Towards all-sky assimilation of MTG-S1 IRS data

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2 Methods and results

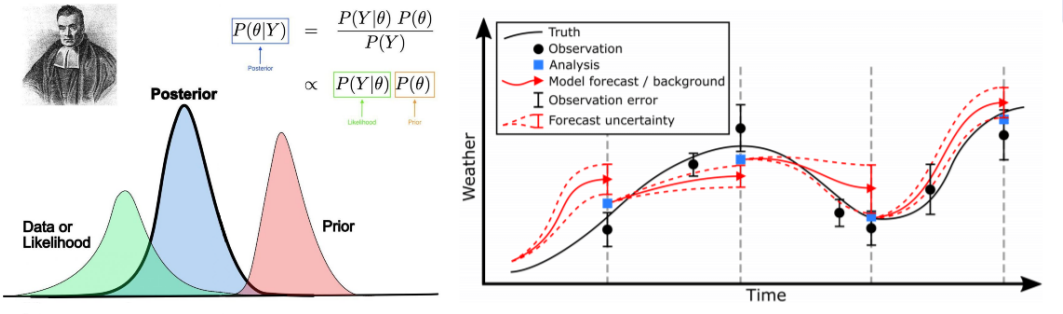
3 Plans

Introduction

- Increasing severity of high-impact weather events over Europe
- Pressing need for accurate and timely weather prediction, especially in areas with complex orography and coastal influence
- Development of high resolution convection-permitting numerical models capable of explicitly resolving processes at a kilometer scale
- Optimal initial atmospheric state is estimated through the process of data assimilation
- Adaptation of model state using relevant data (observations) - model initialization

Introduction

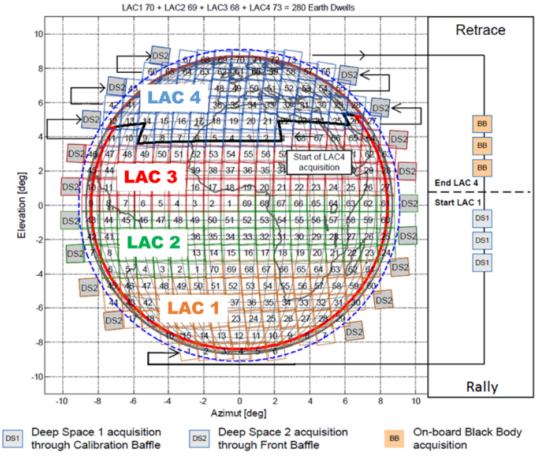
- Bayesian framework



$$-ln(P_a) \equiv J(x) = \underbrace{\frac{1}{2}(x - x_b)^T B^{-1}(x - x_b)}_{\text{model fit}} + \underbrace{\frac{1}{2}(y_o - H(x))^T R^{-1}(y_o - H(x))}_{\text{observation fit}}$$

Introduction

- Assimilation of satellite radiance data has led to significant improvements in weather prediction, especially in areas with no in-situ measurements
- MTG-IRS (InfraRed Sounder)
  - Launched 1.7.2025.
  - Europe's first hyperspectral infrared sounding instrument, designed for operation in a geostationary orbit
  - 1960 channels, measurements provided every 30 minutes with a spatial sampling of 4 km at nadir (7 km over Europe)
  - Currently in the commission phase



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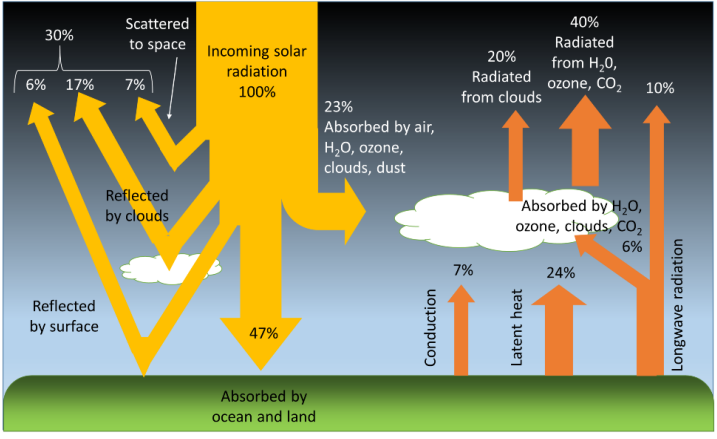
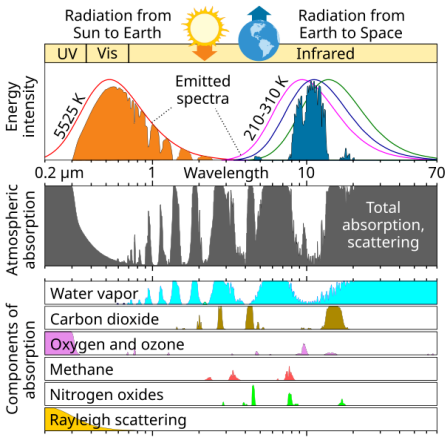
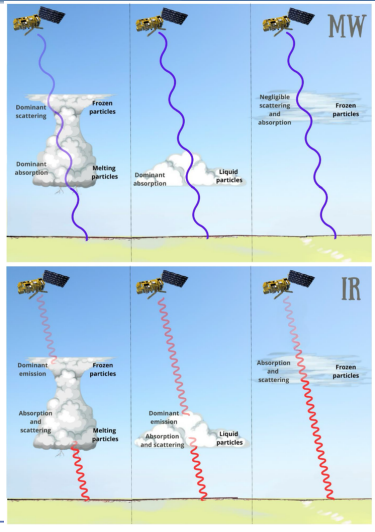




Introduction

- Traditionally, satellite radiance data assimilation has been limited to clear-sky conditions due to unresolved cloud microphysics in the model - cloud detection algorithms
- Development of high-resolution convection-permitting models provided the necessary framework for revisiting the use of cloud and precipitation affected observations
- To fully exploit the potential of high-resolution IRS data in NWP systems, assimilating radiances in all-sky conditions is essential
- Inverse Planck function:

$$T_b(\nu) = \frac{c_2\nu}{ln(\frac{c_1\nu^3}{L(\nu)} + 1)}$$



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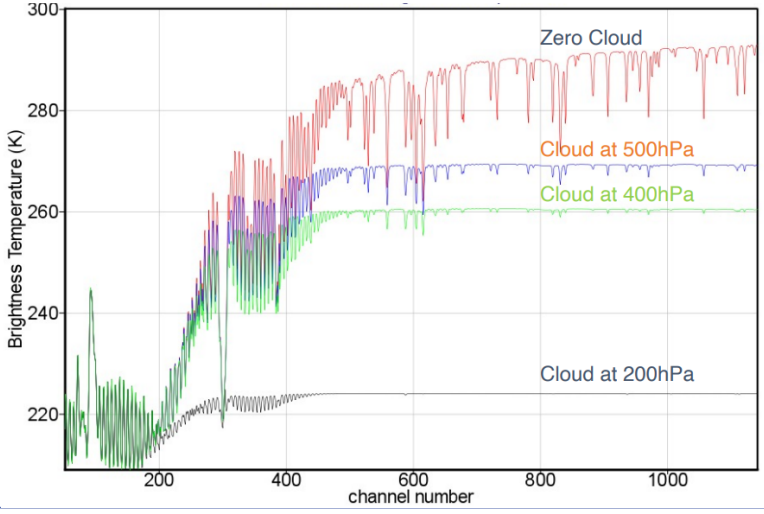

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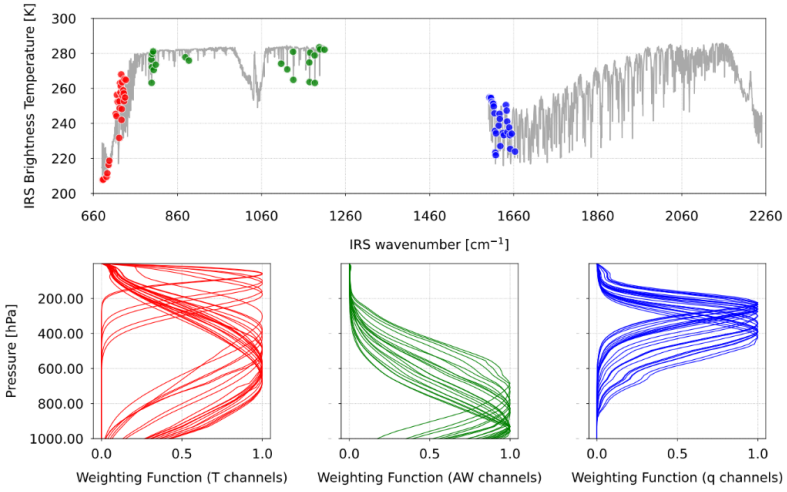

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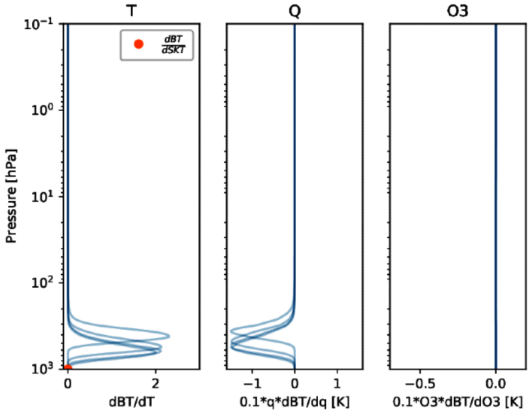
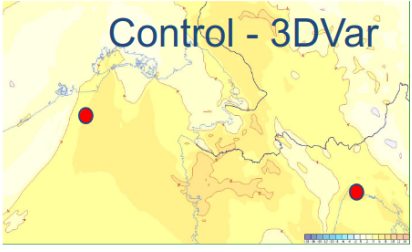
Data

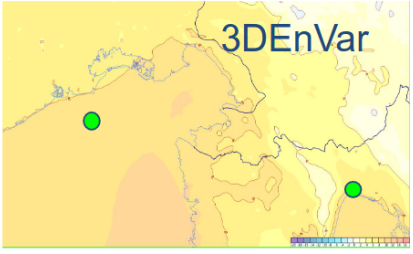
- IASI data used as proxy for technical implementation of all-sky data assimilation in AROME (Applications of Research to Operations at Mesoscale) model
- Satellites:
  - Metop-B and Metop-C
- Period:
  - January 15th - February 15th 2025.
- Channels assimilated in all-sky mode:
  - 2951, 2958, 3049 and 3105

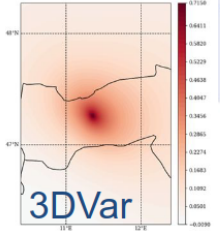


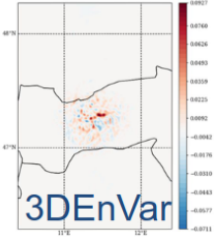
Model

- Usage of the common framework as basis for development
- C-LAEF (Convection-permitting Limited-Area Ensemble Forecasting) AlpeAdria
- 1 km horizontal resolution
- 17 members (1 member using 3DEnVar scheme)



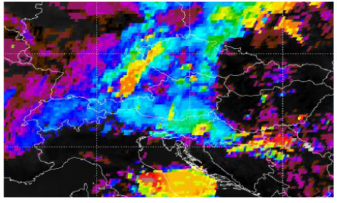


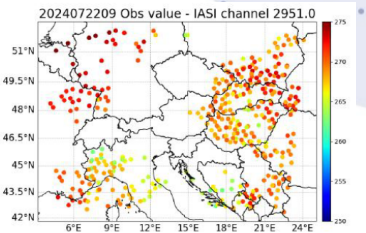


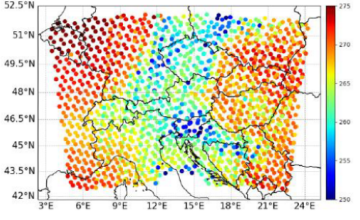


Clear-sky vs all-sky data assimilation

- Traditionally, only clear-sky data are assimilated
- Constant value is assigned as observation error per channel
- Using cloud affected infrared data offers ∼ 3x more data to actively assimilate but observation errors need to be modeled







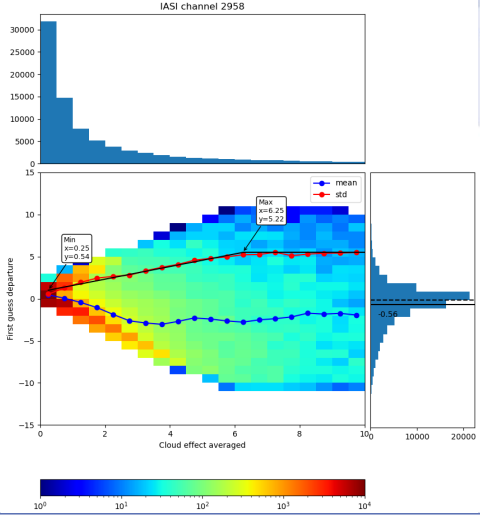
Observation error modeling

- Methodology first proposed by Geer and Bauer (2011.), modified by Okamoto (2023.):

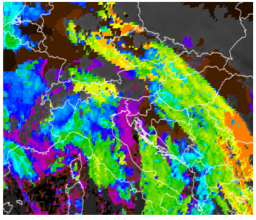
$$O_{err} = \frac{\sigma_{cld} - \sigma_{clr}}{C_{cld} - C_{clr}}(C_A - C_{clr})$$

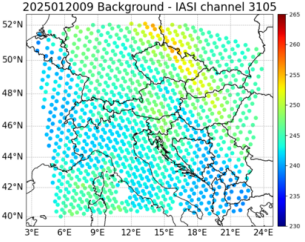
- Averaged cloud effect (Okamoto, 2014.):

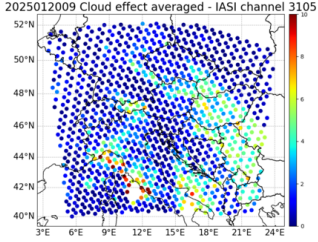
$$C_A = \frac{|B - B_{CLR}| + |O - B_{CLR}|}{2}$$

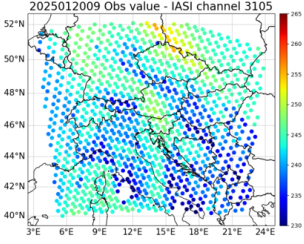


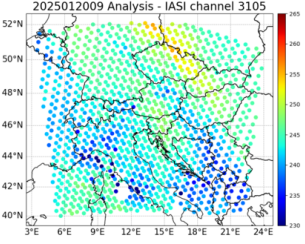
Implementation of all-sky data assimilation

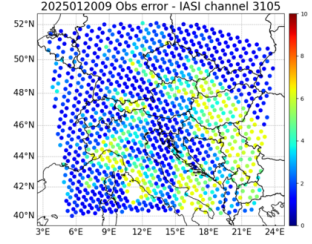






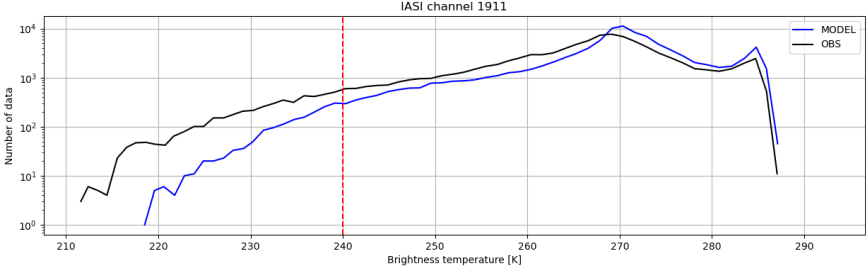






Identification of badly simulated data

- Data that can not be simulated properly by the model should not be assimilated



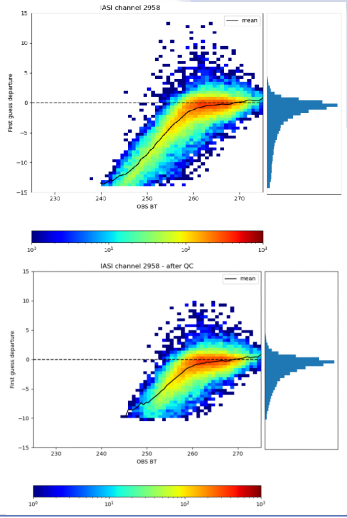
- General lack of clouds in the model
- Problem with high ice clouds representation

Quality control of data

- Cold tail in first guess departure distribution
  - not in line with the theory of data assimilation
- Quality control to remove data strongly affected by cloud

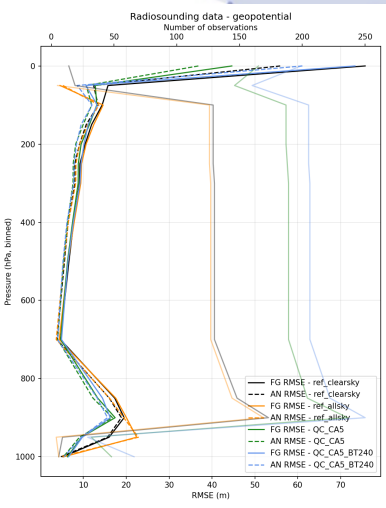
$$C_A > 5$$

- Removes data with large first guess departures



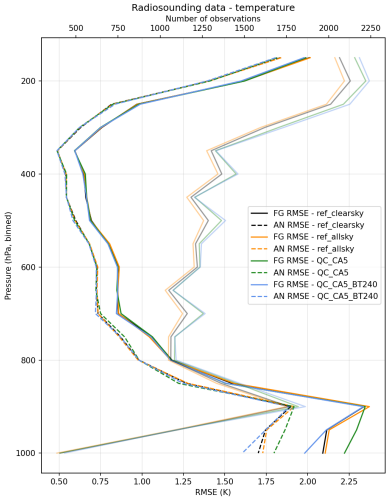
Data analysis

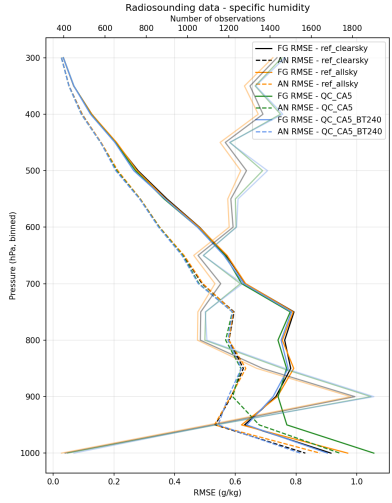
- Experiments
  - ref_clrsky - first reference using data in clear-sky conditions only
  - ref_allsky - second reference using data in all-sky conditions for 4 WV channels and data in clear-sky conditions for rest of the channels
  - QC_CA5 - same as ref_allsky but with rejection of data where $C_A > 5$
  - QC_CA5_BT240 - same as QC_CA5 but with rejection of data where $T_b < 240K$
- Evaluation of impact on different types of assimilated data



Data analysis

- Increased variance and decrease in the number of assimilated radiosounding data when no QC is applied
- Decreased variance and increase in the number of assimilated radiosounding data when QC is applied





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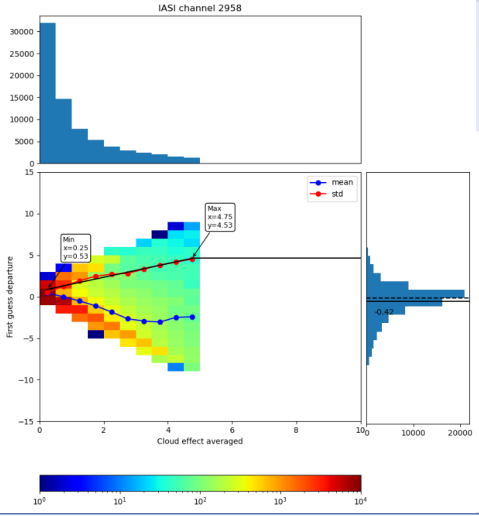
Plans

- Residual unresolved cloud-dependent bias
- Incorporating new cloud-dependent predictor into the variational bias correction (VARBC) scheme

$$J(x,\beta) = \frac{1}{2}(x - x_b)^T B^{-1}(x - x_b) + \frac{1}{2}\sum_{k=0}^{K}(y_k - H(x_k) - b(x_k,\beta))^T R_k^{-1}... + \frac{1}{2}(\beta - \beta_b)^T B_b^{-1}(\beta - \beta_b)$$



Plans

- Extend the 3D-EnVar control variable vector to hydrometeors - expected to capture significant part of the information from all-sky observations
- Explore joint performance of the 3D-EnVar method and adaptive all-sky observation error modeling
- Explore seasonal variability of this method
- Impact study of IRS observations in the 1 km convection-permitting model using the final refined configuration

Thank you for your attention!
Questions?
Contact: panezic@cirus.dhz.hr