Intraseasonal variability in the tropical Atlantic: Observations vs. reduced gravity simulations

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GEOMAR

1) Variability in the tropical Atlantic:

- Spectral peaks at annual and semi-annual, and 120-day periods associated with 4th, 2nd and 1st baroclinic modes
- Peaks correspond to resonant basin modes, composed of equatorial Kelvin and Rossby waves, as well as coastally trapped waves[1]

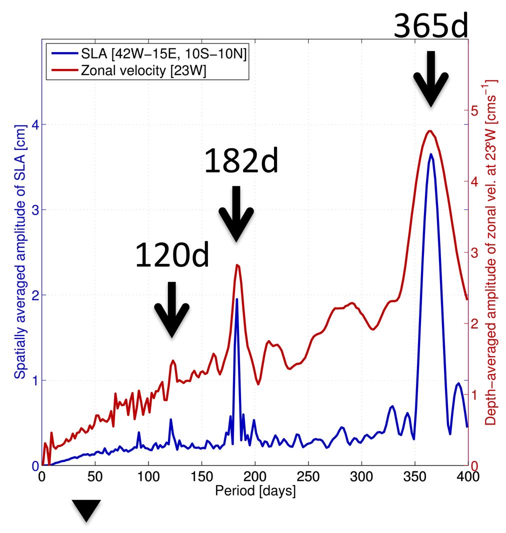

Fig. 1: Periodogram of SLA in the tropical Atlantic and zonal velocity at 23°W, 0°N.

2) Reduced gravity simulations of the tropical Atlantic

- To study the intra-seasonal variability in particular, reduced gravity model (RGM) simulations are used:

$$u_t - fv = -g'_n \eta_x + \frac{\tau_s^x}{\rho_0}, \qquad v_t + fu = -g'_n \eta_y + \frac{\tau_s^y}{\rho_0}, \qquad \eta_t + H(u_x + v_y) = 0, \qquad g'_n = \frac{c_n^2}{H}$$

- The model is run separately for the first five baroclinic modes (c_1=2.47 m/s, c_2=1.32 m/s, c_3=0.94 m/s, c_4=0.74 m/s, c_5=0.57 m/s), forced with interannually varying wind stress from NCEP (1990-2014)
- To allow for comparison of model and observations, the model output is fitted to AVISO sea level anomaly (SLA)[2]

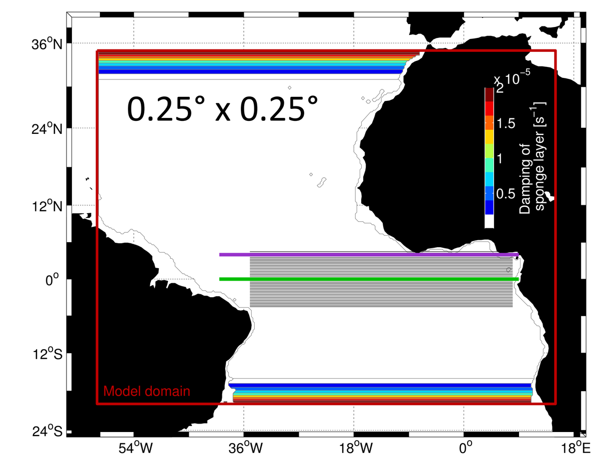

Fig. 2: Model domain with sponge layers at northern/ southern boundaries, and area/sections of interest.

3) Comparison of reduced gravity simulations with AVISO SLA:

- Dominance of the annual and semi-annual cycle, well reproduced by the RGM (Fig. 3 and Fig.4)
- In AVISO, presence of continuous and recurrent eastward propagations[3], with the intra-seasonal climatology representing ~25% of the seasonal cycle amplitude (Fig. 5)
- Only ~50% of the intra-seasonal signal amplitude is reproduced by the RGM, however the phase-lock of the propagations appears to be consistent

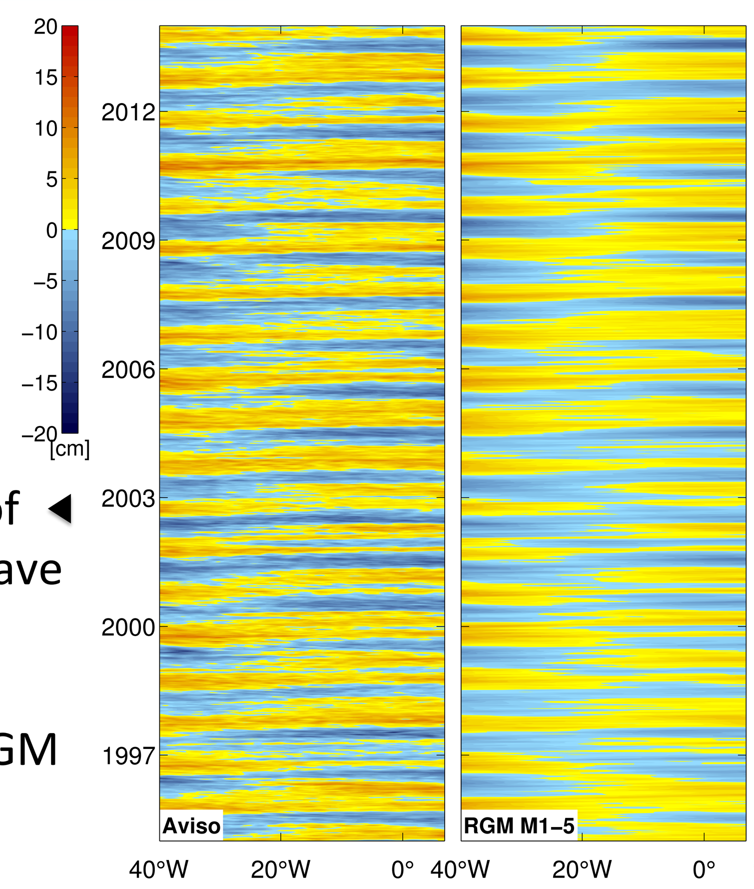

Fig. 3: Hovmöller plot of SLA along equatorial wave guide (green line in Fig. 2). *Left*: AVISO, *right*: Reconstruction from RGM modes 1-5.

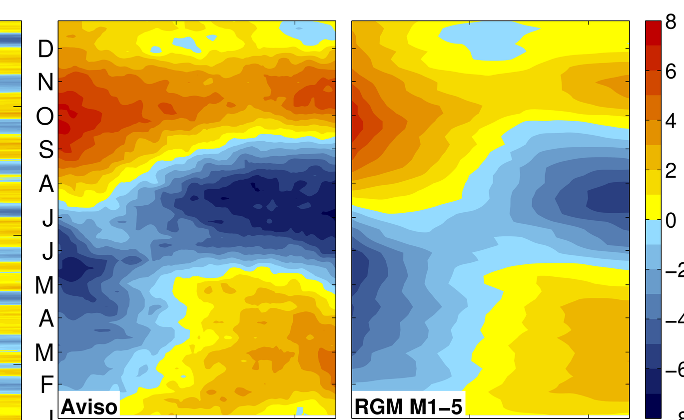

Fig. 4: Climatologic (1995- 2014) seasonal cycle of SLA along equatorial wave guide.

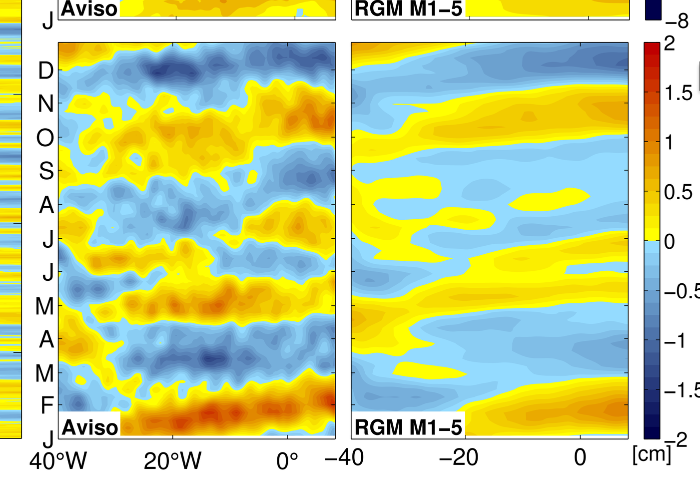

Fig. 5: Climatologic (1995-2014) seasonal cycle of band-passed (25-130d) SLA along equatorial wave guide.

4a) Basin mode of the 1st baroclinic mode

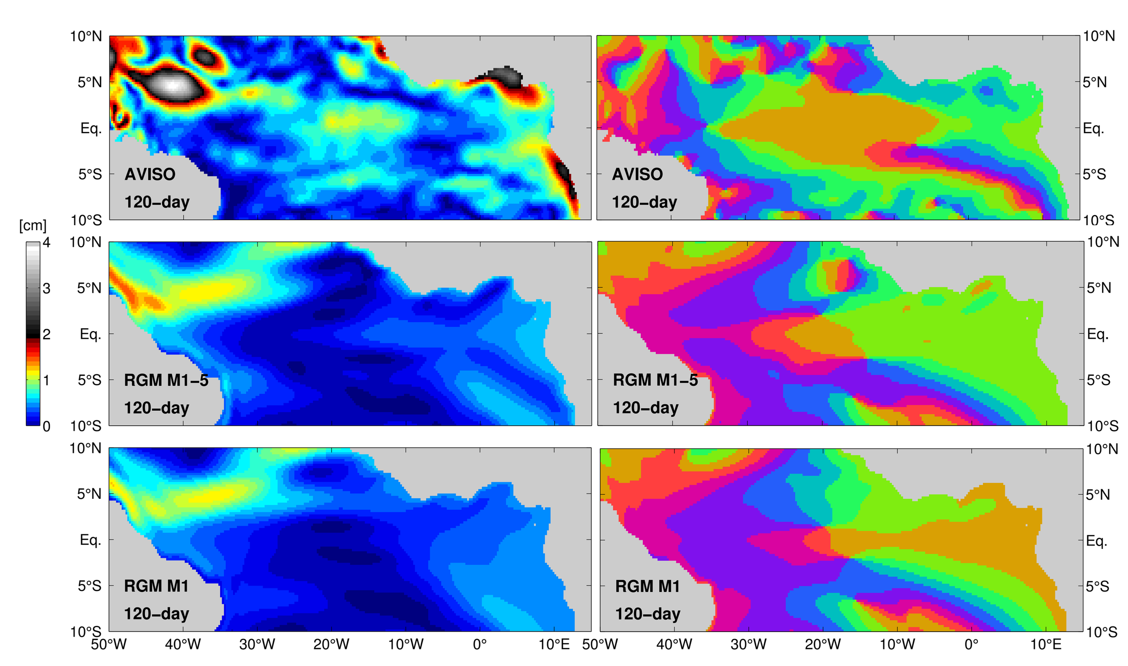

Fig. 6: Maps of amplitude (*left*) and phase (*right*) of 120-day harmonics fitted to SLA data. *Top*: Aviso, *middle*: RGM modes 1-5, *bottom*: RGM mode 1 only.

- Basin-wide structure of SLA associated with the 1st baroclinic mode with variability detectable as far as 10°S
- Consistent pattern in the RGM, although with considerable lower amplitude
- Mode 1 in the RGM simulations explains most of the structure seen in the "full" model

4b) Equatorial wave analysis

- Averaged over the equatorial belt (5°S-5°N), zonal wavenumber-frequency diagrams of SLA exhibit spectral peaks near the theoretical dispersion curves of the first baroclinic mode equatorial Kelvin and Rossby waves
- In the RGM, total energy is lower, however there is considerable energy in the mixed Rossby-gravity wave range

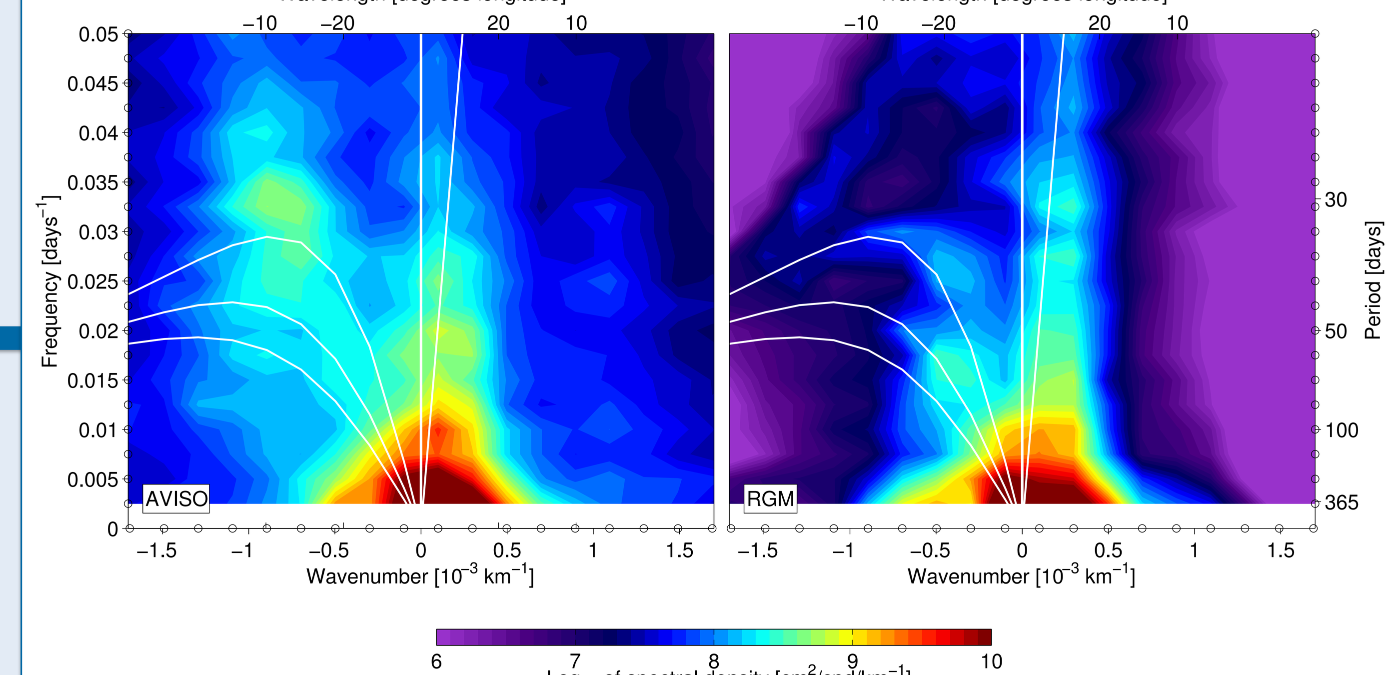

Fig. 7: Mean (5°S-5°N, see horiz. black lines in Fig. 2) wave-number-frequency diagram. *Left*: Aviso, *right*: RGM (modes 1-5). The white lines represent the theoretical dispersion curves of the Kelvin wave and the first three meridional Rossby waves.

5) Summary and outlook

- Intra-seasonal SLA variability in the tropical Atlantic is essentially wind-driven, as it can be reproduced by reduced gravity simulations, although with weaker amplitudes
- Possible reasons for discrepancies to be tested:
  - Bad choice / spatial variability of phase speeds, which leads to the missing of resonance to a periodic forcing
  - Uncaptured (i.e. non-linear) effects of the North Equatorial Counter Current (NECC) on westwards propagating Rossby waves at ~4°N (Fig. 8)

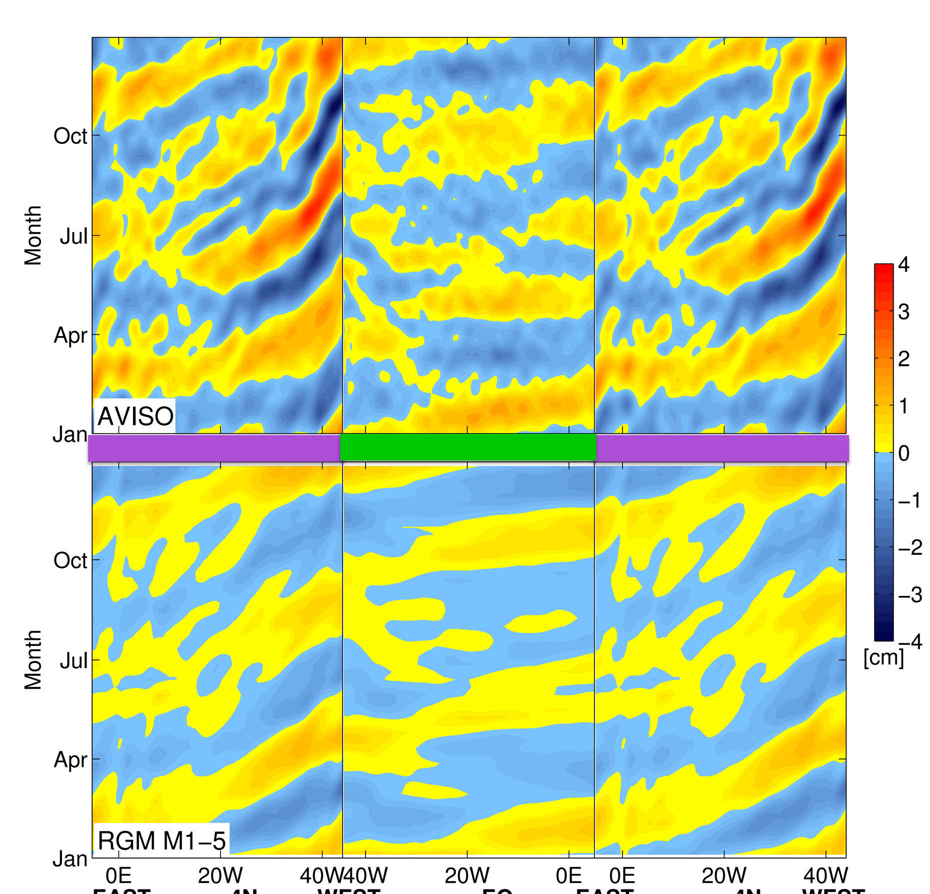

Fig. 8: Climatologic (1995-2014), band-passed (25-130d) SLA along 4°N-Equ.-4°N (see Fig. 2). *Top*: Aviso, *bottom*: RGM modes 1-5.

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References

[1] Cane MA, Moore DW (1981): A Note on Low-Frequency Equatorial Basin Modes. J Phys Oceanogr 11:1578-1584 doi:10.1175/1520-0485

[2] The altimeter products were produced by Ssalto/*Duacs* and distributed by *Aviso*, with support from *Cnes* (http://www.aviso.altimetry.fr/duacs/)

[3] Polo I, Lazar A, Rodriguez-Fonseca B, Arnault S (2008): Oceanic Kelvin waves and tropical Atlantic intraseasonal variability: 1. Kelvin wave characterization. J Geophys Res-Oceans 113:18 doi:10.1029/2007jc004495