A study of the fine-scale dynamics in the North-Western Mediterranean Sea using altimetry, in-situ data and a high resolution regional model

A. Carret[1], F. Birol[1], C. Estournel[2]
1. LEGOS-OMP, Toulouse ; 2. LA-OMP, Toulouse

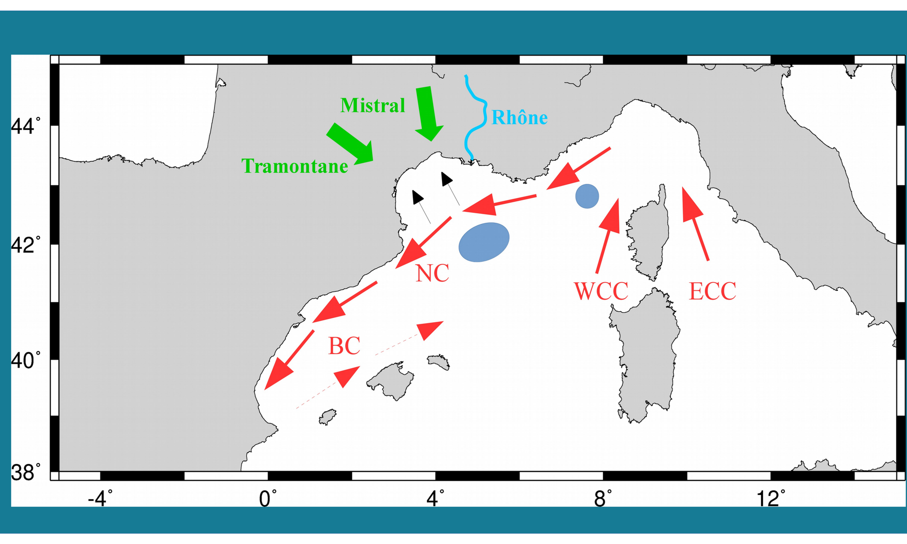
1. Data and region

North-Western Mediterranean Sea :

- Slope current : the Northern Current → velocity: ~ 0.3 m/s in summer, 0.6 m/s in winter ; width: ~ 35-50 km in summer, ~ 20-30 km in winter [2, 3]
- Fine scale structures difficult to monitor

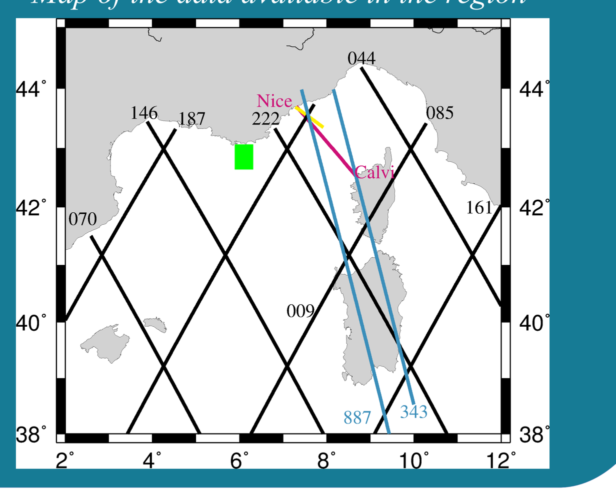
Main currents :
NC = Northern Current
BC = Balearic Current
WCC = Western Corsica Current
ECC = Eastern Corsica Current

Coastal intrusion
Winds regime
Convective area



- First step: to recover the data in the region and to make them consistent between each other
  HF radars: 05/2012 – 09/2014 (daily data)
  Gliders: 2010-2016 (173 transects)
  hull-mounted ADCP data: 2010-2016 (101 transects)
  Jason 2 altimetry: 2008-2015 (every 10 days)
  Saral altimetry : 2013-2016(every 35 days)
- A 3D ocean circulation model developped at the Laboratoire d'Aérologie: The Symphonie model [1] → curvilinear Arakawa C-grid with a kilometric resolution in open sea and a finer resolution near the coast
  Period of the simulation used: 12/06/2011 – 28/04/2015

Map of the data available in the region



2. Motivations

- To analyse how altimetry can capture the NC variability and to quantify the progress made thanks to new technologies
- To study the variability of fine-scale structures (here the Northern Current), using the complementarity of data and the model
- To discuss the contribution of each type of data, especially the altimetry new technologies and to take advantage of long and regular altimetry time series

3. Methodology

In this study, we focused on the Northern Current derived from each dataset. Each of them is processed through different steps to give (as far as possible) coherent information in terms of current variability.

- ADCP: absolute currents (geostrophy, wind-driven,...) from 0 to ~ 200 m
- HF radars: absolute surface currents
- Gliders : temperature and salinity
- Satellite altimetry : sea level anomalies
- Symphonie simulation : 4D fields

→ Outliers removal, filtering (all data)
→ Addition of corrections, of the Mean Dynamic Topography (altimetry)
→ Computation of geostrophic velocities(glider, altimetry)
→ Spatial and temporal colocalisation with observation data (Symphonie)
→ Projections (ADCP, gliders)

- Gliders : geostrophic currents referenced to 1000m
- Satellite altimetry : surface geostrophic currents
- ADCP and radars : absolute currents
- Symphonie model : geostrophic and absolute currents

Intercomparisons

Lots of data → how to extract the maximum information about the NC variability and to synthetize it ?

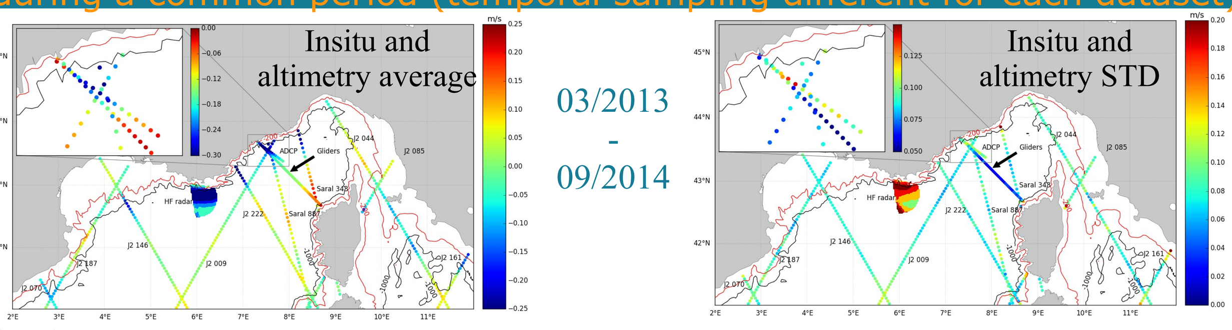
Representation :
- Climatology
- Hovmuller
- Time series
- Maps,...

Parameters Computation :
- Mean
- STD
- Minimum an maximum values, ...

4. Validation of the NC observability

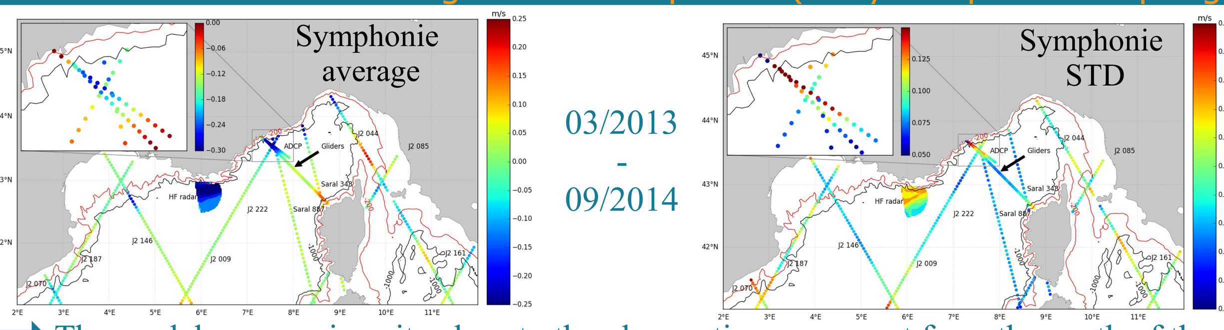
To analyse fine scale dynamics, the representation of the large scale circulation in the model has to be checked. Then the model can be a powerful tool to interpret and fill the spatio-temporal gaps in observations because of its regular sampling and because it will connect the different information.

Representation of the mean and the STD of each observation dataset during a common period (temporal sampling different for each dataset)



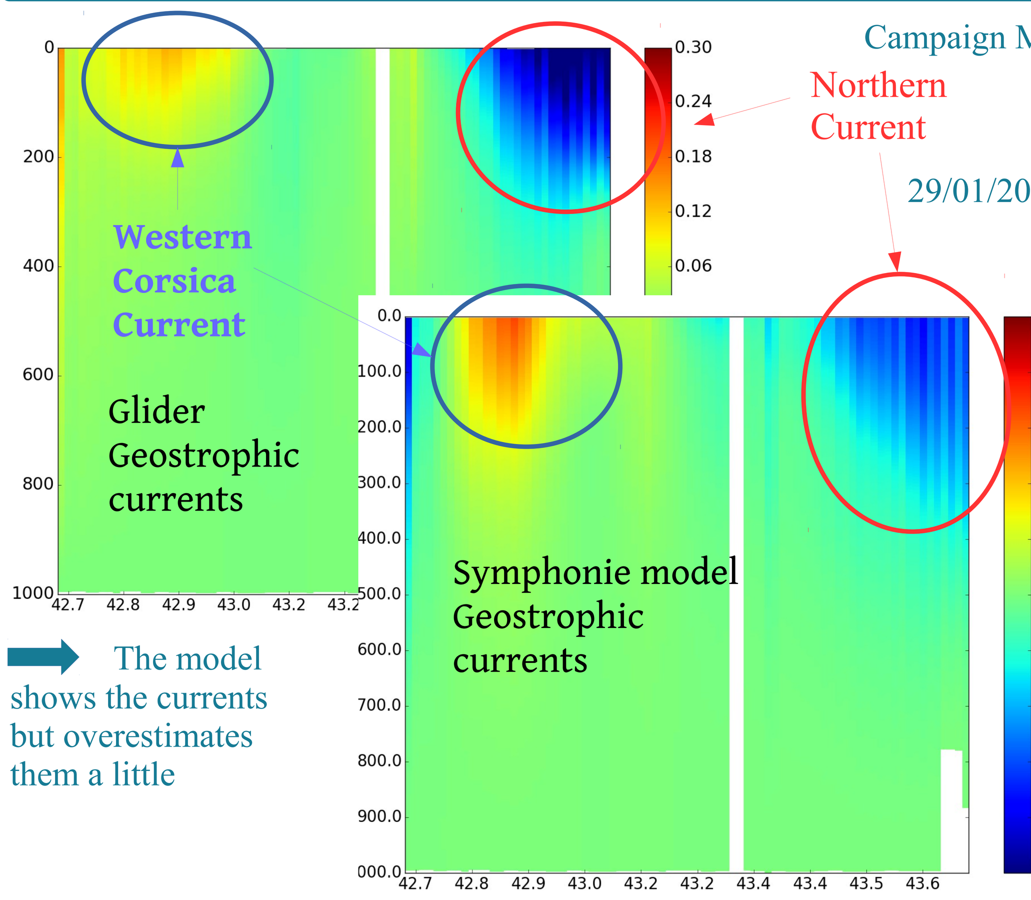
➡ The NC (blue values, denoted a westward current) is represented by each dataset. The mean shows its continuity and the coherence between data. The variability highly depends on the instrument.

Representation of the mean and the STD of the model interpolated on the observation data during a common period (daily temporal sampling)



➡ The model average is quite close to the observation one, apart from the south of the region covered by radars and northern Corsica. The variability map shows more differences → this helps to understand what can be missed due to temporal sampling for example.

Comparison of geostrophic velocities between the gliders and the model



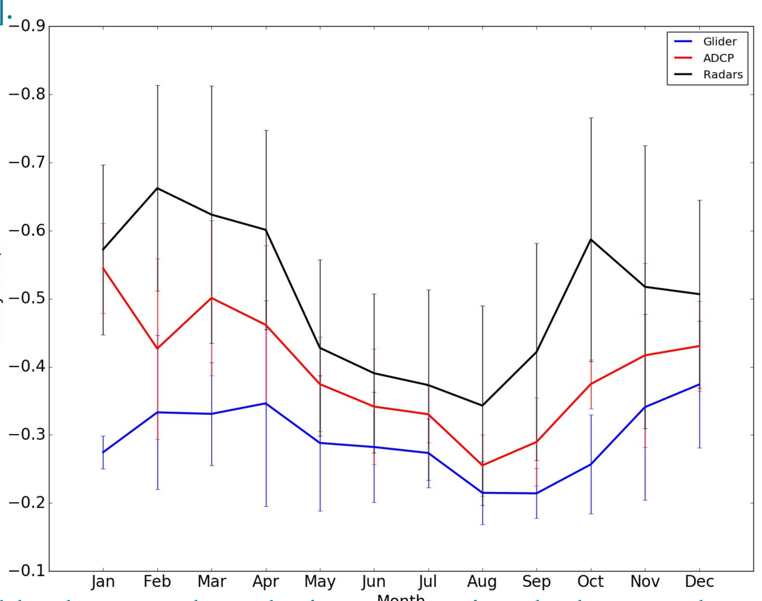
➡ The model shows the currents but overestimates them a little

Climatologies of the amplitude of the NC seen by insitu data

Long time series → computation of climatologies (from 2010 to 2016) to be compared with the literature results [2], [3].

➡ Minimum amplitude always in August - September ; Maximum amplitude in February – March → it is consistent with previous results

➡ Differences due to the physical content :
- Gliders : geostrophic currents
- ADCP : absolute currents
- HF radars : absolute currents but in an other region where the NC is known to be stronger



➡ The Symphonie model leads to good results in representing the large scale circulation and thus enables to go further in understanding fine scale dynamics observed in insitu data

References

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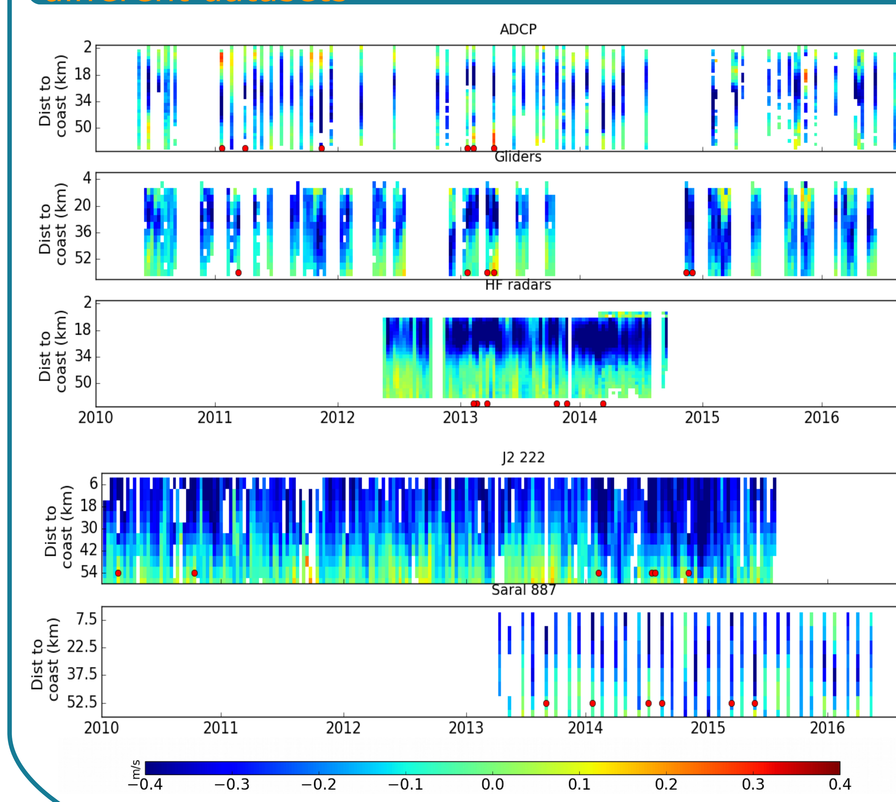
[2] Alberola, C., C. Millot, and J. Font. 1995. On the seasonal and mesoscale variabilities of the Northern Current during the PRIMO-0 experiment in the western Mediterranean-sea.Oceanologica Acta, 18(2):163–192,

[3] Sammari C., C. Millot, and L. Prieur. 1995. Aspects of Seasonal and Mesoscale Variabilities of the Northern Current in the Western Mediterranean-Sea Inferred from the PROLIG-2 and PROS-6 Experiments. Deep-Sea Research Part I-Oceanographic Research Papers,42(6):893–917, https://doi.org/10.1016/0967-0637(95)00031-Z.

5. Results : Complementarity of data

From 2010 to 2016, the NC was observed by a vast panel of data. Some datasets do a regular sampling (altimetry), others present gaps (the gliders). The physical content of these datasets is not the same and they don't always capture totally the NC and thus give us different type of information about the amplitude, position, width of the NC. In addition, the Symphonie model enables to connect the different information.

Time space diagrams of the Northern Current for different datasets



➡ From these time-space diagrams, it is possible to see the highest amplitude values (red dots), to estimate the periods when the NC is the closest or the farthest to the coast and to visualize the data gaps.

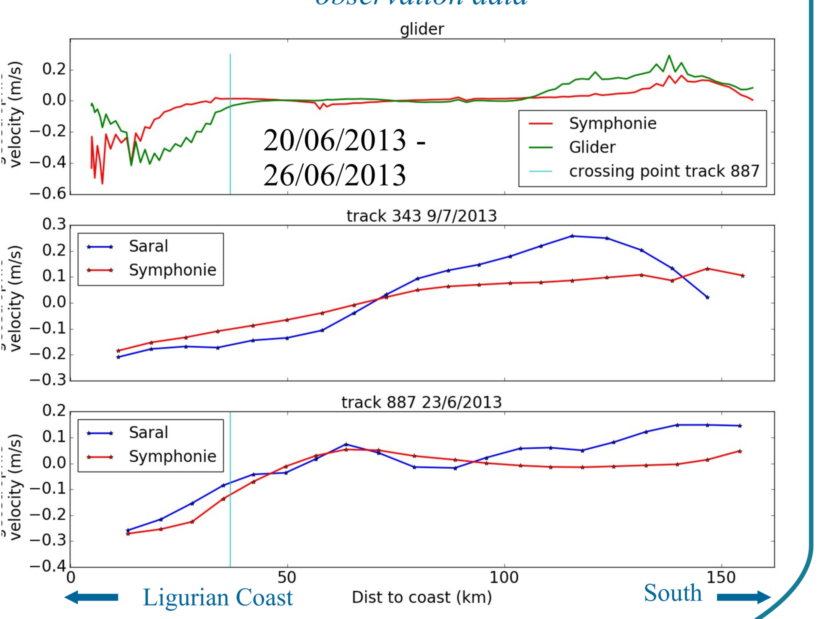
➡ The differences come from the physical content, the resolution, the location, the temporal frequency of each type of instruments, ...

Saral observations capture the NC and are also close to the Symphonie fields, also in good agreement with the glider data ⬅

The different insitu instrument allow to obtain different information on the NC. Altimetry datasets enable to have a synoptic and regular sampling but are not always in agreement with insitu data, even if great progress has been made.

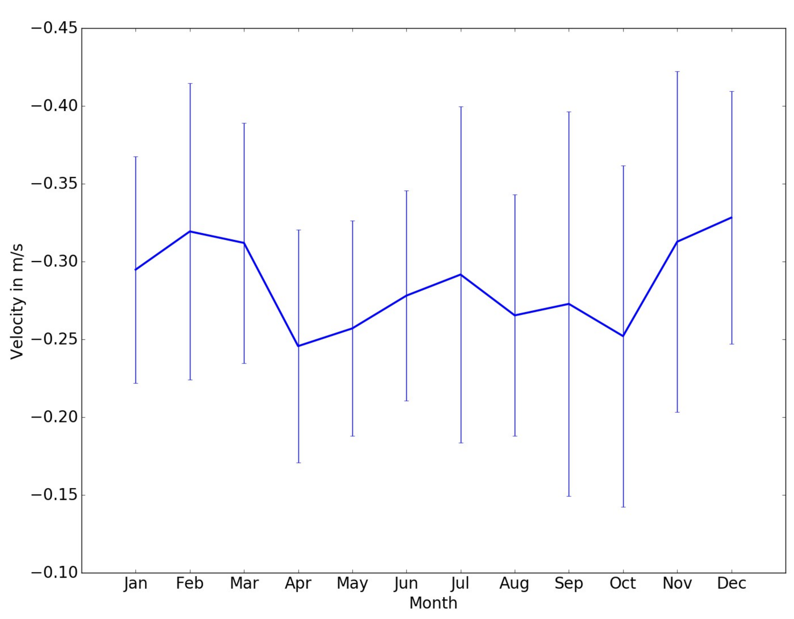
Comparisons of the glider and altimetry geostrophic currents through the model

Comparison of the surface geostrophic currents between the gliders and Symphonie (top) ; Saral track 343 and Symphonie (middle) and Saral track 887 and Symphonie (bottom). Symphonie is taken at the same date than observation data



5. Results : Contribution of altimetry

The Jason 2 mission, launched in 2008, enables to compute a climatology (from 2010 to 2016) of the Northern Current. The differences in amplitude are much smaller than for insitu data but extrema in February and August can be noticed.



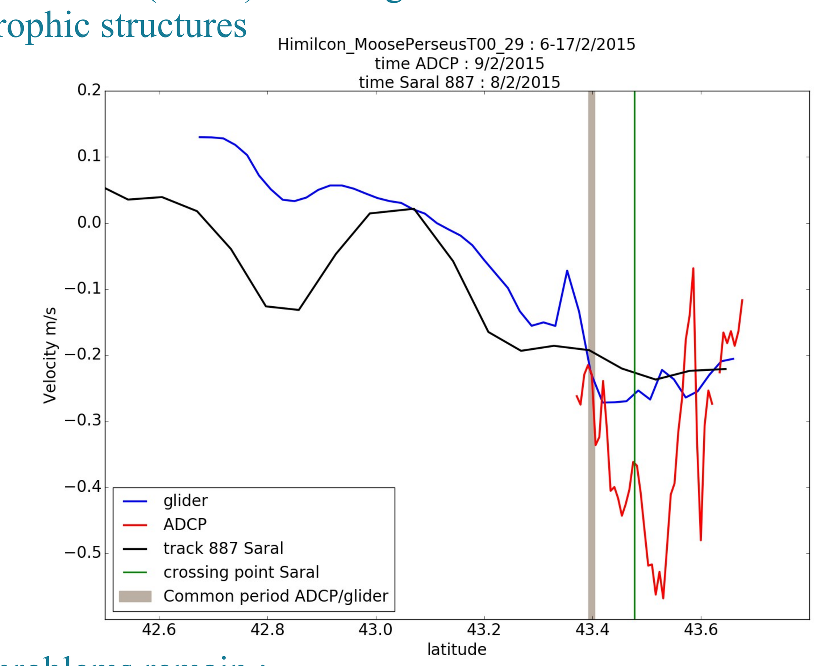
These differences can be explained by different limiting factors in Jason 2 conventionnal altimetry :
- When it is too close to the coast, part of the NC can be missed
- Some points at the end of the track can lead to erroneous data

➡ Existing Jason 2 products are still a bit limited for coastal applications. However, the processing of data has greatly improved. For more information see Fabien Léger's poster.

Saral temporal resolution don't allow to compute a climatology. However, one track (track 887) is very close to insitu data, although it does not capture the NC with the same angle.

➡ For every Saral cycle colocalised in time with insitu data (gliders and ADCP), comparisons are performed. The figure below shows an example for the glider Himilcon from the 6/2/2015 to the 17/2/2015

- Saral currents (in black) agree well with glider currents (in blue).
- The ADCP data (in red) show higher and noisier values → it can be ageostrophic structures



Some problems remain :
- Some corrections can lead to huge variations (for example the wet troposheric correction)
- The temporal colocalisation with insitu data can differ for several days
- The physical content is not the same

➡ The next step will be to perfom comparisons with SST data to investigate the NC variability influence on the difference

Conclusion and perspectives

- The simulation used in the study has been validated with comparisons to observations (insitu and altimetry). It will be useful to study the influence of the resolution of each instrument and to estimate the ratio between geostrophy and ageostrophy components.
- Despite their different physical content, localisation, temporal sampling, all datasets show coherence. The periods with important differences need to be studied to understand the origin of the differences.
- Satellite altimetry shows more and more promising results, thanks to the improvement of the processing and the emergence of new technologies (Ka band, SAR). In the future, recently launched satellites will be studied (Sentinel-3, Jason3)

Acknowledgements

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