Enhanced Vertical Atmosphere Resolution improves Simulation of Tropical Atlantic SST and Variability

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Introduction

Current climate models still have difficulties in simulating Tropical Atlantic (TA) climate (Xu et al., 2014). A prevalent severe bias is too warm sea surface temperatures (SST) in the eastern TA, but also a reversed zonal SST gradient along the equator and wrong precipitation patterns. Further, modes of variability, as the seasonal development of a cold tongue, are not correctly simulated. These inabilities lead to a reduced predictability of SST and related impacts outside the TA.

Many attempts have been made to understand and decrease biases in the TA mean-state and variability. Several mechanisms are revealed and quantified. One possibility is to increase the model resolution. The impact of increased horizontal resolution in the ocean is rather small (e.g. Jochum et al. 2005, Seo et al. 2006). Whereas an increased horizontal resolution in both the atmosphere and the ocean gives promising results (e.g. Delworth et al. 2012, Small et al. 2014, Doi et al. 2012).

Lindzen & Fox-Rabinovitz (1989) highlight the important relationship between horizontal and vertical resolution in a climate model. We show, that at high atmospheric horizontal resolution, enhanced vertical resolution, is indispensable to substantially improve TA climate simulation.

Model configuration

The Kiel Climate Model (KCM) is a coupled atmosphere-ocean-sea ice general circulation model. The ocean component is **NEMO** with a horizontal resolution of 2°x 2° (**ORCA2**), a latitudinal refinement of 0.5° near the equator, and has 31 levels. The ocean model is unchanged in our experiments.

ECHAM5 is the atmosphere model, with a spectral resolution of **T159**, which corresponds to **~0.75°**. The two experiments conducted differ ONLY in the number of atmospheric vertical levels: **L31** and **L62**.

The additional levels are placed in between the original levels. The top levels remain at similar height (~10 hPa).

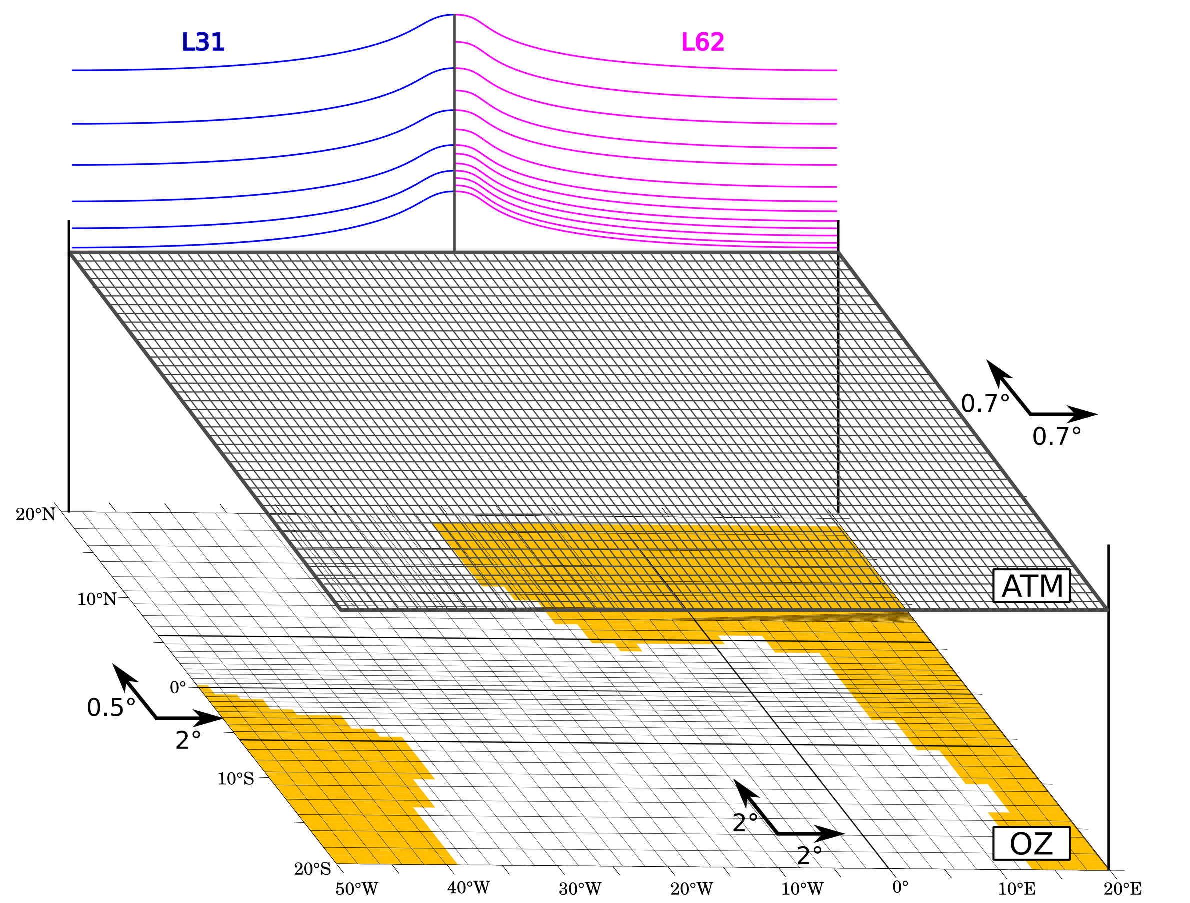


Fig. 1 Illustration of the model configuration.

Results - Mean state

SST bias largest in July-August-September, when seasonal cold tongue fully developed.

T159L31: - Typical warm SST bias up to 6°C
- Southward displacement of ITCZ

T159L62: - SST bias reduced to less than 2°C
- Correct latitudinal ITCZ position, but wetter
- Improved West Africa monsoon system

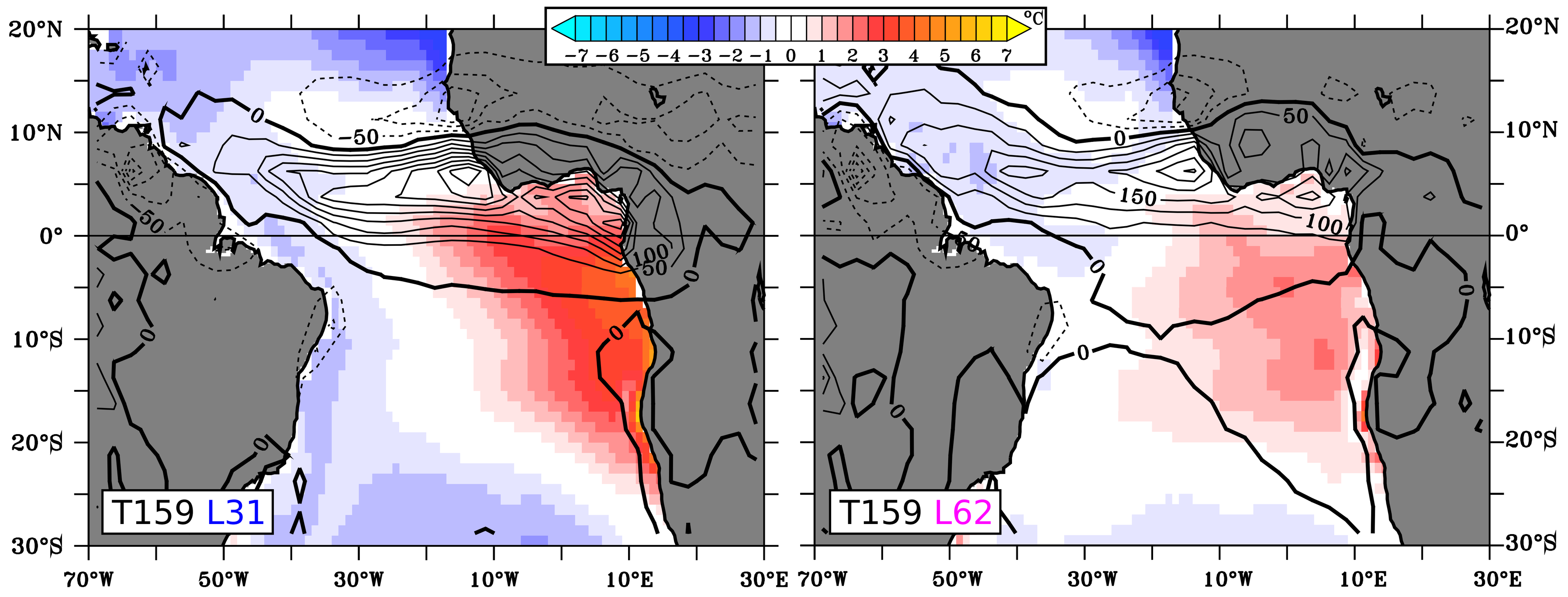
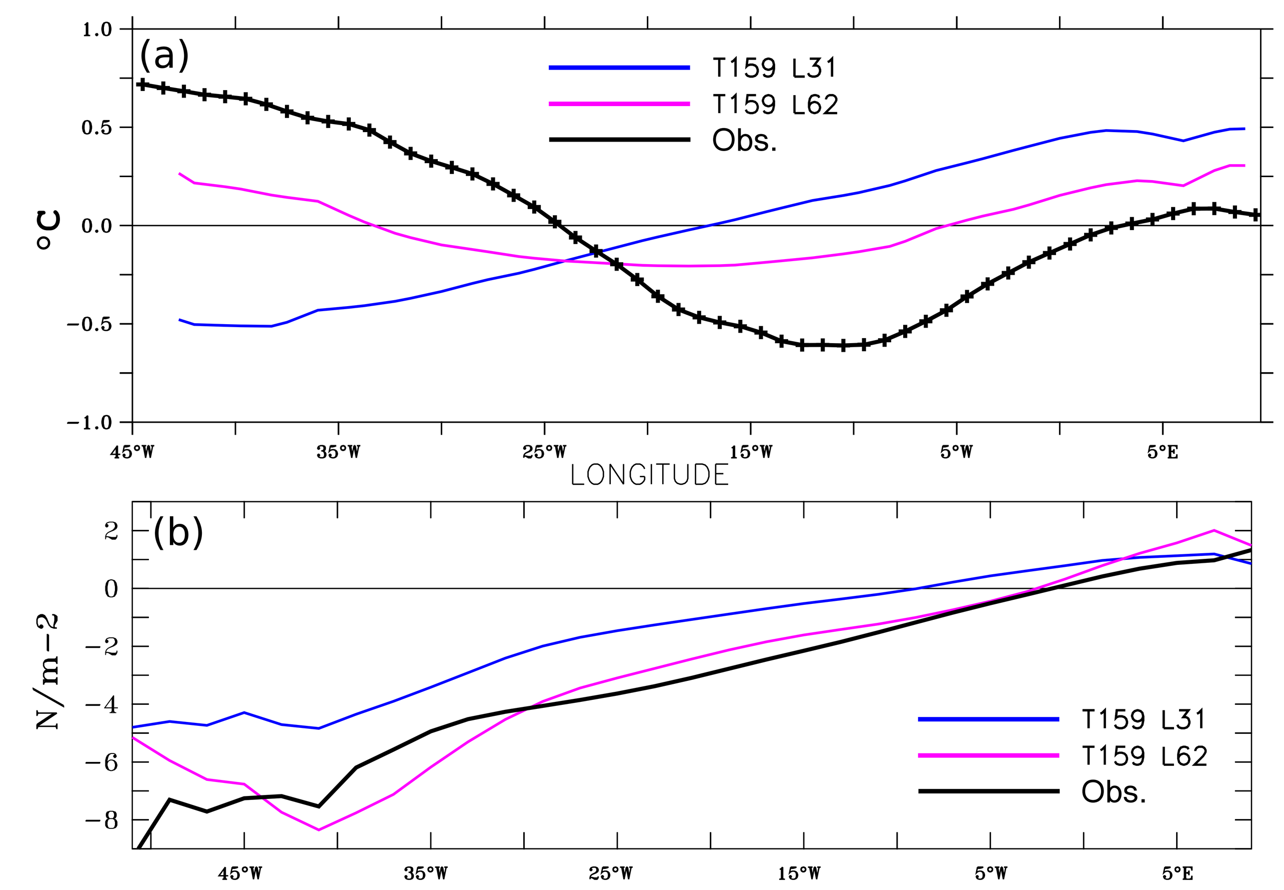


Fig. 2 SST bias with respect to HadISST (shading, °C) and total precipitation bias with respect to GPCPv2 (contours in mm/month, increment 50mm) in July-August-September.



Zonal SST

T159L31: Reversed

T159L62: Correct sign

Zonal wind stress

T159L31: Too weak

T159L62: In good agreement

Fig. 3 Zonal gradient along the equator (3°S-3°N). (a) annual SST anomalies, (b) annual zonal wind stress. HadISST and ERA-Interim as observations.

Hier kleben

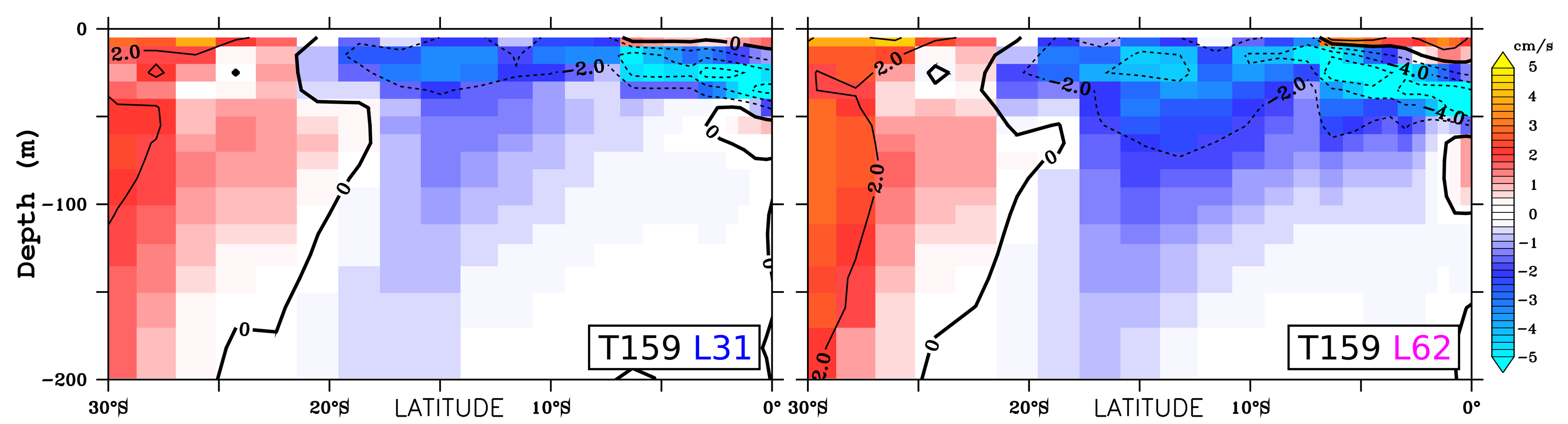


Fig. 4 Zonal average, over a 3 grid box wide band along the coastline, of annual meridional velocities.

Results - Variability

Seasonal cold tongue development along the equator, peak in June

T159L31: No phase locking

T159L62: Level of variability captured with 2 months time lag

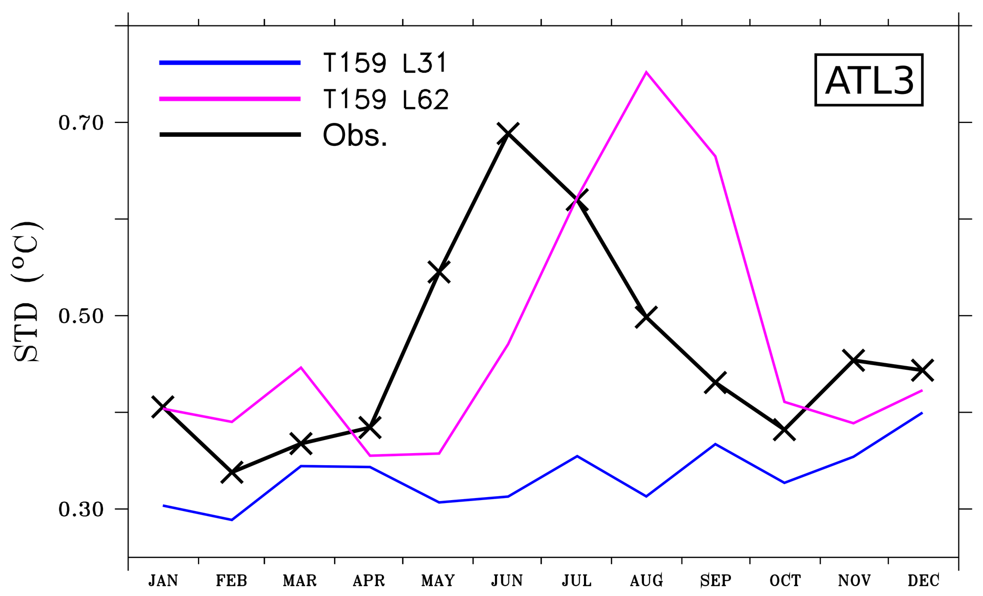


Fig. 5 Standard deviation of SST anomalies in the ATL3 region (3°S-3°N, 20°W-0°) as a function of months.

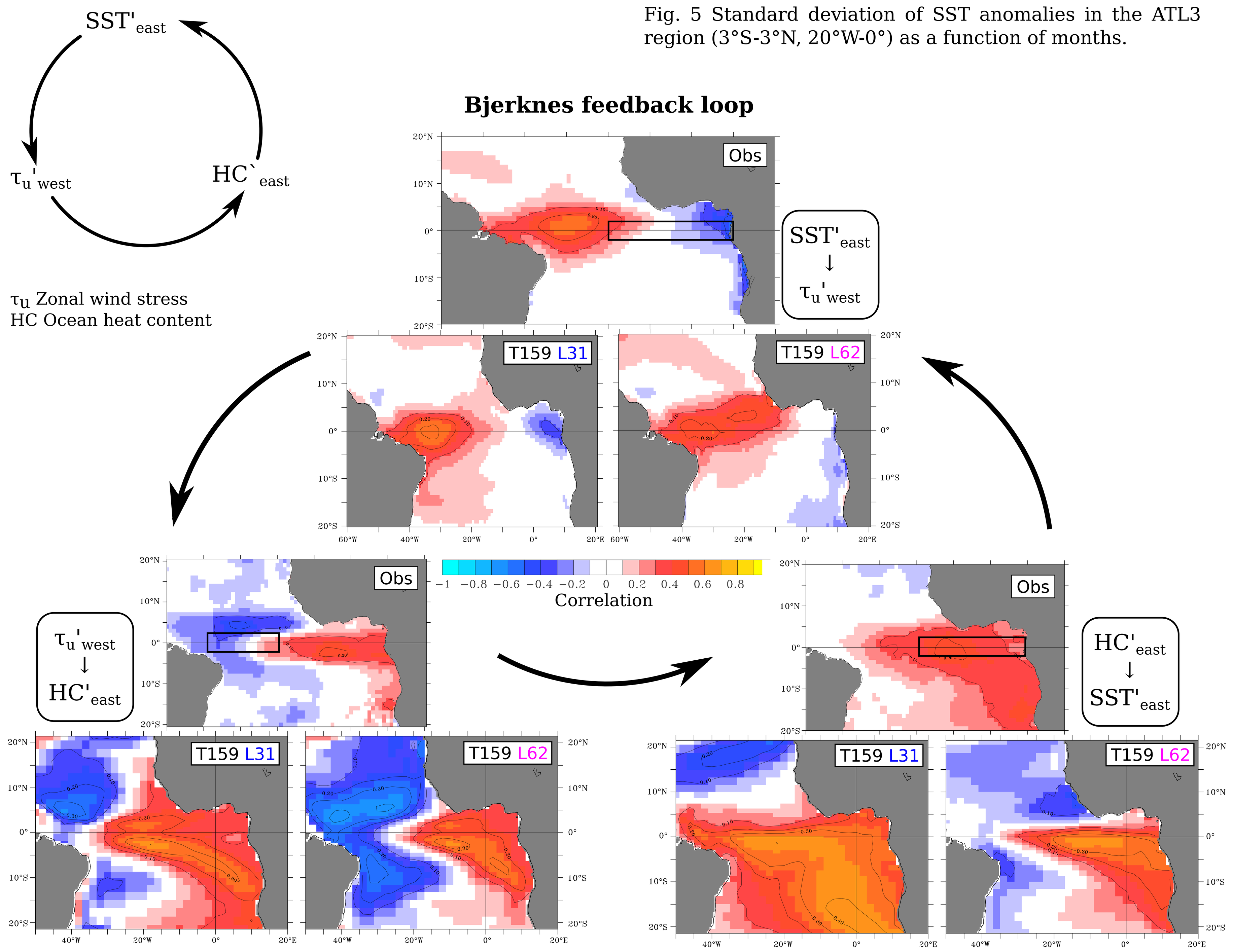


Fig. 6 Bjerknes feedback. Correlation (shading), expl. variance (contours). Boxes define indices east (20°W-10°E, 3°S-3° N), west (40°W-20°W, 3°S-3°N). 20°C isotherm depth proxy for HC. Obs: ERA-Interim (τ), HadISST, HadEN4.0.2 (HC).

Conclusion

→ At high atmosphere horizontal resolution, enhanced vertical resolution strongly improves simulation of TA climate

→ Consistent choice of vertical and horizontal resolution!

Possible mechanisms:

- Enhanced wind stress impacts ocean state - reduces subsurface biases in temperature and strength and position of ocean currents
- Increased (decreased) rainfall over South America (Africa) → correct zonal SLP gradient
- Transport of heat and momentum in lower atmosphere?
- Model sensitivity to resolution?

Literature

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Acknowledgments

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Further Information

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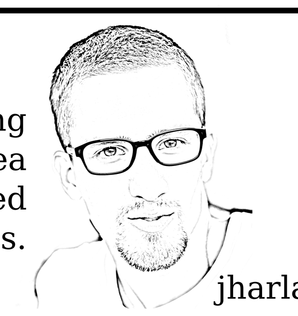

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