Global Energy and Water Exchanges

Helmholtz Alliance: Remote Sensing and Earth System Dynamics – Hydrosphere Presentation

GEWEX Organization, Science Questions & Imperatives

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Some Acronyms

- GEWEX: Global Energy and Water Exchanges Project of the World Climate Research Programme (WCRP)
- WCRP: World Climate Research Programme
- GDAP: GEWEX Data Assessments Panel
- GHP: GEWEX Hydroclimatology Panel
- GLASS: Global Land Atmosphere System Studies Panel
- GASS: Global Atmospheric System Studies Panel

Hydrosphere

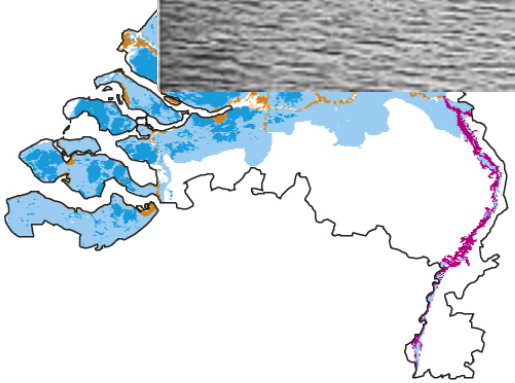
- Goal to present the view of GEWEX as a user representative in the Helmholtz Alliance on the Hydrosphere
- Explain the purpose of GEWEX as organization
- Showcase research results and approaches in the GEWEX and WCRP context

Outline

- **Personal Background**
- **GEWEX and WCRP, history and overview**
- **GEWEX Organization**
- **GEWEX Science**
  - GEWEX Science Questions
  - GEWEX Imperatives
  - GEWEX Science Activities per Panel
  - Showcase the Science – Global Freshwater Availability
- **Conclusion**

GRO

Overstrom



Bron: PBL (2009)

GEWEX and WCRP

Some back ground information

World Climate Research Programme

Sponsored by the World Meteorological Organization, the International Council for Science and the Intergovernmental Oceanographic Commission of UNESCO.

- **The WCRP Mission:** to facilitate analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society.

GEWEX

GEWEX

A brief history

- Born out of the realization that the Earth observational systems at that time (the early 1980's) needed to be improved on if more progress was to be made on the meteorology and global climate research.
- Two feasibility workshops were held in 1987 and 1988 and in the first part of 1990 a science plan was finalized
- In December of 1990 the Global Energy and Water cycle Experiment (GEWEX) was approved by WMO and ICSU as a core project of the World Climate Research Programme (WCRP)

What We Do

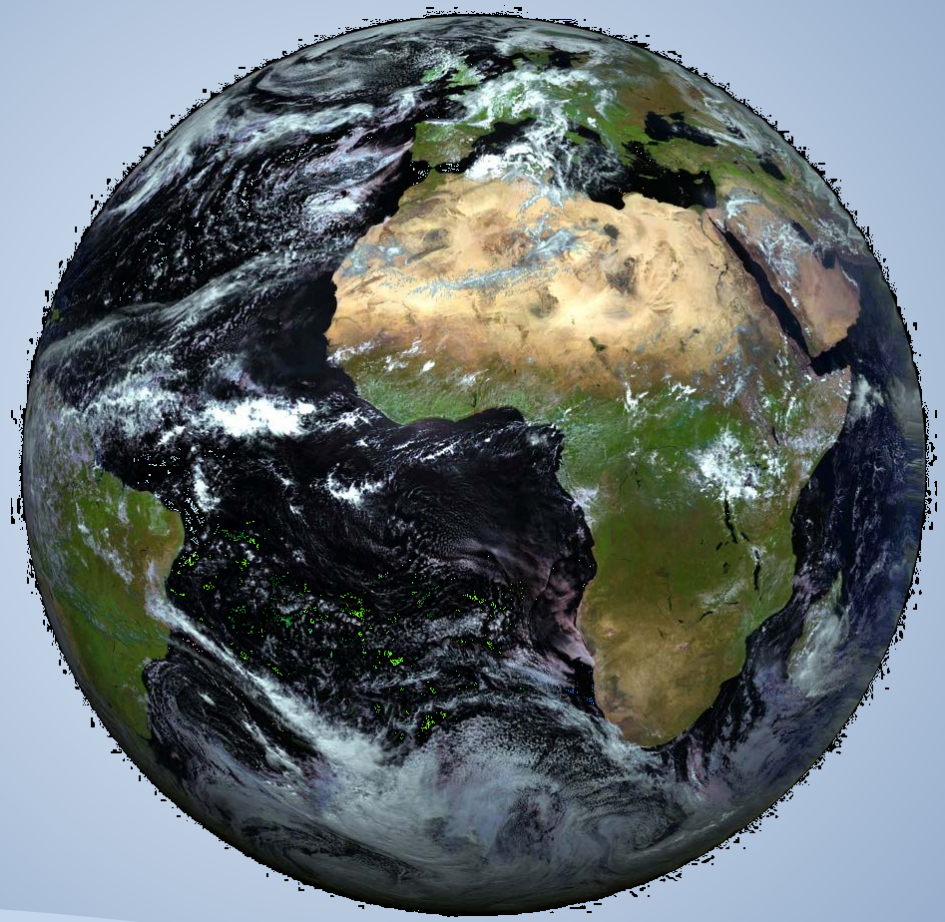
The Global Energy and Water EXchanges (GEWEX) project of the World Climate Research Programme (WCRP) facilitates, enables, coordinates international climate and related research activities with an emphasis on land – atmosphere processes and interactions.

Water

Energy

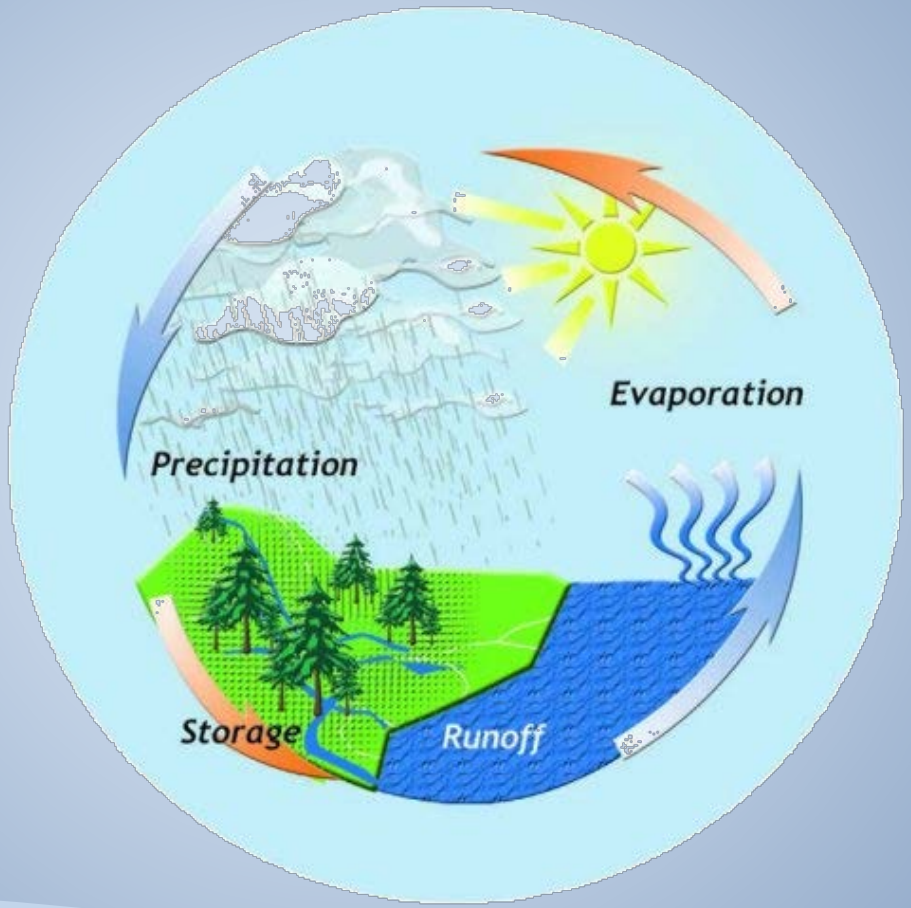
The Subject

The Earth – Global to Local Studies



The Subject

The Earth's Water and Energy Cycle



Phase I: 1990 - 2002

Science Objectives

- Determine the hydrological cycle and energy fluxes by means of global measurements of atmospheric and surface properties.
- Model the global hydrological cycle and its impact on the atmosphere, oceans and land surfaces.
- Develop the ability to predict the variations of global and regional hydrological processes and water resources, and their response to environmental change.
- Advance the development of observing techniques, data management, and assimilation systems for operational application to long-range weather forecasts, hydrology, and climate predictions.

GEWEX

Phase II: 2002 - 2013

Science Objectives

- **In addition to the Phase I Science Objectives GEWEX in Phase II addresses the following principal scientific questions:**
  - **Are the Earth's energy budget and water cycle changing?**
  - **How do processes contribute to feedback and causes of natural variability?**
  - **Can we predict these changes on up to seasonal to interannual scales?**
  - **What are the impacts of these changes on water resources?**

Phase III: 2013 ~ 2022

Science Objectives & Imperatives

- **Building upon the results and experience from Phase I and II the GEWEX community for Phase III has developed through an open and interactive process:**
  - A new Vision and Mission Statement
  - An Imperatives document describing the framework of necessary activities
  - The GEWEX Science Questions to be address in the next 5 to 10 years and which contribute directly to the WCRP Grand Challenges

GEWEX Vision

Water and energy are fundamental for life on Earth. Fresh water is a major pressure point for society owing to increasing demand and vagaries of climate.

Extremes of droughts, heat waves and wild fires as well as floods, heavy rains and intense storms increasingly threaten to cause havoc as the climate changes. Other challenges exist on how clouds and aerosols affect energy and climate. Better observations and analysis of these phenomena, and improving our ability to model and predict them, will contribute to increasing information needed by society and decision makers for future planning.

GEWEX Mission

To measure and predict global and regional energy and water variations, trends, and extremes (such as heat waves, floods and droughts), through improved observations and modeling of land, atmosphere and their interactions; thereby providing the scientific underpinnings of climate services.

World Climate Research Programme

Sponsored by the World Meteorological Organization, the International Council for Science and the Intergovernmental Oceanographic Commission of UNESCO.

- **The WCRP Mission: to facilitate analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society.**
- **The two overarching objectives of the WCRP are:**
- **1) *to determine the predictability of climate*; and**
  2) *to determine the effect of human activities on climate*
- **Progress in understanding climate system variability and change makes it possible to address its predictability and to use this predictive knowledge in developing adaptation and mitigation strategies. Such strategies assist the global communities in responding to the impacts of climate variability and change on major social and economic sectors including food security, energy and transport, environment, health and water resources.**

GEWEX

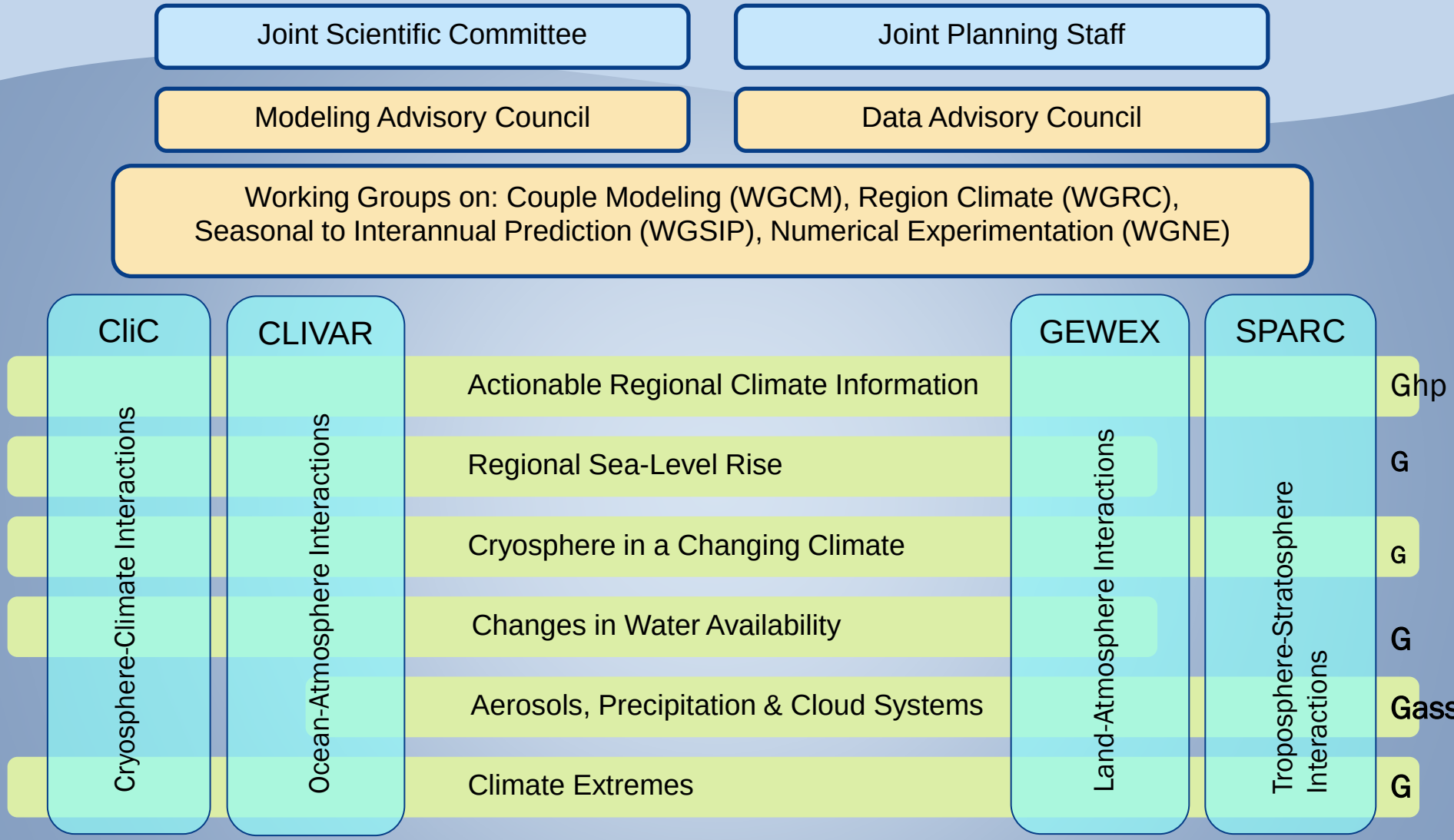
WCRP World Climate Research Programme

Six WCRP Grand Challenges

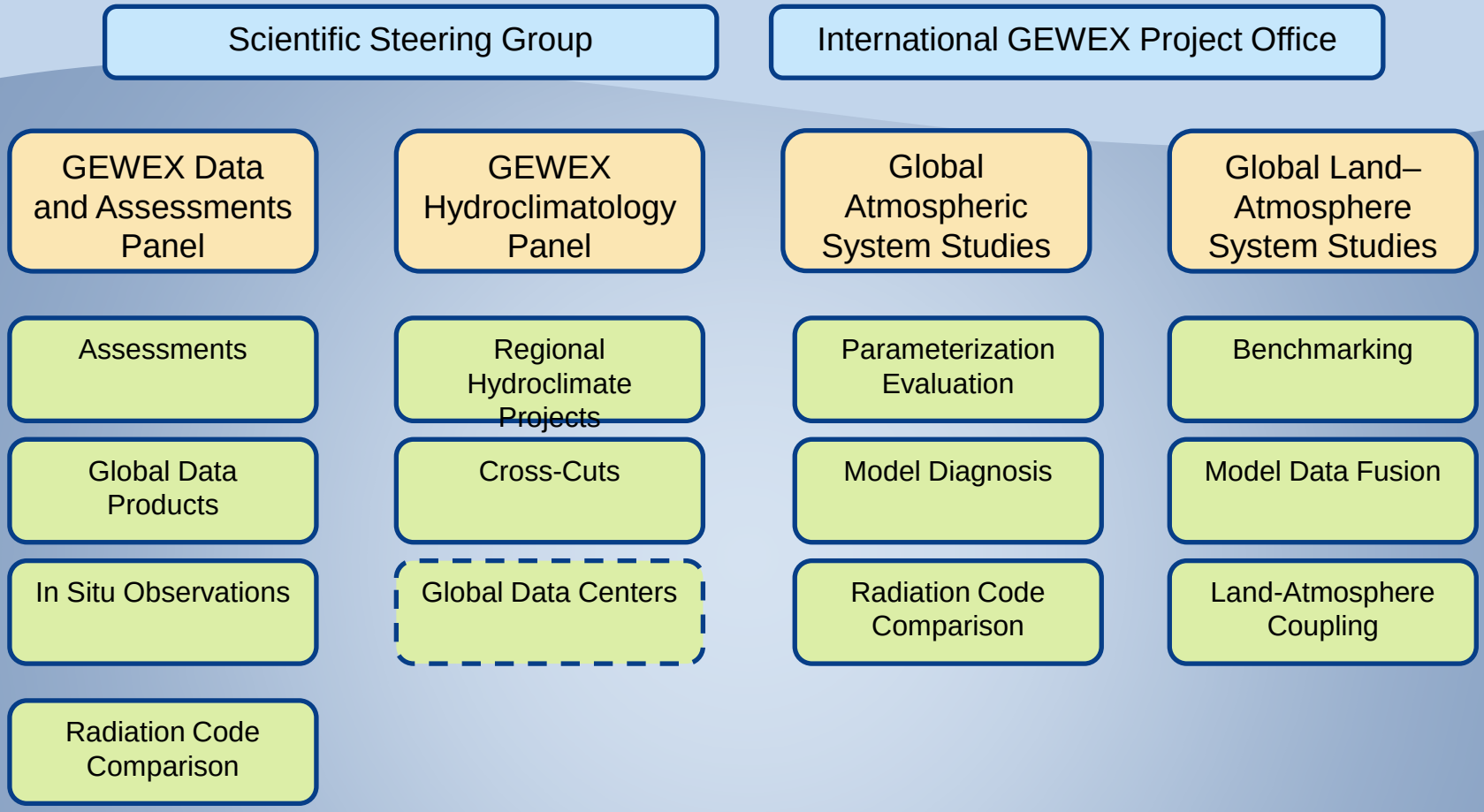
To inspire the community to become involved. They are specific and focused while identifying barriers and ways to advance the science, and they should capture the imaginations of funding agencies, science program managers, and the public.

1	Action-oriented regional climate information
2	Regional sea level
3	Cryosphere in a changing climate
4	Cloud and climate sensitivity
5	Changes in water resources
6	Prediction and attribution of extreme events

WCRP Organization



GEWEX Organization



GEWEX Science

GEWEX Science Questions

- Are these questions actionable/action-oriented?
  - I.e. are they tractable, and is there a way forward?
- What new opportunities have arisen that relate to observations (such as new satellites; proposed field projects), models (computers, better resolution, new models like CMIP5), ideas?
- What benefits might accrue? What are the impacts? Why does it matter? Are there links to food, water, health, energy, biodiversity…?

Four GEWEX Science Questions

For the next 5 to 10 years

1	Observations and Predictions of Precipitation
2	Global Water Resource Systems
3	Changes in Extremes
4	Water and Energy Cycles and Processes

1. Observations and Predictions of Precipitation

How can we better understand and predict precipitation variability and changes?

- How well can precipitation be described by various observing systems and what basic measurement deficiencies and model assumptions determine the uncertainty estimates at various space and time scales
- How do changes in climate affect the characteristics (e.g., distribution, amount, intensity, frequency, duration, type) of precipitation, with particular emphasis on extremes of droughts and floods?
- How much confidence do we have in global and regional climate predictions of precipitation?

GEWEX

2. Global Water Resource Systems

How do changes in land surface and hydrology influence past and future changes in water availability and security?

- **How do changes in land surface and hydrology influence past and future changes in water availability and security**
- **How do changes in climate affect terrestrial ecosystems, hydrological processes, water resources and water quality, especially water temperature?**
- **How can new observations lead to improvements in water management?**

3. Changes in Extremes

How does a warming world affect climate extremes, esp. droughts, floods, and heat waves, and how do land area processes, in particular, contribute?

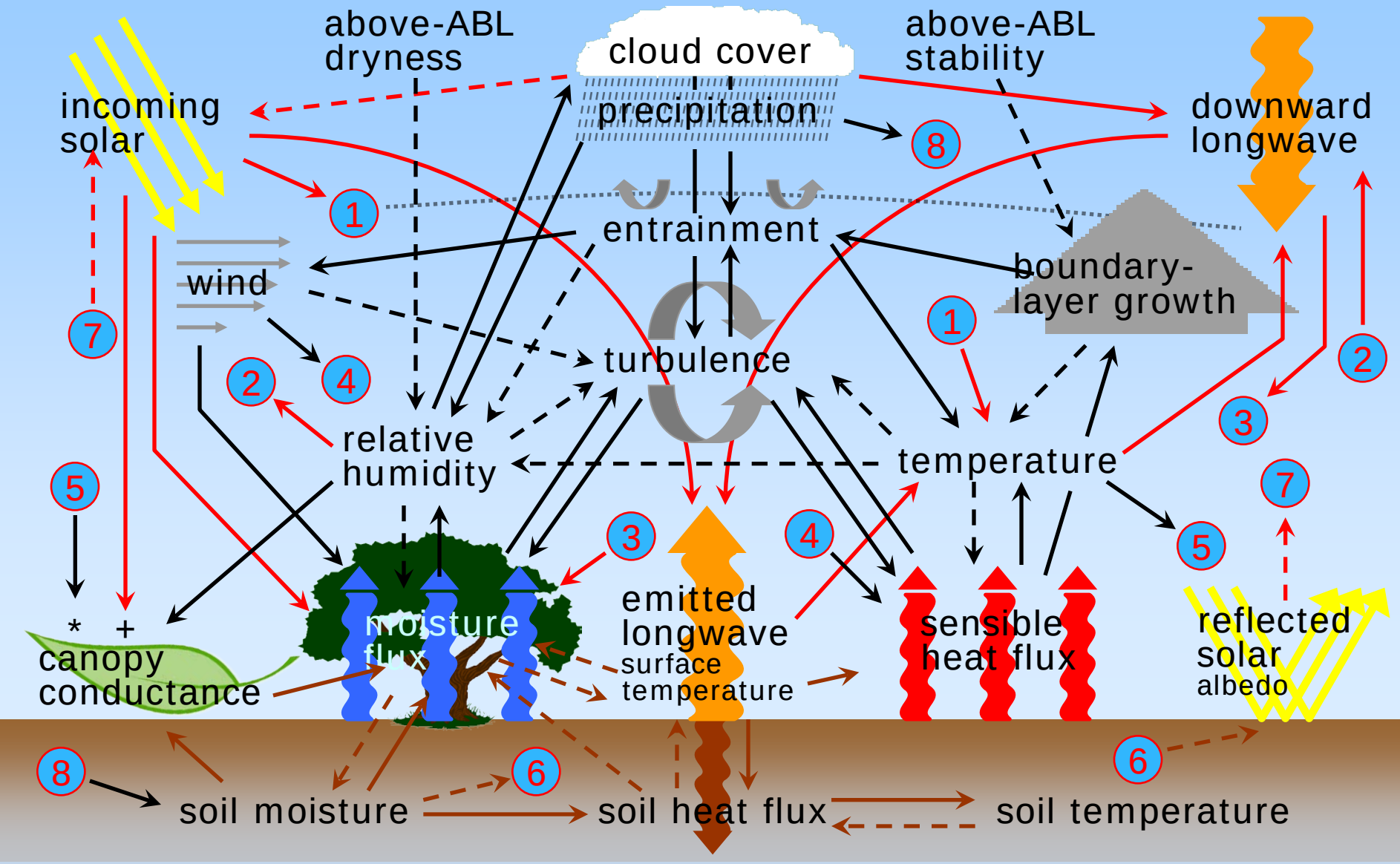
- What are the short-term, mid-term and strategic requirements for the existing observing systems and data sets, and which observations are needed to accurately quantify trends in the intensity and frequency of extremes on different space/time scales?
- How can models be improved in their simulation and predictions or projections of the magnitude and frequency of extremes?
- How can the phenomena responsible for extremes be better simulated in models?
- How can we promote development of applications for improved tracking and warning systems arising from extremes?

4. Water and Energy Cycles and Processes

How can understanding of the effects and uncertainties of water and energy exchanges in the current and changing climate be improved and conveyed?

- Can we balance the energy budget at the top-of-atmosphere?
- Can we balance the energy budget at the surface of the Earth?
- Can we further track the changes over time?
- Can we relate the changes in surface energy budget with atmospheric-oceanic processes and long-term variability
- Can we improve confidence in feedbacks associated with cloud-aerosol-precipitation interactions in the climate system?

Local Land-Atmosphere Interactions



+positive feedback for C3 & C4 plants, negative feedback for CAM plants

*negative feedback above optimal temperature

positive feedback

negative feedback

land-surface processes

surface layer & ABL

radiation

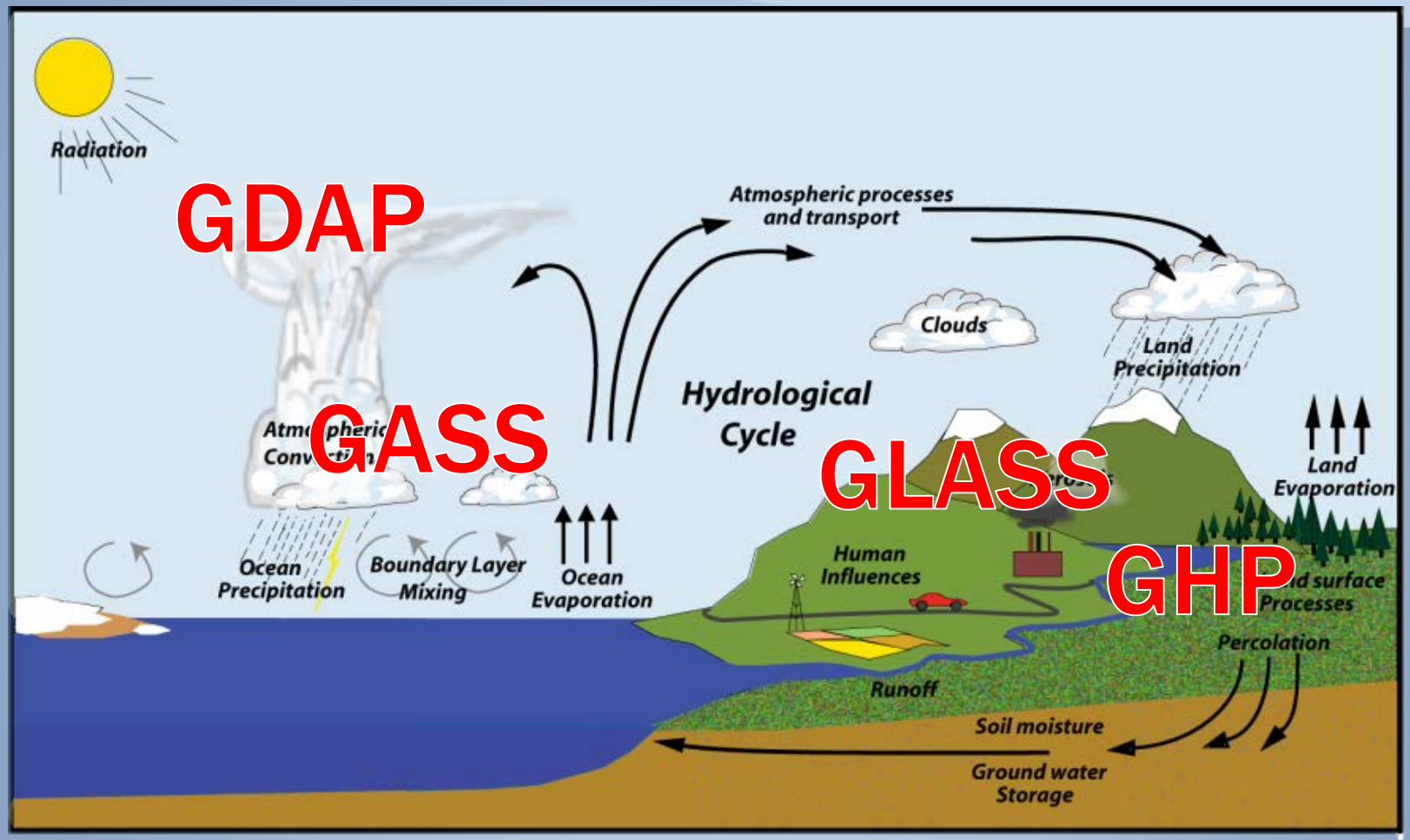
GEWEX Imperatives

The Imperatives – things that must be done - provide a strategic view of GEWEX activities for 15 years beyond 2013. They form the framework for a more focused set of GEWEX Science Questions (GSQs) whose main focus is on the 5-10 year period from 2013-2022.

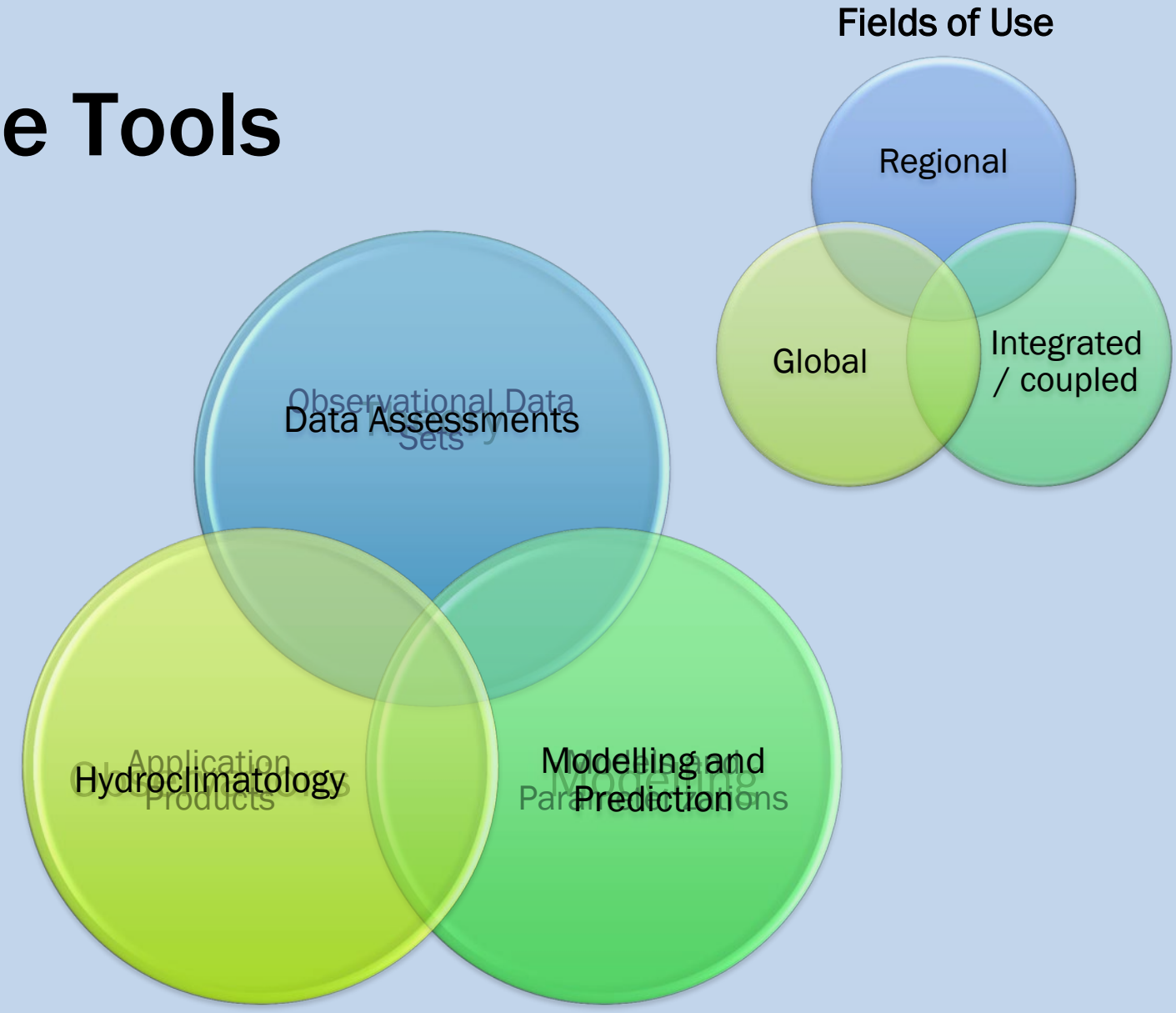
GEWEX Imperatives

Datasets	1	Applications	5
Analysis	2	Technology Transfer	6
Processes	3	Capacity Building	7
Modeling	4		

GEWEX: Major Components



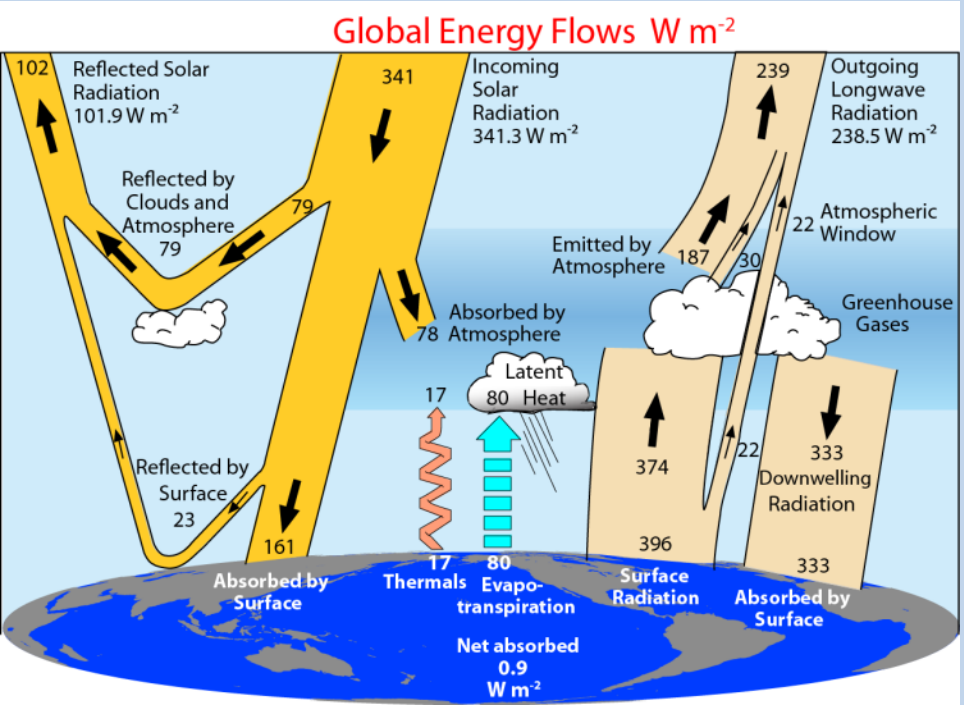
The Tools



GEWEX achieves its goals through data set development and analysis, process studies and model improvement

GEWEX Data and Assessments Panel

- **Radiative processes** and understanding
  - Develop and improve of **radiative transfer** codes, comparisons
- **Global Data sets**
- Global In-situ **observational networks**, development and standardization (radiation, soil moisture)
- Reprocessing of datasets
- **Assessment** and intercomparison studies
- http://www.gewex.org/GDAP.html

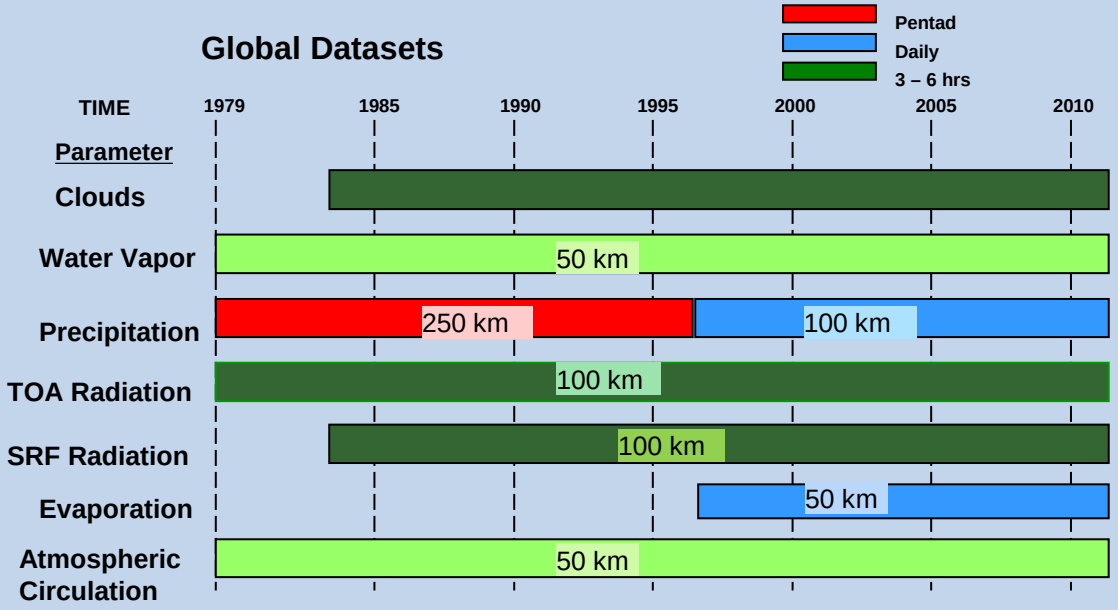


Global datasets

Aerosols
Clouds
Radiation
Water Vapor
Precipitation
Surface fluxes
Soil Moisture

GEWEX Radiation Panel develops **climate data records** of water and energy variables, complete with metadata and error bars.

Clouds - ISCCP
Radiation - SRB
Surface ref. obs - BSRN
Aerosols - GACP
Precipitation - GPCP
Sfc gauge obs GPCC
Turbulent Fluxes
SeaFlux
LandFLux
- Soil Moisture
Water Vapor



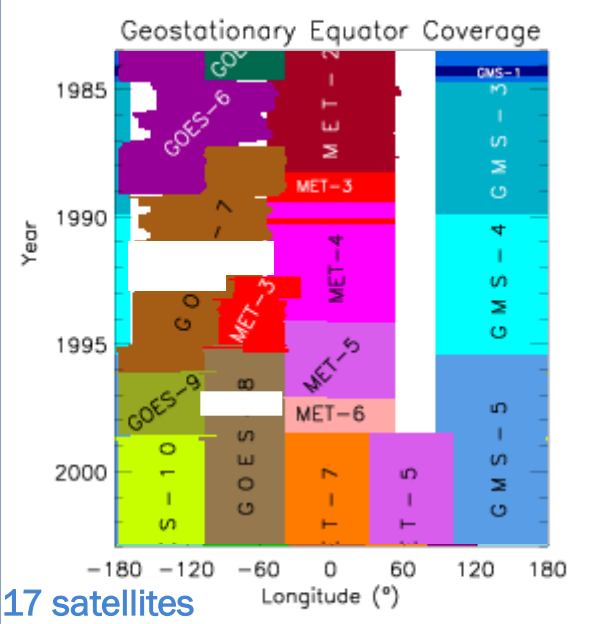
A GRP product is endorsed by GEWEX/GRP to conform to a high standard of production and documentation. It consists of a blend of available satellite and in-situ observations and is periodically compared and assessed against other products in an open and transparent fashion. It is openly available to everyone without restrictions.

GEWEX Data and Assessments Panel

Data Rescue Efforts

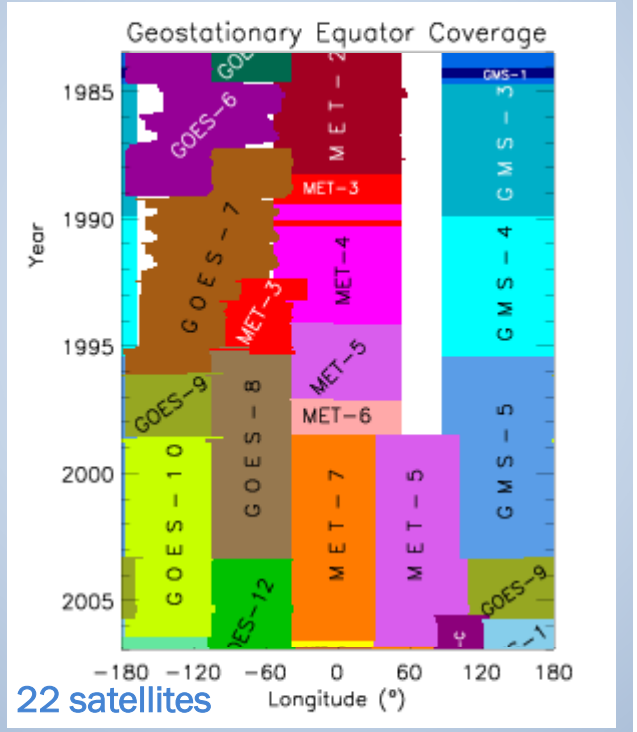
ISCCP B1 Data Product (basically a 'raw' product: 10km)

B1 Status - 2003



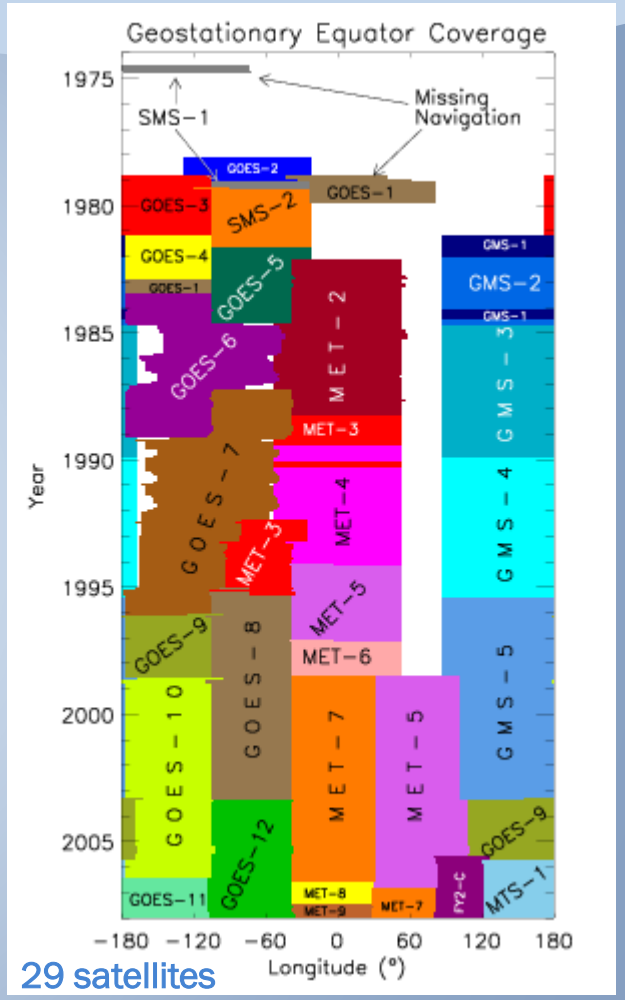
17 satellites

B1 Status - 2006



22 satellites

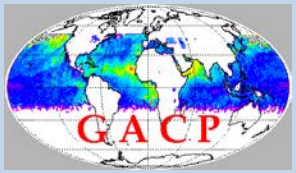
B1 Status - 2007



29 satellites

GEWEX Integrated Products

Common Ancillary Data



+

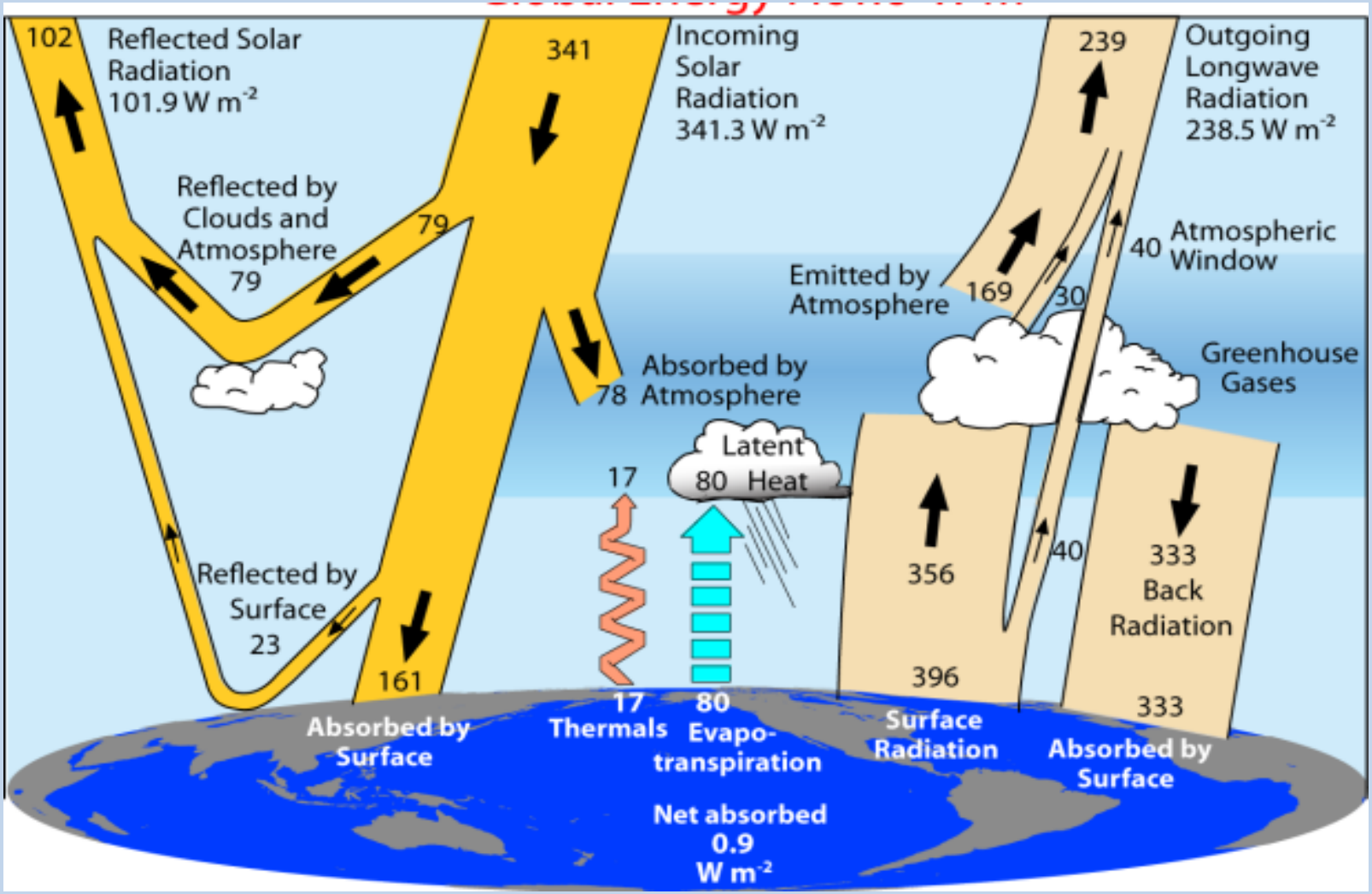
Validation
BSRN

Validation
Buoys/Ships

Validation
Towers

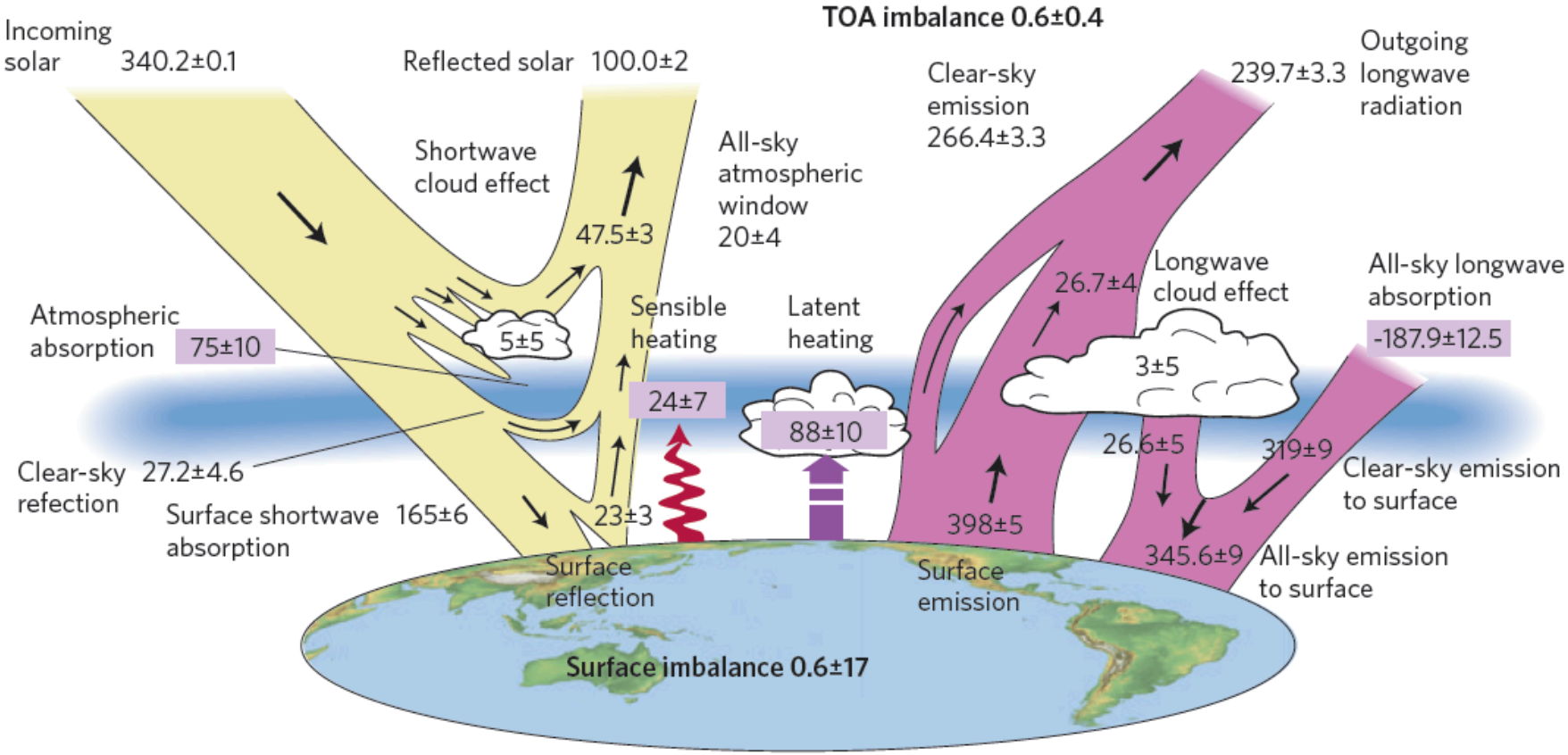
Common Output w. Uncertainty

Global Energy Budget



166 Trenberth et al 2011 J Climate 344

A recent revision by Stephens et al., 2012



Global Data Sets – Climate Data Records

- **Continuity**
  - Grace follow on, GPM, TIR?,
  - What about new missions such as SWOT?
- **Consistency**
  - Product development centered vs sensor development
  - Calibration/sensor stability etc.

Background and need

To assess climate variability and change, consistent long-term data records are needed.

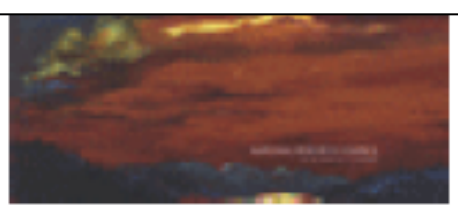
Some activities:

1. GCOS -- Global Climate Observing System.
   This activity has defined "Essential Climate Variables: ECV". As

Climate Data Records from Environmental Satellites: Interim Report

WHAT ARE CDRs?

The National Research Council (NRC) defines a CDR as a time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change. (National Research Council, 2004).



New Technology

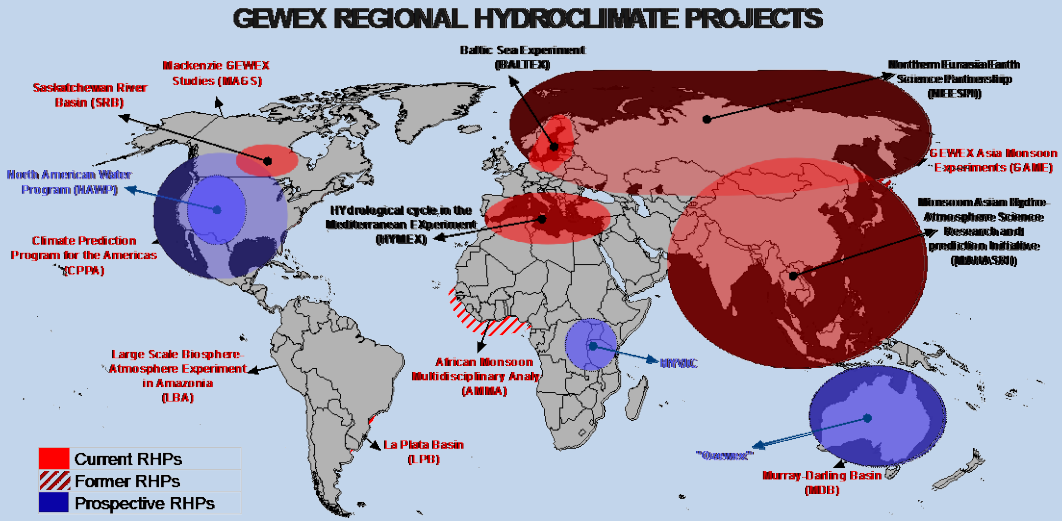
In a climate research context

- **Progress is needed / New type of observations**
- **New technology is desirable**
- **When properly managed!**
  - i.e. not at the cost of continuity!
  - A paradigm shift is necessary from sensor focus to product development

Currently not properly managed…

GEWEX Hydroclimatology Panel

- **Regional hydroclimate projects**
- Globally distributed extensive **regional data sets** : water and energy cycle observations (in situ and space borne and modeling data)
- **Global Data Centers**; data management system / GEO Prototype for Water Cycle Observations
- **Regional climate and hydrological modeling and process** Descriptions
- **Hydrological Applications** and Forecasting (Drought monitoring, Hydrological Ensemble Predictions…)
- http://www.gewex.org/projects-ghp.html

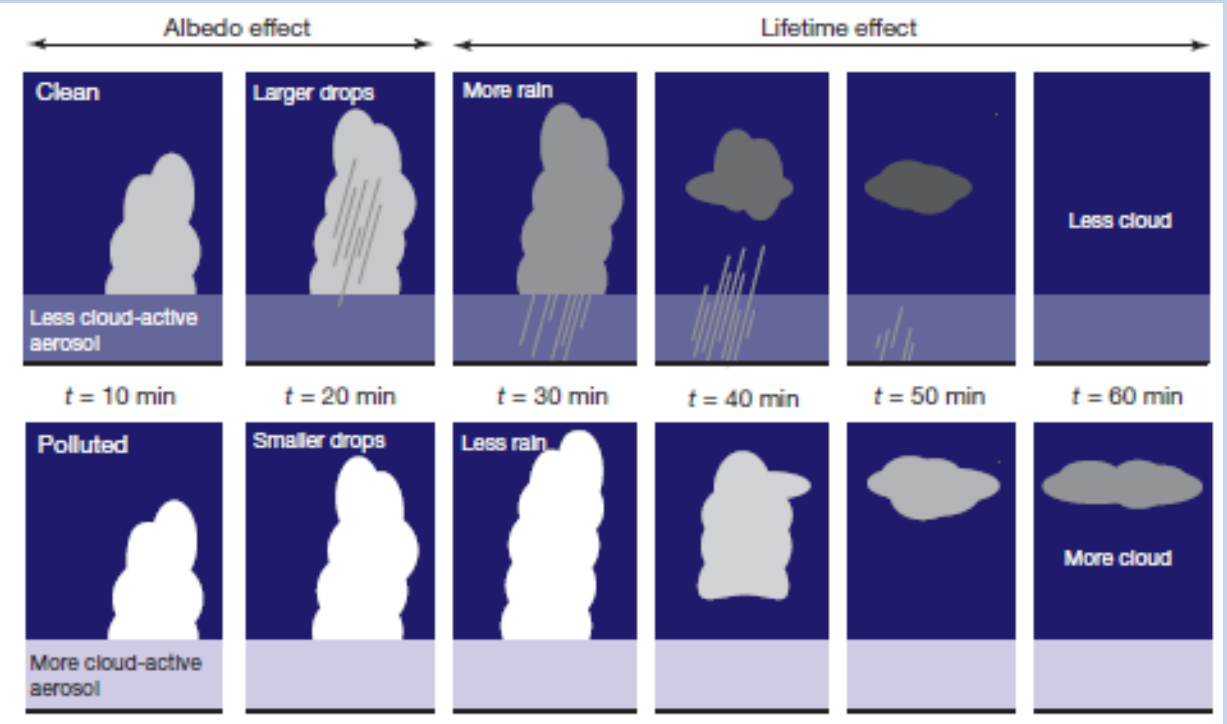


RHPs	Proposed
BALTEX	NAWP
HYMEX	HYVIC
LBA	TPE
LPB	BALTIC-EARTH
MAHASRI	OZEWEX
MDB	
AMMA	New
NEESPI	SasRB

GEWEX Modeling: GASS

Global Atmosphere System Study

- **Atmospheric processes,** esp. clouds, convection, microphysics
- Model **Parameterization** evaluation and development
- **Data sets** and **tools**, intercomparisons
- **Atmospheric Boundary Layer**
- Strong cooperation with NWP via WGNE
- http://www.gewex.org/gass_panel.html



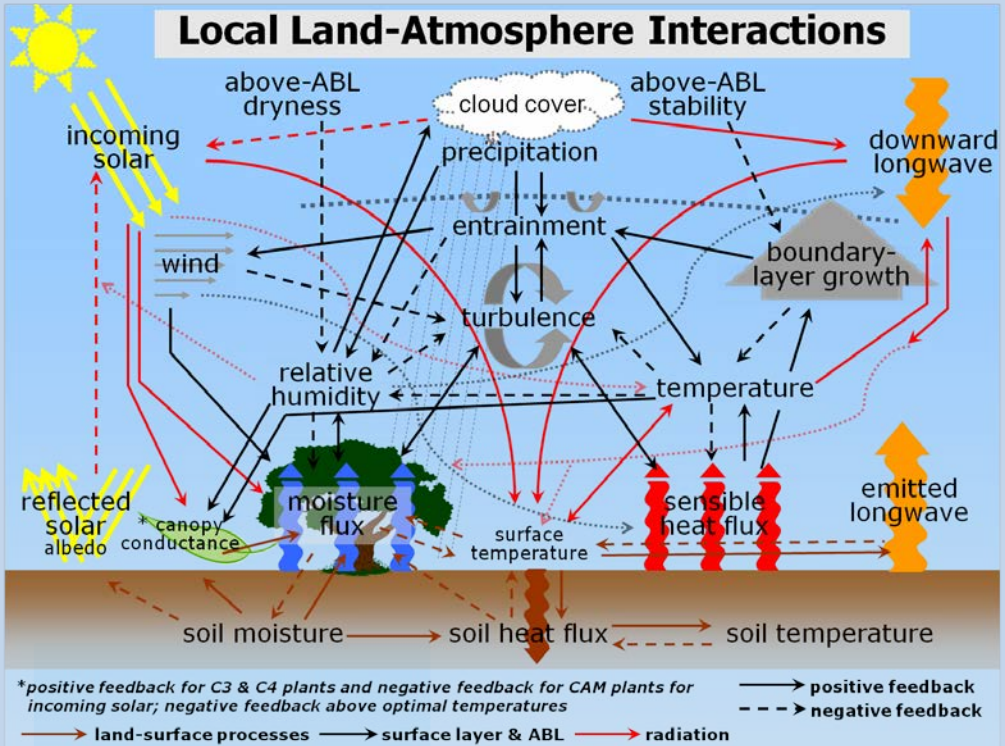
Projects

Boundary Layer clouds
Polar clouds
Convection, clouds
GABLS3
MJO
Single Column Models
Cloud Resolving Models
GASS-GHP links

GEWEX Modeling: GLASS

Global Land Atmosphere System Study

- **Land surface modeling**
- Model **Parameterization** and development from land surface process
- **Data sets** and **tools**, intercomparisons
- **Land-atmosphere coupling**
- **Model Data Fusion**
- Strong cooperation with NWP via WGNE
- http://www.gewex.org/glass_panel.html



Ongoing:

ALMIP2 – Links to GHP

GLACE2-CMIP

LoCo Working Group

LUCID2 – Links to iLEAPS

Launching in next “12” months:

GSWP3 – Links to carbon community

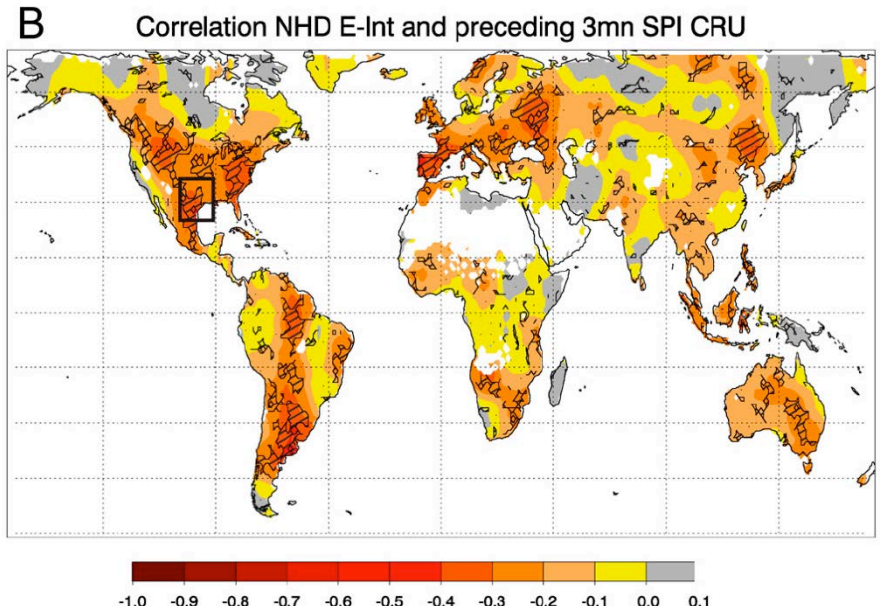
PILDAS – Links to WGNE

DICE – GLASS/GABLS diurnal cycles

PALS/Benchmarking (PLUMBER) – Links to GHP

LoCo/SGP testbed

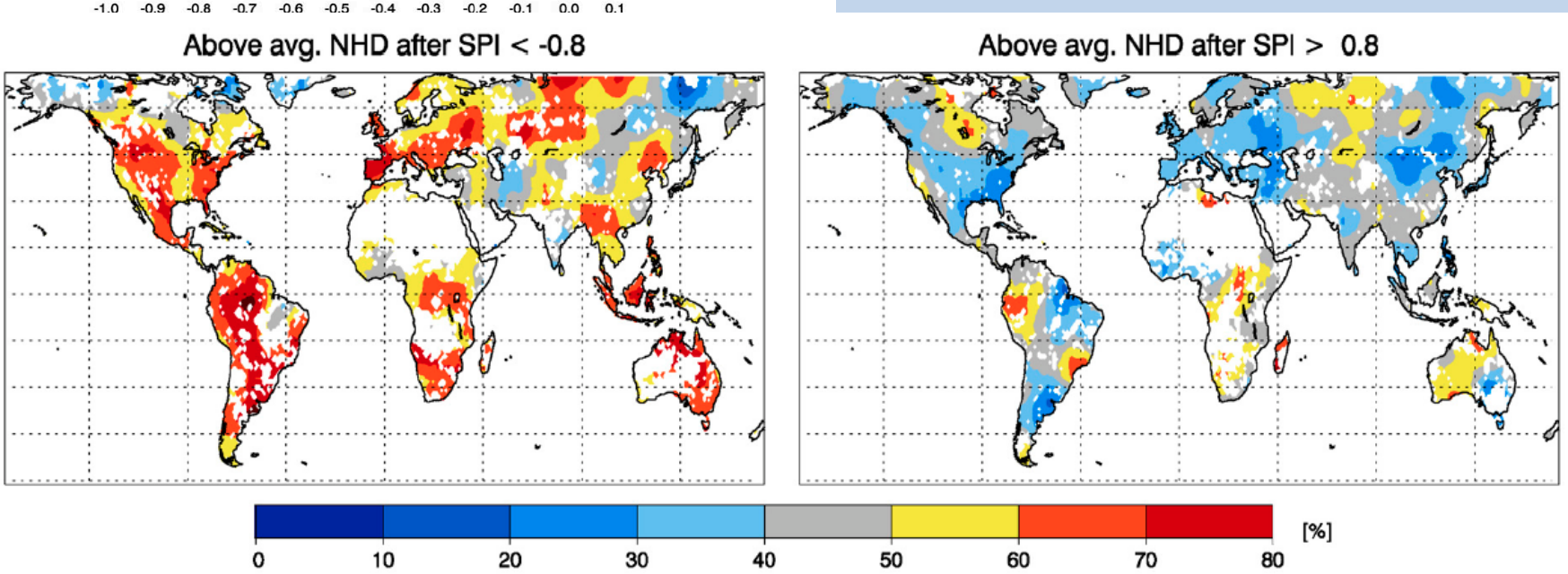
Hot spots of soil moisture-temperature coupling



Analysis for local *hottest month*
(i.e. valid in all regions ≠ JJA)

NHD: Number of hot days (ERA-interim)
SPI: Standardized precipitation index (in 3-month preceding hottest month)

Surface moisture deficits are a necessary condition for the occurrence of hot days in a large fraction of the globe



(Mueller and Seneviratne 2012, PNAS)

Showcase The Challenges

The GEWEX Science Questions shown through two major scientific challenges

The grand environmental challenges facing human society involve the changing of Earth's water cycle.

With a warming planet, perhaps the two most pressing questions facing us are:

- Will the availability of fresh water change and how?
- By how much will sea level rise?

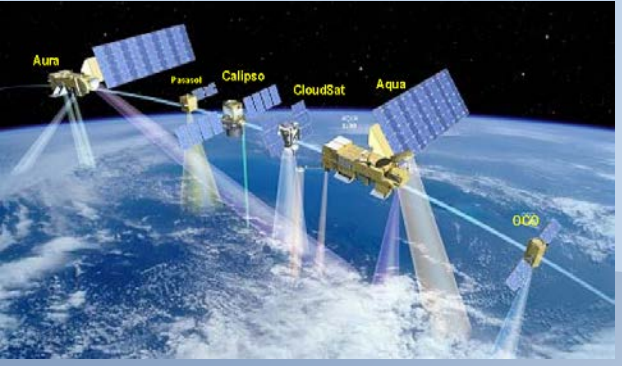
and our challenge is to develop an understanding that can provide quantitative answers to them.

GEWEX

Note to the challenges

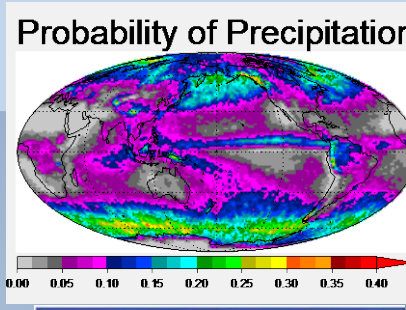
- Those two questions are not independent
- Water availability is a (re)distribution issue (global available water is constant) -> hydrological cycle
- Is the hydrological cycle changing – intensifying?
- Focus on fresh water

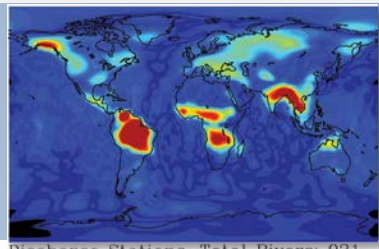
Availability of Fresh Water

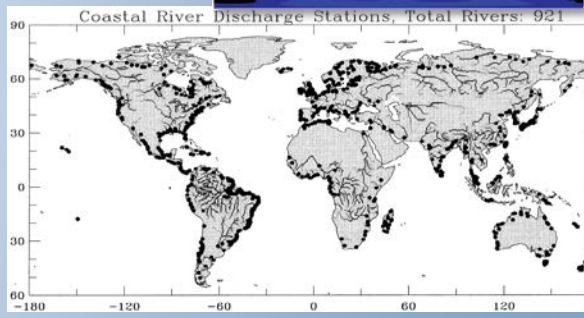


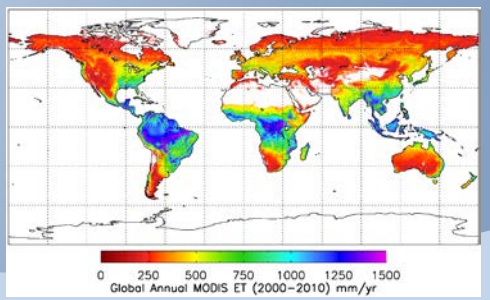
Surface Water balance

$\Delta S = P - Q - ET$









- **Precipitation (P)**
  - Rain gauges, RS (**TRMM,CloudSat,AMSR-E, IR**,….)
- **Change in storage (ΔS)**
  - Groundwater recharge/flow, soil moisture, standing water
  - Wells, RS (**GRACE**, SWOT, AMSR-E→SMOS→SMAP)
- **Runoff (Q)**
  - Stream gauges, Global Runoff Data Center, Dai/Trenberth, RS (SWOT)
- **Evaporation/Evapotranspitation (ET)**
  - RS Quickscat,AMSR-E,MODIS,**ACOS/OCO,…**
  - (RS of ET also requires surface net radiation)
- **Global accuracy/consistency/ability?**

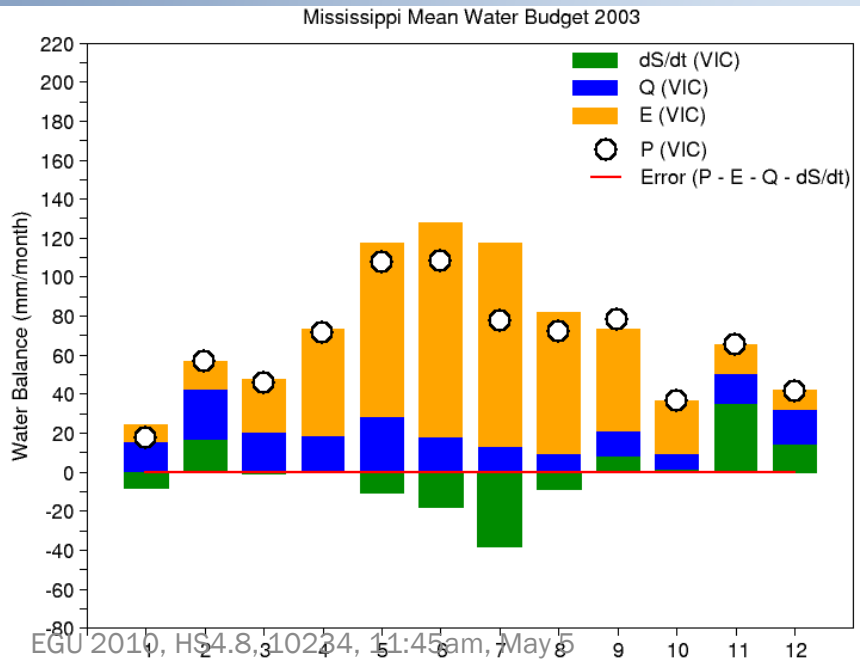
GEWEX

A challenge for Hydrology:

Creating Climate Data Records for the terrestrial water budget using in-situ, remote sensing observations and LSM?

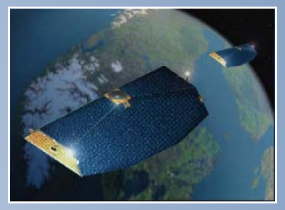
$$\frac{dS}{dt} = P - ET - Q$$

What the budget should look like?
(from off-line modeling, forced closure)

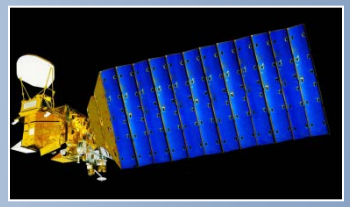


Potential Remote Sensing Datasets

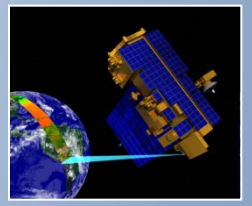
dS/dt from GRACE



ET from
SRB/ISCCP → LandFlux



P from TRMM/CMORPH
PERSIANN → GPM



Q from
TOPEX/POSEIDON/JASON
→ SWOT

Potential global water cycle data sources

Variable	Source	Type	Period	Resolution	Reference
p	CPC	In-situ	1950-	1º	Chen et al., 2002
	CRU	In-situ	1901-	0.5º	Mitchell & Jones, 2005
	WM	In-situ	1900-	0.5º	Willmott & Matsuura, 2010
	GPCC	In-situ	1900-	0.5º	Schneider et al., 2008
	GPCP/TMPA	RS/in-situ	1998-	0.25º-1º	Huffman et al
e	ET (LandFlux) (4 algorithms)	RS	1984-2006	1º	Vinukollu et al., 2010; Ershadi etal., 2013
	ERA-Interim	Reanalysis	1989-	T255	Simmons et al., 2006
	MPI	In-situ	1989-	T255	Jung et al (2009)
	VIC	LSM	1948-	1/2ºx1/3º	Sheffield &Wood, 2007
q	GRDC	In-situ	1900-	basin	GRDC, 2010
	VIC	LSM	1948-	1º	Sheffield &Wood, 2007
Δs	GRACE	RS	2002-	basin	Swenson &Wahr, 2002
	VIC	LSM	1948-	1º	Sheffield et al., 2008

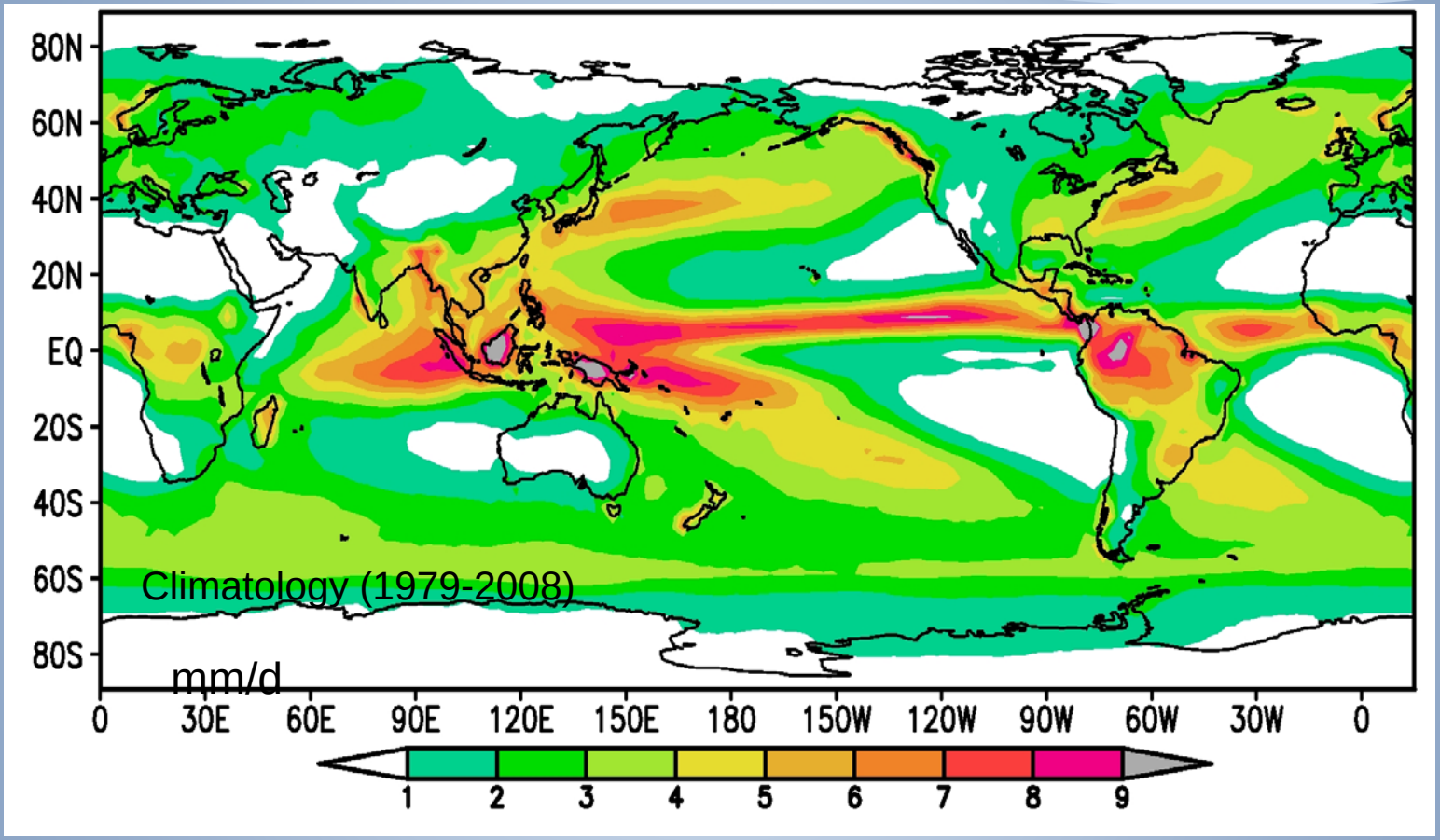
GEWEX

Precipitation

- Direct EO Measurements e.g. GPCP, TRMM, GPM
- Understanding clouds and precipitation processes e.g. Cloudsat
- Aerosols and water vapor
- Rain gauge data e.g. GPCC
- Global Climate Models precipitation representation

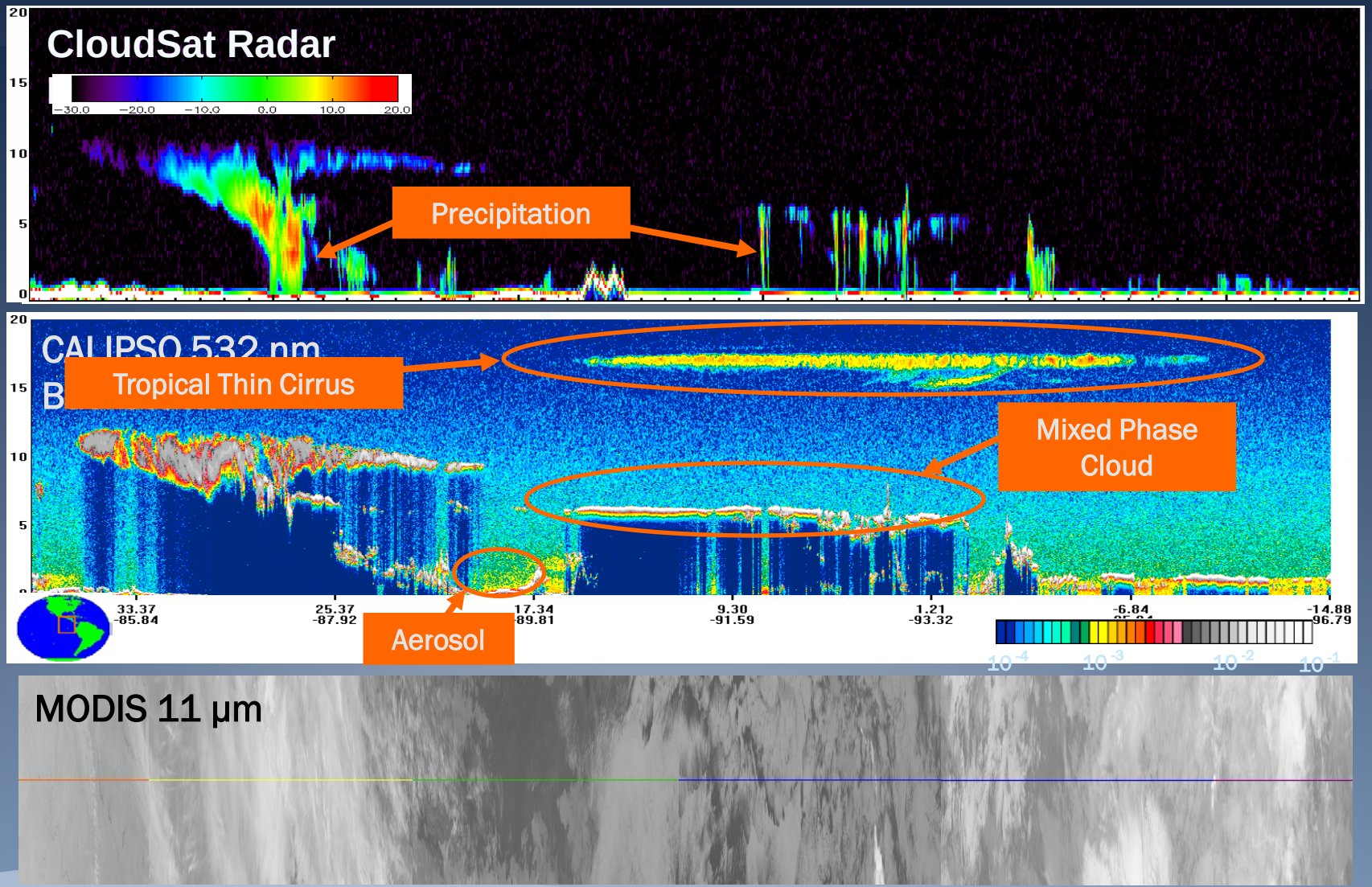
Global Precipitation Climatology Project (GPCP)

Robert Adler, U. of Maryland-College Park, USA



GPCP data used in > 1500 journal articles

Synergy


CloudSat Radar
−30.0 −20.0 −10.0 0.0 10.0 20.0
20
15
10
5
0
Precipitation
CALIPSO 532 nm
Tropical Thin Cirrus
Mixed Phase Cloud
Aerosol
33.37 -85.84
25.37 -87.92
17.34 -89.81
9.30 -91.59
1.21 -93.32
-6.84
-14.88 96.79
10^{-4} 10^{-3} 10^{-2} 10^{-1}
MODIS 11 μm

Challenges - Precipitation

- Models- global models have biases that point to problems in the way precipitation (and cloud) physics is represented. Global models also miss major storm types (e.g. MCSs) that for example deliver large fractions of precipitation to real Earth
- Process perspective- We still do not know the extent to which the water cycle is influenced by aerosol but anecdotal evidence is building
- Observations- we still have a way to go and need to approach the problem in a more integrated way (tie clouds, aerosol and precipitation and then link to soil moisture, etc.) - globally our capabilities to address water cycle processes, while improved, seriously lag behind the science and model development

Change in Storage

Earth Observation

- **Snow**
  - GRACE, GPM
- **Ground water and soil moisture**
  - GRACE, ASCAT, AMSR-E, SMOS, SMAP, Tandem-L?
- **Lakes and rivers**
  - TOPEX/Poseidon, SWOT

Conclusion

The successful implementation of the WCRP Grand Challenges and associated science questions described here depend significantly upon the GEWEX Imperatives: observations and data sets, their analyses, process studies, model development and exploitation, applications, technology transfer to operational results, and research capacity development and training of the next generation of scientists.

They involve all of the GEWEX Panels and will benefit greatly from strong interactions with other WCRP projects such as CLIVAR, SPARC, and CliC and other sister global environmental change research programs such as the IGBP, the International Human Dimensions Programme (IHDP), and DIVERSITAS.

7th International Scientific Conference on the Global Energy and Water Cycles

World Forum
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