Role of equatorial forcing in SST bias development in the South-Eastern Tropical Atlantic in a high resolution version of CNRM-CM CGCM

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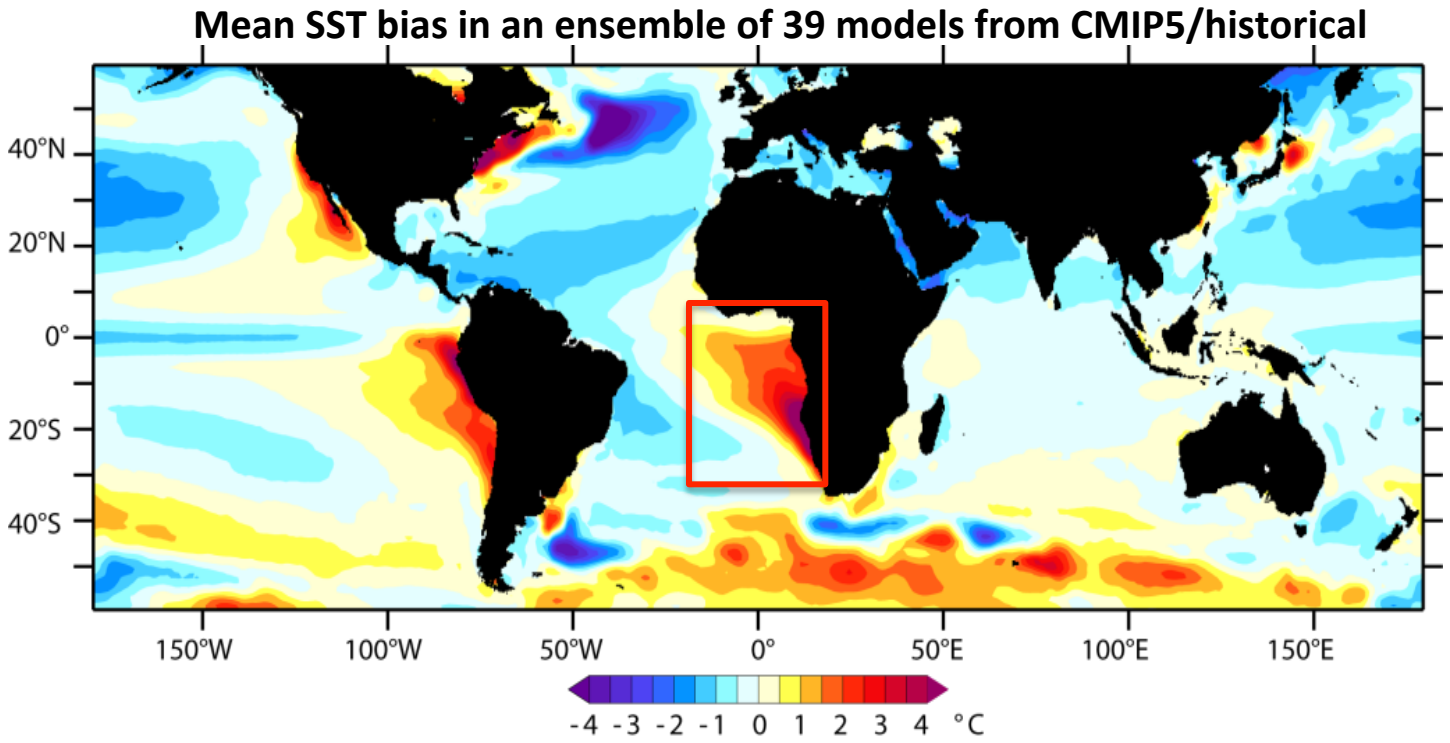
Context and motivation

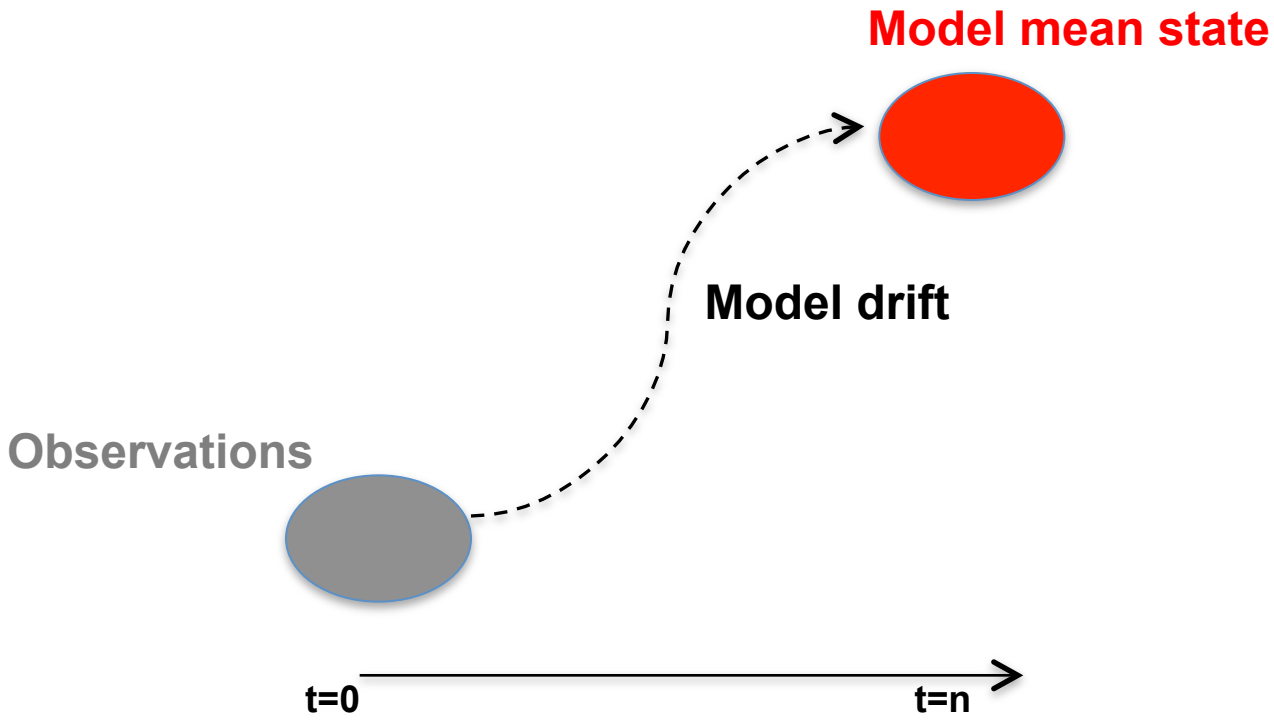


Progress and challenges:

- Systematic warm SST bias in S-E Tropical Atlantic (SETA)
- Quick bias development (weeks to months) (*full-field initialized seasonal hindcasts)*
- Different processes involved in SST errors: local/remote, atmosphere/ocean
- Model-dependent

Methodology:

analysis of model drift in seasonal hindcasts to study bias development



Objectives, models and experimental design

Goals:

1)What is the role of remote forcing from the Equator (westerly wind bias) in developing the warm SST error in the SETA ?

2)Is there an added value of higher resolution for simulating the SETA?

Model:

- **High and Low resolution version of CNRM-CM model**

HR: **ARPEGE (~50km)** (T359L31) and **NEMO ~0.25^0** (ORCA025, 75VL)

LR: **ARPEGE (~140km)** (T127L31) and **NEMO ~1^0** (ORCA1, 42VL)

Experiments:

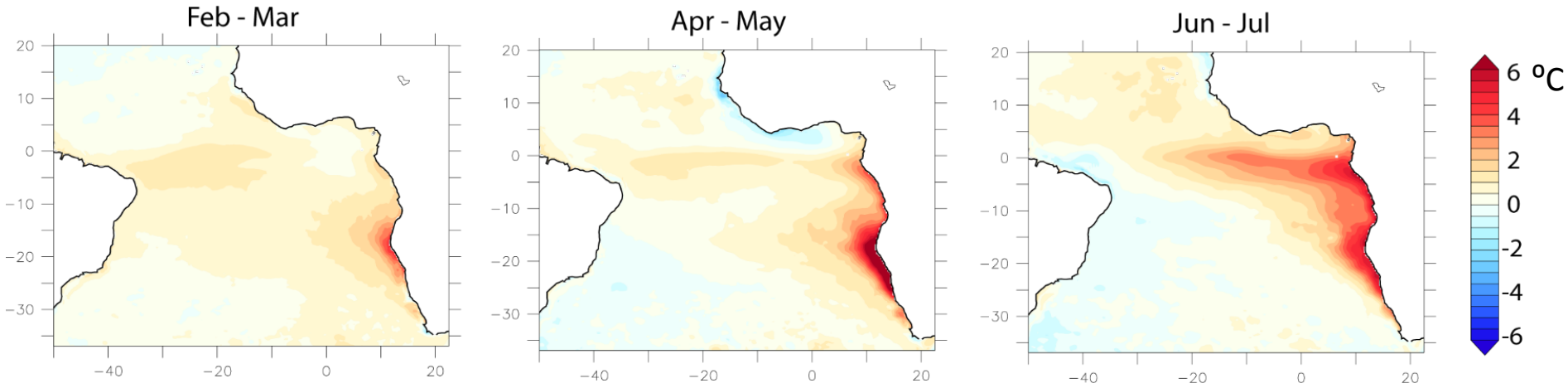
- **CTRL-HR / CTRL-LR: full field initialized seasonal hindcasts**
  - Initialization from ERAI and GLORYS2v3
  - Start date: 1 February
  - 10 years: 2000-2009
  - Three-members, 6 months lead time

- **TAUEQ (HR):** wind stress from ERAI is replaced over the Equatorial Atlantic (5^oS – 5^oN)

1. CTRL-HR biases and their improvement in TAUEQ

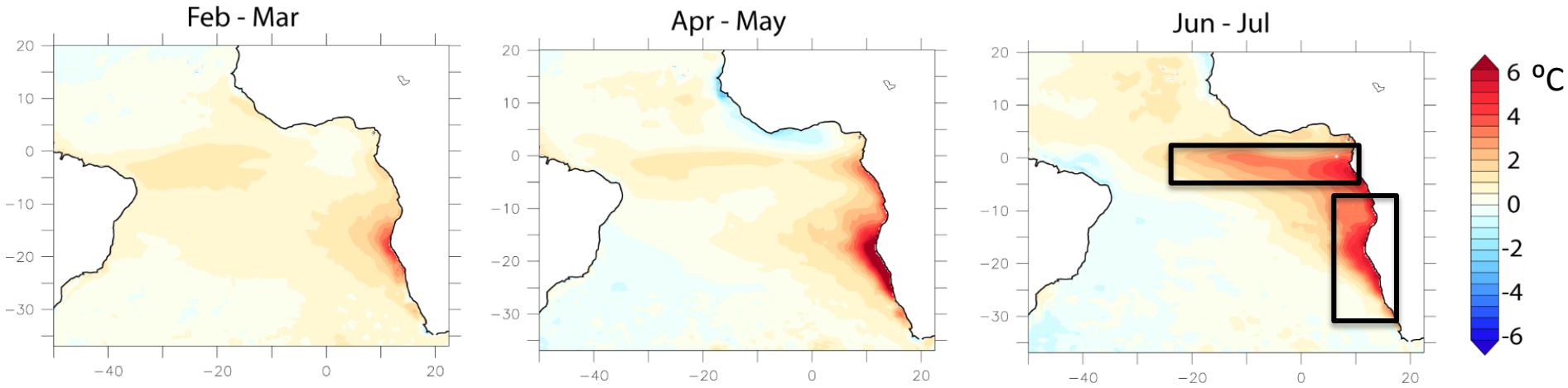
-- > CTRL-HR versus TAUEQ

SST bias evolution in CTRL-HR



2-months averaged evolution of the SST bias with respect to GLORYS2v3

SST bias evolution in CTRL-HR

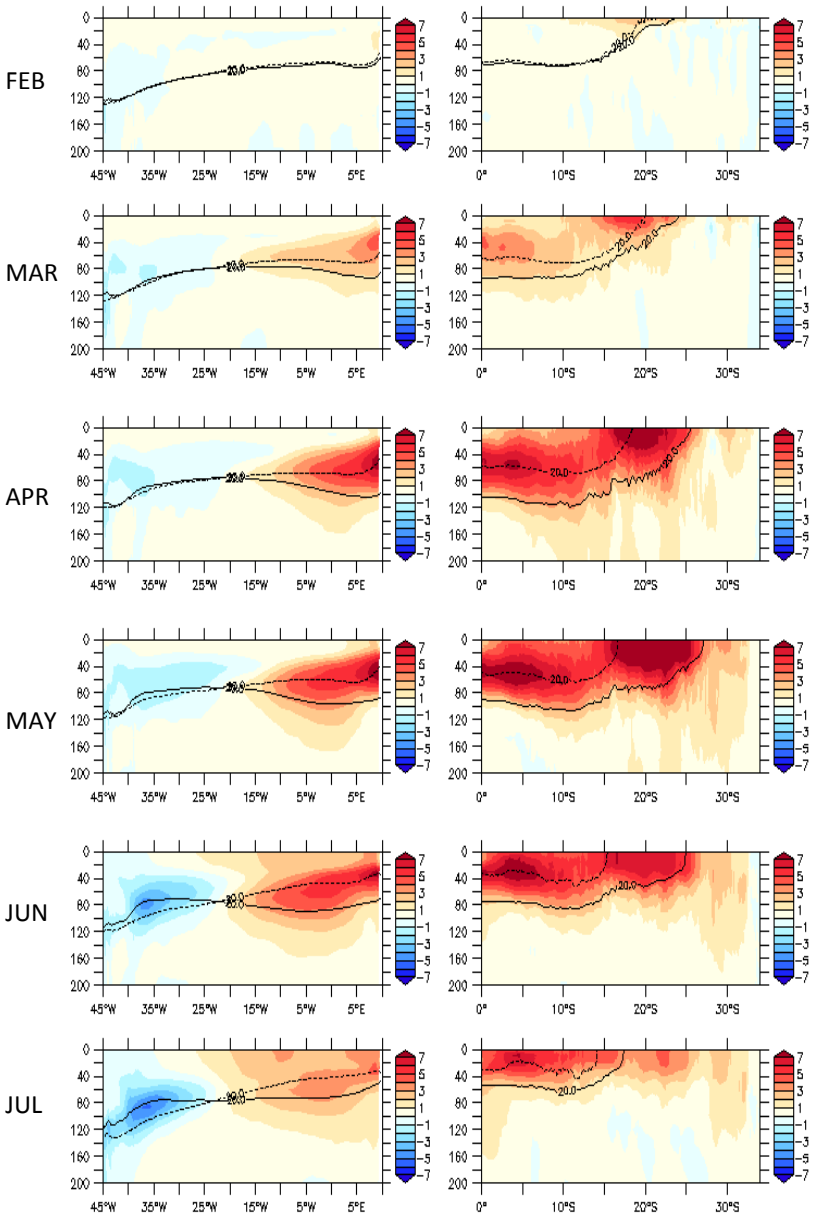


2-months averaged evolution of the SST bias with respect to GLORYS2v3

Evolution of the error in subsurface temperature in respect to GLORYS2V3

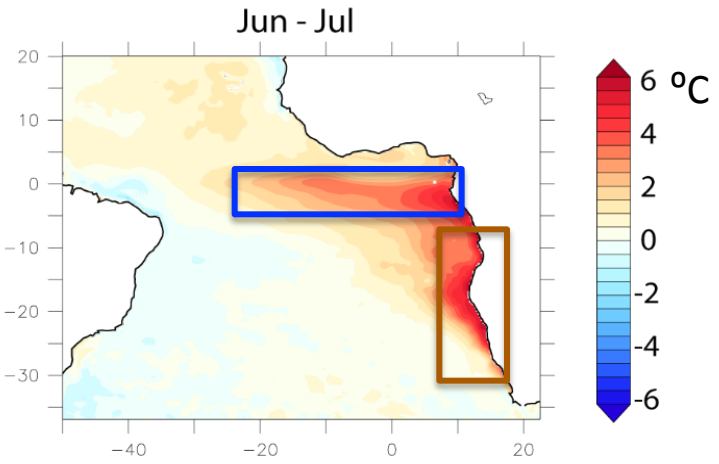
CTRL-HR

T along the equator (2°S-2°N) | T along the coast (2°)



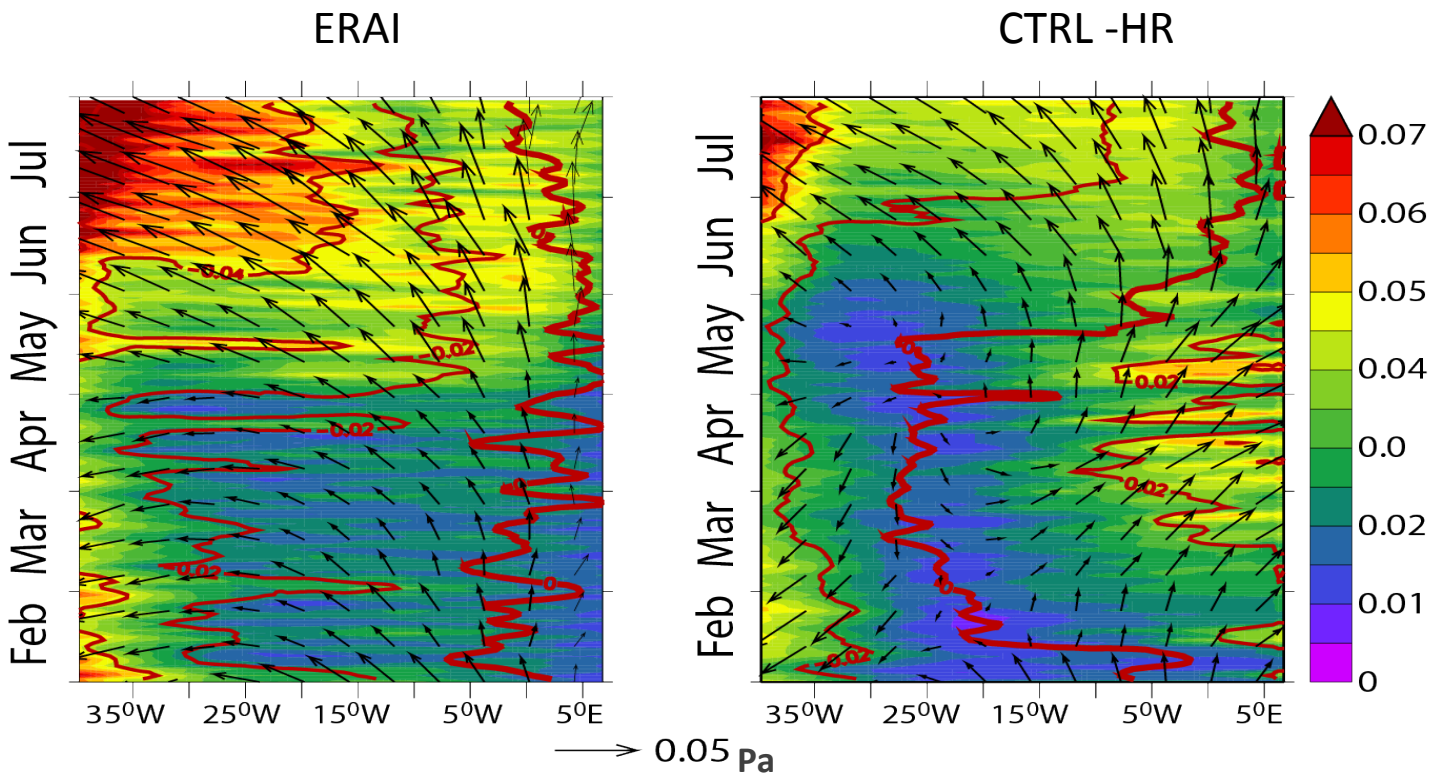
Isotherme 20°C in the model

Isotherme 20°C in GLORYS2v3



Westerly wind bias in CTRL-HR

Mean evolution of the equatorial wind stress (2°S- 2°N)



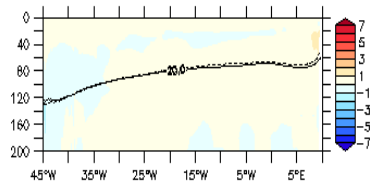
Shading : wind stress amplitude
Vector: wind stress vector
Contour: zonal wind stress

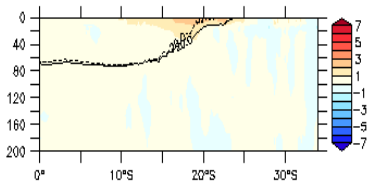
Evolution of the error in subsurface temperature in respect to GLORYS2V3

CTRL-HR

T along the equator (2°S-2°N) | T along the coast (2°)

FEB





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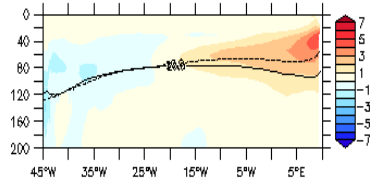

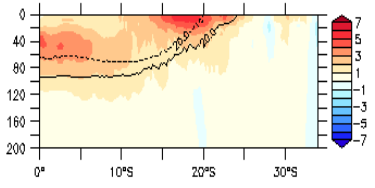

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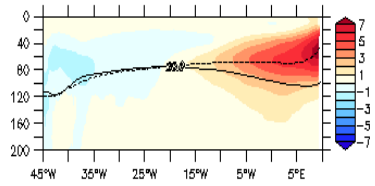

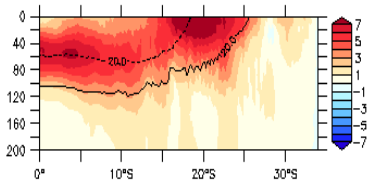

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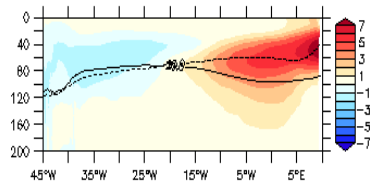

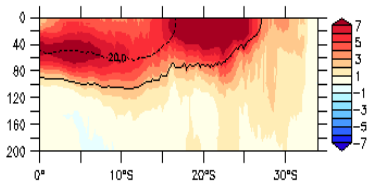

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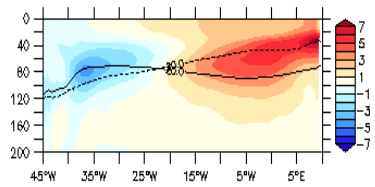

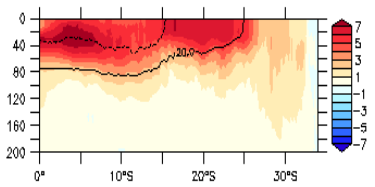

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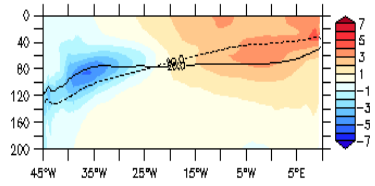
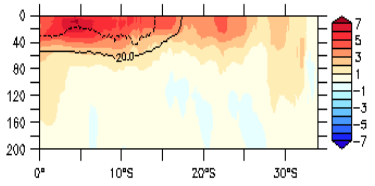
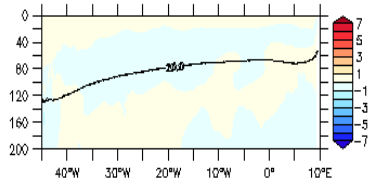


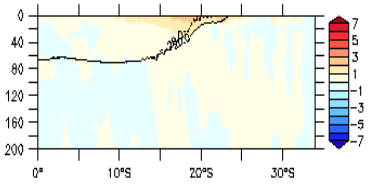


TAUEQ

T along the equator (2°S-2°N) | T along the coast (2°)

FEB





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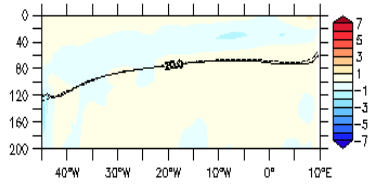

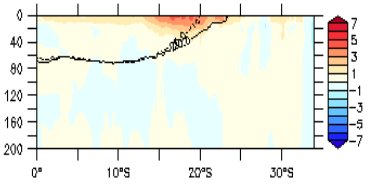

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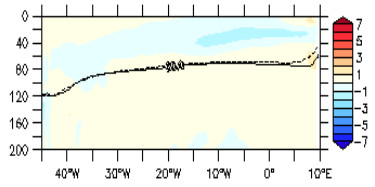

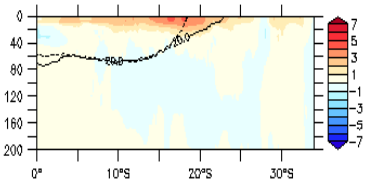

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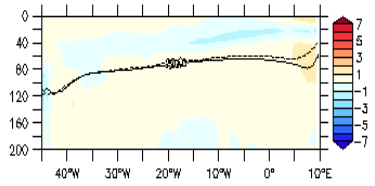

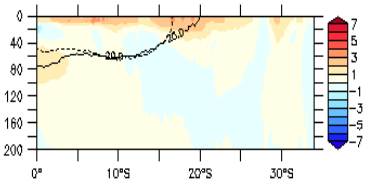

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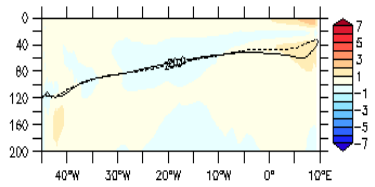

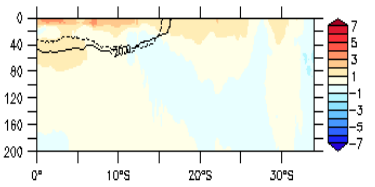

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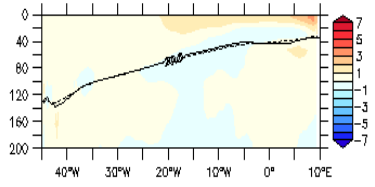
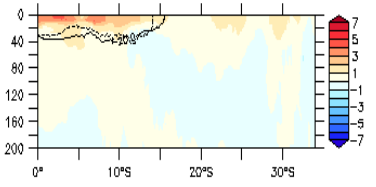
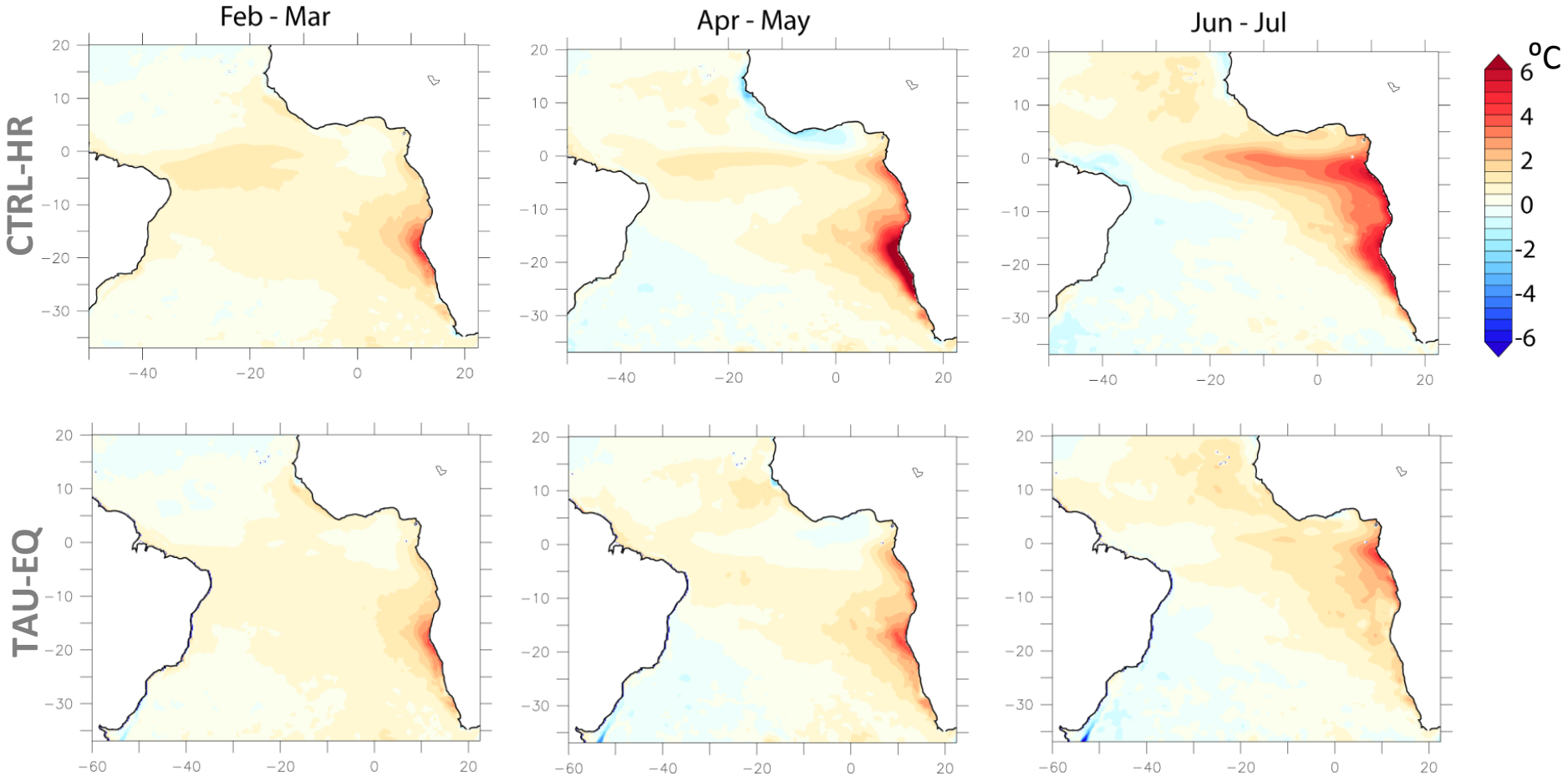




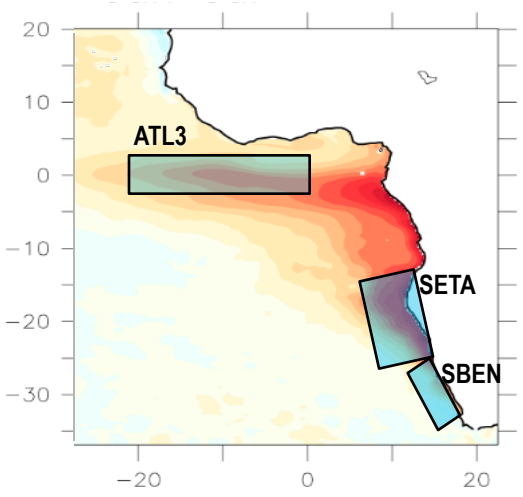
SST bias in respect to GLORYS2V3



2-months averaged evolution of the SST bias with respect to GLORYS2v3

- **Further analysis** on processes involved to the bias development in CTRL-HR, TAUEQ and CTRL-LR
- **Impact of model resolution**

Analysis strategy

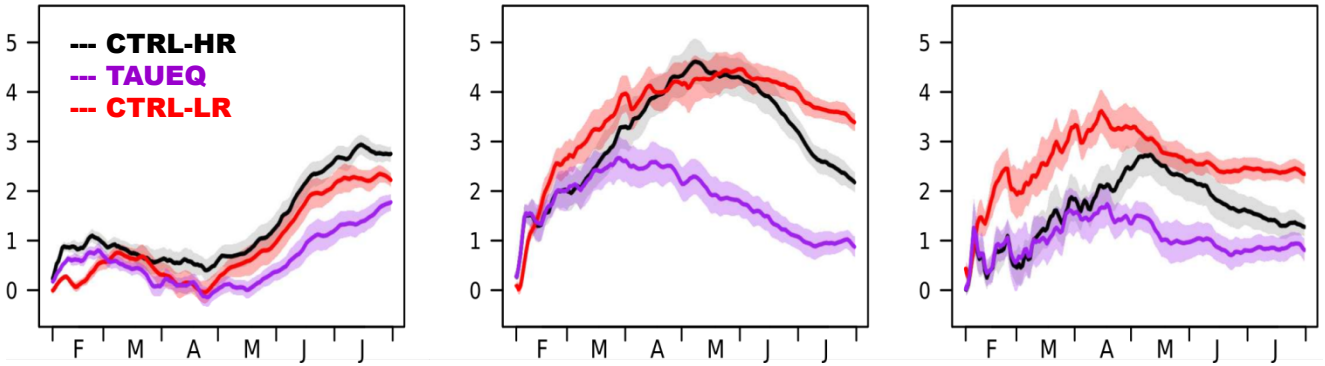


SST bias daily evolution over 3 considered regions (°C):

ATL3
3°S-3°N,
20W°-0°

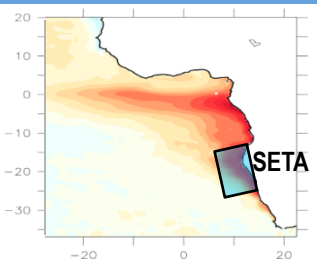
SETA
25°S-15°S
4° off the coast

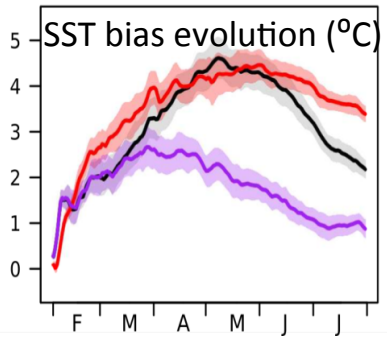
SBEN
34°S-25°S
2° off the coast



TAUEQ: improvement in the costal regions by ~50% (from mid-March) and in ATL3 by ~30%
LR: significantly stronger bias in SBEN and in SETA in June-July

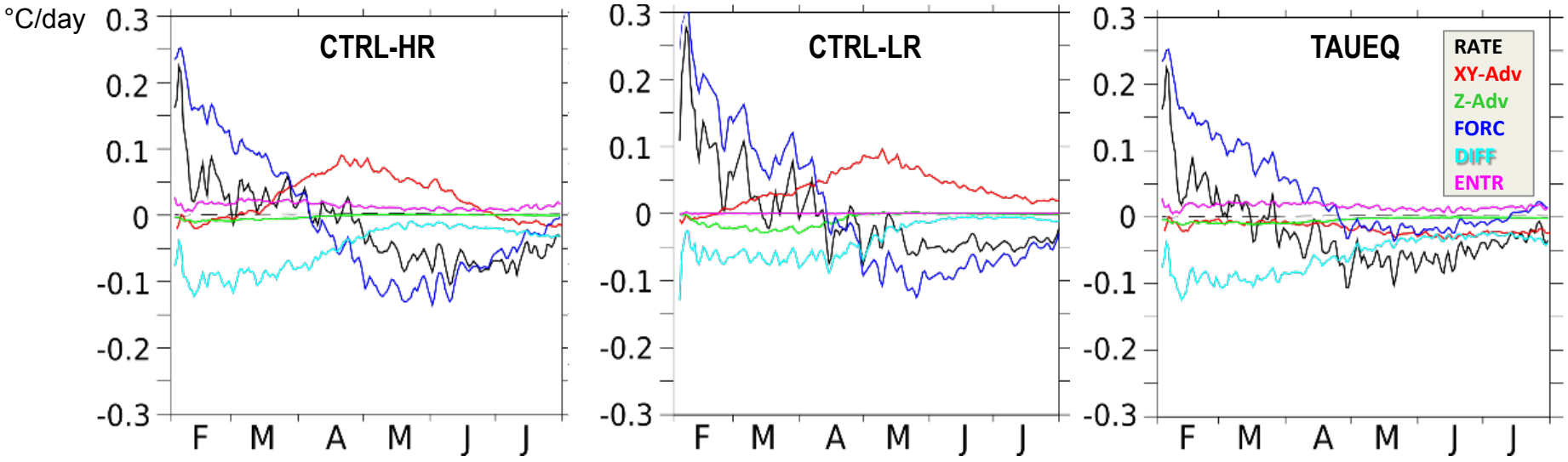
SETA region





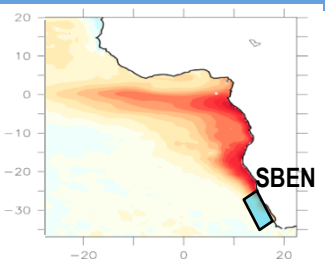
❑ Mixed-layer temperature tendency terms

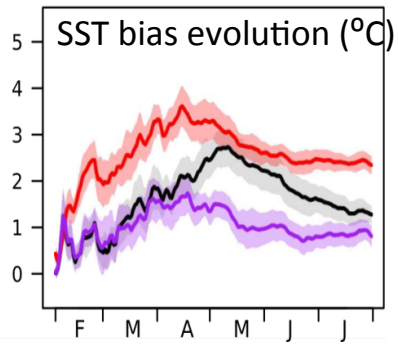
TemperRATE = XY_Adv + Z_Adv + Atm.FORC + Vert.DIFF + ENTR + Res



LR: in general similar processes involved, in particular warm horizontal advection
TAUEQ: warm horizontal advection disappears

SBEN region

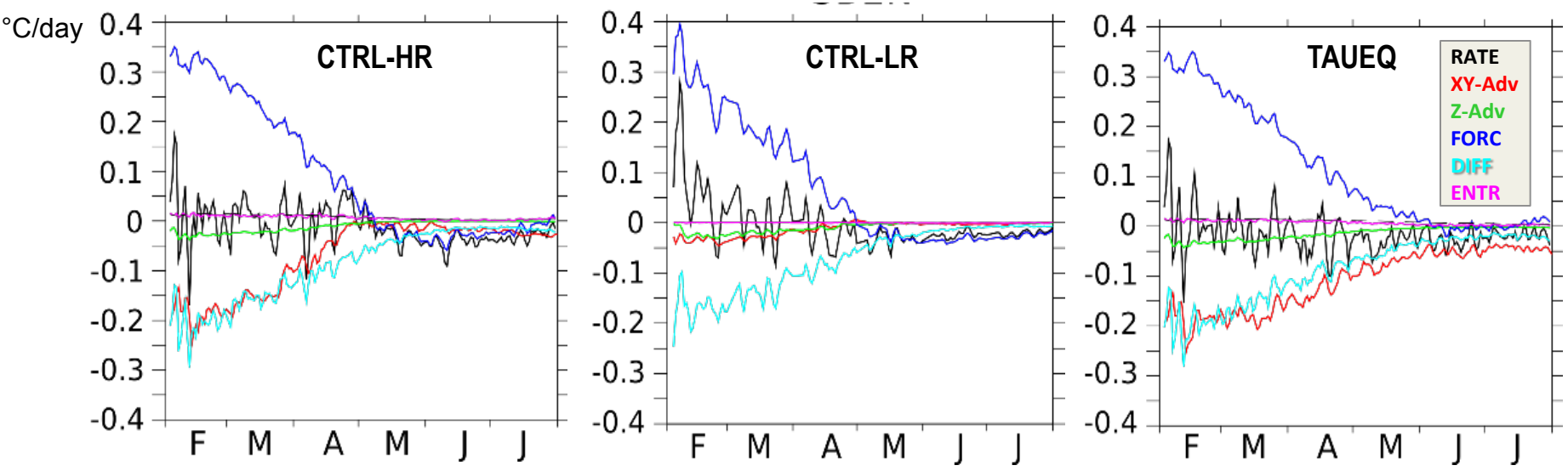




CTRL-HR
CTRL-LR
TAUEQ

❑ Mixed-layer temperature tendency terms

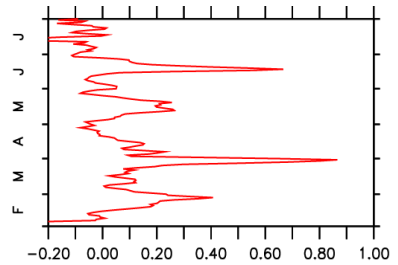
TemperRATE = XY_Adv + Z_Adv + Atm.FORC + Vert.DIFF + ENTR + Res



LR: much smaller cold XYadv (Ekman transport/coastal upwelling)
TAUEQ: cold contribution of XYadv(local upwelling) is stronger since there is no "compensation" by warm contribution of XYadv (remote forcing from the Equator)

Warm advection from the Equator

XYadv at 20°S, °C/day
(1st grid cell from the coast)



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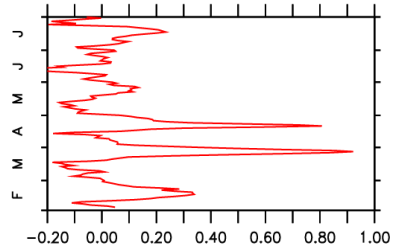

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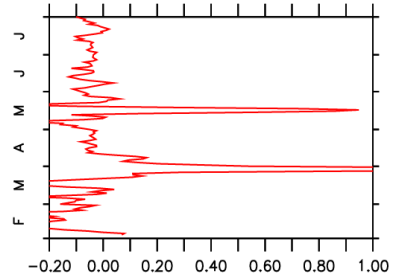

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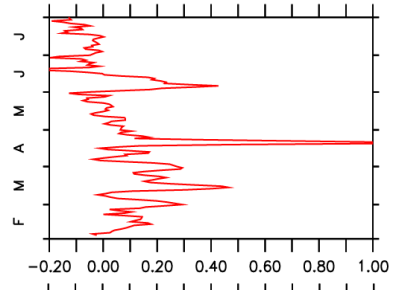
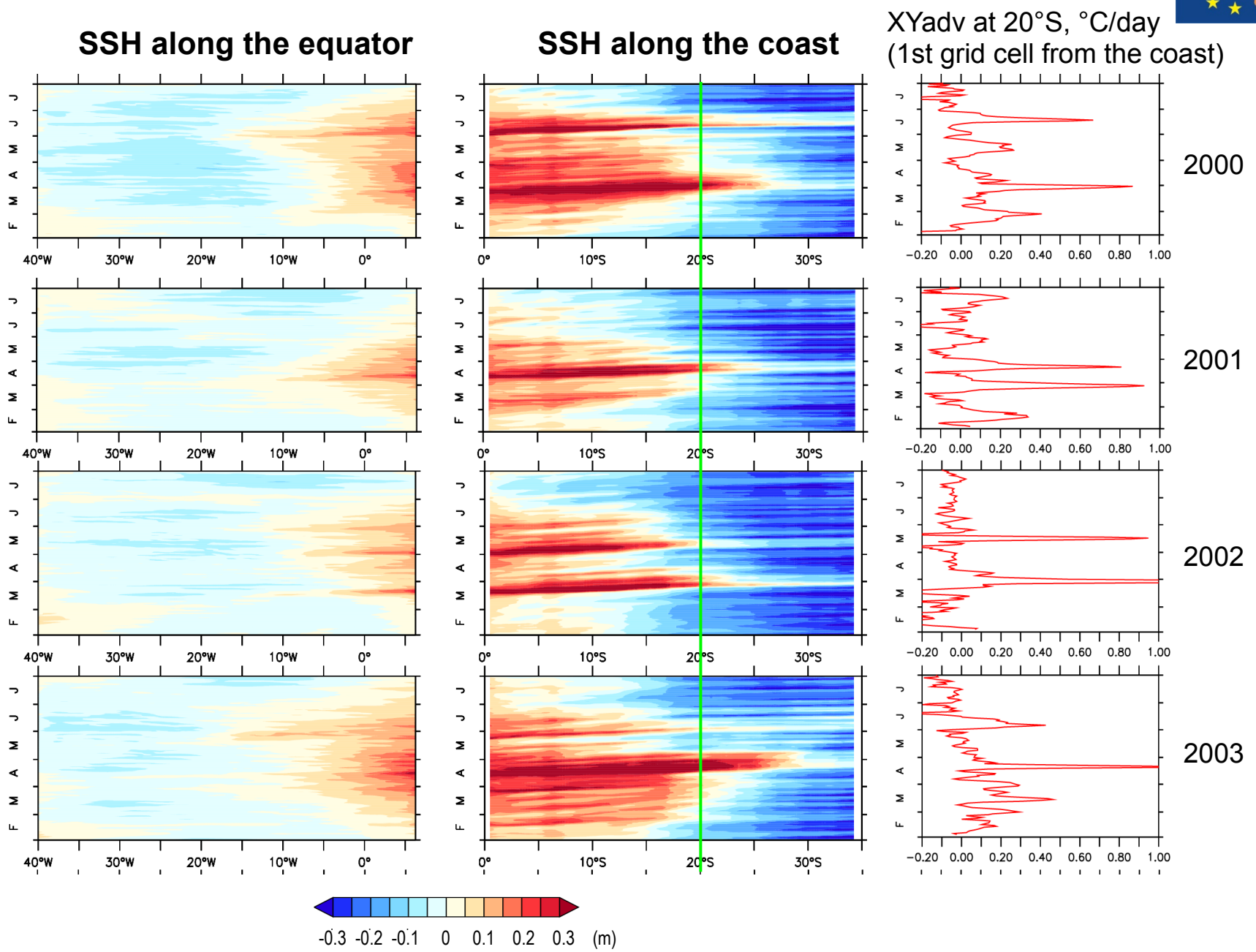


2003

Warm advection from the Equator



Conclusions

→ **Remote forcing from the equator contributes to ~50% of warm SETA** bias in CNRM-CM model

→ **This is due to anomalous warm horizontal advection from the Equator** that penetrates southward of 25°S and **could be associated with propagations of coastal trapped equatorial Kelvin waves**

→ **Restoring of the wind stress over the Equator leads to a general improvement of the equatorial mean state** (thermocline slope, zonal current) and more realistic representation of the relative contributions of the different terms to the mixed-layer temperature budget in ATL3

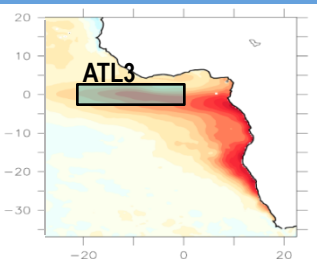
→ **Correction of the wind stress over the Equator results in local reducing of the SST bias by ~30% in the equator**

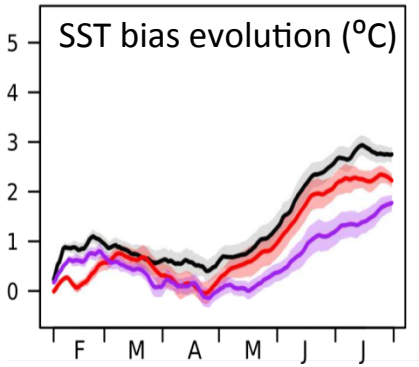
→ **In general LR and HR models show very similar evolution of the SST bias** and similar associated processes. **A significant improvement of the bias in HR is observed locally in the Southern Benguela due to better resolving of fine-scale processes associated with the coastal upwelling.**

Thank you !

Add-on

ATL3 region





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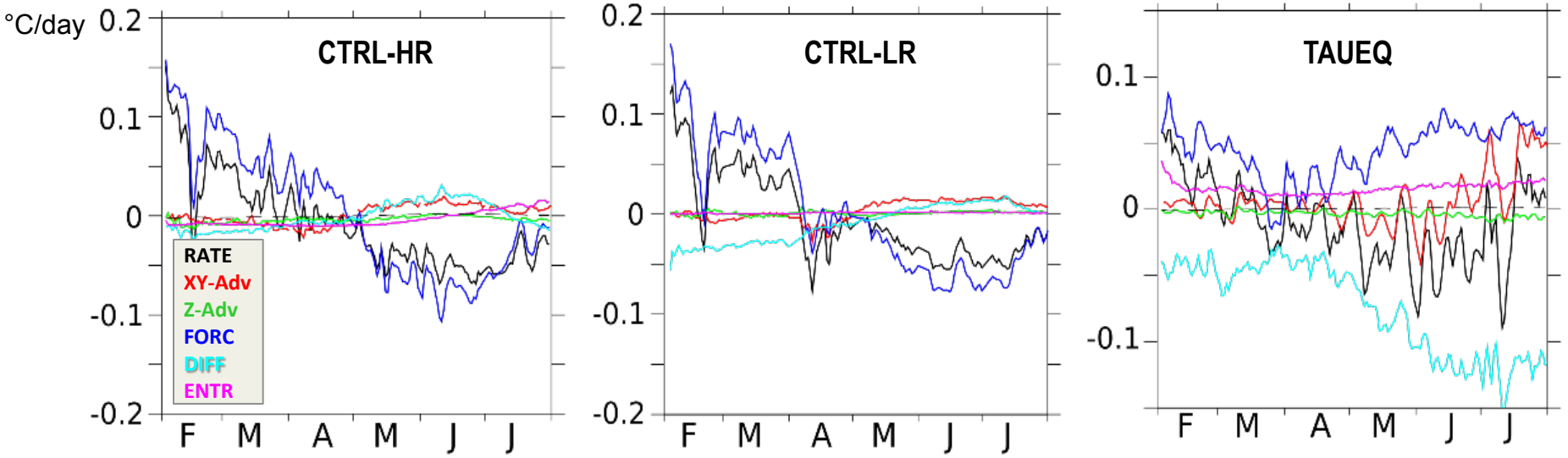
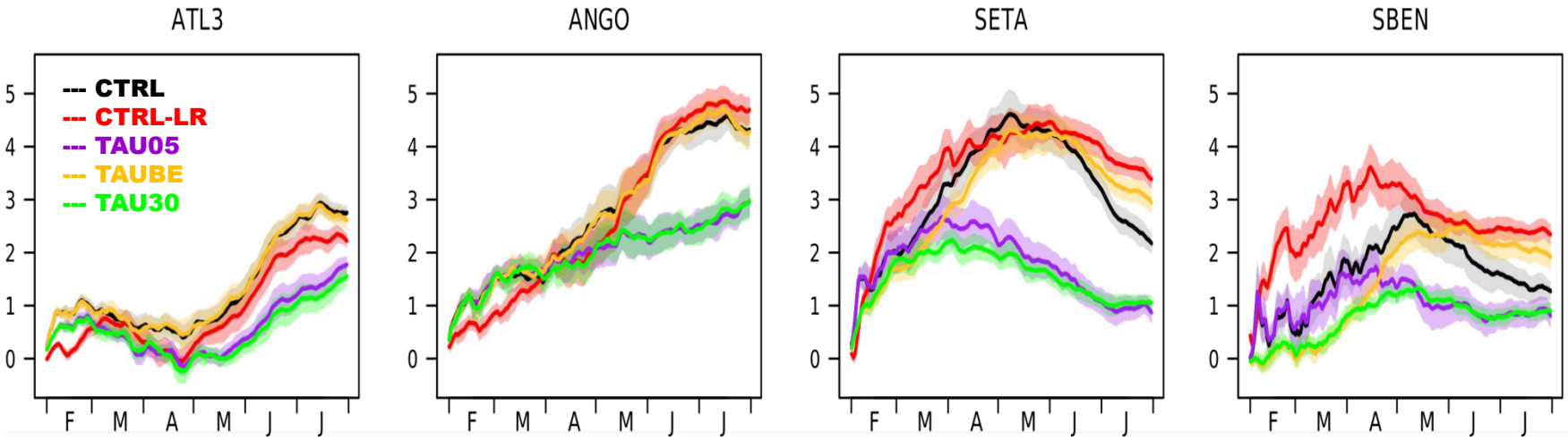


LR: in general similar processes involved

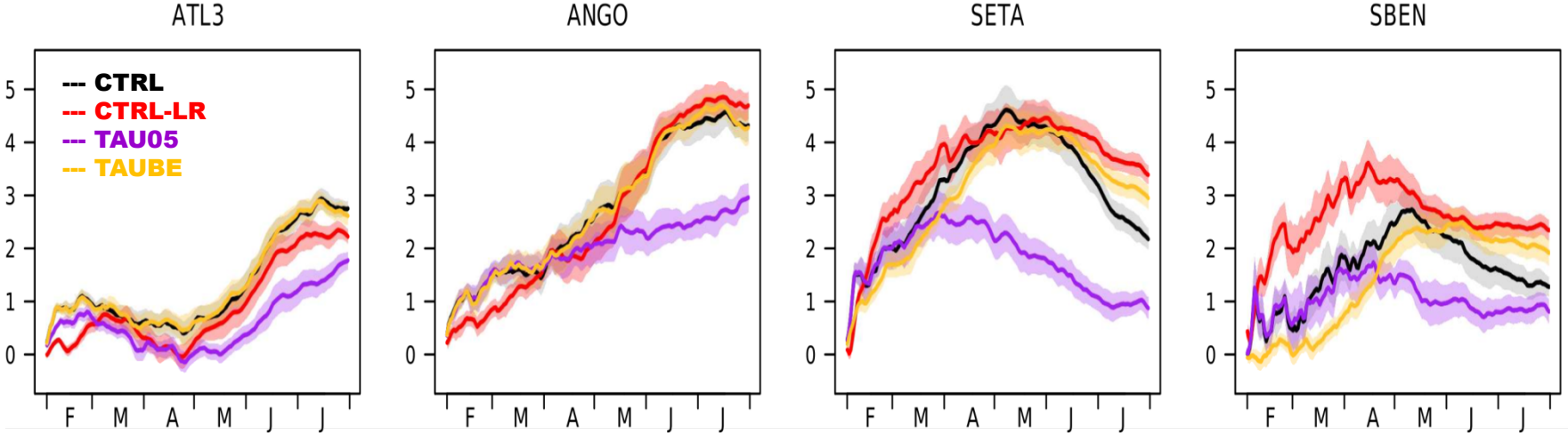
TAUEQ: drastic modification of the ML heat budget, in particular vert.diff and atm.forcing

TAU30: SST bias

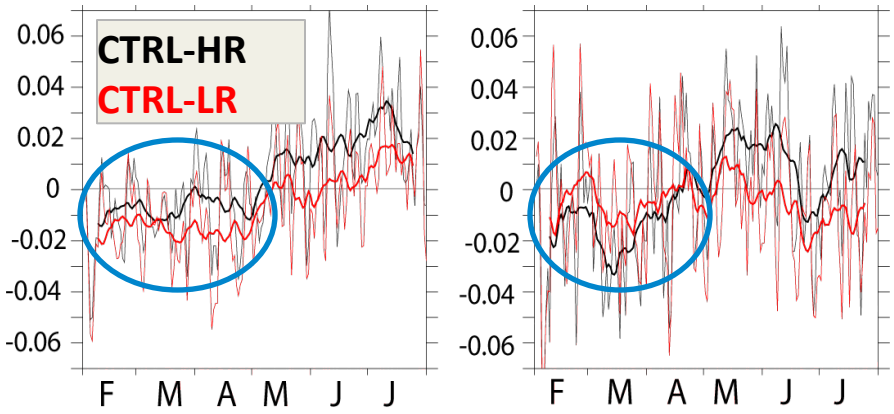


→ Combination of the effects of TAU05 and TAUBE

TAUBE: SST bias

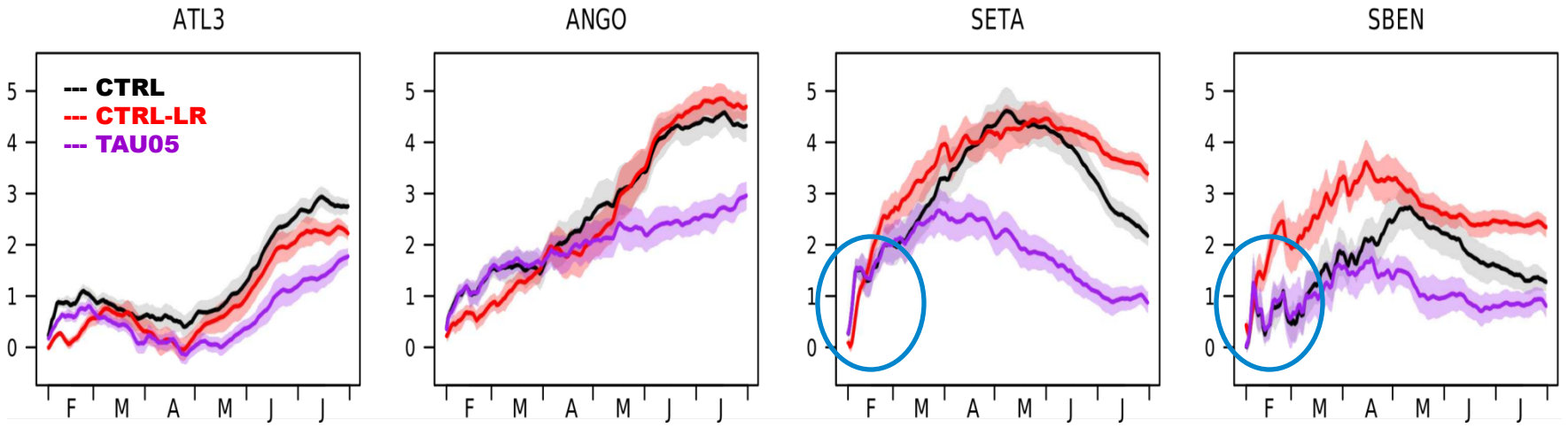


Errors in alongshore wind stress, Pa

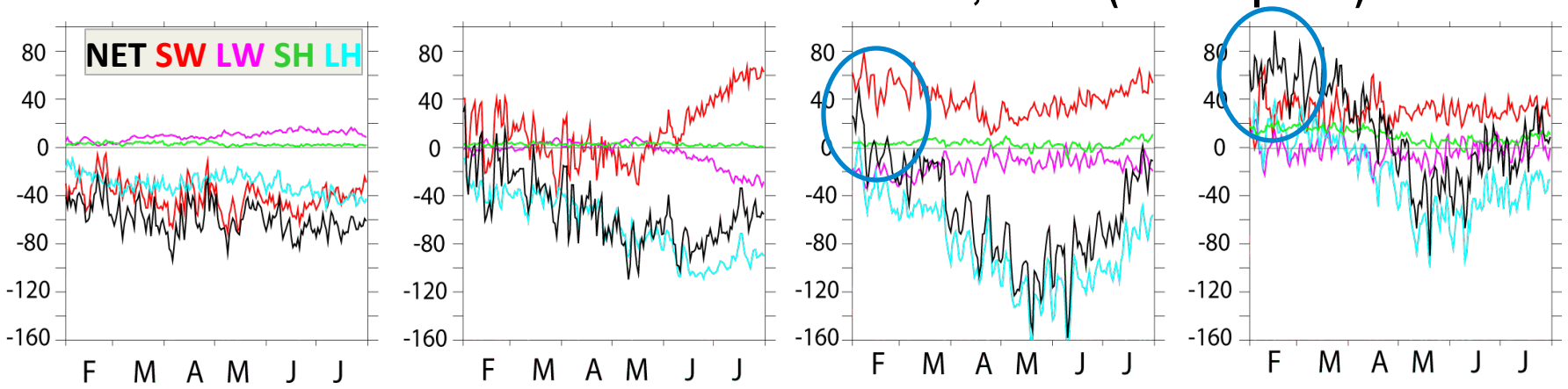


- ✓ Local improving of SST during the first 3 months of hindcasts over SBEN (and in a much lower degree over SETA)
- ✓ Stronger bias in June-July in SBEN and SETA (compensation of errors in CTRL?)
- ✓ There is no remote impact to the Equatorial regions (ATL3 and ANGO) in term of SST

Initial bias: role of heat flux



Errors in net heat fluxes at surface, W/m2 (ref: TropFlux)



✓ Error in net heat flux at surface may contribute to the rapid initial bias development over SETA and SBEN but it doesn't explain slower initial bias development in ATL3/ANGO