Preparation for the exploitation of MTG-IRS in NWP models at DWD

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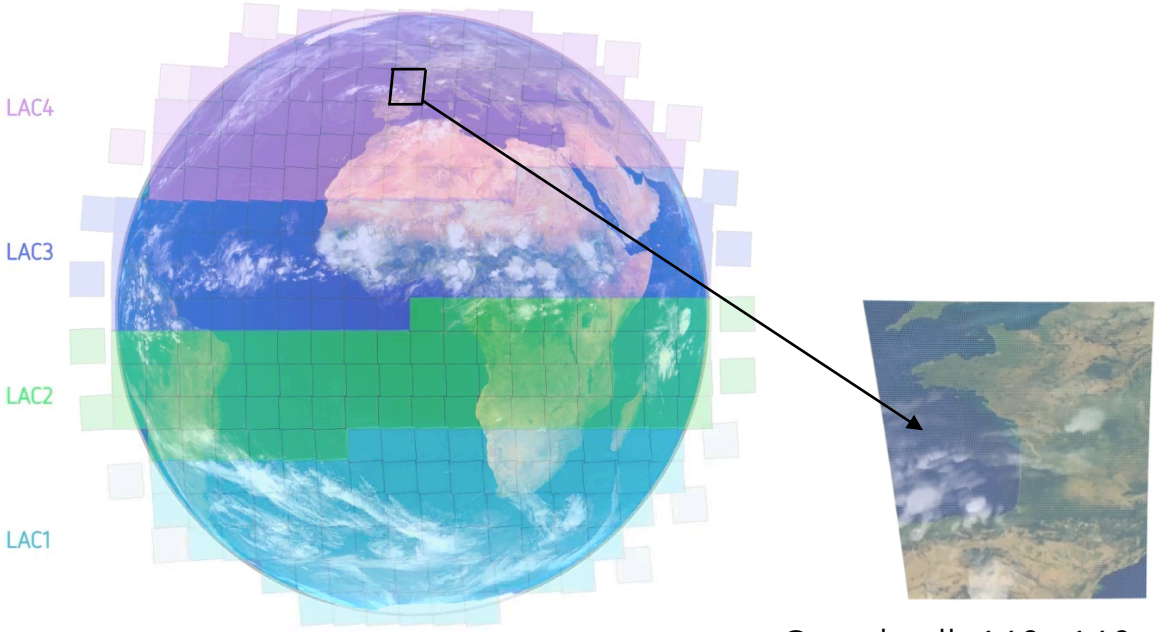
Outline

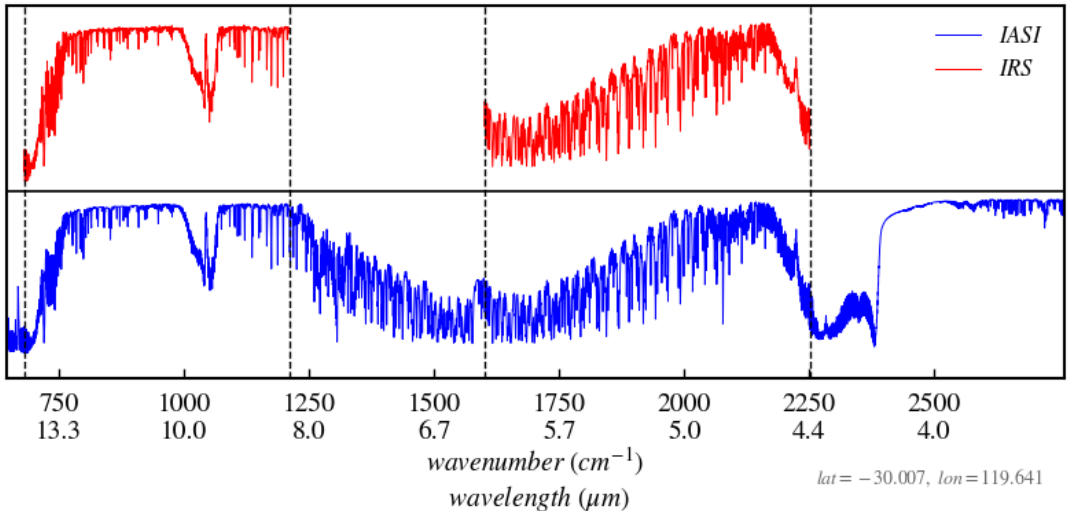
- MTG-IRS overview
- Motivation and general approach
- Synthetic data and channel selection
- Technical preparations in ICON/EnVar and ICON-D2/KENDA
    - Cloud detection
    - Land surface emissivity
    - T_{skin} retrieval
    - Online bias correction
- Summary and Outlook

MTG-IRS measurements overview

- Spatial coverage and scan pattern:
  - 4 Local Area Coverages (LACs)
  - Spatial sampling 4km at nadir —> 10km
  - LAC4 over Europe scanned every 30 minutes



One dwell: 160×160 pixels



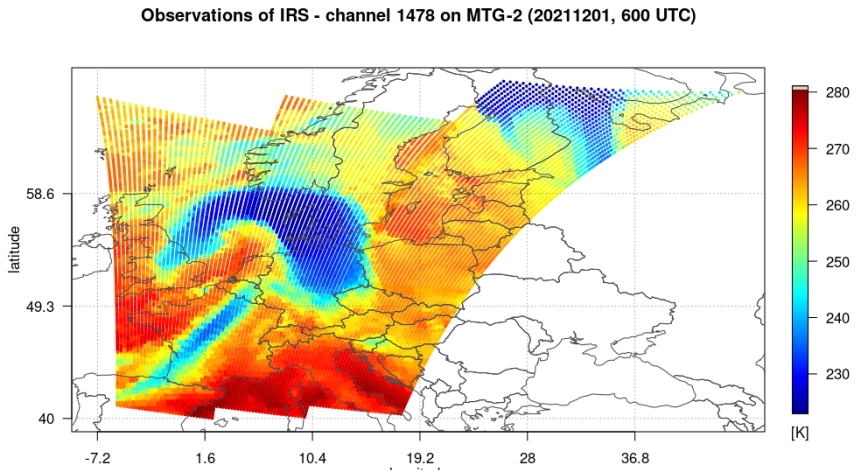
- Two spectral bands - 1960 channels
  1. MWIR (1600 to 2250 cm^{-1}) - 1079 values
  2. LWIR (680 to 1210 cm^{-1}) - 881 values
- Spectral resolution ~ 0.604 cm^{-1}

Motivation and general approach for assimilating IRS

- Motivation:
  - Aim for IRS is to provide mainly stability and humidity information
  - Improve characterization of pre-convective environment
- General considerations:
  - Assimilation of reconstructed radiances using channel selection approach (as in global ICON)
  - Focus on assimilation of ‘clear-sky data’ (i.e. channels not affected by clouds)
  - Cloud information will be provided by FCI
  - Use of inter-channel correlations in R in an all-sky framework requires substantial additional development
  - Use in global ICON important also for ICON-D2 for consistent boundary conditions
  - Keep approaches in ICON and ICON-D2 similar where possible

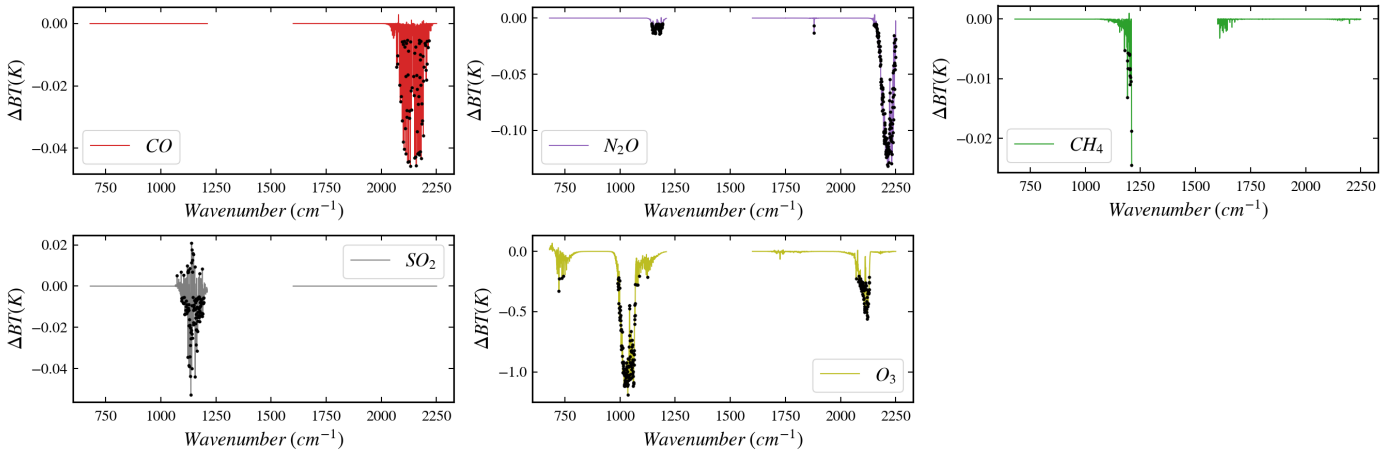
IRS data for testing

- Observations in netCDF format by EUMETSAT
- Pre-processing software is being adapted for IRS
- Test data: Radiance Simulator Package (RadSim)
  - Input: ICON-Model fields, observation locations
  - Output: simulated brightness temperature in feedback file format
- Use of feedback files in DA setup instead of real data for technical tests
- Use of IASI and SEVIRI observations as IRS proxy



Channel selection for IRS obs.

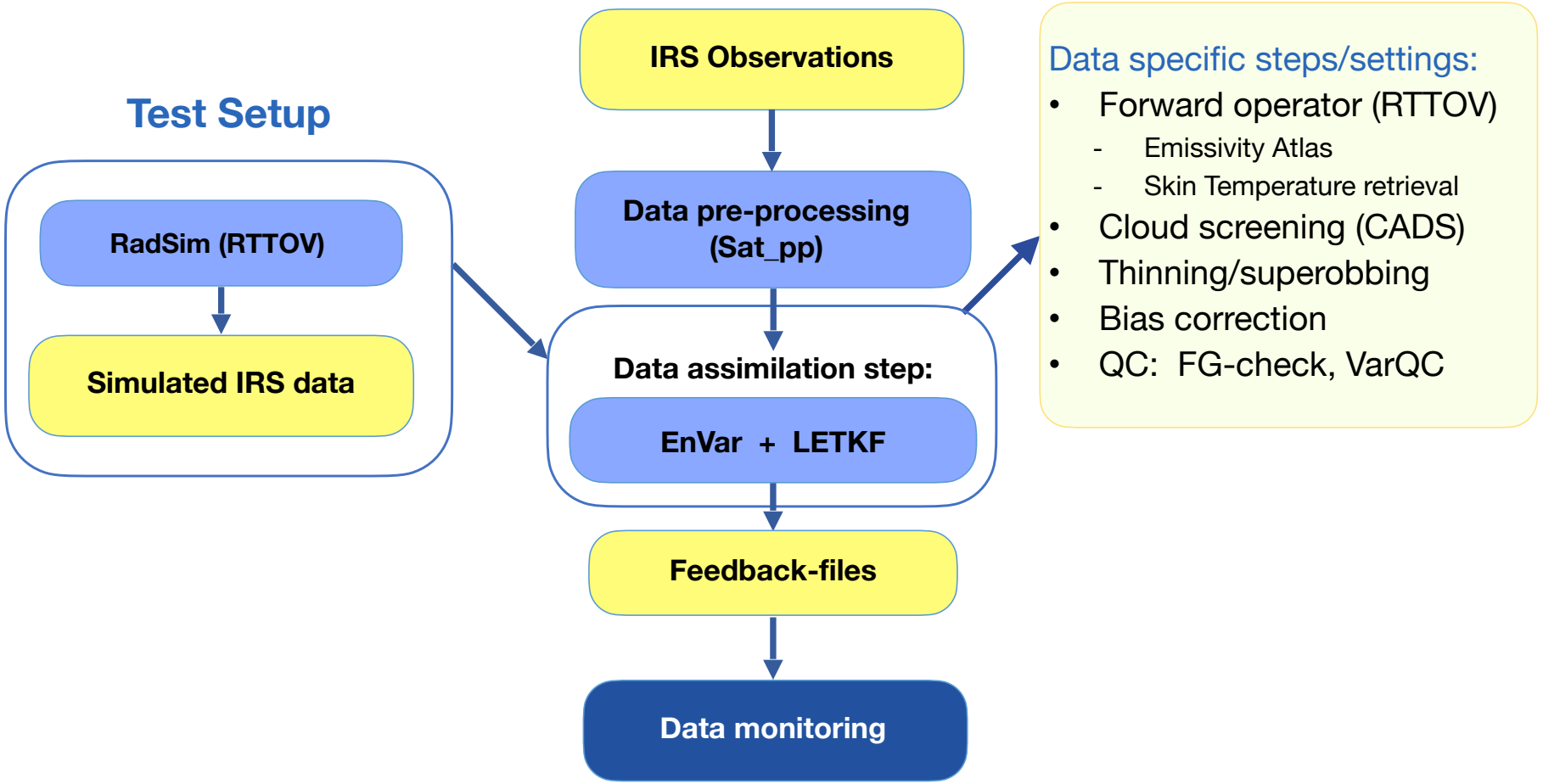
I. Exclusion of trace gas sensitive channels through spectral sensitivity analysis:
   - Uniform perturbations are applied to the vertical profiles of each chemical component
   - Sensitive channels are defined as: $\Delta BT > 0.005$, and $\Delta BT_{O_3} > 0.2$



II. A DFS-based method was developed (O. Stiller) and tested but proved ineffective due to sensitivity to the unavailable R-matrix. IRS channel selection requires **further review**

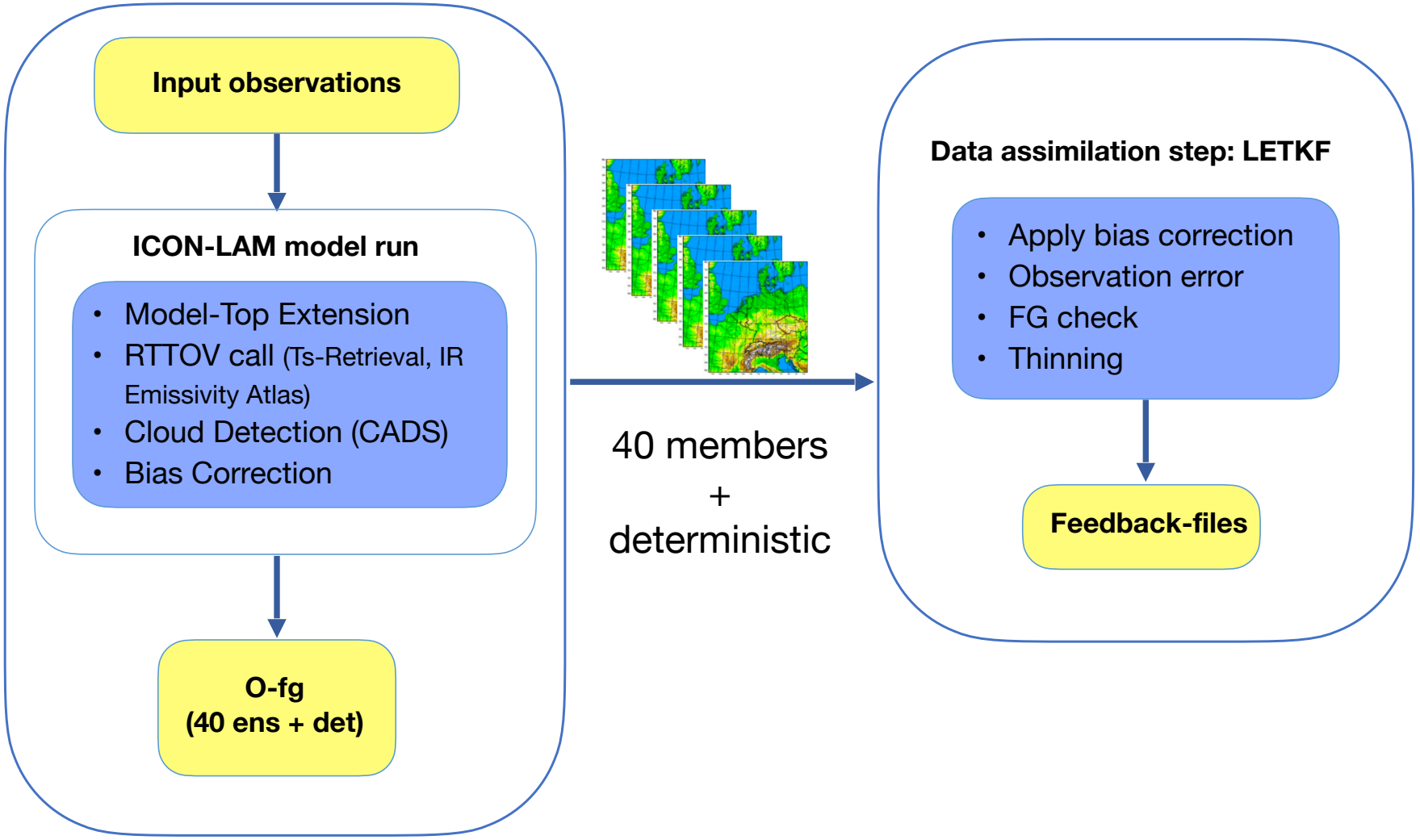
III. Pragmatic approach for initial implementation tests: Select IRS NWP channels within the same spectral range as IASI NWP channels

Preparation for IRS in global ICON/ENVAR



Implementation completed, including successful end-to-end test with synthetic IRS data

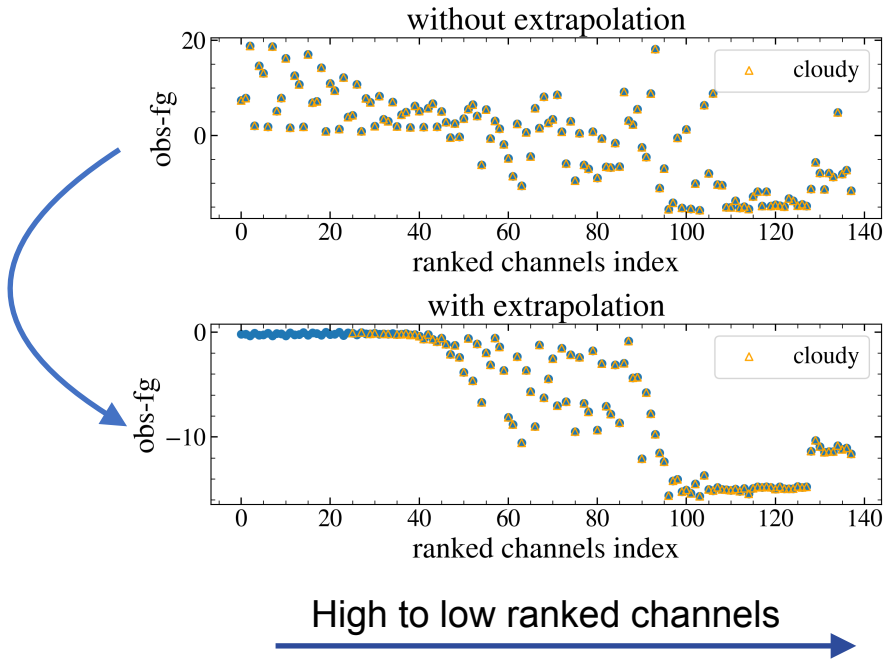
Preparation for IRS in ICON-D2/KENDA

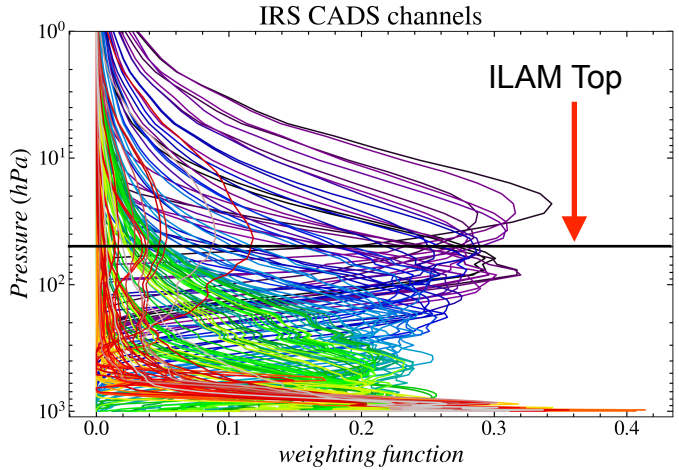


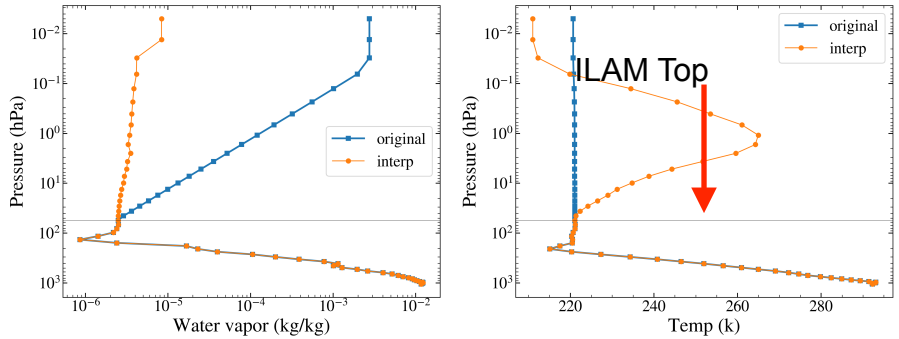
Cloud detection in ICON-D2/KENDA setup

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- Use of CADS software for cloud detection
  - Extend ILAM model top prior to RTTOV calculations using ICON fields



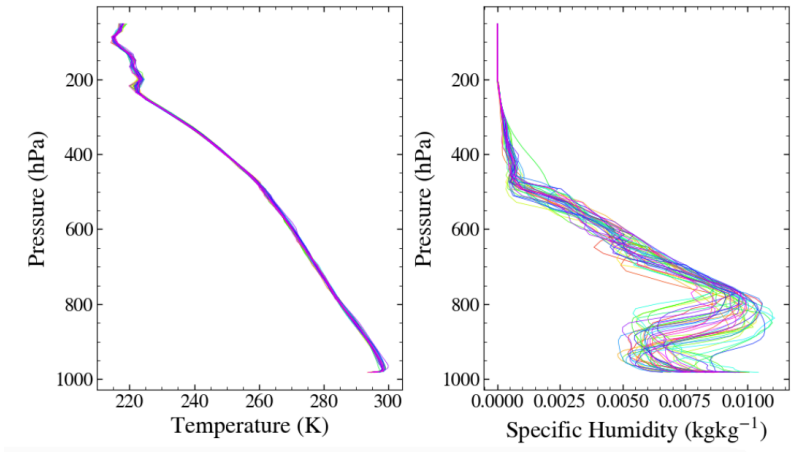


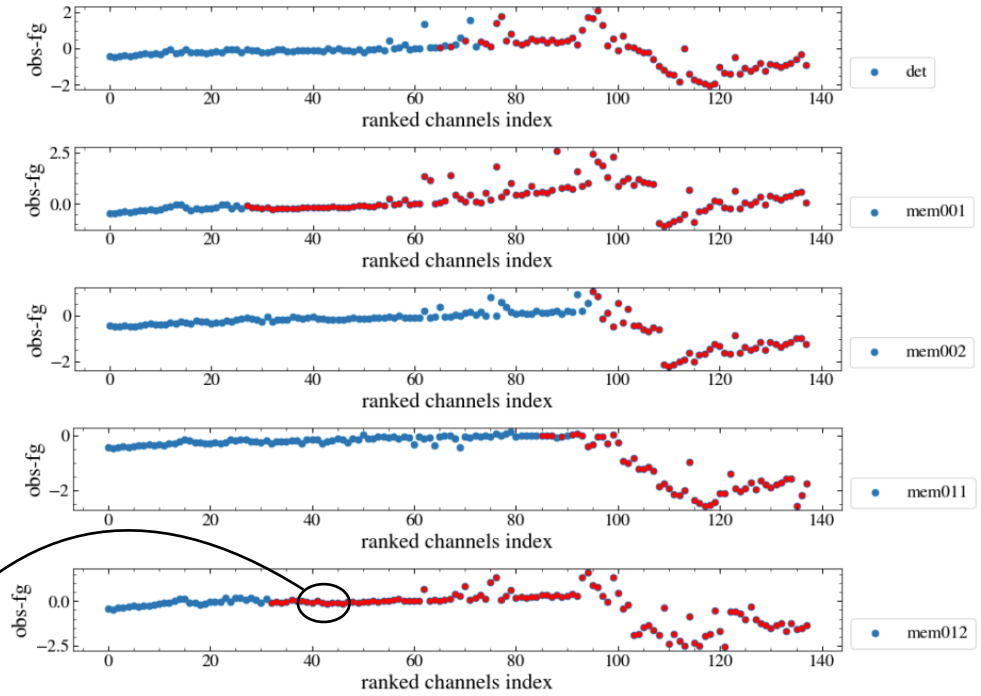


Model FG profiles on RTTOV levels with (orange) and without (blue) the extension

Cloud detection in ICON-D2/KENDA setup

- CADS scheme is sensitive to variations in atmospheric profiles (esp. humidity)
- Cloud detection results differ across ensemble members
- Defining cloud-free conditions: Consider a channel cloud-free when the majority of ensemble members agree





Red dots mark cloudy channels

High to low ranked channels

Cloud detection in ICON-D2/KENDA setup

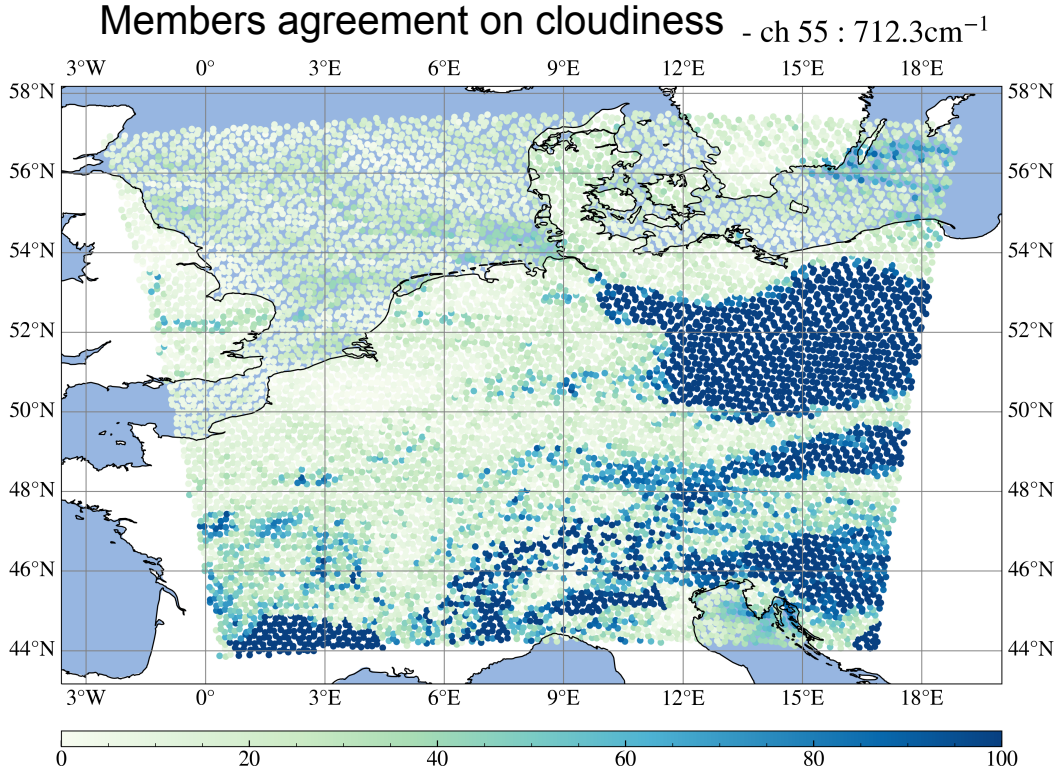
- Observation errors are inflated based on ensemble cloud detection result

$$\text{observation error} = \text{minerr} + (x \times \text{infl})$$

infl : inflation factor

x : cloudiness probability

- Use of FCI cloud mask to be explored



Improve land surface properties

Motivation:

- Use of IRS observations on **land**, especially for ICON-D2 with a high land contribution
- Extend the assimilation of radiances to **surface-sensitive channels** for improved representation of the middle and lower troposphere

Required steps:

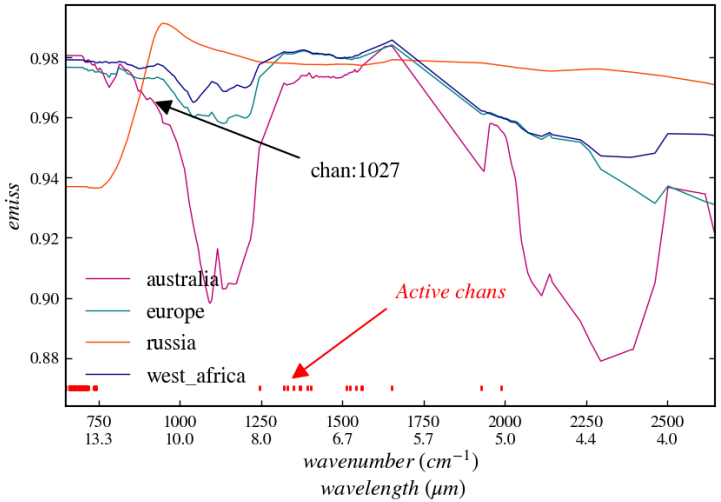
- Improvements of land surface emissivity used in RTTOV
- Improvements of land surface temperature used in RTTOV
-

Use of IR emissivity atlas on land

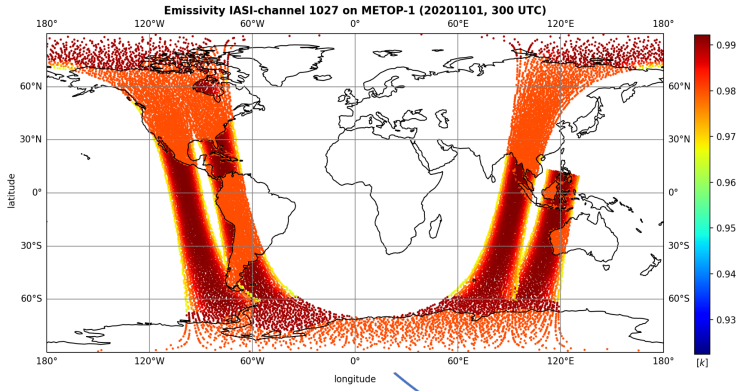
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Improvement of land surface emissivity used in RTTOV:

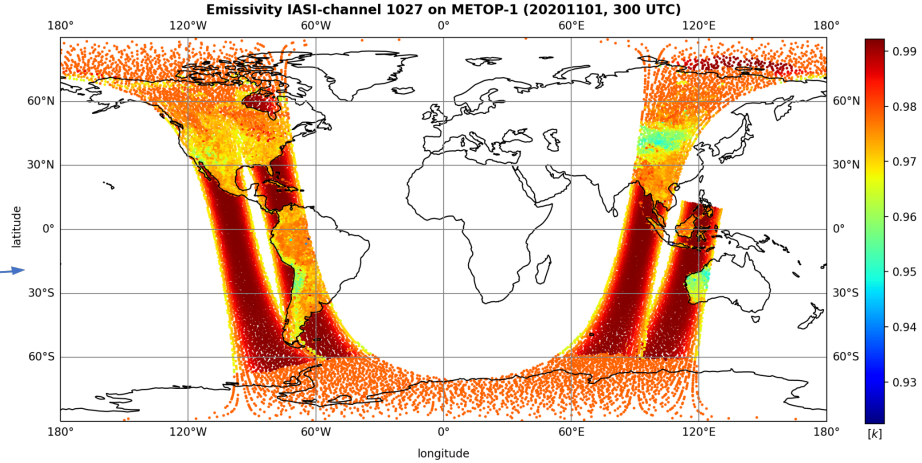
- So far: constant land surface emissivity
- Now: usage of infrared emissivity atlas



A surface Sensitive IASI channel



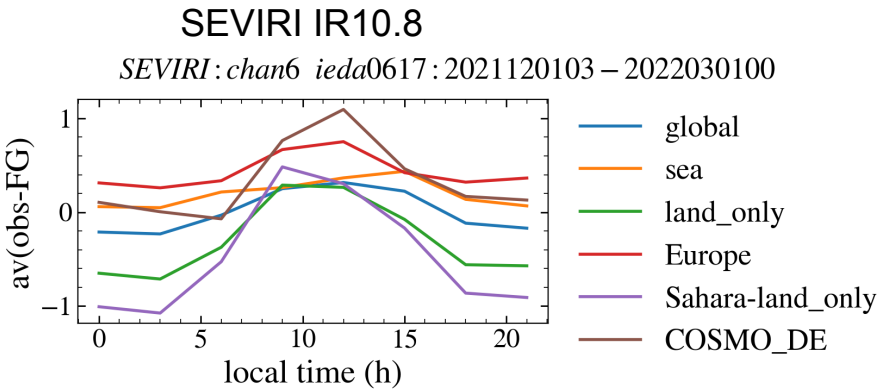
A surface Sensitive IASI channel



Use of IR-emissivity atlas is operational for GEO-sounders

Apply Ts-retrieval on land

- Diurnal variations in obs-fg are greater over land due to higher uncertainty in surface temperature



Improvement of skin temperature:

- Retrieval of Ts from clear-sky radiance (use FCI cloud mask)
- Reduce Ts background error

$$B_{T_s} = \frac{1}{\tau\varepsilon}(L_\lambda^{satellite} - L_\lambda^{down}(1-\varepsilon_\lambda)\tau - L_\lambda^{up})$$

$$T_s = \frac{C_2\nu}{log(\frac{C_1\nu^3}{B_{Ts}} + 1)}$$

The inverse Planck function

Forward Operator → $L_\lambda^{down}, L_\lambda^{up}, \tau_\lambda$

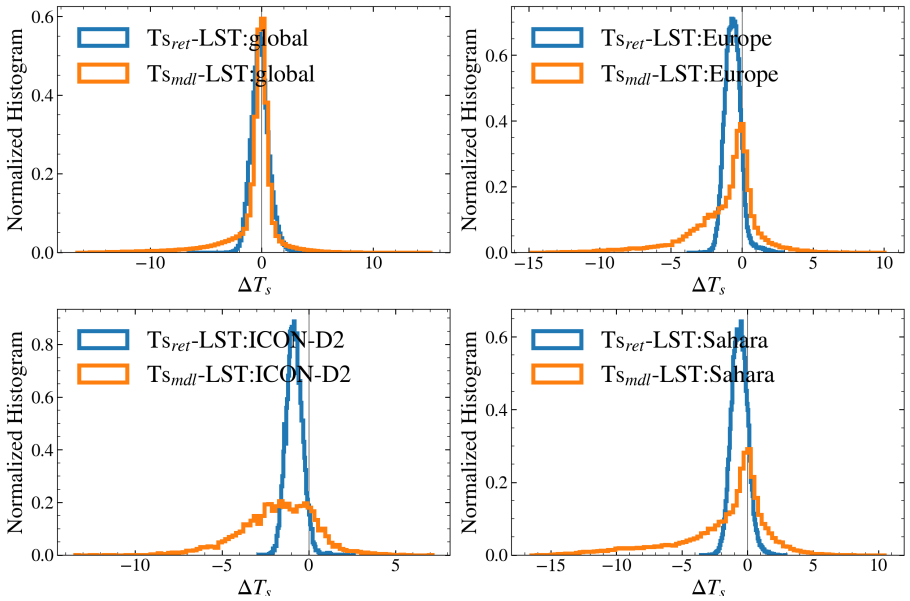
ε : surface emissivity
B_{T_s} : Blackbody radiation
L_λ^{down} : downwelling radiance
τ : total transmittance
L_λ^{up} : upwelling radiance
$L_\lambda^{satellite}$: observed radiance

Apply Ts-retrieval on land

- Clear sky difference of Ts-retrieved and Ts-model to LST product

IASI: EUMETSAT LST-Product

Ts-Retrieval using IASI channel 1027 (901.5 cm^{-1})

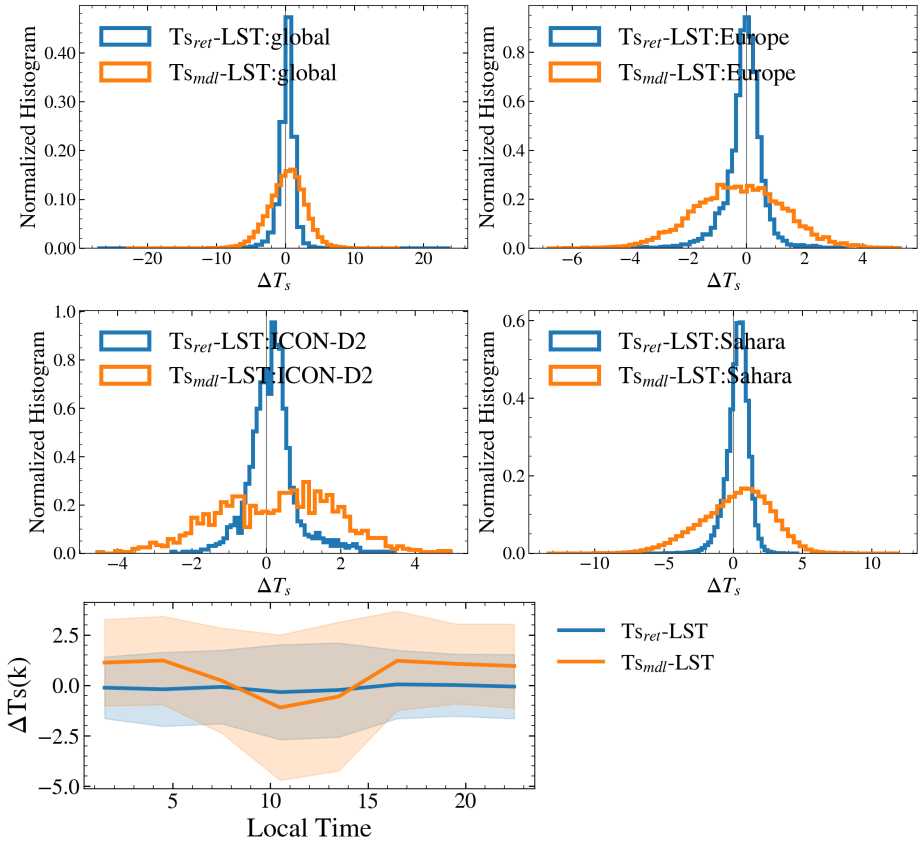


Ts$_{ret}$-LST

Ts$_{mdl}$-LST

SEVIRI: LSA SAF LST-Product

Ts-Retrieval using SEVIRI 10.8 mu



IR-emissivity atlas and Ts-retrieval are operational for GEO-sounders

- Improved diurnal variations visible in Ts

Adaptive Bias correction in regional setup

Adaptive bias-correction:

- Currently being developed based on global bias correction approach
- **Model state** dependent predictors
- Bias corrections are computed **individually** for each ensemble member
- Continuous **update** of correction coefficients in each assimilation cycle
  - Coefficients are computed from **clear-sky** data (use of FCI cloud mask in future additionally to symmetric cloud check)
- The **average bias** of all members is applied to **observations** in LETKF

Summary and outlook

- Completed technical tests to ingest synthetic IRS data into ICON/ENVAR
- Preparation for assimilation of land affected observations by:
  - Improvement of land surface emissivity
  - Improvement of skin temperature
- Technical code adaptations to process IASI and IRS data in ICON-D2 LETKF (Cloud detection, bias correction)

Future work:

- Revisit channel selection
- Implementation of non-diagonal observation error covariance matrix in LETKF
- Tests concerning thinning, height assignment, localization, …
- Finalize IRS implementation in Pre-processing: PC to Reconstructed Radiances
- Code optimization needed for IRS assimilation with many channels

Questions are welcome!