Development of a Parallel River Transport Algorithm: Applications to Climate Studies

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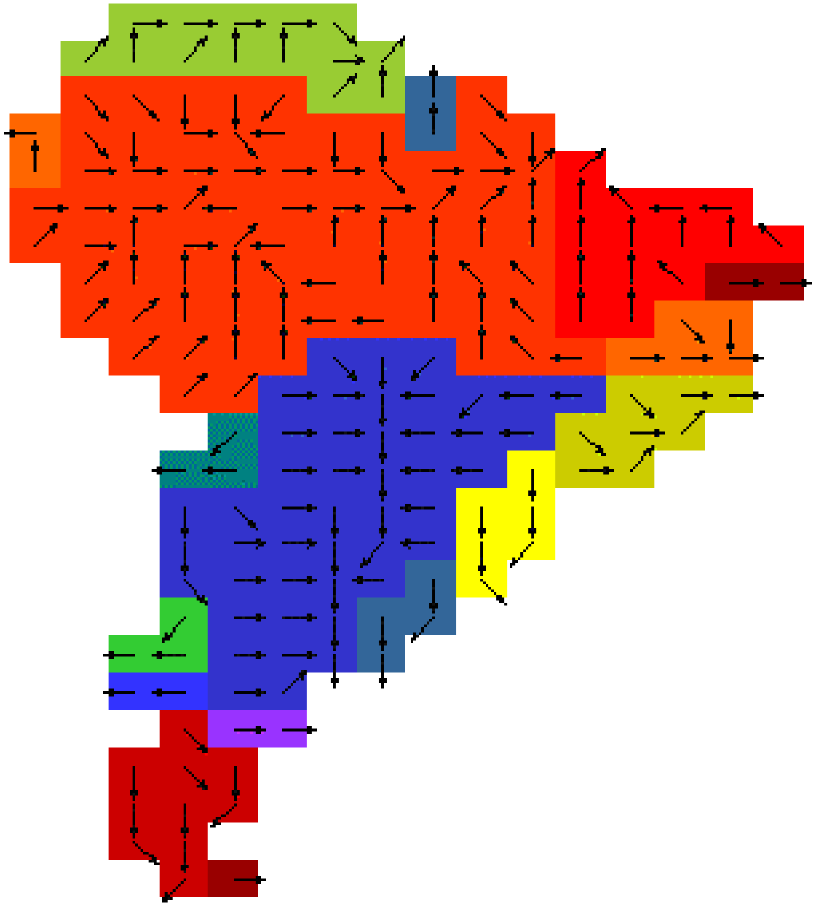
Abstract

The purpose of this research is to study the effect that continental runoff to the oceans has on climate dynamics and to examine the physical mechanisms involved in those processes. A coupled parallel river transport and earth system model is being used to investigate the sensitivity of the ocean to variations in the freshwater flux due to continental runoff. Further indirect effects these changes have on global patterns of precipitation are being examined, along with the coincident feedbacks to the land surface and, therefore, continental runoff.

Outline

- Previous work--development of River Transport Component
- Ocean-only simulations
- Fully-coupled simulations

The River Transport Model (RTM)



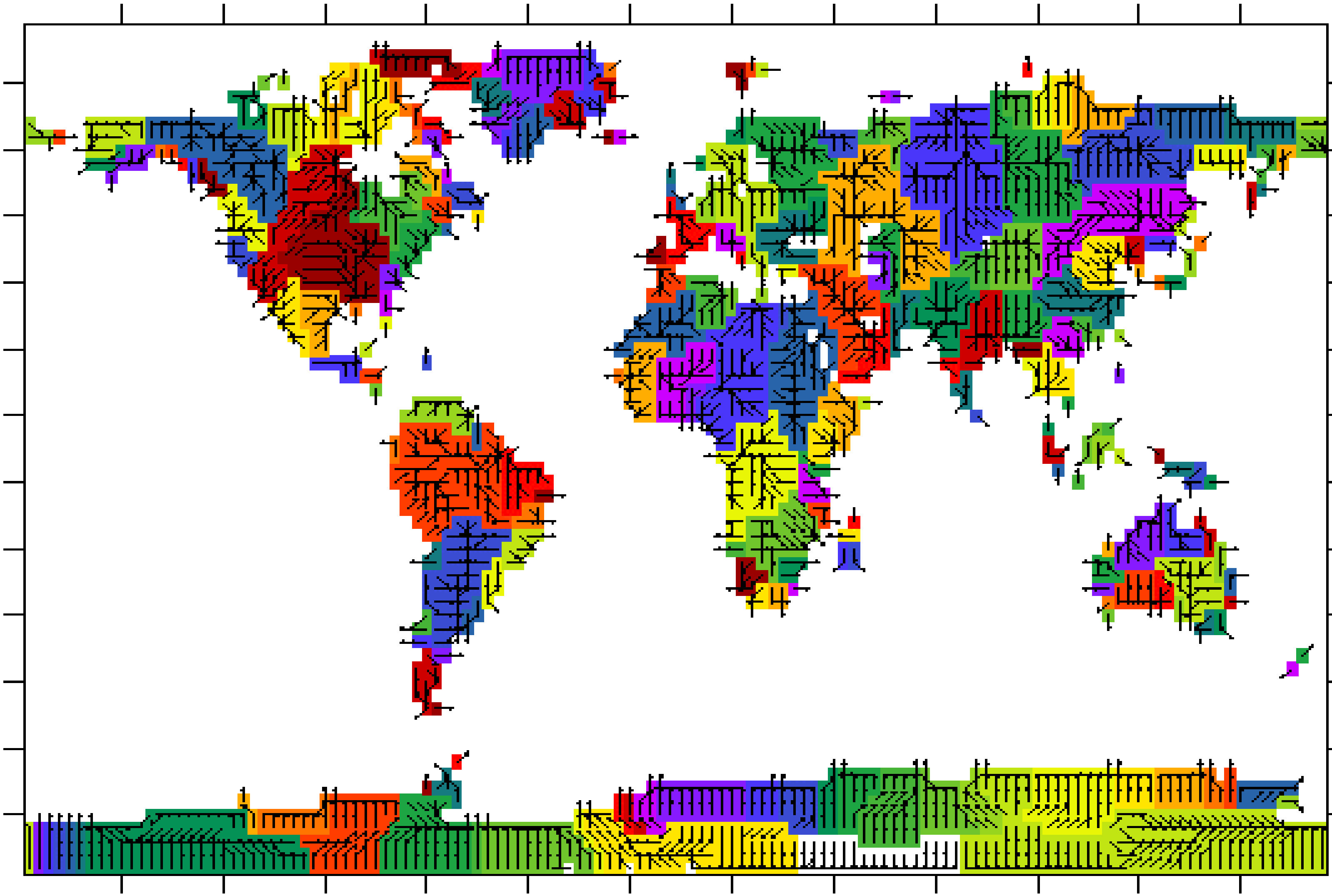
Mass balance on a cell
(after Vorosmarty et al, 1989)

$$\frac{ds}{dt} = \sum F_{in} - F_{out} + R$$

S = storage of river water within cell
F = flux of river water entering/leaving a cell
F = KS
K = v/d
v = flow velocity
d = distance between centers of cells in downstream direction

R = runoff generated within cell

Map of River Directions and Watersheds



PCM Model Description

The DOE Coupled Parallel Climate Model (PCM) is a high resolution climate model designed for use with a variety of highly parallel supercomputers. The atmosphere model component of PCM is NCAR's CCM3 and includes radiation, boundary-layer, and precipitation physics at T42 resolution (2.8125 degrees). The land surface component, NCAR's LSM, includes twenty-eight surface types, twelve soil types, and up to five different subgrid types per land grid cell. This one-dimensional model deals with energy, momentum, carbon dioxide, and water transfers between the land and atmosphere, but does not consider lateral transport of water. The ocean component is the LANL Parallel Ocean Program (POP), using a displaced North Pole to achieve better simulation of the Arctic Ocean and has resolution varying from 2/3 degrees to ½ degrees at the equator. The sea ice component is from the Naval Postgraduate School and uses viscous-plastic ice rheology. The PCM model is part of the DOE-OBER Global Change Research program, in the CHAMMP/CCPP project of the Climate Modeling section.

The missing component is the lateral transport of water. In order to close the global hydrological cycle, the runoff generated by the land component of the model must reach the oceans. One method of doing this is by using a linear reservoir model to route water downslope from cell to cell along the major river networks. Based on this method, we have developed a parallel river transport algorithm, and this has recently been coupled to PCM.

Simulation Setup

Ocean only

- 70 year run
- Only ice and ocean components used
- Atmospheric forcing from earlier 5 year run of CCM3
- Observed runoff forcing

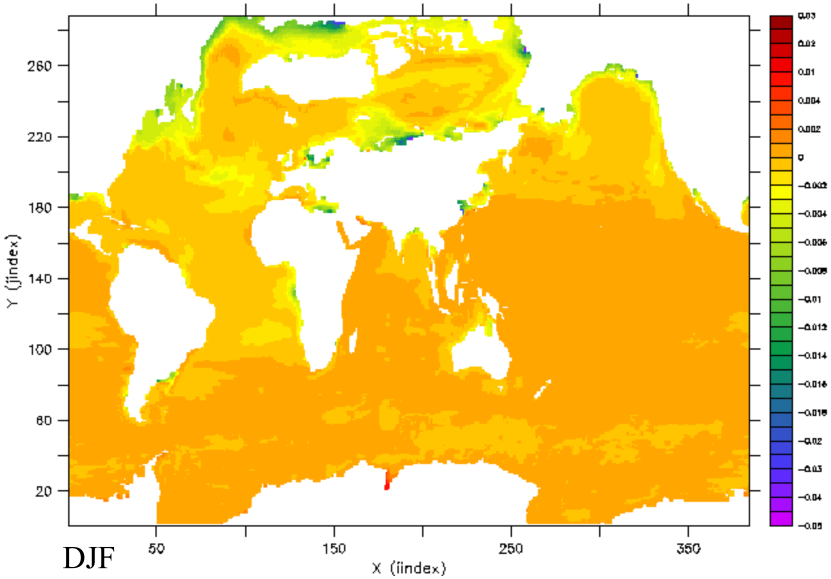
Fully coupled

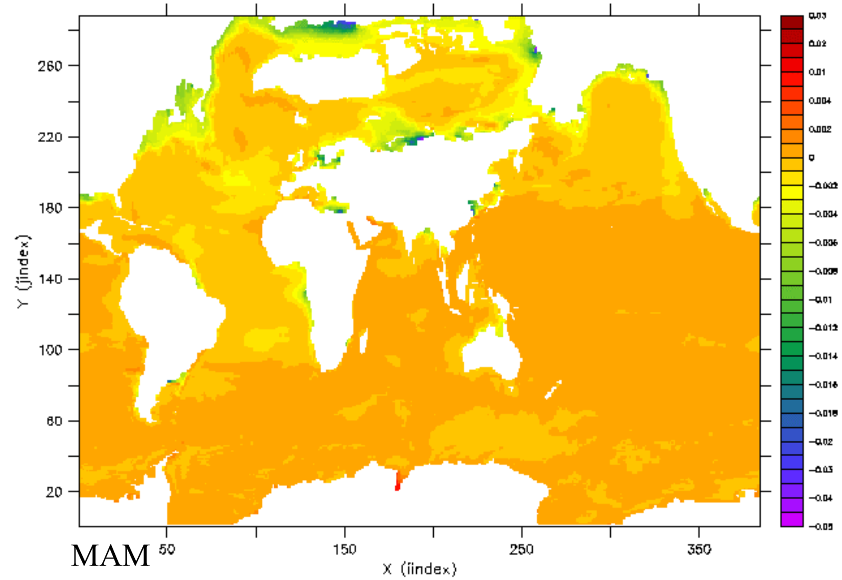
- 200 year run
- Atmosphere, ice, land, ocean, river components included

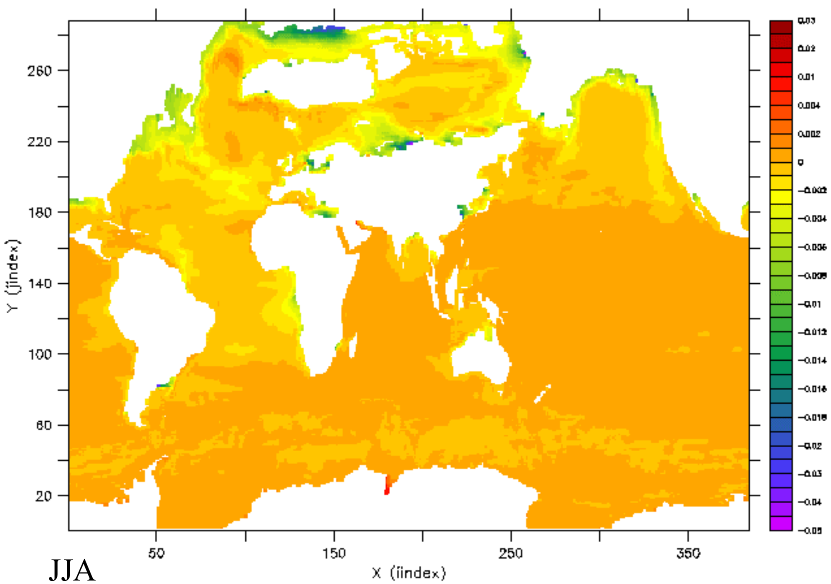
Some Ocean Only Results

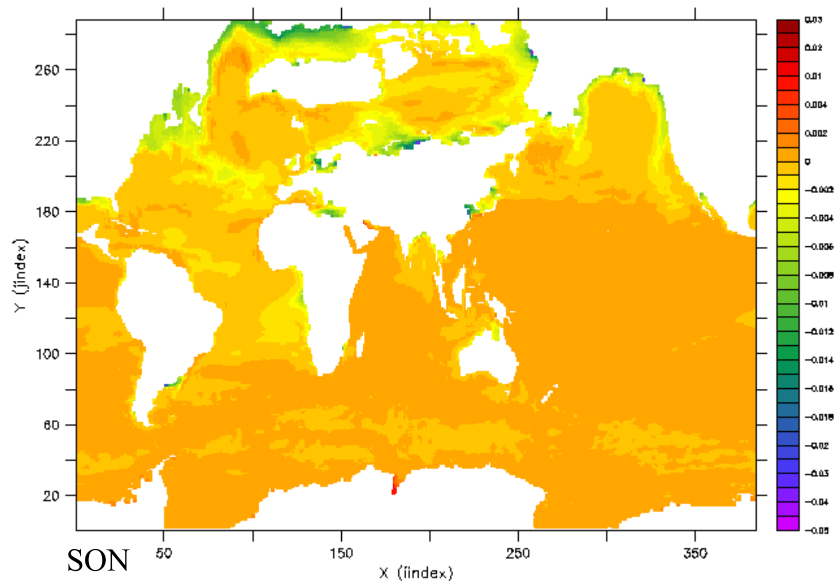
Sea Surface Salinity Difference

(PCM with RTM - PCM without RTM)



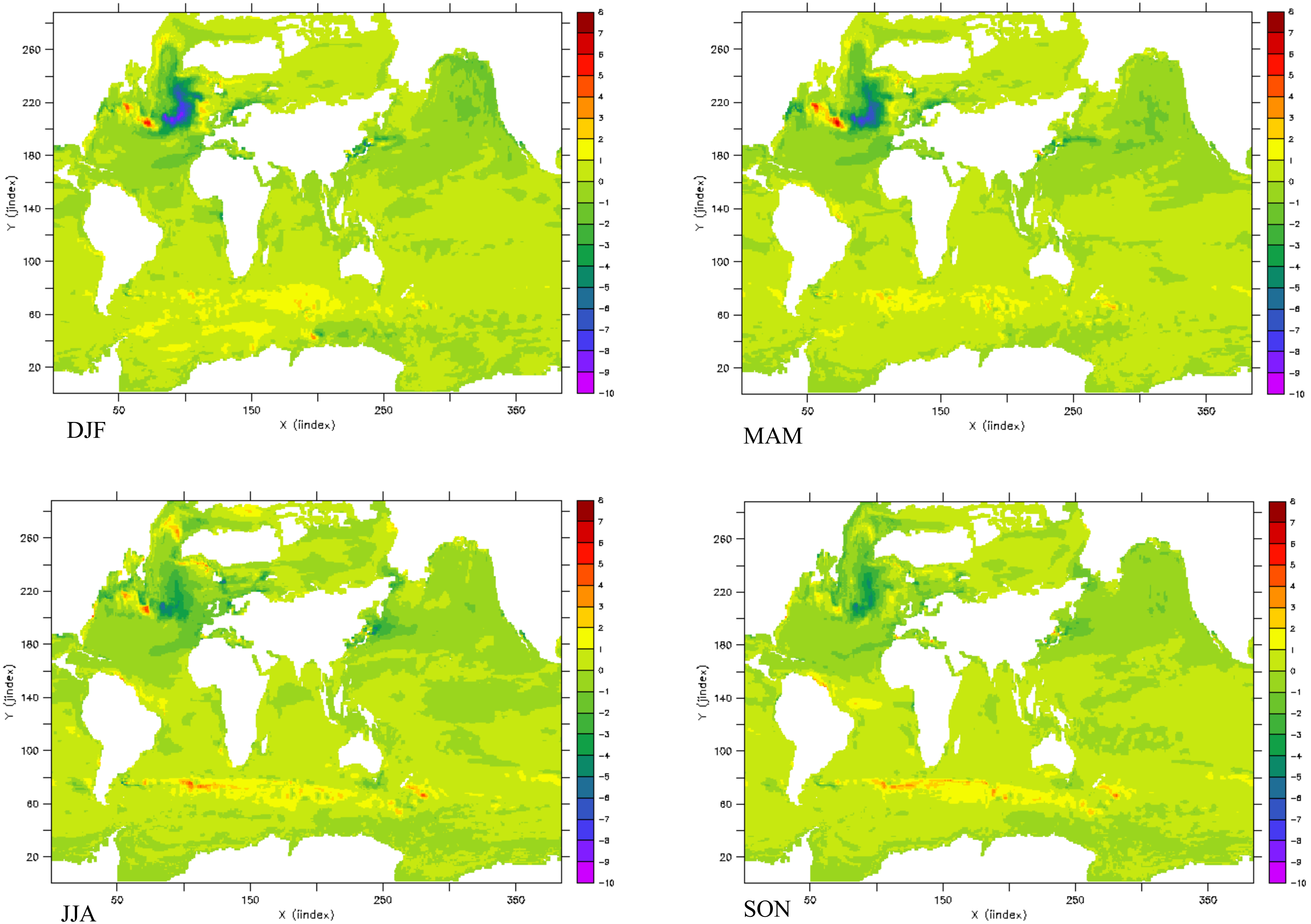






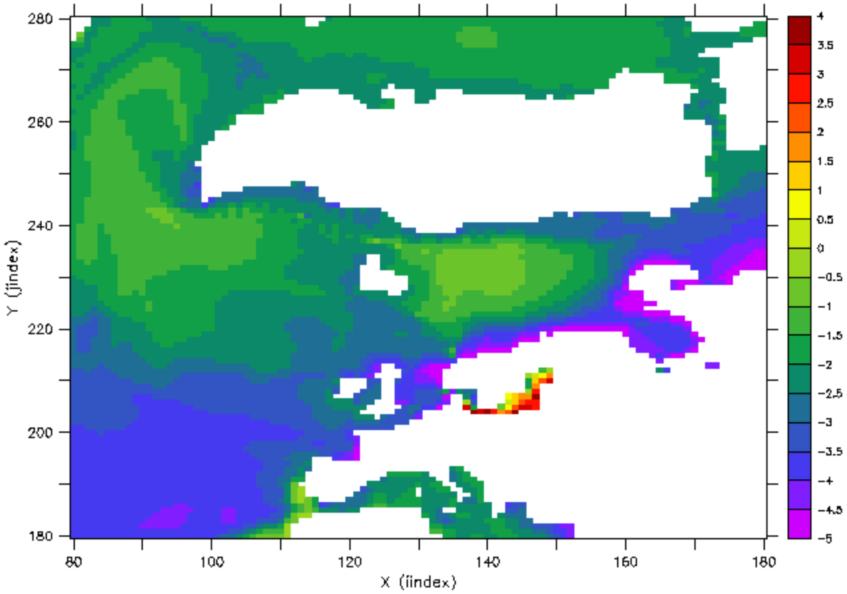
Sea Surface Temperature Difference

(PCM with RTM - PCM without RTM)

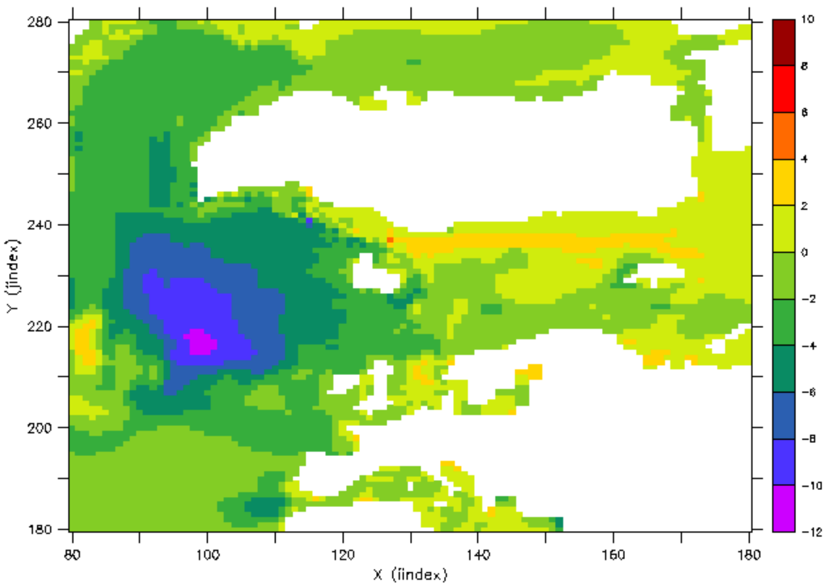


Ocean Only Simulations

Norwegian Sea differences in SSS and SST
Annual average differences between runoff and no runoff



Salinity Difference (ppt)



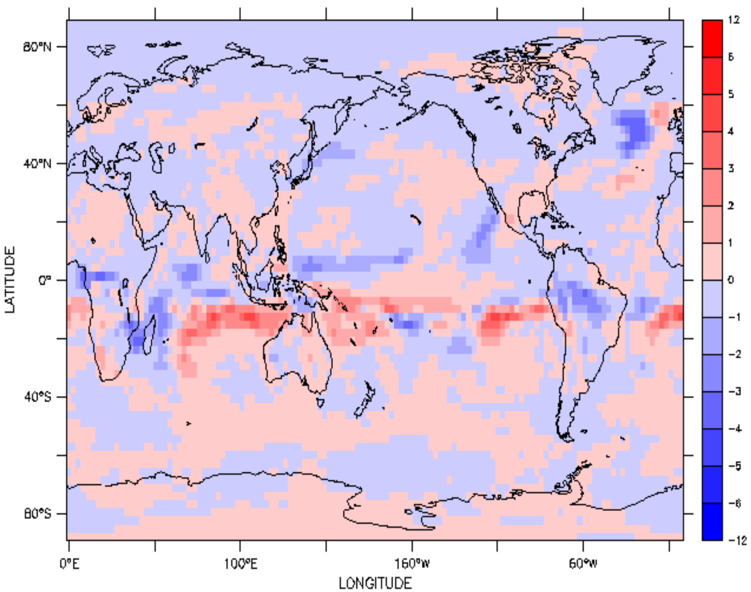
Temperature Difference (C)

Preliminary Fully Coupled Results

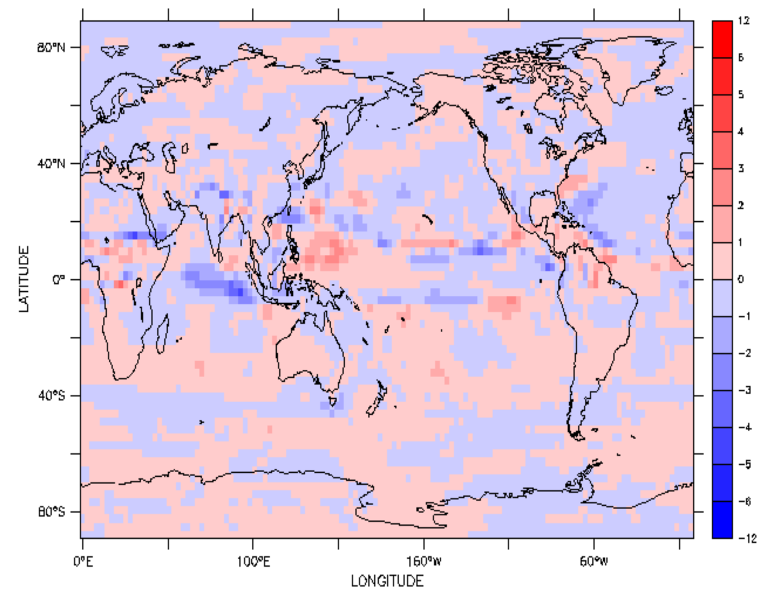
Changing Patterns of Global Precipitation

Difference between river transport and no river transport using DOE/NCAR PCM

Monthly average differences for January and July



January

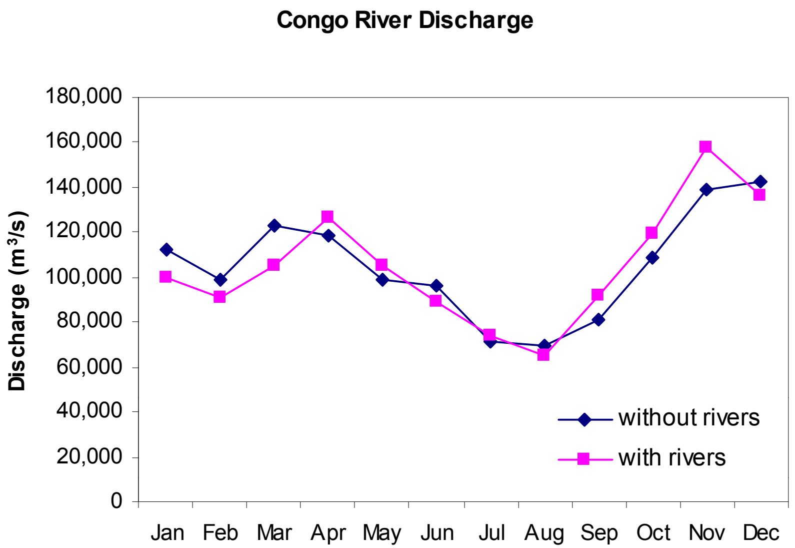


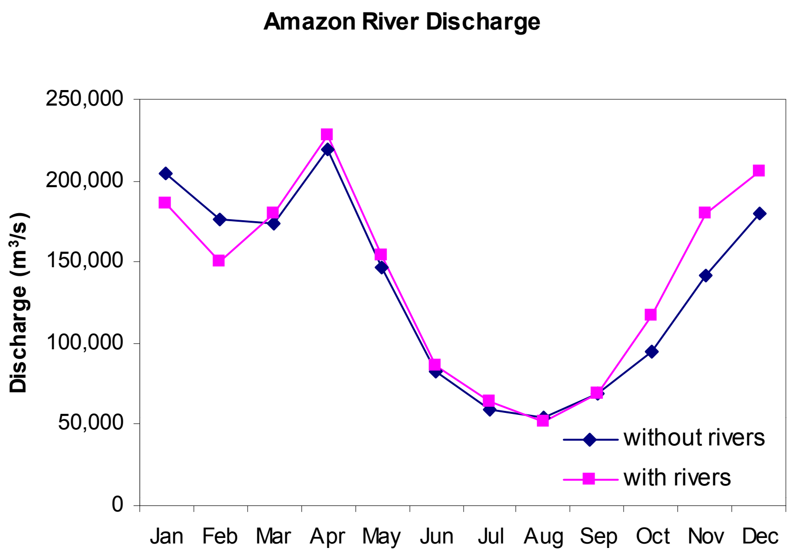
July

mm/day

Runoff Feedback

Graphs of river discharge for two tropical rivers for simulations with and without the RTM component model





Conclusions

- Adding observed runoff to the oceans has a definite impact on sea surface salinity and temperature, particularly in the discharge region.
- In the fully coupled version (pcm/rtm), by changing the sea surface temperature, global patterns of precipitation are also changed.
- This global precipitation shift significantly affects runoff, thus causing a runoff feedback.