SEKF contributions

ECMWF-MO Land Surface DA Meeting

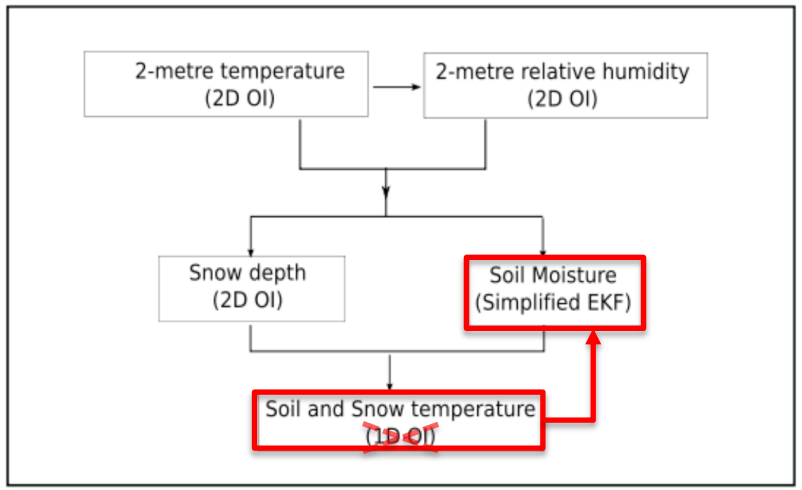
Christoph Herbert and the Coupled Assimilation team

christoph.herbert@ecmwf.int

ECMWF

ECMWF Land Data Assimilation System

Land surface analysis

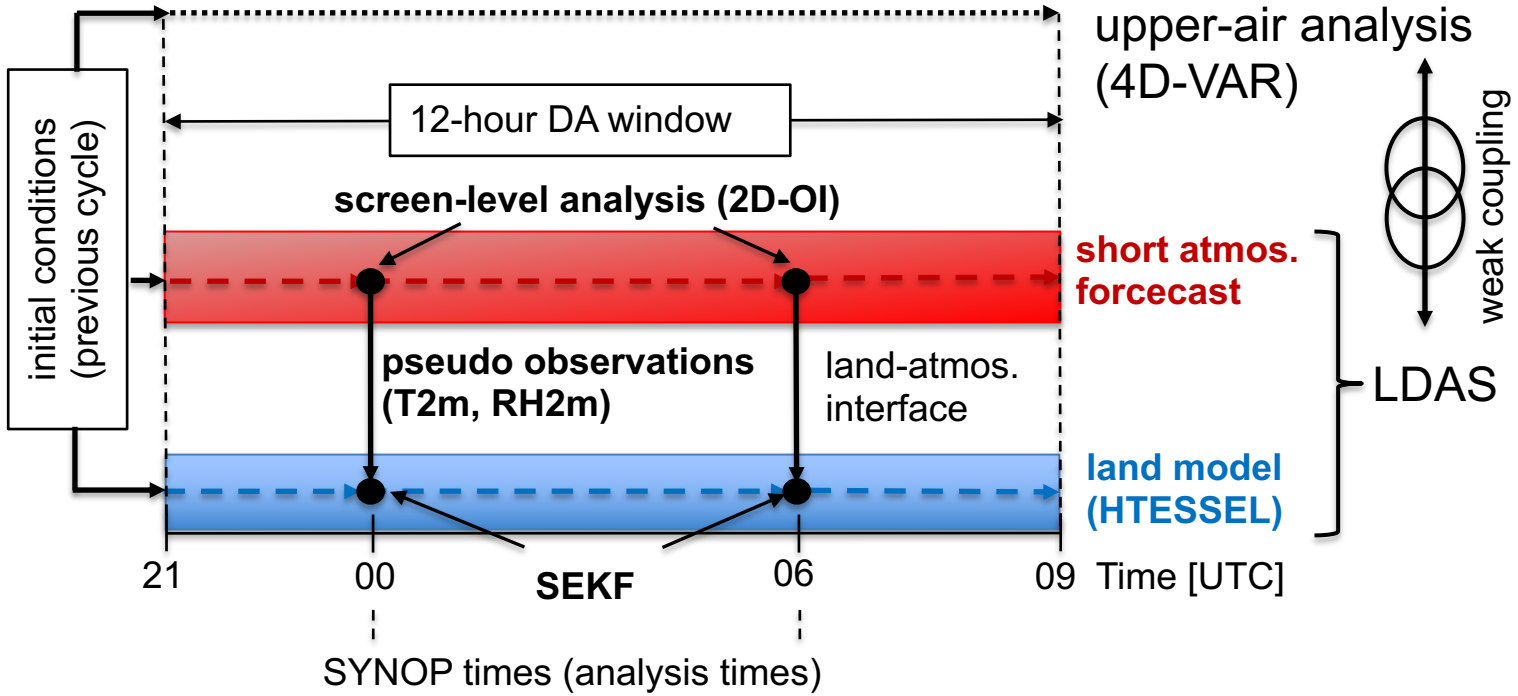


AIM: Extending SEKF control vector

$$x = \begin{bmatrix} swvl1 \\ swvl2 \\ swvl3 \end{bmatrix} \Rightarrow \begin{bmatrix} swvl1 \\ swvl2 \\ swvl3 \\ stl1 \\ stl2 \\ stl3 \\ tsn \end{bmatrix}$$

Simplified Extended Kalman Filter (SEKF)

in the Integrated Forecast System (IFS)



Soil layers:
- **I1**: 0-7 cm
- **I2**: 7-28 cm
- **I3**: 28-100 cm

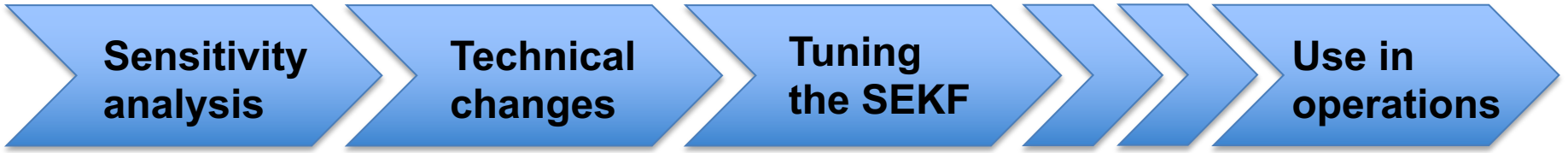
SEKF soil and snow temperature analysis

OBJECTIVES

- **Paving** the way towards a **unified** land data assimilation scheme using an **EDA-based** SEKF
- **More consistent approach** with land variables and in one control vector

SEKF UPDATES

- **Analysis of snow and soil temperature at multiple layers** (3 layers) instead of single layer (currently using 1D-OI)
- Aiming for **more accurate initial conditions** for operational forecast and the Continuous Extremes Digital Twin simulations in Destination Earth



Sensitivity analysis	Technical changes	Tuning the SEKF	Use in operations
Offline pre-assessment	IFS source code updates and script changes	Sensitivity experiments	Targeting cycle 50r1

Sensitivity analysis – EDA-based Jacobians

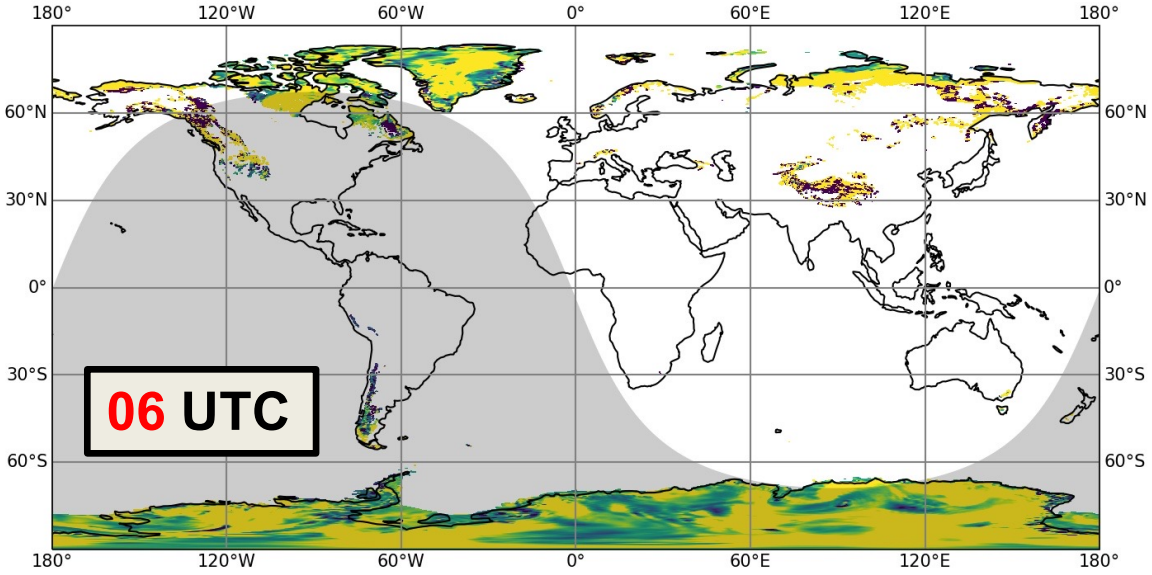
Analyzing Jacobians between **screen-level** variables (T2m and RH2m) and **SEKF control** variables (snow and multi-layer soil temperature)

Jacobian elements $\mathbf{H_{ij}} = \frac{cov(\mathcal{H}_i(\mathbf{x^{eda}}), \mathbf{x_j^{eda}})}{var(\mathbf{x_j^{eda}})}$

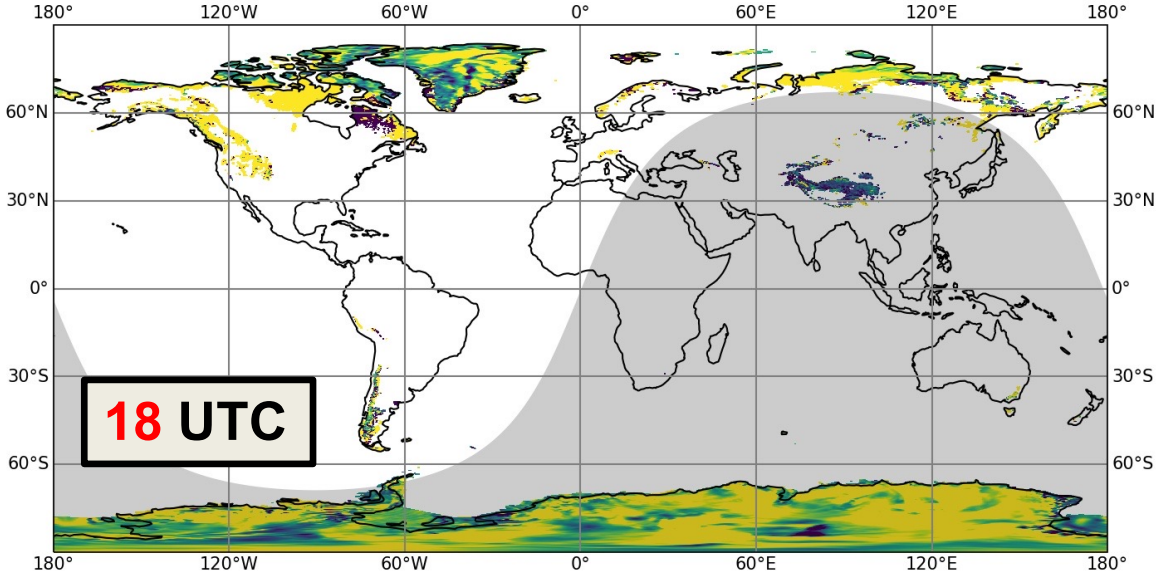
observations y_i^{obs} = [T_{2m}, RH_{2m}, $ASCAT_{sm}$, $SMOS_{sm}$]

control variables x_i = [*swvl1*, *swvl2*, *swvl3*, *stl1*, *stl2*, *stl3*, ***tsn***]

H (tsn, T2m) 2022053106



H (tsn, T2m) 2022053118



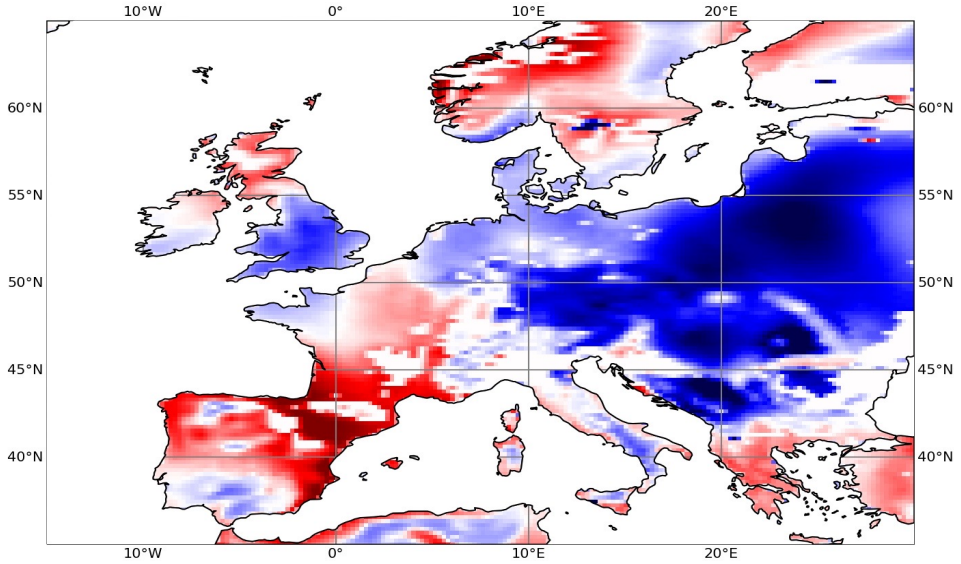
Technical changes in the IFS

Updating the IFS: Including soil and snow temperature analysis in the SEKF

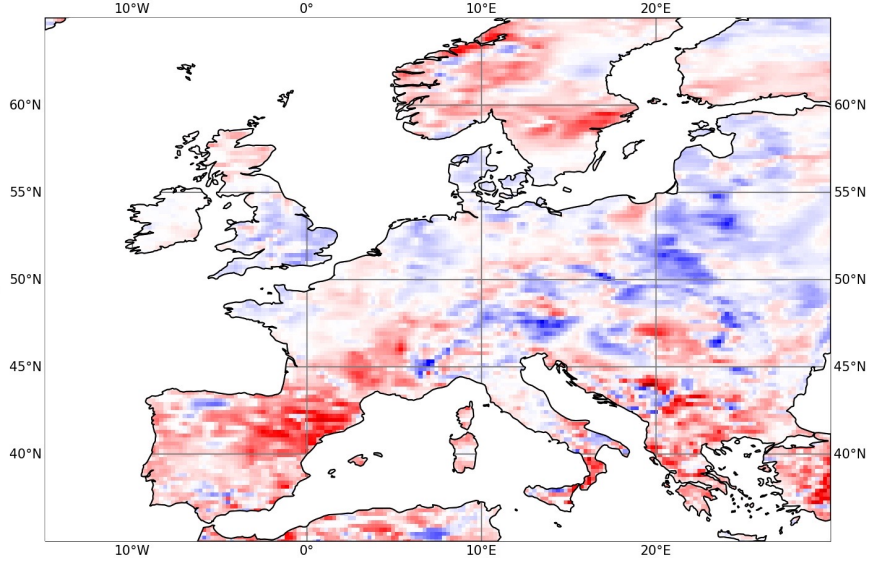
- Getting rid of 1D-OI single-layer snow and soil temperature analyses
- Updating the IFS: extending the SEKF **control vector**
- Computing **snow** and **multi-layer soil temperature analyses**

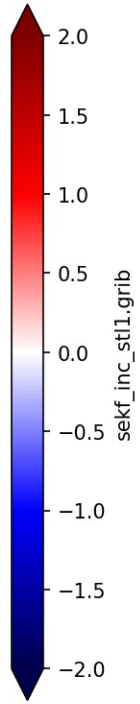
Analysis increments soil temperature layer 1 (stl1)

Current 1D-OI – 2020120212



SEKF (σ_b = 2K) – 2020120212

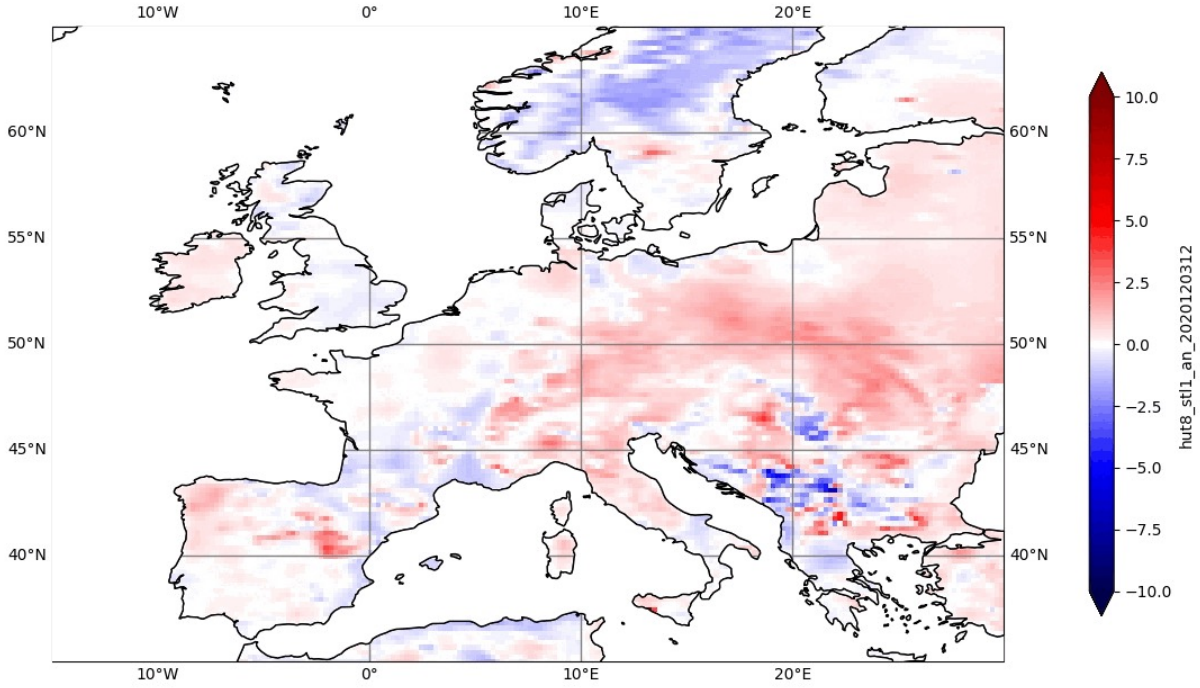




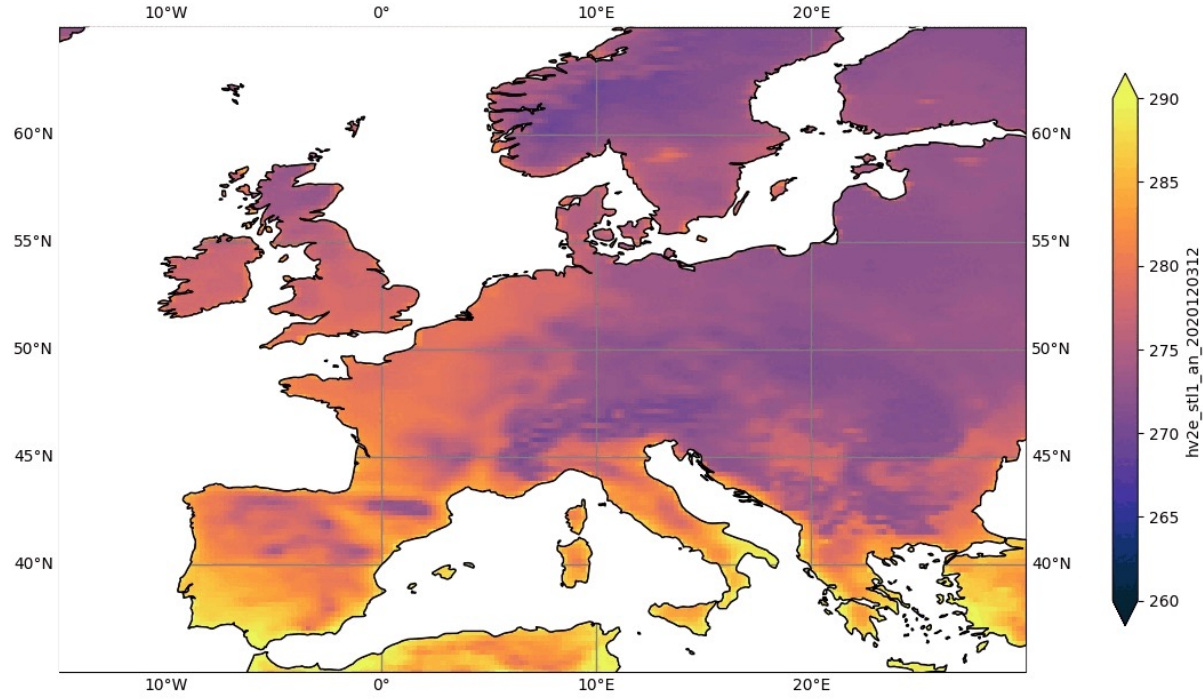
Soil temperature analysis at upper layer

- 3-month winter period (DJF 2020/21)
- SSA-only experiment, TCo399 (CY48R1.0)

Analysis differences: $stl1_{an,\ SEKF} - stl1_{an,\ 1D\text{-}OI}$

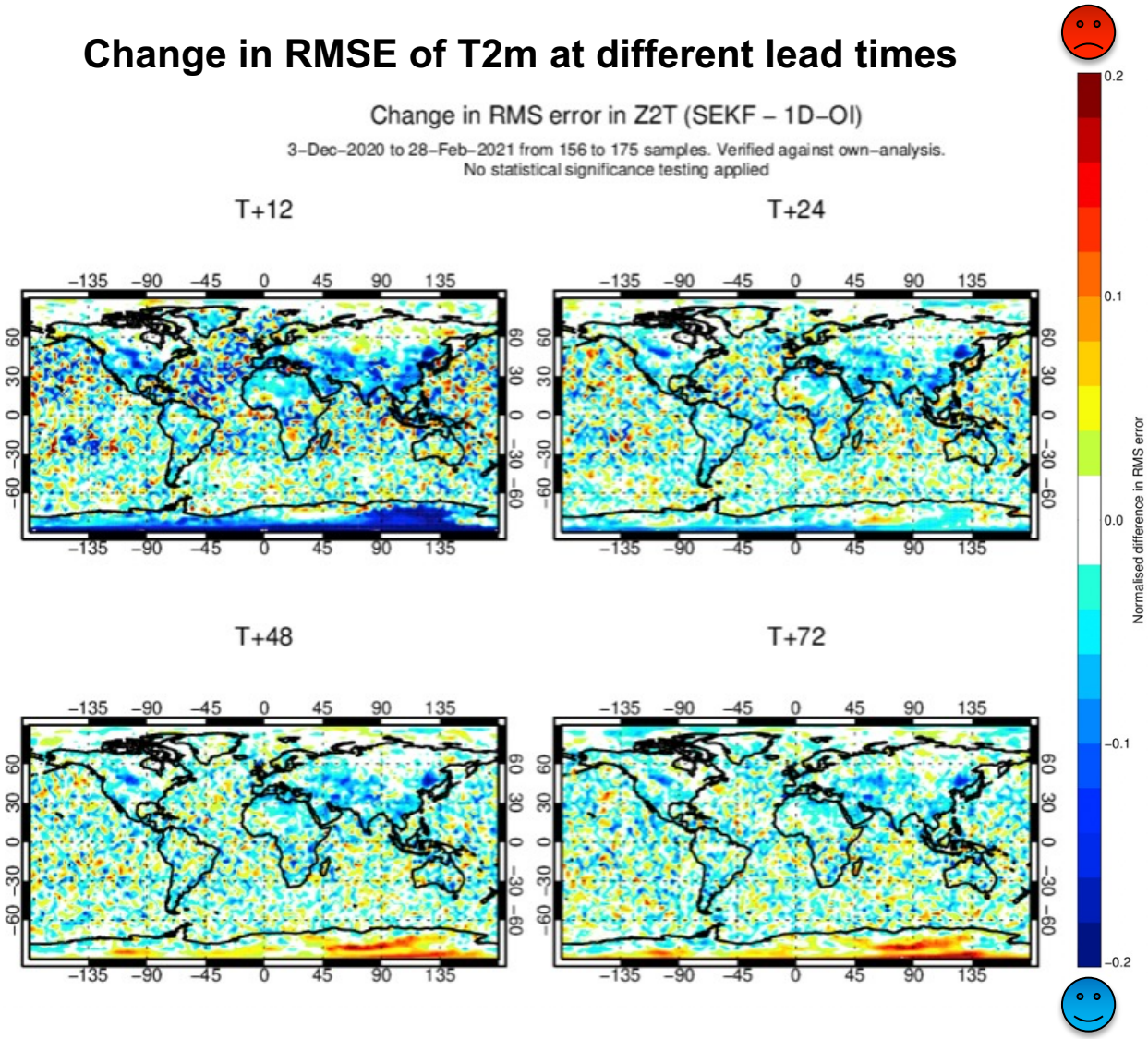


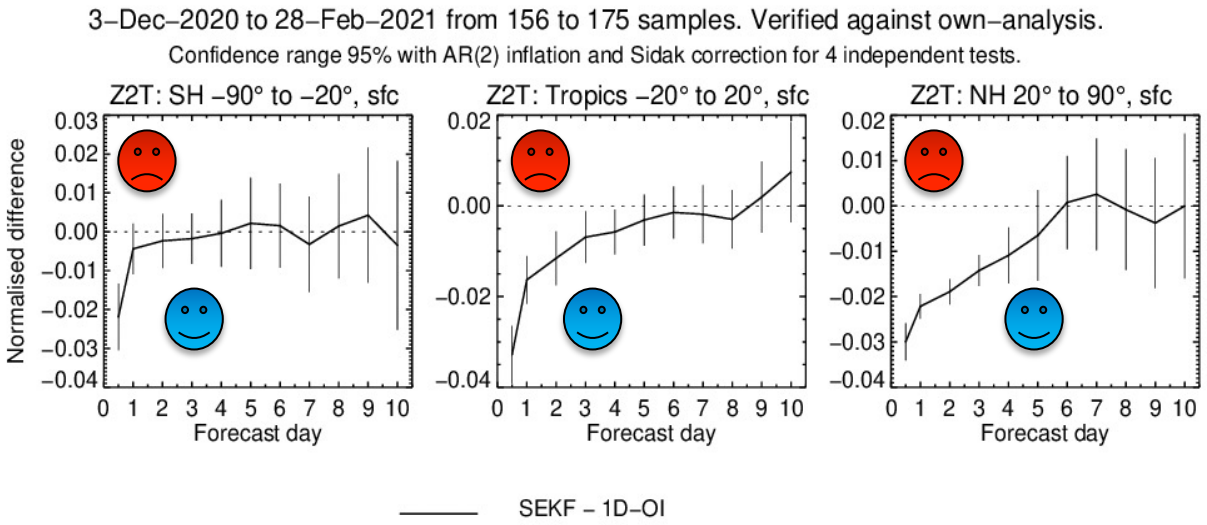
Analysis $stl1_{an,\ SEKF}$ at 12UTC ($\sigma_{b,\ stl1}$ = 1K)



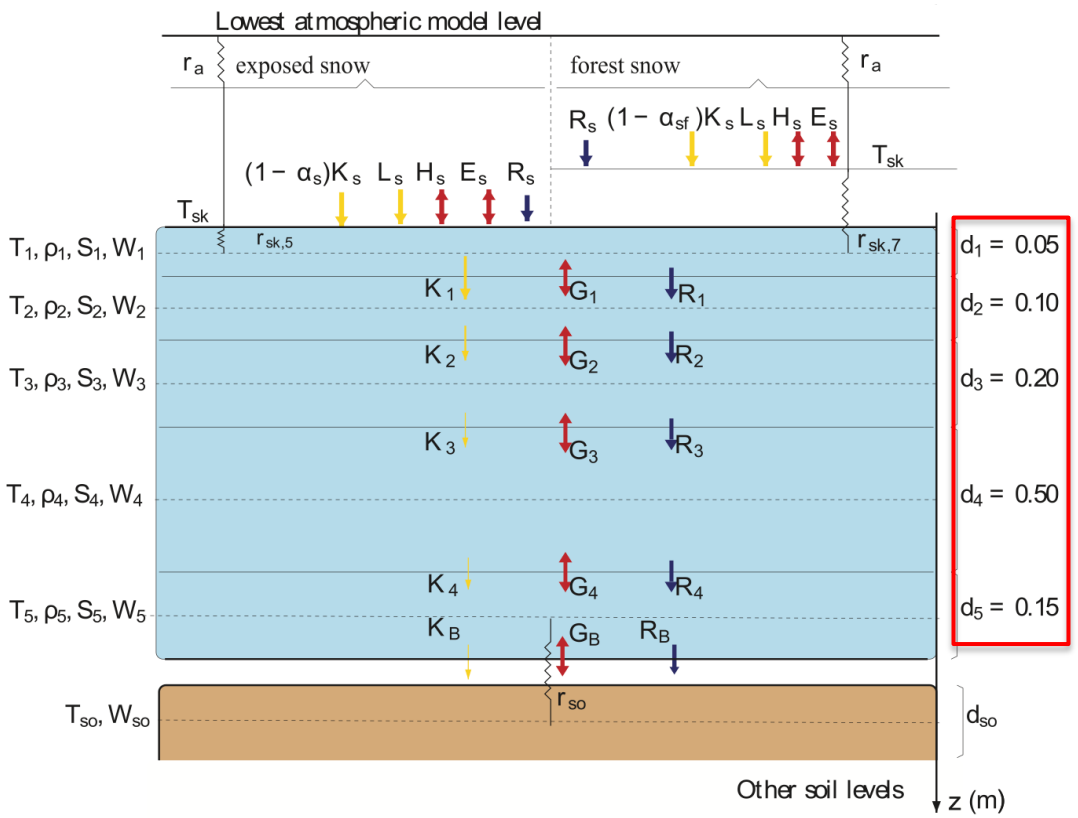
Temperature analysis in SEKF – impact on T2m (preliminary results)

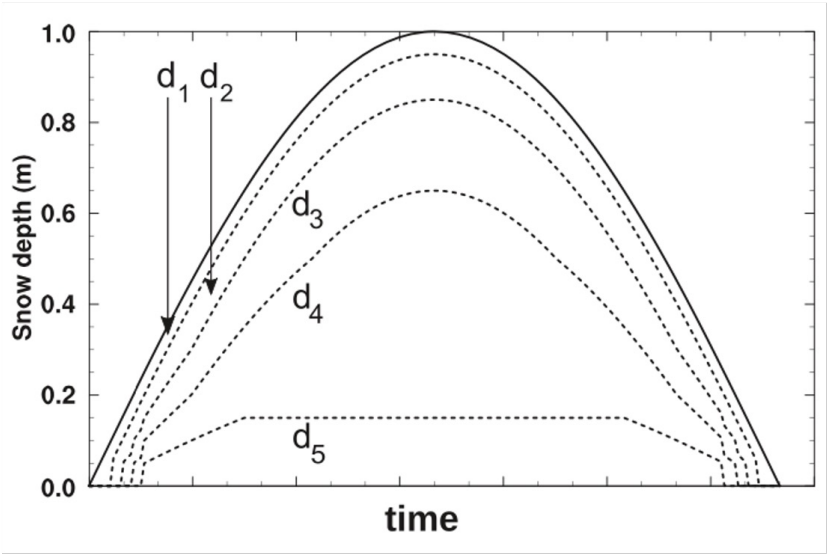
Change in RMSE of T2m at different lead times





Multi-layer snow temperature analysis





Up to **5 active** snow layers
depending on the actual snow depth

Coupled multi-layer snow model (cycle 48r1) [Arduini et al.]

- Multiple layers enable **multiple time scales** to be resolved
- Better **timing** of accumulation

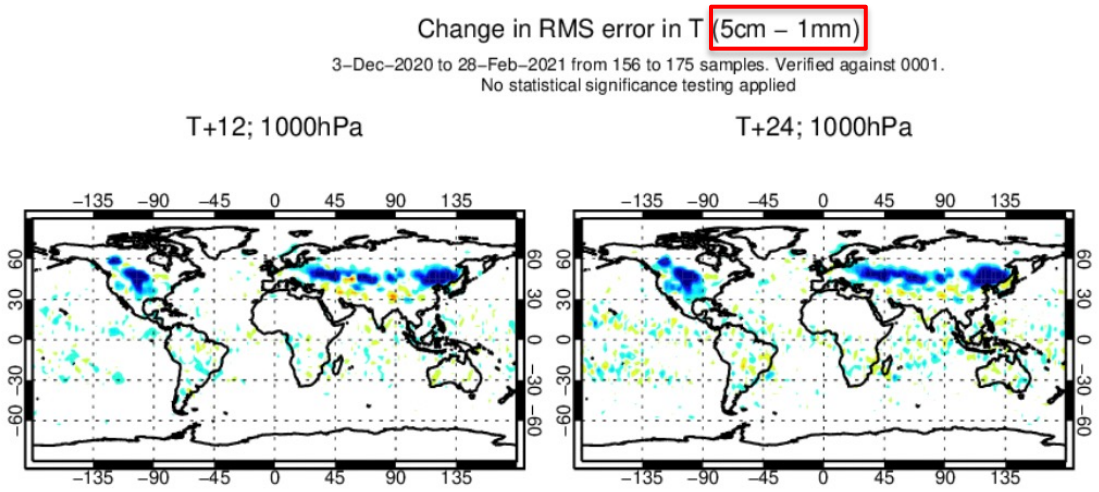
Multi-layer snow temperature analysis

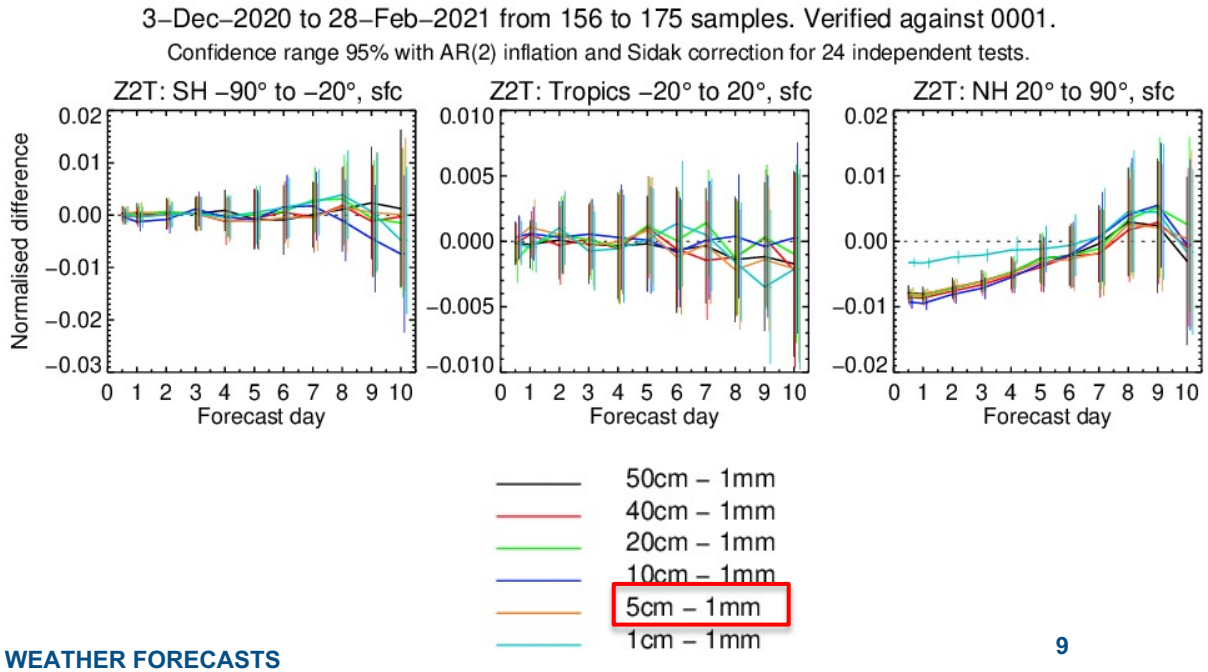
- Better capture **snow variability**
- More accurate estimate of the **snow amount**

SEKF technical improvements and tuning

Technical improvements in the SEKF

- Reasonable **lower bound for variances** of control variables (cycle 49r1)
- Updates in the SEKF to **enhance the consistency with 4D-Var trajectories** (cycle 49r1)
- Sensitivity experiments and tuning of the SEKF (ongoing):
  - More educated **constraints on the Jacobian elements** accepted for analysis
  - **Snow depth-based threshold** for soil temperature analysis:





Summary and future work

- Contributing to **coupled land-atmosphere data assimilation** towards **unified land scheme** based on the **SEKF**
- Including **soil and snow temperature analysis** in the SEKF
- **Technical updates** and **sensitivity experiments** for tuning **the SEKF**
- Investigating **multi-layer soil and snow temperature analysis** in the context of drought conditions and snow accumulation and melting
- Running **high-resolution experiments** to create more accurate initial conditions in the framework of **Destination Earth**