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## 9th Global Energy and Water Exchanges Open Science Conference

Sapporo, Japan | 7–12 July 2024

## Inside This Edition

## Commentary

**Peter van Oevelen**
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We look back with tremendous pride and joy to our 9th GEWEX Open Science Conference held in Sapporo, Japan, from 7–12 July 2024. It was our largest to date with around 1200 attendees, of which well over 900 were scientists and close to 300 were stakeholders. This successful event was made possible through the excellent collaboration with our local host of Hokkaido University, particularly Profs. Tomohito Yamada, Tomonori Sato, and Hiroki Okachi, plus their team. Of course, I'd be remiss not to thank my colleagues at the International GEWEX Project Office (IGPO) as well as many of you in the GEWEX community, without whom we would not have been able to pull it off. So, a big thank you! A more comprehensive overview on this meeting and its side events is given in a short article in this edition of the *Quarterly*.

Let me switch gears a bit here and talk about the role of GEWEX as part of the World Climate Research Programme (WCRP), as not everyone may be fully aware of it. GEWEX, as many of you well know, is not a funding entity. GEWEX is a community that is organized under WCRP's umbrella and supported by IGPO. The organization is led by a Scientific Steering Group (SSG) under which five Panels [the Global Atmospheric System Studies (GASS) Panel, the Global Land-Atmosphere System Studies (GLASS) Panel, the GEWEX Hydroclimatology Panel (GHP), the GEWEX Data and Analysis Panel (GDAP), and the Monsoons Panel, shared with the Climate and Ocean-Variability, Predictability, and Change (CLIVAR) project] are organized that guide and support numerous activities. As such, we are always looking for individuals to support us in various roles from activity lead to SSG co-chair. Of course, we must balance various elements in that selection process of which expertise, along with gender, career stage, and global or regional representation are the most prominent. The organization is structured to support and welcome as many ideas and views as possible, as one of our main goals is to provide strategic science advice to the wider research community as well as to the numerous sponsors and funders of research. That does not necessarily mean we provide a singular consensus view, as science should ideally be about exploration, hypothesis testing, and blue sky thinking. Conflicting ideas and pathways are part of that! Hence, we cannot and should not be bound by the individual sponsors' views to drive the research that is needed. On the contrary, as a community, we should inform and support the funders in their definition of research programs and calls. Surely, an individual researcher must comply with the conditions of a research call, but a community such as GEWEX can help shape those calls and programs and do so in a global context. This is one of the ways for us to facilitate international research collaboration where alignment of research priorities and hence resources can be most effectively employed. This leads to another important aspect, and that is building and maintaining that community of like-minded, but not necessarily agreeing, minds! And that brings me back to why events such as the GEWEX Open Science Conference are so important: they help bring the community together to enjoy the science, learn, gain new insights, share, and teach, but just as importantly, to enjoy the friendships that all this brings. So, thank you!

*Conference attendees enjoy a laugh during the group photo*

***Passing of Prof. Pierre Morel***

*It is with great sadness we report the death of Dr. Pierre Morel, the first director of WCRP and one of the founders of GEWEX, on October 14, 2024. Given Dr. Morel's tremendous impact on the community, we invite you to share your experiences of him with us at gewex@gewex.org so that we can convey them to the family and incorporate them into a special "In Memoriam" piece to celebrate his many achievements.*

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# The FengYun Rainfall Mission: The Characteristics of Instruments and the Designed Products for Applications

**Peng Zhang[1,2], Songyan Gu[1,2], Lin Chen[1,2], Jian Shang[1,2], Manyun Lin[1,2], Aijun Zhu[1,2], Honggang Yin[1,2], Qiong Wu[1,2], Yixuan Shou[1,2], Fenglin Sun[1,2], Hanlie Xu[1,2], Guanglin Yang[1,2], Haofei Wang[1,2], Lu Li[1,2], HongWei Zhang[3], and Naimeng Lu[1,2]**

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Precipitation is one of the most important atmospheric parameters since it actively participates in the Earth's water, energy, and biochemical cycle. Accurate knowledge of precipitation is essential to understand its effects on weather and climate. However, precipitation is hard to measure at a given location using surface-based instruments alone because of the large variations in space and time. In contrast, space-based instruments own the overwhelming capability to measure precipitation occurrence, type, and intensity globally, particularly over oceans and over complex terrain.

FengYun-3 (FY-3) is the second generation of the polar orbiting meteorological satellite program in China. The first satellite operated in the orbit since 2008 and six satellites have been launched successfully. In the FY-3 program, two precipitation missions have been scheduled (Zhang et al., 2019). The FY-3 precipitation mission is the third precipitation mission with precipitation radar after the Tropical Rainfall Measuring Mission (TRMM) and the Global Precipitation Measurement (GPM) mission. The FY-3 precipitation mission is designed to monitor the three-dimensional structure of precipitation for weather systems in the middle and low latitudes of the world. The observed precipitation information will help to improve the accuracy of the precipitation forecast and better understand the characteristics of the precipitation climatology.

The first FengYun-3 precipitation mission, i.e., FY-3G, is the seventh satellite planned in the FY-3 family (Zhang et al., 2023). The satellite platform not only supplies the electric power to support the routine operation of the payloads onboard (see Fig. 1), but also maintains the stable temperature, electromagnetic environment to guarantee the on-orbital performance of the payloads. The FY-3G platform has been specially designed according to the orbital characteristics based on the public platform named Shanghai Academy of Spaceflight Technology (SAST)-3000 satellite, with three-axis mobility for rolling, pitching, and yaw. The platform mobility will support the mission to perform different scientific tasks, such as Earth observation, lunar observation, etc.

FY-3G operates in the inclined orbit, and the nominal orbital altitude of the satellite is 407 km with a nominal lifetime of 6 years. The atmospheric density varies greatly and the orbit decays rapidly (the orbital altitude decays up to 0.9 km a day in solar high year). In order to meet the observation stability of remote sensing instruments, the satellite orbit needs to be maintained and adjusted frequently. Therefore, the propulsion system adopts a drop-pressure single-component hydrazine catalytic decomposition system scheme. This storage tank is newly developed with a surface tension fully managed volume of 930 L and a hydrazine carrying capacity of 740 kg. The storage tank has passed the appraisal-level mechanical environment test. The main characteristics of the satellite platform are listed in Table 1.

| Item Number | Item Name | Main Technical Characteristic | |
|---|---|---|---|
| 1 | Satellite mass | ≤3850kg | |
| 2 | Satellite size | Launch state: 5196mm(X)× 2915mm(Y)× 3103mm(Z) | |
| | | Flight status: 5396mm (X)× 13685mm (Y)× 4153mm (Z) | |
| 3 | Track | Track Type | Non-sun-synchronous inclined orbit |
| | | Nominal track height | 407km |
| | | Inclination | 50°±1° |
| | | Eccentricity | 0.0025 |
| | | Orbital control accuracy | Track half-length axis deviation ≤ 100m (3σ) |
| 4 | Power supply | Solar cell | Triple junction GaAs, 30% efficiency, area 35.2 $m^2$ |
| 5 | | Bus voltage | 42V |
| 6 | | Battery | Two sets of 180Ah lithium batteries |
| 7 | Promote | Thrusters | 24 x 5N thrusters |
| 8 | | Storage box | 1 x 930L storage tank |
| 9 | | Total amount of hydrazine carried | 740±4kg |
| 10 | Design lifetime | 6 years | |

***Table 1**. The main characteristic of the satellite platform*

To realize the goal of the precipitation measurement satellite, the configuration of remote sensing instruments (Fig. 1) is designed to include the active remote sensing dual-frequency (Ku and Ka) precipitation measurement radar (PMR), similar to the GPM Doppler precipitation radar, combined with the passive microwave imager (MWRI-RM), the optical medium resolution spectral imager for rainfall mission (MERSI-RM), and the global navigation satellite system occultation sounder (GNOS) in principle. The microwave imager has added two oxygen detection bands and water vapor bands on the basis of similar instruments in the FengYun satellite precursor, enhancing its detection ability for weak precipitation over land and solid precipitation. The optical imaging instrument cooperates with two

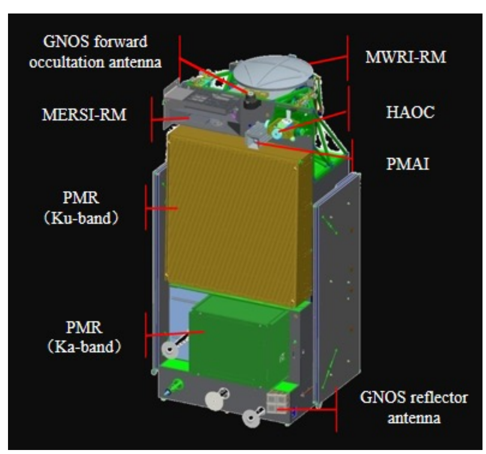


***Figure 1**. Instruments onboard FY-3G satellite*

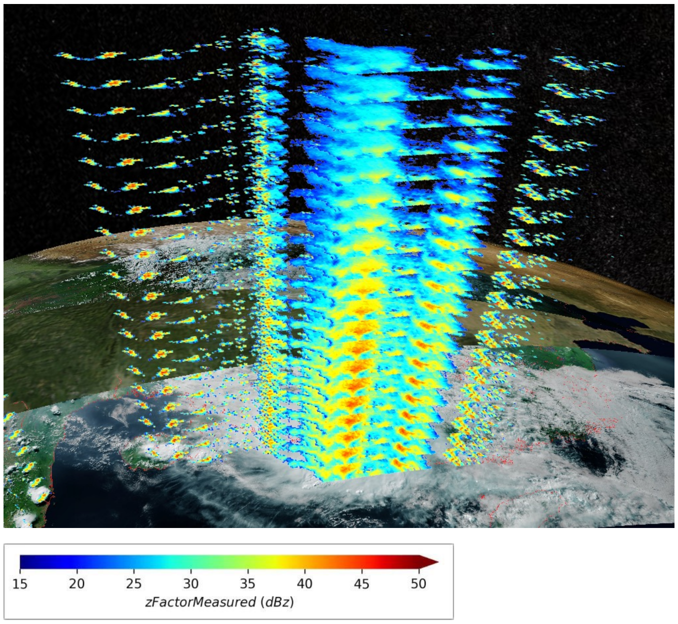


***Figure 2**. The Ku/Ka-band dual-frequency precipitation measurement radar onboard FY-3G captured the rain near Hainan and Yangjiang in Guangdong. The colorbar is as follows, with units in dBz: the precipitation between 0 to 20 km height can be detected with 250 m range resolution and 5 km horizontal resolution. In this figure, 20 height layers are displayed as an example.*

| No. | Instrument Name | Product Name/ Description | Resolution | | Swath Width |
|---|---|---|---|---|---|
| | | | Space | Time | |
| 1 | MERSI-RM | Cloud Mask | 500m | 5min | 1000km |
| 2 | | Snow Cover | | | |
| 3 | | Cloud Phase | | | |
| 4 | | Cloud Top Characteristics (Cloud Top Temperature/ Height/Pressure) | | | |
| 5 | | Sea Surface Temperature | | | |
| 6 | | Land Surface Temperature | | | |
| 7 | | Land Surface Reflectance | | | |
| 8 | | Cloud Amount | 2.5km | | |
| 9 | MWRI-RM | Cloud Liquid Water | | 32 orbits per day | 800km |
| 10 | | Total Precipitation Water | 25km | | |
| 11 | | Land Surface Precipitation Water | | | |
| 12 | | Sea Surface Wind Speed | | | |
| 13 | | Snow Depth/Snow Water Equivalent | | | |
| 14 | | Land Surface Temperature | | | |
| 15 | | Soil Temperature | | | |
| 16 | | Sea Surface Temperature | | | |
| 17 | | Soil Freezing and Thawing | | | |
| 18 | | Microwave Land Surface Emissivity | | | |
| 19 | | Temperature and Moisture Profile | | | |
| 20 | GNOS-II | Sea Surface Wind Speed | Oc-cultation Event | | |
| 21 | | Electron Density Profile | | | |
| 22 | | Dry Air Profile | | | |
| 23 | | Wet Air Profile | | | |
| 24 | PMR | Bright Band Detection | 5km (at nadir), 250m vertical resolu-tion | 32 orbits per day | 300km |
| 25 | | Precipitation Type | | | |
| 26 | | Precipitation Phase | | | |
| 27 | | Precipitation Rate | | | |
| 28 | | Latent Heat | | | |
| 29 | | Combined Active and Passive Microwave Precipitation Water | | | |

***Table 2**. The designed Level 2 products of FY-3G satellite*

main microwave instruments to measure clouds and precipitation, and can serve as a bridge between low orbit precipitation measurement and high orbit infrared precipitation estimation. Such instrument configuration will carry out the detection of precipitation and atmospheric parameters, and obtain melting layer height and thickness, so as to improve the accuracy of precipitation numerical prediction and optimize the cloud microphysical parameterization scheme. The polarized short wave infrared multi-angle imager and high accuracy on-board calibrator are designed and mounted as the experimental instruments.

At 16:35 on May 7, 2023, the Ku/Ka-band dual-frequency precipitation measurement radar onboard FY-3G captured the heavy rain near Hainan and Guangdong (Fig. 2). The image showed the three-dimensional structure of the precipitation system from 3.75 km to 6 km above the surface. The inner structure of the precipitation system was revealed by PMR. The darker the color, the stronger the radar echo and the greater the precipitation intensity.

In addition, a combination of precipitation measurement radar and passive microwave imager will also produce active-passive fused precipitation products. The FY-3G products to be generated in operation are shown in Table 2. On May 1, 2024, FY-3G was in its operational stage. The data and products can be obtained through the dedicated website, FENGYUN Satellite Data Center (*http://satellite.nsmc.org.cn/portalsite/default.aspx*).

In order to maintain operational continuity, the second rainfall satellite has been programmed in the fourth phase of FY-3 series for some time around 2028, which will connect the second-generation satellite (FY-3) effectively with the third-generation polar orbiting meteorological satellite (FY-5) in the future. The satellite will fully inherit the achievements of the FY-3G satellite mentioned in this article and will ensure the continuity of the active precipitation detection, passive microwave detection, and optical imaging. Meanwhile, the stability and accuracy of the satellite platform will be improved and the quantitative constraints of key parameters such as sensitivity and calibration accuracy will be enhanced.

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Zhang, P., Songyan Gu, Lin Chen, et al., 2023. FY-3G satellite instruments and precipitation products: first report of China's Fengyun rainfall mission in-orbit. *Int. J. Remote Sens.*, DOI: 10.34133/remotesensing.0097.

# The On-Orbit Performance of FY-3E in an Early Morning Orbit

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Fengyun-3E (FY-3E), the world's first early-morning-orbit meteorological satellite for civil use, was launched successfully at the Jiuquan Satellite Launch Center on July 5, 2021. There are 11 instruments onboard FY-3E to maintain the capability for atmospheric sounding, low light imaging, sea surface wind detecting, and space weather monitoring. The platform and the instruments were fully tested within a half-year's on-orbit commission test. The FY-3E satellite fills in the vacancy of global early-morning-orbit satellite observation, working together with the FY-3C and FY-3D satellites to achieve the data coverage of early morning, morning, and afternoon orbits. The combination of these three satellites provides global data coverage for numerical weather prediction (NWP) at 6-hour intervals, effectively improving the accuracy and time efficiency of global NWP, which is of great significance to perfecting the global Earth observing system.

Current global NWP requires assimilating satellite-observed data every 6 hours to prepare the initial meteorological field. A two-orbit (morning and afternoon) system covers about 80% of the globe and leaves about 20% of areas without observations. After conducting the risk analysis of the long-term meteorological satellite plans of Europe, the USA, and China, the Coordination Group for Meteorological Satellites (CGMS) addressed this gap by suggesting the early morning orbit in the current and future operational polar-orbit satellites (CGMS, 2011). FY-3E is designed for this purpose (Table 1).

There are 11 instruments onboard the FY-3E satellite, which are listed in Table 2. Three are brand-new instruments, including the wind radar (WindRAD), solar spectral irradiance monitor (SSIM), and solar x-ray and ultraviolet imagers (X-EUVI). The inherited microwave humidity sounder-II (MWHS-II) features better specifications, while the remaining seven are improved instruments.

| No. | Satellite Name | Orbit Attribution | Equator Crossing Time (ECT) |
|---|---|---|---|
| 1 | FY-3C | Mid-morning | 09:07 |
| 2 | FY-3D | Afternoon | 13:29 |
| 3 | NPP | Afternoon | 13:25 |
| 4 | JPSS-1 (NOAA-20) | Afternoon | 13:25 |
| 5 | METOP-B | Mid-morning | 09:30 |
| 6 | METOP-C | Mid-morning | 09:30 |
| 7 | FY-3E | Early-morning | 05:30 |

***Table 1**. Current polar-orbiting meteorological satellites*

| No. | Instrument Suite Catalog | Instrument Name |
|---|---|---|
| 1 | Optical Imager | Medium Resolution Spectral Imager-Low Light (MERSI-LL) |
| 2 | Passive Microwave Sounder | Microwave Temperature Sounder-III (MWTS-III) |
| | | Microwave Humidity Sounder-II (MWHS-II) |
| 3 | GNSS Occultation & Reflection | GNSS Radio Occultation Sounder (GNOS-II) |
| 4 | Active Microwave | Wind Radar (WindRAD) |
| 5 | Hyperspectral Sounder | High Spectral Infrared Atmospheric Sounder-II (HIRAS-II) |
| 6 | Solar Irradiance Observation | Solar Irradiance Monitor-II (SIM-II) |
| | | Solar Spectral Irradiance Monitor (SSIM) |
| 7 | Space Weather Sensor | Solar X-ray and Ultraviolet Imager (X-EUVI) |
| | | Space Environment Monitor-II (SEM-II) |
| | | Triple-angle Ionospheric Photometer (Tri-IPM) |

***Table 2**. FY-3E instruments*

With multiple sensors on FY-3E, a complete remote sensing product generation has been established, producing a total of six categories of products and 40 types of main products (Table 3), including images, cloud and radiation, sea and land surface, atmospheric thermodynamic and dynamic parameters, atmospheric compositions, and space weather, covering the main requirements of the World Meteorological Organization Integrated Global Observing System (WIGOS). As an example, Fig. 1 shows the global distribution of retrieved temperature at 500 hPa. According to the new observation capability of the early morning orbit, unique products from some special instruments such as low-light near constant contrast

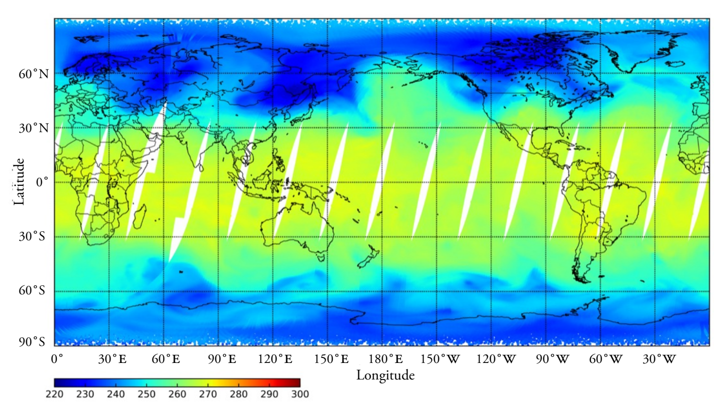


***Figure 1**. Global distribution of temperature at a height of 500 hPa retrieved from FY-3E on 24 December 2021 (Unit: K)*

| Product Catalog | Product Name List | Instrument |
|---|---|---|
| Image | Near constant contrast | MERSI-LL |
| | Nighttime light | MERSI-LL |
| Cloud and Radiation | Cloud mask | MERSI-LL |
| | Cloud amount, Cloud type, Cloud phase, Cloud top temperature, Cloud top height/pressure | MERSI-LL |
| | Outgoing long-wave radiation | MERSI-LL |
| | Cloud-cleared radiance | HIRAS-II |
| Atmospheric Sounding | Atmospheric temperature and humidity profiles | MWTS-III, MWHS-II, HIRAS-II |
| | Dry/wet atmospheric profile | GNOS-II |
| | Ozone profile | HIRAS-II |
| | Total precipitable water | MERSI-LL |
| Atmospheric Dynamic | Ocean vector wind (wind speed/wind direction) | WindRAD |
| | Sea surface wind speed | GNOS-II |
| | Polar atmosphere motion vector | MERSI-LL |
| Land/Sea | Land surface temperature | MERSI-LL |
| | Sea surface temperature | MERSI-LL |
| | Snow cover | MERSI-LL |
| | Sea ice edge & type | WindRAD |

***Table 3****. FY-3E Level 2 Science products list. Note that the solar and space weather monitoring products are not included here.*

and nighttime light, sea surface wind field, sea ice edge and type, vertical ozone profile, etc., have been developed.

FY-3E offers certain advantages for the monitoring of trace gases such as CO and $O_3$ from the hyperspectral infrared observation because of the temperature contrast between the skin temperature and the atmospheric boundary layer that is characteristic of this orbit. The generally smaller amount of cloud and the lower absolute moisture in the early morning can also be an advantage for such air quality monitoring. The early morning orbit also offers the potential to observe the sun in an almost continuous manner. It provides significant advantages for climate monitoring, solar activity, and active regions for space with products such as solar constant, solar spectrum measurements, solar X-ray image, and solar extreme ultraviolet image. Table 3 provides typical Level 2 products from FY-3E. On May 1, 2024, FY-3E was in its operational stage. The data and products can be obtained through the dedicated website, FENGYUN Satellite Data Center (*http://satellite.nsmc.org.cn/portalsite/default.aspx*).

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## Theoretical Water Balance Research


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Making sense of the patterns of evapotranspiration and associated carbon fluxes across scales and climates forms the basis for the 1st and 2nd goals of Phase 4 of GEWEX, which are to: 1) "Determine the extent to which Earth's water cycle can be predicted," and 2) "Quantify the inter-relationships between Earth's energy, water and carbon cycles." In a series of papers, we develop a firm theoretical foundation for addressing the 1st and 2nd goals, as well as the first step towards addressing the part of the 3rd goal relating to climate change.

Our approach is fundamentally related to network, rather than continuum, representations of soil, for which the fundamental equations are not differential equations, but difference equations. Of course, such a theoretical foundation, which has significant theoretical advantages when compared with the continuum approach to soils, including a greater compatibility with the actual networks that represent plants, has also a significant drawback in its increased difficulty of integration with the usual differential equations that represent the atmosphere and the associated boundary conditions at the Earth's surface.

The highly interdisciplinary research foundation lies in scaling expressions for soil production as a function of time and depth, based on universal understanding of solute transport in porous media as derived in percolation theory, and vegetation growth as a function of time, as related to the optimal paths for root growth through the soil. Both of these scaling functions have been verified by multiple publications in *Ecological Modelling* as well as journals of the following societies: American Chemical Society, American Physical Society, American Geophysical Union, European Geosciences Union, Soil Science Society of America, and the British Society of Geomorphology (e.g., Hunt, 2017; Yu and Hunt, 2017; Egli et al., 2018; Yu et al., 2019; Hunt et al., 2020; Hunt et al., 2021a). The non-linear scaling relationships on which the entire theory is based require incorporation of fundamental length scales (a pore separation, or median particle size, or a plant xylem diameter), and a fundamental time scale. The ratio of the fundamental length scale to the fundamental time scale is the associated hydrologic flux, transpiration (approximated as evapotranspiration, ET) for plant growth, and subsurface run-off, approximated as run-off (streamflow), Q, for soil formation. $Q + ET + \Delta S = P$, with $\Delta S$ equal to the annual storage change, then represents the three principal pathways for precipitation, P, on the land surface. Melding the two scaling relationships above provides a basis to develop an expression for the net primary productivity, NPP, which can be used to solve the water balance, generating its direct relevance to the goals of GEWEX.

The work listed above is, despite its relationship with complexity theory, still conventionally described as bottom up, or Newtonian. It is the top-down, or Darwinian component, which then bridges the gap and allows solution of the water balance equation. In our treatment, the Darwinian perspective is represented by applying ecological optimality. Since the water that continues infiltrating into the soil, passing by the plants, is the foundation for soil formation, and the water that the plants use generates the lateral underground plant growth, one can seek for a principle of ecological optimality to guide the understanding of the partitioning of the water. Plants cannot grow effectively without soil (and the water that infiltrates), but they cannot grow at all without water for transpiration. Nevertheless, these two components of the water balance cannot vary independently, as they must sum to P. The quantitative procedure is to express NPP as the product of two factors, one that is a power of ET (from the fractal dimensionality describing the horizontal architecture of the root mass in a thin soil layer), and one that is a power of (P – ET) for the soil depth, or third dimension. Differentiation of this expression with respect to ET, and setting the result equal to zero, gives the maximum NPP, providing the fraction of P given by ET in the case that neither water limitations, nor energy limitations, exist. This parameter, which relates to the fractal dimensionality of the root system, is the only parameter in the equation. For a 2D root model, this parameter is predicted to be 0.623, and 0.813 for a 3D root model (Hunt et al., 2021b; Hunt et al., 2023a). These two values constrain pretty accurately the observed ET for grasslands and forests around the world (Hunt et al., 2023a).

The above method is adapted to energy-limited systems by applying the optimization only to that fraction of P which could have evaporated (i.e., potential ET, or PET), allowing the remainder of P to run off, while adaptation to systems that are water-limited requires restricting the application of the optimization only to the fraction of ground covered by vegetation, assumed equal to P/PET, and letting the evapotranspiration be 100% over the remaining area. These assumptions represent only the lowest level of assumption, yet the theoretical results produce excellent agreement with data for precipitation elasticity of streamflow (defined below), net primary productivity, and tree species richness (the number of tree species) around the world.

All water balance related comparisons have utilized data at annual timescales or multi-decadal averages. NPP has been compared (Hunt et al., 2024) with data that were originally compiled to represent the latitudinal dependence of NPP in Asia (Budyko, 1974). For precipitation elasticity of streamflow, $\varepsilon_p \equiv (P/Q * dQ/dP)$, Q is generated from actual streamflow, requiring data for Q to come from catchment rather than the climatological data used to determination of aridity index AI ≡ PET/P. Overall, our comparison with four major sources of data covered catchment sizes from 50 $km^2$ to 7,000,000 $km^2$, although for the results shown here, the largest catchments were 76,000 $km^2$. Our predictions for $\varepsilon_p$ include the effects of changes in storage, ΔS. We invoked an equal likelihood of positive and negative changes in ΔS to interpret the case ΔS = 0 as being the expected median value of $\varepsilon_p$. For discussion of the ΔS values chosen, see the original paper. For AI < 1, our prediction is that the median $\varepsilon_p$ should rise at first slowly, but on the approach to AI = 1, more rapidly, exceeding 2 for a very small range of AI values, then dropping to 2 for AI > 1. This overall dependence is in line with a summary from Chiew (2006).

| Climate Zone (Koppen) | Number of Catchments | $\epsilon_p$ Median | $\epsilon_p$ Range |
|---|---|---|---|
| **Tropical (A)** | **79** | **1.7** | **(0.8 - 3.1)** |
| Very wet (Af, Am) | 20 | 1.2 | (0.8 - 1.9) |
| Moderately wet (Aw) | 59 | 2.0 | (0.9 - 3.3) |
| **Arid (B)** | **45** | **1.8** | **(0.4 - 2.9)** |
| Cold arid (BWk, BSk) | 32 | 1.6 | (0.4 - 3.1) |
| Warm arid (BWh, BSh) | 13 | 2.0 | (0.5 - 2.5) |
| **Temperate (C)** | **262** | **1.9** | **(0.9 - 3.1)** |
| Wet winter (Csa, Csb, Csc) | 32 | 2.0 | (0.9 - 3.4) |
| Wet summer (Cwa, Cwb, Cwc) | 35 | 1.8 | (0.8 - 2.8) |
| No seasonality (Cfa, Cfb, Cfc) | 195 | 1.9 | (1.0 - 3.1) |
| **Cold (D)** | **135** | **1.1** | **(0.5 - 1.9)** |

***Table 1**. Statistical characteristics of precipitation elasticity of catchments for various Koppen climate zones.*

For ΔS > 0, however, the prediction for $\varepsilon_p$ rises again with increasing AI, generating a second peak in $\varepsilon_p$ in the limit of large AI. While evidence of such a double peak is seen clearly in data for $\varepsilon_p$ represented as a function of AI (shown by all four major global data sets that could be accessed; Hunt et al., 2023b), the peak at AI = 1 is broadened when $\varepsilon_p$ is shown as a function of run-off ratio, Q/P, as in Fig. 1, since AI = 1 corresponds to different Q/P values (horizontal positions) at different values of ΔS. In Fig. 1, this result manifests more as a nonmonotonic curvature in the upper limit of the data. Representing $\varepsilon_p$ as a function of Q/P has the advantage of avoiding the necessity of matching distinct data sets. In the figure, the Budyko (1958) function is shown for comparison. While it appears to follow the centroid of the data more closely, its value approaches 4 in the large AI limit (i.e., small Q/P value in Fig. 1), which is not in accord with the tabulated data. Our predictions for each value of ΔS are cut off at the maximum AI value reported in the data set and do an excellent job of reproducing the entire field occupied by the

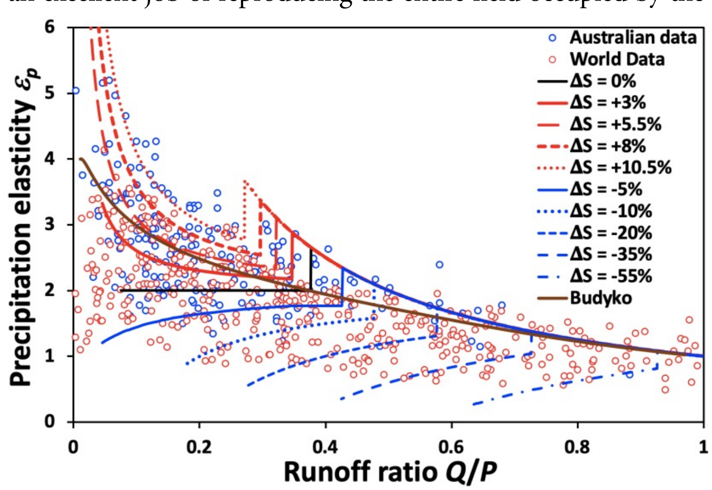


***Figure 1**. Comparison of precipitation elasticity $\varepsilon_p \equiv (P/Q * dQ/dP)$ developed from the analytical solution of the water balance, including annual storages (of the percentages listed) with data for the dependence of elasticity on runoff coefficient from the publications of Chiew (Hunt et al., 2023b). Note that ΔS = 0 is expected to generate a median value of $\varepsilon_p$, which is confirmed by comparison with tabulated values across climate regimes in Hunt et al. (2023b).*

data. Clearly, for a meaningful prediction of precipitation elasticity of streamflow and, by inference, the water balance itself, changes in shallow subsurface storage must be accounted for.

Comparisons across such a wide range of scales also revealed an important and physically sensible result, that the storage change values necessary to constrain the observations decreased with basin area to values less than 10% at the largest scales.

I would like to conclude with a quote from the *Eos* highlight (*https://eos.org/editor-highlights/how-much-terrestrial-precipitation-is-used-by-vegetation*) of Hunt et al. (2023b): "The contribution allows us to predict the impact of changing climatic conditions on the interplay between climate, vegetation, and water resources. The findings open the door to new perspectives in climate change impact assessment."

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# Asian Summer Monsoon Variability during 2022–2023: Beyond Canonical Teleconnection Patterns


**R.S. Ajayamohan[1], Gill Martin[2], Thea Turkington[3], Hatsuki Fujinami[4], Joseph Basconcillo[5], H. Annamalai[6], Shiromani Jayawardena[7], Raghavendra Ashrit[8], Hiroshi Takahashi[9], and Tieh Yong Koh[10], on behalf of the CLIVAR/GEWEX Regional Working Group on Asian-Australian Monsoons**

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The boreal summer monsoon, a seasonal phenomenon vital to the world's most populous regions, paints a broadly contrasting picture between the years 2022 and 2023 (Figs. 1a-b). For example, climatologically dry regions of Pakistan and surrounding Gulf countries received unprecedented rainfall during 2022, resulting in devastating floods, while in 2023, much of the region saw drier conditions overall but did not exhibit the typical El Niño teleconnection pattern. Here, members of the Climate and Ocean-Variability, Predictability, and Change (CLIVAR)/GEWEX Monsoons Panel and Regional Working Group on Asian-Australian Monsoons (WG-AAM) highlight the need for better understanding and predicting monsoon variability at regional scales in a warming planet.

Distinct differences in climate drivers played a role in modulating the monsoons. La Niña conditions were present throughout 2022 as part of the "Triple dip" La Niña that started in 2020. A negative Indian Ocean Dipole (IOD) also developed around the middle of 2022, which gradually returned to neutral in November 2022. The La Niña event returned to neutral in early 2023. Soon afterwards, there were signs of an El Niño developing, with the event well established by September 2023. Also, contrary to 2022, a positive IOD developed in August 2023, only ending at the start of 2024. These past two years also highlighted the challenges of using a single area average as an index to measure El Niño Southern Oscillation (ENSO) under a long-term warming trend. In 2023, sea surface temperatures across much of the tropics were warmer than average, leading to increased interest in alternative indices, such as the Relative Oceanic Niño Index (with implications for both future predictions and research on the role of ENSO on monsoons).

The boreal summer seasonal precipitation patterns in 2022 exhibited above-normal rainfall over the western parts of India, Sri Lanka, and the Maritime Continent (Fig. 1a). Weak monsoon westerlies, characterized by anticyclonic circulation anomalies, were observed over the Bay of Bengal extending to Indochina. These anomalies were associated with suppressed convective activities across eastern India, the Indochina Peninsula, and parts of East Asia. In contrast, in 2023, the wind and rainfall anomalies were insignificant across most of the monsoon-influenced

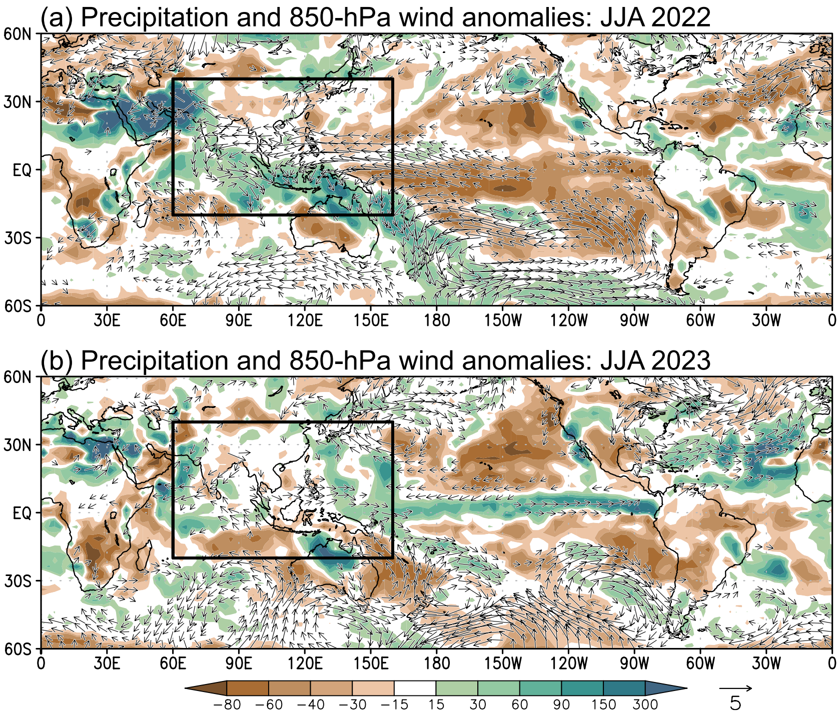


***Figure 1**. (a) Anomalies in precipitation (% difference against climatology) and 850hPa wind fields (vectors; m s$^{-1}$) in 2022 summer (June–August). Wind anomalies less than 1.0 m s$^{-1}$ are omitted. (b) As in (a) but for 2023. Anomalies are estimated with respect to the climatological mean (1991–2020). The black box (60–160°E, 20°S–40°N) indicates Asian-Australian monsoon region. Precipitation: Global Precipitation Climatology Project (GPCP) Version 2.3. Wind fields: Japanese Reanalysis for Three-Quarters of a Century (JRA 3Q)*

countries (Fig. 1b), apart from the suppressed convection in the equatorial western Pacific and northeast India. While the monsoon characteristics observed in both years showed elements reminiscent of known canonical teleconnection patterns, certain regions experienced noticeable deviations. For instance, despite the El Niño event, 2023 witnessed normal rainfall over India due to the positive IOD developing later in the season.

The convective activity and circulation over the Pacific basin were contrasting between 2022 and 2023, but South and Southeast Asian monsoons between the two years were not always contrasting, which implies a complex monsoon variability. El Niño conditions likely induced inactive monsoon convection throughout the South Asian monsoon regions and possibly parts of the Southeast Asia monsoon region in 2023 (Fig. 1b). Over the western North Pacific, the monsoon trough with enhanced convective activity was found, partly strengthening anticyclonic circulation anomalies over East Asia. The distinct inactive convection along the subtropical jet stream of the Northern Hemisphere has been identified, which could be the result of a prolonged global heat wave in 2023. The differences between 2022 and 2023 underscore the intricate interplay of planetary and regional drivers in shaping monsoon variability at regional scales. They also emphasize the importance of a nuanced understanding and modeling of monsoon variability.

A few notable events were evident while dissecting the subseasonal and synoptic variability in these contiguous years. In 2022, the monsoon season featured active subseasonal convection around Pakistan and the equatorial Indian Ocean. The 2023 monsoon season witnessed high variance in subseasonal convection over the South China Sea (SCS), the northwest Pacific, and the area south of Japan, alongside reduced activity in synoptic-scale disturbances over the low-level monsoon westerlies. Weaker eastward propagating Madden Julian Oscillation (MJO) and northeastward propagating Boreal Summer Intraseasonal Oscillation (BSISO) activity in 2023 suggested limited modulation of rainfall by large-scale atmospheric waves, leading to enhanced convection over the western Pacific and East Asia but suppressed convection over India, the Indochina Peninsula, the SCS, and Japan.

The onset of the summer monsoon displayed anticipated variability between 2022 and 2023. The onset was near-normal or earlier than usual in 2022, while 2023 experienced slight delays. A notable event was the emergence of Super Typhoon Mawar over the Philippine Sea on May 19, 2023, disrupting weather patterns. The Indian summer monsoon onset occurred punctually on May 31, 2022, but was delayed by about a week to June 8, 2023. The presence of the super cyclonic storm Biparjoy significantly hindered the advancement of the Indian monsoon in 2023.

Notable extremes were observed in both years (Table 1). In 2022, a notably active weather pattern unfolded. Pakistan encountered significant flooding, alongside

| | | 2022 | 2023 |
|---|---|---|---|
| Warm and/or Dry | Heat wave | Bangladesh (July–August)<br>Eastern China (June–August)<br>Hong Kong, China (July)<br>Eastern, western Japan (June–July) | North China (June–July)<br>Hong Kong, China (June–August)<br>Uttar Pradesh, India (June)<br>Northern, eastern Japan (June–September)<br>Republic of Korea (May–August) |
| | Fog/haze/smog | – | Malaysia (July–October) |
| | Drought/dry spell | Yangtze River, China (July–November)<br>Pakistan (March–June)<br>Eastern parts, Papua New Guinea (May–October) | – |
| Wet | Flood | Assam, India (May–July)<br>Sulawesi, Indonesia (July)<br>Pakistan (July–August)<br>Thailand (August) | Beijing-Tianjin-Hebei, China (July)<br>Raigarh and Shimla, India (July–August) |
| | Landslide/mudslide & debris flow | Noney and Asaam, India (June) | Vietnam (August) |
| | Rain/wet spell | Maldives (July)<br>Myanmar (July–August)<br>Bangkok, Thailand (July) | Pakistan (June)<br>Republic of Korea (July) |
| | Tropical cyclone | South China (July) | South and east China (July)<br>Pakistan (June)<br>Republic of Korea (August) |
| | Thunderstorms/squall lines | Bihar, India (June) | – |
| | Lightning | India (June, July) | – |

***Table 1**. Extreme events reported by National Meteorological and Hydrological Services (NMHSs) to WMO in 2022 (WMO database 2022, https://bit.ly/3RdNJIO) and 2023 (WMO database 2023, https://bit.ly/4aPyPiX) between June and August. These events were either unusual or unprecedented, as reported by the NMHSs.*

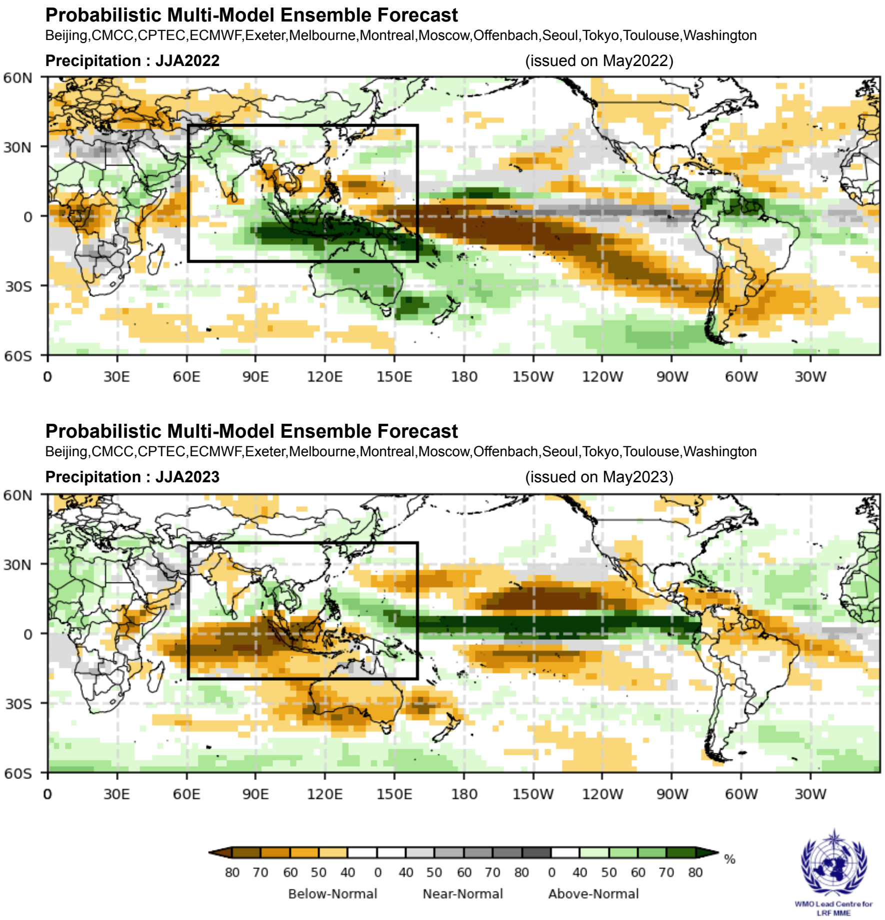


***Figure 2****. Multi-model ensemble (MME) precipitation forecast for June–August 2022 (top) and June–August 2023 (bottom) from the World Meteorological Organization Lead Centre for Long-range Forecast Multi-model Ensemble (https://wmolc.org/). Brown and orange shades indicate a higher chance of below-normal precipitation (lower tercile), while green shades indicate a higher chance of above-normal precipitation (upper tercile). Grey shades indicate a higher chance of near-normal precipitation (middle tercile), and white indicates no dominant tercile/climatological chance of each of the terciles.*

minor flooding incidents in Sri Lanka during May and August, while Malaysia and Brunei Darussalam faced floods in June. Additionally, there were numerous instances of very heavy rainfall, particularly along the west coast of Indonesia and central India. Tropical cyclone activity in the western North Pacific remained within the normal range for typhoon formations and landfalls.

Conversely, 2023 portrayed a generally less active monsoon and typhoon season. Sri Lanka encountered a dry spell until late August, leading to water scarcity issues. East Asia, including Japan, China, and Hong Kong, experienced heatwaves, along with a heatwave in India during June. Furthermore, 2023 witnessed the lowest number of typhoon formations and landfalls in the western North Pacific since 1981, with the Philippines also experiencing the lowest number of typhoon passages and landfalls since 1991. However, major floods struck India in July and August, accompanied by landslides in Vietnam during August. Furthermore, heavy rainfall over Sri Lanka in September (not covered by the June–August, or JJA, outlook) emphasizes the complexity of rainfall patterns and intraseasonal variability.

To what extent were these contrasting features forecast? Many of the key features of the multi-model ensemble outlooks for JJA displayed a reversal of the most likely tercile between 2022 and 2023 (Fig. 2). Over South Asia, much of India and Pakistan had an increase in the chance of above-normal rainfall in 2022 (green shading, Fig. 2 top), while below-normal rainfall was more likely in 2023 (orange shading, Fig. 2 bottom). For Sri Lanka and southern parts of India, below-normal rainfall was more likely in 2022, while above-normal rainfall was more likely in 2023. Elsewhere, for the southern half of Southeast Asia and northern Australia, there was a switch from above-normal to below-normal rainfall between the two years, while mainland Southeast Asia and the Philippines were the opposite (below-normal rainfall more likely in 2022 and above-normal rainfall in 2023). These predictions are in line with model predictions of La Niña conditions in JJA 2022 and developing El Niño conditions in 2023 (also noticeable in Fig. 2 based on the rainfall predictions over the equatorial Pacific Ocean), although the eventual El Niño development was slower than the models were predicting in May 2023. This slower development may account for less agreement between the rainfall anomalies and most likely tercile in 2023 compared to 2022. Furthermore, while the seasonal models may be able to predict the large-scale pattern, these models do not capture sub-seasonal variations and short-term weather events with the largest impact. Understanding and modeling these phenomena remains an urgent challenge, although integrating subseasonal information into seasonal outlooks and updating on a monthly basis could also provide decision-makers with valuable insights.

The differences between the 2022 and 2023 monsoon seasons underscore the mounting challenge of accurate weather and climate prediction at regional scales in a warming climate. The difficulty of predicting weather patterns, characterized by both excessive rainfall and prolonged dry spells, poses significant threats to agricultural productivity and water security. Farmers, who traditionally rely on predictable rainfall, must adapt to this new reality. However, advancements in weather forecasting and early warning systems offer some hope in mitigating the impact of extreme weather events. In essence, both 2022 and 2023 were stark reminders of the potential dangers and financial costs posed by climate extremes. For example, the Pakistan floods led to an estimated loss of 15 billion USD (WMO database 2022; *https://bit.ly/3RdNJIO*). Climate change amplifies extremes, leading to more frequent and intense heatwaves, droughts, and floods. This narrative also highlights that the conventional teleconnection patterns of La Niña and El Niño may not always align with the realities of a changing climate. This necessitates coordinated diagnostic and modeling activities among researchers, the forecasting community, and international resources. The WG-AAM (*https://www.clivar.org/asian-australian-monsoon*) is well-positioned to encourage, coordinate, and facilitate these communities in tackling these challenges.

Meeting/Workshop Reports

# 9th GEWEX Open Science Conference and Side Events

**Sapporo, Japan**
**3–13 July 2024**

**Peter van Oevelen[1], Jan Polcher[2], and Xubin Zeng[2]**
[1]Director, International GEWEX Project Office; [2]GEWEX Scientific Steering Group Co-Chair

The 9th GEWEX Open Science Conference (OSC), *Water and Climate*, and its side events were held from 3–13 July 2024 in Sapporo, Japan. They were co-hosted by Hokkaido University, the Science Council of Japan, and the International GEWEX Project Office.

It turned out to be our most successful event to date, with around 1200 attendees, of which about 900 were scientists and 300 were stakeholders. The attendees came from 46 different countries where 27% identified as female, 71% as male, and 2% did not indicate. In total we had 361 (40%) Early Career Researchers (ECRs) attending, of whom 36% identified as female and 63% as male and 1% did not indicate.

For the first time, we decided to have special stakeholder sessions with tremendous input and organization from our Japanese hosts, including the participation of four ministries of the Japanese government. From the attendance and the feedback, we received on these special sessions, we can only conclude that this was very much appreciated by both researchers and stakeholders and seen as timely and clearly fulfilling a need. Given this outcome, we certainly will continue building upon this success and incorporate interactions with society in our future meetings.

The core program of the conference was organized around three overarching themes:

- Water, Climate, Anthropocene
- Extremes and Risks
- Water, Energy, and Carbon Processes

In the context of the conference themes, the sessions focused on research that contributes to the following areas, which are the goals of GEWEX:

1. Determination of the extent to which Earth's water cycle can be observed and predicted
2. Quantification of the inter-relationships between Earth's energy, water, and carbon cycles to advance our understanding of the system and our ability to predict it across scales
3. Quantification of the anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle
4. Extremes in the water cycle and risks to society

Ultimately, we ended up with 30 sessions, 29 of which were both oral and poster and one session that was posters only. These sessions comprised over 860 abstracts by a little over 800 unique presenters. Some of the topics such as extremes (flooding in particular) were among the most popular. That said, the program naturally covered the core topics for GEWEX such as water and energy cycles, atmospheric process, land-atmosphere interaction, and global climate data set analyses, yet also included newer directions of research such as how to generate robust climate information for -small- stakeholders as well as more controversial topics such as climate intervention for example. A detailed overview of the program and its presentations can be found at [https://www.gewexevents.org/meetings/gewex-osc2024/](https://www.gewexevents.org/meetings/gewex-osc2024/).

Now that the 9th GEWEX Open Science Conference has ended, we can conclude that it has shown the tremendous strength and interest of the Earth system science research community dedicated to the water, energy, and carbon cycle of our planet. Numerous new insights and questions were raised, for example, on precipitation observations and modeling, evaporation, and associated processes, and the human interactions both in terms of interplay with the processes as well as on engagement with communities to tackle mitigation and adaptation. It is now recognized that human intervention in the water cycle is an unavoidable fact and needs to be considered by the Earth system science community in collaboration with socio-economic disciplines to address global changes.

In short:
*The implications of a shifting climate on our water and food resources demands an increased understanding of the intricate interplay between humans and the water, energy, and carbon processes, as well as of the dynamic transformations unfolding within them.*

This conference clearly helps our community to rally around these challenges and shape the way forward.

*Scenes from the 9th GEWEX Open Science Conference, including poster viewing, talks, and enthusiastic GEWEX community members*

Such a big event is the ideal venue to also convene and mobilize the community in different ways and to take care of the management of the many activities taking place under the GEWEX umbrella. Three of our Panels [the GEWEX Hydroclimatology Panel (GHP), the Global Land-Atmosphere System Studies (GLASS) Panel, and the GEWEX Data and Analysis Panel (GDAP)] held their annual meetings in the days prior to the conference. The Monsoons Panel had an Australian Asian Monsoon (AAMP) panel meeting and various new and ongoing activities [e.g., the Impact of Initialized Land Temperature and Snowpack on Sub-Seasonal to Seasonal Prediction Phase II project (LS4P-II), the Asian Precipitation Experiment (AsiaPEX)] also used the opportunity to hold meetings. The groundwater activity had its inaugural workshop in Sapporo to discuss scientific direction and priorities and an organizational set-up for future development in collaboration and within GEWEX.

It is customary for GEWEX to organize an ECR event as part of the OSC, and this time was no exception. With great support from the Young Earth System Scientists (YESS), the local ECR organizing team, and the American Geophysical Union (AGU) Hydrology Section Student Subcommittee (H3S), the ECR workshop had several aims. One was to produce a white paper describing the ECR perspective on research challenges and opportunities related to three overarching topics:

1. Extremes in the water cycle and risks to society
2. Understanding "actionable" information in hydroclimate research
3. Emergent issues: AI/ML applications in the water-energy nexus and climate intervention in the water and energy cycle

Half a day was dedicated to a hands-on session with space agency experts on understanding both satellite observations for climate extremes and the water cycle from space. Special thanks goes to the Japan Aerospace Exploration Agency (JAXA), the National Aeronautics and Space Administration (NASA), and the Centre national d'études spatiales (CNES) for their presentations on technical and operational aspects of satellite function and the lab activity aimed at exploring further resources, products, and tools. A more detailed article with the specific outcomes can be found in the newsletter on page 13.

On the Sunday preceding the OSC, a special Space Agency Event was organized where the various space agencies [NASA, the European Space Agency (ESA), JAXA, CNES, the China Meteorological Administration (CMA), and the Korea Aerospace Research Institute (KARI)] presented their activities and provided an opportunity for ECRs to engage and exchange ideas with the representatives. It was also the first time that space agencies outside of North America, Europe, and Japan were involved in such an event. We thank JAXA for support-

ing the reception that closed this event. Sunday also featured a public lecture to the citizens of Sapporo at the Hokkaido University on the challenges of climate change and water resources.

The conference was also a unique opportunity to thank certain individuals for their long-term and exceptional support to the community. To this end, GEWEX has established a new award only to be granted to up to two individuals at each Open Science Conference: the Lifetime Contribution Award. This event's recipients were Dr. Jack Kaye for his long-term continuous support of the climate research community and the International GEWEX Project Office and Prof. Toshio Koike for his numerous contributions ranging from establishing the Coordinated Enhanced Observation Period (CEOP) to his many years of service to the GEWEX community in various roles.

In addition to these awards, we also named two new GEWEX Ambassadors, Prof. Andrew Pittman and Dr. Christa Peters-Lidard, for their past and ongoing contributions to the GEWEX community. We look forward to further engaging with them!

An ECR presentation competition was organized as part of the conference, and many wonderful posters and oral presentations were given. Only three certificates could be awarded, and we congratulate the following winners:

**Manon Sabot**: *Challenges and Opportunities in Building a Global Model of Plant Hydraulics*

**Kristen Whitney**: *Quantifying Drought Propagation Typology through Remote Sensing and Data Assimilation*

**Daisuke Takasuka**: *Characteristics of Precipitating Convection and Moisture-Convection Relationships in Global Km-Scale Simulations*

While we are very happy with the general outcome of the conference, there are certainly aspects we feel can be improved. We would like to see greater gender balance in our attendees and presenters, and while we certainly strive to make progress overall, we can also target things like keynote presentations. It is encouraging to see that within the ECR population, the balance is better, but even there it must be improved. Although we had attendees from 46 different countries, we would like to see that number increase. Issues relating to travel visas, including slow processing time, difficulties traveling to local consulates, and restrictive documentation requirements presented obstacles. Certainly, for attendees from Africa, it is challenging to attend events like this. The conditions under which we can provide travel funding also limit us in whom we can support and how, and that also influences attendee diversity.

To organize such a big event and side activities, one needs considerable support and resources, and we would like to thank our many sponsors (as there are too many to list here, please take a look at *https://www.gewexevents.org/meetings/gewex-osc2024/sponsors/our-sponsors/*) for making this conference such a success! We also need to thank all of you in our community who helped as a committee member, convener, reviewer, presenter, or other volunteer. A special thank you goes to our co-organizers, Prof. Tomohito Yamada, Prof. Tomonori Sato, Prof. Hiroki Okachi, and their team. It was a true pleasure working with them and we managed together to tackle all our challenges and get around last minute roadblocks! In addition, a special mention to Prof. Toru Terao: as lead of AsiaPEX, he truly supported the community and our office regarding travel support and logistics! Of course, we would be remiss if we did not mention our Panel Co-Chairs, SSG members, who were instrumental in shaping the scientific program and supporting logistics. Last but certainly not least, a very big thank you to the staff at IGPO, particularly Fernande who spent many an hour and late night making sure things would be in order and function on time.

For those who are curious about some of the visuals of the conference and side events, they can be found at *https://www.gewexevents.org/meetings/gewex-osc2024/gallery/*. Thanks to all who participated, and we look forward to welcoming you to our next big conference, the 10$^{th}$ OSC, probably in 2028!

# 9th GEWEX OSC Early Career Researcher Workshop: Key Discussions and Outcomes

**Abhinav Dengri[1], Hiroki Okachi[2], Friso Van Alphen[2], Natsuki Yoshida[3], Carla Gulizia[4], Lucía M. Cappelletti[4], and Valentina Rabanal[5]**

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From July 4 to 6, 2024, the 9th GEWEX Open Science Conference (OSC) Early Career Researcher Workshop brought together 49 Early Career Researchers (ECRs) from over 30 countries at Hokkaido University in Sapporo, Japan. In rooms filled with varied backgrounds, these ECRs discussed the critical issues of extremes in the water cycle and risks to society. Voices from across the globe blended as participants shared ideas, debated challenges, and crafted solutions, with Sapporo's summer landscape just outside the conference room's windows. On July 7, the momentum continued with Space Agency Day, where participants engaged directly with different global space agencies in a series of talks.

This workshop wasn't just a meeting of minds, it was a crucible for new ideas, where consensus and divergence shaped the discussions. The urgency of addressing climate-related challenges was clear, as was the need for research that is both actionable and transparent. By the end, participants left with concrete recommendations, emphasizing the co-production of knowledge, community engagement, and empowering ECRs to bridge the gap between science and society.

The event came together through a joint effort by the Japan ECR community, and the Young Earth System Scientists (YESS) community, and the American Geophysical Union's Hydrology Section Early Career Scientists Subcommittee (AGU H3S). Supported by GEWEX, a core project of the World Climate Research Programme (WCRP), this event was designed to attract ECRs in hydroclimate studies. The goal was to propel professional development through interdisciplinary networking, exposure to the latest tools and methods, and direct engagement with experts. One of the workshop's proposed key outcomes was a white paper capturing ECR perspectives on the challenges and opportunities in hydroclimate research, with a focus on generating actionable information to mitigate the risks posed by extreme events.

### Workshop Overview

The 3-day workshop opened with remarks from Prof. Peter van Oevelen, director of GEWEX, Prof. Jan Polcher, GEWEX Scientific Steering Group co-chair, and Assoc. Prof. Tomonori Sato, co-lead of the local organizing committee. These were followed by introductory presentations, after which participants engaged in an interactive ice-breaker exercise. This activity allowed attendees to learn about each other's research fields and backgrounds. Alongside an explanation of the program schedule and its objectives, this exercise fostered a collaborative and welcoming atmosphere, setting a strong foundation for the discussions ahead.

*Figure 1. Photos of the field trip (top, inside of Izarigawa Dam) and the hands-on activity (bottom)*

Participants were then divided into three Working Groups (WGs) for active discussion, each focusing different aspect of the workshop's overarching theme:

- WG1: Extremes in the Water Cycle and risks to society
- WG2: Understanding "actionable" Information in Hydroclimate Research
- WG3: Emergent issues: Artificial Intelligence (AI)/Machine Learning (ML) Applications in the Water-Energy Nexus and Climate Intervention in the water and energy cycle

Two impulse talks brought a surge of energy. Dr. Monica Morrison [National Center for Atmospheric Research (NCAR)] and Assoc. Prof. Yohei Sawada (University of Tokyo) delivered 30-minute presentations aimed at sparking deeper discussions. Dr. Morrison's presentation, "The Logic and Ethics of Actionable Science", underscored the importance of co-designing metrics, integrating concepts effectively, and ensuring transparency to make research outputs credible and relevant. Dr. Sawada's talk, "Toward Next-Generation Hydroclimatological Modeling", demonstrated

***Figure 2**. Group photo of ECR workshop event*

the merging of process-driven and data-driven methods.

Two hands-on activities were organized to offer the participants the chance to dive deep into cutting-edge tools. Over the course of four hours, ECRs received training on the Application Programming Interface (API) for Quantum Geographic Information System (QGIS) and ML techniques for precipitation prediction, led by the Japan Aerospace Exploration Agency (JAXA), as well as a Surface Water and Ocean Topography (SWOT) session from the National Aeronautics and Space Administration (NASA). These sessions weren't just about learning; they were about applying these tools to ECRs' own research.

As the workshop neared its conclusion, participants stepped out of the conference room and into the field, with excursions to the Chitose River and Izarigawa Dam. Organized in collaboration with the Japanese Ministry of Land, Infrastructure, Transport, and Tourism, these trips offered a firsthand look at the local water resource management practices, bridging the gap between theory and practice. The workshop concluded with presentations from each Working Group, where they summarized their discussions and proposed practical applications for the ideas developed during the working group discussion.

### Summary of Discussions

The workshop's discussions centered on several key topics: the complexities of collaborating with stakeholders to mitigate risks from extreme events, the integration of AI/ML in water-energy research, and the professional development of ECRs. These themes were examined through the perspectives of conducting actionable research, fostering interdisciplinary collaboration, and enhancing transparency and community engagement.

1. **Challenges in Early Career Research**: Participants highlighted significant challenges they face, particularly those from developing regions. Securing funding, accessing advanced research facilities, and coping with the pressures of frequent publication were identified as major hurdles. The competitive nature of the academic environment was seen as both a driver of innovation and a barrier to meaningful societal engagement, as it often prioritizes publication metrics.
2. **Opportunities and innovations**: The workshop underscored several opportunities for innovation in hydroclimate research. AI/ML technologies are now seen as promising tools for improving model accuracy and reducing reliance on computationally expensive physical models. The co-production of knowledge with local communities was another area to explore, with successful examples from South Asia serving as models for future initiatives. Additionally, innovations in risk management, such as public-private partnerships and centralized frameworks, were discussed as a means to enhance stakeholder collaboration and adaptive decision-making.
3. **Career development and networking**: ECRs emphasized the importance of networking, interdisciplinary collaboration, and cross-regional partnerships for professional growth. The workshop provided a platform for building these connections, with participants recognizing the value of diverse research exposure and the exchange of ideas across different cultural and academic backgrounds.

While there was general agreement, several areas of divergence emerged during the discussions.

1. **Risk perception and trust in transboundary cooperation**: Local communities emphasized Indigenous knowledge and historical experience, sometimes conflicting with the data-driven approaches of government agencies and researchers. Trust issues emerged as a key point of contention, with some researchers advocating for stronger agreements and enhanced data sharing across borders. Others pointed to the significant challenges in reconciling divergent interests and legal frameworks across different jurisdictions.
2. **Collaboration and community engagement**: While there was consensus on the importance of involving local communities in research, ECRs differed on the best methods for sustaining engagement after project completion. The challenge of translating complex hydroclimatic data into actionable information for non-academic audiences was a point of contention, with participants debating the most effective strategies for communication and engagement. Contemporary community engagement is still too much focused on transferring information from scientists to the local community, and needs to give way to co-creation together with the local community.
3. **AI/ML and climate intervention**: While some were enthusiastic about AI/ML's potential to replace traditional methods and enhance research efficiency, others cautioned against over-reliance on these technologies, especially given the "black box" nature of many ML models, which can obscure underlying processes and introduce risks. Similarly, discussions on climate intervention and nature-based solutions revealed a divide on the urgency and ethics of these approaches. Some advocated for immediate action to combat escalating climate impacts, while others raised concerns about the risks, unintended consequences, and economic implications, questioning whether financial incentives align with the long-term goals of sustainable development.

### Current Outcomes and Actionable Steps

The workshop's impact was felt instantly. New international connections were made despite differing perspectives. These professional relationships, established just before the start of the GEWEX OSC, allowed ECRs to deepen their engagement during the event by exploring each other's research through poster sessions and presentations. The workshop also reinforced the importance of ECRs in advancing actionable research, with a collective commitment to producing impactful work that bridges the gap between science and society.

The workshop concluded with several actionable recommendations for participants and organizers:

1. **Valuing non-traditional metrics of success**: The scientific community is encouraged to recognize and value non-traditional metrics of success, such as the production of actionable information and effective communication, which are critical for ECRs. This shift in focus would support the development of research that is not only scientifically robust, but also socially relevant.
2. **Facilitating co-production of knowledge**: ECRs are urged to engage in the co-production of knowledge with local communities, ensuring that research outcomes are meaningful and equitable. This involves building and maintaining strong connections with communities and actively involving them in the research process.
3. **Enhancing communication across networks**: The workshop highlighted the need for symmetrical communication across transdisciplinary networks. Participants and organizers are encouraged to foster transparency and trust between scientists, practitioners, stakeholders, and society, ensuring that scientific findings are effectively translated into actionable steps.
4. **Addressing data gaps**: There is a call to address existing data gaps by improving access to hydroclimatic data and ensuring that it is available in formats that are accessible to a broad range of users, including non-academic audiences. This is crucial for supporting informed decision-making and enhancing the impact of research.

The 9th GEWEX OSC Early Career Research Workshop was more than just a meeting—it was a catalyst for change, built on the collective voices and diverse perspectives of its participants. Forty-nine early career researchers gathered to dive into the challenges and opportunities within hydroclimate research, focusing on the pressing issue of extremes in the water cycle and the escalating risks to society. Through active discussions, participants gained a clear understanding of the societal needs in this critical field. As hydroclimate research continues to advance, the insights and collaborations from this workshop are poised to influence future research directions and inform policy decisions.

Special thanks to the International GEWEX Project Office and the Local Organizing Committee for their support in making the 9th GEWEX OSC ECR workshop a success, and to all the participants whose insights and discussions formed the foundation of this report.

## The Tenth Annual Aerosols, Clouds, Precipitation and Climate (ACPC) Initiative Workshop

**London, UK**
**20–22 May 2024**

**Michael P. Jensen[1], Minghuai Wang[2], Matthew Christensen[3], Jiwen Fan[4], Andrew Gettleman[3], Edward Gryspeerdt[5], Meinrat Andreae[6], Guy Dagan[7], Franziska Glassmeier[8], Johannes Quaas[9], Daniel Rosenfeld[7], Philip Stier[10], Kentaroh Suzuki[11], Bethan White[12], and Robert Wood[13]**

[1]Brookhaven National Laboratory, [2]Nanjing University, [3]Pacific Northwest National Laboratory, [4]Argonne National Laboratory, [5]Imperial College London, [6]Max Planck Institute for Chemistry, [7]Hebrew University of Jerusalem, [8]Delft University of Technology, [9]University of Leipzig, [10]Oxford University, [11]University of Tokyo, [12]Monash University, [13]University of Washington

The tenth Aerosols-Clouds-Precipitation-and-Climate (ACPC; *https://www.acpcinitiative.org*) initiative workshop was convened 20–22 May 2024 at Imperial College London, UK, and online to discuss the latest research within the two ACPC working groups. Approximately 40 in-person and another 35 virtual attendees joined the meeting. The first day and a half focused on aerosol effects on shallow clouds while the second half of the workshop concentrated on aerosol interactions and deep convective clouds.

The shallow cloud sessions featured topics on shipping emissions, large scale modeling, satellite observations, and shallow cloud processes. This was followed by a discussion of the "roadmap" for ACPC shallow cloud work in the coming year.

Due to the recent reduction of allowed ship sulfur emissions, there has been a lot of discussion of the shipping emissions change as a "natural laboratory" to understand aerosol-cloud interactions (ACIs). Several talks presented estimates of the ACI from shipping. The value appears to be converging around -0.1 W/m$^2$. Retrieval issues of the liquid water path (LWP) response in ship tracks were identified through examining back trajectories along ship tracks as well as locally near the head of the tracks. These biases may point to a bigger issue of characterizing LWP adjustments from satellite observations.

A number of presentations examined ACIs in large scale models, and how they are related to individual processes or even parameters in models. Important results showed that some models now reproduce the inverted-V relationship between cloud droplet number (Nd) and LWP, but that this doesn't predict how the LWP in these models responds to an aerosol perturbation. Additional studies showed hemispheric symmetry and asymmetry in planetary albedo associated with natural perturbations from models and observations using "natural laboratories".

*In-person attendees at the 2024 ACPC meeting at Imperial College, London, UK*

There were several talks on the response of shallow clouds to aerosols, focusing on environmental factors, with a mix of modeling and satellite studies. An important point was raised that it might be advantageous to look for aerosol impacts on variability, rather than just the mean response. Evidence from large eddy simulations (LES) was presented for the connection between processes (precipitation suppression and entrainment) and LWP–$N_d$ relationships, and observational evidence was shown that both legs of the "inverted V" in the LWP–$N_d$ relationship can be explained by confounding of planetary boundary layer depth and air mass history.

Last year the ACPC shallow cloud roadmap discussed multi-scale modeling and analyzing shipping emissions impacts. Progress was made on both fronts, with a summary paper on the aerosol indirect radiative effects of shipping emissions to be published soon, and a few multi-scale modeling and observation collaborations initiated. New ideas were discussed for evolving the shallow cloud roadmap. There was interest in the need for more high-resolution simulations via LES to capture the detailed processes not resolved in General Circulation Models (GCMs). Some discussion on bringing more of the cloud feedback community into ACPC was raised.

The deep cloud sessions featured discussion of two-way interactions of the environment and deep convective clouds (DCC), continued analysis of observations from the TRacking Aerosol Convection interactions ExpeRiment (TRACER), plans for a new model intercomparison project, and future field campaign ideas.

Several presentations highlighted the important role of supersaturations in the convective updraft for potential aerosol invigoration effects. Modeling studies show that this supersaturation depends strongly on the aerosol concentration, size distribution, and aerosol recycling. In support of these considerations, observations from the Cloud Aerosol Interaction and Precipitation Enhanced Experiment (CAPIEEX) in India and the Cloud, Aerosol and Monsoon Processes Philippines Experiment (CAMP$^2$Ex) campaign were shared that showed large supersaturations in clean deep convective clouds. A couple of community Model Intercomparison Projects (MIPs) focusing on ACIs at the convective permitting scales were presented and called for participation: Radiative-Convective Equilibrium Model Intercomparison Project–Aerosol Cloud Interactions (RCEMIP-ACI) based on RCEMIP and GEWEX Aerosol Precipitation Initiative (GAP) ACI based on the DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains (DYAMOND) initiative.

The latest analysis and modeling efforts related to TRACER and associated campaigns were shared. Notably, this included:

1. quantification of the impacts of the sea breeze circulation on local thermodynamic, aerosol, and convective properties;
2. reporting of some in situ aircraft measurements that indicated maximum supersaturations in intensifying updrafts that were large enough (> 5%) to support warm-phase invigoration processes; and
3. the capabilities of agile scanning of radar systems to capture the rapidly-evolving characteristics of the cores of isolated convective clouds.

A wrap up of the first ACPC MIP, which brought together seven cloud-resolving models to assess the range of responses of DCC to increased aerosols, was presented. It highlighted that differences in cloud and precipitation properties among microphysical schemes were greater than the differences between high and low aerosol loading. A major focus for the ACPC deep clouds group is a new MIP that leverages the detailed observations collected during TRACER. Details on the planning for this activity were shared, including the "golden" cases that are being targeted and their general characteristics, the model configurations including aerosol setup, simulations required, and the desired output variables. A roadmap document will be released soon calling for community participation.

The group began discussion for the next-generation field campaign for the study of aerosol-convection interactions. Specific requirements that were discussed were: (1) the need for accurate measurements of in-cloud supersaturations; (2) targeting a region conducive to achieving high in-cloud supersaturations, i.e., a more pristine environment with occasional intrusions of polluted air; (3) more observations in convective updrafts after initial development; and (4) coincident in situ measurements of aerosol composition and size distribution.

# Workshop Summary for the Proposed Central Asia Regional Hydroclimate Project: Better Data, Modeling & Planning for Climate Adaptation in Central Asia

**Osh, Kyrgyz Republic**
**29 April–1 May 2024**

**Michael Brody[1,2], Ruslan Arapbaev[3], Sagynbek Orunbaev[4], Maksim Kulikov[5], and Peter van Oevelen[2]**

[1]International Agriculture University, Tashkent, Uzbekistan; [2]George Mason University, Fairfax, VA, USA; [3]Osh State University, Osh, Kyrgyz Republic; [4]American University of Central Asia, Bishkek, Kyrgyzstan; [5]University of Central Asia, Bishkek, Kyrgyzstan

The third workshop on the proposed Central Asia Regional Hydroclimate Project was held at Osh State University in Osh, Kyrgyz Republic from 29 April–1 May 2024. There were about 55 participants total, with 40 attending in person and another 15 online, hailing from Kyrgyzstan, Uzbekistan, Kazakhstan, Germany, China, Russia, the United Kingdom, Tajikistan, and the United States.

One of GEWEX's undertakings is to improve understanding of the impacts of climate variability and change on water availability and food security across mountain ranges and river basins, which dovetails with the challenges facing Central Asia. GEWEX has coordinated with local researchers to host a series of workshops in the region. These have examined the difficulties posed by climate change and what local efforts to address those difficulties could look like. Central Asia is extremely vulnerable to climate change. Much of its water resources derive from summer melting of the areas' mountain glaciers and annual snowpack. In a warming world, glacial extent and volume, as well as the snowpack, are declining. Agriculture is an important basis of the region's economies and is highly dependent upon irrigation, but it is also vulnerable to rising growing-season temperatures. For the region to efficiently and effectively adapt to these changes, it needs significantly-improved observational networks and modeling that can provide more useful information for policymakers to invest in climate adaptation.

The major themes for the workshop were:

- Identifying needed existing meteorological, climatological, and hydrological data
- Defining new observational networks—types of data, location of data, etc.
- Developing more relevant climate models for Central Asia and coordination with development of observational networks
- Identifying specific data needs and potential economic analyses for climate adaptation

The plenary session opened with a welcome from the Rector of Osh State University, Kudaiberdi Kozhobekov, who spoke about ongoing changes at the university. Then the Dean of the International Medical Faculty spoke about satellite data in the context of air pollution and health in the region. Toktogul Mamashov, Head of the Osh Regional Administration of the Ministry of Natural Resources, Ecology and Technical Supervision of the Kyrgyz Republic, addressed regional environmental issues. The plenary session ended with a presentation on GEWEX and the World Climate Research Programme (WCRP) by Peter van Oevelen, director of the International GEWEX Project Office. Michael Brody and Sagynbek Orunbaev gave an introduction and overview of the objectives of the workshop.

Much of the workshop was reserved for the 22 technical presentations, available online at *https://www.gewexevents.org/meetings/3rd-workshop-central-asia/agenda/. The* presentations addressed an array of issues, including scales of climate modeling and the need to understand climate adaptation requirements. More of the presentations addressed aspects of water resources than any other general topic. Other subject areas were agriculture, drought, forestry, agro-forestry, and ecotourism. Modeling presentations included scale of resolution, downscaling, and gaps in hydrometeorological, glaciological, and other climate data. During the afternoon of the second day, we had two breakout groups to summarize what people learned and what might be done in the future based on this, and to promote research collaborations.

One consideration facing the group is the nature of current regional research initiatives: there are already many of them, but they are typically externally-driven and focused on their own projects. Key issues for this regional program are ensuring long-term engagement, investing in the region, and generating projects from within the region.

Related challenges include the reality that there are not many young researchers in the region Several participants shared how requirements of some government scholarship programs and opportunities require that recipients return to their country. This is a problem when there are inadequate institutional resources to support good science and reasonable salaries, as often occurs.

There was a clearly-stated need for better scientific exchange in the region, particularly where science addresses regional necessities like transboundary water management, etc. It would be very useful to establish a large annual conference for the region equivalent to the American Geophysical Union Fall Meeting. This can be very expensive, but travel costs to U.S. and other conferences are very high for Central Asian scientists.

Modeling was one of the major discussion points from the workshop, and ranged from considering when models are better than observations to a dive into questions on resolution. Issues around the latter, including the sufficient spatial and temporal resolution required for climate modeling and understanding uncertainty, formed part of the conversation. Currently, participants are looking at eight different climate models running at 25km resolution. Glacier melt is impacting the models, and until this is better understood, higher resolution is not necessary. Re-thinking the resolution of models was a reoccurring theme. An evaluation of biases in regional

*A scene from the plenary session at the third workshop on the proposed Central Asia Regional Hydroclimate Project*

climate models was called for as well, to determine what the biases are and how they can be corrected. Glacial-hydrological modeling is available to use and may be helpful, as would the potential availability of the supercomputer at the University of Wyoming. High-resolution downscaled historical reconstructions of past climate would be useful as well.

Data was another major theme. Generally, long-term observations of any kind are lacking in the region, but especially those from high elevations. Water isotopes can be used to follow and better understand the water cycle, which may be a helpful resource. Data sharing is a sticking point, as water discharge data is sensitive and the level of cooperation from various hydrometeorological agencies depends on where they are based. Not all data are free, either. Kazakhstan does provide some data online, which is helpful. Practical issues also abound, such as the "loss" of data and results when a project ends, and the need to translate more material into Russian to facilitate its use. Open data sharing and maintenance is a good solution to many of these issues, but standardization is important to ensure that the data are high quality.

Other topics touched on the themes of regional self-sufficiency, with participants noting that concepts, plans, and initiatives should be generated internally rather than externally. There was also an appreciation of just how much research is being conducted in Central Asia, and how the workshop brought many interesting projects to attendees' attention. Improving interdisciplinarity, starting by jointly setting an aim and then identifying which researchers and stakeholders could contribute, is a goal for the group.

Participants suggested some solutions to current issues and ways to improve regional research, including holding additional conferences and meetings to successfully connect investigators. More partnerships are needed across entities, including collaborators who are working on future scenarios. Connecting with local agencies, keeping them informed and discussing data and data sharing, is also important, as is engaging with new contacts Shifting mindsets towards a systems approach, where everything is connected, will facilitate complexity.

GEWEX can potentially play several roles to enable regional research efforts. It can start by facilitating research centers or hubs within disciplines, then act as an umbrella forum to bring the disciplines together in annual meetings. To create these hubs, GEWEX should arrange meetings–preferably with department heads rather than broader university administration–to ensure agreement on this approach before moving forward. Other tasks are encouraging the expansion and improvement of the meteorological station network, glacier monitoring, and water resource monitoring in the region, with a focus on high-altitude areas.

GEWEX could also help with science communication and outreach, to enable local scientists to focus on their work. It could regularly publicize research news for Central Asia, perhaps through a series of presentations, a newsletter, or short news email. Ongoing research in Central Asia and climate change impacts in the region should also be highlighted. The Central Asia Research Information Network (CARIN) carries out much of this role currently, so GEWEX should coordinate with CARIN. Generally, more communication and coordination are necessary across languages; often international projects come to the area without understanding what research is currently underway, such as the programming occurring at the local institutes. There is a desire to connect these scientists to more interdisciplinary projects, but no clear way to do so currently. Some participants pointed out that GEWEX is still fundamentally not a local consortium, and so won't generate a sense of local ownership. Others thought GEWEX is the right platform to foster scientific exchange, as GEWEX would start the process and transition it to local parties.

Osh State University can also participate. Its geographic location close to the Fergana Valley and Mountains, often referred to as the heart of Central Asia, situate Osh State as a potential interdisciplinary, international hub for the region. It could invite others to collaborate and become part of a leading group for Central Asia; possible partners include the American University of Central Asia, the University of Central Asia, the Tien Shan Center, the Central Asia Regional Economic Cooperation Program (CAREC), the Central-Asian Institute for Applied Geosciences (CAIAG), and CARIN. Osh State University is also developing new research directions, some of which will be relevant to climate science and policy.

Another initiative that the university could undertake is the establishment of a remote sensing data center for Central Asia. It could provide globally-accessible climate data and beyond, branching into agricultural, ecological, and other types of observations.

GEWEX is now in the early stages of building this effort into a formal Regional Hydroclimate Project by its current co-leads, Michael Brody and Sagynbek Orunbaev. GEWEX planning for workshops and summer schools in Central Asia has already begun. As recommended, this is being coordinated with CARIN. Additional planning is taking place with the University of Wyoming, as it prepares for its regional downscaling modeling endeavor for Central Asia.

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## Call for Submissions to Two Special Issues on the GEWEX Open Science Conference (GEWEX-OSC) in Sapporo

We are pleased to invite you to submit your papers to the special issue of **Hydrological Research Letters** (HRL) and the joint special edition of the **Journal of the Meteorological Society of Japan** (JMSJ) and **Scientific Online Letters on the Atmosphere** (SOLA) dedicated to the outcomes of the 9th GEWEX Open Science Conference (GEWEX-OSC) in Sapporo. All participants of GEWEX-OSC Sapporo have the right to submit manuscripts to any of the journals, and we warmly encourage your submissions.

**HRL Submission Details**:

Publication Charges: The first 15–20 papers published online by June 2025 in HRL will be exempt from publication fees. Please note that this waiver is limited to the first 15–20 submitted papers due to budget constraints.

How to Submit:

Prepare your manuscript according to the HRL submission guidelines, available at http://www.hrljournal.org/data/hrl_gewex.pdf. Submit your manuscript via the HRL submission portal: https://www.editorialmanager.com/hrl/default.aspx.

When submitting, select "GEWEX-OSC Sapporo" from the drop-down list for Question 7 (regarding special collections). Please include your presentation paper number (e.g., 29–53) and the GEWEX-OSC Sapporo title in the comments section.

For submission assistance, please contact kure@pu-toyama.ac.jp.

**JMSJ and SOLA Submission Details**:

Submissions related to GEWEX-OSC Sapporo are encouraged to contribute to the "Special Edition on Recent Advances in the Global Energy and Water Cycle Exchanges (GEWEX) Sciences".

How to Submit:

Follow submission guidelines available at https://www.metsoc.jp/jmsj/special_issues_editions/JMSJ2024_GEWEX.html. Manuscripts should be prepared according to the guidelines of either JMSJ or SOLA. The instructions are available for:

- JMSJ: https://www.metsoc.jp/jmsj/instructions.html
- SOLA: https://www.metsoc.jp/sola/instruction.html

Papers must be submitted online via the respective journal's submission system:

- JMSJ: https://mc.manuscriptcentral.com/jmsj (to be renewed in 2025)
- SOLA: https://mc.manuscriptcentral.com/sola

Choose "GEWEX" during the submission process. Please also mention that your submission is for "GEWEX" in the cover letter.

For more information, please refer to the Call for Papers: https://www.metsoc.jp/jmsj/special_issues_editions/CallforPapers_JMSJ-SOLA_SpecialEdition_GEWEX.pdf.

We look forward to your valuable contributions to both special issues.

## GEWEX/WCRP Calendar

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

23–25 October 2024—2024 Polar CORDEX Annual Meeting—Potsdam, Germany

28–30 October 2024—Micro2Macro Workshop—Laramie, WY, USA

4–8 November 2024—WGNE39-WGSIP25 Annual Meetings—Toulouse, France

4–5 December 2024—2nd Baltic Earth Workshop on "Multiple Drivers in Earth system changes in the Baltic Sea region"—Helsinki, Finland

9–13 December 2024—American Geophysical Union Annual Meeting 2024 (AGU24)— Washington, D.C., USA

12–16 January 2025—105th American Meteorological Society (AMS) Annual Meeting—New Orleans, LA, USA

10–14 February 2025—37th GEWEX Scientific Steering Group (SSG-37) Meeting—Wellington, New Zealand

24–27 February 2025—CLIVAR Climate Dynamics Panel 5th Annual Workshop—Lorne, Australia

24–28 March 2025—7th International Baltic Earth Winter School for Young Scientists—Klaipeda, Lithuania

19–23 May 2025—2025 GDAP Annual Meeting—Paris, France

28–30 April 2025—American Water Resources Association (AWRA) 2025 Spring Conference: Development Risks & Challenges in Changing Climate Conditions—Anchorage, AK, USA

14–16 July 2025—International Soil Modelling Consortium (ISMC)-GEWEX Soilwat Meeting—Reading, UK


### *GEWEX QUARTERLY*

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