Toward AR5: Activity of global water resources model H08

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NIES

Outline

- Global water resources model: H08
- Activities toward IPCC/AR5
  1. Global water scarcity assessment
  2. ~~Impact/adaptation study o~~f Thailand
  3. ~~Global integrated assessm~~ent
  4. ~~Multi-model simulation of~~ CC impact on global hydrological cycle
- Other activity
  - Global virtual water assessment

Application 1:
Global water scarcity assessment

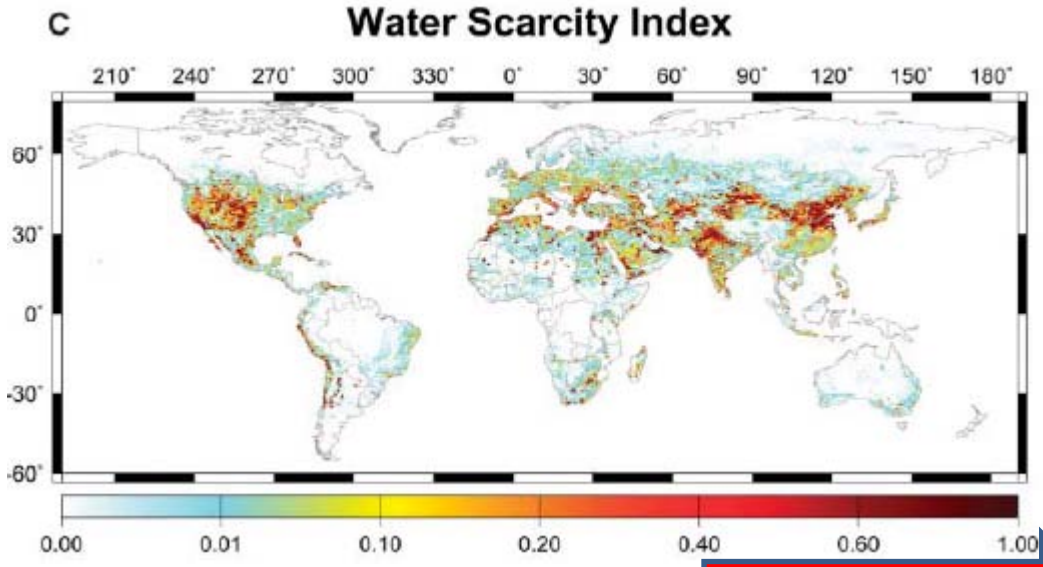
- Hanasaki, N., S. Kanae, T. Oki, K. Masuda, K. Motoya, N. Shirakawa, Y. Shen, and K. Tanaka (2008), An integrated model for the assessment of global water resources - Part 1: Model description and input meteorological forcing, *Hydrol. Earth Syst. Sci., 12, 1007-1025.*

- Hanasaki, N., S. Kanae, T. Oki, K. Masuda, K. Motoya, N. Shirakawa, Y. Shen, and K. Tanaka (2008), An integrated model for the assessment of global water resources - Part 2: Applications and assessments, *Hydrol. Earth Syst. Sci., 12, 1027-1037.*

Water scarcity assessment

- Several indices have been proposed to quantify regional water scarcity.

$$\text{Water scarcity index} = \frac{\text{Mean annual water withdrawal (water use)}}{\text{Mean annual runoff (water availability)}}$$



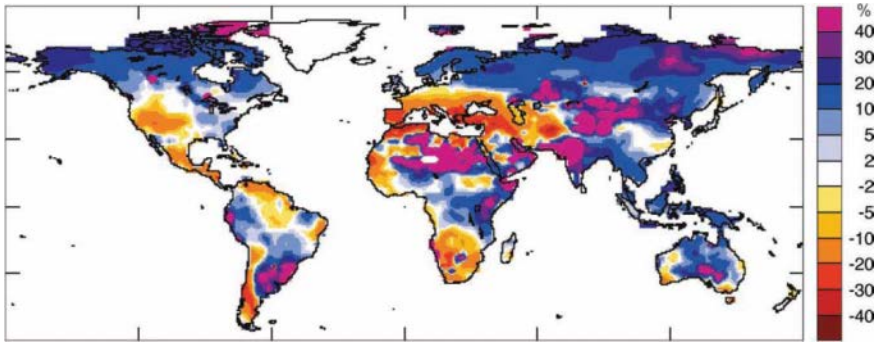
Oki and Kanae, 2006, Science

High water stress

Projection of water scarcity in future

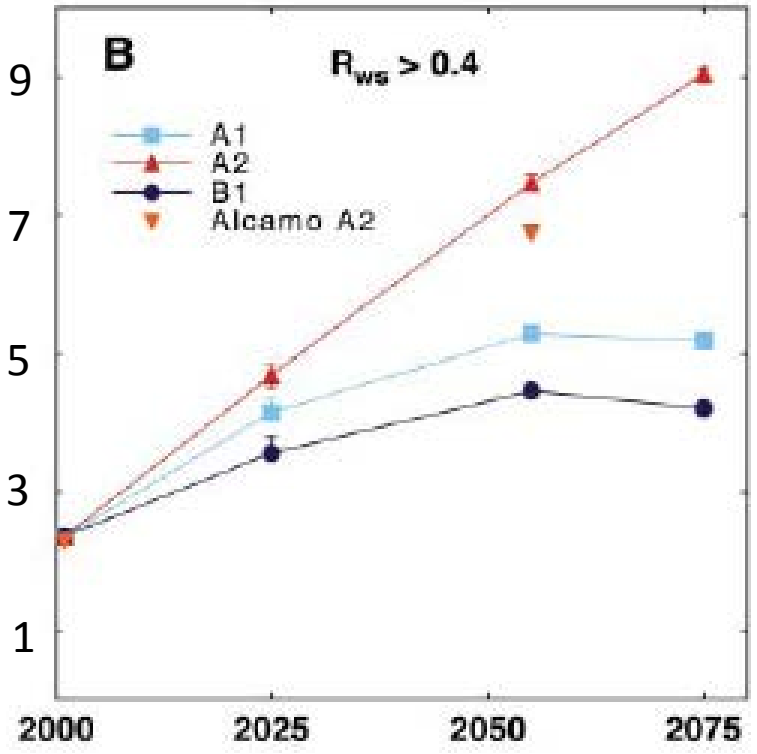
Use of statistical (regression) models
-Population scenario
-Economic scenario

Mean annual water withdrawal
Mean annual runoff



Milly et al., 2005, Nature

Population under high water stress (billion)

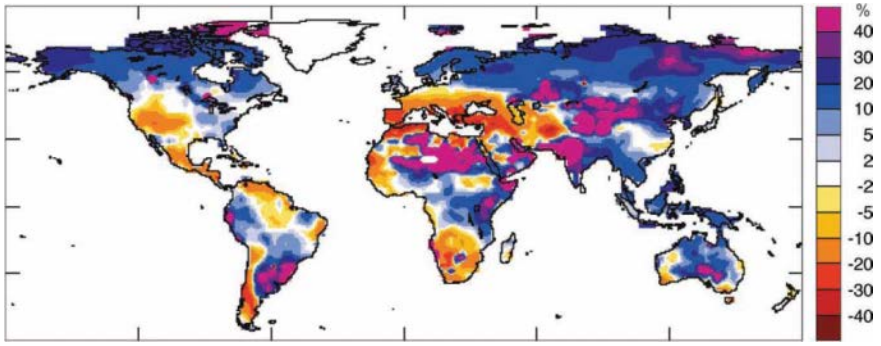


Oki and Kanae, 2006, Science

Impact of climate change on water cycle

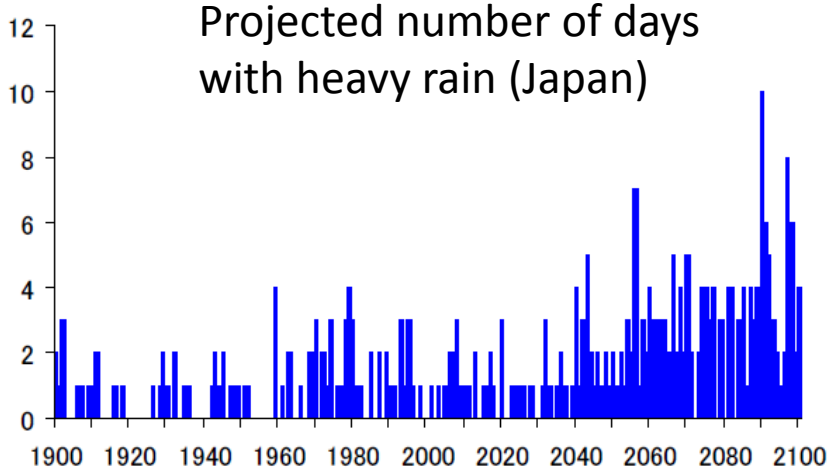
- IPCC AR4/WG2/Ch3
  - Change in annual precipitation/runoff
  - Change in precipitation intensity（強度）/frequency（頻度）
  - Decrease of snowfall, shift of snowmelt season

Projected change in annual runoff by 2041-60 relative to 1900-70



Milly et al., 2005, Nature

Projected number of days with heavy rain (Japan)



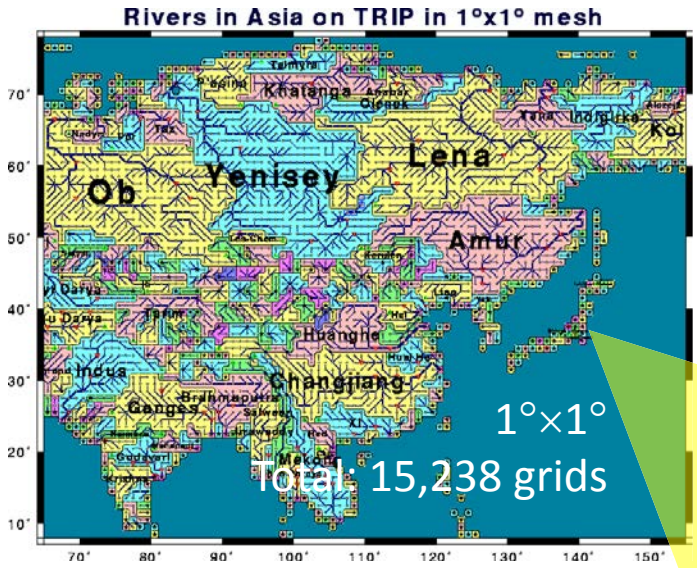
http://www.env.go.jp/earth/earthsimulator/

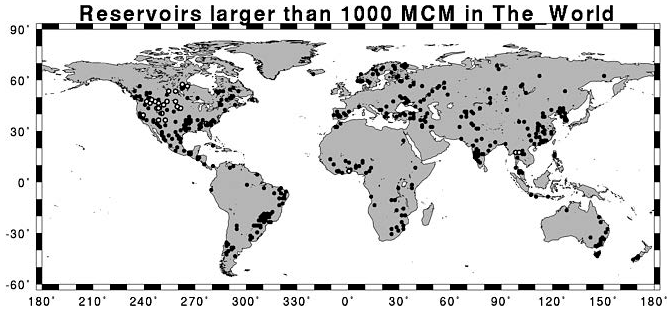
Mean annual water withdrawal
Mean annual runoff
Water stress decreases??

Sub-annual-basis assessment is needed

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

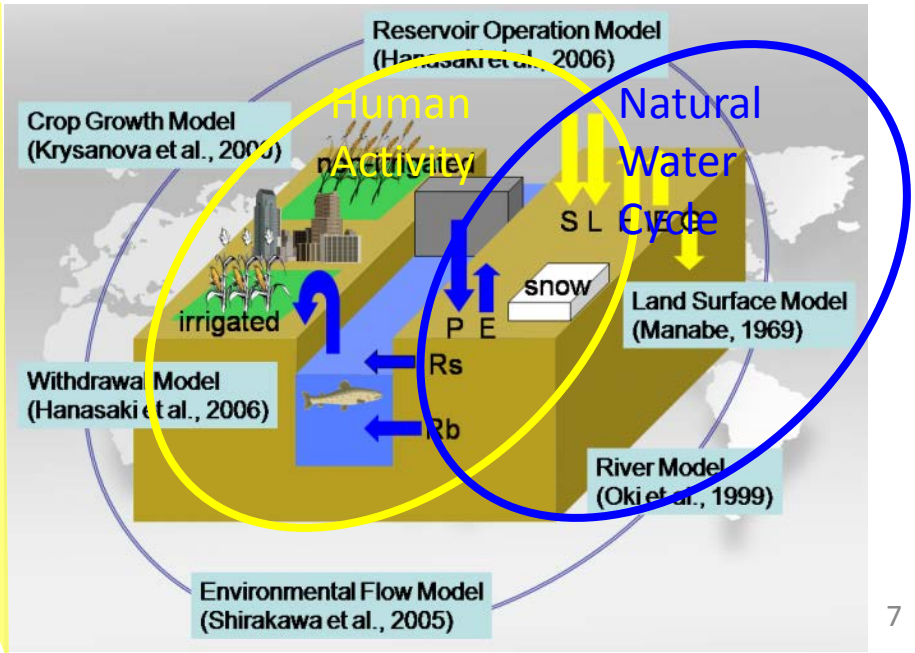
Global water resources model H08

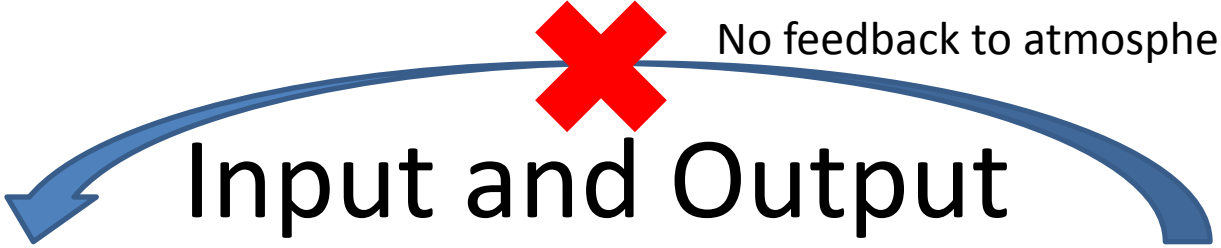




452 reservoirs, 4140 km^3

- 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





Input and Output

Meteorological (1°×1°, 3hourly, 1986-1995)	
Air temperature	Revised GSWP2 (Hanasaki et al., 2008a)
Specific humidity	
Air pressure	
Wind speed	
Shortwave radiation	
Longwave radiation	
Precipitation	

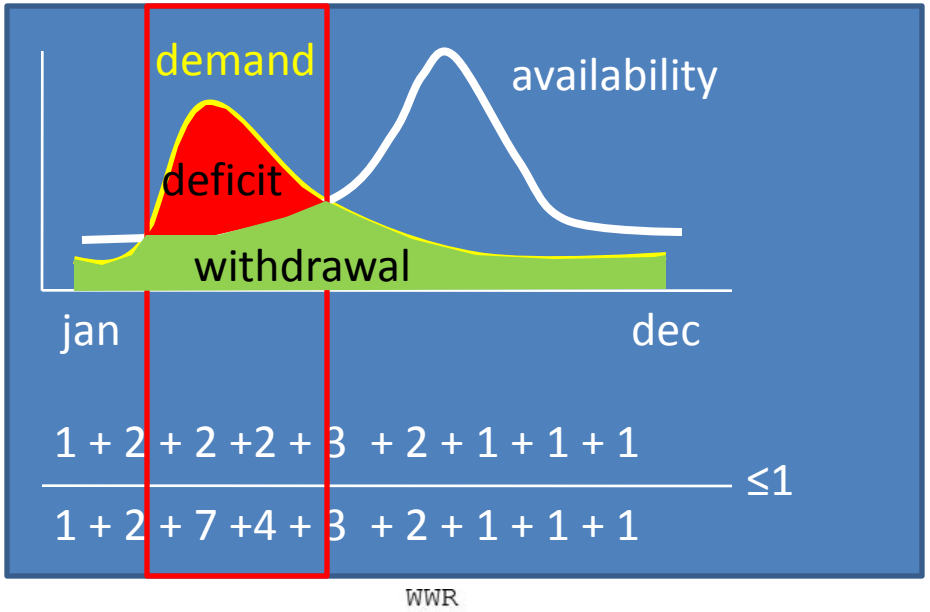
Geographical/other (1°×1°, circa 1990)	
Cropland area	Ramankutty et al. 1998
Irrigated area	Döll and Siebert, 2000
Crop intensity	Döll and Siebert, 2002
Crop type	Leff et al., 2004
River map	Oki and Sud, 1998
Reservoir map	Hanasaki et al. 2006
Industrial water dem.	FAO, 2007
Domestic water dem.	FAO, 2007

H08

Output (1°×1°, daily, 1986-1995)	
Land sub-model	Evapotranspiration
	Runoff
	Soil moisture
	Snow water equivalent
	Energy term
River sub-model	Streamflow
	River channel storage
Crop growth sub-model	Planting date
	Harvesting date
	Agricultural water dem.
	Crop yield (not used)
Reservoir sub-model	Reservoir storage
	Reservoir outflow
	Agri. water withdrawal
	Ind. water withdrawal
	Dom. water withdrawal
Environmental flow	Env. flow requirement

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

Water resources assessment



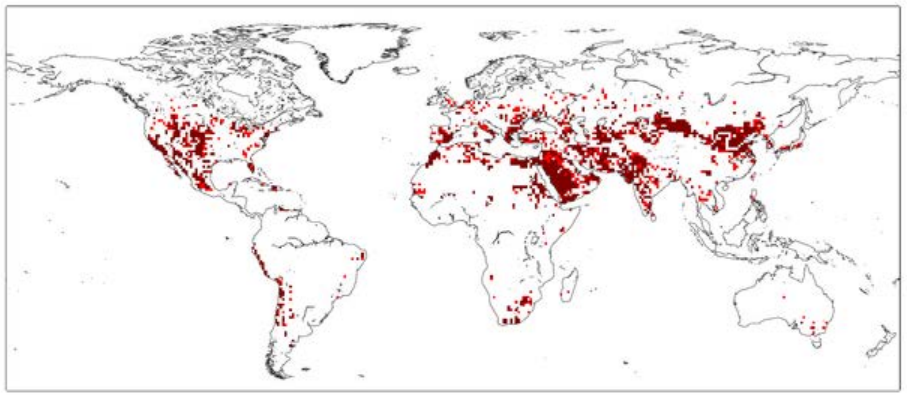
WWR

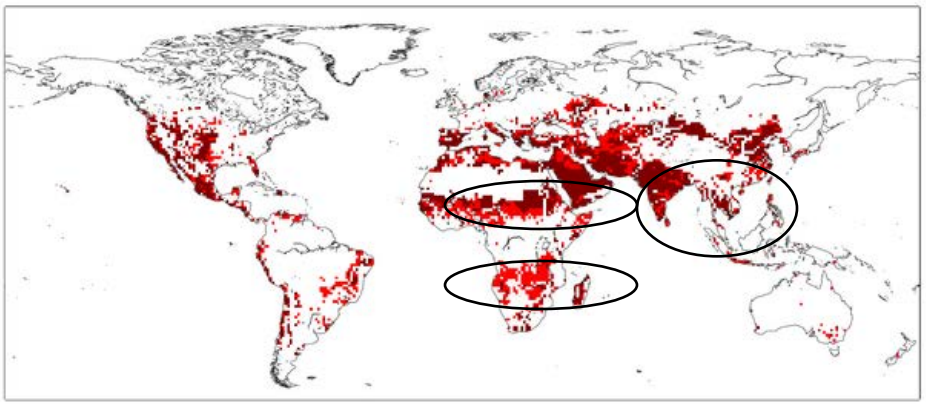
Daily basis

$$\text{Index} = \frac{\sum \text{daily withdrawal (simulated)}}{\sum \text{daily demand (simulated)}}$$

High stress	Index<0.5
Medium stress	0.5≤index<0.8
Low stress	0.8≤Index

CWD





High Stress Medium Stress Low Stress

For future projection

Meteorological (1°×1°, daily?,2001-2100)	
Air temperature	GCM results available. Spatial/Temporal down scaling is needed Bias correction is needed.
Specific humidity	
Air pressure	
Wind speed	
Shortwave radiation	
Longwave radiation	
Precipitation	

→An European group developed a new dataset
→ Some Japanese groups are also working hard.

Geographical/other (1°×1°, 2001-2100)	
Cropland area	RCP?
Irrigated area	
Crop intensity	
Crop type	
Reservoir map	
Industrial water dem	??
Domestic water dem	??

→ Land use & Agriculture model needed?

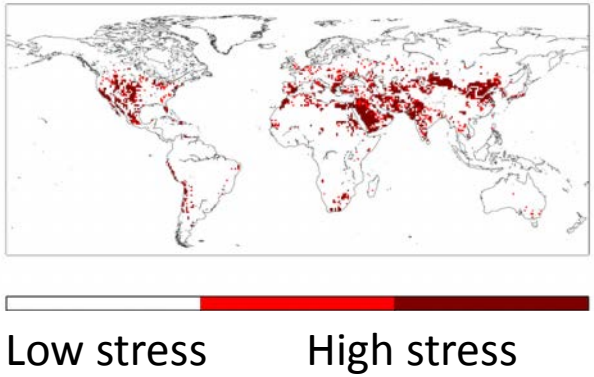
→ New project launched in NIES

Application 2: Estimation of global virtual water flows and sources of water

Hanasaki, N., Inuzuka, T., Kanae, S., Oki, T.: An estimation of global virtual water flow and sources of water withdrawal for major crops and livestock products using a global hydrological model. J. Hydrol. In press, doi:10.1016/j.jhydrol.2009.09.028

Introduction

Water use / Water availability



Low stress High stress

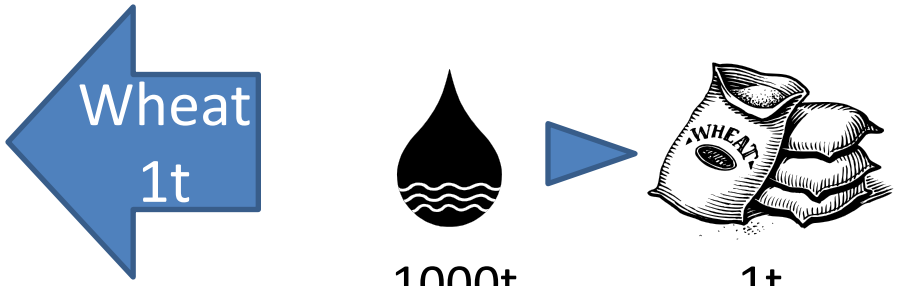
- Global water resources assessments
  - high water stressed regions are sometimes densely populated
- Virtual water (Allan, 1996)
  - Regional water scarcity can be alleviated by importing commodities, especially foods
  - Production of agricultural/livestock products consumes a large volume of water
- Virtual water complements water resource analyses of local water availability and use

Virtual water export

volume of water that an exporting nation consumes to produce the commodities that it trades abroad
（輸出製品を作るために海外の国が消費した水の量）

Importing country (Japan)

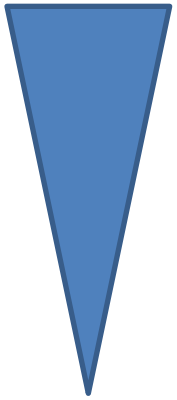
Exporting country (USA)



Export of wheat	1t
Virtual water export	1,000t

Sources of virtual water

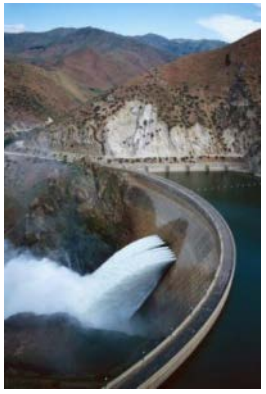
- Evapotranspiration（蒸発散）of cropland originates from
  - Precipitation
  - Irrigation
    - River
    - Reservoirs
    - Aquifers, aqueduct, glacier



Sustainable

Non-sustainable

- <u>Separating the source of virtual water</u>



Objective & Methodology

- Objective
  - Estimate global virtual water flows and their sources
- Research focus
  - International food trade in 2000
  - Five major crop products: barley, maize, rice, soy, wheat
  - Three major livestock products: beef, pork, chicken
- Methodology
  - Virtual water export = $\frac{\text{National average Evapotranspiration from cropland (sim)}}{\text{National crop yield (statistics)}} \times \text{Trade matrix (statistics)}$

Water consumption from cropland

Rainfed: Ramankutty et al. (2008)
Irrigated: Siebert et al. (2005)
Crop type: Monfreda et al. (2008)

Where

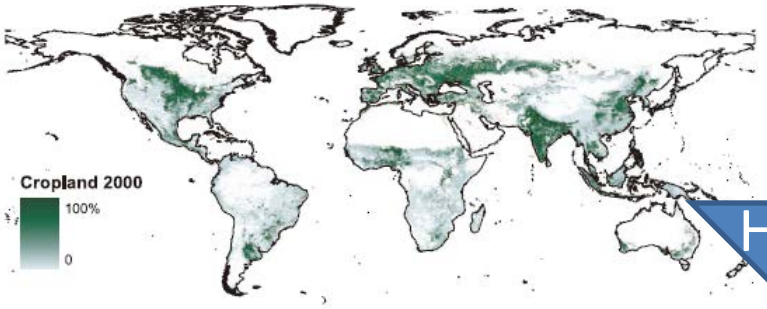
When

How much

Crop growth submodel estimates planting/harvesting date.

Land surface hydrology submodel estimates ET from planting date to harvesting date.

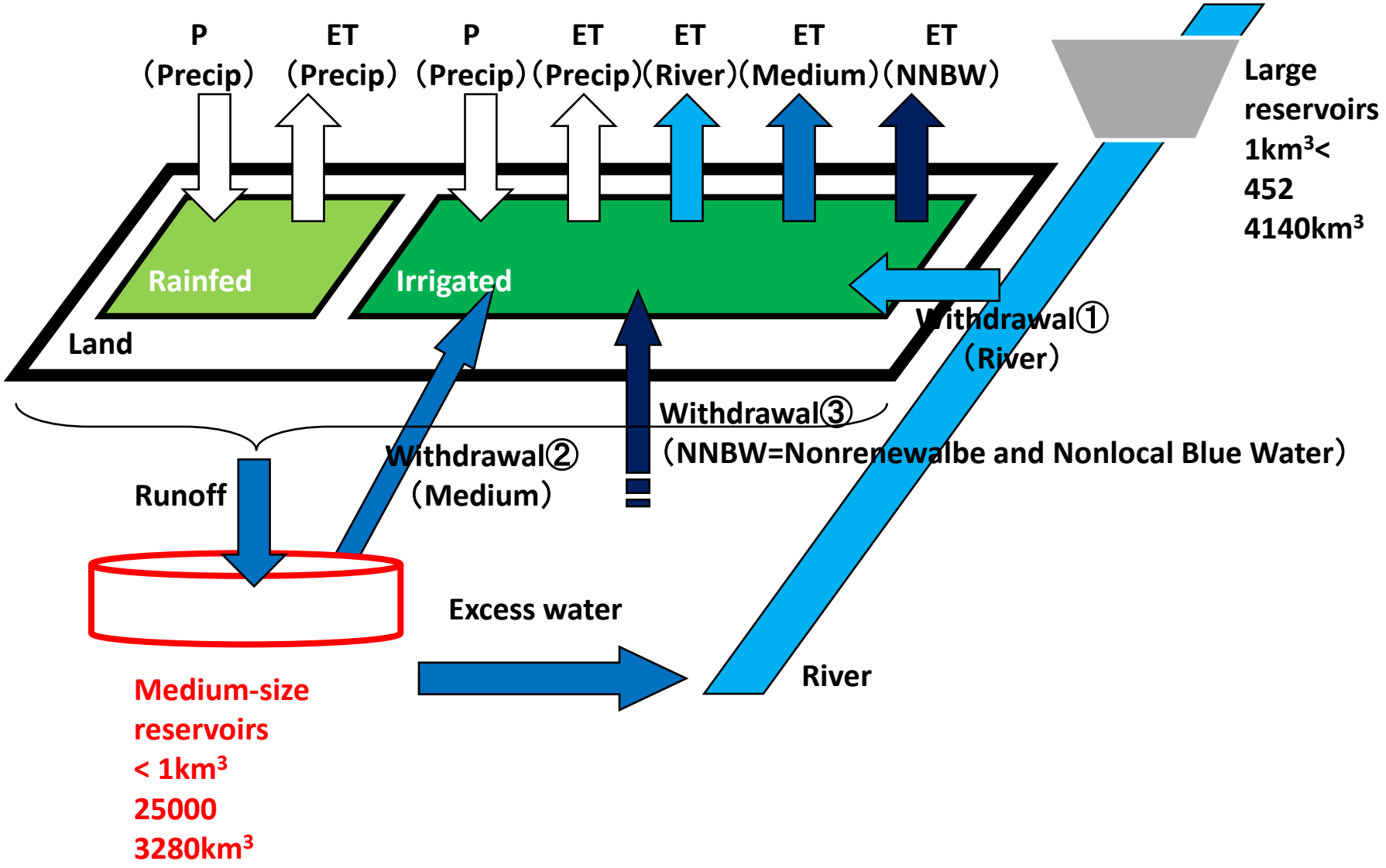
Distribution of rainfed cropland area



Ramankutty et al. 2008

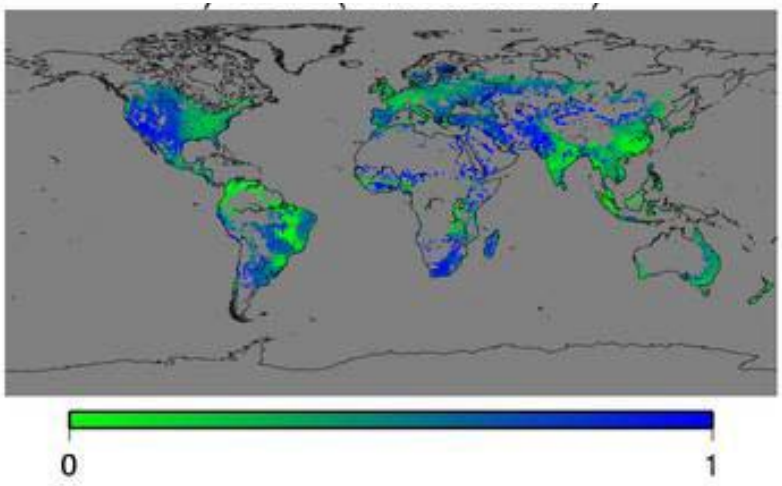
Globally 0.5° ×0.5° , daily-based calculation

Sources of water

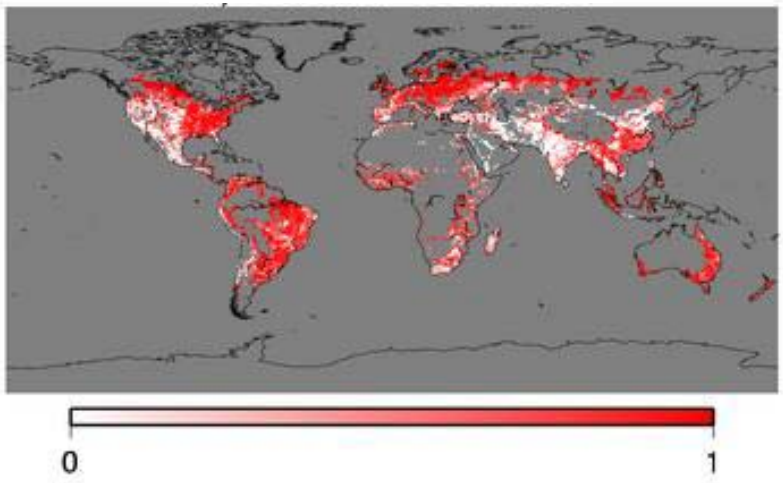


Sources of evapotranspiration from irrigated cropland

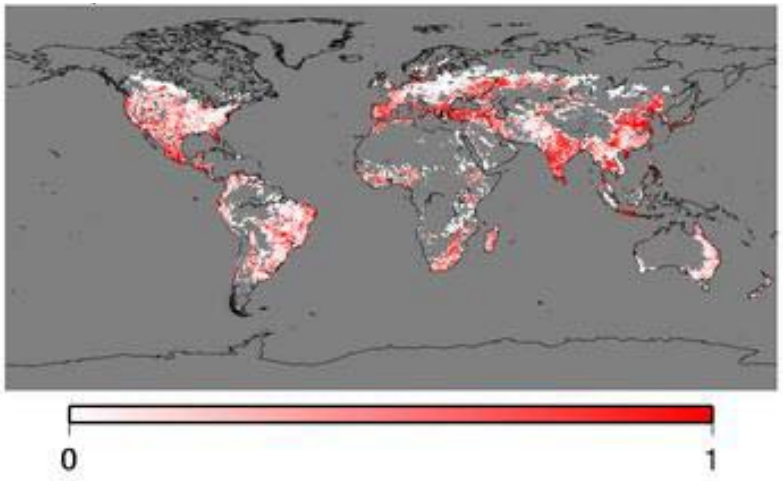
Irrigation/Total evaporation



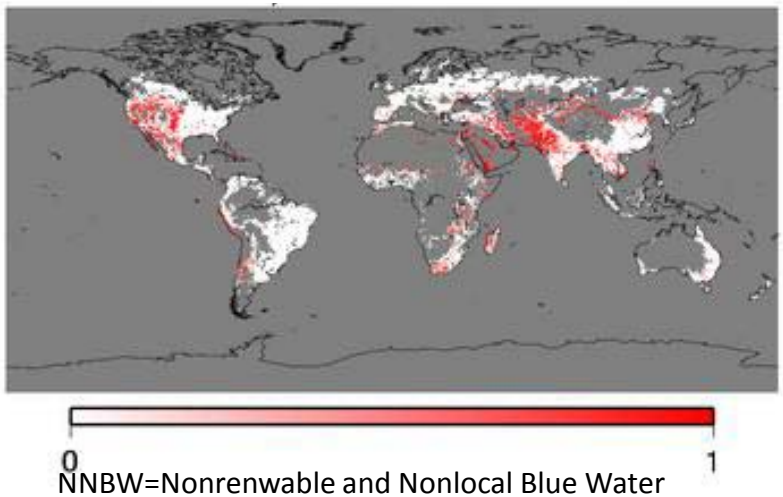
River/Total Irrigation



Medium-size reservoirs/Total irrigation



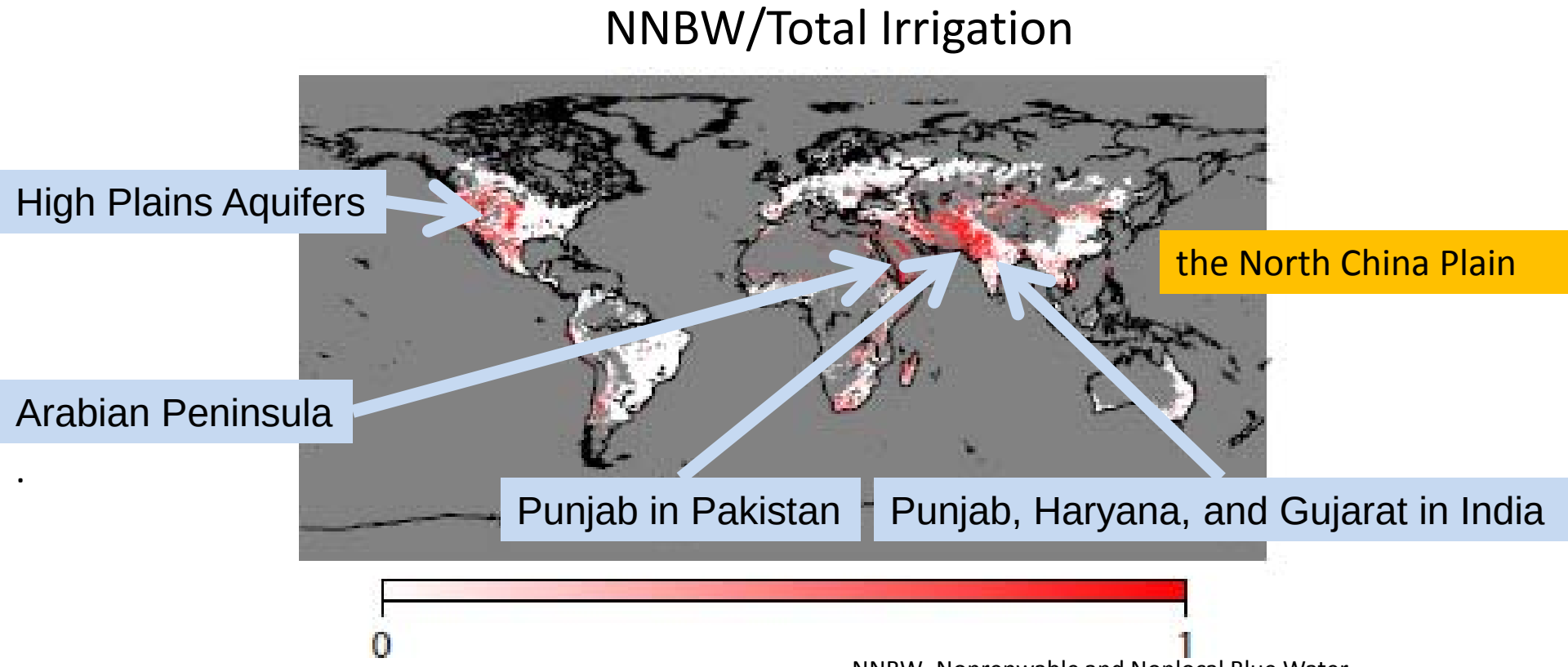
NNBW/Total Irrigation



NNBW=Nonrenwable and Nonlocal Blue Water

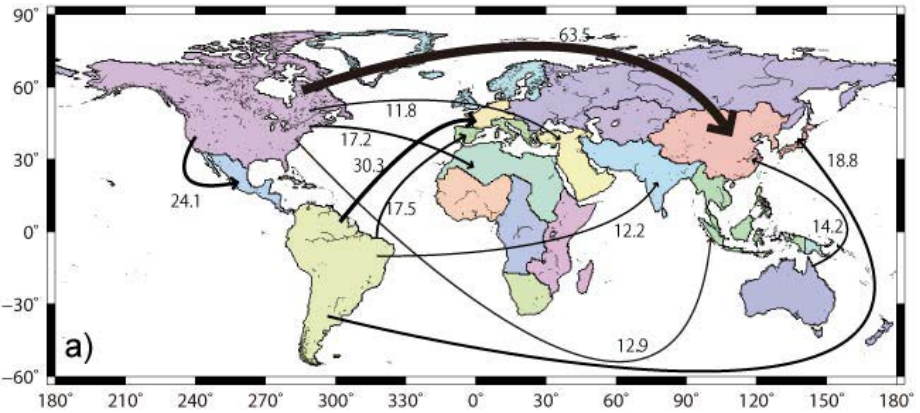
NNBW/Total Irrigation

- Reported regions of aquifer overexploitation (Postel, 1999)



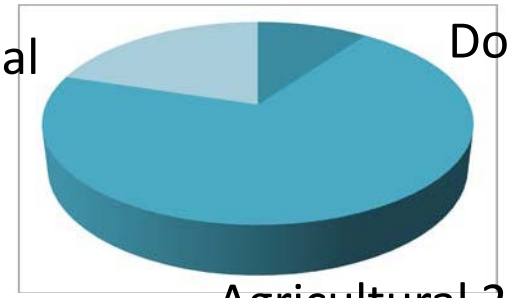
Global flows of virtual water export

Virtual water export (total)



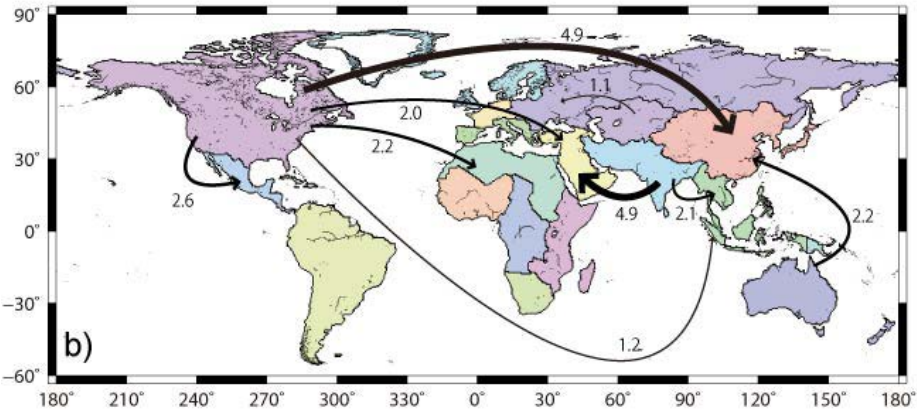
Total 545km^3 yr^{-1}

Total water withdrawal : 3,800km^{3}yr^{-1}



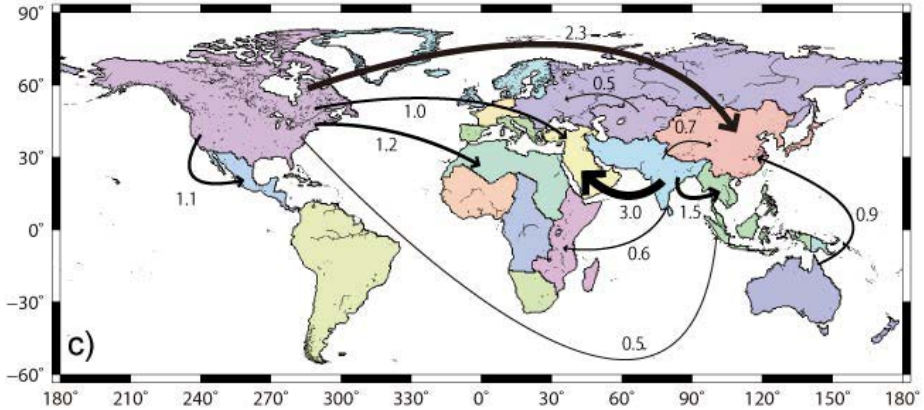
Shiklomanov, 2000

Virtual water export (irrigation)



Total 61km^3 yr^{-1}

Virtual water export (Nonlocal/Nonrenewable Blue Water)



Total 26km^3 yr^{-1}

Summary

- Global water scarcity assessment
  - Daily basis assessment
- Global virtual water assessment
  - The virtual water export of the world was estimated at 545km^3yr^{-1}.
  - Of total, 61km^3yr^{-1} (11%) is irrigation water, and 26km^3yr^{-1} (5%) is NNBW.

References

- Shiogama, H., Hanasaki, N., Masutomi, Y., Nagashima, T., Ogura, T., Takahashi, K., Hijioka, Y., Takemura, T., Nozawa, T. and Emori, S.: Emission scenario dependencies in climate change assessments of the hydrological cycle, Climatic Change, DOI: 10.1007/s10584-009-9765-1, in press. http://www.springerlink.com/content/k4223u6px5677467/?p=1460a4ebf9054aa8ac8ca8befdca0e76&pi=15
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