Eidgenössisches Departement des Innern EDI
Bundesamt für Meteorologie und Klimatologie MeteoSchweiz

Schweizerische Eidgenossenschaft
Confédération suisse
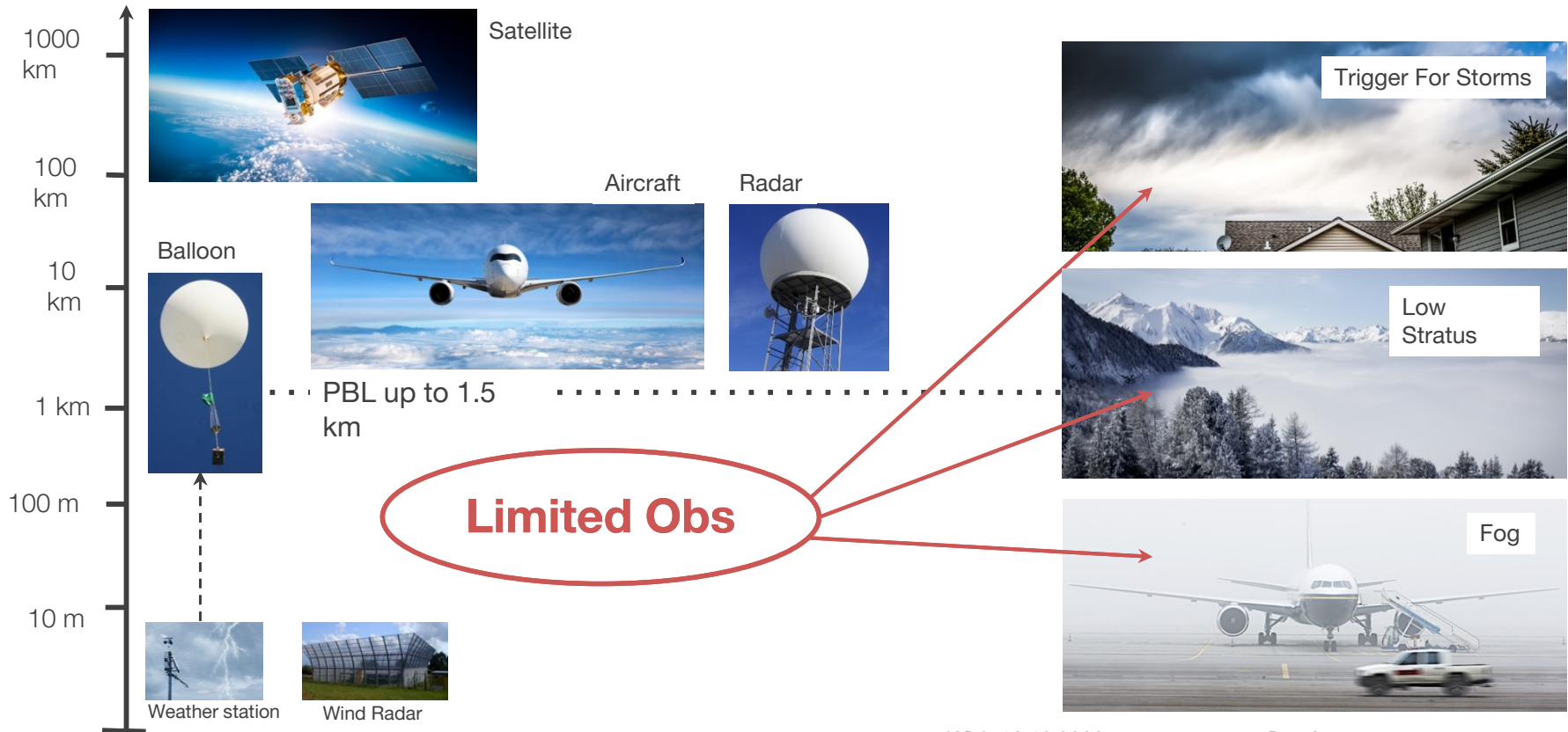Confederazione Svizzera
Confederaziun svizra

Towards an operational assimilation of Raman lidar temperature and WV mixing ratio profiles with COSMO/KENDA-1

Bas Crezee, Daniel Leuenberger, Claire Merker, Giovanni Martucci,
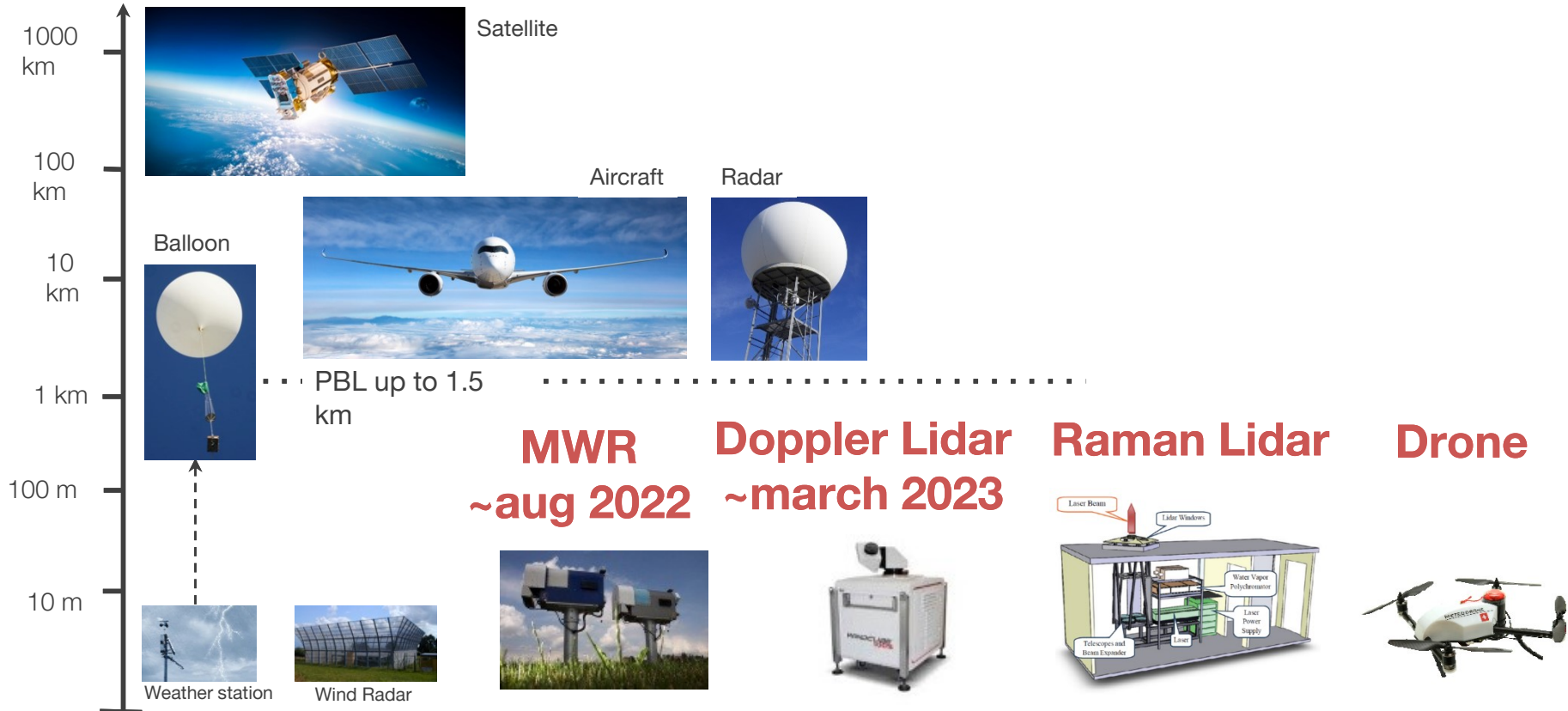Alexander Haefele & Marco Arpagaus
MeteoSwiss, Switzerland
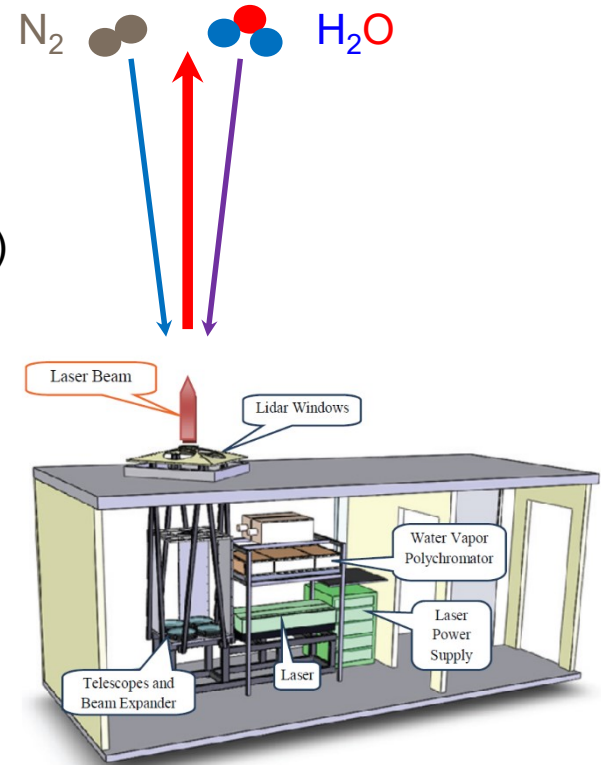
Current Observation Situation

1000 km

100 km

10 km

1 km

100 m

10 m

Satellite

Balloon

Aircraft

Radar

Weather station

Wind Radar

PBL up to 1.5 km

Limited Obs

Trigger For Storms

Low Stratus

Fog

Filling the observation gap in the PBL

Satellite

Aircraft   Radar

Balloon

PBL up to 1.5 km

1000 km

100 km

10 km

1 km

100 m

10 m

Weather station   Wind Radar

MWR ~aug 2022

Doppler Lidar ~march 2023

Raman Lidar

Drone

Raman Lidar: RALMO

- Custom design in collaboration with EPFL

- Situated at MeteoSwiss, Payerne [**PAY**]

- Temperature (T) and water vapour mixing ratio (MIXR)

- Time resolution: 30 min

- Vertical range (day / night): 60 – 5000 m / 10'000 m

- Vertical height bins of 30-300m

- 24/7 automatic operation
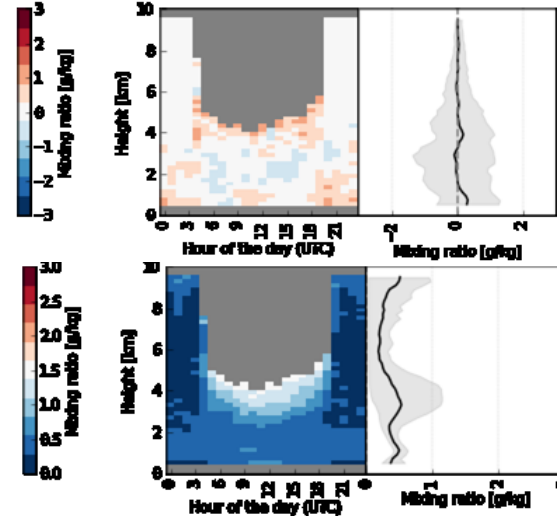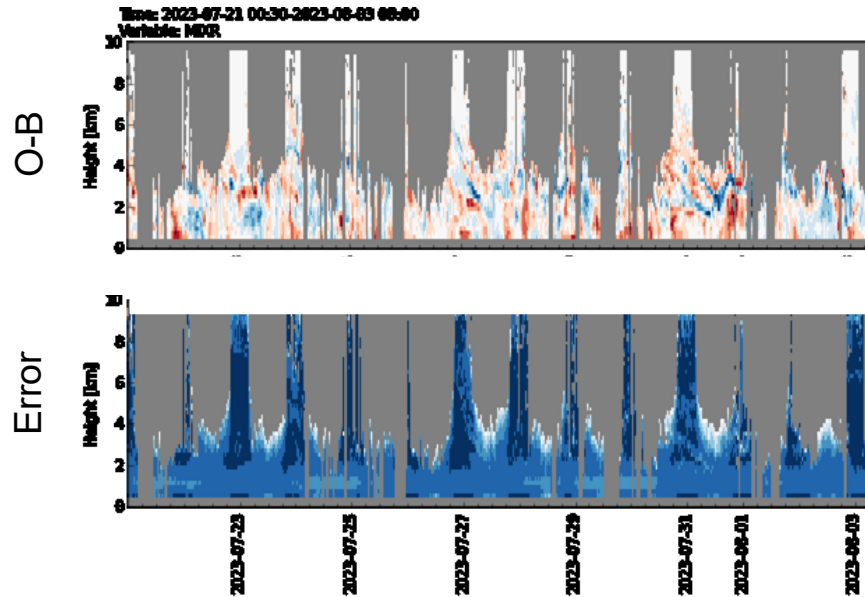
- Not available in rain and low cloud conditions

N_2

H_2O

Laser Beam

Lidar Windows

Water Vapor Polychromator

Laser Power Supply

Telescopes and Beam Expander

Laser

RALMO O-B and observation error
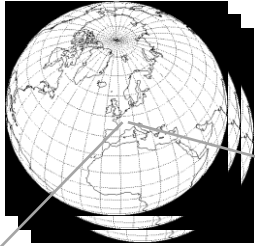
State-dependent observation error:

-MIXR: $e\_o(t,z) = instrument\_error(t,z) + 0.03 * MIXR\_clim(t,z)$ ——— climatological observed mixing ratio at Payerne
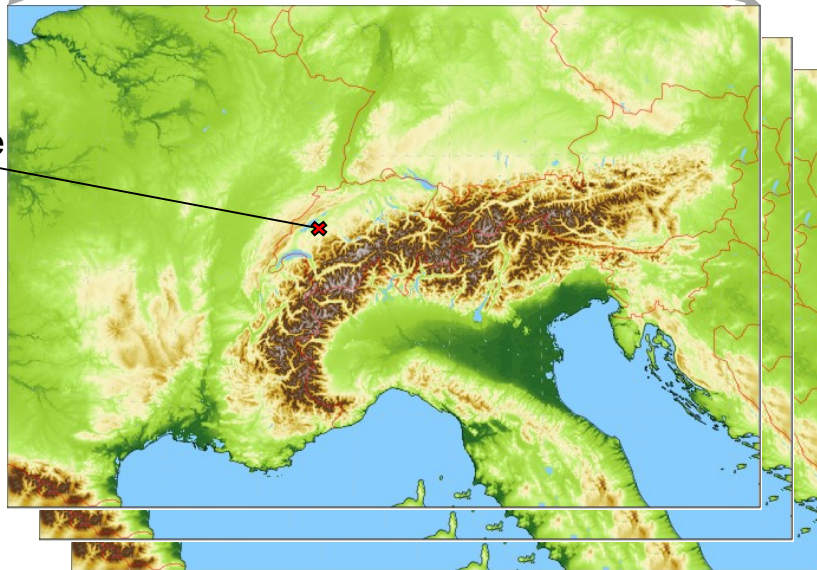
-T: $e\_o(t,z) = instrument\_error(t,z) + 0.5\ K$

The MeteoSwiss NWP System

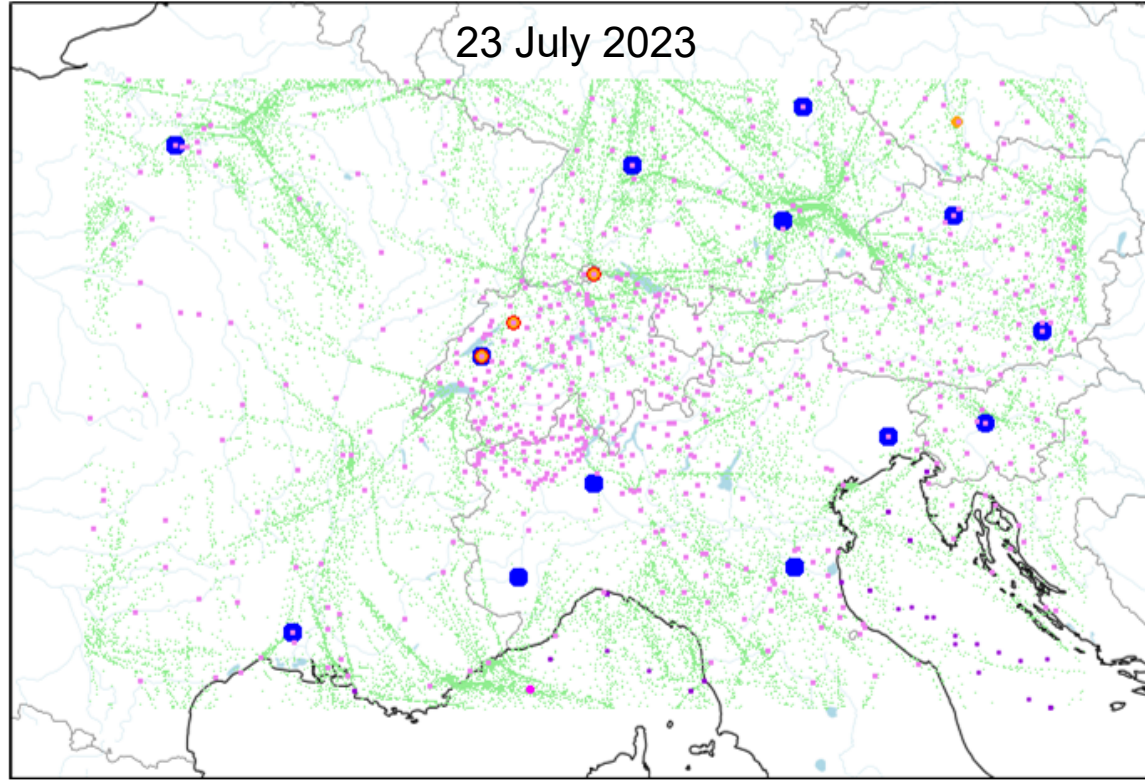Lateral boundary conditions from ECMWF ENS

Payerne (PAY)

Kilometre-Scale Ensemble Data Assimilation (KENDA, Schraff et al., 2016)

- Ensemble Kalman Filter (LETKF, Hunt et al. 2007)
- 40 ensemble members
- COSMO NWP model
- 1.1km grid size (convection permitting)
- Assimilation of
  - Radiosondes
  - Aircraft obs
  - Surface stations
  - Wind radar and lidar
  - Microwave radiometer
  - Weather Radar

Observations assimilated operationally

23 July 2023

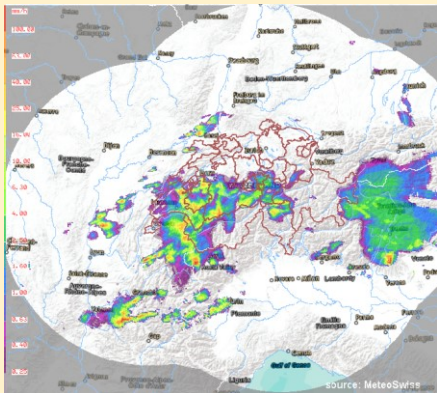|			
· Aircraft	● Radiosondes	● Wind Radar	· Ship Surface Stations
· Aircraft	● Wind Lidar	· Land Surface Stations	· Buoys

Experiment setup

- COSMO-1E
- DA experiments:
  - **REF** (operational setup)
  - **EXP** (including RALMO observations)

Summer period
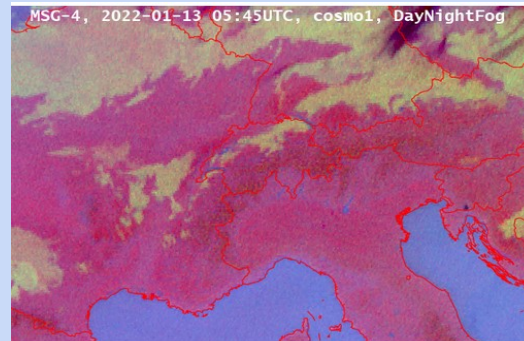- 21 July 2023 - 4 August 2023
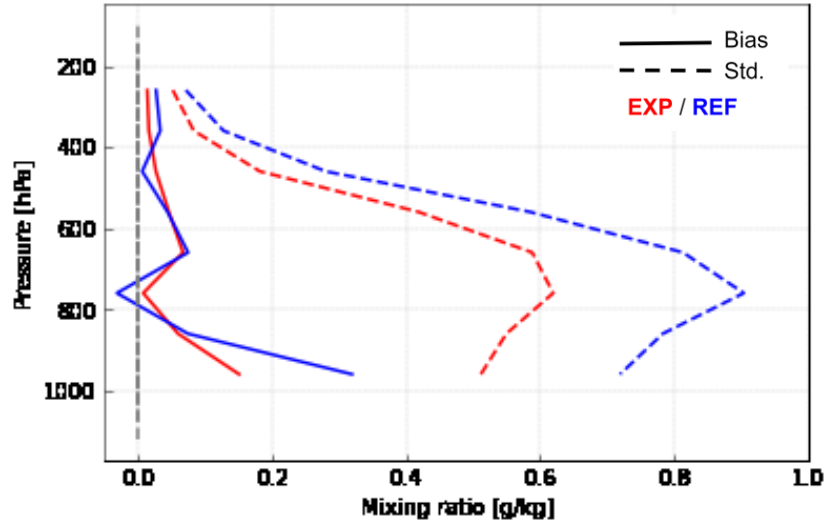- Several convective episodes
- Assimilate WV mixing ratio (MIXR)

Winter period
- 10 January 2022 - 24 January 2022
- Regular fog and low stratus
- Assimilate T and WV mixing ratio (MIXR)
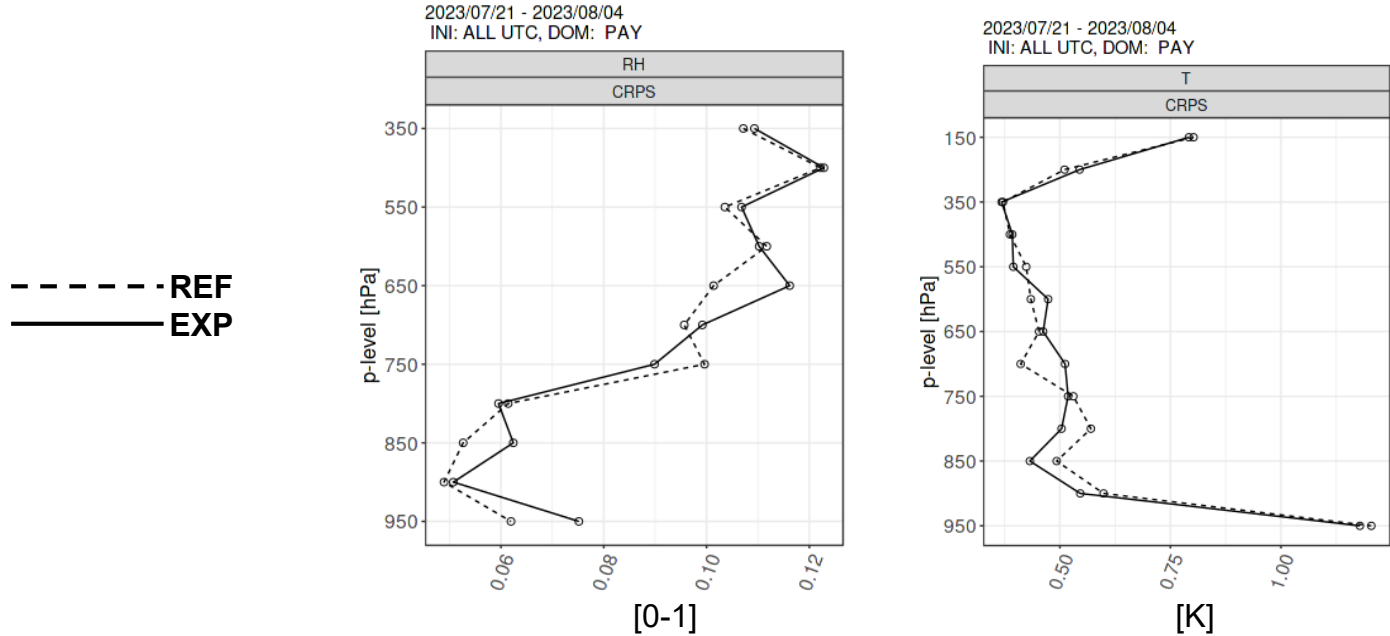
Summer period

O-B profiles against RALMO [PAY]

- Almost bias-free already in REF
- Reduction of std with about ¼ in EXP

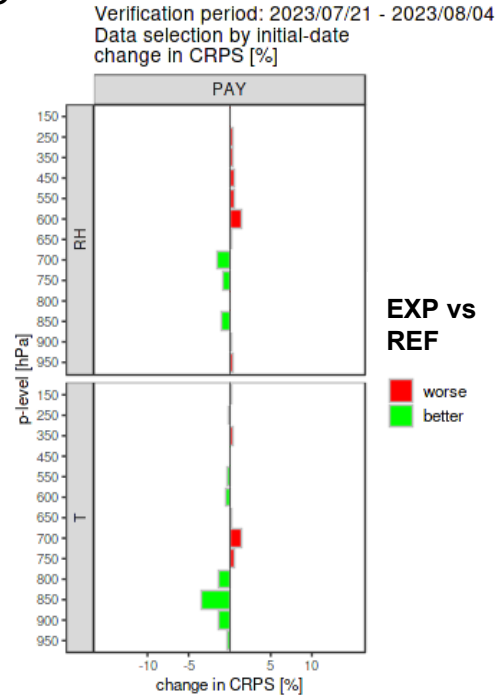# First-guess ensemble verification [PAY]

- (Surface verification mostly neutral.)
- Profile verification against radiosounding in PAY shows mixed results
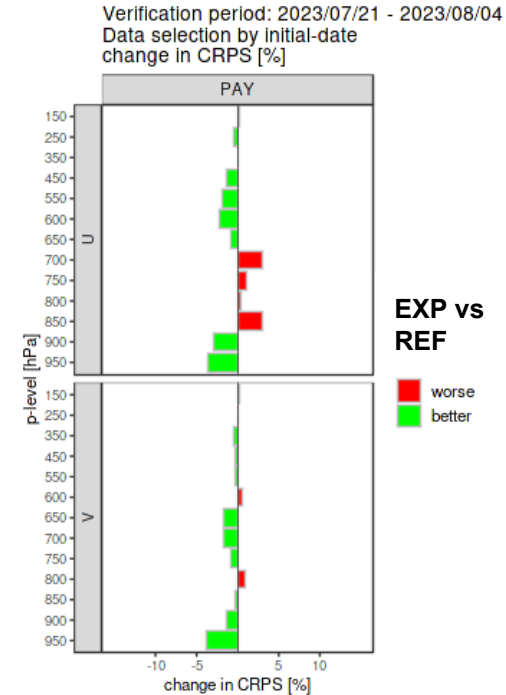
Forecast ensemble verification [PAY]

- Forecasts started at 00; 06; 12; 18 UTC up to +33h
- Mostly neutral for surface verification
- Neutral for RH
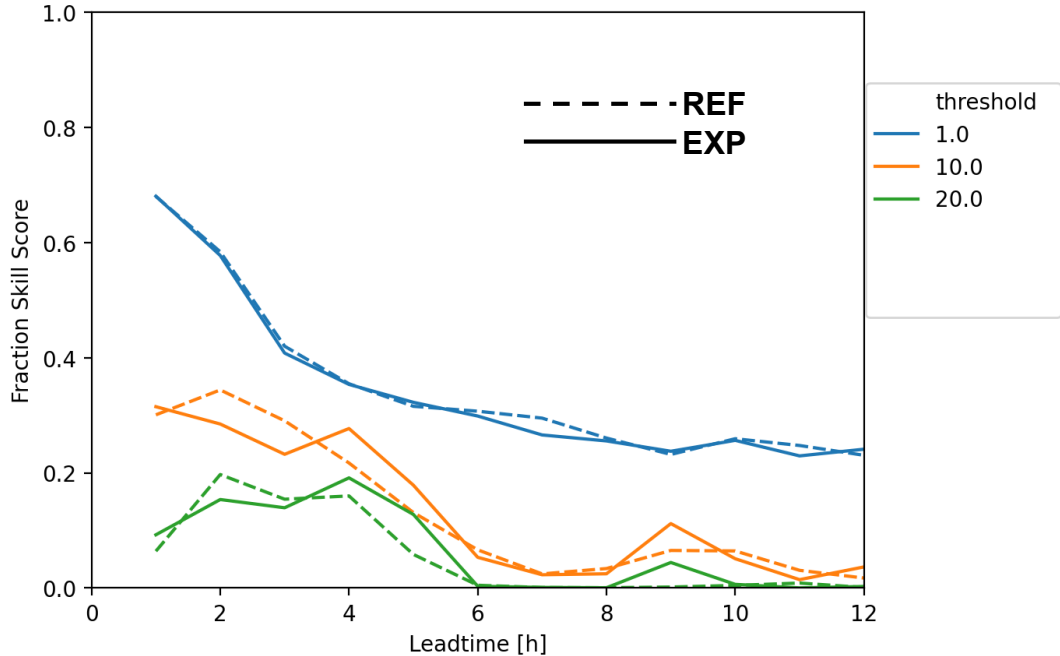- Slightly positive for T and wind

ISDA, 18.10.2023   Bas Crezee   12
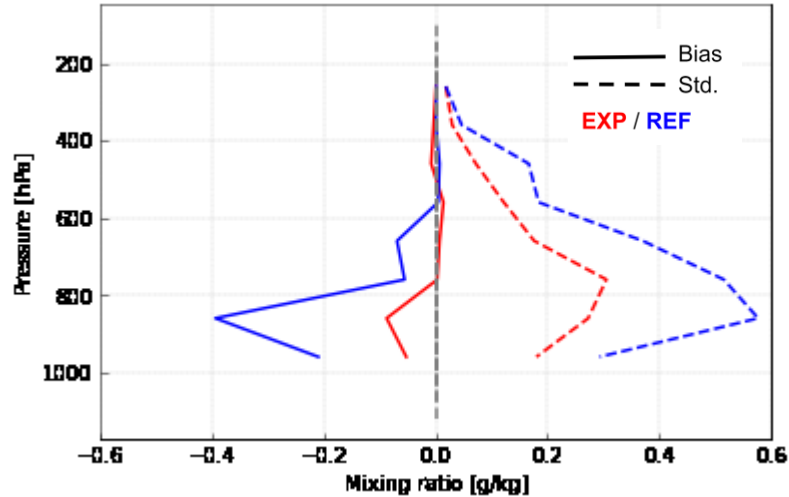
Forecast verification of 1h precipitation

Variable: TOT_PREC_1h
scale: 10.0
Initial time: 2023072100-2023080318

- Neutral for low intensities
- Negative impact at leadtimes 2-3h; positive impact at leadtimes 4-6h for strong precipitation (>10 mm/h)
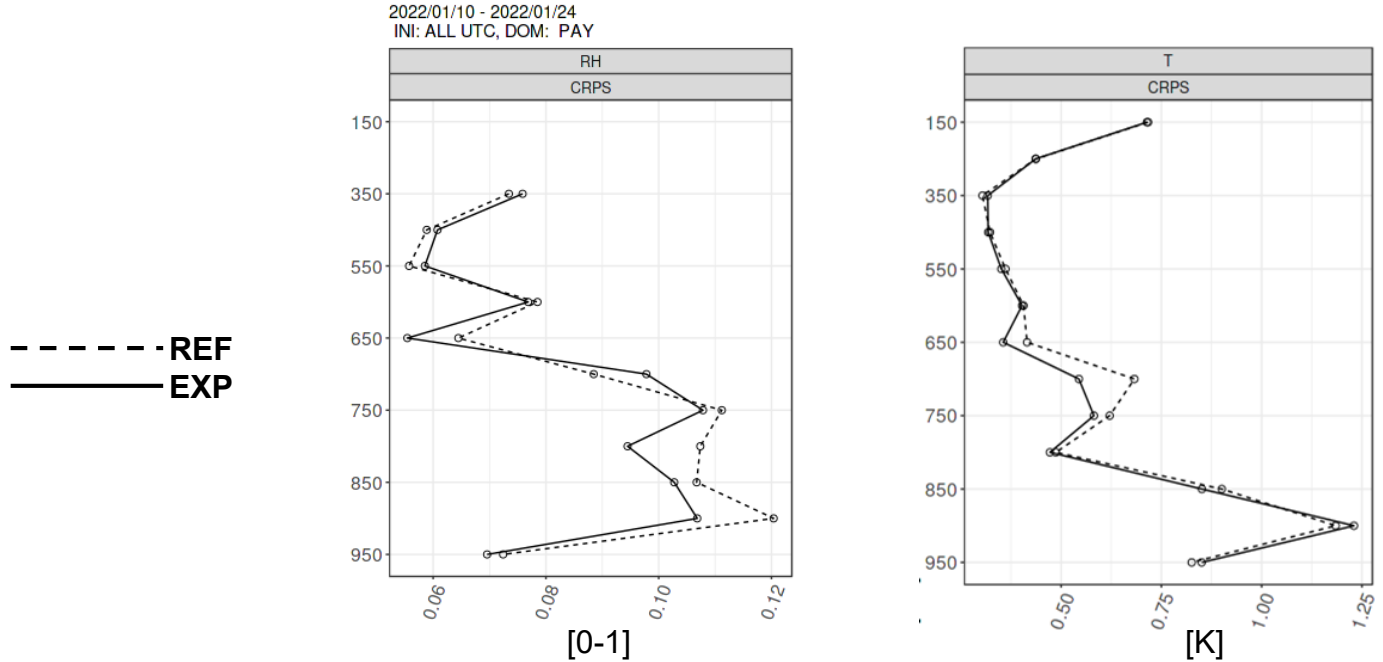
Winter period

O-B profiles against RALMO [PAY]

- Moist bias in REF is greatly reduced in EXP
- STD is reduced with about ⅓ in EXP
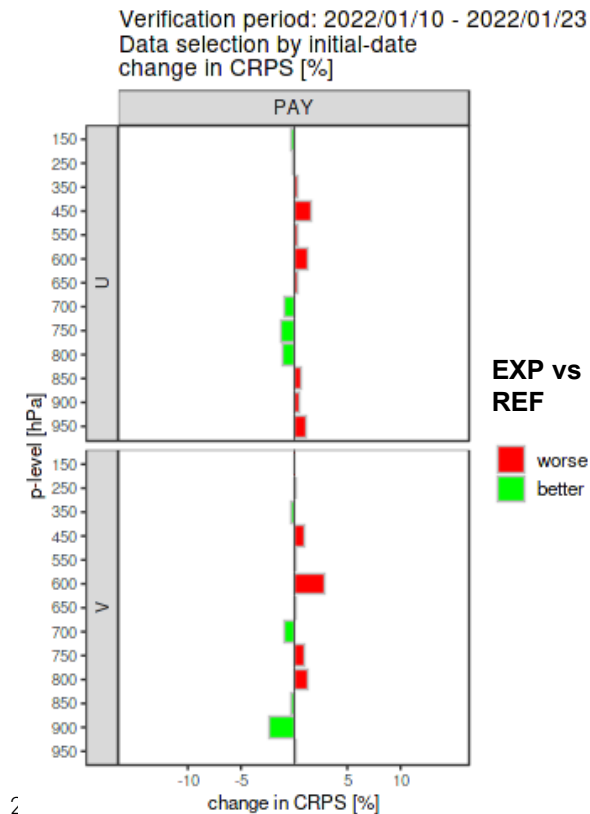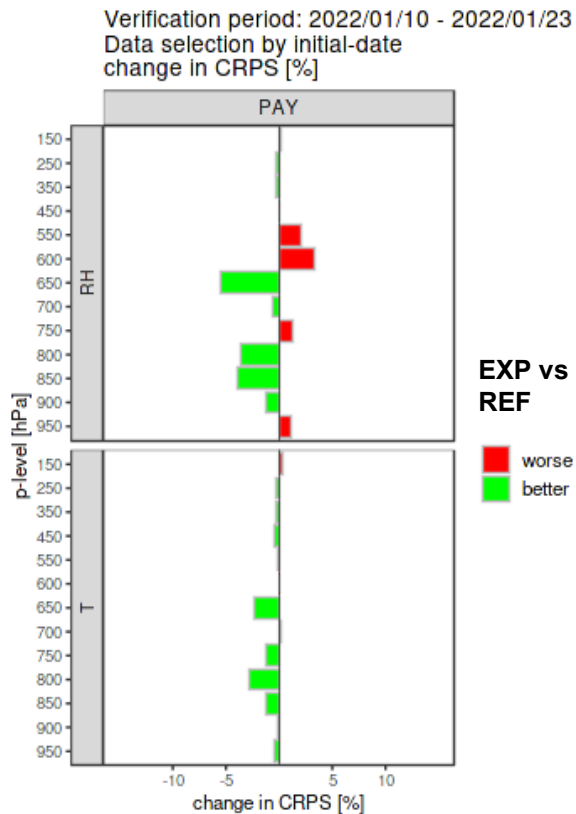
First-guess ensemble verification [PAY]

- (Surface verification mostly neutral.)
- Small improvement in CRPS for both RH and T
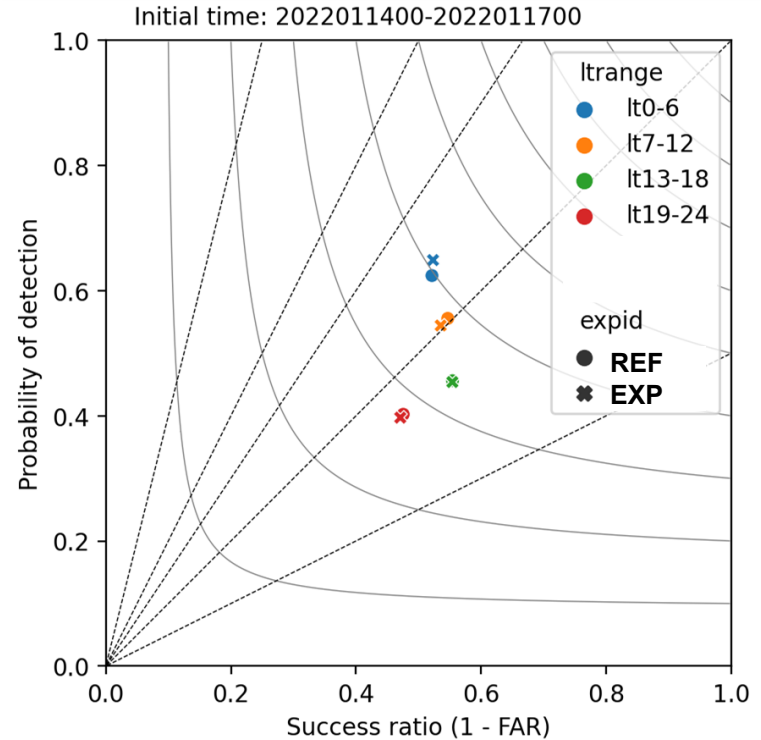
Forecast ensemble verification [PAY]
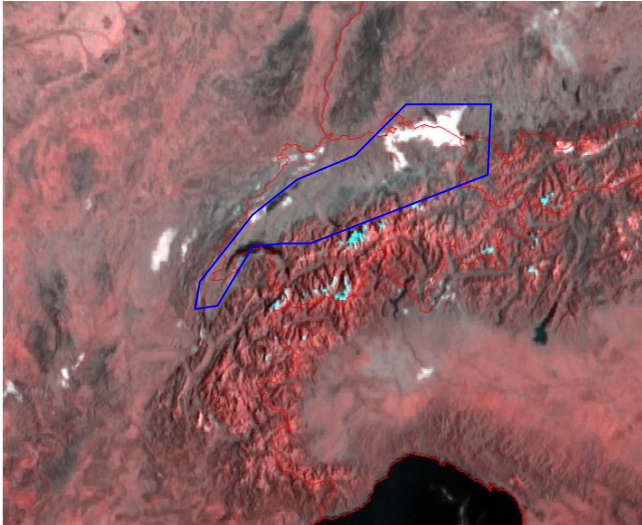
- Improvement in CRPS for RH and T

# Fog and Low Stratus verification

- Verification over extended Swiss Plateau against MSG for a 3-day period (no mid/high clouds present)
- Minor improvement for lead times 0-6h
- However, slight deterioration for lead times 7-12h, neutral afterwards

Challenge: specifying the obs error

- Desroziers suggests we can go even lower with observation error (but correlated observation errors are not accounted for)
- Compare against radio sounding

Summer

RALMO obs error (dashed)
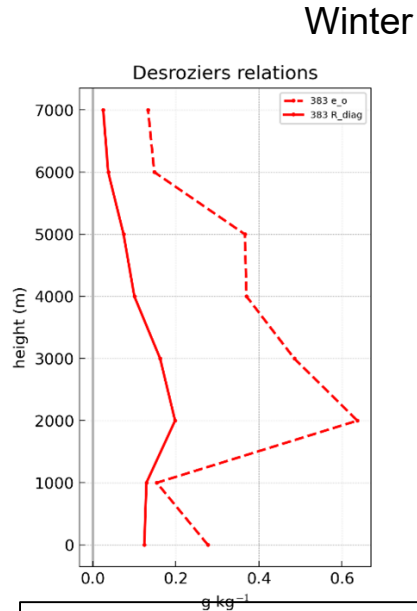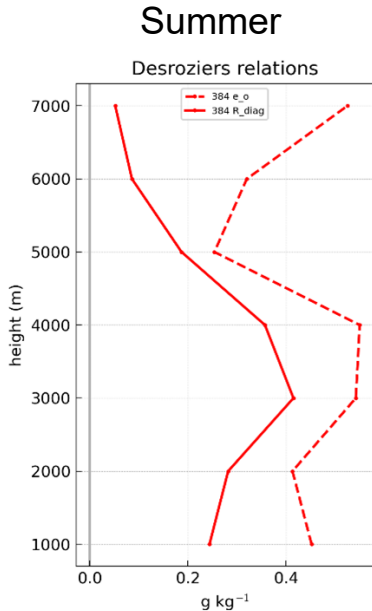Desroziers estimate (solid)
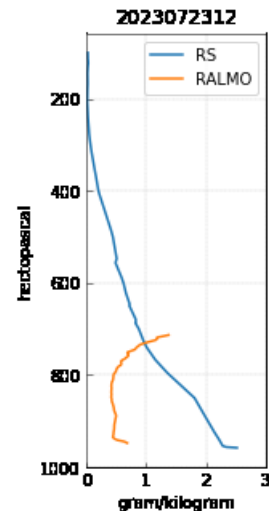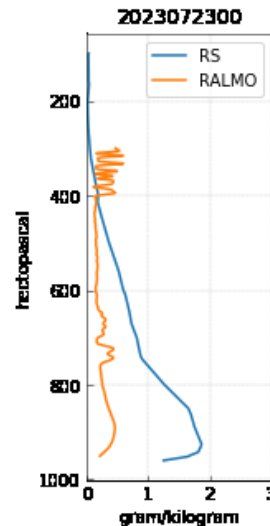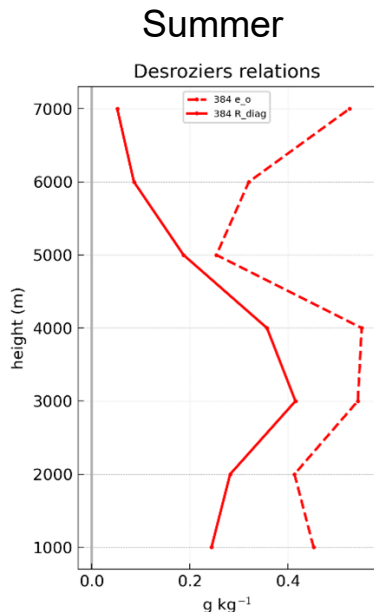
Summary & Discussion

- Additional temperature and humidity information of raman lidar instrument with good temporal and vertical resolution has been succesfully assimilated
- State-dependent instrument error provided by device is used in estimation of observation error
- Neutral to slightly positive impact in forecasts
  - For short lead-times (0-6h) we see a **slight improvement in the forecast of fog and low stratus** during a winter period, but also slight deterioration afterwards.
  - Similarly in summer, we see a slight deterioration of forecasting of heavy precipitation at 2-3h, but a **slight improvement at leadtimes 4-6h**.

- Limited forecast impact due to only one station ?
- How to better specify the observation error ?

Additional slides

Challenge: specifying the obs error

Summer

Winter

TEMP variable RH

RALMO obs error

Desroziers estimate