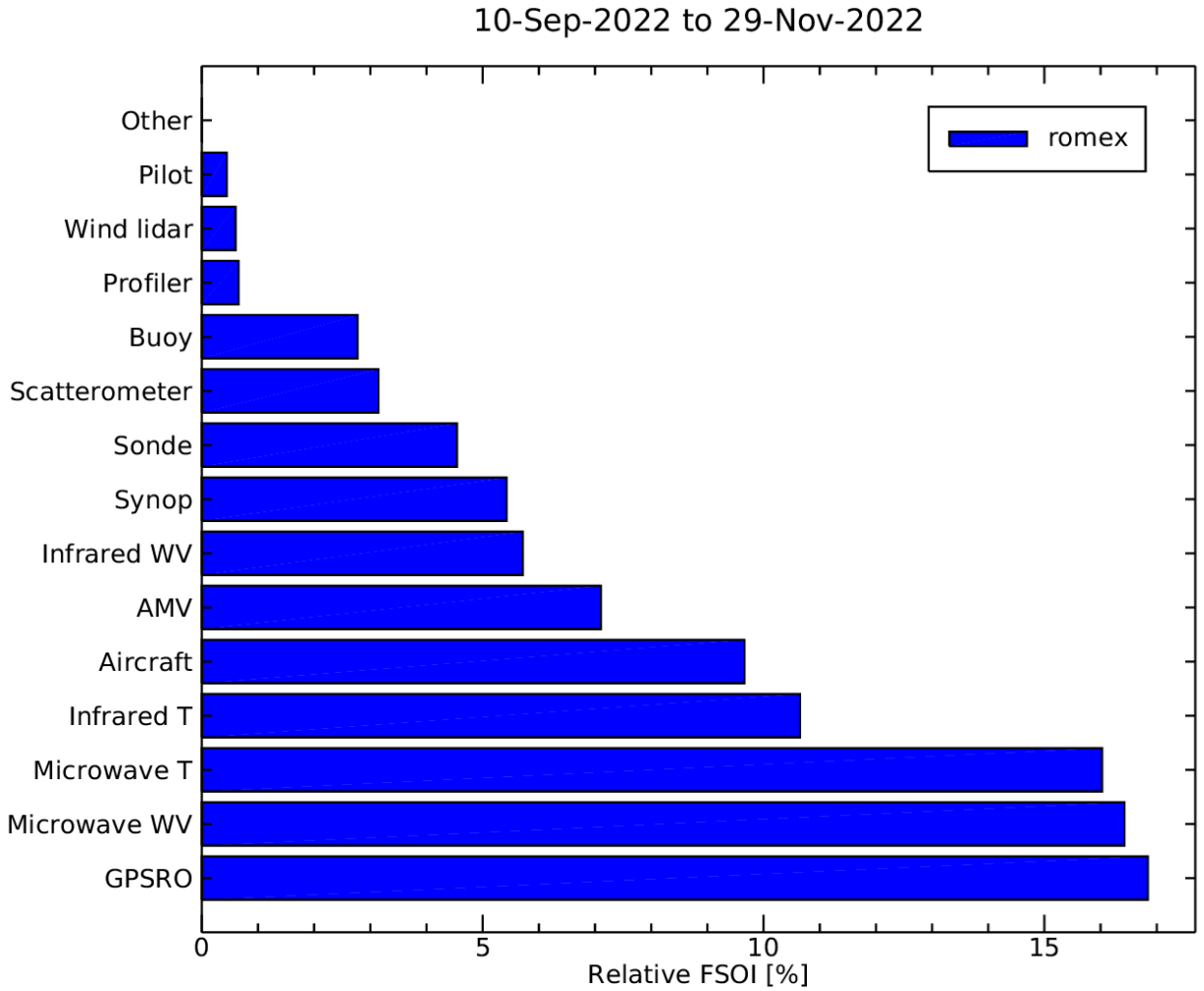
# Addition of ROMEX RO data shows:

- Strong improvement seen in OSEs for temperture, geopotential, wind and humidity throughout the atmosphere in terms of AC and Std Dev. And fits to observations
- Small but significant increase in RMSE for Geopotential linked to additional mean cooling of troposphere & stratosphere
- Correction dR bring further cooling, adjusting the height levels or refract coefficient can counteract this cooling.
- Strong Reduction in spread values for temperature throughout the atmosphere for EDA experiments

# backup

# FSOI


Bin size 4 days
MWWV
MWT
IRT
IRWV
GPSRO
Aircraft
Conv (no air)
Scat
AMV
Wind lidar
Other
Relative FSOI [%]
0
5
10
15
20
25
30
35
40
11
21
01
11
21
31
10
20
Oct 2022
Nov 2022


10-Sep-2022 to 29-Nov-2022
romex
Other
Pilot
Wind lidar
Profiler
Buoy
Scatterometer
Sonde
Synop
Infrared WV
AMV
Aircraft
Infrared T
Microwave T
Microwave WV
GPSRO
0
5
10
15
Relative FSOI [%]

Source: Summary by Healy for ECMWF Seminar on the Use of Satellite Observations in NWP, 8–12 September 2014

# Hydrostatic tail

Large sensitivity to the temperature at the model level directly above and below the ray tangent height

Below 100hPa in this case, there is a long positive “hydrostatic tail’.

- sensitivity of the computed bending angles to the model level heights

→ GNSS-RO measurements provide surface pressure information (Healy, 2013).

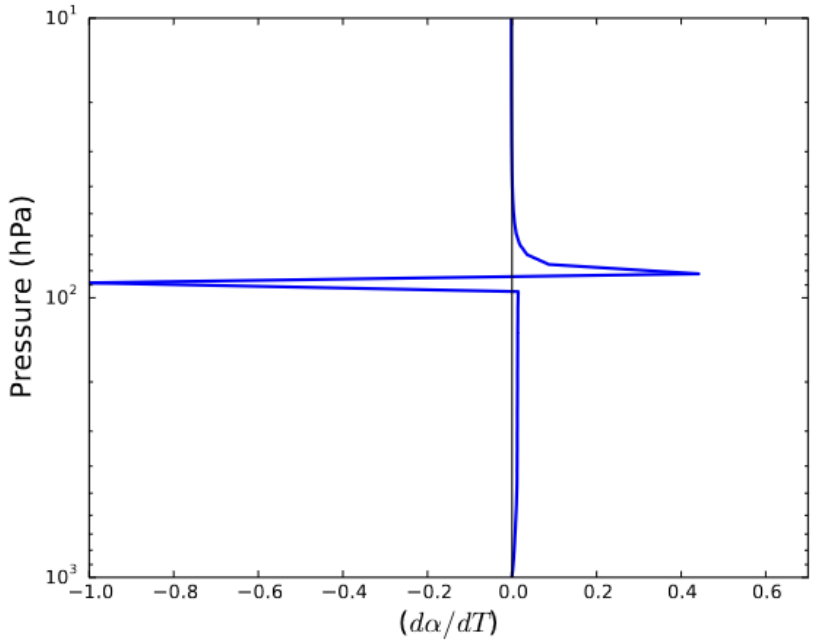



*Figure 2: The temperature weighting function, $(\partial\alpha/\partial T)$, for stratospheric bending angle. The largest contributions are from the model levels directly above and below the observed tangent height. The long “hydrostatic” tail below the tangent point is caused by the sensitivity of the stratospheric model level heights to the tropospheric temperatures.*

# 0.1% refrac coeff.

$N = k_1 P_d/T + k_2 e/T + k_3 e/T^2$ incl. compressibility

Reduced the first refractivity coefficient by 0.1% in the 2D GNSS-RO forward operator to calculate dry part of refractivity calculation (incl. TL & ADJ)

```
!!!REAL(KIND=JPRB), PARAMETER :: Z_AVAL = 0.77643_JPRB
REAL(KIND=JPRB), PARAMETER :: Z_AVAL = 0.77565_JPRB

Z_NDRY = Z_AVAL*Z_PD/P_TEMP(I,J)
```