

# S2S Community Workshop: Toward Minimizing Early Model Biases and Errors in S2S Predictions

June 5-7, 2024 | Boulder, CO

**WEDNESDAY**

## *Morning Sessions*

**8:30 AM | Check-In**

**8:45 AM | Opening Remarks**

**Welcome and Workshop Logistics** | Ray Tanabe and Mark Olsen, NOAA Weather Program Office

**9:15 AM | Keynote Presentation**

**Subseasonal-to-seasonal prediction: Recent advances and challenges** | Frederic Vitart, ECMWF

**10:00 AM | Coffee Break**

**10:30 AM | Lessons Learned: Reducing of Model Biases Part I** | Moderator: Cristiana Stan

**Unified Forecast System – Configurations towards S2S applications** | Avichal Mehra, NOAA Environmental Modeling Center

**Tackling model biases in GFDL climate and prediction models** | Baoqiang Xiang, NOAA Geophysical Fluid Dynamics Laboratory

**Lessons learned at NASA's GMAO: Reduction of GEOS-S2S-3 model systematic error** | Andrea Molod, NASA Goddard Space Flight Center

**Towards reduced error in climate forecasts: A CESM perspective** | Stephen Yeager, NCAR

**12:00 PM Lunch Break**

## *Afternoon Sessions*

**1:15 PM | Lessons Learned: Reducing of Model Biases Part II** | Moderator: Cristiana Stan

**Multi-pronged approaches for addressing model biases relevant to S2S predictions** | Ruby Leung, DOE Pacific Northwest National Laboratory

**Towards reduction of atmospheric forecast errors in Navy ESPC** | Jim Ridout, U.S. Navy

**Enhancing Air Force weather capabilities: Collaboration with NASA on subseasonal-to-seasonal prediction** | Louis Escamilla, U.S. Air Force

**2:15 PM | Discussion Panel: Next Steps and Best Practices** | Moderator: Cristiana Stan

*Panelists:*

**Louis Escamilla**, *U.S. Air Force*

**Ruby Leung**, *DOE Pacific Northwest National Laboratory*

**Avichal Mehra**, *NOAA Environmental Modeling Center*

**Andrea Molod**, *NASA Goddard Space Flight Center*

**Jim Ridout**, *U.S. Navy*

**Frederic Vitart**, *ECMWF*

**Baoqiang Xiang**, *NOAA Geophysical Fluid Dynamics Laboratory*

**Stephen Yeager**, *NCAR*

**3:15 PM | Coffee Break**

**3:30 PM | Discussion Panel: End User Needs and Engagement** | Moderator: Christine Bassett

**Listening to End Users: Lessons Learned from a Series of Workshops Concerning S2S Precipitation Forecasts** | Melanie Schroers, University of Oklahoma

*Panelists:*

**Michael Anderson**, *California Department of Water Resources*

**Jerry Cotter**, *U.S. Army Corps of Engineers (USACE), Fort Worth District*

**Simon Mason**, *Columbia Univ. Int'l Research Institute for Climate and Society (IRI)*

**Melanie Schroers**, *University of Oklahoma*

**Amanda Sheffield**, *National Integrated Drought Information System (NIDIS)*

**Wendy Stout**, *Virginia Tech Coastal Collaborator Center*

**5:00 PM | Adjourn**

## THURSDAY

### *Morning Sessions*

**8:45 AM | Welcome**

**9:00 AM | Model Errors/Biases and Process Studies Part I**

**A process-based evaluation of biases in stratosphere-troposphere coupling in subseasonal forecast systems** | Amy Butler, NOAA Chemical Sciences Laboratory

**A likely cause of rapidly developing model biases in the western tropical Pacific** | Prashant Sardeshmukh, NOAA Physical Sciences Laboratory

**Tropical convective variability in the NOAA UFS – A process level assessment** | Vijit Maithel, NOAA Physical Sciences Laboratory

**Tackling systematic errors over the Indian Ocean in Met Office and partners seamless coupled models** | Charline Marzin, UK Met Office

**10:00 AM | Coffee Break**

**10:15 AM | Model Errors/Biases and Process Studies Part II**

**Tropical origins of subseasonal forecast errors for high-impact precipitation events over California during winter 2022–2023** | Benjamin Moore, NOAA Physical Sciences Laboratory

**Evaluation of biases in UFS hindcasts at seasonal timescales** | Benjamin Green, NOAA Global Systems Laboratory

**The impact of vertical model levels on biases affecting the MJO teleconnections** | Cristiana Stan, George Mason University

**MJO Prediction analysis in S2S forecast models** | Raina Roy, Monash University

**Influence of atmospheric errors on Weeks 2-4 California Current System predictions** | Maria Gehne, NOAA Physical Sciences Laboratory

**Predictive skill and bias of synoptic variables during extended extreme precipitation events in S2S project models** | Melanie Schroers, University of Oklahoma

**Accuracy assessment of weekly accumulated precipitation in the NCEP GFS model in La Plata basin** | Lucia Casatro, National Meteorological Service (Argentina)

**11:45 AM | Open Discussion**

**12:15 PM | Lunch Break**

*Afternoon Sessions*

**1:30 PM | Model Coupling and Development**

**UFS forecast model evaluation and improvement for S2S hydrometeorological prediction in the western United States** | Yifan Cheng, NCAR

**Enhancing snowpack physics in Noah-MP land model to improve S2S prediction of precipitation and droughts** | Cenlin He, NCAR

**An overview of the marine components in NOAA's Global Ensemble Forecast System (GEFS) and Seasonal Forecasting System (SFS)** | Neil Barton, NOAA Environmental Modeling Center

**A contribution to ocean skin temperature parameterization** | Rainer Bleck, NOAA Global Systems Laboratory

**Advancements in physics parameterizations for Global Earth System Modeling: Unveiling GFSv17/GEFSv13/SFSv1 physics under the Unified Forecast System (UFS)** | Lisa Bengtsson, NOAA Physical Sciences Laboratory

**State-dependent Forecast Skill in S2S-Forecasts with and without Stochastic Parameterizations** | Judith Berner, NCAR

**3:00 PM | Coffee Break**

**3:15 PM | Bias Correction**

**Run-time bias correction of CanESM5 and its impact on seasonal forecast skill** | Bill Merryfield, Environment And Climate Change Canada

**Empirical and ML/AI ocean bias correction for GFDL SPEAR predictions** | Feiyu Lu, NOAA Geophysical Fluid Dynamics Laboratory

**Use of AI to perform inline bias correction of NOAA UFS extended-range forecasts** | Stefan Tulich, NOAA Physical Sciences Laboratory

**Tropical and midlatitude S2S prediction using UFS and machine learning** | Eric Maloney, Colorado State University

**Influence of trends on S2S temperature prediction** | Yuan-Ming Cheng, NOAA Physical Sciences Laboratory

4:15 PM | Open Discussion

5:00 PM | Poster Session

6:30 PM | Optional Dinner at Rayback Collective (2775 Valmont Rd, Boulder, CO 80304)\*

\*Please note that the optional dinner is an informal gathering for continued conversations and costs are not covered by the workshop organizing committee.

## FRIDAY

### *Morning Sessions*

8:45 AM | Welcome

9:00 AM | Data Assimilation and Forecast Initialization

**Ensemble versus extended Kalman filter based land data assimilation for the soil diffusion based ISBA model** | Lodh Abhishek, Swedish Meteorological and Hydrological Institute

**Correction of Tibetan Plateau soil temperature bias and regional and global subseasonal-to-seasonal precipitation predictability: The GEWEX/LS4P Project** | Yongkang Xue, University of California, Los Angeles

**Use of analysis increments to advance MJO prediction in the NOAA UFS** | Stefan Tulich, NOAA Physical Sciences Laboratory

**Short term model errors that lead to errors in the structure of ENSO** | Philip Region, NOAA Physical Sciences Laboratory

**The NOAA global Aerosol ReAnalysis (NARA)** | Bo Huang, NOAA Global Systems Laboratory

10:00 AM | Coffee Break

10:15 AM | Diagnostic, Validation, and Verification

**Large-scale surface air temperature bias in summer over the CONUS and its relationship to tropical central Pacific convection in the UFS Prototype 8** | Nakbin Choi, George Mason University

**Point-Biserial Correlation-Based Skill Scores for Probabilistic S2S Forecasts** | Nachiketa Acharya, Science, Analytics, and Innovation (SAI) Consultants LLC

**Rapid development of systematic trend errors in seasonal forecasts and their connection to CMIP6 trend errors** | Jonathan Beverley, NOAA Physical Sciences Laboratory

**Dynamical filtering of tropical variability** | David Marsico, NOAA Physical Sciences Laboratory

**An overview of subseasonal verification at the Environmental Modeling Center** | Shannon Shields, NOAA Environmental Modeling Center

**Towards seasonal verification in the Environmental Modeling Center (EMC) Verification System (EVS)** | Amandeep Vashisht, NOAA Environmental Modeling Center

**Diabatic heating as a diagnostic for predictability on weather and intra-seasonal time scales** | David Straus, George Mason University

**11:45 AM | Open Discussion**

**12:15 PM | Lunch Break**

*Afternoon Sessions*

**1:30 PM | Innovative Forecasting Techniques and Tools |**

**Advances in METplus verification capabilities for subseasonal-to-seasonal evaluation** | Christina Kalb, NCAR

**Hybrid deep learning and model-analog forecasting of ENSO** | Kinya Toride, NOAA Physical Sciences Laboratory

**Analyzing biases in AI subseasonal-to-seasonal (S2S) weather forecasting: A comparative study of temperature and precipitation predictions** | Naveen Sudharsan, University of Texas at Austin

**Improved subseasonal prediction of South Asian monsoon rainfall using data-driven forecasts of oscillatory modes** | Eviatar Bach, California Institute of Technology

**(Withdrawn) Identifying weather regimes and predicting regime-driven renewable energy potential at subseasonal-to-seasonal timescales over Africa** | RajeevS Kurup, University of Hertfordshire Centre for Atmospheric and Climate Physics Research

**Predictability of summer surface maximum temperature extremes on sub-seasonal scale over CONUS** | Murali Nageswara Rao Malasala, UCAR

**An Earth system and process-oriented view of the S2S predictability of weather regimes using machine learning** | Jhayron Pérez-Carrasquilla, University of Maryland

**3:00 PM | Coffee Break**

**3:15 PM | Operational and Research Infrastructure Needs**

**NOAA's Seasonal Forecast System (SFS) Development Plan: A community modeling approach to increase S2S forecast skill** | Yan Xue, NOAA National Weather Service Office of Science and Technology Integration

**Development of hydrostatic Seasonal Forecast System development within the Unified Forecast System** | Xiaqiong Zhou, NOAA Environmental Modeling Center

**Transitioning subseasonal-to-seasonal research from the American weather enterprise to the NWS Operations** | Chandra Kondragunta, NOAA Weather Program Office

**4:00 PM | Panel Discussion: Metrics for Success in S2S Predictions**

**5:00 PM | Summary and Closing Remarks**

**5:15 PM | Adjourn**

## Invited Speaker and Panelist Bios

### Modeling Center Discussion Panelists

#### Dr. Frank Vitart, European Centre for Medium-Range Weather Forecasts (Keynote Speaker)

Dr. Frédéric Vitart is a Senior Research Scientist at the European Centre for Medium-Range Weather Forecasts (ECMWF), where he leads the team on extended-range prediction. With over 20 years of experience in sub-seasonal and seasonal prediction, coupled ocean-atmosphere modeling, tropical and mid-latitude meteorology, and tropical cyclone prediction, he has significantly contributed to the field. From 2013 to 2023, he co-chaired the joint World Weather Research Programme and World Climate Research Programme sub-seasonal to seasonal prediction project (S2S).

#### Mr. Louis Escamilla, U.S. Air Force

Mr. Louis Escamilla serves as the Chief of Environmental Science Integration at HQ USAF, Air Force Weather at the Pentagon, and the Lead Physical Scientist for Climate and Hydrology Plans at the Headquarters Air Force, Directorate of Weather. With a deep expertise in Earth System Science encompassing meteorology, oceanography, climatology, and hydrology, Mr. Escamilla plays a pivotal role in shaping policy and directing scientific analyses for military operations integration. His extensive career spans over 30 years in military meteorology, during which he has managed significant weather programs and advocated for environmental science policies. Mr. Escamilla is currently pursuing a Ph.D. in Strategic Leadership at Liberty University, focusing on integrating Artificial Intelligence and Machine Learning into environmental information services. His career includes providing strategic weather operations support as Acting Chief, Weather Division, at the Pentagon, significantly contributing to military and governmental strategic planning.

#### Dr. Ruby Leung, DOE Pacific Northwest National Laboratory

Dr. L. Ruby Leung is a Battelle Fellow at Pacific Northwest National Laboratory, and a leading scientist in climate modeling, water cycle dynamics, and extreme weather events. She serves as the Chief Scientist for the Department of Energy's Energy Exascale Earth System Model (E3SM), overseeing a collaborative effort of earth scientists and mathematicians to enhance Earth system modeling capabilities. An elected member of the National Academy of Engineering and Washington State Academy of Sciences, Dr. Leung is also a fellow of the American Meteorological Society, American Association for the Advancement of Science, and American Geophysical Union. She has received numerous accolades, including the AGU Global Environmental Change Bert Bolin Award, the AGU Atmospheric Science Jacob Bjerknes Lecture, and the AMS Hydrologic Sciences Medal. Dr. Leung earned her BS in Physics and Statistics from the Chinese University of Hong Kong and her MS and PhD in Atmospheric Sciences from Texas A&M University. She has authored over 500 peer-reviewed publications.



### **Dr. Avichal Mehra, NOAA Environmental Modeling Center**

Dr. Avichal Mehra has approximately 25 years of experience in leading scientific development and research in operational forecasting, dynamics of coupled atmosphere-land-ocean-wave models, numerical analysis, model diagnostics, and the analysis and interpretation of geophysical data and model results. As Chief of the Coupled Modeling Division at the National Weather Service/National Centers for Environmental Prediction (NWS/NCEP), Dr. Mehra provides key scientific and technical leadership. He has played a pivotal role in the development and operationalization of hurricane models and global ocean forecast systems at NWS/NCEP for over a decade. Dr. Mehra serves as Co-lead of the UFS-S2S Global Application Team, Co-chair of the ICAMS implementation team for Global Coupled Modeling, and represents NWS/NCEP in WMO/IOC's Expert Team on Operational Ocean Forecast Systems (ETOOFS).

### **Dr. Andrea Molod, NASA Goddard Space Flight Center**

Dr. Andrea Molod is a Physical Research Scientist at NASA's Goddard Space Flight Center within the Global Modeling and Assimilation Office (GMAO), where she leads the Seasonal Prediction system group. Dr. Molod manages NASA's efforts related to predictions ranging from several weeks to several years and focuses on enhancing the ability of climate models to forecast earth's climate evolution from months to decades. She earned her BA in Physics from Clark University, an MS in Meteorology from the University of Maryland, and a PhD in Atmospheric Dynamics from The Johns Hopkins University. Dr. Molod completed her post-doctoral research at MIT in the department of Earth, Atmospheric and Planetary Sciences.

### **Dr. Jim Ridout, U.S. Navy**

Dr. Jim Ridout received his B.S. in Chemistry from the University of California, Berkeley, and furthered his education at the University of Wisconsin-Madison, earning an M.A. in Mathematics and a Ph.D. in Physics. Since 1991, Dr. Ridout has been with the Naval Research Laboratory in Monterey, California, where he leads model physics development for the atmospheric component of the Navy Earth System Prediction Capability (ESPC) coupled system. His work primarily focuses on atmospheric convection and improving its representation in Navy forecast systems. Dr. Ridout developed the Modified Kain-Fritsch (MKF) scheme, enhancing parameterization in forecast models based on his research with cloud-resolving forecasts and his role as a principal investigator in several Navy projects aimed at unifying physical process representations for extended-range prediction. His contributions have significantly improved the simulation of the Madden-Julian Oscillation within the Navy ESPC, enhancing prediction accuracy on numerical weather prediction time-scales.

### **Dr. Baoqiang Xiang, NOAA Geophysical Fluid Dynamics Laboratory**

Dr. Baoqiang Xiang is a CPAESS Project Scientist at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) within the Weather and Climate Dynamics Division. With more than 15 years of experience in atmospheric and coupled model development, his research focuses on understanding the variability and predictability of various phenomena, particularly subseasonal prediction and predictability. Dr. Xiang currently leads the development of the GFDL subseasonal forecast system using the GFDL SPEAR model and co-leads the development of GFDL's next-generation Atmospheric Model AM5. In 2019, he was honored with the International Prize for Model Development by the World Climate Research Programme (WCRP) and the World Weather Research Programme (WWRP).

### **Dr. Stephen Yeager, National Center for Atmospheric Research**

Dr. Steve Yeager is a Project Scientist IV in the Climate Change Research section of the Climate and Global Dynamics Laboratory at NCAR. Since joining NCAR in 1998, Dr. Yeager has focused on research in large-scale ocean dynamics, decadal climate variability and predictability, and seasonal to decadal forecasting. He holds a M.Sc. in Physics from Brown University and a PhD in Atmospheric and Oceanic Sciences from the University of Colorado at Boulder. Dr. Yeager currently co-chairs the Earth System Prediction Working Group of the CESM project, the World Climate Research Programme's Decadal Climate Prediction Project, and serves as an Editor of the Journal of Climate.

## **End User Discussion Panelists**

### **Dr. Michael Anderson, California Department of Water Resources**

Dr. Michael Anderson is the State Climatologist for California, a collaborative role between the State and the National Oceanographic and Atmospheric Administration to provide climate data services for California. He began his tenure in the Department of Water Resources Division of Flood Management (DWR-DFM) Forecasting Section in July 2005 and was appointed State Climatologist in 2007. Currently, Dr. Anderson works in the Executive Division of the Department of Water Resources, where he provides technical knowledge and advice for climate-resilient resources management.

### **Mr. Jerry Cotter, U.S. Army Corps of Engineers (USACE), Fort Worth District**

Mr. Jerry Cotter is the Chief of Water Resources for the U.S. Army Corps of Engineers (USACE) in the Fort Worth District. Prior to this role, Jerry served as Chief of Water Management for the district. His branch manages 25 multi-purpose reservoirs and conducts hydrologic investigations for watersheds across Texas. Jerry was a founding member and currently serves as past chair of the USACE national organization of Water Management Chiefs (WMIST). In 2014, Jerry collaborated with FEMA, the U.S. Geological Service, and the National Weather Service to establish the Interagency Flood Risk Management Team (InFRM) for the Texas region, and he currently serves on its steering committee. Jerry also serves as the principal district liaison for

the North Central Texas Council of Governments (NCTCOG), the Texas Water Development Board (TWDB), and the General Land Office (GLO). He maintains strong relationships with various river authorities and water districts across the state. Jerry brings a broad range of experience, including 30 years with the federal government and 10 years in the private sector, working on a variety of infrastructure projects, including transportation, water, and wastewater, as well as numerous studies within the region, nationally, and internationally.

#### **Dr. Simon Mason, Columbia University International Research Institute for Climate and Society (IRI)**

Dr. Simon Mason is the Chief Climate Scientist at Columbia University's International Research Institute for Climate and Society (IRI). He has a distinguished career in seasonal climate forecasting that began in the early 1990s. He developed empirical models for predicting southern African rainfall variability at the University of the Witwatersrand, where he was deputy director of the Climatology Research Group. At IRI, he leads international outreach and disaster initiatives, significantly contributing to the World Meteorological Organization's efforts in forecasting and verification standards. He also co-authored the Global Framework for Climate Services Implementation Plan and leads the development of the Climate Predictability Tool (CPT). Dr. Mason's work enhances the usability of climate forecasts globally, tailoring them to diverse user needs and promoting scientific insights for humanitarian efforts.

#### **Ms. Melanie Schroers, Doctoral Candidate, University of Oklahoma School of Meteorology**

Ms. Melanie Schroers is a PhD Candidate within the School of Meteorology at the University of Oklahoma. Since 2018, she has worked alongside the NSF-funded PRES2iP team of researchers, advised by Dr. Elinor Martin, focusing on S2S extreme rainfall events. Her work has concentrated on understanding the perspectives and needs of various stakeholders through hands-on workshops, as well as S2S predictability of extreme rainfall, incorporating stakeholder needs into her research. She plans to defend her dissertation on these subjects later this year and is seeking post-graduation employment that combines science with user needs.

#### **Dr. Amand Sheffield, National Integrated Drought Information System (NIDIS)**

Dr. Amanda Sheffield is a Regional Drought Information Coordinator for NOAA's National Integrated Drought Information System (NIDIS) and a Senior Associate Scientist with CU Boulder's Cooperative Institute for Research in Environmental Sciences (CIRES). She serves as the NIDIS program point of contact for the California-Nevada Drought Early Warning System (DEWS). In this role, she works to strengthen integrated systems for drought monitoring, forecasting, and planning and preparedness jointly with federal agency partners, tribes, states, municipalities, partner academic institutions, and other organizations. Building on her expertise, she also supports NIDIS efforts related to S2S forecasting, including managing a project to improve the NOAA NWS CPC operational Drought Outlooks, as well as big data and cloud computing and western drought issues such as snow drought. Before joining NIDIS, Amanda worked with the California-Nevada Adaptation Program (CNAP), a NOAA CAP/RISA team. She

holds an M.S. and Ph.D. in Atmospheric Science from Colorado State University and a B.S. in Synoptic Meteorology from Purdue University.

### **Dr. Wendy Stout, Virginia Tech Coastal Collaborator Center**

In her role as Director of the Virginia Tech Coastal Collaborator Center in Hampton, VA, Dr. Wendy Stout focuses on leading Virginia Tech's collaboration in the area of coastal resilience and the adaptation economy. Stout's primary focus is connecting the extensive capacity at VT with coastal stakeholders to address coastal resilience challenges. Before her current role, Stout served as the GIS Manager for the Commonwealth of Virginia, a program manager for NASA, and a GIS analyst for FEMA.