Global Climate Projections with Relevance to Regional Climate and Impact Analysis

Seita Emori

Chief, Climate Risk Assessment Research Section
National Institute for Environmental Studies

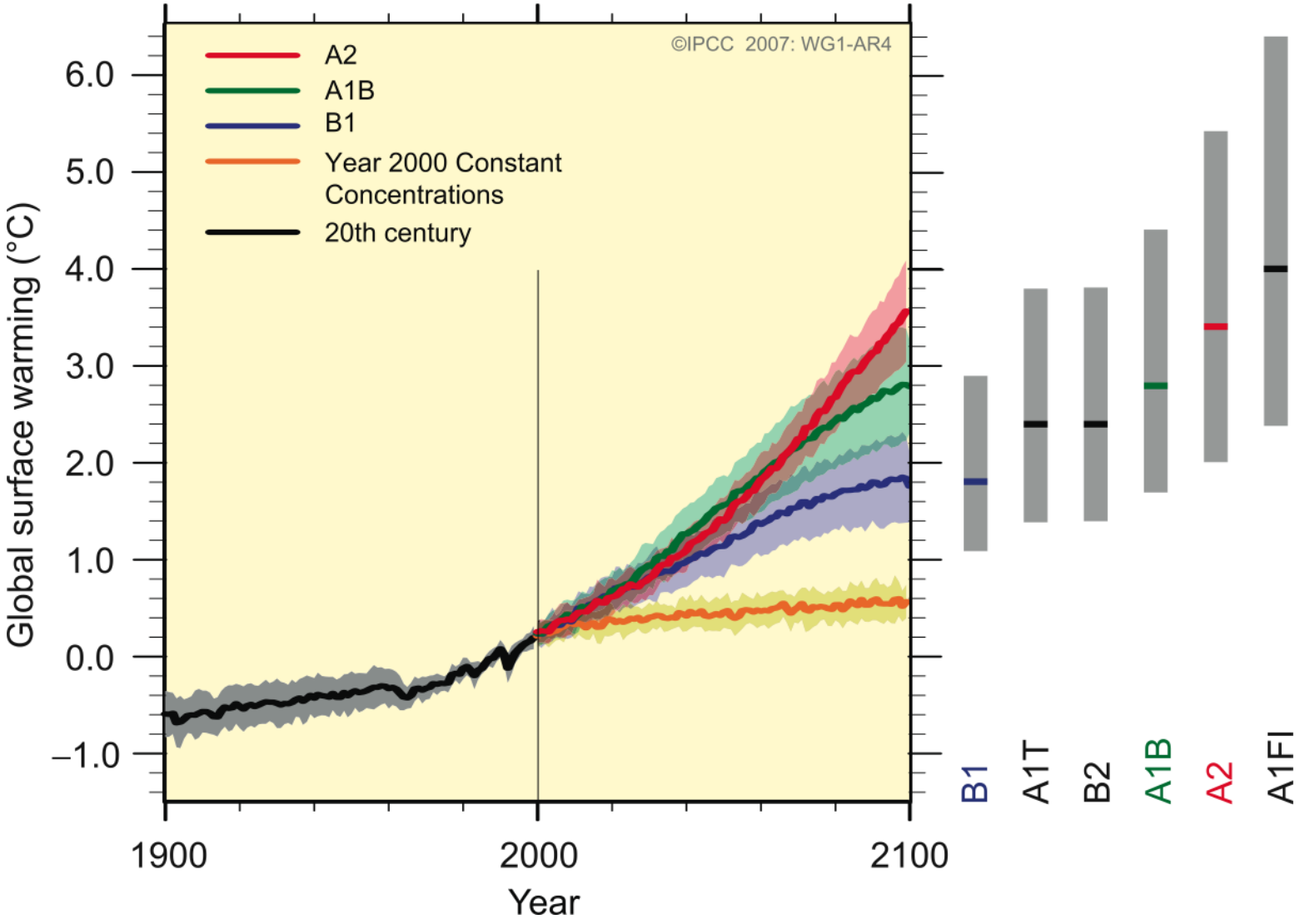
Associate Professor
Center for Climate System Research, Univ. of Tokyo

JAPAN

Outline

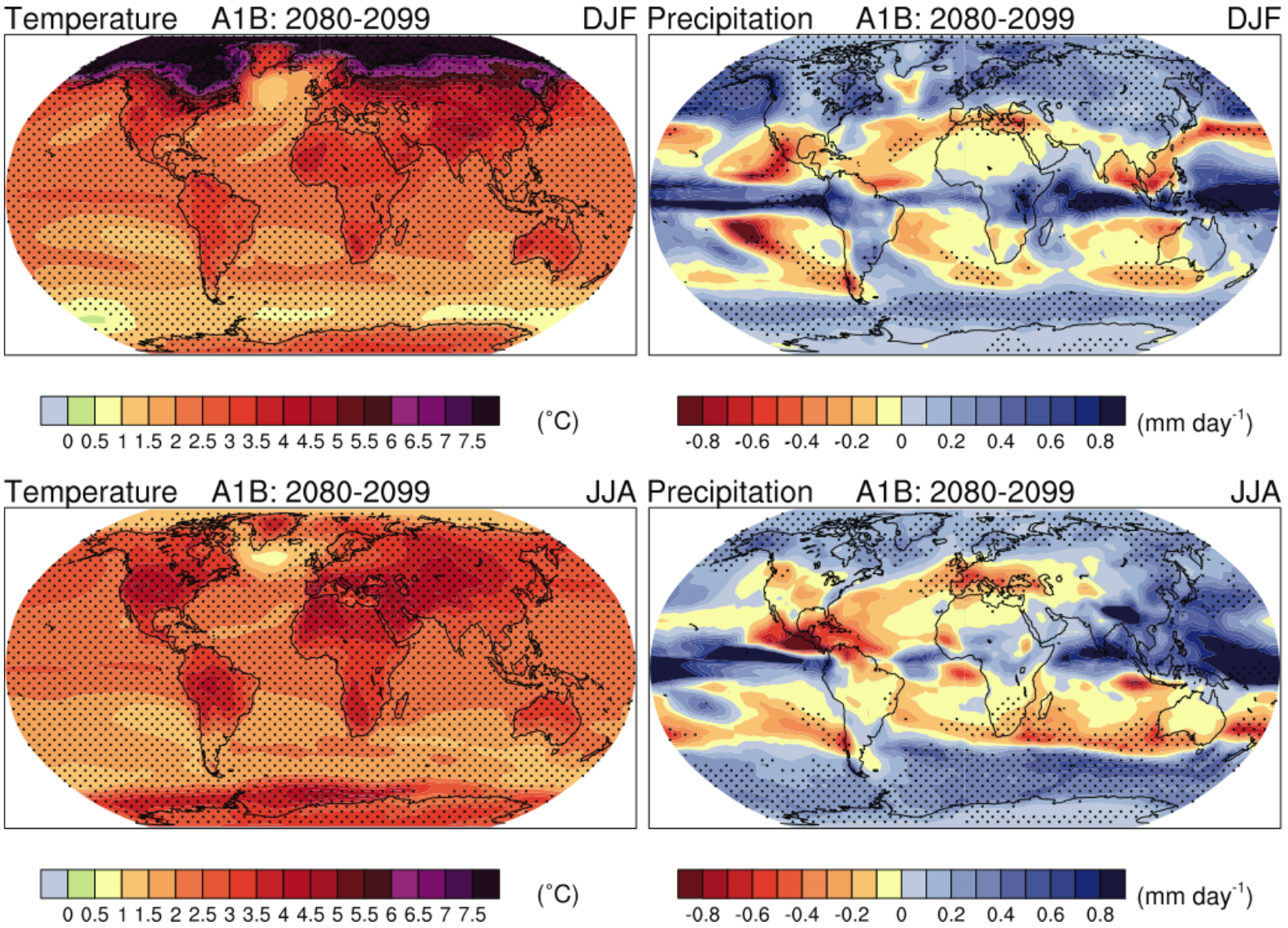
- Overview of global climate projections in IPCC AR4
- High resolution modeling and uncertainty
- Expert judgments on reliable projections
- How to choose reliable models – Metric
- A new approach to constrain uncertainty of projections

Global mean surface warming



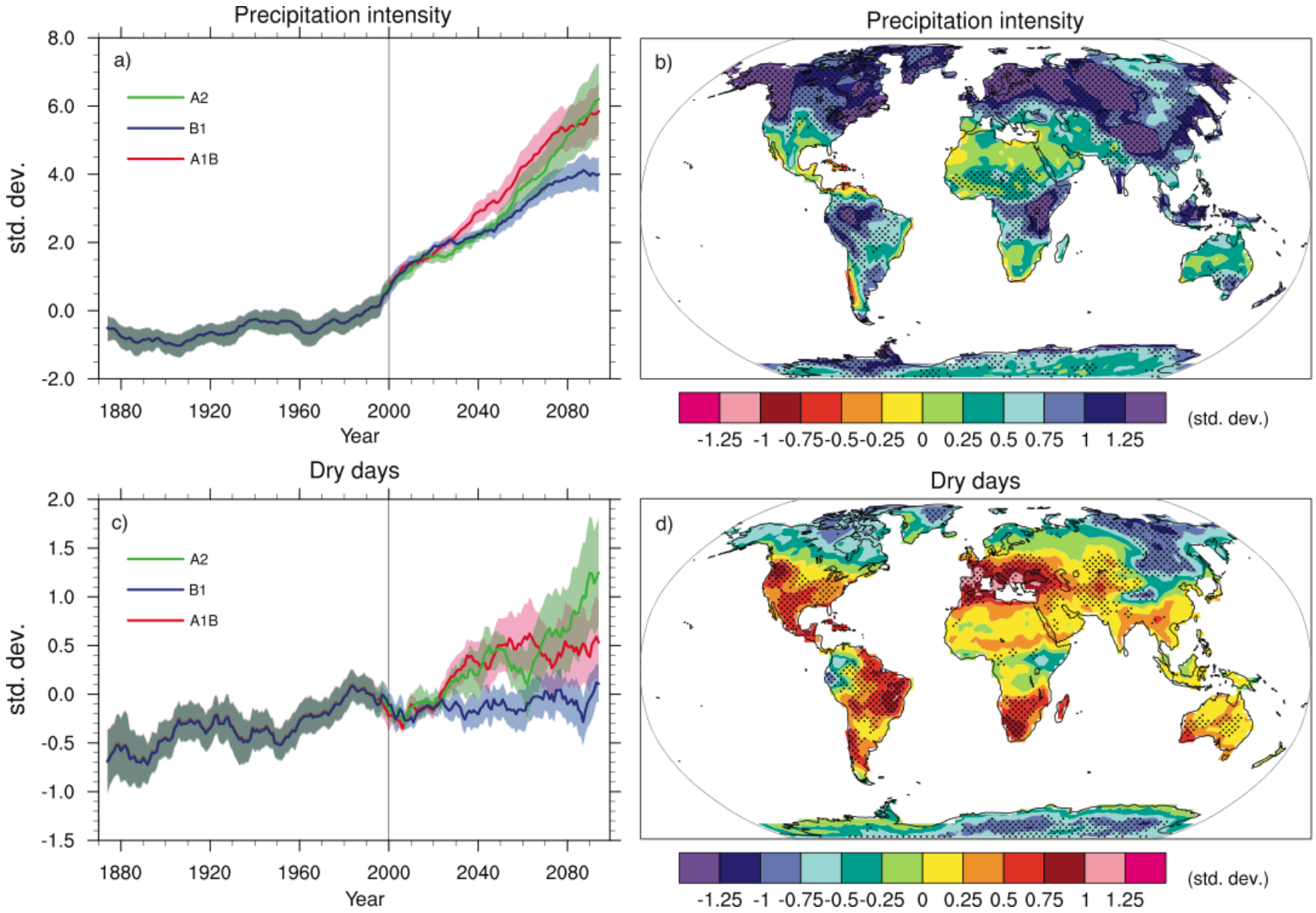
IPCC WG1 AR4 (2007)

Geographical Patterns



IPCC WG1 AR4 (2007)

Extreme Indices



IPCC WG1 AR4 (2007)

Japanese Climate Modeling Activities for AR4 with the "Earth Simulator"

	Conventional		On ES
Coupled Atmosphere-Ocean Model (100s-year)	Atm. ~300 km Ocn. ~100 km	→	**Atm. ~100 km** **Ocn. ~20 km**
Time-slice Global Atmospheric Model (10s-year)	~100 km	→	**~20 km**

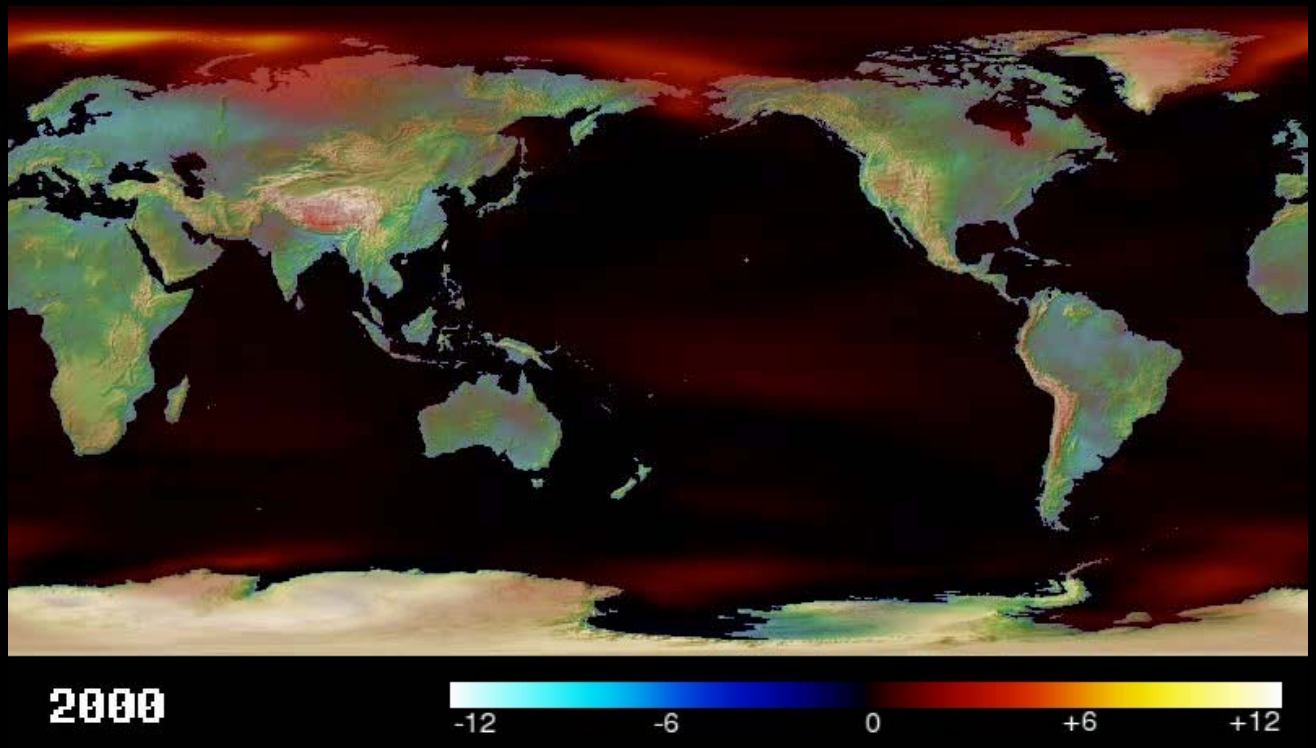
Earth System Model at conventional resolution

Global Cloud Resolving Model (10s-days, ~3.5km)

CCSR/NIES/FRCGC AOGCM: MIROC-hi

Atm. ~100 km, 56 levels
Ocn. ~20 km, 48 levels

+ Land, Sea ice, River,
Interactive Aerosols



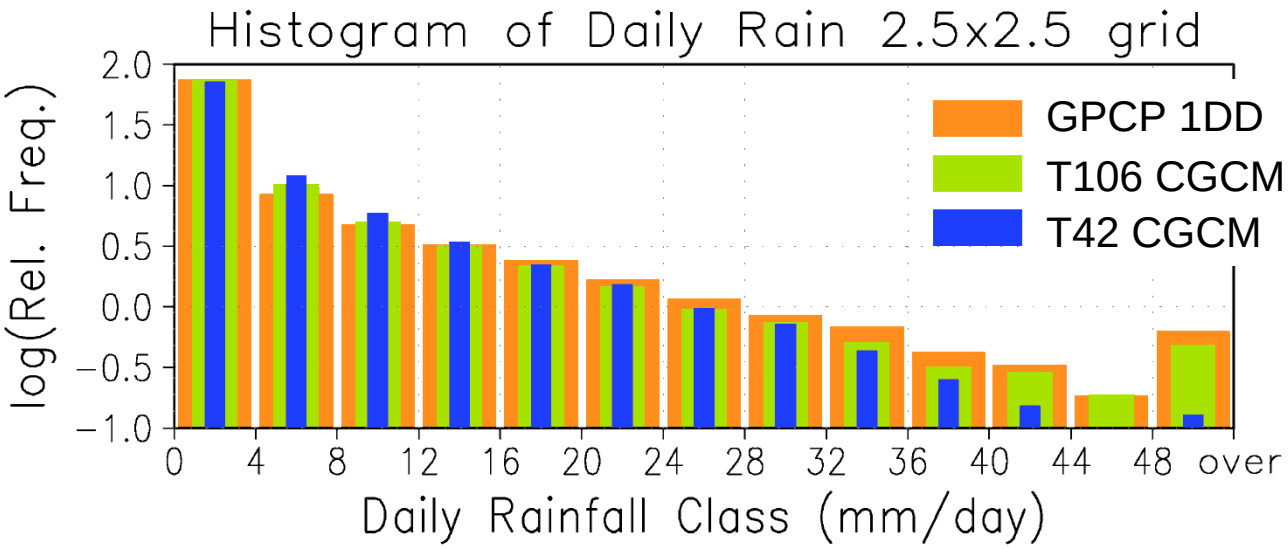
100-year integration
in 30 elapsed days
on 86 ES nodes

- Control
- 1%/yr CO2
- 20C
- SRES A1B
- SRES B2

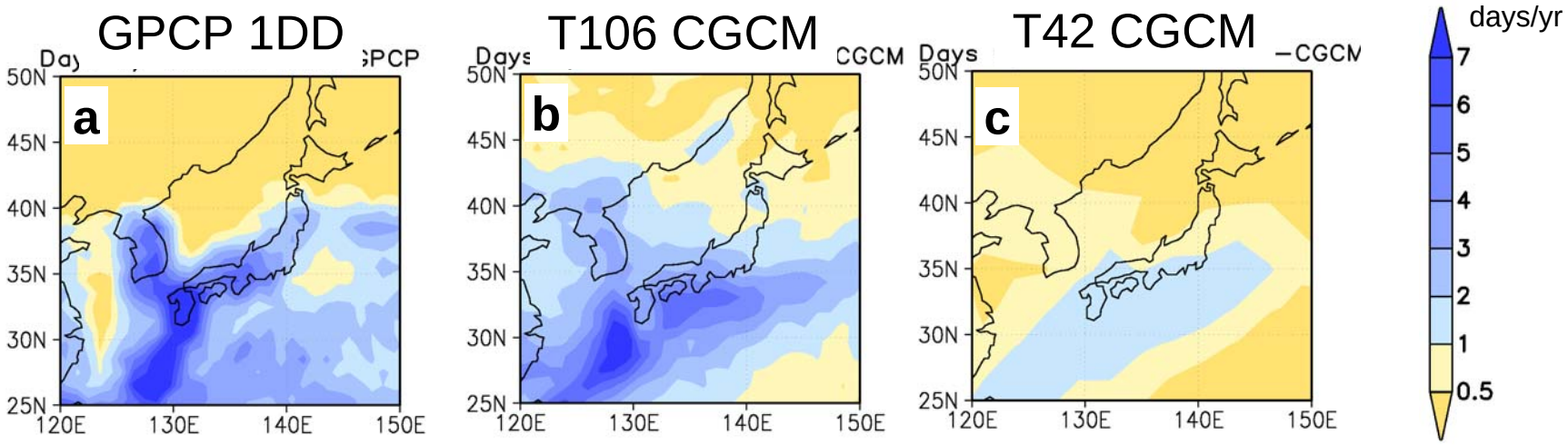
submitted to AR4

CCSR/NIES/FRCGC/MEXT RR2002

High-resolution is *NECESSARY* for extremes



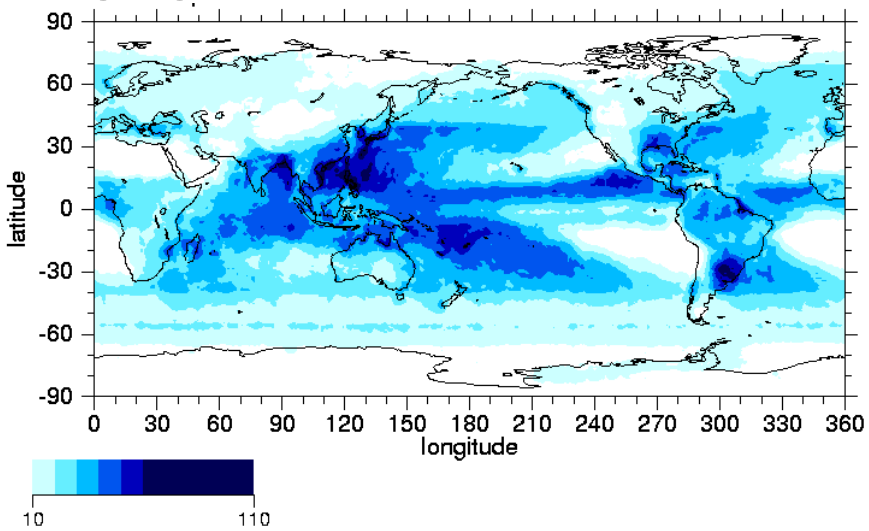
Frequency of daily precipitation > 50mm/day



Kimoto et al. (2005)

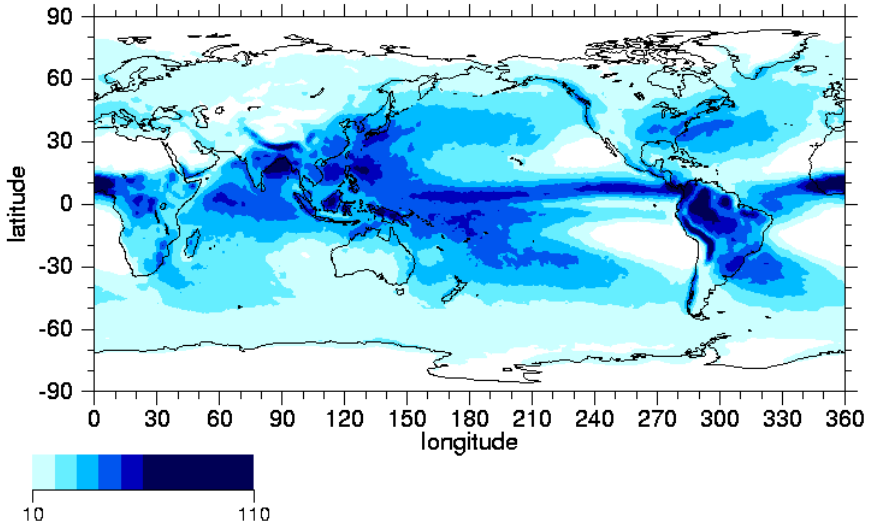
High-resolution is *NOT SUFFICIENT* for extremes

GPCP 1DD

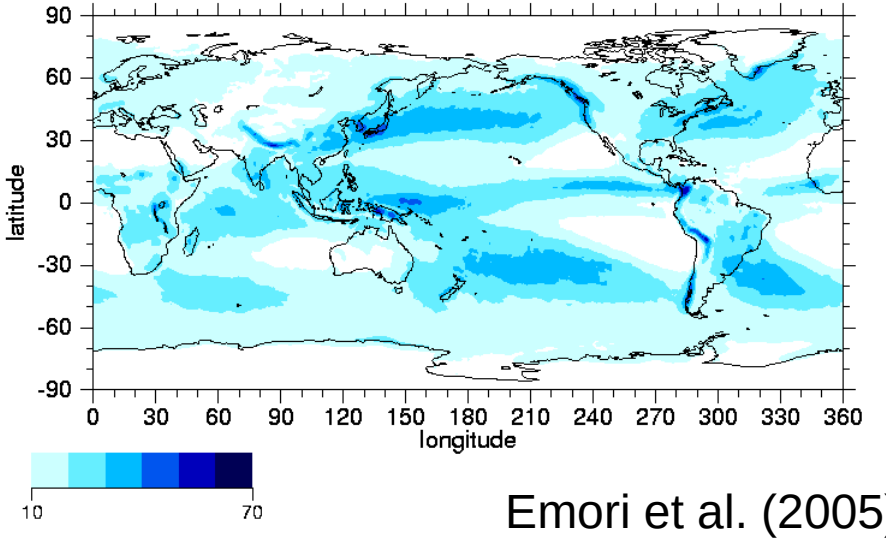


99th %ile daily precipitation intensity

T106 CGCM (RHC=0.8)



T106 CGCM (RHC=0.0)



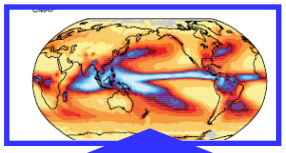
Emori et al. (2005)

Which projection is reliable?

a. Statistical Significance: The climate change signal is distinguishable from natural variability
b. Robustness or Inter-Model Consistency: The change is robustly found in many different models
c. Interpretability: The physical interpretation of the change is clear and reasonable
d. Validity of Key Processes: The key processes to the change is realistically represented in the model and well validated against observational data in current climate

Subjective(expert judgment) -> Objective

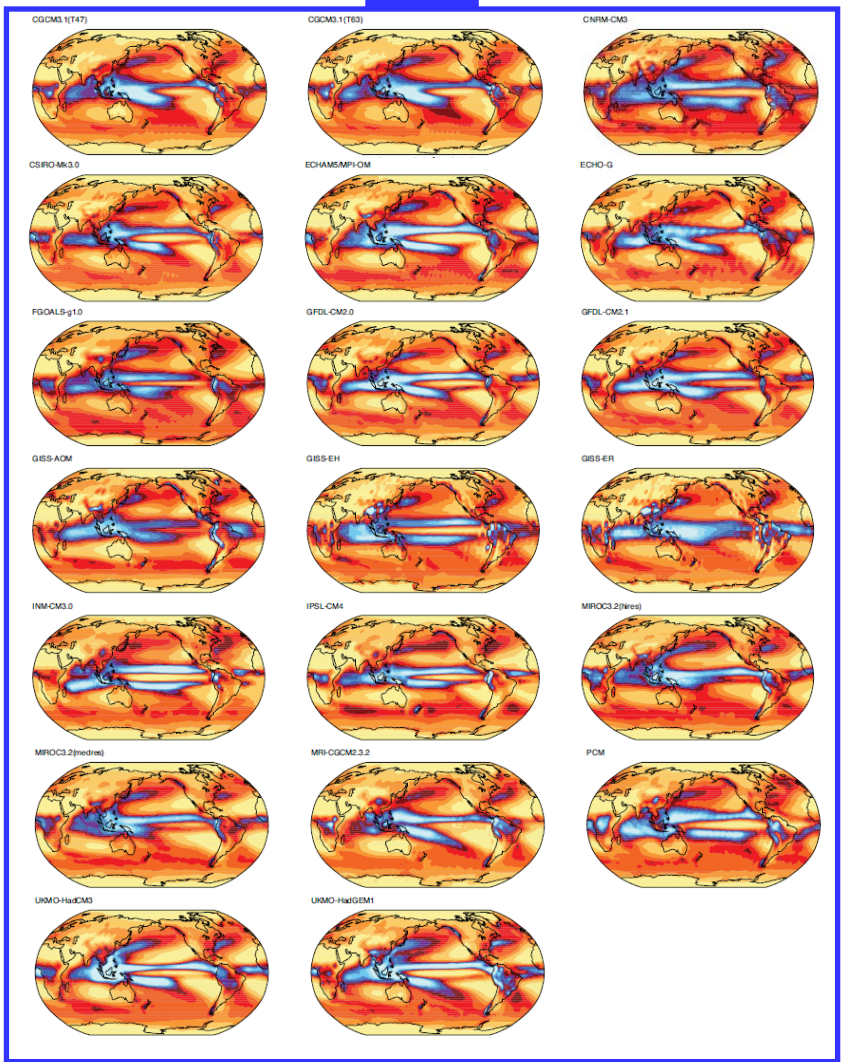
20C Reproduction



Observed Data

Validation

Models

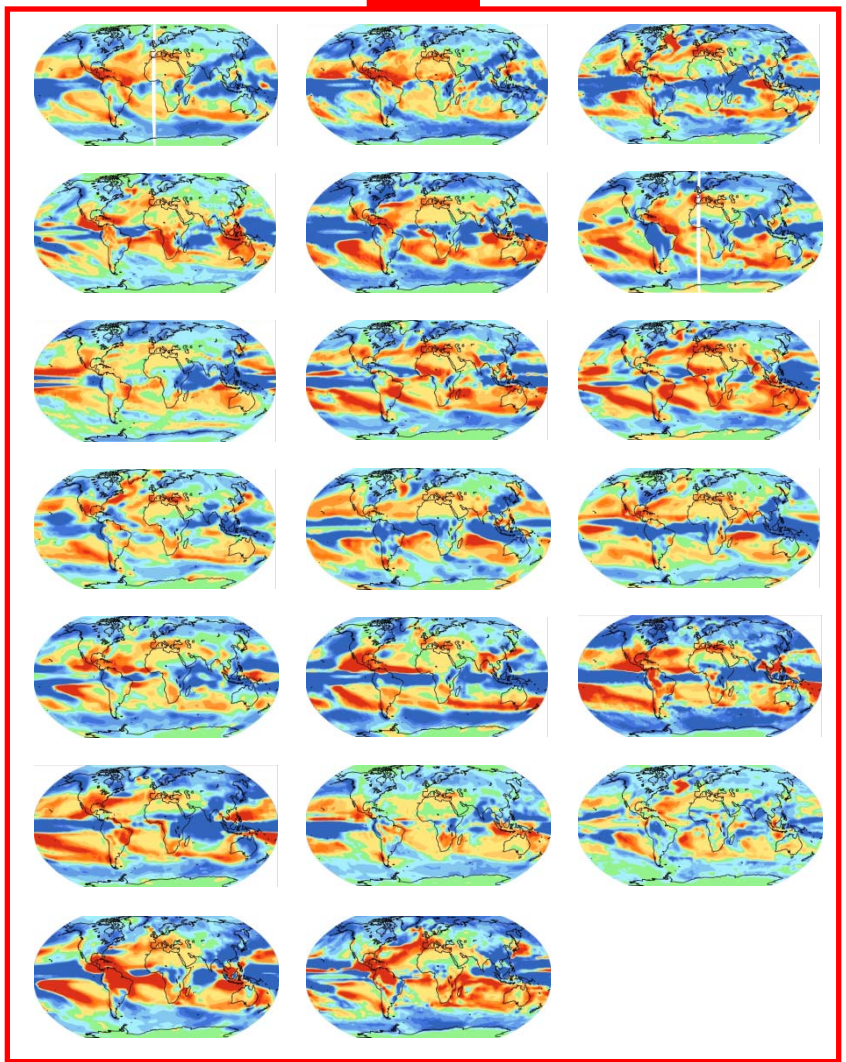


21C Prediction

Observed Data

Validation

Models



Measuring skills of climate models

ex. for global precipitation pattern (Nohara et al., 2006)

Table 2: Annual mean precipitation (MEAN, mm/day), root-mean-square difference (RMS), and pattern correlation (R) for the individual model relative to GPCP.

Models	MEAN	RMS	R	Models	MEAN	RMS	R
CNRM-CM3	3.45	1.62	0.697	MIROC3.2(hires)	3.10	1.30	0.802
CSIRO-Mk3.0	2.65	1.27	0.761	MIROC3.2(medres)	2.83	1.16	0.815
GFDL-CM2.1	3.03	1.32	0.797	ECHAM5/MPI-OM	3.07	1.56	0.747
GISS-AOM	3.00	1.53	0.690	MRI-CGCM2.3.2	2.69	1.10	0.851
GISS-EH	3.13	1.78	0.622	NCAR-CCSM3	2.94	1.42	0.749
GISS-ER	3.10	1.73	0.673	NCAR-PCM	3.25	1.99	0.552
INM-CM3.0	2.98	1.90	0.605	UKMO-HadCM3	3.05	1.63	0.792
IPSL-CM4	2.75	1.43	0.762				
GPCP	2.74						

Measuring skills of climate models

ex. for global precipitation pattern (Nohara et al., 2006)

Table 2: ifference (RMS), a

Models	R
CNRM	0.802
CSIRO	0.815
GFDL-	0.747
GISS-A	0.851
GISS-E	0.749
GISS-E	0.552
INM-C	0.792
IPSL-C	
GPCP	

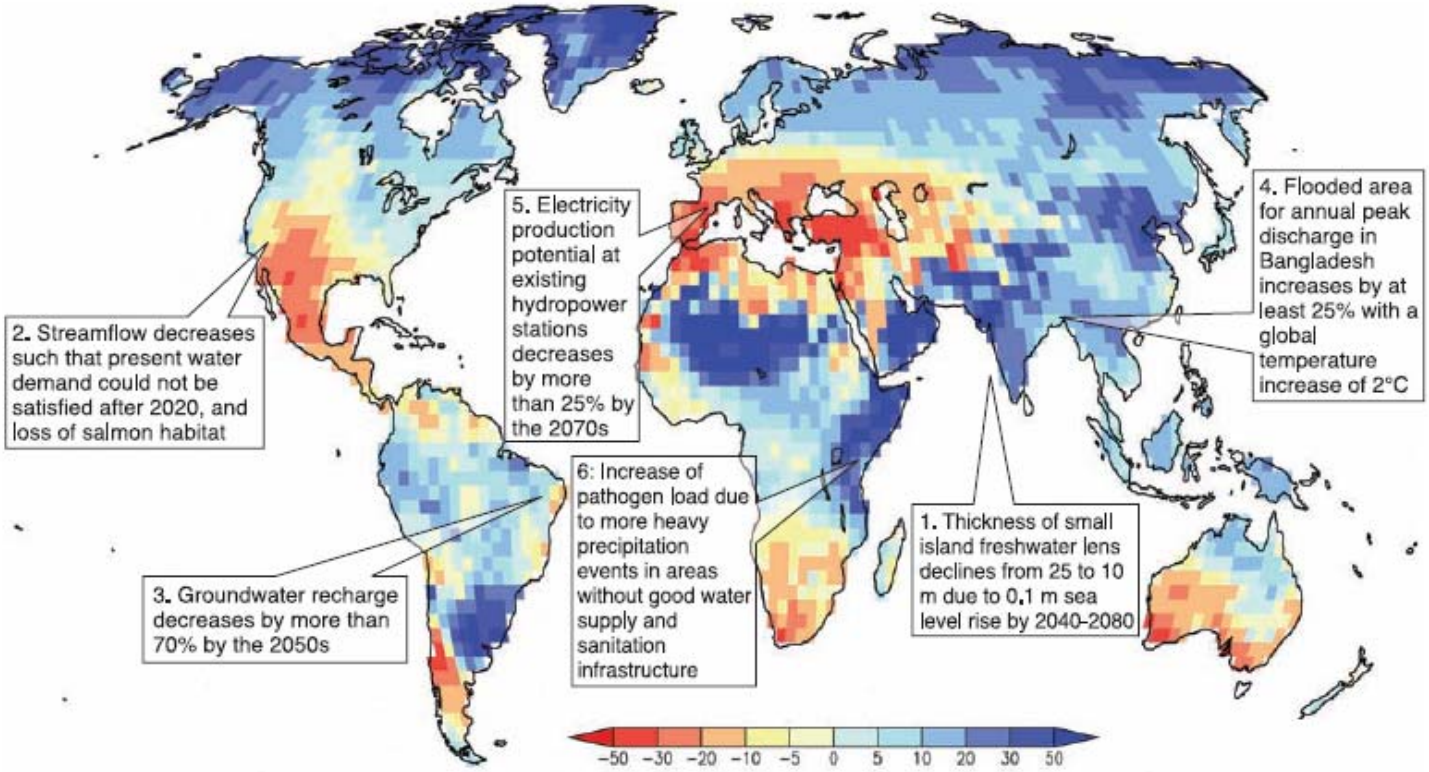


Figure TS.5. *Illustrative map of future climate change impacts on freshwater which are a threat to the sustainable development of the affected regions. Background shows ensemble mean change of annual runoff, in percent, between the present (1981-2000) and 2081-2100 for the SRES A1B emissions scenario; blue denotes increased runoff, red denotes decreased runoff. Underlying map from Nohara et al. (2006) [F3.8].*

Weighted Multi-Model Ensemble Mean of Runoff

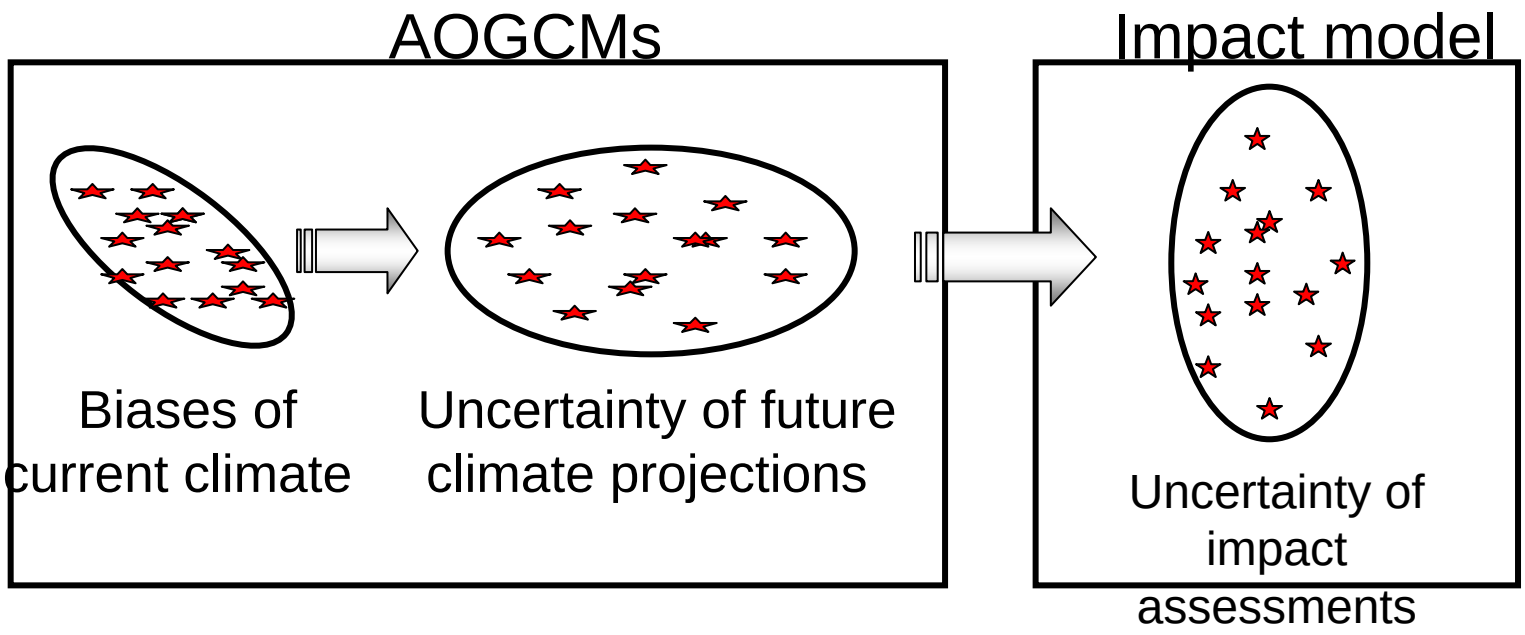
How to choose the metric?

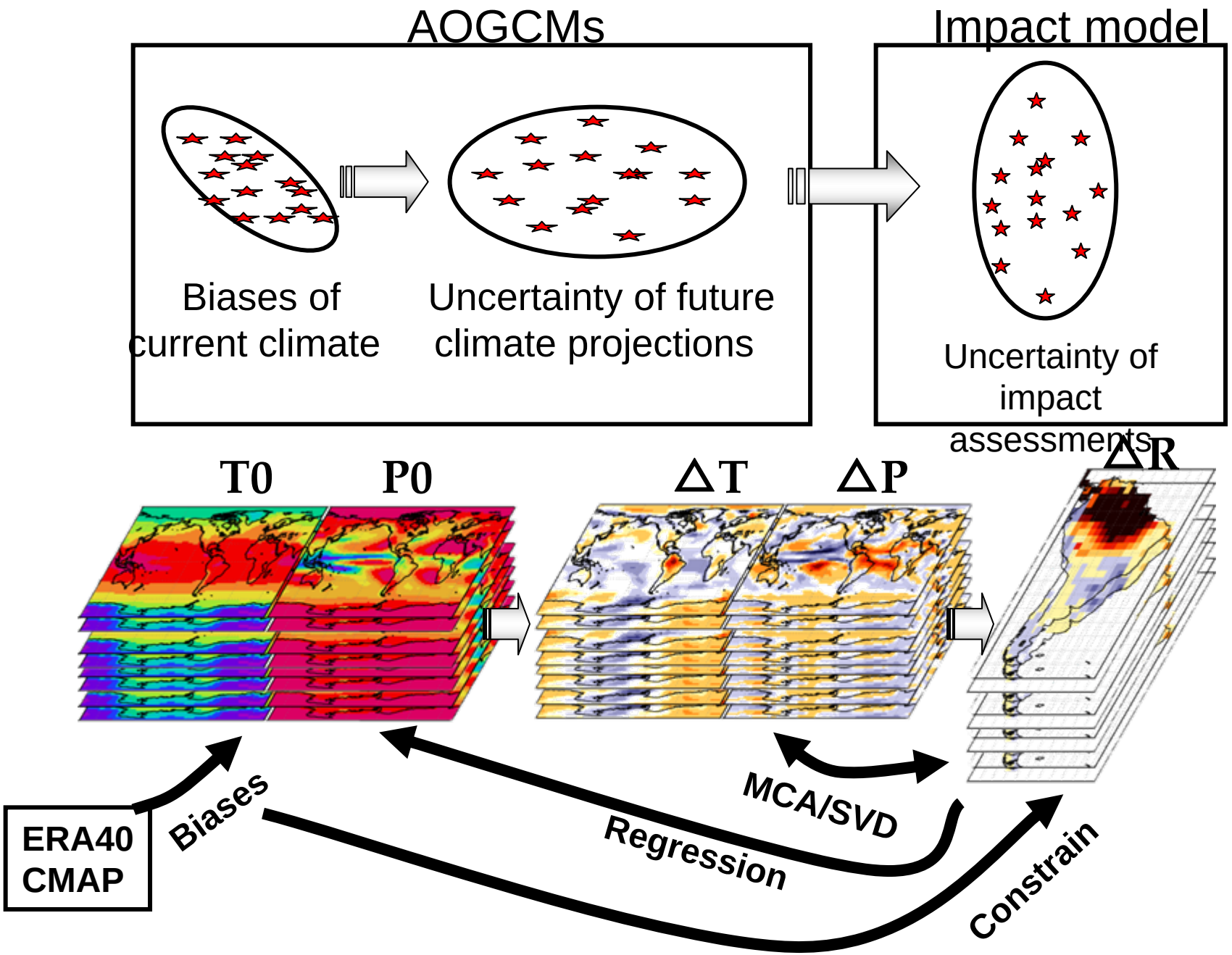
Is RMS or pattern correlation a good indicator of *reliability of future projection*?

-> not obvious

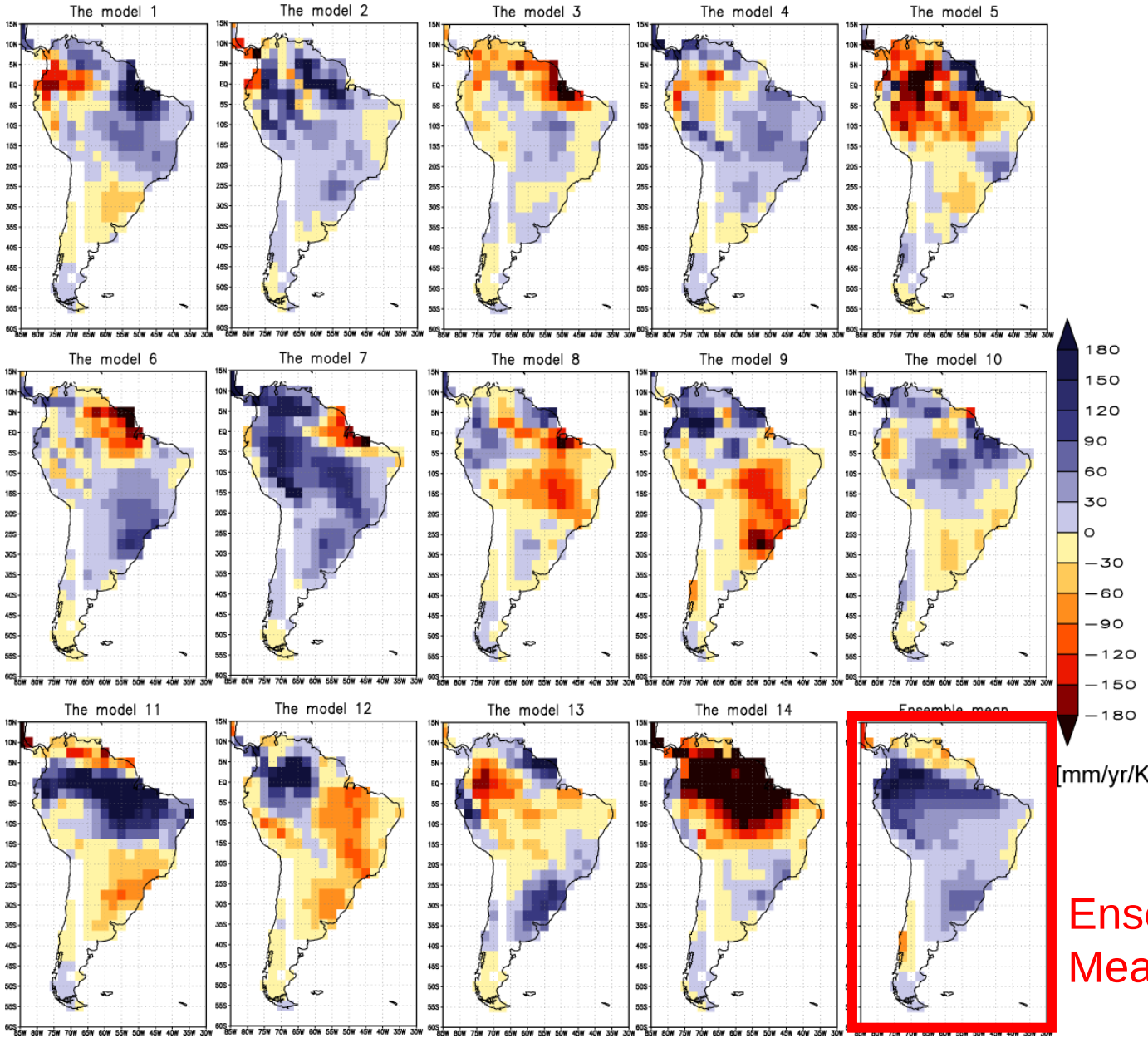
Key Uncertainties:
A proven set of model metrics comparing simulations with observations, that might be used to narrow the range of plausible climate projections, has yet to be developed.

(IPCC AR4 TS)


AOGCMs
Impact model
Biases of current climate
Uncertainty of future climate projections
Uncertainty of impact assessments

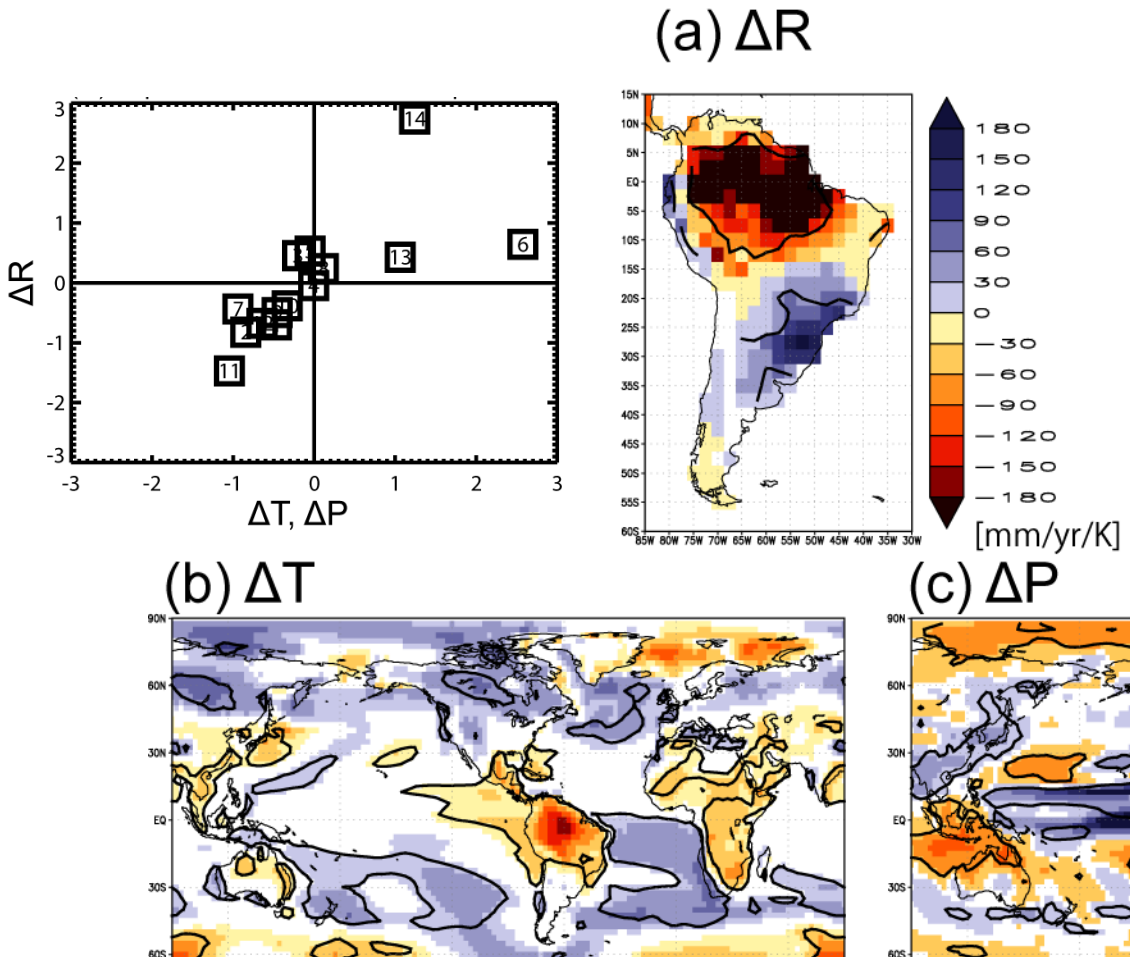

AOGCMs
Impact model
Biases of current climate
Uncertainty of future climate projections
Uncertainty of impact assessments
T0
P0
ΔT
ΔP
ΔR
ERA40
CMAP
Biases
Regression
MCA/SVD
Constrain

Runoff Changes from Various Models



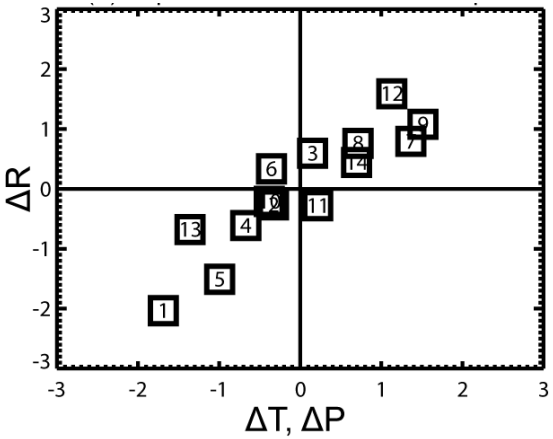
Ensemble Mean

1st mode (47%)

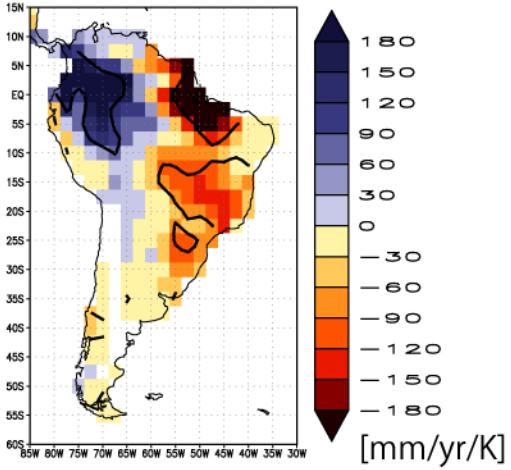


Principal mode of inter-model variation extracted from Maximum Covariance Analysis of ΔR and (ΔT, ΔP)

2nd mode (19%)

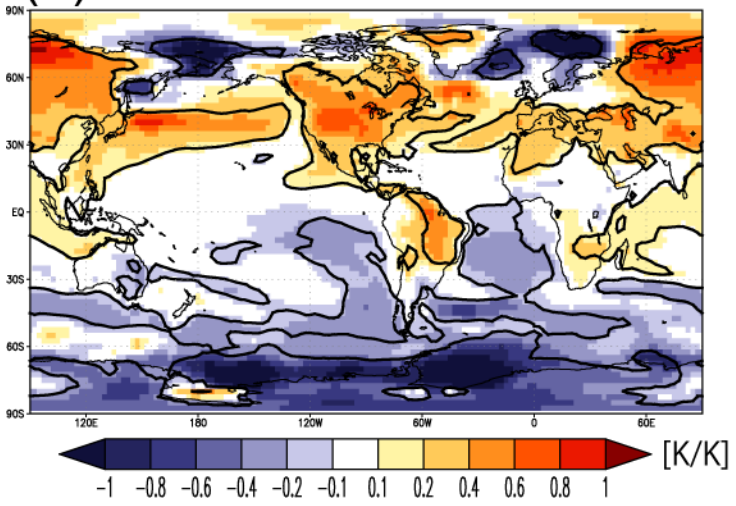


(a) ΔR

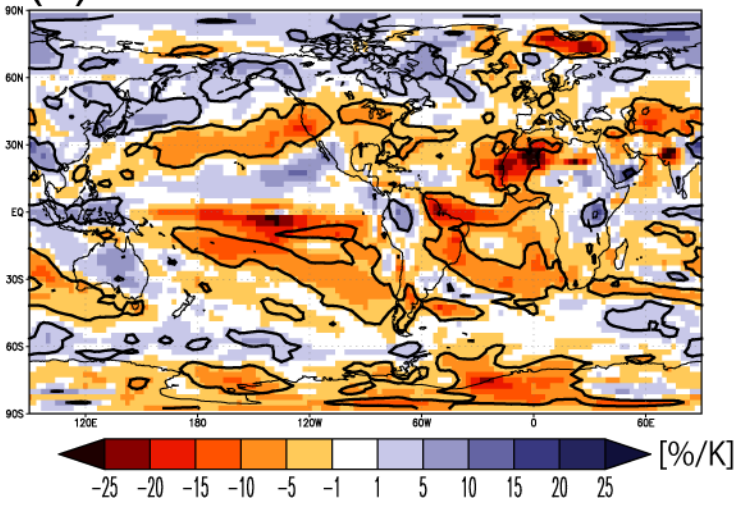


Principal mode of inter-model variation extracted from Maximum Covariance Analysis of ΔR and (ΔT, ΔP)

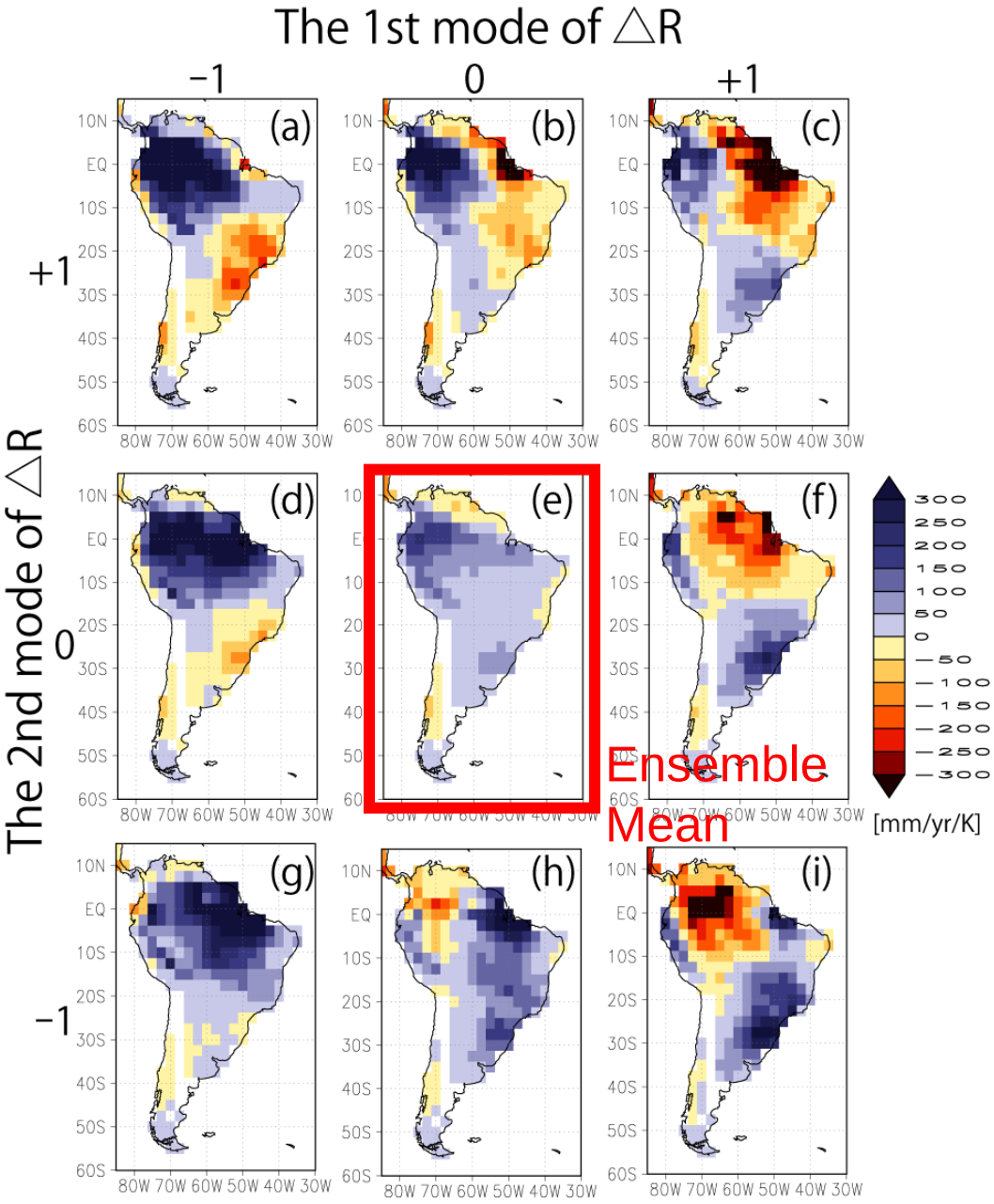
(b) ΔT



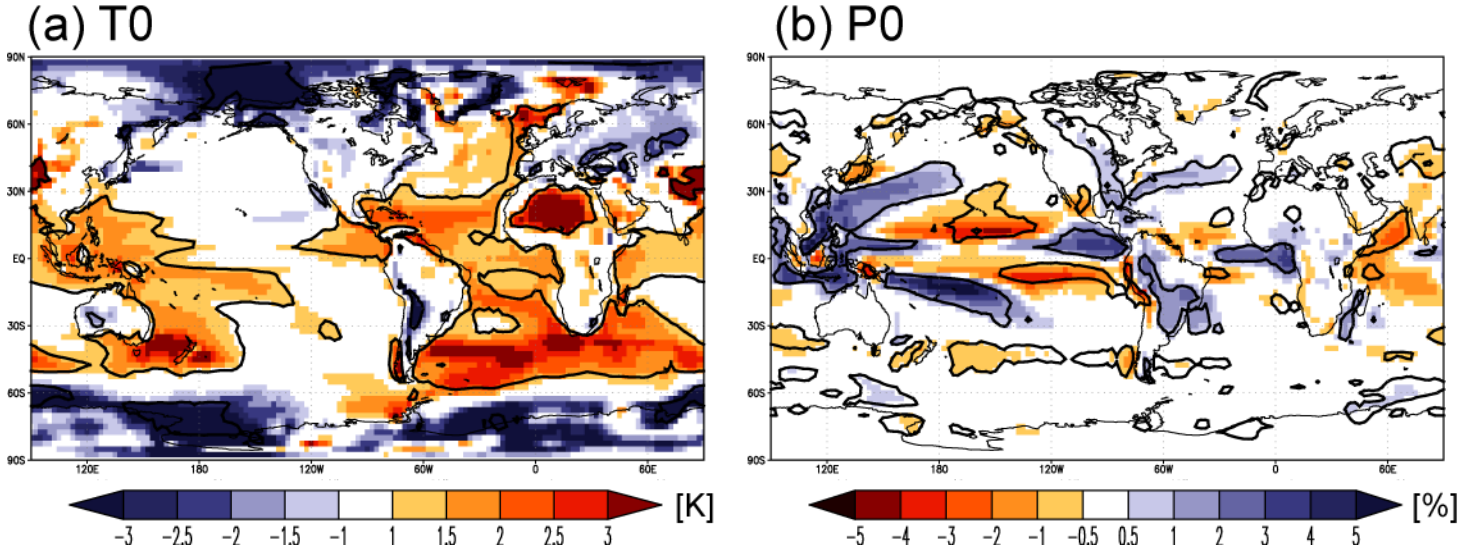
(c) ΔP

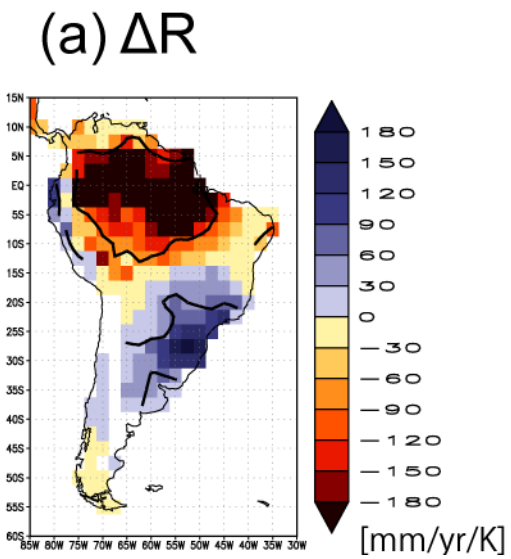


Inter-model variation in the two modes

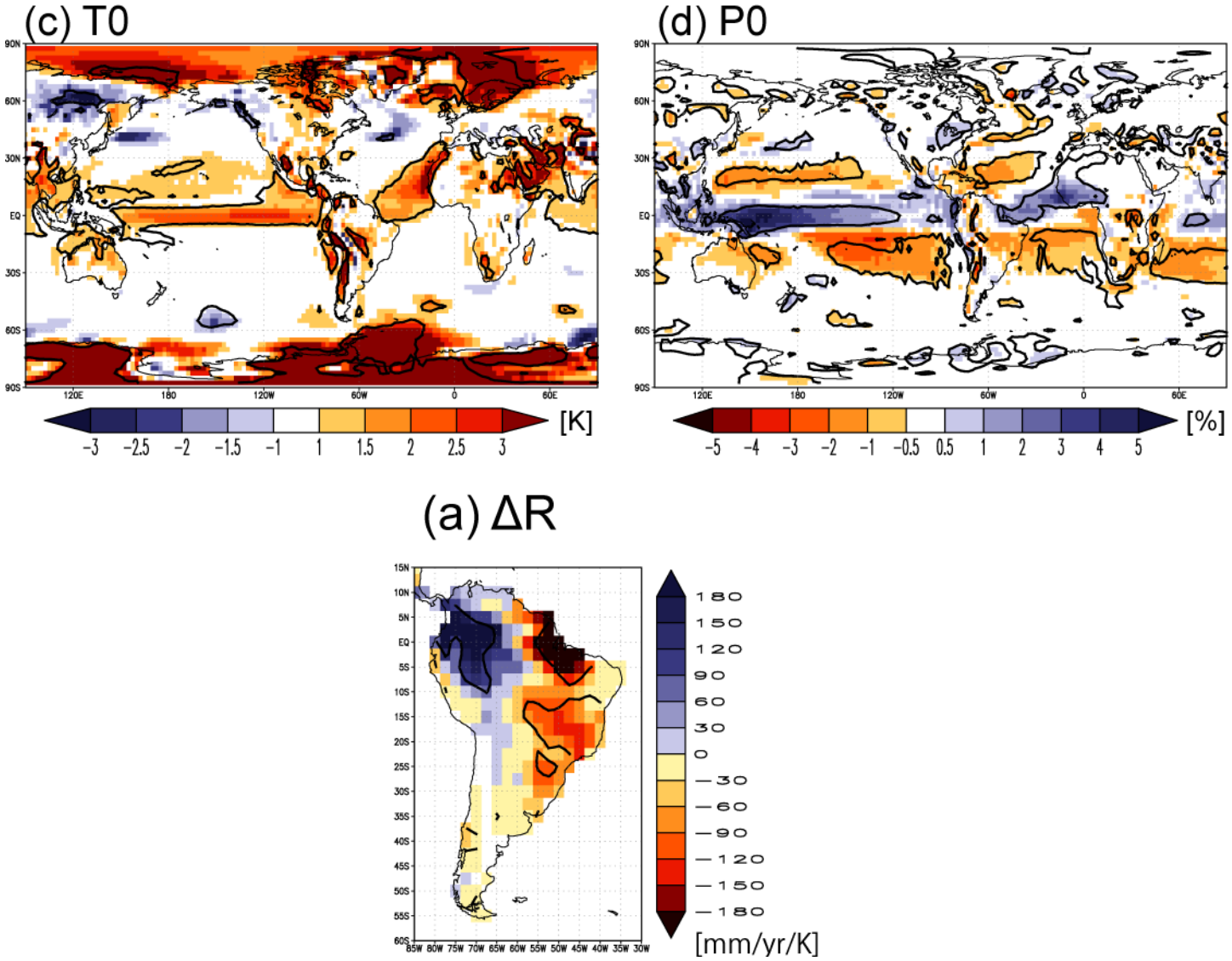


Patterns of Present Climate Biases regressed on the 1st mode

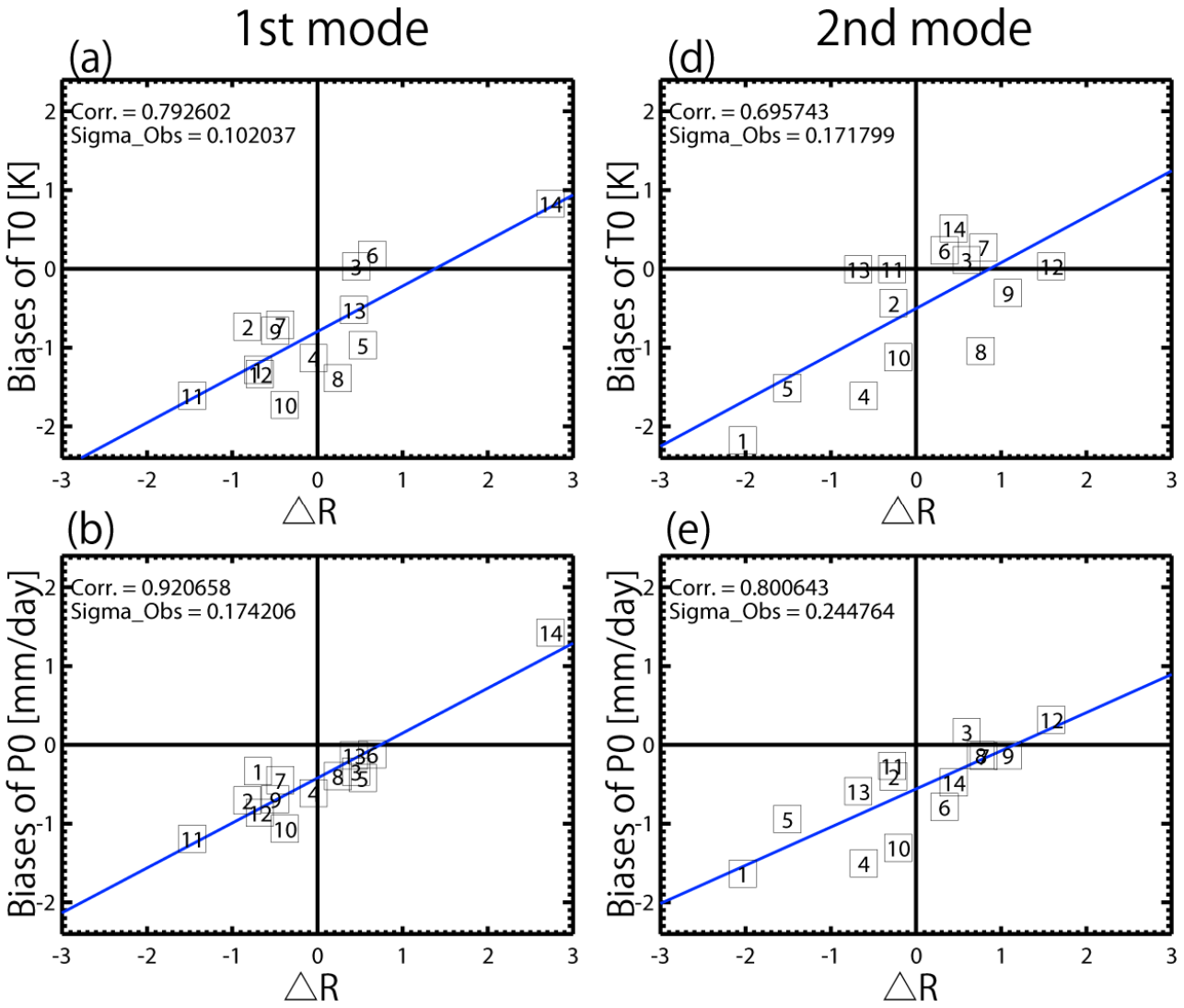




Patterns of Present Climate Biases regressed on the 2nd mode



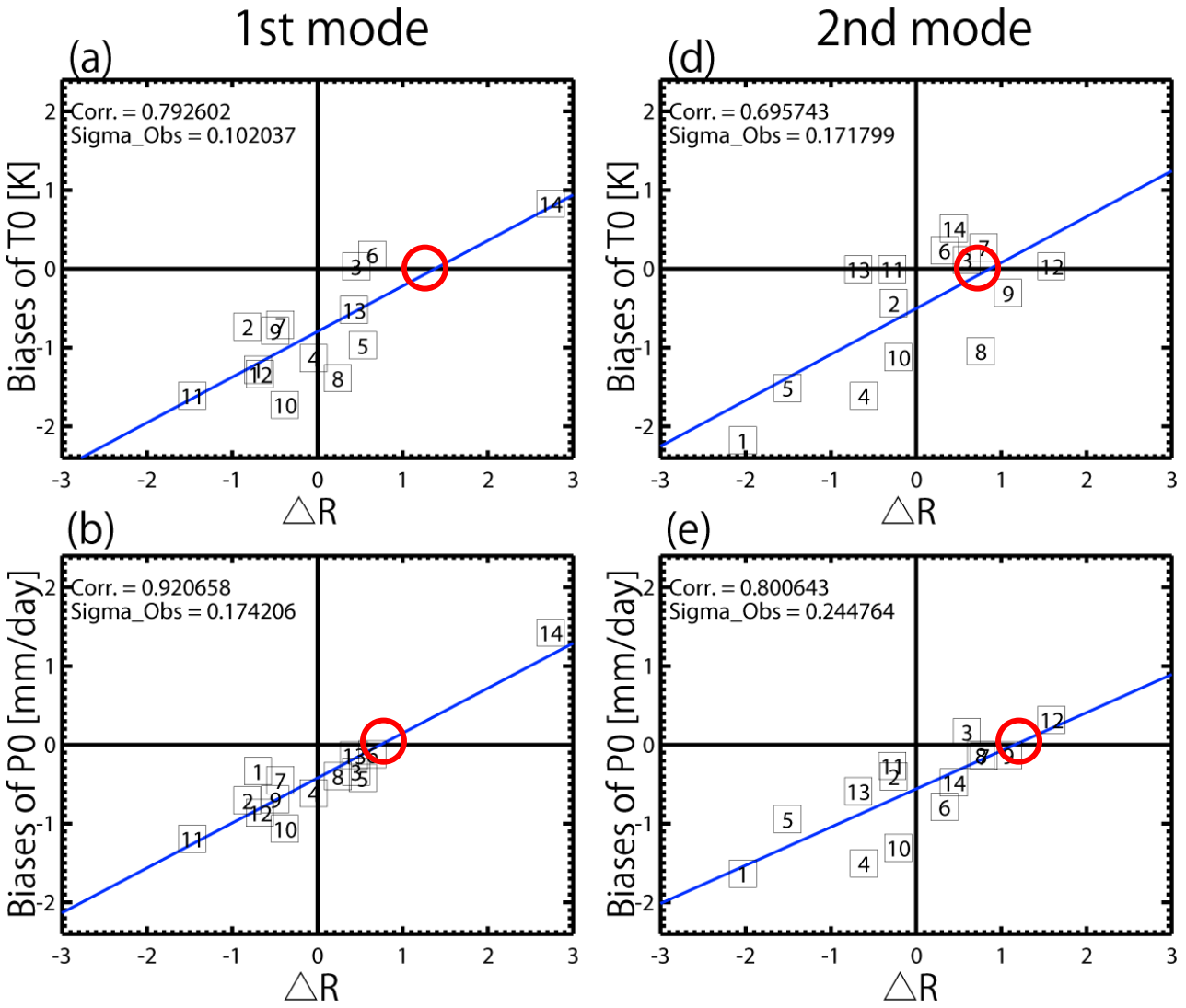
Biases of models along the principal modes



Biases = Model minus ERA40 (T) or CMAP (P)

Biases of models along the principal modes

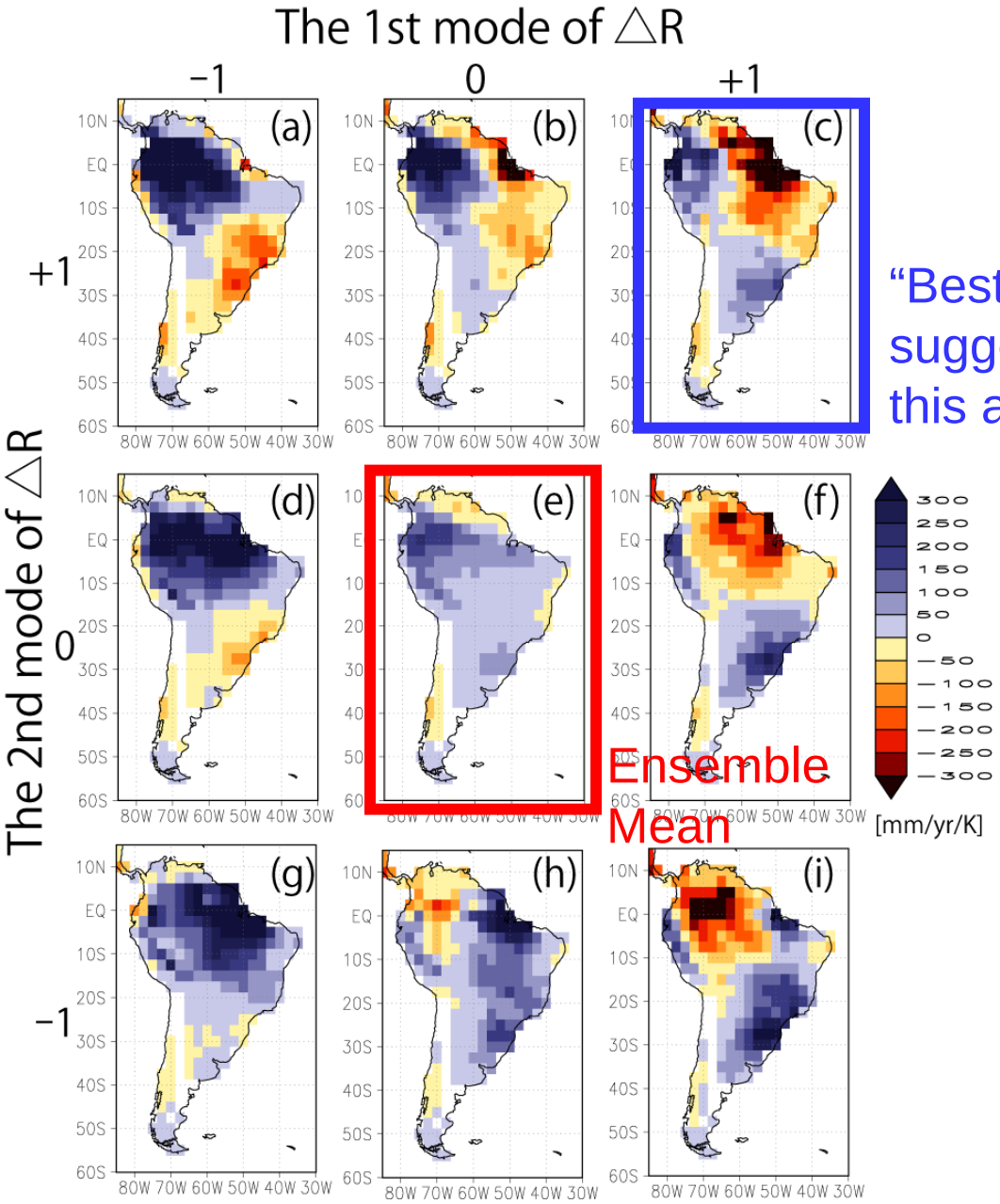
~+1 stdv. gives the Minimum Bias for 1st mode



~+1 stdv. gives the Minimum Bias for 2nd mode

Biases = Model minus ERA40 (T) or CMAP (P)

Constraining Uncertainty



"Best Estimate" suggested by this analysis

Summary

- Climate change patterns projected by global climate models are fairly robust for a semi-continental scale, but not so for finer scales.
- Higher-resolution models don’t necessarily give more reliable projections.
- Some subjective measures for reliability of projections can be raised.
- Observed data of current climate could be used for constraining uncertainty, but the question is how to choose a metric.
- Statistical analysis could help find an appropriate metric for a particular aspect of climate change over a particular region.