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Drivers of the Atlantic Niño II – the role of warm water volume changes

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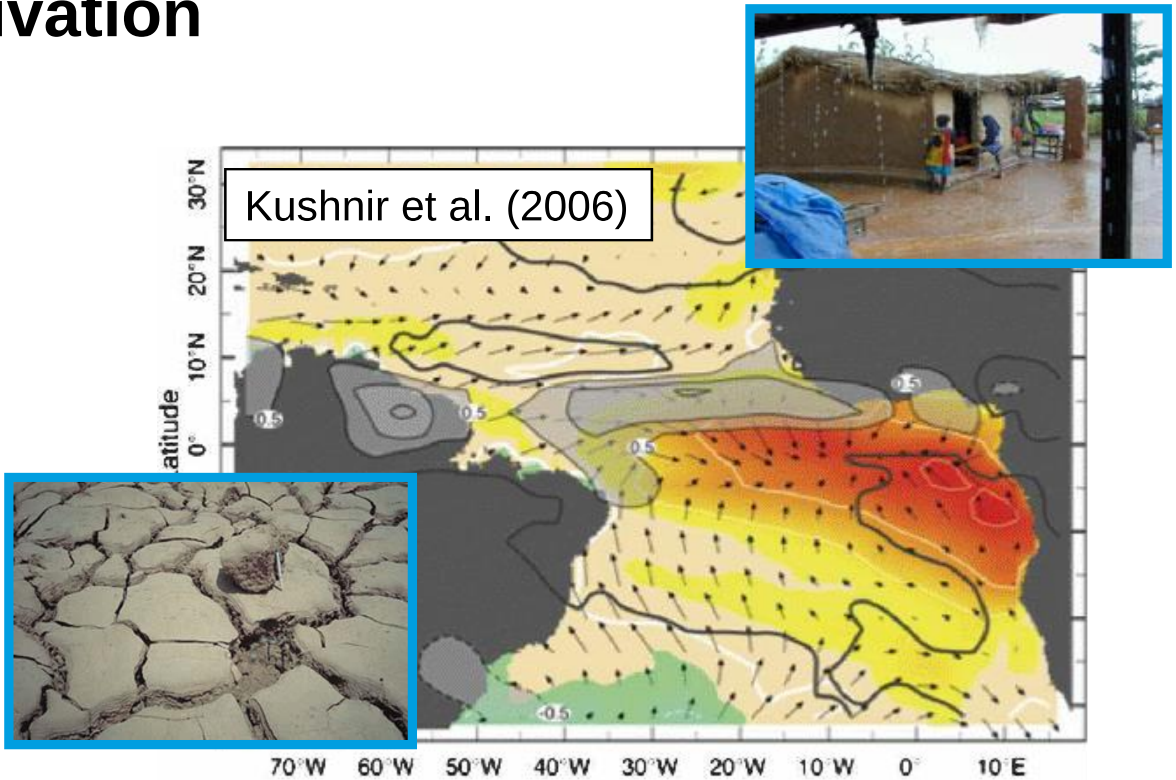
HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

GEOMAR

Tropical Atlantic SST variability

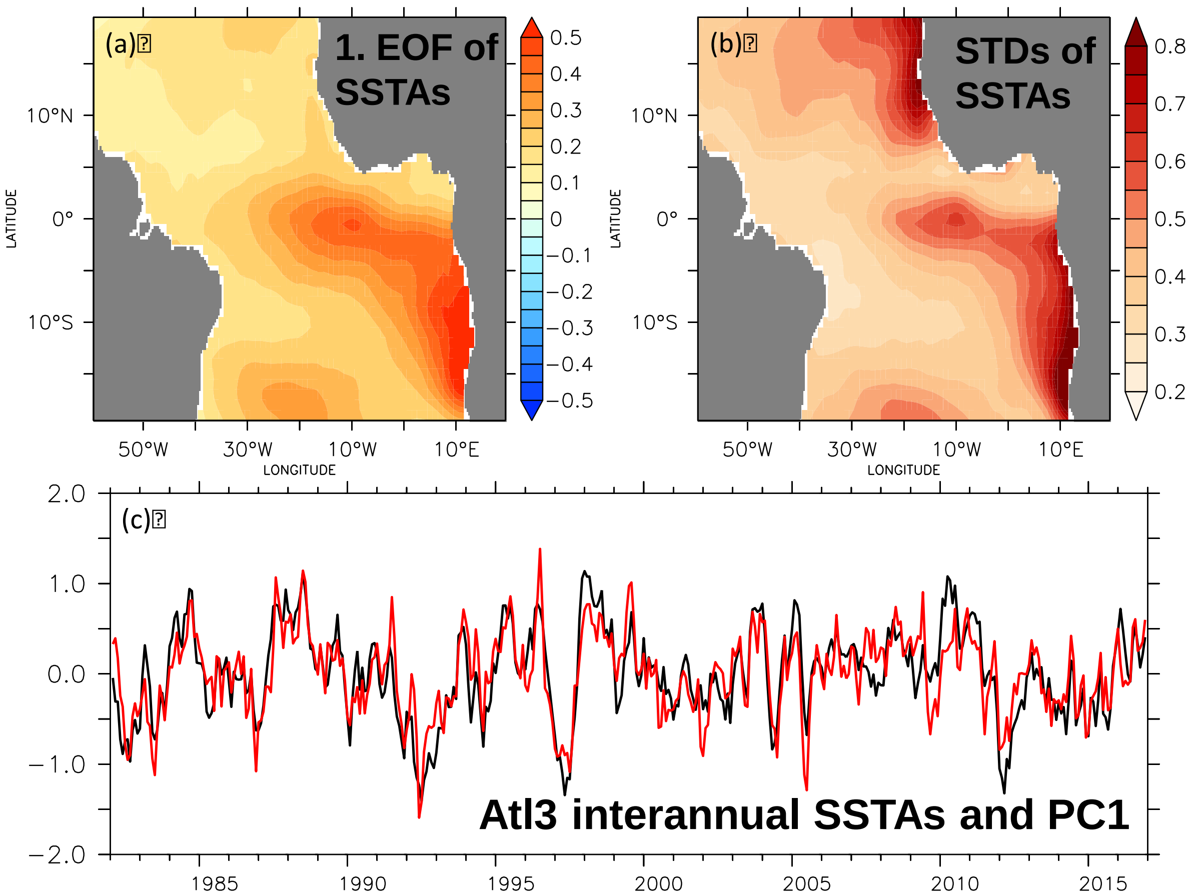
Motivation



1. EOF of the rainfall variability (grey) in JJA and SST and wind anomalies

Tropical Atlantic SST variability

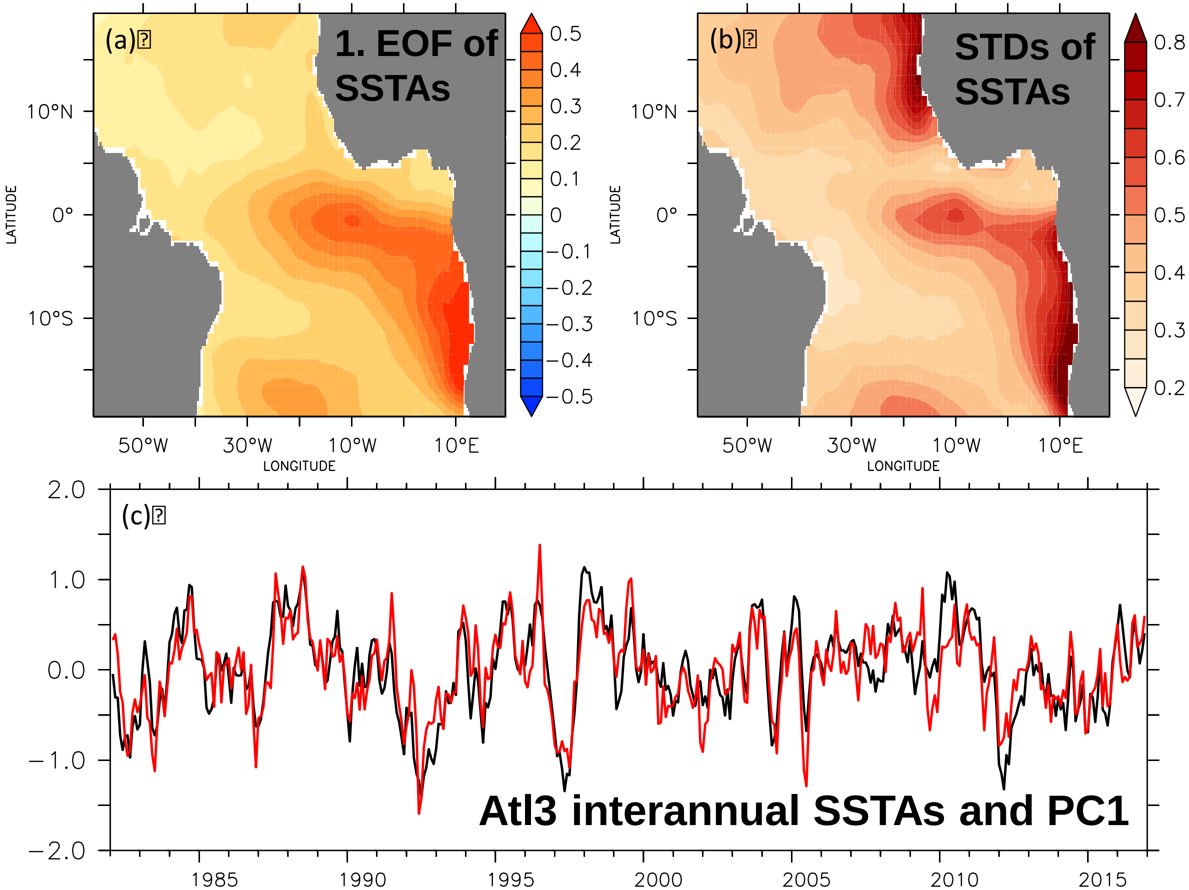
Atlantic Niño mode

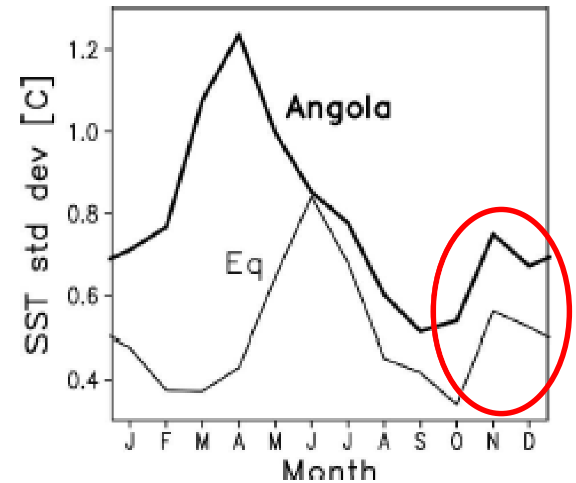


(Lübbecke et al., 2018)

Tropical Atlantic SST variability

Atlantic Niño mode - seasonality





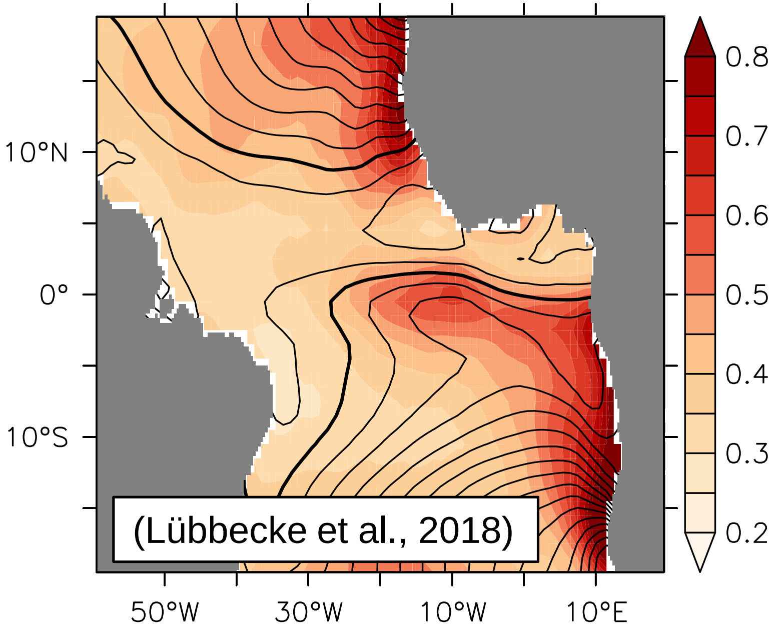
(Okumura & Xie, 2004)

- Main peak in summer
- Second maximum in Nov/Dec

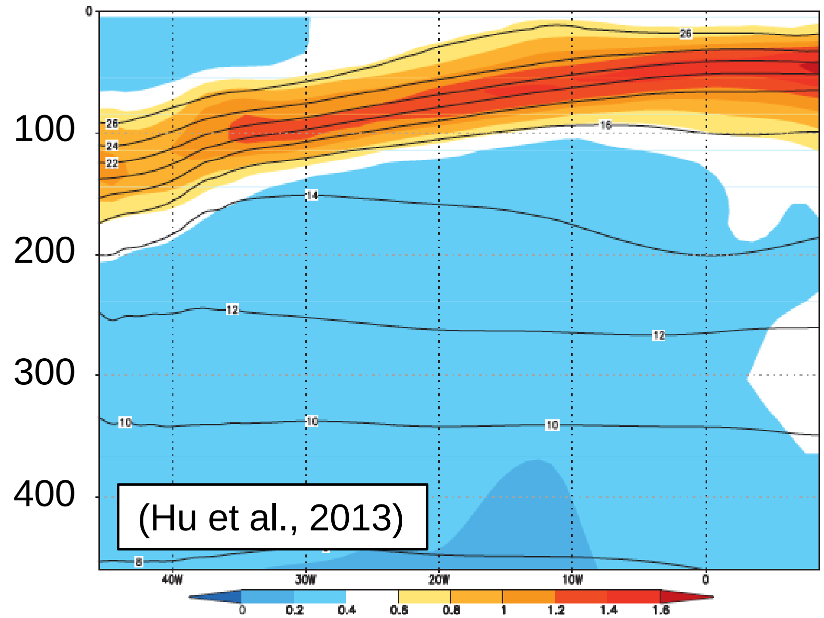
➢ "Atlantic Niño II"

Tropical Atlantic temperature variability

Temperature variance



Mean SST and STD of NOAA SSTA (1982 to 2016)



Mean Temp and STD of GODAS temp from 2ºS to 2ºN (1979 to 2011)

- ➢ Highest temperature variability along thermocline

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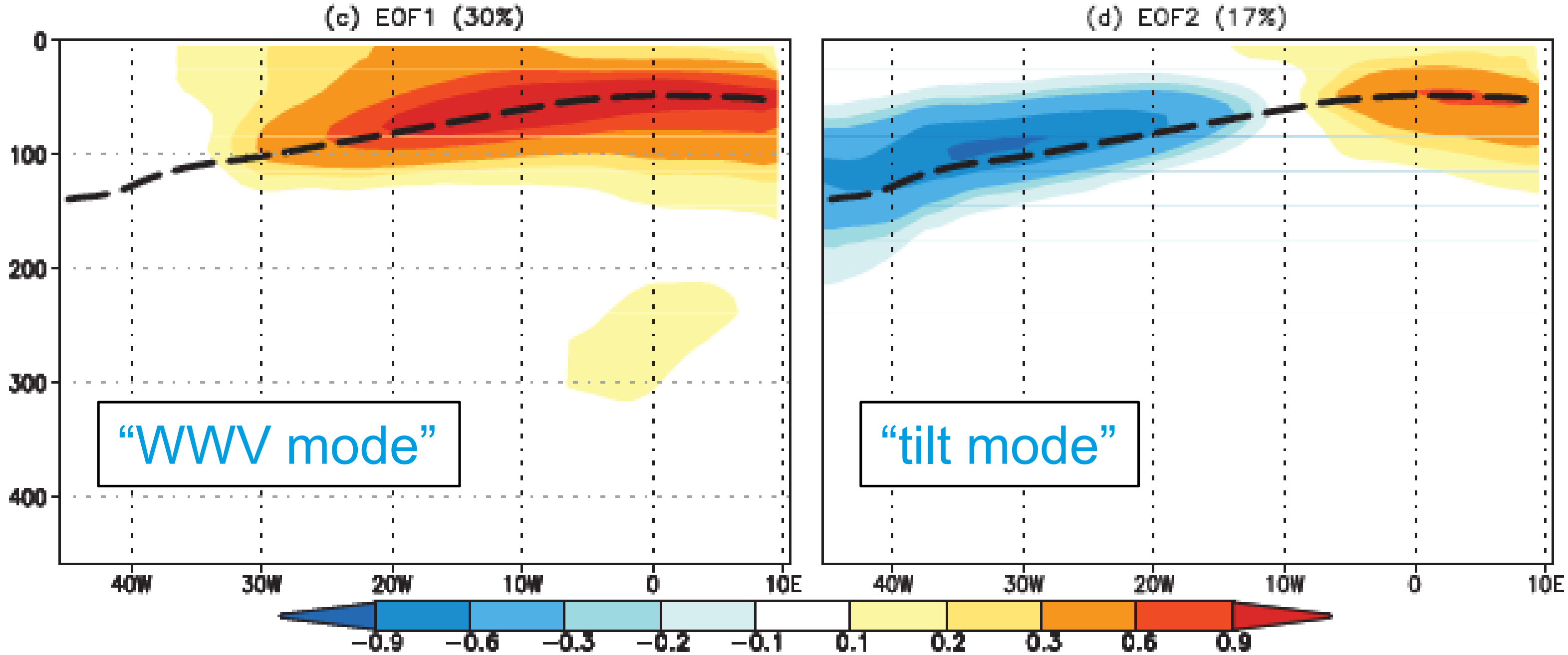
Tropical Atlantic temperature variability

Tilt and warm water volume (WWV) modes



(Hu et al., 2013)

represents changes in the

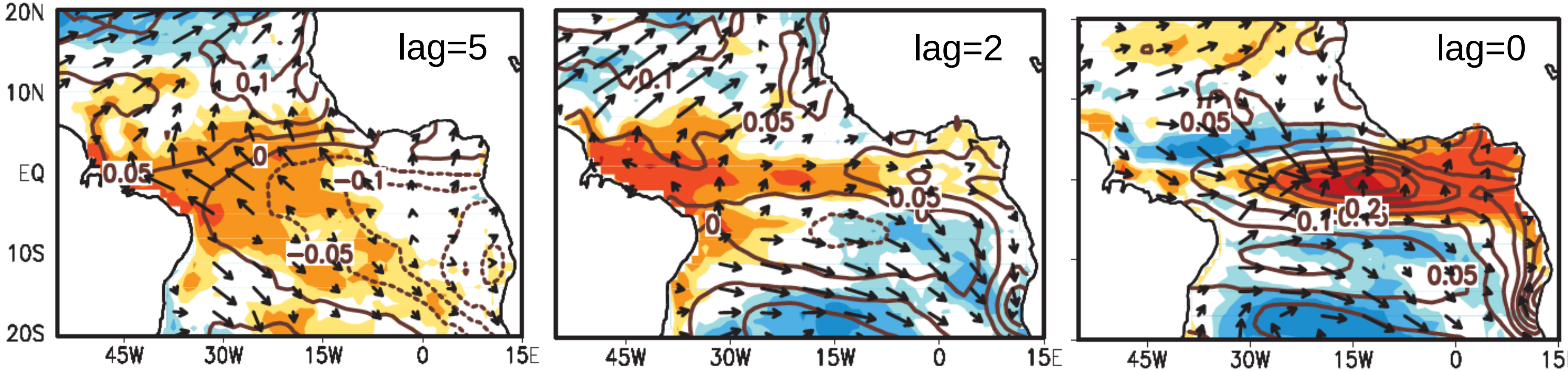
mean depth (zonally symmetric) east-west slope (zonally asymmetric)

of the equatorial thermocline

Tropical Atlantic temperature variability

WWV mode and Atlantic Niño

Relation between WWV mode and occurrence of Atlantic Niño events has been suggested by Ding et al., 2010 and Hu et al., 2013



Regression of z20, SST, and wind stress anomalies onto PC1, leading PC1 by 5, 2, and 0 months

(Hu et al., 2013)

- Heat accumulation in the northwestern tropical Atlantic
- ➢ Propagates eastward along Equator

WWV mode and Atlantic Niño

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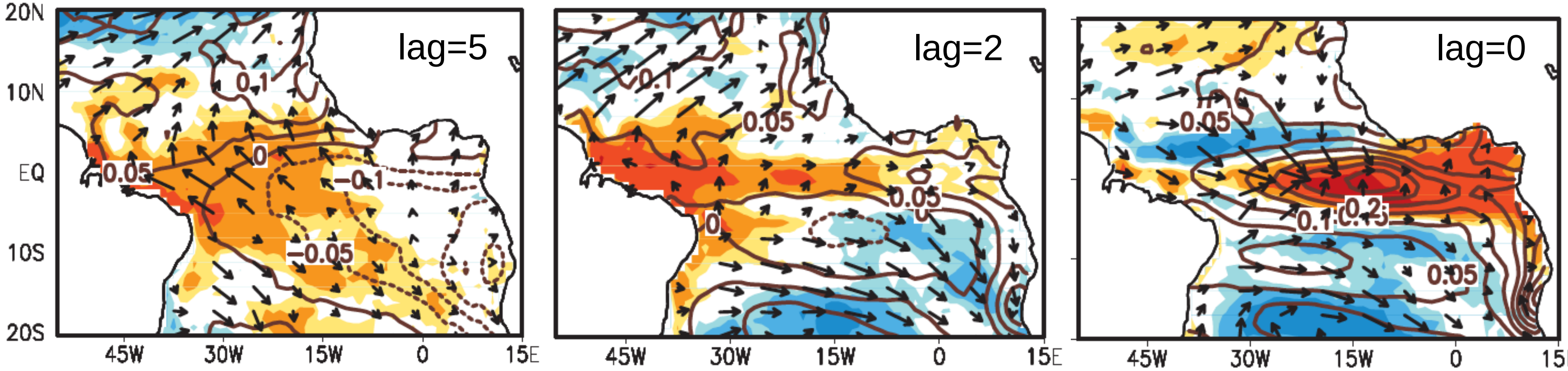


Regression of z20, SST, and wind stress anomalies onto PC1, leading PC1 by 5, 2, and 0 months

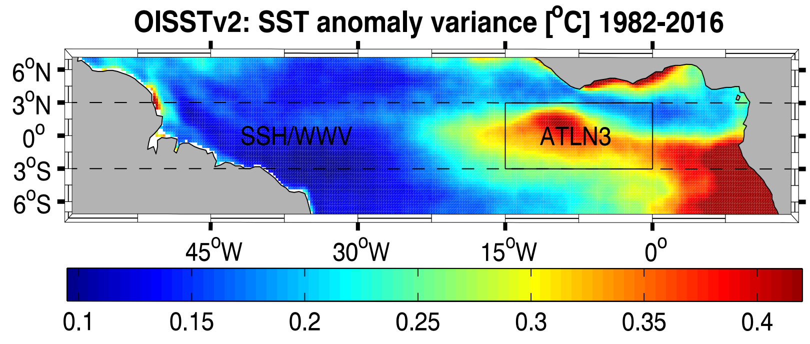
(Hu et al., 2013)

Seasonality of relationship?

Data Sets

Observational Data Sets

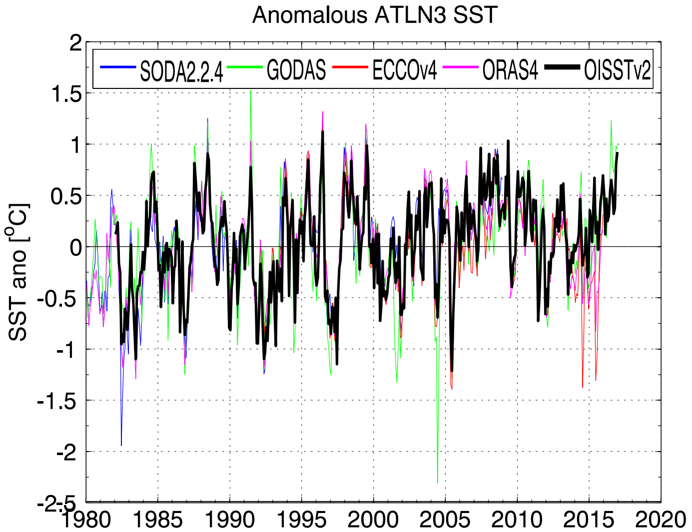
- SST
  - NOAA OI SST (1982 to 2016)
  - HadISST (1980 to 2016)
- SSH (as proxy for thermocline depth)
  - AVISO (1993 to 2015)



Reanalysis Products

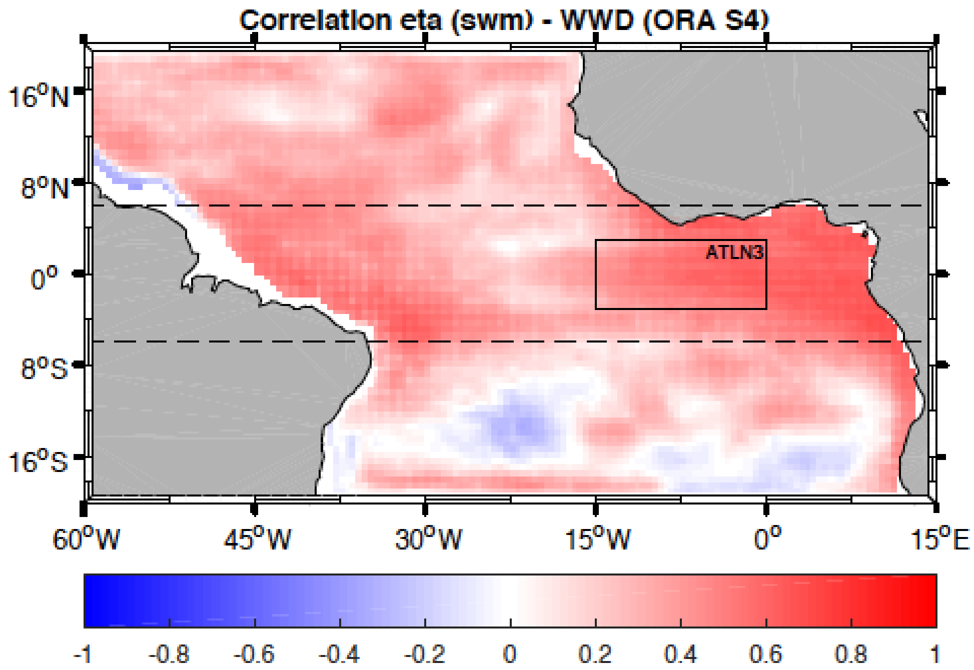
Monthly temperature and SSH output from

- NCEP GODAS (1980 to 2016)
- ECMWF ORA-S4 (1980 to 2015)
- SODA 2.2.4 (1980 to 2008)
- ECCOv4 (1992 to 2015)



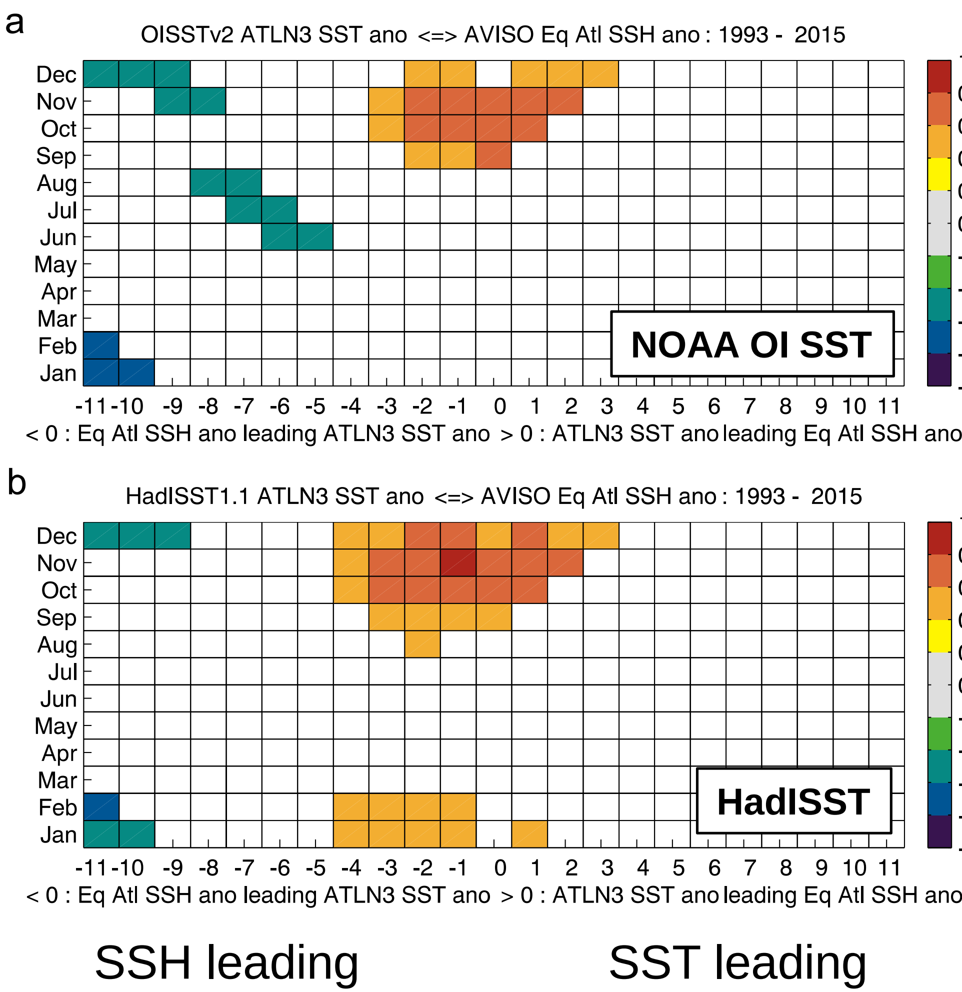
Shallow Water Model

- linear SWM to examine purely wind-driven component of SST and WWV
- reduced gravity and depth of interface at rest are set such that the gravity wave speed is 1.5 ms^{-1} (2nd baroclinic mode in the tropical Atlantic)
- forced with monthly wind stress from ERA Interim for the period 1979-2011
- Interface displacement anomalies as proxy for the thermocline displacement or warm water depth (WWD)



Correspondence between ORA-S4 WWV and WWD anomalies from the SWM for 1984 to 2011

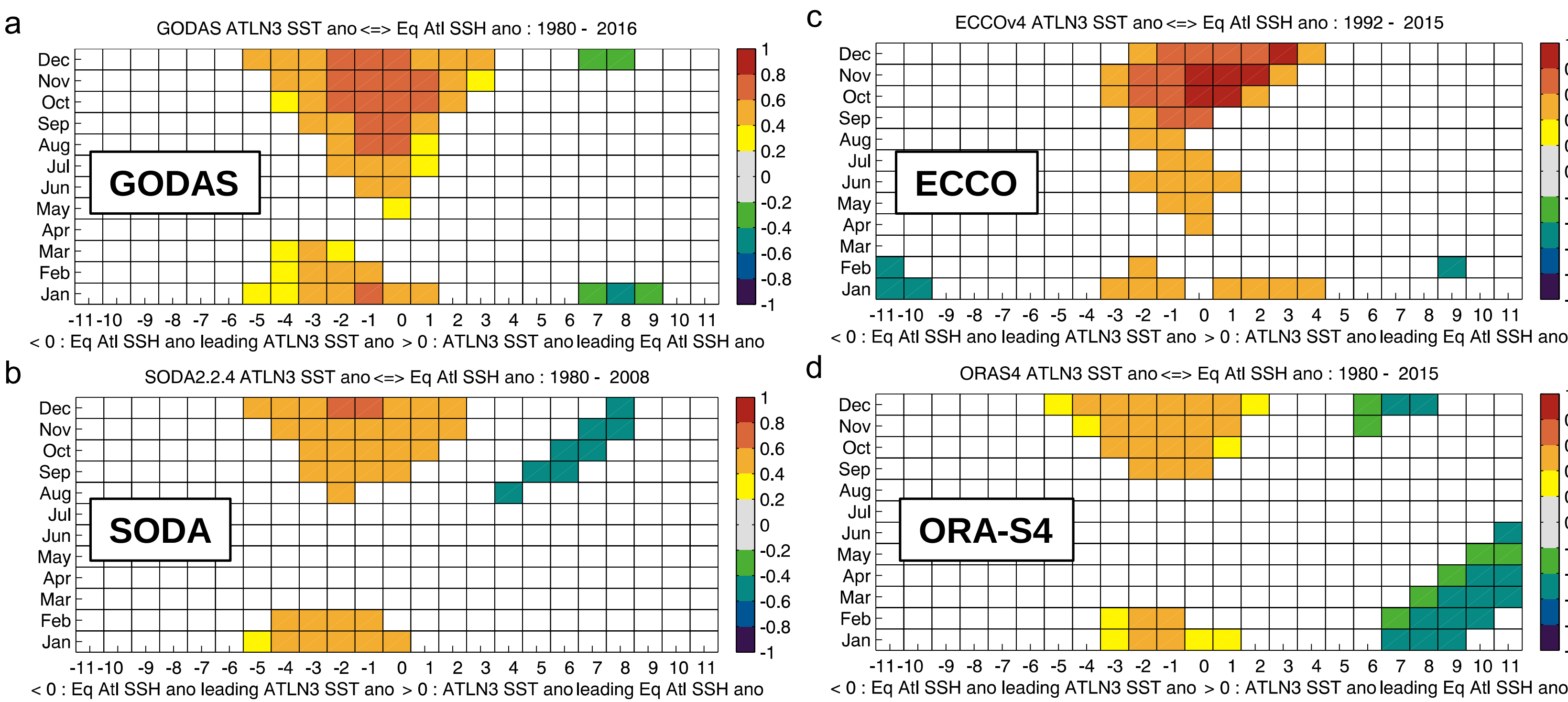
Relationship between heat content and SST anomalies



- No significant correlation in boreal summer, when Atlantic Niño mode peaks
- Highest correlation for September to December EEA SSTA with equatorial SSH leading by a couple of months

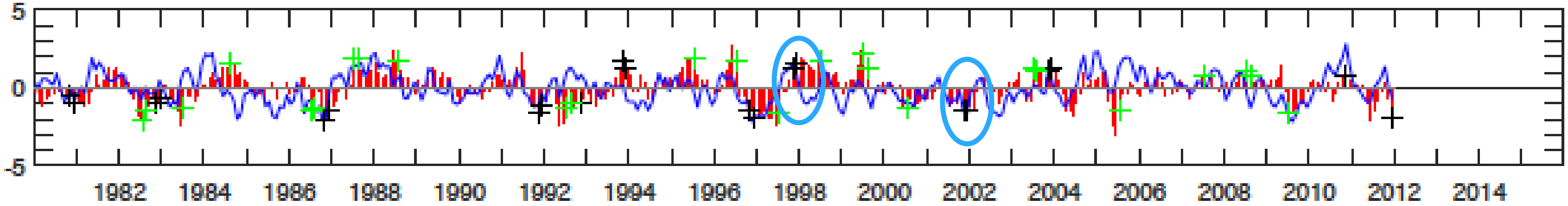
➢ influence of equatorial HC anomalies mainly on the development of EEA SST anomalies in boreal fall/winter, i.e. the Atlantic Niño II

Relationship between heat content and SST anomalies



Reanalysis products agree that strongest relation between EEA SST and equatorial SSH occurs during boreal fall and winter months,
Very similar results when WWV is used instead of SSH

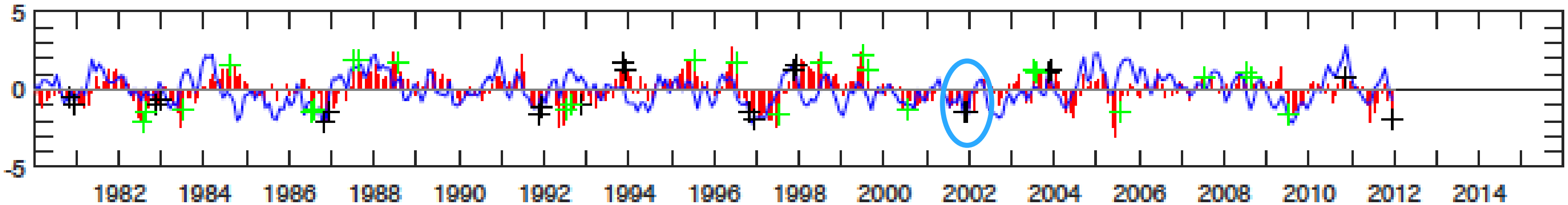
Atlantic Niño II events



Equatorial WWV and EEA SST an. from ORA-S4, with + Atlantic Niños, + Atlantic Niños II

- ➢ Look at 2001 cold and 1997 warm winter event (Atlantic Niño II)

Atlantic Niño II events



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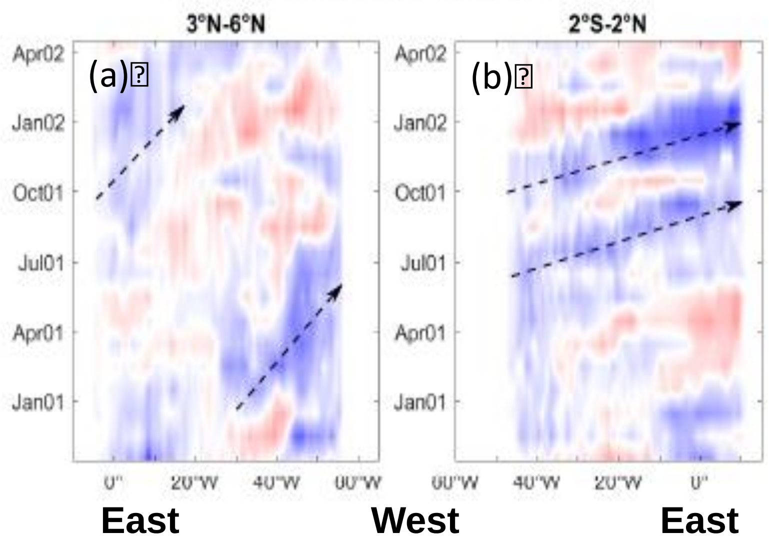
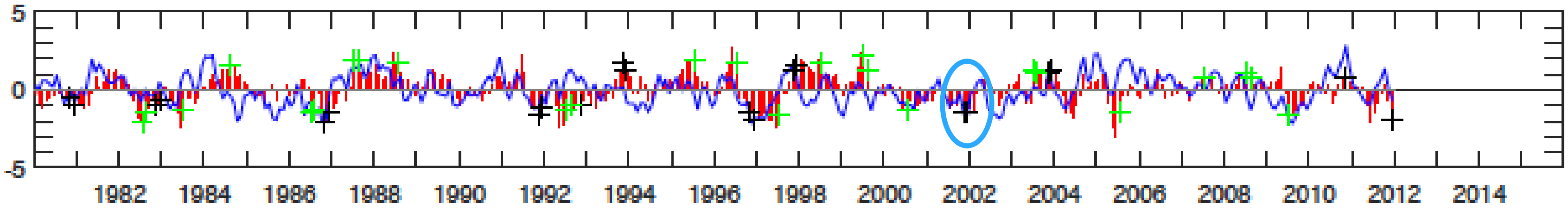
2001 cold event



ORA-S4 WWV an. [10^{11} m^3]

- Low WWV (thermocline shoaling) along the Equator in late summer, reinforced in fall/winter
- Connection to northwestern tropical Atlantic

Atlantic Niño II events



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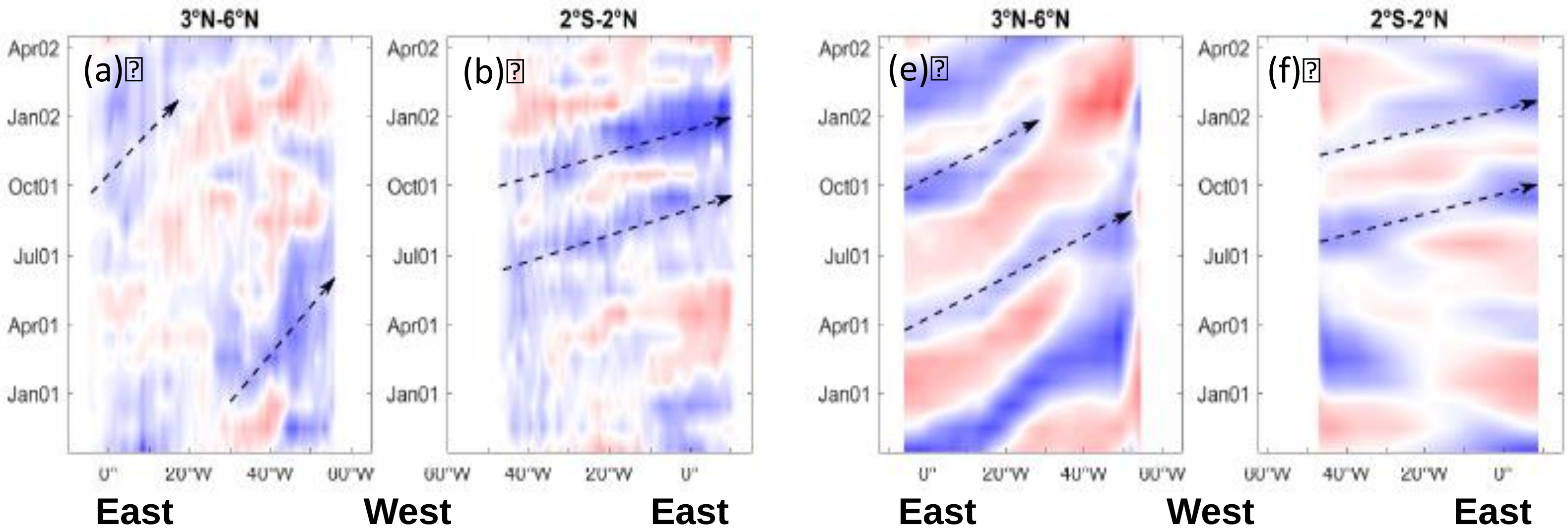
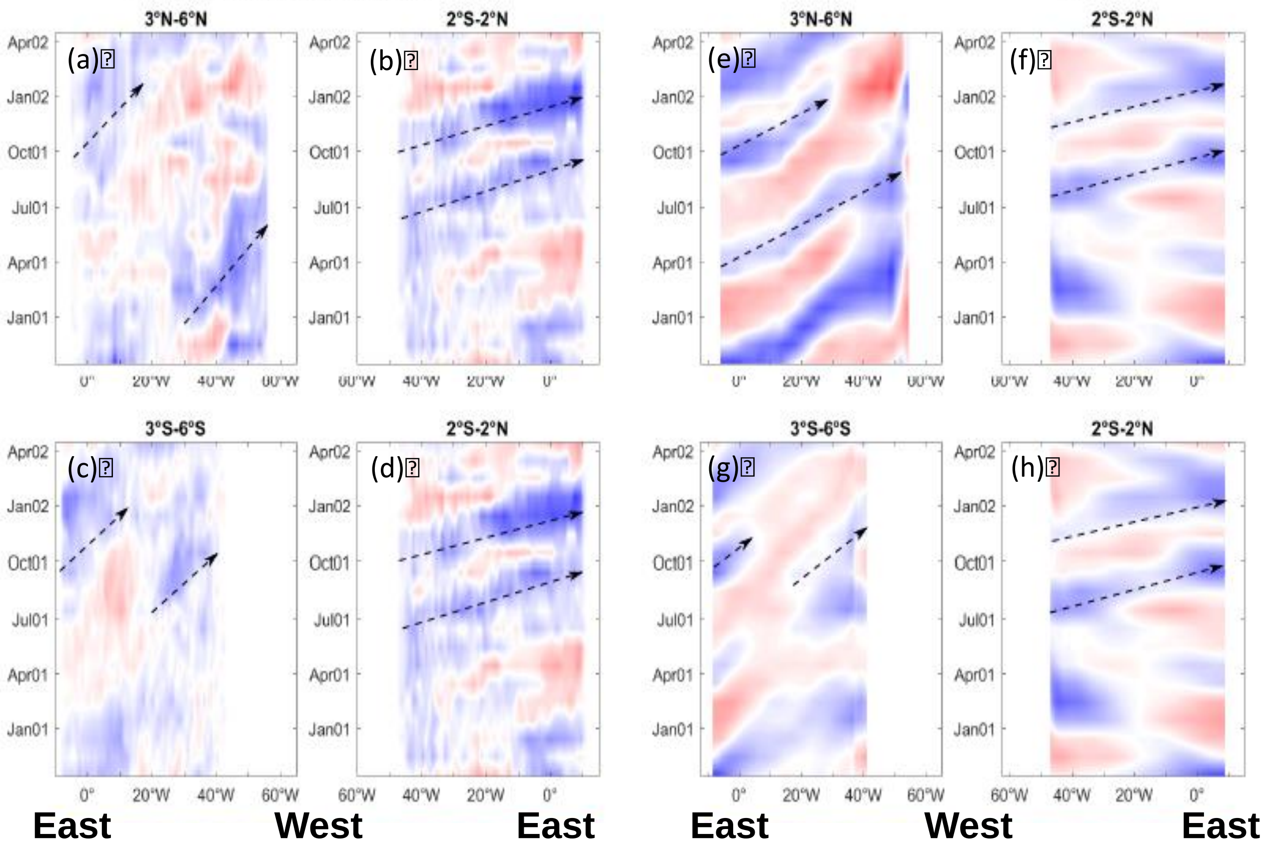


ORA-S4 WWV an. [10^{11} m^3]

SWM WWD an. [m]

Atlantic Niño II events

2001 cold event



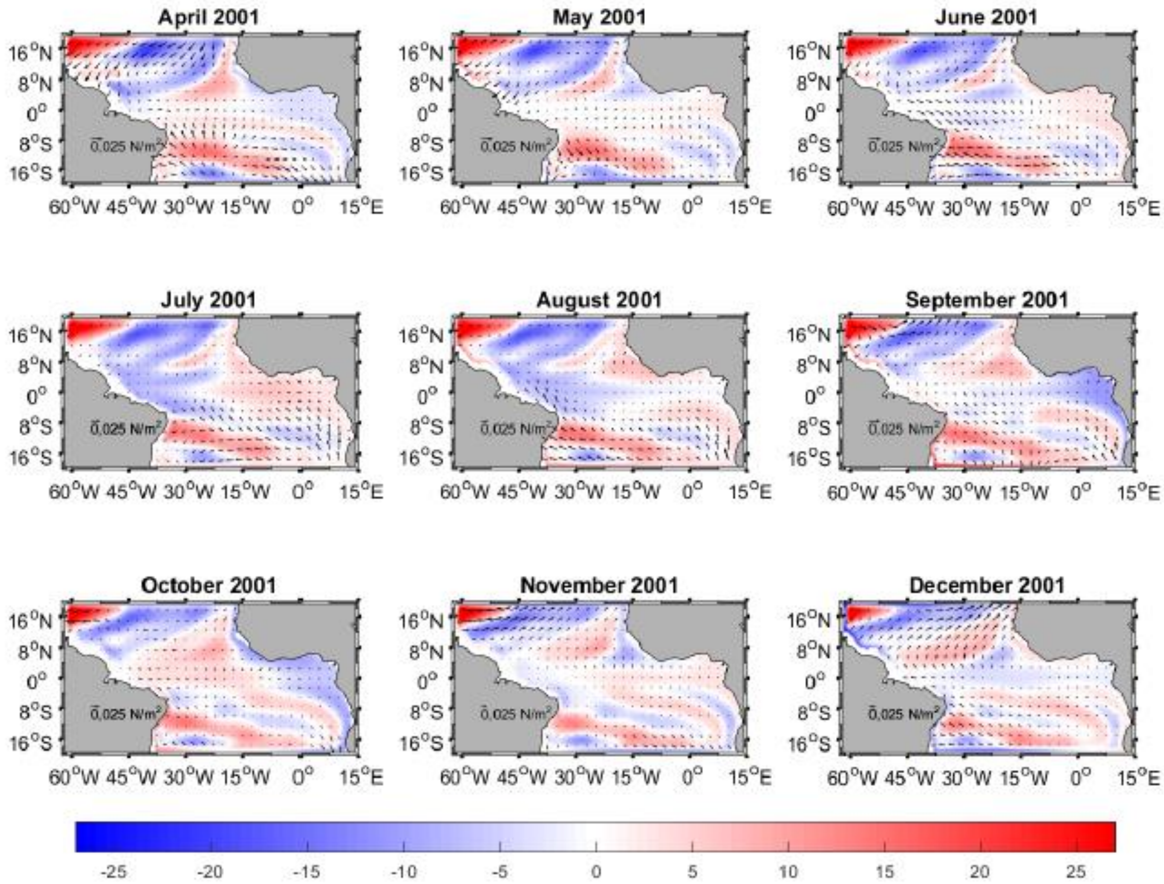
ORA-S4 WWV an. [10^{11} m^3]

SWM WWD an. [m]

- Also some indication of connection to the south
- Well reproduced by SWM

Atlantic Niño II events

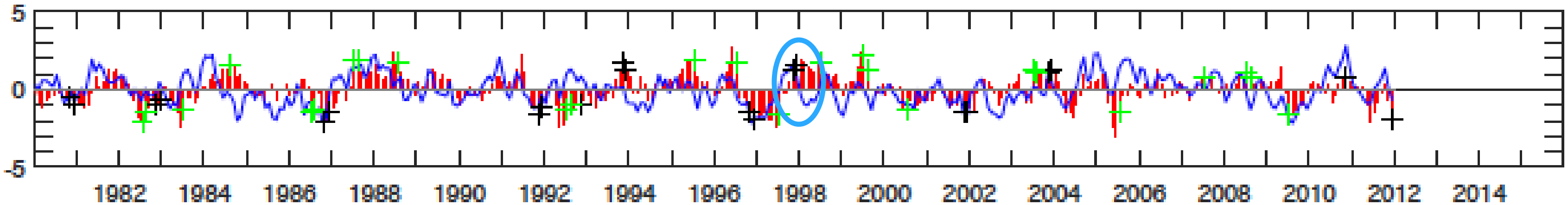
2001 cold event



- Anomalous Ekman suction leads to a shoaling of the thermocline in the NTA in boreal spring
- Signal spreads westward, then equatorward

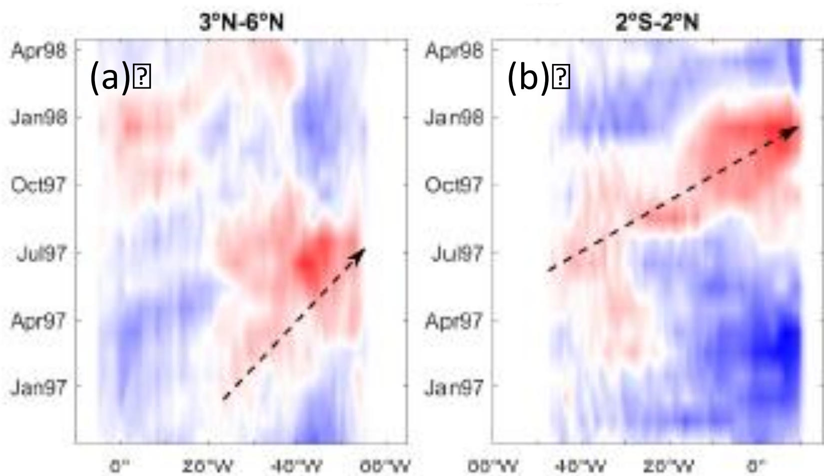
WWD [m] and wind stress anomalies [Nm^{-2}] from SWM

Atlantic Niño II events



Equatorial WWV and EEA SST an. from ORA-S4, with + Atlantic Niños, + Atlantic Niños II

1997 warm event



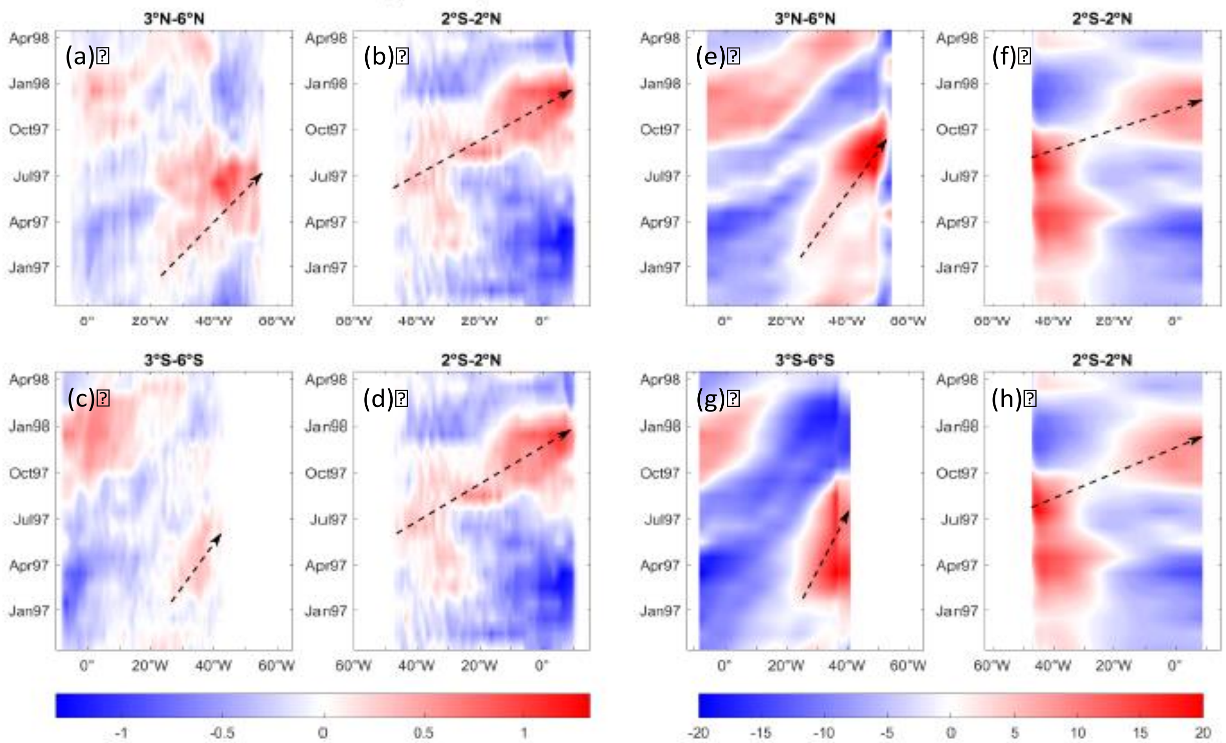
East **West** **East**

ORA-S4 WWV an. [10^{11} m^3]

- High WWV (thermocline deepening) along the Equator from late summer, intensifying in fall/winter
- Connection to northwestern tropical Atlantic

Atlantic Niño II events

1997 warm event



East **West** **East** **East** **West** **East**

ORA-S4 WWV an. [10^{11} m^3]

SWM WWD an. [m]

- strong build-up of heat in the western basin, both north and south of the equator, in spring and summer
- Signal propagates towards EEA in late boreal summer and intensifies there until fall/winter
- SWM is able to reproduce evolution

Conclusions

- “Tilt" and "WWV" modes to describe equatorial Atlantic upper ocean temperature variability (Bunge and Clarke, 2009; Hu et al., 2013)
- WWV mode plays more important role for development of Atlantic Niño II events in boreal winter
- Both Atlantic Niño II cold and warm event connected to off-equatorial HC anomalies that propagate to western boundary and along Equator
- Origin of the HC anomalies in off-equatorial northwestern Atlantic in agreement with Hu et al., (2013) who attributed this to anomalous wind stress curl associated with the Atlantic meridional mode