JST-NSERC Workshop
on Sustainable Water Use,
21st October, 2013
Fujisoft Akiba Plaza, Tokyo, Japan

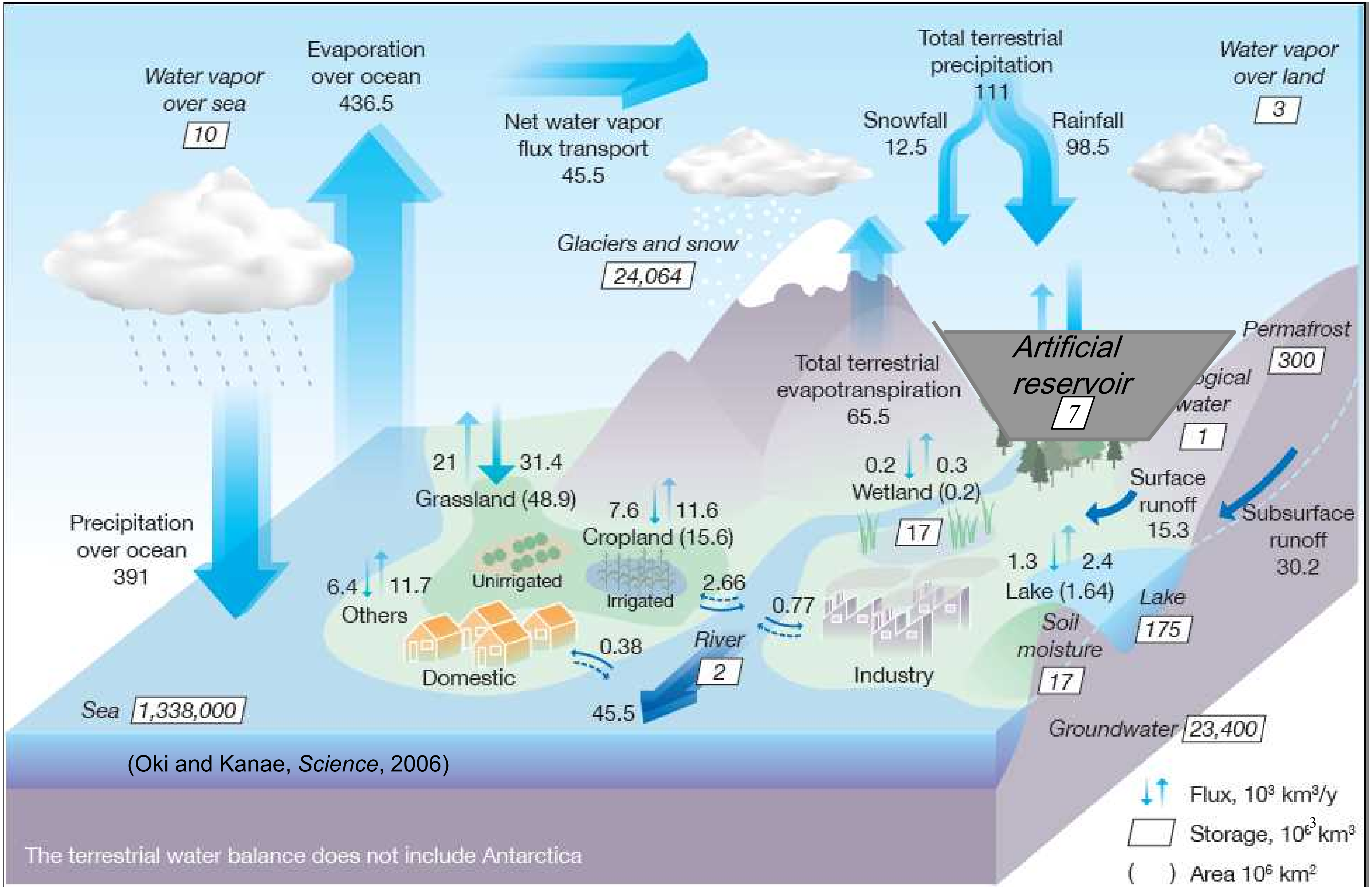
Global Hydrology in the Anthropocene

Taikan OKI

Institute of Industrial Science,
The University of Tokyo

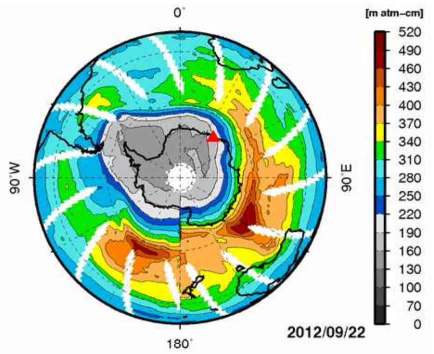
special thanks to
Dr. Y. Hirabayashi (T/UTokyo), Dr. N. Hanasaki (NIES),
Mr. N. Utsumi and Mr. Yusuke Sato (IIS/UTokyo)

Synthesized Global Water Cycle



Views on nature and science in the era of global changes

- ***Real*** **nature is not** ***natural*** **anymore.**
  - **Anthropocene (P. J. Crutzen, *Nature*, 415, 2002)**
  - **Nature is modified by anthropogenic activities.**
    - **Land Use and Land Cover Changes**
    - **Changing atmospheric components GHGs, aerosols, …**
      - **Climate change by global warming**
    - **Human interventions on water and material cycles.**

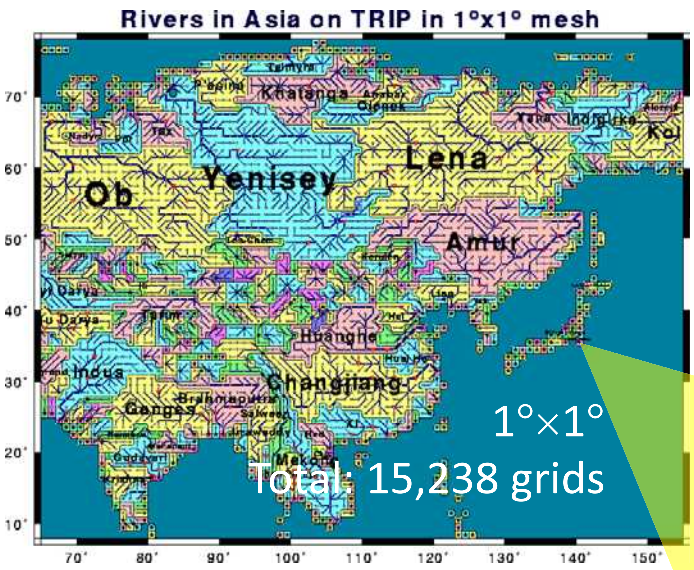


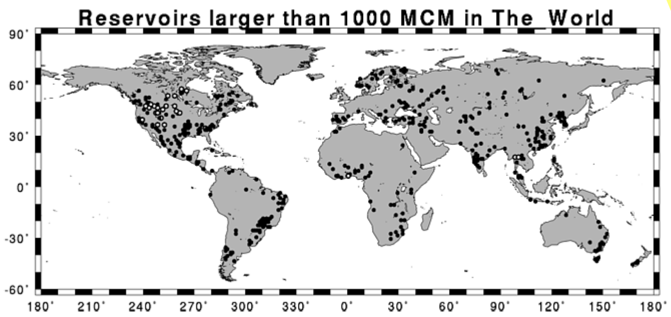
米国航空宇宙局(NASA)の衛星観測データを基に作成　気象庁

- **Global change science handles real nature including human activities**
  - **Further, *recognition* science to *design* science?**

Hanasaki et al., 2006, *J. of Hydrol.*
Hanasaki et al. ,2008a,b, *Hydrol. Earth Sys. Sci.*
Hanasaki et al., 2010, *J. of Hydrol.*
Hanasaki et al., 2013a,b, *Hydrol. Earth Sys. Sci.*

Global water resources model H08

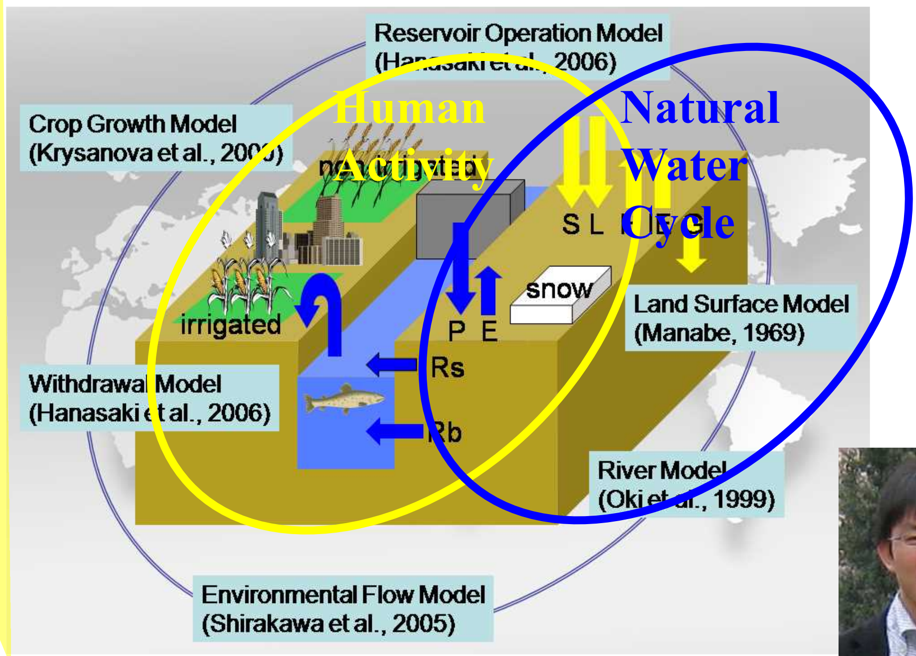




452 reservoirs, 4140 km^3

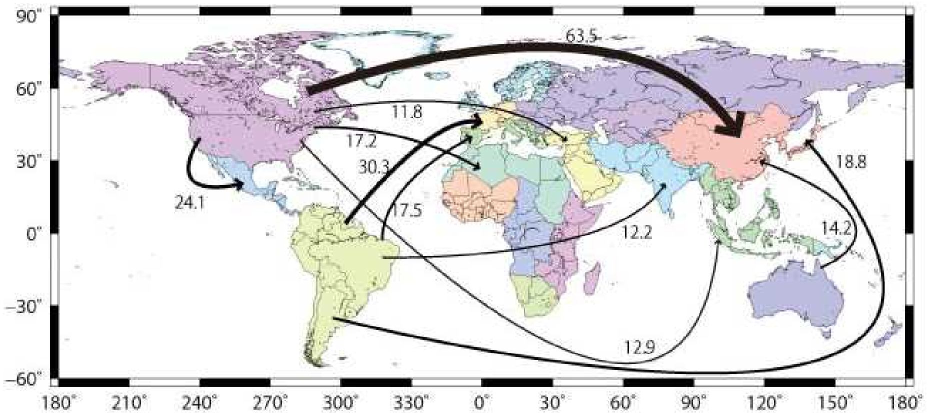
- **Requirements**

1. Simulate both water availability (streamflow) and water use at daily-basis
2. Deal with interaction between natural hydrological cycle and anthropogenic activities
3. Applicable for future climate change simulation



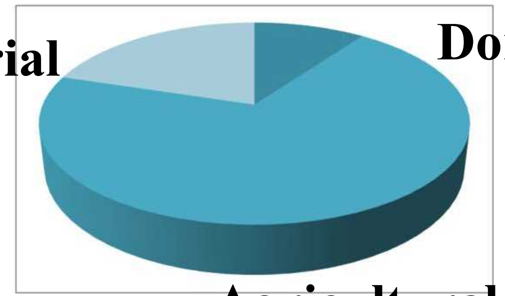
Global flows of virtual water export

Virtual water export (total)



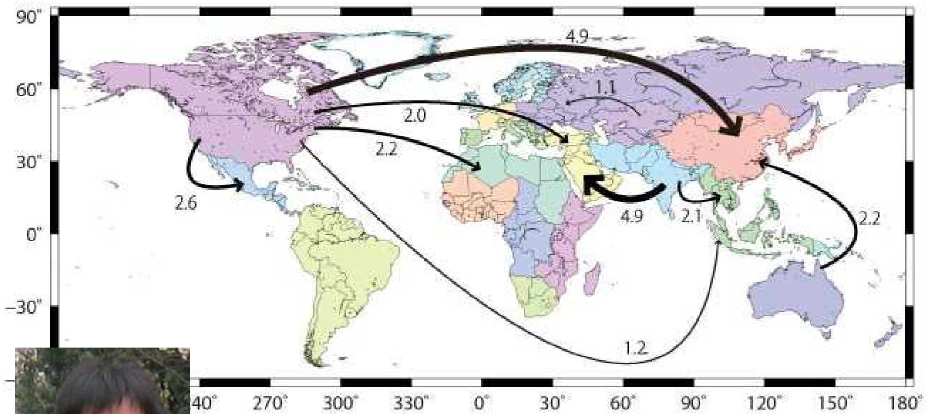
Total 545km³ yr⁻¹

Total water withdrawal: 3,800km³yr⁻¹



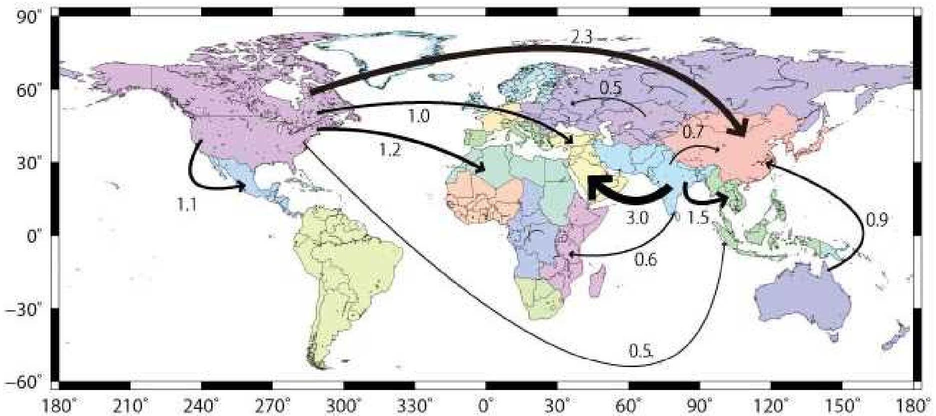
Shiklomanov, 2000

Virtual water export (irrigation)



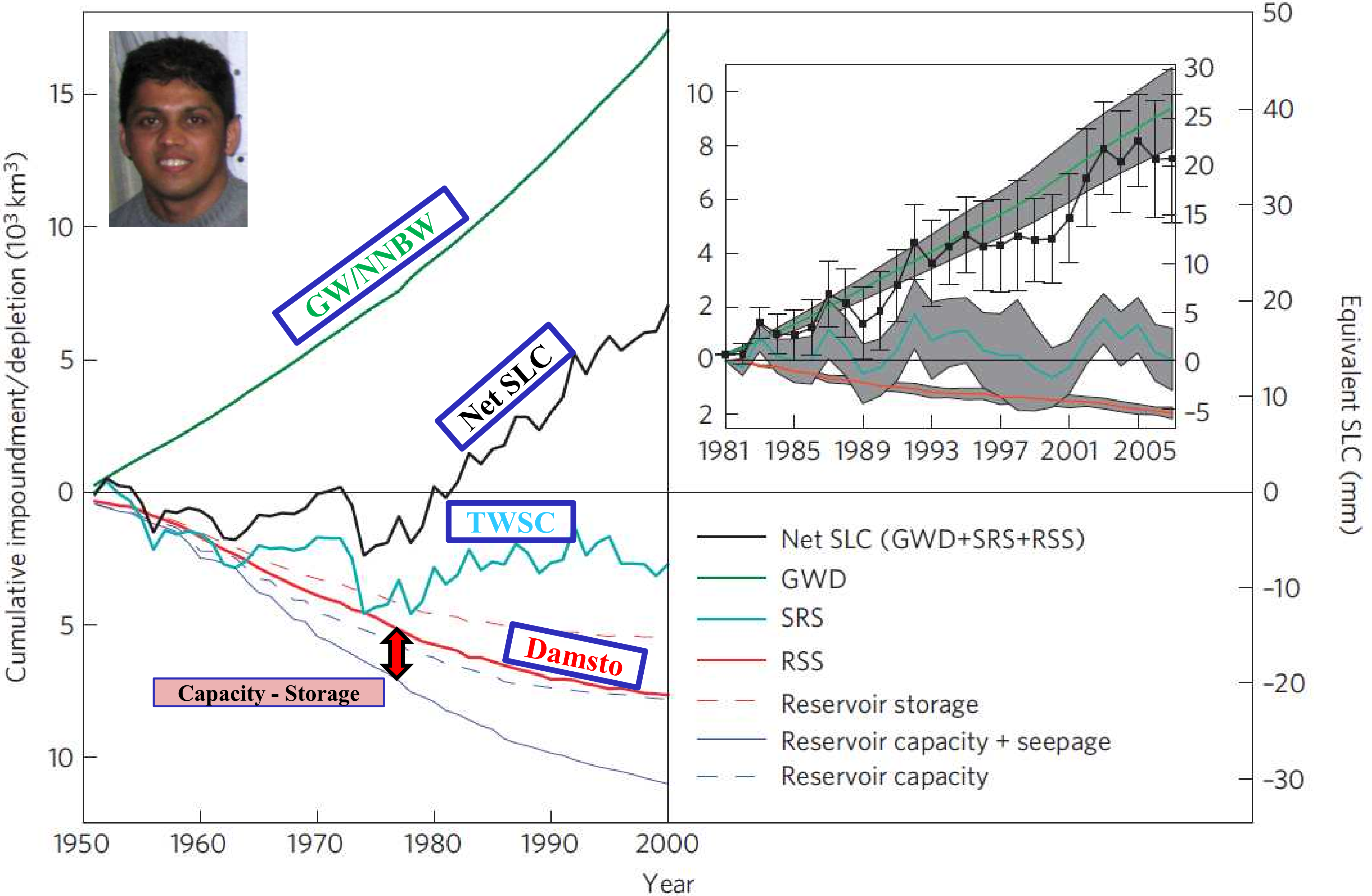
Total 61km³ yr⁻¹

Virtual water export (Nonlocal/Nonrenewable Blue Water)

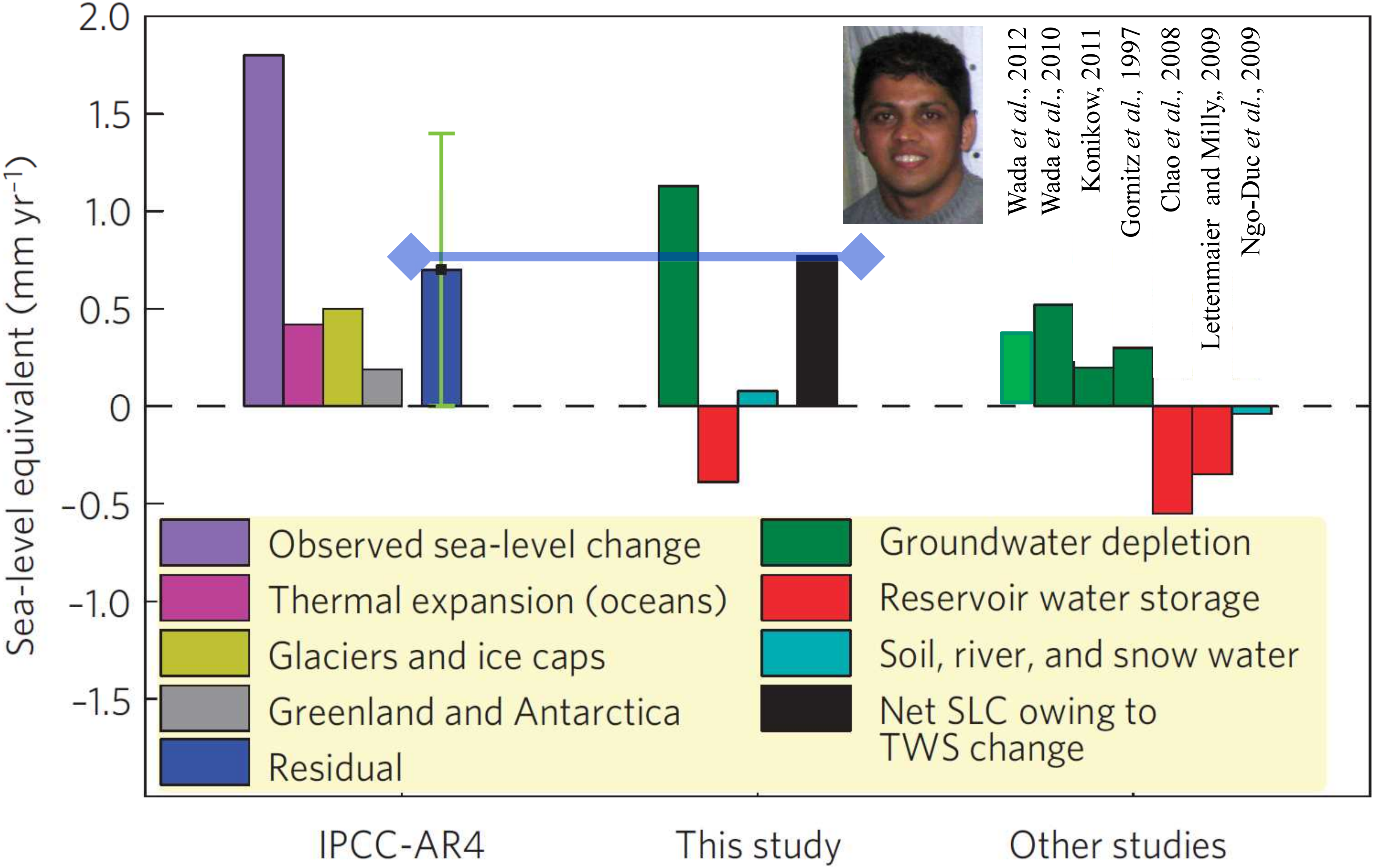


Total 26km³ yr⁻¹

Sea Level Change: Anthropogenic TWS Contributions



Contributions to Sea-level change in previous estimates



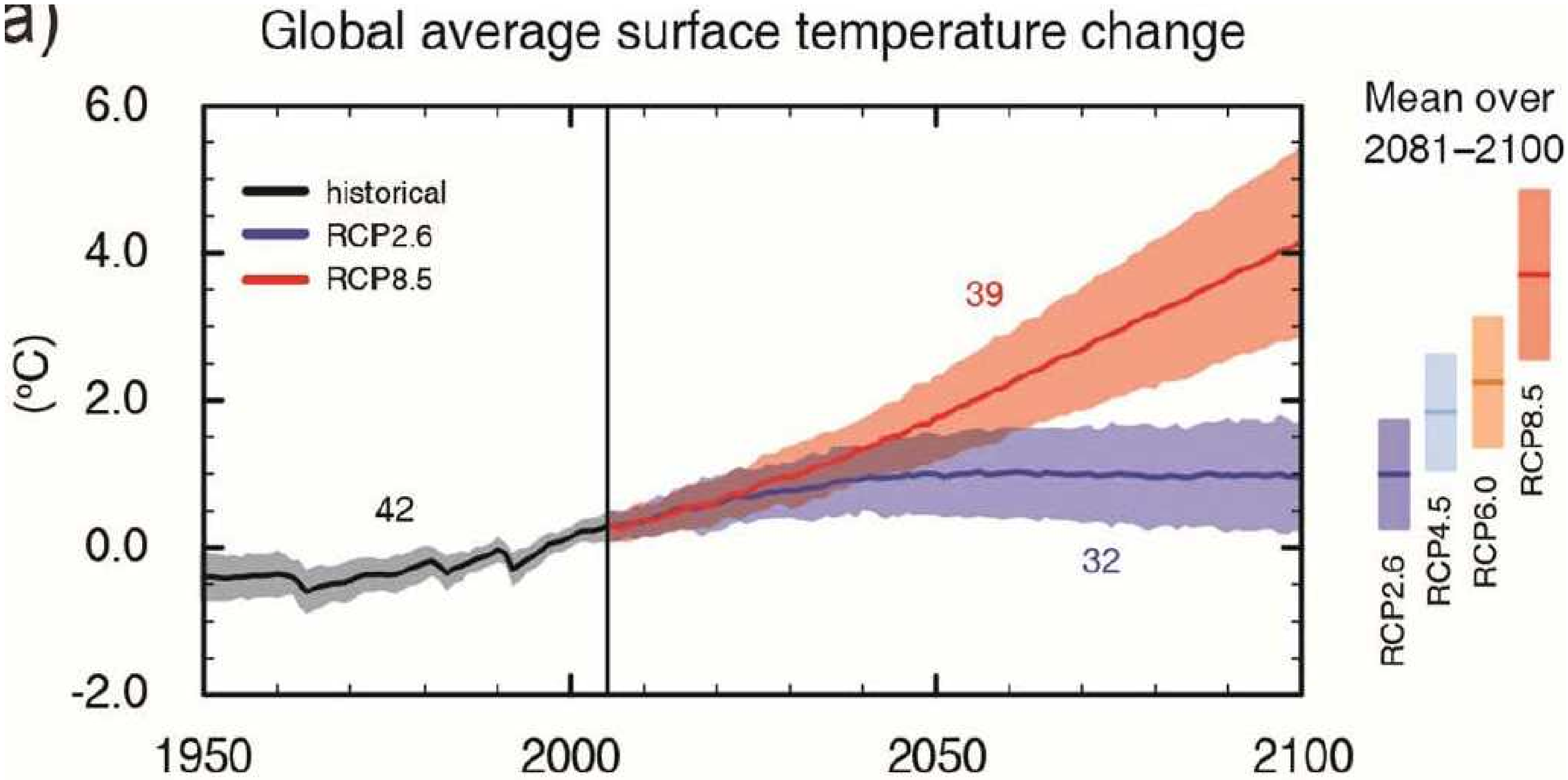
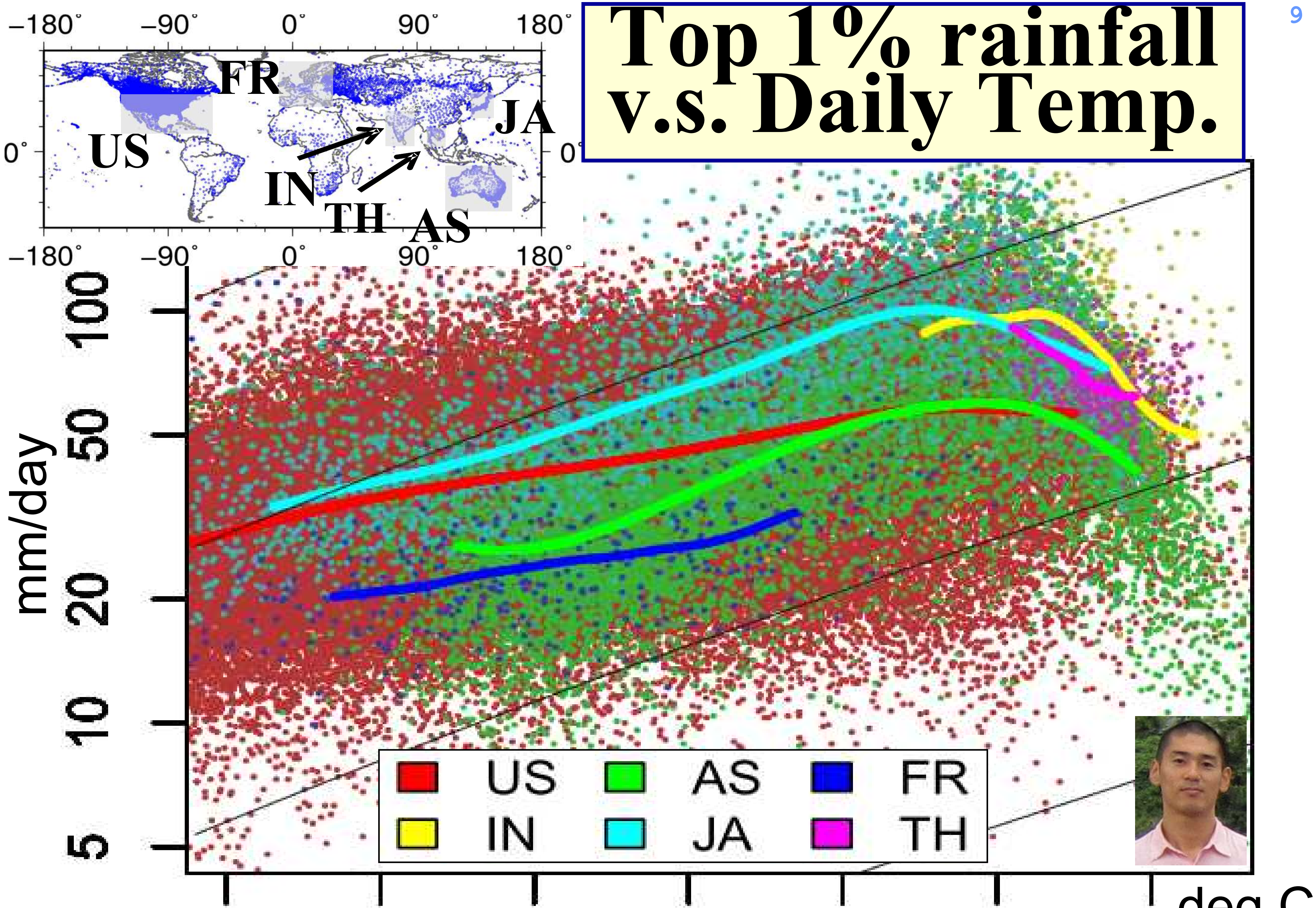


Figure SPM.7: CMIP5 multi-model simulated time series from 1950 to 2100 for (a) change in global annual mean surface temperature relative to 1986–2005.

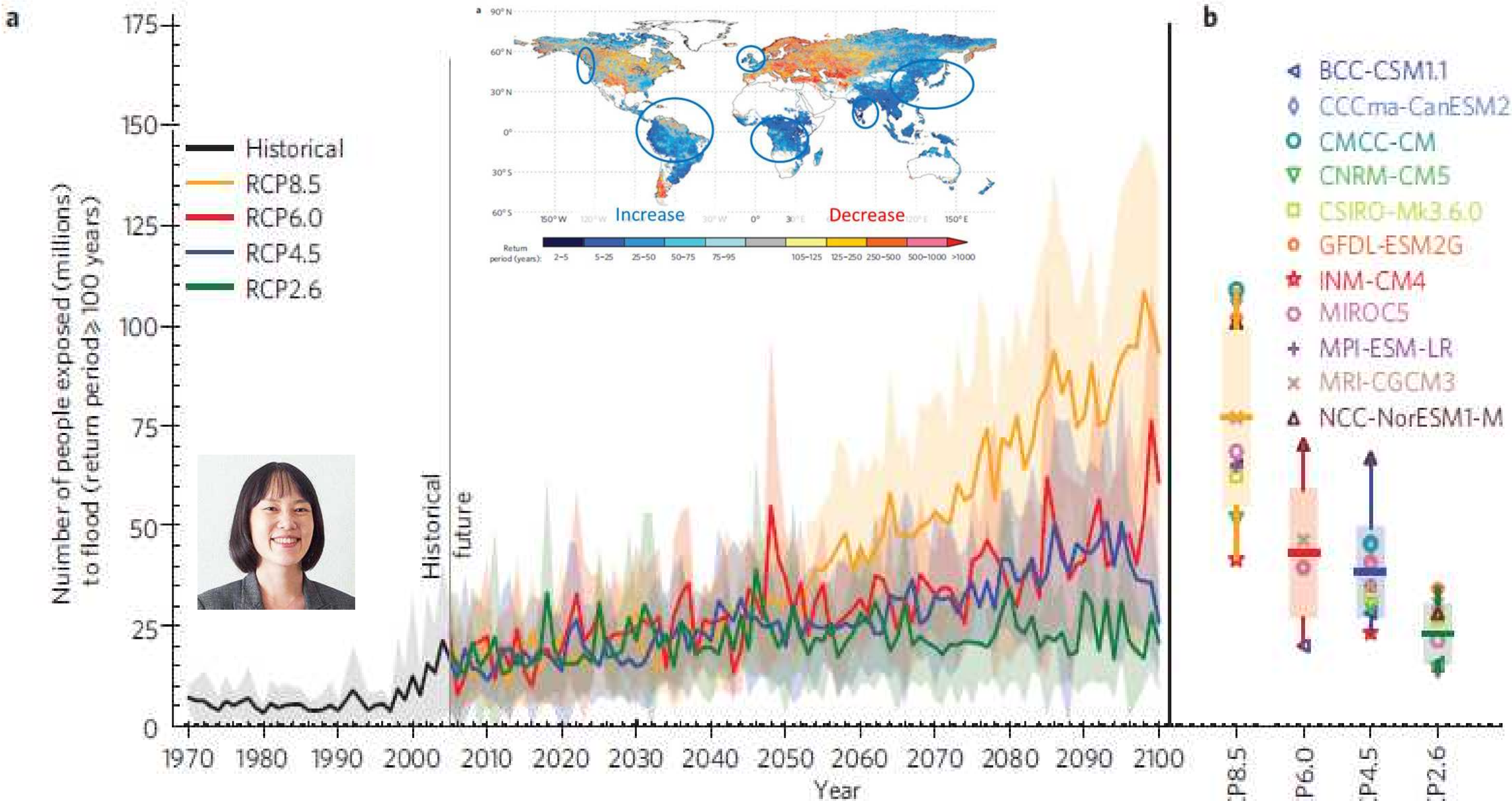
Top 1% rainfall v.s. Daily Temp.



(Utsumi et al., 2011, *GRL*)

(Hirabayashi **et al.**, *Nature Clim. Change*, 2013)

Number of people exposed to 1% flood in the 21st century with the threshold of the 20th century

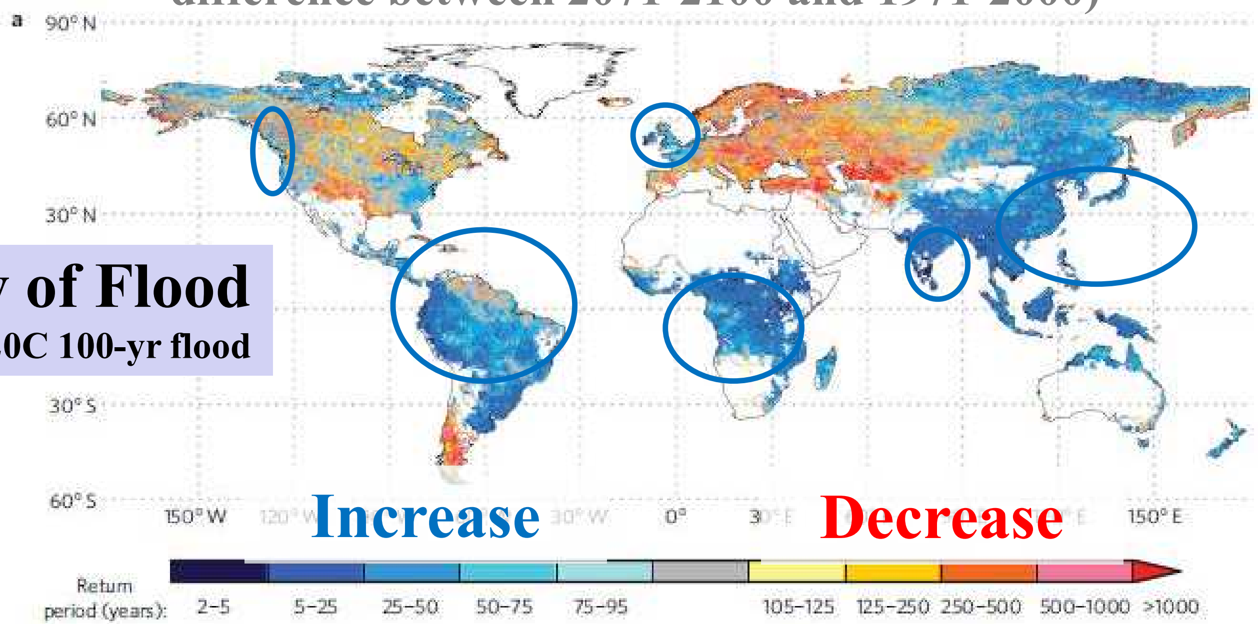


The ensemble means of the historical simulations (black thick line) and the future simulations for each scenario (coloured thick lines). The shading denotes the 1 s:d. b, The maximum and minimum range (whiskers), mean (horizontal thick lines within each bar), 1 s:d: (height of box) and individual values among AOGCMs (coloured markers within each bar) averaged over 21C

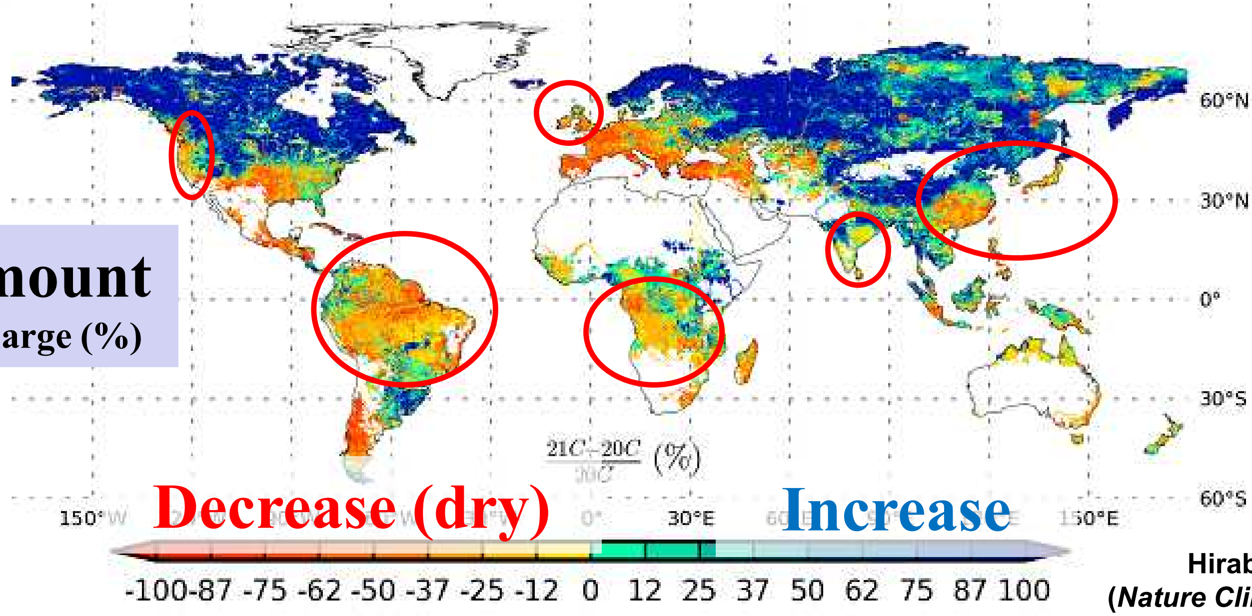
Future change in flood frequency and low flow

(Median of 11 GCMs under the extreme future scenario, RCP 8.5 difference between 2071-2100 and 1971-2000)

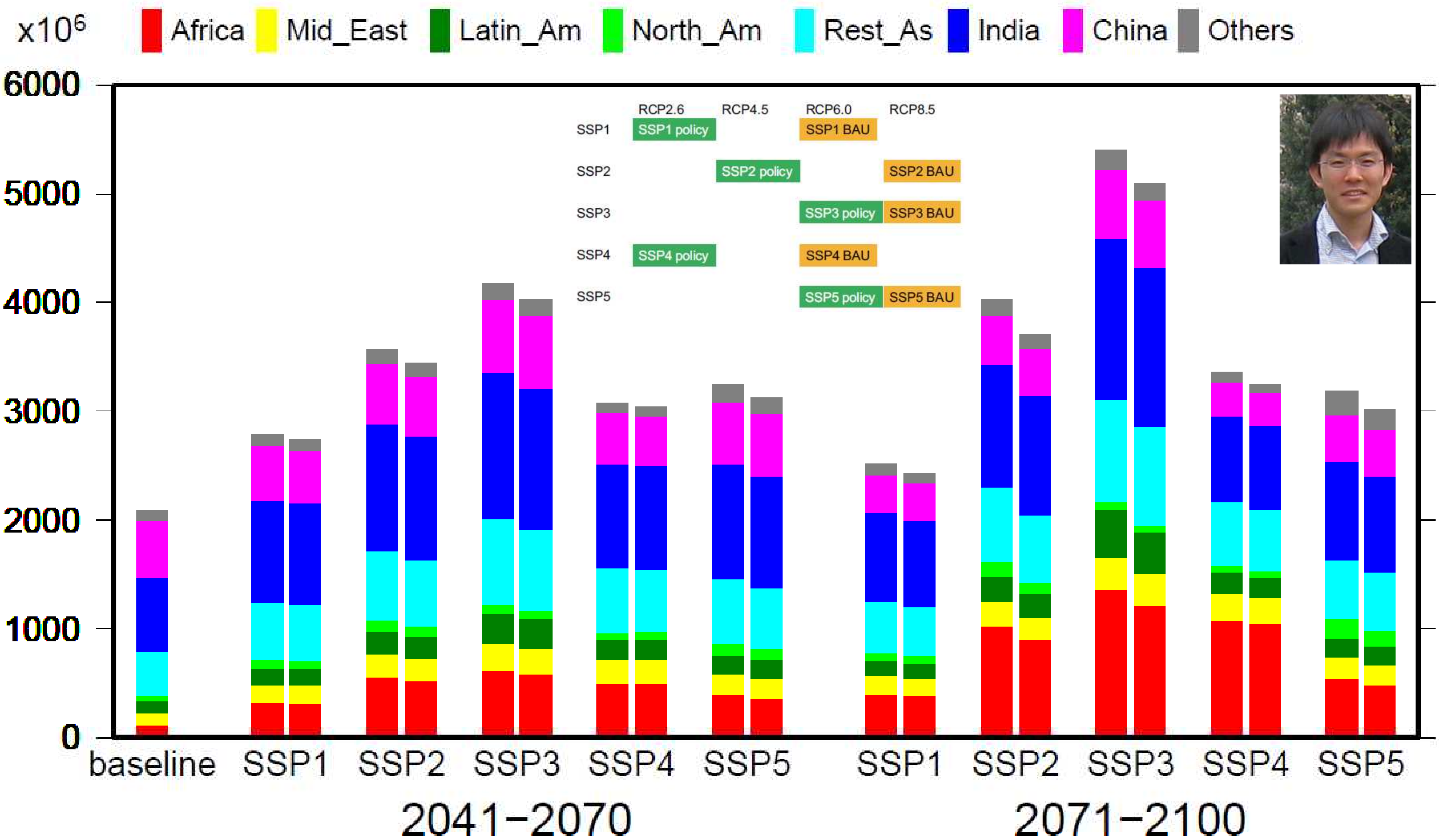
Frequency of Flood
return period of 20C 100-yr flood



Low flow amount
change in Q95 discharge (%)



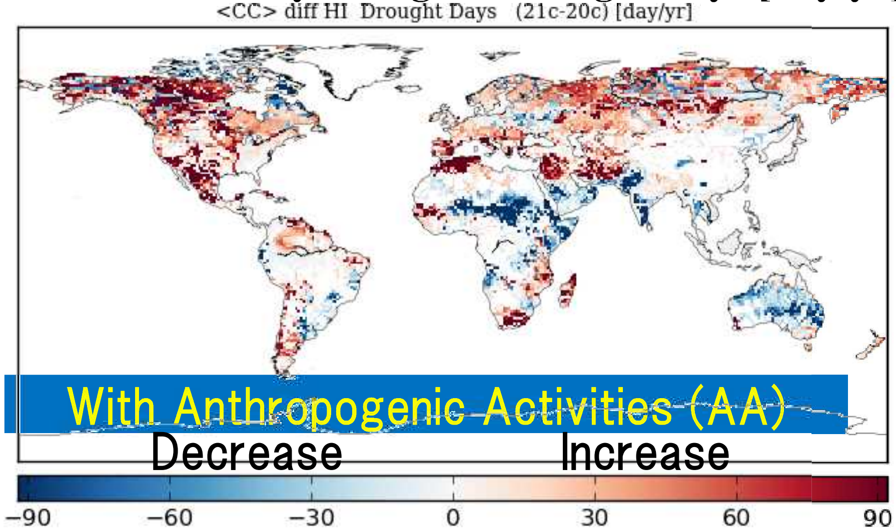
Hirabayashi et al.,
(*Nature Climate Change*, 2013)

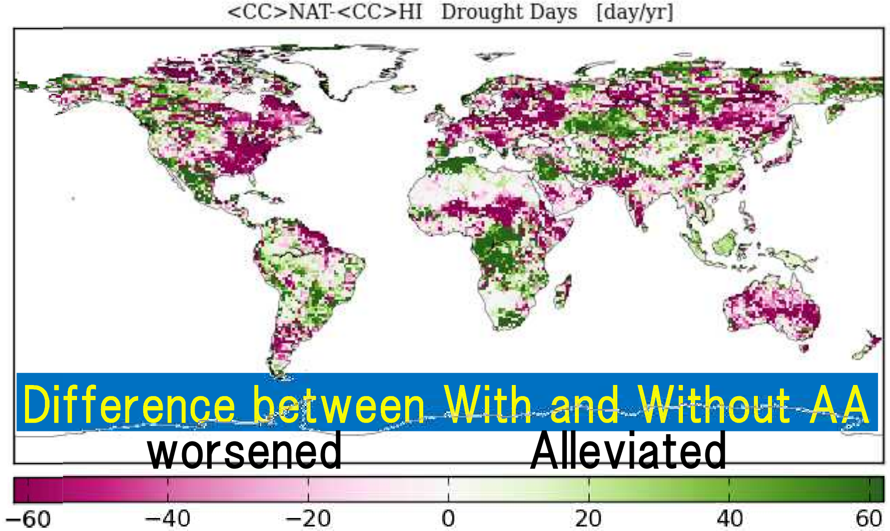


Region-wise total global population living in grid cells where CAD (Cumulative Abstraction to Demand) ratio <0.5. The bars on the left and right show the results of HUM-BAU (no climate policy) and HUM-Policy (with climate policy), respectively.

Impact of Climate Change on Low Flow

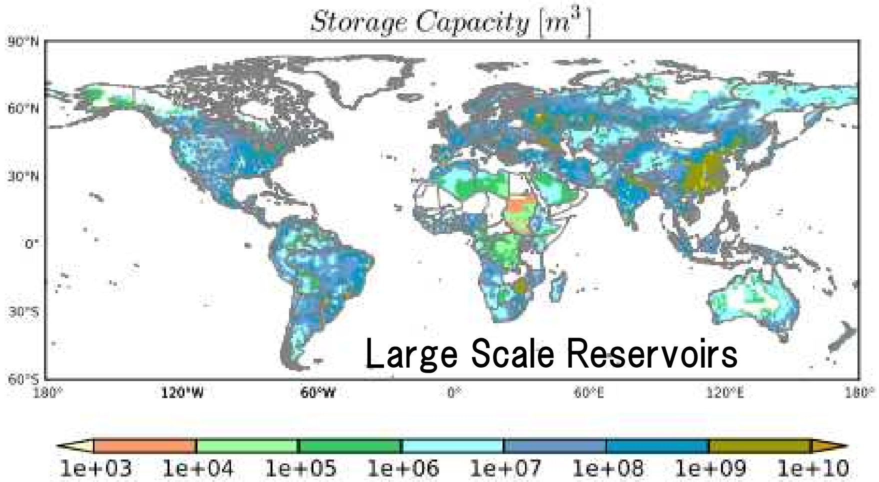
The number of hydrological drought days [day/yr]

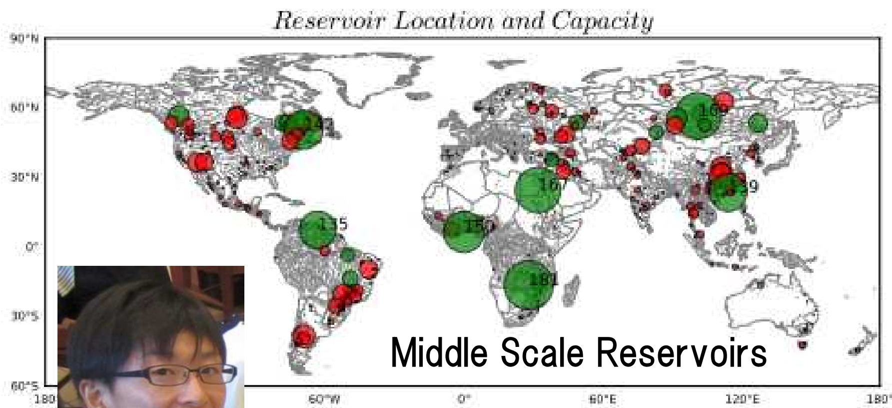




Changes in the Future (RCP8.5)
Days below Q90 in the 20th Century

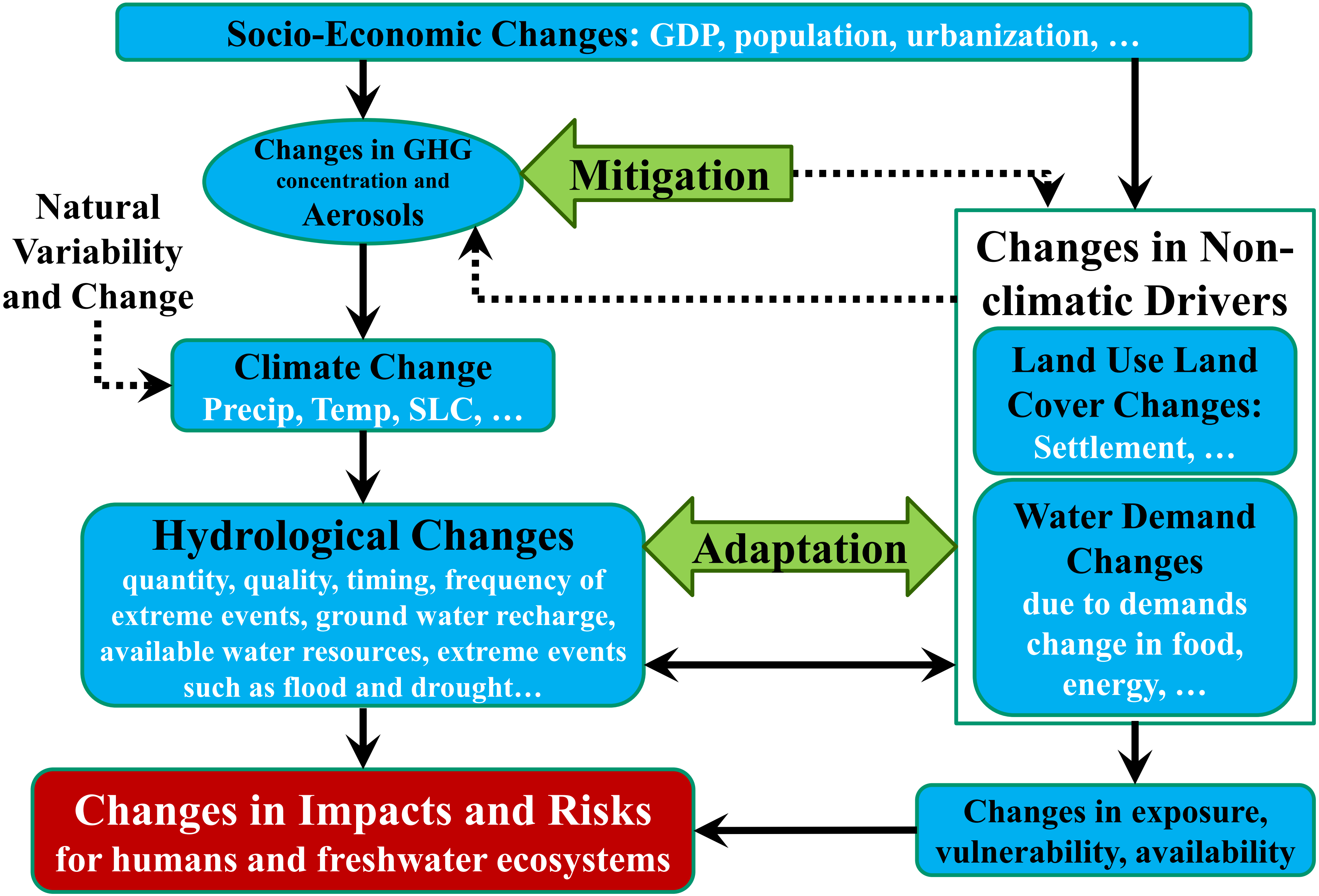
Drought days will be alleviated by reservoirs and worsened by withdrawal





[no GW limit] (Sato et al., in preparation)

“water is the delivering mechanism of climate change impacts”



Counter Measures against CC

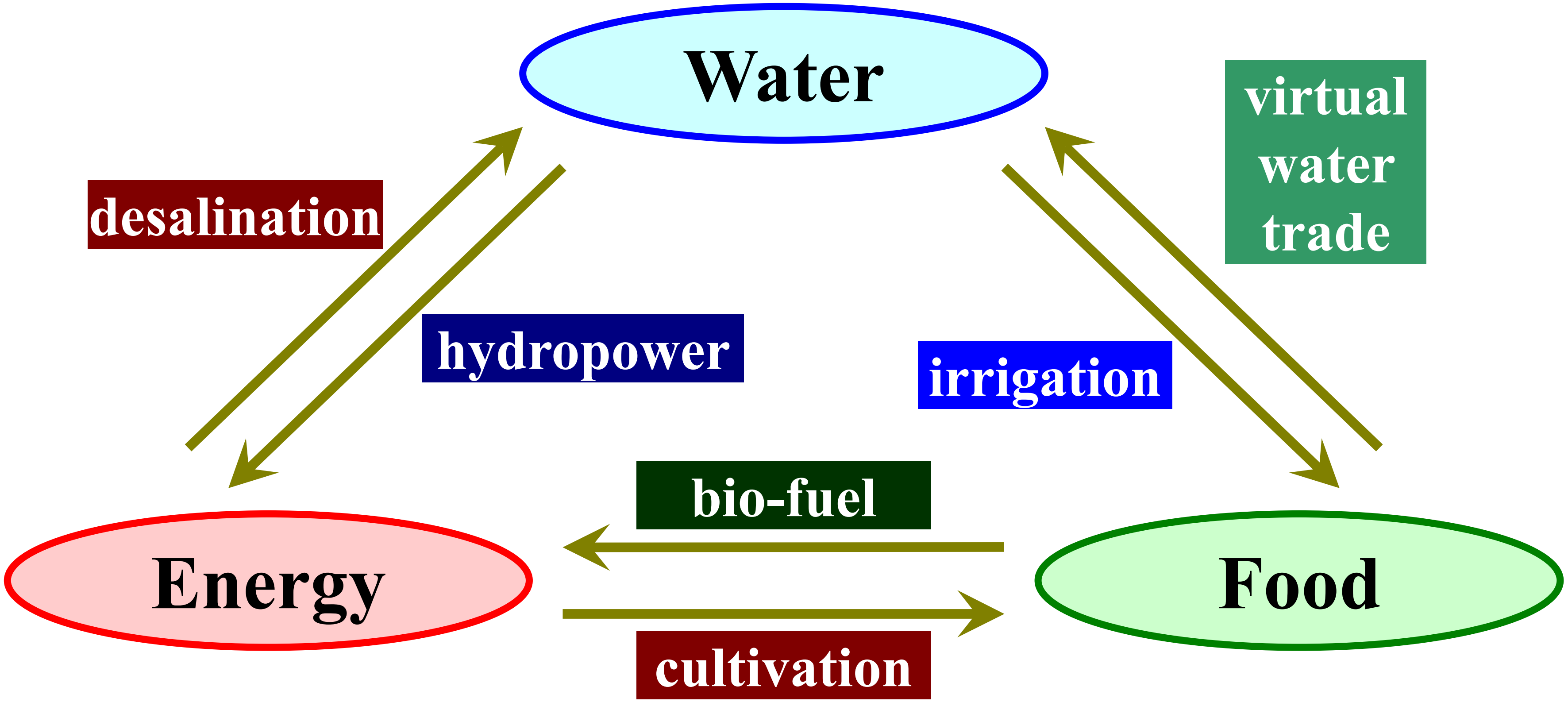
- Mitigation (slow down the speed of CC)
  - Reduce the emission of green house gases
  - Also good for energy saving, air pollution, energy security (⇔nuclear power), new industry (solar panel, eco-car, …)
- Adaptation (reduce disasters due to CC)
  - Enhance the resilience of the society
  - Also solves the existing social issues: poverty, vulnerabilities for natural disasters, sustainable energy, health, food and agriculture, ecosystem, transportation, …

DRM and CCA can be integrated.

Disaster Risk Management	Climate Change Adaptation
considers hazards other than those that are climate-derived, such as earthquakes and volcanoes	considers and addresses vulnerabilities related to phenomena that would not normally be classified as discrete disasters, such as gradual changes in precipitation, temperature, or sea level
civil defense agencies	environment ministries
bottom-up	top-down process
short-term	long-term

Develop sustainability in societies

- Water should not be dealt alone separated from food and energy. ←Limited Resources = "LAND"



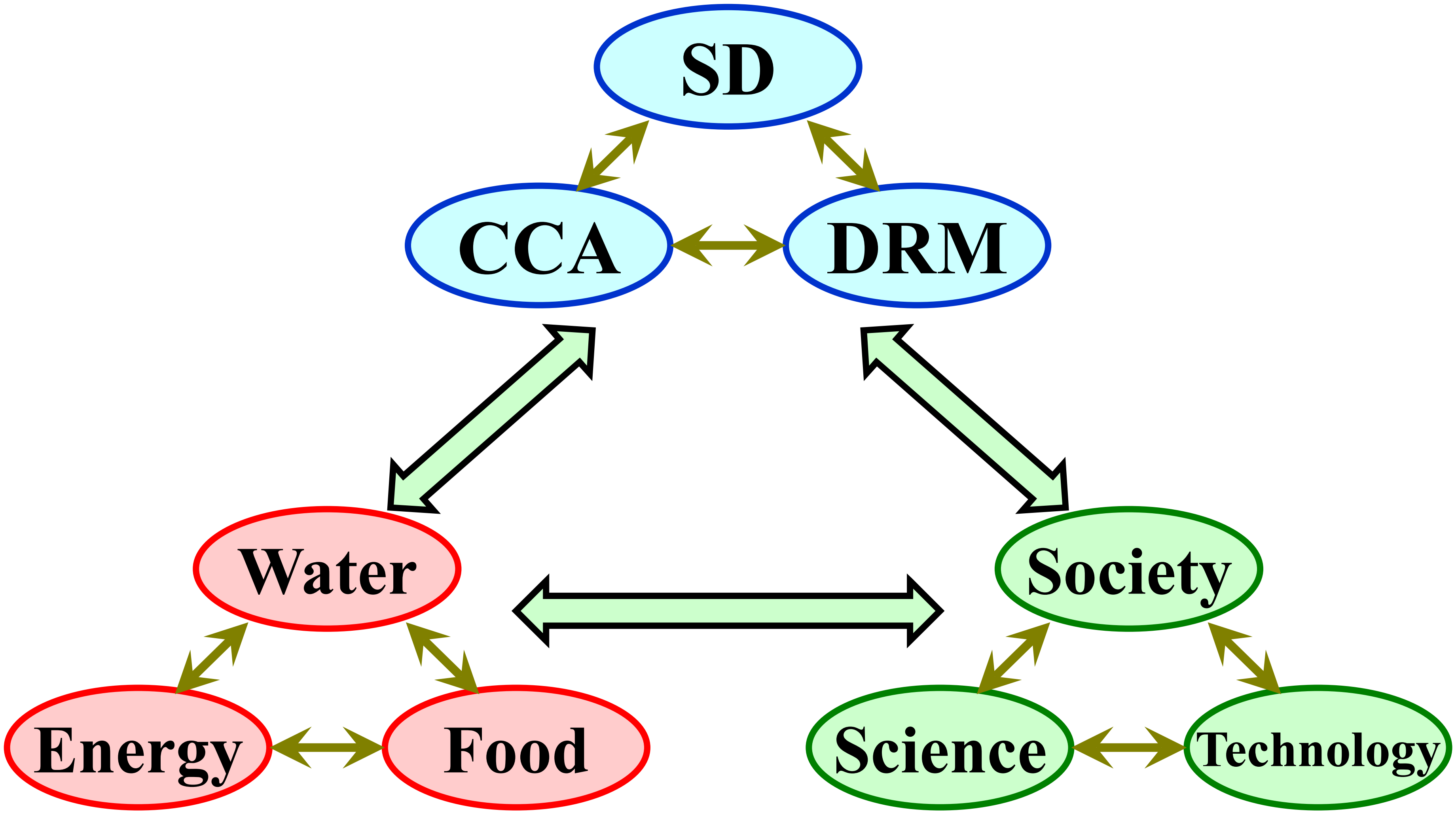
Remarks

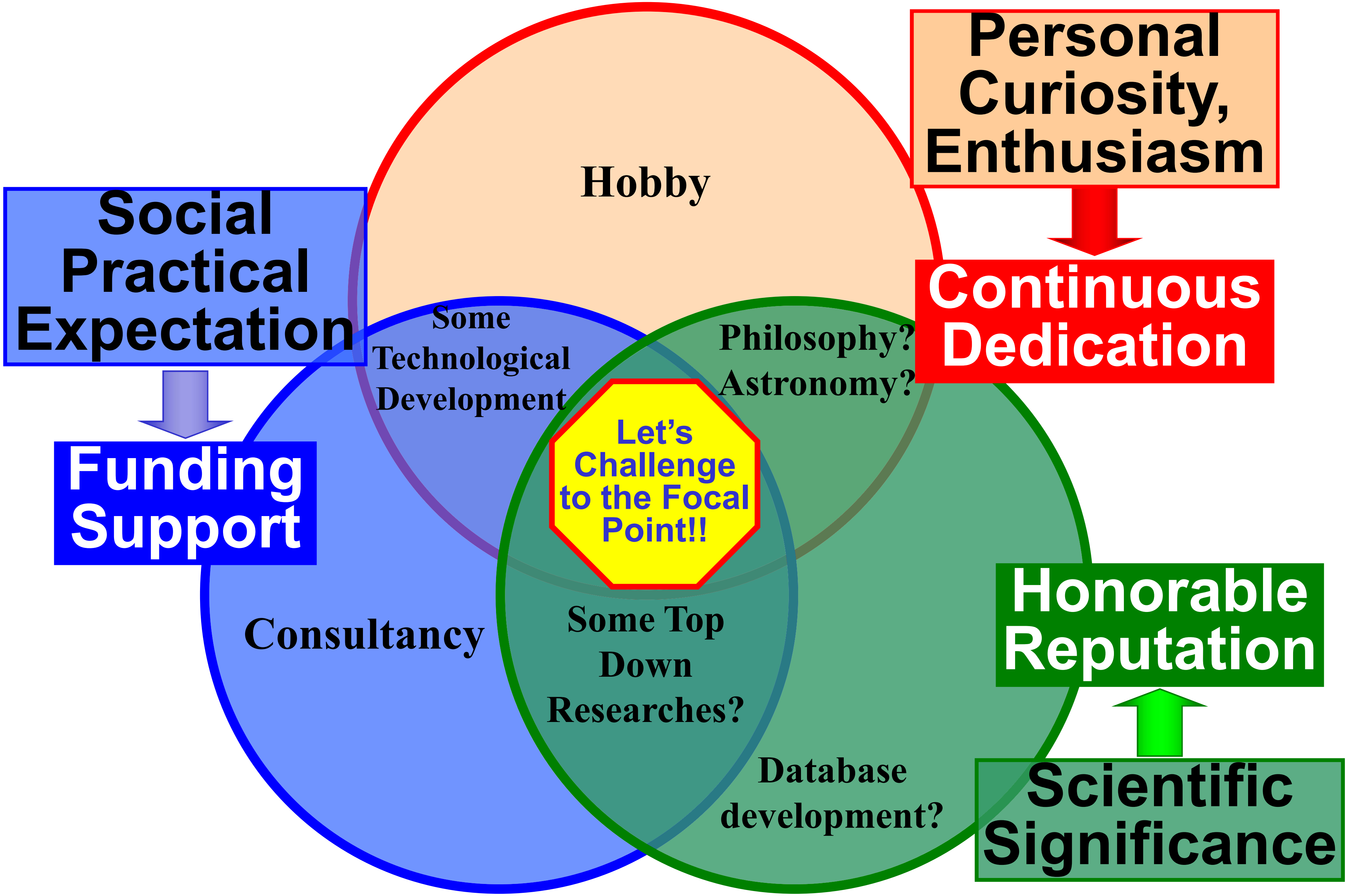
- Human beings are extensively altering hydrological cycles directly and indirectly.
  - Both climate change and social change will demand adaptation in the water management in the future.
- Science (observation, modeling, and prediction), technology (mitigation and adaptation), and social system should have intimate links.
- Disaster risk management (DRM) and climate change adaptation (CCA) should have synergy toward sustainability development (SD).

JST-NSERC Workshop on Sustainable Water Use

- Workshop is not a symposium nor a conference.
  - We have to develop friendship and mutual understandings.
  - For international collaboration under joint funding.
    - Seeds, tools, targets, and opportunities.
- Integration and synergy of wisdom from various discipline always trigger innovation.
  - In academic field, and in societies.

Hydrologists are integrators!!




Personal Curiosity, Enthusiasm
Continuous Dedication
Social Practical Expectation
Funding Support
Hobby
Some Technological Development
Philosophy? Astronomy?
Let's Challenge to the Focal Point!!
Consultancy
Some Top Down Researches?
Database development?
Honorable Reputation
Scientific Significance

Contacts for Topics

- Eutrophication of large lakes: Dr. Yachi
- Mercury issues: Dr. Asami
- PPCP: Dr. Furumai
- Climate Change: Dr. Kanae
- Cyanobacteria in Drinking Water: Dr. Asami
- Environmental Effects Monitoring: Dr. Furumai
- Sci & Eng. For Physical Habitat: Dr. Tsujimoto
- RES'EAU-WaterNET: Dr. Asami, Dr. Embutsu
- Canadian Aquatic invasive Species: Dr. Hayashi

Session 1 (1)

- **Dr. Mari Asami**
  - **Trends in drinking-water quality issues in Japan**
  - **Radioactive nuclides: I131 more than 300 Bq/kg**
  - **Perchlorate contamination (μg/L)and counter measures**
  - **Formaldehyde precursor contamination←870K people suffered.**
  - **Risk management of water supply**

Session 1 (2)

- **Prof. Madjid Mohseni**
  - **Community drinking water quality and treatment**
    - **Is there a place for advanced technologies? (For small communities)**
  - **On boil water and drinking water advisories**
  - **Innovative and integrated treatment processes**
  - **Water health assessment and monitoring**
  - **Risk management, compliance, and governance**
  - **disinfection, removal of organics & algal toxins/Effective and robust, little waste generation, chemical free, simple operation.**
  - **Ion exchange, UV based AOPs, electro-coagulation**
  - **Small community: 30 L/minutes $\Leftarrow$ 2 m^3/h=50 m^3/day=50 people.**

Session 1 (3)

- **Dr. Furumai**
- **Significance of rainwater and reclaimed water uses**
- **Watershed-based sustainable urban water use.**
  - **Rainwater harvesting and enhanced infiltration**
- **Water Quality evaluation of water resources in urban area**

Session 1 (4)

- **Overview of the research activities of the Canada research Chair in Source Water Protection, Sarah Dorner, Ph.D**
- **Adaptation to global change, urban source water protection, …**
- **North American Great Lakes Basin: more than 1 million km2, 40 million people.**
- **90 combined sewer overflow to the river for water source**
- **"Cows don't drink coffee."**
- **A leaky sewer**
- **Spring snowmelt**
- **CSO**

Session 1 (5)

- Shinjiro Kanae
- Future flood and food risks under climate change + some more potential applications of global water cycle modeling
- IPCC WG2: temperature rise v.s. impacts and adaptation
- NCC 2013: flood and drought
- CaMa-Flood
- Food, under-nutrition, …, DALYs (Murray et al., 1996)
- Diarrhea, Malaria, respiratory infections, …
- Bioenergy potential
- Glaciers, nitrogen cycling, …

Session 1 (6)

- Prof. Graham Gagnon, Civil and Resource Engineering, Dalhousie
- Water quality and treatment: A research perspective from Atlantic Canada
  - Drinking water plant optimization
  - Maintaining water quality during distribution
  - Maximizing the environmental sustainability of drinking water treatment plant operations
- Hydrophilic NOM (non-organic material)
  - Membrane separation
  - THMs (tri-halo-methane)
  - Bio-filtration at full-scale
- Water and wastewater research in Canada's North Nunavut, Canada

Session 2 (7)

- Ichiro EMBUTSU, Hitachi Research Laboratory
- Water treatment systems for safe and secure water use
- Water Business
- Hitachi's R and D activities on Water
- Water Market in Japan: 50 billion US$/year
- Desalination RO unit, MBR system pump, …
- Water HACCP (ISO), bio-assay for Toxicant, satellite monitoring, CFD simulation, wastes treatment, ICT, flood control, …
- Quick Bird, SPOT, Landsat, …
- Intelligent Water System: IWS: demand forecasting, production planning, and distribution control ➔ safe, secure and energy savin

Session 2 (8)

- Shinjiro Yano
- Natural Water Sanctuaries, Rich in Biodiversity
- Founded in 1899. In Harmony with people and Nature. Bringing happiness into lives by alcoholic and soft drinks.
- Water neutral : accomplished in 2011. 7,600 ha in 17 areas.
  - Natural recharge of ground water in forests
- Natural water sanctuary project
  - Ecological pyramid and groundwater pyramid
  - Forest soil management. Thinning, reforestation → organic A-zone
  - Groundwater flow simulation
- Groundwater recharge in paddy fields → improve biodiversity
- 1 million US$/year in investment

Session 3 (9)

- Hugh J. MacIsaac
- Areas where current Japanese and Canadian engineering and science are strong and complementary (Venn Diagram)?
- Do these areas of mutual expertise correspond with societal needs?
  - What are the needs?
  - How many people are impacted? Mode of impact?
  - Does it affect economy or industry?
  - How severe is the need? Can it be solved without joint collaborations?
- Funding from Canada will likely require an approach dependent on joint collaborations, …
- NSERC CAISN II (2011-2015) Research Themes
  - Early detection and identification of AIS, rapid response to new AIS, AIS as part of multiple stressors, reducing uncertainty in management of AIS

Session 3 (10)

- **Linking exposure and effects in Assessing risk of aquatic contaminants to Fish by Dr. Natacha Hogan, Assistant Professor**
- **Pulp and paper, oil sands mining, municipal waste water**
- **Aquatic toxicology, contaminant risk, in vivo/vitro studies**
- **Clearer understanding of modes of action associated with complex mixtures.**

Session 3 (11)

- Steven Cooke, Professor, Carleton University, Canada
- Ecology of Stress in Wild Fish: fundamental and applied perspectives. Marine/freshwater fish.
- Hobby "I love fish" - Fish are integrators of environmental system.
- Why do some salmon die before reaching spawning grounds?
  - River-captured fish had lower survival probability.

Session 3 (12)

- **Hironori Hayashi, Assistant Professor, Kyushu University**
- **Stream restoration project in Kami-saigo river**
- **Flood control, natural environment, and water use should be integrated. Resident's participation, local approach are important.**

Session 3 (13)

- Joanna Wilson, Assoc. Professor, McMaster University, Montreal
- Aquatic biology @ McMaster
  - Environmental physiologists, fish behavior, ecology and evolution
  - Cytochrome P450 Enzymes, evolution, function, expression
  - Aquatic toxicology: PPCPs, ..
- Environmental exposures complex, cellular response pathways may intersect, mixture interactions difficult to predict, pharmaceutical research, temperature research.
- Genes ➔ Cells ➔ Organs ➔ Systems ➔ Organisms
  - Multi-disciplinary. Field and laboratory based. Mechanistic perspective.
  - Compounds, doses, exposures.
- "Team Whitefish"

Session 3 (14)

- Modeling river temperatures and Modeling a river revisited: to refurbish or remove a large dam by Allen Curry, Canadian Rivers Institute, University of New Brunswick.
- Road density, stream density, ...
- Mactaquac Dam (MD) will reach its full life epectancy by 2030.

Session 3 (15)

- Prof. Tetsuro Tsujimoto, Professor, Nagoya University
- Development of Eco-hydraulics and …
- Physical basement, biological aspect, and material cycles
- Ecology and civil engineering
- Hydrology, hydraulics, and geomorphology…
- Fluvial hydraulics, mechanics of sediment, flow with vegetation, …
- Evaluation of ecosystem function “ecosystem services”
- Contribution to IPBES

Session 3 (16)

- Aquatic ecosystem responses to changing nutrients…
- Global Institute for Water Security
  - Climate change, climate variability and ecosystem function
  - Land-water management and environmental change: urbanization, …
  - Sustainable development of natural resources, …
- Global biogeochemical cycles

Session 2 (17)

- Shigeo Yachi, Associate Professor, Kyoto University
- Hierarchical watershed management – bridging the stakeholders dispersed over the different spatial levels.
- Community is only a part of watershed.
- Rule/governance
- Irrigation system change.
- No pond for controlling turbidity.
- Sediment into lake is illegal in Canada.

Opportunities?

- Alleviate CSO (Combined Sewage Outflow) in urban areas
- Aquatic toxicology: quality + temperature, sediments, …
- Comparative study how to secure safe drinking water supplies
  - Risk management strategy, high-tech counter measures, …
- Multiple anthropogenic stressors on aquatic eco-systems/water
  - LULC Changes, social and climate changes, …
- Impacts of multiple stressors on:
  - Sustainable water supply, water (+food & energy) security, …
  - Restoration and conservation of river environment, …
  - Wild fish, recreational fishing
- Communicating water environment/“healthy river” with public
  - Refurbish or remove dams – environmental flows/controlled flooding, …
- Transferring technology and wisdom on water to developing world.

International Collaborations

- **Exchange ideas, views, scholars…**
- **Sharing common targets, motivations, tools, datasets, observational sites, numerical models, knowledge, …**
- **For example,**
  - **Joint case study in Canadian/Japanese lakes/watersheds?**
  - **Comparative study on watershed managements?**
  - **Joint summer school on water security?**
- **Needs social scientists (?) ← Belmont Forum**

Discussions (1)

- <u>Joint efforts by ecologists and engineers</u>
- Solution oriented approach
  - Scale issues: temporal, spatial
- Specific versus general approaches
  - Best practices in watershed management
- Threshold study of silt and sediment on fish
  - Turbidity, pH, temperature, oxygen, shading, feeding, …
- Dams/reservoirs
  - Flow management, removal, …
- Water source protection/conservation. Regulation issues.

Discussions (2)

- **Water quality at the outlet from waste water plant should be monitored and criteria should be examined/revised.**
- **Urban water management**
- **Practical use of developed technology.**
  - **Solution technologies can be developed for sharp issues**
- **Comparative study**
  - **Lake Biwa and Canadian Lake cases. ← gigantic engineering**
  - **Governance issues and/or management systems as well.**
  - **Understanding the water use/management in paddy fields.**
  - **Different states have different ways of management in Canada.**

Discussions (3)

- Impacts of Geo-engineering (as mitigation of climate change) on water.
  - Impacts of producing oil sand & biofuel crops on water.
- Communication design among stakeholders.
- Ecology side and engineering side 2.5 hour on the 2nd day to develop possible collaborations.
  - Identify the “Big Picture” (good questions and ideas) first, then think about the comparative advantages.

Discussions (4)

- **Need to identify a few to several topics with higher priorities in the "sustainable water use" research.**
- **Requires integration and synergy among possible future projects under the joint call.**
- **Other tools/issues**
  - **Stable isotopes**
  - **Point source *v.s.* non point source**
  - **Empirical numerical models ⇔ physically based models**
    - **Enable to develop more universally applicable prediction tool.**

Discussions?!