Western boundary currents (WBC) and coastal sea-level variability [Northern Hemisphere]

EGU 2021 Display

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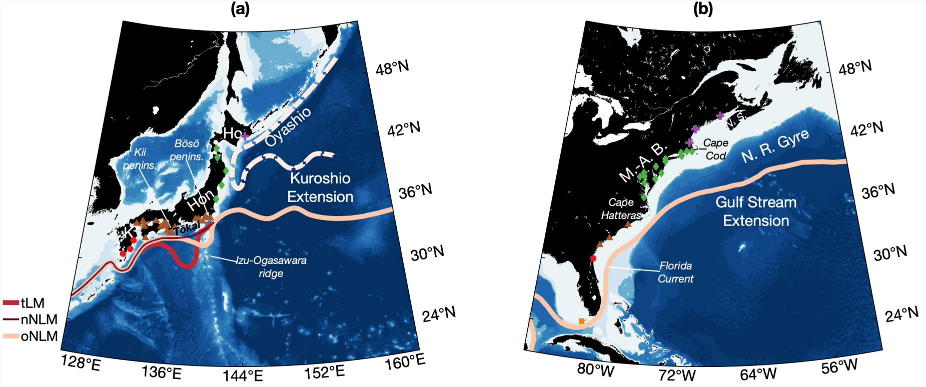
Results presented here have been summarised in a paper (Diabaté et al., 2021) which has been submitted to *Ocean Science* and is now under discussion.

`https://os.copernicus.org/preprints/os-2021-24/`

Tide Gauge Selection

- www.psmsl.org,
- Only records with sufficient length and completeness (>90%),
- Start in: 1948 (Atlantic) and 1968 (Pacific).

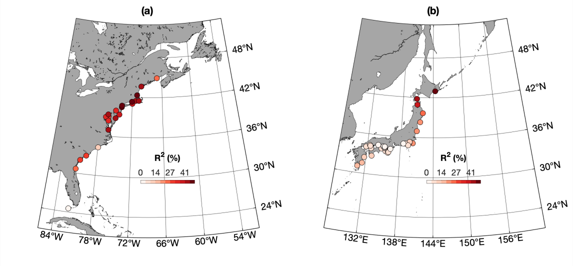


Tide gauge records treatment

1. Detrending and interpolating missing values,
2. East of Honshu: Missing values from 2011 onwards filled with altimetry-obtained Sea Surface Heights (SSH),
3. Corrective applied for atmospheric surge (Dangendorf et al., 2013),
4. Filtering of 1.5 year applied,
5. Interpolation on an alongshore grid with regular spacing.

Atmospheric effect corrective

$$\zeta = -\alpha_1 \tilde{p} + \alpha_2 \tau_{||} + \alpha_3 \tau_{\perp} + \mathcal{O}$$



Northward increase of the role of the atmosphere. The surge-effect explains 25–50% of the variability North of the separation points.

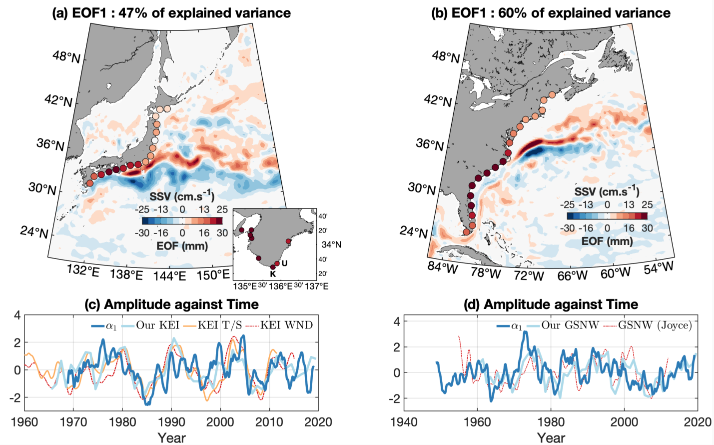
Analysis

EOF analysis allows to objectively separate the tide gauge-obtained sea-level anomaly $\zeta(x, t)$ into modes of variability, each composed of a time varying coefficient $\alpha(t)$ (the *principal component*) and a spatial coefficient $\phi(x)$ (the *empirical orthogonal vector or function*). EOF analysis is computed for each basin sea-level anomaly separately.

$$\zeta(x, t) = \sum_i \alpha_i(t)\phi_i(x).$$

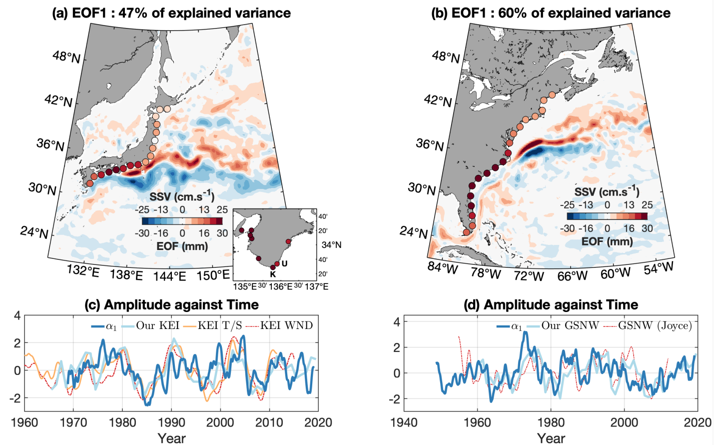
Composites of altimetry-obtained sea surface velocity (SSV) are computed for each EOF mode using the high and low values of the principal components.

Comparison of the principal components with indices of northern–southern shifts of the extension of the WBCs is made. We use existing indices (Joyce et al., 2000, Qiu et al., 2016), but also create our own following Frankignoul et al. (2001).



- EOF amplitudes (ϕ_1) are indicated on (a) and (b) by circular markers along the coastline,
- The associated principal components (α_1) are plotted on (c) and (d) as thick blue lines,
- Composite analysis of SSV magnitude shown on (a) and (b) as shadings.

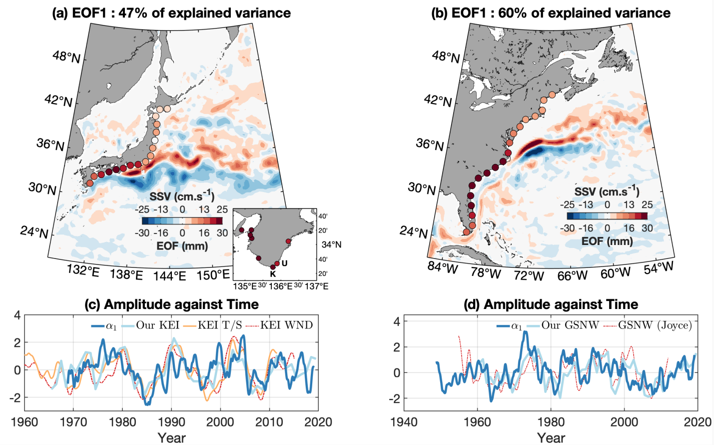
The leading EOF in each basin (2/4): *similar features*



- EOFs decrease in amplitude northward after the separation point,
- Velocity composite derived from the principal components highlights meridional shifts of the extension,
- Moderate to good* correlations with extension location indices extending further back in time (all other lines on (c) and (d)).

*r ∈ [0.27–0.52], and when excluding Joyce et al. (2000), r ∈ [0.40–0.52].

The leading EOF in each basin (3/4): *an explanation?*



Framework proposed by Sasaki et al. (2014):

1. SSH anomalies formed in the open ocean,
2. Anomalies propagate westward as jet-trapped waves,
3. Shift the WBC extension *en-route*,
4. Break into coastally trapped waves which progress equatorward and affect the coastal sea level.

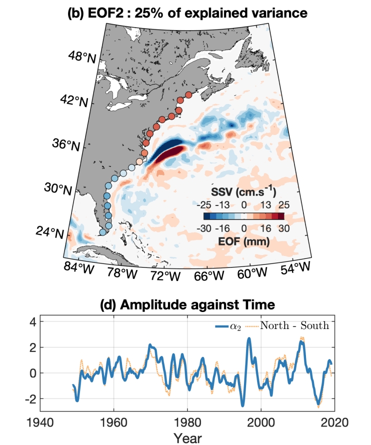
The leading EOF in each basin (4/4)

Main result

Northern (southern) shifts of WBC extensions associated with high (low) upstream sea levels in both altimetry and indices based on subsurface temperature and winds.

- Possible role of jet-trapped Rossby waves breaking into coastally trapped waves when arriving at the coast (Sasaki et al., 2014) — but other frameworks should be considered too,
- Potential for coastal sea-level change prediction,
- New paradigm for Gulf Stream North Wall?

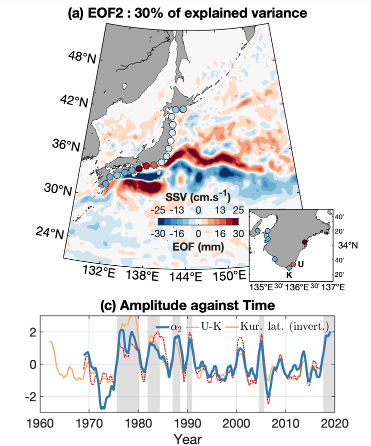
Second EOF — Atlantic



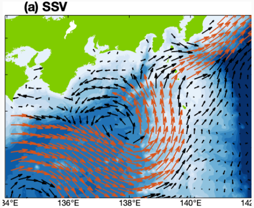
Rather puzzling mode!

- Strong signature on the SSV magnitude composite, mainly restricted to 77–69°W.
- **However**, good correlations with extension location indices are restricted to recent period since ∼1990,
- Corresponds to change in the variance of the principal component α_2 (blue line on (d)) around ∼1990.

Second EOF — Pacific



- Red composite patterns corresponds to the **typical Large Meander (tLM)** :
  - Meandering South of Tokai (135° – 140° E),
  - Kuroshio Extension to the North.
- Large positive value of the principal component (α_1) concurrent with the tLM (grey shading) ; α_1 also strongly anticorrelated with Kuroshio location at 137° E (orange line).
- Coastal current brings warm water to the coast (see figure below, also see Sugimoto et al., 2019) $\Rightarrow$ sea level rises.



Thank you for your interest.

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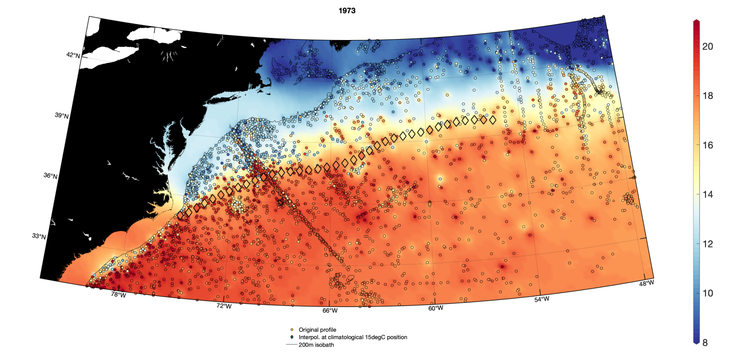
Additional slides: WBC Extensions' shifts (1/2)



- EN4 profiles interpolated at climatological axis position (diamond markers on figure) for each year to create a 2-D temperature matrix (time $\times$ along stream distance),
- Idem for Kuroshio Extension,
- EOF analysis isolates main mode of variability of the 2D temperature matrix (Frankignoul et al., 2001).

Additional slides: WBC Extensions' shifts (2/2)

(a) and (b) show the climatological position of the Gulf Stream Extension and of the Kuroshio Extension (solid thick line) and the EOF of the yearly temperature anomaly matrix (dashed line). The associated principal components are shown in light blue in (c) and (d). Also showns are the indices of Joyce et al. (2000) and Qiu et al. (2016).