RSM2010,

Effects of freshwater forcing on a simulated climatology in the HadGEM2

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Introduction

Lucas-Picher et al. 2003; Liston et al. 1994; Oki et al. 1999

➔ They have been done to determine the quantity of flow along river at various points in time and space.
➔ They focused on small watersheds using the LSM or RCM.

Oki et al. 1999

➔ They calculated the mean runoff estimated by the LSM for drainage areas upstream of 250 operational gauging stations.

Mean Annual Runoff [mm/y] by Mean 11 models for 1988

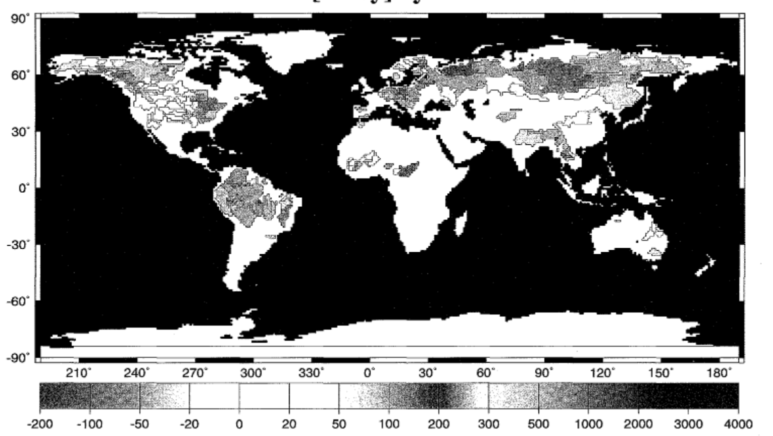
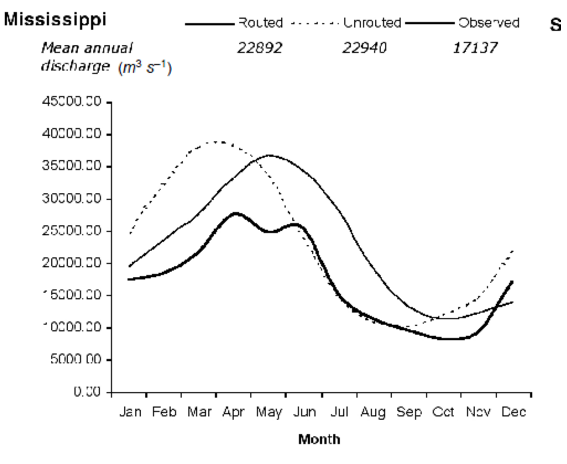


Fig. 4. Mean annual runoff [mm/y] by 11 LSMs averaged within each incremental drainage area for 1988.



Lucas-Picher et al. 1994

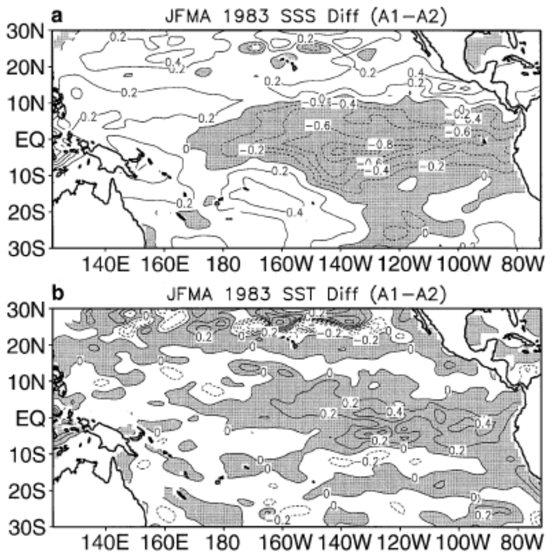
➔ They showed that the inclusion of flow routing in the Canadian RCM produces a better agreement with observation-based streamflow estimates.

Introduction

Yang et al. 1999; Zhang and Busalacchi 2009; Wu et al. 2010

➔ Climate modeling community has focused on the need for routing models to track the flow of water from continents to oceans at global scale.

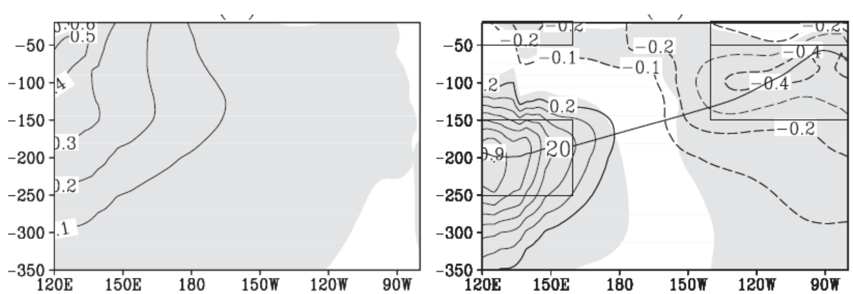
➔ The simulated freshwater flux into the oceans alters their salinity and may affect the thermohaline circulation.



Yang et al. 1999

➔ They showed that the inclusion of freshwater input from precipitation could lead to increases in SST by as much as 0.5 K in the tropical ocean in an OGCM

Wu et al. 2010



➔ Using the fully coupled ocean-atmosphere GCM, the mechanisms response to idealized freshwater flux forcing in the western tropical Pacific were investigated.

Introduction

In this study,

fully coupled GCM + real freshwater forcing

the effects of river flows in the HadGEM2-AO on a simulated climate are investigated.

HadGEM2-AO version 6.6

Sensitivity test

- Initial time : 0000UTC 1 Sep, 1978
- Analysis : 1979 – 1988 (10yr)
- Resolution:
  - Atmosphere: 1.25°X 1.875°(horizontal); 38 levels (vertical)
  - Ocean: near 1°X 1°;360*216 (horizontal); 40 levels (vertical)
- River Routing scheme (TRIP; Oki and Sud 1998)
- Land surface scheme (MOSES; Cox et al. 1999)

- RIV – Including River Routing scheme
- nRIV – Not including River Routing scheme

MOSES (Land surface scheme)

Features of MOSES

❖ The Met Office Surface Exchange Scheme (MOSES), **Cox et al.1999**

❖ **4 layer soil hydrology model**
based on a discretised version of the Richards'equation

❖ Including of the effects of soil water phase changes
on the permeability and heat balance of the soil

❖ The surface energy partitioning:
Pennman-Monteith flux equations using a resistance formulation

❖ The sensible heat and the various evaporation components:
dependent on atmospheric stability and the surface roughness

❖ Evapotranspiration from soil moisture store:
limited by a surface resistance that is represented
by a "bulk stomatal" resistance model

➔**hydrology section**
: calculates the interception of rainfall by the plant canopy, and the "surface" and "drainage" components of the runoff.

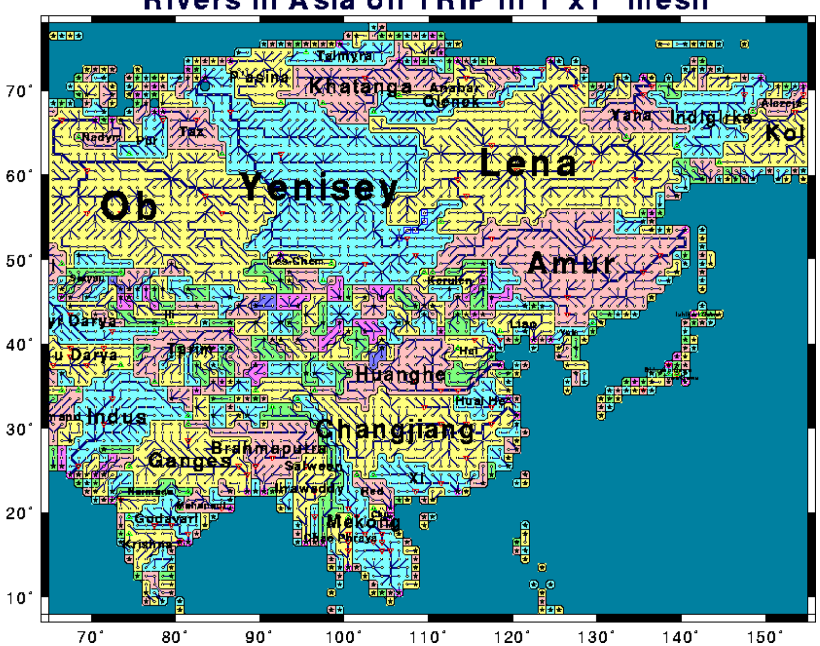
TRIP (Total Runoff Integrating Pathways)

What is TRIP ?

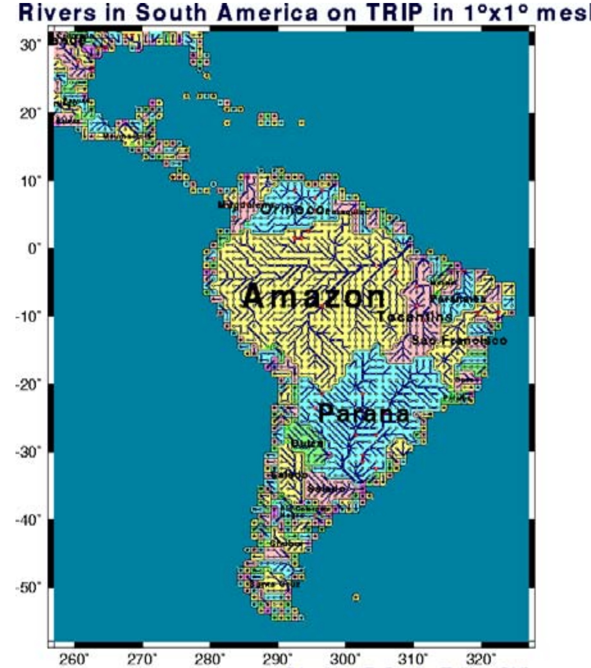
- developed by **Oki and Sud (1998)**
- homepage http://hydro.iis.u-tokyo.ac.jp/~taikan/TRIPDATA/TRIPDATA.html

- advection method to route total runoff along prescribed river channels
-representation of isolate the river basins, inter-basin translation of water through river channels, as well as collect and route runoff to the river mouth(s) for all the major rivers.
- To produce the first guess of TRIP, river flow directions were determined from a global DEM (ETOPO5, Edwards 1986).

Rivers in Asia on TRIP in 1°x1° mesh



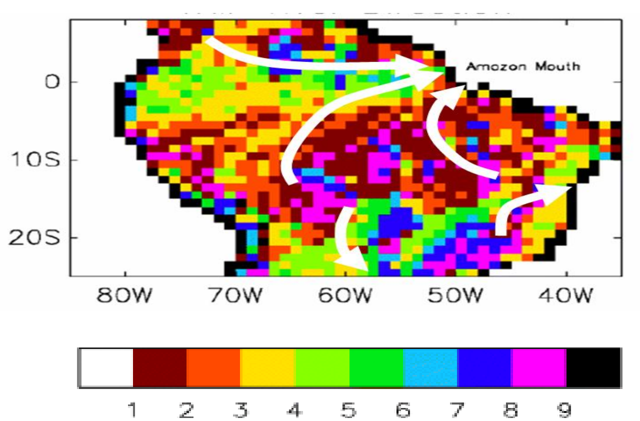
Rivers in South America on TRIP in 1°x1° mesh



[Version 970522 by Taikan Oki]

River channel in TRIP

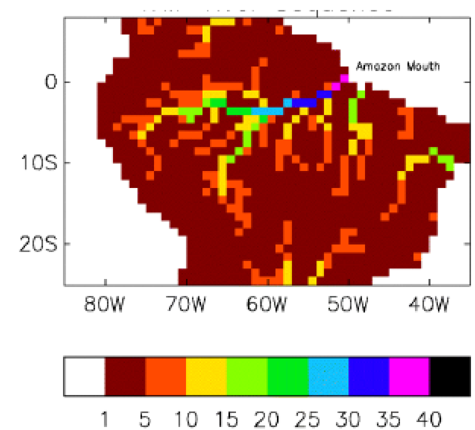
1) Direction



1:N, 2:NE, 3:E, 4:SE, 5:S, 6:SW, 7:W, 8:NW, 9:river mouth

(1 to 8 clockwise from north)

2) Sequence



Eachbox in the channel - numbered starting at 1 (head of a channel) until it meets a major channel or reach the sea

Features of TRIP

1.The outflow direction was toward the lowest land point of the eight neghboring grids, provided the point was lower than the originating point.

2.If a grid point was lower than all neighboring grids, it was marked as “hollow” and was left for the subjective evaluation and manual correction.

3. No river channels are allowed to crisscross.

4. All river channels flow from one land grid box to another.

5. Every land grid box has one, and only one river mouth toward its down-stream, which eliminates the possibility of grid boxes counterflowing toward each other

Linear routing algorithm of TRIP

Conservation of river storage

$$\frac{dS_{rc}}{dt} = D_{IN} - D_{OUT}$$

S_{rc} : river water storage (kg) in a gridbox
D_{IN} : sum of inflow (kg/s) from neighboring gridboxes runoff (kg/s) produced within the gridbox
D_{OUT}: outflow from a gridbox (one direction only),
~ cS_{rc} , c = u/d, u : effective velocity (m/s) (Miller et al. 1994)
d : distance (m) across the gridbox * meandering ratio

Meandering ratio = a : b

input: runoff(surface + subsurface) from LSM
output: daily mean outflow at river mouths

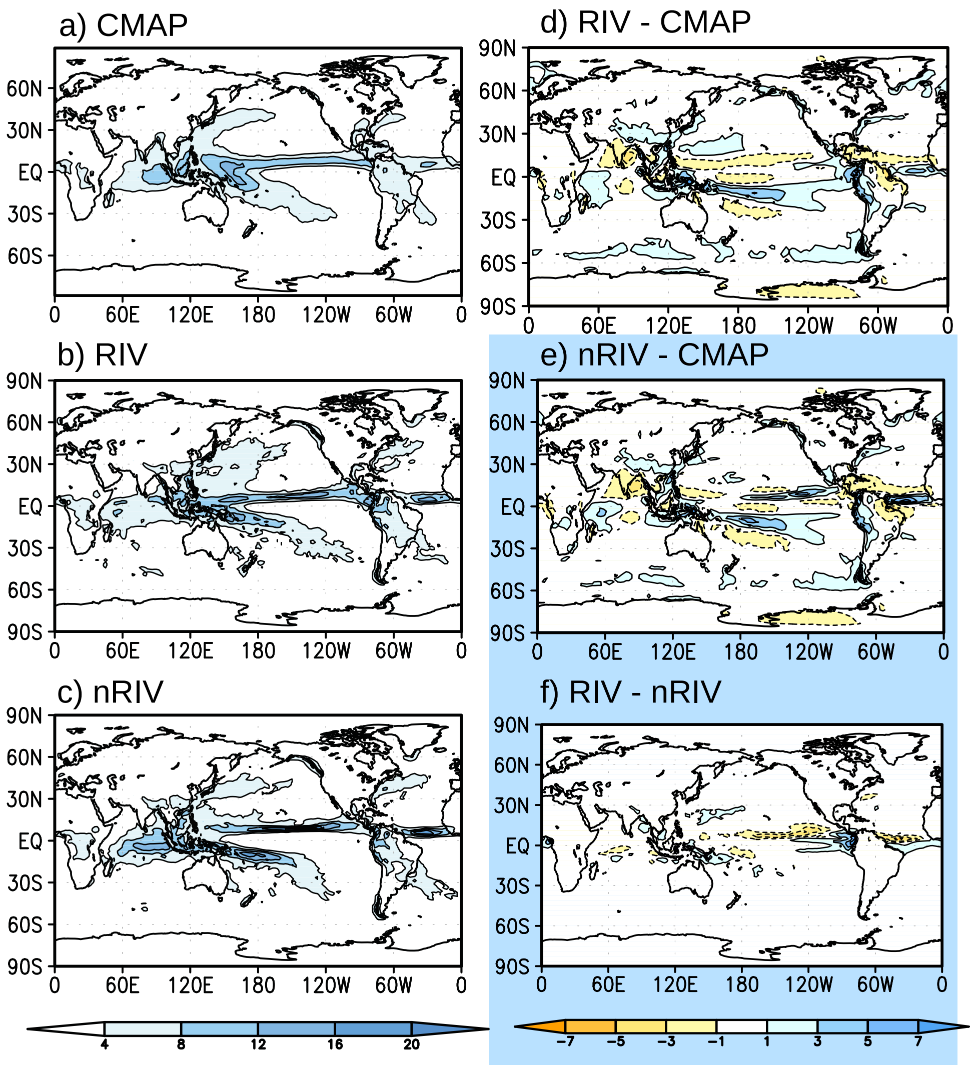
output (1 * 1) → regridded between the HadGEM2 and TRIP grids

→ providing output to ocean grid
(Falloon et al., 2007)

Results ~
(10yr mean)

Effects of river routing processes

Precipitation



nRIV & RIV : satisfactorily reproduced.

nRIV run

overestimated:

(central tropical ocean, western South America, central Indian Ocean)

underestimated:

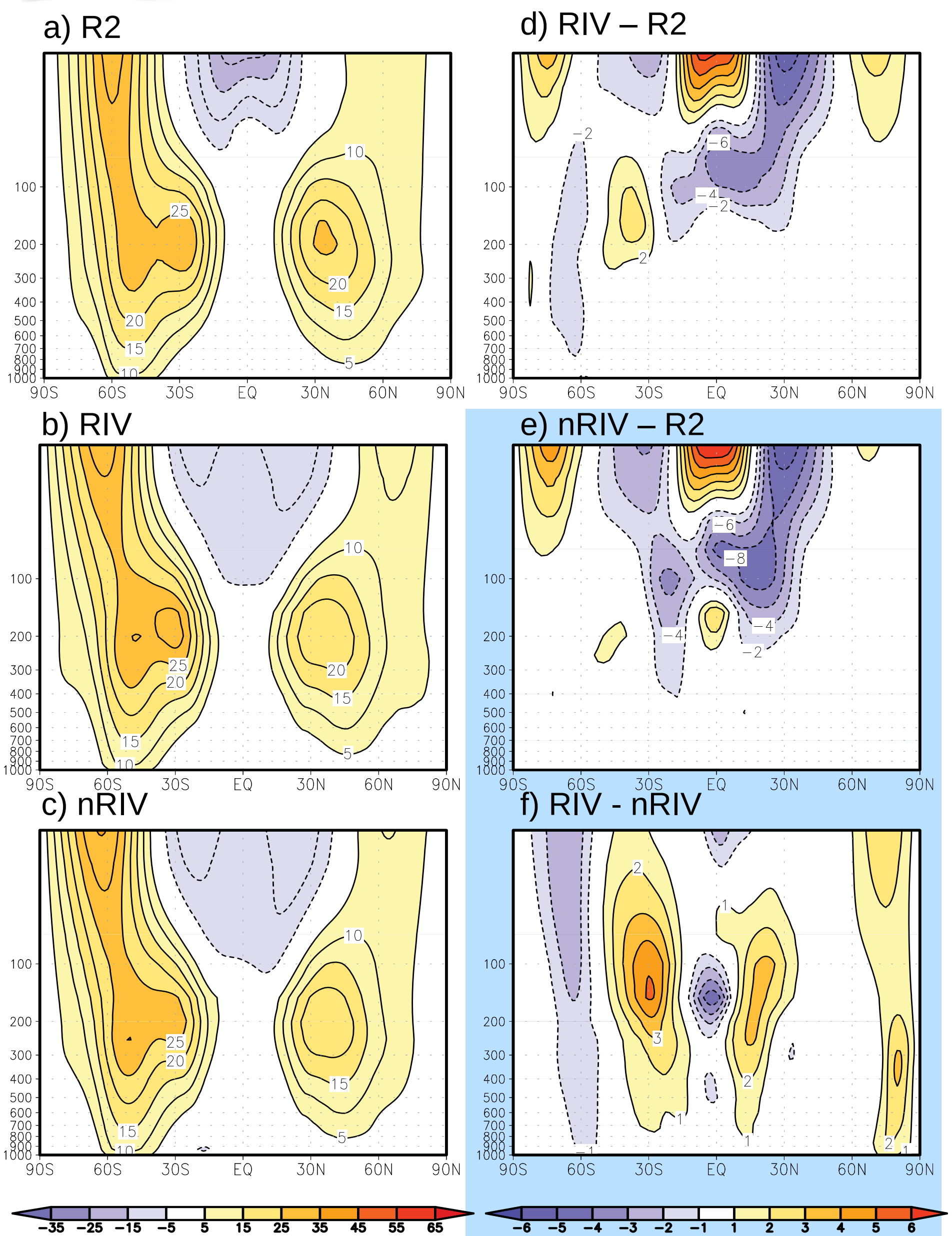
(eastern equatorial Pacific, Atlantic Ocean)

RIV run

decreased over the north of the equator in the central Pacific,

increased over the eastern equatorial Pacific

Effects of river routing processes



Zonal mean zonal wind

nRIV & RIV : satisfactorily reproduced.
separation between the polar night and subtropical jet streams

nRIV run

underestimated over the tropics and mid-latitude region

overestimated over the tropics and polar region

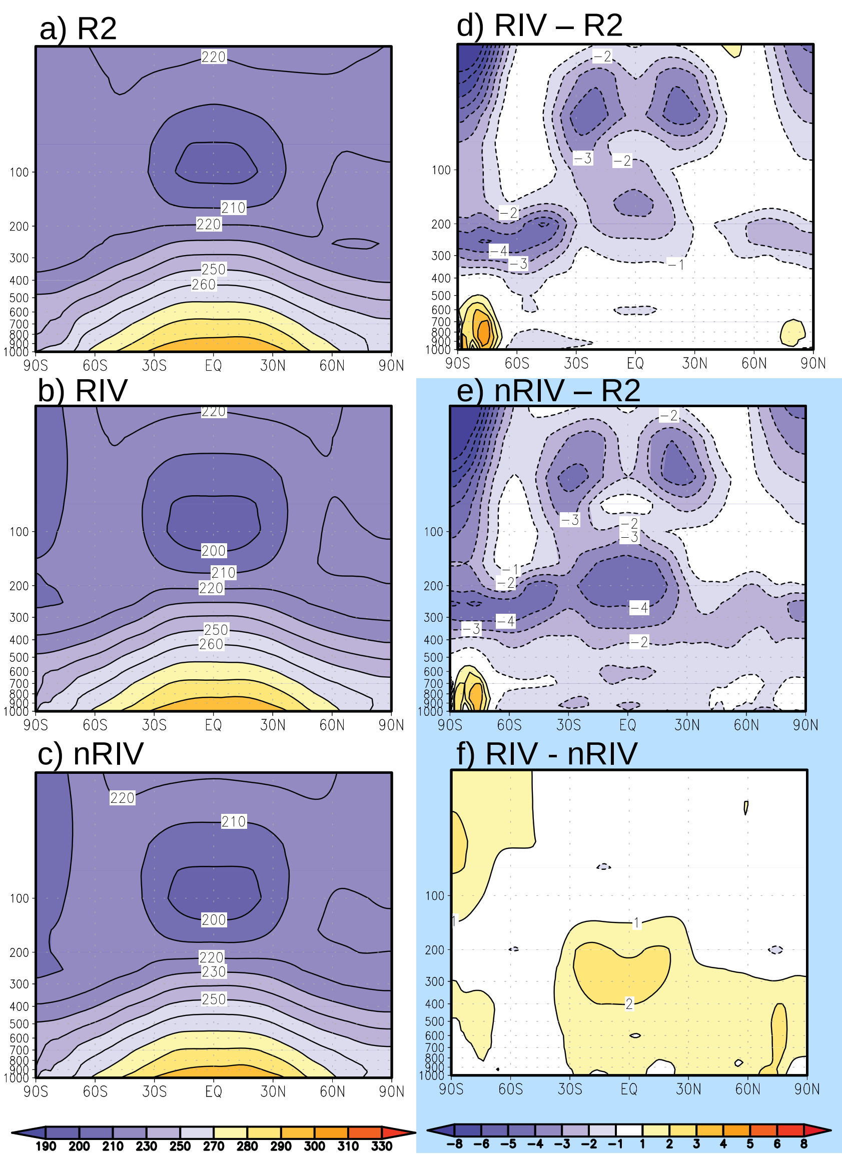
RIV run

increased over the mid-latitude region

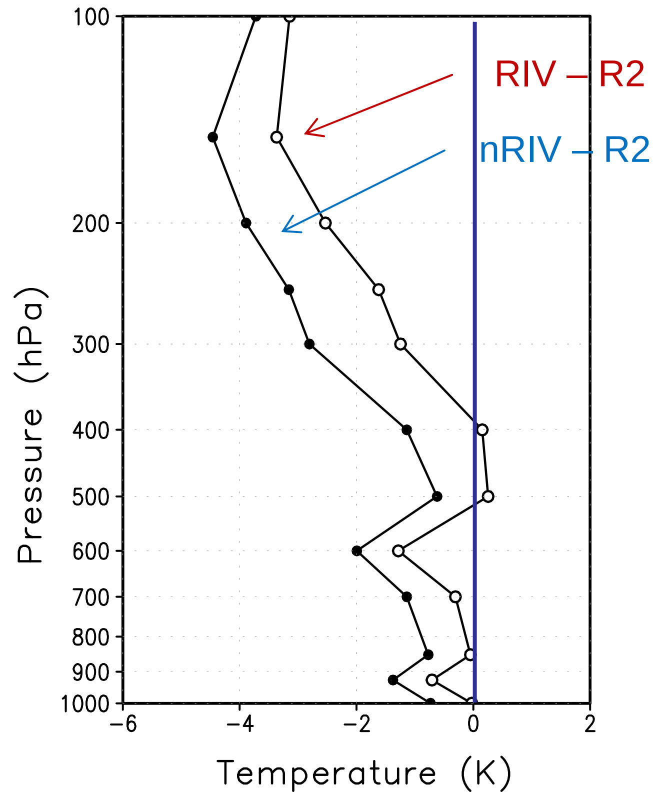
decreased over the tropics

Effects of river routing processes

Zonal mean temperature



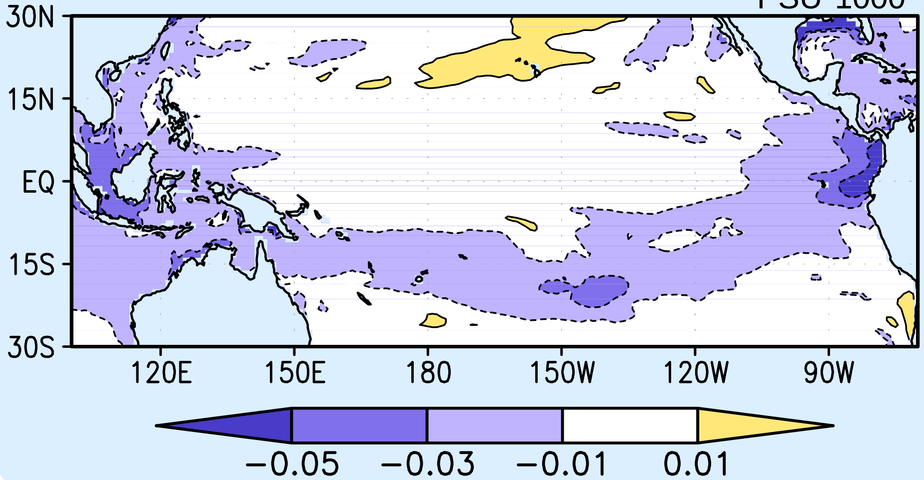
Vertical temperature profile



nRIV:
 cold biases in most of the layer
RIV:
 warmer than the nRIV experiment

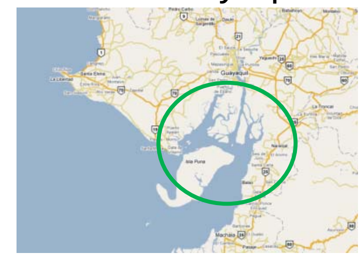
Tropical Pacific Climate

Salinity (RIV – nRIV)



Indonesia

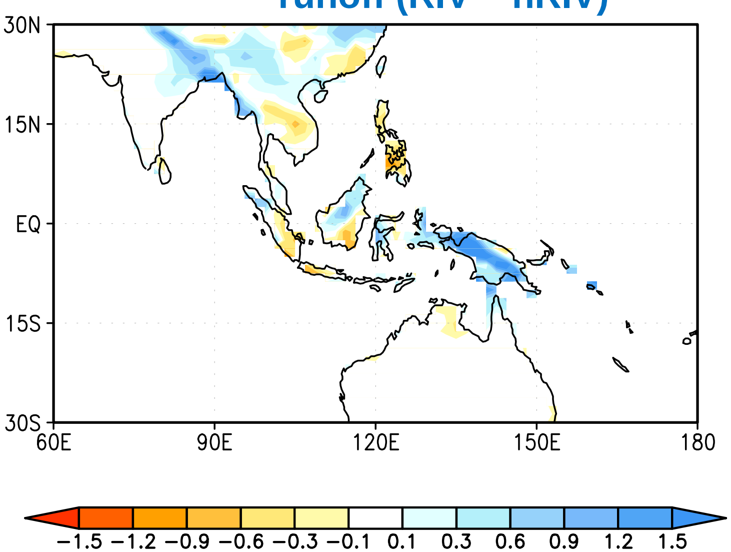
Gulf of Guayaquil

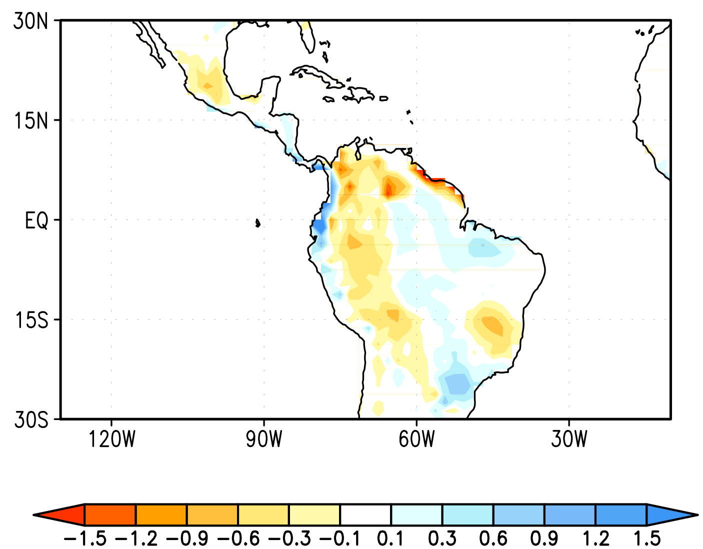


It is noticable that salinity from the RIV run is reduced over the coastal region!!

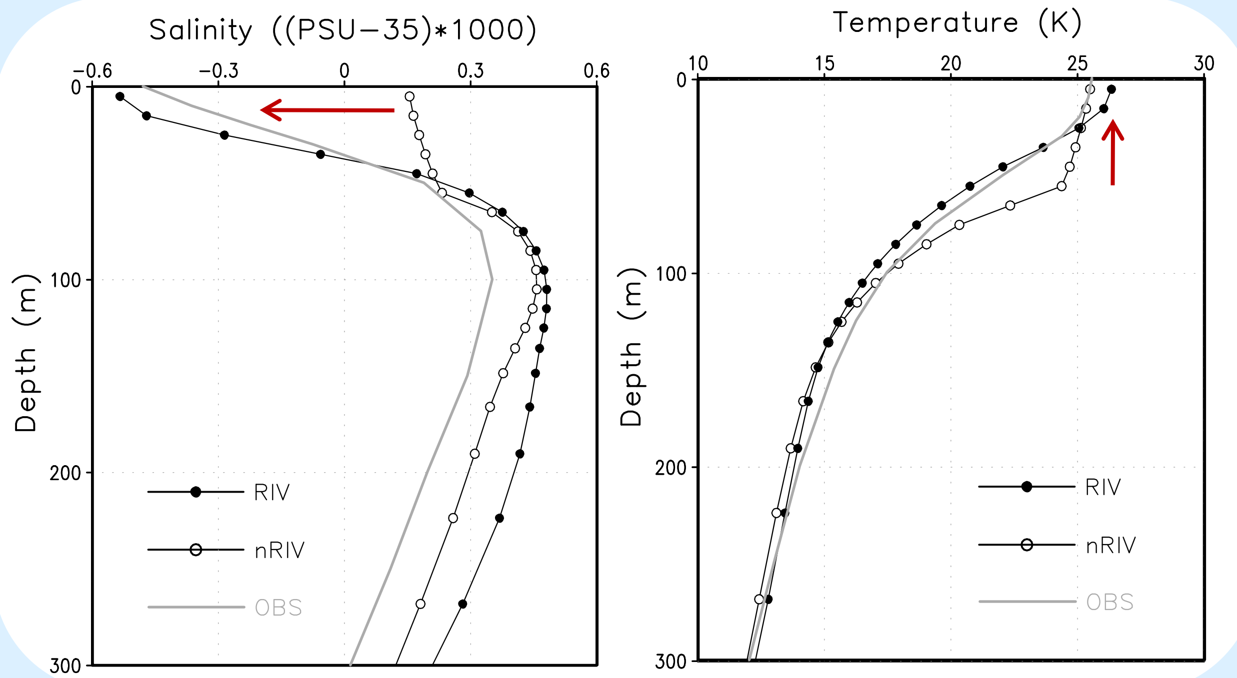
→ It is due to the fact that runoff is increased (induced-precipitation, river discharge)

Surface + Subsurface runoff (RIV – nRIV)





Tropical Pacific Climate



averaged for
eastern Pacific region
15° S ~ 15° N;
70° W ~ 110° W

RIV

nRIV

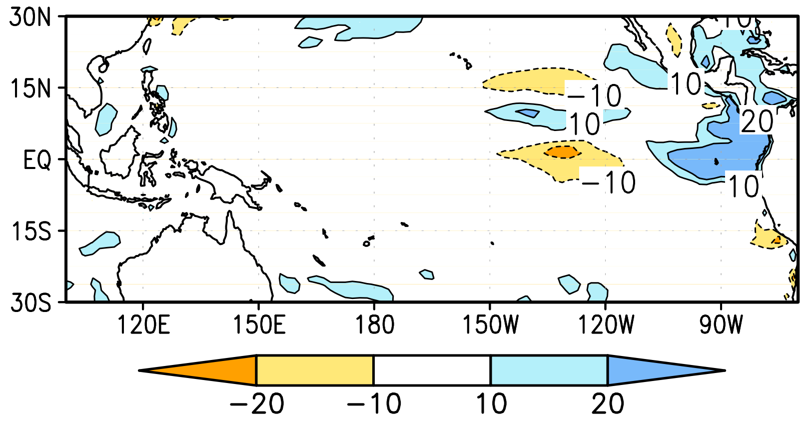
OBS
(Levitus, 1998)

Surface salinity from the RIV run : reduced!!
→ due to freshwater forcing
(induced-precipitation, river discharge)
→ It is closer to Levitus observed data, although the results in deep ocean is not good.

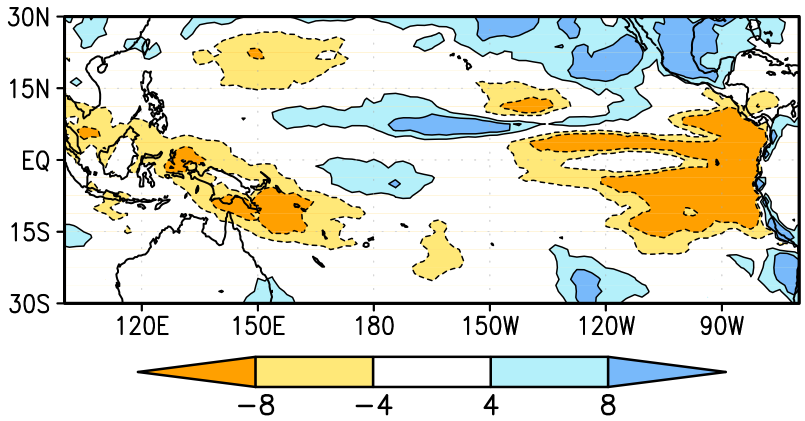
Surface temperature from the RIV run: increased!!
→ due to shallower ocean mixed layer depth; → leads to a weakening of trade winds
→ leads to a reduction of upwelling
→ produces an increase in SST

Tropical Pacific Climate

Latent heat flux (RIV – nRIV)



Surface downward Shortwave flux (RIV – nRIV)



LH

increased over the eastern Pacific
due to warm SST and convection

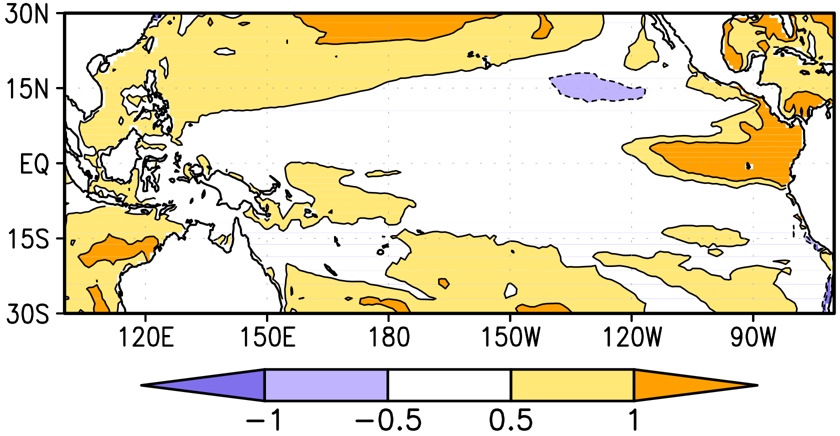
Surface downward SW flux

increased
over the mid-latitude region
decreased
over the tropics

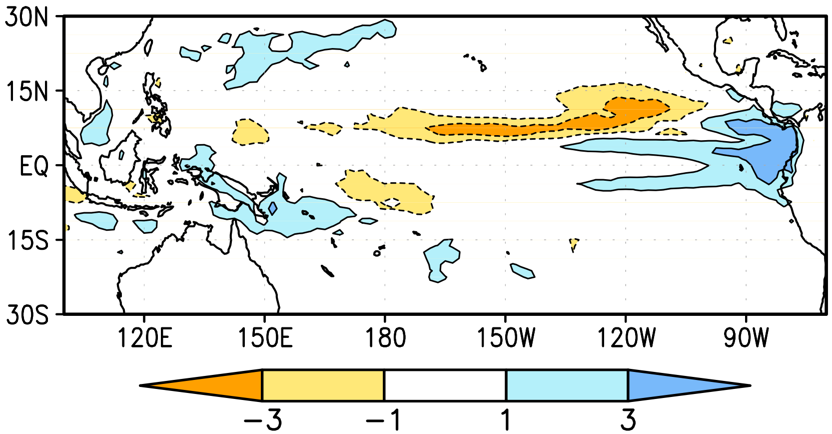
→ It is closely affected by the reflection and absorption of solar radiation associated with the increase of cloud amount.

Tropical Pacific Climate

SST (RIV – nRIV)



Precipitation (RIV – nRIV)



SST

increased over the eastern Pacific
due to reduced salinity

Precipitation

decreased
over the north of the equator in the central Pacific,
increased
over the eastern equatorial Pacific

In other words,

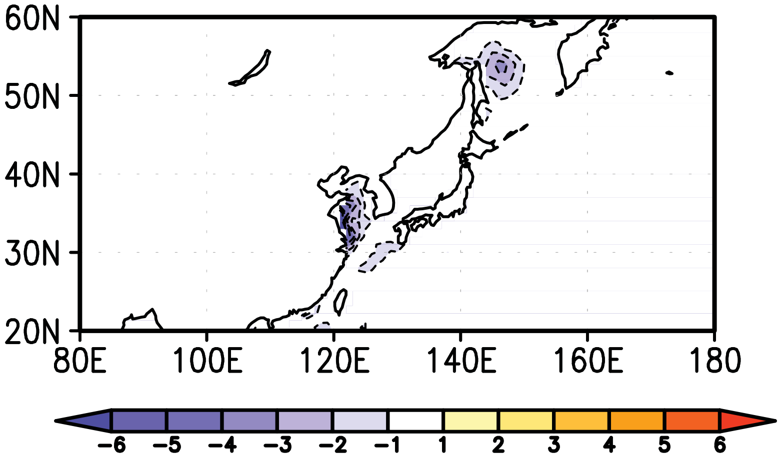
: reduction of salinity → surface warming over the eastern Pacific → increase in clouds by convection → enhanced LH, reduced SW
→ increase in precipitation

➔ An overall increase of precipitation activity on a globe reduces the biases in the large-scale features by warming and moistening the troposphere.

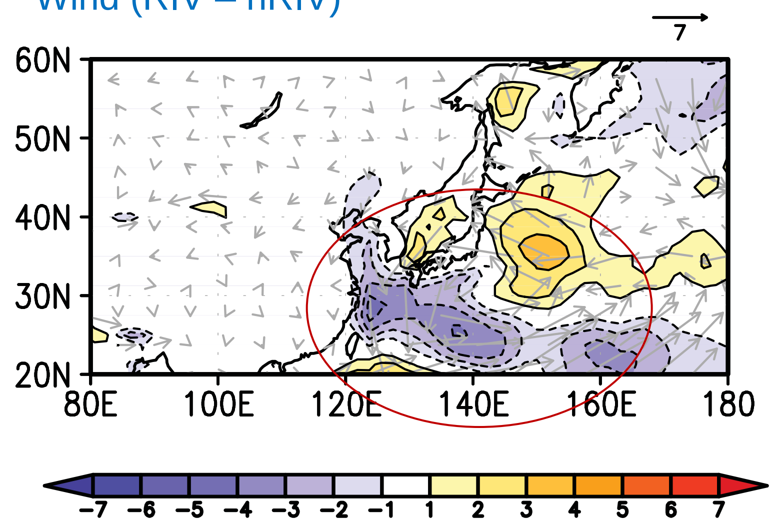
East Asian Monsoon (Summer:JJA)

Freshwater forcing also affects the EASM

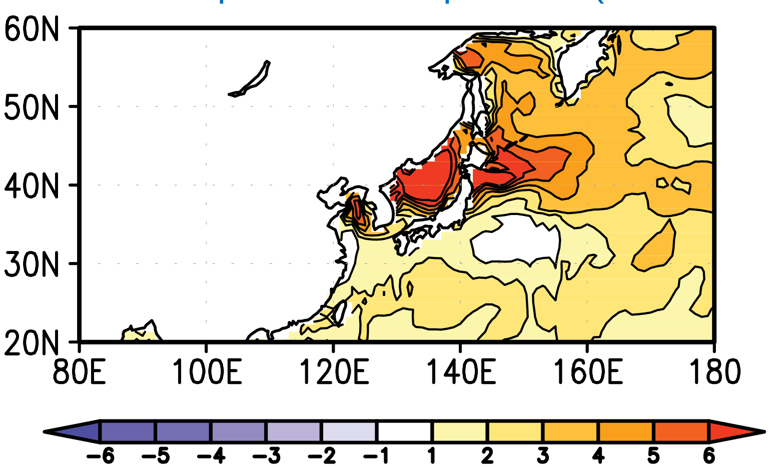
Salinity (RIV – nRIV)



Wind (RIV – nRIV)



Sea Surface potential Temperature (RIV – nRIV)



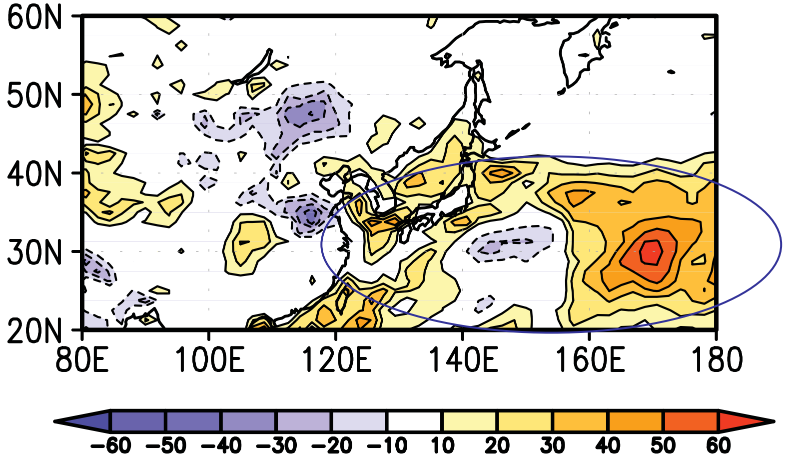
Reduced salinity

→ increase in SST due to reduction of vertical mixing
→Alters the largescale circulation
→ leads to a decrease in North Pacific high

Cyclonic circulation
→North Pacific High decrease

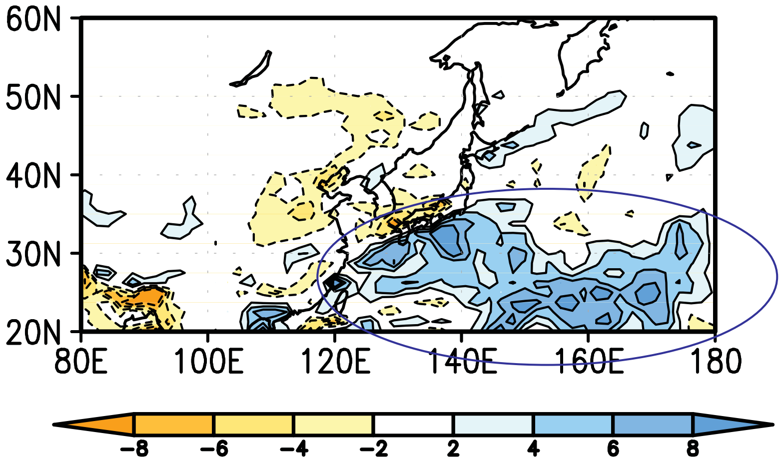
East Asian Monsoon (Summer:JJA)

Latent heatflux (RIV – nRIV)



Cyclonic circulation
→North Pacific High decrease

Precipitation (RIV – nRIV)



As a results

Latent heat increase
Precipitation increase

➔ the **River Routing processes**
can affect the
East-Asian Summer Monsoon system

Summary

- The simulated fresh water flux into the oceans alters their salinity and may affect the thermohaline circulation.
- Recently, climate modeling community has focused on the need for routing models to track the flow of water from continents to oceans at global scale.
- The effect of river routing processes in a HadGEM2-AO on the simulated climate is significant. It is evident that biases in temperature and precipitation are reduced.
- In tropical Pacific, Sea Surface Temperature is increased by reduction of trade winds and shallower mixed layer depth, in turn, precipitation is increase due to convection.
- In East Asia, freshwater can affect large-scale circulation, as well as precipitation.

Conclusion

❖ River routing processes affect both ocean and large-scale circulation. Thus, it is not negligible in climate simulation since it alters the SST, which is the external boundary condition for the atmospheric model.

❖ There are a few issues to be cleared.

- First, the structure of thermohaline needs to be verified over an observation.
- Further, the modulation of surface evaporation due to the runoff over land needs to be considered.

❖ Despite these uncertainties, the freshwater runoff and its interaction with atmosphere should be considered in climate simulation

Thank you

for your attention ~ !!!