Water Cycle Projection in Asia by Super-High-Resolution Climate Model

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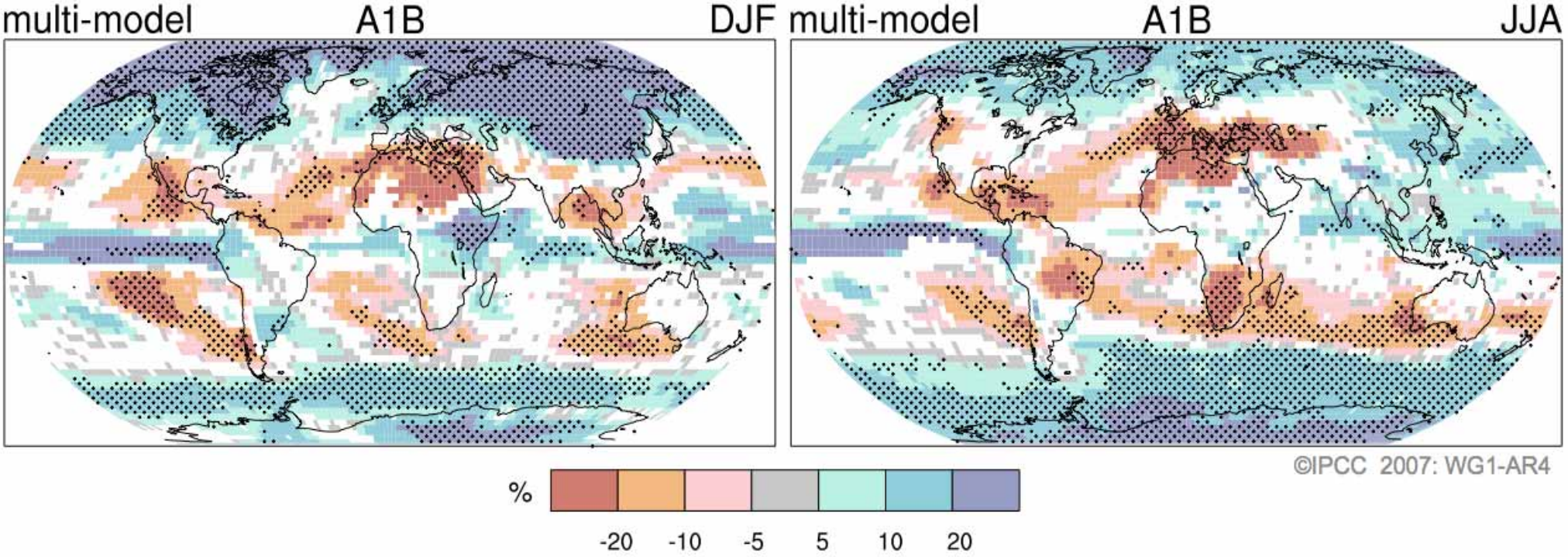
Precipitation changes

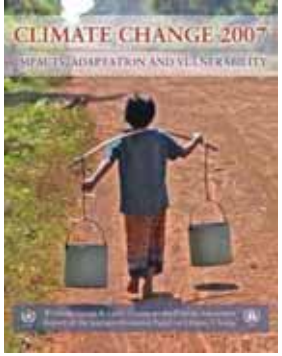


White: <2/3 of models agree on sign of change

Stippled: >90% of models agree on sign of change

Precipitation increases *very likely* in high latitudes

Decreases *likely* in most subtropical land regions



IPCC AR4

Impacts: Freshwater

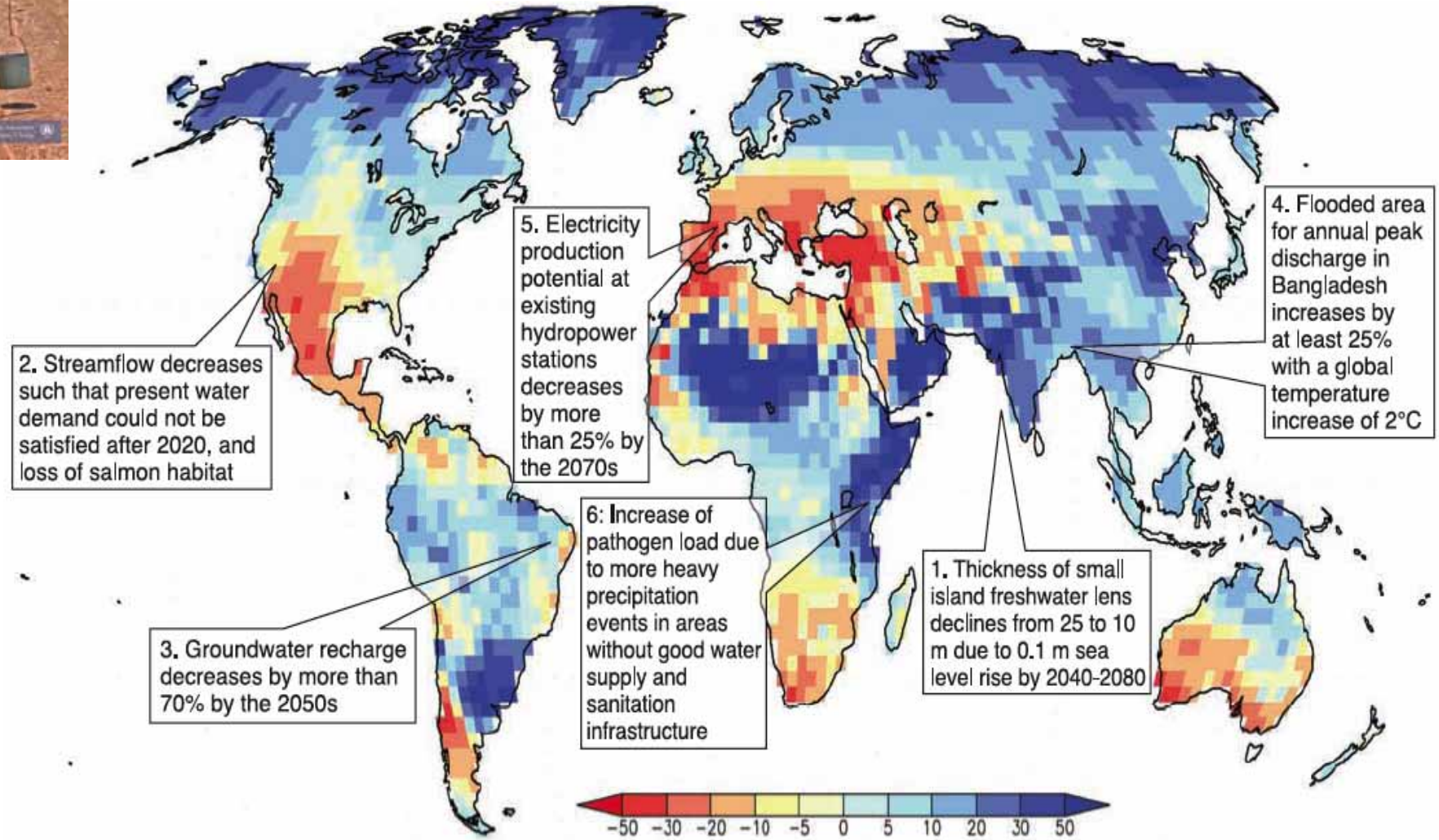
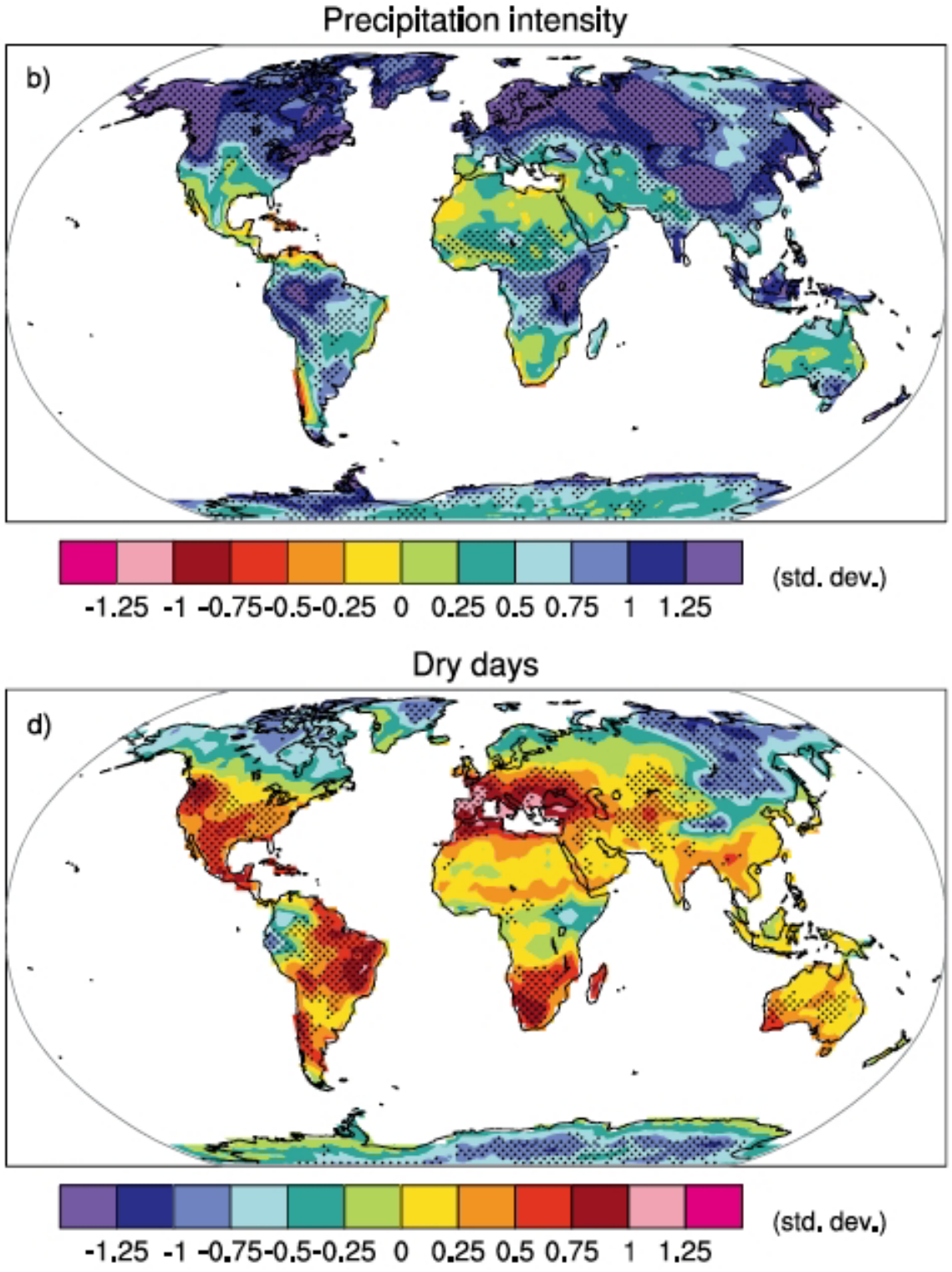


Figure 3.8. *Illustrative map of future climate change impacts on freshwater which are a threat to the sustainable development of the affected regions. 1: Bobba et al. (2000), 2: Barnett et al. (2004), 3: Döll and Flörke (2005), 4: Mirza et al. (2003) 5: Lehner et al. (2005a) 6: Kistemann et al. (2002). Background map: Ensemble mean change of annual runoff, in percent, between present (1981 to 2000) and 2081 to 2100 for the SRES A1B emissions scenario (after Nohara et al., 2006).*

Increases in the frequency of droughts and floods are projected to affect local crop production negatively, especially in subsistence sectors at low latitudes.



Projected changes in extremes

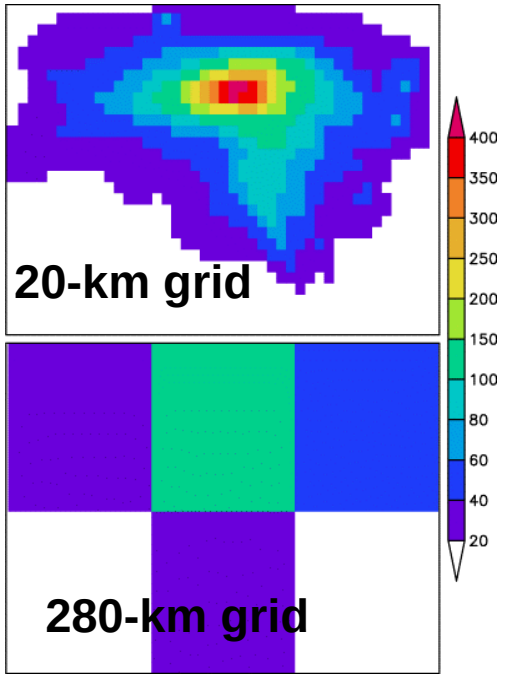
Warming of day and night extreme temperatures is *virtually certain*.

It is *very likely* that heat waves and heavy precipitation events will continue to become more frequent.

Based on a range of models, it is *likely* that future tropical cyclones will become more intense.

Needs for High-Resolution Model

Daily precipitation amount on certain day (mm/day)



Extreme events are **highly local phenomena**

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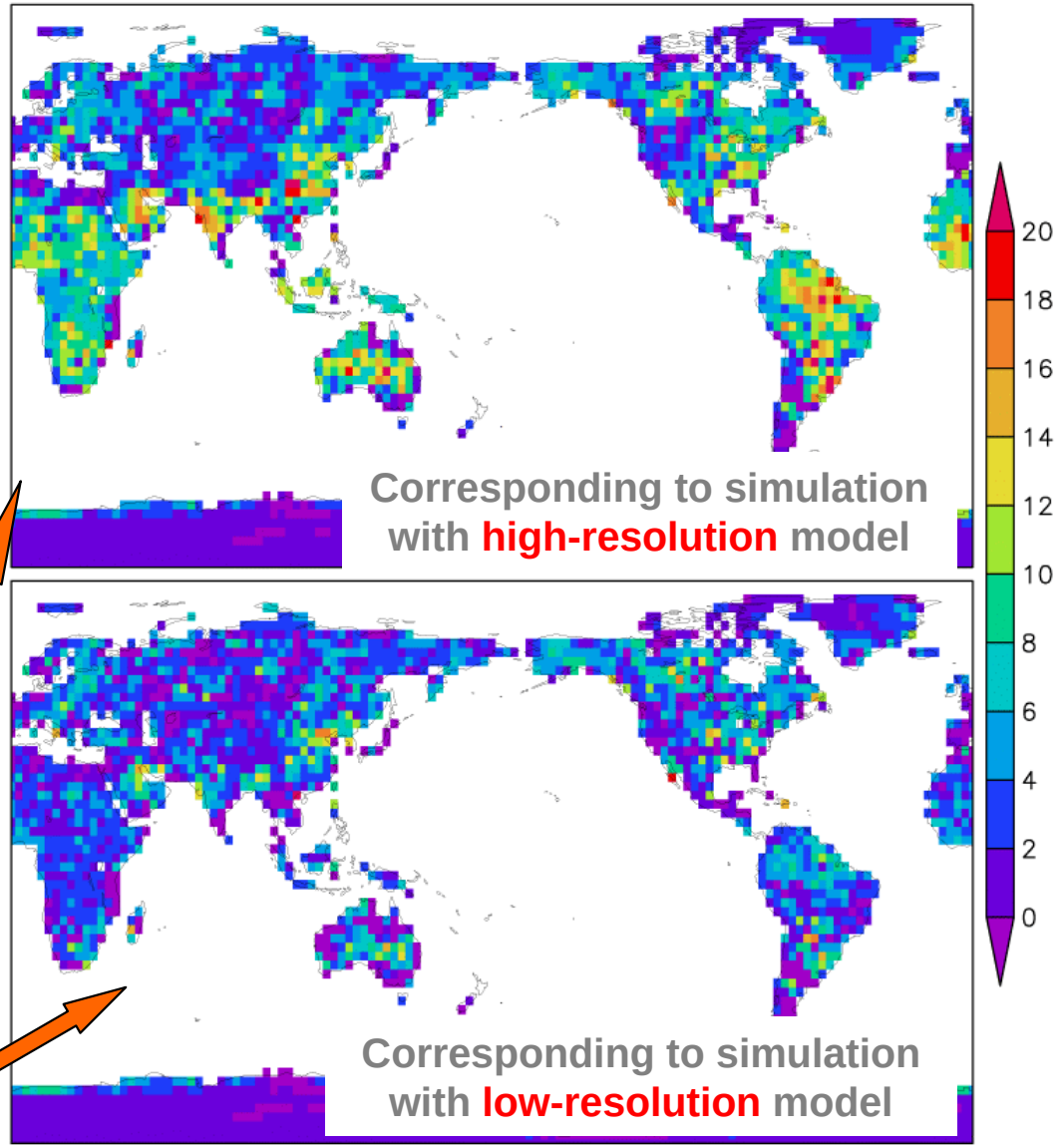
In the **low-resolution** model, heavy rain is **smoothed out**

Future Change in the Annual Maximum Precipitation
Future – Present (mm/day)

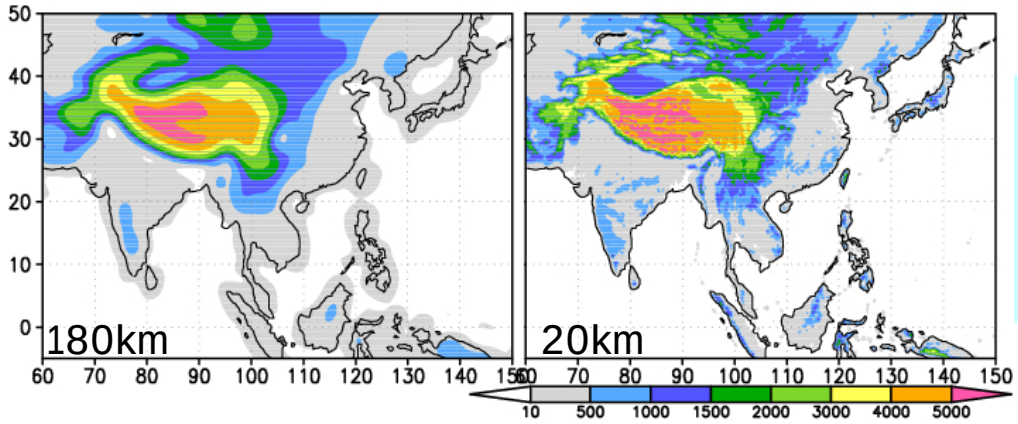


Right upper	**The annual maximum rain calculated by original 20-km mesh daily rain** **To compare with the lower figure, the annual maximum rain is regridded to low resolution (280-km) grid**
Right lower	**The annual maximum rain calculated by regridded daily rain, which is interpolated to 280-km gird from original 20-km grid** **This can be considered as a proxy of low resolution model**

Change in precipitation

MRI/JMA Atmospheric GCM

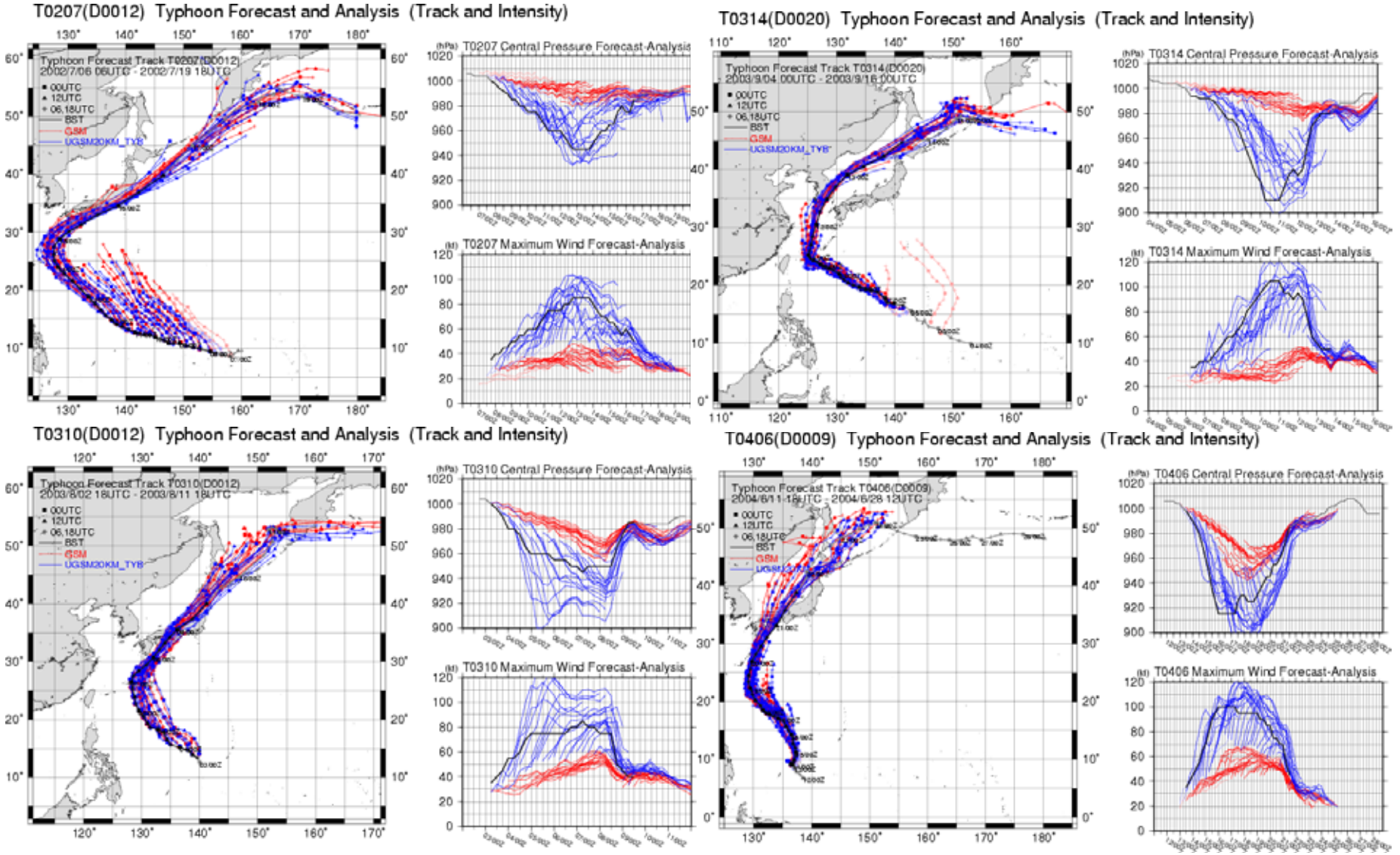
- JMA : Operational global NWP model from Nov 2007
- MRI : Next generation climate model
- Based on operational JMA-GSM
- Resolution: TL959(20km) with 60 layers
- Time integration: Semi-Lagrangian Scheme (Yoshimura, 2004)
  2 days/1 year integration with DT=6 min and
  30 nodes of Earth Simulator (ES has total 640 nodes)
- Physics
  - SW radiation: Shibata & Uchiyama (1992)
  - LW radiation: Shibata & Aoki (1989)
  - Cumulus convection: Prognostic Arakawa-Schubert (Randall and Pan, 1993)
  - Land hydrology: MJ-SiB: SiB with 4 soil-layers and 3 snow-layers
  - Clouds: large-scale condensation, Cumulus, stratocumulus
  - PBL: Mellor & Yamada (1974,1982) level-2 closure model
  - Gravity wave drag: Iwasaki et al. (1989) + Rayleigh friction



This model is used in MRI-CGCM3 after introducing additional physics and tuning.

JMA

Typhoon track and intensity: 60km vs 20km

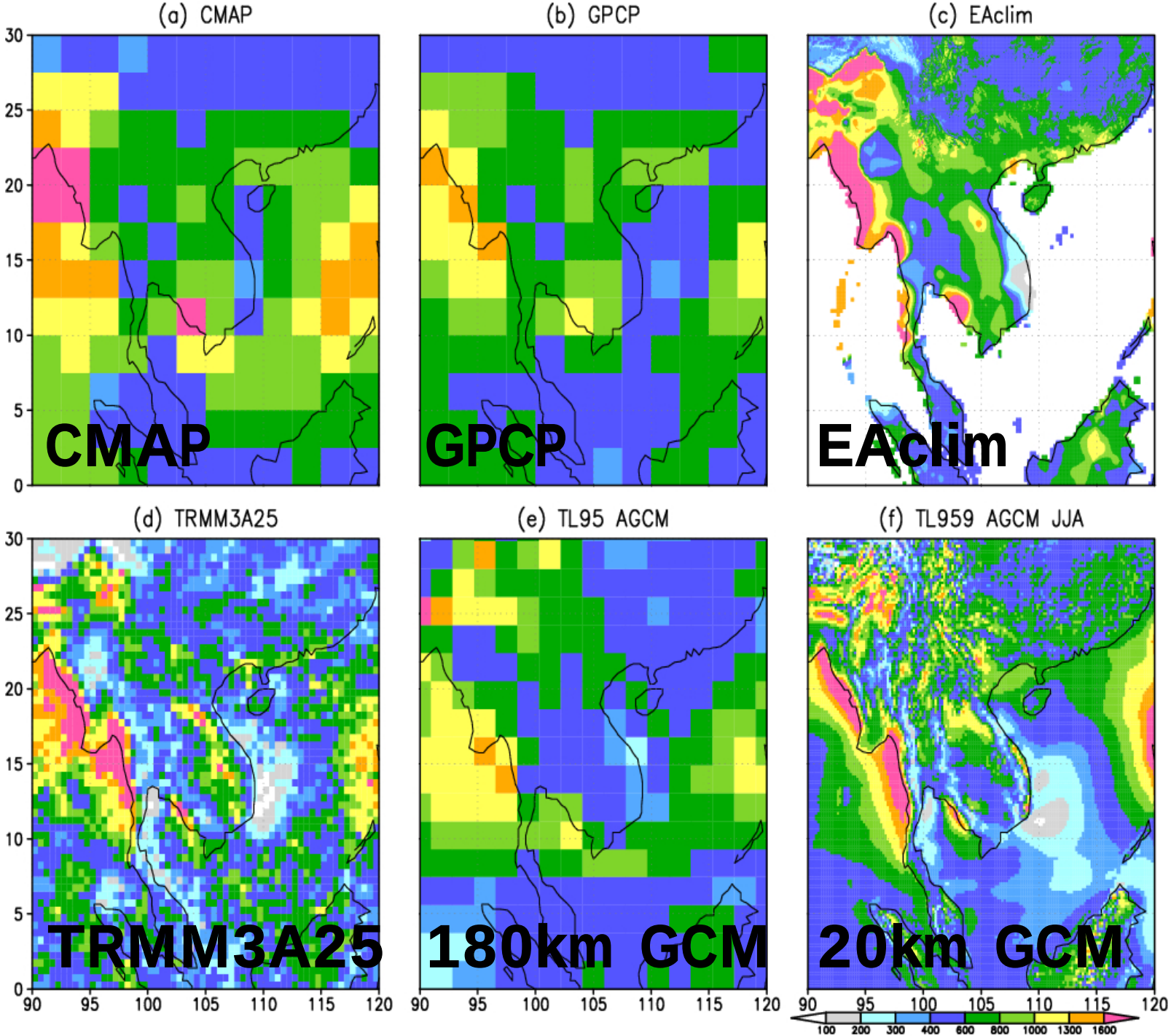


60-km model forecasts shallower central pressures and weaker maximum winds. 20-km model represents typhoon development closer to the observations.

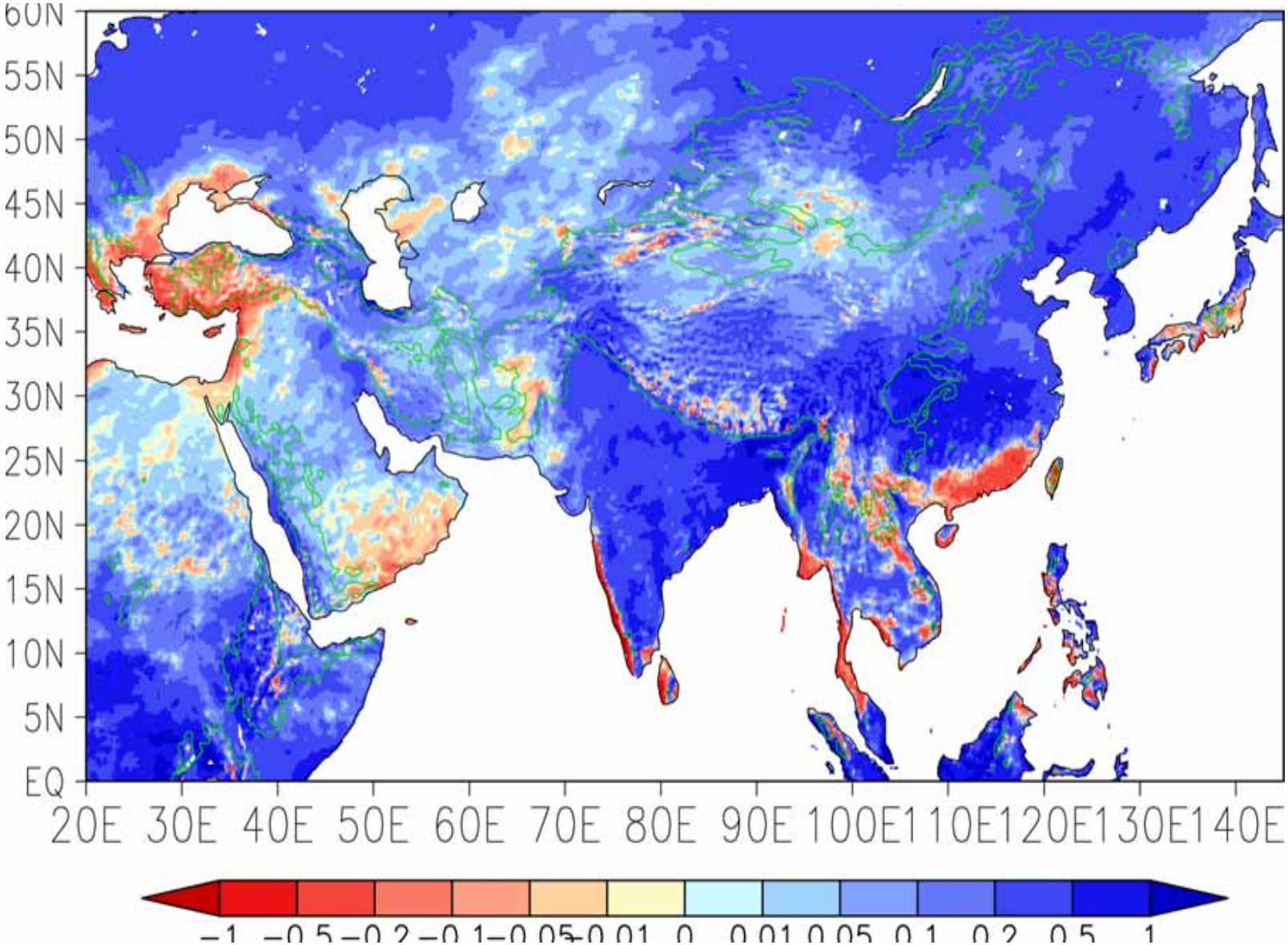
60km mesh model

20km mesh model

JJA precipitation climatology

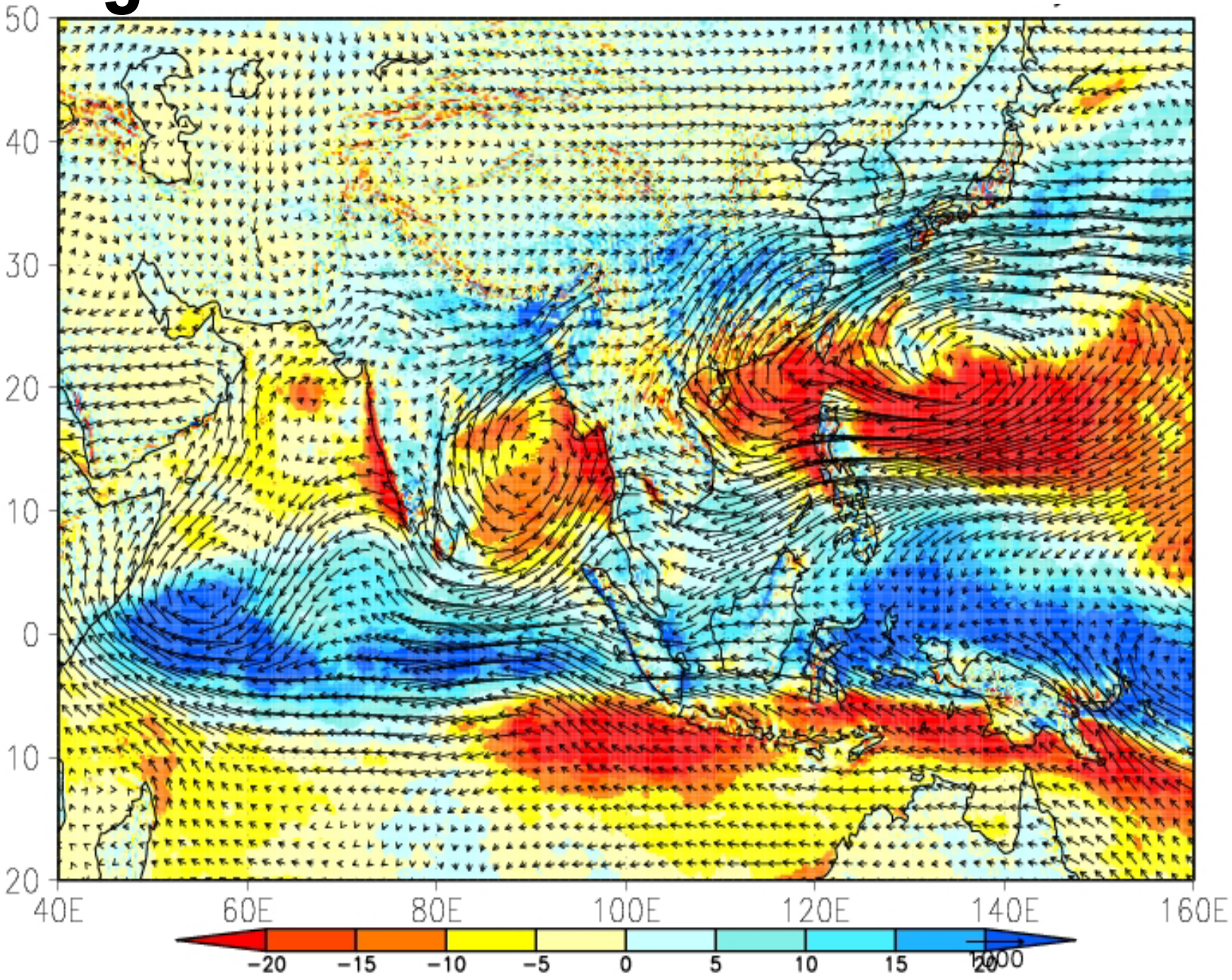


Changes in annual mean precipitation

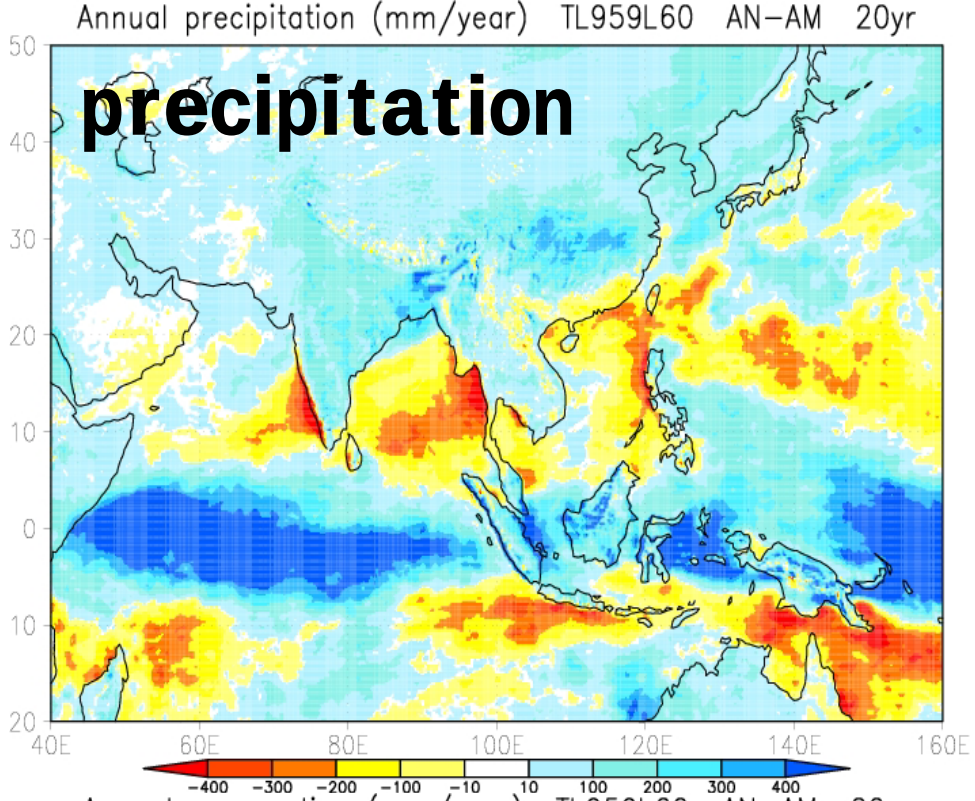


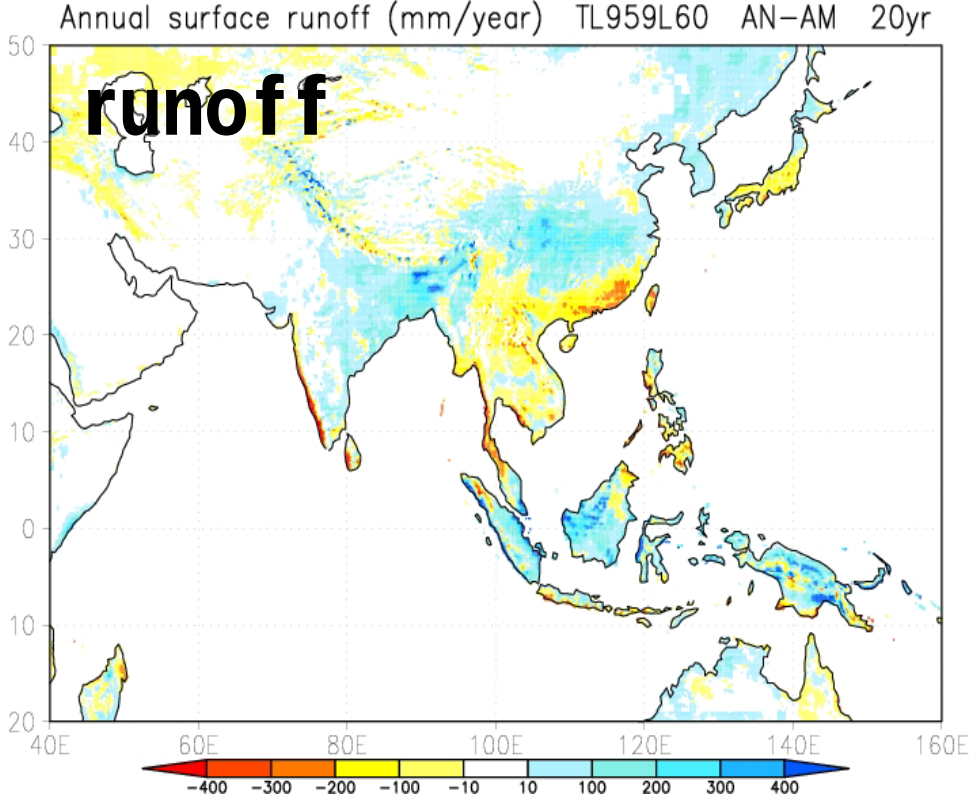
Overall increase in Asian precipitation, but there are areas with decreased precipitation, related to moisture flux changes …

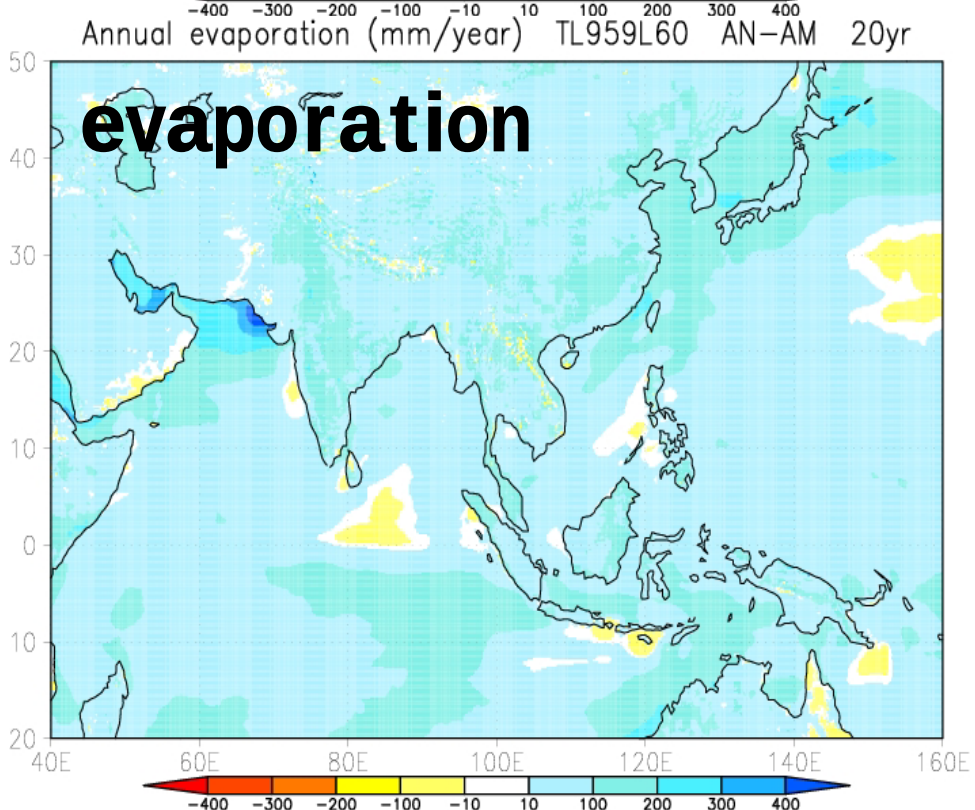
Changes in JJA mean moisture flux



Over the oceans, large moisture flux divergence and convergence is found; mostly convergence over land

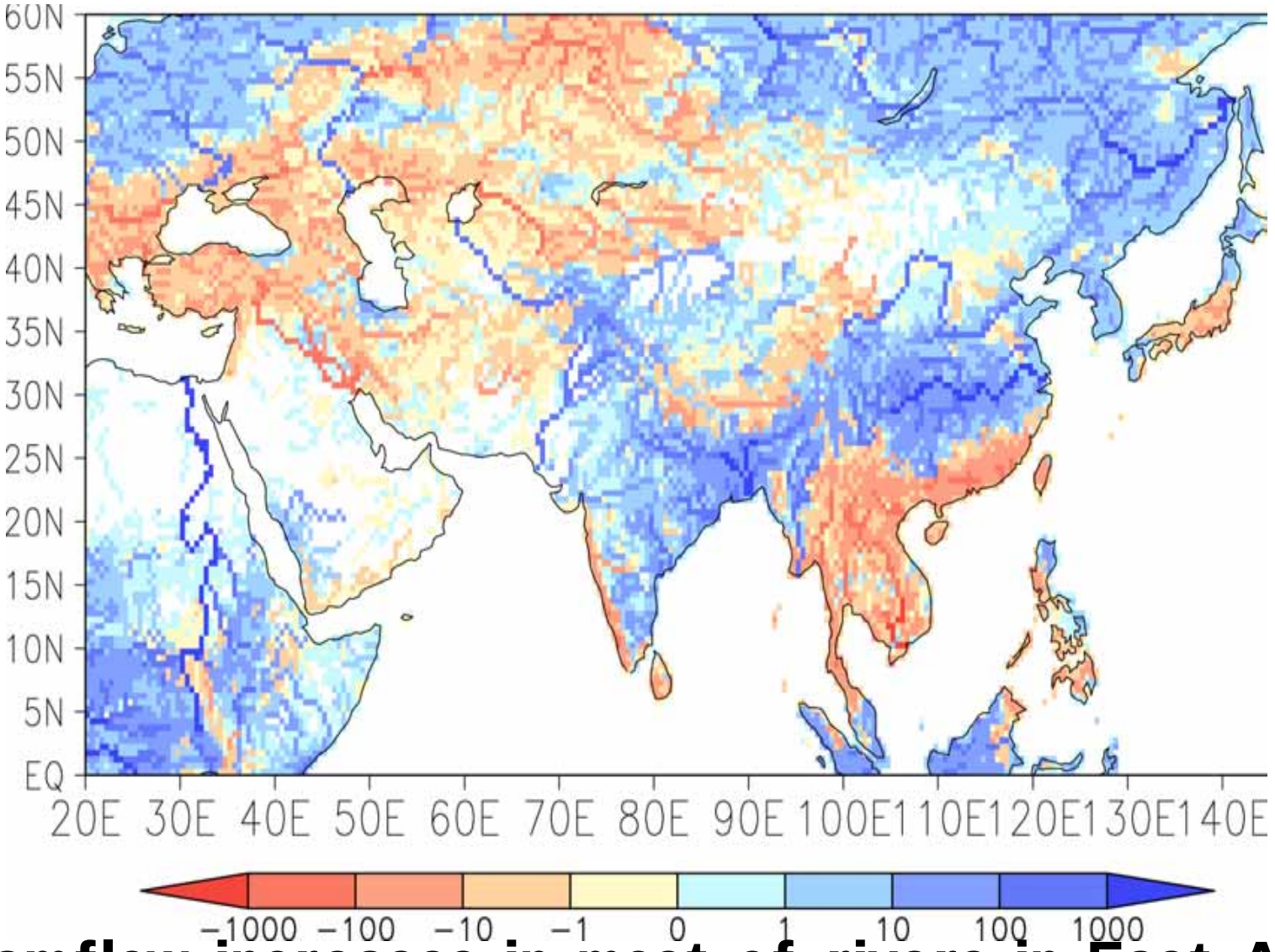






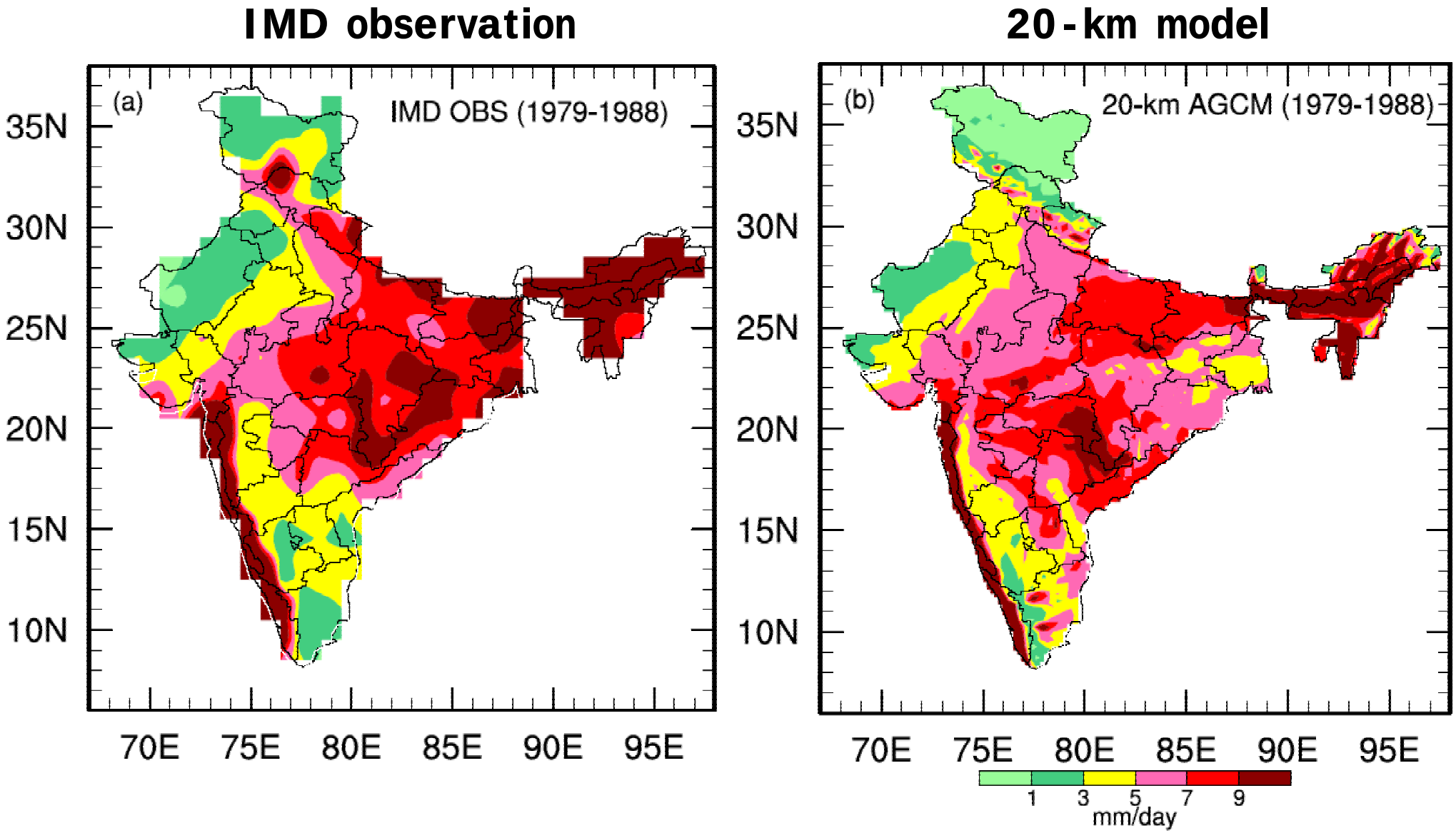
Due to general increase in evaporation, there are regions with decreased runoff though precipitation increases; an example is Thailand.

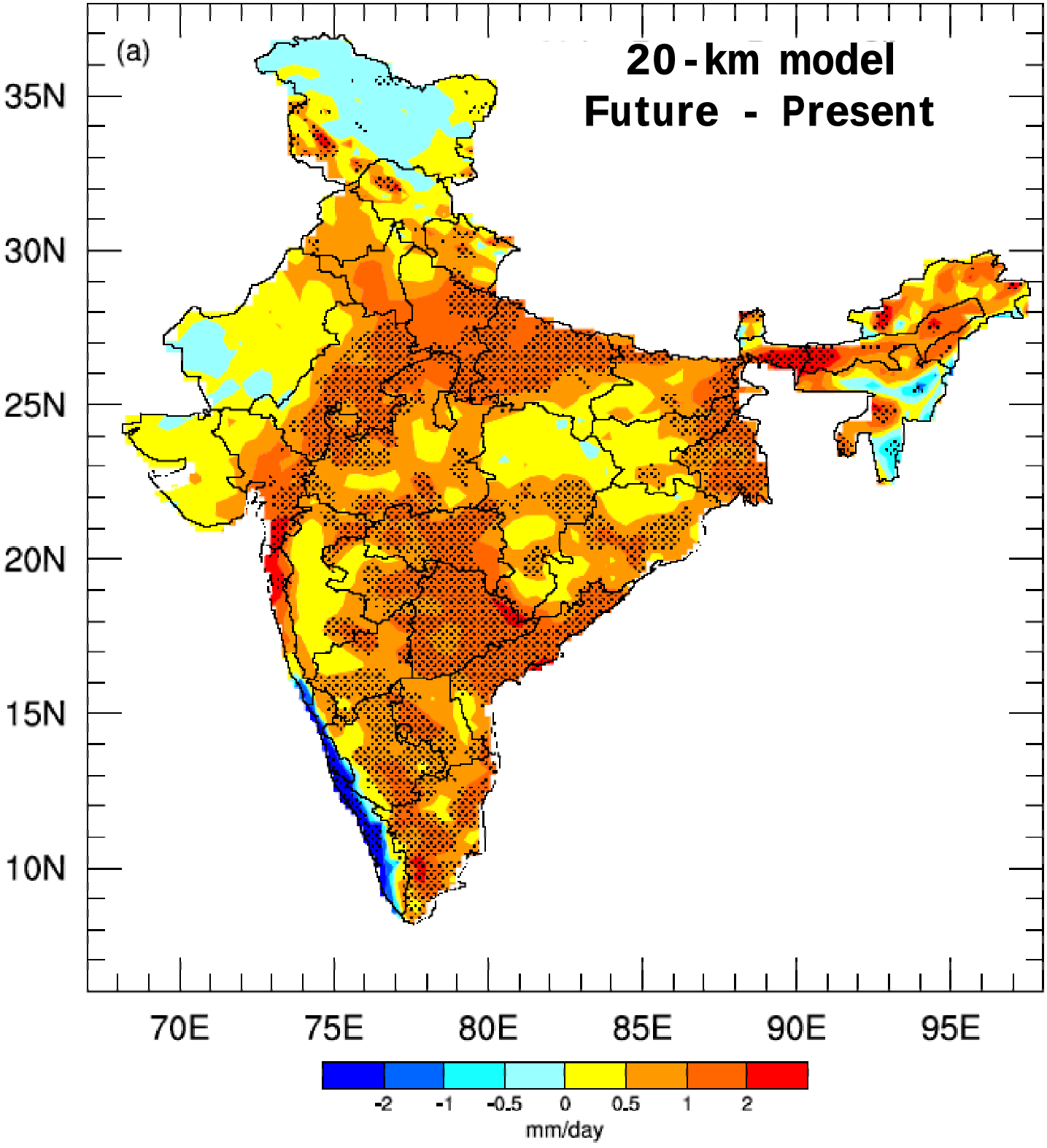
Changes in annual streamflow



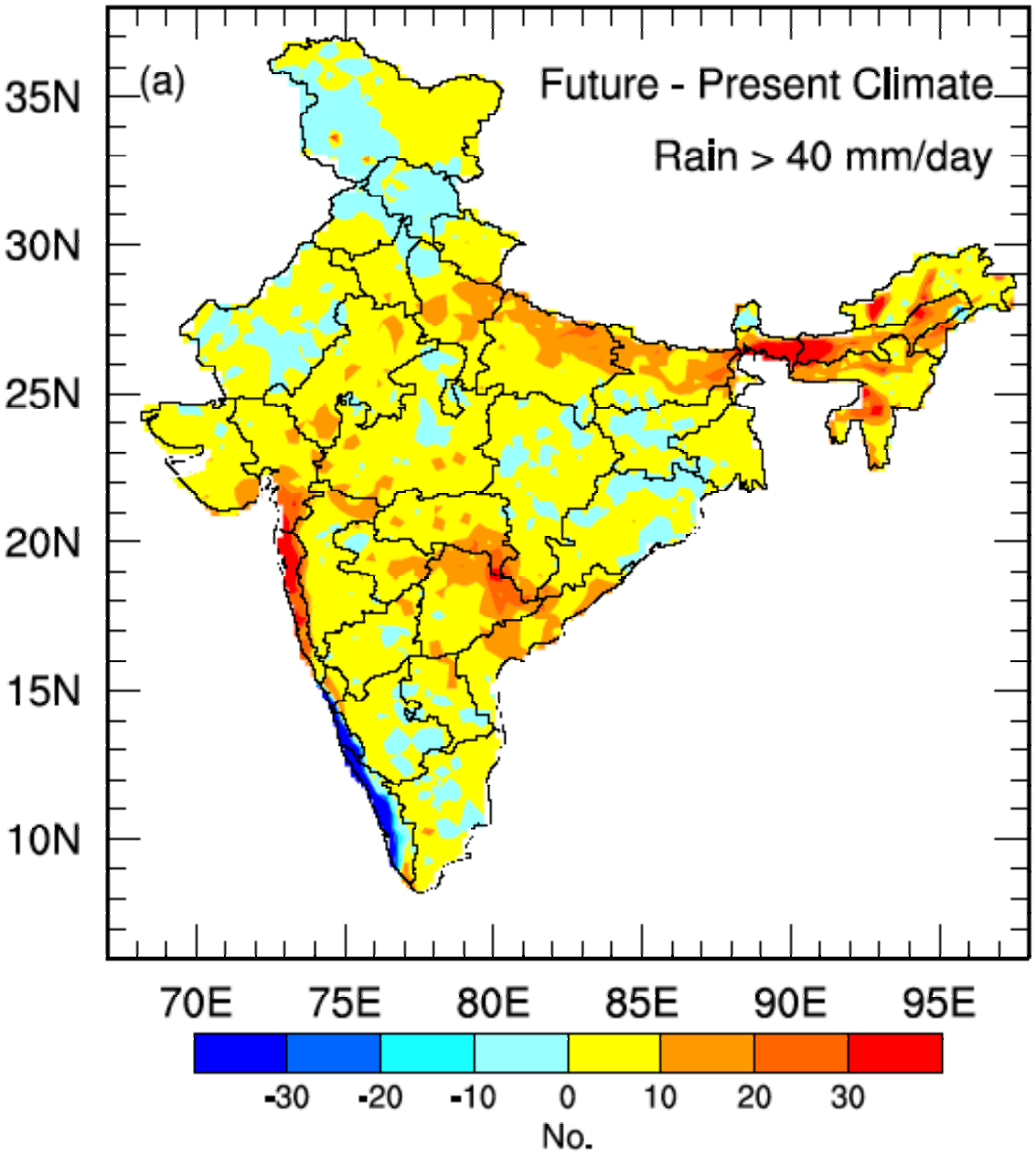
Streamflow increases in most of rivers in East Asia and South Asia, but decreases in Southeast Asia, western Asia and the Mediteranean region

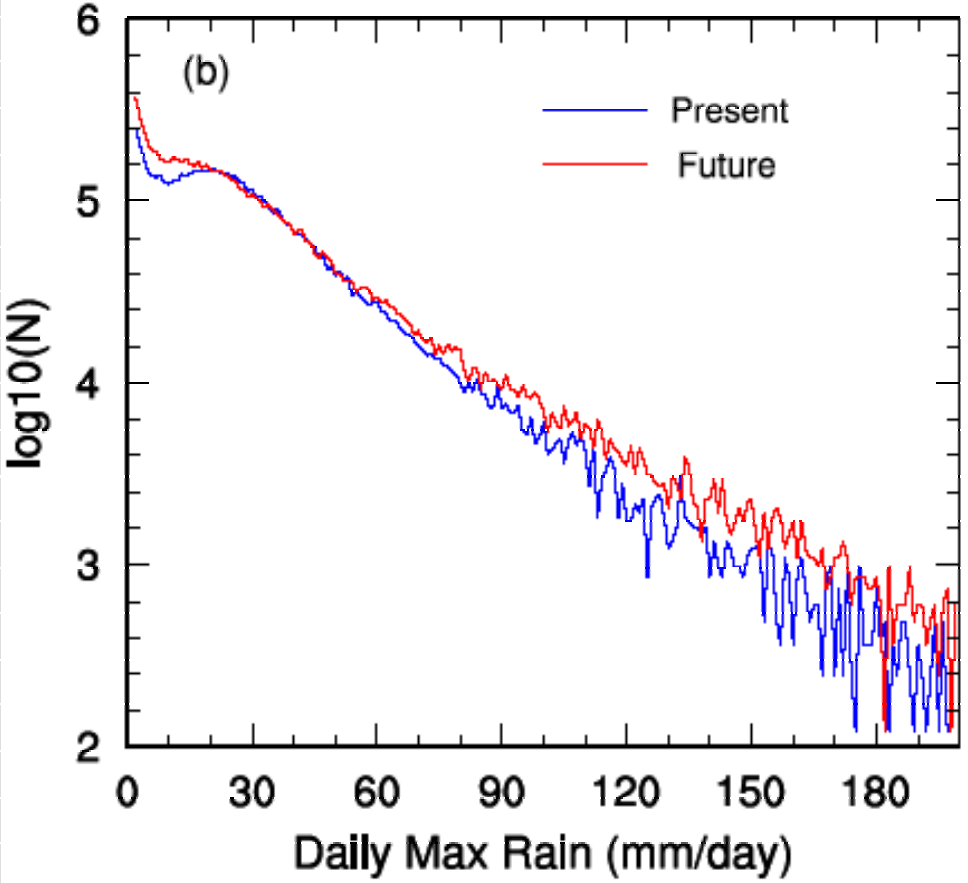
Indian summer monsoon rainfall




(a)
20-km model
Future - Present
35N
30N
25N
20N
15N
10N
70E
75E
80E
85E
90E
95E
-2
-1
-0.5
0
0.5
1
2
mm/day

Heavy rainfall days

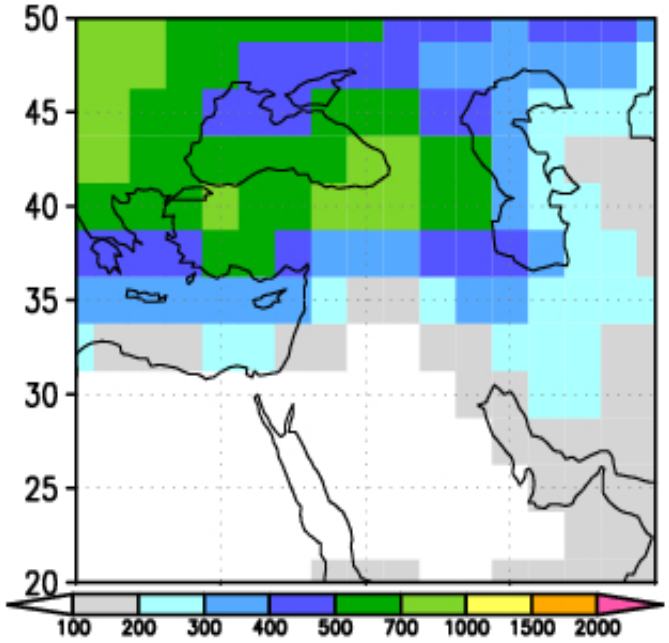




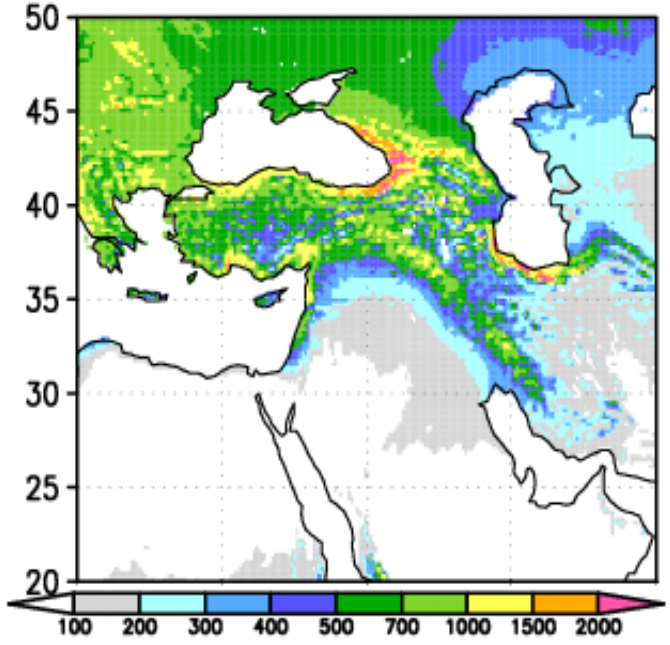
Fertile Crescent: Annual Precipitation

Present

CMIP3 models



20-km model

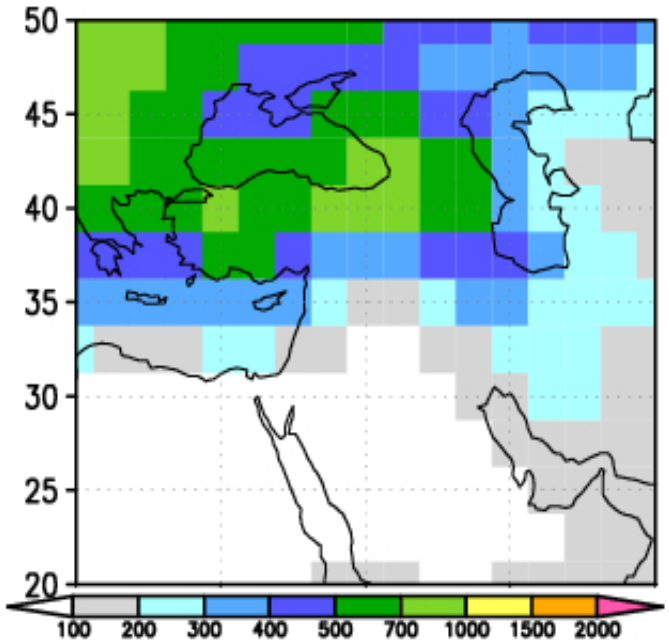


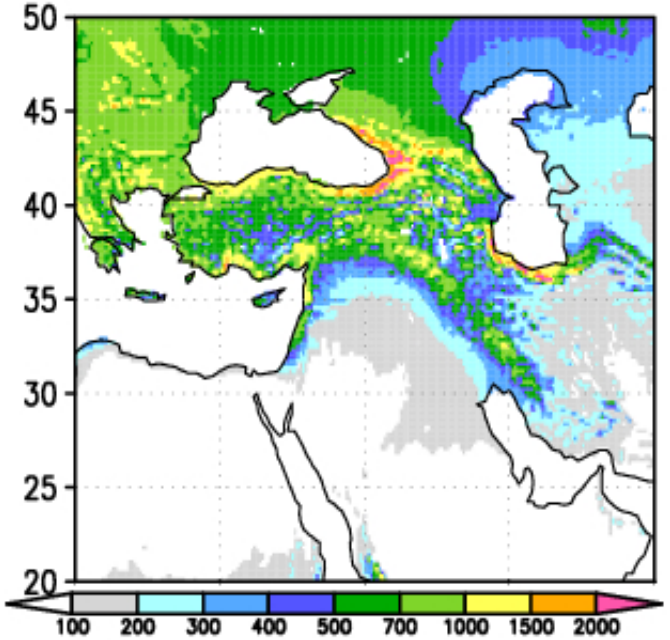
Annual Precipitation

CMIP3 models

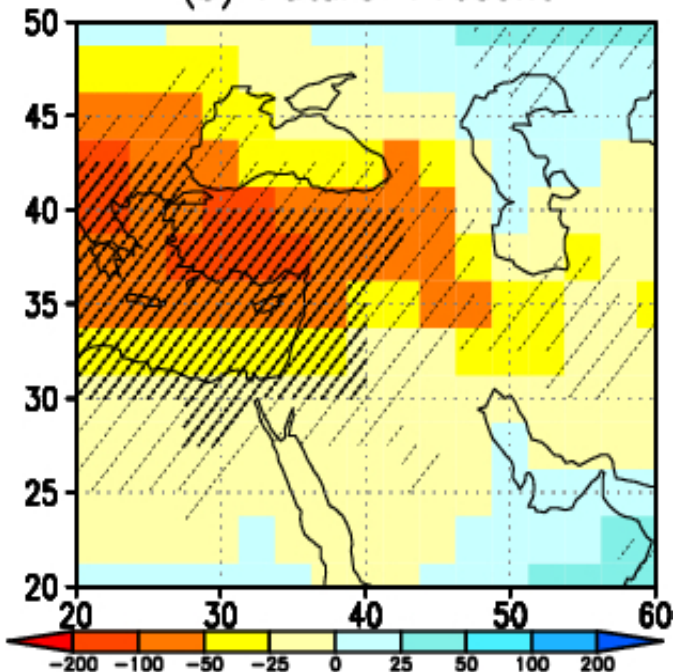
20-km model

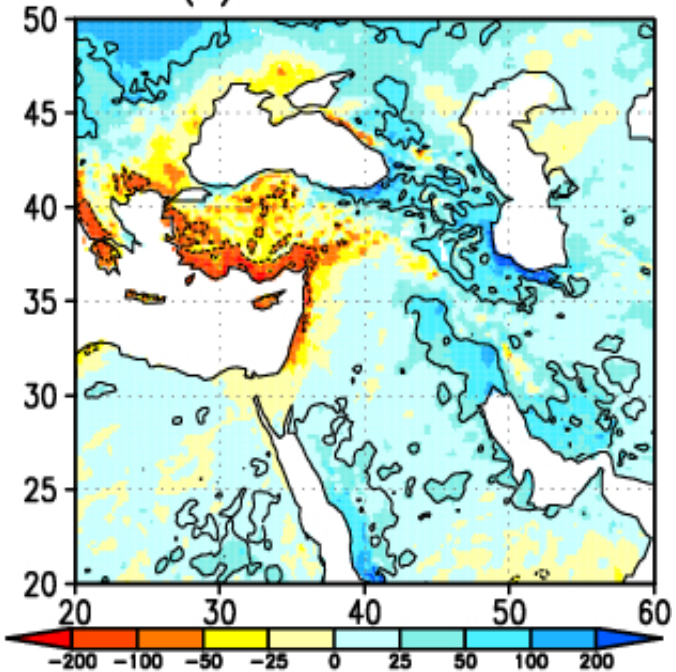
Present



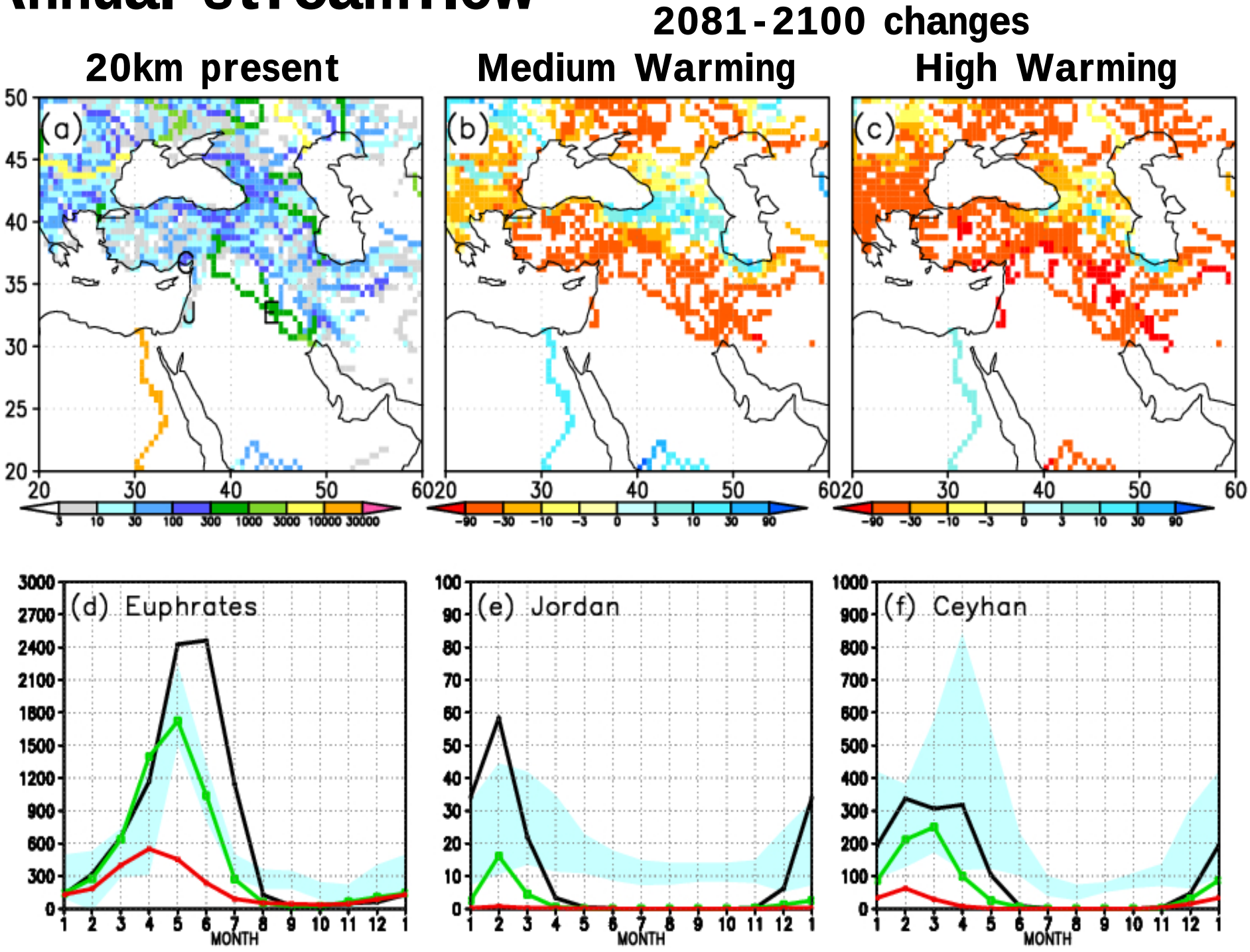


Future-Present

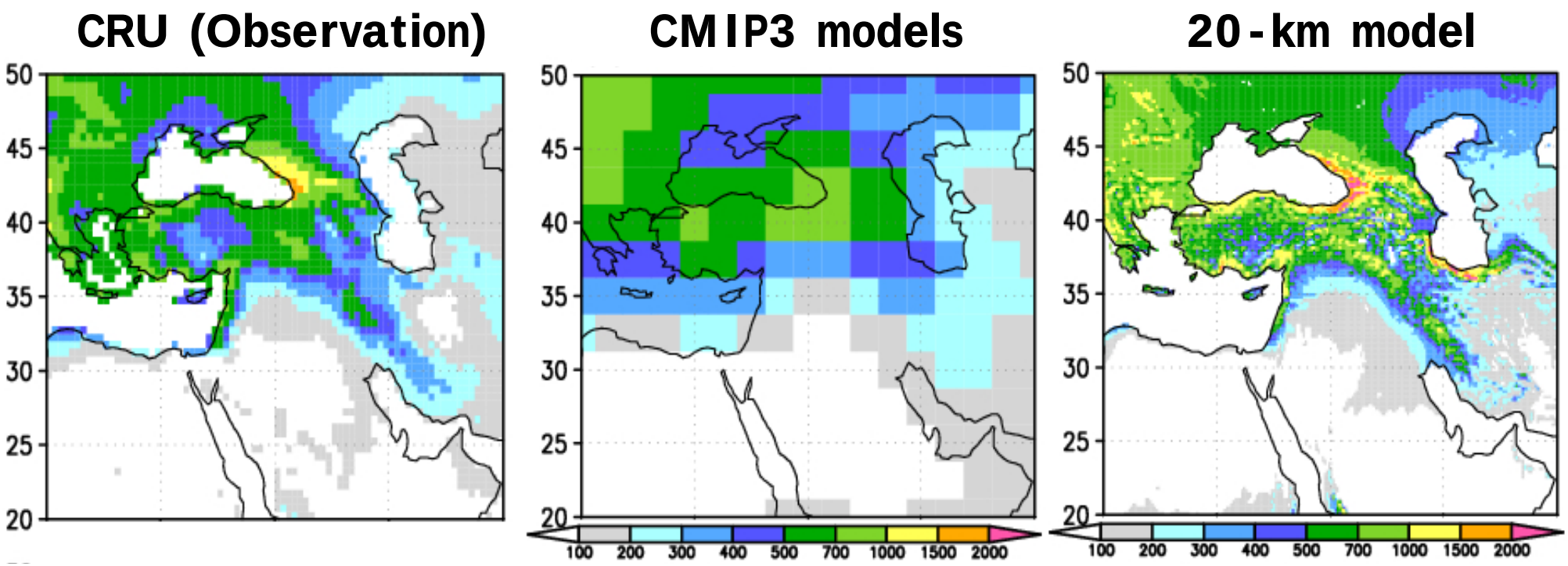




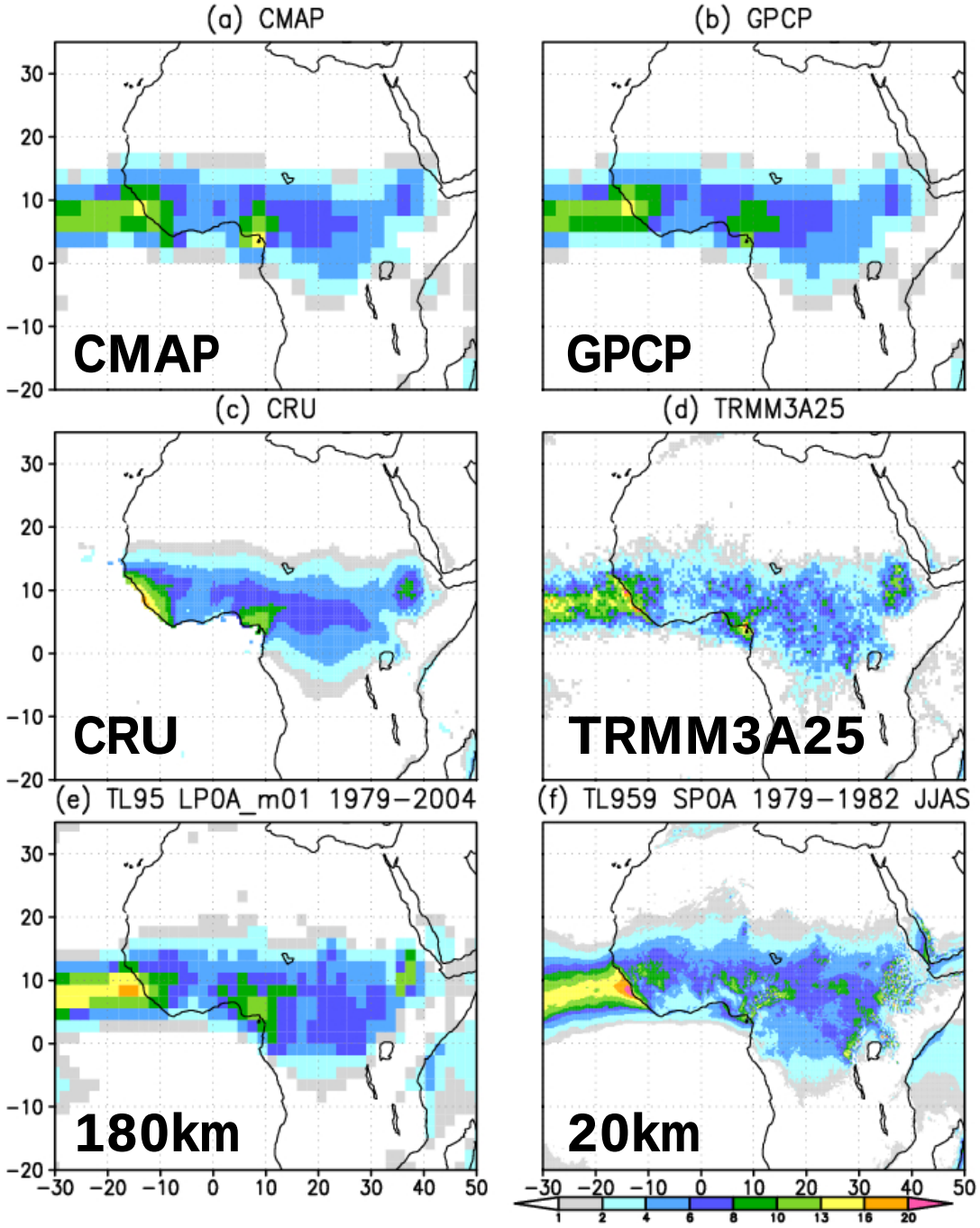
Annual streamflow

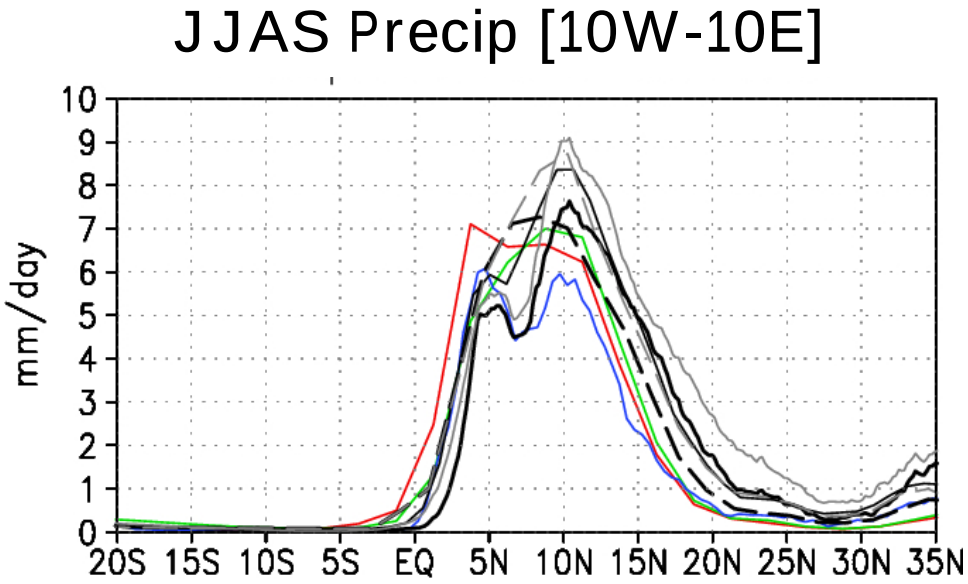


Annual Precipitation



West African monsoon





Black solid: 20km Black dashed: 180km

Thin black solid: 120km

Red: CMAP Green:GPCP Blue: TRMM

Precipitation diurnal cycle: control run

MRI/JMA TL959L60

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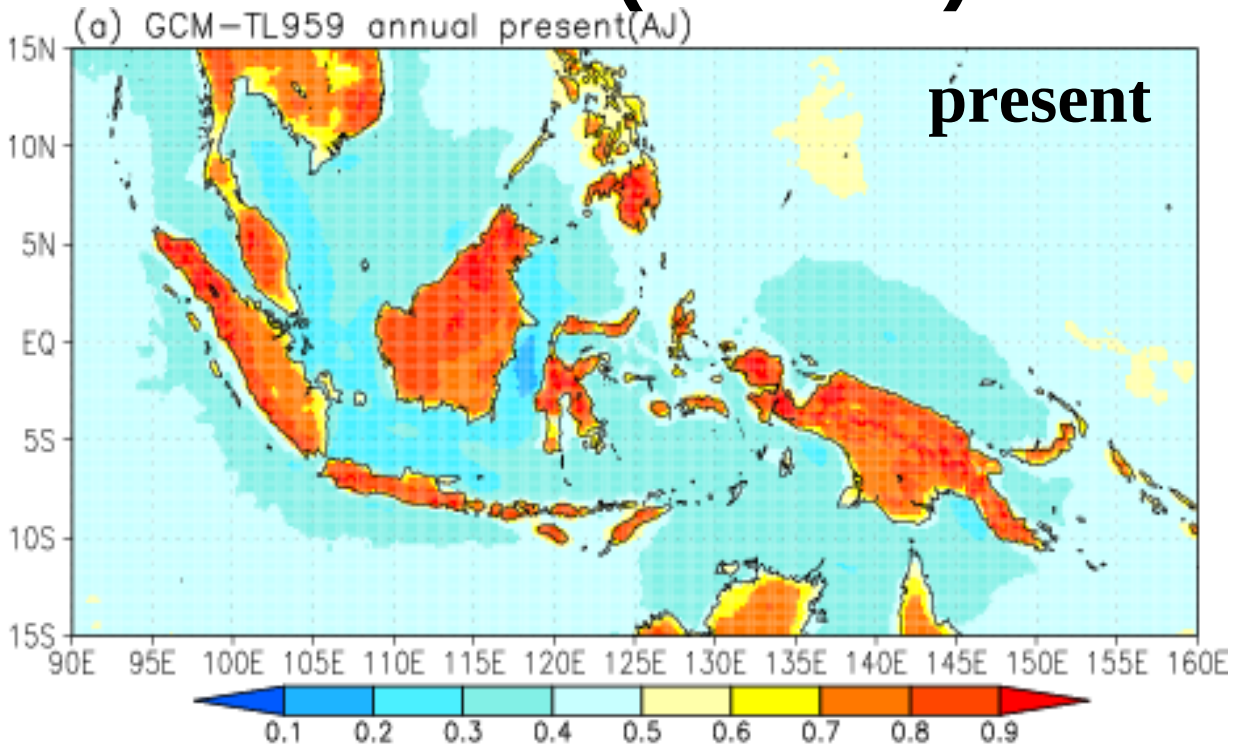
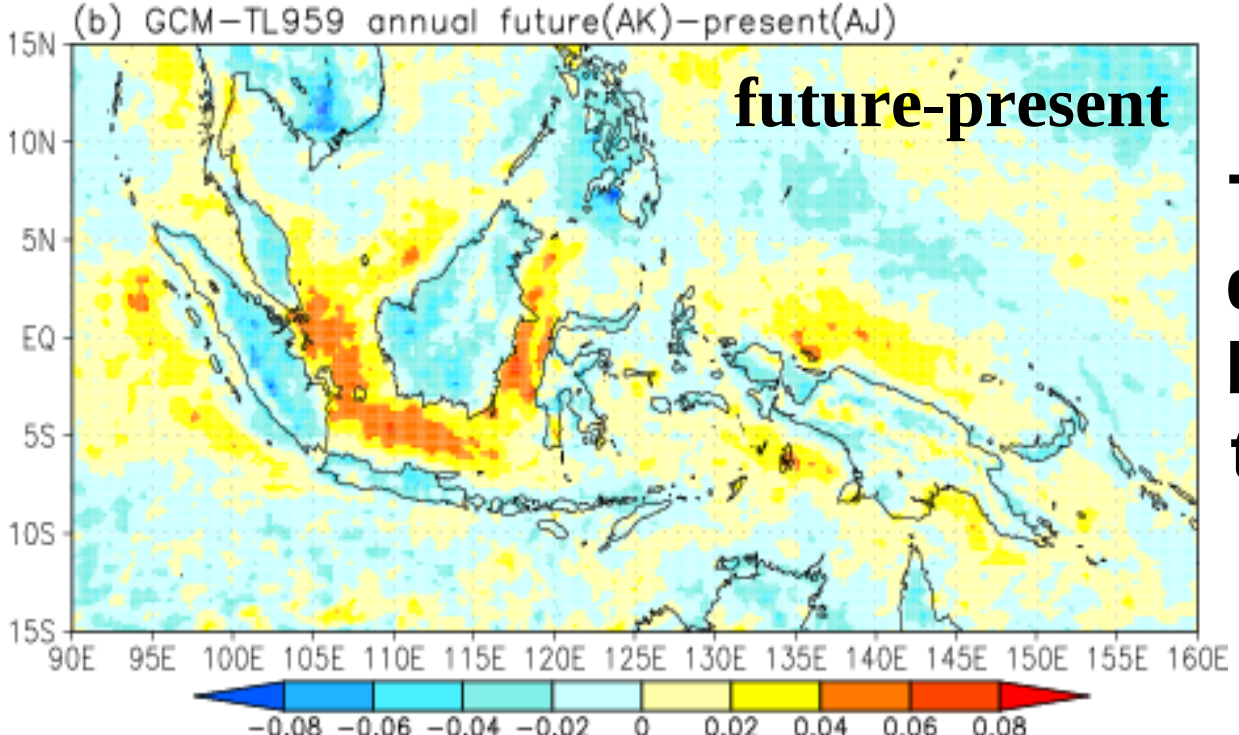
AM rain vs PM rain

PM / (AM+PM)

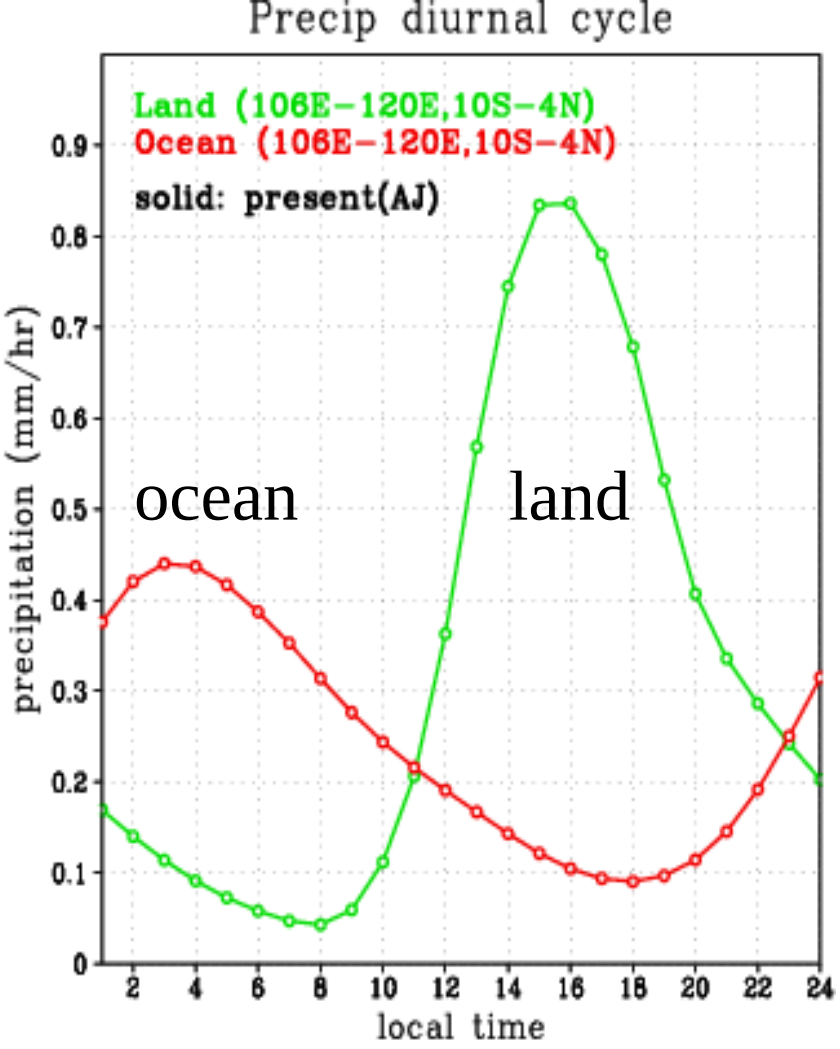


PM rain over land
AM rain over the ocean



The ratio decreases over both land and the ocean

MRI/JMA TL959L60



MRI/JMA TL959L60

nighttime decrease over ocean and nighttime increase over land is noted

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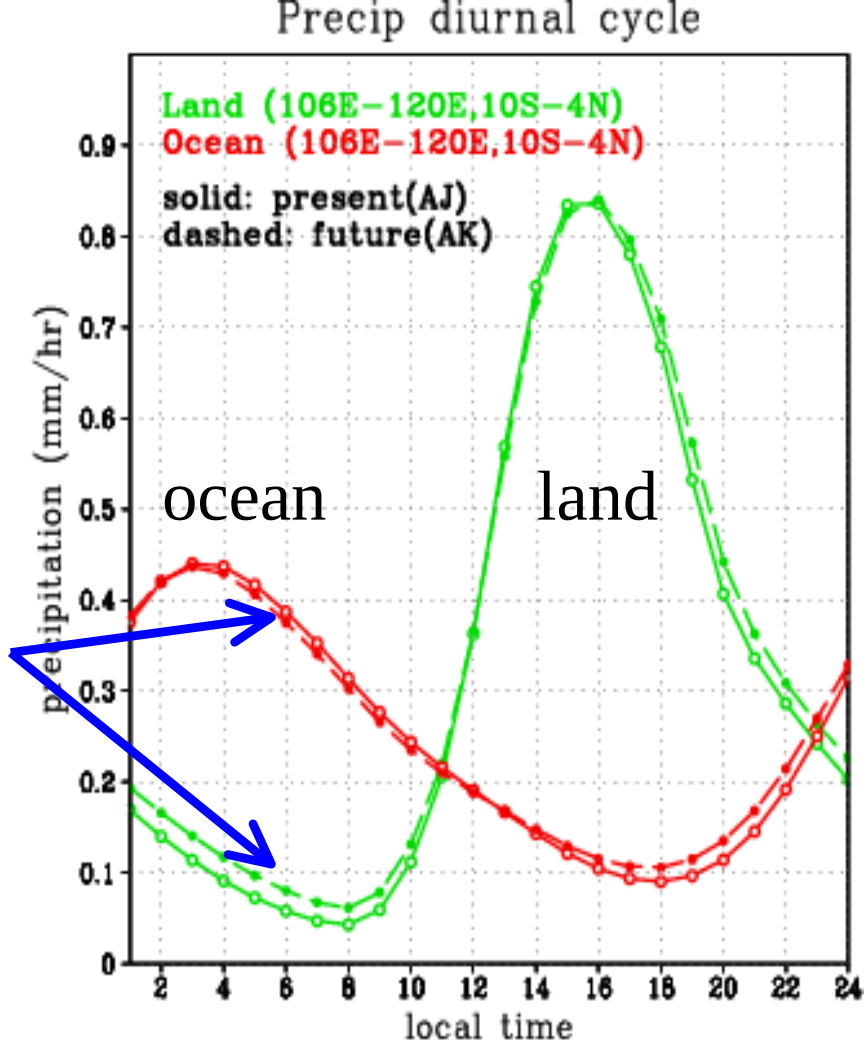
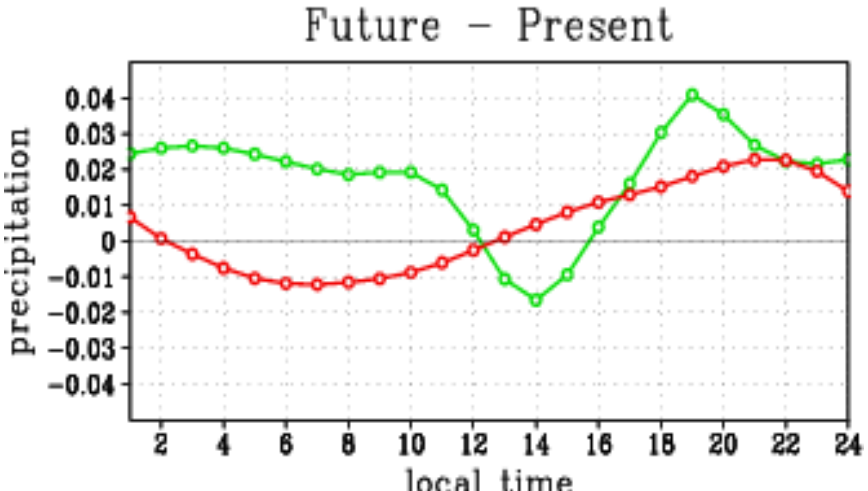
decrease in day-night precipitation contrast





Summary

Resolution of climate models becomes finer; now we are using 60-km or even 20-km mesh global climate models.

But, for model validation, we still rely on conventional observed data, whose resolution is coarser than than that of the model.

Therefore, reliable fine resolution verification data is highly needed.