Two examples of advanced global climate change impact assessment on water and agricultural sectors

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Outline

- Global impact assessment on
  - water sector using H08 model
  - agricultural sector using GAEZ model

Global impact assessment on water sector

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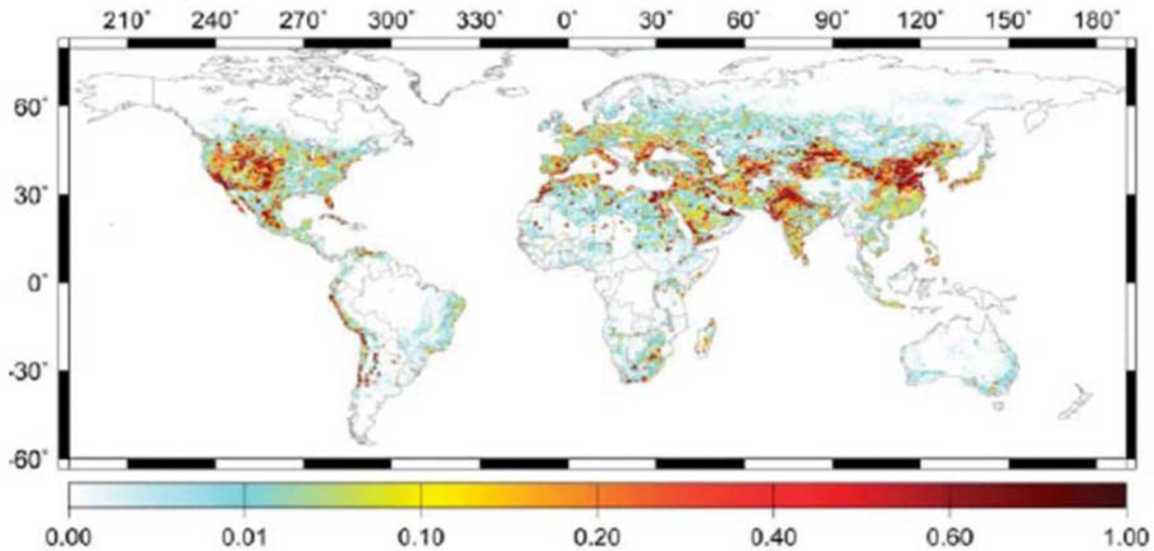
Assessing water scarcity

- A number of report have been published to assess water scarcity globally using a widely accepted index Withdrawal to Water Resources ratio.

$$WWR = \frac{annual\ water\ withdrawal}{annual\ river\ discharge}$$



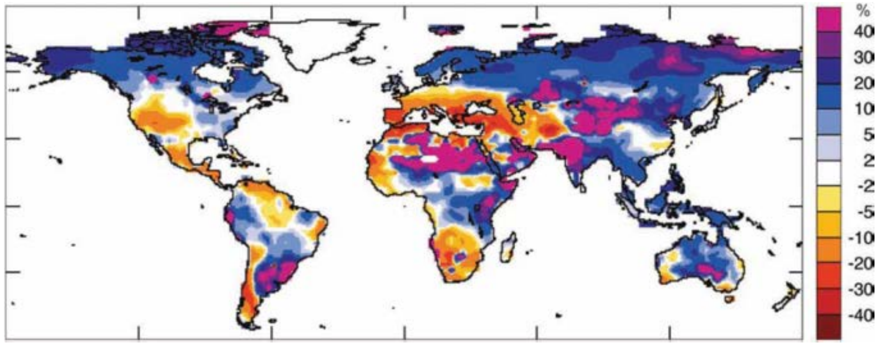
Oki and Kanae, 2006, Science

High water stress

Assessing climate change impact

- WWR is widely used in climate change impact assessment.
- Global warming is projected to increase the mean annual runoff in many parts of the world. Therefore, the WWR (= withdrawal / water resources) decrease by its definition in these regions.

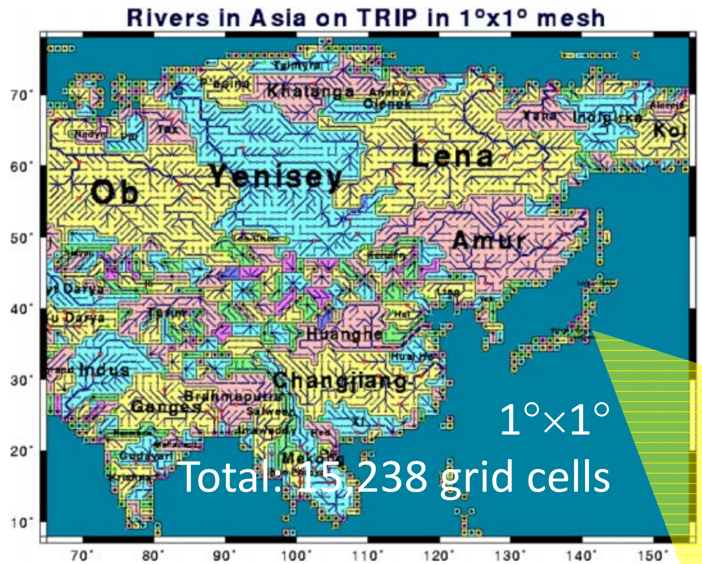
Projected change in annual runoff
by 2041-60 relative to 1900-70

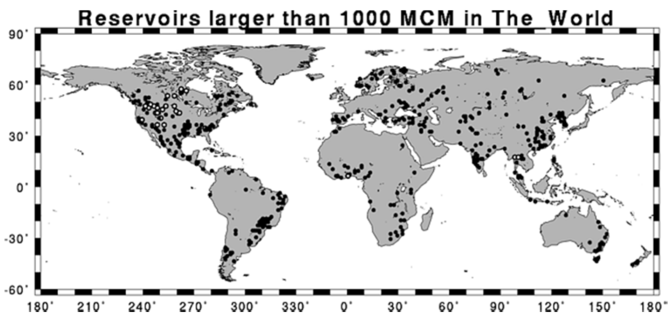


Milly et al., 2005, Nature

- However, global warming is also projected to increase the intensity and frequency of precipitation. WWR neglects sub-annual variation.
- Is it appropriate to apply the WWR for climate change impact assessment?

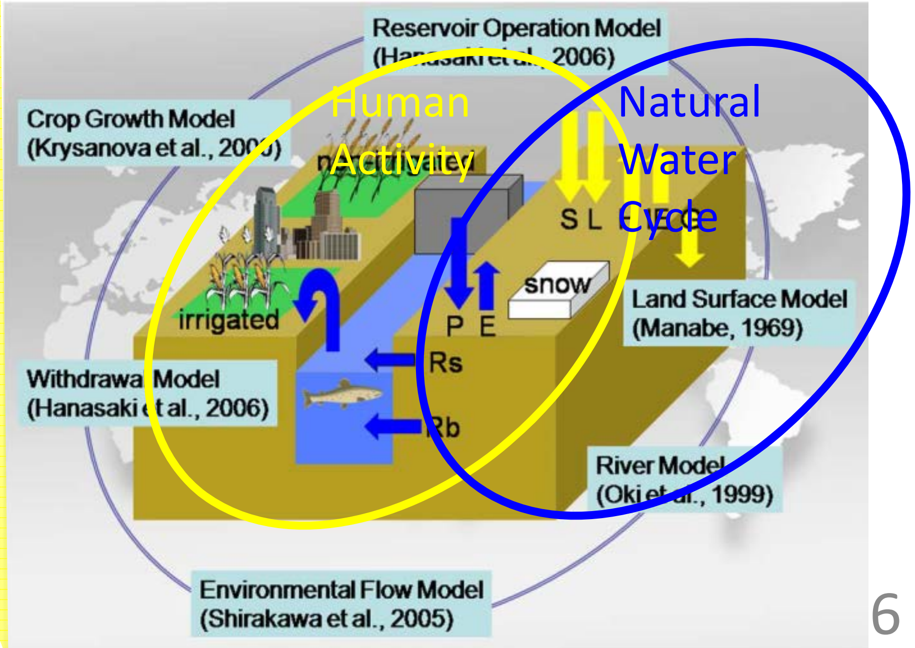
Global water resources model H08





452 reservoirs, 4140 km^3

- Characteristics
1. Simulate both water availability (streamflow) and water use at sub-annual basis
2. Deal with interaction between natural hydrological cycle and anthropogenic activities



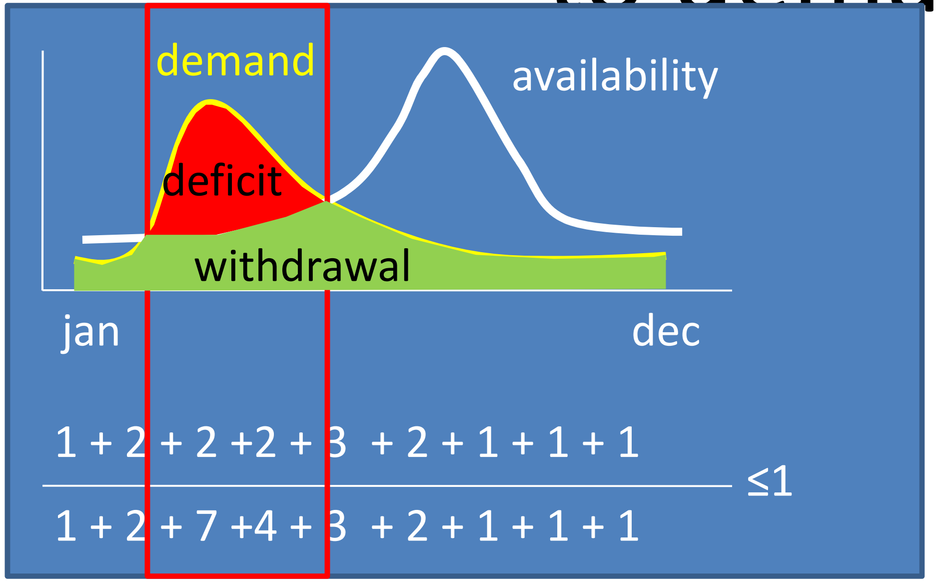
Hanasaki et al., 2006, J. of Hydrol.
Hanasaki et al. ,2008a,b, Hydrol. Earth Sys. Sci.

Simulation settings

Meteorological (1°×1°, daily)	
Temperature	Present climate condition : •GSWP2(1986-1995) Future climate condition : •MIROC3.2medres is used (SRES A2 scenario) •Simplistic bias correction for Tair, Precip, Lwdown
Relative humidity	
Pressure	
Wind speed	
Short-wave radiation	
Long-wave radiation	
Precipitation	

Geographical/other(1°×1°)	
Cropland area	Fixed at the present condition
Irrigated area	Fixed at the present condition
Crop intensity	
Crop type	
Industrial Dem.	Fixed at the present condition
Domestic Dem.	
Agricultural Dem.	Simulated
Population	SRES A2

New index: Cumulative withdrawal to demand ratio

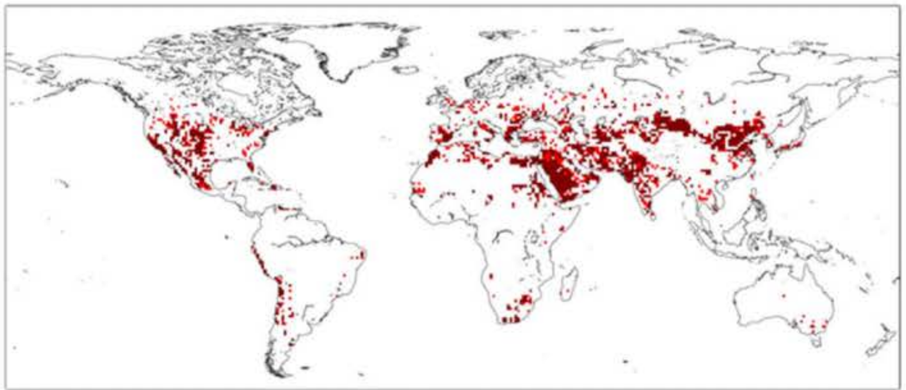


Daily basis

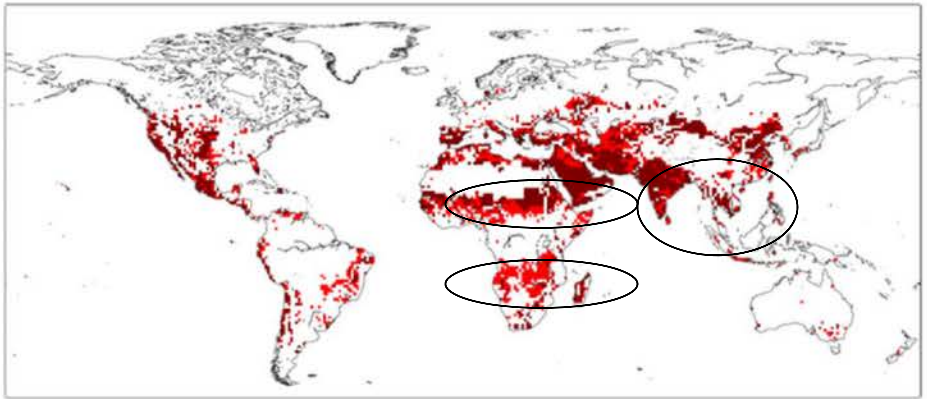
$$CWD = \frac{\sum \text{daily withdrawal (simulated)}}{\sum \text{daily demand (simulated)}}$$

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

WWR



CWD



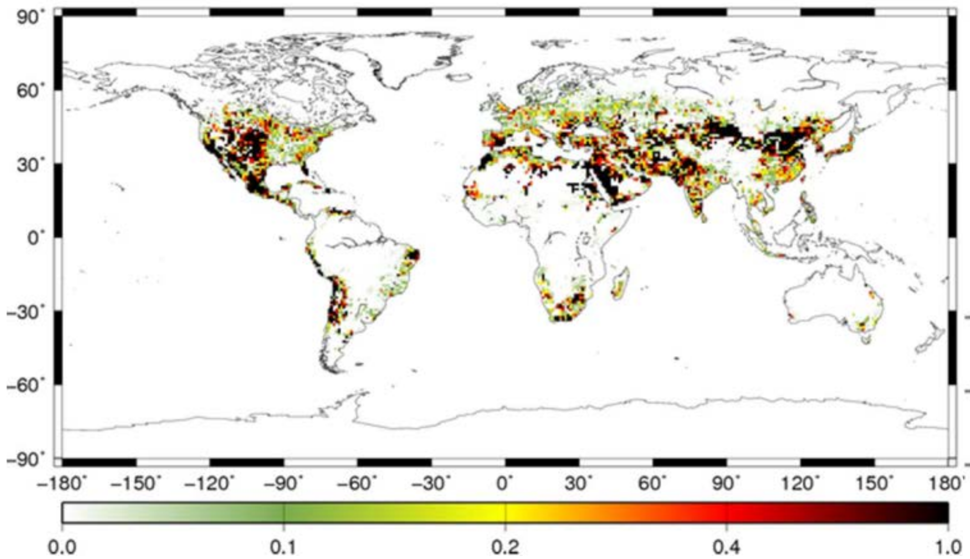
High Stress Medium Stress Low Stress

Water scarcity assessment

Annual basis

$$\text{WWR}=\frac{\text{Annual water withdrawal (statistics)}}{\text{Annual river discharge (simulated)}}$$

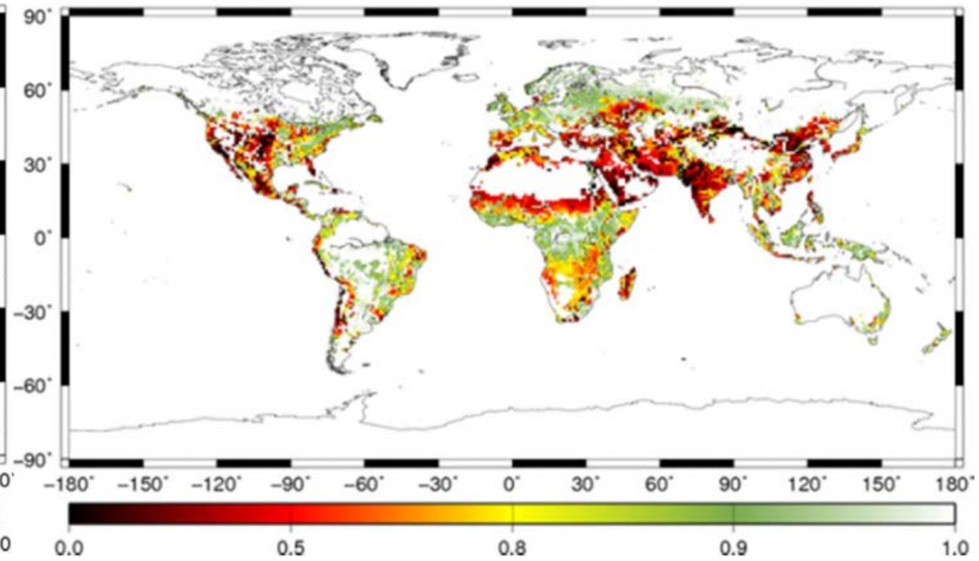
WWR (2080s)



Daily basis

$$\text{CWD}=\frac{\sum \text{daily withdrawal (simulated)}}{\sum \text{daily requirement (simulated)}}$$

CWD (2080s)



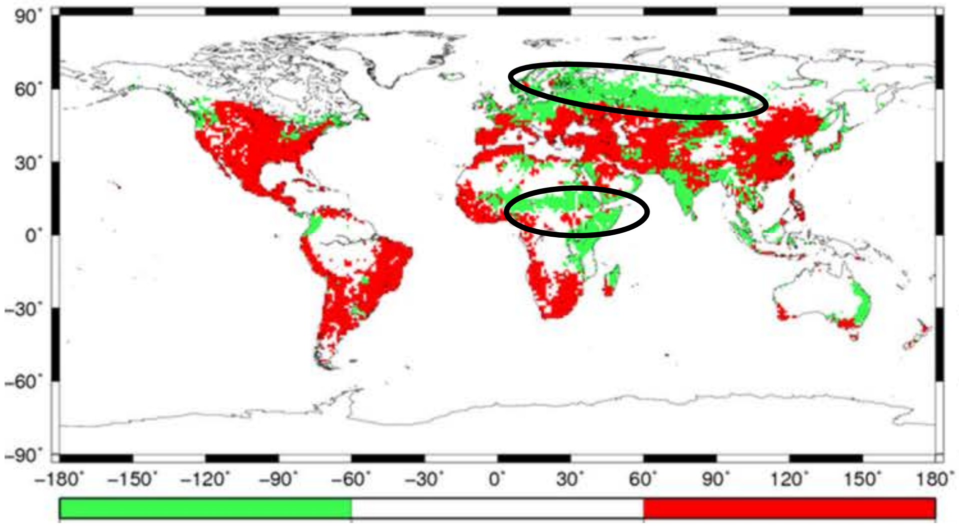
Highly stressed population=5.85 billion (1.81 billion at present. 2.00 billion if population is fixed at present)

Change in water stress

Annual basis

$$WWR = \frac{\text{Annual water withdrawal (statistics)}}{\text{Annual river discharge (simulated)}}$$

Change in WWR (2080s – 1980s)



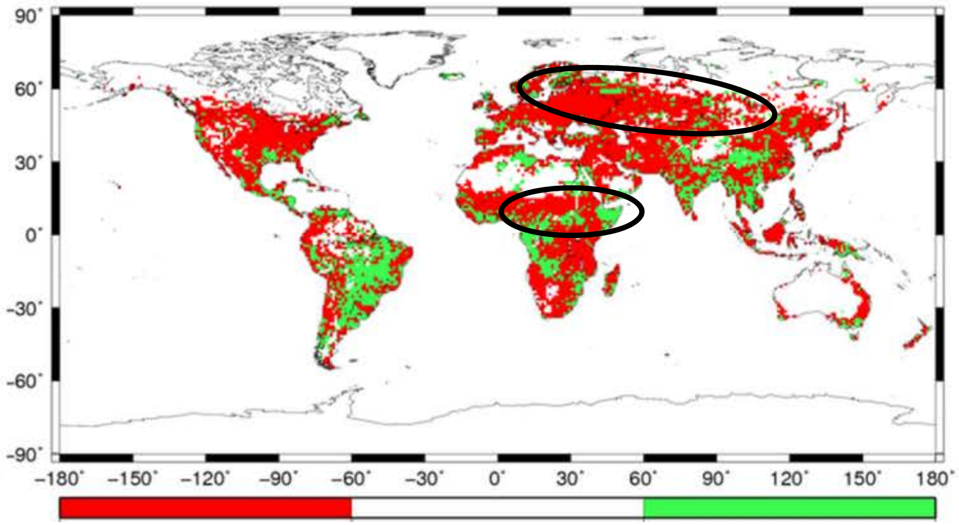
stress decreases stress increases

Basically, water scarcity decreases where mean annual runoff increases

Daily basis

$$CWD = \frac{\sum \text{daily withdrawal (simulated)}}{\sum \text{daily requirement (simulated)}}$$

Change in CWD(2080s – 1980s)

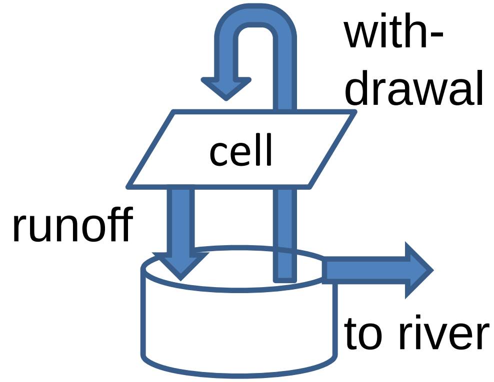


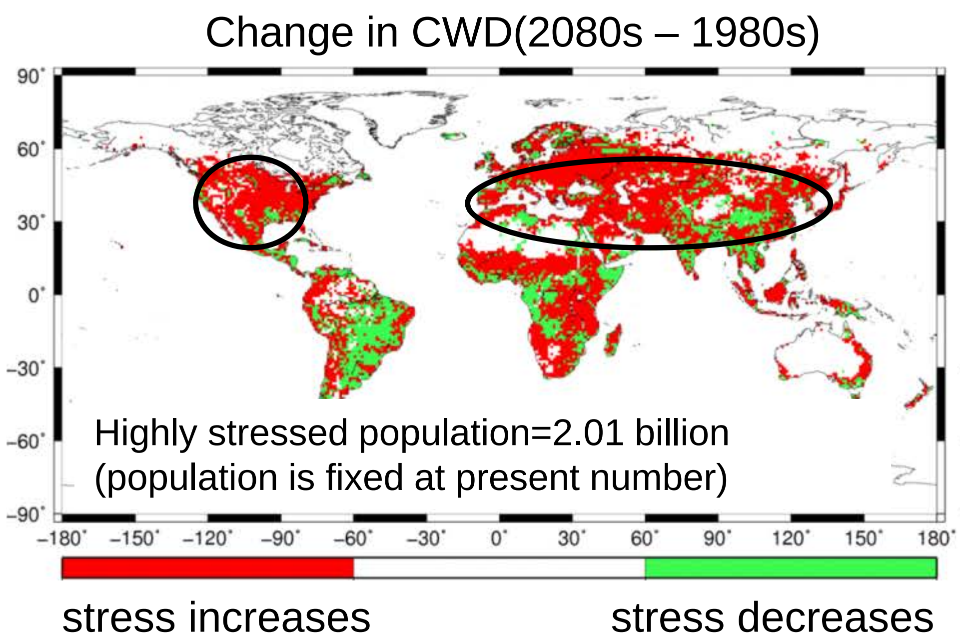
stress increases stress decreases

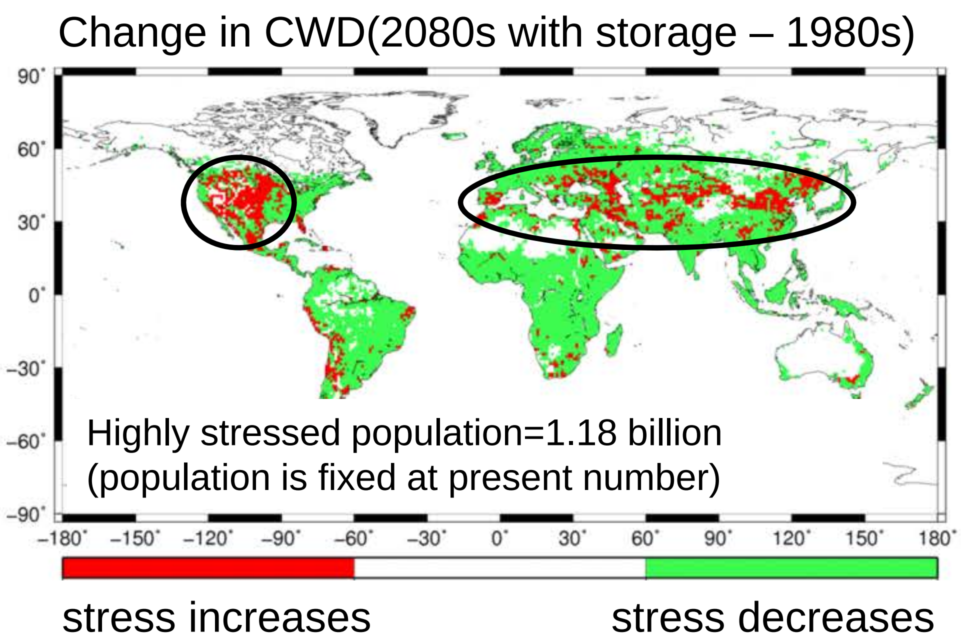
Water withdrawal from river increased at limited regions.

Sensitivity of local water storage

- Adding reservoirs to increase local storage capacity
- Method:
  - Added ideal water storage to every grid cell
  - Storage capacity: 2% of mean annual runoff







Summary

- Climate change impact assessment was conducted.
- Conventional water scarcity index WWR on an annual basis showed decrease in water scarcity where runoff increased.
- New water scarcity index CWD on a daily basis showed increase in water scarcity for 42% of the above region.
- The difference was attributed to seasonal gap in water resources and water use.
- As a sensitivity study, simple imaginary water storage was introduced. It drastically decreased water scarcity for many parts of the world.
- However, chronic water scarce regions such as western USA and northern China remained highly water stressed.

References

About this presentation

- Paper
  - Yamamoto et al., 2011, Annual Journal of hydraulic Eng.
  - Yamamoto et al., Selected Papers of Environmental Systems Research, in preparation
- Presentation (domestic)
  - Yamamoto et al., 2011, Japan Society of Hydrology and Water Resources
- Presentation (international)
  - Hanasaki and Yamamoto, 2010, 2nd HESSS
  - Yamamoto et al., 2010, 5th APHW
  - Yamamoto et al., 2010, AGU fall meeting

About H08

- Paper
  - Hanasaki et al., 2006, J. Hydrol.
  - Hanasaki et al., 2008a, Earth Sys. Sci.
  - Hanasaki et al., 2008b, Earth Sys. Sci.
  - Hanasaki et al., 2010, J. Hydrol.

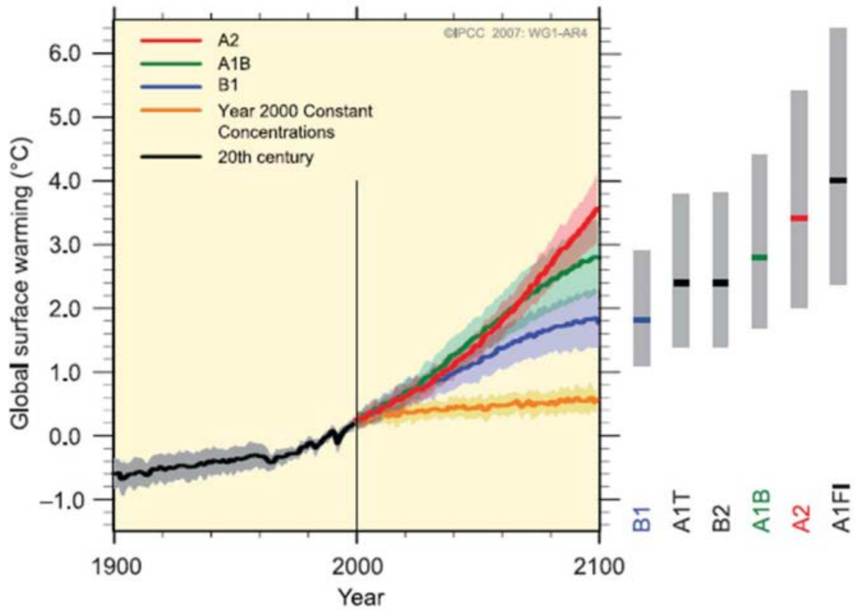
ASIA-PACIFIC INTEGRATED MODEL

Impact on agricultural sector

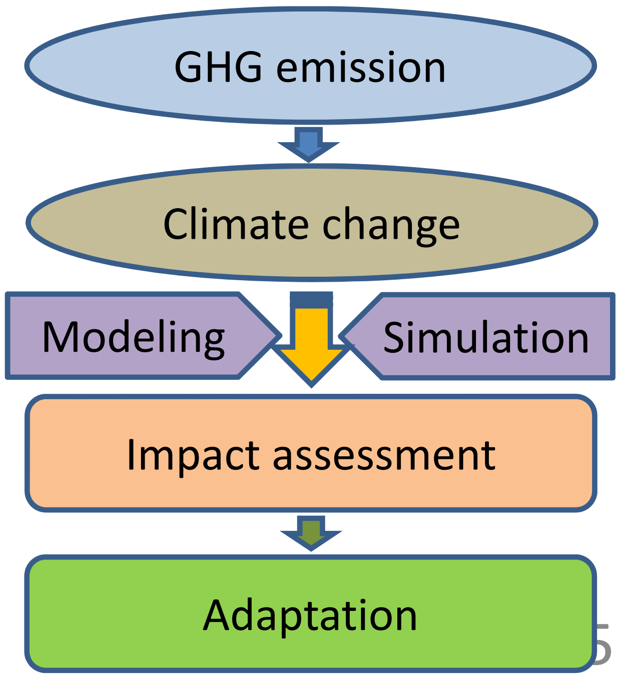
Yonghee Shin
and
Kiyoshi Takahashi

Introduction

- IPCC AR4 : Average temperature rise due to anthropogenic greenhouse gas emissions has a large impacts on crop's productivity in the future
- Maize : One of the world's three basic staple crops
- The prediction of productivity change is important



(IPCC AR4, 2007)

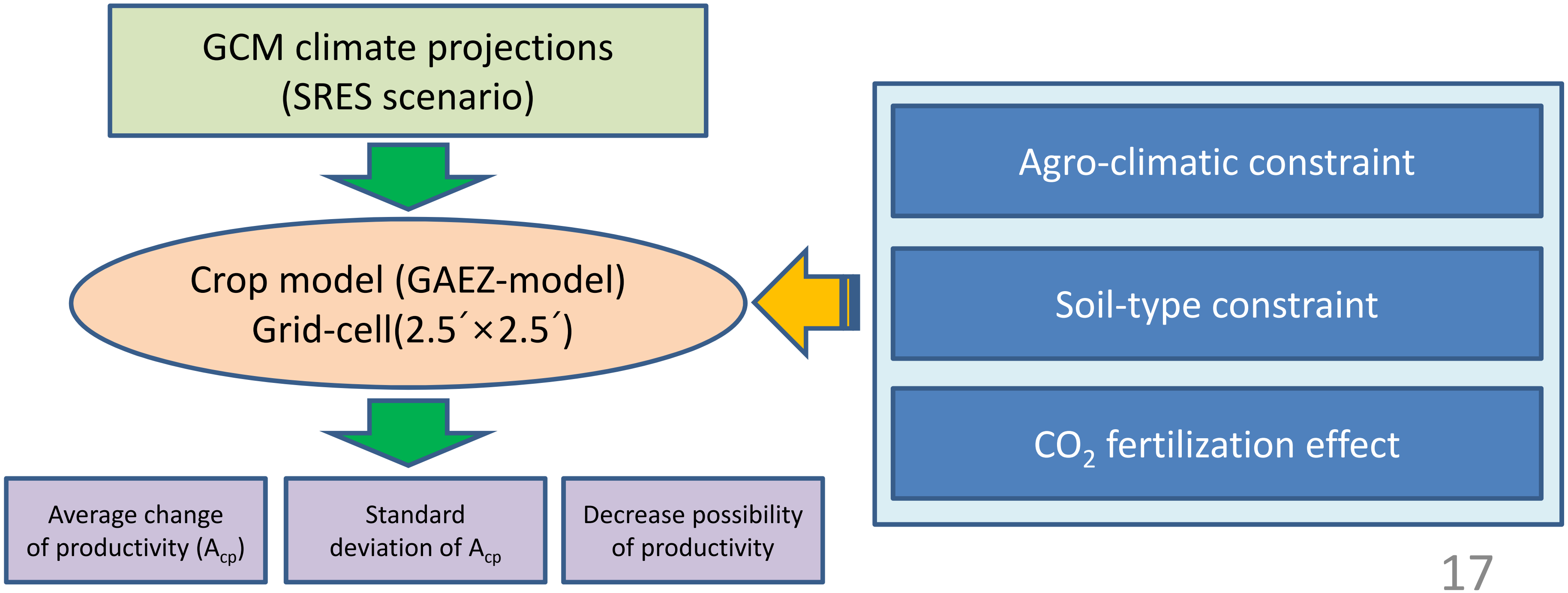


GAEZ

- Global agro-ecological zone study (GAEZ) is a long standing initiative of FAO since 1978 to evaluate biophysical constraints and potentials which determines the yield potential of crops worldwide under different land management conditions
- GAEZ-model was Developed by IIASA and FAO (Fischer et al., 2002) was used for the assessment of global food security in IPCC AR4.

Simulation settings

- Area: Worldwide
- Crop: Maize
- Period: 2020s, 2050s, and 2080s; Base: 1990s
- Emission scenario: SRES A1B, A2, and B1
- Input: Climate data - Temperature, precipitation, radiation, and wind speed
  Other data - Soil, elevation, fertilizer use, and administrative boundary

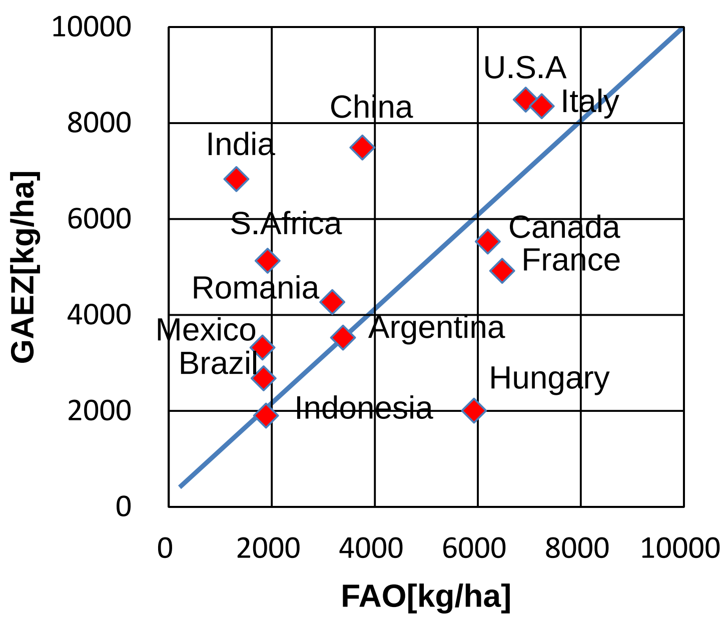


Climate projections (from PCMDI)

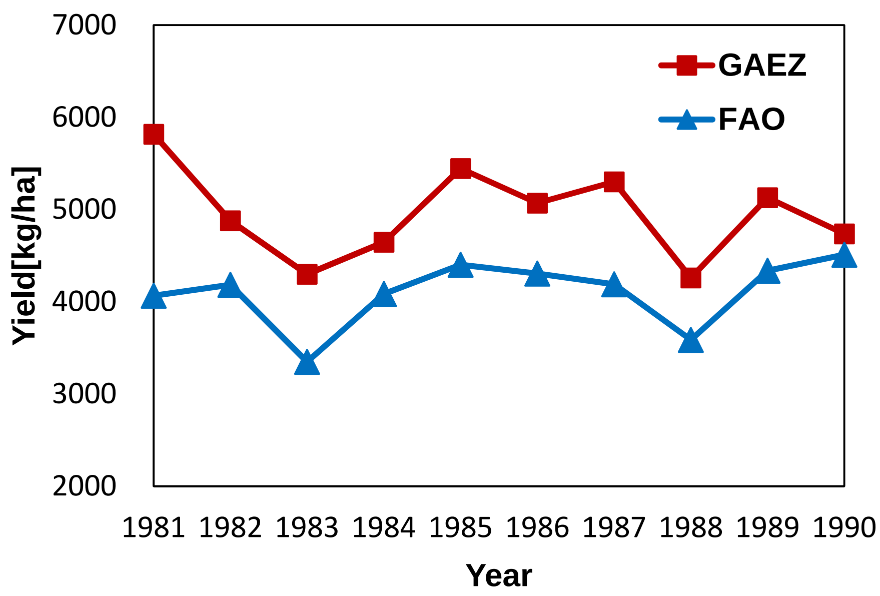
Country	Model name	A1B (18 GCMs)	A2 (14 GCMs)	B1 (17 GCMs)
Norway	BCCR-BCM2.0		○	○
Canada	CGCM3.1(T47)	○	○	○
Canada	CGCM3.1(T63)	○		○
France	CNRM-CM3	○	○	○
Germany	ECHAM5/MPI-OM	○	○	○
Germany / Korea	ECHO-G	○	○	○
China	FGOALS-g1.0	○		○
USA	GFDL-CM2.0	○	○	○
USA	GFDL-CM2.1	○	○	○
USA	GISS-AOM	○		○
USA	GISS-EH	○		
USA	GISS-ER	○	○	○
Russia	INM-CM3.0	○	○	○
France	IPSL-CM4	○	○	○
Japan	MIROC3.2(hires)	○		○
Japan	MIROC3.2(medres)	○	○	○
Japan	MRI-CGCM2.3.2	○	○	○
UK	UKMO-HadCM3	○	○	○
UK	UKMO-HadGEM1	○	○	

Validation of GAEZ-model

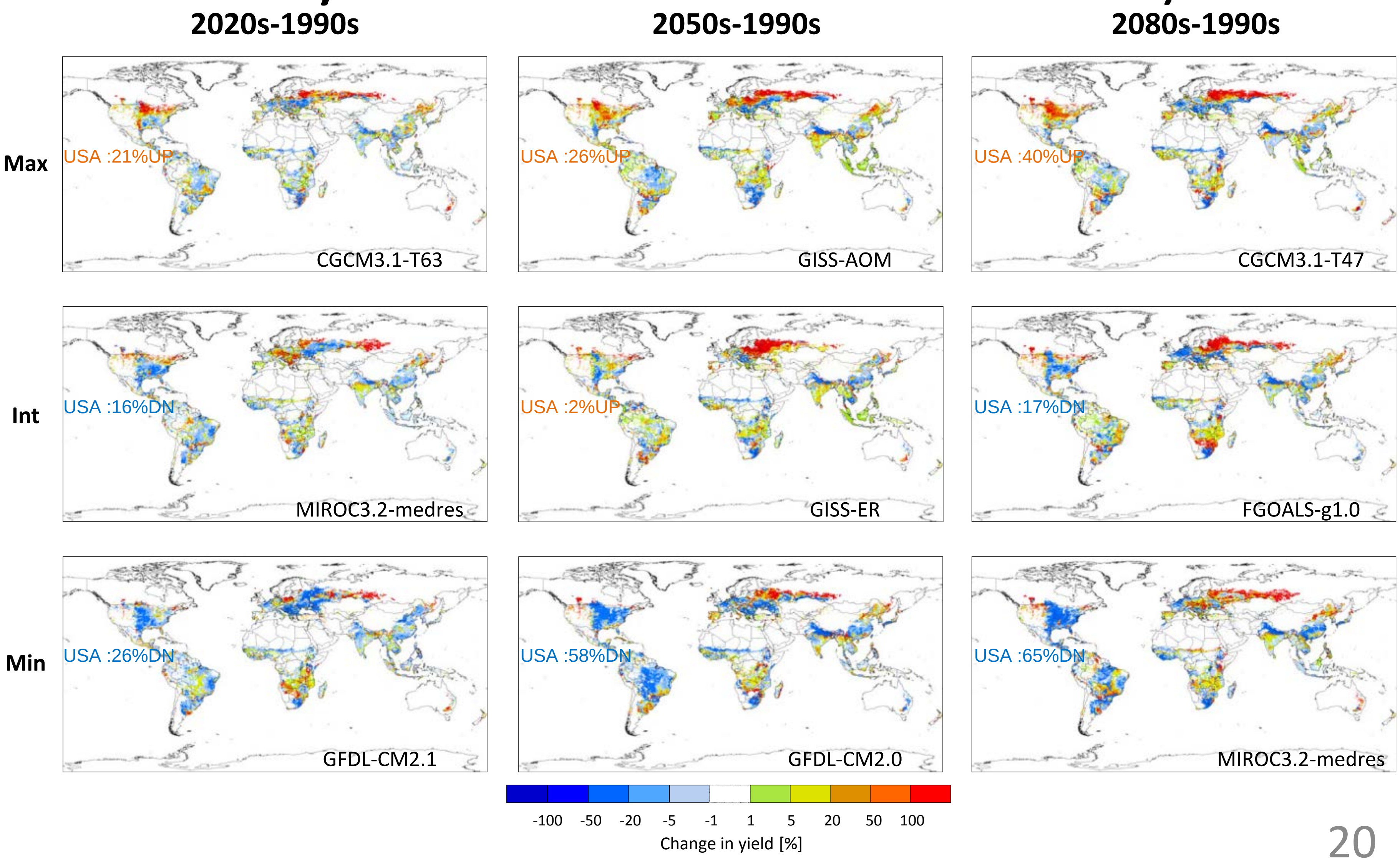
Average maize yield for 1980s
by main producing countries



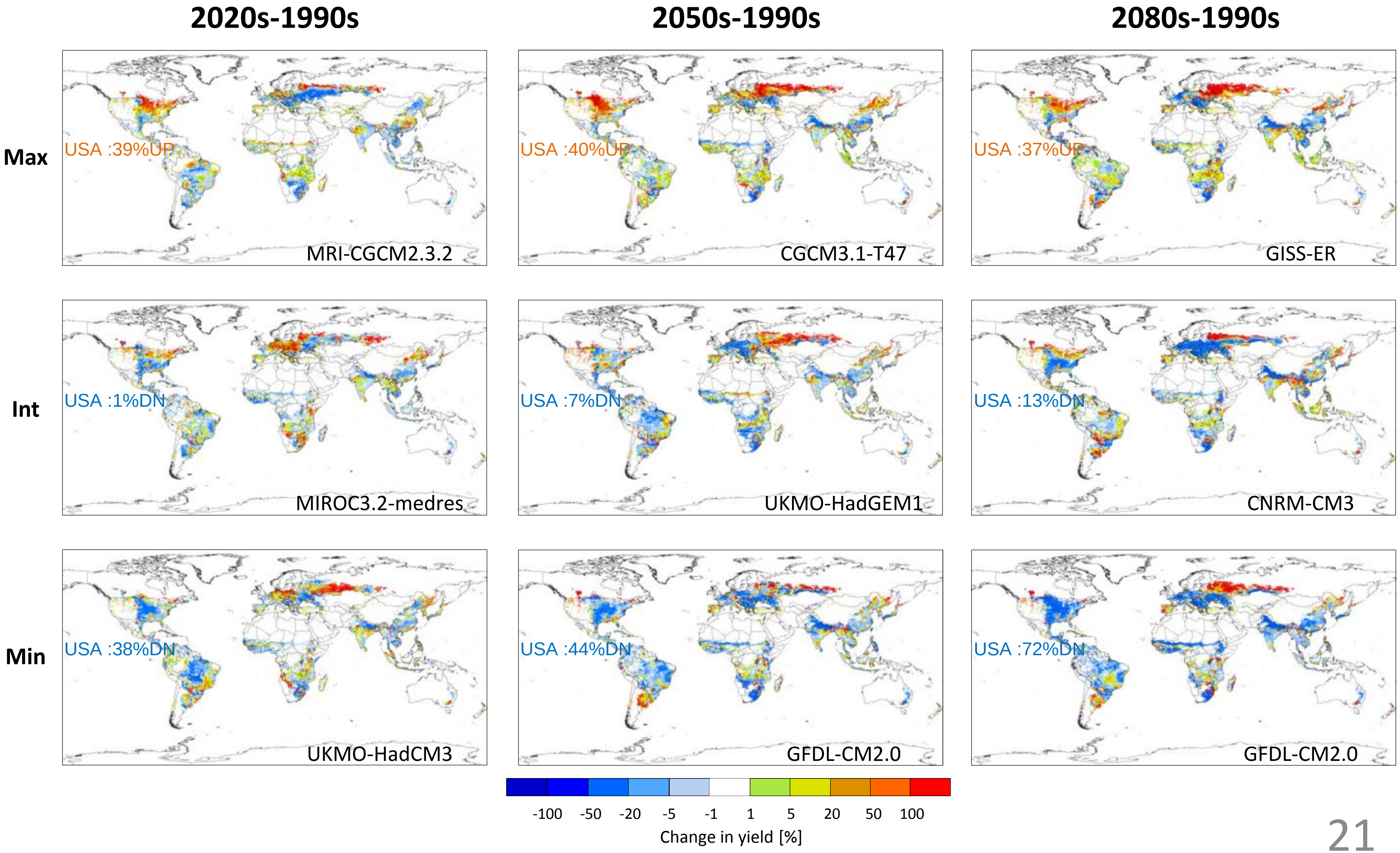
Average annual maize yield
for top 13 producing countries



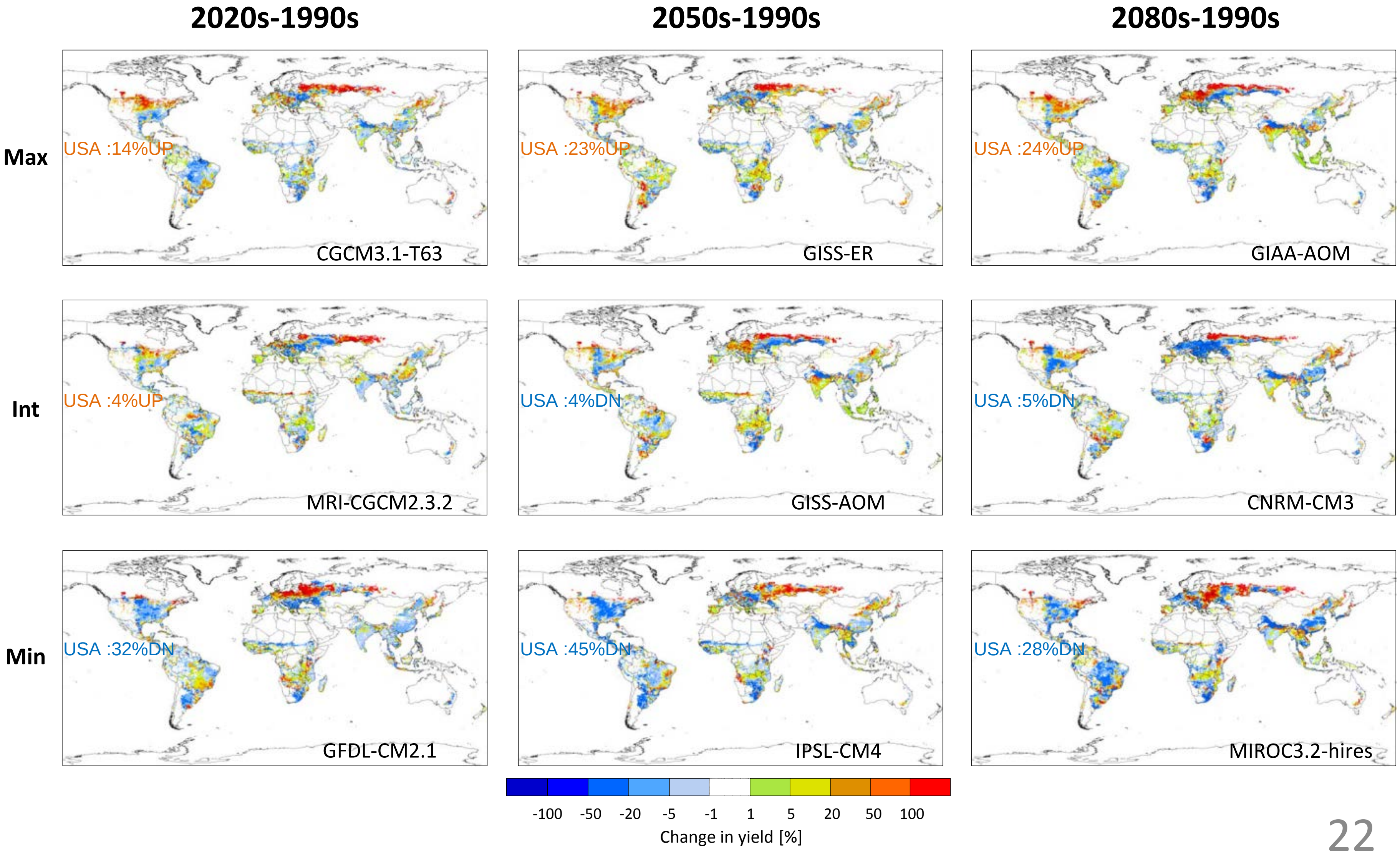
Uncertainty of Maize productivity change by multi GCMs（A1B Scenario)



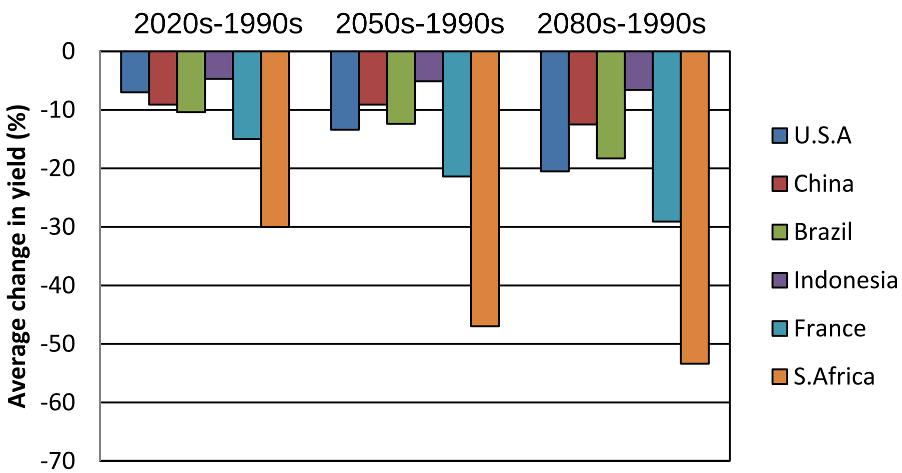
Uncertainty of Maize productivity change by multi GCMs（A2 Scenario)



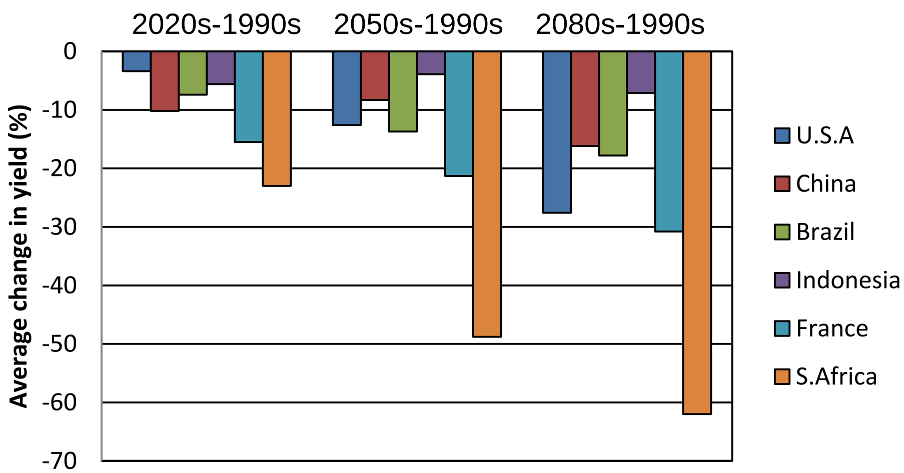
Uncertainty of Maize productivity change by multi GCMs（B1 Scenario)



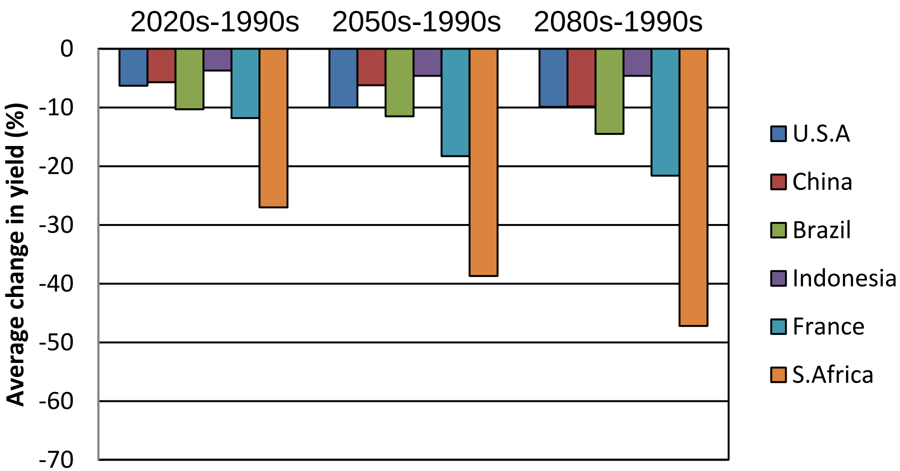
Average change in maize yield



A1B scenario

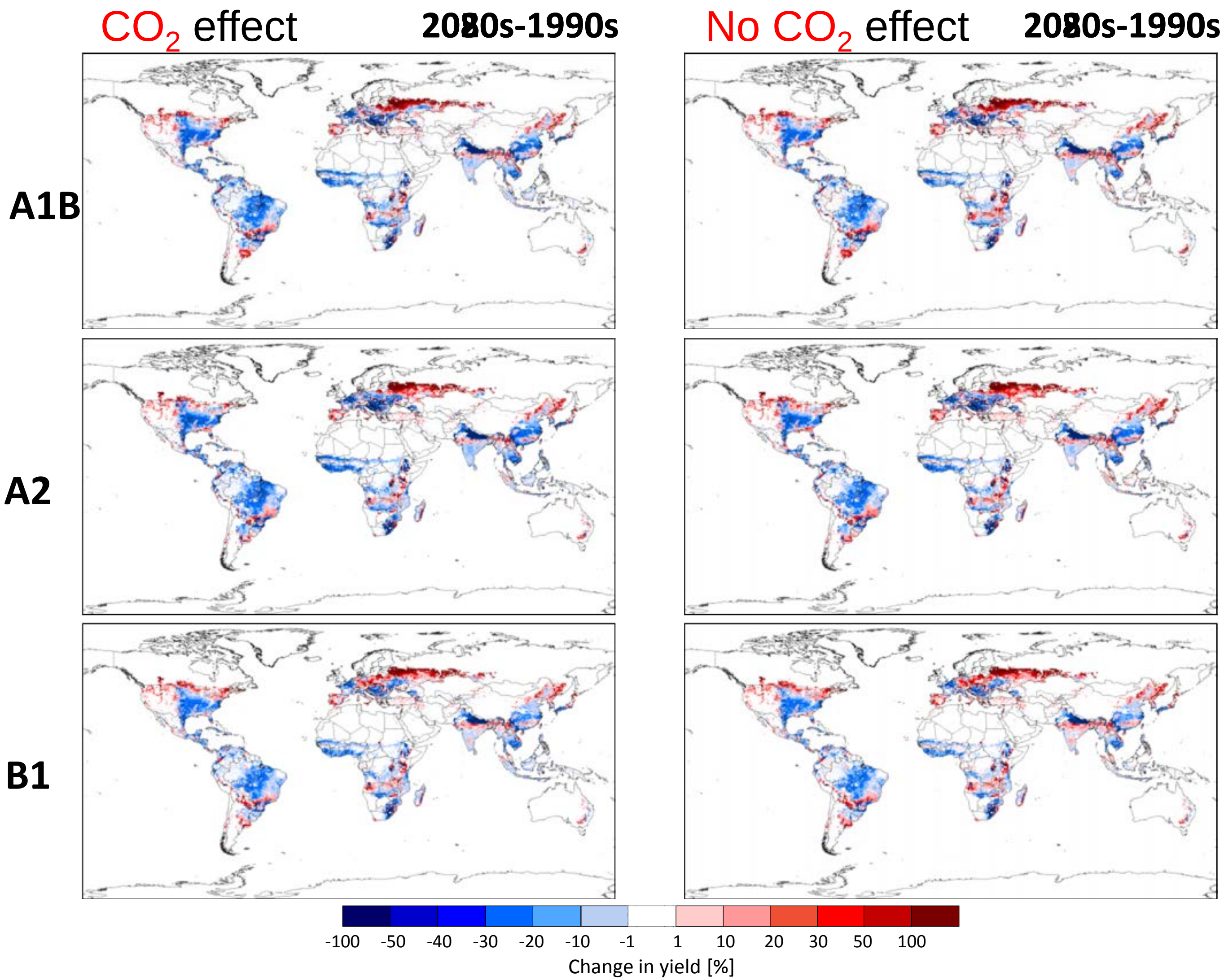


A2 scenario



B1 scenario

CO_2 Fertilization effect



CO_2 Fertilization effect

Average productivity change in maize for the top 13 producing countries

	Scenario		20s-90s	50s-90s	80s-90s
CO_2	A1B	Av.	-8.46	-11.74	-16.29
		S.D.	9.05	15.56	16.51
		D.P.	83.33	72.22	77.78
	A2	Av.	-6.49	-11.79	-21.51
		S.D.	12.60	15.49	22.94
		D.P.	64.29	71.43	71.43
	B1	Av.	-7.32	-8.86	-10.13
		S.D.	7.49	11.63	11.19
		D.P.	88.24	76.47	76.47

	Scenario		20s-90s	50s-90s	80s-90s
NO_ CO_2	A1B	Av.	-9.10	-14.94	-20.91
		S.D.	8.99	14.99	15.60
		D.P.	83.33	77.78	88.89
	A2	Av.	-7.12	-15.04	-26.88
		S.D.	12.51	14.92	21.43
		D.P.	64.29	78.57	92.86
	B1	Av.	-7.85	-10.92	-13.15
		S.D.	7.45	11.37	10.81
		D.P.	88.24	82.35	82.35

Av. : Average, S.D. : Standard Deviation, D.P. : Decrease Possibility

Summary

- Average productivity change in maize
  - In the 2020s - A1B: -8.8%, A2: -6.8%, B1: -7.5%
  - In the 2050s - A1B: -12.0%, A2: -12.4%, B1: -9.1%
  - In the 2080s - A1B: -16.2%, A2: -22.0%, B1: -10.2%
- Uncertainty of the Maize productivity
  - In the 2020s (A2 scenario) - Max: 12%, Min: -26%
  - In the 2050s (A1B scenario) - Max: 12%, Min: -40%
  - In the 2080s (A2 scenario) - Max: 10%, Min: -50%
- CO_2 fertilization effect is the most large for A2 scenario in the 2080s(5.37% increase)

References

About this presentation

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About GAEZ

- Paper
  - Fischer, G., et al.: Global Agro-ecological Assessment for Agriculture in the 21st Century: Methodology and Results, IIASA RR-02-02, International Institute for Applied Systems Analysis, Laxenburg, 2002
  - Masutomi, Y., et al.: Impact assessment of climate change on rice production in Asia in comprehensive consideration of process/parameter uncertainty in general circulation models, Agriculture, Ecosystems and Environment, 131, 281-291, 2009

Conclusion

- Water sector
  - Climate change impact assessment on water scarcity focusing on sub-annual issues.
- Agricultural sector
  - Propagation of uncertainties: climate projection into impact assessment.