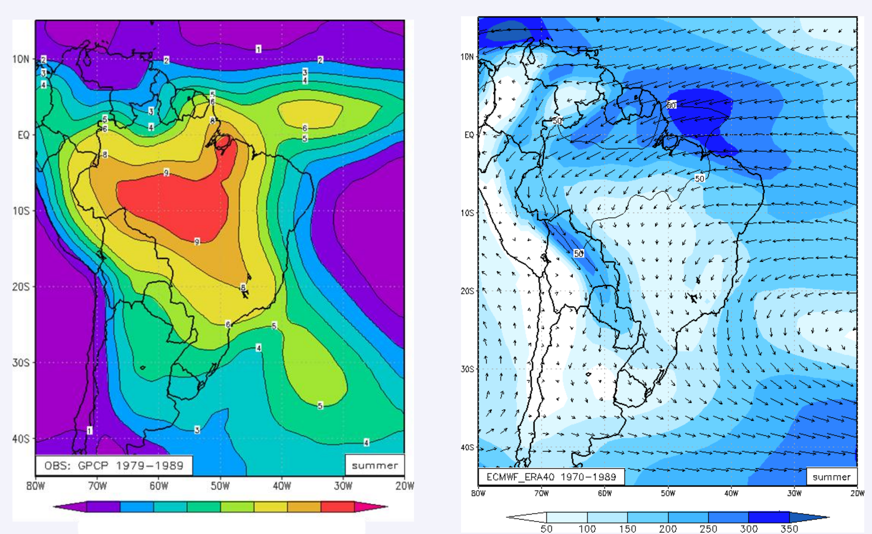
WATER IN THE AIR

Henrique Barbosa[1], Josefina Arraut[2] and Carlos Nobre[2]
[1]IF/USP, Rua do Matão, 187, São Paulo – SP 05508-090
[2]CCST/INPE, Av. dos Astronautas, 10758, São José – SP

Telefone: *+55-11-3091-7070*
Email: *hbarbosa@if.usp.br*

Introduction

Water evaporated from the tropical Atlantic Ocean's enters South America at its northern coast, traverses the Amazon and is deviated southward by the Andes to end up contributing to subtropical precipitation. This moisture flux is modulated by the South American Monsoon and receives in-land contributions from surface evaporation and vegetation transpiration over the Amazon and Pantanal regions. How this picture might be changed under anthropogenic climate change? What is the importance of the Amazon forest to the precipitation south of it?



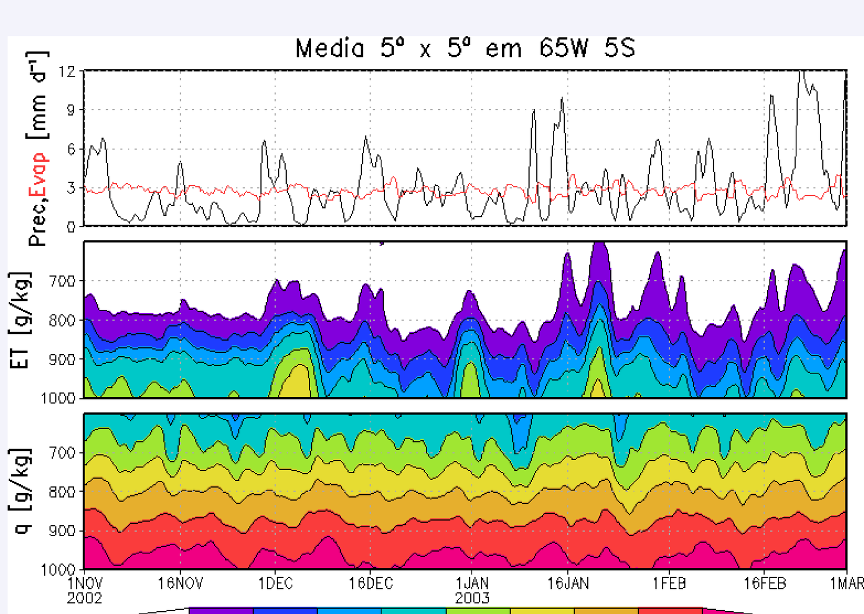
Moisture flux from ECMWF ERA40, Dec-Feb 1970-90. **Observed precipitation** GPCP, Dec-Feb 1970-90.

Amazon Evapotranspiration and Sub-Tropical Precipitation

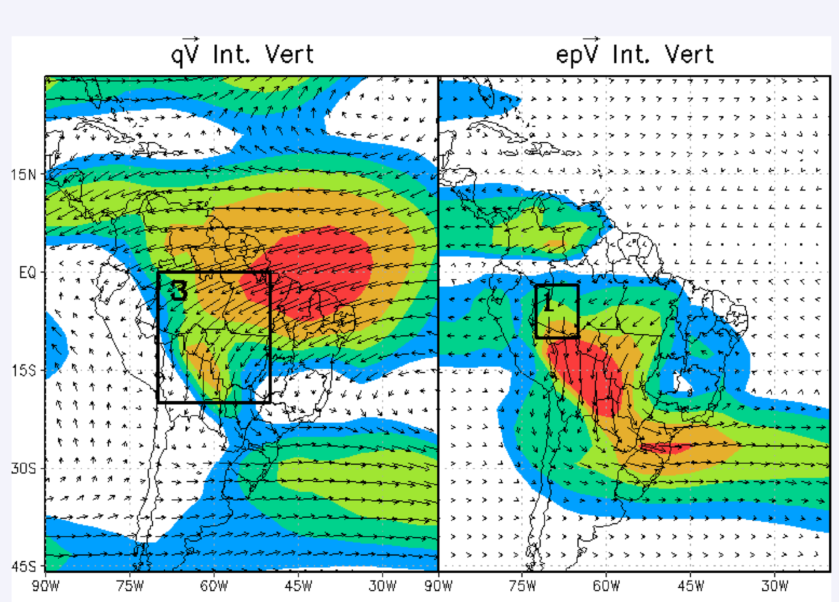
The semi-Lagrangian version of the Brazilian Model of the Global Climate Systems (BMGCS) is used to track the moisture evaporated and transpired (ET) from the Amazon forest as it travels over South America. The contribution of Amazon-ET to the large scale moisture flux is evaluated by comparing the total moisture flux and precipitation with their ET-only counterparts.

Transport processes considered in the model include: advection by large scale circulation, turbulent mixing in the boundary layer and convective mixing aloft. For convective mixing a quasi-equilibrium regime is assumed and removal of ET-vapor is considered as a fraction of the total humidity. Model was integrated for 5 years starting at September 1st 2002 with a spatial resolution of about 250km. Observed sea surface temperature was used as boundary conditions. Details can be found in Barbosa and Nobre (AGU, 2010).

Our results for the rainy season (Nov – Mar) show that 30% of the moisture flux leaving the Amazon (70-50W 15S-EQ) southwardly is due to the forest-ET. The ratio of ET to total moisture flux shows a maximum of about 40% over Bolivia/Pantanal with a secondary maximum of about 30% over southern Brazil.

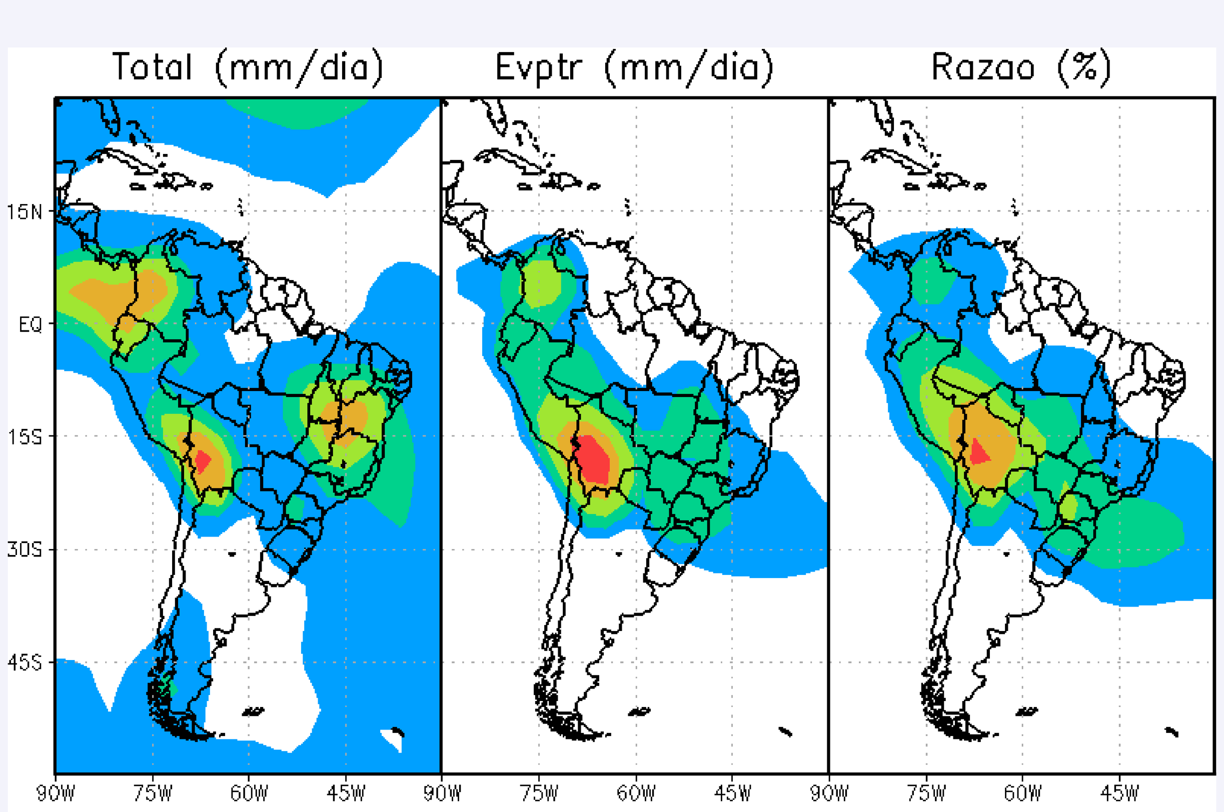


Precipitation and ET time series and vertical profiles of over west Amazon for the first rainy season



Vertically integrated humidity transport (kg/m/s) for total water vapor (left) and ET-only (right).

The contribution to precipitation follows the same pattern but should be taken with extra care as it intrinsically depends on the model's deep convection scheme. Our coarse resolution preliminary results indicate that 40% of the precipitation over Bolivia and 30% of that over southern Brazil comes from moisture recycled by the Amazon forest at least once.

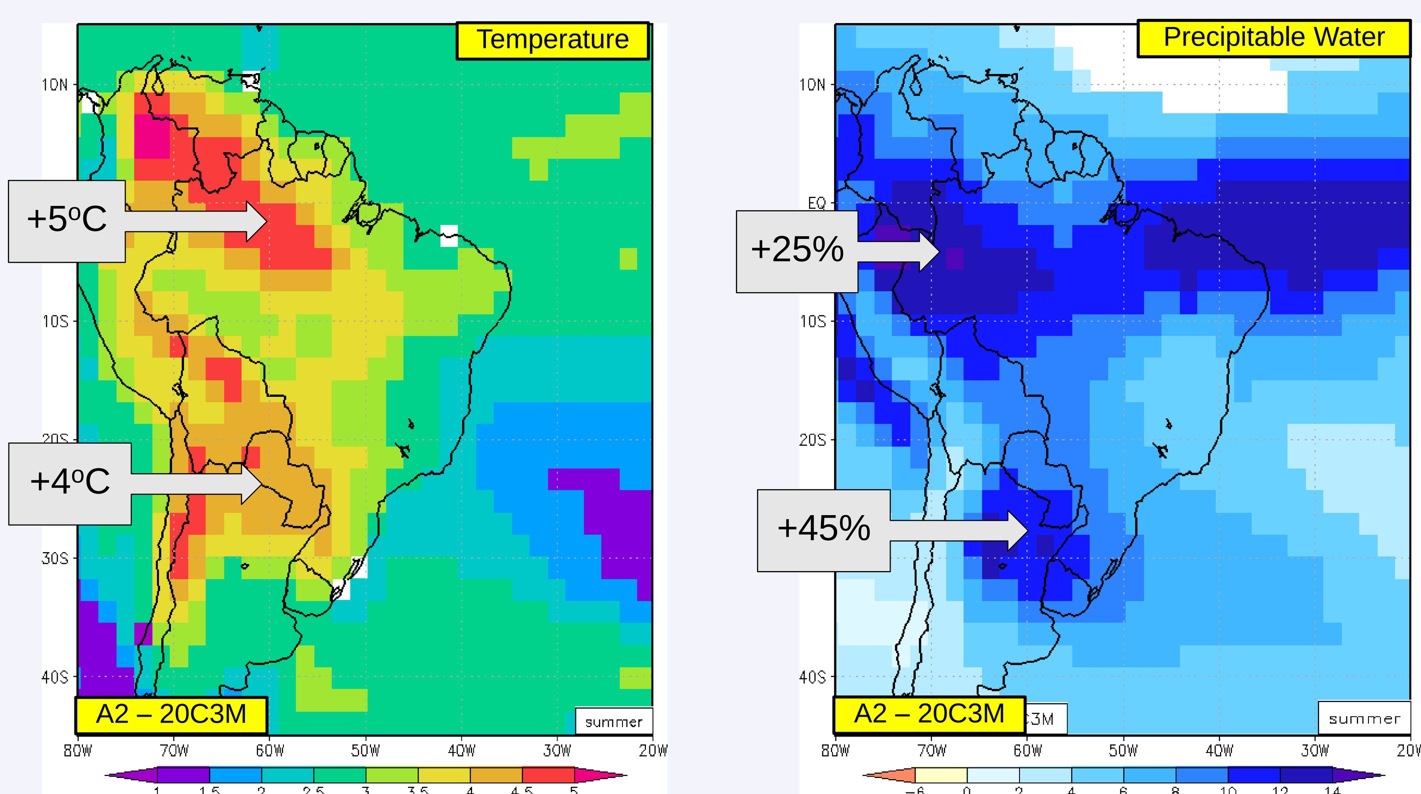


Summer precipitation (Nov-Mar) from total vapor (left) and ET-only (middle). The ratio is shown in the right panel.

Climate Change

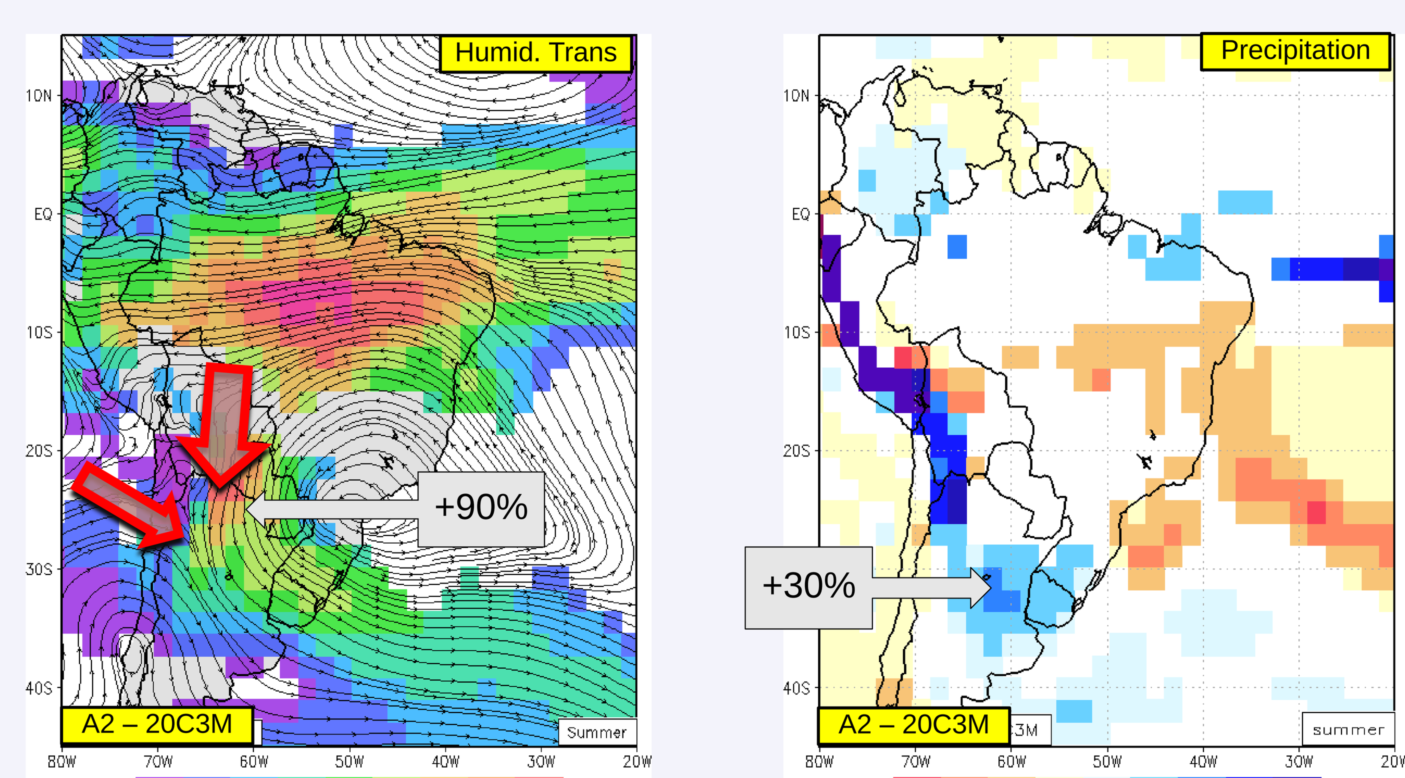
BMGCS was modified to include a time variation of greenhouse gases concentration, following Johns et al (ClimDyn, 2003). Sea surface temperature from selected IPCC-AR4 atmosphere ocean coupled models (HadCM3, GFDL-CM2.1 and MPI-ECHAM5) were then used to drive the model under different scenario assumptions (20C3M, SRES A2 and B1). Model were integrated for 230 years, from 1870 to 2100, using a horizontal resolution of about 200km. Details in Barbosa and Marengo (CBMet 2008) and Barbosa and Arraut (AGU, 2010).

Here results from BMGCS forced by GFDL for 20C3M (1960-90) are compared with A2 scenario (2070-100) to access climate change impacts on moisture flow over South America. Our model results indicate an increase of about +5ºC in summer temperature over both Amazon and subtropical South America. This allows for an increase in precipitable water of about 25% and 45% respectively.



Temperature and Precipitable Water difference between scenarios A2 (2070-100) and 20C3M (1960-90) for summer (Nov-Mar)

This combination of a more hot and humid atmosphere means also more unstable conditions, particularly in the subtropics where frontogenesis by deformation in equivalent potential temperature is both strong and recurrent.



Moisture transport and Precipitation difference between scenarios A2 (2070-100) and 20C3M (1960-90) for summer (Nov-Mar)

Results for the rainy season show an anticyclonic anomaly over the Andes which contributes with at least part of the moisture necessary to the +30% subtropical precipitation. The rest comes from an intensification of the moisture flux across the continent. This is in agreement with other studies that shown an intensification of the global hydrological cycle for a warmer climate and particularly those that points to increased precipitation in subtropical South America. Over the Amazon, changes in temperature were smaller than indicated by other models, and changes in precipitation were not statistically significant.

References

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