Welcome to this week's presentation & conversation hosted by the **Canadian Association for the Club of Rome**, a Club dedicated to intelligent debate & action on global issues.

The views and opinions expressed in this presentation are those of the speaker & do not necessarily reflect the views or positions of CACOR.

CACOR Live

Global Terrestrial Water Cycle Simulations and Climate Change.

Biography: Dr. Taikan Oki, professor of Civil Engineering at U Tokyo, is a man of many talents. Oki has held the titles of Special Advisor to the President at U Tokyo, the Senior Vice Rector for the United Nations U, and Assistant Secretary General at the UN. In 1995, Oki and his wife (also a scientist) spent two years as visiting scientists at the NASA Goddard Space Flight Center in Maryland, USA. He is a member of The Club of Rome and won the 2024 Stockholm Water Prize.

Description: In the 2010s, Dr. Oki's research led to the development of realistic global terrestrial water cycle simulations, global water supply and demand assessments, and climate change impact assessments. He envisioned the development of hydrology by emphasizing links between scientific aspects of hydrology and water policy, social issues, and interdisciplinary research. His work has contributed to more sustainable management of water on a global scale, through more realistic and practical climate adaptation measures, the inclusion of human activity in the water cycle, and a more accurate depiction of the world's river flows.

CACOR acknowledges that we all benefit from sharing the traditional territories of local Indigenous peoples (First Nations, Métis, & Inuit in Canada) and their descendants.

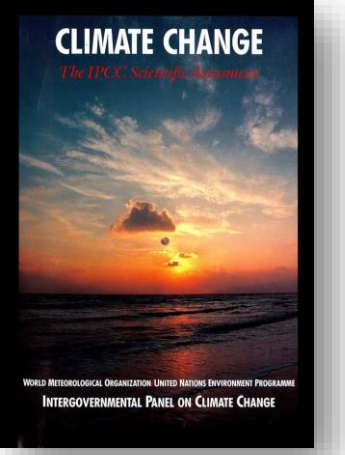
Website: canadiancor.com
YouTube: Canadian Association for the Club of Rome
2025 Jun 03 Zoom #248

1984

"The Climate System"

Figure 3.1 in the IPCC First Assessment Report (1990)

from Houghton "The Global Climate" (1984)



No Water Cycle

Change of Solar radiation

Space

Terrestrial Radiation

Atmosphere

Clouds

H_2O, N_2, O_2, CO_2, O_3 etc., aerosol

Precipitation

Evaporation

Ice-sheets snow

Atmosphere-land coupling

Atmosphere-ice coupling

biomass

Sea-ice

Heat exchange

Wind stress

Land

Ice-ocean coupling

Atmosphere-ocean coupling

Ocean

Change of atmospheric composition

Change of land features orography vegetation albedo etc.

Change of ocean basin shape salinity etc.

Earth

No River
No GW

No people

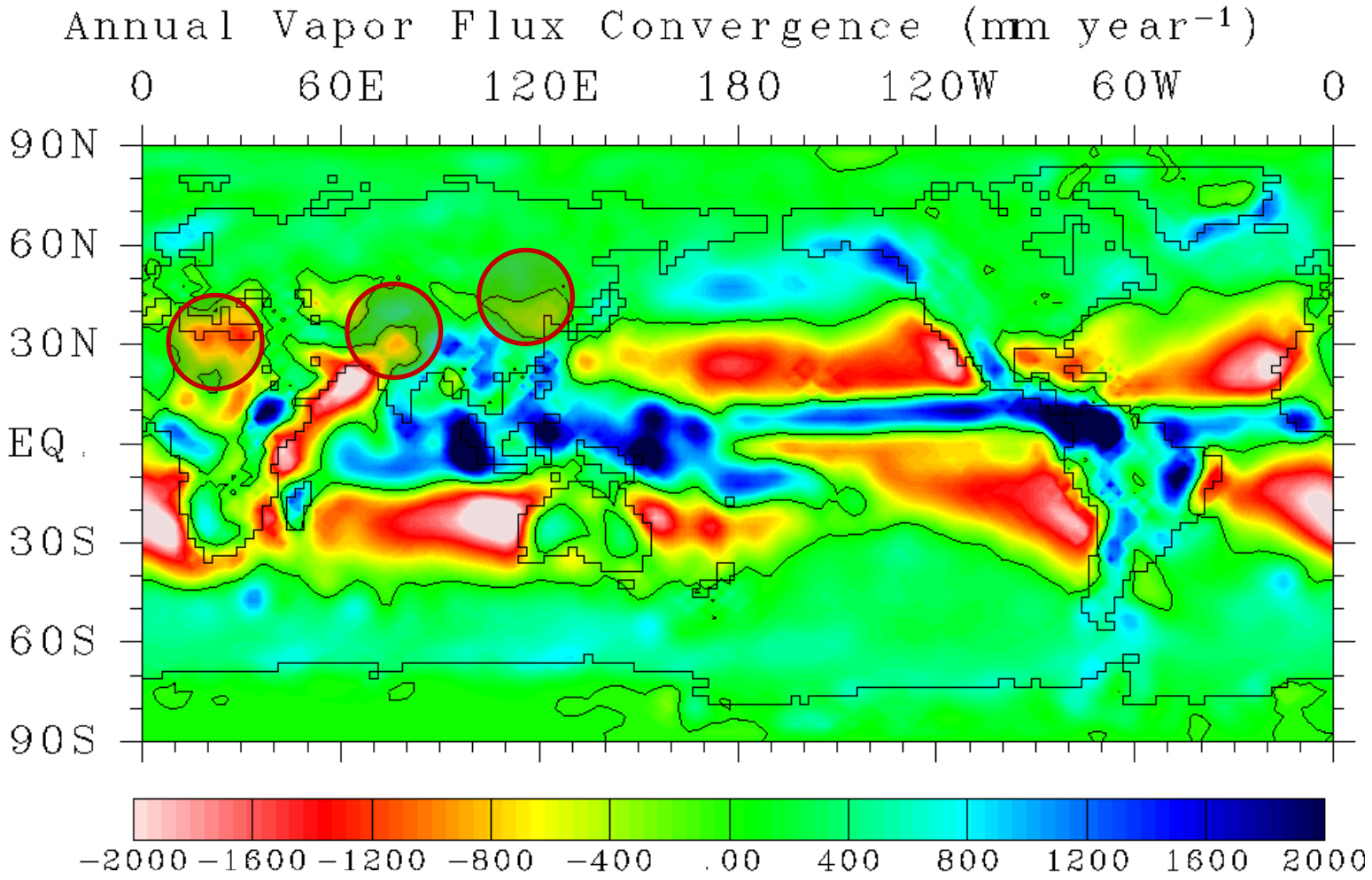
Hydrology
The Forgotten Earth Science

1987

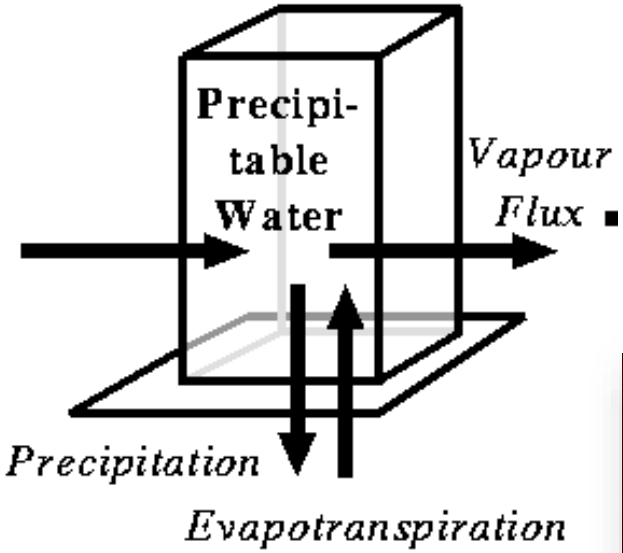
- Hydrology has a natural place as one of the geosciences; yet in the modern science establishment, this niche is vacant. Why is this?
- The cultivation of hydrology as a science per se has not occurred, and there has been no established platform within the hierarchy of science on which to build a coherent understanding of the global water cycle.

1995

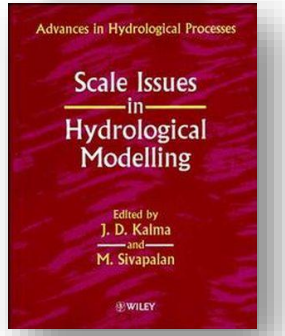
Atmospheric Water Balance



- Net water vapor divergence in a few places over land: ➔ Is evaporation larger than precipitation?



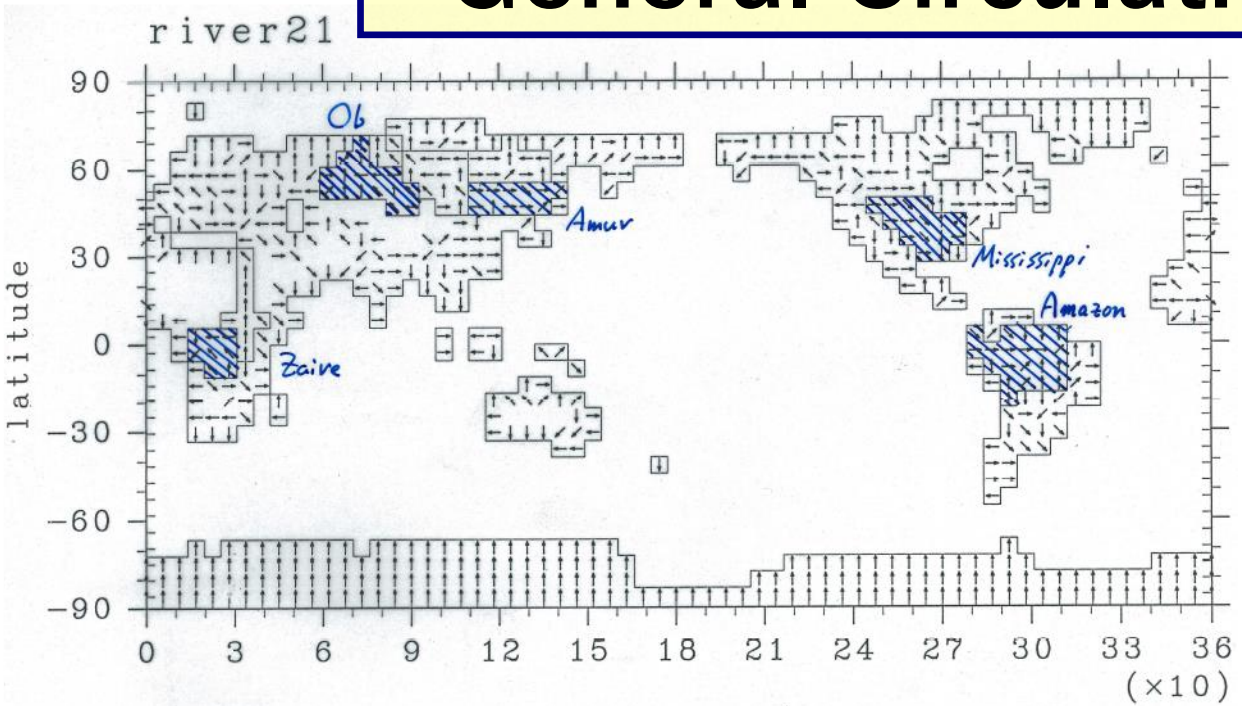
(b) Water balance in the atmosphere



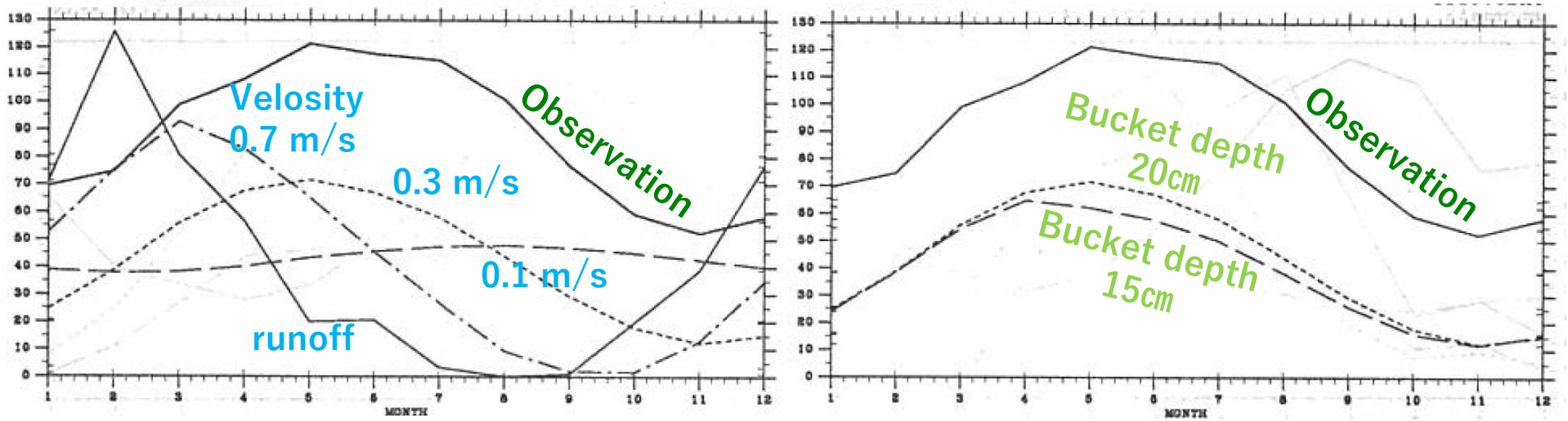
$-\nabla_H \cdot \vec{Q} \fallingdotseq$ Precipitation − Evaporation (mm/y)

General Circulation Model on WS

1995



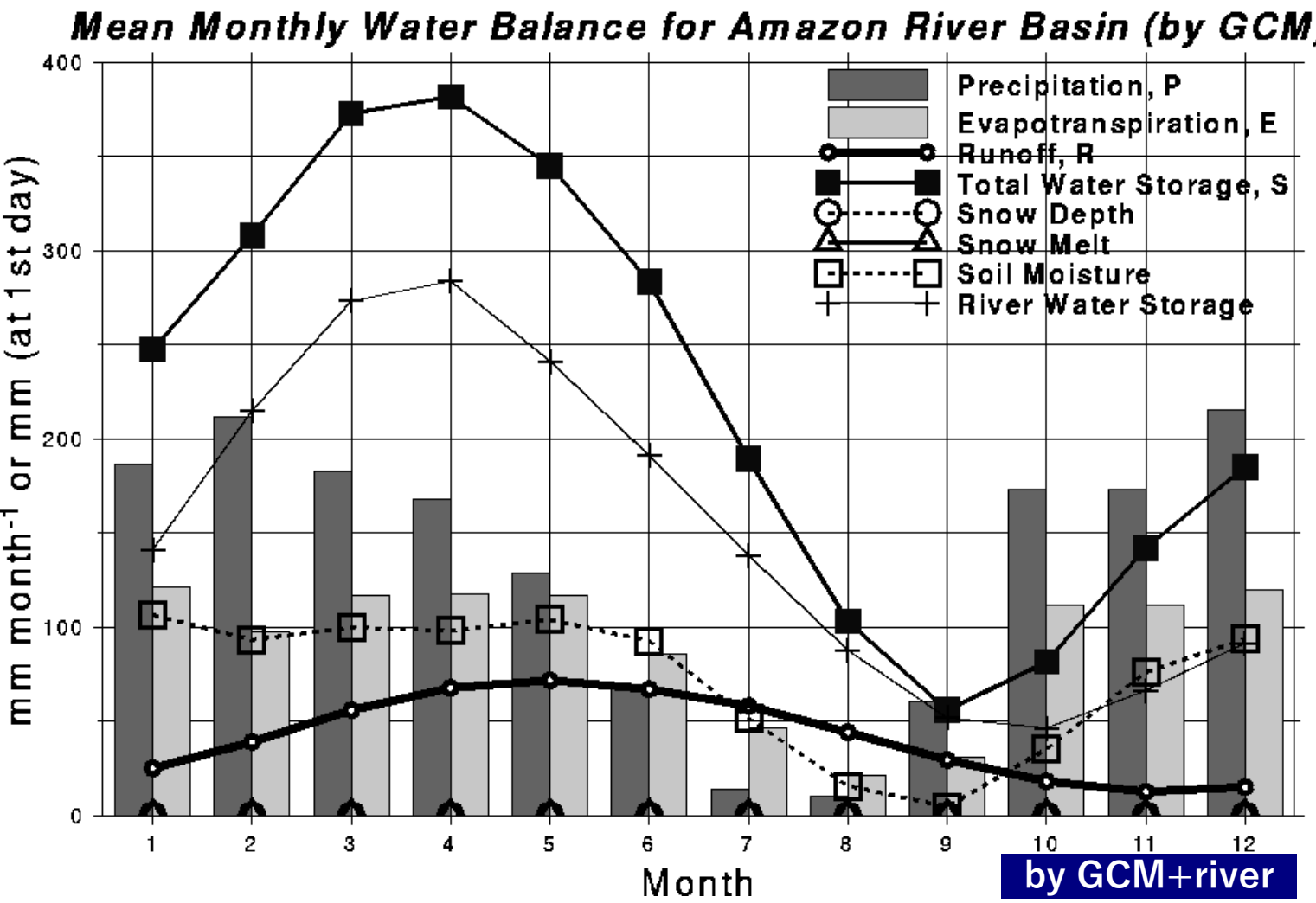
- Global river routing network for "T21" spatial resolution of GCM (≈560km) was developed by Shinjiro Kanae when he was a M1 student.
- River routing was applied for runoff from CCSR-NIES AGCM with Kondo's modified "leaky" bucket model as for its land surface.



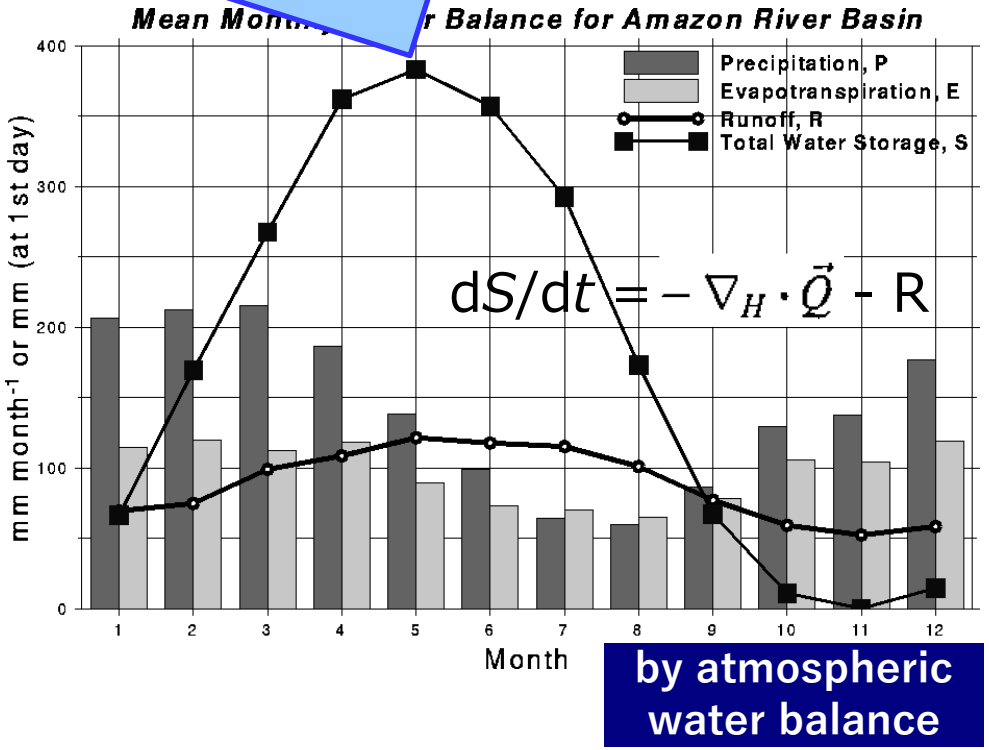
Mean monthly river discharge at Obidos station in the Amazon River basin

S. Kanae (1998)

1999



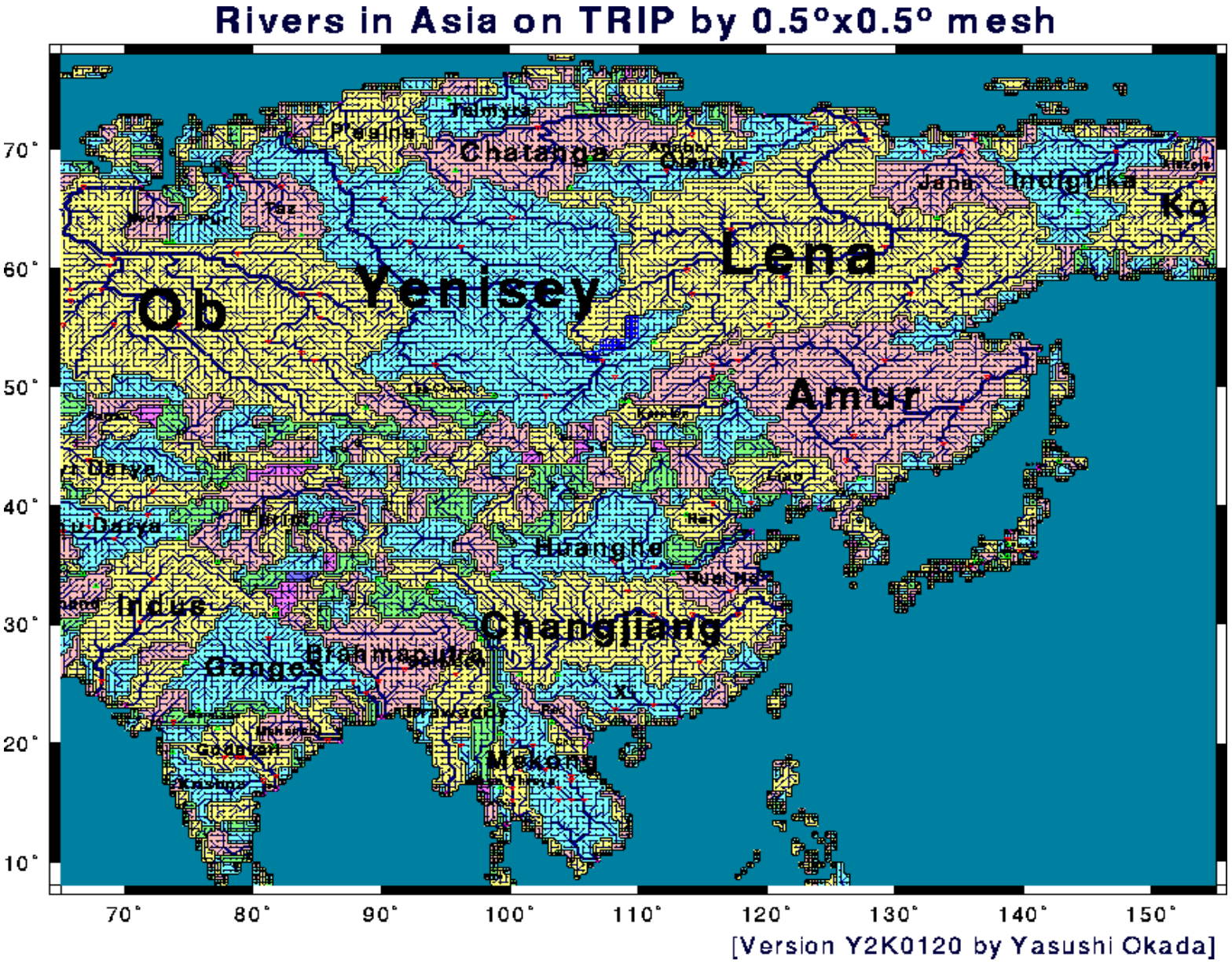
How can such a large seasonal change of terrestrial water storage occur?



- Loosely coupled simulation of mean water cycle in the Amazon River Basin supported the inferred result by atmospheric water balance that large seasonal cycle of terrestrial water storage is mainly caused by river water storage.

1998

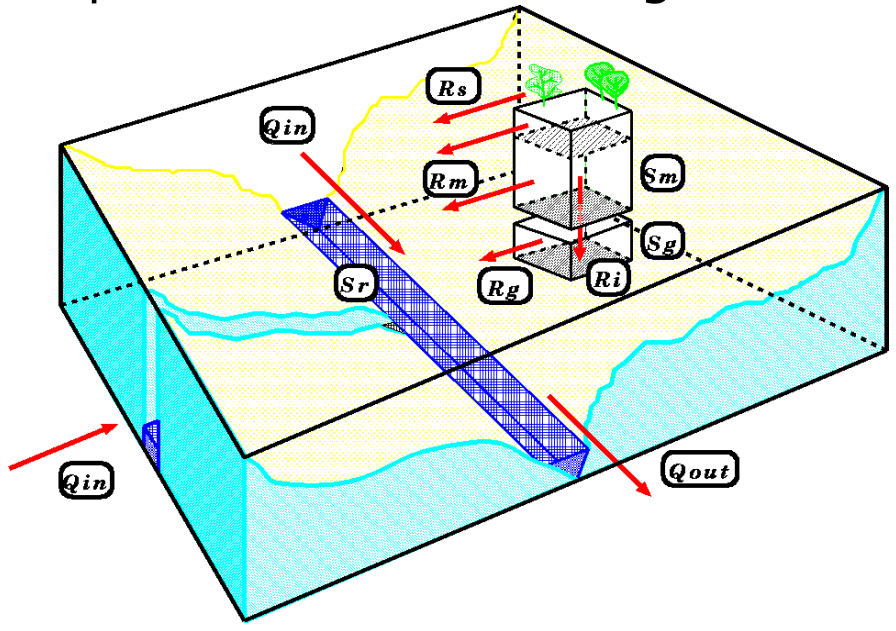
Total Runoff Integrating Pathways (TRIP)



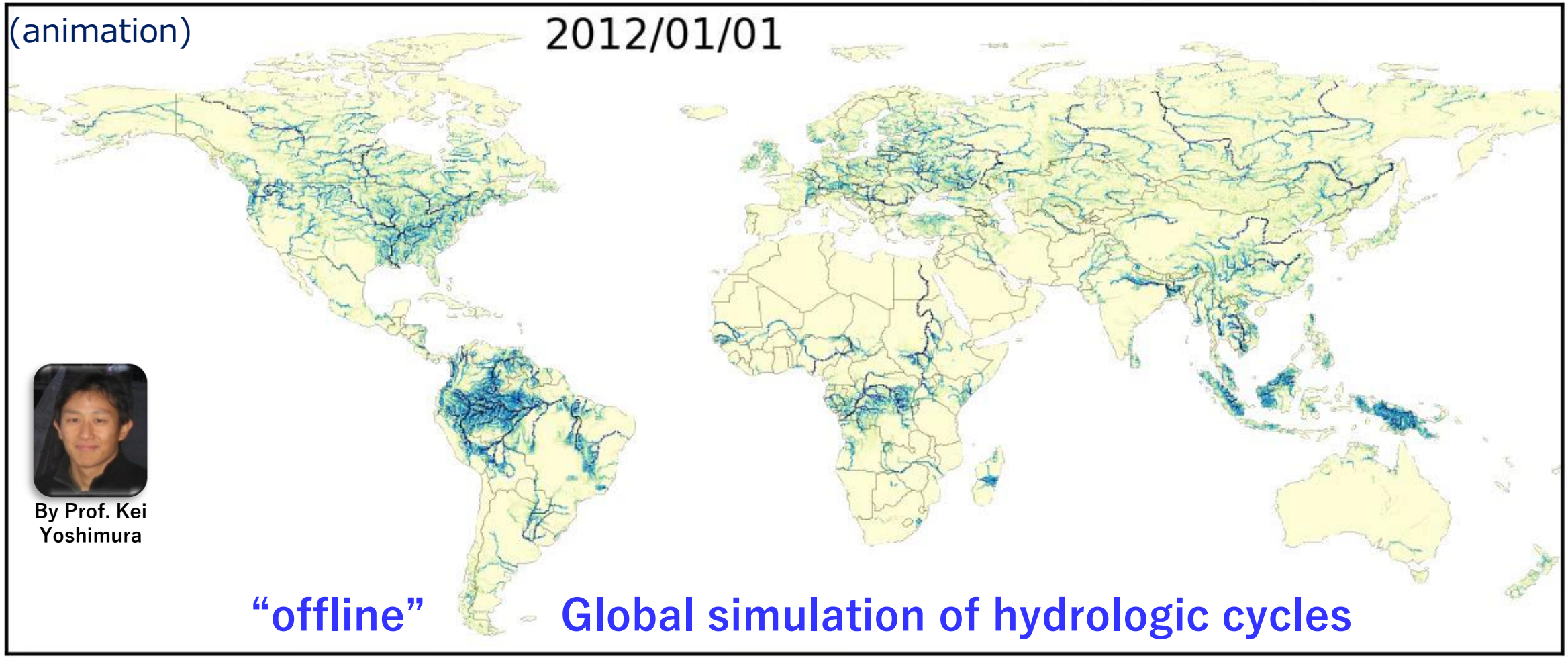

Y. Sud


(Dec. 1998)

- Translate runoff into discharge.
- Enables atmosphere-river-ocean coupling and assessing the impacts of climate change.



River Discharge (m^3/s)



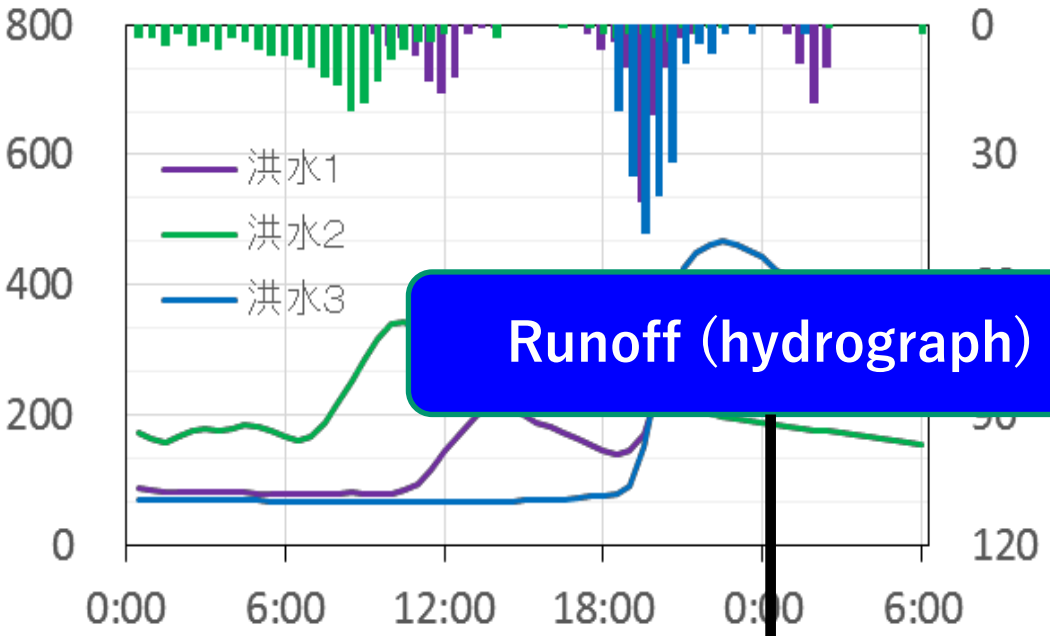
Traditional Hydrological Analysis

In-situ Observation

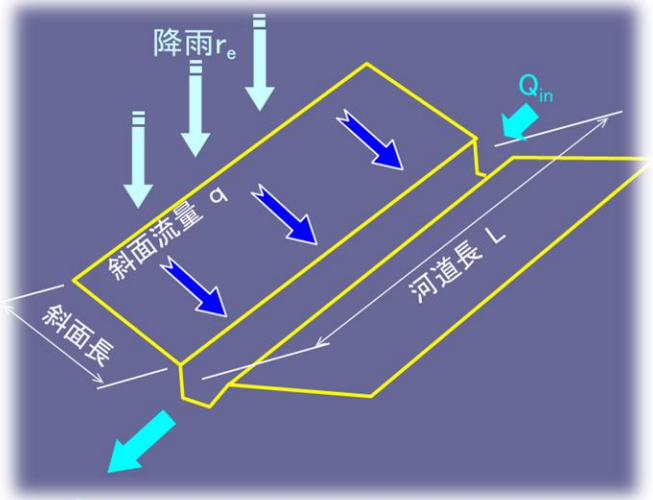
Time-varying B.C.
(Precip., Temperature, …)

Stable Boundary C.
(Land cover, …)

Hydrologic model



Runoff (hydrograph)

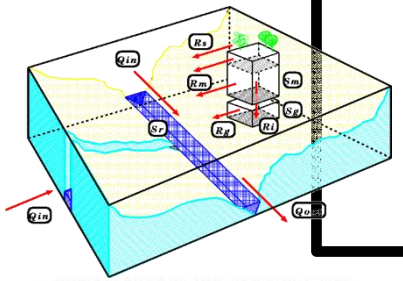


Design flood, real-time prediction, …

The Framework of Global Hydrology

NWP, 4DDA, GCM, …

In-situ obs. + remote sensing

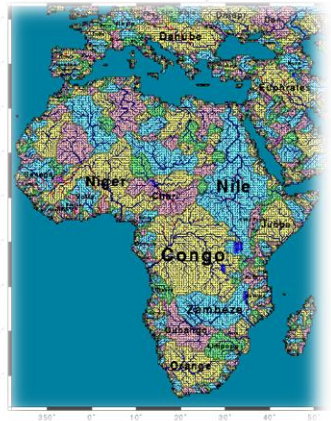


Time-varying B.C.
(Precip., Radiation, Temp., …)

Stable Boundary C.
(Vegetation, LC, Soil, …)

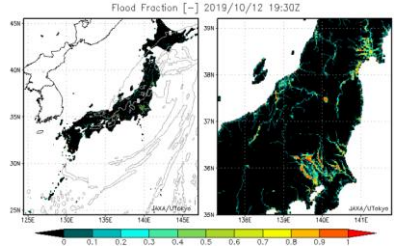
Initial Condition
(Soil Moisture, GW, G-Temp, …)

Land Surface Model



Runoff, soil moisture, GW, ET, CO_2,…

River Model



Discharge, Temp., Quality, Sediment, …

Impact Assessment

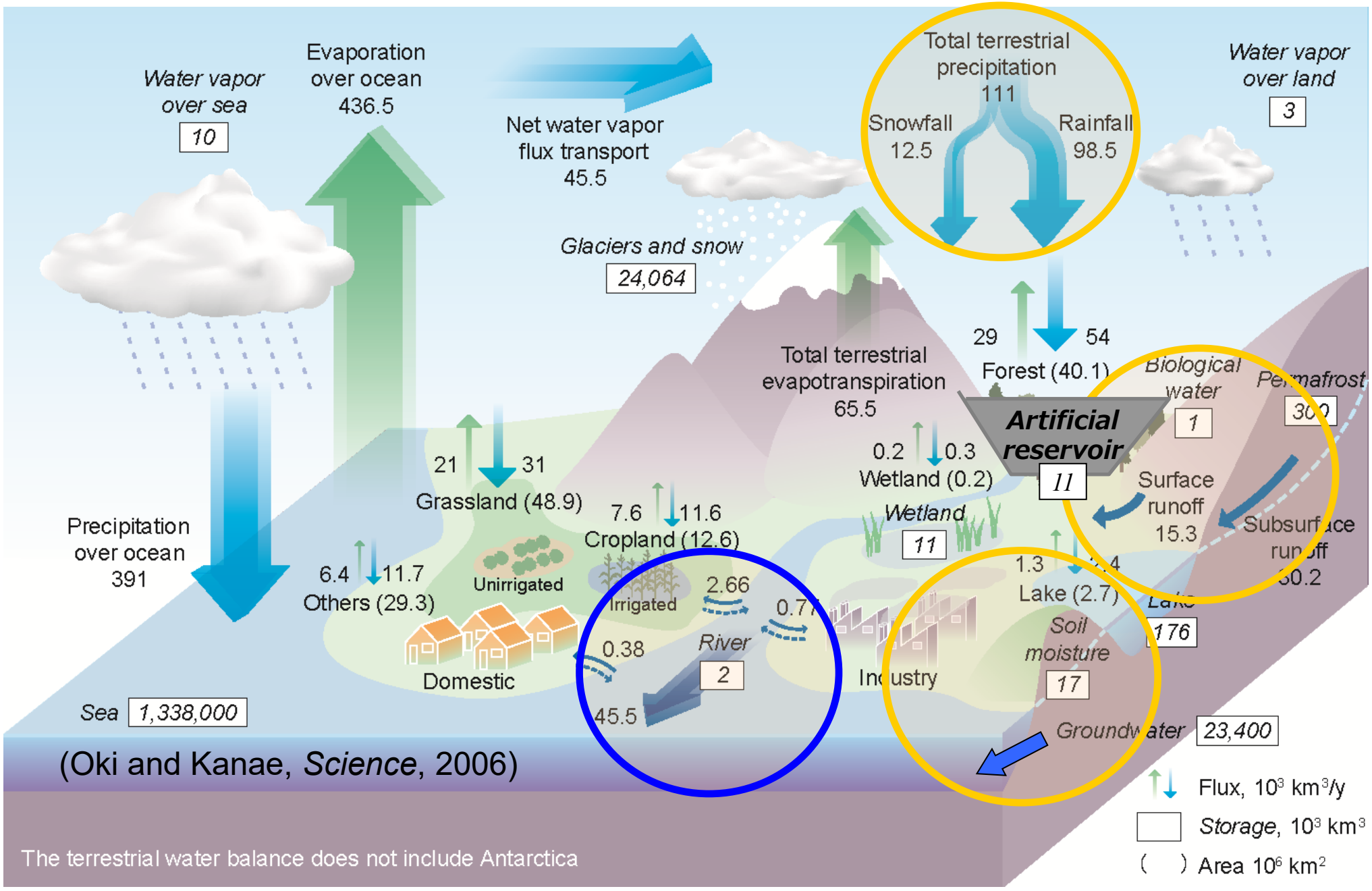
Monitoring, Warning, Climate C. Prediction, …

(Oki and Kanae, 2006, *Science*)

Global Hydrological Cycles and World Water Resources

2006

S. Kanae

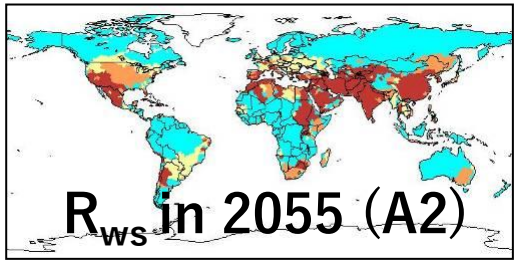


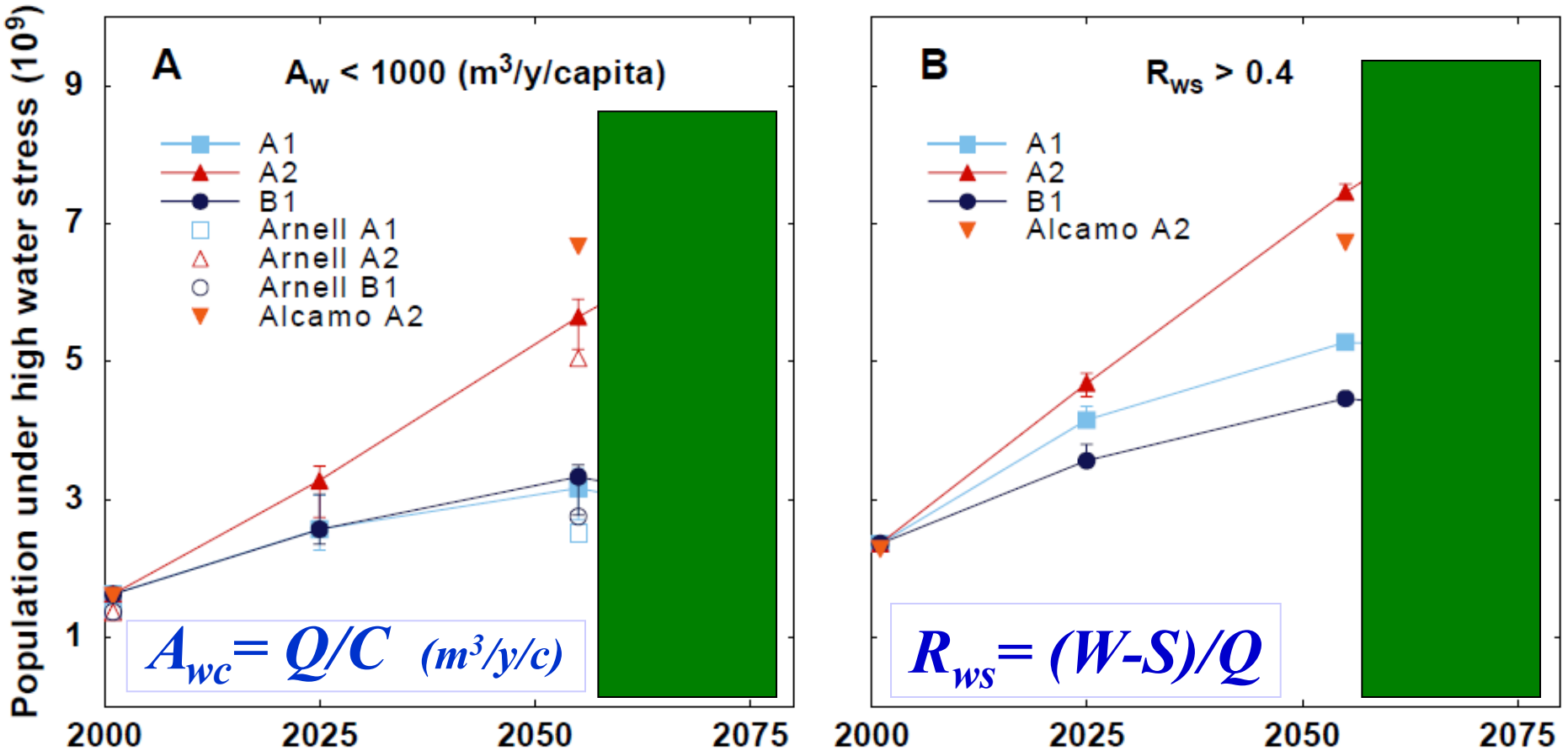
- First schematic diagram of global water cycles and storages in major land covers including human activities (but not artificial reservoirs).
- It is like the Mendeleev's "periodic table" (in Chemics) of hydrology.

(Oki and Kanae, 2006, *Science*)

2006

Number of people under serious water stress





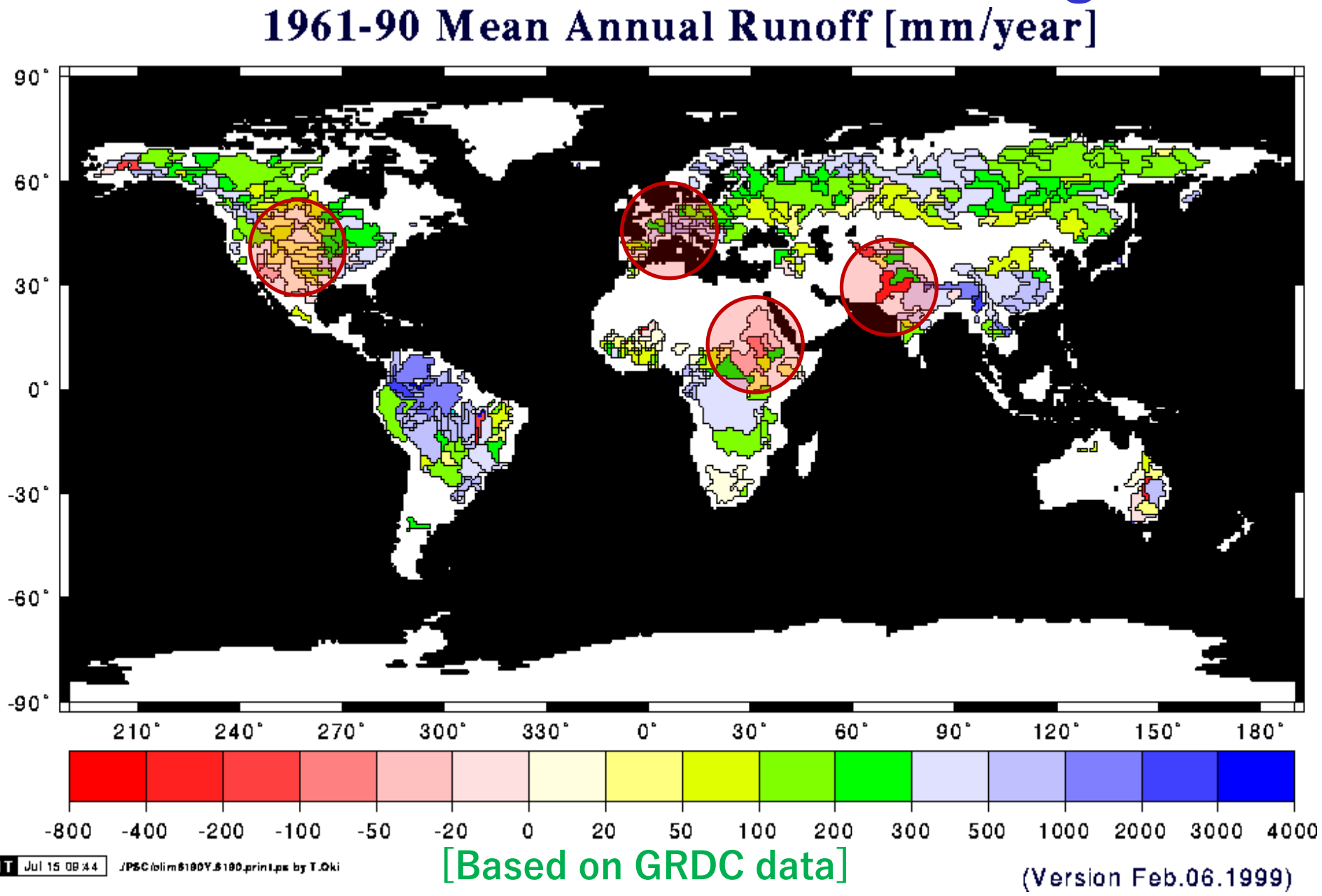
(2006.08)

Q: How can we realize B1 society?

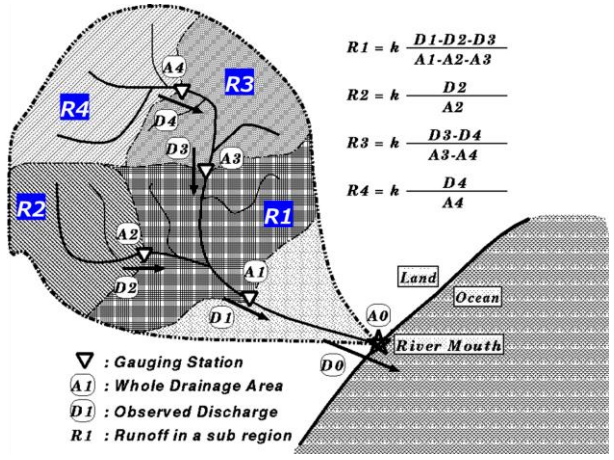
(Oki, Entekhabi, and Harrold., 2004)

Runoff estimated from discharge observation

2004



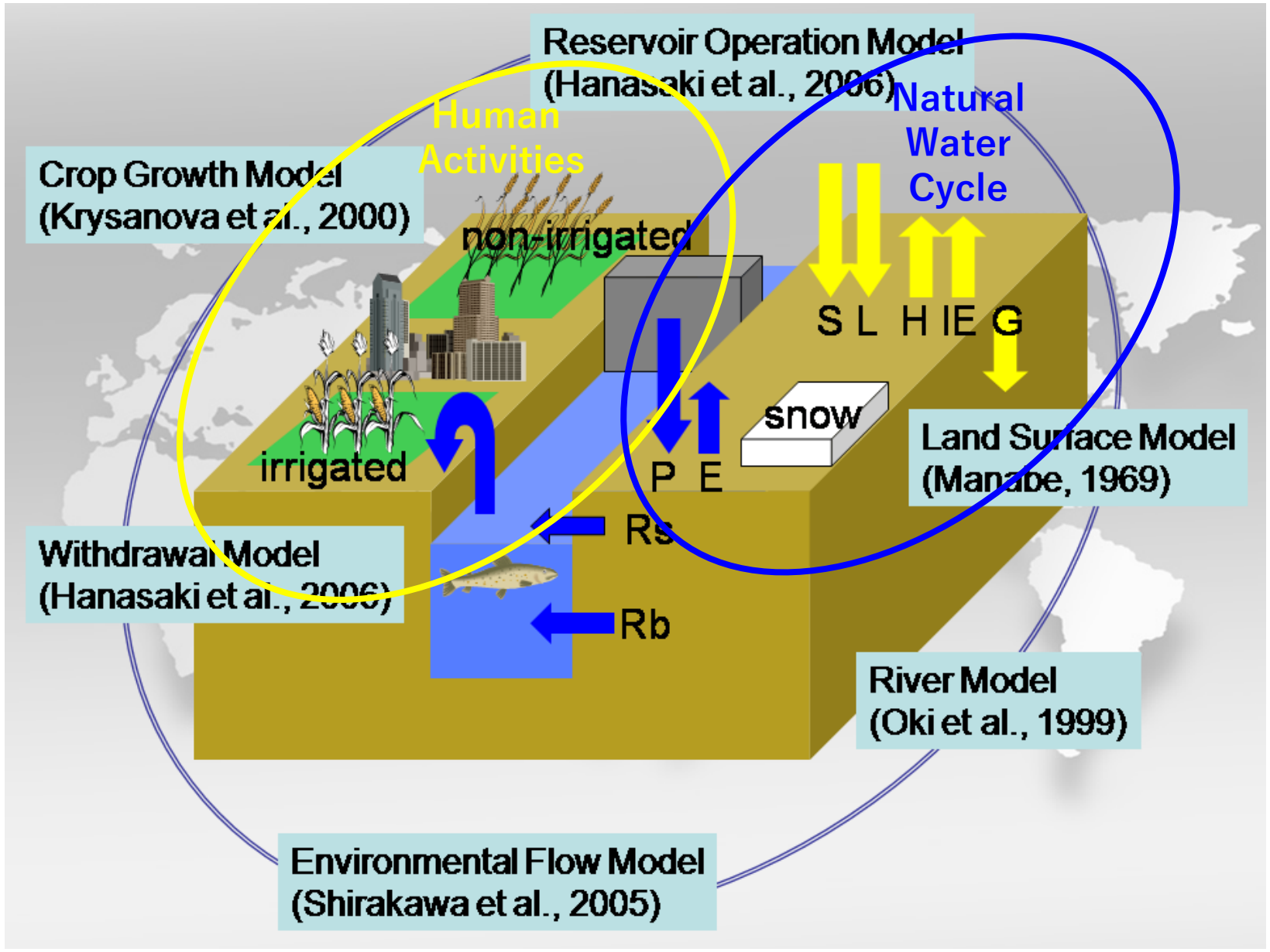
- Negative runoff was estimated even from observation for cases upstream discharge > downstream discharge.
- It should be due to anthropogenic water withdrawals.



Coupling human activities

2008

N. Hanasaki

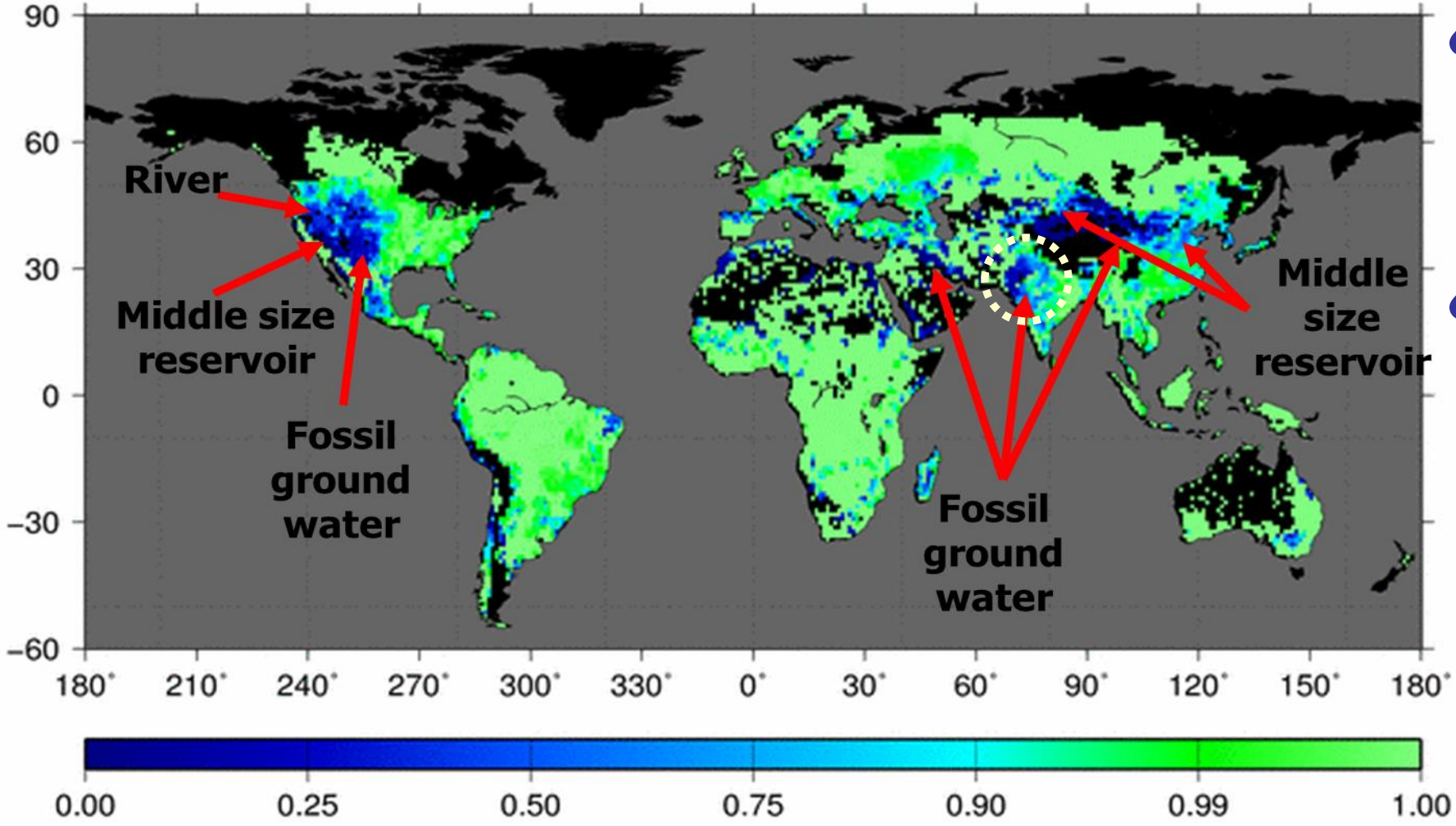


- Pioneering coupled social-ecological system model.
  - Both natural water cycle (water and energy balance) and human activities (reservoir operation, water withdrawals, environmental flow, …) are considered and coupled.
  - A simple crop model is also coupled to estimate the timing or irrigation needs between seeding and harvest.

(Hanasaki et al., 2010, *J. Hydro.*)

2010

Coupling human activities and trades



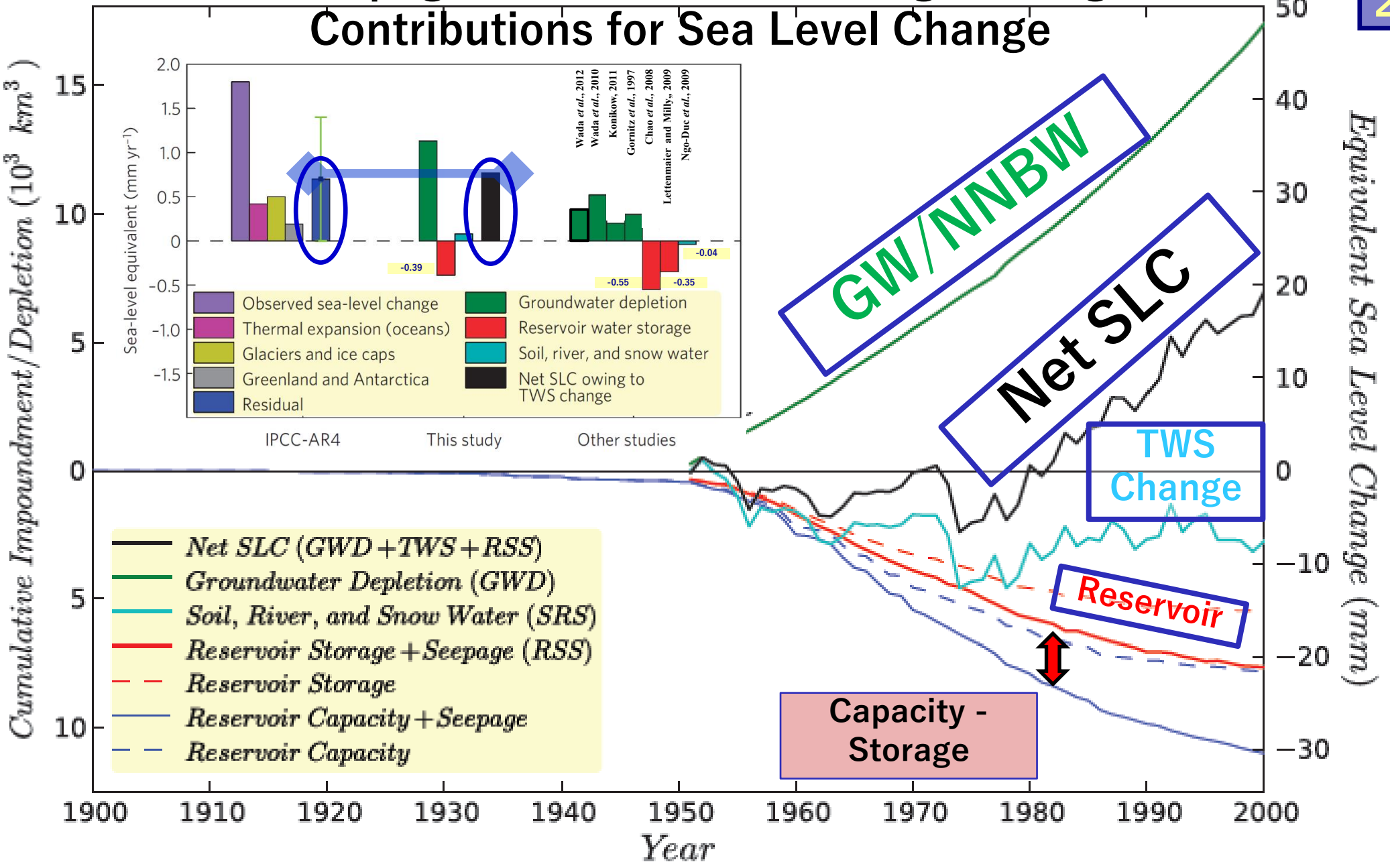
- Share of green (rain) water resources used for plant growth estimated by H08.
- Crops mostly use rainwater for their growth except for several regions in the world.
  - Significant fossil (non-renewable) ground water use in the Northwest India!

- Total non-local non-renewable GW withdrawal ≈ 703 km³/y (for 1985-99)
  - ⇔ 389-840 km³/y by Vörösmarty et al. (2005), 730 km³/y by Rost et al. (2008)

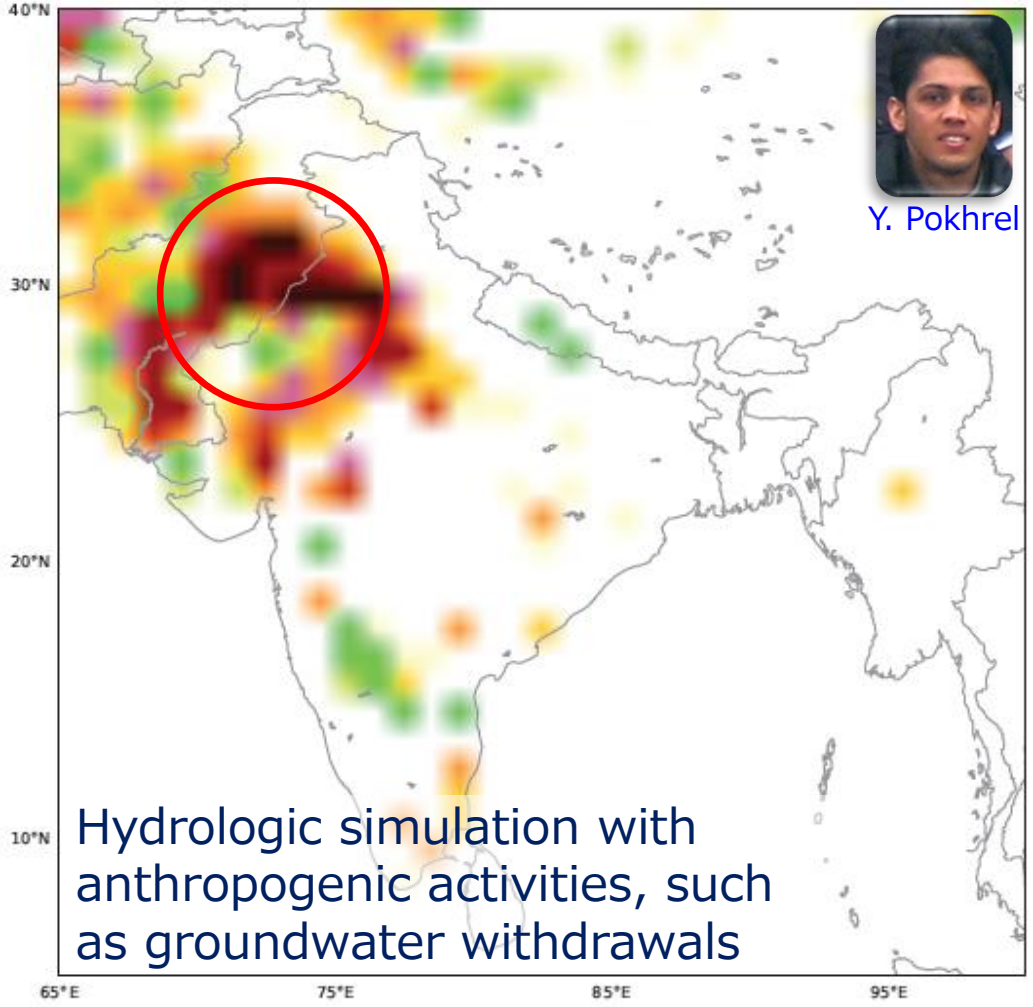
N. Hanasaki

Anthropogenic Total Water Storage Change Contributions for Sea Level Change

2012



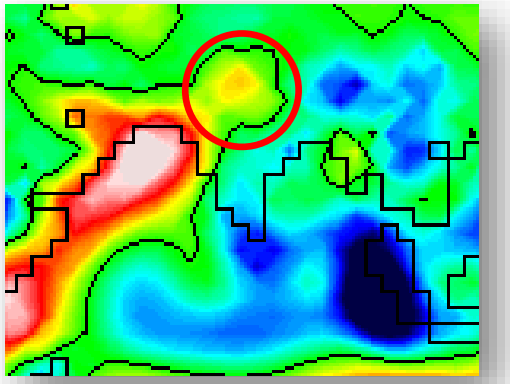
Groundwater Depletion in NE India



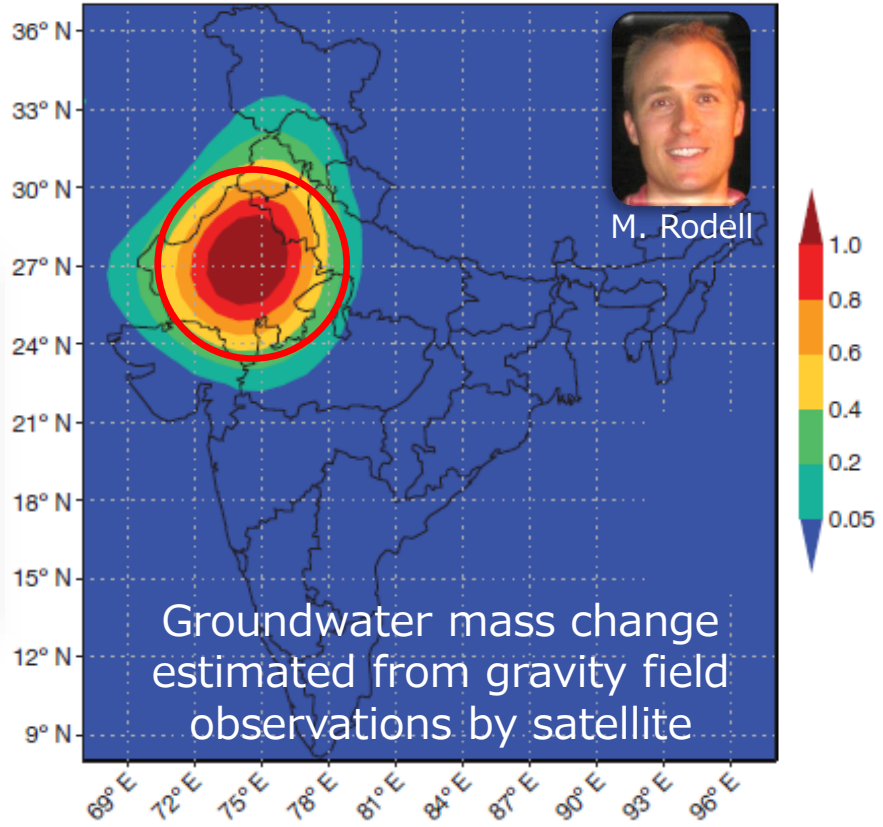
(Data from Pokhrel, et al., *Nature Geoscience*, 2012)

Atmospheric Water Balance
Areas with
Precipitation < Evaporation
over land

(Oki, et al.,1995)



Evaporative water
=Precipitation
+river discharge
from upstream
+pumped
groundwater



(Rodell , et al., *Nature*, 2009)

Groundwater depletion during 2002-08 is estimated as:

- 45 $km^3\ yr^{-1}$ (Pokhrel et al., 2012)
- 18±4.5 $km^3\ yr^{-1}$ (Rodell et al., 2009)
- 13 $km^3\ yr^{-1}$ (Indian Government)

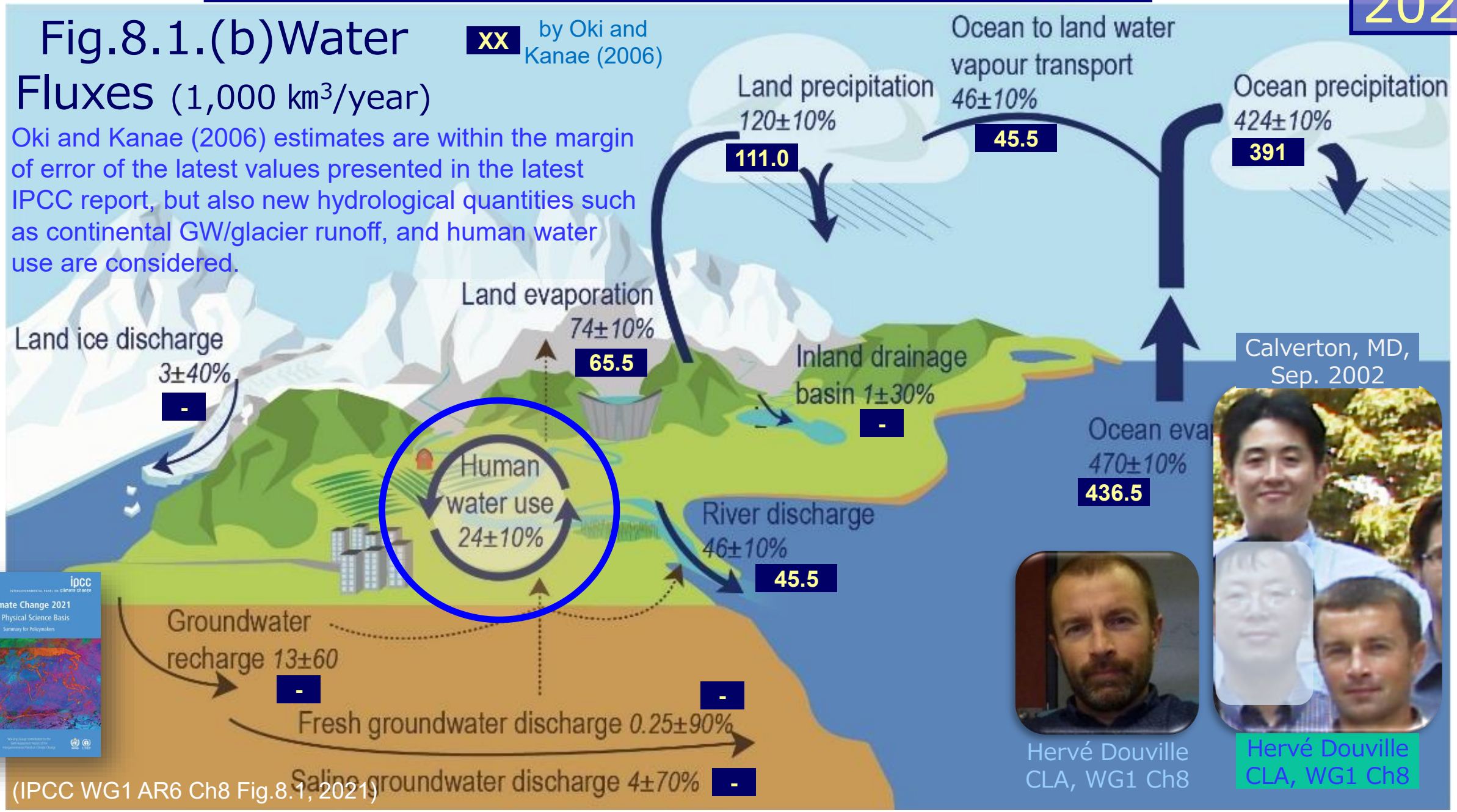
AR6 WGI Ch8 “Water cycle changes”

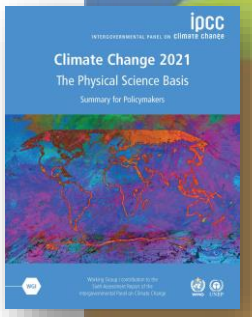
2021

Fig.8.1.(b)Water Fluxes (1,000 km^3/year)

XX by Oki and Kanae (2006)

Oki and Kanae (2006) estimates are within the margin of error of the latest values presented in the latest IPCC report, but also new hydrological quantities such as continental GW/glacier runoff, and human water use are considered.





(IPCC WG1 AR6 Ch8 Fig.8.1, 2021)

Hervé Douville
CLA, WG1 Ch8

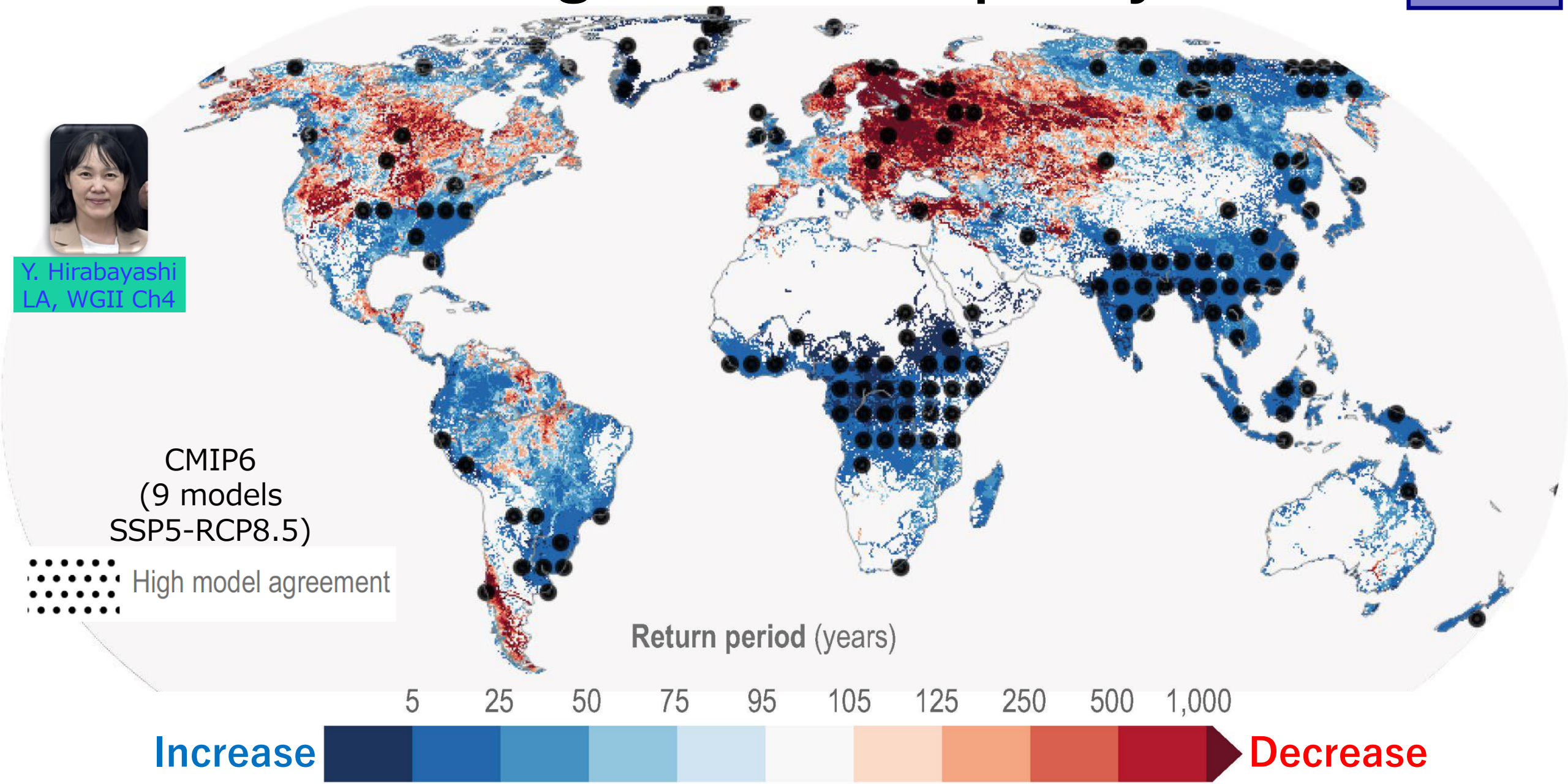
Calverton, MD, Sep. 2002

Hervé Douville
CLA, WG1 Ch8

Change in flood frequency

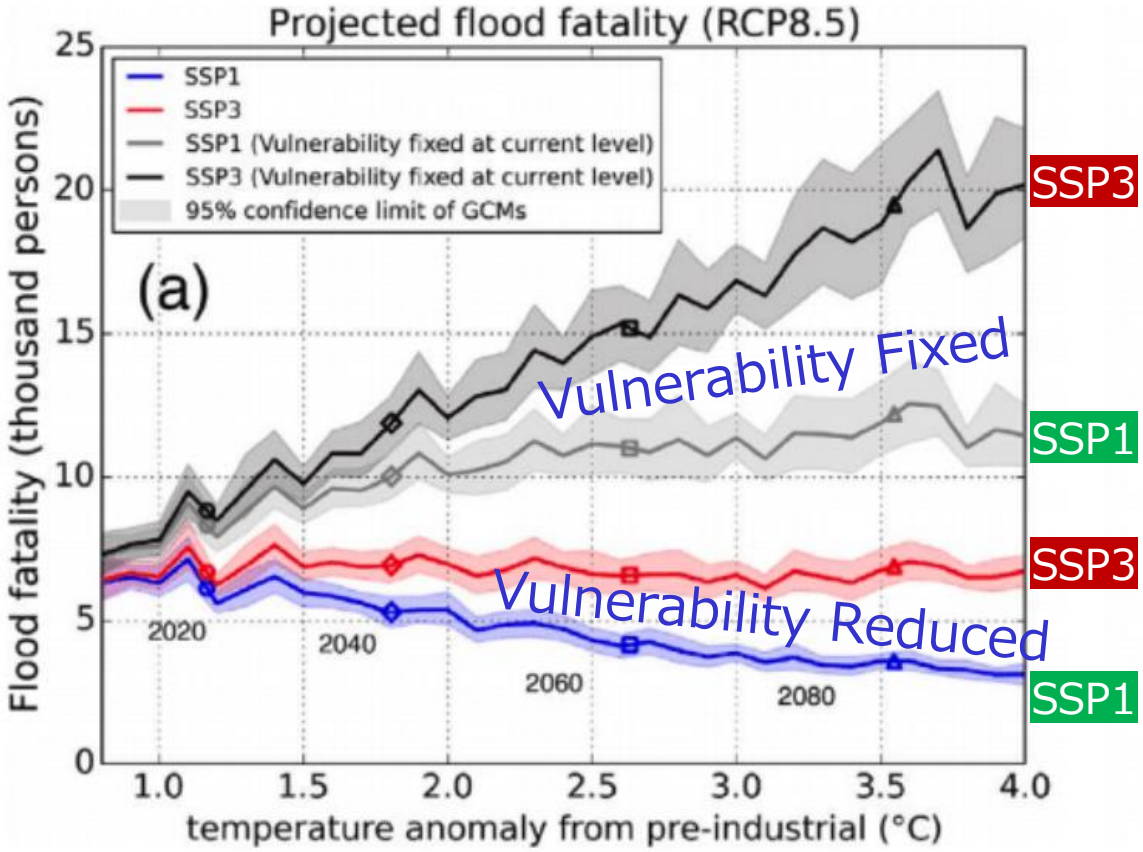
2021

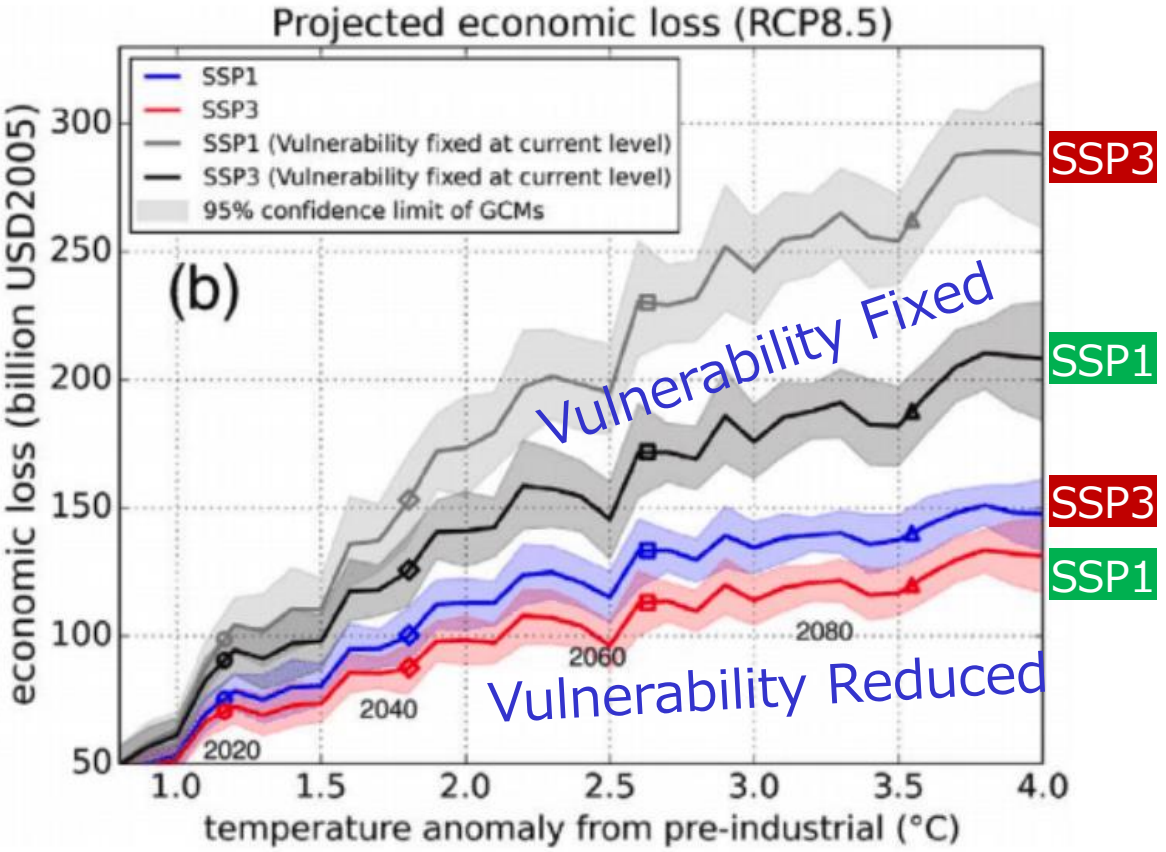
Y. Hirabayashi
LA, WGII Ch4



2021

Flood Damage in the Future





- Global 30 second (1 km) flood exposure (population and goods in flooded areas) from MATSIRO and CaMa-Flood by bias-corrected external meteorological forces, with vulnerability scenarios (Kinoshita et al., 2018) based on past river flood vulnerability data (Tanoue et al., 2016).

Additional cost by CC ⇔ Total 170 B$ in 2021

28 Aug. 2024

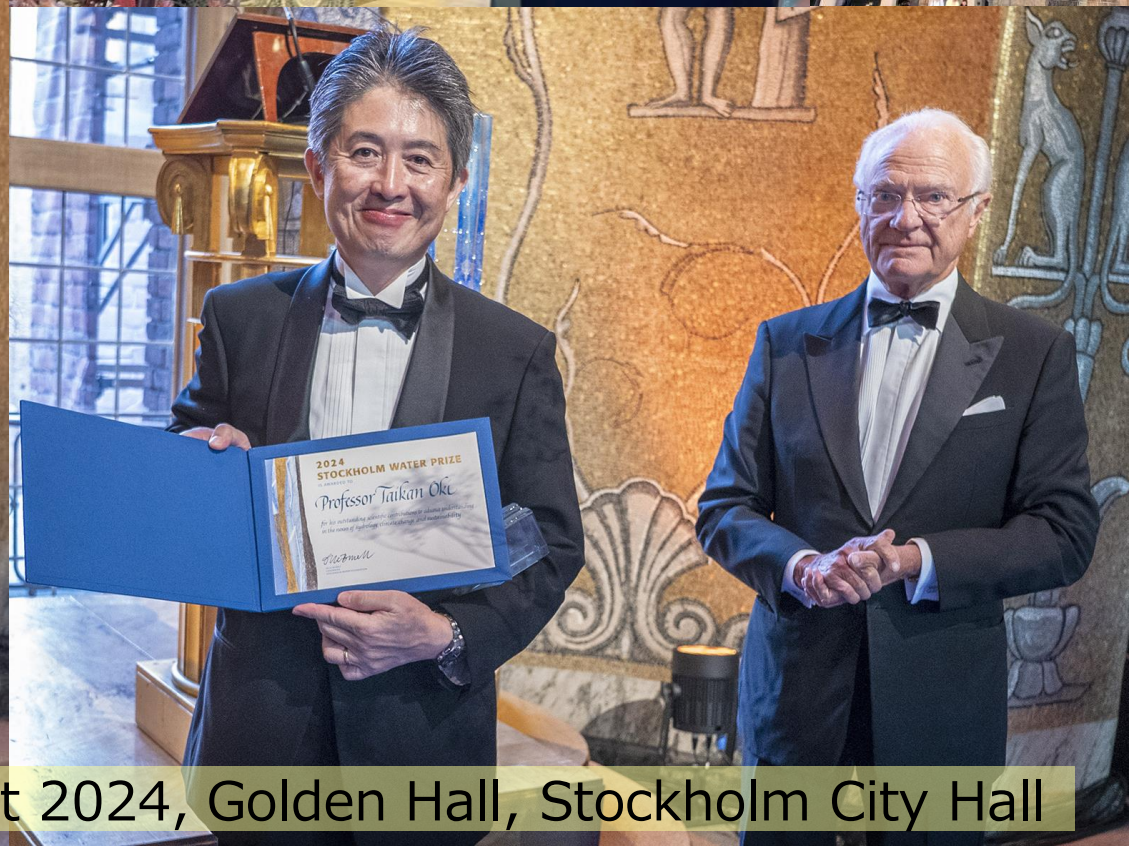
The Royal Court Trumpeters with Mr. Olle Hermansen (conductor)

Stockholm Water Prize Award Ceremony, 28 August 2024, Golden Hall, Stockholm City Hall (Photo: Stockholm Water Foundation)

28 Aug. 2024

Stockholm Water Prize Award Ceremony, 28 August 2024, Golden Hall, Stockholm City Hall (Photo: Stockholm Water Foundation)

H.M King Carl XVI
Gustaf of Sweden



Stockholm Water Prize Award Ceremony, 28 August 2024, Golden Hall, Stockholm City Hall

2024 STOCKHOLM WATER PRIZE

IS AWARDED TO

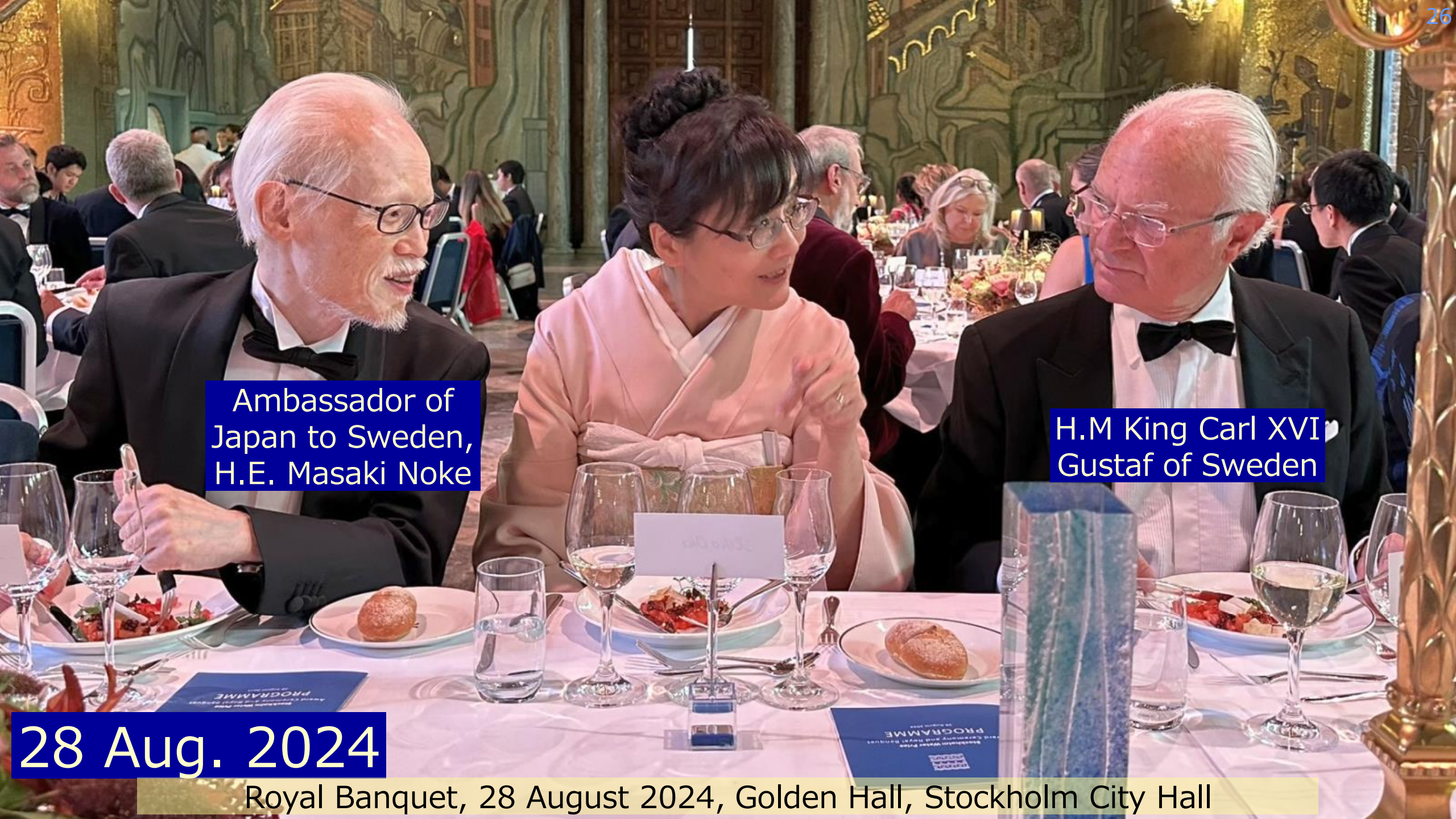
Professor Taikan Oki

for his outstanding scientific contributions to advance understanding in the nexus of hydrology, climate change and sustainability

OLLE BURELL
CHAIRMAN
STOCKHOLM WATER FOUNDATION

28 Aug. 2024

Stockholm Water Prize Royal Banquet, 28 August 2024, Golden Hall, Stockholm City Hall (Salmon tartare with salmon roe)


Ambassador of Japan to Sweden, H.E. Masaki Noke
H.M King Carl XVI Gustaf of Sweden
28 Aug. 2024
Royal Banquet, 28 August 2024, Golden Hall, Stockholm City Hall

28 Aug. 2024

Stockholm Water Prize Award Ceremony, 28 August 2024, Golden Hall, Stockholm City Hall (Photo: Stockholm Water Foundation)

28 Aug. 2024

Mr. Elias Xie (grand piano)

Ms. Dominique Pålsson Wiklund

Rosa Kvartetten (string quartet)

28 Aug. 2024

Stockholm Water Prize Royal Banquet, 28 August 2024, Golden Hall, Stockholm City Hall (Steak of Reindeer)

- “*Art* is long, life is short.”
- “Life is short, *articles* are long.”

(Photo: Norihide Takeda)

Speech at the Royal Banquet, 28 August 2024, Golden Hall, Stockholm City Hall

Remarks

- Global hydrology has evolved and is “big data driven”
  - also “community supported discipline”
    - Nobody can do global hydrology alone: sharing data, codes, knowledge, …
- “Real” hydrological cycle is not “pristine” anymore even on the global scale in the Anthropocene.
  - Integrated hydrology and water resources model with human activities is promising for reliable predictions.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Oki Taikan
Shedding Light on the Global Water Cycle
NHK World
"Shedding Light on the Global Water Cycle"
Oki's Research life
in 15 minutes.
Thank You!
https://www3.nhk.or.jp/nhkworld/en/shows/2105152/