Impact of multisatellite altimetric missions on the Tropical Atlantic circulation from OSSEs

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Abstract

Observing System Simulation Experiments (OSSE) are performed over the tropical Atlantic domain in order to assess the performances of multi-satellite altimetric missions to control the oceanic circulations in this basin through altimeter data assimilation. A particular interest is given to Tropical Instability Waves (TIW) and North Brazil circulation which are most prominent variability features of the tropical Atlantic, and models have still difficulties to represent it properly.

Various satellite scenarios are investigated, especially the coupled situation of JASON-2 and AltiKa flying simultaneously.

One objective is to estimate how beneficial is the addition of one satellite over a JASON-like satellite.

OSSEs are conducted within the 15° S-17° N Atlantic domain with OPA ocean model and radiative boundaries embedded in a ¼° global model. Data assimilation is performed with the SEEK filter. In the following, we present methodological aspects and results obtained assuming errors are in the model initial conditions.

Observation satellite: A large spectra of temporal and spatial sampling

Satellites with a cycle from 10 days (like Jason) to 35 days are evaluated, as well as the possibility and the benefit of a multi-satellite configuration.

The large range of orbital parameters (from 800km to 1500km, various inclinations..) offers many different sampling in time and space.

In 2009, the beginning of AltiKa mission should allow a two satellite configuration when Jason2 will be flying

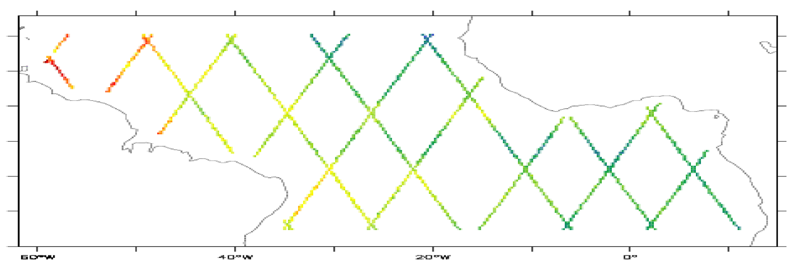


Fig.1: Three days tracks of Jason (units: meter)

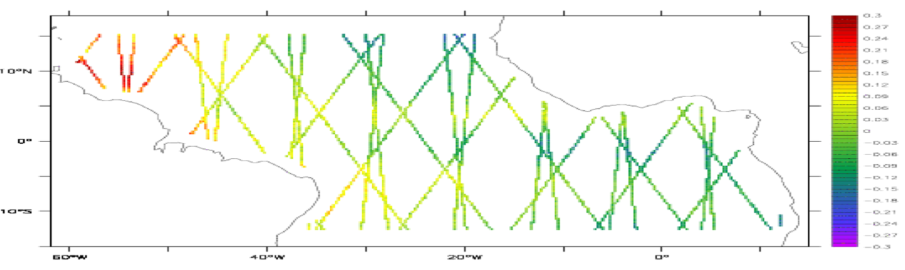


Fig.2: Three days tracks of Jason+AltiKa35days (units: meter)

Sub-cycles:

Track intervals (and direction) of sub-cycle are an important characteristic because ocean dynamic propagates quickly in the tropics.

For example, on a 10 days cycle satellite with h=1300km (fig. 3) we can distinguish three sub-cycle in the first sub-cycle in brawn and the second in purple are represented) . The sub-cycle sampling is about 5° westward for this satellite.

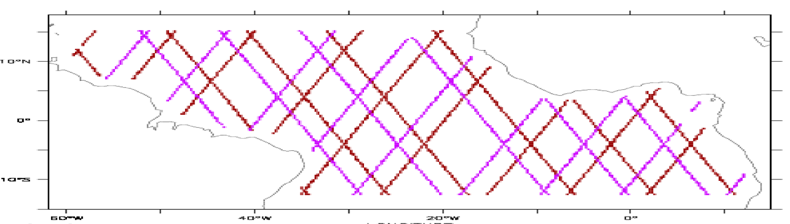


Fig.3: tracks over days 1,2,3 in brawn and tracks over days 4,5,6 in purple.

The comparison with the oceanic dynamic propagation (about 1.5° westward during three days in the equatorial area) is to take into account. Definition of the sampling in reference to dynamic speed can be relevant.

Tropical Atlantic specificities

Numerical models are relatively reliable in tropical regions of Pacific and Indian oceans. By comparison, in the Tropical Atlantic, the correlation between observed and modelled Sea Level Anomaly (fig. 1) is weaker than in other tropical regions.

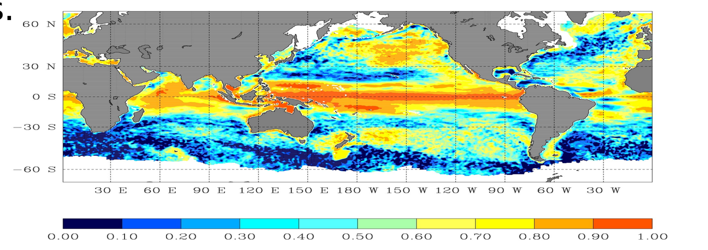


Fig.1: Correlation between 0.25° DRAKKAR simulation and observed SLA on the 1993-2001 period

Indeed, low frequencies (well resolved) are weak and the mesoscale signal (with Tropical Instability Waves as example) is dominant. This dynamic is very sensitive to fluxes and especially winds fluxes, which errors are significant. That is why data assimilation in Tropical Atlantic is relevant to control the short and meso scale circulation.

It can also be inferred from the model that Sea Level Anomaly and temperature structure at 93m depth are highly correlated (see on fig.2).

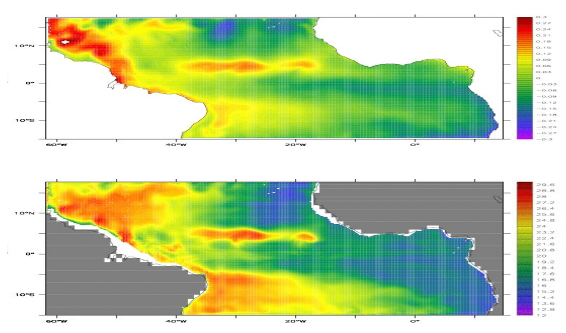


Fig.2: Snapshot of SLA (meter) and Temperature (°C) at 93m depth. From opa9-tatl4 configuration

Particular zones of interest: An active dynamic is seen along the West coast and along equator from 5S to 5N. Those two regions appear clearly on the Turbulent Kinetic Energy map (fig. 3).

- Tropical Instability Waves, from 5S to 5N are generated by barotropic instability of the shear between the Equatorial Under-Current and the Northern South Equatorial Current. Typical scales: ~500km ~10 days. Waves are particularly strong in boreal summer.
- Brasil current instabilities (eddies) are very active all year long. Typical scales: ~200km ~10 days

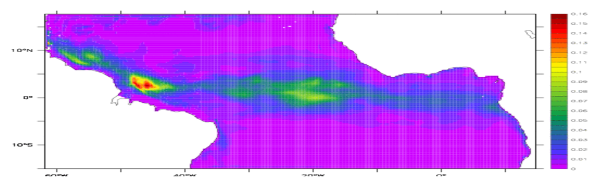


Fig.3: Turbulent Kinetic Energy from opa9 configuration averaged during the three summer months

The model and the assimilation system

A regional model in the DRAKKAR configuration

A regional configuration of OPA9 has been built.

CORE fluxes are used with a 24 hours frequency for winds, short and long wave radiation.

Boundaries are radiative, using DRAKKAR climatological data.

The resolution is ¼°, allowing the TIW dynamic resolution and a good representation of North Brazil eddies.

A successful validation has been made between the DRAKKAR and the regional model simulation in the same conditions.

A spin-up as been realised to simulate a particular year : The first initial condition is the DRAKKAR state after 10 years of a climatological fluxes run (with a realistic variability). Then, inter-annual CORE fluxes are used from 1999 and the run study begins in 2000.

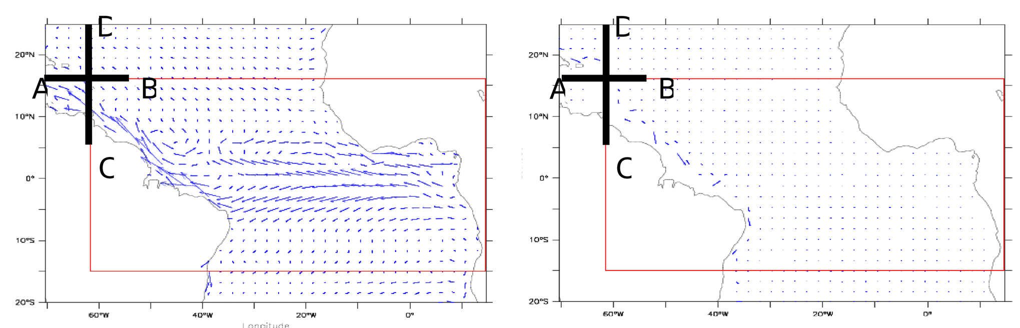


Fig.1: Annual mean velocity at surface (left) and 1655m depth (right) in the 0.25° DRAKKAR simulation

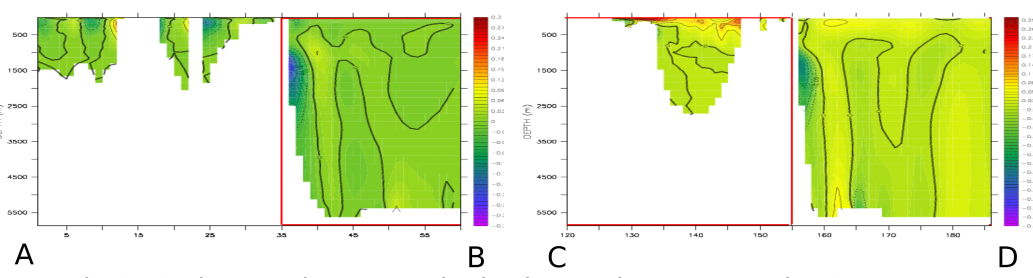
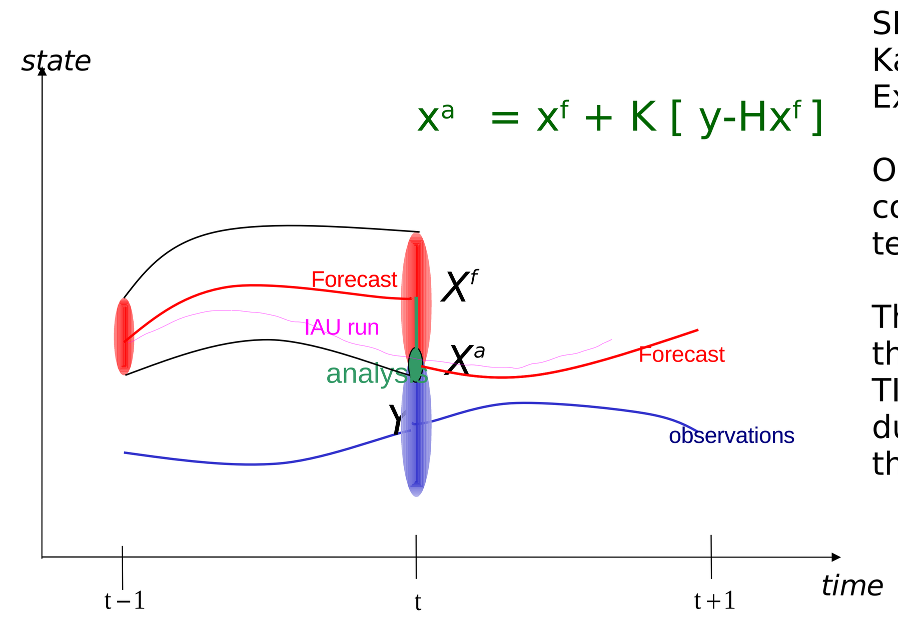


Fig.2: Orthogonal mean velocity in sections A-B and B-C represented fig. 1

The domain has been chosen to simulate both the tropical dynamic (very active from 7°S to 10°N) and the North Brazil eddies.

On fig.1 and fig.2, the red rectangle symbolises the domain. Antigua island (Caraïbes) separates the western and northern boundaries, so that the North Brazil Current crosses the eastern boundary and the deep western current crosses the northern one.

The SEEK filter



SLA is assimilated with a reduced order Kalman filter (SEEK, Singular Evolutive Extended Kalman filter).

Observations are Sea Level Anomalies. The control vector includes velocity, temperature and salinity.

The assimilation cycle length is as short as three days because dynamic time scales of TIWs and eddies are short. Observations during the cycle are gathered at the end of the third day to perform the analysis step.

As for any data assimilation method, a key aspect is the definition of covariance errors. A current process is to use a free run covariance to compute an EOF basis used for error reduction. The 15 first modes are kept.

To prevent discontinuities due to assimilation cycles, the innovation vector is incremented every time step in a second model run. (Incremental Analysis Update method)

The OSSE context

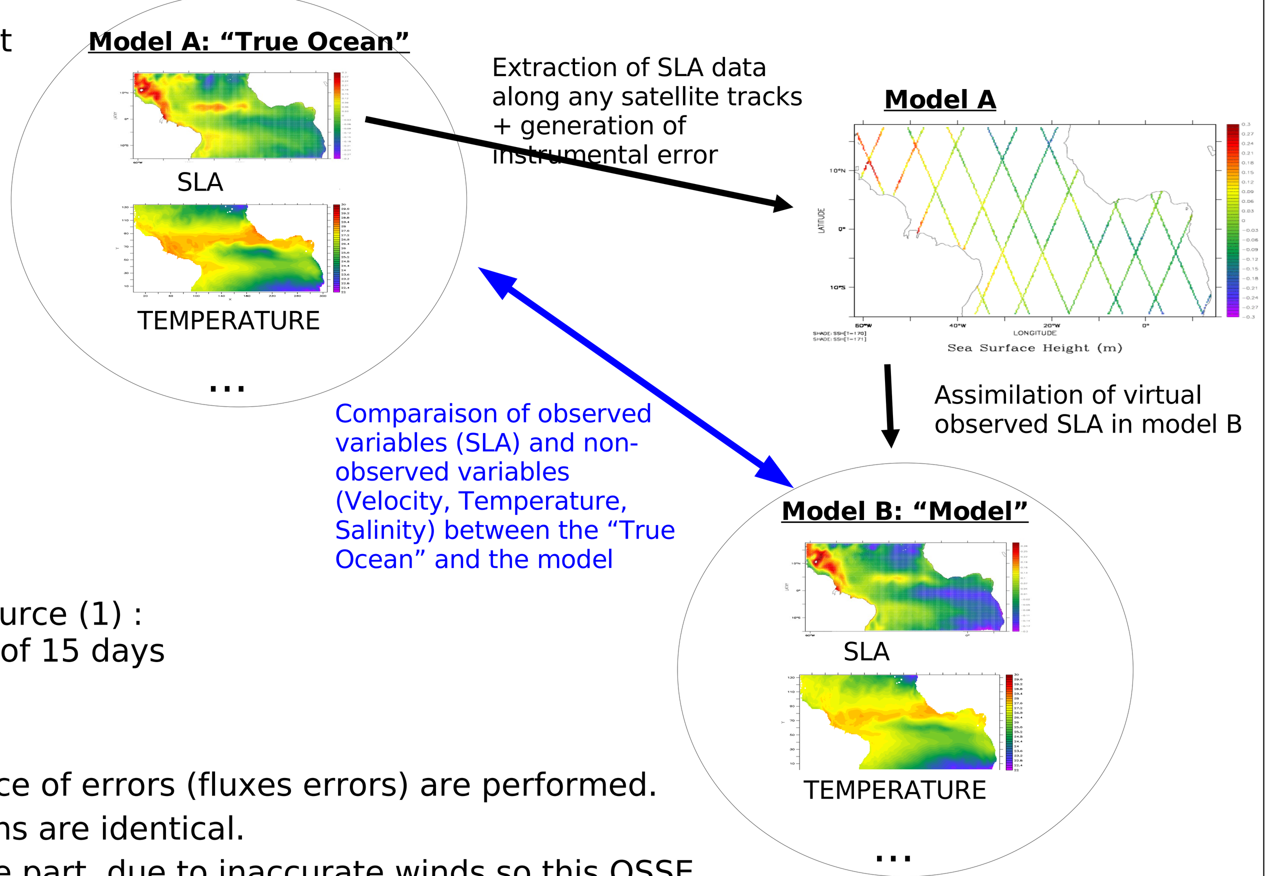
- **OSSEs generalities**

The basis principle is to consider two models (Model A and B on fig.1). The first is considered as the "true ocean", and allow to generate virtual observations: A program extracts SLA data along any satellite tracks. It is then assimilated in model B, considered as the "false ocean", and corrections are compared to the "true ocean".

Errors between "true ocean" and "model":
The most realistic OSSE would consist in building a false ocean model with errors that are statistically the same as real errors from ocean models.
Errors sources for models are principally (1) bad initial conditions, (2) fluxes errors, (3) representativity errors, (4) parametrization errors and (5) Errors in the model dynamics.

- **Experiment context**

A first OSSE experiment is performed with source (1) : it consists in a time delayed initial condition of 15 days (typical time scale of TIWs).



- **Ongoing work**: OSSEs with the second source of errors (fluxes errors) are performed.

Wind fluxes are perturbed and Initial conditions are identical.

Indeed, errors in tropical models are, in a large part, due to inaccurate winds so this OSSE configuration is more realistic. But covariance errors are difficult to estimate.

- **Limitations of OSSEs**: Error structures are anyway simplified from reality. We must keep in mind that conclusions about the quantity and sampling of SLA observations necessary to control oceanic circulation are only valid for the errors simulated in the false ocean.

Experiment strategy and first results

- **Strategy**

Various scenarios are compared. Three cycle lengths are tested for AltiKa: 35 days, 17.5 days and 10 days. The experiment is performed during the three summer months (development of TIWs).

A run with assimilation of the whole SLA cover (without extraction along tracks) is performed. All SLA data are observed: It shows the optimal limit of correction (See the red curve on fig.1)

Different metrics:

- Rms error (global, regional, function of depth) for all variables
- TIW phasing: control of TIW speed, position of vortices ...
- Integrated variables: Meridian heat transport, Turbulent Kinetic Energy ...

- **Results**

- Statistical diagnostics: The reduction of error with one satellite (Jason or AltiKa) is significant, but adding a second satellite only reduces weakly rms errors in the equatorial region. Globally, one satellite controls almost 70% of the rms error that can be controlled with full SLA (red curve on fig.1), and two satellites control only 75%. That figures are almost the same for all variables, see fig. 3 for temperature).

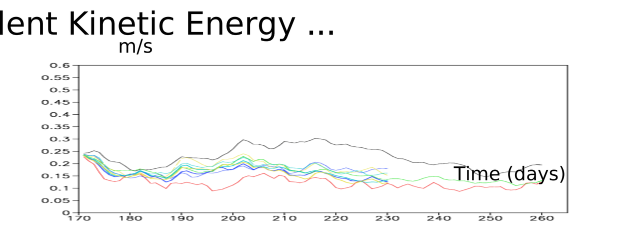


Fig.1: rms error of zonal velocity in the mixed layer over June and July. Merged in the TIW zone from 5S to 5N. Black: free-run, dark blue: Jason+AltiKa35days, red: full SSH

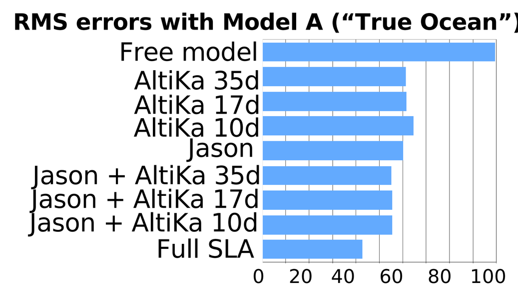


Fig.2: Percentage of temperature rms error for various scenarios compared to the "free run" error. Merged in the TIW zone

- TIW phasing

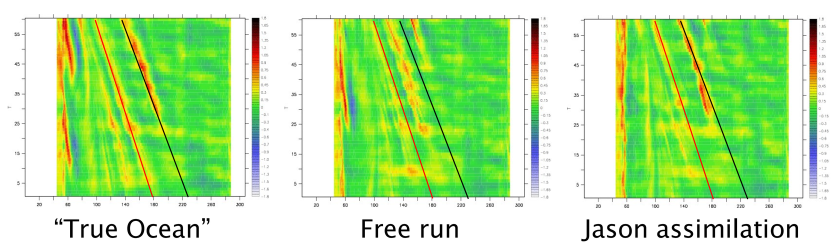


Fig.3: Hovmüllers of meridional velocity showing TIWs propagation

One satellite as Jason can put TIWs in phase. Addition of a second satellite is required to control EKE (not shown).

Conclusions

Preliminary OSSE experiments in the Tropical Atlantic Ocean with a special emphasis on equatorial dynamic shows:

- With one satellite: The data assimilation reduction error is about 40%. Jason is, in most situations, slightly better than an AltiKa 35days and an AltiKa 17days.
- With two satellites: Any satellite added to Jason gives approximately the same results. The additional data assimilation reduction error is hardly more than 5%. However, the Eddy Kinetic Energy is improved.

Specifically TIWs control shows that:

- Any single satellite can re-phase TIWs properly.
- But two satellites are required to control precisely the corresponding EKE.