Diurnal variations in the tropical Atlantic from a data assimilation system

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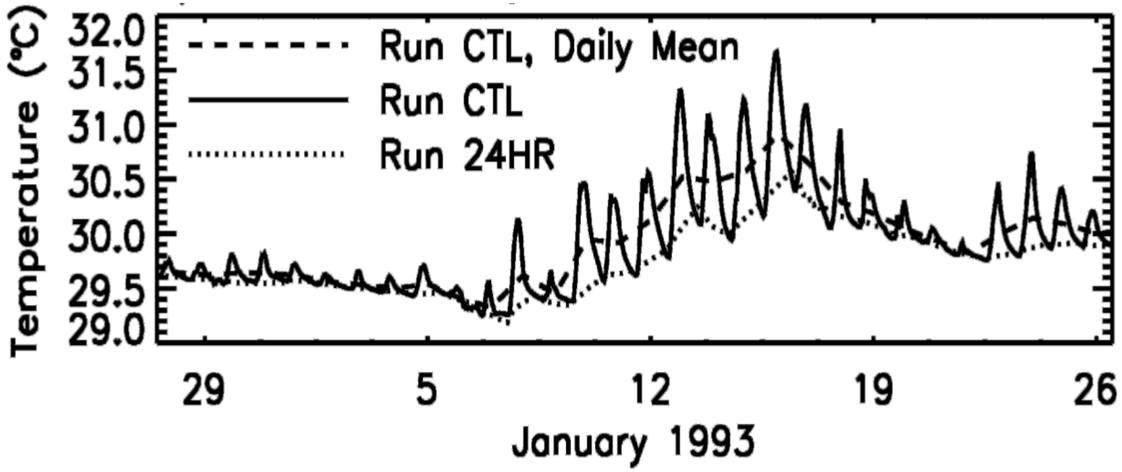
DIURNAL VARIABILITY IN THE OCEAN MIXED LAYER IN OCEAN MODELS

Mixed layer processes affect ocean models at all time scales !

1. Rectification effect on intraseasonal/seasonal variability

Model SST with hourly (CTL) and 24-hour (24HR) atmospheric forcing

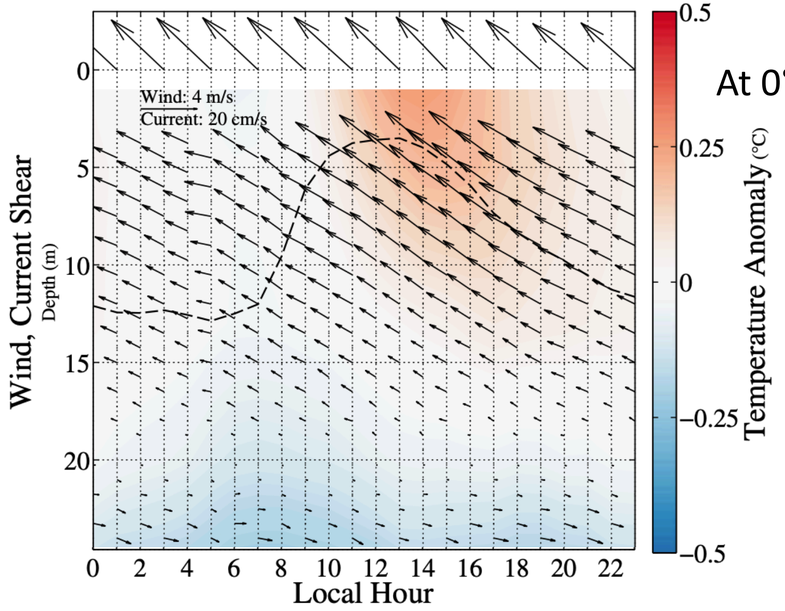


Bernie et al., (2005)

- SST is a key variable for coupled processes
- Strong impact on deep atmospheric convection in coupled forecasts (Woolnough et al., 2007)

2. Contribution to vertical exchanges of heat and momentum

Diurnal composites of wind (arrows z=0) and currents (arrows below z=0) and temperature anomaly (shading)



Wenegrat and McPhaden, (2015)

- Diurnal oceanic processes trapped heat and momentum in the surface layer and mix it downwards

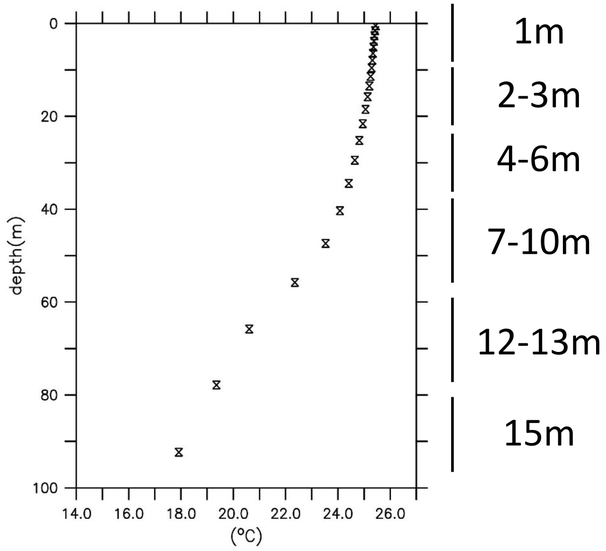
THE DIURNAL CYCLE IN NEMO

Most models have now required characteristics

Bernie et al., (2005)

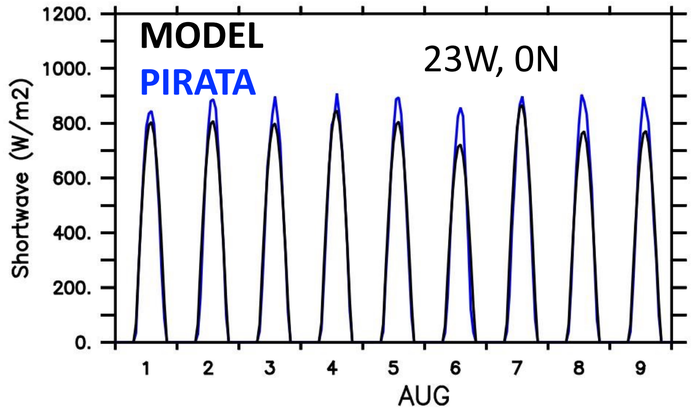
1. Vertical resolution in the surface layer (≈1m)

Vertical resolution sufficient to capture diurnal variability

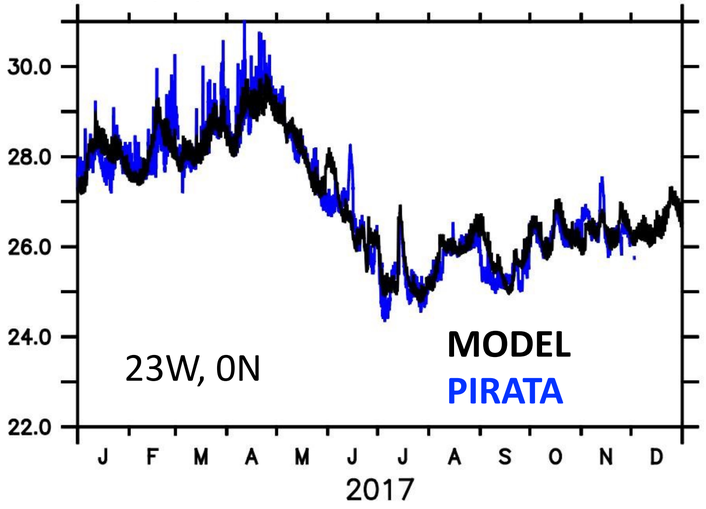


2. Atmospheric forcing frequency (≦ 3h)

3-hour forcing are reconstructed from daily averaged fields from atmospheric reanalyses

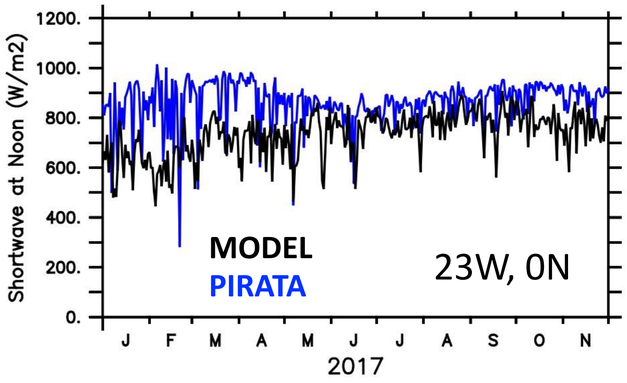


SST (°C)

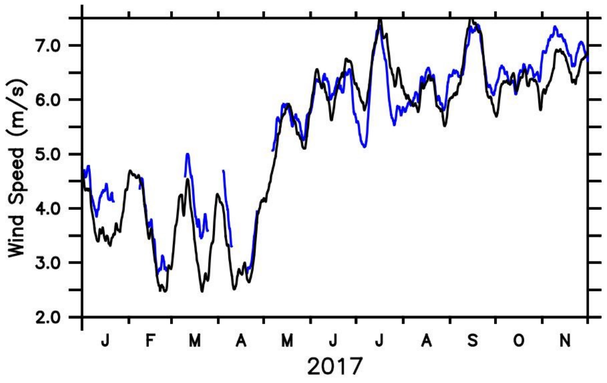


A smaller SST diurnal cycle in MODEL at the beginning of the year is associated with smaller shortwave radiation

Shortwave radiation at noon (W/m2)



Wind speed (m/s)



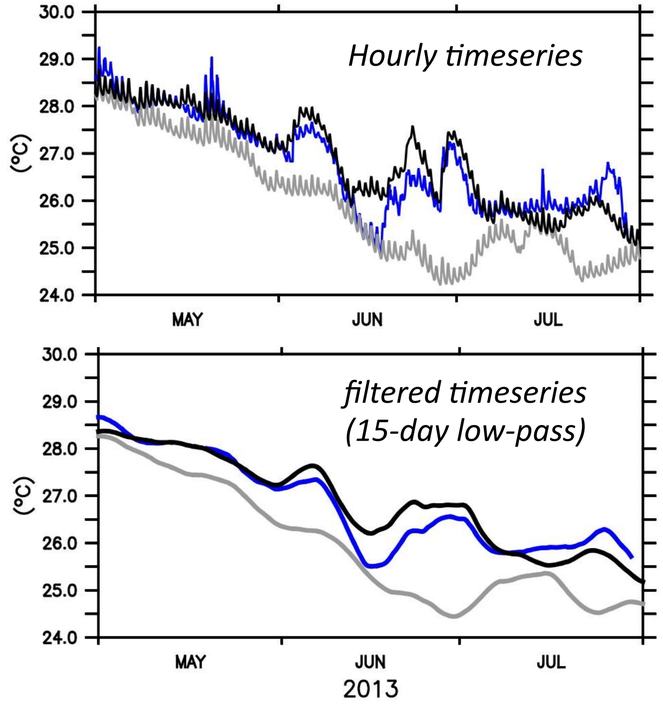
STRONG SENSITIVITY OF THE DIURNAL CYCLE IN MODELS

How do more recent models represent diurnal processes ?

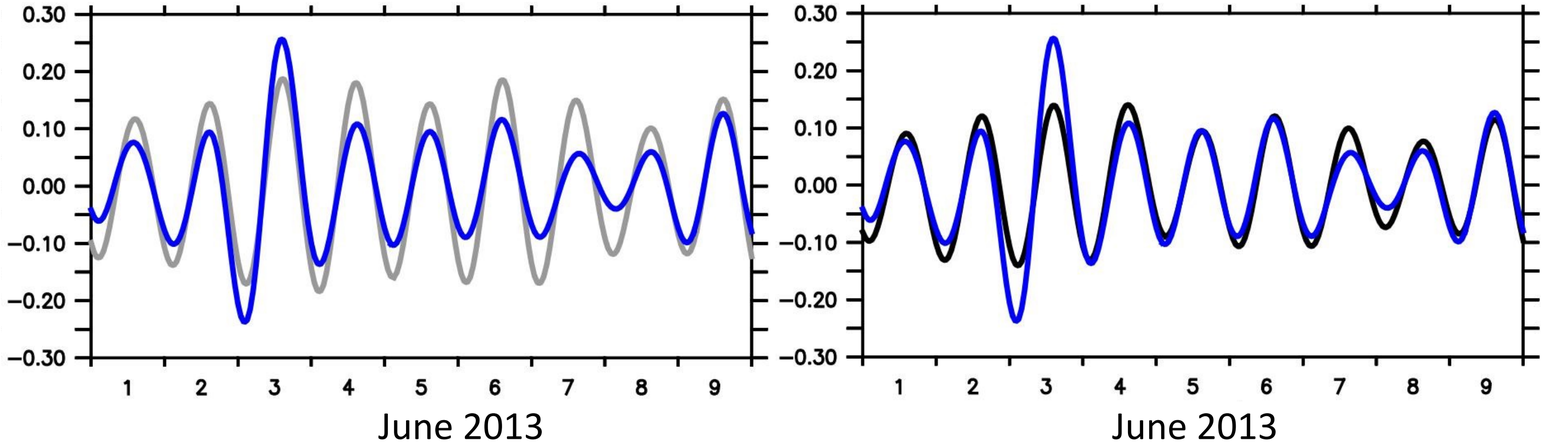
Main ingredients for a good diurnal cycle in models

- Accurate **atmospheric forcing** (wind, solar radiation)
- Validated **model parameterizations** (mixing)
- Good **oceanic background conditions** (temperature, currents)
- **Highly-resolved observations** in the surface layer to evaluate diurnal processes

SST from **PIRATA,** **FREEGLORYS12,** **GLORYS12** at 23W, 0N



SST diurnal cycle from **PIRATA,** **FREEGLORYS12,** **GLORYS12** at 23W, 0N (Complex demodulation)



Changes in background conditions associated with changes in the SST diurnal cycle

THE GLORYS12 OCEAN REANALYSIS (1993-PRESENT)

Comparing two simulations to evaluate impacts of data assimilation

Two sister reanalysis simulations, with the same atmospheric forcing (Wind, heat flux)

1/12° NEMO OCEAN GENERAL CIRCULATION MODEL
FORCED WITH ECMWF ATMOSPHERIC REANALYSIS (ERAI, 3-HOUR)

FREEGLORYS12

NO DATA ASSIMILATION

GLORYS12

SATELLITES (SST, SLA)
T/S IN SITU

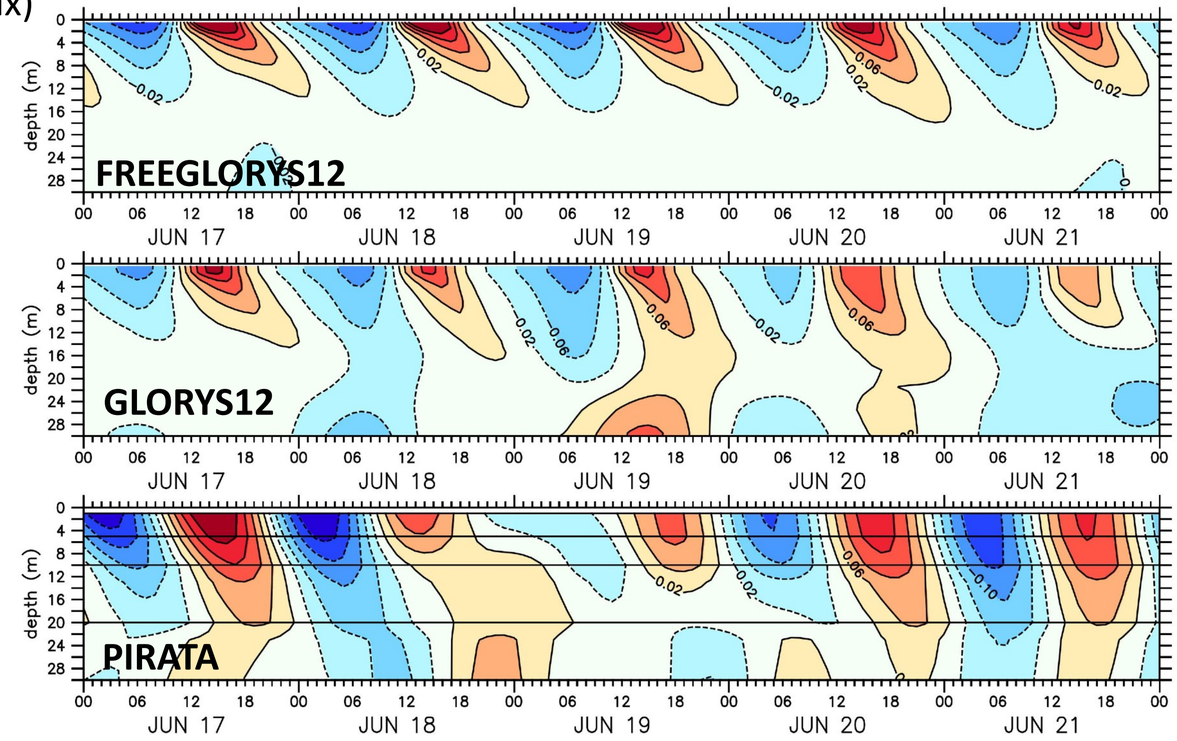
(Lellouche et al., 2021)

7-day window (≈ 1 correction per week)

The diurnal cycle is not directly constrained

Only oceanic background conditions are controlled

Temperature vertical structure at 23W, 0N (Complex demodulation)



Important differences compared to PIRATA

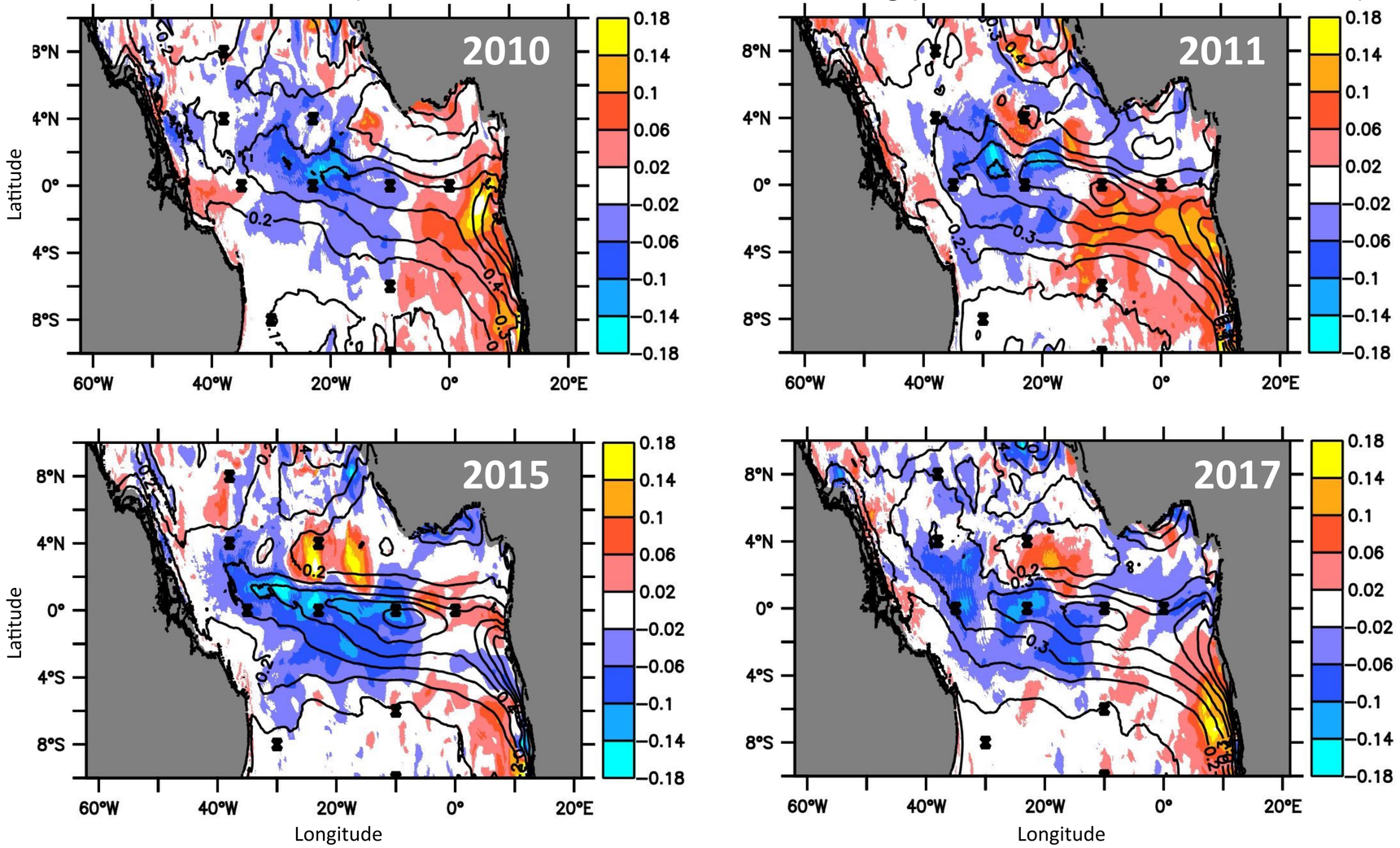
Modifications due to data assimilation (heat less confined in the top meters)

DATA ASSIMILATION MODIFIES SST DIURNAL CYCLE IN JUNE

Recurrent dipole pattern in June

dSST=SST diurnal cycle amplitude

dSST (FREEGLORYS12) in contours, **dSST differences** in shading (GLORYS12-minus-FREEGLORYS12)



- Stronger dSST in the equatorial cold tongue

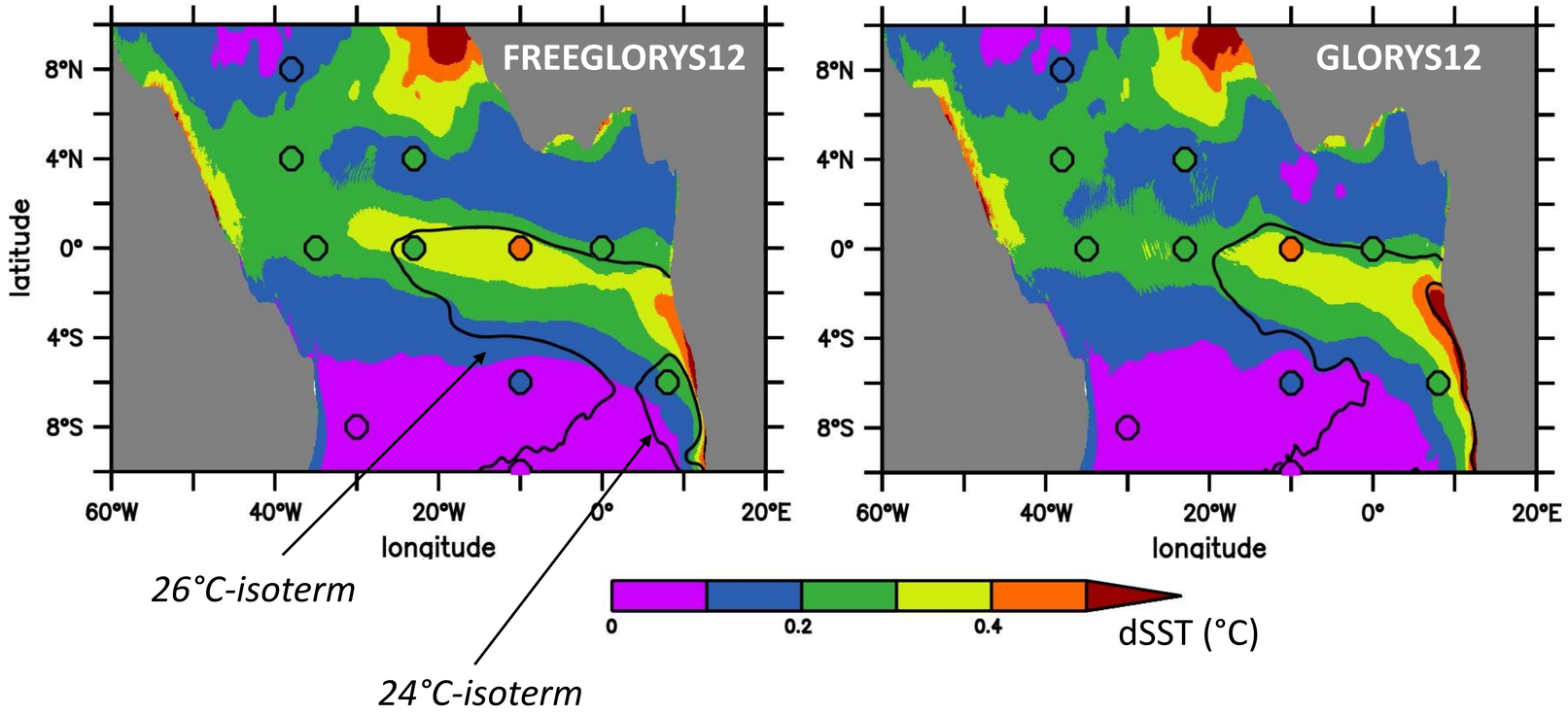
- GLORYS12 reduces dSST in the west and amplifies in the east

DATA ASSIMILATION MODIFIES SST DIURNAL CYCLE IN JUNE

dSST=SST diurnal cycle amplitude

Comparing dSST with PIRATA in June 2013

SST in contours, **model dSST** in shading, **PIRATA dSST** in circles

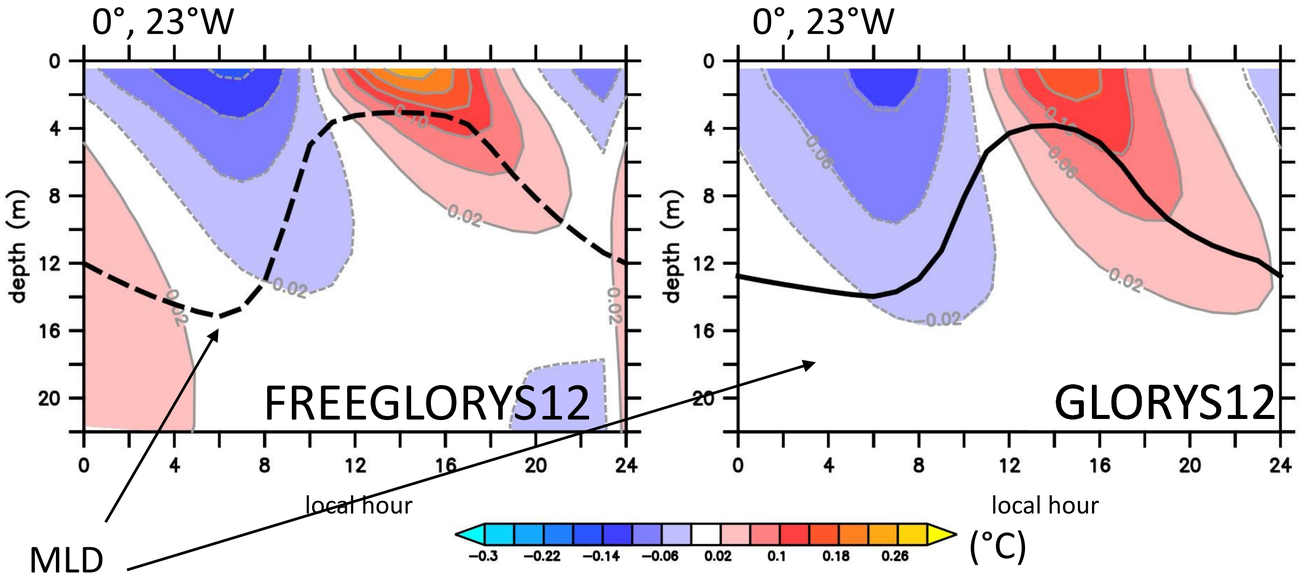


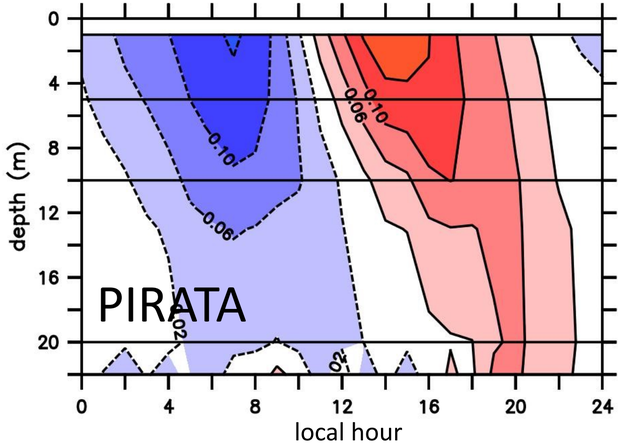
- *Data assimilation reduces the westward extension of the cold tongue*
- *dSST decrease in the west of the cold tongue*
- *Model dSST consistent with PIRATA dSST*

VERTICAL STRUCTURE OF THE MEAN THERMAL DIURNAL CYCLE IN JUNE 2013

The depth penetration is not well-reproduced

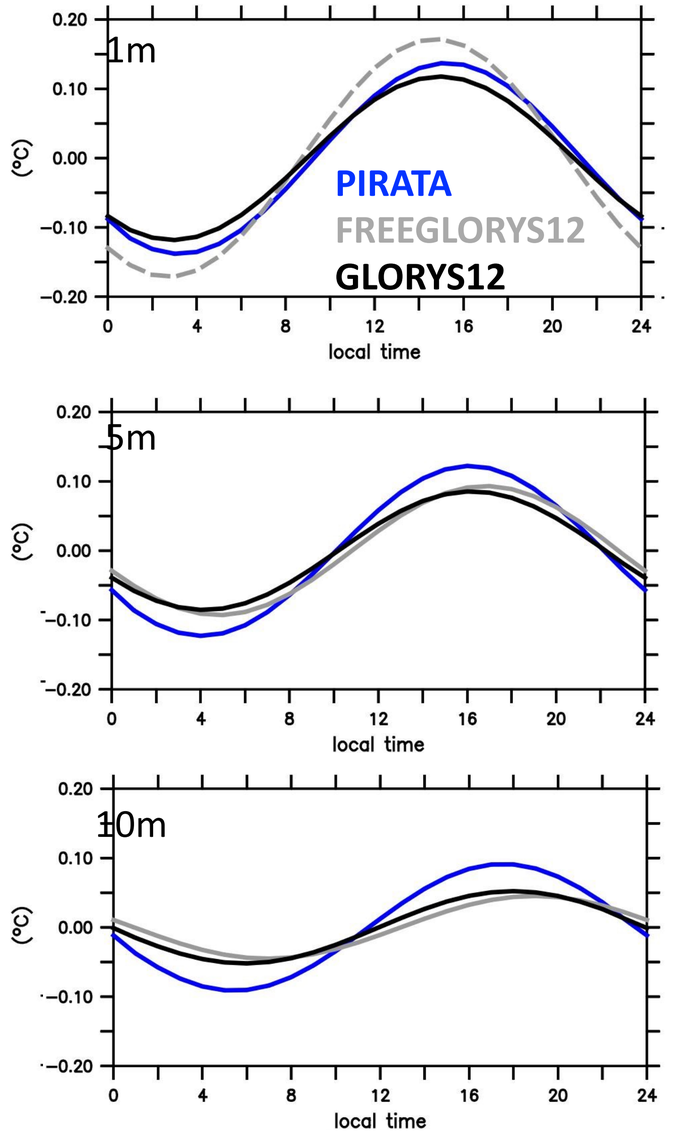
Temperature diurnal cycle time-averaged in June 2013





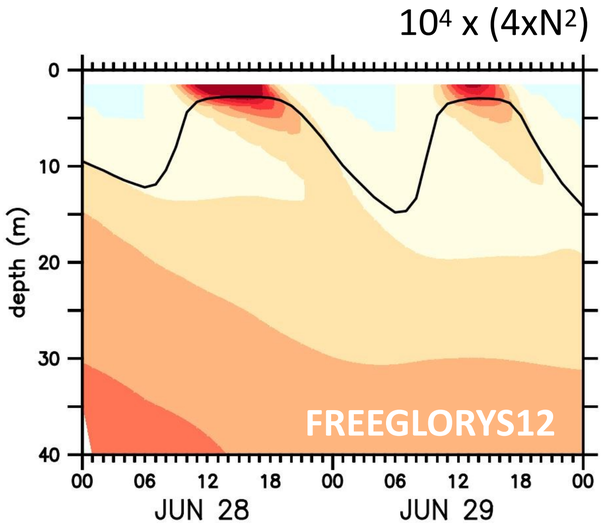
In GLORYS12, (i) smaller SST diurnal cycle
(ii) stronger depth penetration
(iii) deeper MLD
Better consistent with PIRATA only at 1m

Temperature diurnal cycle

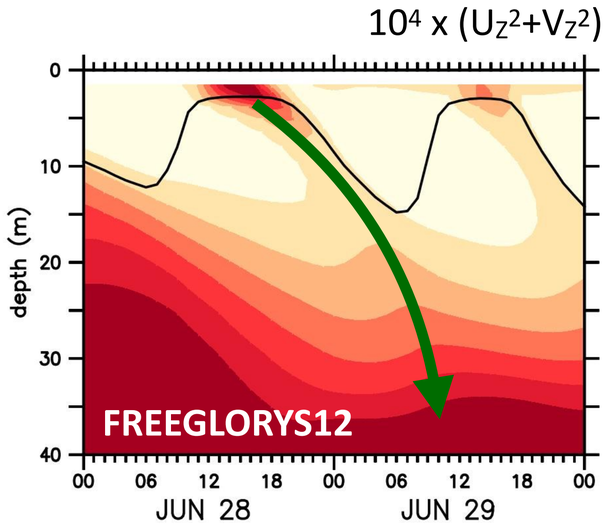


FOCUS ON TWO DAYS

Stratification



Squared shear

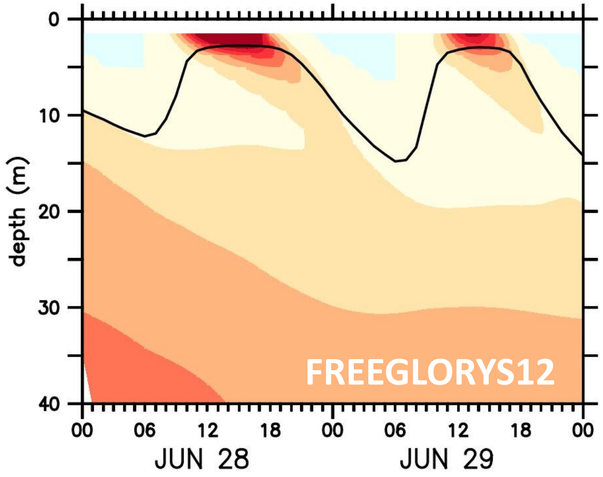


Strong extension in depth of the diurnal stratification and shear in FREEGLORYS12

FOCUS ON TWO DAYS

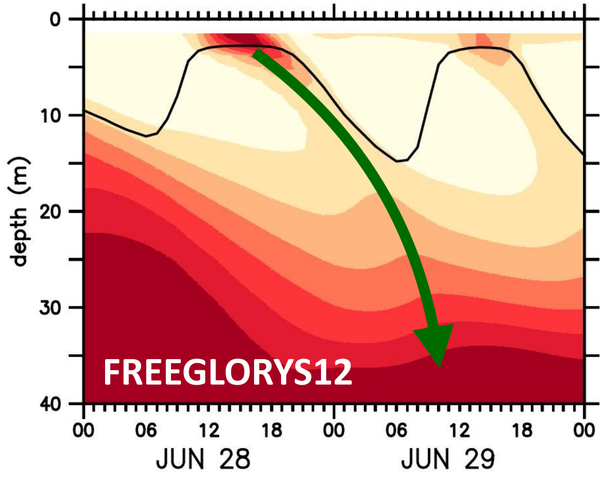
Stratification

$10^4 \times (4xN^2)$

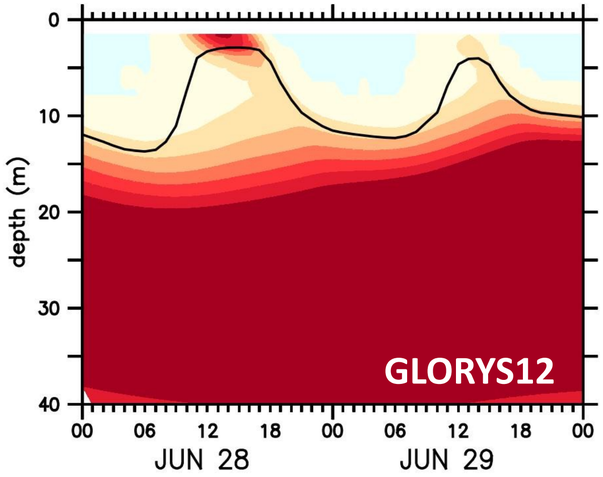


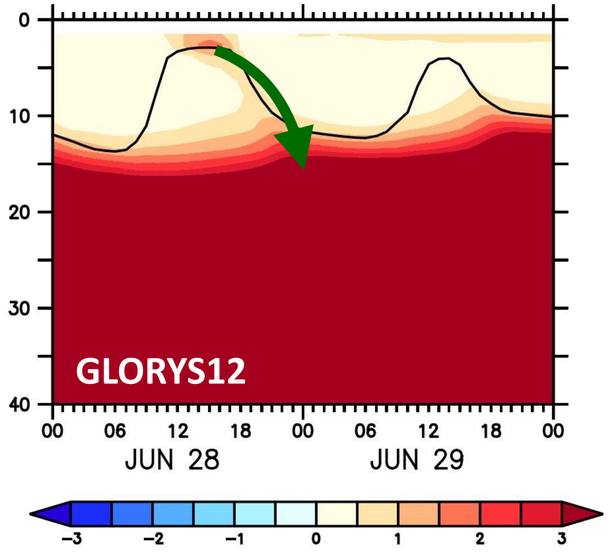
Squared shear

$10^4 \times (U_Z^2+V_Z^2)$



Strong extension in depth of the diurnal stratification and shear in FREEGLORYS12





Reduced extension in depth

Impact on vertical exchanges ?
Turbulent kinetic energy dissipation rate ?

CONCLUSION

1. A better understanding of **the subtle balance of diurnal processes** is needed for ocean models, with large benefits expected for modeling energy transfer between atmosphere and ocean

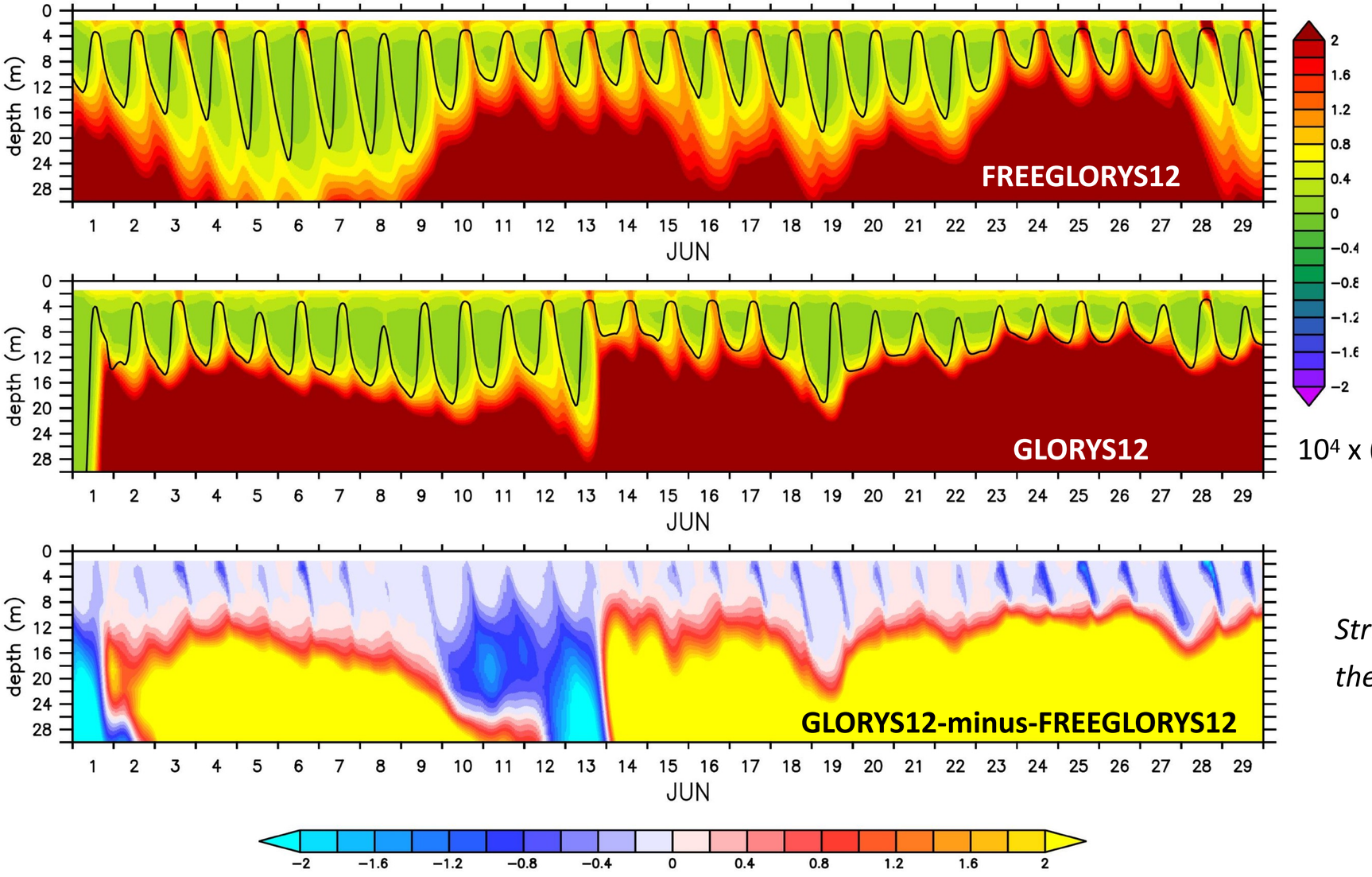
2. As atmospheric forcing and model parameterization, **representing background conditions** is key to accurately represent diurnal cycle

3. However, there is a strong dependency to the availability of high-resolution observations

    - *The unique information of PIRATA over a large spectrum of variability is essential to capture the strong interaction of the diurnal cycle with other timescales*
    - *Supplementary temperature and current observations at high vertical resolution in the surface layer should strongly benefits to our understanding of mixed layer processes*

SHEAR CHANGES IN JUNE 2013

The depth penetration is not well-reproduced



$10^4 \times (U_Z^2+V_Z^2)$

Despite no wind stress diurnal cycle, there is a diurnal cycle is in the near-surface squared shear

More visible in FREEGLORYS12 than in GLORYS12

Stronger shear in GLORYS12 at the upper flank of the Equatorial Undercurrent (EUC)

STRATIFICATION CHANGES IN JUNE 2013

10^4 x ($4xN^2$)

Similar diurnal stratification patterns than that of the shear

Smaller diurnal stratification in GLORYS12 in the surface layer

Stronger stratification in GLORYS12 at the upper flank of the Equatorial Undercurrent (EUC)