GLISEN project : Fine scale structures of an anticyclonic eddy off Cape Verde Peninsula observed from Gliders

N. Kolodziejczyk[1], P. Testor[1], A. Lazar[1], V. Échevin[1], G. Krahmann[2], A. Chaigneau[3], M. Wade[4], S. Faye[4], P. Estrade[4], X. Capet[1], P. Brehmer[5]

Affiliations : [1]Sorbonne University LOCEAN-IPSL, Paris, France/ [2]G EOMAR, Kiel, Germany
[3]IRD, IMARPE, Perù/ [4]LPAOSF, UCAD, Dakar, Sénégal/ [5]IRD, Brest, France

Corresponding author : nicolas Kolodziejczyk, nklod@locean-ipsl.upmc.fr

Introduction

The upper Eastern Tropical North Atlantic (ETNA) is characterized by the Dome of Guinea centered around 10°N-23°W. This region is of importance for climate study because of strong air-sea coupling. This coupling is believed to be active during boreal winter and spring and to control the northward excursion of the Inter-Tropical Convergence Zone during boreal spring and summer (*Doi et al.*, 2010), impacting on the Westeran African Monsoon (*Chang et al.*, 2008). This region is also characterized by Oxygen Minimum Zone (OMZ) and very old water masses (*Karstensen et al.*, 2008; *Brandt et al.*, 2014) observed at shallow and intermediate level (100-800m) within the fresh North Atlantic Central Water (NACW). In spite of zonal tropical jets which transports saline and oxygenated water from western Tropics, in the ETNA the transport of water masses and the supply of dissolved oxygen is supposed to be mainly explained by eddy transport and mixing (*Brandt et al.*, 2014)

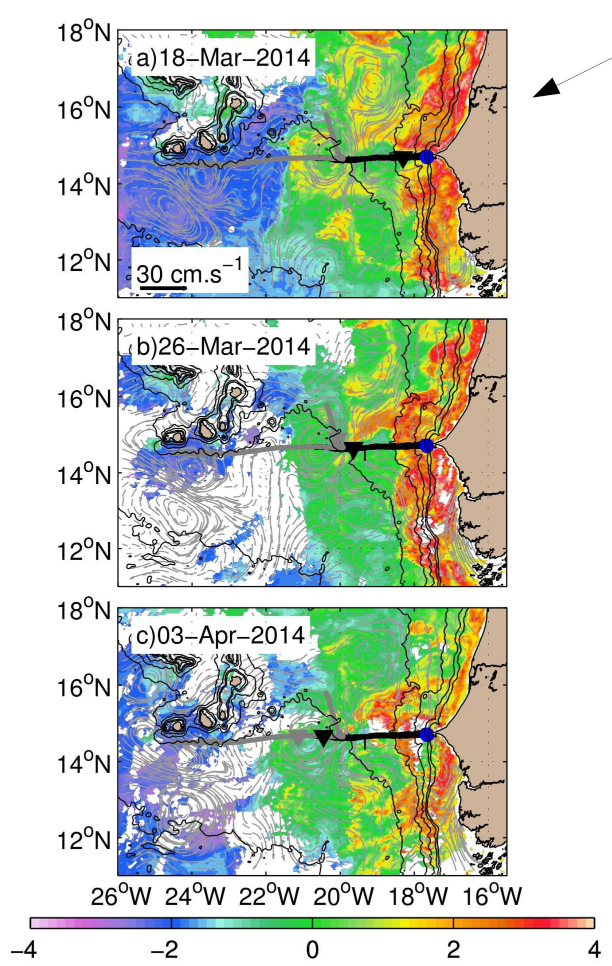
In this study, measurements from a joint French and German Glider transect along 14.7°N between Dakar, Senegal, and the Cape Verde archipelago in ETNA during March-April 2014 are used to investigate the transversal structure of an anticyclonic eddy and hydrological and dynamical associated features.

The GLISEN project (Glider observations off Senegal)

The GLISEN project is led in the framework of PREFACE European project, with the main purpose of documenting the large scale to fine scale circulation off Cape Verde, and to provide a comprehensive description the thermohaline and tracer ventilation processes of the Guinea Dome in the ETNA region.

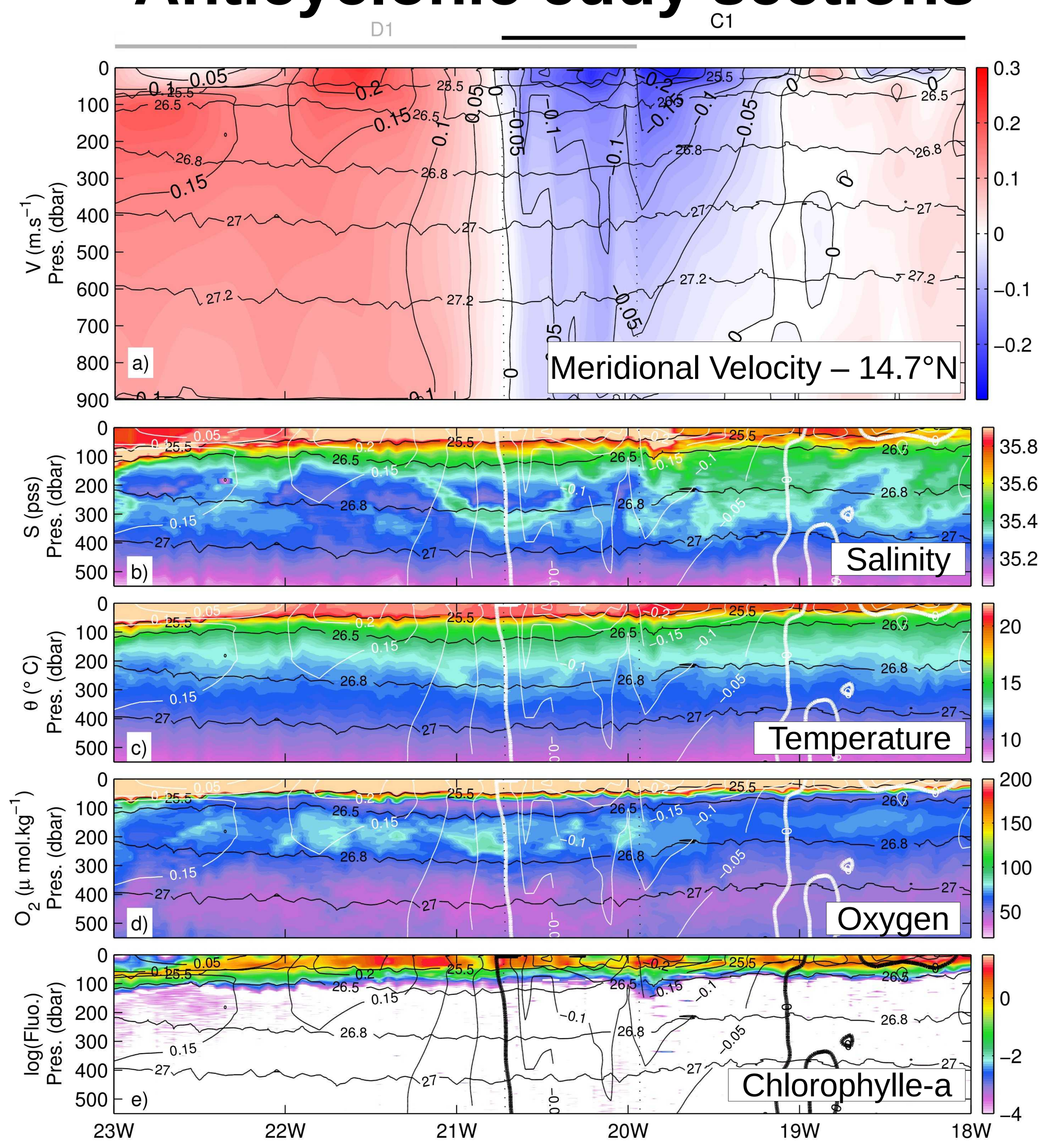
The GLISEN glider campaign was also devoted to enhance the observational data base in still poorly sampled area off West Africa. The GLISEN glider campaign is joint experiment with German GEOMAR glider deployment 21 (see http://www.ego-network.org), and the February-March 2014 IRD AWA campaign devoted to physical and bio-geochimical observations within the the Senegalo-Mauritanian Upwelling System (SMUS).

Gliders provide high resolution 1000 m deep profiles (~1 m x 5 km) of temperature, salinity, oxygen, fluorimetric measurements and integrated velocity along with each profile.



The tracks of both French (black; 2 repeated sections up to 21°W and 2 up to 19°W) and German (gray; 1 sections from 20°W to Cape verde) gliders during the GLISEN campaign in March-May 2014. The position of each glider is indicated by triangles. AVISO surface currents fields (gray arrows) reveals the mesoscale eddy fields. MODIS Chlorophyll-a products reveals the rich surface filamentation features originated from the SMUS. **An anticyclonic eddy (AC) centered around 20.8°W-14.7°N** as been sliced both both gliders along a transect between Dakar/Senegal and Cape Verde Archipelago along 14.7°N.

Anticyclonic eddy sections

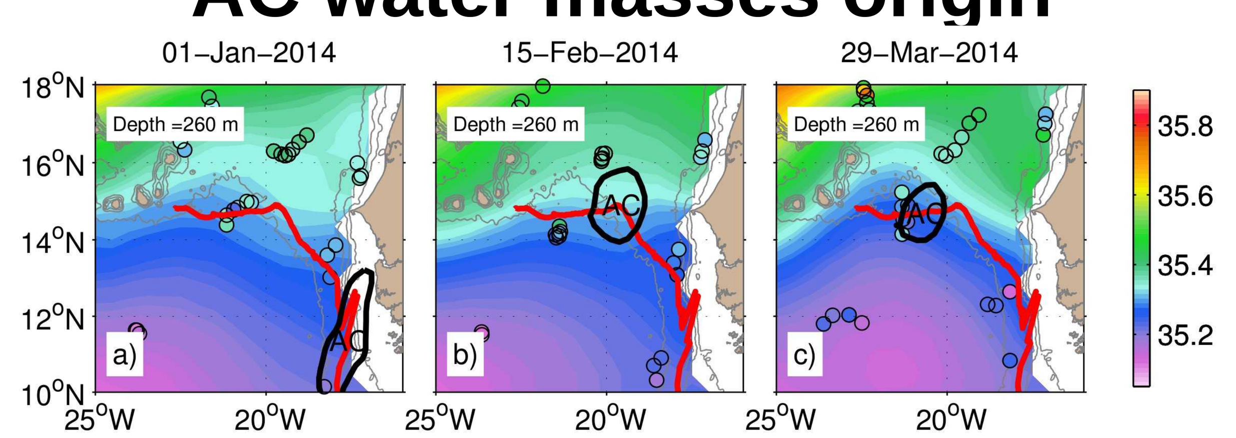


Reconstruction of geostrophic merdional velocities (a) from gliders hydrological measurements and integrated velocities reveals velocities of the order of 0.2-0.3 m.s^{-1} at surface and shallower depth extension of the AC eastern edge.

Around 100-300 m depth, hydrological measurements shows (b-d) a fresher (NACW) but more oxygenated AC core, than surrounding water. At this depth, **remarkable saline (fresher) and low oxygenated (oxygenated) fines scale structure (~20 km) are typically observed within the core of AC**.

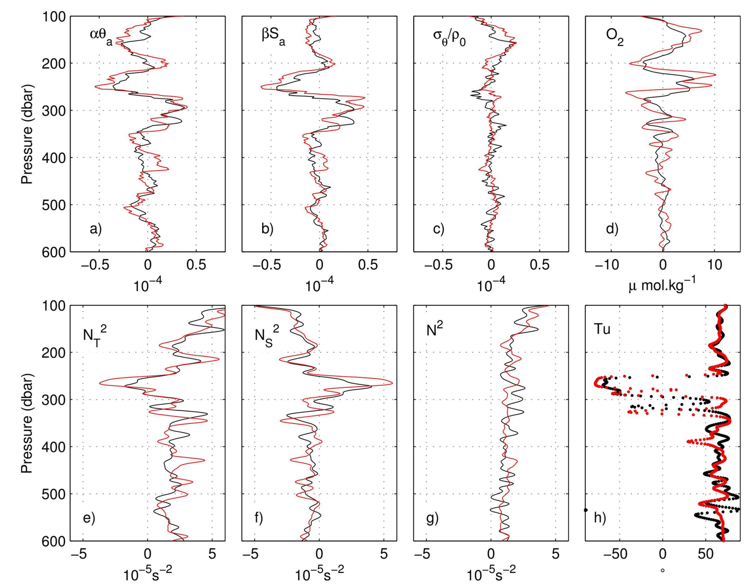
Chlorophyll-a surface distribution (e) is compatible with the MODIS observations (left box), especially the chlorophyll enriched filament associated with salinity and temperature front in surface. This filament shows deep extension down to 150 m depth, likely due to vertical velocities associated with the fonrtal dynamic.

AC water masses origin



Eddy tracking from AVISO fields (red curve; *Chaigneau et al.*, 2008) and Argo salinity measurements (colored circle) and interpolated products (color shading; *Gaillard et al.*, 2009) reveals that **the eddy is originated from southern coastal region (~12°N), transporting low salinity (NACW).** AC trajectory appears to be constrained by topography. Saltier fines scales structures are likely associated with surrounding water masses originated from the north of Cape Verde/Dakar ridge and swirled around the AC.

Fines scale features



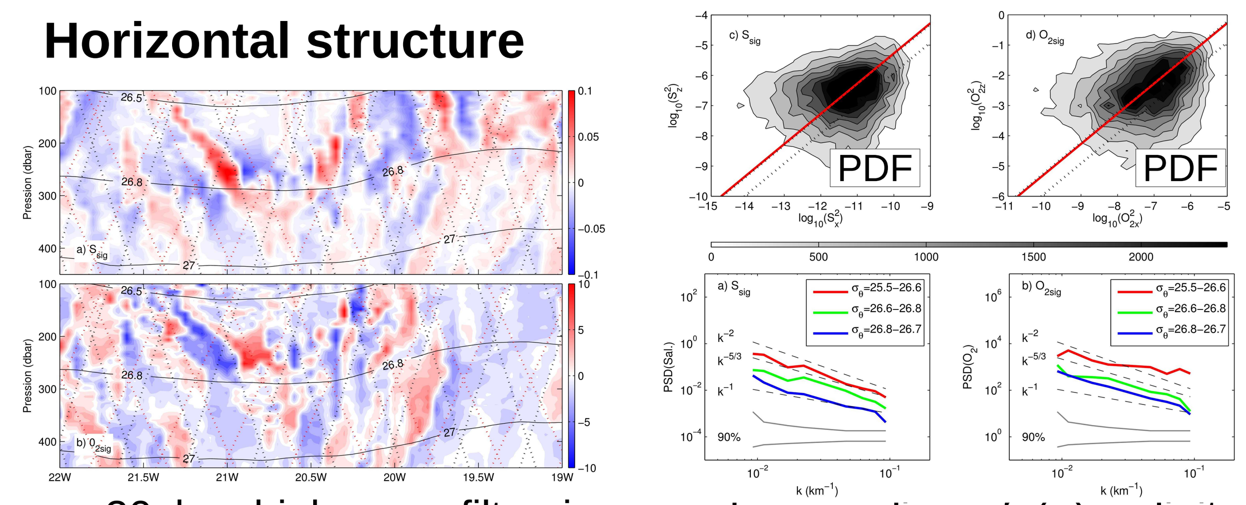
Vertical structure

Vertical Turner angle :

$$Tu_v = \mathrm{atan}\left(\frac{\alpha\,\partial_z\theta + \beta\,\partial_z S}{\alpha\,\partial_z\theta - \beta\,\partial_z S}\right) \quad (1)$$

Vertical profiles (100 m high-pass filtered) taken at the center of AC (20.8°W-14.7°N) shows, below 100 m depth, the vertical structures of temperature (a), salinity (b), density (c) and oxygen (d). 10-to-100 m thick layers and strong correlation (anti-correlation) is observed between temperature and salinity (and oxygen) vertical structures. The decomposition of Brünt-Väisälä frequency (g) into thermal (e) and haline (f) contribution confirms the **vertical density compensation of fine scale layers** associated with high absolute values of vertical Turner angle (1). This suggests passive tracer 'like' behaviors of this fines scales anomalies

Horizontal structure

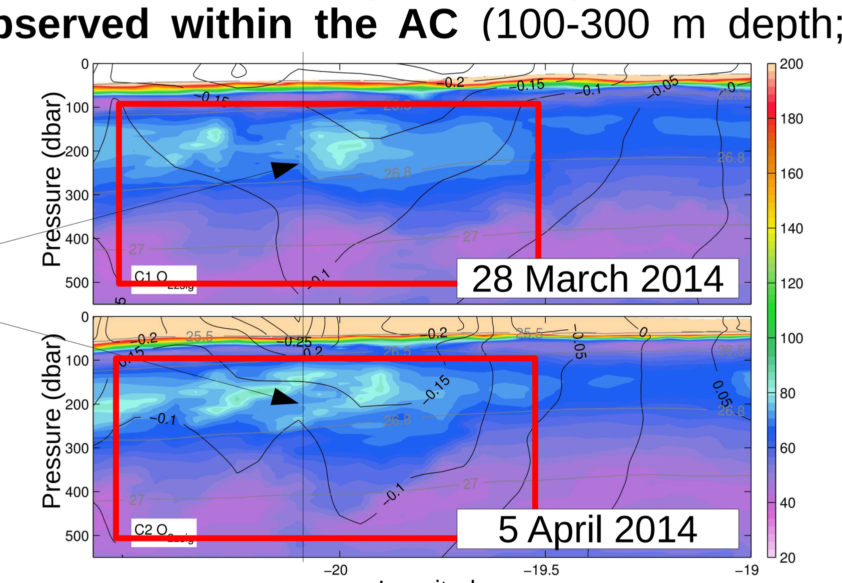


30 km high-pass filter isopycnal anomalies of (a) salinity (spiciness) and (b) oxygen underlines the characteristic horizontal scales of the sloped fine scale structures. Slopes of fine scale structures (red; c and d) are not exactly compatible with the theoretical f/N (dotted black) slope of stirred passive tracer, probably because of background tracer vertical in the lower thermocline gradient (*Smith and Ferrari*, 2009). **Spectra shows up tracer slopes in k$^{-5/3}$-k^{-2} within 100-400 m depth layer** (*Hua et al.*, 2013).

Temporal evolution

From repeated sections of glider on the eastern edge, temporal evolution of tracer (here dissolved oxygen in color shading) can be observed and compared with meridional geostrophic velocities fields (in m.s^{-1}; black contours). **Between 28 March and 5 May 2014 strong slopping fine scales structures are observed within the AC** (100-300 m depth; within red box)

Elapsed time:
8 days



Dynamics of tracer stirring

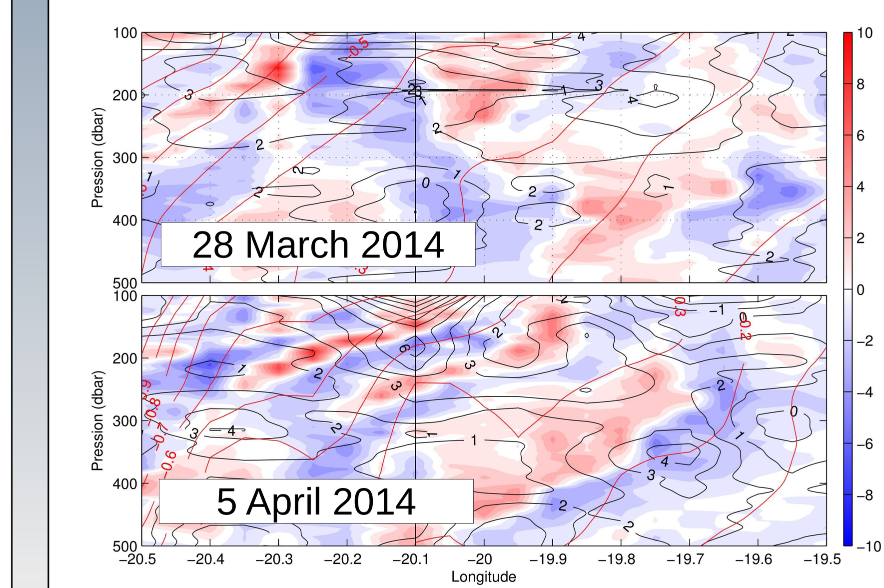
Following *Meunier et al.* (2014), equation of evolution of pure tracer in an eddy velocity fields is:

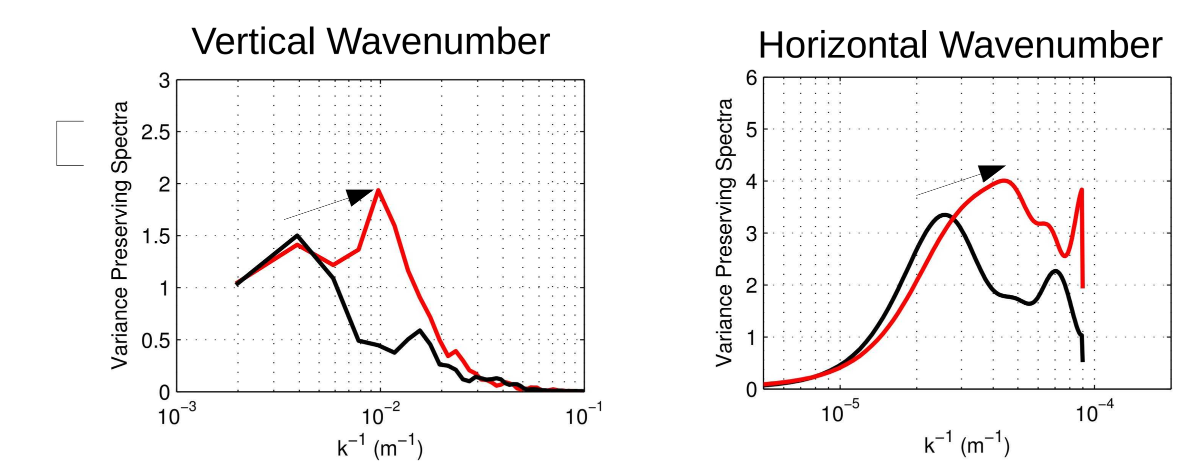
$$\frac{d\gamma}{dt} = -\partial_z \overline{u_\varphi} \quad (2)$$

where $\gamma = k_z/k_\varphi$, the vertical and azimuthal wavelengths of tracer distribution and u_φ the azimuthal velocity.

$$\frac{d\kappa}{dt} = \frac{u_\varphi}{r} - \partial_r \overline{u_\varphi} \quad (3)$$

where $\kappa = k_r/k_\varphi$, the radial and azimuthal wavelengths of tracer distribution and u_φ the azimuthal velocity.





Conclusion

- Evidence of AC coming from coastal-southern ETNA regions transporting, below 100 m depth, fresh (NACW) and oxygenated water masses into saline and low oxygenated water off Senegal and Cape Verde.
- Small scale features surrounding the AC core are evidenced
- Stirring of spice and oxygen tracers is suggested by spatial distribution and temporal evolution of small scale features

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Mailing adress : Nicolas Kolodziejczyk, LOCEAN/IPSL, Université Pierre et Marie Curie, Paris VI, Place Jussieu, 75005 Paris, FRANCE