GCOS

KEEPING WATCH OVER OUR CLIMATE
The Global Climate Observing System

United Nations Educational, Scientific and Cultural Organization · International Centre for Water Resources and Global Change under the auspices of UNESCO

# Global Observations of the Water Cycle

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GCOS Joint Panel Meeting, Marrakech, Mar 19 2019

# Outline

1. Objectives
2. Recent knowledge of CC-influence on the water cycle
3. Data availability
4. Observed state of the water cycle
5. Discussion and next steps

# GCOS target

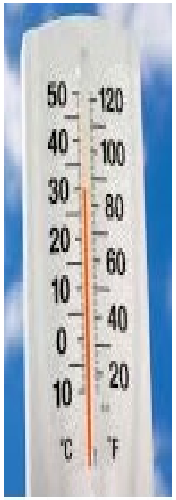
| BOX 1: Closing the global water cycle | |
|---|---|
| **Targets** | Close water cycle globally within 5% on annual timescales |
| **Who** | Operators of GCOS-related systems, including data centres |
| **Time frame** | Ongoing |
| **Performance indicator** | Regular assessment of the uncertainties in estimated turbulent flux of latent heat |

Simultaneous closing of the energy and water budget via the equivalence of both ET and latent heat fluxes.

# Why does it matter?
# Impact of climate change:

## General global risks

- The increase in greenhouse gases significantly increases the risks to water resources.
- Per degree of warming,
  - the renewable water resource is reduced by 20%,
  - with a simultaneous population growth of 7%.




1°C = 20%↓ → population growth of 7%.

# Outline

1. Objectives
2. **<u>Recent knowledge of CC-influence on the water cycle</u>**
3. Data availability
4. Observed state of the water cycle
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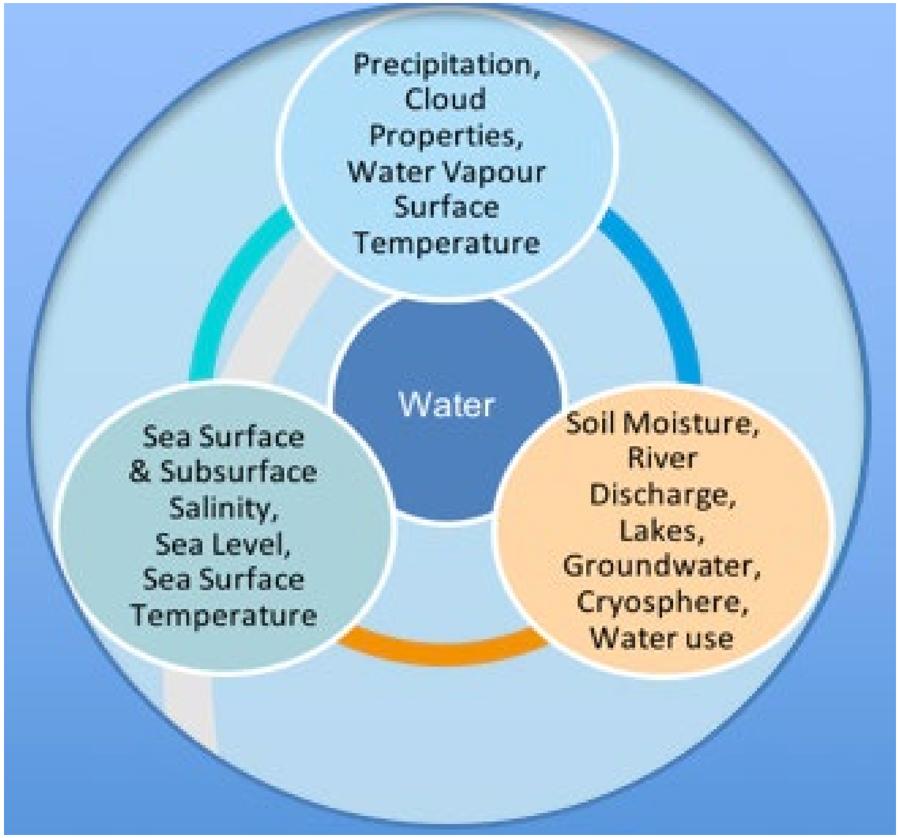
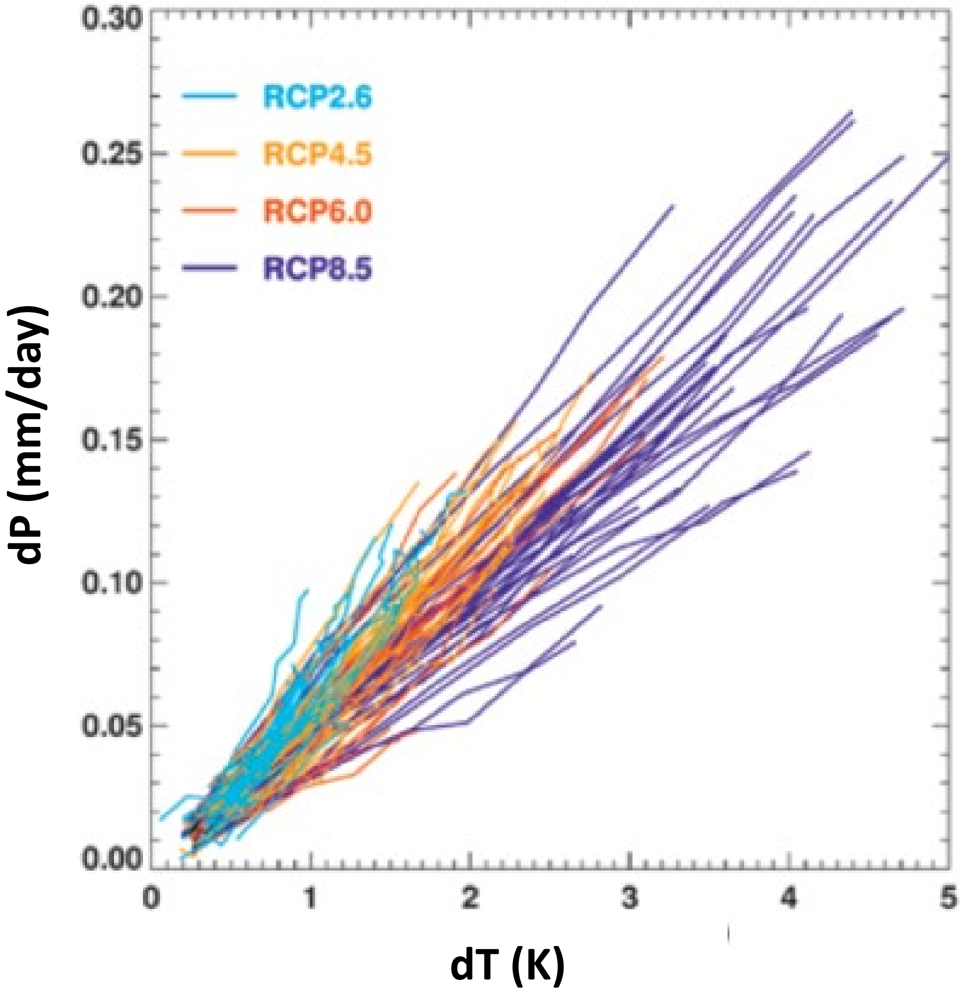
# The global water cycle

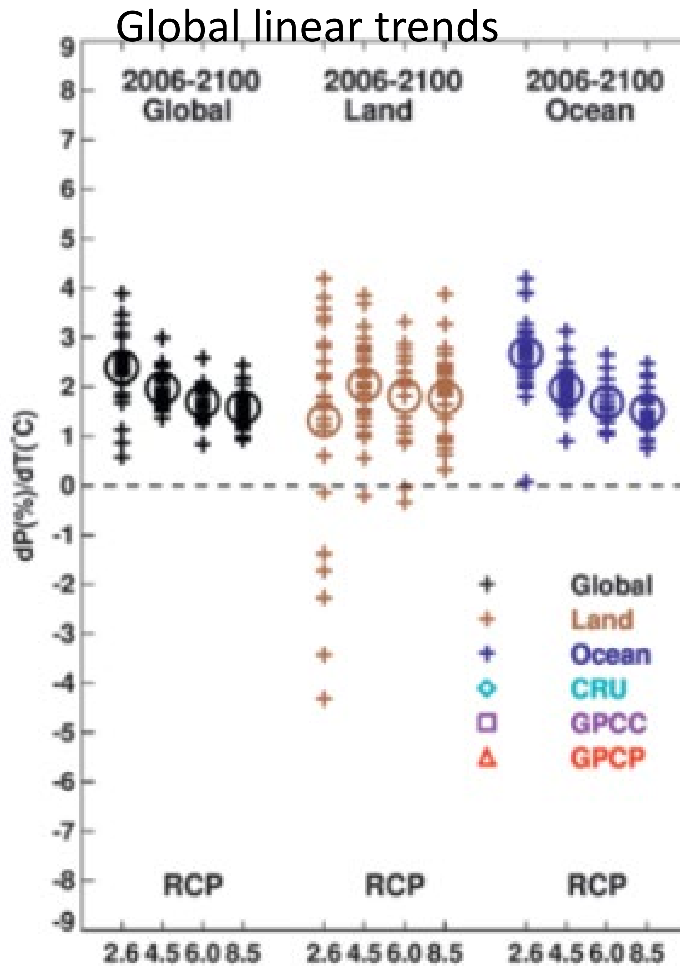



## Key Processes

- Evaporation, transpiration and water vapor generation
- Atmospheric transport of water vapour
- Precipitation
- Storage and release by the cryosphere, lakes and reservoirs, soil moisture, and groundwater
- Water flow on the surface
- River discharges to the ocean
- Groundwater discharges to the oceans

# Expected Changes in the Water Cycle

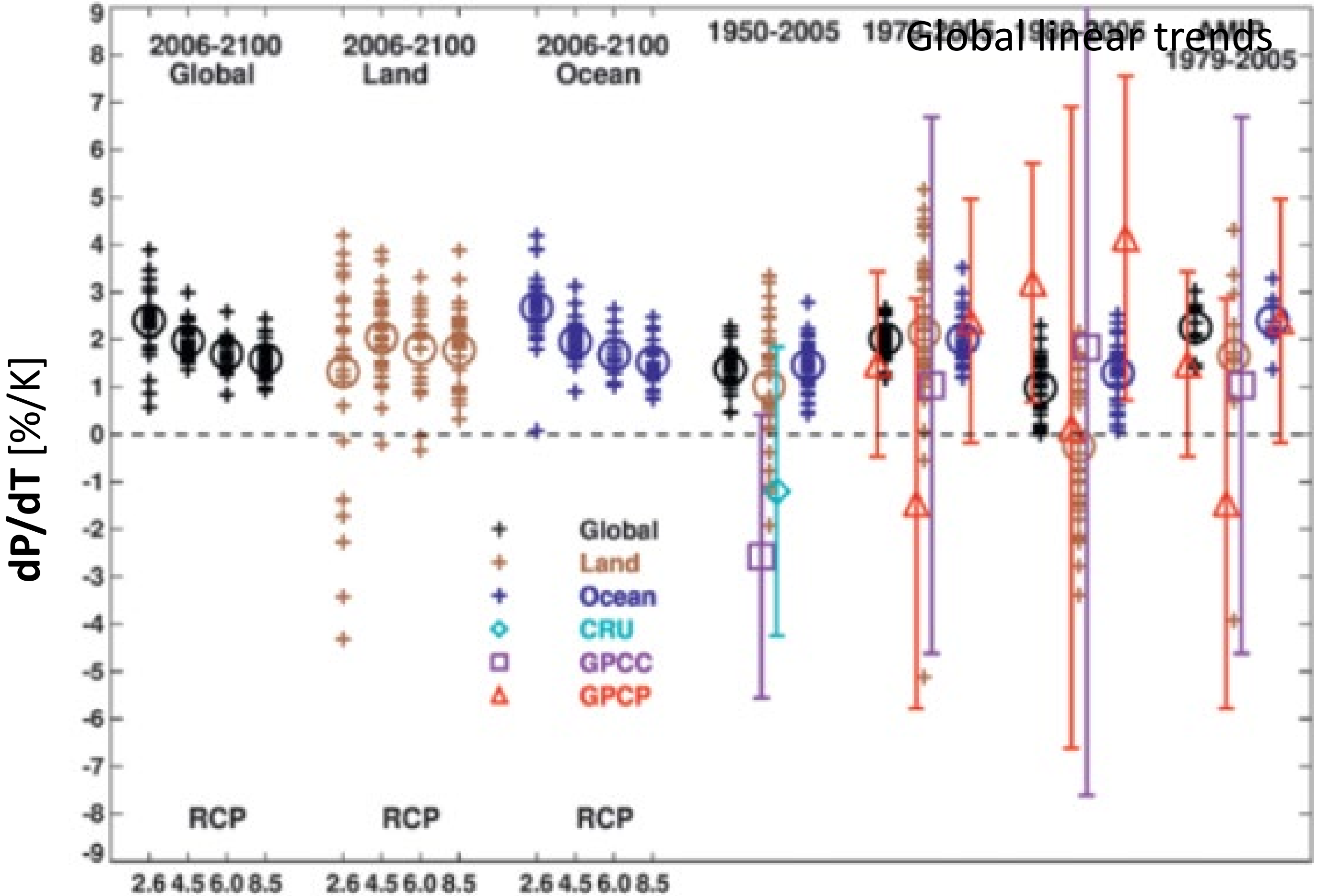



Hegerl et al., 2015/BAMS

**Hydrological Sensitivity: +1K → 2-3% increase in precip.**

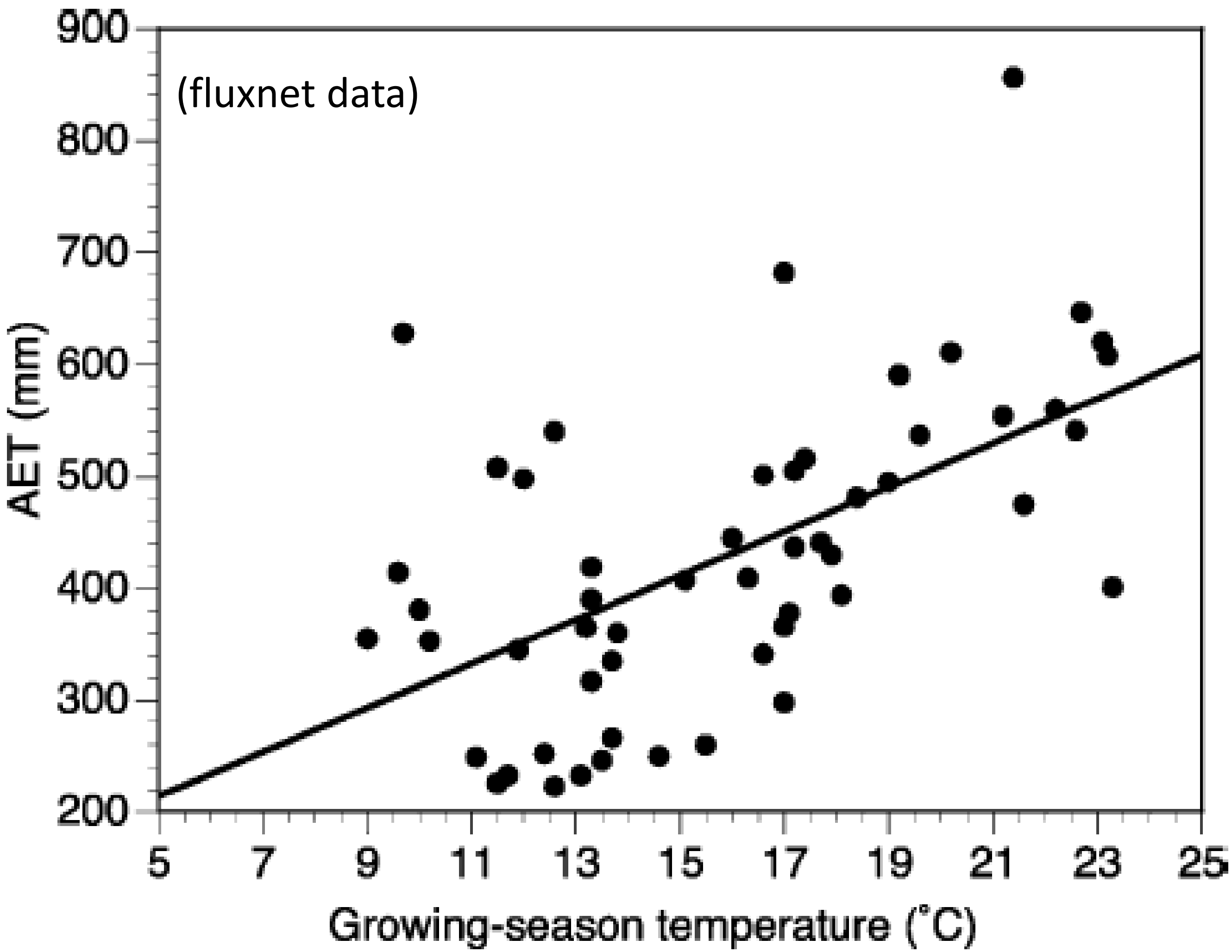
# Expected Changes in the Water Cycle




**Hegerl et al., 2015/BAMS**

## A lot of uncertainty are covered by the observations

# Expected Changes in the Water Cycle




**observed temperature increases during the 20th century may have resulted in increasing ET where moisture is not limiting**

**Huntington, 2006/JHydrol**

# Impact of climate change

**Intensification of the water cycle**

- 1 °C more temperature accelerates the cycle of evaporation and precipitation by 2-3% (*likely safety).*

**This leads to** changes P-E patterns and intensification of inequalities in the global water supply.

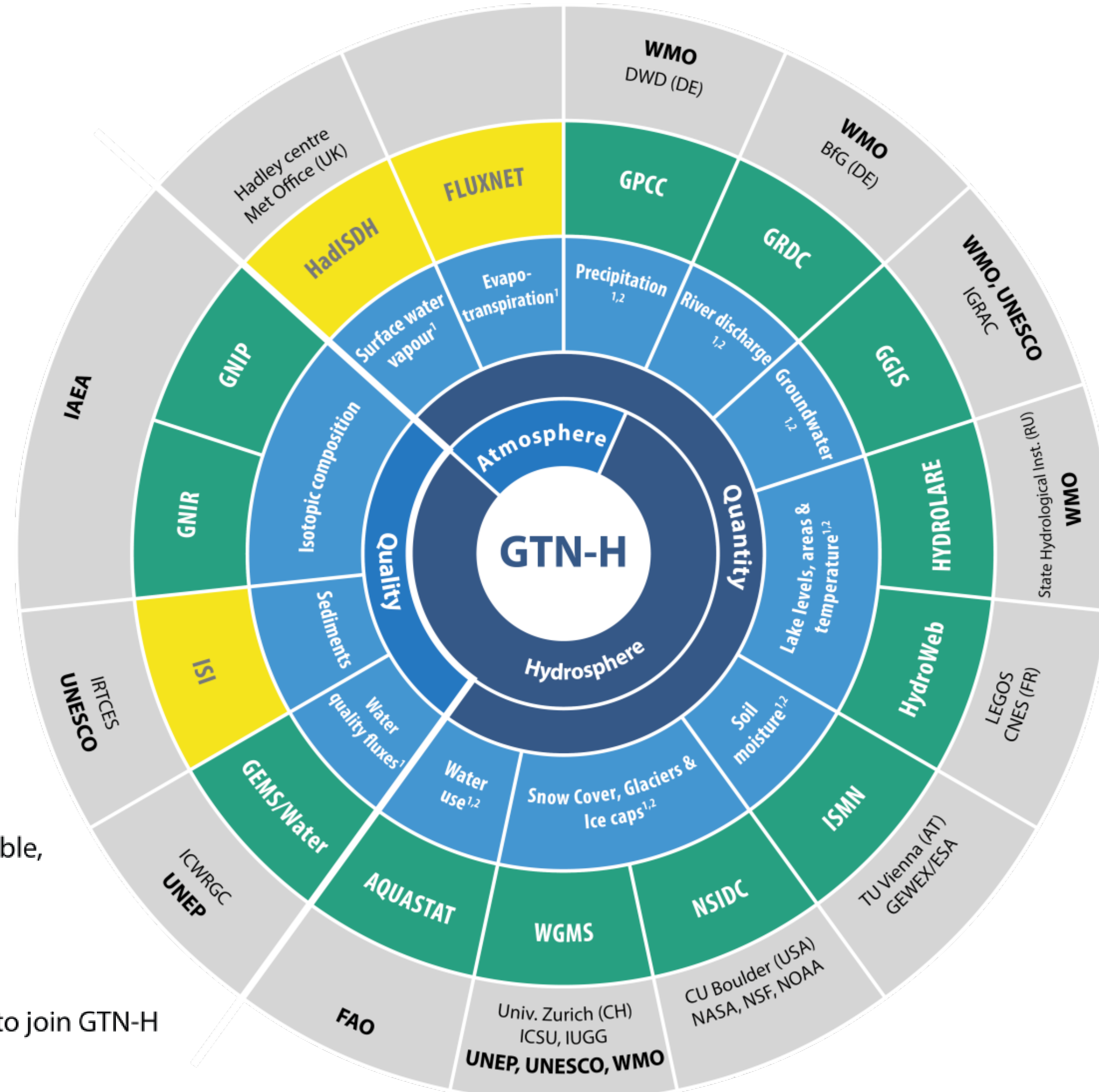
**But:**

- Estimates extremely difficult due to lack of measurement data, especially over the oceans.
- Small S/N ratio makes it difficult to detect/attribute changes of the water cycle
- Also missing: uncertainty estimations on long-term trends
  - Difficult to provide
  - Account for natural (multi)decadal variability

# Outline

1. Objectives
2. Recent knowledge of CC-influence on the water cycle
3. **<u>Data availiability</u>**
4. Observed state of the water cylce
5. Discussion and next steps

# The existing operational global water data centers (mostly in situ)




Variable, [1]GCOS Essential Climate Variable, [2]GEO Essenstial Water Variable

GTN-H member network

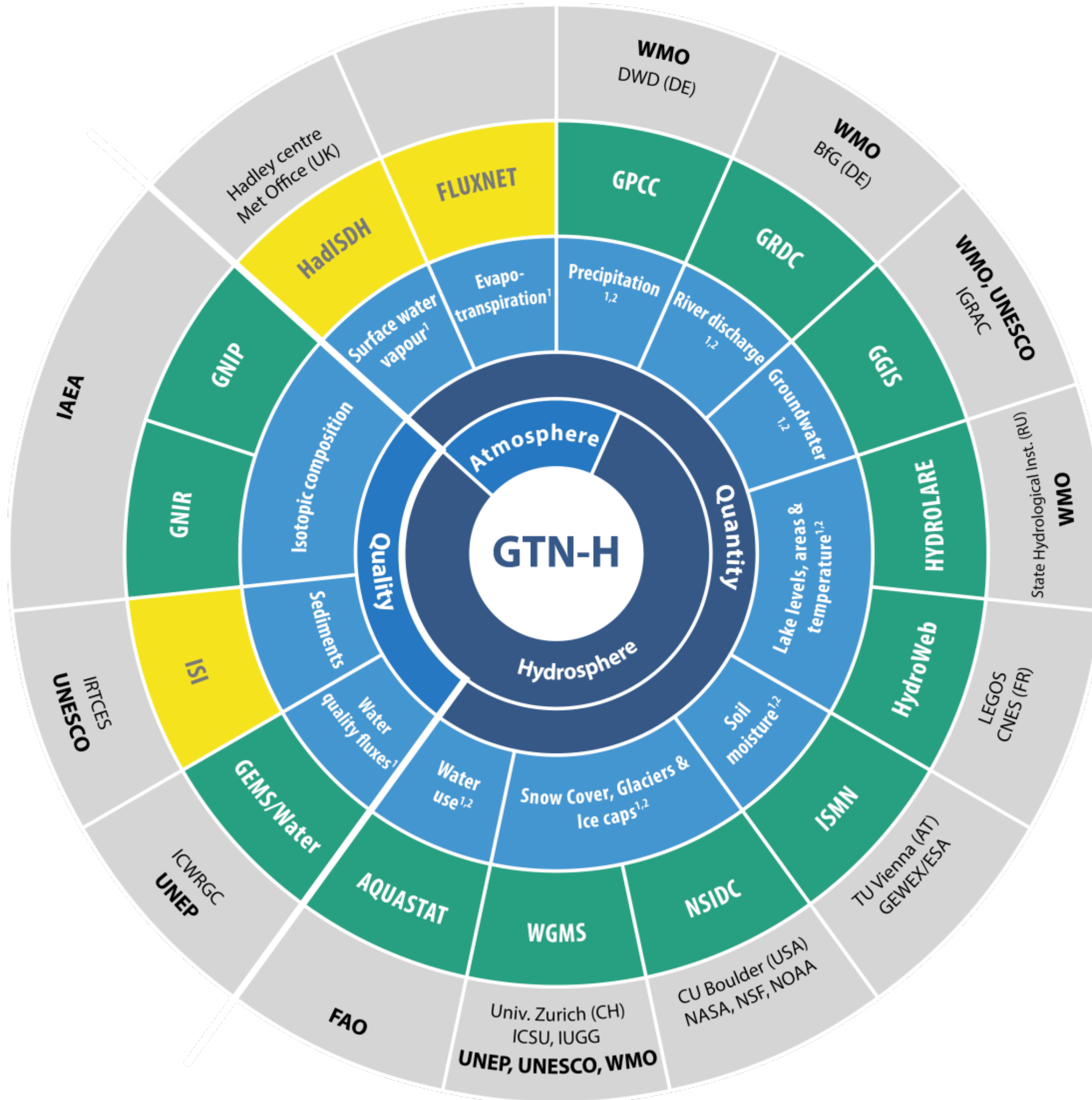
Global network/identified/suggested to join GTN-H

# The existing operational global water data centers (mostly in situ)

**Network** of the global water data centres

**Joint project** of GCOS and WMO;

implementated in 2001

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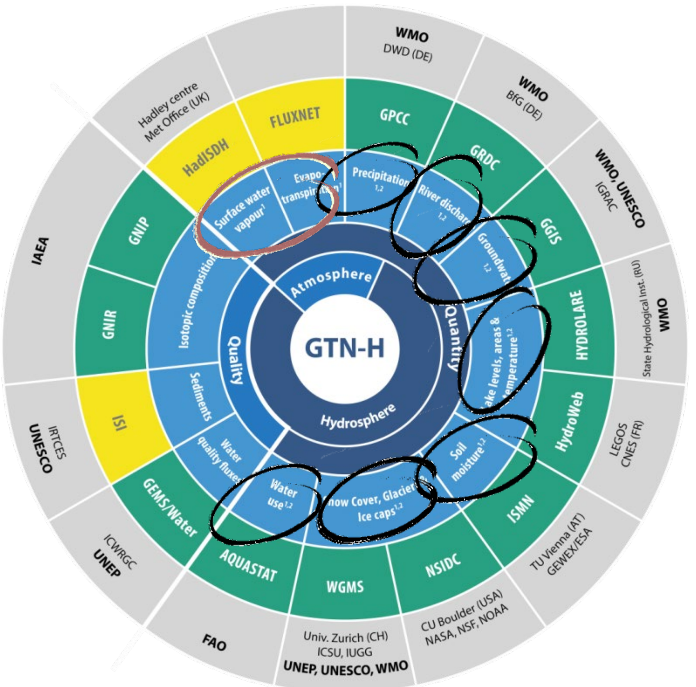
WORLD METEOROLOGICAL ORGANIZATION

# GTN-H: Synergies at development of requirements for hydrological ECV


GCOS
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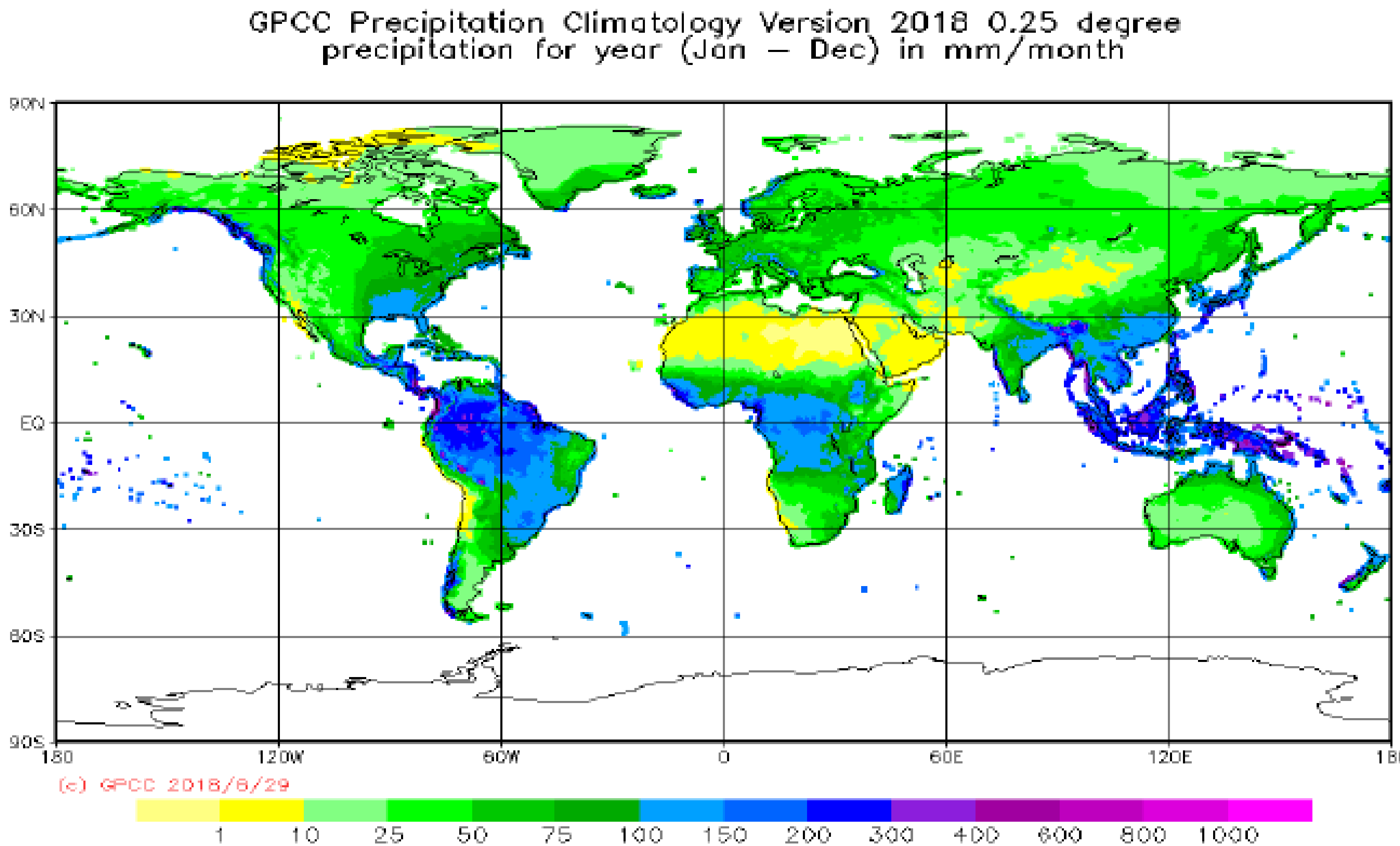
GCOS specifies 54 Essential Climate Varibales (ECV) that are key for sustainable climate observations

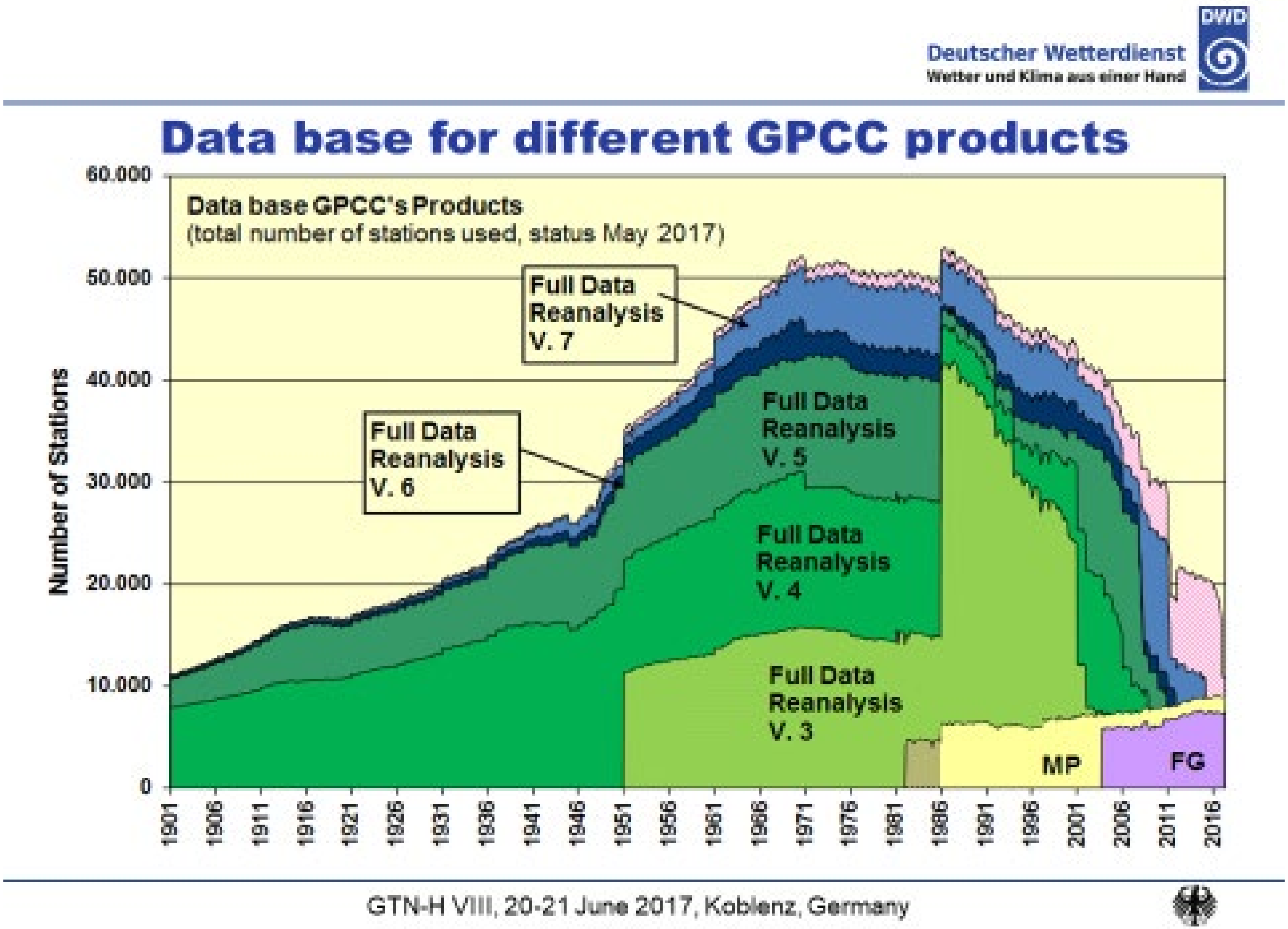
# Global precipitation data



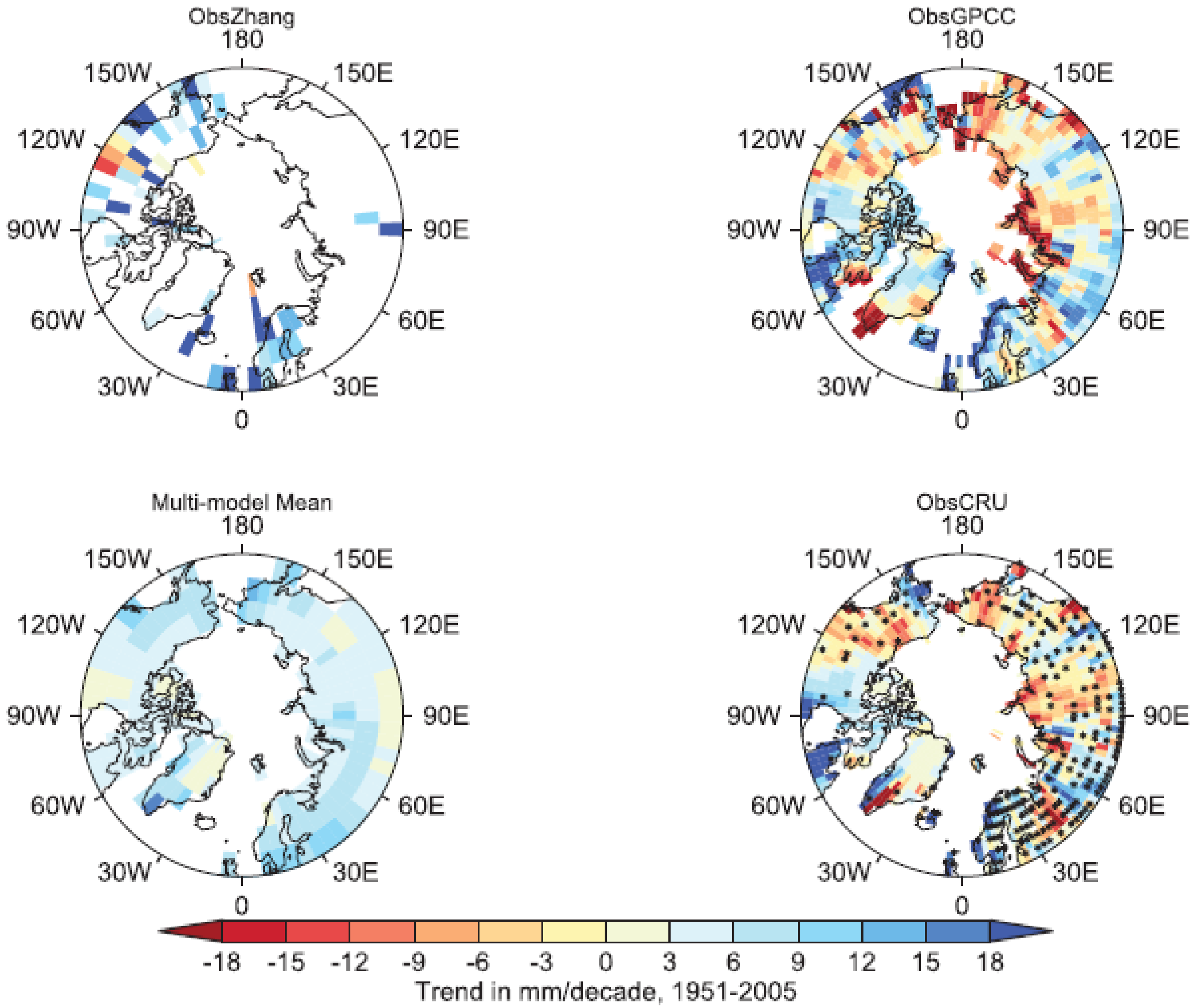

**Global Precipitation Climatology Centre (GPCC)**

The Global Precipitation Climatology (over land) is the background for all other GPCC precipitation analysis products and is based over 75,100 stations with climatological normal. Overall, the GPCC data base consists of over 110,000 stations.

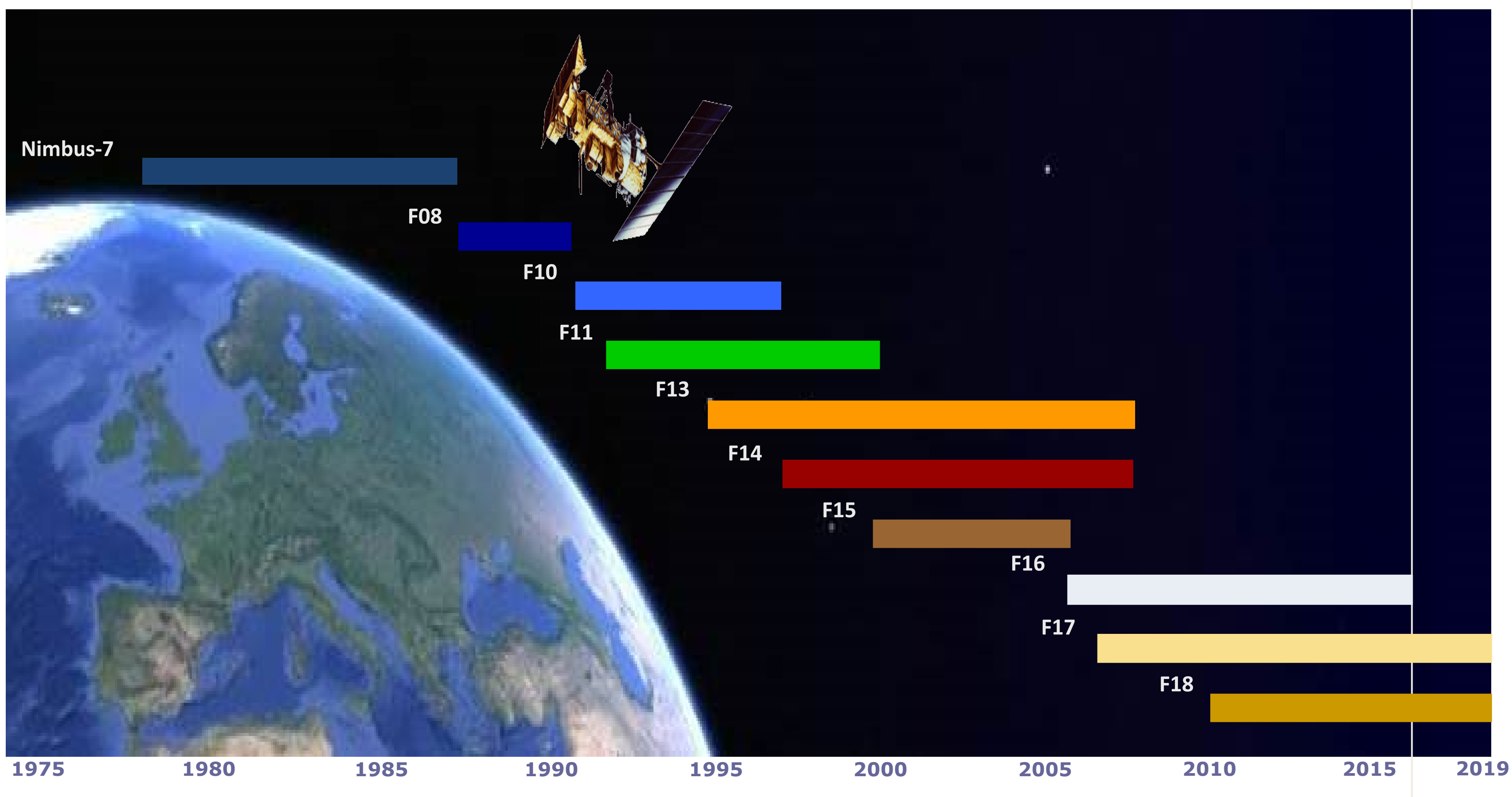
# Timeliness issue



# High-latitude (55°–90°N) annual-mean precipitation trends (mm decade–1) from 1951 to 2005

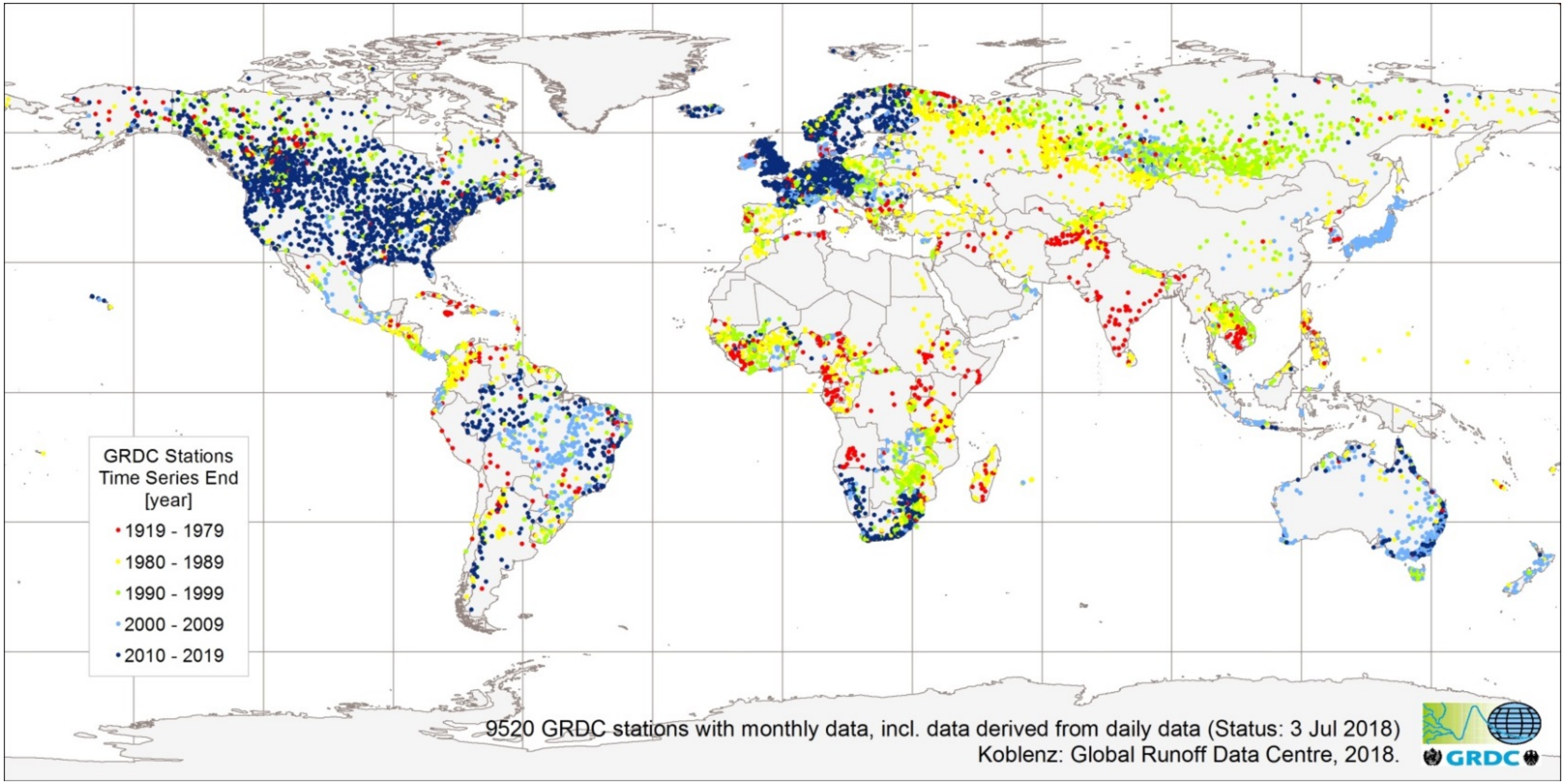


# Temporal coverage of microwave imagers



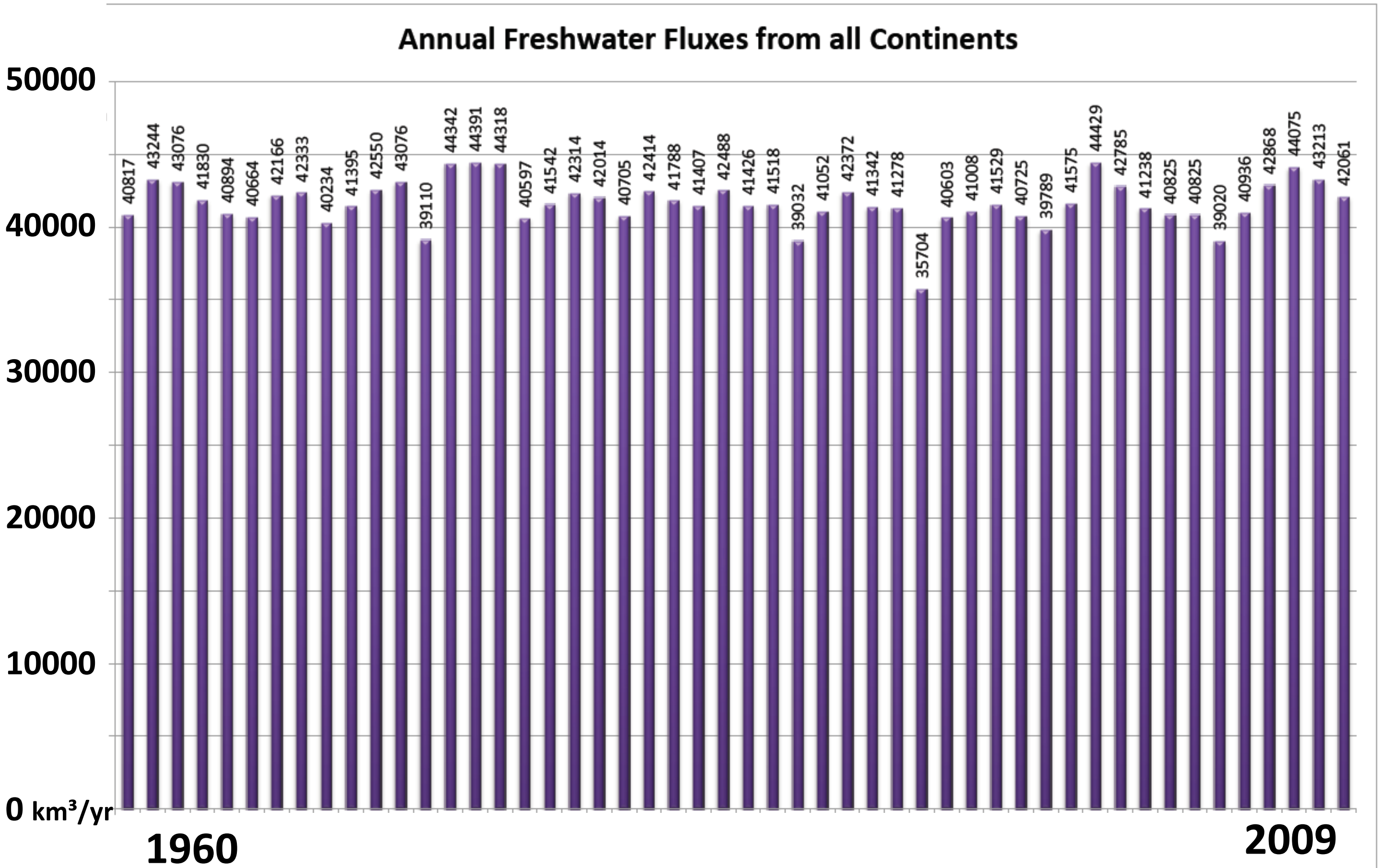

Temporal coverage of SMMR, SSM/I and SSMIS instrument aboard Nimbus-7 and DMSP satellite platforms.

# Global Runoff Data Centre (GRDC)




- International archive of river discharge times series supporting global change research
- Operated by the German Federal Institute of Hydrology (BfG) under the auspices of the WMO.

# Annual Freshwater discharge from all continents




Koblenz: Global Runoff Data Centre, 2014

Rain – discharge relation:

Application of WaterGAP (no glacier/ice sheet dynamics)

Future SWOT mission

**Average annual river runoff: 41,900 km³/yr**

# Relevant open tasks

- data limitations (in time and/or space),
- the spatial representativeness of point-based measurements,
- scaling issues between observations (in situ and remotely sensed) and models,
- uncertainties in variable estimates from satellite retrievals and numerical modelling,
- differences in how extremes are defined.

GCOS.wmo.int

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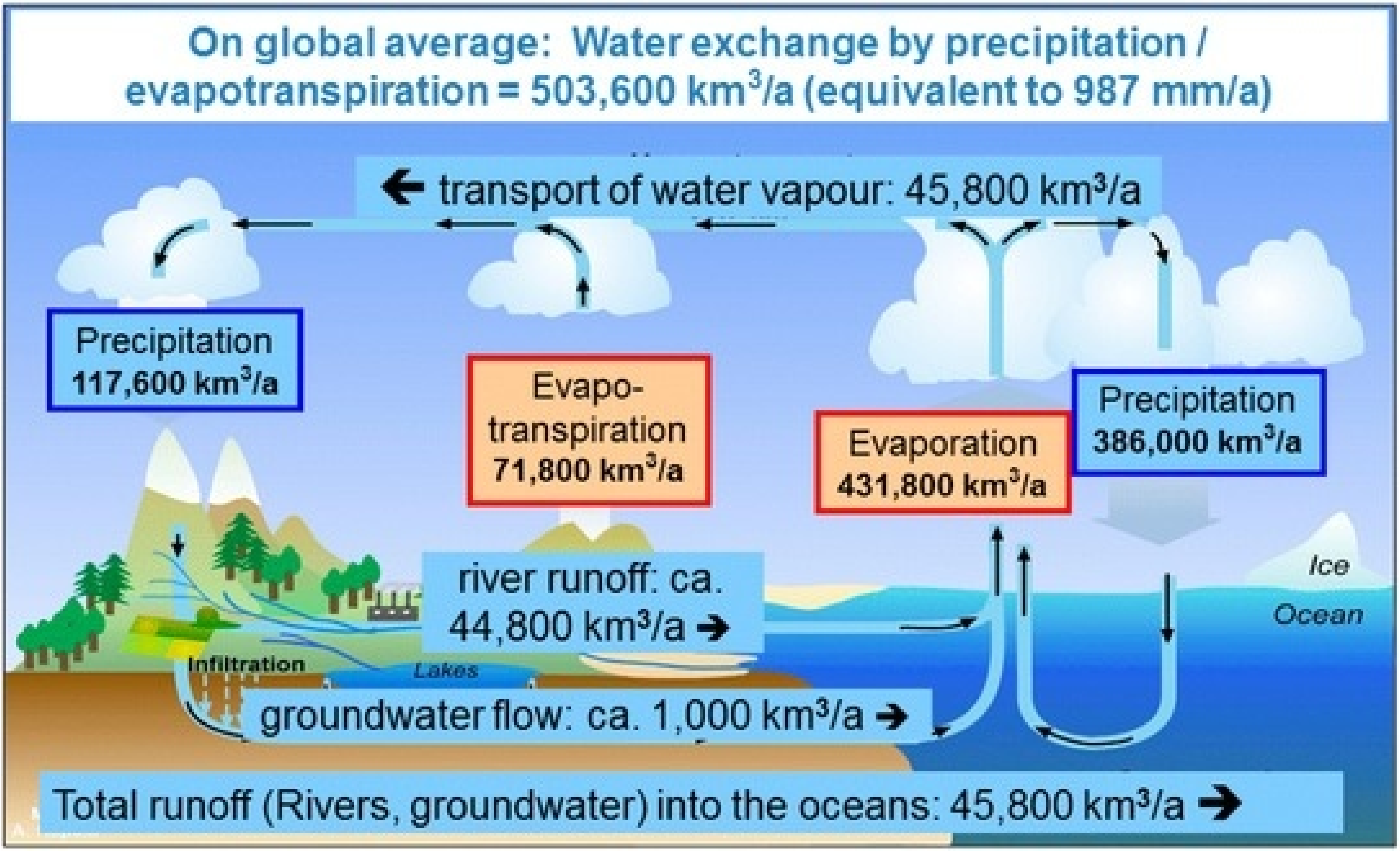
# The global water cycle (in-situ focus)




*Schneider et al., 2017*

# Satellites + data-integrating models

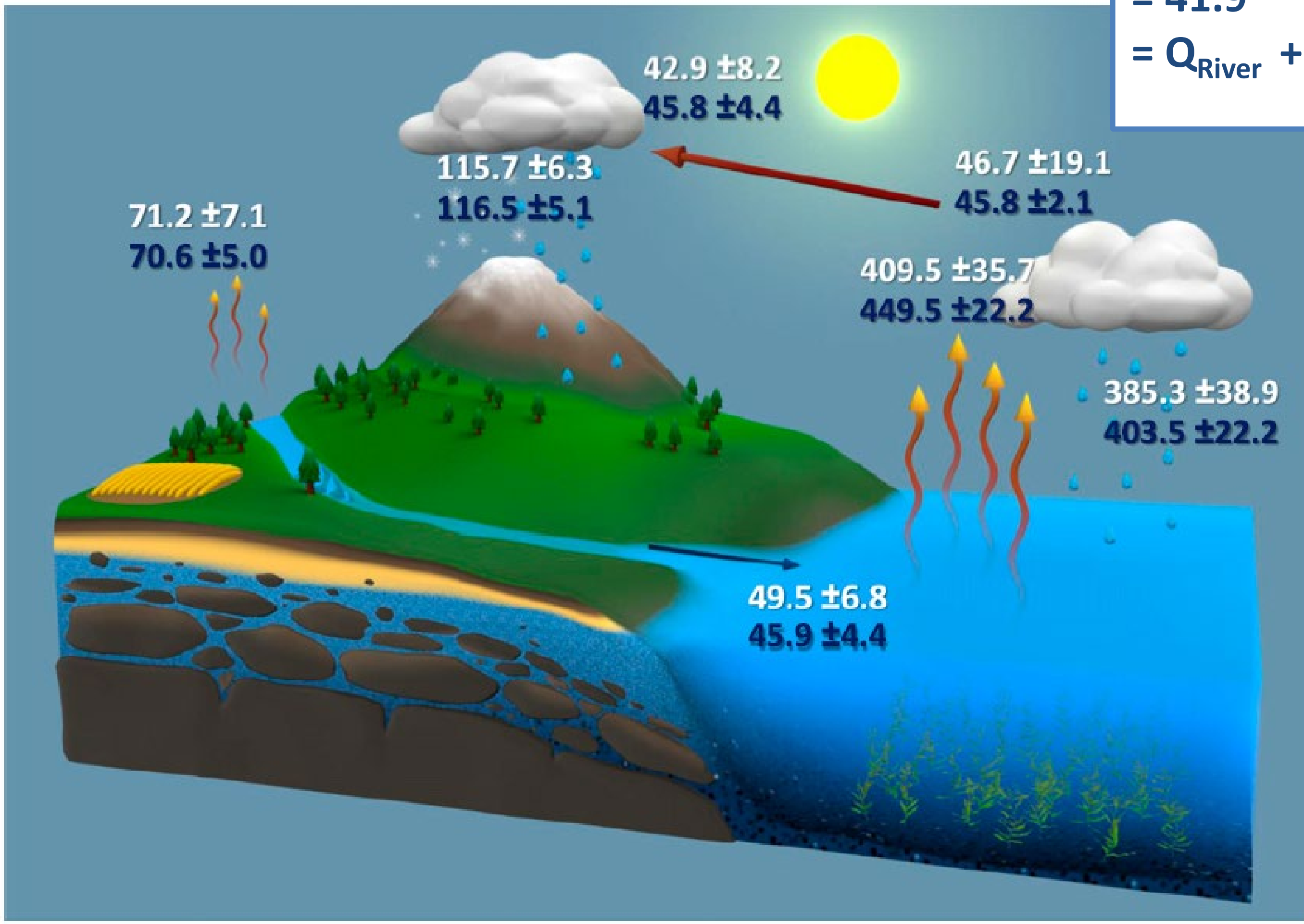
TABLE 1. Sources of data used in this study.

| Parameter | Dataset name | Contributing remote sensing instruments | Key references |
|---|---|---|---|
| Precipitation | GPCP v2.2 | SSM/I, SSMIS, GOES-IR, TOVS, and AIRS | Adler et al. (2003) and Huffman et al. (2009) |
| Ocean evaporation | SeaFlux v1.0 | SSM/I, AVHRR, AMSR-E, TMI, and WindSat | Clayson et al. (2015, manuscript submitted to *Int. J. Climatol.*) |
| Terrestrial evapotranspiration | Princeton ET | AIRS, CERES, MODIS, and AVHRR | Vinukollu et al. (2011) |
| | MERRA and MERRA-Land | MSU, HIRS, SSU, AMSU, AIRS, SSM/I, *ERS-1*/*-2*, QuikSCAT, MODIS, GOES | Rienecker et al. (2011), Bosilovich et al. (2011), and Reichle (2012) |
| | GLDAS | SSM/I, SSMIS, GOES-IR, TOVS, AIRS, TRMM, MODIS, and AVHRR | Rodell et al. (2004b) |
| River runoff | University of Washington runoff | TRMM, GOES-IR, TOVS, SSM/I, ERS, and ATOVS | Clark et al. (2015) |
| Atmospheric convergence | MERRA | See MERRA above | See MERRA above |
| | QuikSCAT water balance | QuikSCAT, TRMM, and GRACE | Liu et al. (2006) |
| | PMWC v2.0 | SSM/I, AMSR-E, TMI, and WindSat | Hilburn (2009) |
| Water storage changes | Chambers/Center for Space Research (CSR) Release 05 (RL05) | GRACE | Chambers and Bonin (2012), Johnson and Chambers (2013), Bettadpur (2012), and Tapley et al. (2004) |
| Precipitable water vapor | AIRS and AMSR-E precipitable water | AIRS and AMSR-E | Fetzer et al. (2006) |

***Rodell et al., 2015/JClim***

# Satellites + data-integrating models

Total continental runoff = 47.1
= 41.9 + 2.3 + 2.9
= $Q_{River}$ + $Q_{submar.\ GW}$ + $Q_{ice\ sheet}$




*Rodell et al., 2015/JClim*

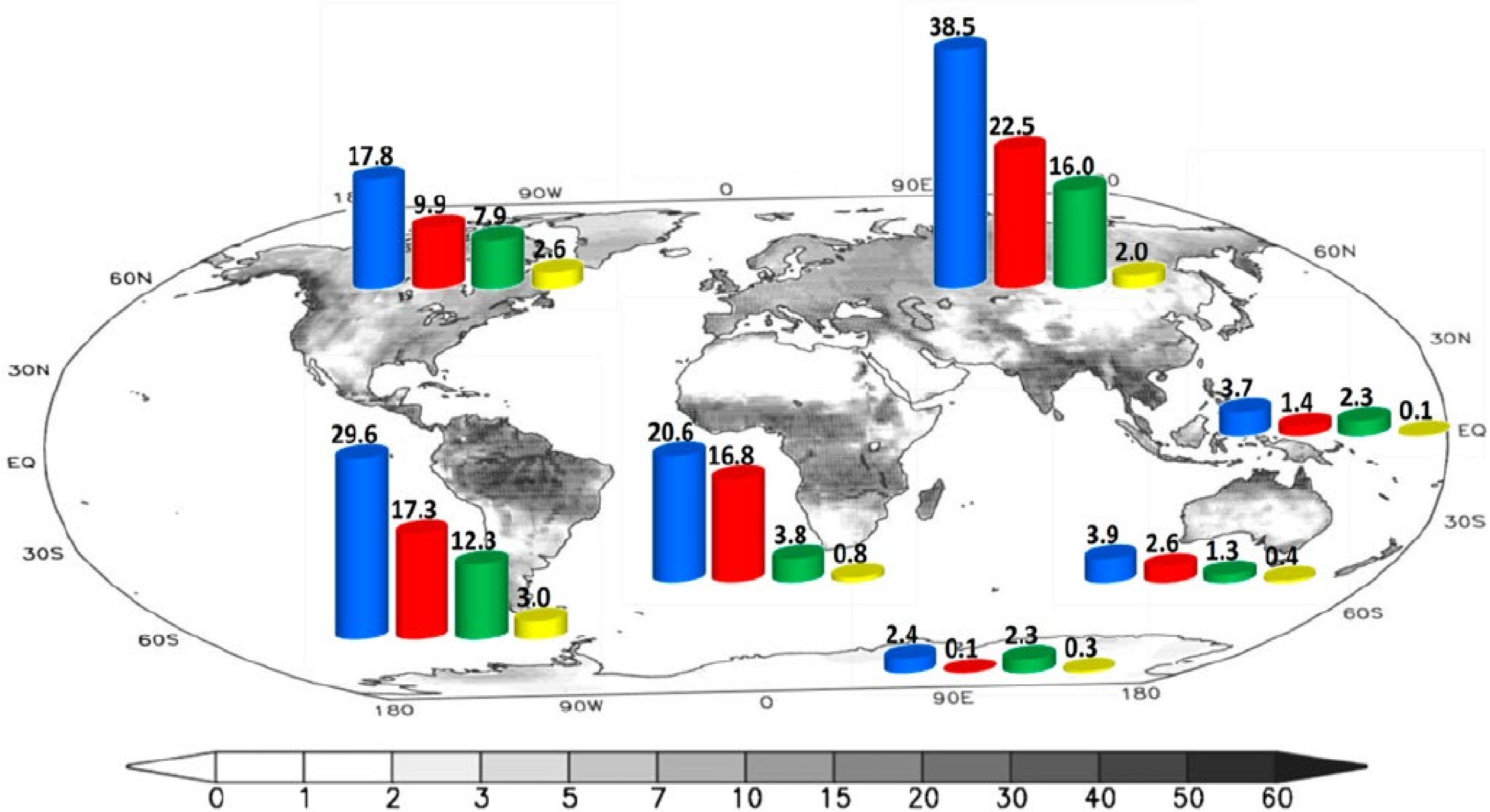
**Mean annual fluxes (2001-2010)**

Obs records + models (white)

Optimized estimates by forcing water and energy budget closure (blue)

Annual total water exchange: 520.1 ± 27.2 $10^3 km^3 yr^{-1}$

# Satellites + data-integrating models




*Rodell et al., 2015/JClim*

**Optimized annual-mean fluxes ($10^3 km^3/yr$) for 2001-2010.**
**Precip., ET, runoff, annual amplitude of terrestrial water storage (yellow)**
**GRACE-based amplitude of terrestrial water storage (gray)**

# Residuals

*Rodell et al., 2015/JClim*

| | Observed residual | Predicted closure error | Optimized uncertainty* |
|---|---|---|---|
| **Global water budget** | 3.9% | 12.5% | 7.4% |
| • Land | 4.3% | 10.1% | 7.2% |
| • Ocean | 6.6% | 13.8% | 7.8% |
| • Atmosphere | 4.7% | 13.6% | 7.5% |

* Residual being forced towards zero

- Changes are indicated as % relative to $P_{L/Oc/Atm}$
- Expected errors of optimized water budgets: <10%
- Observed residuals < expected errors

# Outline

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4. Data availibility
5. **Discussion and next steps**

# Necessary steps

1. Significant enhancement in the ability to **sustainably measure key spatial components** of water cycle

2. Strengthening the **observing system** to provide better understanding of the physical mechanisms and interactive processes that **control variability in the water cycle**

3. Developing improved **physical models and use of data assimilation methods** that are critical to:
   – distinguish natural variability in the water cycle from human-induced variability
   – deliver better hydrological prediction
   – obtain new insight on coupling of water, carbon, and energy cycles

# Priority List

**Improved and sustained observations of**

- **precipitation** (both over ocean and land) to quantify global and regional trends in the water cycle;
- **snow water equivalent, soil moisture, and land cover change**
  - assimilation into dedicated high spatial resolution hydrological land surface models to better quantify stream flow, soil moisture and evapotranspiration and the carbon cycle
- **ground water monitoring** from satellite gravity observations
- quantitative observation of **river discharges**
- **snow- and ice inventories** as important water storage and frozen soil/permafrost monitoring
  - the surface albedo (e.g. from changes in snow cover and composition, sea ice extent, glacier and ice sheet extent) and its influence on evaporation, cloud formation and precipitation.
- **sea surface salinity** regarding the oceanic branch of the hydrological cycle
- socio-economic trends of **water use** (e.g., agricultural water demands, water quality demands)

AOPC GCOS • WCRP

GCOS • GOOS • WCRP OOPC

GCOS • WCRP TOPC

**Need for increased international collaboration and the use of observations from**

- **many satellites and/or satellite constellations**
- **together with dedicated in-situ observation networks**
- **From both, research as well as operational observational networks**

WCRP World Climate Research Programme

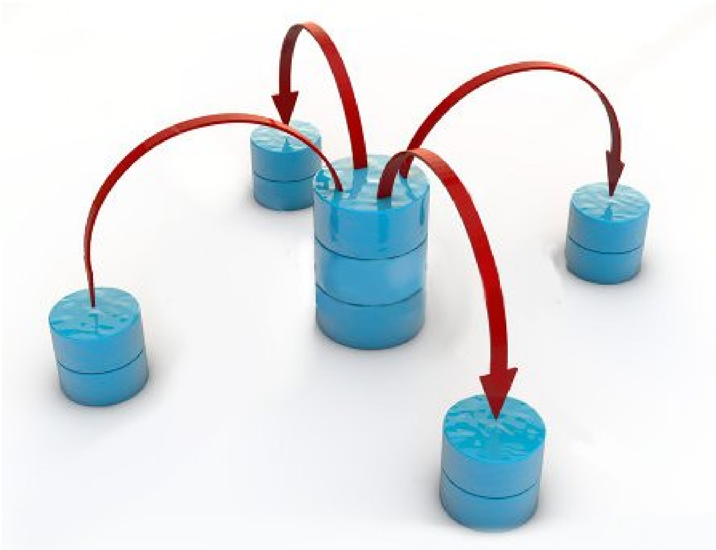
Global Energy and Water Exchanges Project GEWEX WCRP

CEOS WGClimate

CGMS

GEO GROUP ON EARTH OBSERVATIONS

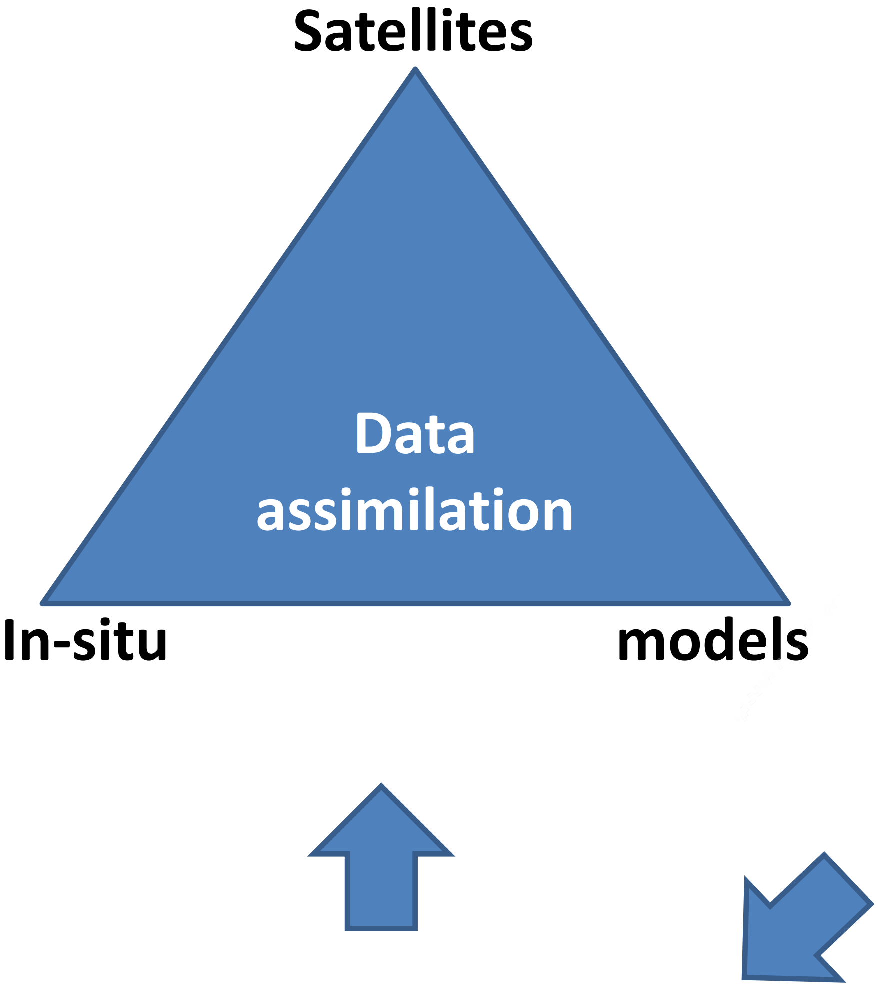
GTN Hydrology Global Terrestrial Network



*„Interoperability seems to be about the integration of information. What it‘s really about is the coordination of organizational behavior.“*

David Schelle, Founder and Chairman of the OGC

# Improvement of interoperability




**GTN-H Questionaire 2018**

**Do you follow an international standard for metadata description?**

Building a discoverability service GEOSS Portal WHOS

# Questions?

*Table 1, the Water Cycle and its uncertainty, (LIT)*

| Component | Estimated Water Fluxes: Water Flux $10^3\ km^3 yr^{-1}$ | Estimated Water Fluxes: Uncertainty ± 1σ | Estimated Water Fluxes: Uncertainty (%) | References and Data Sources | Significant ECV |
|---|---|---|---|---|---|
| Precipitation | | | | | Precipitation |
| Water storage in ice and snow | | | | Global ice volume (glaciers and ice caps) of 158000 cubickilometer (uncertainty of 25%) (study by Farinotti et al. 2019, Nature Geoscience)<br><br>About 1mm/a SLE (sea level elevation) from glacier melt (glaciers and ice caps), glaciers contribute 30% of the observed SLE (Zemp et al. in press, Nature Geoscience) | Glaciers, Ice Caps, Snow |
| Lakes | | | | | Lakes |
| River discharge | 41,867 | Not known | Not known | GRDC (2014) Global Freshwater Fluxes into the World Oceans | River Discharge |
| Water vapour | | | | | Surface and Vertical water vapour |
| Soil moisture | 123930 | No idea… | likewise | Jones 1997, Global hydrology | Soil Moisture |
| Groundwater | 13,000 - 15,000 * | | | Taylor et al. 2012 | Groundwater |
| Sea level | | | | | Sea Level |
| Evapotranspiration | | | | | Evaporation from Land |
| Budget imbalance | | | | | |
| Not included: Total water storage | | | | | |
| Not included: salinity | | | | | |
| Not included: | | | | | |

**Kommentar [WD29]:** Some of the variables mentioned, including SM, are not fluxes.

**Kommentar [WD30]:** Estimated total amount of SM. With a lot of assumptions.

**Kommentar [CR31]:** Highly uncertain

**Kommentar [StD32]:** Salinity as proxy?

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# Thank you!

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# Koblenz

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