ISDA-Online

Thursday, June 12, 2025, from 7-9h UTC

"Topic: Satellite Data Assimilation"

Organizers: Alan Geer *(ECMWF, UK)*,
Philipp Griewank *(University of Vienna, Austria)*,
Tobias Necker *(ECMWF, Germany)*

Invited Speakers: Kozo Okamoto *(JMA, Japan)*, *Cristina Lupu (ECMWF, UK)*

Satellite observations substantially contribute to the accuracy of initial conditions and forecasts in geoscience and beyond. The high importance and variety of satellite observations, including various ongoing and future satellite missions, call for further advances in satellite data assimilation. We invite all contributions from this active and exciting research field.

Program (UTC):

07:00 – 07:05 **Welcome**

(30 min invited talk + 5min Q&A)

07:05 – 07:40 **All-sky infrared radiance assimilation for imagers and sounders**
Kozo Okamoto, Toshiyuki Ishibashi, Izumi Okabe, Hiroyuki Shimizu

(17min +3min Q&A)

07:40 – 08:00 **Advances in Variational Bias Correction (VarBC) for All-Sky Satellite Data Assimilation to Improve GFDL SHiELD Analysis and Forecasts**
Chih-Chi Hu, Mingjing Tong

(17min +3min Q&A)

08:00 – 08:20 **Importance and Assimilation of Satellite Infrared and Microwave Radiances in the Copernicus Arctic Regional Second Generation Reanalysis**
Swapan Mallick

(30 min invited talk + 5min Q&A)

08:20 – 08:55 **Seeing the unseen - All-sky visible reflectance assimilation at ECMWF**
Cristina Lupu, Tobias Necker, Samuel Quesada-Ruiz, Volkan Firat, and Angela Benedetti

08:55 – 09:00 **Closing / Outlook**

Please note:

- The times in UTC are approximate. In case of technical problems, we might have to change the order of the presentations.
- **Time Zones**: **07 – 09 UTC**
  08 – 10 am BST (London) | 09 – 11 am CEST (Berlin)
  03 – 05 pm CST (Shanghai) | 04 – 06 pm JST (Tokyo) | 05 – 07 pm AEDT (Sydney)
  00 – 02 am PDT (San Fran.) | 01 – 03 am MDT (Denver) | 03 – 05 am EDT (New York)
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All-sky infrared radiance assimilation for imagers and sounders

Kozo Okamoto[1],
Toshiyuki Ishibashi[1], Izumi Okabe[1], Hiroyuki Shimizu[2]

[1] Japan Meteorological Agency (JMA/MRI), Japan
[2]Numerical Prediction Development Center, Japan Meteorological Agency (JMA), Japan

All-sky infrared radiance assimilation is more beneficial than traditional clear-sky radiance assimilation because it significantly enhances the observation availability. Despite many challenges involved with high sensitivity to clouds in infrared radiances, we successfully developed the all-sky infrared radiance assimilation for water vapor channels of infrared imagers and hyperspectral sounders in a global data assimilation system.

Essential assimilation procedures of this infrared all-sky assimilation are cloud-dependent quality control, bias correction, and observation error models, including inter-band error correlation, as well as data assimilation systems, radiative transfer models (RTMs) and forecasting models that can handle cloud effects. Because of the limited capability to reproduce cloud-affected radiances in current forecasting models and RTMs, we still remove, correct, or underweight radiances strongly affected by the cloud. Nonetheless, the all-sky approach significantly increased the available data compared to the clear-sky approach. This better mitigated drying bias and significantly improved forecasting skills.

This presentation will overview lessons we have learned from the development and examination of the all-sky infrared radiances assimilation.

Advances in Variational Bias Correction (VarBC) for All-Sky Satellite Data Assimilation to Improve GFDL SHiELD Analysis and Forecasts

Chih-Chi Hu[1], Mingjing Tong[2]

[1]Princeton University, US
[2]Geophysical Fluid Dynamics Laboratory (NOAA), US

The satellite radiance observations are known to contain biases, and correcting these biases plays a crucial role in effective assimilation. The biases can be very complex and state-dependent, mainly due to the representation error. Variational Bias Correction (VarBC) has been commonly used to estimate and correct these biases dynamically. Despite the success of VarBC, its performance is known to rely on the presence of anchor observations when systematic model biases are present. Nevertheless, anchor observations are not sufficiently available in some regions, for example, in the lower troposphere over the ocean, where many window-channel radiances have sensitivity to.

This work investigates strategies to enhance VarBC under the conditions of limited anchor observations, with a focus on all-sky microwave channels. In all-sky satellite DA, cloud proxies are often used to define cloud-dependent observation error models. We explore leveraging this cloud proxy information as an additional source of “anchor information”. In particular, following the approach of Zhu et al (2014), we adopt a stricter data control strategy that excludes samples likely affected by significant model errors, identified using the cloud proxy, from contributing to VarBC bias estimation. We further expand on this by testing different data selection criteria and by incorporating the cloud proxy as additional predictors in VarBC. Our experiments demonstrate that these refinements to VarBC improve the assimilation of all-sky microwave observations, leading to more accurate low-level humidity and temperature analyses, and improved forecasts up to 48-72 hours, particularly over the oceanic regions.

Importance and Assimilation of Satellite Infrared and Microwave Radiances in the Copernicus Arctic Regional Second Generation Reanalysis

Swapan Mallick
Swedish Meteorological and Hydrological Institute (SMHI), Sweden

Reanalysis data provides highly accurate information on weather and climate conditions over long periods and at regular intervals. Recently, it has gained more importance in weather and climate research, especially with the integration of artificial intelligence and machine learning methods and for climate projection. Copernicus Arctic Regional Reanalysis Second Generation (CARRA-2), covering the pan-Arctic region, is a high-resolution climate data product. Copernicus is the Earth observation component of the European Union's space programme. The European Centre for Medium-Range Weather Forecasts (ECMWF) has been appointed by the European Commission with funding from the EU to operate the Copernicus Climate Change Service on its behalf. CARRA-2 reanalysis uses a 3D variational data assimilation system with three-hourly cycles to achieve precise estimations of atmospheric and surface conditions by integrating an extensive time series of conventional and satellite remote sensing observations spanning over 30 years. Given the large domain and limited conventional observations available across the pan-Arctic region, satellite data from various platforms help to fill these observational gaps. These include microwave clear-sky radiance from AMSU and MHS, hyperspectral radiances from IASI and CrIS, satellite-derived wind products and few more. A wide array of these observing platforms are assimilated into the HARMONIE-AROME model at ~2.5 km resolution. This study will focus on the assimilation of satellite microwave and infrared radiances, their impact and significance within CARRA-2. Further details will be provided on various satellite types, sensors, and bands, along with an analysis of impact on the reanalysis.

Seeing the unseen - All-sky visible reflectance assimilation at ECMWF

Cristina Lupu, Tobias Necker, Samuel Quesada-Ruiz,
Volkan Firat, and Angela Benedetti

European Center for Medium-Range Weather Forecasts (ECMWF)

Satellite observations are critical for numerical weather prediction (NWP), yet the full potential of visible spectral data remains to be explored. In recent years, ECMWF has been advancing efforts to incorporate visible and near-infrared satellite observations to enhance the analysis and forecasts of clouds and aerosols in the Integrated Forecasting System (IFS). This progress was accelerated by ESA's CLOVIS projects and the Horizon Europe-funded CAMEO and CERTAINTY projects. Our talk will discuss the potential of low-earth orbit (LEO) and geostationary orbit (GEO) visible reflectance observations in the 655 nm range. We will present the first-ever successful experimental assimilation of visible all-sky satellite observations in the IFS using cycle CY49R1, declared operational in November 2024. These experiments include monitoring and assimilation tests using observations from the Ocean and Land Color Instrument (OLCI) onboard ESA's Sentinel 3A and 3B satellite missions. A comprehensive evaluation of our experiments demonstrates that visible reflectance assimilation can improve the model analysis of clouds by better fitting the model trajectory to observations in visible reflectance space. We will also discuss the outstanding challenges related to successful future operational assimilation of visible observations, including observation operator refinements, observation error modelling, and the role of model errors and biases. Our findings underscore the vast potential of visible spectral data for operational NWP and future re-analysis products.