GEWEX QUARTERLY

WCRP

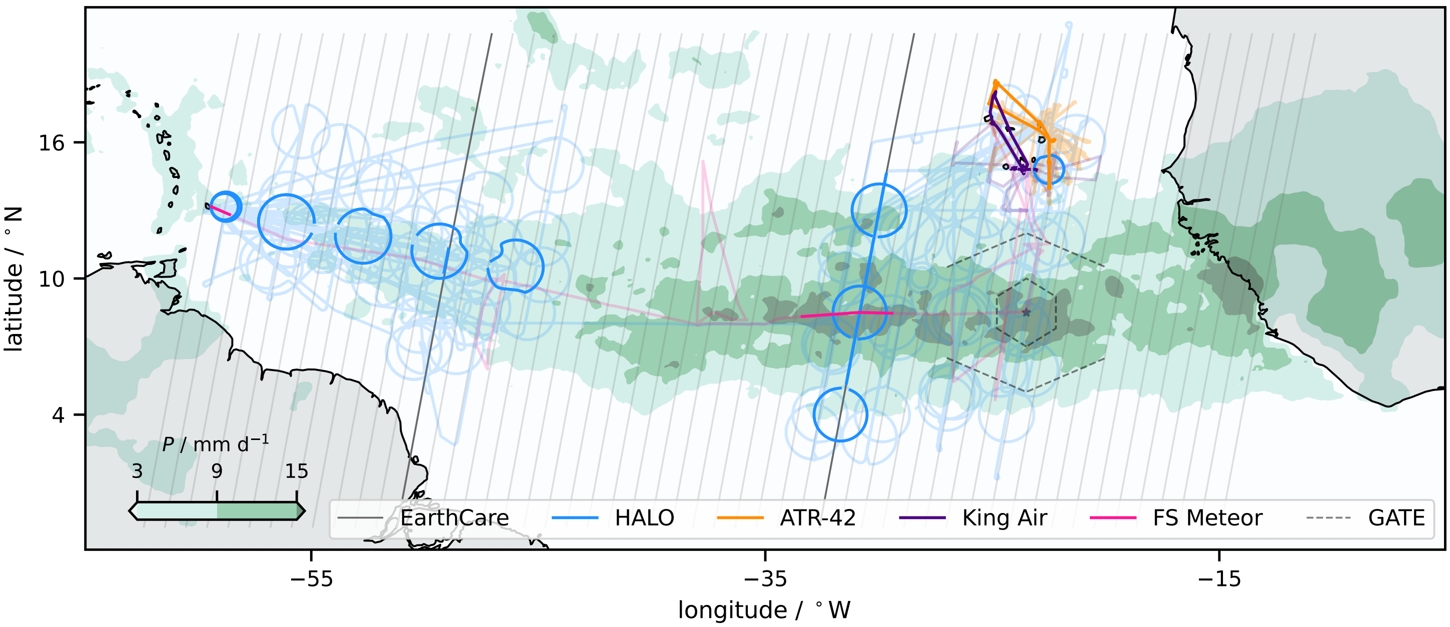
United Nations Educational, Scientific and Cultural Organization | Intergovernmental Oceanographic Commission

World Meteorological Organization | International Science Council

Vol. 35, No. 2 | Quarter 2 2025

GEWEX is a Core Project of the World Climate Research Programme on Global Energy and Water Exchanges

The ORCESTRA Field Campaign



This figure illustrates the location and scope of the ORCESTRA field campaign, which focuses on the impact of deep convection in the tropical Atlantic. The tracks taken by different platforms during the campaign in the research area in August and September 2024 are shown here, highlighting example tracks through thick lines. Green patches represent the precipitation from JAXA's Global Satellite Mapping of Precipitation (GSMaP) global rainfall watch during the campaign period. EarthCARE is the latest satellite by ESA/JAXA (grey). The High Altitude and Long Range Research Aircraft (HALO, blue), ATR-42 (orange), and King Air (purple) represent the German, French, and Romanian aircrafts respectively, while FS METEOR (pink) is the German research vessel. The dashed dark grey lines represent the area where the Global Atmospheric Research Program's Atlantic Tropical Experiment (GATE), an influential early atmospheric field campaign, took place in 1974. (Credit: Bjorn Stevens.) See page 8 for the full article.

Inside This Edition

Commentary

Peter van Oevelen
Director, International GEWEX Project Office

Early this February, we had our 37th GEWEX Scientific Steering Group (SSG) meeting in Wellington, New Zealand, graciously hosted by Victoria University and Rogier Westerhoff and colleagues. We thank them for being such excellent hosts in such a wonderful environment. Only while I am writing this am I realizing it was my 20th SSG meeting. Sure, time flies, and I'd rather not further reminisce on that, but what struck me most is that I still enjoy these meetings (as I do our Panel meetings!), and they still reinvigorate me. It's always good to see your colleagues and friends again and certainly in enjoyable places such as Wellington. Yet the open discussions, scientific progress presented, and a sense of community that one is exposed to during these meeting is what makes it such a delight to experience. My wish is that we can hold on to that in these challenging times. As always, a short summary of the meeting is available in this edition of the *Quarterly*, and soon there also will be a more extensive report published on our website.

The world is changing rapidly, and the certainties of a few months ago are gone. For GEWEX and the International GEWEX Project Office (IGPO), it is still not clear what that exactly will entail, but we can already see the effects and fallout. Longtime colleagues in U.S. institutions and universities are working under great uncertainty, and some have already left their jobs through early retirement or other circumstances. Aside from the many personal tragedies, the losses of research infrastructure, satellite missions, data, and knowledge will prove dreadful in their own right. But it is the inevitable change in culture that is taking place that has me especially worried. Scientific collaboration is not just sharing data and resources: it is about creating mutual understanding and respect. It fosters the realization that we as humans face the same problems and that we are not alone. By tackling these challenges together in a multi-institutional and multi-national, even global, framework, we not only create more and better knowledge and solutions, but also better science, scientists, and thus societies.

It is encouraging to see many researchers, institutions, and countries around the world stepping up and creating opportunities, for example, supporting backups and alternative infrastructure. This needs to continue and expand. Science and the arts are society's pathways to progress. We cannot afford to falter now. And if you are wondering what you can do, you could start by reaching out to your U.S. colleagues, or for example, by sharing job opportunities. Think also about what the consequences for your research project could be if you lose access to U.S.-funded data or infrastructure, and what possible mitigation strategies are. GEWEX Scientific Steering Group Co-Chair Jan Polcher asked for your support in safeguarding the continuation of the IGPO in the first *Quarterly* of this year, and as we are still facing uncertainty, we would love to hear from you. Yet it goes beyond the IGPO: our research community is facing one of the biggest challenges it has ever faced. We need your help!

Table of Contents

New GEWEX Panel Members

Dr. Carla Gulizia is a climate scientist at the Research Centre of the Sea and the Atmosphere (CIMA/CONICET-UBA) and the Franco-Argentine Institute for the Study of Climate and its Impacts (IFAECI). She is also Professor at the University of Buenos Aires. Her research explores hydroclimate variability and change in South America, with emphasis on climate extremes, El Niño-Southern Oscillation teleconnections, and impacts on water resources. Dr. Gulizia has been engaged with GEWEX for about a decade, co-organizing early-career researcher activities with the Young Earth System Scientists (YESS) community and serving on the Global Atmospheric System Studies (GASS) Panel (2020–2023). She is part of the Argentine Regional Hub of the World Climate Research Programme (WCRP) My Climate Risk Light House Activity, the Scientific Committee of the ANDEX Regional Hydroclimate Project, and serves as Vice-Chair of the World Meteorological Organization EC-Capacity Development Panel. She is also President of the Argentine Meteorological Society. As a new GEWEX Hydroclimatology Panel (GHP) member, she brings regional hydroclimate expertise and a strong commitment to advancing inclusive and collaborative science.

Georgia (Gia) Destouni is a new member of GHP. She is a Professor of Hydrology and Water Resources at Stockholm University, and a Guest Professor of Engineering Hydrology at KTH Royal Institute of Technology, in Stockholm, Sweden. She is further a member of the Baltic Earth Science Steering Group, and Editor in Chief of the journal Water Resources Research of the American Geophysical Union (AGU). The topics of her expertise include hydroclimate, water systems, diffuse water pollution, water environment and environmental change. Her research is on the flows, quality, and storage of water in various forms/phases at and below the land surface, their coherent integration in the terrestrial water system continuum, and the interactions of the terrestrial water system with the atmosphere, climate, ocean, and the various social, environmental, and ecosystem conditions around the world. Overall, her research interests align very well with and she is enthusiastic about contributing to the aims and scope of GHP.

Marc Calaf is an Associate Professor in the Department of Mechanical Engineering and is jointly appointed as Associate Professor in the Department of Atmospheric Sciences at the University of Utah. He received his B.S. degree in Physics from the University of Barcelona, Spain, in 2006, and a Ph.D. degree from École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, in 2011. Between 2007 and 2009, he was a visiting scholar in the Department of Mechanical Engineering at Johns Hopkins University. After his Ph.D., he was a postdoctoral fellow at EPFL for one year. He has been on the University of Utah faculty since 2013. His area of research is focused on understanding and modeling environmental fluid mechanics and renewable energy systems. Dr. Calaf is an Associate Editor of the *Journal of Atmospheric Sciences*, and a former Associate Editor of the *Journal of Sustainable and Renewable Energies*. Dr. Calaf is a member of the American Physics Society, the American Geophysics Union, and the American Meteorological Society. As a member of the GEWEX GLASS Panel, he will contribute in developing new understanding and exploring alternative representations of land-atmosphere interactions on heterogenous and complex terrain in Earth System Models.

John Pomeroy Awarded Dooge Medal

Congratulations to Prof. John Pomeroy of the University of Saskatchewan, winner of the Dooge medal for 2025. The Dooge medal is one of two International Hydrology Prizes awarded each year by the International Association of Hydrological Sciences (IAHS) together with UNESCO and WMO, and Prof. Pomeroy was selected for "critical advancements to improve our understanding of climate warming as well as the cryosphere, hydrological processes, and hydrological predictions in cold regions and ungauged basins around the world" (*https://iahs.info/News/news/2025-iahs-unesco-wmo-international-hydrology-prize/*). Prof. Pomeroy has long been involved in GEWEX, leading Global Water Futures (GWF) and the International Network for Alpine Catchment Hydrology (INARCH), two GEWEX Hydroclimatology Panel projects, as well as hosting the 8th GEWEX Open Science Conference in Canmore, Canada, in 2018. His contributions to our understanding of cold region hydrology have benefitted GEWEX science and beyond.

Activities from the Young Earth System Scientists (YESS) Community

Gerbrand Koren[1], Valentina Rabanal[2], and the YESS Executive Committee

[1]Copernicus Institute of Sustainable Development, Utrecht University, Utrecht, The Netherlands; [2]Servicio Meteorológico Nacional (SMN), Buenos Aires, Argentina

The Young Earth System Scientists community is a bottom-up network with members taking up leadership positions through a process of (self-)nomination and open election. The annual election procedure for regional representatives and executive committee members was recently concluded. This open process ensures that we have motivated leaders with the wide support of the community. The role also provides early career researchers (ECRs) the opportunity to gain valuable leadership and managerial experience. If you or your colleagues want to participate as candidates or cast your vote in the next election cycle, then do not hesitate to join our growing community by signing up at *https://www.yess-community.org*.

Earlier this year, a group of early and mid-career researchers published the perspective papers "*Connecting climate science and society: reflections from early and mid-career researchers at the World Climate Research Programme Open Science Conference 2023*" (*https://doi.org/10.3389/fclim.2024.1501216*) and "*Balancing Earth science careers in an unequal world*" (*https://doi.org/10.1038/s43247-024-01964-w*), which were both following up from discussions that took place at the World Climate Research Programme (WCRP) Open Science Conference (OSC) 2023 in Kigali, Rwanda. We are expecting to write more opinion papers about the role of early and mid-career researchers. We encourage everyone who is interested in upcoming opportunities to connect with the YESS community and attend our (virtual) monthly meetings.

Finally, YESS is also active through organizing webinars. An overview of some of the past webinars is available at *https://www.yess-community.org/activities/past-webinars/*, which includes recordings for webinars on land-atmosphere interactions, artificial intelligence, the science-policy interface, and many other topics. Currently, the YESS community is hosting a series of webinars called "Bottom-up methods for climate information" together with WCRP's My Climate Risk ECR group. The aim of the seminar series is to highlight the various methods that are implemented in My Climate Risk hubs across different disciplines. Each seminar has two presentations followed by a discussion to stimulate knowledge exchange and spark new ideas. A schedule for the planned webinars (with titles and speakers) is available at *https://www.yess-community.org/yess-mcr-webinarseries/*, including links to sign up for the webinar. We hope to see many of you in these webinars!

Shaping the Future Together: Fostering Community Among Students and Early Career Hydrologists

Adam Price[1], Sujana Timilsina[2], and Amanda Donaldson[3]

[1]2025 H3S Chair, Research Hydrologist, U.S. Forest Service; [2]2025 H3S Chair elect, Ph.D. student, University of Texas, Austin, TX, USA; Postdoctoral Fellow, University of Texas, Austin, TX, USA

Happy summer from the American Geophysical Union (AGU) Hydrology Section Student and Early Career Subcommittee (H3S)! Our group consists of 36 members representing 26 institutions internationally.

We are excited to announce the 2025 professional development fall seminar series, "Navigating (Beyond) Academic Waters", and a specific webinar focusing on effective and relevant best practices for writing Broader Impact statements in research proposals and job applications. Registration is available at *https://us06web.zoom.us/webinar/register/2117519065757/WN_q4TnJRFXR6WNwKKMIAiMkQ#/registration* and please be on the look out for specific event details on our socials and CUAHSI's website at *https://www.cuahsi.org/cyberseminars*. Leading up to that, H3S is excited to highlight previous "Navigating Academic Waters" webinars co-developed with the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI). The 2024 and 2025 series can be viewed on YouTube (*https://www.youtube.com/@CUAHSI/playlists*) and focused on a range of topics, including elements of the faculty job market and helping early career hydrologists build new collaborations and balance service in their developing careers.

Similar to prior years, H3S members are convening multiple sessions at the AGU Fall Meeting in December 2025. This year we will host a town hall on *Strategies to Navigate Early-Career Path*, which will include a panel discussion, and we will also host a town hall titled *What's next for the AGU Hydrology Section: Building an Equitable and Inclusive Community in Hydrologic Sciences* in collaboration with the AGU Hydrology section. Additionally, for the third consecutive year, we will lead a science communication session on *Thinking Outside the Box Plot: Communicating Science Beyond the Paper*.

Looking forward, we have a lot of great events planned for 2025! Stay up to date with all our happenings through our various platforms (visit our website at *https://www.agu-h3s.org/* for more information) and subscribe (*https://www.agu-h3s.org/contact*) to our newsletter.

Email: *h3s.agu@gmail.com*
Link Tree: *https://linktr.ee/H3S.AGU*
Website: *https://www.agu-h3s.org/*
Twitter (X): *https://twitter.com/AGU_H3S*
LinkedIn: *https://www.linkedin.com/company/agu-h3s*

COMBLE MIP: Connecting Mesoscale Organization to Cloud-Radiation Feedbacks in the Arctic

Timothy W. Juliano[1,2], Florian Tornow[3,4], and Ann Fridlind[4]
[1]U.S. National Science Foundation (NSF) National Center for Atmospheric Research (NCAR), Boulder, CO, USA; [2]AiDASH, Palo Alto, CA, USA; [3]Columbia University, New York, NY, USA; [4]National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies (GISS), New York, NY, USA

The Arctic is undergoing rapid climate change, warming several times faster than the global average due to strong regional feedbacks, many of which are not fully captured by current Earth system models (ESMs). Among these feedbacks, mixed-phase clouds (MPCs) that form during cold-air outbreaks (CAOs) play a critical role, yet their effects on the climate system are represented inconsistently amongst ESMs. CAOs bring cold air over relatively warm open waters, leading to vigorous air-sea exchanges and the formation of a turbulent, convective boundary layer where MPCs thrive. These clouds are often organized at the mesoscale, taking on roll and cellular structures that evolve as the boundary layer deepens downstream. Despite the prevalence of CAO MPCs, the processes driving these transitions, including the role of surface heterogeneities, wind shear, and precipitation phase partitioning, remain difficult to observe and model, contributing to persistent uncertainty in ESM predictions.

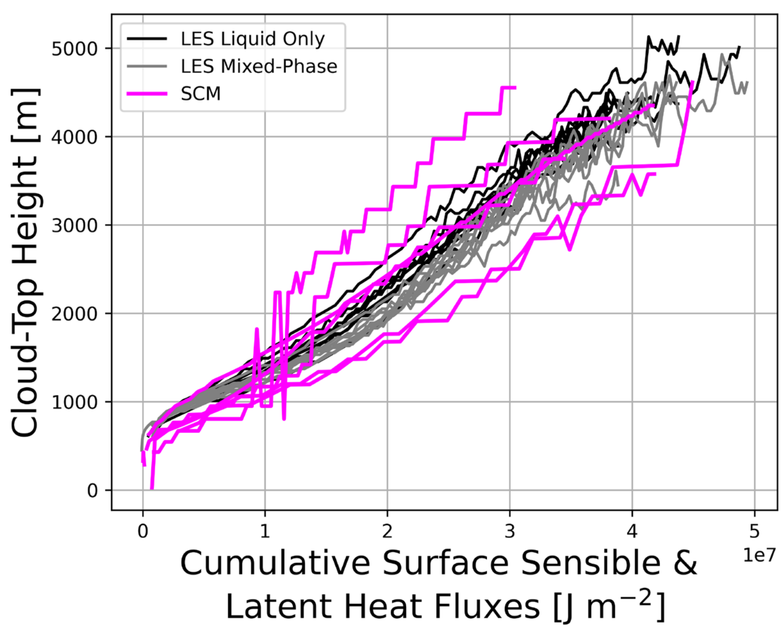


***Figure 1**. A nearly linear relationship between cumulative surface heat fluxes and cloud-top height. The x-axis is a proxy for time, following the CAO airmass.*

Modeling challenges in ESMs arise partly because these models, with their relatively coarse horizontal grid spacings (~10–100 km), cannot resolve the fine-scale dynamics that govern CAO cloud evolution. For example, roll structures initiate in shallow boundary layers and thus typically can be resolved only with large-eddy simulations (LES) and with the right boundary conditions. LES, especially when driven by detailed observations, is critical for resolving cloud-microphysics interactions and testing process-level hypotheses. This study addresses these gaps by simulating a highly supercooled CAO in a quasi-Lagrangian, or "airmass-following", framework. By examining the coupling of dynamics, radiation, and microphysics, our work aims to improve our understanding of Arctic MPCs and inform the development of better parameterizations for use in ESMs.

To better understand shallow convection during CAO conditions in the Arctic, DOE deployed the ARM Mobile Facility #1 (AMF1) to a coastal site near Andenes, Norway (Geerts et al., 2020). Additional ground-based measurements were also deployed to the remote Bear Island. CAOs occurred roughly 20% of the time during the Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE), and recent studies have reported on the MPC structures observed at the AMF1 site (e.g., Wu and Ovchinnikov, 2022; Mages et al., 2023; Lackner et al., 2023, 2024; Juliano et al., 2024). Of the 17 CAO events documented, the 13 March 2020 case was the most intense CAO event, featuring a strong postfrontal airmass moving into the Fram Strait, with satellite imagery showing a full-fetch CAO transitioning from rolls to closed and then open cellular structures. Downwind observations at Andenes captured the open cells, with cloud tops reaching 3–5 km and cloud top temperatures nearly -40°C, along with strong vertical motions, enhanced turbulence, and cold pool formation due to intense snowfall and graupel. Because a distinct cloud transition occurred during the 13 March case, and data availability was good, we selected it to form the basis of a model-observational intercomparison project (MIP) called COMBLE MIP.

The main focus of COMBLE MIP is to evaluate the capability of numerical models to reproduce the evolution (~1000 km fetch) of Arctic convective MPC features under strong surface forcing and highly supercooled conditions. We aim to understand fundamental boundary layer and MPC properties, including the spread between state-of-the-art models, as well as explore which factors control mesoscale cloud organization and cloud physical properties in simulations under the observed conditions. One unique aspect of COMBLE MIP is the participation of both large-eddy simulation (LES) and single-column model (SCM) frameworks.

To properly simulate the full CAO cloud evolution from the ice edge to the AMF1 site, all models adopt a quasi-Lagrangian (QL) framework. This approach, informed by the European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis v5 (ERA5) and Hybrid Single-Particle Lagrangian Integrated Trajectory model (HYSPLIT) reanalysis, treats the model domain as an advected airmass, eliminating the need for horizontal advection terms. Surface and large-scale forcings are applied along a trajectory beginning over the ice edge

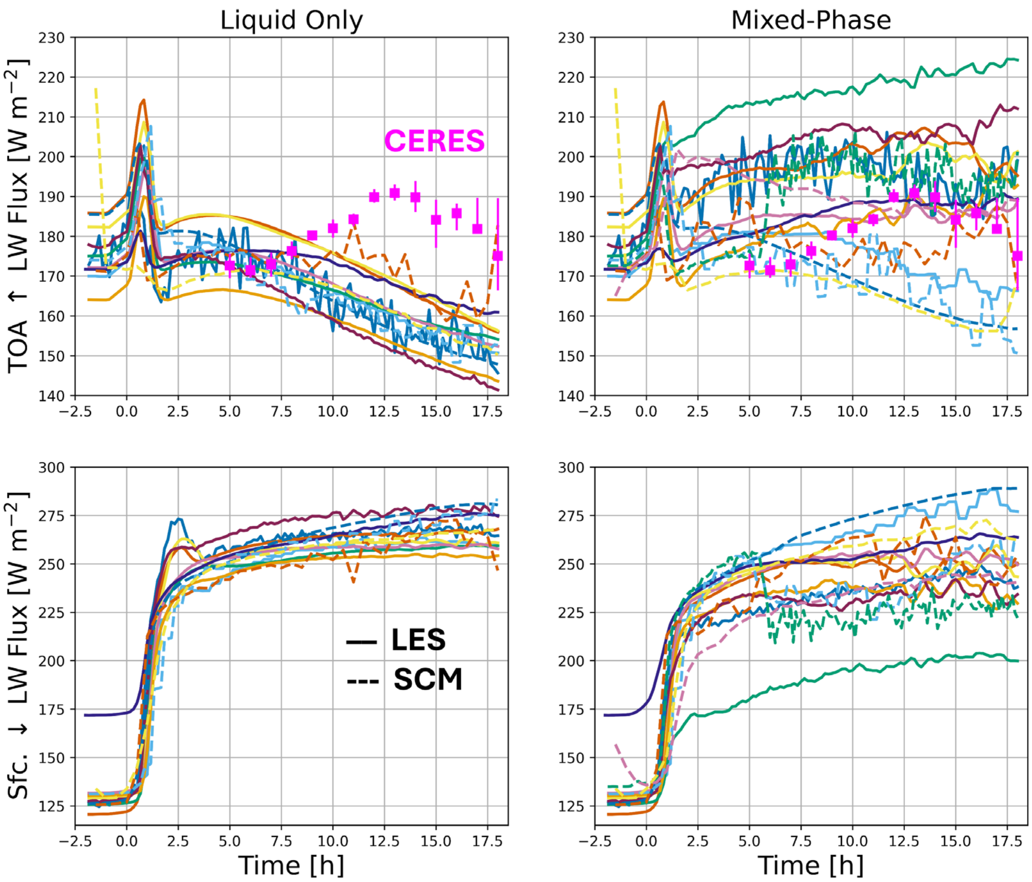


***Figure 2**. Time series of (top row) TOA upwelling LW fluxes and (bottom row) surface downwelling LW fluxes for (left column) liquid-only and (right column) mixed-phase LES (solid) and SCM (dashed) results. Each LES / SCM result has a unique color assigned to it.*

at 00 UTC on 13 March 2020 and ending at 18 UTC on 13 March 2020 at the AMF1 site. LES and SCM participants simulate a 20-hour period using doubly periodic boundary conditions, with two horizontal domain sizes (25.6 km and 128 km) and 100 m grid spacing for LES. Time-varying surface skin temperature is prescribed to allow the models to fully express turbulent exchanges (and to allow for heterogeneous surface fluxes in the LES models), with all models fixing their roughness lengths. Wind forcing is applied via geostrophic adjustment. Shortwave radiation is disabled and subsidence neglected owing to their weak impact in this particular case, and longwave (LW) radiation is model-specific. All models impose a fixed cloud droplet number concentration and diagnostic ice formation following previous Arctic MIPs (Ovchinnikov et al., 2014). Ice nucleation occurs when sufficient liquid water is present at subfreezing temperatures, mimicking immersion-mode freezing. Participants were also requested to run a liquid-only simulation, in which all ice processes were inactive.

Initial wind, temperature, and moisture profiles, as well as time-varying surface skin temperature and geostrophic wind profiles, are extracted from ERA5. We use Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) retrievals to constrain cloud top height and temperature in the upwind region (~1.5 hours downwind of the ice edge), and cloud microphysics are constrained from ~4–17 hours downwind of the ice edge using Multisensor Advanced Climatology of Liquid Water Path (MAC-LWP) satellite data (Elsaesser et al., 2017). Ground-based COMBLE measurements are leveraged to constrain surface heat fluxes, cloud top height, cloud top temperature, cloud optical depth, and liquid water path at the end of the trajectory.

To illustrate the role of surface forcing in driving vertical cloud development during the intense 13 March CAO event, we compared cumulative surface sensible and latent heat fluxes against cloud-top height (Fig. 1). A strong linear relationship emerges, with greater surface heat and moisture input corresponding to deeper cloud tops. LES liquid-only runs exhibit slightly greater cloud growth than their mixed-phase counterparts due to faster initial boundary layer growth. The LES traces overlap one another quite well, and while most SCMs capture the LES trend, there is generally more variability.

The temporal evolution of LW radiative fluxes highlights key differences between liquid-only and mixed-phase simulations (Fig. 2). Initially, when the airmass is over the pack ice and clouds have not yet formed, top-of-atmosphere (TOA) upwelling LW fluxes are relatively low. As clouds form over the warmer ocean surface, LW fluxes drop sharply due to increased contribution from the relatively cold cloud tops. While liquid-only simulations produce consistent LW flux trends across models, they significantly underestimate TOA LW fluxes later in the event compared to Clouds and the Earth's Radiant Energy System (CERES) observations. Mixed-phase simulations, on the other hand, show more variability across models, with some over- or underestimating TOA LW fluxes depending on how they represent ice processes.

Surface downwelling LW fluxes also show distinct behavior between simulations. Both liquid-only and mixed-phase runs show a rapid increase in LW fluxes after cloud formation, but the mixed-phase simulations exhibit greater inter-model spread. Analyzing the ratio of LW fluxes between liquid-only and mixed-phase cases reveals that adding ice to the models typically results in increased TOA upwelling LW flux and decreased surface downwelling LW flux, due to more broken cloud fields and smaller optical depths in the mixed-phase cases. SCMs diverge from LES in how they represent the radiative impact of ice, often underestimating its effect on cloud structure and fluxes.

Initial results reveal that both cloud cover and optical depth play critical roles in controlling LW radiative fluxes (Fig. 3). In liquid-only runs, cloud cover quickly reaches overcast conditions and remains constant for the remainder of the trajectory, while mixed-phase simulations show reduced and more variable cloud coverage, especially in LES. Higher cloud cover and larger optical depths correlate with reduced TOA LW flux as a result of the warm ocean LW emissions playing less of a role, whereas a more broken cloud field and lower optical depths allow more surface LW radiation to escape. LES models represent these relationships clearly, but SCMs generally fail to capture the effects of mesoscale cloud organization, which are necessary to accurately represent LW radiative impacts in mixed-phase conditions. Moving forward, COMBLE MIP may foster the potential for SCMs to "learn" from LES; that is, the role of mesoscale organization on SCM subgrid-scale assumptions can be improved for the CAO regime, and more broadly, convective boundary layer clouds.

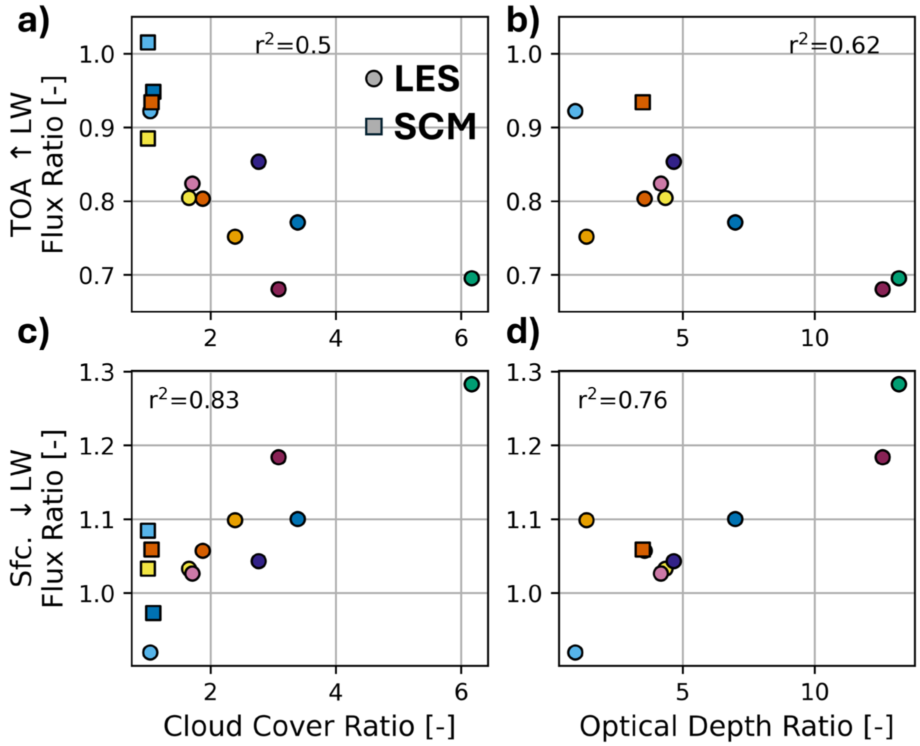


***Figure 3**. Relationship between (a) cloud cover ratio and TOA upwelling LW flux ratio; (b) optical depth ratio and TOA upwelling LW flux ratio; (c) cloud cover ratio and surface downwelling LW flux ratio; (d) optical depth ratio and surface downwelling LW flux ratio. A "ratio" is defined as the ratio of the respective quantity from the liquid-only simulation to that from the mixed-phase simulation. For example, there is more cloud cover in the liquid-only configuration for nearly all LES, hence the ratio is >1. The r2 values are computed for only the LES results.*

Upcoming work will examine the role of interactive aerosol to mediate aforementioned cloud evolution. Aerosol is primarily driven by sea-spray emissions, free-tropospheric entrainment, and collisional loss during mixed-phase precipitation formation. Early results suggest that moving from fixed to interactive aerosol shifts the relatively small amount of rain condensate towards cloud, enabled by initially greater Cloud Condensation Nuclei (CCN) concentrations that approximately match fixed values towards the final stage of the simulation. Simulations with interactive aerosol show greater cloud optical depth throughout as a result.

COMBLE-MIP is still open to new participants! Please contact Florian Tornow (*ft2544@columbia.edu*), Ann Fridlind (*ann.fridlind@nasa.gov*), or Timothy Juliano (*tjuliano.ncar@gmail.com*), and find further information at *https://arm-development.github.io/comble-mip/*.

References

Elsaesser, G.S., C.W. O'Dell, M.D. Lebsock, R. Bennartz, T.J. Greenwald, and F. J. Wentz, 2017. The multisensor advanced climatology of liquid water path (MAC-LWP). *J. Clim.*, 30(24), 10193–10210.

Geerts, B., et al., 2022. The COMBLE Campaign: A study of marine boundary layer clouds in Arctic cold-air outbreaks. *Bull. Amer. Meteor. Soc.*, 103(5), E1371–E1389.

Juliano, T.W., C.P. Lackner, B. Geerts, B. Kosović, L. Xue, P. Wu, and J.B. Olson, 2024. Simulating mixed-phase open cellular clouds observed during COMBLE: Evaluation of parameterized turbulence closure. *J. Geophys. Res. Atmos.*, 129(18), e2024JD040889.

Lackner, C.P., B. Geerts, T.W. Juliano, L. Xue, and B. Kosović, 2023. Vertical structure of clouds and precipitation during Arctic cold-air outbreaks and warm-air intrusions: Observations from COMBLE. *J. Geophys. Res. Atmos.*, 128(13), e2022JD038403.

Lackner, C.P., B. Geerts, T.W. Juliano, B. Kosović, and L. Xue, 2024. Characterizing mesoscale cellular convection in marine cold air outbreaks with a machine learning approach. *J. Geophys. Res. Atmos.*, 129(14), e2024JD041651.

Mages, Z., P. Kollias, Z. Zhu, and E.P. Luke, 2023. Surface-based observations of cold-air outbreak clouds during the COMBLE field campaign. *Atmos. Chem. Phys.*, 23(6), 3561–3574.

Ovchinnikov, M., A.S. Ackerman, A. Avramov, A. Cheng, J. Fan, A.M. Fridlind, S. Ghan, J. Harrington, C. Hoose, A. Korolev, G.M. McFarquhar, H. Morrison, M. Paukert, J. Savre, B.J. Shipway, M.D. Shupe, A. Solomon, and K. Sulia, 2014. Intercomparison of large-eddy simulations of Arctic mixed-phase clouds: Importance of ice size distribution assumptions. *J. Adv. Model. Earth Syst.*, 6, no. 1, 223–248.

Wu, P., and M. Ovchinnikov, 2022. Cloud morphology evolution in Arctic cold-air outbreak: Two cases during COMBLE period. *J. Geophys. Res. Atmos.*, 127(10), e2021JD035966.

The ORCESTRA Field Campaign: What Controls the Structure of the Tropical Rain Belts and How Do They Respond to Global Warming?

Yuting Wu
Max Planck Institute for Meteorology, Hamburg, Germany

In the summer of 1974, 39 ships gathered in the tropical eastern Atlantic Ocean to study how cloud clusters influence global circulation, forming concentric nested hexagons. They were supported by 13 aircraft, several satellites, and observatories from over 70 countries. This campaign, known as the Global Atmospheric Research Program's Atlantic Tropical Experiment (GATE; Kuettner, 1974), was the most ambitious atmospheric field campaign ever conducted at the time. It laid the groundwork for the modern understanding of convection and has inspired generations of atmospheric research ever since. More recent field campaigns, such as Next-Generation Aircraft Remote Sensing for Validation (NARVAL) I & II (Stevens et al., 2019) and ElUcidating the RolE of Cloud–Circulation Coupling in ClimAte (EUREC^{4}A, Stevens et al., 2021), have built on the foundations laid in the summer of 1974.

Fifty years after GATE, in August and September of 2024, over 50 institutions from around the world came together once again—this time under the Organized Convection and EarthCARE Studies over the Tropical Atlantic (ORCESTRA, *https://orcestra-campaign.org*) initiative—to study convection over the tropical Atlantic. With global anthropogenic greenhouse gas emissions continuing to rise, a pertinent question is how clouds and convection influence climate sensitivity (e.g., Vial et al., 2013; Medeiros et al., 2015; Sherwood et al., 2020). Despite decades of research, climate sensitivity and the dynamic response to warming remains uncertain—yet these are two of the most crucial factors determining the extent of climate change (Bony et al., 2015).

In this context, ORCESTRA offered a new dimension in exploring cloud-circulation interactions, focusing particularly on the impact of deep convection on the Earth's energy budget and the structure of the Intertropical Convergence Zone (ITCZ).

Beyond its scientific goals, ORCESTRA provided essential ground truth data for validating the recently-launched Earth Cloud, Aerosol and Radiation Explorer (EarthCARE) satellite, the most advanced Earth Explorer mission to date. EarthCARE was developed through a collaboration between the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA)/National Institute of Information and Communications Technology (NICT). It uses lidar, radar, multispectral imaging, and radiometry to observe clouds and aerosols with unprecedented detail from space.

The ORCESTRA campaign consisted of eight interconnected sub-campaigns unified by two overarching objectives:

1. To identify the drivers of mesoscale organization in tropical convection and their influence on both small-scale weather systems and large-scale circulation, especially within the Atlantic ITCZ.

2. To serve as a benchmark for satellite remote sensing and a new generation of high-resolution, storm-resolving models.

Spanning the entire vertical extent of the atmosphere—from outer space to the ocean surface—ORCESTRA integrated three airborne, one ship-based, and two ground-based measurement platforms, alongside satellite observations. These platforms were coordinated to provide complementary, multiscale perspectives of tropical convection (read more about the sub-campaigns in the section below), a concerted effort that honors the metaphor insinuated by the acronym. Unlike GATE's hexagons in the East Atlantic, ORCESTRA's track pattern covered the tropical Atlantic from east to west and crossed the edges of the ITCZ several times.

In total, ORCESTRA produced an extraordinary volume of data, including over 5,500 radar scans, over 2,000 atmospheric soundings, 90 oceanographic profiles, 70 research flights, and around 45 drone missions, among others. Additionally, nearly 14 TB of data was produced using the Icosahedral Nonhydrostatic (ICON) climate model, as the campaign not only included field observations, but also numerical simulations with a horizontal grid spacing of 1.25 km. These simulations provided daily hindcasts of atmospheric conditions, enriching the observational data set and offering a powerful tool for interpretation and analysis.

Close cooperation with scientists from the region and support from local authorities were also vital to ORCESTRA's success, thanks to the Instituto Nacional de Meteorologia e Geofisica (INMG) in Cape Verde; the Weather Service (ANACIM) in Dakar, Senegal; and the Caribbean Institute for Meteorology and Hydrology (CIMH) in Barbados.

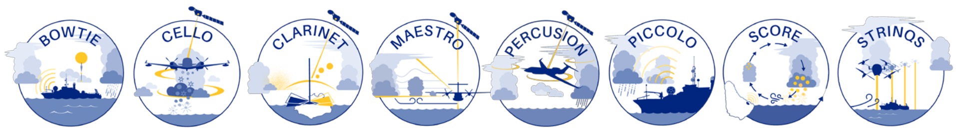
While the full scientific insights are still forthcoming, the ORCESTRA initiative already stands as a landmark effort, uniting the latest technology, global collaboration, and scientific ambition to deepen our understanding of tropical convection and its role in the Earth's climate system.

ORCESTRA Sub-Campaigns Overview

Persistent EarthCARE Underflight Studies of the ITCZ and Organized coNvection (**PERCUSION**) is a German initiative that employed the HALO research aircraft alongside ESA/JAXA's EarthCARE satellite to investigate deep convection near and within the ITCZ, its interaction with aerosols, and its impact on large-scale circulation. The campaign built on past field campaigns to advance understanding and support satellite validation for global applications.

The French-led Mesoscale Organisation of Tropical Convection (MAESTRO) campaign used the Service des Avions Français Instrumentés pour la Recherche en Environnement

ORCESTRA



The ORCESTRA sub-campaigns

(SAFIRE) ATR-42 aircraft to understand the physical processes that control the mesoscale organization of convection and its impact on the Earth's radiation budget, and validate EarthCARE satellite data.

Cloud and EarthCARE caL/vaL Observations (**CELLO**) was a Norwegian-led effort employing the Romanian National Institute for Aerospace Research "Elie Carafoli" (INCAS) King Air aircraft for in situ cloud measurements around Cape Verde. It contributed to the ORCESTRA consortium by validating EarthCARE data and improving the understanding of cloud microphysics.

The Beobachtung von Ozean und Wolken–Das Trans-ITCZ Experiment (**BOWTIE**) used the German research vessel FS METEOR to study convective-scale atmospheric processes and their interaction with the ocean in order to understand how such interactions shape the broader structure of the ITCZ.

Process Investigation of Clouds and Convective Organization over the AtLantic Ocean (**PICCOLO**) was a U.S.-led campaign deploying the SEA-going POLarimetric (SEA-POL) radar on the FS METEOR to explore the structure, drivers, and impacts of mesoscale convective organization across the Atlantic Ocean. PICCOLO focused on precipitation, microphysics, radiative effects, and the entropy budget.

Soundings and TuRbulent eddy measurements in the ITCZ with a Network of QuadcopterS (**STRINQS**) was a Dutch initiative that used a fleet of coordinated meteorological drones launched from the FS METEOR to investigate boundary-layer processes, such as turbulence, cold pools, and vertical motions, and their role in shaping the structure of the ITCZ on a mesoscale.

CLoud and Aerosol Remote sensing for EarThCARE (**CLARINET**) enhanced cloud radar capabilities at the Ocean Science Center Mindelo (OSCM) on the island of São Vicente in Cape Verde through dual-frequency radar observations during the campaign period. It supported EarthCARE validation, contributed to the ORCESTRA measurement network, and evaluated the site's representativeness for long-term climate monitoring.

Sub-Cloud Observations of Rain Evaporation (**SCORE**) focused on quantifying sub-cloud rain evaporation and downdrafts at the Barbados Cloud Observatory (BCO) using advanced radar and radiosonde measurements. The campaign aimed to improve retrieval techniques for shallow and deep convection and link these findings to the long-term observational record at the BCO.

References

Bony, S., B. Stevens, D.M.W. Frierson, C. Jakob, M. Kageyama, R. Pincus, T.G. Shepherd, S.C. Sherwood, A.P. Siebesma, A.H. Sobel, M. Watanabe and M.J. Webb, 2015. Clouds, circulation and climate sensitivity. *Nat. Geosci.,* 8(4): 261–268.

Medeiros, B., B. Stevens, and S. Bony, 2015. Using aquaplanets to understand the robust responses of comprehensive climate models to forcing. *Clim. Dyn*., 44(7–8), 1957–1977.

Kuettner, J.P., 1974. General Description and Central Program of GATE. *Bull. Am. Meteorol. Soc*., 55(7), 712–719.

Sherwood, S.C., M.J. Webb, J.D. Annan, K.C. Armour, P.M. Forster, J.C. Hargreaves, G. Hegerl, S.A. Klein, K.D. Marvel, E.J. Rohling, M. Watanabe, T. Andrews, P. Braconnot, C.S. Bretherton, G.L. Foster, Z. Hausfather, A.S. Heydt, R. Knutti, T. Mauritsen, J.R. Norris, C. Proistosescu, M. Rugenstein, G.A. Schmidt, K.B. Tokarska, and M.D. Zelinka, 2020. An Assessment of Earth's Climate Sensitivity Using Multiple Lines of Evidence. *Rev. Geophys*., 58(4).

Stevens, B., F. Ament, S. Bony, S. Crewell, F. Ewald, S. Gross, A. Hansen, L. Hirsch, M. Jacob, T. Kolling, H. Konow, B. Mayer, M. Wendisch, M. Wirth, K. Wolf, S. Bakan, M. Bauer-Pfundstein, M. Brueck, J. Delanoe, A. Ehrlich, D. Farrell, M. Forde, F. Godde, H. Grob, M. Hagen, E. Jakel, F. Jansen, C. Klepp, M. Klingebiel, M. Mech, G. Peters, M. Rapp, A.A. Wing, and T. Zinner, 2019a. A High-Altitude Long-Range Aircraft Configured as a Cloud Observatory: The NARVAL Expeditions. *Bull. Am. Meteorol. Soc*., 100(6): 1061–1077.

Stevens, B., S. Bony, D. Farrell, F. Ament, A. Blyth, C. Fairall, J. Karstensen, P.K. Quinn, S. Speich, C. Acquistapace, F. Aemisegger, A.L. Albright, H. Bellenger, E. Bodenschatz, K.A. Caesar, R. Chewitt-Lucas, G. de Boer, J. Delanoe, L. Denby, F. Ewald, B. Fildier, M. Forde, G. George, S. Gross, M. Hagen, A. Hausold, K.J. Heywood, L. Hirsch, M. Jacob, F. Jansen, S. Kinne, D. Klocke, T. Kolling, H. Konow, M. Lothon, W. Mohr, A.K. Naumann, L. Nuijens, L. Olivier, R. Pincus, M. Pohlker, G. Reverdin, G. Roberts, S. Schnitt, H. Schulz, A.P. Siebesma, C.C. Stephan, P. Sullivan, L. Touze-Peiffer, J. Vial, R. Vogel, P. Zuidema, and 240 other authors, including S. Crewell, A. Ehrlich, B. Mayer, and M. Wendisch, 2021. EUREC4A. *Earth Syst. Sci. Data,* 13(8): 4067–4119.

Vial, J., J.L. Dufresne, and S. Bony, 2013. On the interpretation of intermodel spread in CMIP5 climate sensitivity estimates. *Clim. Dyn*., 41(11–12), 3339–3362.

Bridging Science and Society for Flood Resilience: The WWRP InPRHA Project Charts its Course

Rachel Hogan Carr and Céline Cattoën-Gilbert
InPRHA Co-Chairs

Extreme precipitation and flood events are increasing in frequency and severity under a warming climate, placing vulnerable populations at even greater risk (WMO, 2024). Despite progress in weather forecasting and hydrological modeling (Bauer et al., 2015; Cloke and Pappenberger, 2009; Lavers et al., 2020; McCabe et al., 2017), significant gaps remain in translating flood hazard predictions into timely, effective early actions (Budimir et al., 2020; Pagano et al., 2014; Wu et al., 2020). The "Integrating Prediction of Precipitation and Hydrology for Early Actions" (InPRHA) project, launched under the World Meteorological Organization (WMO)'s World Weather Research Programme (WWRP), seeks to change this narrative.

InPRHA is a five-year, international research initiative focused on improving multi-hazard flood forecasting systems by integrating hydrology and precipitation predictions alongside social sciences. The project, which focuses its research on the scale of minutes to days, responds to a growing recognition that early warning systems (EWS) must do more than generate accurate forecasts. They must also connect across disciplines and scales, account for climate change impacts, engage communities, and support adaptive, real-world decision-making in local communities. Details of the project plan have been published in the *Bulletin of the American Meteorological Society* (*https://doi.org/10.1175/BAMS-D-24-0332.1*).

Rethinking the Flood Warning Value Chain

InPRHA is grounded in the understanding that helping communities take early action is not just about improving forecast models, but depends on how we integrate science, policy, and human behavior. InPRHA explicitly acknowledges the value of Indigenous and local knowledge systems in flood risk management, and seeks to co-produce tools and strategies that are culturally relevant, context-specific, and grounded in lived experience.

At its core, InPRHA aims to address a foundational question: How can communities most vulnerable to floods reduce disaster risk through improved information and early action?

To answer this, the project re-examines the entire flood warning value chain, from the initial meteorological and hydrological predictions to the final decision-making processes at the local level, with an emphasis on integration of skills and knowledge from across the fields of hydrology, meteorology, and social sciences. The project is structured around four transdisciplinary work packages (ENGAGE, DEFINE, CONSTRUCT, and EXPERIMENT) that outline a series of collaborative research tasks related to flood predictability and assessment, the improvement of hydro-meteorological warnings, and co-developing sound communication strategies for decision-making and early warning. InPRHA's long-term deliverables center on providing shared experiments and research opportunities, building collective knowledge of integration within the research and operational communities, and delivering guidance for good practices on integration through a culminating special journal issue highlighting the knowledge gathered through the project.

Science Meets Society

InPRHA takes a wide view of the challenge of improving the early warning value chain to achieve the condition where "no one is surprised by a flood." The project proposes a set of research questions across seven key themes to the broader research and operational community. These questions form the backbone of InPRHA's research agenda and guide its community engagement efforts.

1. **State-of-the-art for flood prediction and risk in a changing world**: What are the key research priorities for advancing reliable and impact-based flood early warning systems in the context of evolving prediction capabilities, storm types, user trust, and environmental change?
2. **Research to Operations**: What knowledge is needed to improve end-to-end forecasts in operational settings?
3. **Emerging technologies**: How can AI, digital twins, and next-generation models improve flood hazard prediction?
4. **Hydrometeorological observing and forecasting–Challenges and synergies**: How can we leverage both traditional and non-traditional data sources to better inform hydrometeorological models?
5. **Socio-economic, cultural, and environmental challenges**: How do cultural norms, risk perceptions, and Indigenous knowledge systems influence the effectiveness of warnings and better policy frameworks and behavioral interventions that support flood resilience?
6. **Uncertainties throughout the value chain**: How can we quantify and communicate uncertainty more effectively across the value chain?
7. **Perceptions and actions for flood risks**: How do individuals and institutions respond to multi-hazard warnings under uncertainty?

A Four-Pillar Framework for Action

InPRHA's four work packages create interdisciplinary scopes of work to engage research and operational community members in addressing these questions. Task Teams, comprised of physical and social scientists internationally working on key research questions and also driving workflow challenges for InPRHA, will contribute directly to the four interlinked work packages:

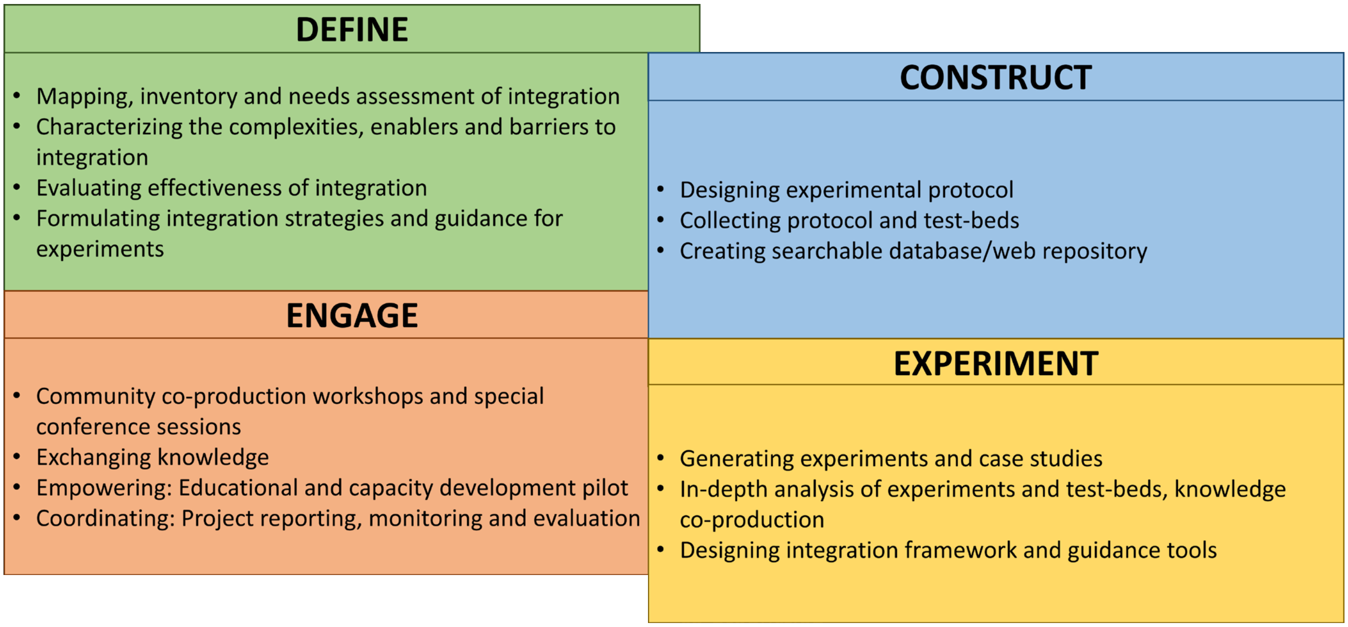


***Figure 1**. Key milestones of InPRHA work packages*

ENGAGE—Coordinating and Sharing Knowledge

The ENGAGE work package ensures that the knowledge created through DEFINE, CONSTRUCT, and EXPERIMENT reaches and resonates with its intended audiences. Members of Task Teams in various domains will assist engagement activities through stakeholder workshops, webinars, and outreach and publications.

Importantly, ENGAGE will promote cross-cultural exchange and capacity building, potentially developing educational materials with a particular focus on low-resource and high-risk settings. The work package will also coordinate InPRHA's contribution to broader WMO initiatives like the "Early Warnings for All" (EW4All) campaign.

DEFINE—Framing the Integration Challenge

The DEFINE work package sets the groundwork by reviewing the current state-of-the-art and identifying existing gaps in the integration of meteorology, hydrology, and social sciences. Through a series of micro-reviews, surveys, and stakeholder consultations, InPRHA will develop a living repository of knowledge and a synthesized framework to guide integration strategies across the value chain.

CONSTRUCT—Building a Community Testbed

CONSTRUCT focuses on collecting and curating case studies and experiments that exemplify effective (or failed) integration practices. It draws heavily from recent experiences under projects like High Impact Weather (HIWeather), while inviting new collaborations. A searchable, open-access database will be developed to support the replication and adaptation of integration experiments globally.

EXPERIMENT—Testing What Works

The EXPERIMENT work package will implement selected integration experiments and assess their effectiveness using diverse methods, including serious games, operational prototypes, and behavioral studies. Special attention will be paid to understanding how risk communication—especially under uncertainty—affects public and institutional responses.

Key experiments may examine the role of probabilistic hydrological forecasts, co-design warning messages with communities, and test the utility of emerging technologies like AI-generated flood maps.

Looking Ahead: Collaboration, Not Silos

InPRHA's Steering Group will develop and implement activities with a wide range of stakeholders and partners in the research projects identified, including end users for social science research and testing, forecast audiences, emergency managers and other professional stakeholders, as well as larger institutions, such as research institutions, operational centers, and national agencies.

Partnerships will be key. InPRHA is actively engaging with the Global Flood Partnership, the United Nations Educational, Scientific and Cultural Organization (UNESCO)'s Intergovernmental Hydrological Programme, the World Climate Research Programme's GEWEX Hydroclimatology Panel, and the International Association of Hydrological Sciences. The project also supports the WMO Advancing Weather Research to Reduce Risk to SociEties (AWAR3E) principles, which emphasize actionable, inclusive, and accessible weather-related research.

A Call to the GEWEX Community

InPRHA invites members of the GEWEX community to get involved. Whether you are a climate scientist, hydrologist, modeler, social scientist, or operational forecaster, your expertise is needed.

There are multiple entry points for collaboration:

- Share ongoing or planned case studies that align with InPRHA's mission
- Contribute to micro-reviews or thematic webinars
- Participate in community workshops or co-design integration experiments
- Propose innovations for uncertainty communication or inclusive engagement

For more information or to join the network, visit *https://wpo.noaa.gov/inprha*.

References

Bauer, P., A. Thorpe, and G. Brunet, 2015. The quiet revolution of numerical weather prediction. *Nature*, 525, 47.

Budimir, M., et al., 2020. Communicating complex forecasts: an analysis of the approach in Nepal's flood early warning system. *Geosci. Commun.*, 3, 49–70.

Cloke, H.L., and F. Pappenberger, 2009. Ensemble flood forecasting: A review. *J. Hydrol.*, 375, 613–626.

Lavers, D.A., et al., 2020. A Vision for Hydrological Prediction. *Atmosphere*, 11, 237.

McCabe, M.F., et al., 2017. The future of Earth observation in hydrology. *Hydrol. Earth Syst. Sci.*, 21, 3879–3914.

Pagano, T.C., et al., 2014. Challenges of Operational River Forecasting. *J. Hydrometeorol.*, 15, 1692–1707.

Wu, W.Y., R. Emerton, Q.Y. Duan, A.W. Wood, F. Wetterhall, and D.E. Robertson, 2020. Ensemble flood forecasting: Current status and future opportunities. *Wiley Interdiscip Rev Water*, n/a, e1432.

WMO, 2024. State of Global Water Resources report 2023WMO-No. 1362, 80 pp.

Inclusion of Spatially-Explicit Vertical Land Movement in Sea Level Rise Studies: A New Zealand Case Study

Ian Hamling and Rogier Westerhoff
Earth Sciences New Zealand, formerly GNS Science

There is a growing acknowledgement of the importance of including local variations in coastal vertical land movement (VLM) in projections of future sea-level rise. Uplift and subsidence of a coastline can modify relative sea level projections with impacts on coastal hazard risk assessment. However, due to the challenges of estimating global VLM at high spatial and temporal resolutions, current projection frameworks generally rely on regional linear estimates.

For nations which sit astride active plate margins, these challenges are exacerbated by the influence of tectonic and volcanic processes, which can introduce non-stationarity into VLM projections. In 2022, New Zealand researchers released new probabilistic relative sea-level projections (Naish et al., 2024) using the Framework for Assessing Changes to Sea-level (FACTS) from the Intergovernmental Panel on Climate Change (IPCC) Assessment Report 6 (Fox-Kemper et al., 2021; Garner et al., 2021). Unlike past estimates of relative sea-level rise for New Zealand, this approach incorporated a novel component to include local VLM data (Kopp et al., 2023), providing projections at 2 km intervals along New Zealand's coast (Naish et al., 2024). However, in order to measure VLM along the entire ~15,000 km-long coastline, traditional approaches, such as with tide gauges, are near impossible. To help overcome this problem, we combined spaceborn geodetic observations from interferometric Synthetic Aperture Radar (InSAR) and Global Navigation Satellite Systems (GNSS) from 2003–2011 to increase both the spatial extent and density of VLM estimates around the entire New Zealand coastline. This period was selected to reduce potential temporal biases introduced by local earthquakes, as it largely preceded many of the magnitude (Mw) >6 earthquakes that have struck New Zealand since late 2009 and is therefore representative of the interseismic VLM, or VLM occurring between major earthquakes. Over this period, the highest rates of subsidence were found along the southeastern North Island where coupling along the subduction zone drives long-term regional subsidence at average rates of ~4 mm/y, but approach 8 mm/y in some areas due to localized sources of deformation. For the New Zealand capital, Wellington, interseismic rates of subsidence were estimated to be ~3 mm/yr and would likely bring forward the threshold exceedance for coastal inundation by decades.

Unfortunately, while these VLM estimates are providing a best estimate of the deformation between earthquakes, there are a number of areas around New Zealand that have been impacted by moderate to large earthquakes in the last 10–20 years. Notably, areas around Christchurch and central New Zealand, which were impacted by the 2010–2011 Canterbury earthquake sequence and 2016 Mw 7.8 Kaikoura earthquake (Beavan et al., 2012; Hamling et al., 2017) respectively, are

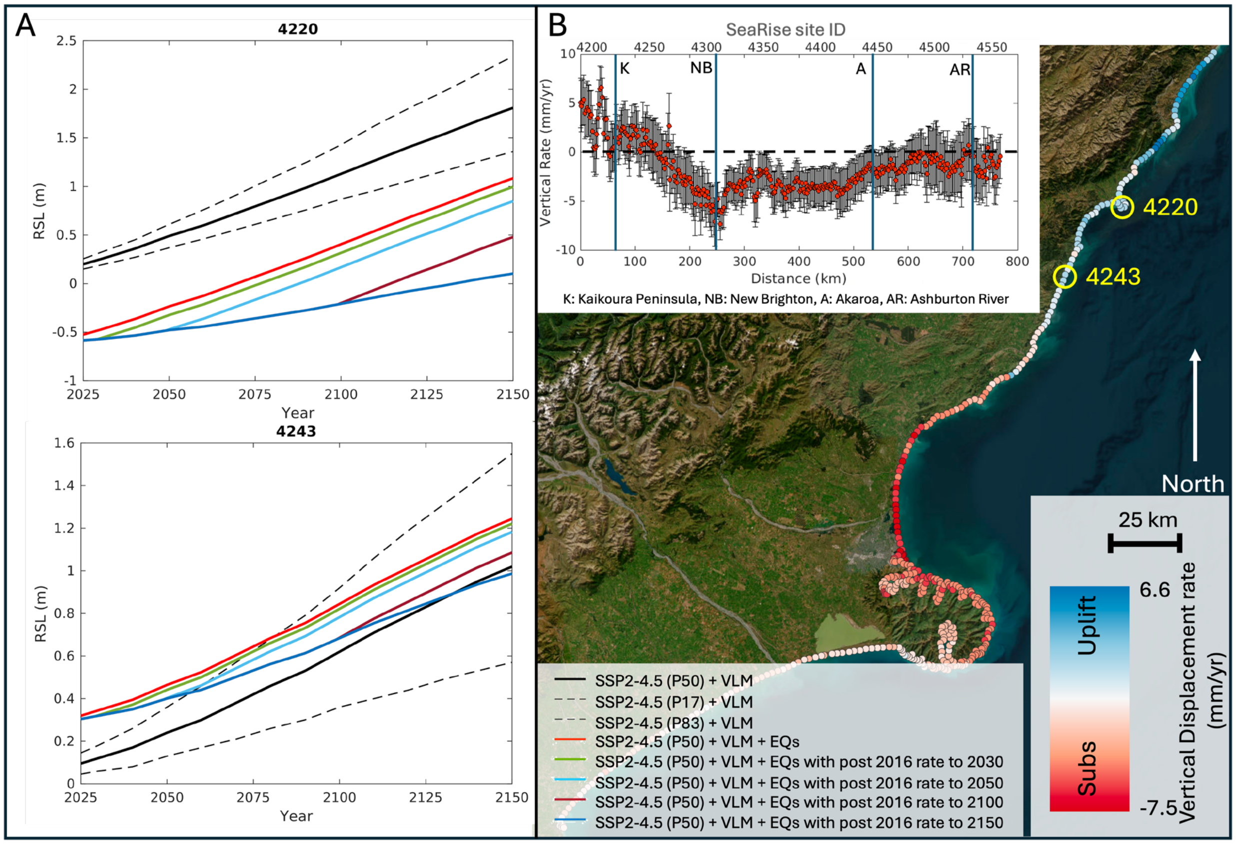


***Figure 1**. Example of post-earthquake VLM estimates for the Canterbury coastline and updated relative sea level rise (RSLR) projections modified from Hamling (2025). A) Re-projected RSLR for points near Kaikōura (virtual station 4220) and Hundalee (virtual station 4243). The colored lines show the influence of different post-earthquake VLM scenarios on the projections where current post-seismic rates return to the previously-estimated interseismic values at different times (2030, 2050, 2100). The numbered titles reference the original NZ SeaRise identification numbers. Note that the offset between the NZ SeaRise (black) and updated projections are a result of the net uplift or subsidence caused by all of the earthquakes and the applied change in VLM rate from 2016 to 2025. B) Map of post-earthquake VLM binned at 2 km increments. The inset in the top left shows a profile through all of the coastal sites from north to south.*

currently experiencing significantly different vertical land movements to those observed during the interseismic period. Furthermore, in the case of the Kaikoura earthquake, parts of the northern South Island were almost instantaneously uplifted by ~5–10 m, suggesting that even if interseismic subsidence resumes, it will take 5000–10000 years to undo the co-seismic uplift. In contrast, areas ~50 km to the south underwent ~0.5–1 m of subsidence.

Since the completion of the SeaRise program, studies are now underway to improve the spatial and temporal resolutions of VLM around the New Zealand coast utilizing Sentinel-1 Synthetic Aperture Radar (SAR) observations. In addition, we are aiming to better incorporate temporal uncertainties into future VLM projections and build in probabilistic impacts of potential future earthquakes (Fig. 1). Results of these new studies are envisaged to be completed in the next 12–24 months to help support adaptive planning for New Zealand's regional governments and policy makers.

With the improved temporal and spatial resolutions offered by the current and future generations of SAR missions [e.g., Sentinel Next Generation, the National Aeronautics and Space Administration (NASA)–Indian Space Research Organization (ISRO) Synthetic Aperture Radar (NISAR)], the analysis of the coastal VLM in dynamic environments requires regular reassessment to provide robust, up-to-date estimates of current rates and their likely future evolution. We encourage readers to reach out for potential new collaborations; please contact us at *i.hamling@gns.cri.nz* and *r.westerhoff@gns.cri.nz*.

The studies were funded under New Zealand Endeavour Research Programmes funded by the New Zealand Ministry of Business, Innovation and Employment (MBIE): (1) NZ SeaRise: NZ SeaRise: Te Tai Pari O Aotearoa; (2) Te Ao Hurihuri: Te Ao Hou: Our Changing Coast.

References

Beavan, J., M. Motagh, E.J. Fielding, N. Donnelly, and D. Collett, 2012. Fault slip models of the 2010–2011 Canterbury, New Zealand, earthquakes from geodetic data and observations of postseismic ground deformation. *N. Z. J. Geol. Geophys*., 55(3):207–221. https://doi.org/10.1080/00288306.2012.697472.

Fox-Kemper, B., H.T. Hewitt, C. Xiao, G. Aðalgeirsdóttir, S.S. Drijfhout, T.L. Edwards, N.R. Golledge, M. Hemer, R.E. Kopp, G. Krinner, et al.,

2021. Ocean, cryosphere and sea level change. In: Climate change 2021: the physical science basis—Working Group I contribution to the sixth assessment report of the Intergovernmental Panel on Climate Change (V. Masson-Delmotte, P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, et al., eds.). Cambridge and New York, Cambridge University Press, p. 1211–1361. *https://doi.org/10.1017/9781009157896.011.*

Hamling, I.J., S. Hreinsdóttir, K. Clark, J. Elliott, C. Liang, E. Fielding, N. Litchfield, P. Villamor, L. Wallace, T.J. Wright, et al., 2017. Complex multifault rupture during the 2016 Mw 7.8 Kaikōura earthquake, New Zealand. *Science*, 356(6334):eaam7194. *https://doi.org/10.1126/science.aam7194.*

Hamling, I.J., 2025. *Co-seismic and post-seismic rates of vertical land movement in the Canterbury Region and implications for future changes in sea level.* GNS Science Consultancy Report. 2025/40LR. Prepared for Christchurch City Council; Environment Canterbury.

Kopp, R.E., G.G. Garner, T.H.J. Hermans, S. Jha, P. Kumar, A. Reedy, A.B.A. Slangen, M. Turilli, T.L. Edwards, J.M. Gregory, et al., 2023. The Framework for Assessing Changes To Sea-level (FACTS) v1.0-rc: a platform for characterizing parametric and structural uncertainty in future global, relative, and extreme sea-level change. *Geosci. Model Dev.*, 16(24):7461–7489. *https://doi.org/10.5194/gmd-16-7461-2023.*

Naish, T., R. Levy, I. Hamling, S. Hreinsdóttir, P. Kumar, G.G. Garner, R.E. Kopp, N. Golledge, R. Bell, R. Paulik, et al., 2024. The significance of interseismic vertical land movement at convergent plate boundaries in probabilistic sea-level projections for AR6 scenarios: the New Zealand case. *Earth's futur.*, 12(6):e2023EF004165. *https://doi.org/10.1029/2023EF004165.*

Meeting/Workshop Reports

Highlights of the 37th Annual SSG Meeting

Fernande Vervoort and Peter van Oevelen
International GEWEX Project Office

In-person attendees of the 37th GEWEX Scientific Steering Group Meeting in Wellington, New Zealand

This year's 37th Session of the Global Energy and Water Exchanges (GEWEX) Scientific Steering Group (SSG) annual meeting was hosted by the Victoria University of Wellington and the Institute of Geological and Nuclear Sciences (GNS) and took place from Monday to Friday, 10–14 February 2025. This short report documents the proceedings of this annual meeting of scientists who guide the formation, implementation, and execution of GEWEX's scientific program as well as Co-Chairs of the GEWEX Panels.

During this session of the GEWEX SSG, participants reviewed the progress made by GEWEX and its five Panels throughout 2024, assessing the program's relevance to current and future global challenges. Each of the five Panels reported on a range of activities undertaken in 2024, which included the onboarding of new Panel members, the initiation of new projects, the development and marketing of various scientific products, and the organization of both virtual and in-person meetings and workshops. The Panel reports indicated that ongoing projects are progressing as planned, while some have concluded successfully. Moreover, working groups across the Panels have made significant contributions to the scientific community, publishing articles in leading journals with additional manuscripts currently under review. Discussions on how to proceed, what is lacking, other possible topics to explore, and discussions on existing or possible obstacles resulted in new action items and recommendations. In this context, the future of the International GEWEX Project Office (IGPO) was also discussed as the current funding situation has become opaque.

SSG-37 participants at the Matiu/Somes Island Wharf

This year's SSG session also saw the third selection for the GEWEX Ambassador Awards, bestowed to Irina Sandu of ECMWF and Germán Poveda of the Universidad Nacional de Colombia. This award has been created to honor colleagues who have contributed a significant amount of their time and energy to GEWEX and who can continue to promote GEWEX in the broadest sense, e.g., encourage other colleagues to be part of the GEWEX community, keep funders and stakeholders abreast of the latest developments when opportunity arises, and represent the GEWEX community at selected events.

Part of this SSG session was reserved for presentations of research activities from our hosts, the Victoria University of Wellington and GNS. Discussions on areas of collaboration with GEWEX activities may lead to the formation of a potential Regional Hydroclimate Project, possibly jointly with parties in Australia.

Contributions from GEWEX partners and WCRP core projects and activities completed the program of this year's SSG meeting.

In 2024, the support required to meet the obligations and responsibilities of the IGPO was provided by George Mason University under the Center for Ocean-Land-Atmosphere Studies (COLA).

In Phase IV (2023–2032) of GEWEX, the GEWEX Science Plan 2023–2032 (https://www.gewex.org/gewex-content/uploads/2022/05/GEWEX-science-plan-v8.pdf), *Addressing the challenges in understanding and predicting Changes to water availability in the coming decades*, was published (WCRP publication no. 9/2021). It serves as the backbone of, and provides direction to, the GEWEX strategic plan and science questions for the coming years.

GEWEX/WCRP Calendar

For the complete Calendar, see http://www.gewex.org/events/

27 July–1 August 2025—2025 Asia Oceania Geosciences Society 2025 (AOGS2025)—Singapore

5–7 August 2025—IX Convection Permitting Climate Modeling Workshop—Hong Kong

18–25 August 2025—11th Baltic Earth Summer School—Askö, Sweden

27–29 August 2025—Hackathon on Machine Learning for the Earth System—Bonn, Germany

1–5 September 2025—International School on Satellite Meteorology (ISSM)—Bologna, Italy

5 September 2025—Global Flood Crosscutting Initiative Monthly Meeting—Online

9 September 2025—Machine Learning for Land Surface Models (ML4LM) Webinar—Online

9–11 September 2025—Summer school on extreme temperature and precipitation events—Cluj-Napoca, Romania

12–14 September 2025—International Network for Alpine Research Catchment Hydrology (INARCH) Workshop—Obergurgl, Austria

14–18 September 2025—International Mountain Conference—Innsbruck, Austria

16–19 September 2025—2nd International Scientific Conference on "Agricultural Challenges to Climate Change"— Osijek, Croatia

24–26 September 2025—Systemic Risks and Climate Extremes Conference and Workshop—Hamburg, Germany

GEWEX QUARTERLY

Published by the International GEWEX Project Office

Peter J. van Oevelen, Director
Shannon Macken, Editor

International GEWEX Project Office
c/o George Mason University
111 Research Hall, Mail Stop 6C5
4400 University Drive
Fairfax, VA 22030 USA

E-mail: contact@gewex.org
Website: *http://www.gewex.org*