High Resolution Modeling and the GEWEX Science Goals

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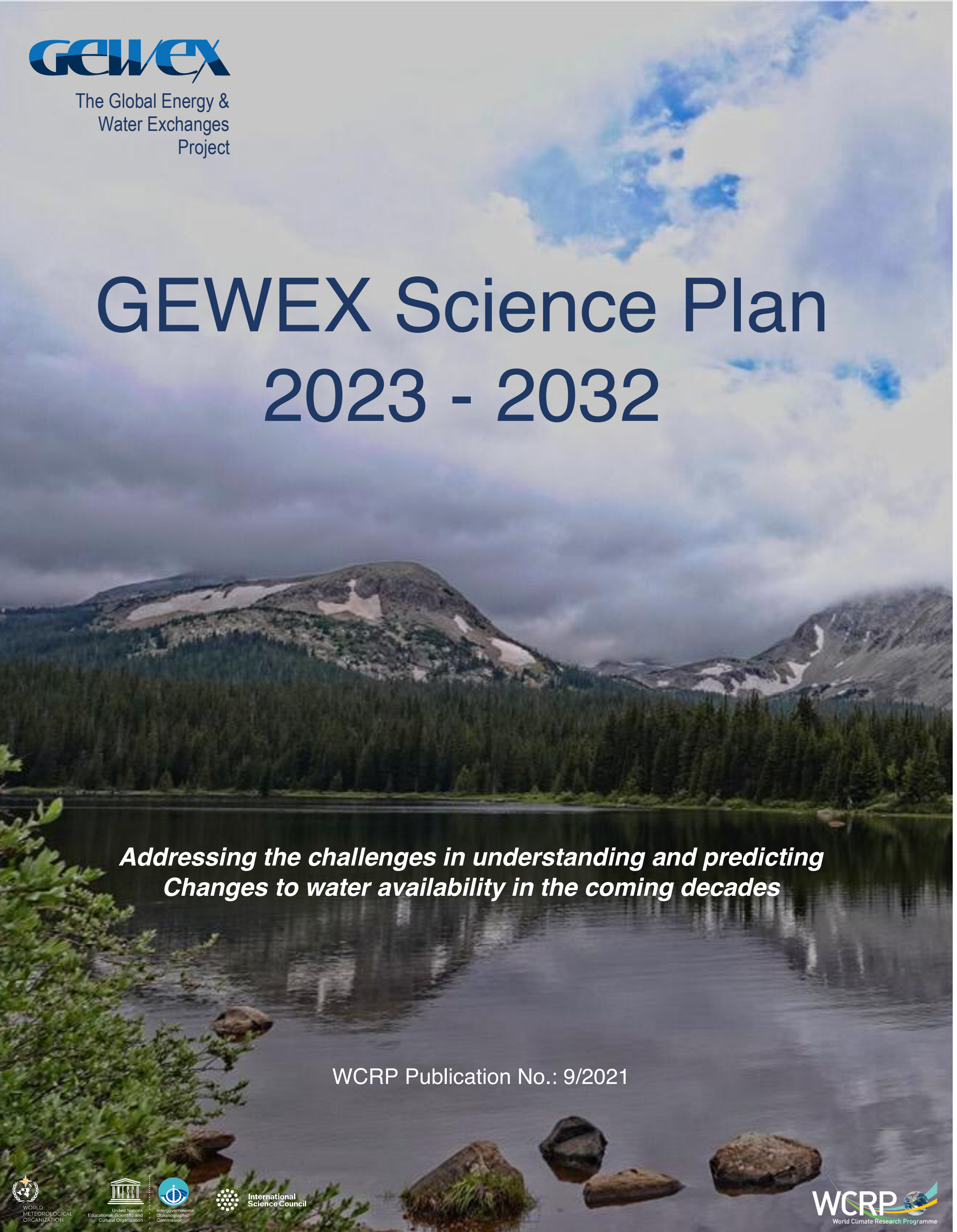
Based upon inputs from entire GEWEX community

GEWEX Science Priorities

GEWEX Science Plan 2023-2032

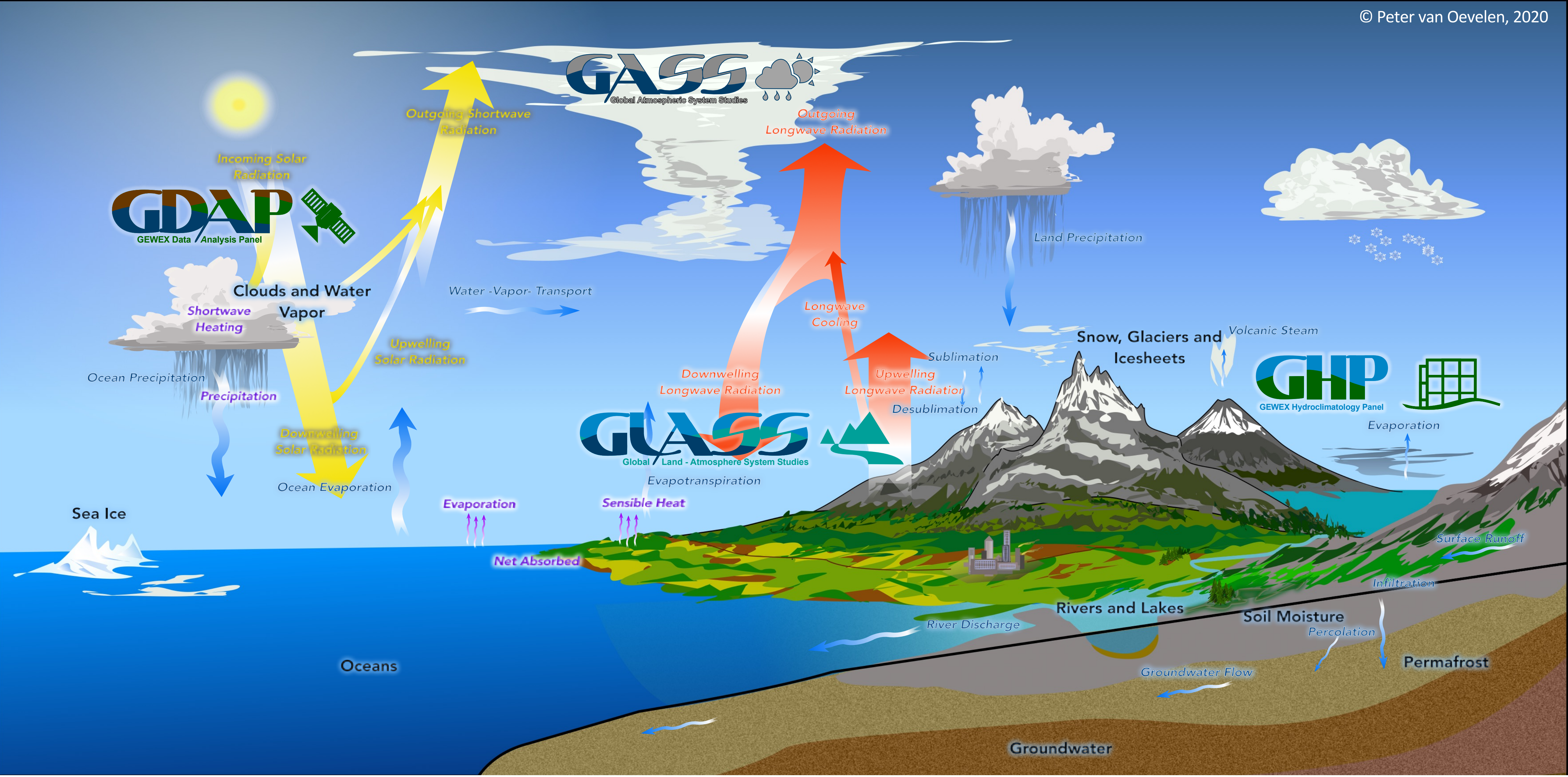
Addressing the challenges in understanding and predicting changes to water availability in the coming decades

An Earth Observation Perspective



https://www.gewex.org/about/science/gewex-science-goals/

- https://www.gewex.org/gewex-content/uploads/2022/05/GEWEX-science-plan-v8.pdf



GEWEX

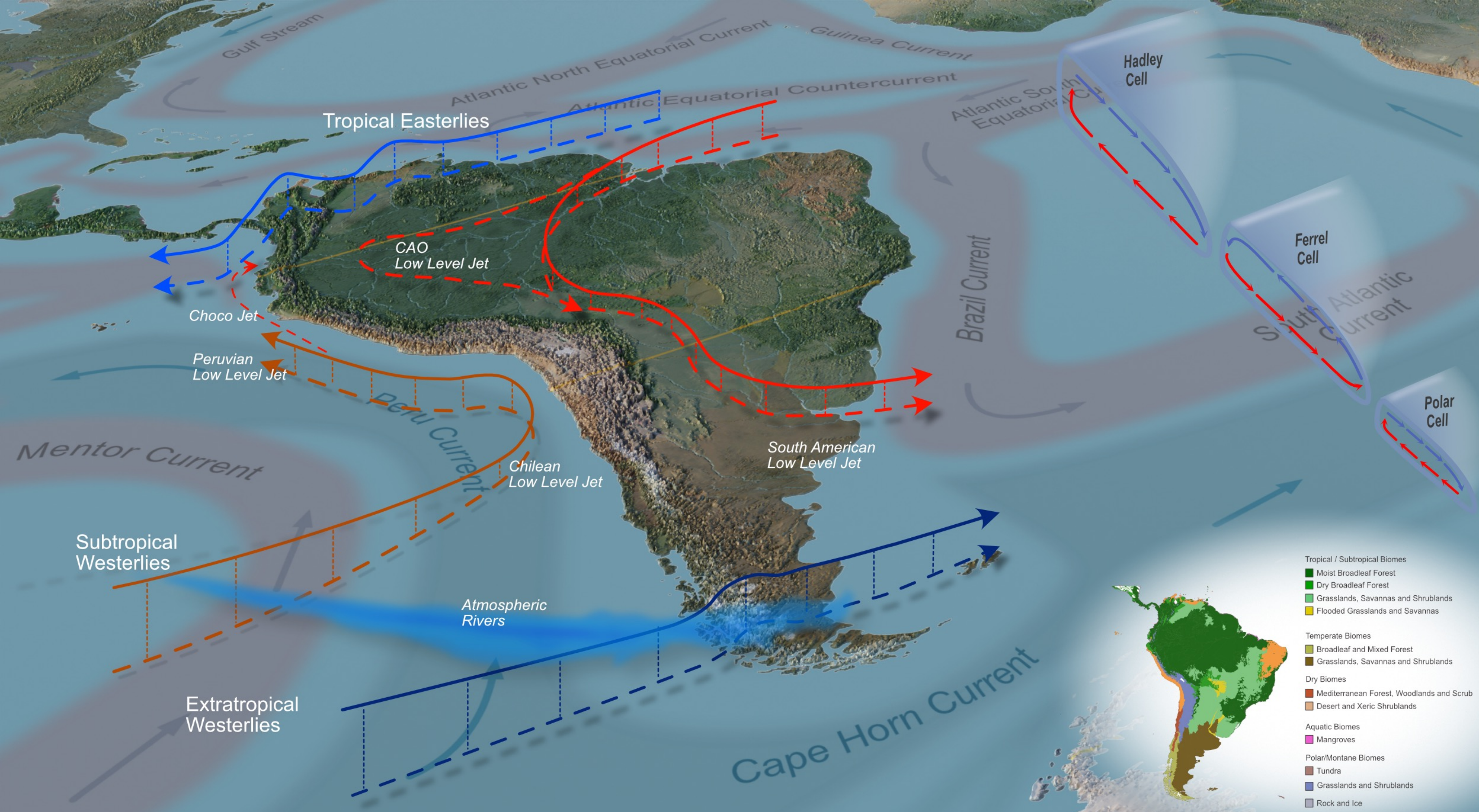
The GEWEX Panels:

- GEWEX Data Analysis Panel — *Global Datasets Analysis and Assessments*
- Global Atmospheric System Studies — *Atmospheric Processes - Dynamics*
- Global Land–Atmosphere System Studies — *Land-Atmosphere Interactions and Processes*
- GEWEX Hydroclimatology Panel — *Regional Focused Processes and Hydroclimate Projects*

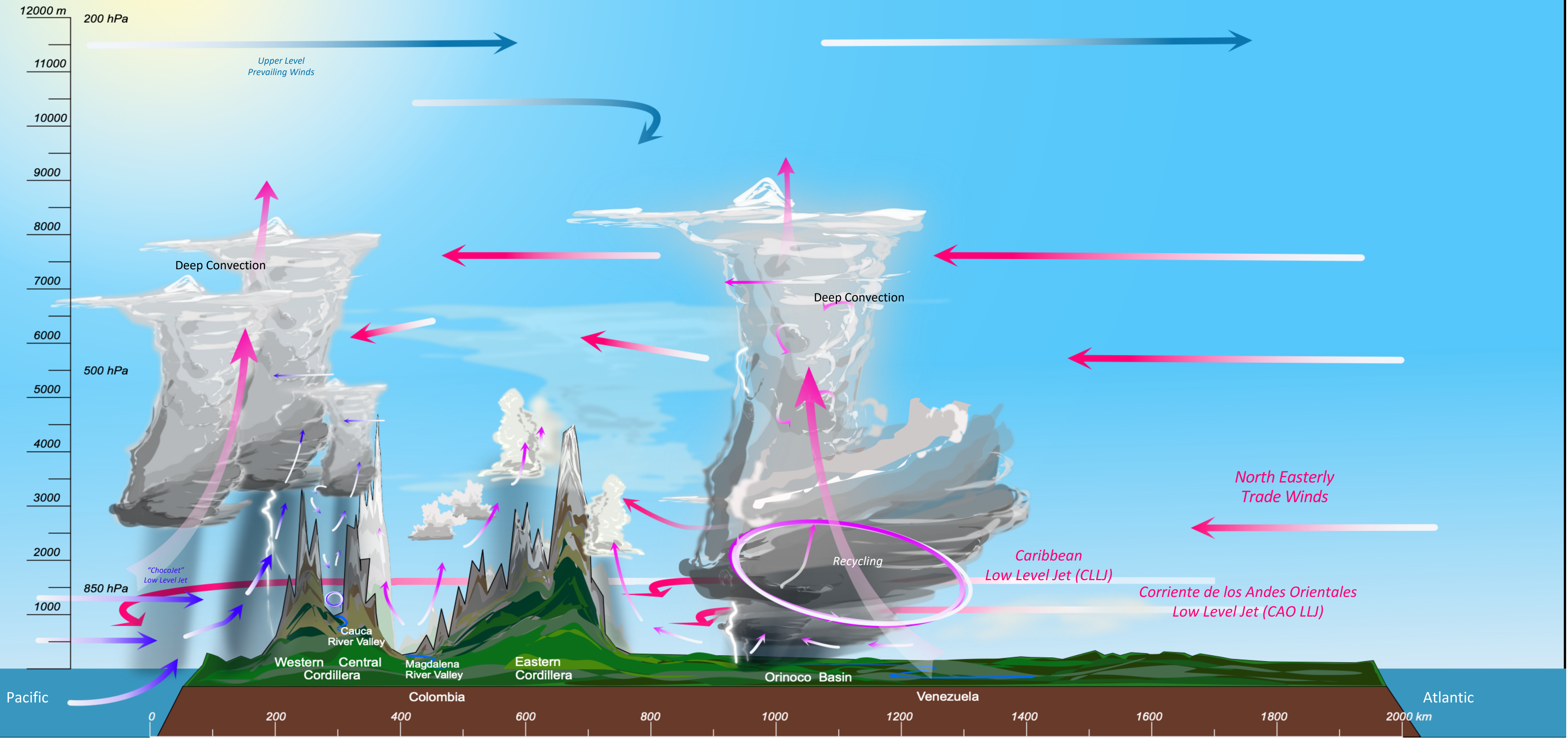
WCRP World Climate Research Programme

Why High Resolution Modeling?

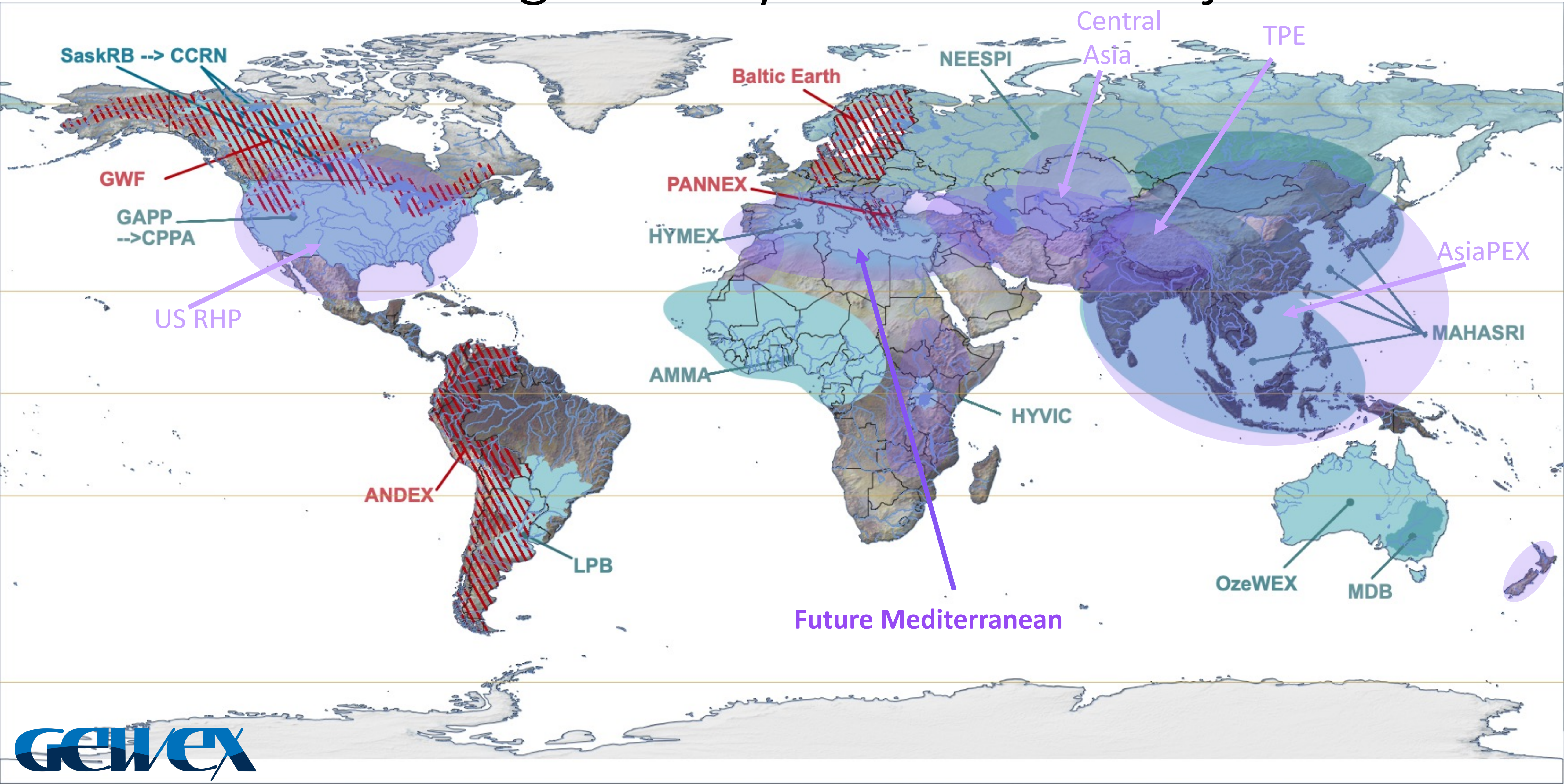
- Climate change is more than a change in the mean state -> the (change in) spatial and temporal distribution of phenomena (incl. extremes) is as important
- We want to understand the genesis of events and their evolution both in occurrence and manifestation under climate change -> prediction and projection
- Representation of the processes and phenomena closer to the actual direct human interaction scale -> enables linking to (sub) surface processes at scale relevant for e.g. operational hydrology


Gulf Stream
Atlantic North Equatorial Current
Guinea Current
Atlantic Equatorial Countercurrent
Atlantic South Equatorial Current
Tropical Easterlies
Hadley Cell
Ferrel Cell
Polar Cell
CAO
Low Level Jet
Choco Jet
Peruvian
Low Level Jet
Brazil Current
South Atlantic Current
Peru Current
Mentor Current
Chilean
Low Level Jet
South American
Low Level Jet
Subtropical
Westerlies
Atmospheric
Rivers
Extratropical
Westerlies
Cape Horn Current
Tropical / Subtropical Biomes
Moist Broadleaf Forest
Dry Broadleaf Forest
Grasslands, Savannas and Shrublands
Flooded Grasslands and Savannas
Temperate Biomes
Broadleaf and Mixed Forest
Grasslands, Savannas and Shrublands
Dry Biomes
Mediterranean Forest, Woodlands and Scrub
Desert and Xeric Shrublands
Aquatic Biomes
Mangroves
Polar/Montane Biomes
Tundra
Grasslands and Shrublands
Rock and Ice

Schematic Cross Section South America from Colombia to Venezuela: 5°N 77°W – 9°N 60°W



Envisioned Regional Hydroclimate Projects



GEWEX Science Goals

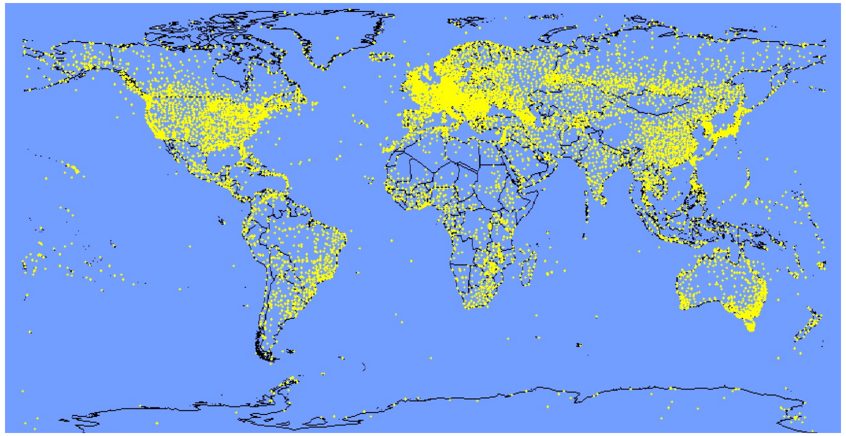
Goal # 1: Determine the extent to which Earth's water cycle can be predicted

a) **Reservoirs:** What is the rate of expansion of the fast reservoirs (atmosphere and land surfaces), what is its spatial character, what factors determine this and to what extent are these changes predictable?

b) **Flux exchanges**: To what extent are the fluxes of water between Earth's main reservoirs changing and can these changes be predicted and if so on what time/space scale?

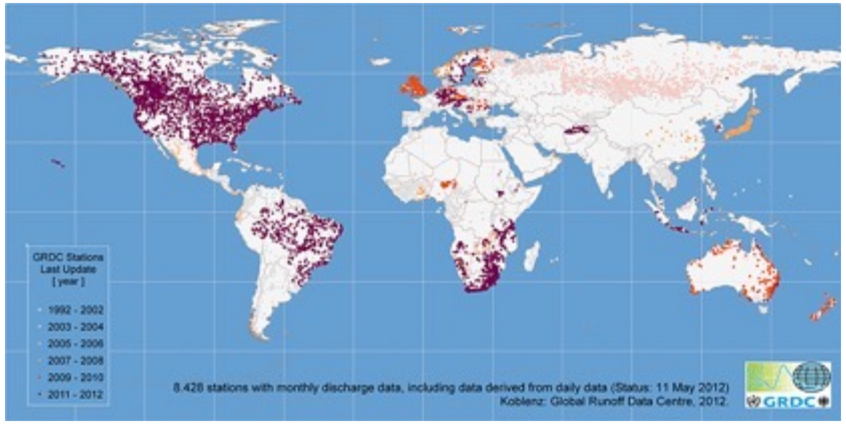
c) **Precipitation Extremes:** How will local rainfall and its extremes change under climate change across the regions of the world?

Inadequacy of Surface Observations

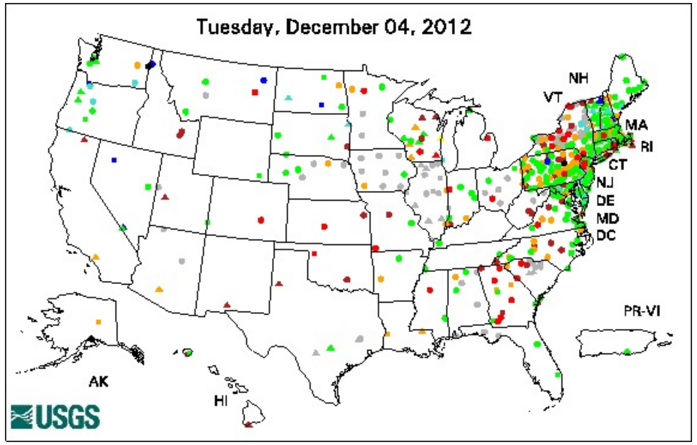


Global Telecommunication System meteorological stations. Air temperature, precipitation, solar radiation, wind speed, and humidity only.

Eight countries make groundwater data publicly available through the Global Groundwater Monitoring Network.



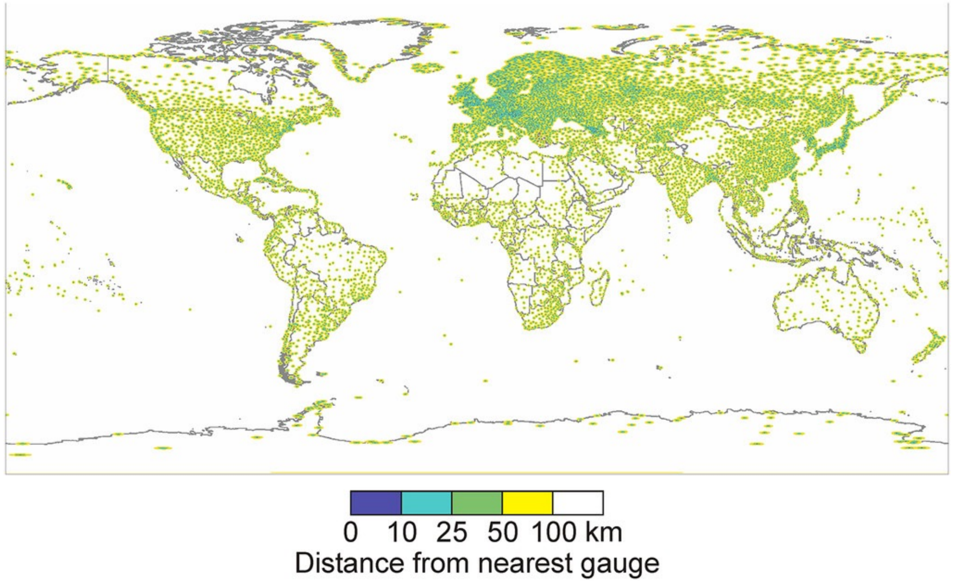
River flow observations from the Global Runoff Data Centre. Lighter circles indicate greater latency in the data record.



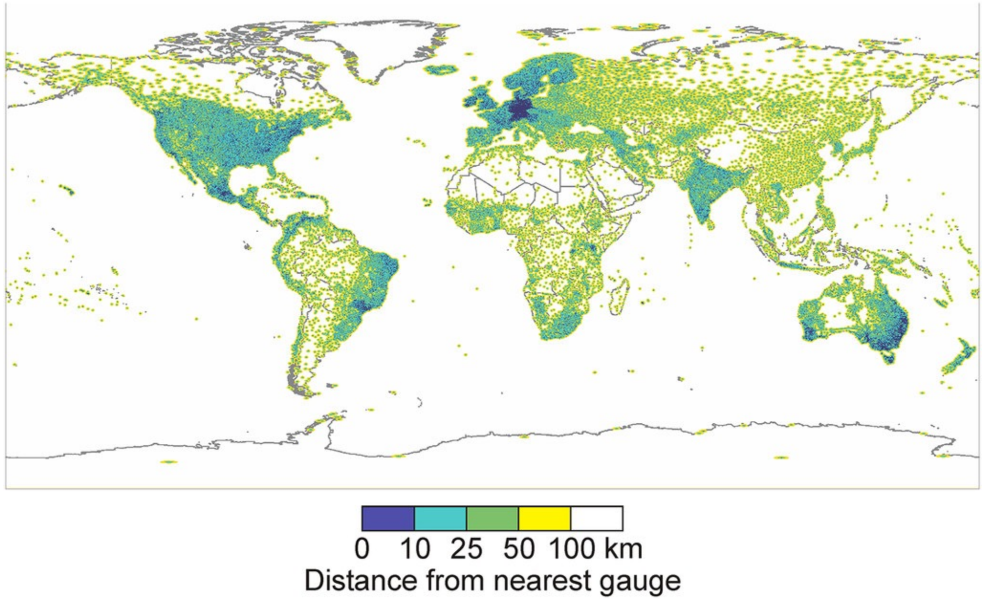
USGS Groundwater Climate Response Network.

Issues include coverage gaps, delays, measurement continuity and consistency, data format and QC, political restrictions

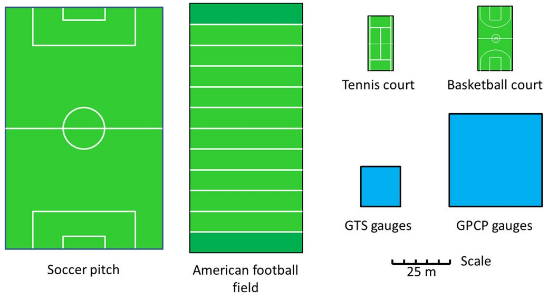
So, How Much of the Earth's Surface *Is* Covered by Rain Gauges?



Map showing the distance to nearest GTS gauge, typical of 3-hourly/daily measurements available in near–real time; blank areas in the figure are beyond 100 km from the nearest gauge. (8 – 12K first class stations)



Map showing the distance to nearest GPCC gauge, typical of all regular and reliable gauge measurements; blank areas in the figure are beyond 100 km from the nearest gauge. (~65K-100K stations)

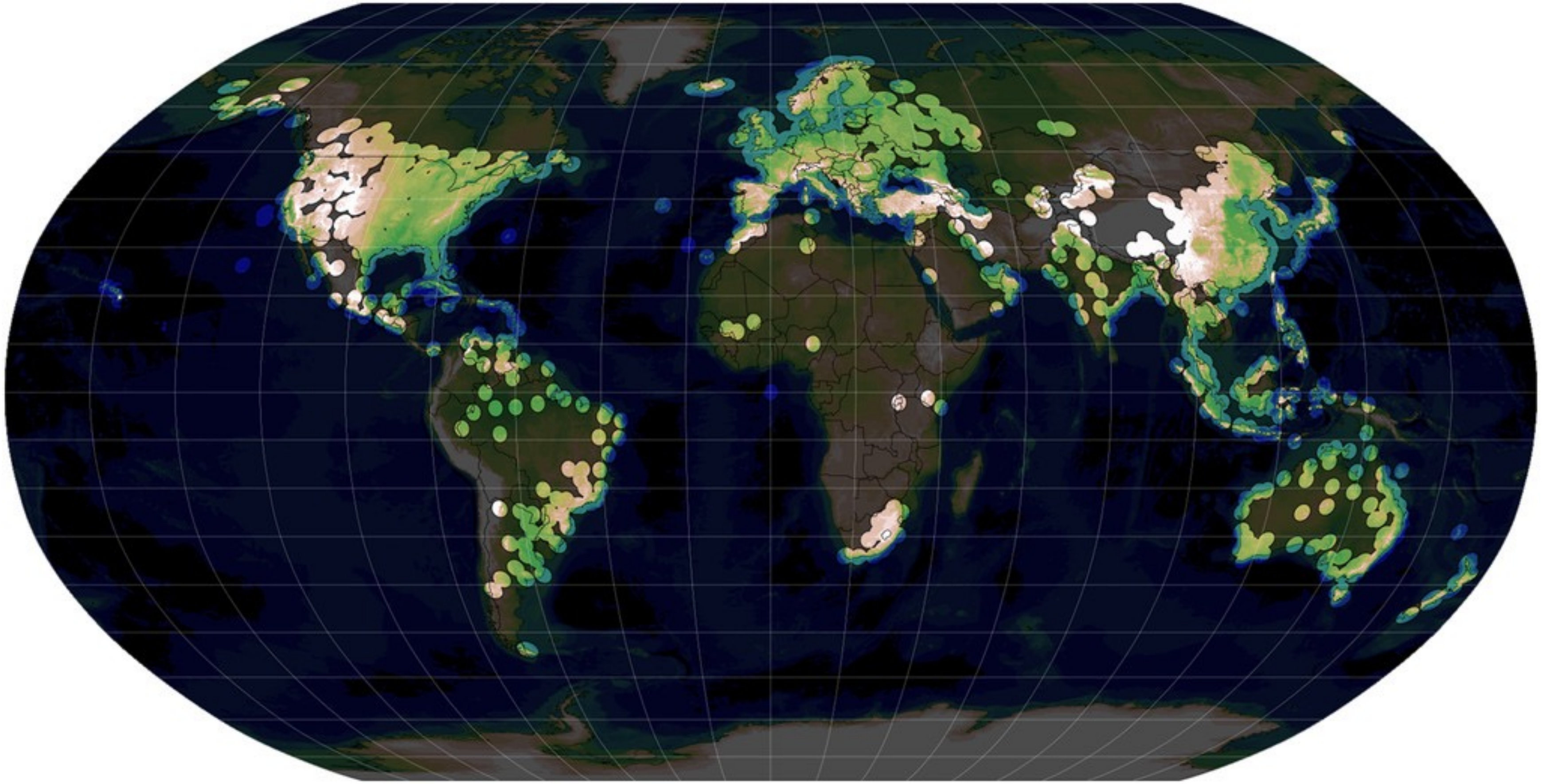


	Dimensions	Area	Equivalent gauges[a]
Soccer pitch	105 × 68 m	7140.0 m^2	178,500–562,204
Center circle of soccer pitch	9.15-m radius	263.0 m^2	6,575–20,709
American football	109.7 × 48.8 m	5353.4 m^2	133,834–421,524
Tennis court	23.78 × 10.97 m	260.9 m^2	6,522–20,541
Basketball (FIBA)	28.0 × 15.0 m	420.0 m^2	10,500–33,071

[a] Range based upon 400- to 127-cm^2 orifice areas.

Kidd, C., Becker, A., Huffman, G. J., Muller, C. L., Joe, P., Skofronick-Jackson, G., & Kirschbaum, D. B. (2017). So, How Much of the Earth's Surface Is Covered by Rain Gauges?, *Bulletin of the American Meteorological Society*, *98*(1), 69-78. Retrieved Jul 6, 2022, from https://journals.ametsoc.org/view/journals/bams/98/1/bams-d-14-00283.1.xml

Rain Radars – Global Coverage (2017)



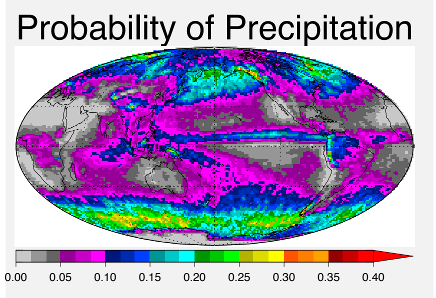
A map of weather radar coverage in the world (in Robinson projection). To compute and map the areas “illuminated” by radar, we used the wradlib library (https://wradlib.org), assuming each radar has a range of 200 km irrespective of bandwidth, polarization, and local terrain. Most radar locations included in this map have been retrieved from a WMO database (WMO 2019). Note that not all operational radars are included in the database. Additional radar locations have arbitrarily been added for China (manually digitized from WMO 2013), the Philippines (I. Crisologo 2018, personal communication), Vietnam (locations estimated in 2017 from the webpages of the National Centre for Hydro-Meteorological Forecasting in Vietnam, www.nchmf.gov.vn/Web/en-US/73/Default.aspx), and Myanmar (locations estimated in 2017 from the webpages of the Department of Meteorology and Hydrology in Myanmar, www.moezala.gov.mm/radar-image).

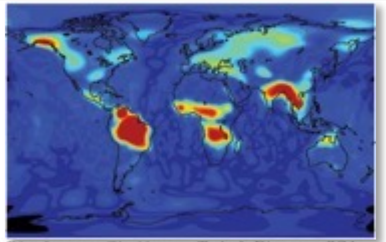
Saltikoff, E., Friedrich, K., Soderholm, J., Lengfeld, K., Nelson, B., Becker, A., Hollmann, R., Urban, B., Heistermann, M., & Tassone, C. (2019). An Overview of Using Weather Radar for Climatological Studies: Successes, Challenges, and Potential, *Bulletin of the American Meteorological Society*, *100*(9), 1739-1752. Retrieved Jul 6, 2022, from https://journals.ametsoc.org/view/journals/bams/100/9/bams-d-18-0166.1.xml

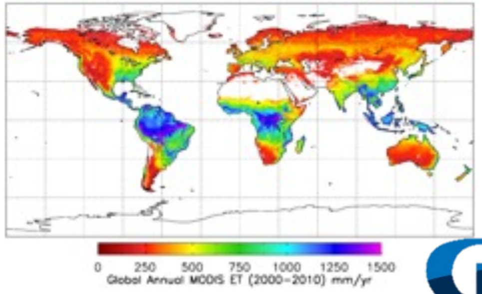
Surface Water balance

$$\Delta S = P - Q - ET$$

- **Precipitation (P)**
  - In situ: Rain gauges, Snotel
  - RS (TRMM, CloudSat, AMSR-E, IR, GPM….)
- **Change in storage (ΔS)**
  - In situ: Groundwater recharge/flow, soil moisture, standing water, wells
  - RS (GRACE (-FO), SWOT, AMSR-E→SMOS→SMAP, CIMR)
- **Runoff (Q)**
  - In situ: Stream gauges, Global Runoff Data Center,
  - RS (SWOT, ..)
- **Evaporation/Evapotranspitation (ET)**
  - In Situ: Fluxnet
  - RS Quickscat, AMSR-E, MODIS, CERES, AIRS, FLEX etc.
    (RS of ET also requires surface net radiation)
- **Global accuracy/consistency/ability**
- See also: M. F. McCabe et al. (2017): The future of Earth observation in hydrology







After E.F. Wood 2017

Goal # 2 (GS2): Quantify 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

a) **Forcing-feedback understanding**: How can we improve the understanding of climate forcings and feedbacks formed by energy, water and carbon exchanges?

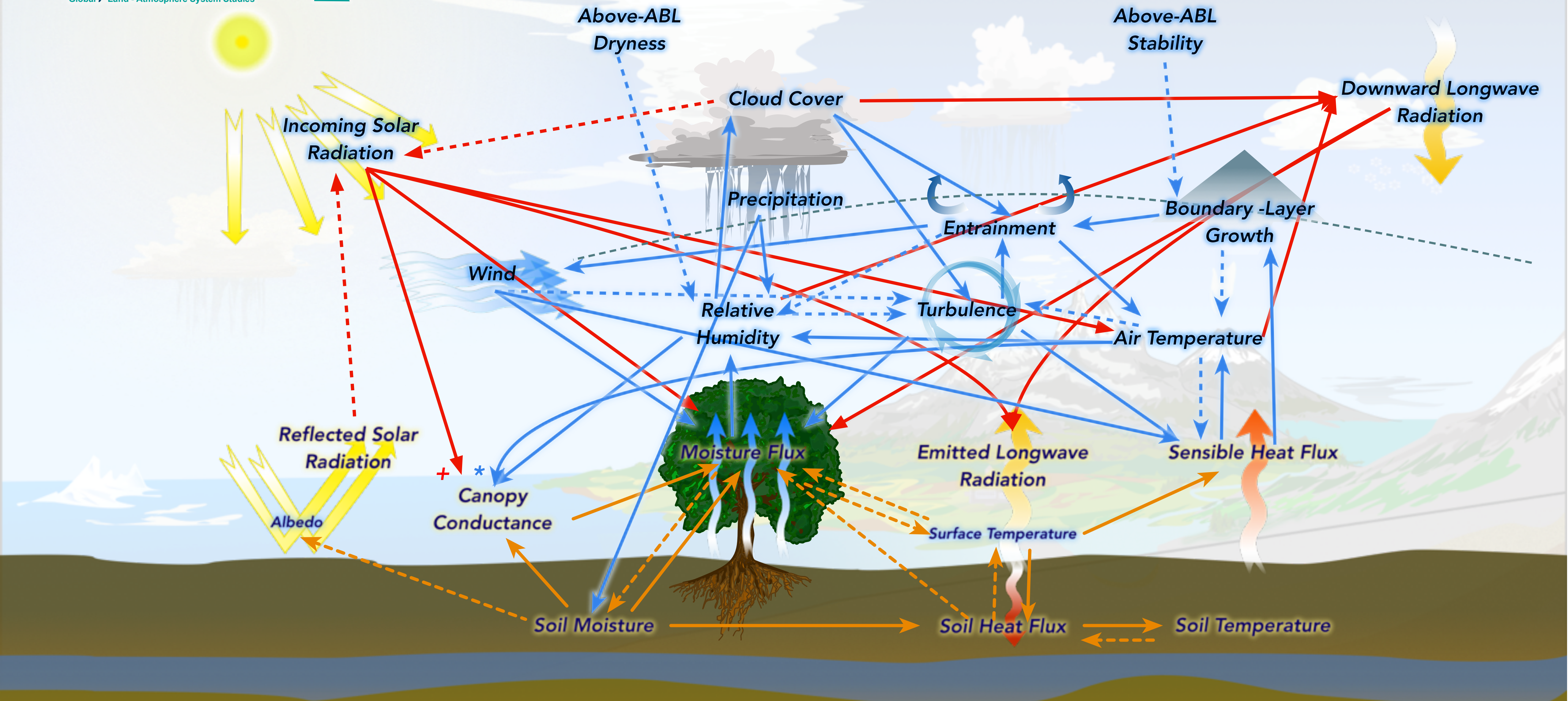
b) **ABL process representation**: To what extent are the properties of the atmospheric boundary layer (ABL) defined by sensible and latent energy and water exchanges at the Earth's surface versus within the atmosphere (i.e., horizontal advection and ABL-free atmosphere exchanges)?

c) **Understanding Circulation controls:** To what extent are exchanges between water, energy and carbon determined by the large-scale circulations of the atmosphere and oceans?

d) **Land-atmosphere interactions**: How can we improve the understanding of the role of land surface-atmospheric interactions in the water, energy and carbon budgets across spatiotemporal scales?

Local Land-Atmosphere Interactions – All Processes

Global Land - Atmosphere System Studies



+ Positive Feedback for C3 & C4 Plants, Negative Feedback for CAM Plants

* Negative Feedback Above Optimal Temperature

Radiation

Land Surface Processes

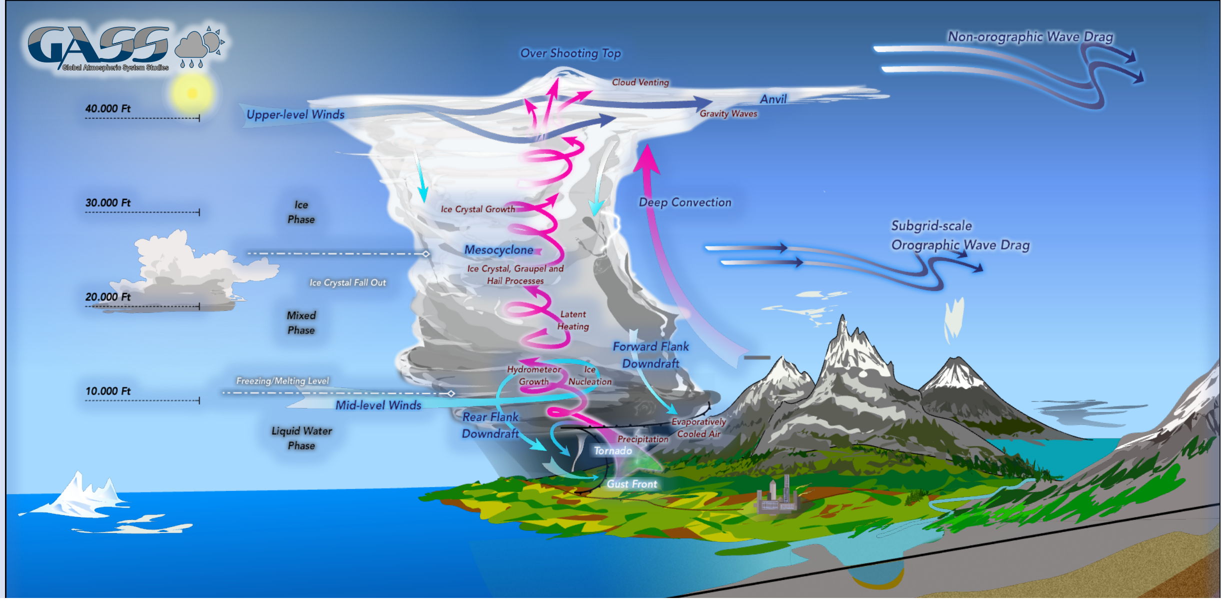
Surface Layer & ABL

Positive Feedback

Negative Feedback

After: Ek and Mahrt, 1994
Ek and Holtslag, 2004

Priorities



- 1) Atmospheric Boundary Layer
  - – Land-Atmosphere Interactions

- 2) Convection in particular deep convective processes and MCSs -> Precipitation

- 3) Earth Energy Imbalance: consistent observations are key!

GEWEX

Goal # 3 (GS3): Quantify anthropogenic influences on the water cycle and our ability to understand and predict changes to Earth's water cycle.

a) **Anthropogenic forcing of continental scale water availability**: To what extent has the changing greenhouse effect modified the water cycle over different regions and continents?

b) **Water management influences**: To what extent do water management practices and land use change (e.g., deforestation) modify the water cycle on regional to global scales?

c) **Variability and trends of water availability**: How do water & land use and climate change affect the variability (including extremes) of the regional and continental water cycle?

Anthropogenic influences on the water cycle

- Requires a multidisciplinary approach with a variety of observational methods (incl. EO in broadest sense but also citizen science, socio-economic indicators etc.) – consistency and continuity in observations
  - Irrigation, Land use and land cover change incl. urbanization, land use practices, water management
- Primary a retrospective and descriptive approach as prediction is difficult (think stock market)
- Huge potential within Digital Twin concept (bringing together the numerous information channels) → High Resolution Modeling key

Thank You

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