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IN THIS ISSUE

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NEWS IN THIS QUARTER

Role of GSICS in NWP satellite data assimilation

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Introduction

The aim of GSICS (the Global Space-based Inter-Calibration System) is to organize the production of satellite inter-calibration information to enable improved and consistent accuracy among space-based observations worldwide for climate monitoring, weather forecasting, and environmental applications. GSICS has been active for over fifteen years and its product catalog for monitoring biases in satellite instrument measurements contains over 60 active entries covering instruments operating in the Microwave, Infrared, and Visible spectral domains.

While these products are routinely used by the instrument teams to validate, characterize, monitor, and improve their measurements, they are not as well-known or utilized by the Numerical Weather Prediction (NWP) community. The purpose of this article is to advance communication and understanding between GSICS and the NWP communities by identifying and describing common ground in their capabilities and goals.

The first section reviews the GSICS products, tools, and deliverables. The second section describes how GSICS interacts with the satellite instrument calibration teams. The third section considers how to take advantage of similarities in the NWP bias monitoring and model information and GSICS products, and lays out common ground for future interactions.

I. GSICS Products and Deliverables

GSICS researchers have developed, documented, and applied systematic approaches for estimating calibration differences among satellite instruments. These include the use of Simultaneous Nadir Overpasses (SNOs) for LEO-LEO comparisons and LEO under-flights of GEO (both ray tracing and deep convective cloud statistical approaches). Articles on these methods and tools have appeared in previous issues of the GSICS Quarterly:

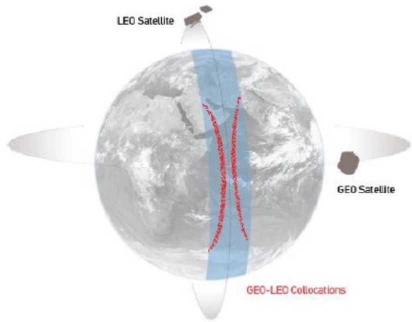
https://www.star.nesdis.noaa.gov/smcd/GCC/newsletters.php

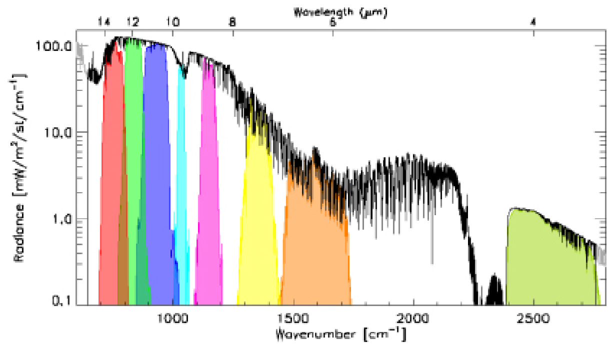
(Interested persons can subscribe to the quarterly announcements by sending an e-mail to **gccnewsletter-subscribe@list.woc.noaa.gov** with the word "subscribe" in the subject line.)

The product catalog, https://www.star.nesdis.noaa.gov/smcd/GCC/ProductCatalog.php, provides links to the data and documents, including algorithm theoretical basis documents (ATBDs), and has plotting capabilities to present time series of the results. There is a system to provide notices if products are not generated as scheduled.

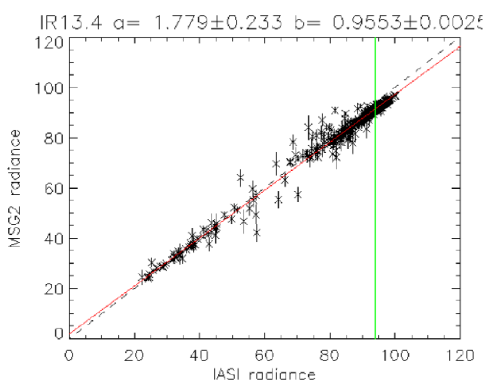
The products make use of comparisons to GSICS Reference Sensors. Currently, the IR references are Metop-B & -C IASI, Aqua AIRS, and NOAA-20 CrIS, the Vis/NIR references are S-NPP and NOAA-20 VIIRS and Aqua MODIS, and the MW reference is S-NPP ATMS. The GRWG makes a report to the GSICS Executive Panel each year on the state of the observing system. Summaries of the statuses of the reference instruments for 2021 are provided in articles in two issues of the GSICS Quarterly, 14(4) and 15(1). GSICS recognizes the value planned SI-traceable Satellite Instruments such as the CLARREO (and its Pathfinder), TRUTHS and LIBRA missions will provide, and participates in workshops and receives updates on these missions [See, for example, reports and articles in the GSICS Quarterly 13(3), 14(2) and 15(1).], and on the existing SI-traceable GNSS-RO products. These new instruments are designed to be able to tie future GSICS to absolute scales with significant improvements in monitoring measurements for climate data records and to provide measurements without the need for bias corrections.

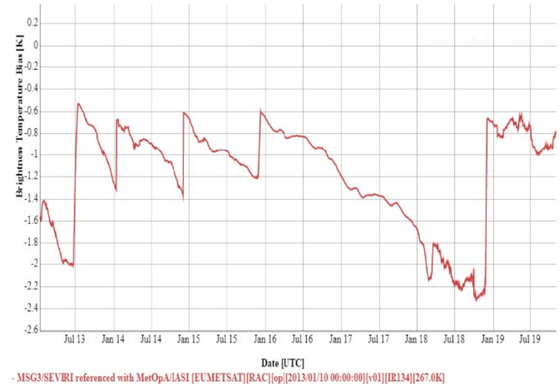
As an example of the creation of GSICS products, we outline the creation of products for SEVIRI IR measurements on EUMETSAT MSG (GEO) platforms with IASI on Metop (LEO) platforms. The first step is to collect matchup data sets. In this case a region of Simultaneous Nadir Overpasses of the GEO platform above a LEO platform are selected with appropriate limits on time and viewing angle differences. The hyperspectral IASI instruments are used as references.





A region for colocations is shown above on the left. The second step is to convolve the IASI Spectrum with the Spectral Response Functions (SRFs) of the measured instrument. The figure above on the right shows an IASI spectrum with shaded coloring of SEVIRI SRFs. Sensitivity studies of the biases can be conducted to identify or diagnose SRF errors.





The third step is to perform statistical analysis of the collocated radiances. A typical scatter plot for one day of data for IASI versus MSG2 SEVIRI for the IR 13.4μ channel is presented above on the left. Finally, the time series of bias corrections are updated and distributed through GSICS servers to provide monitoring of the instrument behavior. A time series is provided in the figure above on the right – Title: **Time Series of Bias in Meteosat-10/SEVIRI IR13.4 channel from GSICS Re-Analysis Correction for standard scene (267K) based on inter-calibration with Metop-B/IASI.** GSICS Plotting Tool: gsics.tools.eumetsat.int/plotter.

The GSICS wiki (http://gsics.atmos.umd.edu/wiki/Home) provides links to GSICS deliverables, product reviews documenting the acceptance process, meeting calendars (with links to past presentations and agendas) and other information. Most of the GSICS Research and Development is performed by researchers at GSICS member agencies with support from their organizations. Coordination and exchanges are managed by a GSICS Research Working Group (GRWG) and a GSICS Data Working Group (GDWG). The GRWG is divided into spectral subgroups – IR, MW and Vis/NIR subgroups, and a (UVN-)Spectrometer subgroup with reach from the Ultraviolet to the Visible to the Near IR. See the summary of the 2021 annual meeting in 15(1) of the GSICS Quarterly for more information on their activities. Most of the subgroups meet monthly. Meeting announcements are provided to a mailing list of registered users; to become one, visit: http://gsics.atmos.umd.edu/bin/view/System/UserRegistration

Information on this year's Annual GSICS Meeting which took place 14-18 March 2022 including the agenda and links to the presentations can be found at http://gsics.atmos.umd.edu/bin/view/Development/Annualmeeting2022. The first day of the meeting was a mini-conference with NWP interactions as one of the topics.

The member agencies also maintain additional resources for GSICS called GSICS Processing and Research Centers (GPRCs). For example, the Japanese Meteorological Agency (JMA) page at https://www.data.jma.go.jp/mscweb/data/monitoring/calibration.html reports on its Himawari series of instruments. The links to associated pages there provide information on calibration events, data outages, instrument specifics (including spectral response functions) and bias monitoring for JMA's geostationary satellite instruments.

GSICS also makes recommendations for tools and other data sets. These include:

1. a lunar model, called GIRO – the GSICS implementation of the ROLO (USGS Robotic Lunar Observatory) model. Details are provided at http://gsics.atmos.umd.edu/bin/view/Development/LunarWorkArea .
   GSICS has helped to organize multiple workshops on the use of the Moon as a calibration target and links to meeting pages and presentations are provided.

2. a high-resolution reference solar spectrum from the Laboratory for Atmospheric and Space Physics at the University of Colorado – http://gsics.atmos.umd.edu/bin/view/Development/ReferenceSolarSpectrum,

3. a Simultaneous Nadir Overpass (SNO) prediction tool – http://gsics.atmos.umd.edu/bin/view/Development/SimultaneousNadirOverpassMethod ,

4. the NASA Spectral Band Adjustment Factor (SBAF) calculation tool described at – http://gsics.atmos.umd.edu/pub/Development/AnnualMeeting2019/4q_SBAF_Update_GSICS_2019_Bhatt.pdf .

5. tools to plot GSICS products, e.g., GSICS Plotting Tool (eumetsat.int) ,

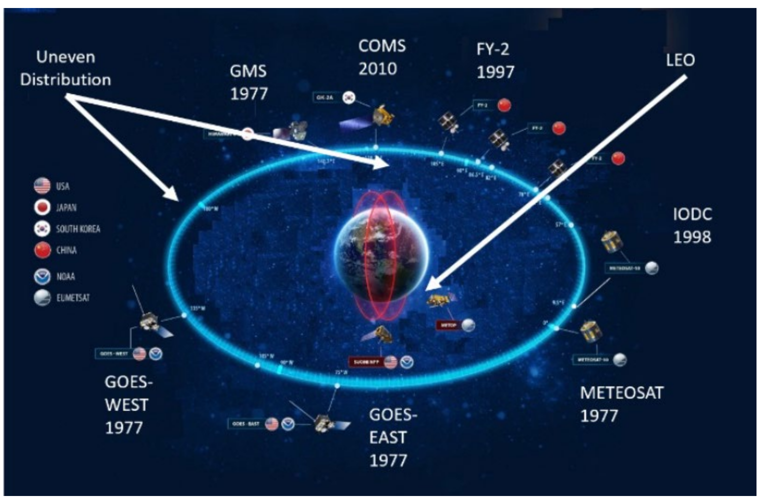
6. and links to spectral response functions for many instruments https://www.star.nesdis.noaa.gov/smcd/GCC/instrInfo-srf.php .
   with open requests for updates to landing page links and new additions to the content to all GSICS members.

In addition to the GSICS products in the product catalog, GSICS also provides access to four deliverables: two subsets tools to aid in GEO-LEO comparisons Hyperspectral Reference Radiance in NetCDF Format by *Masaya Takahashi (JMA)*, Google Colab and subsets for GEO-LEO Intermediate Collocation (Himawari/MTSAT V Hyperspectral) by *Masaya Takahashi (JMA)*, a Spectral Response Function processor for use with a lunar model: SRF for GIRO by *Masaya Takahashi (JMA)*, Google Colab, and a compilation of MW instrument inter-calibration results: Level 1C Inter-Calibration Tables by *Wes Berg (CSU)* and *Racheal Kroodsma (NASA)* Google Colab.

II. Application of GSICS Products to Improve Level 1

The primary applications of the GSICS products are to identify, monitor, and correct the calibration of instruments relative to the GSICS reference instruments with a goal of improving the consistency of measurements among instruments to reduce biases in Level 1 and Level 2 products, thus increasing their inter-operability. GSICS provides traceability of the measurements relative to the reference instruments with comprehensive uncertainty estimates for its operational products. The ability to track the evolution of biases with time supports monitoring of operational instruments in space, more rapid characterization and validation of new instruments, improves the consistency of re-analysis efforts, and provides starting points for the creation of fundamental climate data records.

At this point, almost all of the IR channels on GEO platforms have been compared to one or more of the IR references (IASI or CrIS) and many of the visible channels have been compared to one or more of the Visible references (formerly MODIS and now VIIRS). Most of the instrument teams have used these comparisons to reset their calibration (if needed)



to have better agreement with the references. We call this constellation of inter-calibrated instruments the GEO-Ring as it has coverage around the globe. The figure above shows the timing of the introduction of these platforms. For examples, see the time series for NOAA ABI instruments at

https://www.star.nesdis.noaa.gov/GOESCal/index.php

and the validation document at

https://www.ncdc.noaa.gov/sites/default/files/attachments/GOES-16_ABI-L1b-CMI_Full-Validation_ProductPerformanceGuide_v2.pdf

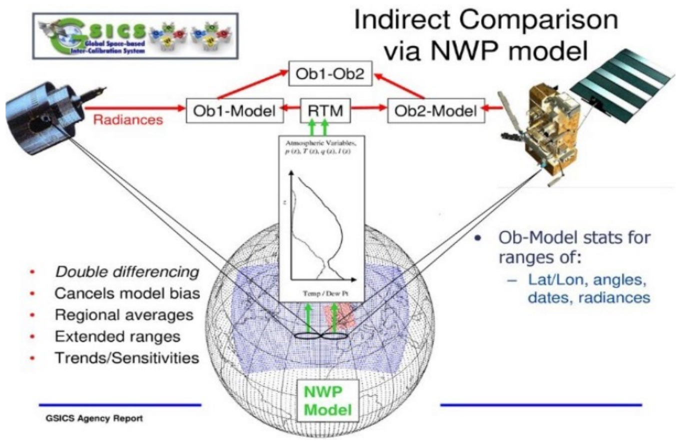
[For more information on the GEO Ring and GEO/GEO comparisons see the talks available from GSICS links at 20191017 < Development < GSICS Wiki (umd.edu).]

While the monitoring for the GSICS products is often provided as daily (or moving average) bias estimates, the statistics of the matchups have been examined to provide information on instrument performance and calibration beyond simple bias offsets. These include the following: (1) Tracking response changes in-flight (e.g., Hewison and Müller, 2013) or spectral response changes from prelaunch to in-flight (e.g., Wu & Fu, 2013), (2) detecting increased noise in measurements, (3) identifying diurnal variations in biases, (4) improving calibration of GEO-bases sensor measurements for devising ISCCP records, and (5) creating long-term Microwave Fundamental Climate Data Records (FCDRs) (e.g., Zou et al., 2018 and Zou et al., 2021).

III. Synergy among NWP and GSICS activities and goals

Since both GSICS and NWP researchers and practitioners develop estimates of measurement biases, the most straightforward cooperative effort is to *close-the-circle* by looking at classes of instruments and checking to see how closely the relative biases among them agree between the two fields. For example, one can compare the bias adjustments for two instruments' measurements in NWP models to those estimated relative to a GSICS reference instrument. This can easily be extended to re-analysis products where instrument records begin and end over the period of interest.

Depending on the approach used in GSICS, there may be a need to consider specific regions or measurement ranges. For example, NWP bias monitoring for IR channels is most reliable in clear sky conditions over the ocean, whereas counterpart GSICS products cover all-sky conditions and may include land. The variability of observed minus forecast statistics (O-B) over the global range of measurements available from NWP will provide additional checks on the GSICS products as well as provide instrument teams with possible areas for investigation beyond identification of simple bias offsets, e.g., scan-angle dependence.



Further, when a measurement anomaly is detected for an instrument on one system, such as a shift in O-B for a specific channel, the other system can be checked to see if there is a similar anomaly, such as a shift in the bias with respect to a GSICS reference. Saunders et al., 2021, examined the capability of the European NWP Satellite Application Facility (SAF) to monitor biases as provided at their https://nwp-saf.eumetsat.int/site/monitoring/nrt-monitoring/ website.

Interaction with GSICS product development teams will allow NWP practitioners to gain insight into how instrument teams perform validation and calibration tasks and apply them to improve the products. This can be useful as there may be preferences on whether adjustments to Level 1 products create jumps or discontinuities in the records or are introduced as smaller, incremental adjustments over time. Through better collaboration the NWP community will gain insight into the calibration update process and gain influence on the timing and impact, or on the use of calibration correction coefficients. This area is facing new challenges as constellations of small satellites are launched. The rapid validation and calibration of these resources is needed to ensure their full exploitation. Methods developed and applied to create GSICS products will be applied to these new systems.

Both GSICS and NWP communities have a vested interest in well-maintained instrument landing pages where calibration information including spectral response functions are provided and significant events are logged. GSICS has been providing recommendations for the content of instrument pages to the Coordinating Group for Meteorological Satellites (CGMS), e.g., the reports at

https://earth.esa.int/eogateway/documents/20142/1367699/CGMS-45-EUMETSAT-WP-33.pdf.

An example or these landing pages for the European Space Agency (ESA) can be found:

ESA satellites and instruments calibration landing page - Earth Online.

GSICS also supports the development of satellite instrument calibration, validation and monitoring systems, such as the NOAA Integrated Calibration/Validation System at

https://www.star.nesdis.noaa.gov/icvs/index.php

The scripts and codes to create the monitoring pages for this site have been shared with meteorological agencies around the world.

The interests of GSICS and NWP communities intersect in other areas. One major one is the development and selection of radiative transfer models and their physical parameters. (See Lee & Ahn, 2021 for an application.) By using consistent models, the two communities can eliminate some sources of differences when comparing to forward model results from radiosondes (e.g., NPROVS (NOAA Product Validation System) matchup datasets), Global Position System Radio Occultation (GPS-RO) retrievals, or measurements over Pseudo-Invariant Calibration Sites (PICS), Marine Optical BouYs (MOBY) or other surface-based networks. Similarly, the two groups can work with CEOS to identify and agree upon the best high-resolution solar spectrum for use with UV and Visible backscatter measurements.

GSICS products are already improving the quality and quantity of data assimilated into the NWP system, and the GSICS bias estimates will get even better as planned SI traceable instrument missions are realized, and either become GSICS reference instruments or confirm the performance of other reference instruments. (See Hewison et al., 2020.) Direct comparisons to the GSICS reference instruments are already at uncertainty levels such that they can provide information on the numerical weather model errors or inconsistencies.

GSICS researchers participated in a ECMWF/NWP-SAF Workshop on the Treatment of Random and Systematic Errors in Satellite Data Assimilation. The workshop report is available at

> https://events.ecmwf.int/event/170/attachments/723/1690/ErrorWS_WorkshopReport_v1.pdf

It includes the following statement:

> *An overarching recommendation from all four working groups is the call for more work regarding metrological/physical understanding of systematic as well as random observation-related errors, as it is seen as fundamental in informing their treatment in data assimilation.*

The workshop recognized that observation errors play a crucial role in determining the skill of the NWP forecasts. Given that the bulk of the observation data in NWP systems is ingested from satellites, efforts need to be put in place to improve information on biases/trends/errors in satellite data and develop chains that can allow traceability of this data to acceptable standards. In the light of this, missions such as TRUTHS, CLARREO, and LIBRA were also discussed. However, until the time when SI traceable systems are in orbit, the satellite data can be compared with GSICS references. GSICS references are in-orbit instruments that are more stable than most of the contemporary satellites and are selected using a Quality Assurance for Earth Observations (QA4EO) based selection matrix.

One of the recommendations in the report was the following:

> *Recommendation: establish greater dialogue between NWP centres and GSICS leading to a systematic data exchange system for biases and alerts.*

The report supported the investigation of bias statistics from NWP or GSICS in support of root cause analysis allowing biases to be corrected at source. The recent studies with Aeolus were seen as a good example of careful analysis, enabling the bias root causes at the instrument level to be identified and understood (See Rennie et al., 2021.). The mini-conference in the 2022 Annual GSICS Meeting on March 14th provided an opportunity to continue and expand the dialogue. Readers may view the agenda and other information at this link.

References:

Issues of the GSICS Newsletters can be accessed with links at:

https://www.star.nesdis.noaa.gov/smcd/GCC/newsletters.php

Dec. 2019, Vol. 13, No. 3 - DOI: 10.25923/77r0-wm17

Sep. 2020, Vol. 14, No. 2 - DOI: 10.25923/s4c9-cq85

Mar. 2021, Vol. 14, No. 4 - DOI: 10.25923/jmbt-d994

Jun. 2021, Vol. 15, No. 1 - DOI: 10.25923/m6pq-w122

Sep. 2021, Vol. 15, No. 2 - DOI: 10.25923/w710-y903

Hewison, T., et al., 2020, "Extending the Global Space-based Inter-Calibration System to Tie Satellite Radiances to an Absolute Scale", **Remote Sens. 12**(11), doi:10.3390/rs12111782.

Hewison, T.J., & J. Muller, 2013, "Ice Contamination of Meteosat/SEVIRI Implied by Intercalibration Against Metop/IASI," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 51, no. 3, pp. 1182-1186, March 2013, doi: 10.1109/TGRS.2012.2236335.

Lee, S.J., & M.-H. Ahn, 2021, "Synergistic Benefits of Intercomparison Between Simulated and Measured Radiances of Imagers Onboard Geostationary Satellites," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 59, no. 12, pp. 10725-10737, Dec. 2021, doi: 10.1109/TGRS.2021.3054030.

Rennie, M.P., L. Isaksen, F. Weiler, J. de Kloe, T. Kanitz, O. Reitebuch, 2021, "The impact of Aeolus wind retrievals on ECMWF global weather forecasts". **Quarterly Journal of the Royal Meteorological Society**, 147(740), pp 3555-86, https://doi.org/10.1002/qj.4142.

Saunders, R., P. Francis, T. Blackmore, B. Candy & T. Hewison, 2021, "10 years of satellite infrared radiance monitoring with the Met Office model", GSICS Quarterly 15(2), doi: 10.25923/w710-y903.

Wu, X., & F. Yu, "Correction for GOES Imager Spectral Response Function Using GSICS. Part I: Theory," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 51, no. 3, pp. 1215-1223, March 2013, doi: 10.1109/TGRS.2012.2236100.

Zou, C.-Z., M.D. Goldberg & X. Hao, 2018, "New generation of U.S. satellite microwave sounder achieves high radiometric stability performance for reliable climate change detection", **Science Advances 4**(10), doi10.1126/sciadv.aau0049.

Zou, C.-Z., H. Xu, and X. Hao, 2021, Reference Microwave Sounder Instruments for FCDR Development, GSICS Quarterly 14(4), doi: 10.25923/jmbt-d994.Hewison, T., et al., 2020, "Extending the Global Space-based Inter-Calibration System to Tie Satellite Radiances to an Absolute Scale", **Remote Sens. 12**(11), doi:10.3390/rs12111782.

EDITOR’S NOTE

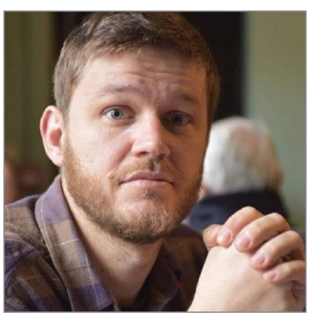
The Joint Center for Satellite Data Assimilation exists at the intersection of a number of communities, including, of course, the bureaucratic ones defined by the sponsoring partner agencies, but also those associated with science and technology applications spanning environmental modeling, data assimilation, satellite operations, remote sensing science, and observations. At our most successful we are able to accelerate and improve the use and impact of environmental satellite data by sharing development and avoiding duplication of effort as much as possible.

The Global Space-based Inter-Calibration System (GSICS) works with a similar sense of purpose focused on improving the accuracy and consistency of satellite observations. In this role GSICS touches the foundation of many of the applications with which the JCSDA is concerned. In this issue of the newsletter we present an article by Lawrence Flynn and co-authors summarizing GSICS activities and products and prospects for supporting environmental modeling, and offering potential for collaboration with the data assimilation community and the JCSDA.

Speaking of community, this issue includes biographical introductions to several new colleagues in the Joint Center: Jerome Barré, Lindsey Hayden, Dom Heinzeller, and Christian Sampson. You can learn what these folks are working on, and a little bit about their outside interests as well.

Jim Yoe
Editor

PEOPLE



Jérôme Barre

Jérôme joined the JCSDA in October 2021. He leads the effort on atmospheric composition data assimilation (DA). Jérôme has experience in operations and research for atmospheric composition applications using variational, ensemble and hybrid systems. He had the opportunity to work on regional and global scale systems for air quality applications and global monitoring of pollutants.

He started his career at Météo-France where he focused on satellite 3D-Variational DA of ozone and carbon monoxide with a specific focus on pollution transport between the troposphere and the stratosphere. He then started to work at NCAR in 2013 focusing on observation simulation system experiments, ensemble DA methods and source inversion techniques. In 2017, he moved back to Europe to work at ECMWF where he maintained and developed the Copernicus Atmosphere Monitoring Service’s greenhouse gases operational 4D-Variational DA system. He also contributed to the development of the source inversion capability in the IFS system. He also served as a technical officer for the CAMS regional operational forecast ensemble that includes 11 models and teams across Europe. He recently developed an interest in machine learning to make the best use of operational products, such as automatic detections and classification of emissions and accurate assessment of air quality changes during pandemic lockdowns.

When he is not working on science and taking care of his family, Jérôme loves thru-hiking, playing music, Jiu-jitsu, fine art photography, and painting.

Dr. Dominikus (Dom) Heinzeller

Dom Heinzeller is a computational scientist and the JEDI infrastructure lead at the Joint Center for Satellite Data Assimilation. In this role, he oversees the software environment for the JEDI applications to deliver the necessary portability, performance and stability on the multitude of computational systems in use at JCSDA and partner organizations. Dom's career spans from theoretical astrophysics to numerical weather prediction, work that he pursued in Japan, New Zealand, Germany, West Africa, and the United States.

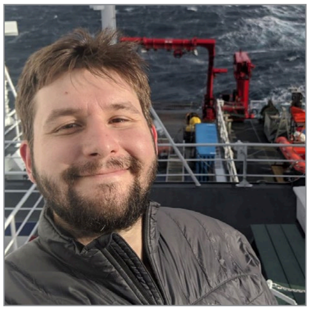
Born and raised in the beautiful Bavarian Alps in southern Germany, Dom graduated from the Ruprecht Karls University of Heidelberg with a M.Sc. in physics in 2005 and a PhD in astronomy in 2008, specializing on radiative properties of black hole accretion disks, and with a strong interest in computational sciences. He pursued his first postdoc in Kyoto, Japan, from 2008 on, where he worked on the physical and chemical evolution of protoplanetary disks. A major outcome of this work was the first ever protoplanetary disk model that combined the physical and chemical evolution and predicted observations of methane and ammonia in the inner regions of the disks – later to be confirmed by the Spitzer Space Telescope.

While living in Japan, Dom met his future wife Kanako. Together, they decided to start all over and move to New Zealand in 2010. There, Dom accepted a position as research scientist at the Meteorological Service of New Zealand Ltd in Wellington, New Zealand, specializing on pre-operationalization and data ingest pipelines. In 2011, Dom was sent to Boulder, CO, to attend the WRF Users' Workshop and immediately fell in love with Colorado.

The next move in 2013, however, brought him back to his hometown Garmisch-Partenkirchen, where he worked at the Institute of Meteorology and Climate Research of the Karlsruhe Institute of Technology. His job duties covered regional climate modeling, extreme scaling experiments with the MPAS model (including the implementation of a new I/O layer), HPC system administration, and the installation and maintenance of automatic weather stations and Eddy covariance flux towers in Sub-Saharan West Africa.

In 2017, a long-term dream came true when he and his family moved to higher grounds (5400-ish feet) and joined CU/CIRES and NOAA-GSL in Boulder. At NOAA-GSL, Dom held the roles of the lead developer of the Common Community Physics Package (CCPP) and of a code manager for the NOAA Unified Forecast System. In 2021, he joined JCSDA across town to help with integrating JEDI for research and operations.

In his free time, Dom enjoys trail running, rock climbing, mountaineering, Nordic skiing, backcountry skiing, and camping in the magnificent Colorado Rocky Mountains. He is also an aspiring DIYer working endlessly (too much according to his family) on his house, the garden, the family car fleet and the camping trailer. Prior to his family life, Dom also sang in various choir groups, with some of the highlights being appearances in opera choirs for "Nabucco" and "The flying Dutchman", and a concert with the unsurpassed master of choir conducting, Eric Ericson.



Dr. Christian Sampson

Dr. Christian Sampson joined JCSDA in December of 2020 as a Project Scientist with the JEDI core team to help develop hybrid 4D-VAR methods for the JEDI system.

Originally from Salt Lake City, Utah, Christian studied mathematics, Physics, and Earth Science as an undergraduate and graduated from the University of Utah with a PhD in Mathematics in 2017. As a graduate student in mathematics, Christian focused on modeling physical processes in Sea Ice and Climate using novel approaches from mathematics. Christian also participated in Sea Ice Physics and Ecosystem Experiment II (SIPEX II) aboard the Aurora Australis in Antarctica measuring fluid flow through the porous structure of sea ice as well as participating in field work in Utqiaġvik, Alaska studying sea ice in the Arctic Ocean. As a postdoc, Christian participated in the Breaking Bubbles Cruise aboard the RV Sikuliaq in December 2019 studying wave energy dissipation in stormy seas in the Gulf of Alaska. These experiences showed Christian how powerful a blend of data and models is for forwarding our understanding of complex physical processes.

Prior to joining JCSDA, Christian was a postdoc at the Statistical and Mathematical Sciences Institute (SAMSI) in 2017 participating in a year on the mathematics and statistics of climate. This was followed by a position at the University of North Carolina at Chapel Hill where he was introduced to Data Assimilation developing EnKF schemes for models with adaptive moving meshes. During this time Christian became heavily involved in Data Assimilation and never wanted to stop. He is very excited to continue at JCSDA as a part of the JEDI team.

Originally from the mountain west, Christian is excited to call the Front Range home and enjoys recreation of all types in the mountains.

Lindsey Hayden

Lindsey Hayden joined the JCSDA in February of 2022 as visiting scholar with the observation team. She is working on observation error estimation of GPS radio occultation data.

Lindsey is originally from Oregon, but grew up in Colorado in the Denver/Boulder metro area. In 2013, she received a Bachelor's in Meteorology from Metropolitan State University of Denver. She then moved to Saint Louis, where she received a Master's in Meteorology from Saint Louis University in 2015. She started work on her PhD in the fall of 2016 at Texas A&M University - Corpus Christi, under the direction of Dr. Chuntao Liu. Her work during this time was focused on satellite remote sensing of clouds and precipitation using multiple satellite precipitation datasets. She successfully defended her dissertation at the beginning of February and will officially graduate with her PhD in May.

Outside of work, Lindsey enjoys reading, knitting, and playing games, as well as outdoor hobbies such as hiking, camping, and skiing. She currently lives in Arvada with her fiance Jeremy.

SCIENCE CALENDAR

Meetings of Interest

TITLE	DATE	LOCATION	WEBSITE
International Symposium on Data Assimilation	June 6-10, 2022	Fort Collins, CO	https://www.cira.colostate.edu/conferences/ isda/
20th JCSDA Technical Review Meeting and Science Workshop	Sep 7-9, 2022	Boulder, CO and online	To be provided
11th AMS Symposium on the JCSDA (as part of the 103rd AMS Annual Meeting)	Jan 8-12 2023	Denver, CO and online	https://annual.ametsoc.org/index.cfm/2023/program-events/conferences-and-symposia/11th-ams-symposium-on-the-joint-center-for-satellite-data-assimilation-jcsda/
JEDI Short Course (as part of the 103rd AMS Annual Meeting)	Jan 8-12 2023 TBC	Denver, CO	

CAREER OPPORTUNITIES

Opportunities in support of JCSDA may be found at https://www.jcsda.org/opportunities as they become available.