Investigating the Tropical and South Atlantic variability during the last Millenium

Volcanism and air-sea interaction processes in the equatorial Atlantic

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Outline

- Introduction
- Equatorial Atlantic variability
- Data and Methods
- Results
- Discussion - Conclusions

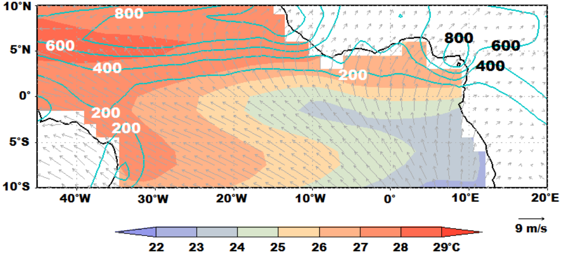

Pinatubo eruption, June 12, 1991

Volcanism impacts on climate

- Radiative cooling of the surface and warming of the stratosphere.
- Cooling of SSTs (ocean)
- SW radiation deficit on the surface
  - weakens the evaporation
  - Decrease of monsoonal precipitation *(Iles et al., 2013; Iles and Hegerl, 2014)*

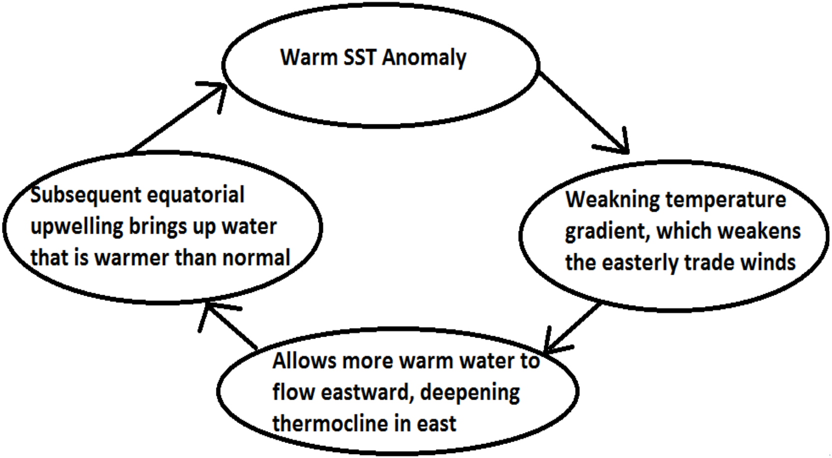
The Atlantic Equatorial Mode (AEM)

- Interannual mode of variability: tongue-shaped spatial pattern in tropical Atlantic SST that peaks during JJA.
- The AEM mechanisms is similar to ENSO [Bjerknes feedback]



JJA climatology: SST (° C) in colors and winds (m/s) in arrows (both from Dee et al., 2011), *PPT (mm/month) in green lines* (Adler et al., 2003).

The Bjerknes Feedback



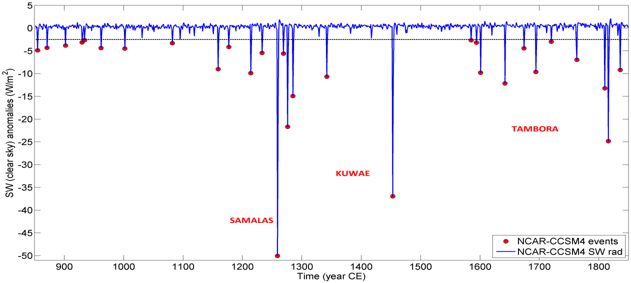
Positive feedback loop reinforces initial anomaly

Data and Methods

- CCSM4 LM run *(Landrum et al., 2013)*
- 1850 control
- AEM $= \frac{(SST_{EAST} - SST_{WEST})}{\sigma}$ which we regress with:
  - SST
  - Zonal wind stress
  - Upwelling on the African coast (depth of the 20°C isotherm).

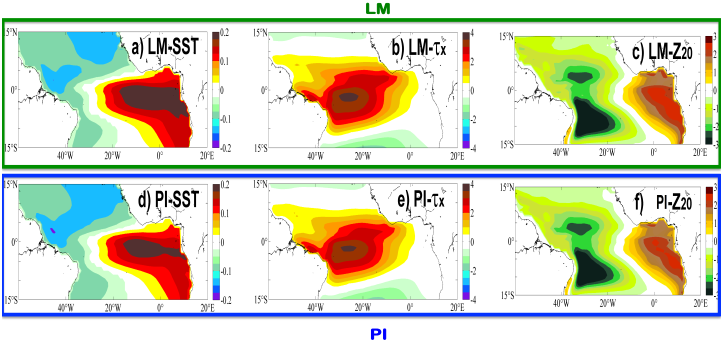
Data and Methods (cont)

- Composite analysis
  1. Select the years of volcanic eruptions - threshold of -2.5 W/m2 to select each eruption event
  2. Volcanic events of interest: the year before (-1), the eruption year (0), and four years after the eruption (+1 to +4).



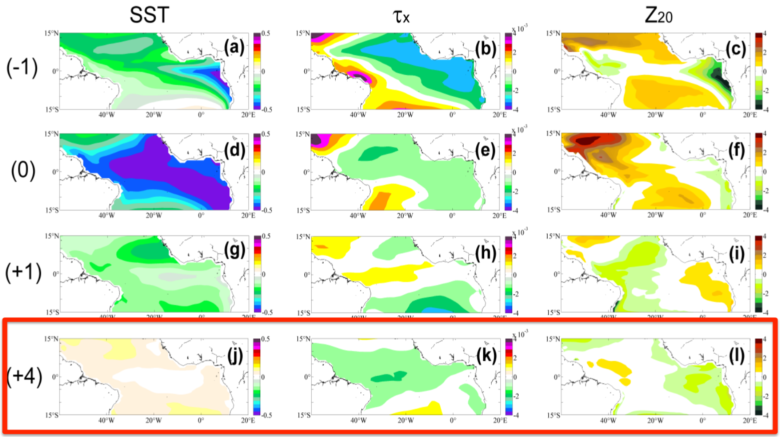
Was the Bjerknes feedback active for the Atlantic?

Regression results



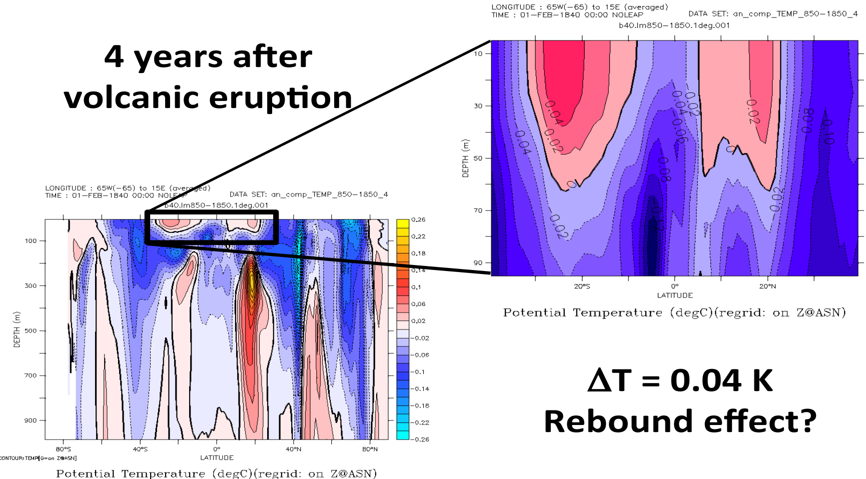
Regression of the AEM reconstructed index on (a and d) SST (°C); (b and e) t_X *(N/m²); and (c and f) 20°C isotherm depth anomalies* (Z_{20}).

Composite analysis



NCAR-CCSM4 volcanic composites. From (a) to (c): year (-1); from (d) to (f): year (0); from (g) to (i): year (+1); from (j) to (l): year (+4). First column: SST anomalies (°C); second column: t_X anomalies (N/m^2); third column: 20°C isotherm depth anomalies (m).

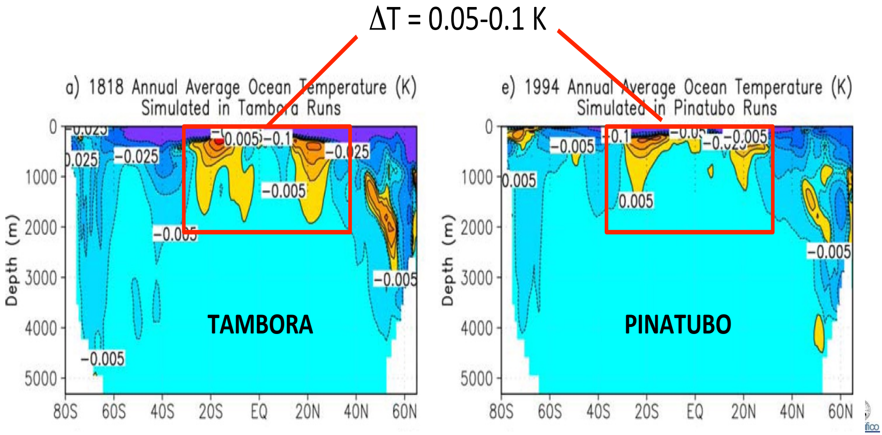
Sub-surface warming of the Atlantic



Warming of global ocean

Consistent with previous results

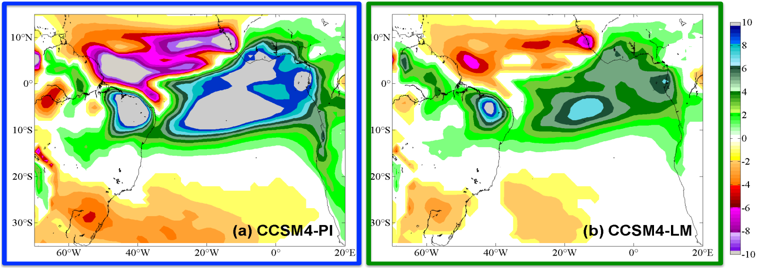
Stenchikov et al. (2009)



Volcanism impacts on rainfall in SA

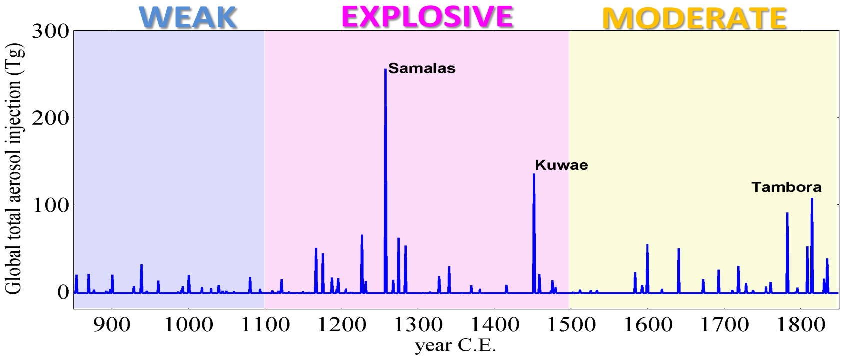
Regression of the AEM-index onto PPT

- Stronger relationship between the AEM index and ppt-anomalies in the PI experiment



NCAR-CCSM4 AEM reconstructed index regressed onto precipitation anomalies (mm^{-1}*/month). Panel (a) refers to* ***PI*** *results, and panel (b) refers to* ***LM*** *results. (*$p < 0.05$*).*

Weak/Moderate/Explosive Eruptions

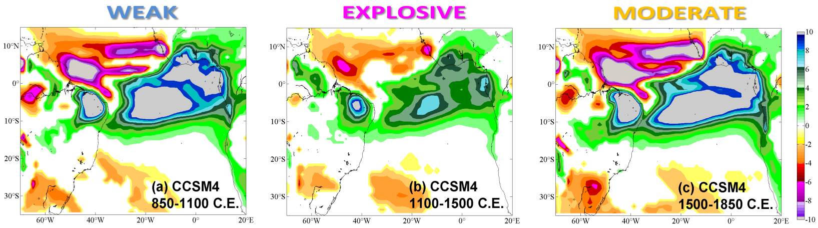


- *Global total sulfate aerosol injection from 850 to 1850 C.E. (blue solid line, Tg, from Gao et al., 2008).*

- Subperiods in colors refer to the intensity of volcanic activity. Blue: weak volcanic activity (850-1100 C.E.); pink: explosive volcanic activity (1100-1500); and yellow: moderate volcanic activity (1500-1850 C.E.).

Impacts on Precipitation

AEM-index regressed onto precipitation anomalies (mm-1/month).



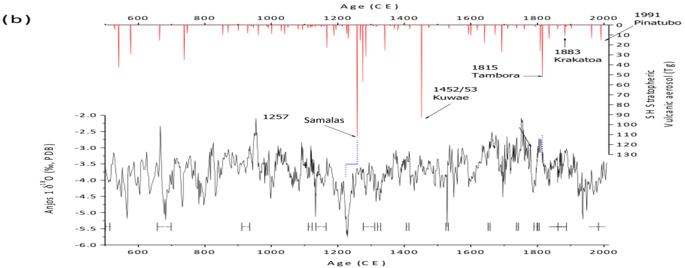
Weak volcanism (850-1100 C.E.): low impact on PPT over South America and the Atlantic Ocean.

Explosive volcanism (1100 to 1500 C.E.): intense radiative cooling in the tropical region weakens the relationship between the AEM and PPT over SA/Atl.

Moderate volcanism (1500-1850 C.E.): opposite effects whe compared to the explosive volcanic activity: intensifies the impact of the AEM and PPT over SA/Atl.

Volcanic impact on PPT proxy

From stalagmites (SA cave)



(a) Central-eastern Brazil $\delta^{18}O$ record from Anjos1 stalagmite with volcanic sulfate aerosol accumulation[17].

Discussion - Conclusions

Impact of the volcanic activity Radiative cooling

- Radiative cooling of the Eq. Atl. in the year of eruption is followed by warming in the Eq. Atl. four years later.
- Eq. Atlantic warming observed in the 4th year after the eruption.
- Positive AEM + volcanic activity **weakens** PPT in the Amazon basin and NE-Brazil.
- *Pinatubo showed decrease in continental PPT in the Amazon and NE-Brazil (Trenberth and Dai, 2007) .*
- The radiative cooling caused by the explosive volcanic eruptions during the LM was so intense that it weakened (decoupled) the thermodynamics of air-sea interactions.

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THANK YOU