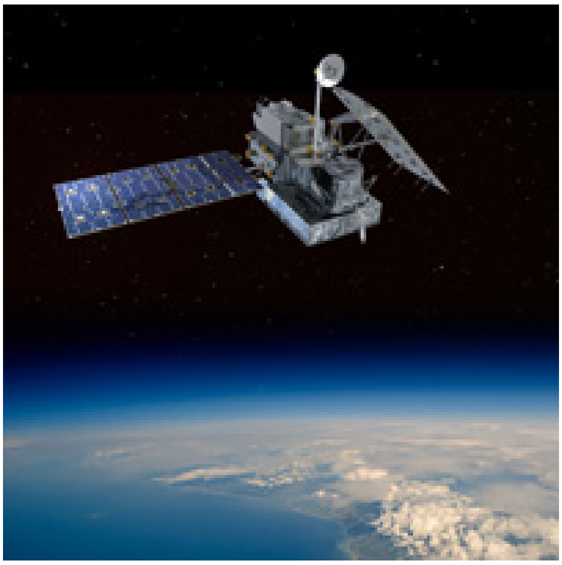
4th workshop on assimilating satellite cloud and precipitation observations for NWP



Report of Contributions

Contribution ID: **1** Type: **Oral presentation**

Welcome

Monday, 3 February 2020 11:00 (10 minutes)

Presenters: BROWN, Andy (ECMWF); JOHNSON, Ben (JCSDA); ACCADIA, Christophe (EUMETSAT)

Contribution ID: **2** Type: **Oral presentation**

Workshop organisation

Monday, 3 February 2020 11:10 (20 minutes)

Presenter: BORMANN, Niels (ECMWF)

Contribution ID: **29** Type: **Oral presentation**

Lightning modelling and assimilation

Tuesday, 4 February 2020 16:45 (25 minutes)

A lightning parametrization was developed at ECMWF, which became operational in June 2018. It can predict total lightning flash densities (cloud-to-ground plus cloud-to-cloud) both in the deterministic and the ensemble forecasting system. Its tangent-linear and adjoint versions were also developed and have been used over the past two years to investigate the possibility to assimilate lightning flash observations from the new GOES-16 Geostationary Lightning Mapper (GLM) using the 4D-Var approach. This presentation will describe the lightning parametrization, its validation as well as the first results from the assimilation of lightning observations in ECMWF's 4D-Var system. Issues that are specific to the assimilation of lightning data in a variational context will also be summarized.

Primary author: Dr LOPEZ, Philippe (ECMWF)

Presenter: Dr LOPEZ, Philippe (ECMWF)

Session Classification: Session 2: Cloud and precipitation modelling

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **35** Type: **Oral presentation**

Space-based Cloud & Precipitation Observing Systems in the 2020-2040 Period

Monday, 3 February 2020 12:15 (40 minutes)

In this presentation, we will go over the evolution of the collective capability to observe cloud and precipitation from space-based observing systems, as planned or envisioned by major international space agencies. We will highlight potential gaps if any and assess its compatibility with the evolution of the global NWP requirements. Both research and operational missions will be explored, as well as potential missions of opportunities from non-governmental entities. We will attempt to cover capabilities from microwave (active and passive) as well as infrared sensors. The capabilities that will be covered in this presentation will include the ability to measure the suspended cloud and the precipitating water in all phases but will also cover the additional characteristics that are critical for meteorological and hydrological applications such as global NWP: these include temporal update rate, spatial coverage, footprint resolution and vertical resolution. We will be targeting the 2020-2040 timeframe when assessing the capabilities.

Primary author: Dr BOUKABARA, Sid (NOAA)

Co-authors: Dr LUKENS, Katie (UMD); HOFFMAN, Ross (UMD); BUNIN, Stacy (RTI); ZHANG, Peng (CMA); WEHR, Tobias (ESA)

Presenter: Dr BOUKABARA, Sid (NOAA)

Session Classification: Overview talks

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **36** Type: **Poster presentation**

Assimilating All-Sky Infrared Brightness Temperatures in an Ensemble Data Assimilation System using a Nonlinear Bias Correction Method

Ensemble data assimilation experiments were used to assess the ability of satellite all-sky infrared brightness temperatures and a nonlinear bias correction (BC) method to improve the accuracy of short-range model forecasts. Infrared brightness temperatures from the SEVIRI sensor that are sensitive to clouds and water vapor in the upper troposphere were assimilated at hourly intervals during a 3-day period using a regional-scale assimilation system. Linear and nonlinear conditional biases were removed from the all-sky satellite observations using a Taylor series polynomial expansion of the observation-minus-background departures and BC predictors sensitive to clouds and water vapor. Assimilating all-sky infrared brightness temperatures without BC degraded the forecast accuracy based on comparisons to radiosonde observations. Removal of the linear and nonlinear conditional biases from the satellite observations substantially improved the results, with predictors sensitive to the location of the cloud top height having the largest positive impact, especially when higher order nonlinear BC terms were used. Overall, experiments employing the observed cloud top height or observed brightness temperature as the bias predictor had the smallest water vapor, cloud, and wind speed errors, while also having less degradation to temperatures than occurred when using other predictors. The forecast errors were smaller during these experiments because the cloud-height-sensitive BC predictors were able to effectively remove the large conditional biases from lower brightness temperatures associated with a deficiency in upper-level clouds in the model background.

Primary authors: OTKIN, Jason (University of Wisconsin-Madison / CIMSS / SSEC); POTTHAST, Roland (Deutscher Wetterdienst); LAWLESS, Amos (University of Reading)

Presenter: OTKIN, Jason (University of Wisconsin-Madison / CIMSS / SSEC)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **37** Type: **Poster presentation**

Ensemble-Based Data Assimilation of GPM/DPR Reflectivity into the Nonhydrostatic Icosahedral Atmospheric Model NICAM

This study aims to improve the precipitation forecasts from numerical weather prediction models through effective assimilation of satellite-observed precipitation data. The assimilation of precipitation data is known to be difficult mainly due to highly non-Gaussian statistics of precipitation-related variables. We have been developing a global atmospheric data assimilation system NICAM-LETKF, which comprises the Nonhydrostatic ICosahedral Atmospheric Model (NICAM) and Local Ensemble Transform Kalman Filter (LETKF). Using the NICAM-LETKF system, Kotsuki et al. (2017, JGR) successfully improved the weather forecasts by assimilating the Japan Aerospace eXploration Agency (JAXA)'s Global Satellite Mapping of Precipitation (GSMaP) data into the NICAM at 112-km horizontal resolution. However, assimilating space-borne precipitation radar data remains to be a challenging issue.
This study pioneers to assimilate radar reflectivity measured by the Dual-frequency Precipitation Radar (DPR) onboard the Global Precipitation Measurement (GPM) core satellite into the NICAM. We conduct the NICAM-LETKF experiments at 28-km horizontal resolution with explicit cloud microphysics of a single-moment 6-class bulk microphysics scheme. To simulate GPM/DPR reflectivity from NICAM model outputs, the joint-simulator (Hashino et al. 2013; JGR) is used. Our initial tests showed a better match with the observed reflectivity by assimilating GPM/DPR reflectivity into NICAM forecasts. However, the results from a 1-month data assimilation cycle experiment showed general degradation by assimilating GPM/DPR reflectivity. For better use of GPM/DPR reflectivity data, we are exploring to estimate model cloud physics parameters by assimilating them. This presentation will include the most recent progress up to the time of the workshop.

Primary authors: KOTSUKI, Shunji (Center for Environmental Remote Sensing, Chiba University); Dr TERASAKI, Koji (RIKEN CCS); Prof. SATOH, Masaki (The University of Tokyo); MIYOSHI, Takemasa (RIKEN)

Presenter: KOTSUKI, Shunji (Center for Environmental Remote Sensing, Chiba University)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **38** Type: **Poster presentation**

Local Particle Filter Implemented with Minor Modifications to the LETKF Code

Cloud and precipitation processes are generally highly nonlinear, resulting in strongly non-Gaussian PDF. Particle filters treat non-Gaussian PDF explicitly and would be potentially effective for data assimilation of cloud and precipitation variables. Penny and Miyoshi (2015) developed a Local Particle Filter (LPF) in a form as the ensemble transform matrix of the Local Ensemble Transform Kalman Filter (LETKF). The LETKF has been widely used for various geophysical systems including global and regional numerical weather prediction (NWP) models and Martian atmospheric models. Therefore, implementing consistently with an existing LETKF code is useful. The particle weights of LPF, or equivalently the ensemble transform matrix of LPF, consist of 0 and 1 entries, and the smooth spatial transition of local weights is essential. German Weather Service (DWD) implemented the LETKF for their operational global model ICON based on an icosahedral grid system, where the LETKF weights are computed at a coarser analysis grid and interpolated into a higher-resolution icosahedral model grid. The interpolation brings spatial smoothing similarly to weight interpolation (Yang et al. 2008). The spatial smoothing is beneficial for smooth spatial transition of local weights, particularly for LPF. Potthast et al. (2018) applied the LPF weights in the German LETKF system and reported a stable performance in the operational setup. They called their LPF system LAPF (Local Adaptive Particle Filter). Further, Walter and Potthast (2019) improved their LAPF as a Gaussian mixture filter, what they call the LMCPF (Local Mixture Coefficients Particle Filter). This study aims to sort out the various implementations of LPF consistently with an existing LETKF code. Here we use the LETKF code first developed by Miyoshi (2005) based on an intermediate AGCM known as the SPEEDY model. In this presentation, we would like to focus on the theory and code designs of the LPF and its Gaussian mixture extension, with only minor modifications to the existing LETKF code.

Primary authors: MIYOSHI, Takemasa (RIKEN); KOTSUKI, Shunji (RIKEN); KONDO, Keiichi (Japan Meteorological Agency); POTTHAST, Roland (German Weather Service (DWD))

Presenter: MIYOSHI, Takemasa (RIKEN)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **39** Type: **Oral presentation**

Is it possible to find average snow scattering properties that can be applied globally? A first attempt using Self-similar Rayleigh Gans Theory and a new aggregation model

Wednesday, 5 February 2020 11:30 (25 minutes)

The assimilation of all-sky radiance data requires a fast and accurate radiative transfer model capable of simulating the scattering and absorption effects of hydrometeors. In the past decade, complex Discrete Dipole Approximation (DDA) scattering calculations have demonstrated that commonly used simplifications in frozen particle shape (i.e., sphere and spheroids) are insufficient for representing the snow scattering properties across multiple microwave frequencies and that the internal snowflake microstructure plays an important role in the definition of the scattering effects. Nonetheless, abandoning the simplified spheroidal shape model opens a whole new problem that is deciding which ice particle shape is the most realistic out of the enormous variety of natural ice particles.
Recently, microphysical schemes used in weather models have made a lot of progress in representing the natural variability of snow properties. The consistency of scattering calculations with such spread of assumptions is difficult to ensure with DDA datasets.
The Self-Similar Rayleigh-Gans Approximation (SSRGA) has been developed as a tool to estimate the scattering properties of self-similar ensembles of snowflakes. The power of SSRGA relies on the fact that it takes the form of an analytic function and can easily calculate the scattering properties of realistically shaped snowflakes for various sizes, mass-size relations, aspect-ratios and for any frequency.
Using a realistic snow particle model, we have derived the SSRGA parameters of various types of snowflakes. We have tested the simulated scattering properties against a long-term dataset of multi-frequency ground-based radar measurements. The particle habit that most consistently matched our observations is a snow aggregate composed of a mixture of dendrites and columnar prisms. The results of this study also confirm that it is possible to constrain the microwave scattering properties of frozen particles by means of a statistical comparison of simulated and observed microwave measurements.

Primary authors: ORI, Davide (University of Cologne); Dr KNEIFEL, Stefan (University of Cologne); Ms VON TERZI, Leonie (University of Cologne); Mr DIAS NETO, Jose (University of Cologne); Mr KARRER, Markus (University of Cologne)

Presenter: ORI, Davide (University of Cologne)

Session Classification: Session 3: Observation operators

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **40** Type: **Oral presentation**

Fast methods for simulating visible satellite images

Wednesday, 5 February 2020 11:00 (25 minutes)

Visible satellite images provide high-resolution information on clouds. However, so far they have not been assimilated directly for operational purposes, as multiple scattering dominates in the visible spectral range and makes radiative transfer computations with standard methods complex and slow. Only recently, sufficiently fast and accurate forward operators have become available. Here we report on the design of a lookup-table based forward operator and developments aimed at increasing its accuracy. Approximations for three-dimensional radiative transfer effects and corrections for mixed-phase clouds are addressed. Moreover, the potential of alternative approaches based on machine learning is discussed. These approaches could be competitive in terms of speed and accuracy and allow for including additional radiative transfer effects and aerosols.

Primary author: Dr SCHECK, Leonhard (Hans-Ertel Centre for Weather Research, LMU Munich)

Presenter: Dr SCHECK, Leonhard (Hans-Ertel Centre for Weather Research, LMU Munich)

Session Classification: Session 3: Observation operators

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **41** Type: **Poster presentation**

Comparing airborne sub-millimetre observations of ice clouds with model simulations

The next generation of European polar-orbiting weather satellites (EPS-SG), due to be launched in the 2020s, will carry the novel Ice Cloud Imager (ICI) which has 13 channels measuring frequencies between 183 and 664GHz that are sensitive to scattering by ice crystals in clouds. As well as providing global estimates of bulk ice mass, these observations also have the potential to be assimilated directly into operational Numerical Weather Prediction (NWP) models using the "all-sky" approach. It is therefore of considerable interest to consider whether the representation of ice clouds within current NWP and radiative transfer models is sufficiently accurate to simulate realistic brightness temperatures at millimetre and sub-millimtere wavelengths.

The International Sub-Millimetre Airborne Radiometer (ISMAR) has been developed as an airborne demonstrator for ICI and flown on the UK Facility for Airborne Atmospheric Research (FAAM) BAe-146 aircraft since 2014. Together with the Microwave Airborne Radiometer Scanning System (MARSS) it provides observations between 89GHz and 874GHz covering the majority of ICI channels. Here we consider case studies from several flight campaigns that took place between 2015 and 2019. Atmospheric fields from high-resolution Met Office NWP models are used as input to the ARTS radiative transfer model, which is run using optical properties for realistic ice crystal habits from the state-of-the-art ARTS scattering database. Where possible, we aim to achieve a consistent representation of cloud microphysics between the NWP and radiative transfer models. Simulated brightness temperatures for cloudy scenes are compared to observations from MARSS and ISMAR. We show that the modelled brightness temperatures at these frequencies are strongly sensitive to the ice cloud optical properties, but by using particular ice crystal habits it is possible to produce realistic simulations across the range of frequencies observed by ICI.

Primary author: Dr FOX, Stuart (Met Office)

Presenter: Dr FOX, Stuart (Met Office)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **42** Type: **Poster presentation**

Assessing the Vertical Inhomogeneity Impact of Ice Particle Habits in Tropical Cyclones for Microwave Radiative Transfer Simulations

Frozen hydrometeors in tropical cyclones are nonspherical. Moreover, depending on the ambient temperature and ice-supersaturation [1], the vertical inhomogeneity of ice particle habit could exist. Significant efforts have been devoted to studying the nonsphericity effect in microwave radiative transfer [e.g., 2]. However, the vertical inhomogeneity effect has not been addressed so far. In this presentation, we report our preliminary attempts on addressing the vertical inhomogeneity effect of ice habits for the microwave radiative transfer simulations. For simplification, we focus on a "two-habit-layer"scheme; namely, two different ice habits (thin plate and dendrite) are assumed to be above and below the pressure level of 325 hPa according to the Ref. [3].The aforesaid inhomogeneity scheme was implemented into the RTTOV [4], which allows for close examination of the inhomogeneity effect on the radiative transfer process. Four scenarios (thin plate, dendrite, thin plate over dendrite, and dendrite over thin plate) were considered in the simulations at 10 quasi-atmospheric-window channels ranging from 10 to 183GHZ. We found that the vertical inhomogeneity has a clear impact on the brightness temperature (BT) simulations. Specifically, the BTs over different frequency ranges demonstrate different sensitivities with respect to the vertical inhomogeneity. For real case studies, we considered the typhoon Feiyan and several other storms in the Western Pacific basin. The hydrometeor profiles predicted from the GRAPES model were used. The simulated results were compared with observations from the instruments of MWRI, MWHS and MWTS aboard on the Fengyun-3D satellite. We found that the overall performances of the forward radiative transfer simulation over multi-channels can be improved by considering the vertical inhomogeneity of ice habits.

Primary authors: Mr XIE, Hejun (Department of atmospheric science, Zhejiang University); Prof. BI, Lei (Department of atmospheric science, Zhejiang University); Dr HAN, Wei (Numerical Weather Prediction Center of Chinese Meteorological Administration, Beijing, China); Dr WANG, Jincheng (Numerical Weather Prediction Center of Chinese Meteorological Administration, Beijing, China)

Presenter: Mr XIE, Hejun (Department of atmospheric science, Zhejiang University)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **43** Type: **Oral presentation**

Cloudy IR assimilation at the Met Office

Tuesday, 4 February 2020 09:00 (25 minutes)

Work is under way at the Met Office to develop a new all-sky assimilation scheme for infrared radiances from hyperspectral sounders. The aim is to assimilate IR radiances in the majority of cloudy scenes using the multiple-scattering capabilities available in RTTOV. Using a variable observation error model, it is hoped that this will lead to both a significant increase in the usage of IR radiances and useful improvements in NWP performance. This talk will describe the background and progress so far, details of the methodology and some preliminary forecast impact experiments.

Primary author: PAVELIN, Ed (Met Office)

Co-author: MIGLIORINI, Stefano (Met Office)

Presenter: PAVELIN, Ed (Met Office)

Session Classification: Session 1a: Assimilating satellite observations sensitive to cloud and precipitation

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **44** Type: **Oral presentation**

Biases in all-sky data assimilation: ignore, screen, correct?

Tuesday, 4 February 2020 16:15 (25 minutes)

This talk will give an overview of the cloudy and rainy biases our community have to face in order to assimilate all-sky satellite data successfully. Furthermore, we will discuss which different options have been explored or are in the pipeline to treat all-sky biases.
One option would be either to ignore or to screen the data in the presence of model bias. For example, at ECMWF the all-sky assimilation of microwave radiances revealed a lack of supercooled liquid water in cold-air outbreak regions over ocean, which explained a long-standing bias in the short wave net radiation. Using this data would degrade the forecast and while work is in progress to resolve this model bias, the affected microwave data is screened in the mean-time. Another option to tackle all-sky biases is using bias correction schemes. To our knowledge, most NWP centres do not use specific cloud or precipitation predictors for the all-sky assimilation. At the MetOffice, work is in progress in developing a selective VarBC for MHS channels 3, 4 and 5 where only a subset of radiances are chosen for bias correction, e.g. clear-sky only radiances. This is motivated by findings showing a bias for scenes affected by frozen cloud. A number of other centres and research groups also have to deal with biases and these strategies will also be covered.
Which option in treating biases in the all-sky assimilation is best ultimately depends on the source of the bias and how the all-sky data is used inside the assimilation system.

Primary author: LONITZ, Katrin (ECMWF)

Presenter: LONITZ, Katrin (ECMWF)

Session Classification: Session 2: Cloud and precipitation modelling

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **45** Type: **Oral presentation**

Cloud radar and lidar assimilation at ECMWF

Tuesday, 4 February 2020 11:30 (25 minutes)

Cloud related observations, such as those from microwave radiances, have been at the forefront of recent developments in assimilation, but contain limited information on the vertical structure of clouds. Active observations from profiling instruments such as cloud radar or lidar contain a wealth of information on the structure of clouds and precipitation, providing the much-needed vertical context of clouds, but have never been assimilated in global NWP models. Inspired by the success of previous experiments, in which CloudSat radar reflectivity and Calipso attenuated backscatter profiles were indirectly assimilated via pseudo-observations of temperature and humidity, the European Centre for Medium-range Weather Forecasts (ECMWF) 4D-Var system has been adapted to allow their direct assimilation.

In this presentation, several important developments required to prepare the data assimilation system for the new observations of cloud radar reflectivity and lidar backscatter will be summarized. This includes the specification of sufficiently accurate observation operators, i.e. models providing equivalent model fields to observations. Another important aspect is observation error definition; the observation error of cloud observations is highly situation dependent, so a flow-dependent error model will be presented that accounts for both the spatial representativity error and the uncertainty in the microphysical assumptions. In addition, for the proper handling of observations in the context of an assimilation system, an appropriate quality control strategy and bias correction scheme are required and will also be discussed. Finally, the potential of EarthCARE data for directly improving weather forecasts by assimilating cloud radar and lidar observations into a global NWP model will be demonstrated. Prospects for increasing the direct benefit of cloud radar and lidar assimilation will also be discussed.

Primary author: JANISKOVA, Marta (ECMWF)

Co-author: FIELDING, Mark (ECMWF)

Presenter: JANISKOVA, Marta (ECMWF)

Session Classification: Session 1b: Emerging observations

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **46** Type: **Oral presentation**

How to make changes in hydrometeors at the observation location - adjoints, incrementing operators and ensemble correlations

Wednesday, 5 February 2020 15:00 (25 minutes)

The quality of a numerical weather prediction (NWP) system depends on the reliability of its forecasts in both its deterministic and probabilistic configurations. Forecast skill then is affected by the accuracy of the NWP model and its physical parametrizations, as well as by initial condition errors, which include the contributions from observation errors, both random and systematic. It follows that one of the avenues to improve the NWP scores is to assimilate more observational information, particularly on water in its different phases due to its high spatial variability and relatively high forecast uncertainty.

This is why all major NWP centres are currently assimilating satellite microwave radiances in all-sky conditions and have plans to extend their all-sky assimilation system to infrared radiances. However, a critical condition to benefit from observational information is to be able to estimate increments in all relevant cloud and precipitation forecast fields. In a hybrid variational data assimilation system, these updated fields need to be given as input to observation operators as well as to tangent linear (or perturbed forecast) and adjoint models. This can be achieved using one or more cloud control variables as well as a complete description of the forecast fields as part of the forecast ensemble used to describe flow-dependent forecast errors. In alternative to cloud control variables it is possible to make use of physical-statistical relationships to distribute increments to a single control variable. Finally, water increments can arise from moist physics parametrizations, both in their nonlinear and linearized configurations.

In this talk an outline of the design of the moist control variables, moisture incrementing operator and tangent linear physics that are currently operational at the Met Office and other operational centres will be provided.

Primary author: MIGLIORINI, Stefano (Met Office)

Presenter: MIGLIORINI, Stefano (Met Office)

Session Classification: Session 4: Data assimilation methods

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **47** Type: **Oral presentation**

Treatment, Estimation, and Issues with Representation Error Modelling

Wednesday, 5 February 2020 14:30 (25 minutes)

Data assimilation schemes blend observational data, with limited coverage, with a short term forecast to produce an analysis, which is meant to be the best estimate of the atmospheric state. Appropriately specifying error statistics is necessary to obtain an optimal analysis. However, observations often measure a higher resolution state than coarse resolution model grids can describe. Hence, the observations may measure spatial or temporal scales or physical processes that are poorly resolved by the filtered version of reality represented by the model. This inconsistency, known as observation representation error, must be accounted for in data assimilation schemes. Further, representation error is a key, if not dominant, contributor to correlated observation errors which are often neglected.
This talk will provide an overview of current methods for estimating observation error and their ability to diagnose error of representation. Shortcomings of these methods will be addressed, including the implications of non-zero correlations between the background and observation error. Finally, we will discuss recent methods that aim to include flow dependence in the representation error model.

Primary author: Dr SATTERFIELD, Elizabeth (Naval Research Laboratory)

Presenter: Dr SATTERFIELD, Elizabeth (Naval Research Laboratory)

Session Classification: Session 4: Data assimilation methods

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **48** Type: **Oral presentation**

Assimilating All-Sky Microwave Brightness Temperature Data to Improve NASA GEOS Forecasts and Analyses

Tuesday, 4 February 2020 09:30 (25 minutes)

The NASA Global Modeling and Assimilation Office (GMAO) has been pursuing efforts to utilize all-sky (clear+cloudy+precipitating) MW radiance data and has developed a system to assimilate all-sky GPM Microwave Imager (GMI) radiance data in the Goddard Earth Observing System (GEOS) during the last PMM funding period. The system provides additional constraints on the analysis process near the storm regions and adjusts the geophysical parameters such as precipitation, cloud, moisture, surface pressure, and wind by combining information from GMI radiance measurements and model forecasts in an optimal manner. The system proved that assimilating the GMI all-sky radiance data improve the GEOS atmospheric analyses and forecasts. This all-sky data framework has been included in the GEOS Forward Processing (FP) system since July 11, 2018 and assimilates all-sky GMI data in real-time for GEOS global analysis and forecast production at the GMAO. We are currently extending this all-sky GMI radiance data assimilation system to assimilate more all-sky MW radiance data from other sensors such as the Microwave Humidity Sounder (MHS), the Advanced Technology Microwave Sounder (ATMS), the Special Sensor Microwave Imager/Sounder (SSMIS), Advanced Microwave Scanning Radiometer 2 (AMSR2), and the Sounder for Atmospheric Profiling of Humidity in the Intertropics by Radiometery (SAPHIR) onboard the GPM constellation spacecrafts. Preliminary results from this extended all-sky system show increased benefit from cloud- and precipitation-affected MW radiances with much larger spatial and temporal coverages compared to the all-sky system assimilating GMI alone and improved GEOS forecast skills especially for lower tropospheric humidity fields.

Primary author: Dr KIM, Min-Jeong (NASA GMAO/Morgan State University)

Presenter: Dr KIM, Min-Jeong (NASA GMAO/Morgan State University)

Session Classification: Session 1a: Assimilating satellite observations sensitive to cloud and precipitation

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **49** Type: **Oral presentation**

Uncertainty characterization of sub-mm and MW in all-sky radiative transfer

Wednesday, 5 February 2020 09:30 (25 minutes)

Nowadays, satellite microwave (MW) observations are gaining weight in weather and climate applications. The upcoming Ice Cloud Imager (ICI) mission covering frequencies between 183 and 670 GHz aims at improving the representation of cloud ice in models. Ultimately, ICI will extend the scope of MW assimilation. In stand-alone retrievals and data assimilation, several simplifications are still employed. Particularly, particle size distributions (PSDs) and particle models (PM) of ice hydrometeors are poorly considered and three-dimensional (3D) radiative transfer is ignored. Thus, an assessment of these simplifications was conducted by means of ARTS (Atmospheric Radiative Transfer Simulator). A framework was developed, employing the ARTS scattering database and generating synthetic scenes based on CloudSat observations over Tropics. Firstly, we evaluated the performance of different PMs and PSDs to model observations by GMI (GPM Microwave Imager) and the impact to the derived ice water content is assessed. At frequencies between 186 and 190 GHz and above 180 K, the simulated brightness temperature is fairly insensitive to PM. However, at lower temperatures, large discrepancies are found, with no clear indication which PM performs best. Of tested PSDs, McFarquhar and Heymsfield (1997) provides the best agreement to GMI. The analysis was extended towards the highest frequencies of ICI (above 328.65 GHz) and revealed a higher sensitivity to the assumed PM with great potential for constraining ice properties. Secondly, an effort was conducted to quantify the errors induced by neglecting 3D effects, i.e., horizontal photon transport (HPT) and beam-filling (BF), at mm/sub-mm wavelengths of current and proposed satellite instruments. The analysis reveals a small HPT effect introducing mostly random errors and an overestimation (below 1 K), while a substantial BF effect that increases with frequency and footprint size. Overall, the BF effect can be up to 4 and 13 K at 183.6 and 668 GHz, respectively.

Primary authors: Dr BARLAKAS, Vasileios (Chalmers University of Technology); Prof. ERIKSSON, Patrick (Chalmers University of Technology); Mr EKELUND, Robin Nils (Chalmers University of Technology)

Presenter: Dr BARLAKAS, Vasileios (Chalmers University of Technology)

Session Classification: Session 3: Observation operators

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **50** Type: **Oral presentation**

Challenges propagating innovations on precipitation and cloud to other state variables

Wednesday, 5 February 2020 16:00 (25 minutes)

In the presence of clouds and precipitation, there is a greater need for information on all state variables in a context where both data assimilation and remote sensing become more complicated, because:

1) Clouds, and to a lesser extent precipitation, shut atmospheric windows at optical (UV to IR) and upper-microwave frequencies while also introducing challenges to observation simulation, limiting the number of high-quality constraints that can be obtained via many remote sensing approaches;

2) Errors grow faster in areas of atmospheric instabilities that often cause clouds and precipitation to appear and evolve, making precipitation the least predictable of atmospheric properties;

3) Clouds and precipitation fields have greater errors, especially at smaller scales, than other fields. Because smaller-scale errors dominate, they are correlated with errors in other fields over shorter distances, limiting the benefit of information propagation that is the key to successful data assimilation. In addition, fields at small scales are not as well simulated by models of limited resolution, making any observation innovation both harder to reproduce by measurement simulation and to use for assimilation;

4) The information propagation component of many common traditional assimilation approaches often assumes a linear correlation of errors, an approach that works better given small background errors, a rarer situation in precipitating areas;

5) Innovations in precipitation have the least benefit for forecasting the future evolution of the atmosphere as, by definition, precipitation quickly gets out of the atmosphere. Successful precipitation forecasting relies more on improving the other state variables than on improving precipitation fields;

All this occurs while we also have two additional categories of model state variables to characterize, cloud and precipitation properties, that are otherwise trivial to set in the absence of clouds.

This state of affairs calls for the exploration of approaches better designed to handle such difficult situations.

Primary author: FABRY, Frederic (McGill University)

Presenter: FABRY, Frederic (McGill University)

Session Classification: Session 4: Data assimilation methods

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **51** Type: **Oral presentation**

All-sky assimilation of temperature-sounding microwave data

Monday, 3 February 2020 15:30 (25 minutes)

Satellite radiances affected by cloud and precipitation are usually associated with meteorologically important regions. As research development has been intensified in the past decade in major NWP centers on the use of all-sky radiance observations, the assimilation of cloudy radiances from the Advanced Microwave Sounding Unit-A (AMSU-A) for ocean fields of view became operational in the hybrid 4D Ensemble-Variational (EnVar) Global Forecast System (GFS) at Environmental Modelling Center (EMC) at NCEP in 2016. Later, with the implementation of the FV3 GFS data assimilation system in 2019, the all-sky assimilation was expanded to the radiances of Advances Technology Microwave Sounder (ATMS). To deal with model errors, especially the errors of clouds, only selected data sample was used in the variational radiance bias correction scheme and situation-dependent observation error inflation was applied. The all-sky radiance assimilation has improved GFS analysis and forecast. The configuration of the all-sky radiance assimilation at NCEP, with the flow-dependent background error covariance provided by the ensemble forecasts, will be presented. The application of VIIRS cloud products in the all-sky microwave data quality control will also be briefly discussed. In addition, efforts have been invested at EMC on the all-sky assimilation of radiances sensitive to land, and the status and progress of this work will be given. At the workshop, a brief overview of other AMSU-A assimilation work (e.g. Met Office and ECMWF) will be presented as well.

Primary author: Dr ZHU, Yanqiu (NOAA)

Presenter: Dr ZHU, Yanqiu (NOAA)

Session Classification: Session 1a: Assimilating satellite observations sensitive to cloud and precipitation

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **52** Type: **Oral presentation**

Ice cloud imager (ICI) and microwave imager (MWI)

Tuesday, 4 February 2020 10:30 (25 minutes)

The second generation of the EUMETSAT Polar System (EPS-SG) will include the Micro-Wave Imager (MWI) and the Ice Cloud Imager (ICI) conically-scanning radiometers that will be flown on the Metop-SG B satellites.
MWI will have 18 channels ranging from 18 to 183 GHz. The frequencies at 18.7, 23.8, 31.4 and 89 GHz provide continuity to key microwave imager channels for weather forecasting and surface parameter retrieval. MWI includes also innovative set of channels near 50–60 GHz and at 118 GHz, sensitive to weak precipitation and snowfall. Dual polarisation is implemented up to 89 GHz, at higher frequencies only vertical polarisation will be provided.
ICI is a novel mission, the first operational radiometer of this type designed for the remote sensing of cloud ice. ICI will have 11 channels in the mm/sub-mm spectrum from 183 GHz to 664 GHz. Three sets of channels will sample the water vapour absorption lines around 183, 325 and 448 GHz and two channels are in the atmospheric windows at 243 and 664 GHz. The window channels are implemented with dual polarisation, while the other channels are vertically polarised only. The ICI will provide an innovative characterisation of clouds, with information on humidity and ice hydrometeors, particularly the bulk ice mass.
The channel and scanning characteristics of both instruments will be detailed, and the activities related to the preparation of the operational products will be discussed.

Primary authors: Mr ACCADIA, Christophe (EUMETSAT); Dr MATTIOLI, Vinia (EUMETSAT); Dr DE ANGELIS, Francesco (EUMETSAT); Dr SCHLÜSSEL, Peter (EUMETSAT); Mr COLUCCI, Paolo (EUMETSAT); Mr CANESTRI, Alessio (EUMETSAT)

Presenter: Mr ACCADIA, Christophe (EUMETSAT)

Session Classification: Session 1b: Emerging observations

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **53** Type: **Poster presentation**

Initial Implementation of All-Sky Microwave Radiance Assimilation in NAVGEM

Precipitation and visibility forecasts are crucial for the US Navy; the assimilation of satellite observations in close proximity to the where relevant weather is occurring or will occur is of great value for tactical guidance and decision aids. Assimilation of all-sky microwave imager and sounder data for both temperature and moisture in cloudy areas is an increasingly important source of information and forecast skill at other centers such as ECMWF, NOAA, the Met Office, JMA, DWD, etc.

We have begun implementation of all-sky microwave assimilation in our global weather prediction and data assimilation system NAVGEM. Using the latest version of the Community Radiative Transfer Model (CRTM v2.3.0), we can now include cloud liquid water and cloud ice species from the NAVGEM forecasts into the radiative transfer call for microwave radiances. We will present the first look at the differences between the present system, where cloudy microwave observations are excluded, and the initial implementation of the new system that allows most cloudy radiances with increased observation error variance.

Primary author: Dr CAMPBELL, William (U.S. Naval Research Laboratory)

Co-author: Dr RUSTON, Benjamin (U.S. Naval Research Laboratory)

Presenter: Dr CAMPBELL, William (U.S. Naval Research Laboratory)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **54** Type: **Poster presentation**

Development of an active sensor module for the RTTOV-SCATT radiative transfer simulator

Active microwave sensors are becoming widely used observations within the Numerical Weather Prediction community, either for validating model forecasts or for assimilation purposes. Like for the forward simulation of passive microwave observations, radar data simulations require to make assumptions on the scattering properties of hydrometeors. With the objective of simulating both active and passive microwave instruments within a single framework using the same radiative transfer assumptions into a widely-used tool in the NWP community, an active sensor module is currently under development within the RTTOV-SCATT software. The first simulations of the Cloudsat/CPR instrument with this simulator will be shown, based on the ARPEGE global model running operationally at Météo-France. In particular, the usefulness of specifying profiles of hydrometeor fractions within the observation operator will be discussed. Then, an inter-comparison of Cloudsat observations with cloud forecasts from two versions of the ARPEGE model using two different convection schemes will be shown.

Primary author: Mr MANGLA, Rohit (Indian Institute of Technology Bombay)

Co-authors: Dr CHAMBON, Philippe (Météo-France, Toulouse); Dr GEER, ALan (ECMWF, UK); Prof. J., Indu (Indian Institute of Technology Bombay)

Presenter: Mr MANGLA, Rohit (Indian Institute of Technology Bombay)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **55** Type: **Poster presentation**

Assimilation of microwave observations of cloud and precipitation through a bayesian framework : sensitivities studies

Microwave observations are becoming more and more useful for numerical weather prediction ; in particular in an all-sky context which is under development at Météo-France. Indeed those observations can bring highly relevant information content on the vertical distribution of water vapor and hydrometeors. The method under investigation at Meteo-France is called the '1D-Bay+4D-Var' and corresponds to a two step process : (i) a Bayesian inversion algorithm to retrieve profiles of temperature and humidity from the microwave radiances using the RTTOV-SCATT observation operator, (ii) the 4D-Var assimilation of these retrieved profiles. The first assimilation experiments using this framework result in a good impact on forecast scores especially on wind forecast. However, many parameters need to be specified for the inversion process like scattering properties of hydrometeors, channels used within the inversion, observation errors in the R-matrix or the choice of the estimator (e.g. maximum likelihood / weighted average). In this poster, sensitivities studies of the Bayesian inversion to the parameters mentioned above will be presented. Those sensitivities studies will be based on AROME model simulations and GMI observations. Results highlight the importance of selecting the pressure levels of the retrievals to be assimilated depending on the channels used for the inversion process.

Primary author: BARREYAT, Marylis (Meteo-France)

Co-authors: CHAMBON, Philippe (Météo-France); MAHFOUF, JEAN-FRANCOIS (METEO-FRANCE); Mr FAURE, Ghislain (Meteo-France)

Presenter: BARREYAT, Marylis (Meteo-France)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **56** Type: **Oral presentation**

Background errors and control variables for clouds and precipitation

Wednesday, 5 February 2020 14:00 (25 minutes)

Thanks to their explicit microphysical parameterization, non-hydrostatic Cloud Resolving Models (CRM) allow realistic representations of non linear diabatic processes. Forecast errors of thermodynamical variables and hydrometeors can be computed specifically in cloudy and precipitating conditions by applying e.g geographical masks to ensemble of forecasts obtained with such CRMs and by performing statistics on forecast differences. The resulting covariances generally strongly differ from climatological statistics that are used in operations, which demonstrate that observations performed in those conditions, as those from e.g Doppler Radar and microwave radiometers, are clearly under-exploited. Such covariances are indeed clearly flow-dependent and are characterized by strong inhomogeneities and by non-Gaussianities. Change of variables may be considered at that point to work with more Gaussian pdfs. Illustrations will be given for different meteorological phenomena such as strong convective cases or fog. Studies have shown that specific background error covariances can be modeled in those conditions (and thus used in purely variationnal DA techniques), but frequent updates are required. When considering hydrometeors in the Control Variable (CV), modeled covariances are however hardly usable, as their spatial inhomogeneities are enhanced and furthermore vertically stratified.

To account for these flow dependencies in a deterministic DA process, a direct approach consists in sampling background error covariances from an ensemble of forecasts run in parallel and to use them in sequential (e.g. EnKF) or in variationnal (e.g. EnVar) DA systems. In those methods, an important step consists in reducing the sampling noise by applying localization functions, which aim to damp sampling noise of the covariances with distance. Localization length-scales can be directly diagnosed in the model space from the ensemble and geographical masks can also be used to compute specific values for hydrometeors. Here again, great variability between variables occurs, especially for the latter variables. Illustrations will be given by using background error perturbations from the operational EDA based on AROME-France, which is run at Météo-France with at 3.2 km horizontal resolution. Such localization length-scales can then be exploited in an EnVar context.

Even without direct observations of cloud and precipitation related variables, increments of hydrometeors can be obtained from those DA algorithms thanks to the background error cross-covariances between control-variables. Such cross-covariances allow indeed to project increments of thermodynamical variables implied by the assimilation of e.g. Doppler wind and pseudo-profiles of relative humidity deduced from the Radar reflectivities onto those of hydrometeors. Improvements in the forecast of cloud coverage and accumulated precipitation have been obtained considering such covariances within an EnVar applied to AROME, but for very short ranges. Many challenges remain to reduce the spin down effect and to get more lasting impacts. Favorable analyzed thermodynamical conditions may be key aspect, as hydrometeors are transient by nature. Moreover, the assumptions made in classical DA, especially the linearity of the prominent processes and the Gaussianity of uncertainties's pdf, are likely to be violated to some degree. Some options that may help will be finally discussed.

Primary author: MONTMERLE, Thibaut (Météo-France)

Co-authors: Dr MICHEL, Yann (CNRM (Météo-France/CNRS)); DESTOUCHES, Mayeul (CNRM

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Presenters: MONTMERLE, Thibaut (Météo-France); DESTOUCHES, Mayeul (CNRM (Météo-France/CNRS))

Session Classification: Session 4: Data assimilation methods

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **57** Type: **Poster presentation**

Cloud Process Nonlinearity and Model Uncertainty in Data Assimilation and Remote Sensing

Cloud Process Nonlinearity and Model Uncertainty in Data Assimilation and Remote Sensing

Derek J. Posselt and Masashi Minamide

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

Assimilation of remote sensing observations of clouds and precipitation is challenging for many reasons, including:

- Nonlinearity in cloud and precipitation processes, and in the relationships between state variables (e.g., hydrometeor profiles) and observations (e.g., radar reflectivity).
- Large spatial and temporal variability in cloud features, leading to large forecast-observation innovations
- Parameterizations of cloud processes with poorly understood uncertainty, and whose error is state-dependent (e.g., one set of parameter values does not work equally well for all precipitating cloud systems)

The nonlinear and spatially and temporally variable nature of clouds will continue to present challenges for data assimilation for the foreseeable future. New observing systems, new data assimilation algorithms, and new methodologies for characterizing and quantifying uncertainty in forward models offer pathways forward. In this presentation, we present the results of experiments that utilize new techniques that offer the potential to advance cloud and precipitation data assimilation, including:

- Quantification of uncertainty in cloud microphysical parameterizations
- Development of new data assimilation algorithms that may be better suited to positive definite quantities and nonlinear cloud and precipitation processes
- Adaptive ensemble techniques that make use of high time frequency geostationary satellite data for constraint of isolated and organized convective systems

Primary authors: POSSELT, Derek (Jet Propulsion Laboratory); Dr MINAMIDE, Masashi

Presenter: POSSELT, Derek (Jet Propulsion Laboratory)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **58** Type: **Poster presentation**

Assimilating all-sky Himawari-8 radiances in the heavy rainfall event on 23 August 2018 in Taiwan

Assimilating all-sky Himawari-8 radiances in the heavy rainfall event on 23 August 2018 in Taiwan

Takumi Honda, Shu-Chih Yang, and Takemasa Miyoshi

In August 2018, a tropical depression stayed near Taiwan and induced heavy precipitation over the southwest region of Taiwan. Detailed evolution of this depression was well captured by the Himawari-8 geostationary satellite of the Japan Meteorological Agency. Previous studies have investigated impact of all-sky assimilation of Himawari-8 radiance observations on predicting rapid intensification of a typhoon over the ocean and typhoon-associated precipitation. However, it is an open question if Himawari-8 observations can improve the prediction of tropical depression and associated precipitation in a warm and moist environment. This study aims at exploring the impact of assimilating all-sky Himawari-8 observations on the analyses and forecasts of the heavy rainfall event on 23 August 2018, in Taiwan.

Primary authors: HONDA, Takumi; Prof. YANG, Shu-Chih (National Central University, Taiwan); MIYOSHI, Takemasa (RIKEN)

Presenter: HONDA, Takumi

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **59** Type: **Poster presentation**

Preparation for the assimilation of the upcoming Meteosat Third Generation Lightning Imager data in AROME

Total lightning (inter/intra-cloud + cloud-to-ground) is a proven marker of deep convection. Total lightning activity can be documented from low Earth orbit platforms (e. g. the Lightning Imaging Sensor on the Tropical Rainfall Measuring Mission satellite and the International Space Station) and from ground-based lightning locating systems (LLSs). With the advent of optical imagers on geostationary orbit such as the Geostationary Lightning Mapper (GLM) on the Geostationary Operational Environmental Satellite (GOES) 16 and GOES 17 or the future Lightning Imager (LI) on the Meteosat Third Generation (MTG) imaging mission satellites, total lightning can be efficiently and continuously mapped over large areas of the Earth, including seas and other areas not well covered by ground-based instruments sensitive to thunderstorms such as radars.

Research is underway to prepare the assimilation of future LI data into the AROME numerical prediction system. To do this, the LI data are simulated from the Météorage ground-based LLS, using a transfer function developed from the National Lightning Detection Network and GLM data over the United States. The transfer function has been designed using machine learning methods on a large amount of coincident flash data. The similar measurement techniques of both ground-based (NLDN and Météorage) and geostationary (GLM and MTG-LI) instruments allow for this approach. The physical quantity assimilated is the flash extent density (FED). It is diagnosed from model fields in a statistical way. Since the current AROME three-dimensional variational (3DVar) assimilation system does not allow the assimilation of deep convection variables such as hydrometeor contents or vertical velocity, FED is assimilated using the one-dimensional Bayesian retrieval followed by three-dimensional variational (1DBay+3DVar) data assimilation method originally designed to assimilate radar reflectivity.

The presentation will report on the latest progress made in the assimilation of synthetic LI data in AROME.

Primary authors: Mr ERDMANN, Felix (CNRM and Laboratoire d'aérologie); CAUMONT, Olivier (CNRM, Université de Toulouse, Météo-France, CNRS); DEFER, Eric (Laboratoire d'Aérologie, CNRS)

Presenter: CAUMONT, Olivier (CNRM, Université de Toulouse, Météo-France, CNRS)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **61** Type: **Poster presentation**

Ensemble-Based All-Sky Infrared and Microwave Radiance Assimilation for the Analysis and Prediction of Tropical Cyclones and Severe Thunderstorms

During the past five years, the Penn State Center for Advanced Data Assimilation and Predictability Techniques (ADAPT) has been devoted to the development and application of techniques to assimilate all-sky radiance at both infrared (IR) and microwave (MW) bands. For radiance from IR imagers, we have developed the Adaptive Observation Error Inflation (AOEI) error model that is able to provide more Gaussian innovations, the Adaptive Background Error Inflation (ABEI) to help initiating clouds in the model where mismatches of cloud conditions between the observations and the model predictions occur, and a channel synthesizing technique to reduce errors associated with uncertainties from surface emissivity for the window channels. We have also tested the feasibility of using principal component analysis (PCA) to select channels and compress information content for IR hyperspectral sounders. For the MW bands, we have tested the influence of different scattering properties of non-spherical particles instead of homogeneous soft spheres on microwave radiance simulated by the Community Radiative Transfer Model (CRTM), and built look-up tables of scattering for CRTM that are consistent with the assumed particle size distributions of different microphysics schemes.

With the help of these techniques, we have successfully assimilated all-sky IR radiance observations from the Advanced Himawari Imager (AHI) onboard the Himawari-8 satellite and the Advanced Baseline Imager (ABI) onboard the GOES-16 satellite using the PSU WRF-EnKF data assimilation system for convection-allowing analyses and predictions of several tropical cyclones (TCs) in the western North Pacific and north Atlantic basins as well as severe thunderstorms in the Great Plains of the United States. It is found that significant improvement on the track and intensity predictions of the TCs can be gained by assimilating all-sky IR radiance observations over the data-sparse regions of the open ocean with the structure of the TC improved as well. For severe thunderstorms, accurate probabilistic prediction of the mesocyclone tracks can be achieved even before the initiation of the thunderstorms as observed by the weather radars, and a forecast lead time of 20 to 40 minutes can be gained compared with assimilations of radar reflectivity and radial velocity observations.

Built upon the success of the predictions of Hurricane Harvey (2017) with the assimilation of all-sky IR radiance observations from ABI, we have also started exploring the assimilation of all-sky MW radiance observations from the Global Precipitation Measurement (GPM) project for TC predictions. Preliminary results indicate that MW observations are able to compensate the lack of hydrometeor distributions beneath the cloud top from IR observations, which may potentially lead to improved analyses of the structure of the TC. However, how to better constrain the model when IR and MW observations are simultaneously assimilated is still an open question, and we are currently actively exploring different treatments of the radiance observations.

Primary authors: Dr ZHANG, Yunji (The Pennsylvania State University); Dr MINAMIDE, Masashi (Jet Propulsion Laboratory); Dr SIERON, Scott (The Pennsylvania State University); Dr LU, Yinghui (The Pennsylvania State University); Mr NYSTROM, Robert (The Pennsylvania State University); Mr CHAN, Man Yau (The Pennsylvania State University); Mr HARTMAN, Christopher (The Pennsylvania State University); Ms YAO, Zhu (The Pennsylvania State University); Dr CLOTHIAUX, Eugene (The Pennsylvania State University); Dr CHEN, Xingchao (The Pennsylvania State University); Dr STEN-

SRUD , David (The Pennsylvania State University); Dr GREYBUSH, Steven (The Pennsylvania State University); Dr ZHANG, Fuqing (The Pennsylvania State University)

Presenter: Dr ZHANG, Yunji (The Pennsylvania State University)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **62** Type: **Oral presentation**

Dual-frequency precipitation radar (DPR) for NWP data assimilation

Tuesday, 4 February 2020 11:00 (25 minutes)

A reflectivity data assimilation technique has been developed to enhance GPM/DPR assimilation in JMA. The data assimilation method is hybrid-4DVar using flow-dependent background-errors estimated from ensemble perturbations. This 4D-Var includes TL/AD of 3-ice cloud microphysics scheme as a strong constraint. In the TL of cloud microphysics scheme, the perturbations of thermodynamic variables were ignored and some approximations to prevent numerical divergence was implemented. As a result, the TL became possible to predict the linear-perturbation of hydrometeors while maintaining the practically sufficient accuracy during the 3-hour assimilation window in the system.

In addition, a radar simulator as observation operators has been developed. A function to simulate the melting layer and an artificial noise-filter to reproduce the detection limit of radar were implemented into the simulator. Using the radar-simulator and RTTOV, we verified the predictions of the operational regional NWP model of JMA called MSM against GPM satellite observation data. Compared to DPR, the amount of rain in the lower troposphere was underestimated, and compared to GMI using RTTOV-SCATT, the amount of cloud ice was further underestimated. We found that the reasons for the underestimation were due to the large evaporation rate of rain and the large conversion rate of cloud ice into snow. These errors were successfully reduced by revision to the PSD for rain and the conversion methods between water species. This improvement has a large impact not only for the nonlinear model forecasts but also for the TL predictions for hydrometeors.

In the presentation, I would like to demonstrate the impact of assimilation for GPM in the system including the modifications mentioned above.

Primary author: IKUTA, Yasutaka (Japan Meteorological Agency)

Presenter: IKUTA, Yasutaka (Japan Meteorological Agency)

Session Classification: Session 1b: Emerging observations

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **63** Type: **Oral presentation**

Overview of the assimilation of microwave imagers and humidity sounders observations within clouds and precipitation

Monday, 3 February 2020 14:45 (40 minutes)

Microwave observations are characterized by a very rich information content with respect to water in all its different states, from water vapor to condensed water mass. Various developments in the past decade, including major advances regarding radiative transfer, allowed the assimilation of microwave observations within clouds and precipitation. The international community gained a lot in understanding of the mechanisms which can lead to progresses onto forecasts with microwave cloudy and rainy observations, at various scales from large scale global forecasts to kilometric scales with mesoscale regional forecasts.

This presentation will attempt to review the use of the various microwave observing systems which have been experimented for all-sky assimilation and did or did not make it yet to an operational system. Impacts reported by several operational and research centers from the use of microwave imagers and humidity sounders will be summarized, with a particular focus on extreme events. Some current limitations and challenges of microwave assimilation will be discussed like the tuning of radiative properties of hydrometeors within observation operators. Finally, verification methods for measuring the progresses made through microwave all-sky assimilation will be discussed with a particular focus on precipitation forecasts.

Primary author: CHAMBON, Philippe (Météo-France)

Presenter: CHAMBON, Philippe (Météo-France)

Session Classification: Session 1a: Assimilating satellite observations sensitive to cloud and precipitation

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **64** Type: **Poster presentation**

Satellite and lightning assimilation within SINFONY, the seamless combination of Nowcasting and NWP ensembles for storm-scale convective forecasting

At DWD the pilot project SINFONY has been set up in 2017 to develop a seamless ensemble prediction system for convective-scale forecasting with forecast ranges of 6 up to 12 hours, which integrates ensemble nowcasting techniques with ensemble numerical model prediction (NWP) in a more or less seamless way. The focus is on severe summertime convective events with associated hazards such as heavy precipitation, hail and wind gusts. Efforts are undertaken on the one hand by enhancements to both nowcasting and NWP separately and on the other hand by mutual information exchange and combination between these two methods.

For the NWP system, a rapid update cycle (RUC) based on the new ICON-LAM model is under development, with hourly ensemble forecasts on the km-scale with improved model physics (e.g., 2-moment cloud microphysics). To improve the initial conditions, additional high-resolution observational data including Meteosat SEVIRI satellite data (IR and VIS channels), 3D radar data (dBZ and radial wind) and lightning densities are added to the existing LETKF based assimilation system, as well as the assimilation of nowcast cell objects.
We are currently at an early stage of experimenting with all these new observation types separately and simultaneously.

The poster will give an overview of the goal, the concept and the progress of the SINFONY project as a whole, and its status about data assimilation.

Primary authors: Dr BLAHAK, Ulrich (Deutscher Wetterdienst); Dr BACH, Liselotte (Deutscher Wetterdienst); Dr CHRISTIAN, Welzbacher (Deutscher Wetterdienst); Dr DE LOZAR, Alberto (Deutscher Wetterdienst); Dr ULBRICH, Sven (Deutscher Wetterdienst); SEIFERT, Axel (Deutscher Wetterdienst); POTTHAST, Roland (Deutscher Wetterdienst); Dr SCHRAFF, Christoph (Deutscher Wetterdienst)

Presenter: Dr BLAHAK, Ulrich (Deutscher Wetterdienst)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **65** Type: **Poster presentation**

Towards activation of all-sky AMSU-A at ECMWF

The significant positive impact of assimilating AMSU-A in clear sky at ECMWF has long been challenging to replicate when AMSU-A is instead treated in the all-sky data stream. Through various technical changes in the treatment of all-sky AMSU-A data, it is nearing the point where all-sky AMSU-A can outperform its clear-sky counterpart. In hopes of achieving this, the impacts of changes to data thinning, variational quality control (VarQC), and scene-dependent observation errors are probed in a series of experiments. The relative improvement of these individual technical changes in the treatment of all-sky AMSU-A data is primarily judged against short-range forecast fits to other observations.

Primary authors: DUNCAN, David (ECMWF); WESTON, Peter (ECMWF); BORMANN, Niels (ECMWF); GEER, Alan (ECMWF)

Presenter: DUNCAN, David (ECMWF)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **66** Type: **Oral presentation**

Assimilation of visible data: Experiments with convective-scale NWP

Monday, 3 February 2020 16:00 (25 minutes)

Observations in the visible range contain a wealth of information which is in many ways complementary to measurements from thermal infrared and microwave sounders. Radiances or reflectances in the visible can see low clouds and fog as well as small scale clouds and also provide data of cloud characteristics themselves. Therefore these data, represent an important data source for assimilation.
Also, for convective-scale NWP, convective precipitation and cloud cover are among the most challenging user-relevant predicted variables. Therefore, given the availability of geostationary imager data at high spatial and temporal resolution, we see great potential for improving the representation of these processes through assimilating visible channels. The aim is to better represent convective situations already at the stage of convective initiation where clouds usually form at low levels and at small scales as well as low cloud situations like winter stratus. Using visible channels for this purpose is enabled through the new fast and accurate forward operator MFASIS (Scheck et. al, 2016), which has recently also been implemented into RTTOV.
The current work is part of the development of a seamless forecasting system with the aim to transition smoothly from observation based nowcasting to short range NWP. Assimilation experiments use the SEVIRI/MSG 0.6 µm channel with the Kilometre scale ENsemble Data Assimilation (KENDA) based on an Local Ensemble Transform Kalman Filter formulation (LETKF, Schraff et. al, 2016). Experiments are done with the COSMO model as well as the new limited area version of ICON (ICON-LAM), currently being implemented at DWD. The focus is on the improvement obtained for cloud cover, precipitation and surface variables. Furthermore, we discuss various assimilation challenges related to vertical localization and ambiguities of the observations, as well as gaussianity of first guess departures and non-linearity of the forward operator.
Additionally to the convective-scale assimilation, visible reflectances are also used with the global ICON model. As a first step, this part of the work focuses on analysing and further improving the MFASIS operator and its RTTOV implementation over the full range of atmospheric situations and on evaluating model clouds using visible channels.

Primary author: KÖPKEN-WATTS, Christina (DWD)

Co-authors: BACH, Liselotte (DWD); SCHECK, Leonhard (DWD / LMU); STUMPF, Christina (DWD); STILLER, Olaf (DWD); SCHRAFF, Christoph (DWD); WEISSMANN, Martin (LMU); POTTHAST, Roland (DWD)

Presenter: KÖPKEN-WATTS, Christina (DWD)

Session Classification: Session 1a: Assimilating satellite observations sensitive to cloud and precipitation

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **67** Type: **Poster presentation**

Multiple Hydrometeors All-sky Microwave Radiance Assimilation in FV3GFS

Motivated by the use of the GFDL microphysics scheme in the FV3GFS, the all-sky radiance assimilation framework has been expanded to include precipitating hydrometeors. In this upgraded all-sky framework, the five hydrometeors, including cloud liquid water, cloud ice, rain, snow and graupel, are the new control variables, replacing the original cloud water control variable. Radiance observations from AMSU-A and ATMS over ocean are assimilated in all-sky approach. Precipitation screening, which screened out 2% to 3.6% of observations, was turned off. The Community Radiative Transfer Model (CRTM) was interfaced with the newly added precipitating hydrometeors. Subgrid cloud variability was considered in radiative transfer by using average cloud overlap scheme. Including precipitating hydrometeors generally increased the first guess departures, particularly in deep convection regions. This is likely caused by the inappropriate optical properties of precipitating hydrometeors in current released CRTM. Therefore, the original quality control based on scattering indexes were retained. More observations were assimilated in the Southern hemisphere and less observations were assimilated in tropical deep convection regions. This newly constructed all-sky framework shows neutral to positive impact on overall forecast skill. Improvement was found in 500 hPa geopotential height forecasts in both Northern and Southern Hemispheres. Temperature forecasts were also improved at 850 hPa in the Southern Hemisphere and the Tropics.
The new all-sky framework is being adopted in the GFDL SHiELD model, which is also a FV3 based global model with enhanced features in dynamical core and microphysics. To address the first guess departure biases observed in tropical deep convection region, and to effectively assimilate more observations in strong scattering areas, efforts are focused on including convective cloud and improving optical properties of precipitating hydrometeors. The updated results will be reported at the workshop.

Primary author: Dr TONG, Mingjing (SAIC @ NOAA/GFDL)

Co-authors: LIU, Emily; Dr ZHOU, Linjiong; CHEN, Ming; Dr LIU, Quanhua; ZHU, Yanqiu

Presenter: Dr TONG, Mingjing (SAIC @ NOAA/GFDL)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **68** Type: **Oral presentation**

All-sky infrared assimilation overview

Monday, 3 February 2020 14:00 (40 minutes)

This presentation intends to cover recent development of all-sky infrared assimilation in the research and operational system. Development on all-sky IR assimilation have been recently significantly progressed although it has not yet been implemented in operational systems. Studies showed the value of frequent measurement of all-sky infrared radiances from new generation geostationary satellites in regional assimilation systems. Some global assimilation studies also showed positive impacts of assimilating all-sky radiances of hyperspectral sounders and geostationary imagers. The ongoing developments, issues and achievements of all-sky infrared assimilation will be overviewed based on the information given by operational centers and recent publications.

Primary author: Dr OKAMOTO, Kozo (JMA/MRI)

Presenter: Dr OKAMOTO, Kozo (JMA/MRI)

Session Classification: Session 1a: Assimilating satellite observations sensitive to cloud and precipitation

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **69** Type: **Poster presentation**

Application of EnVAR using the mixed-lognormal PDF of and a new displacement correction method for precipitation to all-sky MWI TB assimilation

The present study introduced a non-Gaussian Probability Distribution Function (PDF) and a new displace correction method for precipitation into the dual scale neighboring Ensemble-based Variational assimilation (EnVar) scheme in order to assimilate all-sky Microwave Imager (MWI) brightness temperatures (TBs) into a Cloud-Resolving Model (CRM).

The present study chose the precipitation forecast error from the existing non-Gaussian PDFs which were applicable for all rainy regions. We validated the fitness of these PDFs to the precipitation forecast error of various disturbance cases with the chai-square values of Lien et al (2016) to find that the mix-lognormal distribution was optimal. We introduced two PDF regimes, rain-free and rainy, to apply the mix-lognormal distribution to the EnVar.
Next, we developed a new precipitation displacement correction method which employed pseudo PDF regimes at points where ensemble forecast did not give PDF regimes corresponded with the observation.

We performed assimilation experiments using real MWI TB observations for a Typhoon Etau (T1518) case (17 UTC 7th -8th Sep. 2015). The results showed that the impact of the mixed-lognormal PDF was insignificant, and that use of the pseudo regimes greatly reduced the precipitation displacement error.

Primary author: Dr AONASHI, Kazumasa (MRI/JMA)

Presenter: Dr AONASHI, Kazumasa (MRI/JMA)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **70** Type: **Poster presentation**

Assimilation of Precipitation-Affected Microwave Radiances in NCEP FV3DA and Its Transition to JEDI

The operational FV3-GFS hybrid data assimilation system assimilates microwave radiances, including those affected by non-precipitating clouds. The cloudy scenes are assumed to be overcast. In recent years efforts have been made to improve the observation operator (CRTM), quality control procedures, and the analysis to make the assimilation of precipitation-affected radiance feasible.

The capability of the observation operator (CRTM) was validated and improved for its accuracy under scattering conditions. In addition, a two-column radiance calculation approach to handle partial cloud coverage with four types of cloud overlapping schemes were also developed. The cloud optical table for solid hydrometeors used in the assimilation was parameterized according to MODIS Collection 6 - a single habit ice model. The precipitation screening was removed from both data thinning and quality control to maximize the use of radiances affected by precipitation. The field-of-views containing highly scattering conditions were screened out due to large uncertainties in both the forecast model and observation operator. The radiances affected by cold-air-outbreak areas at the winter pole where the model forecast suffers from predicting the correct hydrometeor phase were also removed from the assimilation. The analysis variables, as well as the ensembles, were augmented to include precipitating hydrometeors such that the ensemble perturbations can effectively facilitate the use of observations.

The preliminary assessments of the impact on forecast were positive from the Microwave radiances, which includes precipitation-affected ones. The on-going work includes: (1) investigating the linearity of the observation operator under scattering condition; (2) enhancing cloud optical property table to take into account the temperature dependency for solid hydrometeors; (3) testing 4DIAU with hydrometeor increments for forecast initialization; and (4) transitioning the current work to JEDI.

Primary author: Dr LIU, Emily (JCSDA/UCAR/NOAA)

Co-authors: Dr COLLARD, Andrew (IMSG/EMC/NOAA); Dr JOHNSON, Benjamin (JCSDA/NOAA); Dr KLEIST, Daryl (EMC/NOAA); Dr STEGMANN, Patrick (JCSDA/UCAR)

Presenter: Dr LIU, Emily (JCSDA/UCAR/NOAA)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **71** Type: **Poster presentation**

Assimilating TRMM Microwave Imager Radiance Data in Future GEOS Reanalyses

The Tropical Rainfall Measurement Mission (TRMM) Microwave Imager (TMI) observed the Earth in lower latitudes between 1997 - 2015. Its conical-scan radiometer has nine channels and measured microwave irradiance between 10 and 89 GHz. These data provide information on atmospheric temperature, humidity, clouds, precipitation, as well as sea surface temperature. Radiance data from other microwave radiometers such as Special Sensor Microwave Imager (SSM/I) and Special Sensor Microwave Imager Sounder (SSMIS) onboard various Defense Meteorological Satellite Program (DMSP) satellites are assimilated in clear-sky conditions in the Modern-Era Retrospective analysis for Research and Applications (MERRA) and its version 2 (MERRA-2) data sets at the Global Modelling and Assimilation Office (GMAO) at NASA Goddard Space Flight Center. The GMAO's Hybrid 4D-EnVar-based Atmospheric Data Assimilation System (ADAS) is enhanced with an all-sky microwave radiance data assimilation capability in the real-time GEOS-Forward Processing (FP) system. Currently, the FP system assimilates Global Precipitation Measurement (GPM) microwave imager (GMI) radiance data utilizing this all-sky capability, and is being extended to use more all-sky data from other microwave radiometers. In this presentation, we will focus on impacts of all-sky TMI radiance data on GEOS analyses of atmospheric moisture, precipitation and other fields, and discuss their applications for future GEOS reanalyses.

Primary authors: JIN, Jianjun (GMAO, NASA); Dr MCCARTY, Will (GMAO, NASA); KIM, Min--Jeong (NASA GMAO/Morgan State University); EL AKKRAOUI, Amal (NASA-SSAI)

Presenter: JIN, Jianjun (GMAO, NASA)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **72** Type: **Oral presentation**

Fast infrared modelling of cloudy infrared radiances

Wednesday, 5 February 2020 10:00 (25 minutes)

Cloudy infrared observations are not currently fully exploited in operational NWP models. There are many reasons for this and the one we are interested in is the need to have an accurate and fast radiative transfer model to simulate cloud scattering in infrared. In most NWP centers, cloudy infrared observations are assimilated using the grey-cloud approximation. In this approximation clouds are considered as a single opaque layer without any scattering. By assuming this, cloudy simulations are very fast but only information on the atmosphere above the cloud top is gained in the assimilation, then excluding in-cloud information. Furthermore, the selection of observations to overcast situations reduces drastically the percentage of assimilated cloudy observations estimated between 3 and 5%. In order to go a step beyond the single layer opaque cloud model, fast infrared modelling of cloudy radiances including scattering have been proposed for many years in radiative transfer models. The three contributors to the fast infrared modelling of cloudy radiances will be discussed: fast scattering models, cloud optical properties and cloud overlap methods.

Primary author: VIDOT, Jerome (Météo-France)

Presenter: VIDOT, Jerome (Météo-France)

Session Classification: Session 3: Observation operators

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **73** Type: **Oral presentation**

Recent advances in the Community Radiative Transfer Model (CRTM) in support of all-sky radiance assimilation

Wednesday, 5 February 2020 09:00 (25 minutes)

The Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) is a fast, 1-D radiative transfer model used in numerical weather prediction, calibration / validation, etc. across multiple federal agencies and universities. The key benefit of the CRTM is that it is a satellite simulator, in that it provides a highly accurate representation of satellite radiances by making appropriate use of the specific sensor response functions convolved with a line-by-line radiative transfer model (LBLRTM). CRTM covers the spectral ranges consistent with all present operational and most research satellites, from visible to microwave. The capability to simulate ultraviolet radiances are being added over the next two years.
Another unique aspect of the CRTM is that it also provides the tangent-linear, adjoint, and Jacobian outputs needed for satellite data assimilation applications. The ability to compute a Jacobian for various geophysical input parameters significantly expands the capabilities beyond traditional forward RT models, such as those used in remote sensing retrieval algorithms and other "Bayesian" or "1D-VAR" applications.

The present talk will focus on recent advances in the ability of the CRTM to simulate satellite radiances in the presence of cloudy and precipitating scenes, with a particular emphasis on ice-phase microphysics. We'll explore the radiance sensitivity to cloud microphysical parameters through a series of experiments that will form the basis of the next generation of operational satellite data assimilation and numerical weather prediction. This represents a significant and necessary expansion of the CRTM capabilities to perform in an all-weather, all-surface, all-sensor environment.

Primary author: Dr JOHNSON, Benjamin (Joint Center for Satellite Data Assimilation)

Co-authors: Dr STEGMANN, Patrick (JCSDA/UCAR); Dr GREENWALD, Thomas (CIMSS/Univ. Wisconsin); Mr ROSINSKI, James (UCAR/JCSDA); CHEN, Ming (NOAA); Dr LIU, Quanhua (NOAA); AULIGNE, Thomas (JCSDA)

Presenter: Dr JOHNSON, Benjamin (Joint Center for Satellite Data Assimilation)

Session Classification: Session 3: Observation operators

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **74** Type: **Oral presentation**

Recent developments in microphysical modelling

Tuesday, 4 February 2020 14:45 (25 minutes)

This presentation will discuss the most recent developments of the Thompson-Eidhammer aerosol-aware bulk microphysics parameterization in the Weather Research and Forecasting (WRF) model. Detailed comparisons of many types of observed data have been used to improve the scheme over numerous years including satellite, radar, surface, and aircraft observations. The most recent observational data comparison came from an aircraft field campaign in winter 2019 in the Great Lakes region of the United States versus a WRF model run in real time to support flight planning using a 600-meter grid increment. Also a new technique to improve cloud initialization was incorporated in the absence of a full-scale data assimilation system. Further improvements leveraging the latest satellite data resources can provide aerosol, cloud particle phase and size retrievals to make larger improvements. A specific focus of the presentation will be the prediction of supercooled liquid water clouds and very hazardous freezing drizzle conditions. The former is a well-known shortcoming of nearly all global circulation models and the latter is a significant aviation hazard.

Primary author: Dr THOMPSON, Gregory (NCAR-RAL)

Presenter: Dr THOMPSON, Gregory (NCAR-RAL)

Session Classification: Session 2: Cloud and precipitation modelling

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **75** Type: **Oral presentation**

Observation-informed model development for cloud and precipitation

Tuesday, 4 February 2020 14:00 (40 minutes)

The representation of clouds, precipitation and their impacts are fundamental for weather forecasting and climate, yet many regime-dependent systematic errors continue to be present in global atmospheric models. There are a wealth of data from passive and active satellite instruments that can help to identify and understand the causes of these errors. In particular, monitoring and assimilation of cloud- and precipitation-sensitive satellite observations in an NWP data assimilation framework is an under-utilised source of information for physical parametrization development.

This presentation will discuss model cloud and precipitation evaluation with satellite observations, highlighting how the evaluation can lead to identification and improvement of specific parametrized processes, such as rain formation and cloud glaciation. A number of examples with the ECWMF global NWP Integrated Forecast System (IFS) will be shown. First guess departures from the assimilation of all-sky microwave channels sensitive to liquid water path continue to play an important role in reducing cloud and radiation errors over the marine stratocumulus and extratropical storm tracks. Active observations from radar and lidar (CloudSat/CALIPSO) continue to be highly valuable for evaluating many aspects of the cloud and precipitation fields.

Looking to the future, there is potential for extracting much more information on cloud and precipitation from active and passive satellite observations across the electromagnetic spectrum, and a question to what extent the properties of the global cloud and precipitation fields can be constrained by observations from space.

Primary authors: FORBES, Richard (ECMWF); LONITZ, Katrin (ECMWF); GEER, Alan (ECMWF)

Presenter: FORBES, Richard (ECMWF)

Session Classification: Session 2: Cloud and precipitation modelling

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **76** Type: **Oral presentation**

Particle filters for convective-scale assimilation

Wednesday, 5 February 2020 16:30 (25 minutes)

Roland Potthast, Anne Walter, Andreas Rhodin, Nora Schenk, Liselotte Bach, Takemasa Miyoshi, Shunji Kotsuki, Peter Jan van Leeuwen

We discuss the development of non-linear filtering methods for very high-dimensional systems. In this talk, non-linear filtering is developed in the framework of the convective-scale ensemble data assimilation system ICON-KENDA of DWD with upcoming 2km operational resolution at DWD. ICON-KENDA will also be used by the COSMO consortium (Germany, Switzerland, Italy, Russia, Poland, Romania, Greece and Israel) and its partner countries to provide initial conditions for high-resolution ensemble forecasting systems. We have ported the particle filter to the new ICON-D2 model framework, also including incremental analysis update (IAU). We also discuss recent experiments with conventional plus SEVIRI all-sky Satellite data in the visible range.

In a broader framework, we discuss ongoing research and results on the localized adaptive particle filter (LAPF) and a Localized Mixture Coefficient Particle Filter (LMCPF). We discuss how to overcome filter collapse or divergence by adaptive rejuvenation by mapping into ensemble space and by using adaptive spread estimators. Recent progress is shown on the LMCPF particle filters for Lorenz 63 and 96 models, where now with Gaussian mixture particles and proper covariance inflation the particle filter usually shows comparable or better o-b statistics than the LETKF. We also discuss recent activities on localised particle filter implementations at RIKEN, Japan.

Primary author: Prof. POTTHAST, Roland (DWD)

Co-authors: Dr RHODIN, Andreas; Mrs WALTER, Anne (Deutscher Wetterdienst); Dr BACH, Liselotte; Mrs SCHENK, Nora (Deutscher Wetterdienst); Prof. VAN LEEUWEN, Peter-Jan; Dr KOTSUKI, Shunji; Prof. MIYOSHI, Takemasa

Presenter: Prof. POTTHAST, Roland (DWD)

Session Classification: Session 4: Data assimilation methods

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **77** Type: **Poster presentation**

Assimilating solar reflectances in ICON-D2

Enabled by the new fast and accurate forward operator MFASIS (Scheck et. al, 2016), we work on assimilating solar reflectances measured by the SEVIRI instrument on Meteosat Second Generation in our new convective-scale NWP system ICON-D2-KENDA. We discuss key challenges calling for progress in research areas such as cloud microphysics, data assimilation algorithms to deal with the non-linearity of the forward operator and approaches to handle the non-local character of the observations. Subsequently, we show that despite these challenges we obtain promising positive impact in forecasting cloud cover and precipitation in numerical experiments with a local ensemble transform Kalman filter.

Primary authors: Dr BACH, Liselotte (Deutscher Wetterdienst); Dr SCHECK, Leonhard (Deutscher Wetterdienst); Dr STUMPF, Christina (Deutscher Wetterdienst); Dr SCHRAFF, Christoph (Deutscher Wetterdienst); Dr KÖPKEN-WATTS, Christina (Deutscher Wetterdienst); Prof. POTTHAST, Roland (Deutscher Wetterdienst)

Presenter: Dr BACH, Liselotte (Deutscher Wetterdienst)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **78** Type: **Poster presentation**

Evaluation of the fast visible RT model RTTOV-MFASIS and use for model cloud validation of ICON

MFASIS is a novel fast radiative transfer method for the simulation of visible satellite images that is fast enough to cope with the computational constraints of operational data assimilation systems and has therefore recently been implemented into RTTOV v12.2 and v12.3. First evaluation and data assimilation experiments using MFASIS in combination with regional models have demonstrated its value by improving the representation of cloud cover and precipitation.
As a further step towards using visible satellite images in operational data assimilation, we perform a detailed validation of the accuracy of MFASIS and apply it in evaluating the representation of clouds in DWD's global NWP system ICON+EnVAR in comparison to visible channel observations from the SEVIRI instruments on board MSG.

We evaluate RTTOV-MFASIS by comparing forward simulations to results from the discrete ordinate method RTTOV-DOM based on global ICON model fields which offer a large variety of atmospheric situations. This is done in a suitable test setup with controlled viewing conditions and by studying dependencies on relevant quantities, such as optical depths, to identify any systematic errors resulting from the approximations made in MFASIS. These investigations pave the way for further improvements to MFASIS, e.g., for an improved description of mixed-phase cloud situations.
Additionally, we compare reflectances simulated with RTTOV-MFASIS based on ICON model fields to real visible channel observations using geostationary satellites. This aims at validating the accuracy of the model cloud fields, also in conjunction with all-sky simulations of corresponding IR channels. Here, the visible channel information is complementary especially for the analysis of the representation of low clouds.

Primary author: STUMPF, Christina (DWD)

Co-authors: SCHECK, Leonhard (DWD); KOEPKEN-WATTS, Christina (DWD); STILLER, Olaf (DWD); BACH, Liselotte (DWD); POTTHAST, Roland (DWD)

Presenter: STUMPF, Christina (DWD)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **79** Type: **Poster presentation**

All-sky microwave radiances assimilated with an ensemble Kalman filter

The ability of variational data assimilation to deal with moderate non-linearity and non-Gaussianity is thought to have underpinned recent success in assimilating cloud and precipitation-affected satellite observations using the all-sky approach. A pure ensemble assimilation framework relies on linear and Gaussian assumptions, so its ability to handle all-sky observations is less clear. This work evaluates all-sky assimilation in a 50-member global ensemble Kalman filter (EnKF) system of near operational quality, derived from the four-dimensional variational (4D-Var) system used at the European Centre for Medium-range Weather Forecasts (ECMWF). The assimilation of 8 microwave instruments in all-sky conditions has similar benefit in the 4D-Var and EnKF, generating similar increments in winds, temperature and humidity, and giving around a 2% to 4% improvement in medium-range forecast scores. Ensemble correlations show that information from the all-sky observations in water vapour channels is on smaller vertical and horizontal scales than clear-sky temperature sounding channels, and there is stronger sensitivity to wind. This boosts the evidence that both 4D-Var and ensemble data assimilation can make good use of all-sky observations, including the extraction of wind information. Two new all-sky observation error models were investigated to replace the standard symmetric approach. One model inflates errors as a multiple of the ensemble nonlinearity, and the most successful inflates as a multiple of the ensemble spread. However, further testing is needed to confirm the best approach. In absolute terms the EnKF forecast performance in the troposphere was still worse than the 4D-Var, though the gap was reduced by going from 50 to 100 ensemble members. EnKF errors are however much larger in the stratosphere, where there is a need to address excessive gravity-wave increments that are not connected with all-sky assimilation.

Primary authors: BONAVITA, Massimo (ECMWF); GEER, Alan (ECMWF); Dr HAMRUD, Mats (ECMWF)

Presenter: GEER, Alan (ECMWF)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **80** Type: **Oral presentation**

Cloud and precipitation assimilation from satellites: 20 years and 4 joint workshops

Monday, 3 February 2020 11:30 (40 minutes)

With the introduction of improved data assimilation methods around the turn of the millenium, direct assimilation of cloud and precipitation observations became more feasible. Since then, ECMWF-JCSDA workshops have been held every 5 years to assess and progress the state of the art. This talk will overview past progress and introduce the current workshop and its key questions. These are: (1) the observing system, progress in operational all-sky assimilation from nowcasting to global weather forecasting, and the exploitation of a wider array of novel observations including cloud and precipitation lidar, lightning and passive sub-millimetre; (2) progress in cloud micro- and macro-physical modelling - to find out how the models can help constrain observation operators, and how much the observations can help better constrain the models; (3) progress in cloud and precipitation-capable observation operators, particularly the need to handle macrophysical details such as 3D effects and cloud overlap, and microphysical details including the shape, orientation and size distributions of hydrometeors; (4) improved methods for data assimilation, particularly as cloud and precipitation observations challenge many of the assumptions made in current operational systems, particularly the Gaussian and linear assumptions.

Primary author: GEER, Alan (ECMWF)

Presenter: GEER, Alan (ECMWF)

Session Classification: Overview talks

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **81** Type: **Poster presentation**

Updates on the all-sky assimilation at ECMWF

We present some highlights from recent updates to the all-sky assimilation at ECMWF.

- Changes to consider interchannel correlation in the error model of microwave imagers. For the all-sky assimilation it has been found that a fully-specified covariance matrix that adapts with the cloud amount was needed for this purpose. We find that the tuning of the eigenvectors and the interplay with variational quality control is key to a successful assimilation considering correlated observation errors.
- In the latest ECMWF IFS model cycle SSMIS-F17 150h GHz and GMI 166 v/h GHz channels have been added. This improves medium-range humidity forecasts and decreases the additional drying through the assimilation of microwave imagers by 50%.
- RTTOV-SCATT has been updated to version 12.2 in the latest ECMWF IFS model cycle along with the rest of RTTOV. This update adds the ARTS scattering database with 16 shapes including aggregates, hail and graupel and covering frequencies from 1 to 886 GHz to support all microwave/sub-mm bands: SMOS to ICI. Furthermore, a new liquid water permittivity model (Rosenkranz, 2015) is now a part of RTTOV-SCATT.

Primary authors: LONITZ, Katrin (ECMWF); GEER, Alan (ECMWF)

Presenter: LONITZ, Katrin (ECMWF)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **82** Type: **Poster presentation**

Cloud and Solar Power Prediction within the Helmholtz Analytics Framework

Solar photovoltaic power plants and grid operators rely on highly accurate and reliable short-term predictions of solar power and the related prognostic variables such as the surface solar irradiance. These on the other hand strongly depend on the proper forecasting of cloudiness and cloud evolution. Cloud scenarios are best observed by satellites. The use of satellite information in prognostic models, resulting in the improvement of the short-term prediction of cloud movement, is an (as yet) unresolved issue.

In operational weather forecast, ensemble forecasts of 50 members are standard. However, to better account for uncertainties resulting from small-scale processes like convection much more samples would be needed. In this project, a large ensemble forecast consisting of 512 members over the time span of 6 months (soon to be one year) and on a 20km resolution grid roughly covering Europe has been created using an ensemble version of the Weather Research and Forecasting (WRF) model. The ensemble members have been evaluated and calibrated using deep neural networks.

In the next step a particle filter will be used for the data assimilation of cloud fields using satellite observations. To overcome the problem of high dimensionality machine learning approaches will be investigated to sample new ensemble members with high probability mass.

This project is part of the Helmholtz Analytics Framework, a cooperation between data scientists and domain scientists to boost the development of domain specific Scientific Big Data Analytics methods.

Primary author: Dr JERGER, Dorit (Institut für Energie- und Klimaforschung: Troposphäre (IEK-8), Forschungszentrum Jülich)

Co-authors: Dr BERNDT, Jonas; Dr ELBERN, Hendrik; Dr KRAJSEK, Kai; Mr TODT, Daniel

Presenter: Dr JERGER, Dorit (Institut für Energie- und Klimaforschung: Troposphäre (IEK-8), Forschungszentrum Jülich)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **83** Type: **Poster presentation**

Impact of Hydrometeor Initialization on Short-Term Convective-Scale Numerical Weather Prediction

Cloud and precipitation forecasting is both an essential and challenging task in Numerical Weather Prediction (NWP). In this process, a significant part of the errors can be traced back to imperfect initialization of the models. As regards the 3D fields of rain, cloud water, ice crystals, rain and graupel (hydrometeor content fields), several barriers make their initialization a sensitive issue: strong non-linearity of observation operators, strong non-Gaussianity of model errors, spatial discontinuity and positivity of the variables. Hence, these variables are generally neglected in the initialization process, and assumed to adapt to large-scale fields such as temperature and humidity. This poster aims to challenge this practice.

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Could hydrometeor initialization substantially improve short-term forecasting? Two NWP experime

The improvement in forecast skill for precipitation and cloud cover is then respectively assess
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Primary author: Mr DESTOUCHES, Mayeul (CNRM (Météo-France/CNRS))

Co-authors: Dr MONTMERLE, Thibaut (CNRM (Météo-France/CNRS)); Dr MICHEL, Yann (CNRM (Météo-France/CNRS))

Presenter: Mr DESTOUCHES, Mayeul (CNRM (Météo-France/CNRS))

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **84** Type: **Poster presentation**

Fast Radiative Transfer Algorithms applied in 3-D for multi-spectral visible wavelengths and in 1-D for visible and IR for use in NWP evaluation and Data Assimilation

High spatial and temporal resolution image data of the Earth's environment reflecting cloud, precipitating hydrometeor, aerosol, and lower boundary surface conditions abound. Yet the bulk of the information in such observations isn't yet exploited for the initialization of Numerical Weather Prediction (NWP) model forecasts. This is because most information contained in the imagery data is inaccessible via the operationally used 2D radiative transfer models while their 3D versions are computationally prohibitively expensive.

Here we describe a recently developed fast 3-D visible light radiative transfer package called Simulated Weather Imagery (SWIm). SWIm produces visually and physically realistic displays of sky and landscape conditions from any vantage point in or above the atmosphere, based on digital analysis or forecast fields from NWP systems. The resulting RGB images can be used for subjective visual interpretation, while radiance and reflectance values at various visible light wavelengths permit objective comparison of image data (from ground-, air- or space-borne observations) with simulated conditions (from NWP analysis or forecast fields).

While 3-D radiative transfer can be used within a tomographic hydrometeor analysis, we are testing ray-tracing methods and cloud masks derived from ground-based all-sky camera imagery to improve a 500m resolution hydrometeor and aerosol analysis. Other data for this analysis includes GOES-ABI visible and IR, NEXRAD radar reflectivity, METARs, PM2.5 measurements, and a forecast first guess.

In addition to the 3-D visible multi-spectral ray-tracing algorithm described above, fast 1-D forward operators are being developed for use in hydrometeor assimilation and being compared with CRTM in the context of a non-variational global cloud analysis. These operators are being used to compare simulated radiances produced by CRTM using GOES ABI visible and IR channels centered at 0.64 and 10.3 microns, with the goal of performing variational assimilation experiments.

Primary author: Mr ALBERS, Steven (Spire Global)

Presenter: Mr ALBERS, Steven (Spire Global)

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **86** Type: **not specified**

Introduction to the working groups

Thursday, 6 February 2020 09:00 (10 minutes)

Presenters: GEER, Alan (ECMWF); BORMANN, Niels (ECMWF)

Contribution ID: **87** Type: **Poster presentation**

Potential, application and questions of DBNet Data in Regional NWP in CMA

At present, there are four kinds of sources of ATOVS AMSU-A data available in CMA, including two kinds of DBNet data (as RARS and EUMETcast) and two kinds of global data (as NESDIS and EUMETSAT). There are some differences on satellite kinds, observation coverages and timeliness among different sources.
Up to 2018 only global data are used in global models in CMA. DBNet data have been used neither in global model nor regional model, which has advantage in timeliness.
So firstly, the observation numbers and brightness temperature differences between DBNet data and NESDIS data are studied. It is reflected that some differences in calibration and positioning in satellite data preprocessing, either between RARS stations and NESDIS way or among different RARS stations.
After that, both DBNet data and global data are putting into a real-time regional assimilation system in NSMC. The framework of the real-time regional assimilation system is shown, as well as the assimilation impact both on typhoon Maria in 2018 and on the continuous experiment lasting from January 2018 to September 2018.

Primary author: XI, Shuang

Presenter: XI, Shuang

Session Classification: Poster session with self-serve tea and coffee

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **88** Type: **Oral presentation**

Beyond bulk cloud top quantities: A climate perspective on using satellite observations (and assimilation) to better inform cloud simulation

Tuesday, 4 February 2020 15:15 (25 minutes)

The challenges of cloud modeling in large scale models and for climate time scales (sub-seasonal to centuries) will be explored. Key problems related to clouds in longer term climate prediction include extreme precipitation, climate forcing and cloud feedbacks. Satellites provide a wealth of data on clouds that are used for evaluation of models in many different ways. Examples of innovative approaches to using data will be shown, with a discussion of the current generation of passive and active sensors, as well as some prospects for the future observation systems, and how they can be better integrated with models for weather and climate.

Primary author: GETTELMAN, Andrew (NCAR)

Presenter: GETTELMAN, Andrew (NCAR)

Session Classification: Session 2: Cloud and precipitation modelling

Track Classification: 4th workshop on assimilating satellite cloud and precipitation observations for NWP

Contribution ID: **89** Type: **Poster presentation**

New precipitation and cloud ice observations with polarimetric GNSS RO aboard the PAZ satellite

The GNSS Polarimetric Radio Occultations (GNSS PRO) is a new measurement concept being proved aboard the PAZ satellite, operating since May 2018. The technique is based on the 'traditional' GNSS Radio Occultations (GNSS RO), widely used for atmospheric profiling of thermodynamic parameters and assimilated in operational NWP. Adding polarimetric capabilities to the RO system enables to sense hydrometeors, especially big rain droplets in heavy rain, and some frozen particles. The system, thus, is the first technique with joint and synchronous sensitivity to both types of parameters: thermodynamic and hydrometeor profiling. Whereas the geophysical content of the GNSS RO signals to infer the 'traditional' products lays on the bending of the signal propagation (atmosphere acting as a lens because of its vertical gradients in T, p and q), the physical principle to sense hydrometeors is the excess propagation delay of the horizontally polarized signal with respect to the vertically polarized one. These are two independent sensing principles obtained from a single set of data.
This poster will present the technique, the facts demonstrated during the PAZ mission so far, the current identified limitations, and potential areas of interest and opportunities for scientists working on precipitation, micro-physics modeling and large scale convective systems, elements towards improved understanding, monitoring and prediction of some extreme events.

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