Subthermocline and intermediate ocean circulation in the Southwest tropical Pacific: Preliminary results of the CASSIOPEE cruise

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Frédéric Marin[1], Sophie Cravatte[1], Enzo Gronchi[1], François Baurand[2], Gérard Eldin[1], Elodie Kestenare[1], Nolwenn Lamande[3]

[1]LEGOS, IRD/CNES/CNRS/UPS, Toulouse [2]US IMAGO, IRD, Brest
[3]LDCM, IFREMER, Brest

Contacts: Frederic.Marin@ird.fr, Sophie.Cravatte@ird.fr

1. Motivation

From the analysis of the drift of Argo floats at their parking depths, Cravatte et al. (2012) have shown the presence of a system of meridionally-alternating intermediate zonal jets at 1000 meters depth in the tropical Pacific (**Fig. 1**). These jets are coherent in longitude at basin scale from 10°S to 10°N, appearing from the western boundary and disappearing in the easternmost part of the basin. They have a typical meridional scale of about 3° in latitude and a stronger amplitude (+/-5cm/s) in the West and south of the Equator.

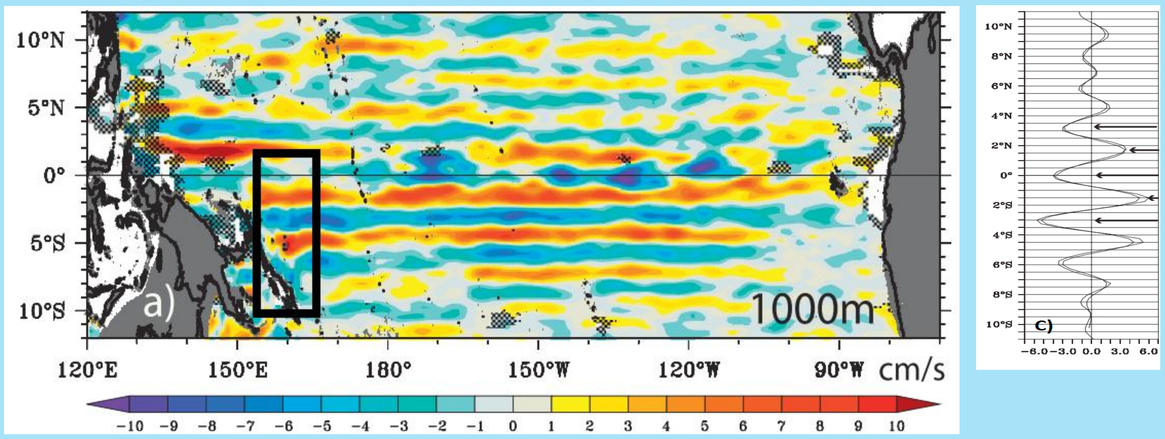

Fig. 1: *Horizontal distribution at 1000m (left) and mean meridional profile between 120°E and 120°W (right) of mean zonal currents estimated from an optimal interpolation of Argo floats drift (Cravatte et al., 2012). Unit is cm.s^{-1}. The rectangle indicates the region of the CASSIOPEE cruise.*

The main objective of the LEFE/IMAGO and LEFE/GMMC ZEBRE projects (2012-2016) was to provide a better description of this system of currents through the combined analysis of in situ observations and numerical simulations.

The main scientific questions are:

- what is the associated vertical structure of the intermediate jets?
- what are the hydrological / biological properties of the water masses they transport?
- do they extend beyond 10°S/10°N? Are they present in the 3 tropical oceans?
- are they permanent or do they vary in time?
- are they correctly represented in numerical simulations?

2. Vertical structure of the mean subthermocline and intermediate zonal jets

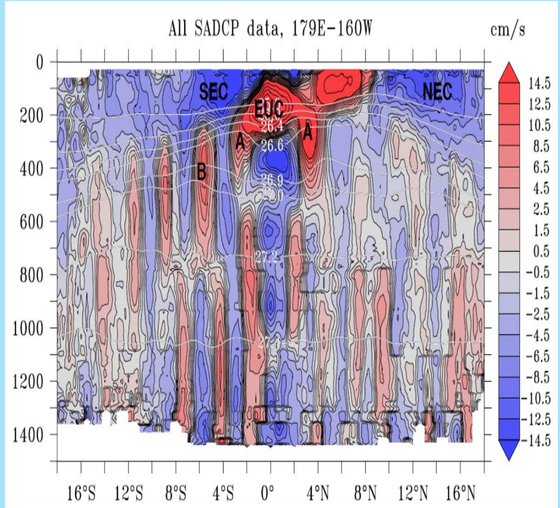

Fig. 2: *Meridional section of mean zonal velocities near 180°, estimated from all available historical-ADCP data etween 179°E and 160°W (Cravatte et al., 2017). Unit is cm.s^{-1}.*

Historical S-ADCP data in the tropical Ocean were compiled to obtain a vertical section of mean zonal currents at 140°W (**Fig.2**). Two independent systems of meridionally-alternating jets are found below the thermocline:

- a system of Low-Latitude Subthermocline Currents (LLSC) extending from the thermocline to about 800m depth, including the eastward-flowing Tsuchiya Jets and Subsurface Countercurrents.
- a system of Low-Latitude Intermediate Currents s (LLIC), encompassing the intermediate zonal jets, extending from 800m to at least 1400m depth.

These two systems are observed from 10°S to 10°N, and seem to merge poleward. They have different meridional scales and appear to be disconnected in the vertical, suggesting they are independent features of the mid-depth tropical circulation.

3. The CASSIOPEE cruise

As part of the ZEBRE projects, the CASSIOPEE cruise took place from 18 July to 24 August 2015 in the South-West Pacific onboard R/V Atalante. The cruise track (**Fig. 3**) was defined to provide a high-resolution (1/3°) meridional section from 10°S to 2°N along 165°E, and 2 additional lower-resolution (1/2°) sections at 157.5°E and 152.5°E to infer the horizontal evolution of the jets near the western boundary.

Besides en route S-ADCP measurements (down to 1100m depth) and the deployment of 7 Argo floats, 71 hydrological stations were carried out during the cruise, providing surface-to-bottom vertical profiles of L-ADCP currents, CTD-O2 properties, nutrients, turbulence (chipods) and biogeochemical properties (Neodyme).

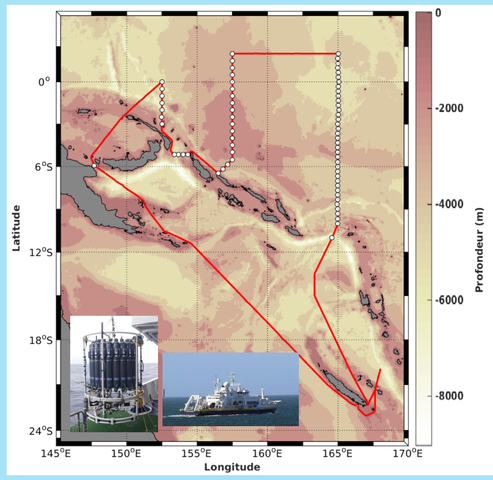

Fig. 3: *Track of the CASSIOPEE cruise. Circles indicate the position of the hydrological stations.*

4. Mid-depth currents observed during CASSIOPEE

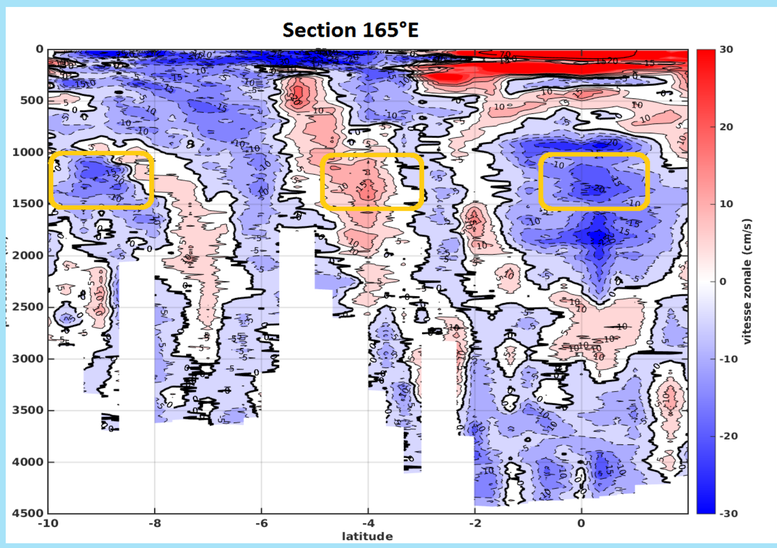

Fig. 4: *Meridional section of L-ADCP zonal velocity at 165°E during the CASSIOPEE cruise. Unit is cm.s^{-1}.*

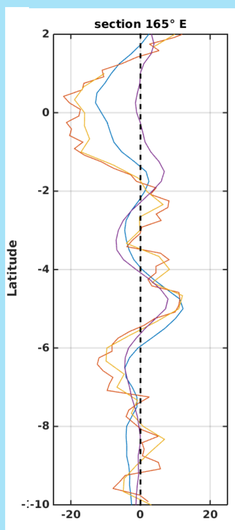

Fig. 5: *1000m zonal velocities at165°E from CASSIOPEE L-ADCP (yellow) and S-ADCP (red), and from Argo mean (purple) and July (blue).*

L-ADCP currents at 165°E during CASSIOPEE (**Fig. 4**) are similar to the mean currents from historical S-ADCP observations (**Fig. 2**) from the surface to 1200 meters, and capture both the LLSC and LLIC systems. LLIC currents extend to at least 2500m.

Note the presence of three additional features:

- an intense eastward-flowing flow near the equator, due to strong El Nino conditions.
- a larger-scale tripole between 1000-1500m, associated with seasonal anomalies (**Fig. 5**) due to the vertical propagation of an annual Rossby wave forced at by the seasonal wind stress variability (Marin et al., 2010).
- deep currents below 3000 meters.

5. Zonal evolution of the jets

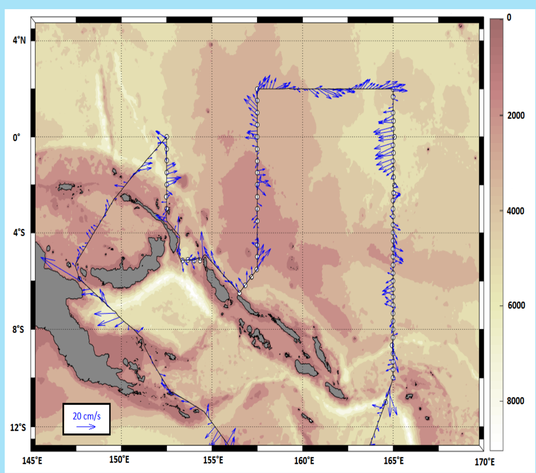

Fig. 6: *1000m S-ADCP zonal currents during CASSIOPEE.*

Intermediate jets at 1000m are seen to be continuous from West to East, with indication of recirculations at the western boundary (**Fig. 6**)..

6. Chemical properties of the jets

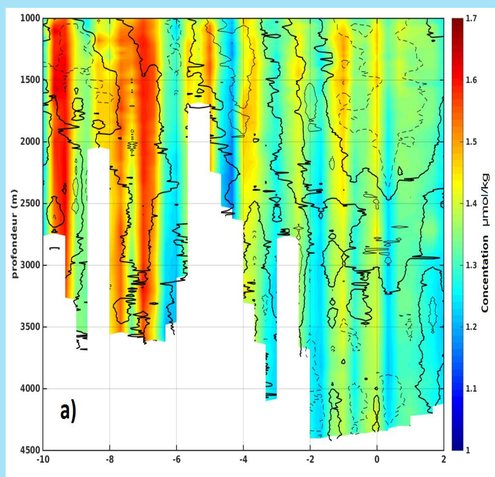

Fig. 7: *phosphate along 165°E during CASSIOPEE.*

The phosphate distribution at 165°E reveals vertical chimneys that are not correlated to the jets (**Fig. 7**). Are they realistic features?

7. Hydrological properties of the intermediate jets

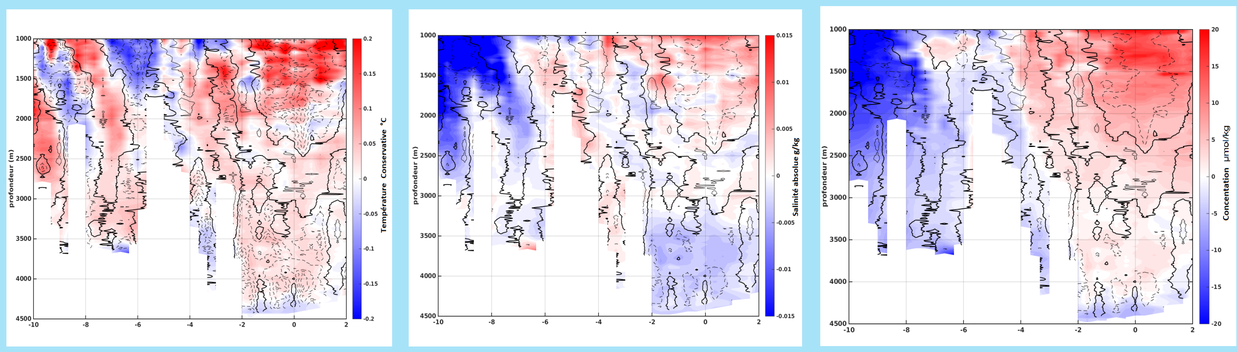

Fig. 8: *Meridional sections of temperature (left), salinity (middle) and Apparent Oxygen Utilization (AOU, right) at 165°E during CASSIOPEE. The mean vertical profile over the section of corresponding CARS2009 climatologies has been subtracted.*

We observe a strong correlation between LLIC jets and hydrological parameters (**Figs. 8 and 9**):

- in terms of temperature and salinity: zonal currents reversals are in phase with temperature and out-of-phase in salinity north of 6°S; the opposite phase relationship is true south of 6°S.
- in terms of AOU: eastward jets are associated with AOU fronts, while AOU is homogenized within westward jets..

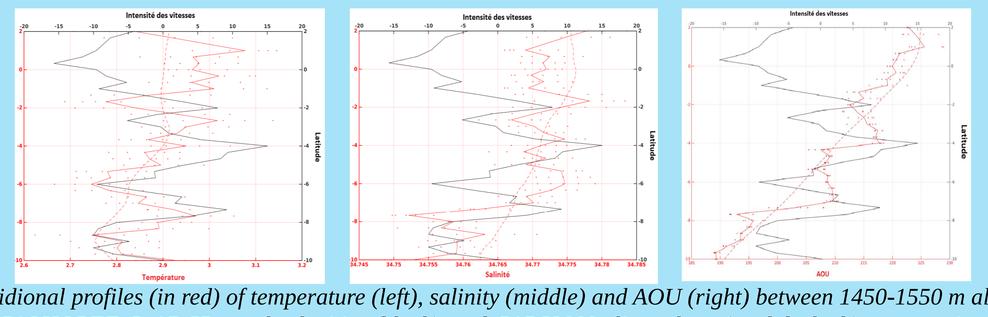

Fig. 9:*, Meridional profiles (in red) of temperature (left), salinity (middle) and AOU (right) between 1450-1550 m along165°E during CASSIOPEE. L-ADCP zonal velocities (black) and CARS2009 climatology (read dashed) are superimposed.*

8. Conclusion / Discussion

A complex large-scale system of alternating zonal jets is evidenced at both subthermocline and intermediate levels in the tropical Pacific from various in situ observations. Preliminary results from the CASSIOPEE cruise provides new insights on the hydrological and chemical properties of the jets.

The analysis of a large set of numerical simulations shows that these jets are badly represented in ocean models. If some individual zonal jets have been explained in the literature, a unified theory to explain the LLSC and LLIC systems as a whole is still lacking, and their importance for the general ocean circulation still needs to be assessed.

References

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