Global Energy and Water Exchanges(GEWEX)

Presented at the 46th Session of the WCRP JSC

- Overview of GEWEX and its panels
- Scientific highlights
- Capacity Building and Training Highlights
- Linkages and Partnerships
- New Directions and Activities
- Challenges and Comments

Jan Polcher, Xubin Zeng, Peter van Oevelen

May 2025, Paris

WCRP World Climate Research Programme

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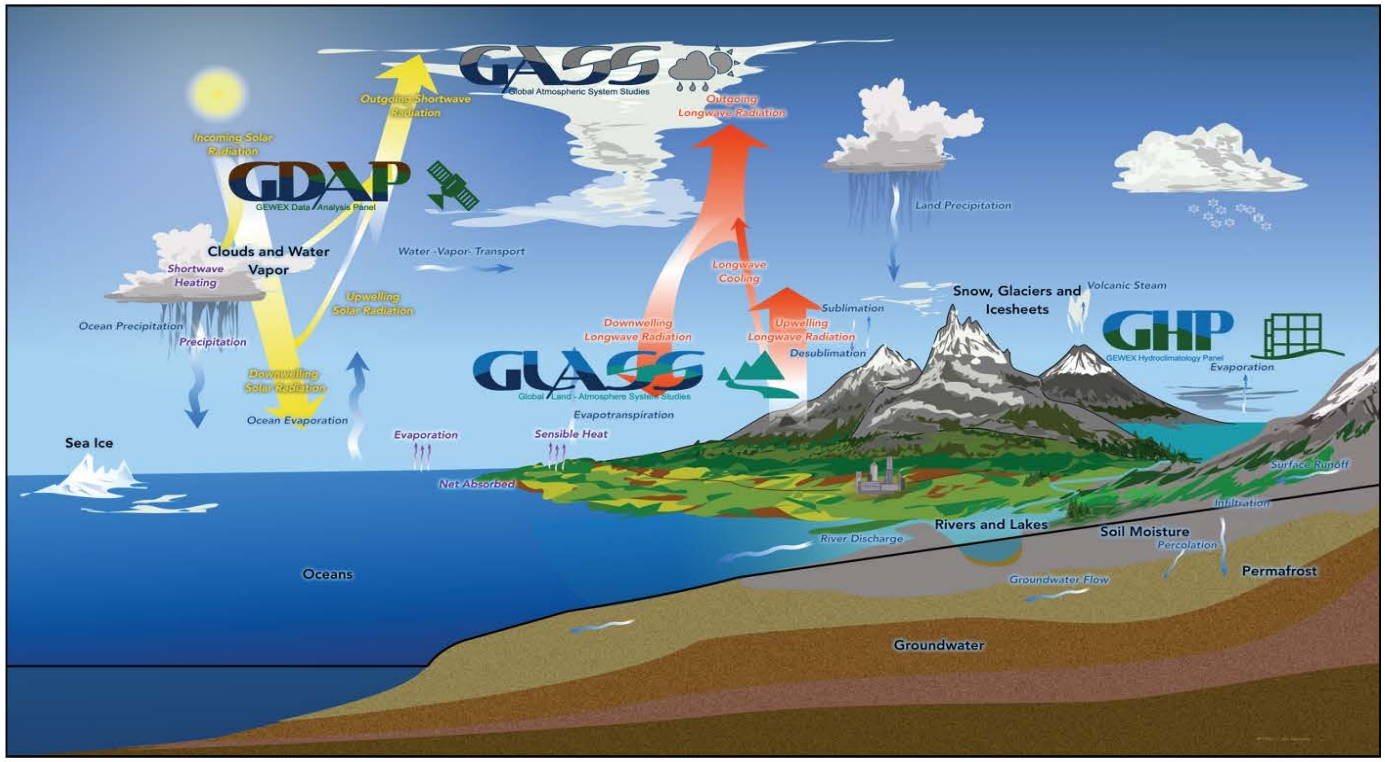
GEWEX Panels and their Activities



The focus of the four GEWEX panels in relation to the global and regional water and energy cycles
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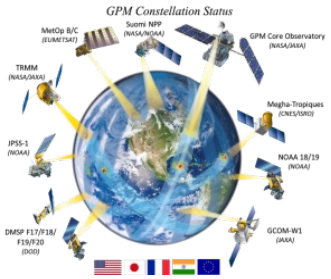
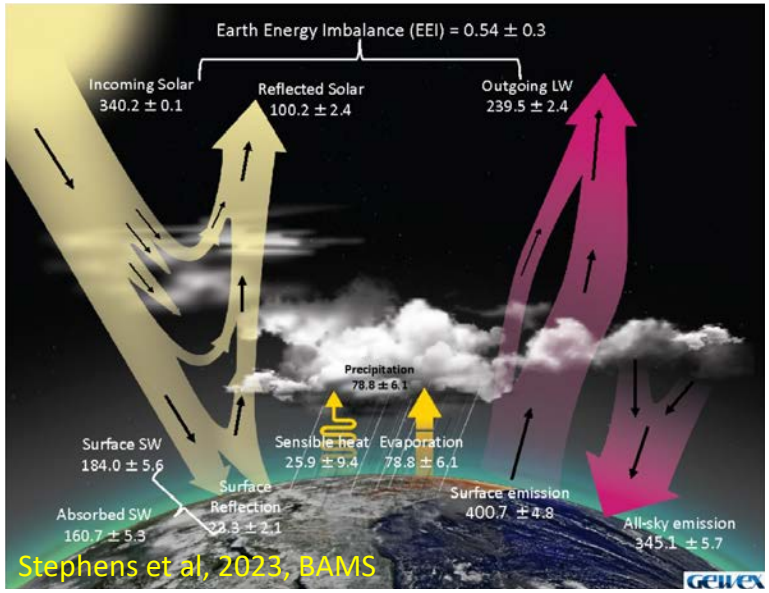
The GDAP Vision

GDAP
GEWEX Data Analysis Panel

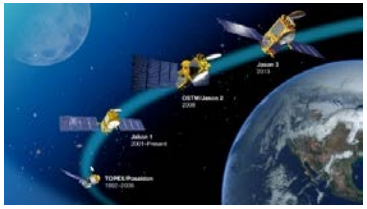
Observation-centric, climate-oriented, consistency-driven, global, research-focused

Precipitation



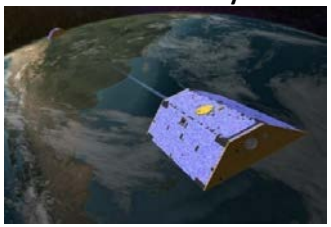


Sea level



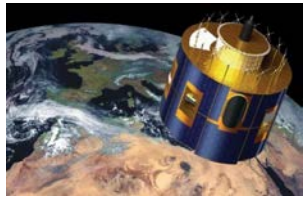
Radiation

Gravimetry



Surface Fluxes

Clouds

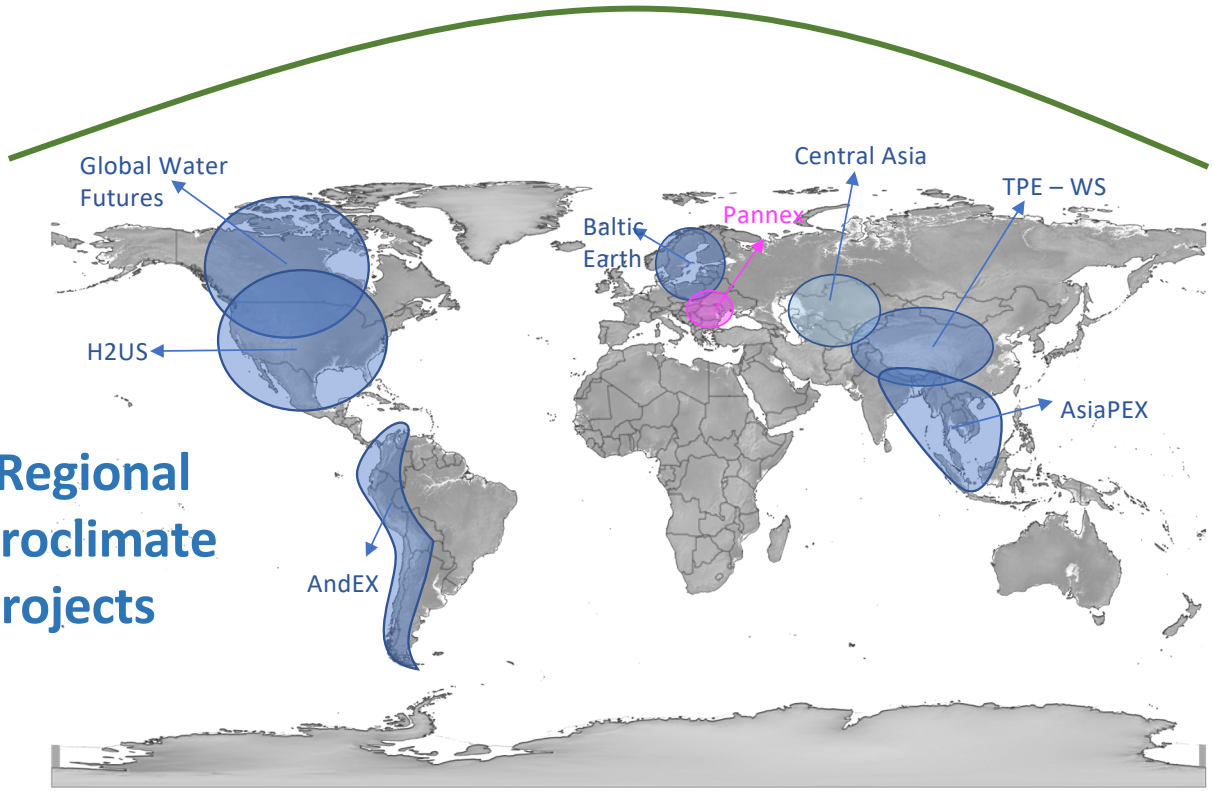


GEWEX Hydroclimatology Panel

2) Cross-Cut Projects

TEAMx CC
INARCH-II CC
d-ET CC
RivEx CC
FLOOD CC
MOUNTERRAIN CC

1) Regional Hydroclimate Projects



3) Global Data Centers

Global Precipitation Climatology Center (GPCC)

Global Runoff Data Center (GRDC)

4) GHP Networks

Pannex
Global Groundwater Network (GGN)

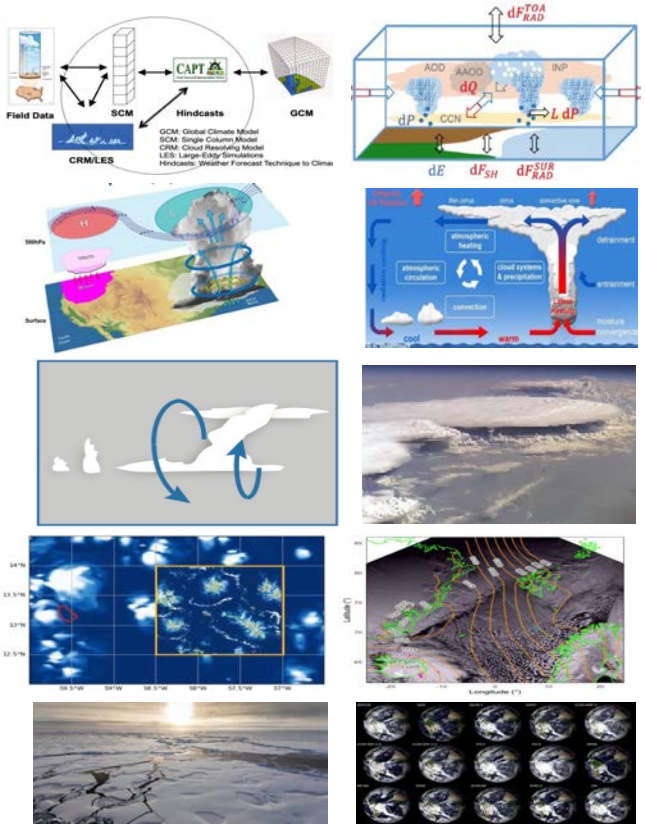
Ten Ongoing GASS projects

Start before 2022

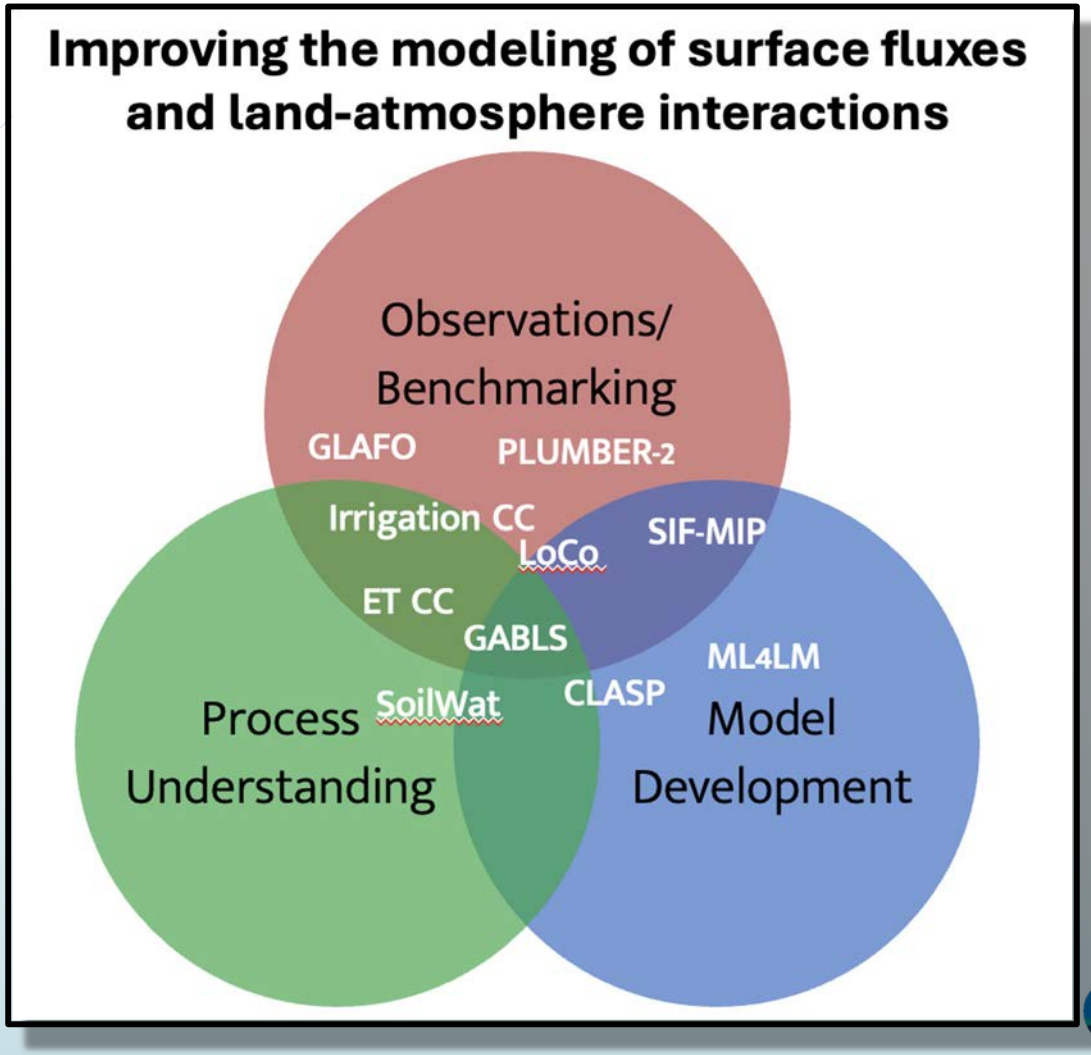
- DCP: Diurnal Precipitation Project
- GAP: GEWEX Aerosol Precipitation Initiative
- LS4P: Land Surface Temperature and Snowpack Teleconnection Processes
- UTCC-PROES: GEWEX upper tropospheric clouds and convection process evaluation study

Start in 2022 or 2023

- Cumulus Friction: Shallow cumulus friction experiment
- MesoDeep: Mesoscale organisation of deep convection
- EUREC4A-MIP: Mesoscale organization of shallow convection in present and future climates
- COMBLE: Evaluating simulated convective clouds during Arctic cold-air outbreaks
- MOSAIC: Nudged climate model runs for MOSAiC
- DYAMOND: Global storm-resolving models intercomparison project



New summary figure of GLASS activities



Global Land - Atmosphere System Studies

Some scientific highlights from GEWEX

One example from each panel

Earth's Energy Imbalance: Status

Leads: B. Meyssignac (CNES) and T. Boyer (NOAA)

GEWEX Data Analysis Panel

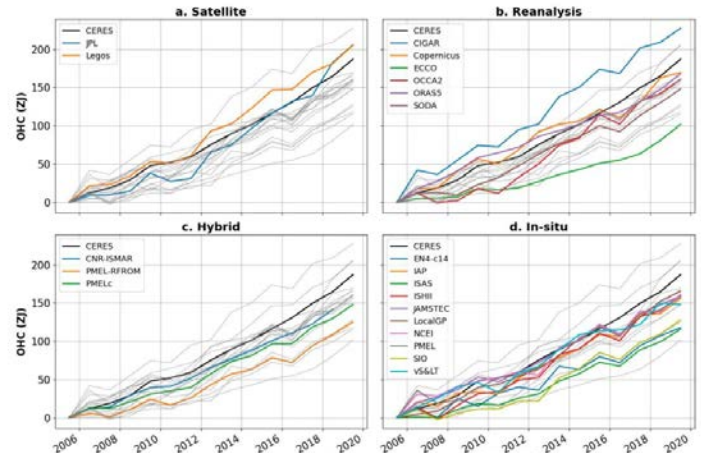
- Review paper on the intercomparison of EEI estimates from different techniques in survey of geophysics special edition on the water and energy cycle

Trends and Variability in Earth's Energy Imbalance and Ocean Heat Uptake Since 2005

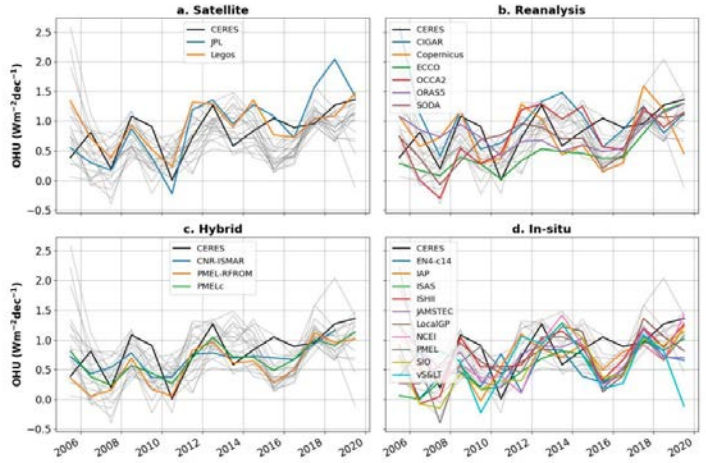
Maria Z. Hakuba[1] · Sébastien Fourest[2] · Tim Boyer[3] · Benoit Meyssignac[2] · James A. Carton[4] · Gaël Forget[5] · Lijing Cheng[6] · Donata Giglio[7] · Gregory C. Johnson[8] · Seiji Kato[9] · Rachel E. Killick[10] · Nicolas Kolodziejczyk[11] · Mikael Kuusela[12] · Felix Landerer[1] · William Llovel[11] · Ricardo Locarnini[3] · Norman Loeb[9] · John M. Lyman[8,13] · Alexey Mishonov[3,14] · Peter Pilewskie[7,15] · James Reagan[3] · Andrea Storto[16] · Thea Sukianto[12] · Karina von Schuckmann[17]

Received: 10 December 2023 / Accepted: 17 June 2024

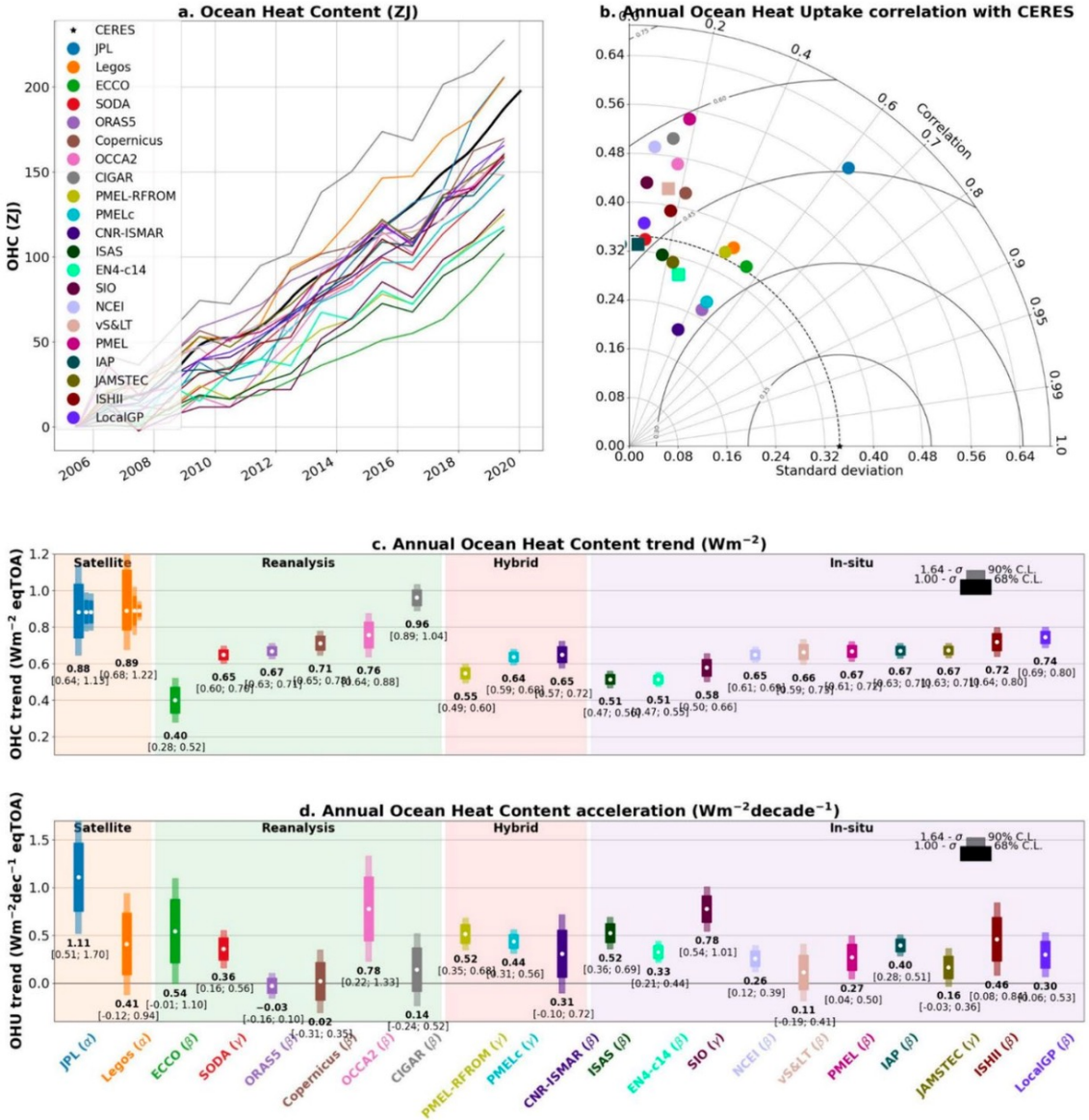
OHC



OHU



- prepare a workshop in 2025
- Invited talk at EGU, CFMIP


a. Ocean Heat Content (ZJ)
OHC (ZJ)
CERES
JPL
Legos
ECCO
SODA
ORAS5
Copernicus
OCCA2
CIGAR
PMEL-RFROM
PMELc
CNR-ISMAR
ISAS
EN4-c14
SIO
NCEI
vS&LT
PMEL
IAP
JAMSTEC
ISHII
LocalGP
b. Annual Ocean Heat Uptake correlation with CERES
Correlation
Standard deviation
c. Annual Ocean Heat Content trend (Wm⁻²)
OHC trend (Wm⁻² eqTOA)
Satellite
Reanalysis
Hybrid
In-situ
1.64 - σ 90% C.L.
1.00 - σ 68% C.L.
d. Annual Ocean Heat Content acceleration (Wm⁻²decade⁻¹)
OHU trend (Wm⁻²dec⁻¹ eqTOA)
JPL (α)
Legos (α)
ECCO (β)
SODA (γ)
ORAS5 (β)
Copernicus (β)
OCCA2 (β)
CIGAR (β)
PMEL-RFROM (γ)
PMELc (γ)
CNR-ISMAR (β)
ISAS (β)
EN4-c14 (β)
SIO (γ)
NCEI (β)
vS&LT (β)
PMEL (β)
IAP (β)
JAMSTEC (γ)
ISHII (β)
LocalGP (β)

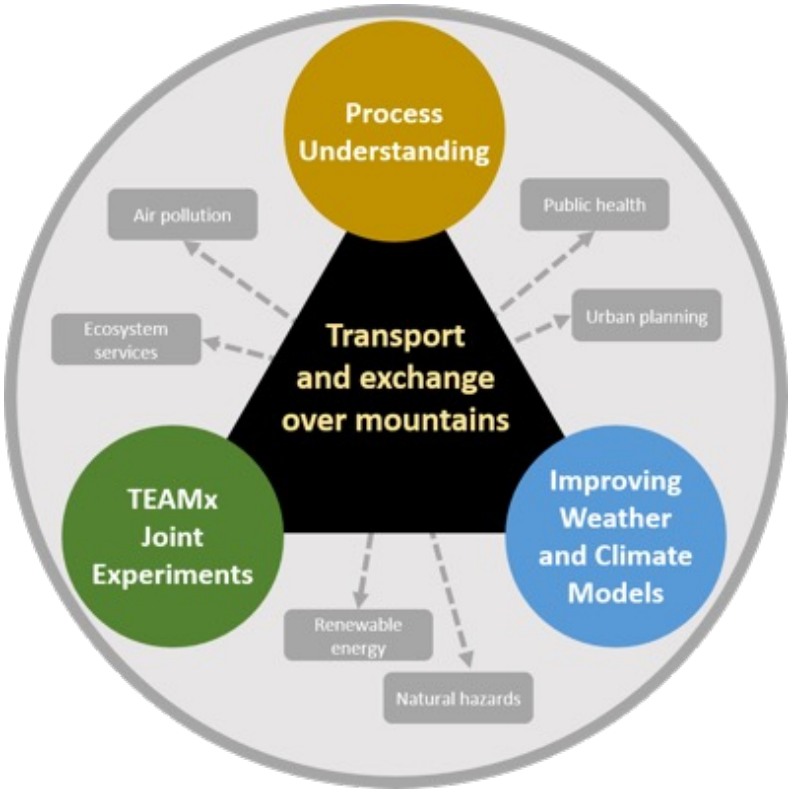
Earth's Energy Imbalance: Future

Leads: B. Meyssignac (CNES) and T. Boyer (NOAA)

GEWEX Data Analysis Panel

- **Make a common dataset** with all estimates of the EEI at the same resolution with DOI for easy handling by the community.
- Geodetic approach: Interest for a best practice list, Interest for a gap analysis, EEH analysis, Correct for the barotropic signal with Ecco, Analysis of the 2016 dip in OHU, synthetic data approach for uncertainties
- In situ approach: synthetic data approach for mapping uncertainty, ensemble approach for comprehensive estimate of the uncertainties, analyse the differences in time scales annual, month to month, ENSO, mean trend. Analysis of the 2016 dip
- Reanalyses approach: An intercomparison of the OHU estimate in reanalyses. Propose an ensemble of reanalyses
- **Redo these kind of workshop** on an annual basis: a 2025 EEI workshop was scheduled early June in Caltech but postponed due to the LA fire (new dates TBD).
- Will **write a first assessment report to GEWEX** within the next two years

In close collaborations with CLIVAR



The TEAMx Observational Campaign (TOC) is taking place between September 2024 and September 2025.

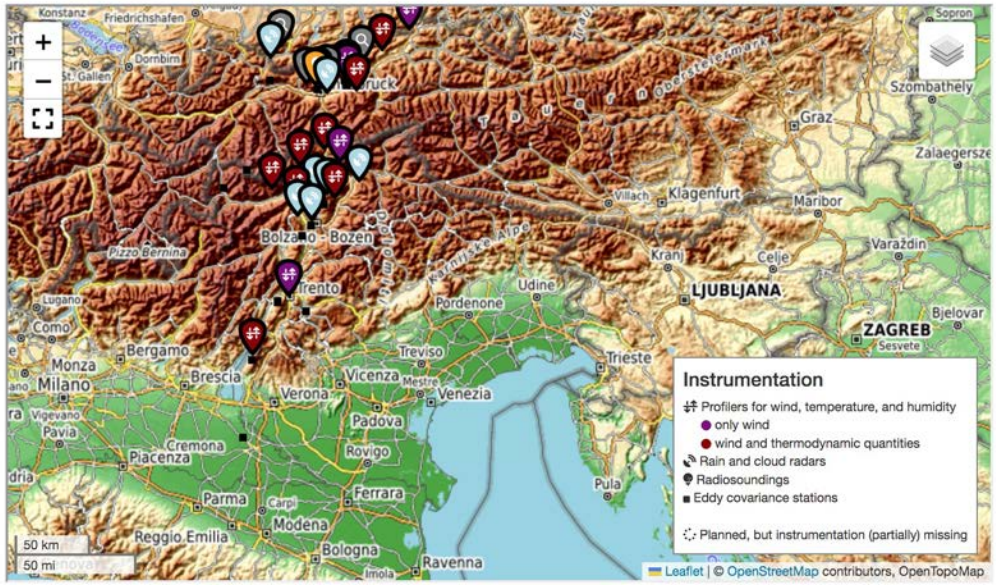
TEAMx

TEAMx seeks to improve the current understanding of exchange processes in the atmosphere over mountains and how these processes are parameterized in climate models.

Targets:

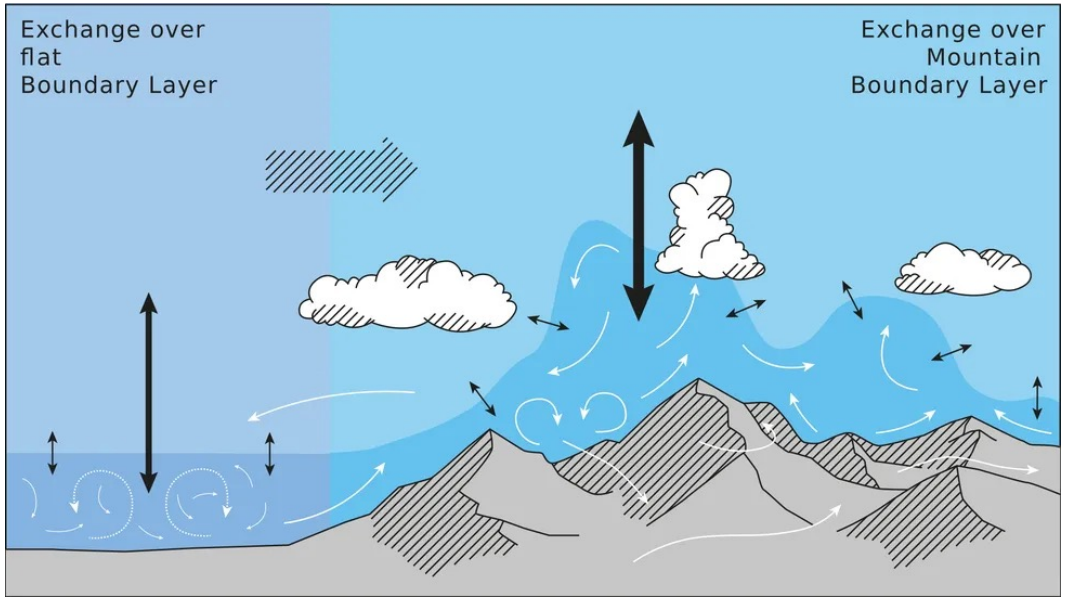
- Numerical models and observations
- Improved weather forecasts
- Characterization of the global water and energy cycles over the Alpes

Mathias Rotach
(Chair of the Coordination and Implementation Group)



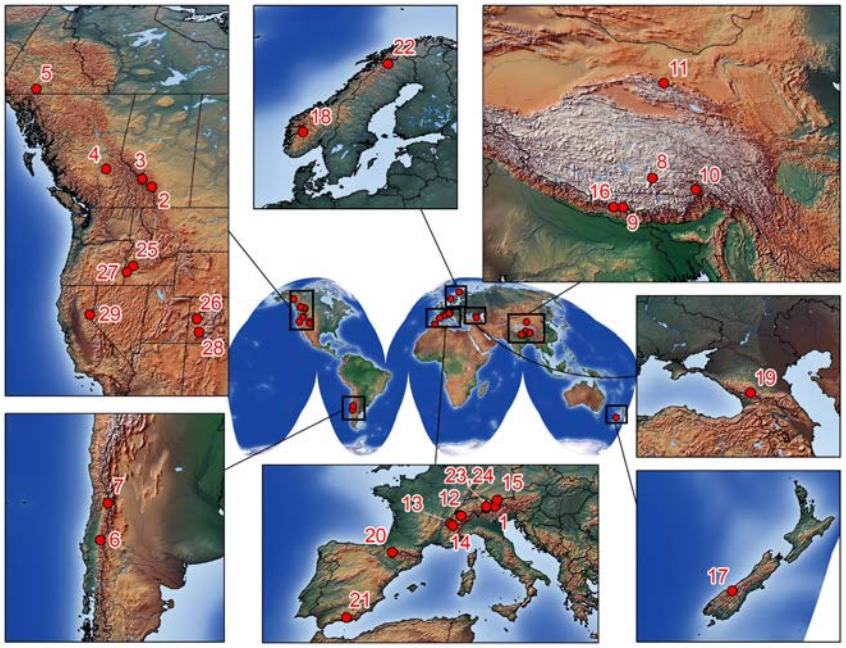
Backbone of the TEAMx Observational Campaign (TOC): Atmospheric profilers and eddy covariance stations which will be deployed during the TOC in addition to existing instrumentation.

TEAMx



- Understanding turbulent transport, at the surface and in the planetary boundary layer in complex terrain.
- Close the water and energy balances over these regions.
- A combination of observatories, operational observations, instrumented sites and mobile platforms.
- The regions of focus are the Alpine foreland, valleys and crests.
- All data are distributed through an Earth Data Portal.

Other mountain activities within GEWEX :



- Mountain hydrology: INARCH
- Regional Hydroclimate projects over America: ANDEX, GWF-O, H2US
- Regional Hydroclimate projects over Asia: TPE-WS, AsiaPEX

Given the rapid climate change in mountainous regions it should be a focal point for inter-WCRP collaborations :

- Impact on atmospheric circulations and waves : APARC
- Region of rapid melting glaciers : CliC
- Climate information for the societies living and depending on the mountain regions : RIFS & CORDEX

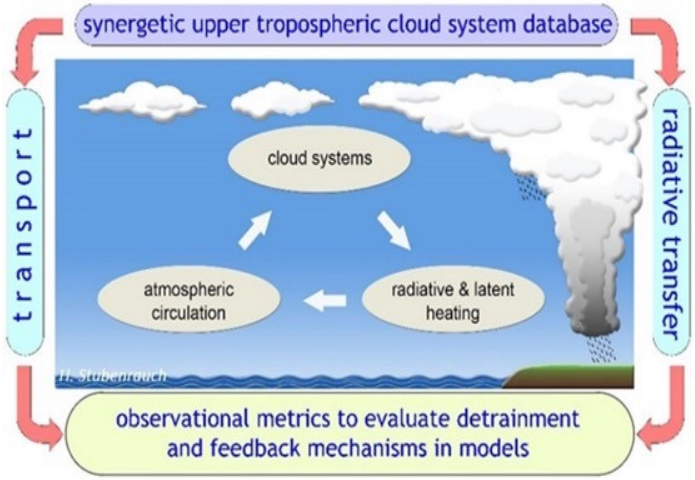
UTCC-PROES *https://gewex-utcc-proes.aeris-data.fr*

PROcess Evaluation Study on Upper Tropospheric Clouds and Convection
by Claudia Stubenrauch and Graeme Stephens

Objective: Advance our knowledge on climate feedbacks of Upper Tropospheric clouds

Activities:

- assess convection-cloud-precipitation-diabatic heating datasets
- characterize convection & deep convective organization
- exploit data & simulations at km-scale to improve CRM (& GCM) parameterizations
- ice microphysical processes, convective organization, convective transport, influence of aerosols



Results of the year:

- Analysis of relation between latent & radiative heating in MCSs:

  Stephens et al., Surv. Geophys. 2024; Masunaga & Takahashi, J. Atmos. Sci. 2024; Chen et al., EGUsphere prepr. 2024

- Evaluation of MCS identification in DYAMOND simulations:

  Prein et al., J. Geophys. Res. 2024; Feng et al., ESS Open Archive prepr.2024

Relevant to APARC

UTCC-PROES *https://gewex-utcc-proes.aeris-data.fr*

Synergistic datasets for process studies & model evaluation:
3D description of UT cloud systems (CIRS-ML) based on IR sounder - radar - lidar & ML (Stubenrauch et al. ACP 2021, 2023)

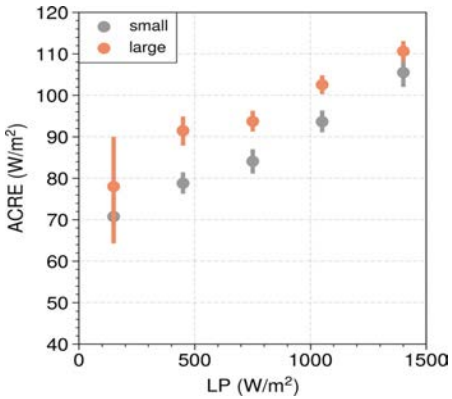
Lagrangian Convection Tracking based on cold T IR (Fiolleau et al. 2020), cold T IR & precipitation (Feng et al. 2021, Takahashi et al. 2021)

next: combined analysis

AOS-INCUS-GEWEX Convection tracking algorithm & science workshop (Apr 2024)

Next UTCC-PROES – GDAP meeting:
19-21 May and 21-25 May 2025, Paris, France

One example on latent & radiative heating in mesoscale convective systems (MCSs; Chen et al. 2024): At similar rain intensity (LP), larger, more organized MCSs generally heat atmosphere more than smaller MCSs

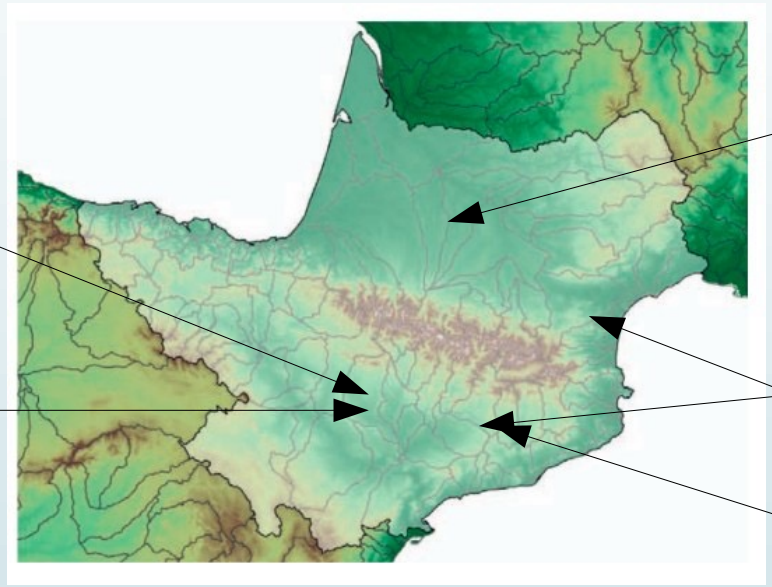


Where/How do LSMs at km-scales break ?

The proposal is to do a model inter-comparison over a well observed area.

Semi-arid climate

Mid-latitude oceanic climate



Dense network of hydrological observations.

Strong human intervention in the water cycle

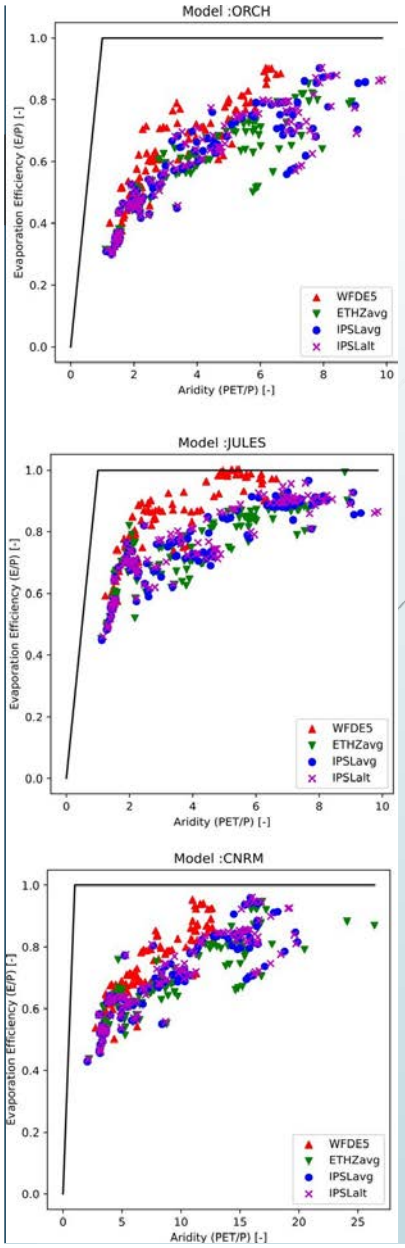
This area offers a nice set of issues for land surface models.

- **4 Sets of obs. Based forcing over the area : 3 at 3km and 1 at 50km.**
- **3 LSMs have run the experiments so far.**

A 2021 field campaign on the impact of irrigation

LIAISE

GLASS Global Land - Atmosphere System Studies



Characteristics of the largest catchments

WFDE5 = 50km grid
Others = 3km grid

Budyko's representation of hydrological regimes : aridity (PET/P) vs. Evap. Efficiency (E/P)

- Only 128 catchments are well represented at both resolutions.
- For energy limited catchments (low PET/P) the higher resolution has little impact on evaporation.
- The more arid catchments have lower evaporation at 3km.
- The catchments also tend to become more arid (move to higher PET/P values).

Global Land - Atmosphere System Studies

Implications

- LSMs pose new challenges when going to km-scales : Issue common to GLASS (& GHP) and Digital Earth.
- The role of lateral flowing water (surface and aquifers) becomes important and modify the interactions with the vegetation and atmosphere.
  - Human intervention on the water cycle become prominent at these resolutions.
  - The land scape organisation can be explicitly represented and its evolution can be predicted at km-scales.
- Surface flux gradients will become more pronounced and need to be explicitly represented for the coupling to atmospheric models (e.g., over S. America)

Global Land - Atmosphere System Studies

Capacity Building and Training highlights

Two examples

- 9th GEWEX OSC
- ML4LM

Not highlighted are:

- Summer schools (e.g. Baltic Earth)

GEWEX's interaction with stakeholders

Scientists : 901 (40% ECRs) from 46 countries,
Stakeholders : 400, invited by 4 ministries :

- Ministry of Land, Infrastructure, Transport and Tourism
- Ministry of Agriculture, Forestry and Fisheries
- Ministry of Environment
- Japan International Cooperation Agency & Japan Science and Technology

Both communities mixed and were interested by the activities of the other.

Topics covered :

- Flood risk and management
- Challenges for agricultural production
- Climate Resilience - Toward Science-Based Adaptation Practices
- Addressing Global Issues with Partner Countries

- For each of these topics a non-Japanese perspective was also given.
- The international scientists could witness the issues most pressing for Japan.
- Japanese stakeholders could get inspiration from emerging scientific discussions.

The changing water cycle is a challenge for each and everyone which requires a stronger interaction between scientists and practitioners!

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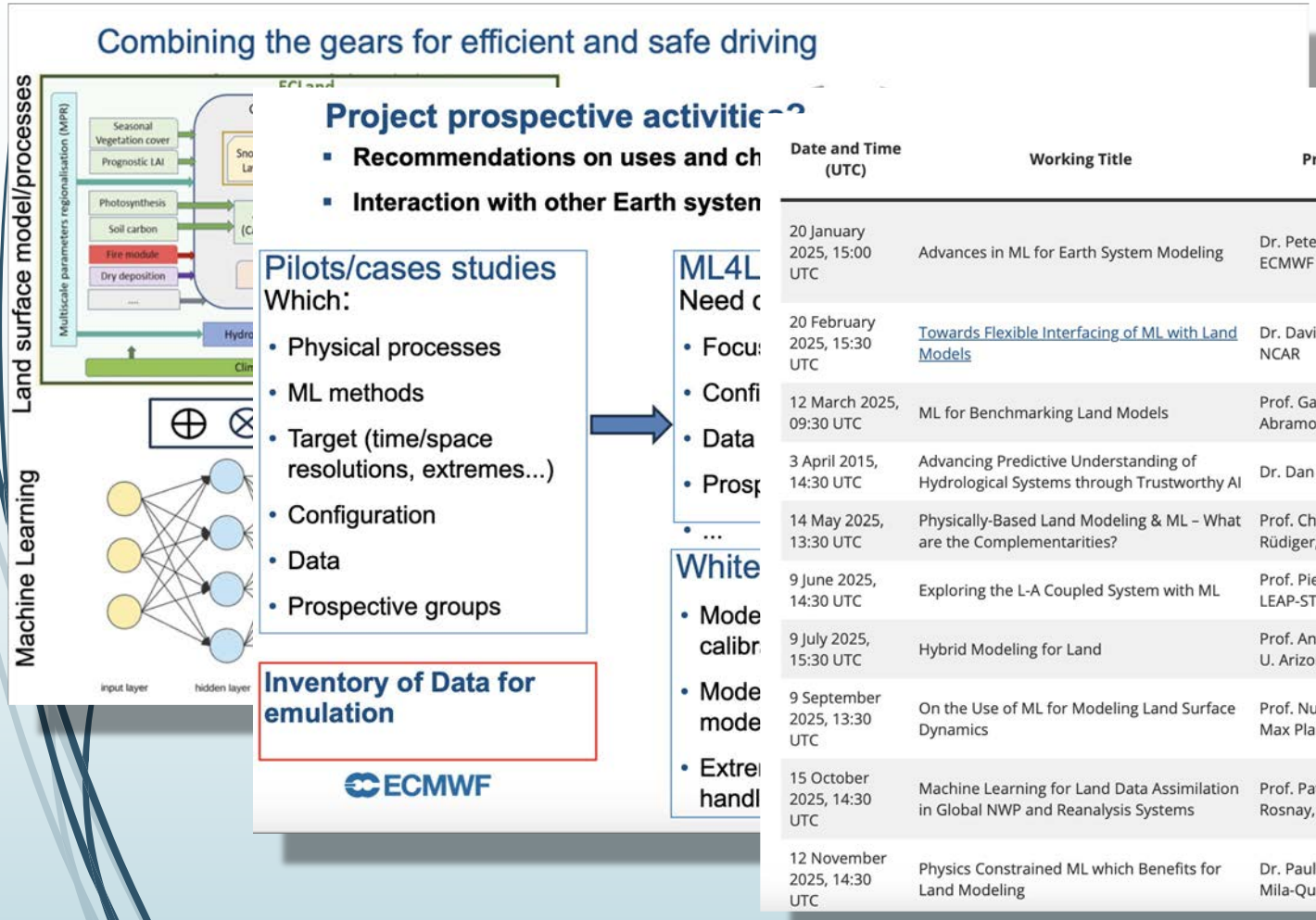
GLASS project updates: ML4LM



Date and Time (UTC)	Working Title	Presenter	Recording and Presentation
20 January 2025, 15:00 UTC	Advances in ML for Earth System Modeling	Dr. Peter Dueben, ECMWF	Presentation Recording Presentation Slides
20 February 2025, 15:30 UTC	Towards Flexible Interfacing of ML with Land Models	Dr. David Lawrence, NCAR	
12 March 2025, 09:30 UTC	ML for Benchmarking Land Models	Prof. Gab Abramowitz, UNSW	
3 April 2015, 14:30 UTC	Advancing Predictive Understanding of Hydrological Systems through Trustworthy AI	Dr. Dan Lu, ORNL	
14 May 2025, 13:30 UTC	Physically-Based Land Modeling & ML – What are the Complementarities?	Prof. Christoph Rüdiger, ECMWF	
9 June 2025, 14:30 UTC	Exploring the L-A Coupled System with ML	Prof. Pierre Gentine, LEAP-STC U Colombia	
9 July 2025, 15:30 UTC	Hybrid Modeling for Land	Prof. Andrew Bennett, U. Arizona	
9 September 2025, 13:30 UTC	On the Use of ML for Modeling Land Surface Dynamics	Prof. Nuno Carvalhais, Max Plank Inst.	
15 October 2025, 14:30 UTC	Machine Learning for Land Data Assimilation in Global NWP and Reanalysis Systems	Prof. Patricia de Rosnay, ECMWF	
12 November 2025, 14:30 UTC	Physics Constrained ML which Benefits for Land Modeling	Dr. Paula Harder, Mila-Quebec	

Lead: Souhail Bousetta

Global Land - Atmosphere System Studies

Linkages Within WCRP

- CliC: Collaboration on their new initiative IC-MontC
- ESMO (including) WGNE: GASS and GLASS
- RIfS: GHP regional projects and interaction with stakeholders
- APARC: km-scale modelling and convection/waves interactions
- CLIVAR: Monsoon panel, EEI

- Digital Earth: support their various activities and new interest in urban modelling and km-scale land surface modelling.
- GPEX: GEWEX Co-Chair (Zeng) led its establishment
- Cycles: GEWEX Co-Chair (Polcher) led the Cycles activity
- Other LHAs: interactions ongoing

Partnerships Outside Of WCRP

- All our RHPs have connections outside of WCRP, be it institutional or organizational; e.g., IAI with ANDEX, Mountain Research Initiative Etc.
- Close interactions with WWRP on hydrological forecasting in a changing climate.
- Continued building on Central Asia network as preparation for an RHP, primarily institutional first, strong interest from Pakistan National Institute of Disaster Management as well as from Chinese side (CAS)
- Continued collaboration with WMO-Hydrology,
- Continued collaboration with Future Earth (iLEAPS, ACPC),
- Continued collaboration with Space Agencies (NASA, ESA, JAXA, NOAA, EUMETSAT, CNES, etc.), AIRCAS and DBAR in China etc.

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New Directions and Activities

Potential for new coastal zone activities : coupling of the hydrologic processes and coastal circulation and biological activities to be explored with CLIVAR, with relevance to various Lighthouse Activities (e.g., Digital Earth, GPEX).

Two additional examples

River Experiment (RivEx): a new CC in GHP

- The RivEx CC aims to answer these questions:
  - What is the current state of surface water modeling capabilities? When, where and why do models perform well or fail to perform?
  - What are the hotspots of anthropogenic influences on global surface water, and can their footprint be accounted for in models?
  - How can global hydrological models be enhanced to ingest an increasing number of observations for more accurate reproduction of surface water stores and fluxes?
- Monthly meetings of the Steering Group.
- Quarterly community meetings.
- One proposal supported by the NASA ES2A program.
- Two projects funded by NASA's SWOT Science Team.
- The RivEx CC proposal has been **conditionally approved** by the GHP.

Cedric David (JPL/Caltech)
Augusto Getirana (NASA Goddard)
21 more active members

Global Groundwater Network (GGN): a new GHP network

- Mission:
  Bring together scientists from the hydrogeologic and groundwater flow modeling communities with the land surface and Earth system modeling communities to constructively link hydrogeology and groundwater modeling to Earth system models in GEWEX.
- Monthly Steering Group meetings.
- GGN held a successful workshop during the 9th GEWEX OSC and one session in the IAH World Groundwater Congress.
- GGN proposal **conditionally approved** by the GHP.
- A new version of the proposal was submitted and is under review for the final approval.

GGN Workshop in Sapporo, Japan
July 2024
More than 25 attendees

Stefan Kollet and Laura Condon
Leaders

Challenges and Comments

- **Within GEWEX**, to ensure continuation of activities and maintain a thriving community, we strive currently to:
  - focus on consolidation of activities rather than adding news ones,
  - focus on stewardship to foster and support global observational networks such as BSRN, GRDC, GPCC etc, and
  - build a network of future leads and leaders within our community.
- **At WCRP**, the wide range of programs and structures hinders a closer and constructive collaboration between activities. Project offices and chairs do not have the time to truly engage with other activities and develop collaboration strategies.
- The **WCRP** support for the core projects has effectively been going down while the number of activities to support has gone up. This is unsustainable in the long term, particularly considering the funding situation in the U.S.

Thank You

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