International Conference on Science and Technology for Sustainability
Building up Regional to Global Sustainability: Asia vision,
13-16 September 2011

Water Footprinting for Sustainable Development and Wise Management of Global Water

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**special thanks to
Drs. Naota Hanasaki (NIES) and Yadu Pokhrel**

Introduction

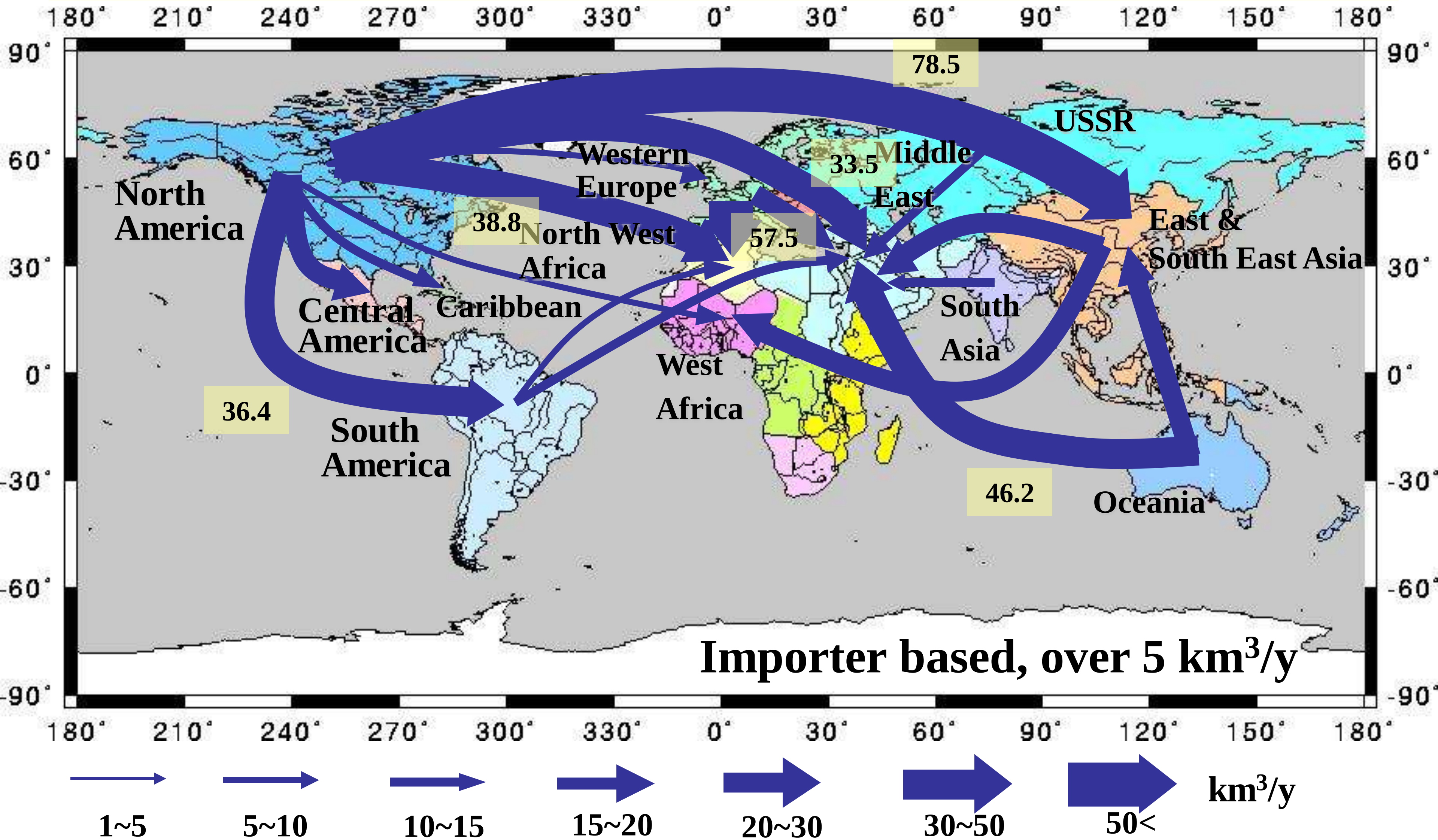
- **Worked for:**
  - **WCRP/GEWEX/GAME/GAME-Tropics**
  - **Research Institute for Humanity and Nature**
  - **Global Water System Project**
  - **LA for IPCC AR4/TP on Water/SREX, CA for MA**
  - **3rd Science and Technology Policy Plan, CSTP, Japan**
- **Currently working for:**
  - **IPCC AR5/WGII/Ch3 CLA**
  - **Task force for UNESCO IHP VIII**
  - **WCRP OSC Papers on Water/Land**
  - **ISO/TC207/SC5/WG8 “Water Footprint”**

Required Water for Fast Food

Beef Bowl	Hamburger Sandwich	Hamburger Sandwich	Buckwheat noodle	Pasta (Udon)
Regular JY280	2 regular Small Fries JY268	Teriyaki Burger Regular Fries JY430	With Egg JY300	Plain JY290
710kcal	745kcal	911kcal	377kcal	341kcal
1890L	2020L	530L	750L	120L

(M. Sato, 2003, Thesis, The Univ. of Tokyo.)

"Virtually Required Water" Trade between Regions in 2000 (cereals only)



(Oki, et. al, 2004)

(Based on Statistics from FAO etc., for 2000)

Can we quantify water withdrawals by sources?

- **The source of evapotranspiration**
  - **Precipitation**
  - **Irrigation water**
    - **Stream flow**
    - **Reservoirs and ponds**
    - **Renewable groundwater**
    - **Fossil groundwater**

Low environmental impact
Sustainable
Low opportunity cost

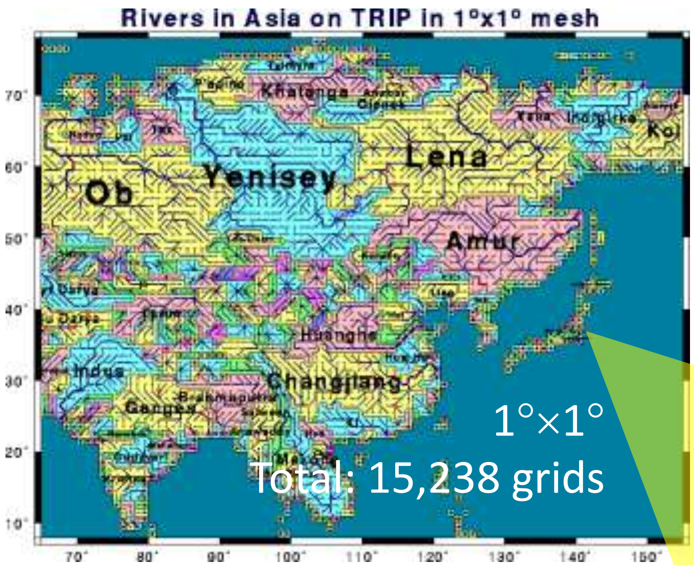
High environmental impact
Less-sustainable
High opportunity cost

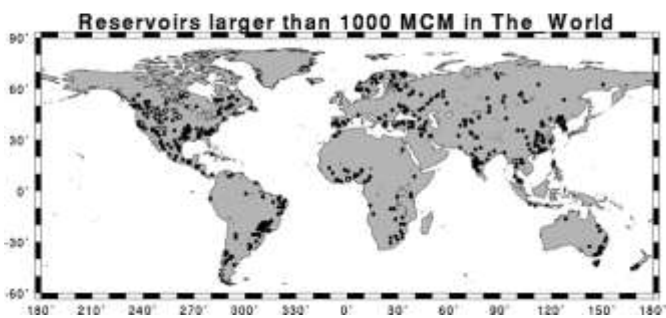
model

Step 1

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

Global water resources model H08

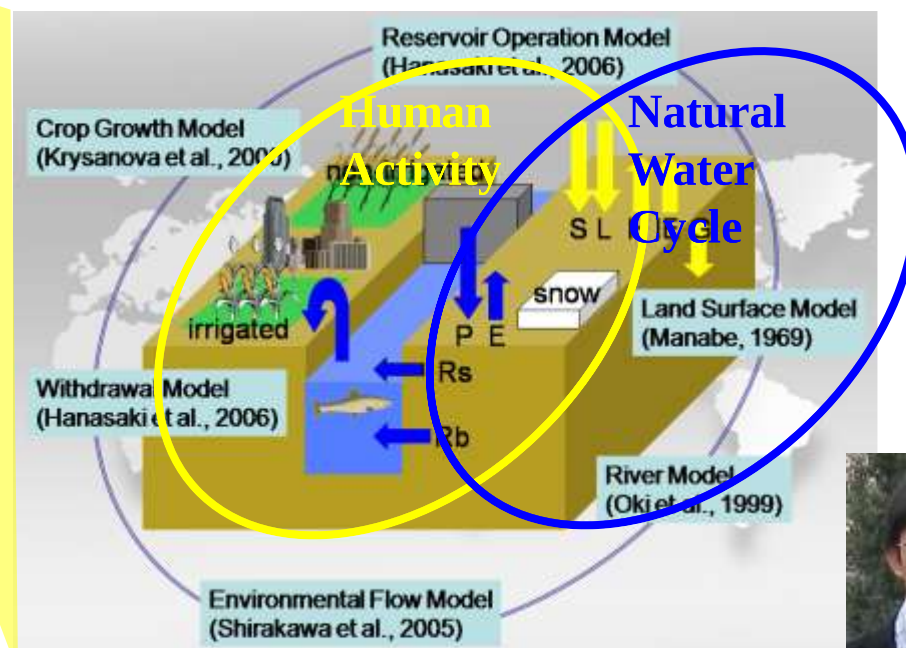




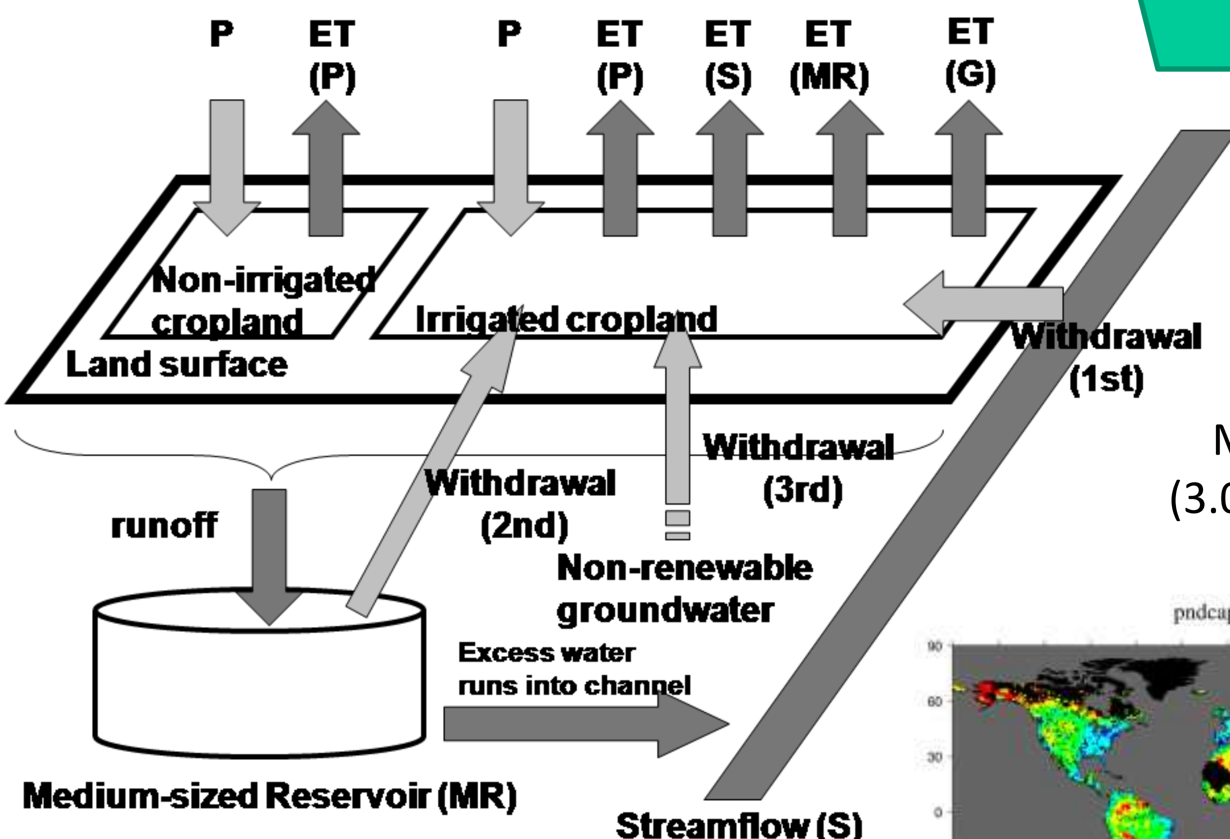
452 reservoirs, 4140 km^3

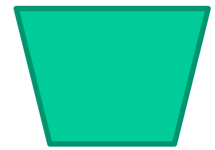
•Requirements

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



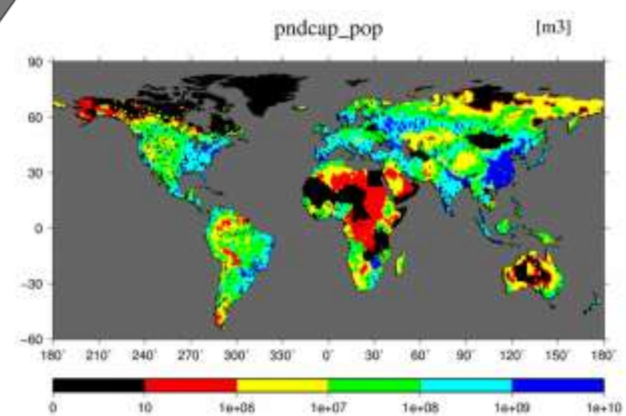
Enhancement of the H08 model





Large reservoirs
($1.0 \times 10^9 m^3 \leq S$)
$4140 km^3$

Medium-sized reservoirs
($3.0 \times 10^6 m^3 \leq S < 1.0 \times 10^9 m^3$)
$3280 km^3$



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

Results 1: Green water*

(*evapotranspiration originates from precipitation in cropland)

Unit：km^3/yr	This study	Molden (2007)	Falkenmark and Rockström (2004)
ET from cropland	7650	7130	6800
ET from non-irrigated cropland (green)	5080	4910	5000
ET from irrigated cropland (green)	1220	650	
ET from irrigated cropland (blue)	1350	1570	1800

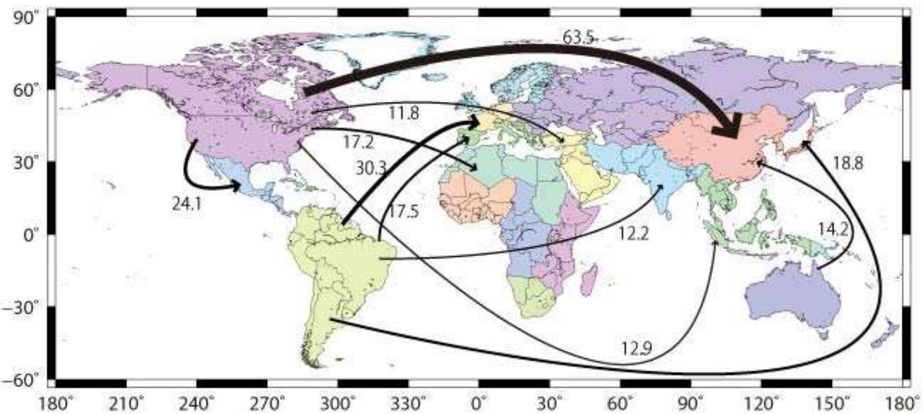
Direct simulation of ET

$$\frac{\text{Yield per area}}{\text{Water use efficiency}} = \text{ET}$$

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

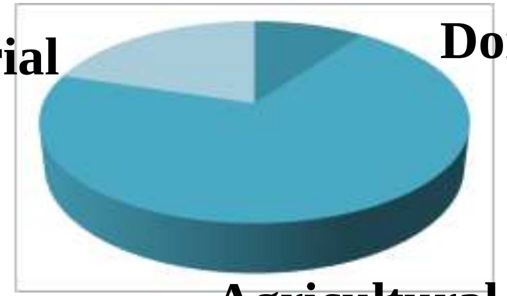
Global flows of virtual water export

Virtual water export (total)



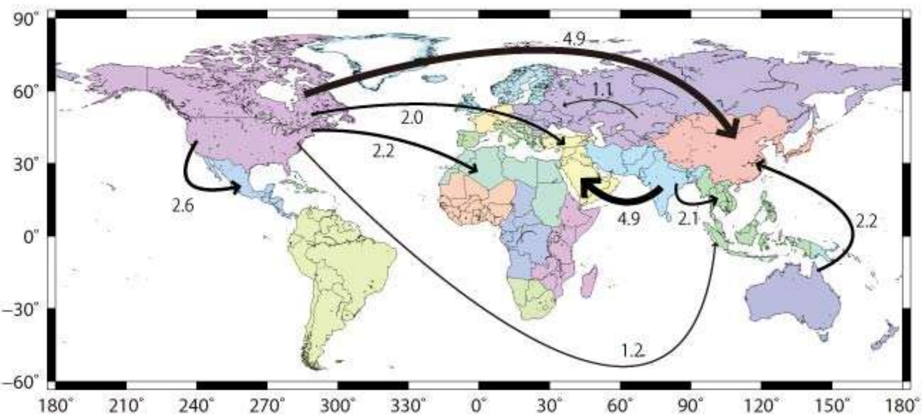
Total 545km³ yr⁻¹

Total water withdrawal : 3,800km³yr⁻¹



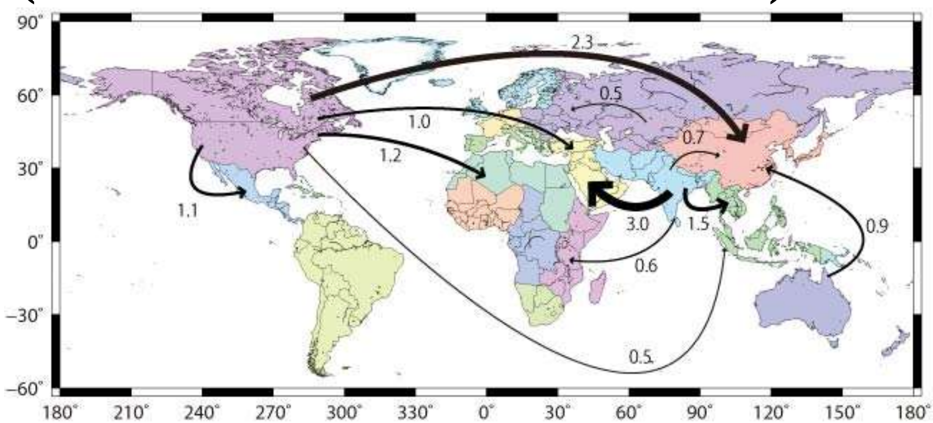
Shiklomanov, 2000

Virtual water export (irrigation)



Total 61km³ yr⁻¹

Virtual water export
(Nonlocal/Nonrenewable Blue Water)



Total 26km³ yr⁻¹

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

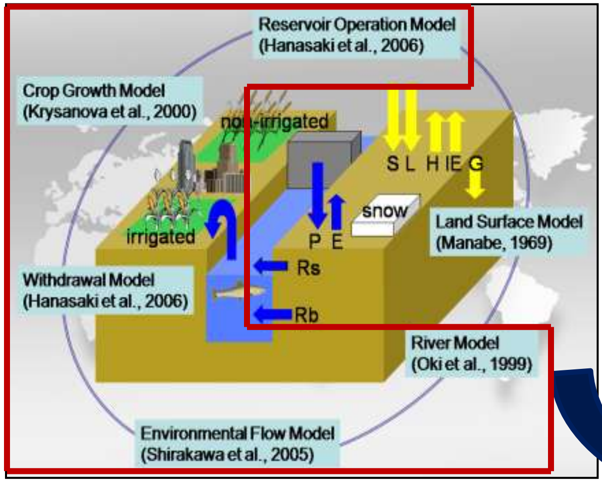
model

Step 2

MODELS: MATSIRO & H08

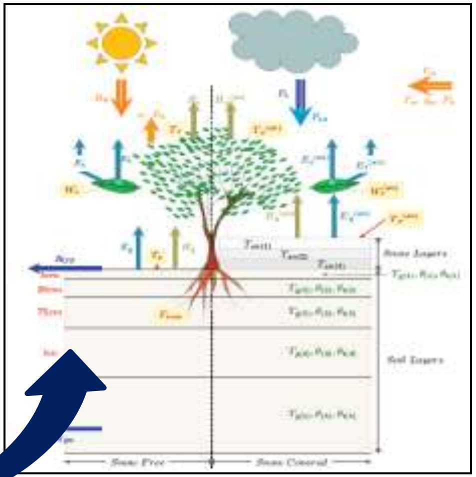
- ☑ Land Surface Models (LSMs) are designed to be coupled with GCMs
  - No Human Impacts (HI) representation
- ☑ Numerous Global Hydrological Models (GHMs) with HI representation exist, but
  - Mostly designed for **offline simulations**
  - Simple ET parameterizations (**energy balance not considered**)
  - Vegetation dynamics/Carbon cycle not accounted

H08: *Hanasaki et al. (2008a, 2008b)*



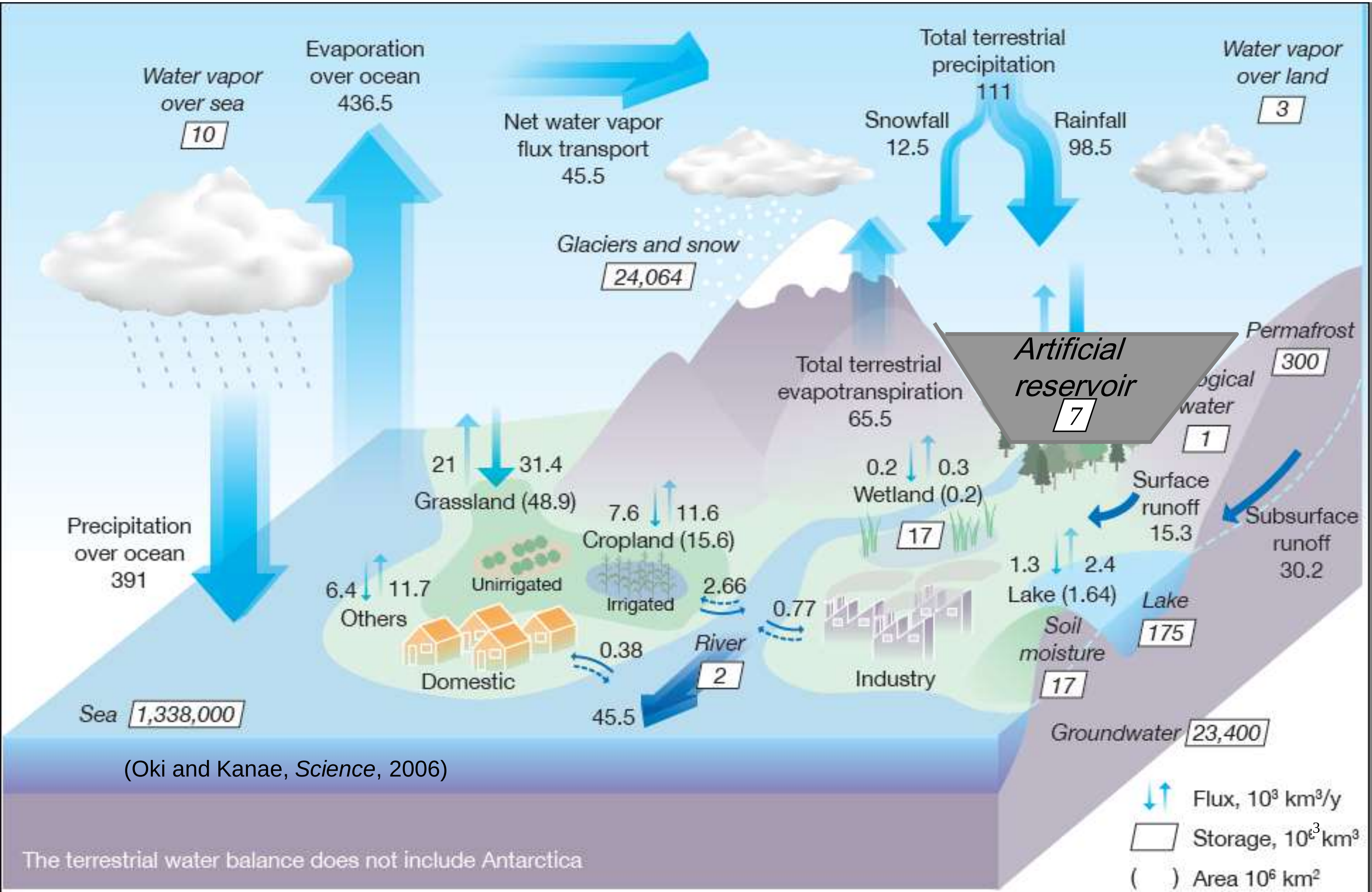
- ✓ Land surface hydrology scheme is a simple **Bucket Model**
- ✓ **Vegetation** : accounted implicitly

MATSIRO: *Takata et al. (20003)*



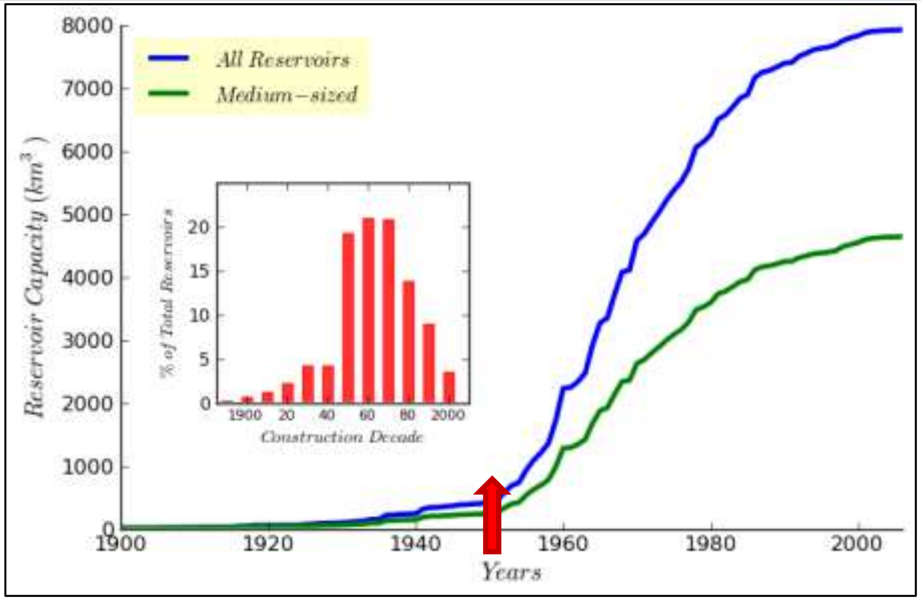
- ✓ **Further, new irrigation scheme for MATSIRO LSM is developed**
- ✓ **Water table dynamics and a newly developed pumping scheme**

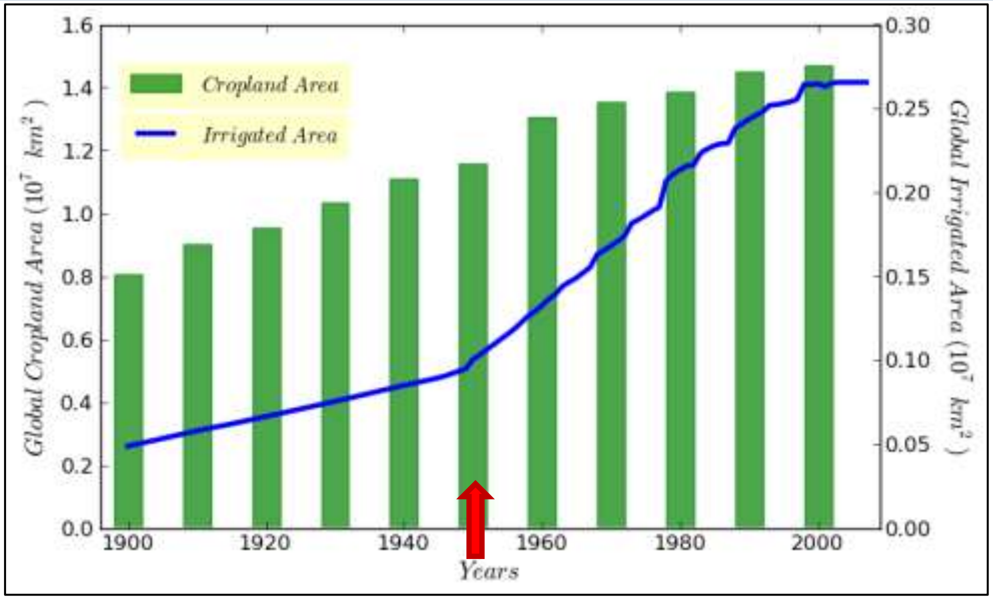
Synthesized Global Water Cycle



(Oki and Kanae, *Science*, 2006)

Historical Reservoir Storage & Irrigated Areas





- ☑ Reservoir storage and irrigated areas largely increased from 1950s
- ☑ 1950—2000 simulation is conducted:
  - Simulations: **MAT-NAT-NCC** (no HI), **MAT-HI-NCC** (with HI)
  - Forcing data: **NCC** (Ngo-Duc et al., 2005)
  - Historical Reservoirs/Land Use Change/Irrigated Areas Data:
    - ✓ Compiled from various sources: time-varying gridded datasets