The role of scatterometry in ocean model forcing

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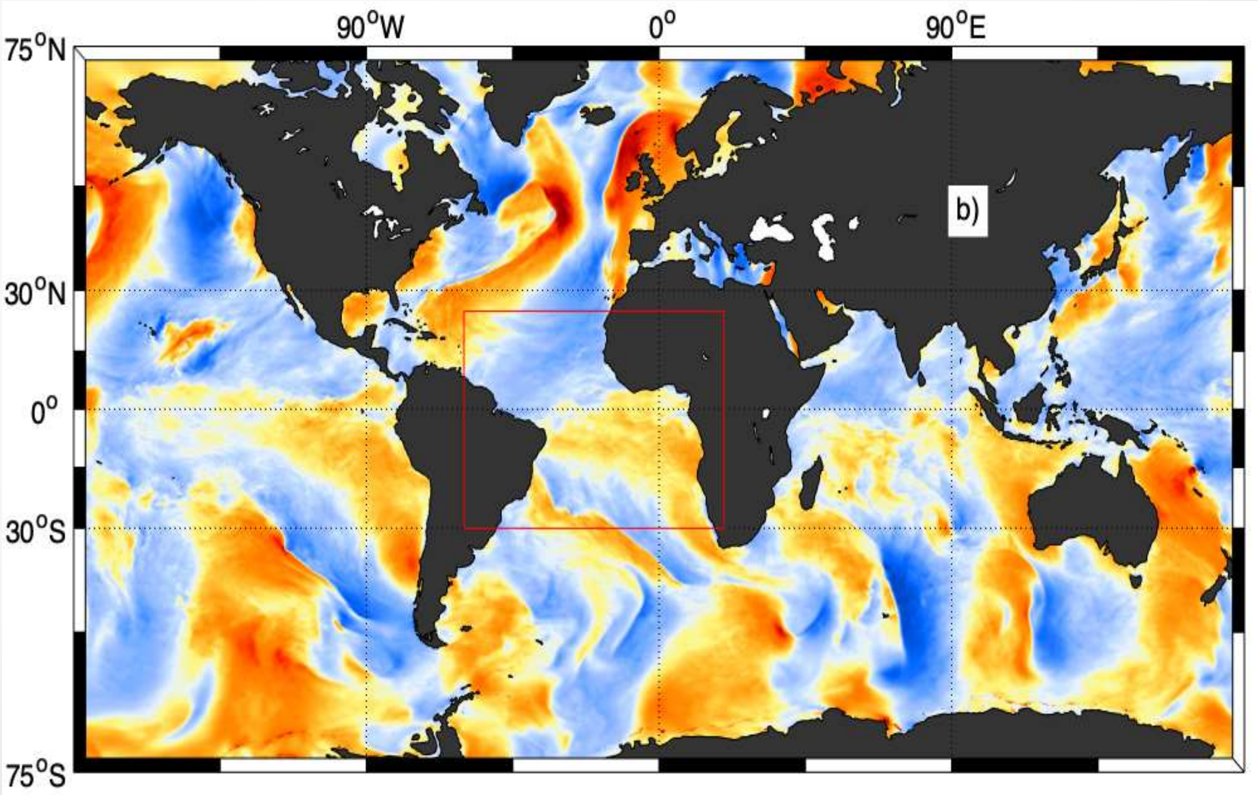
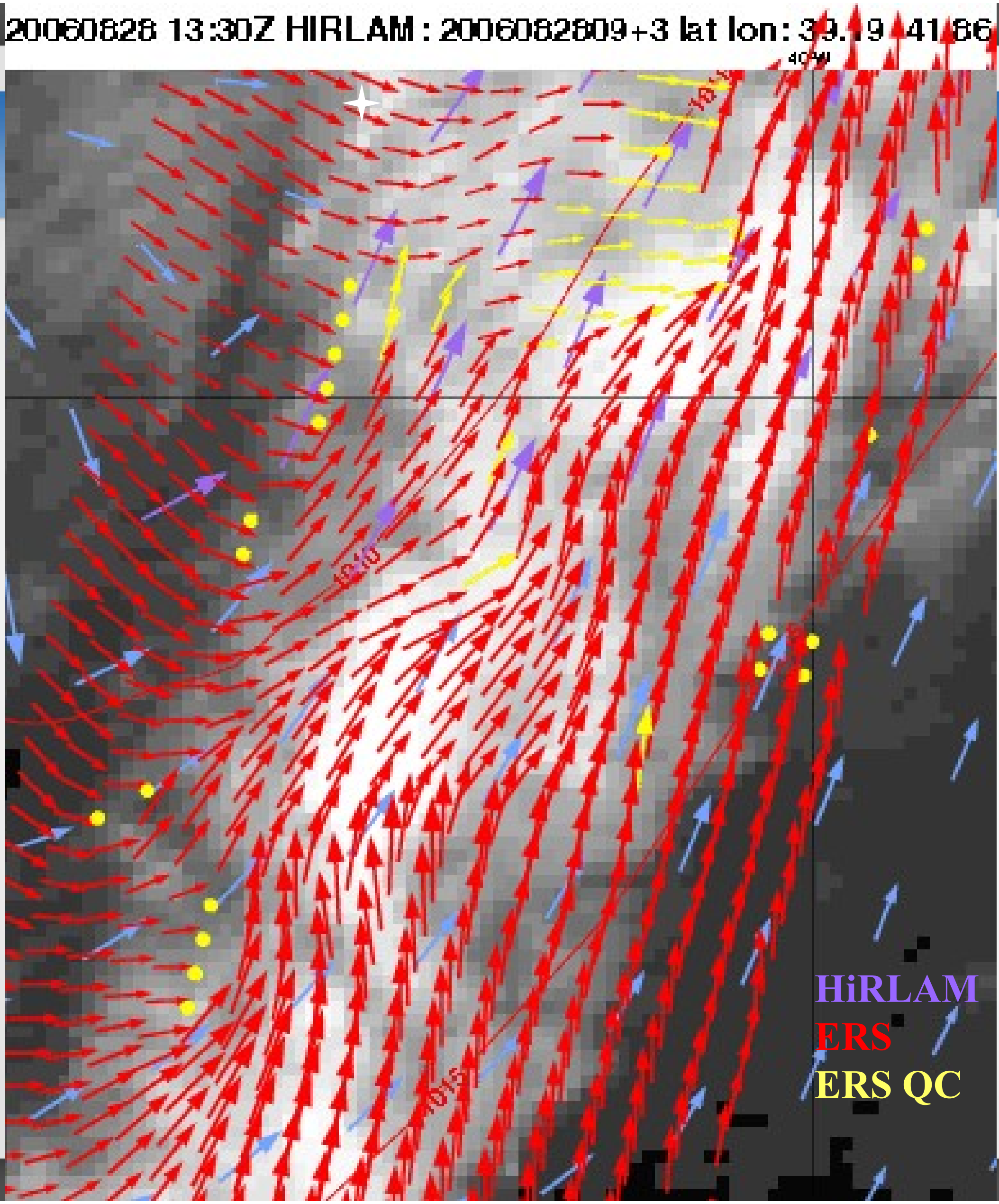


Scatterometry

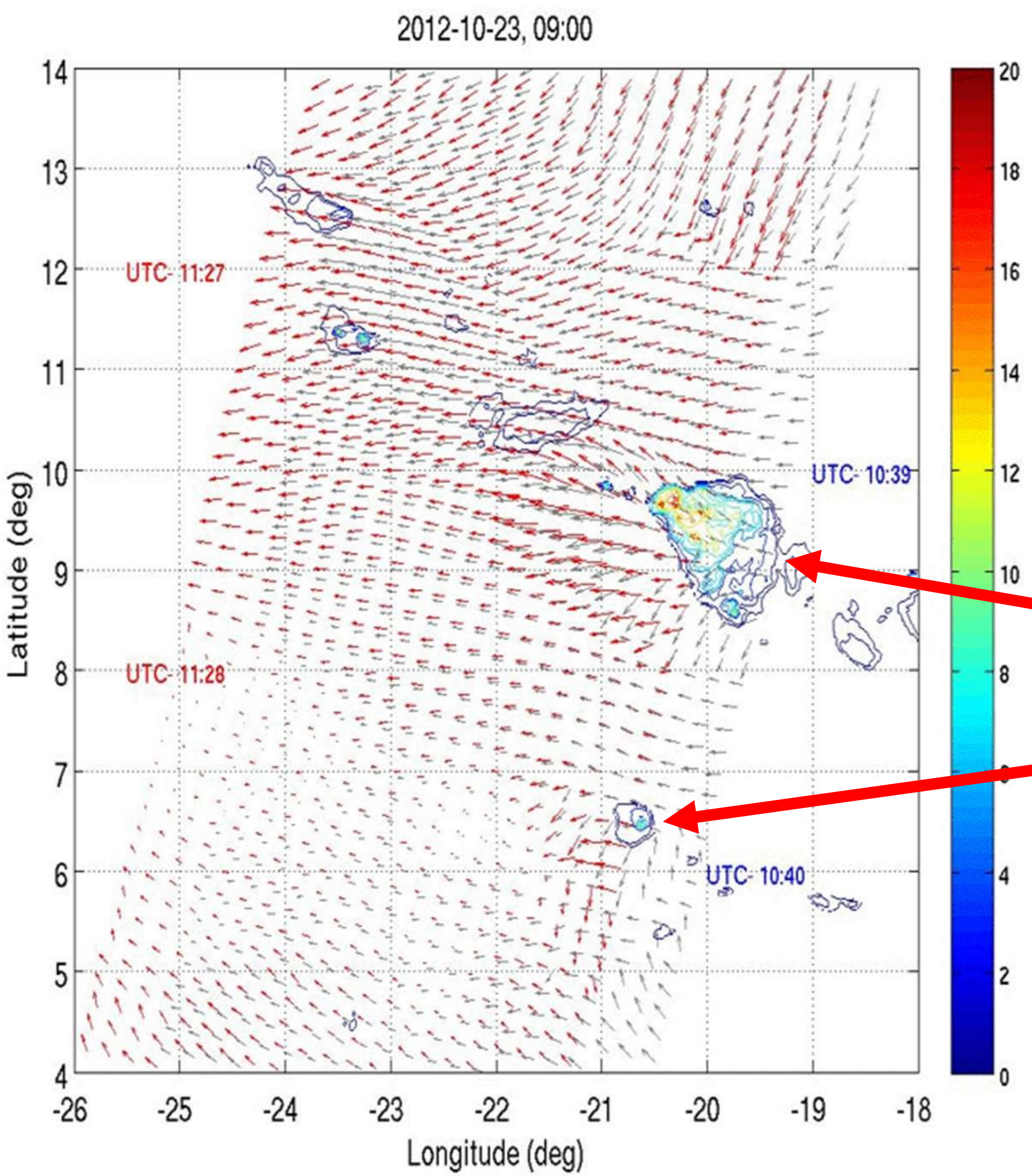
- Scatterometers provide high-resolution (25-km), accurate sea surface wind field information up to 15-20 km off the coast
- Active microwave sensors, operating at C- & Ku-band, i.e., almost all-weather capabilities
- They are used in a wide variety of applications, e.g., assimilation into global and regional NWP, nowcasting, hurricane advisories, climate trend analyses, air-sea fluxes, etc.
- They measure the sea surface roughness, which is a good proxy for wind stress



- ERS scatterometer observes wave train
- HiRLAM model (and other NWP models) miss the wave train (too smooth)
- The MSG clouds are aligned with the wave train, but in themselves provide little dynamical information

- Next day a forecast burst occurred for cloud and precipitation in England and the Netherlands

Rain-induced dynamics



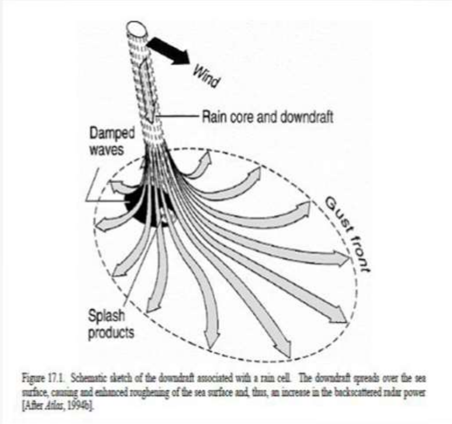


Figure 17.1. Schematic sketch of the downdraft associated with a rain cell. The downdraft spreads over the sea surface, causing and enhanced roughening of the sea surface and, thus, an increase in the backscattered radar power [After Atlas, 1994b].

Convective downbursts

ASCAT-A and ASCAT-B come together. Red arrows:ASCAT-A; Blue arrows:ASCAT-B; color contours: MSG RR.

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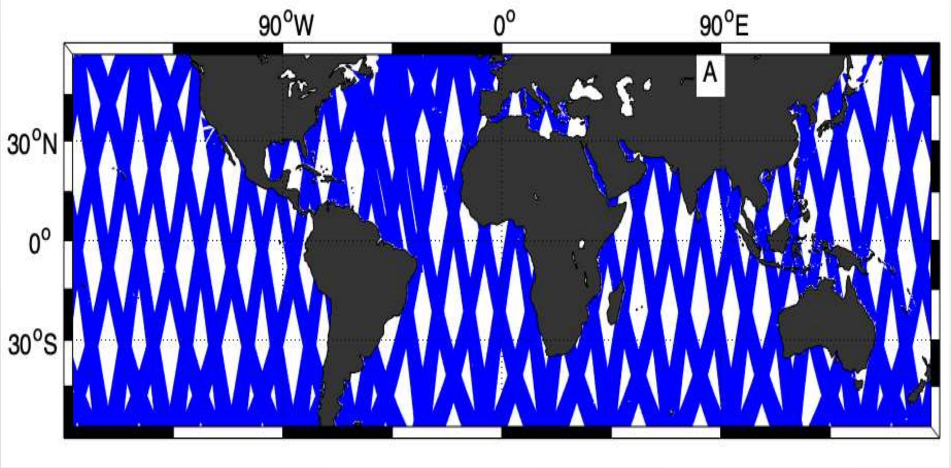
Ocean forcing

- NWP wind output is generally used as ocean forcing since it's ubiquitous.
- NWP winds resolve up to 100-150 km scales in open ocean, and miss small scale processes like moist convection, wind stress-SST coupling, coastal effects, etc.
- Can scatterometers be used to improve current NWP ocean forcing products?
- Can they bring higher resolution & more accurate forcing?

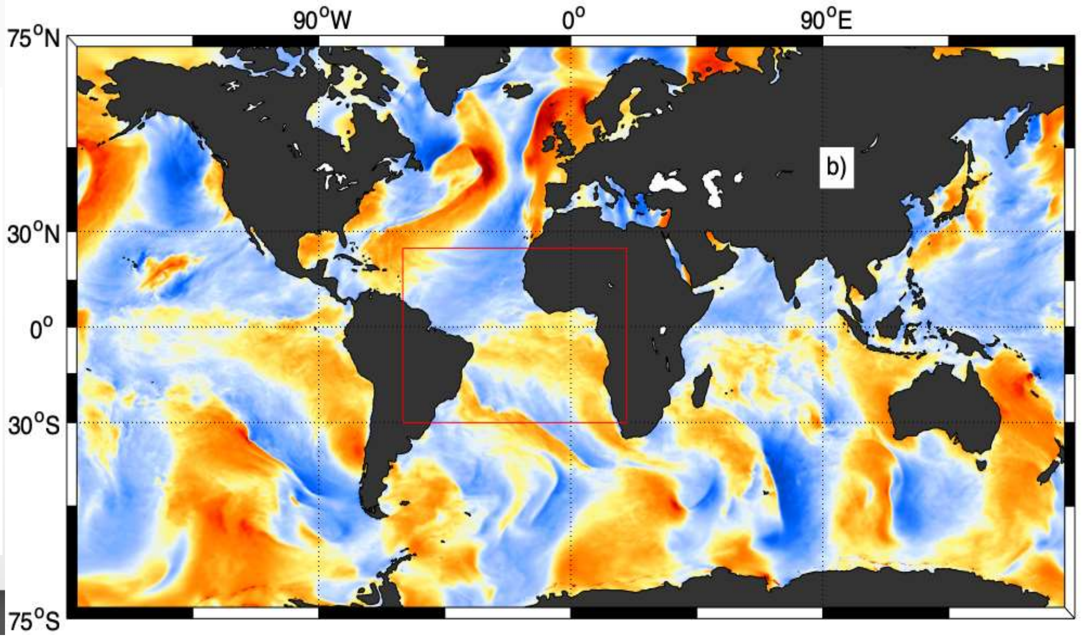
Higher Level Wind Processing

- Level 3: spatio-temporally consistent wind product from a single wind source
- Level 4: spatio-temporally consistent wind product from combined wind sources
  - Optimal interpolation (Bentamy)
  - Bayesian Hierarchical model (Milliff)
  - Local bias corrections method – ERA* (Trindade)

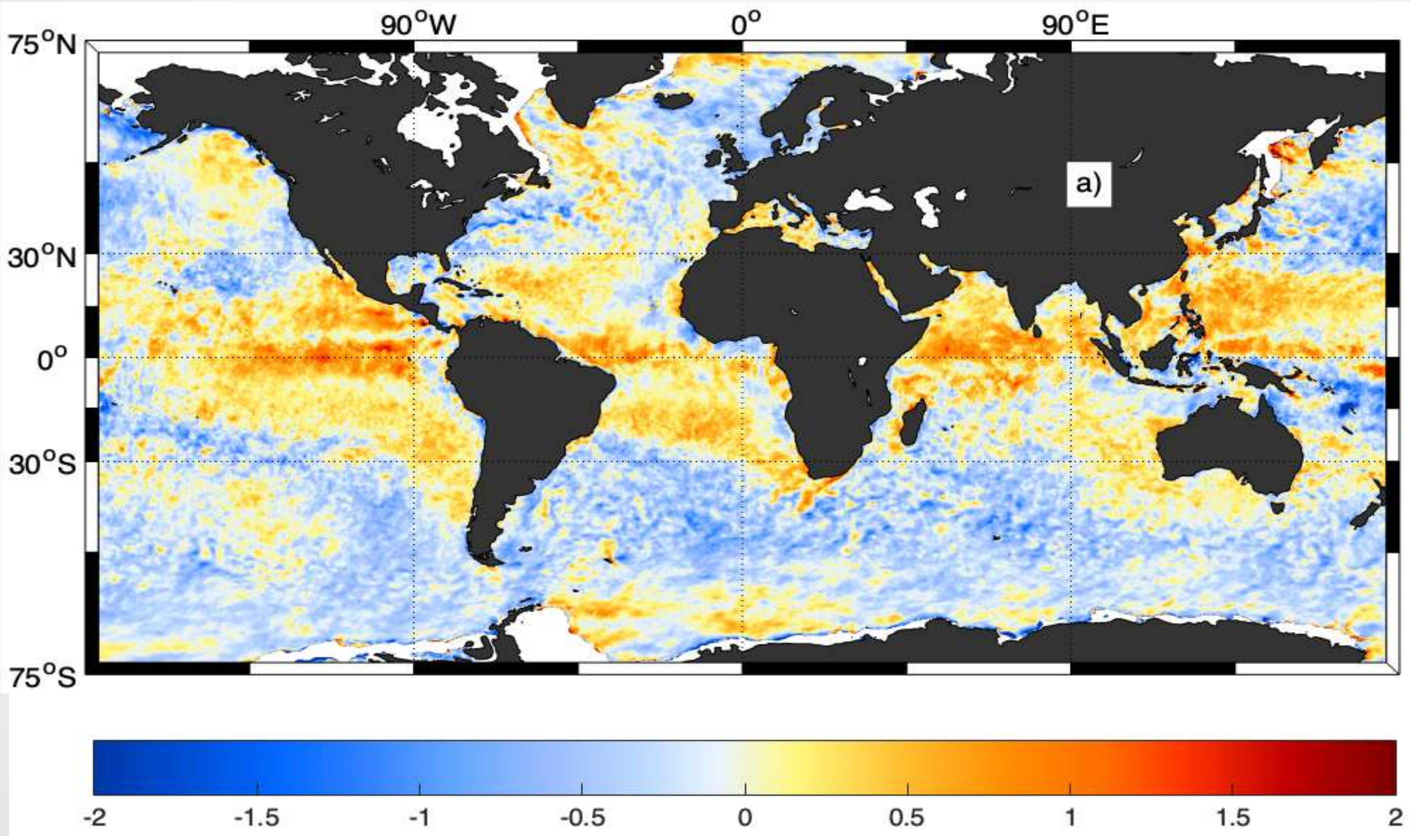
DAILY COVERAGE FROM A SINGLE SCATTEROMETER (over ocean)



ERA* HOURLY L4 WIND PRODUCT



SYSTEMATIC DIFFERENCES BETWEEN NWP AND SCATT



Zonal component (v10S)

COLLOCATIONS

- ASCAT-A/B/C – ERA5 u10S
- 30-d Temporal Window

CORRECTION ERA5 SURFACE WINDS

$$SC(i,j,t_f) = \frac{1}{M}\sum_{t=1}^{M}\left(u_{10s}^{SCAT_k}(i,j,t) - u_{10}^{ERA5}(i,j,t)\right)$$

N length of the temporal window (d);

k Scatterometer combinations

M is the number of scatt. and ERA collocations

Applied at every forecast time

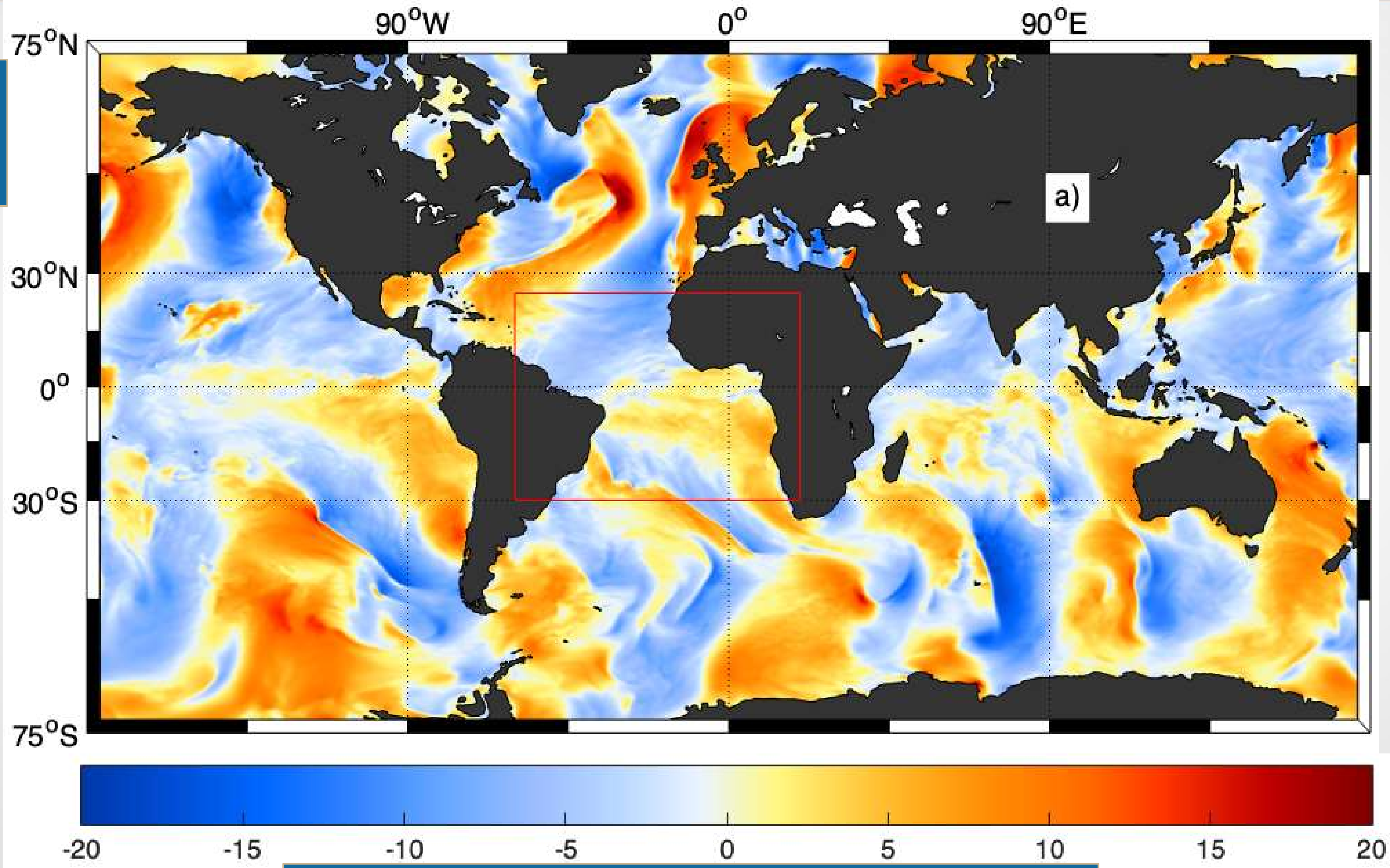
$$u_{10}^{ERA*}(i,j,t_f) = u_{10s}^{ERA5}(i,j,t_f) + SC(i,j,t_f)$$

Trindade et al., *TGRS*, 2020.

- **How long should the winds be accumulated?**
- **How many scatterometers?**

ERA* vs. ERA5

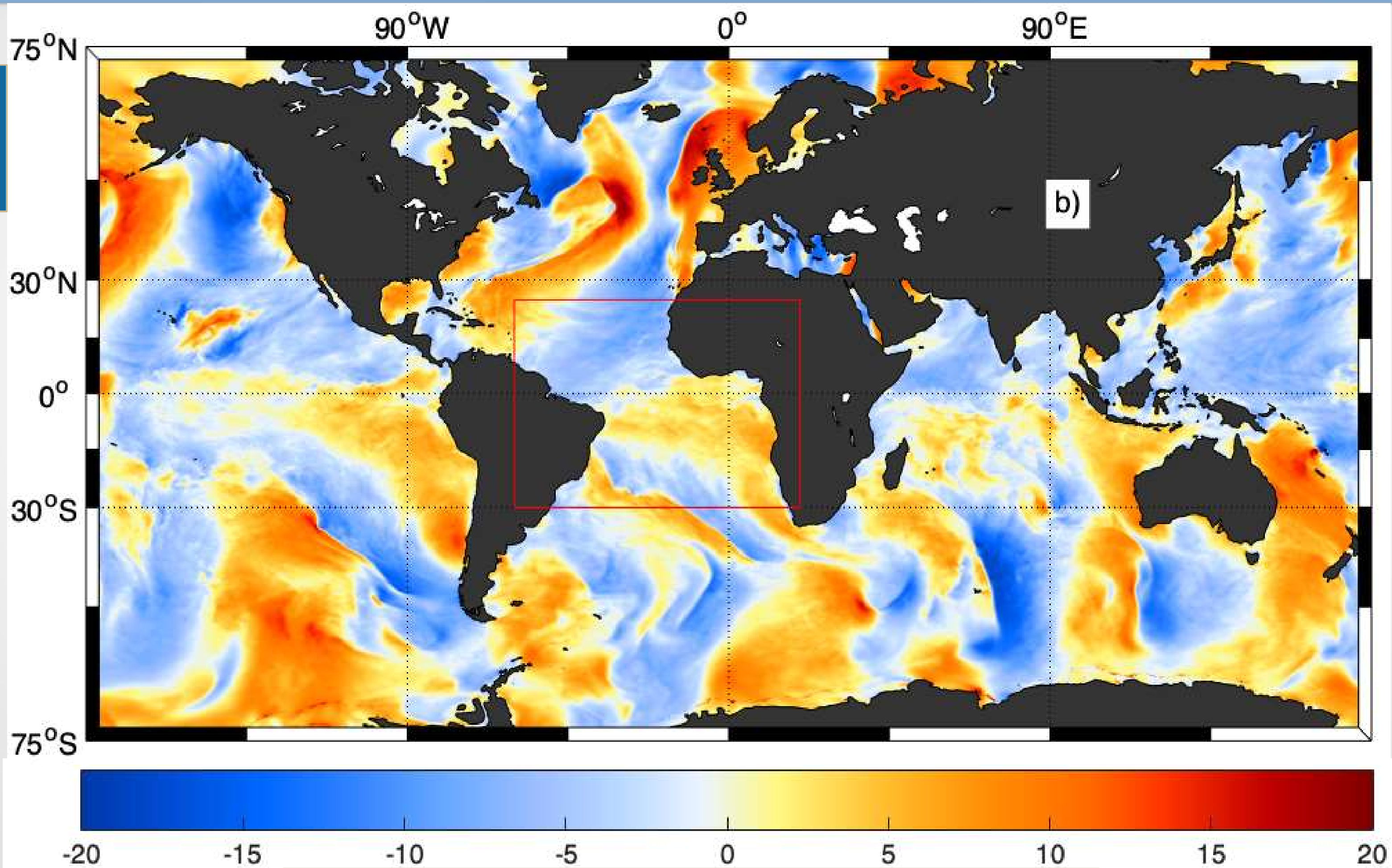
ERA5



Meridional component (v10S) 20190215 at 09 UTC

ERA* vs. ERA5

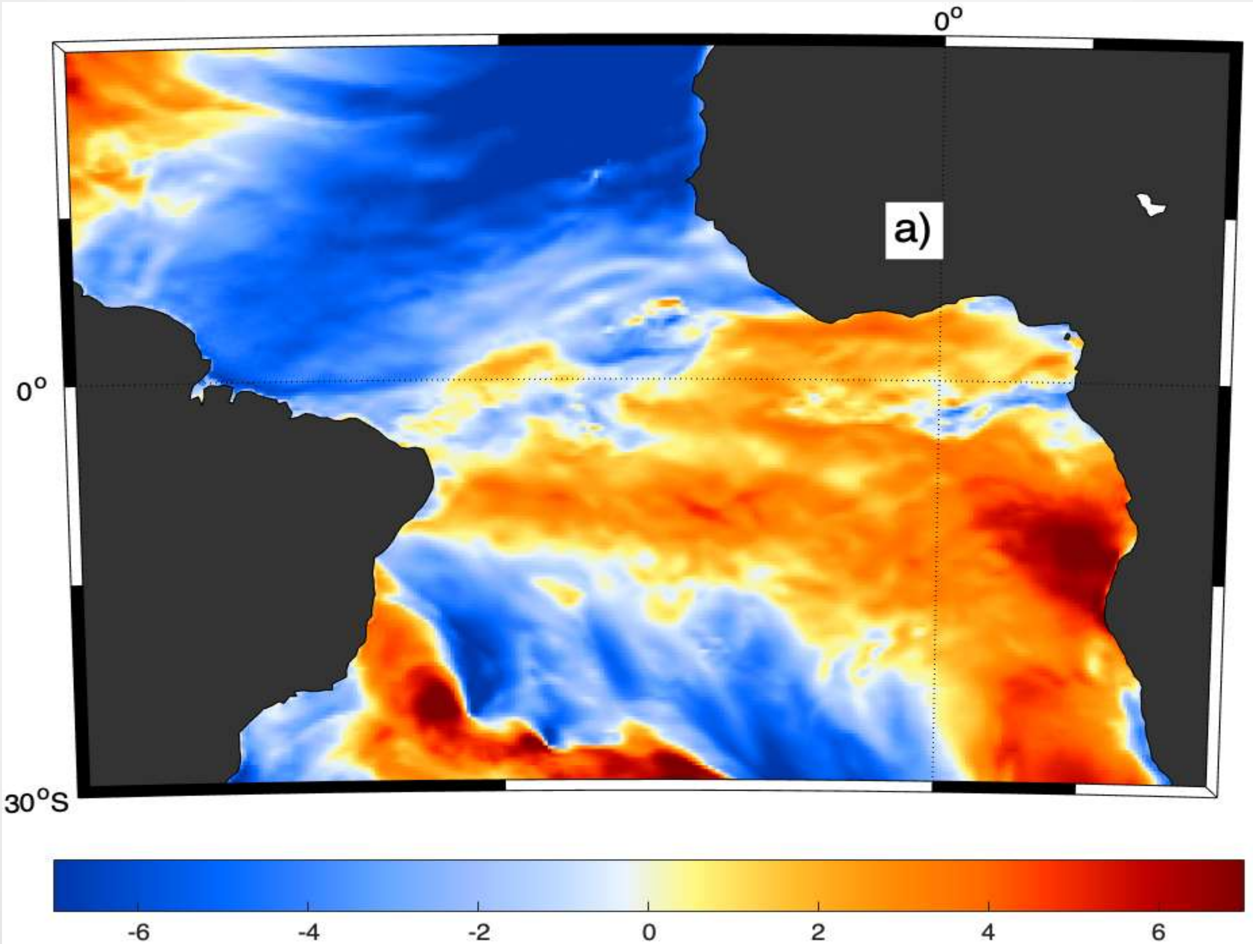
ERA*



Meridional component (v10S) 20190215 at 09 UTC

WEST AFRICAN COAST

ERA5 stress-equivalent wind (U10S)



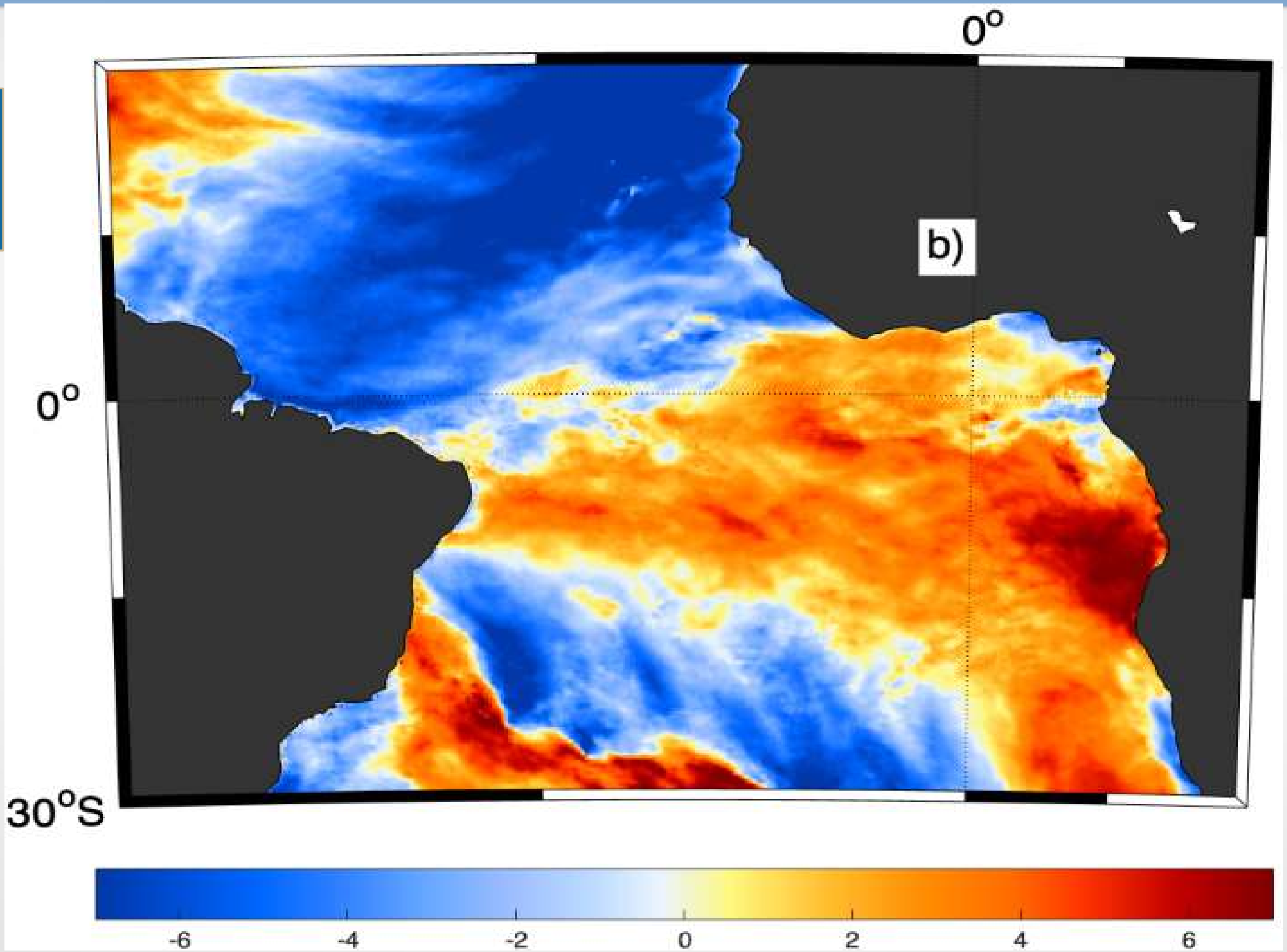
Meridional component (v10S) 20190215 at 09 UTC

WEST AFRICAN COAST

ERA* U10S
ABCO & 3-day
temporal window

<u>ABCO</u>:

ASCAT-A &
ASCAT-B &
ASCAT-C &
OSCAT2



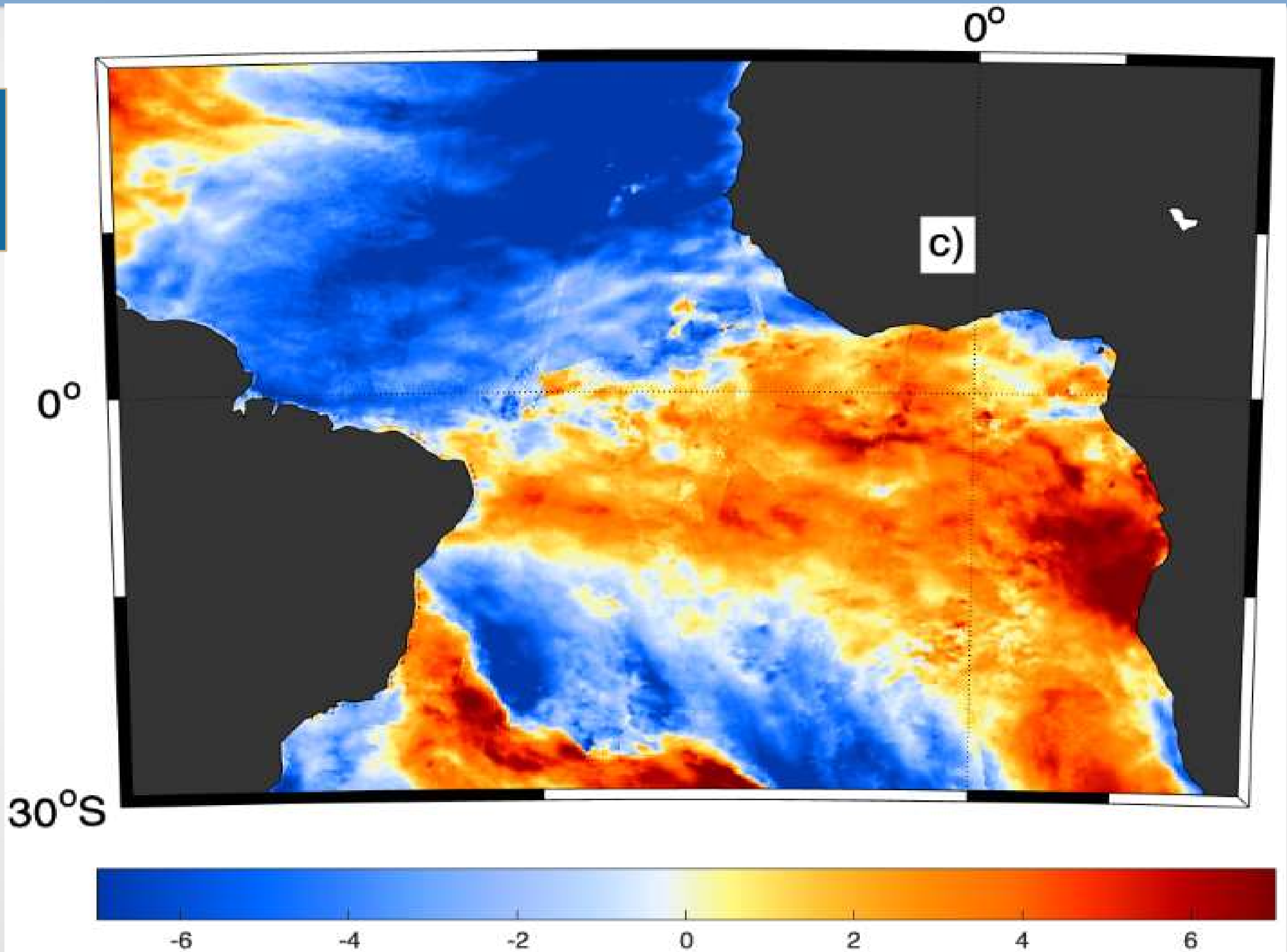
Meridional component (v10S) 20190215 at 09 UTC

WEST AFRICAN COAST

ERA* U10S
ABCO & 1-day
temporal window

ABCO:

ASCAT-A &
ASCAT-B &
ASCAT-C &
OSCAT2



Meridional component (v10S) 20190215 at 09 UTC

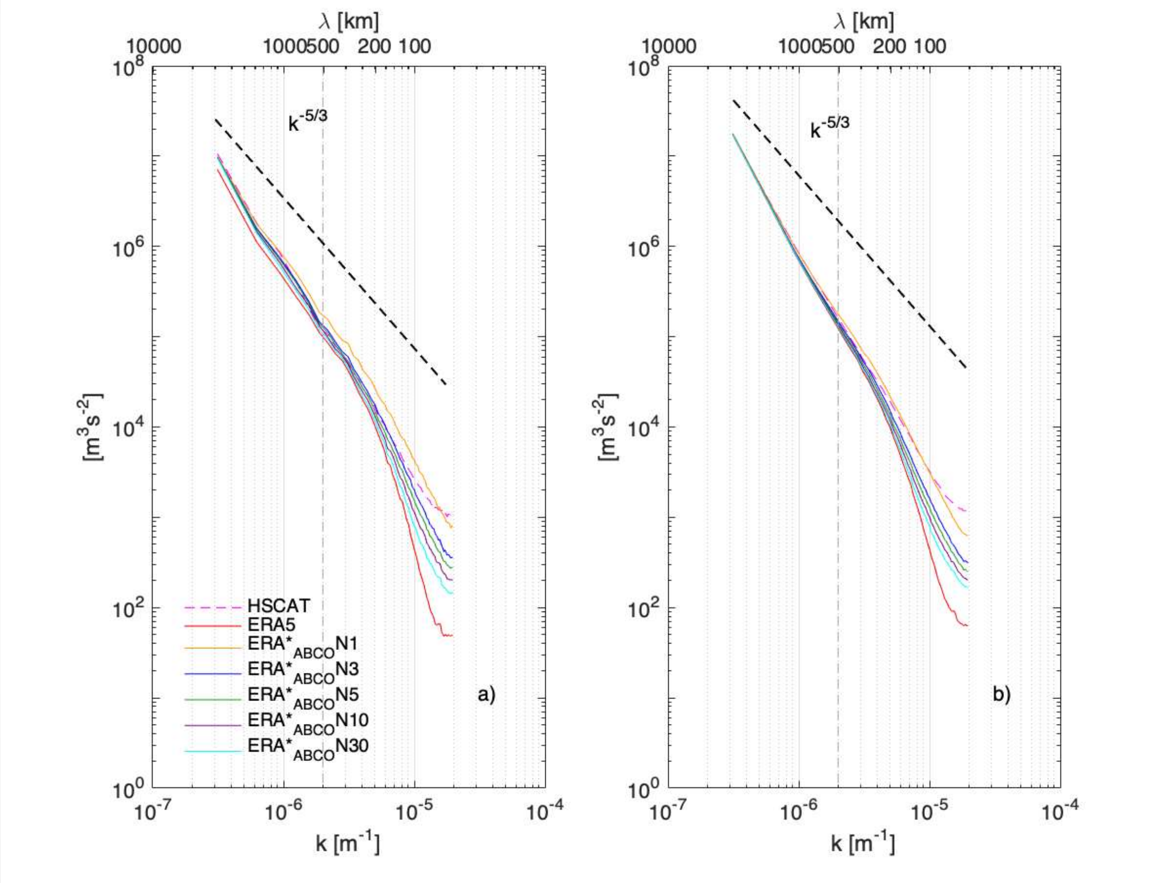
*ERA** PRODUCT VALIDATION: SPECTRAL ANALYSIS

Febuary 2019

Meridional U10S component

ABCO:

ASCAT-A & ASCAT-B & ASCAT-C & OSCAT2



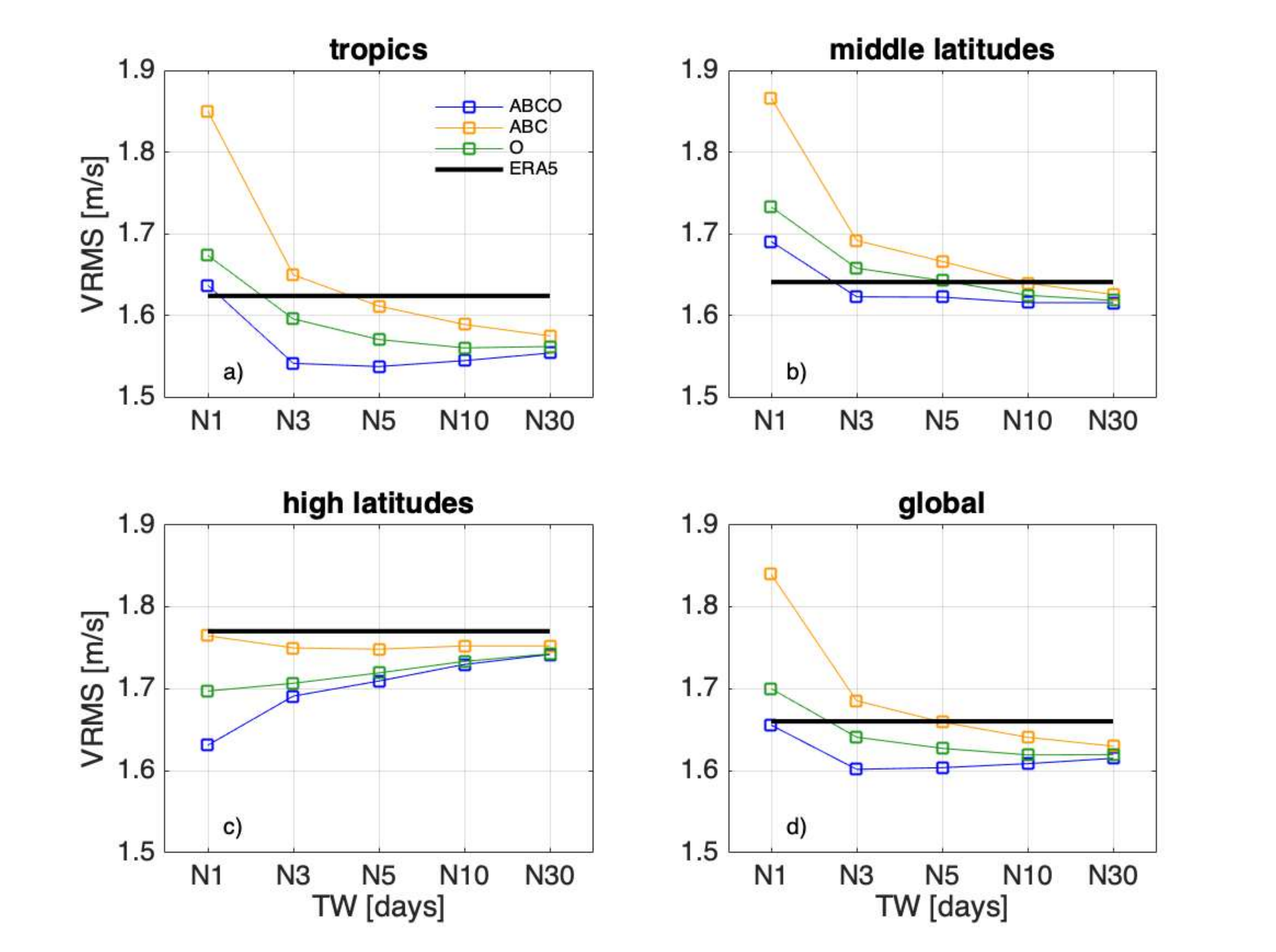
Tropics **Middle Latitudes**

*ERA** PRODUCT VALIDATION: VRMS REDUCTION

Statistics over month of February 2019

Independent verification: HSCAT-B LST (6 am/6 pm)

ERA*ABCO-N3 U10S generally has the lowest VRMS scores against HSCAT-B



Case study: Warm 2017 North Tropical Atlantic event

Sensitivity experiments with the EC-Earth3 model:

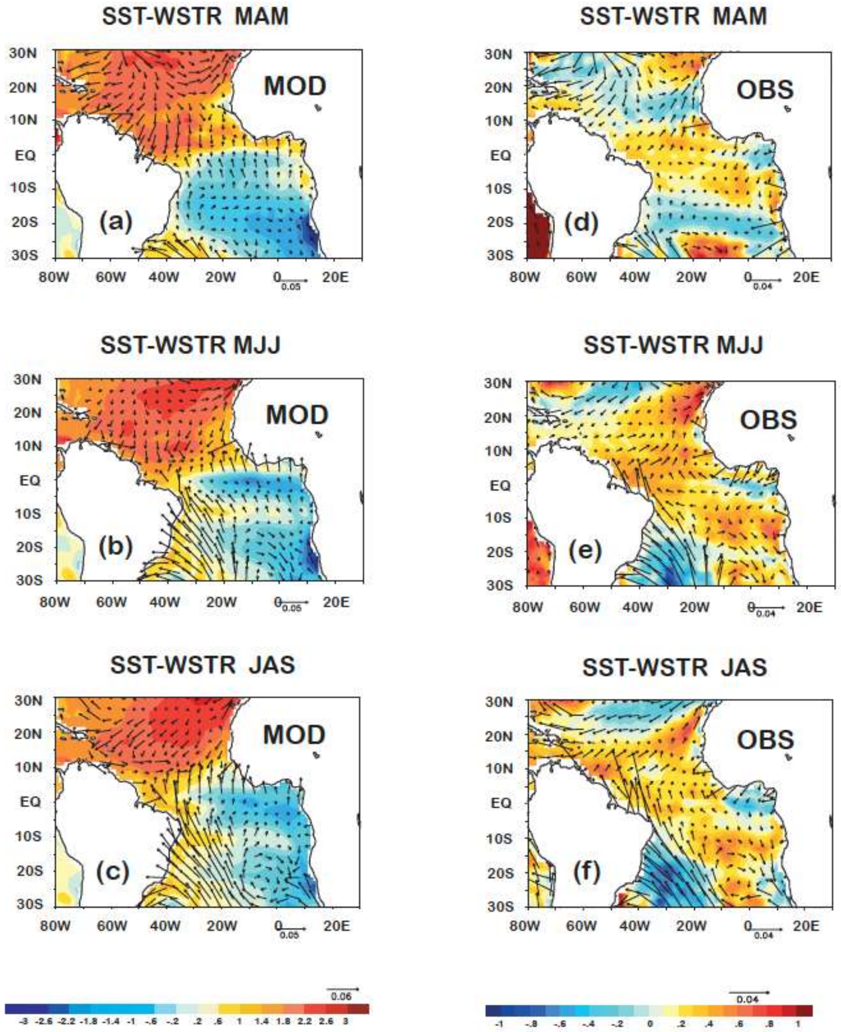
- **MOD:** 11-month initialized forecast simulation from February to December 2017, in which the model wind runs free in the tropical Atlantic region.
- **ERAI**: 11-month forecast simulation forced by wind stress from ERA-interim in the tropical Atlantic region from February to December 2017.
- **ERA*:** 11-month forecast simulation forced by wind stress from ERA* in the tropical Atlantic region from February to December 2017.

Technical specifications:

- ERA* consists of a scatterometer-based correction of ERA-interim, able to introduce true smaller scale signal that corresponds to physical processes absent or misrepresented in the ERA-interim output.
- Forced tropical Atlantic region [35° N-35° S, 70° W-20° E] with 4° buffering zone.
- Initial conditions on the 1st of February of 2017 from ORA-S4 and ERA-interim
- 10 members for each simulation perturbing atmospheric initial conditions

Case study: Warm 2017 North Tropical Atlantic event

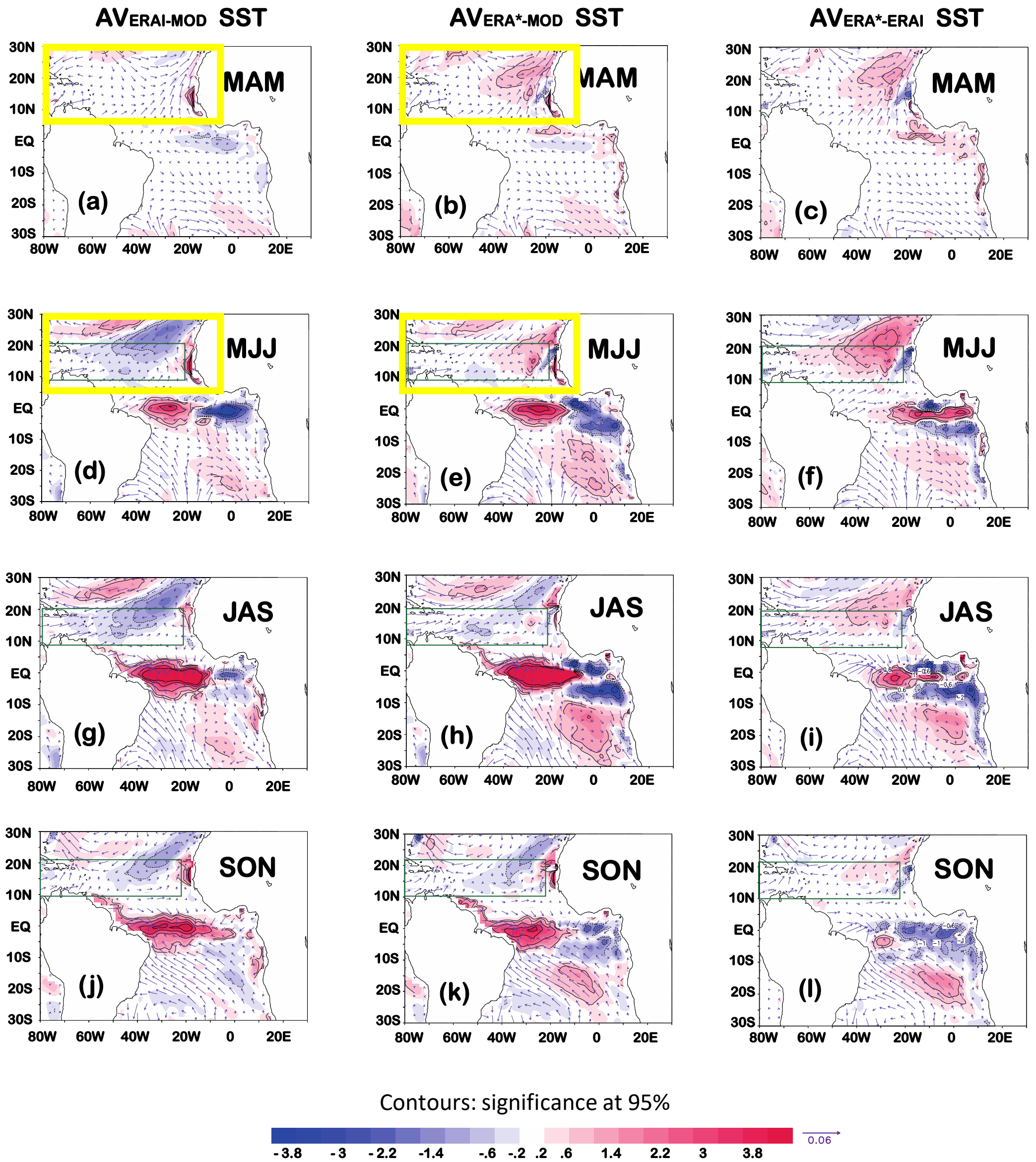
New findings



MOD forecast:

is not able to correctly capture the observed 2017 warm pattern just with initialized conditions.

Case study: Warm 2017 North Tropical Atlantic event



New findings

- ✓ **ERAI and ERA* (vs MOD):** improved SST at eastern NTA and along Senegal coast.
- ✓ **ERA* vs ERAI:** ameliorated representation of off-shore NTA.
- ✓ **ERAI and ERA* (vs MOD) and ERA* vs ERAI:** significant improvement of equatorial 2017 SSTs during summer to fall

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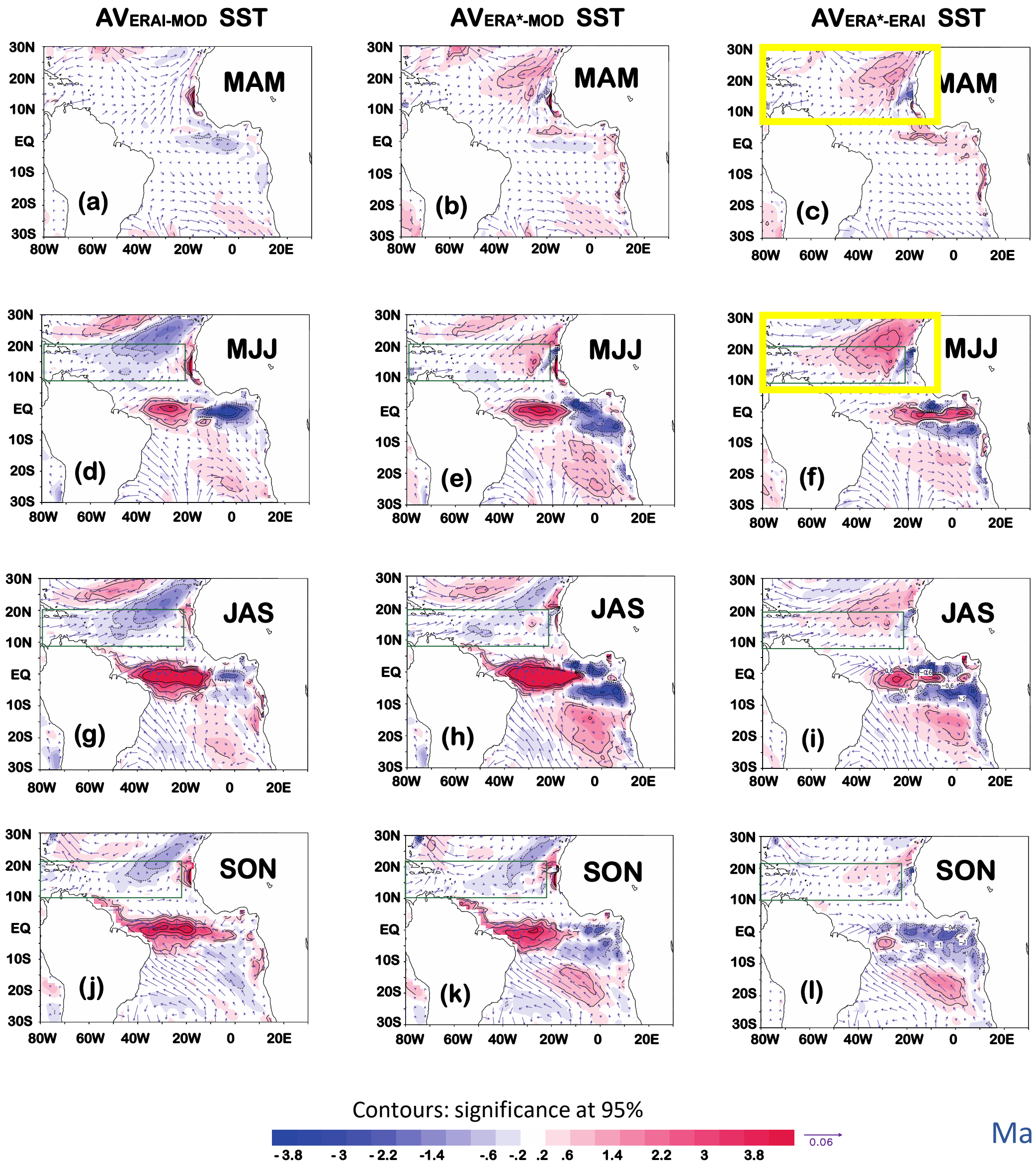

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Martín-Rey et al 2021a, to be submitted

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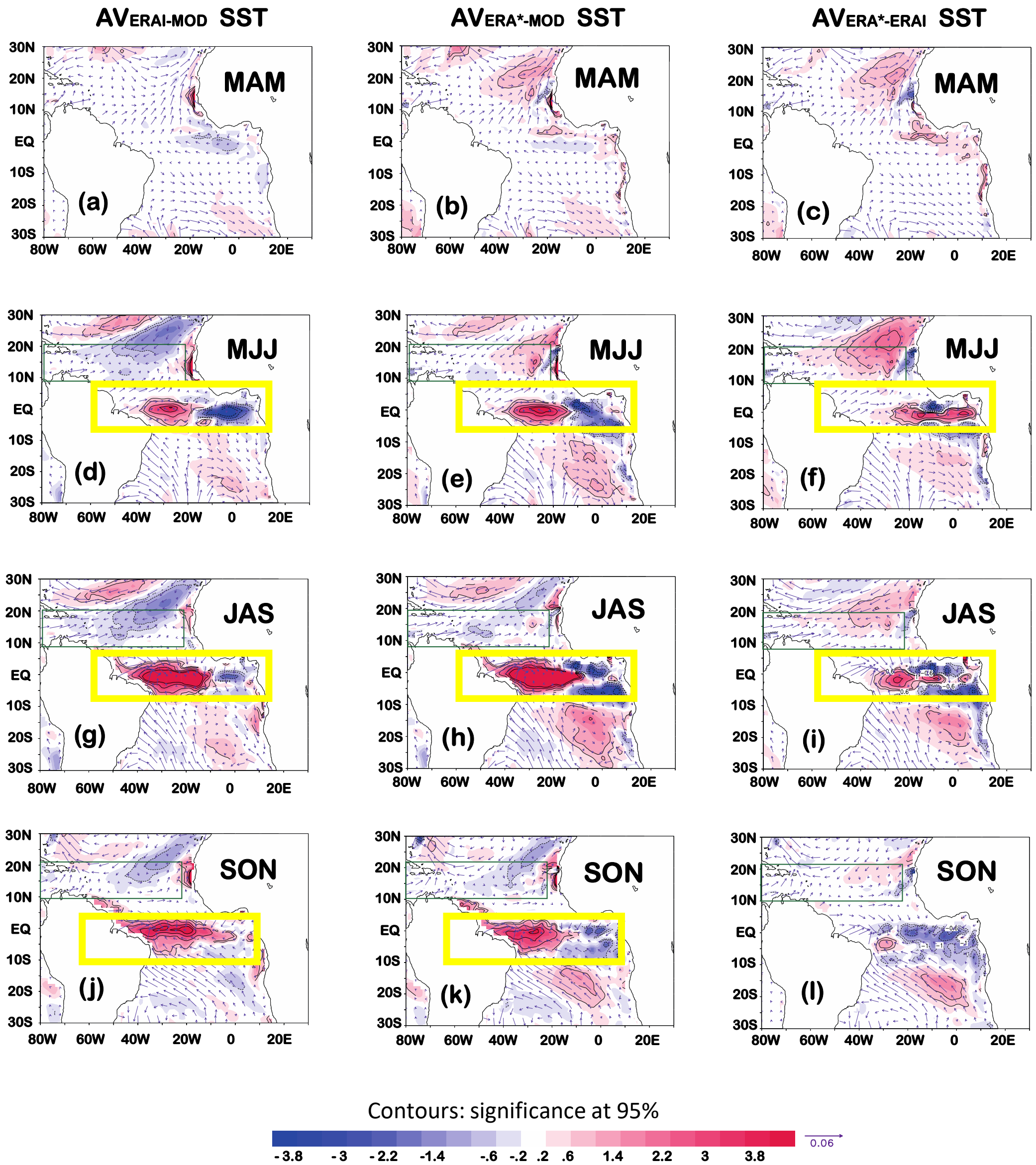

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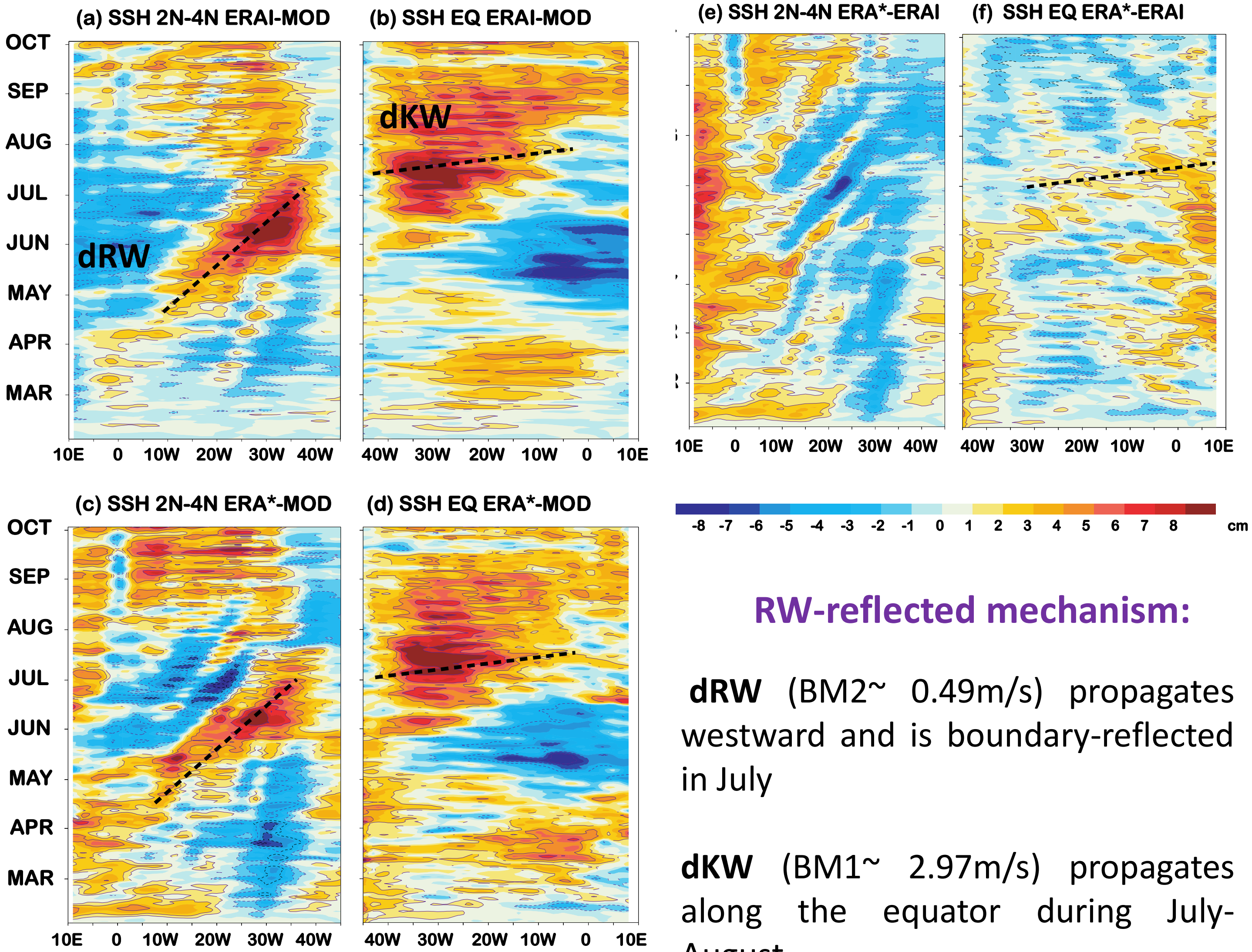


Contours: significance at 95%

RW-reflected mechanism:

dRW (BM2~ 0.49m/s) propagates westward and is boundary-reflected in July

dKW (BM1~ 2.97m/s) propagates along the equator during July-August

- NTA-equatorial linkage in the 2017 event via wind-induced remote ocean waves
- RW-reflected mechanism arises when realistic surface stress is used
- Despite stronger ERA* wind curl, similar dRW w.r.t ERAi
- Enhanced dKW for ERA* experiment w.r.t. ERAi

ERA* product - summary

- Due to the persistence of the ERA5 local biases, it is possible to add smaller scale information, i.e., include some of the physical processes that are missing or misrepresented in ERA5, and still keep the large scale circulation patterns.
- ERA* shows a significant increase in small-scale true wind variability, due to oceanic features such as wind changes over SST gradients and ocean currents.
- Short temporal windows are preferred, to avoid over smoothing of the forcing fields and to address persistence effects.
- From the statistical and spectral analyses, the optimal configuration to introduce the oceanic mesoscale is the use of complementary scatterometers and a temporal window of three days.
- ERA* effectively resolves spatial scales of about 50 km, substantially smaller than those resolved by global NWP output (about 100-150 km).
- Overall, ERA* ABCO 3-day product shows the best performance with a **global error variance reduction of 9.1%** w.r.t. ERA5 U10S performance.

ERA* impact on simulations - 2017 warm event

- During extreme 2017 warm event, NTA and equatorial SST variability were connected.

- Realistic wind stress required to improve the simulation of SSTs in eastern NTA, along Senegalese coast and at the Equator.

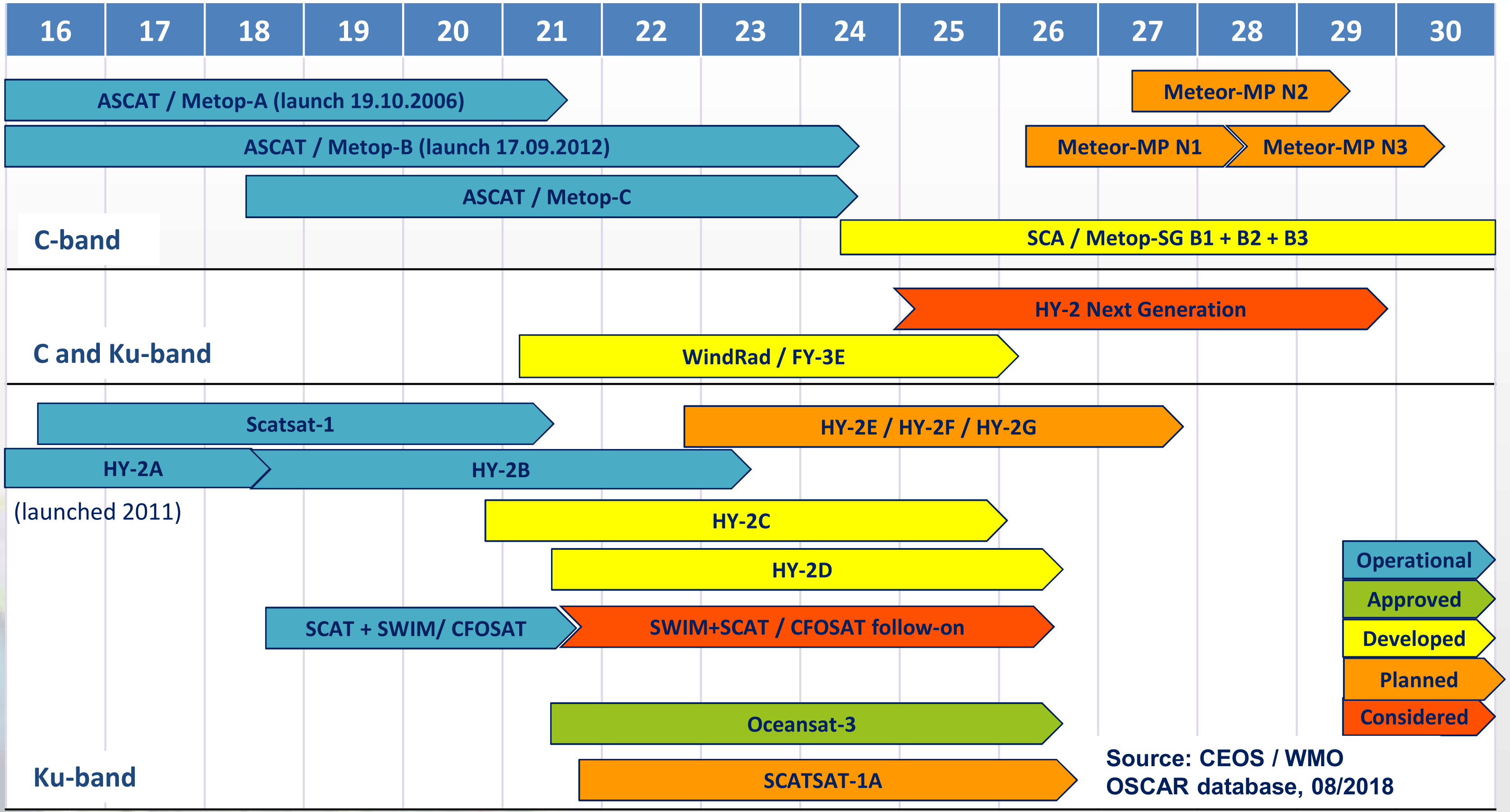
- The ocean wave activity is highly sensitive to realistic wind stress products: only ERAI and ERA* winds are able to reproduce the RW-reflected mechanism linking NTA and EQ regions.

- ERA* does provide an enhanced propagation of the downwelling equatorial Kelvin wave in the boreal summer.

FUTURE WORK

- ERA* developments:
  - Test in ERA* the upcoming OSI SAF OSCAT2 version, with reduced across-track biases
  - Test new scatt-ERA5 outlier rejection strategies
  - Test ERA* quality as a function of scatterometer sampling
  - Verify ERA* (notably ERA*ABC-N3) against buoy U10S
  - Test optimal configuration in the period 2010-2018 to complete the 10-year ERA* dataset (ESA WOC project)
- ERA* impact experiments
  - Test ERA* impact on improved surge prediction capabilities in the Adriatic Sea (in collaboration with ISMAR & NIB)
  - Test new ERA* product on, e.g., ENSO predicting capabilities or stress/SST coupling
  - Test ERA* impact on improved ocean current products in the context of WOC

CEOS OSVW-VC current status and outlook



Note: Near real-time and open data access not assured for all missions listed

Operational = on orbit but does not distinguish between research and operational mission