Institut de recherche pour le développement

Intermediate zonal jets in the tropical oceans as observed by ARGO floats: a new challenge for theoreticians

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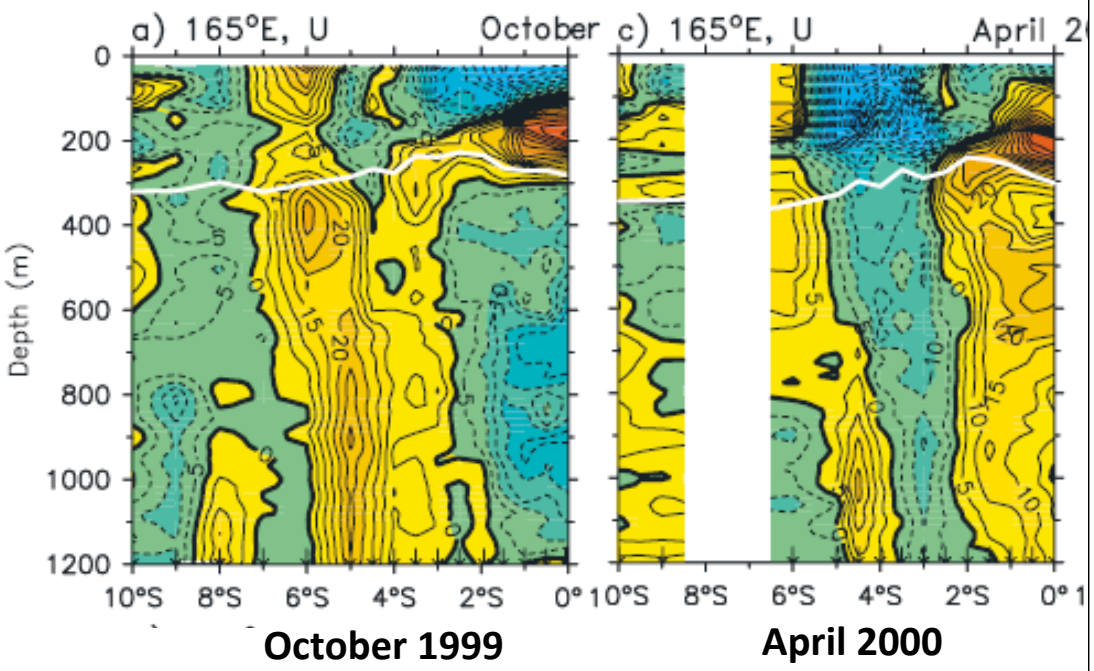
Ocean Scale Interactions symposium, A tribute to Bach-Lien Hua, Brest, 23-25 June 2014

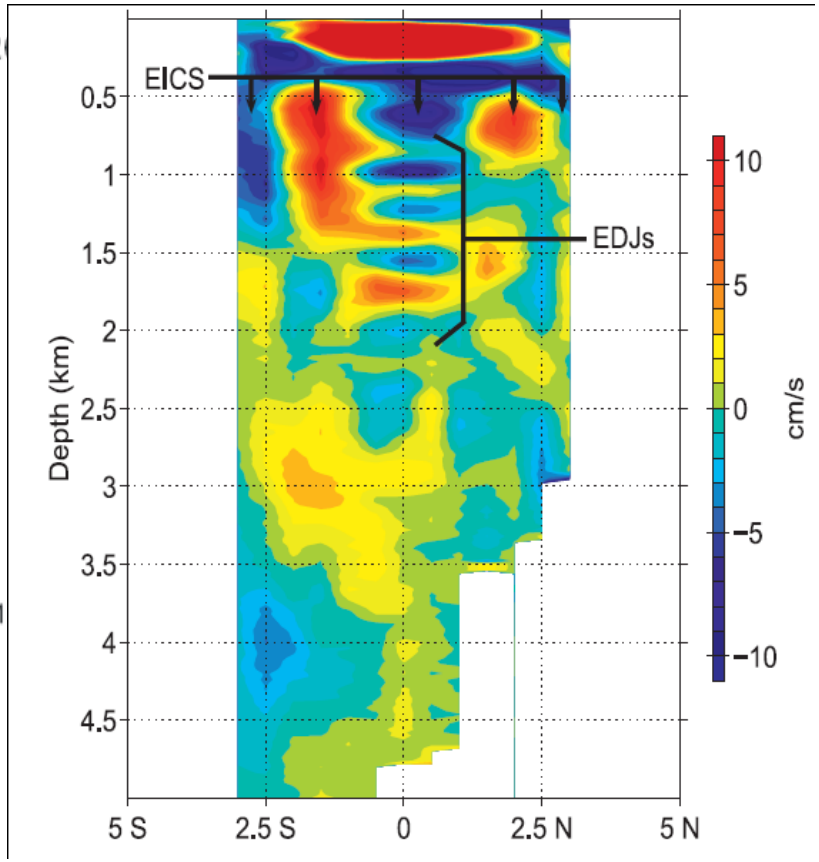
DEEP CURRENTS IN THE PACIFIC OCEAN

synoptic U at 165°E



(Gouriou et al. 2006)

mean U at 159°W

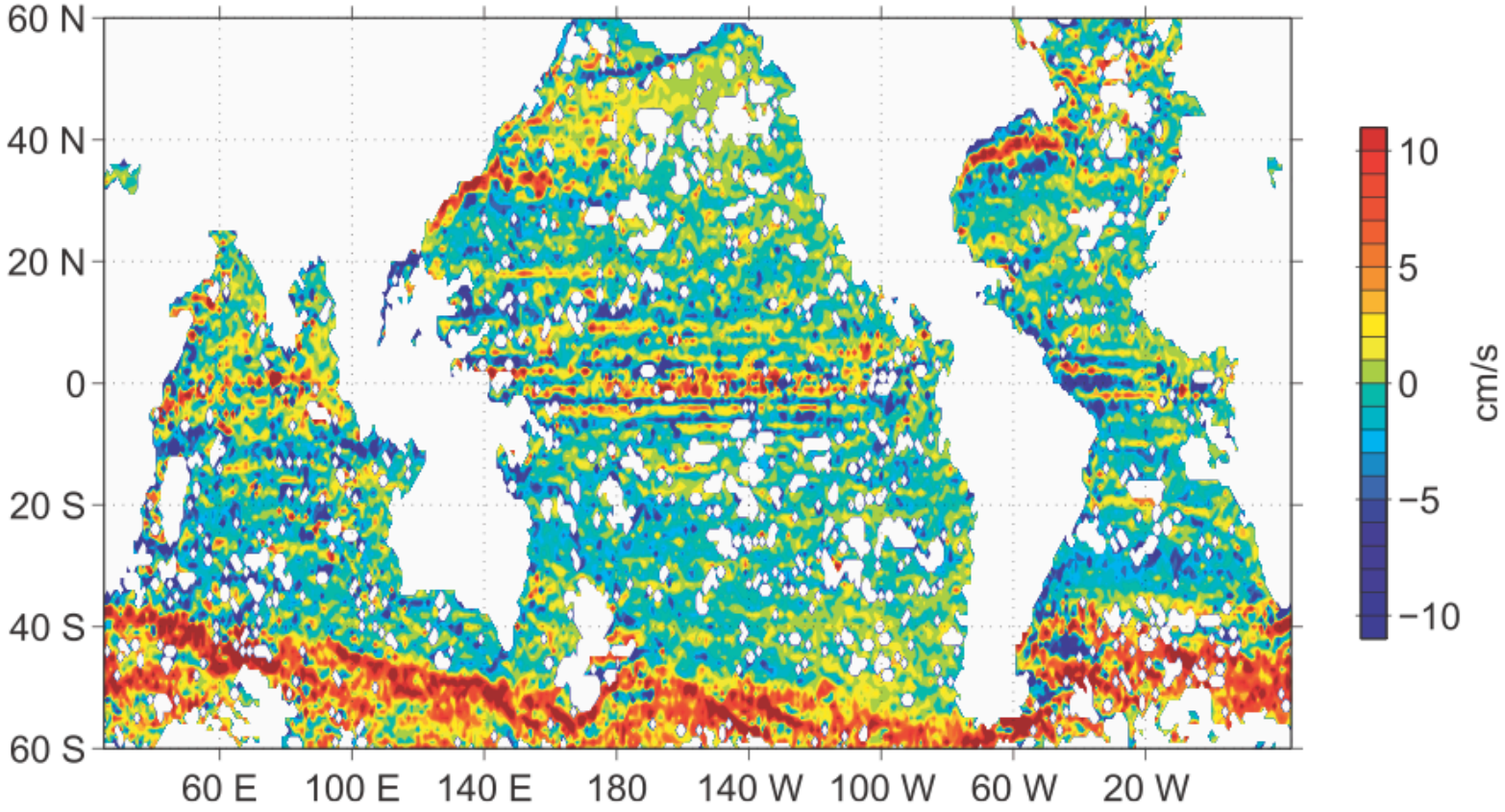


(Firing et al. 1998; Ascani et al. 2010)

• Some years ago… the mid-depth circulation in the equatorial Pacific ocean was only known through synoptic repeated transects (including large variability)

MEAN CURRENTS AT 1000m

Mean u at 1000 m deduced from Argo floats

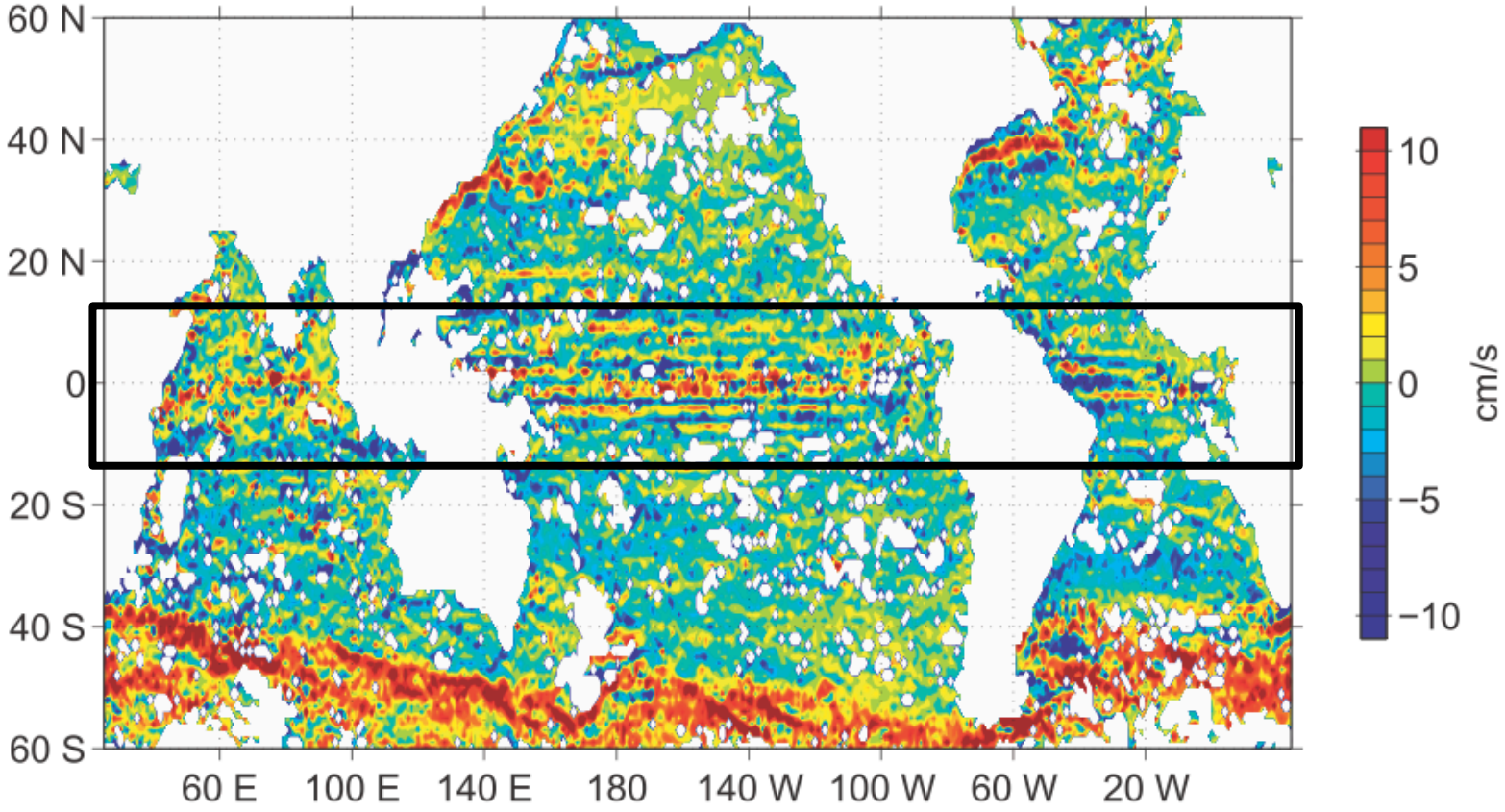


Ascani et al. (2010), Lebedev et al. (2007), Ollitrault et al. (2013, 2014)

- Since the Argo era, we have access to the mean 1000m global circulation

MEAN CURRENTS AT 1000m

Mean u at 1000 m deduced from Argo floats



Ascani et al. (2010), Lebedev et al. (2007), Ollitrault et al. (2013, 2014)

- Since the Argo era, we have access to the mean 1000m global circulation **system of intense alternating zonal jets in the tropical oceans**

OUTLINE

- **Mid-depth zonal jets in the Pacific** (update from Cravatte et al. 2012)

  → methodology

  → main properties of the jets

  → variability and persistence of the jets

- **Are these jets ubiquitous features of the tropical oceans?**

  → characteristics of the jets in the Indian and Atlantic Oceans

  (Ollitrault and Colin de Verdière, 2014)

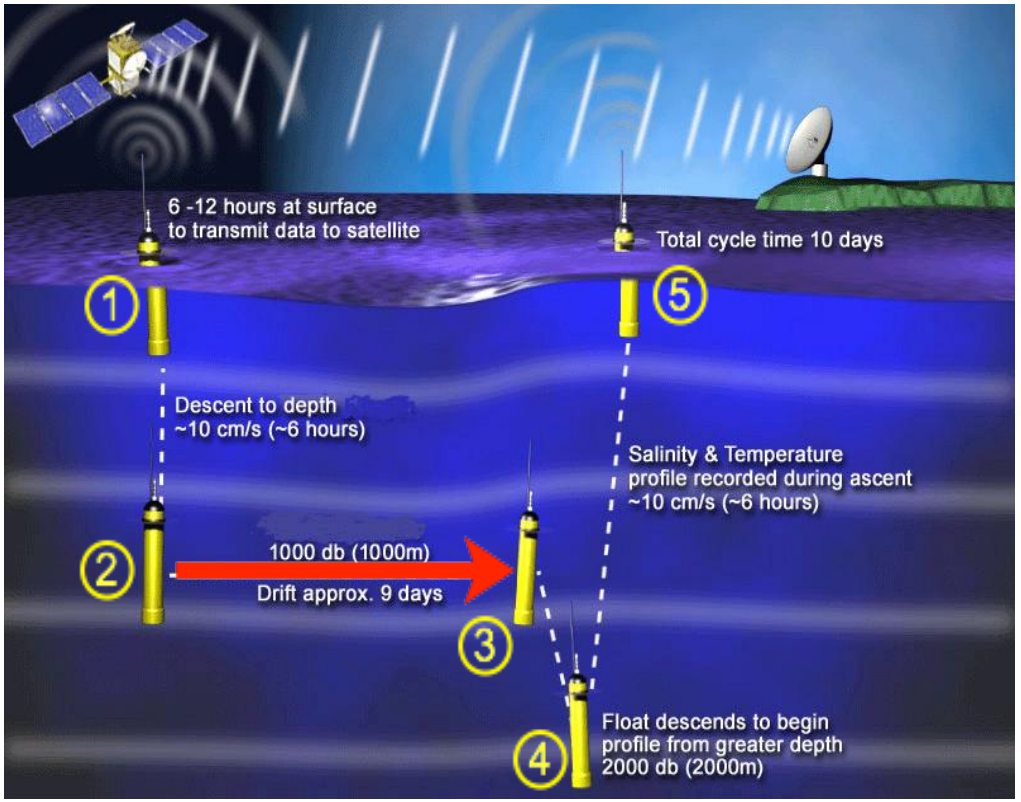
- **How well are they represented in numerical models?**

- **What do we know about the dynamics of mid-depth jets in the ocean?**

METHODOLOGY: treatment of ARGO trajectory data

1- Select all Argo floats between 15°S-15°N, from January 2003 to December 2013

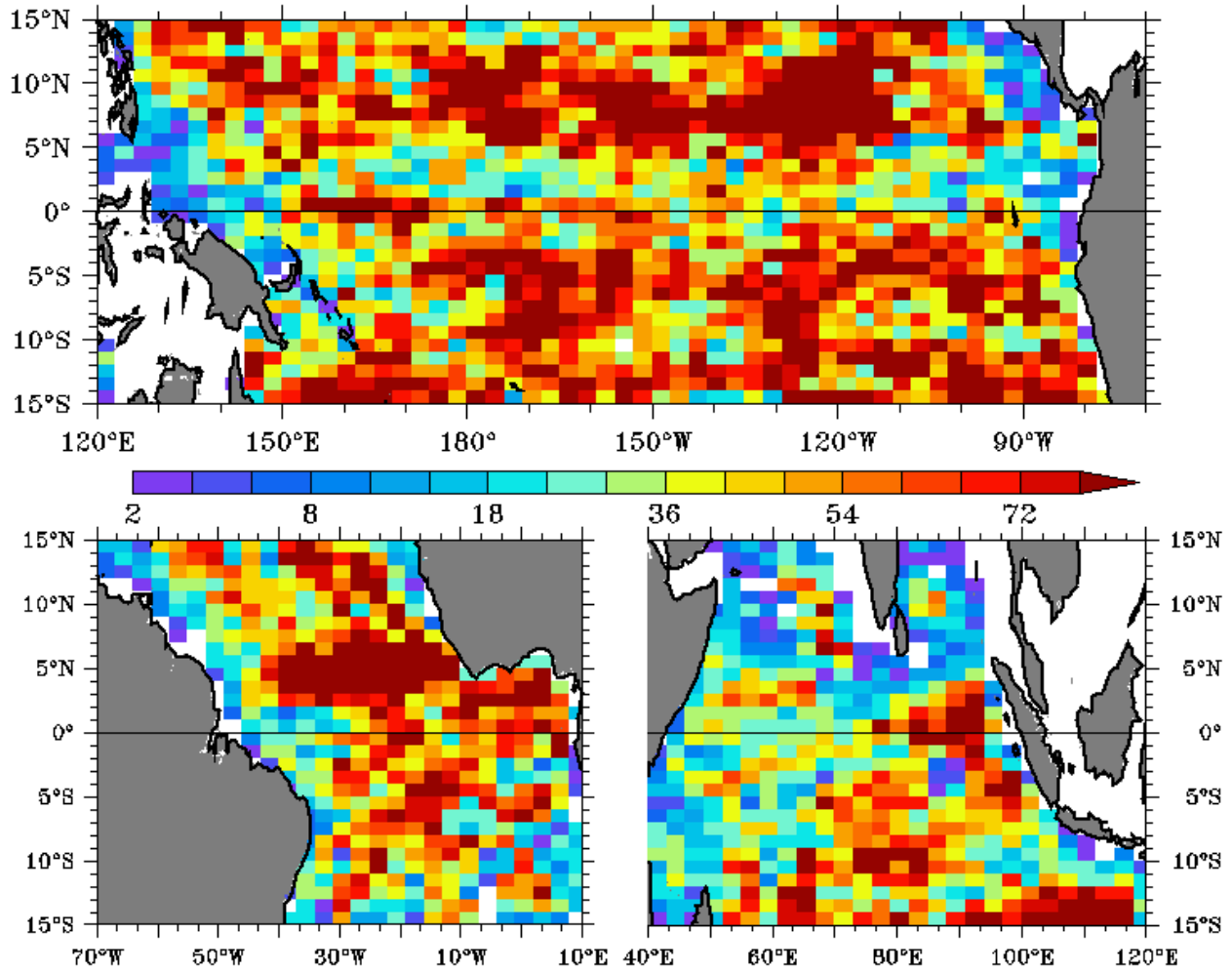
2 - Calculate subsurface velocities from floats motion at their parking depths
(Park et al., 2005; Cravatte et al., 2012; Ollitrault and Rannou, 2013)



3 – CAREFUL quality control: many visual and statistical checks, estimation of errors

METHODOLOGY: ARGO data distribution

Number of velocity values in 3°x1° boxes between 950-1050m for the period 2003-2013

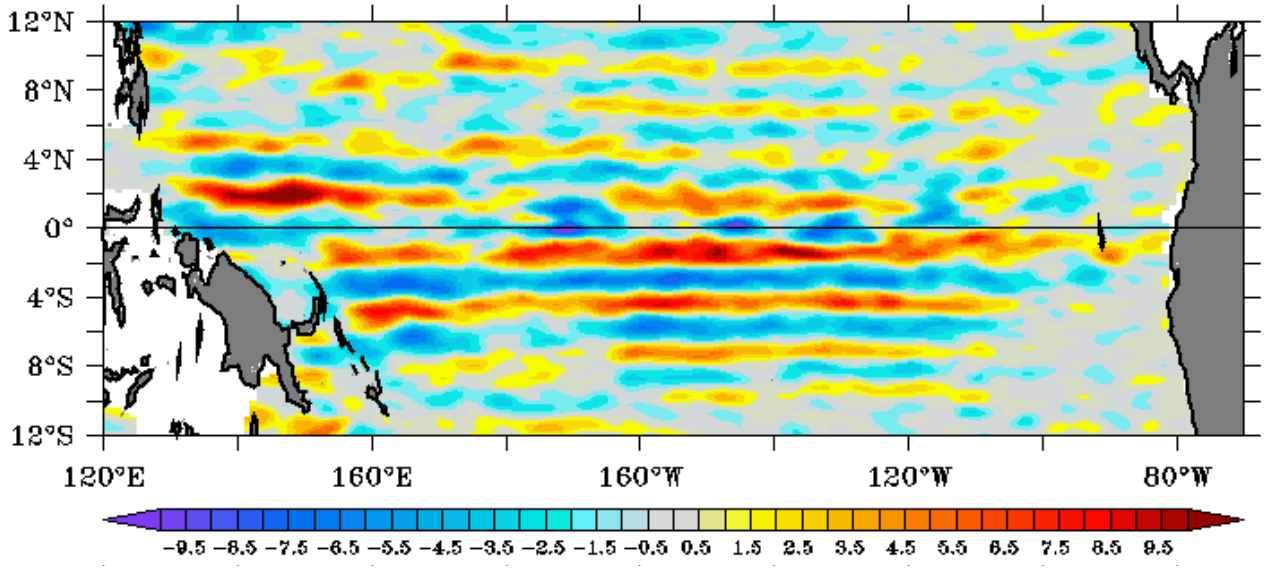


Objective analysis of u and v (decorrelation scales: 3° in longitude, ½° in latitude, 3 months)

→ gridded product of mean velocities + seasonal climatology at 1000m (and 1500m)

INTERMEDIATE ZONAL JETS IN THE PACIFIC

U (cm/s)



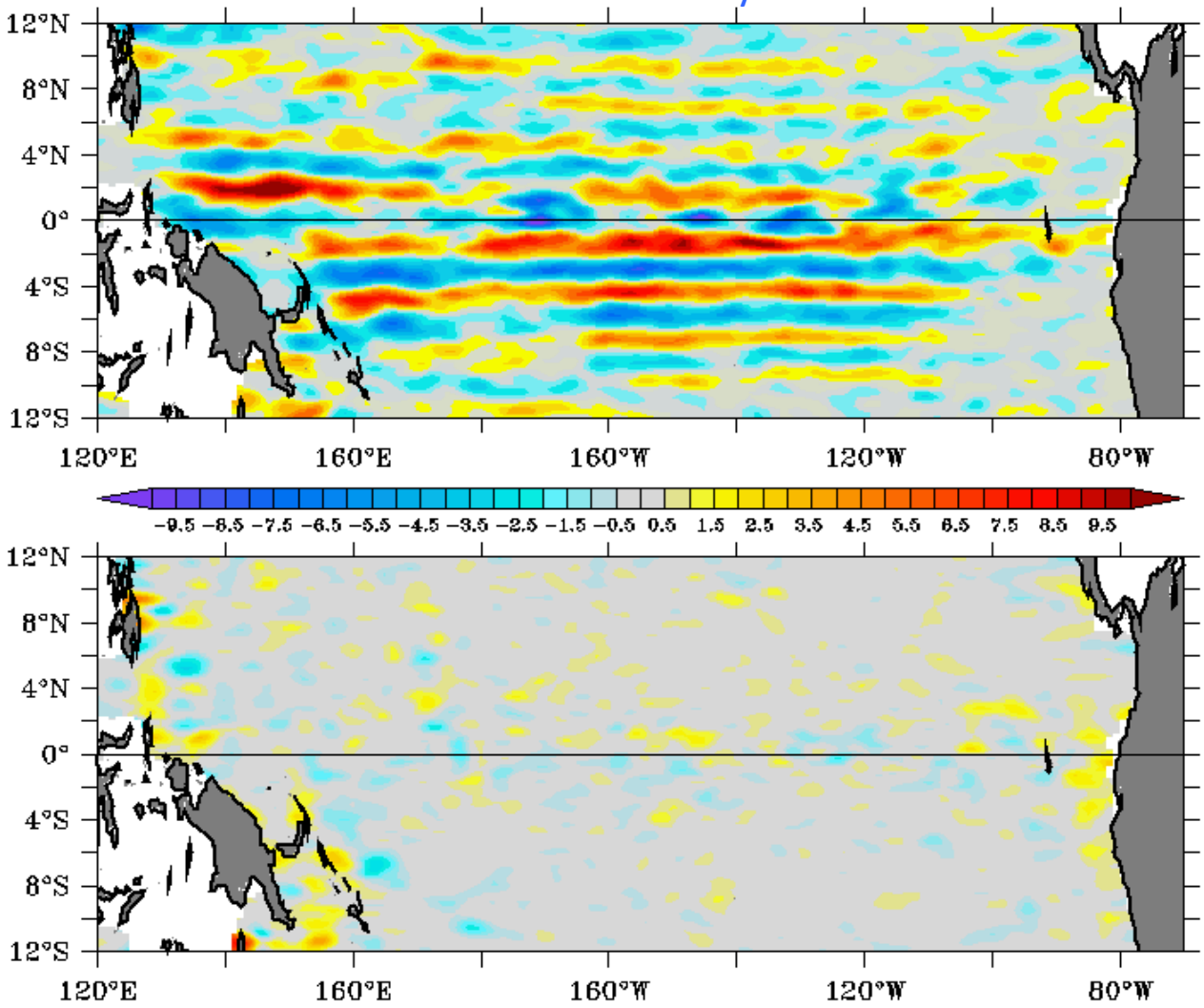
- **Alternating jets are coherent in longitude at basin scale from 10°S to 10°N**
- **Jets are present from the western boundary, but disappear in the east**
- **Larger amplitude in the west and in the south (about ±5 cm/s)**
- **Meridional scale: about 300km**
- **Slant poleward in the west**

INTERMEDIATE ZONAL JETS IN THE PACIFIC

2003-2013 mean velocity at 1000m

U (cm/s)

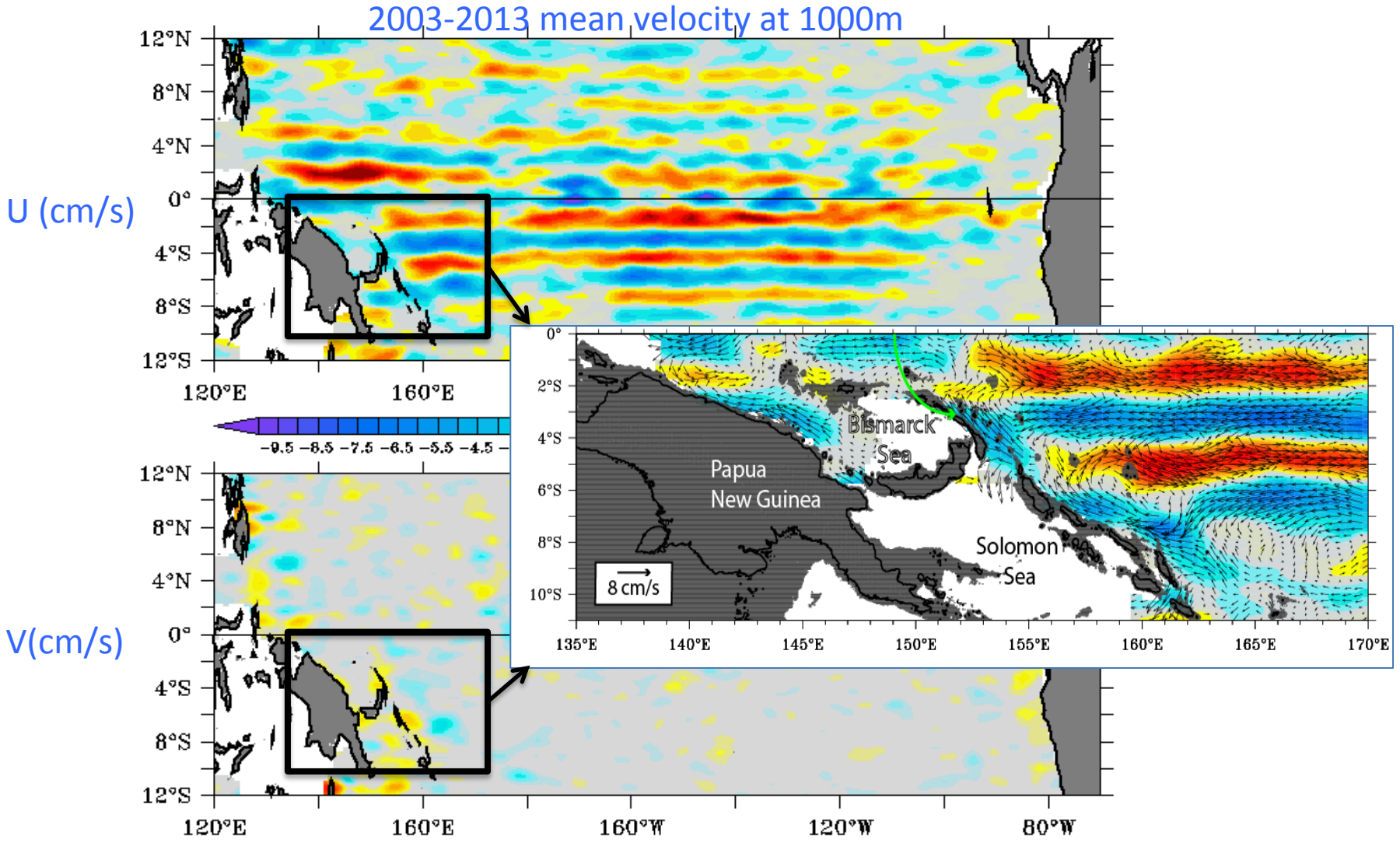
V(cm/s)



Updated from Cravatte et al. 2012

- **meridional velocity is almost zero**

INTERMEDIATE ZONAL JETS IN THE PACIFIC

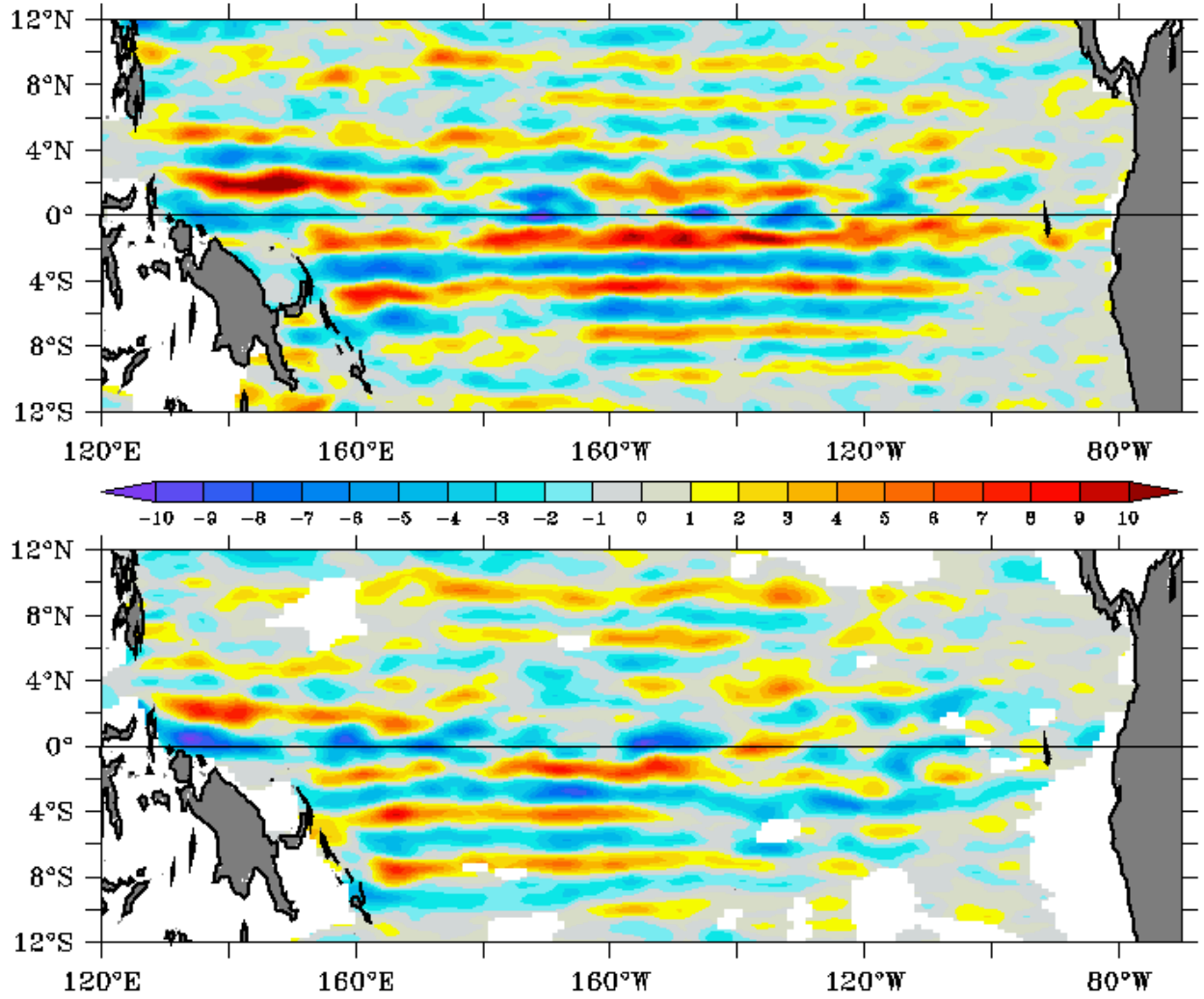


- **meridional velocity is almost zero, apart from recirculations at the western boundary**

VERTICAL EXTENSION

2003-2013 mean U (cm/s)

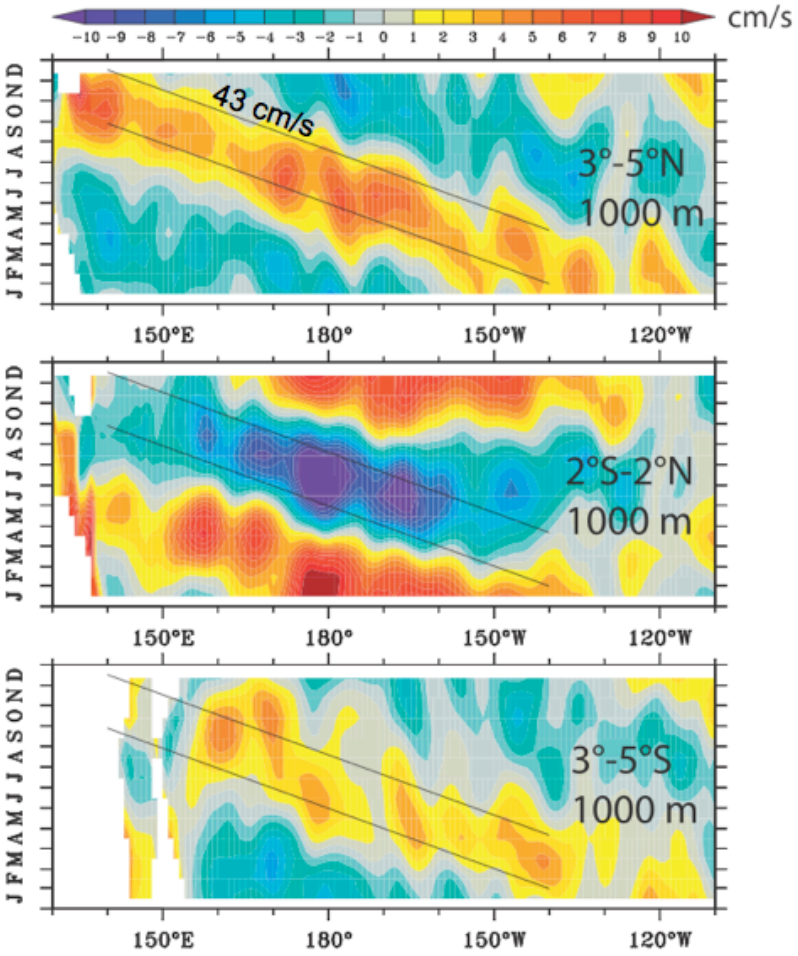
1000m



1500m

- **Zonal jets extend deep (similar at 1000 and 1500m)**

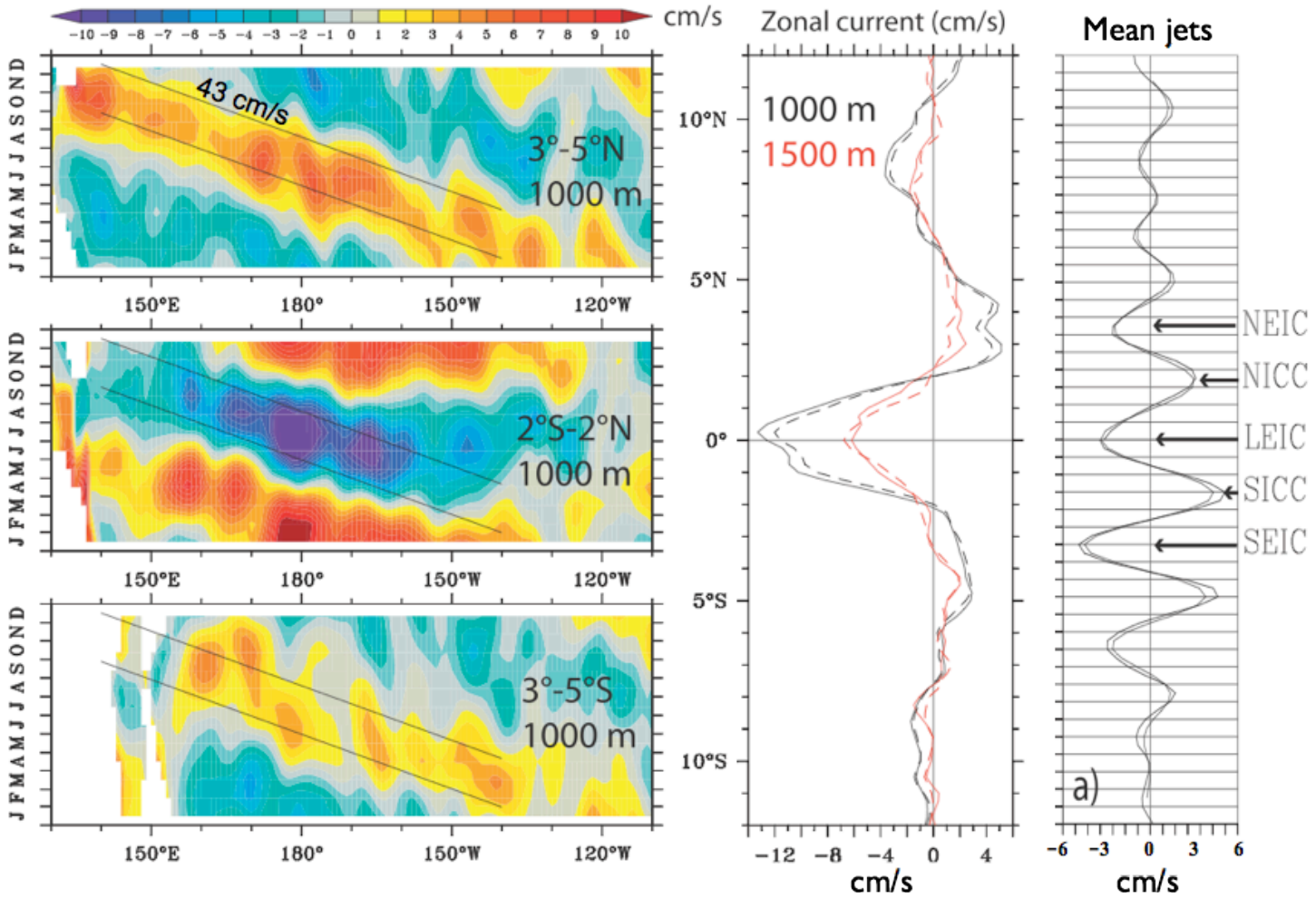
ARE THESE ALTERNATING JETS PERSISTENT?



- **Annual cycle of u: well-known vertically propagating Rossby waves**

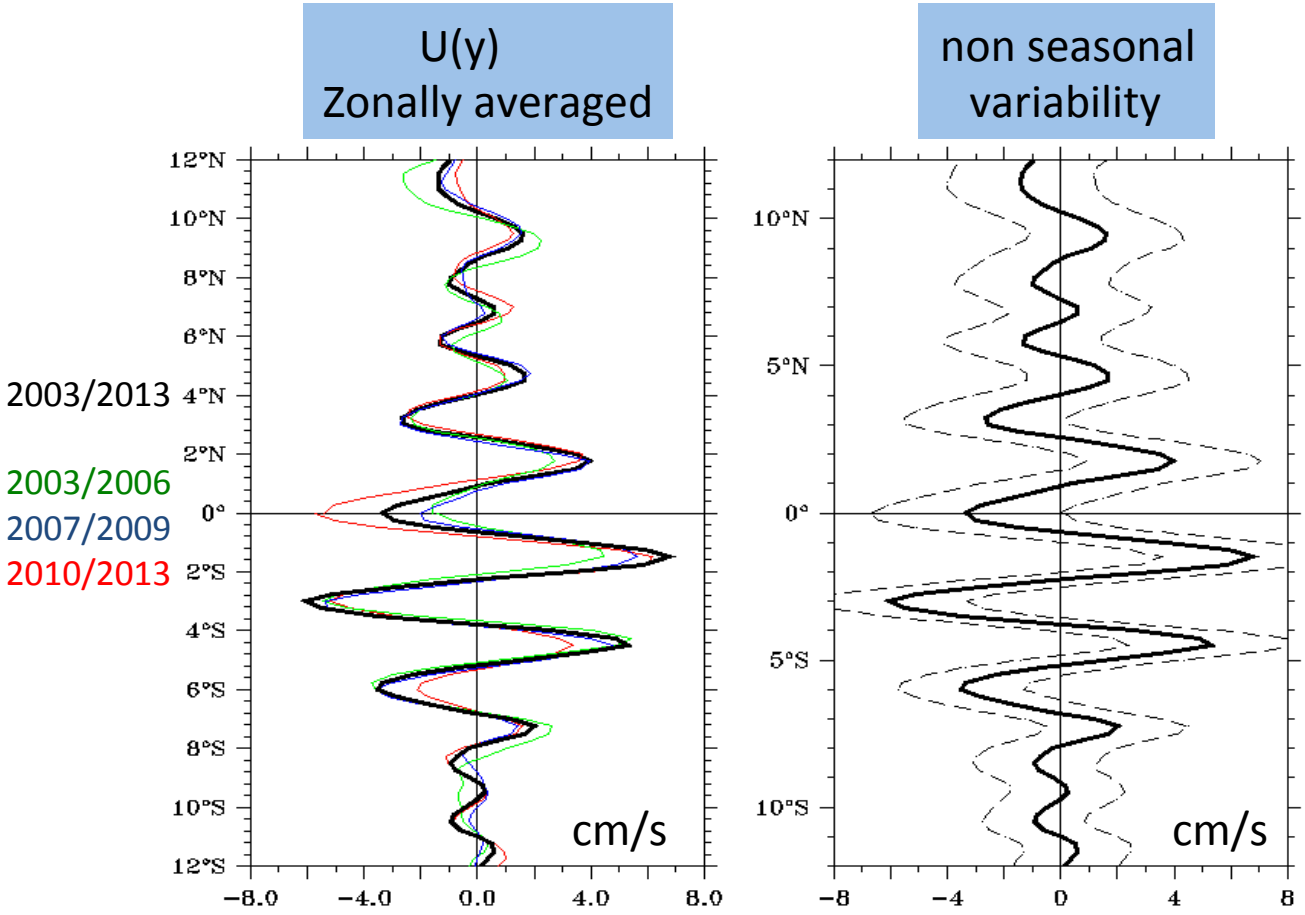
  (Lukas and Firing, 1985; Kessler and McCreary, 1993; Marin et al., 2010)

ARE THESE ALTERNATING JETS PERSISTENT?



- **Annual cycle of u: well-known vertically propagating Rossby waves**
- **Annual cycle variance has <u>different meridional structure from the mean jets</u>**
- **<u>Large annual amplitude (→ jets can seasonally “reverse”)</u>**

ARE THESE ALTERNATING JETS PERSISTENT?



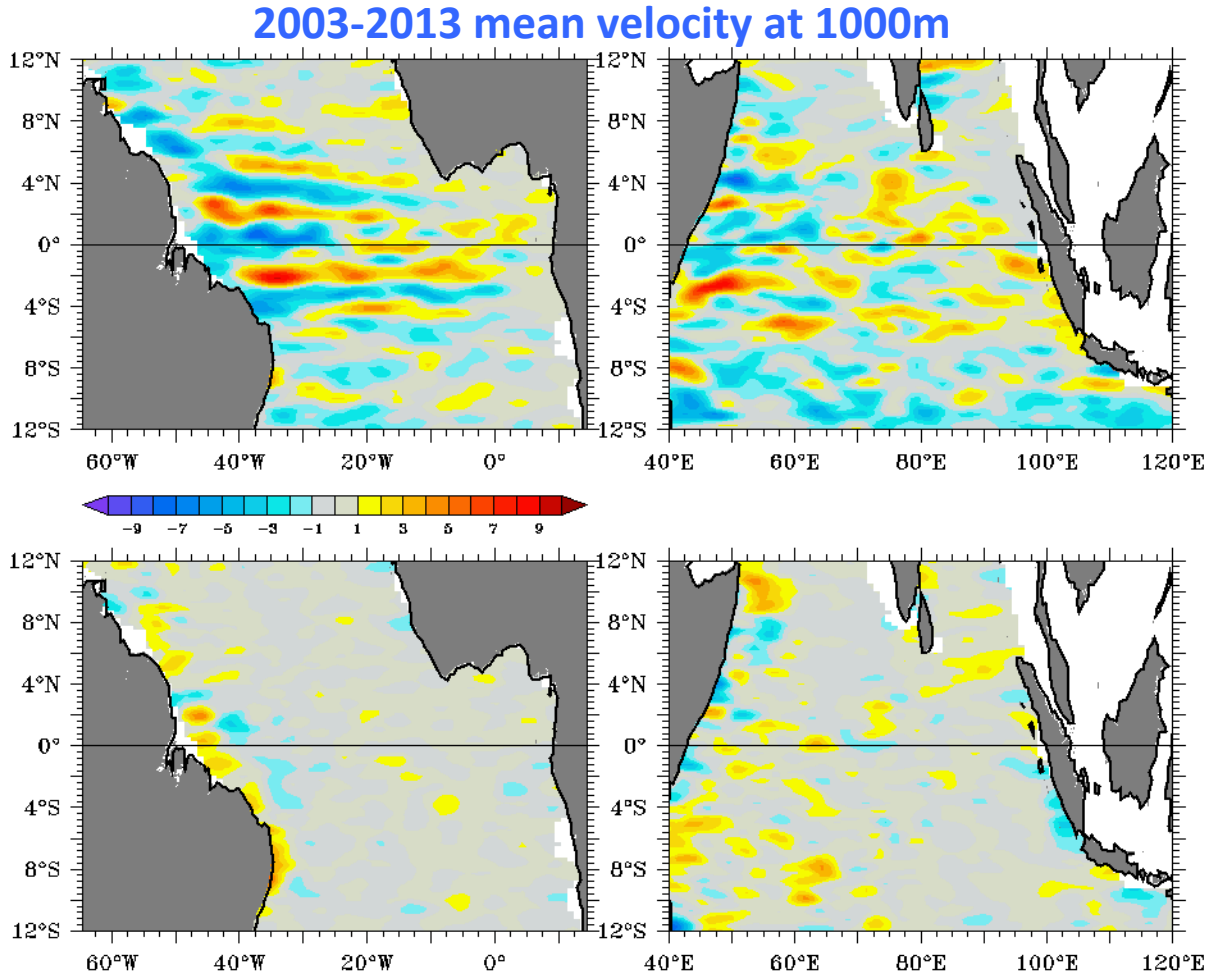
- **The 1000m jets are stable in position from year to year**

- **Some intraseasonal/interannual variability, but these mean jets are unlikely residuals of strong transient phenomena.**

INTERMEDIATE ZONAL JETS IN THE ATLANTIC AND INDIAN OCEANS

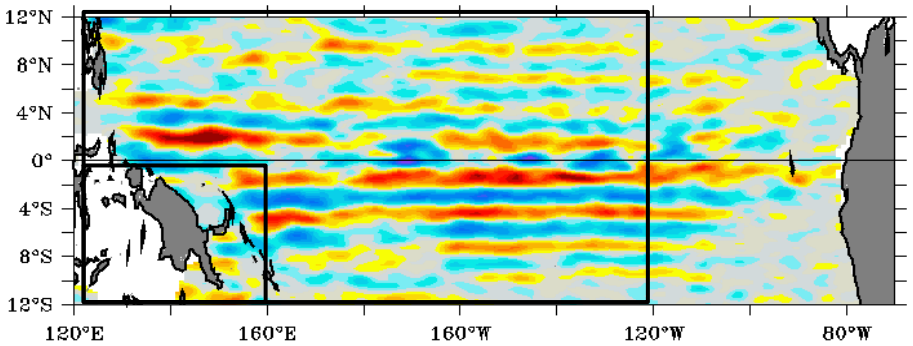
U (cm/s)

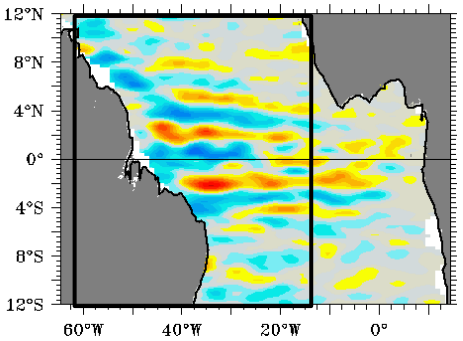
V(cm/s)



The 1000m jets are present in the eq. Atlantic (cf Ollitrault et al. 2006, 2014)
No coherent structures in the Indian Ocean!!!

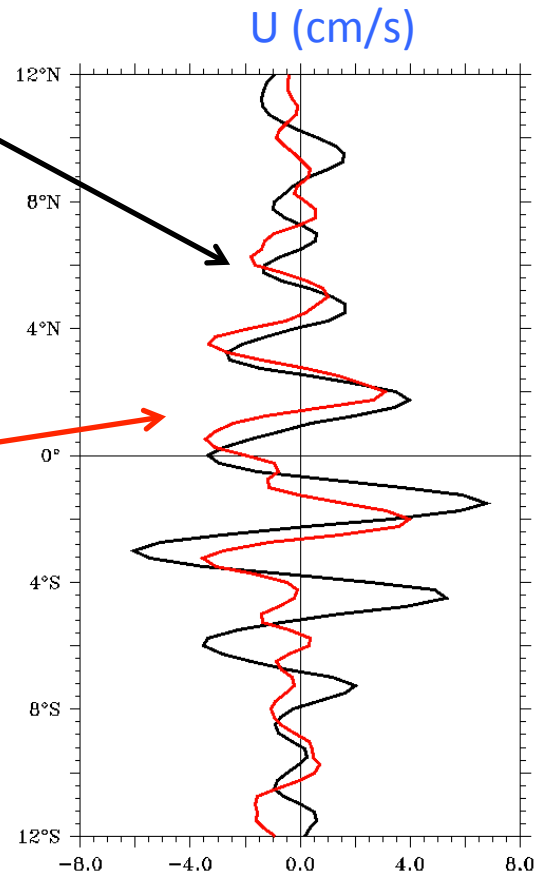
ZONAL JETS IN THE ATLANTIC VS PACIFIC





Pacific
120E-120W

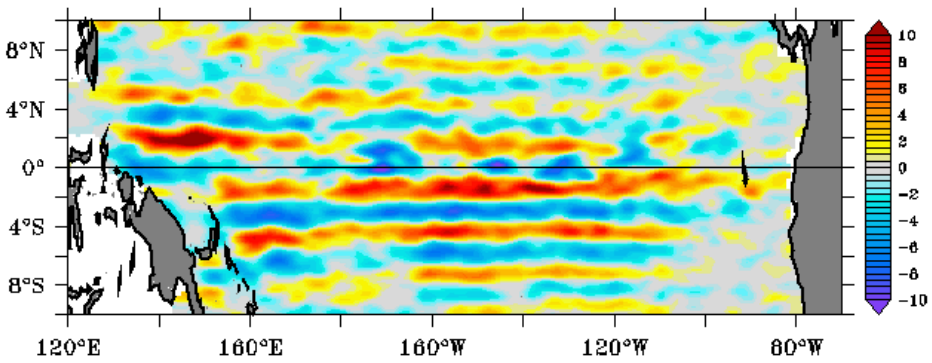
Atlantic
60W-15W



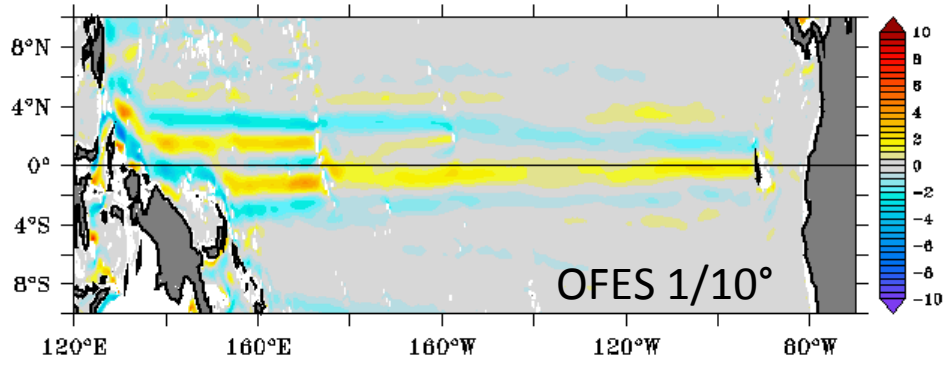
The 1000m jets are present in the eq. Atlantic (cf Ollitrault et al. 2006, 2014) BUT:

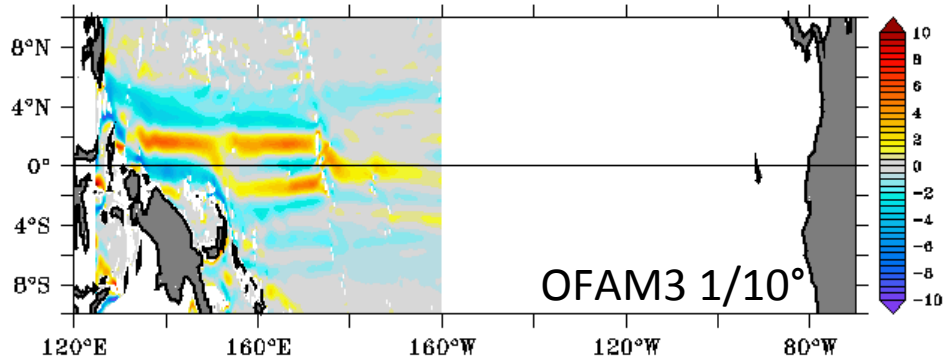
- **Weaker than in the Pacific, with larger amplitude in the north**
- **Meridional scale: about 400km (slightly larger than in the Pacific)**
- **Also weak in the east, and slant poleward in the west**

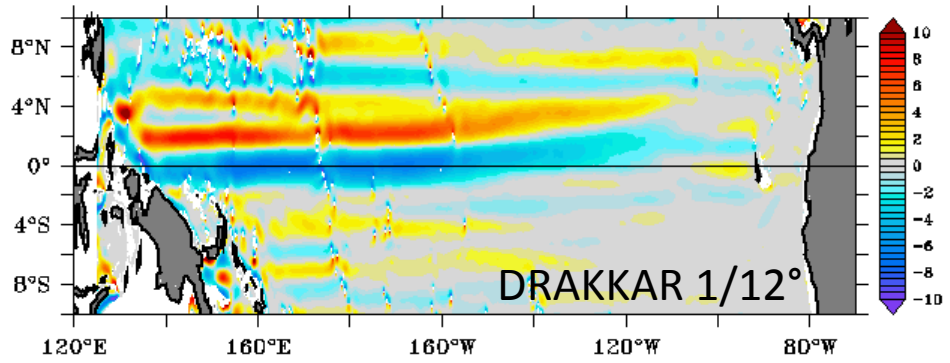
OCEAN SIMULATIONS : U (cm/s) at 1000m



ARGO observations







- Zonal jets not well simulated in high-resolution ocean models

- Some structures, strongly influenced by topographic features

Modern models apparently do not include the correct physical processes

CONCLUSIONS / DISCUSSION (1/3)

- **Argo floats trajectories** are a useful source of mid-depth circulation

- **A zonal jet « striation » pattern is present in the equatorial Pacific**
  - The jet region is broader than equatorial (at least 10°S-10°N)
  - Crest to crest scale ~300km, slant poleward in the west
  - persistent from year to year
  - the jet pattern does not reach the eastern boundary
  - importance for zonal redistribution of properties and mixing?

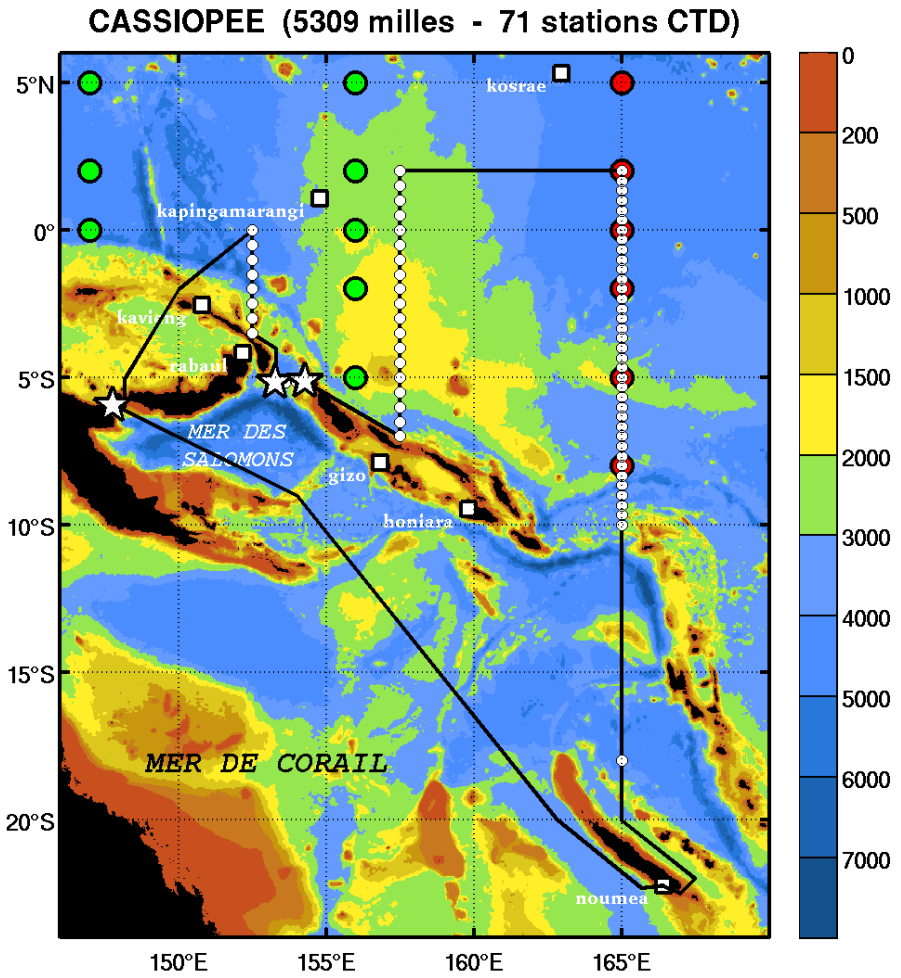
- **Zonal jets also present in the Atlantic, with similar properties**
  - weaker
  - larger meridional scale

- **No coherent jets in the Indian Ocean**.

- **Not correctly simulated in state-of-the-art ocean models**: consequences for current biogeochemical models? *(Dietze and Loeptien, 2013)*

DISCUSSION (2/3): need further observations?

- **what is the vertical structure of the jets?**
- **what are properties of the water masses they transport?**



CASSIOPEE cruise

(July 2015)

Objectives:

to describe the surface-to-bottom circulation in the western tropical ocean, with focus on zonal jets, their zonal evolution and hydrological/biogeochemical properties

DISCUSSION (3/3): dynamics of these alternating jets?

Do they have their own dynamics?

Do they result from the equatorward extension of tropical/midlatitudes dynamics?

- link with surface striation ? (Melnichenko et al. 2010)

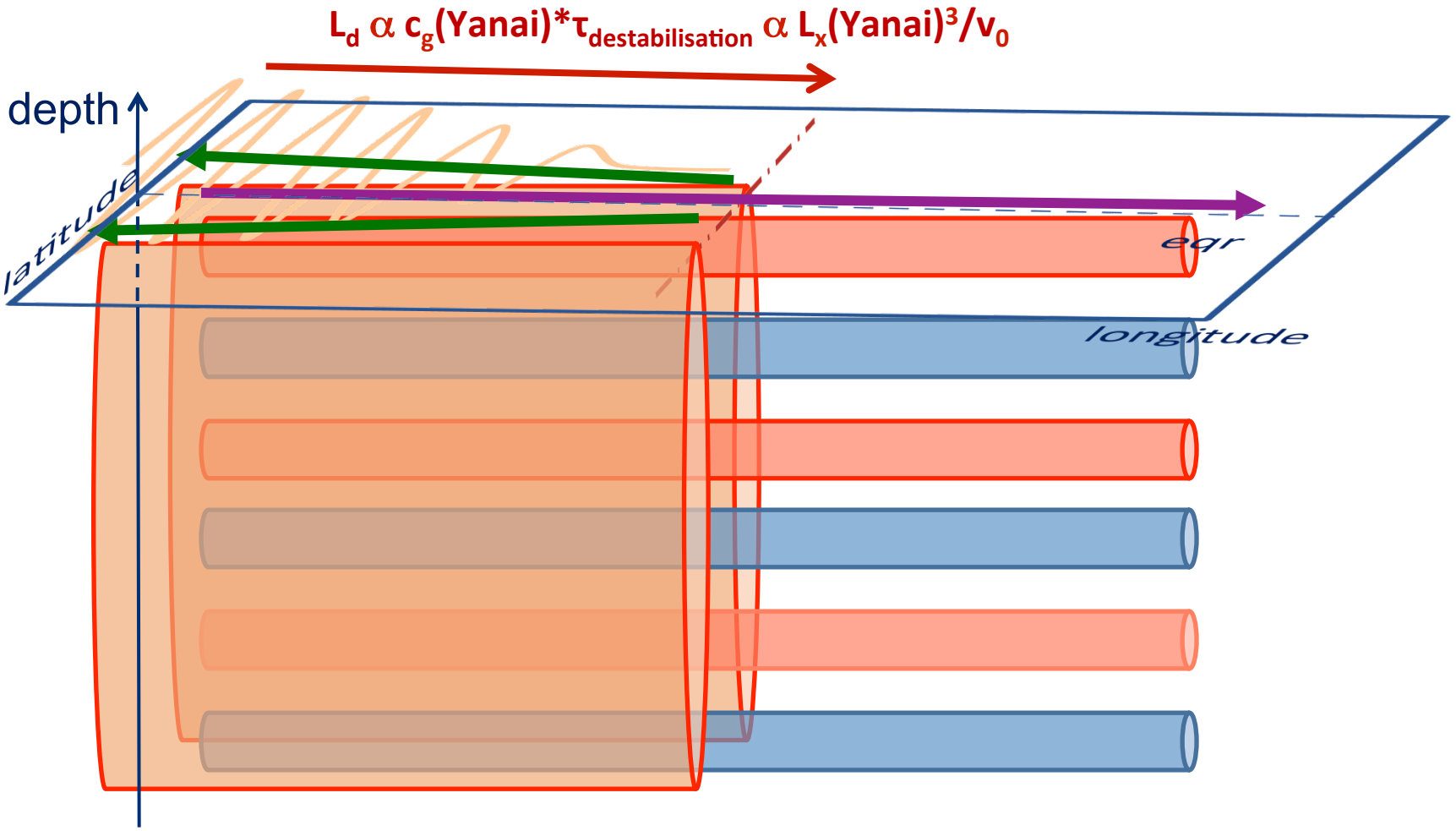
- non-linear triad interaction from the wind-forced first baroclinic annual Rossby wave, as demonstrated in the north Tropical Pacific? (Qiu et al., 2013)

- arrest of the inverse cascade of energy in 2D turbulence due to β effect? (Rhines, 1975)

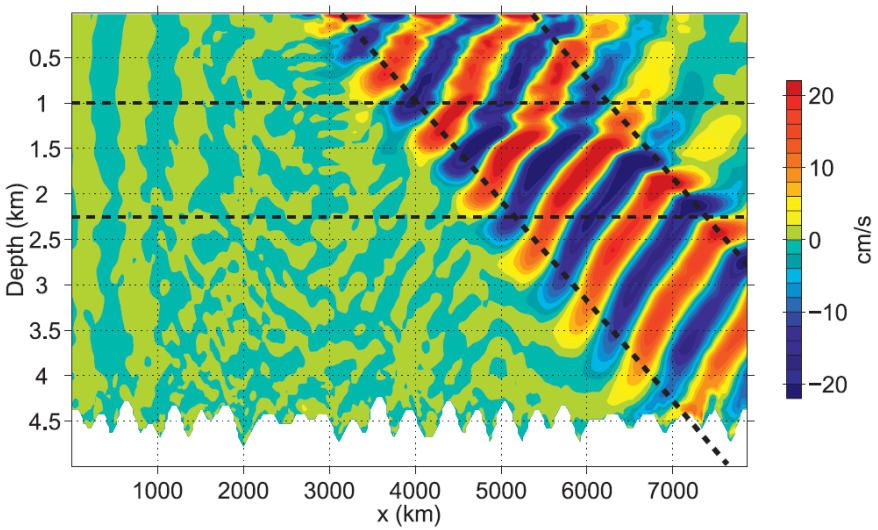
Do they result from the poleward extension of theories for equatorial EICs?

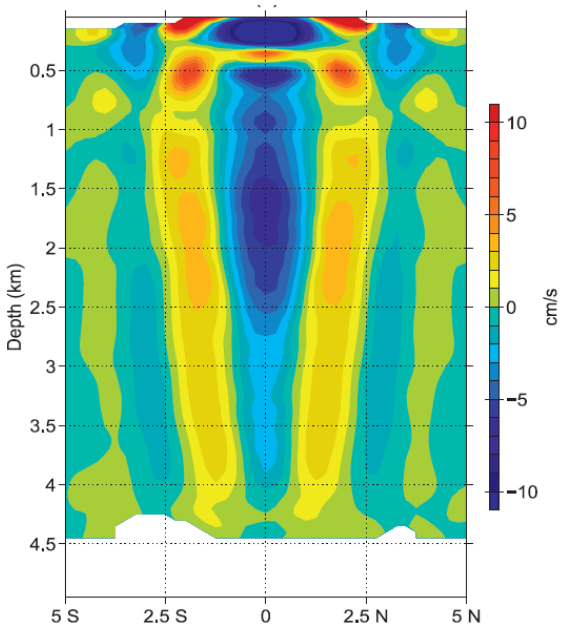
- instability of short barotropic Rossby waves ? (Menesguen et al. 2009)

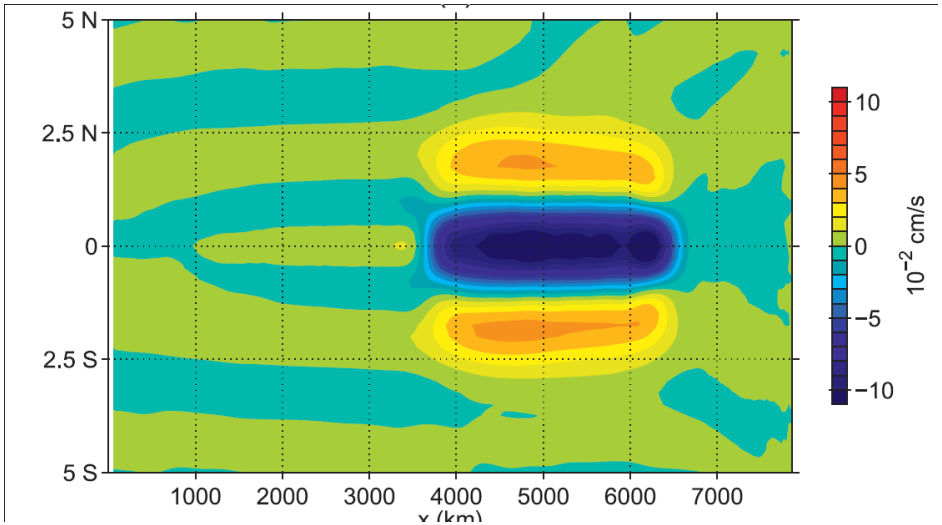
- self-advection and dissipation of a downward-propagating beam of Yanai waves ? (Ascani et al. 2010)?



Instability of short (50-day) waves (Menesguen et al. 2009) ?







self-advection and dissipation of a downward-propagating beam of 30-day Yanai waves ? (Ascani et al. 2010)?