Coastal altimetry improves the understanding of sea level variability at regional scales

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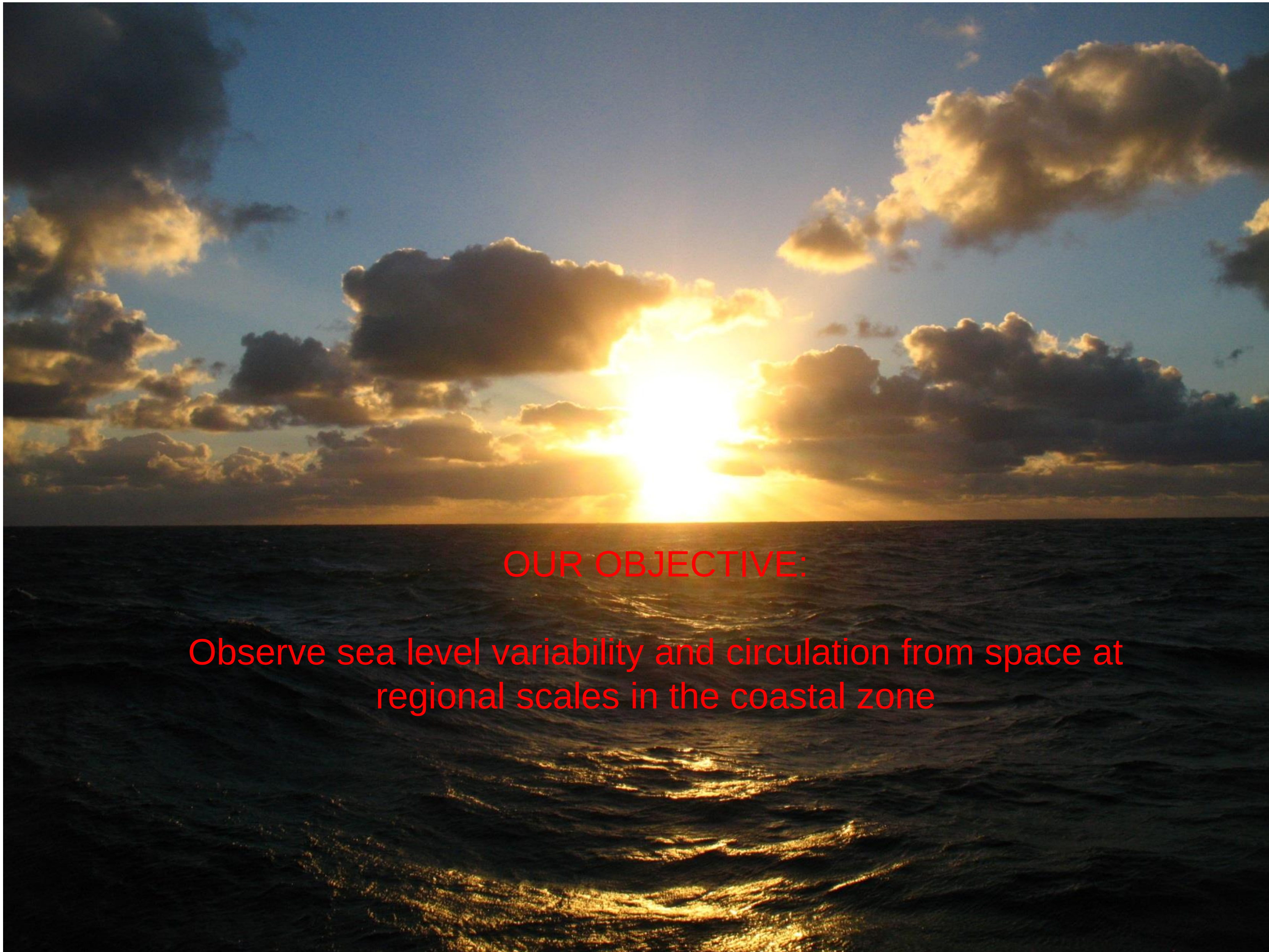
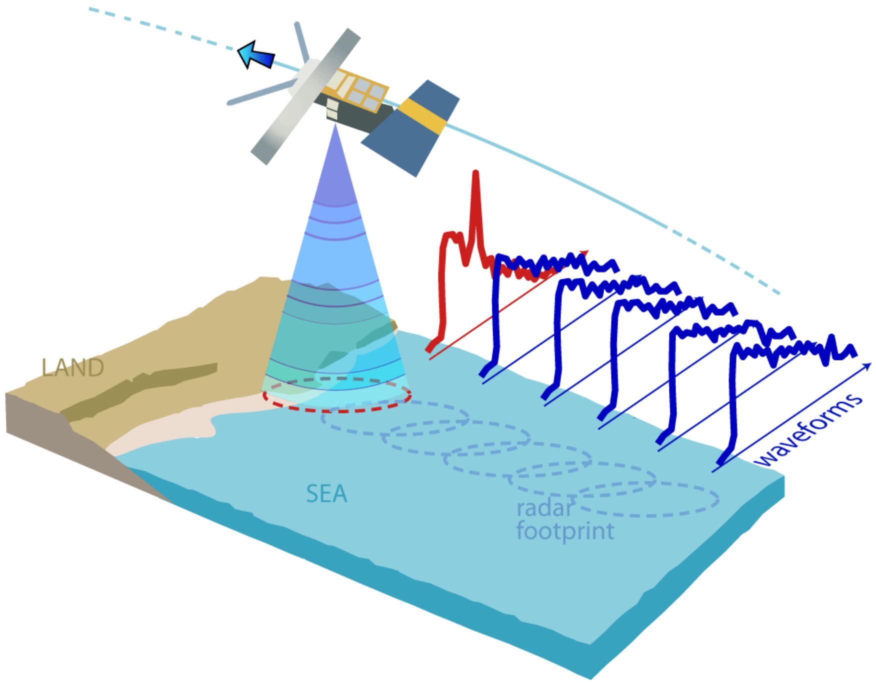
Objective


OUR OBJECTIVE:
Observe sea level variability and circulation from space at regional scales in the coastal zone

Background: Coastal Altimetry



~~The old rule of altimetry: disregard data closer than 50 km to the coast~~

Today:

- Dedicated signal processing -> retrieval of old coastal data
- Dedicated geophysical corrections + improved tide models and mean sea surface -> more accurate coastal sea level anomalies
- New mission concepts -> less signal perturbations in the coast

Motivation

ALES dataset: coastal reprocessing of Envisat (2002-2012) and Jason (2001-now)

Freely available from
ftp://podaac.jpl.nasa.gov/allData/coastal_alt/L2/ALES/

SARvatore dataset: SAR processing of Cryosat-2 data (2010-now)

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https://gpod.eo.esa.int/

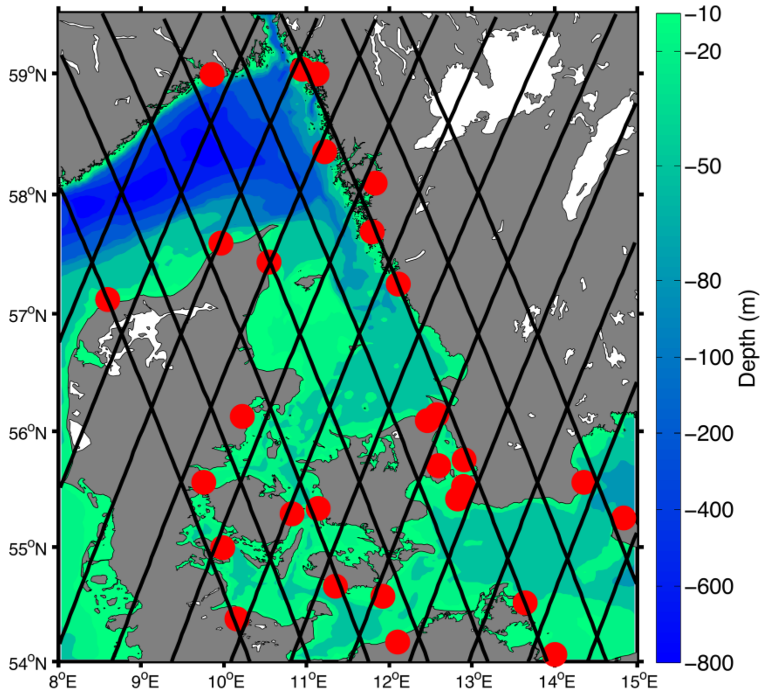
+ new tide models, MSS, atmospheric corrections,…

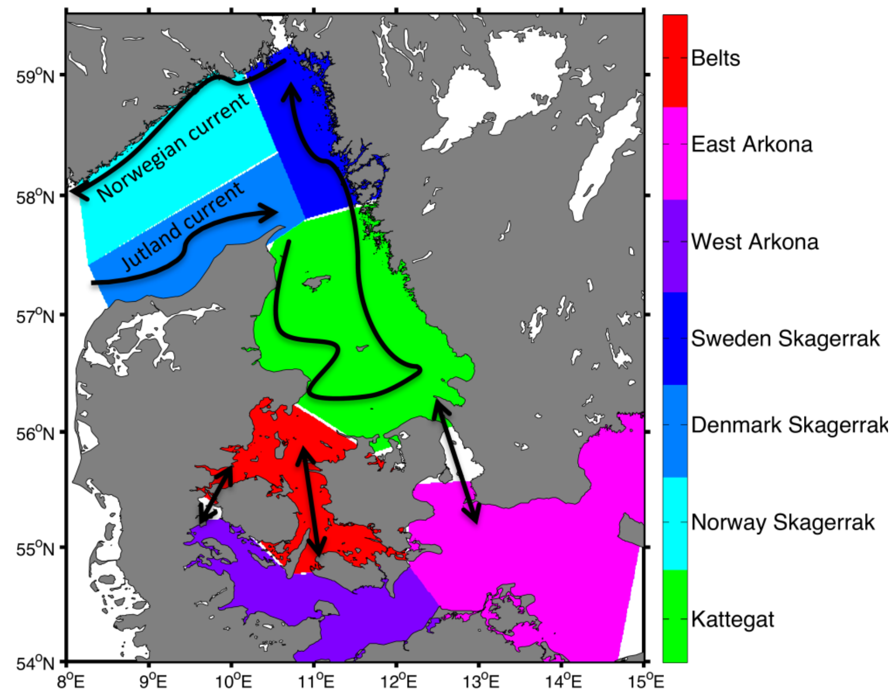
What can we learn from dedicated coastal altimetry datasets for sea level studies?

Summary

- The areas of study
- Benefits of the new dataset
- Variability in the North Sea: closing the gap with tide gauges
- Variability in the Indonesian Seas: interpreting the seasonal signals

Areas of study

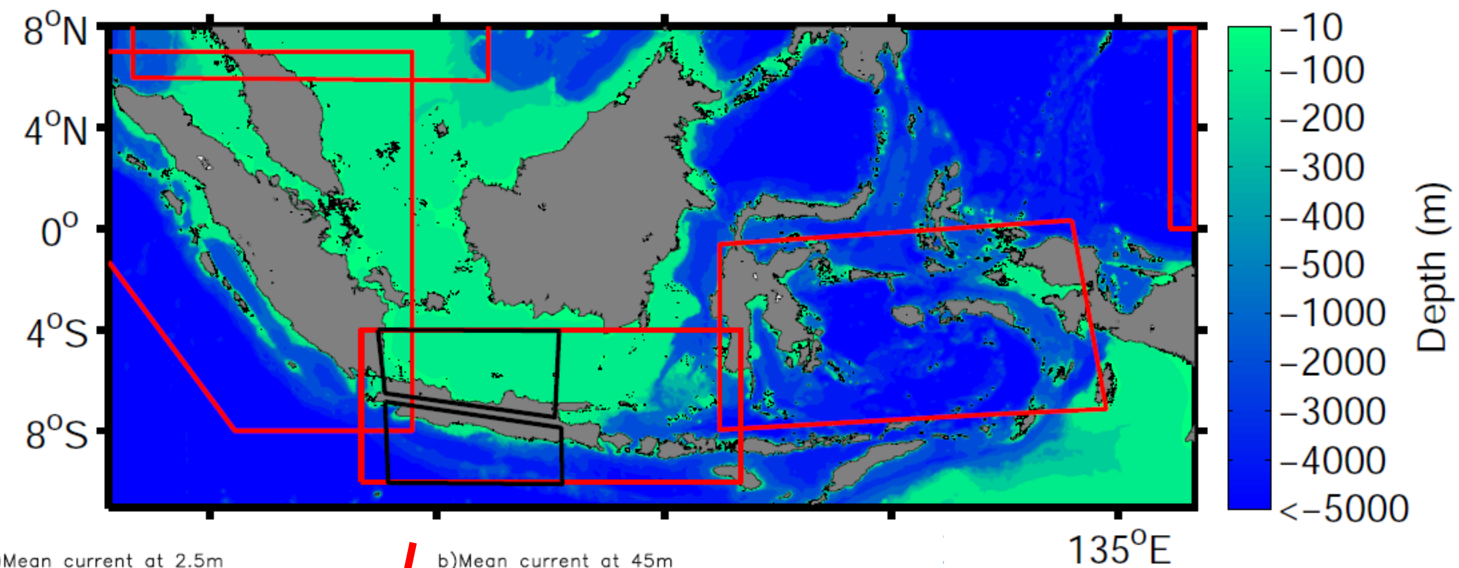


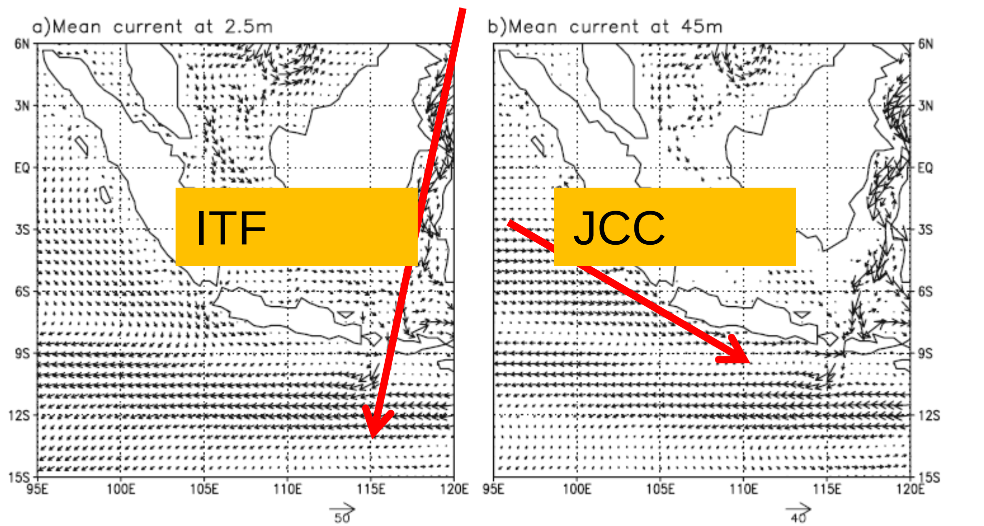


AREA OF STUDY: North Sea/Baltic Sea Transition (2002-2010)
- challenging for altimetry (small scales, shallow water, jagged coastline)
- several tide-gauges (TGs) for coastal validation

CIRCULATION CHARACTERISTICS:
- Outflow/Inflow: Brackish waters in the Arkona Basin vs warmer and saline waters from Atlantic
- Atlantic waters enter through the Jutland Current (D Skagerrak) and exit through the Norwegian Current (N. Skagerrak)

Areas of Study



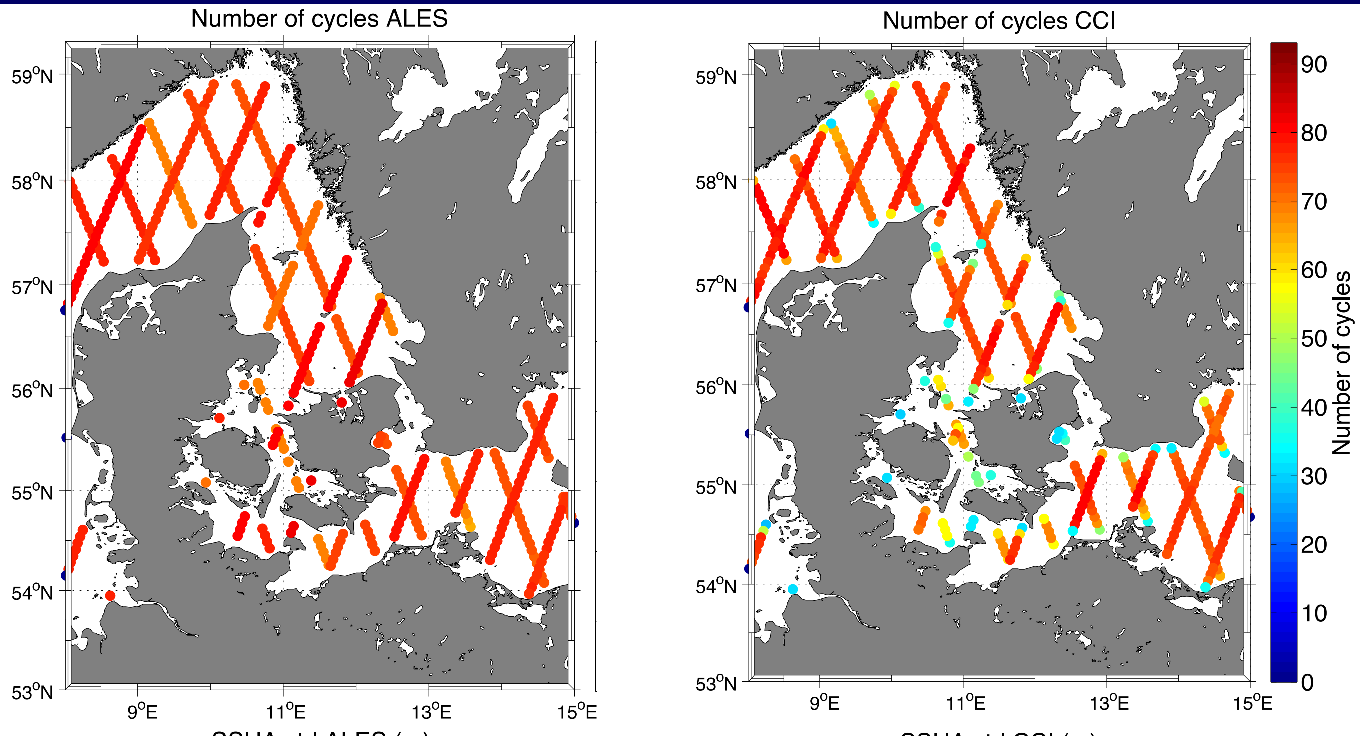


Iskandar, I., Tozuka, T., and Sasaki, H. (2006). Intraseasonal variations of surface and subsurface currents off Java as simulated in a high-resolution ocean general circulation model. J. Geophys. Res.-Oceans, 111, C12015.

North Java (NJ) and South Java (SJ):

- Different bathymetry
- Different sea level variability
- Different circulation

Benefits of the new dataset

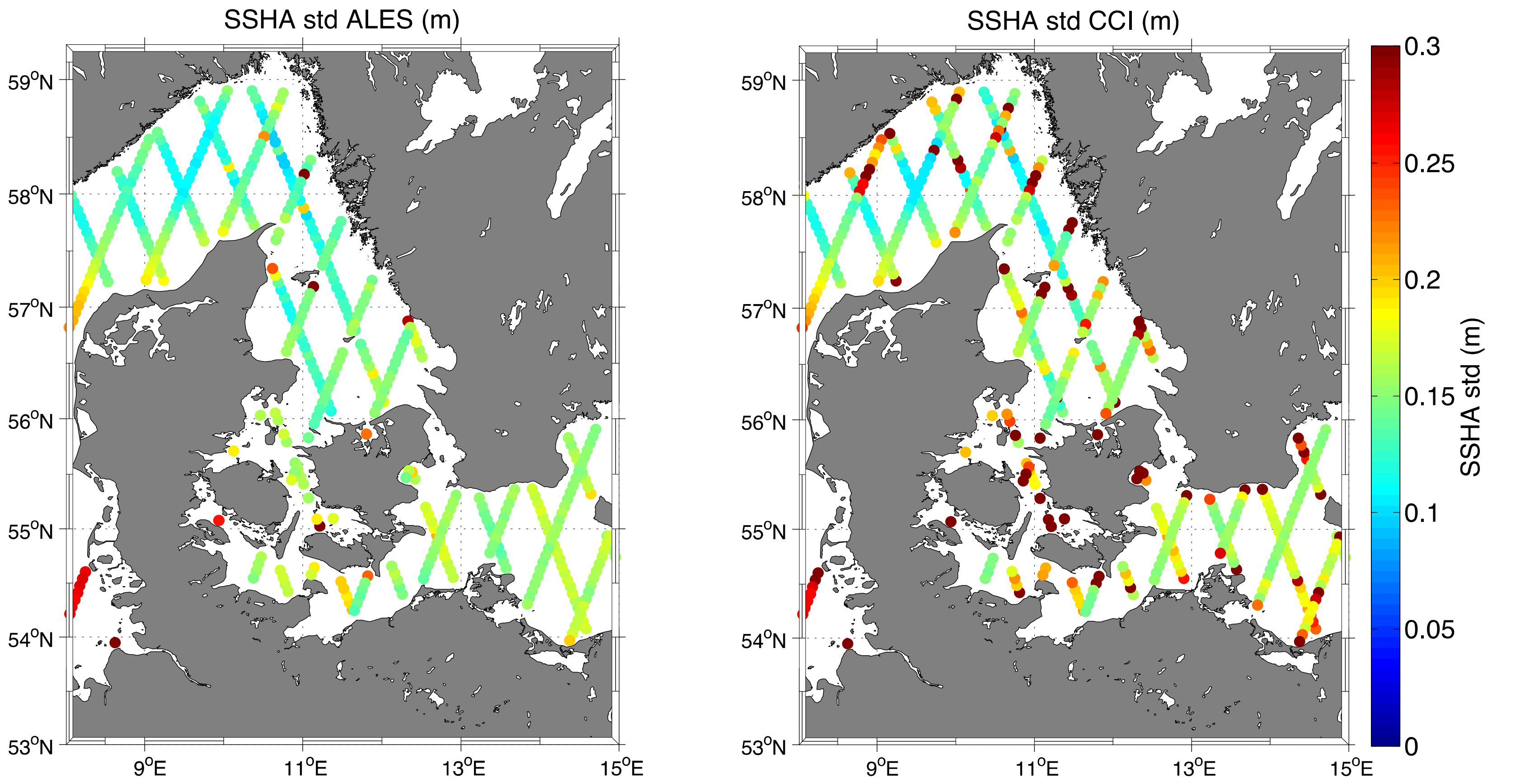


ALES

=

MORE DATA

Benefits of the new dataset



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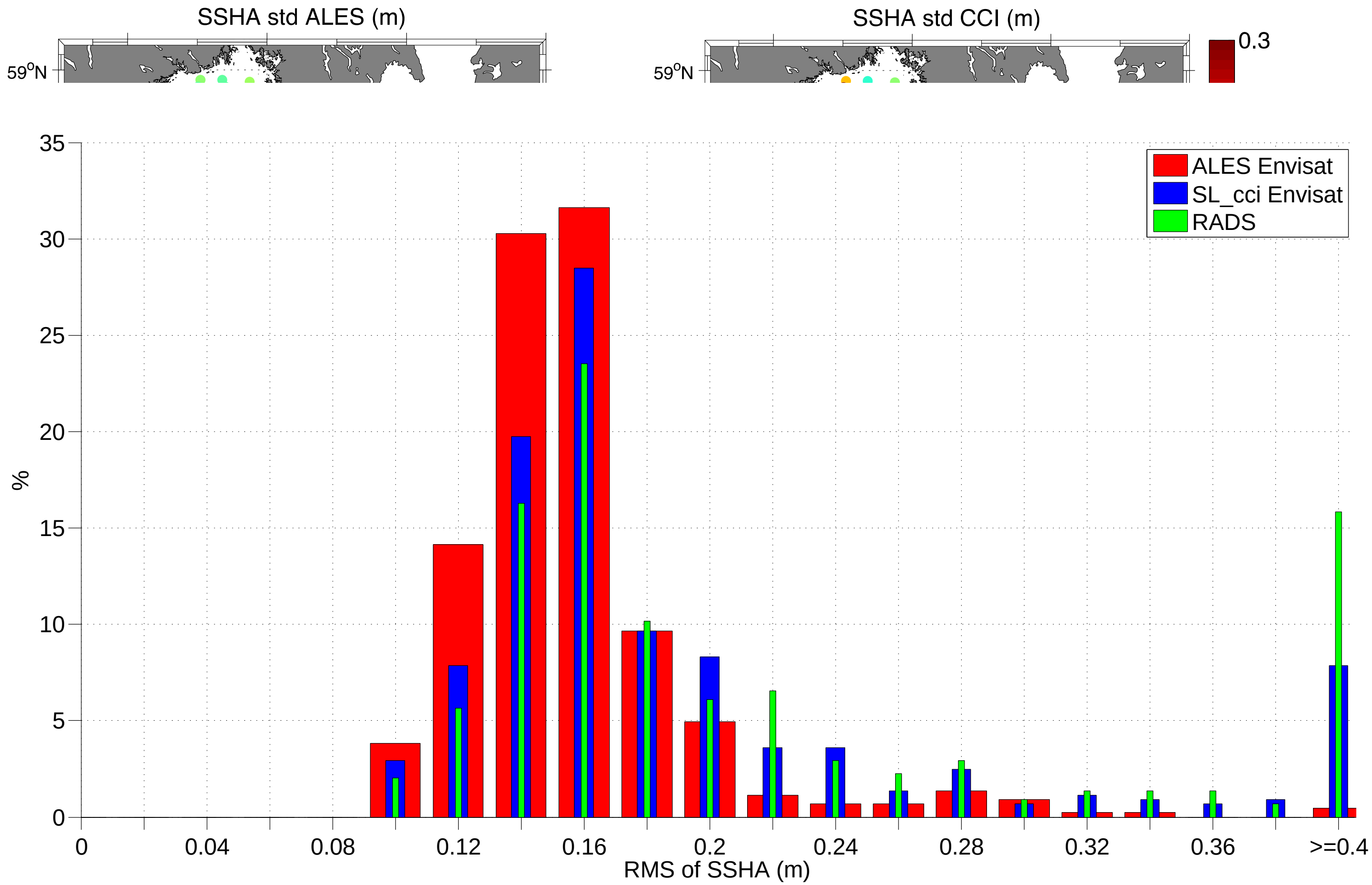
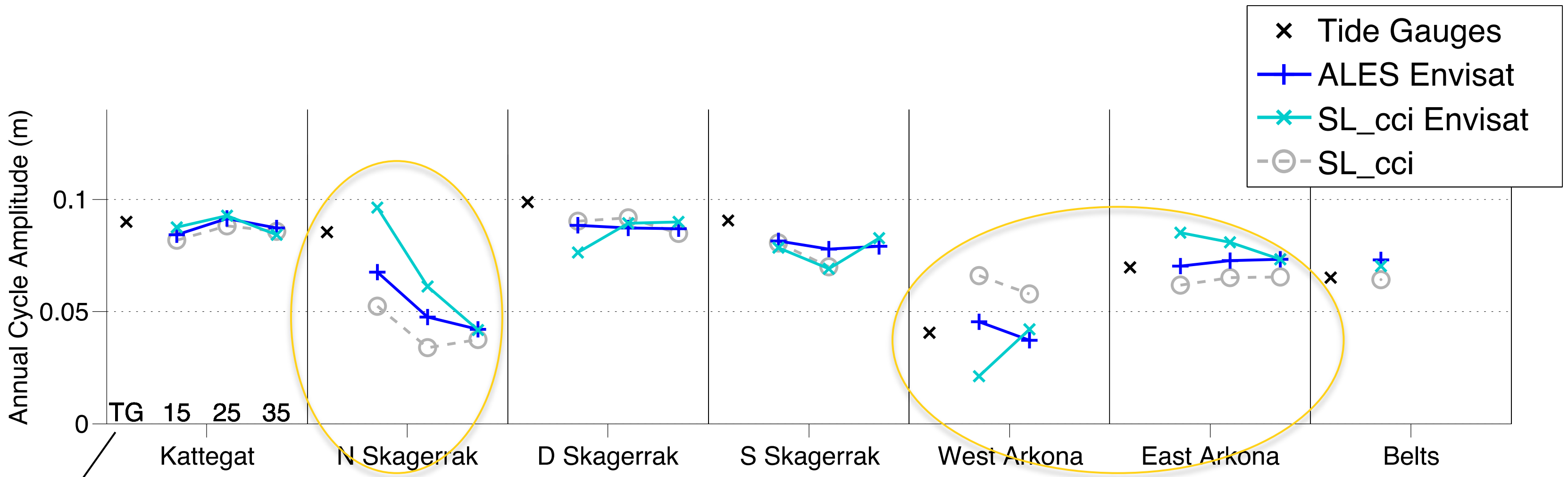


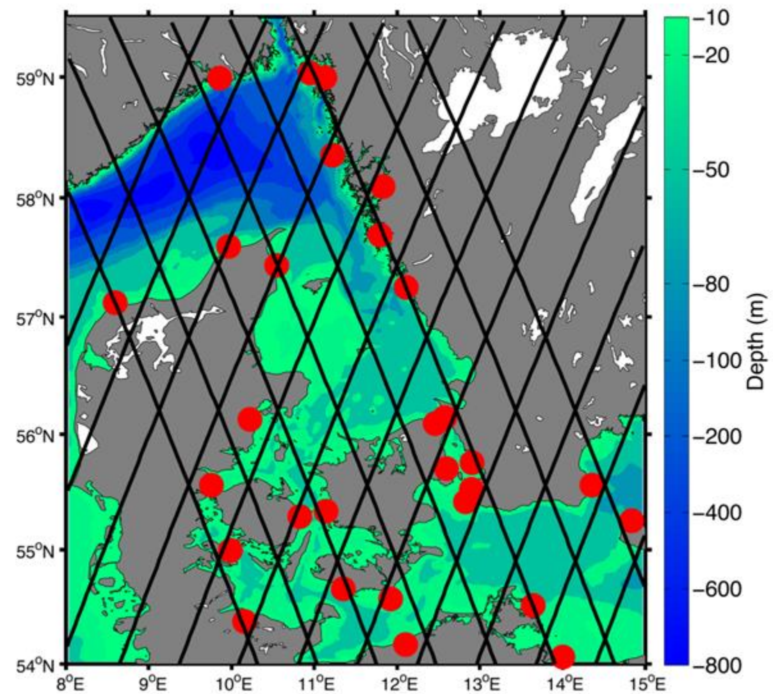
ALES=
BETTER DATA

Closing the gap with tide gauges



Km from the coast

! Slope in N Skagerrak -> Norwegian Current circulation & Bathymetry

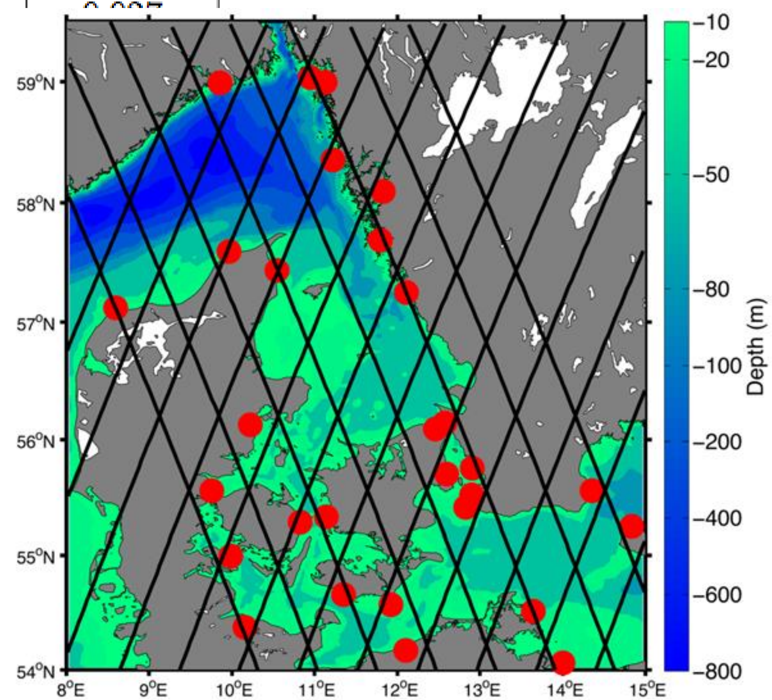


Closing the gap with tide gauges

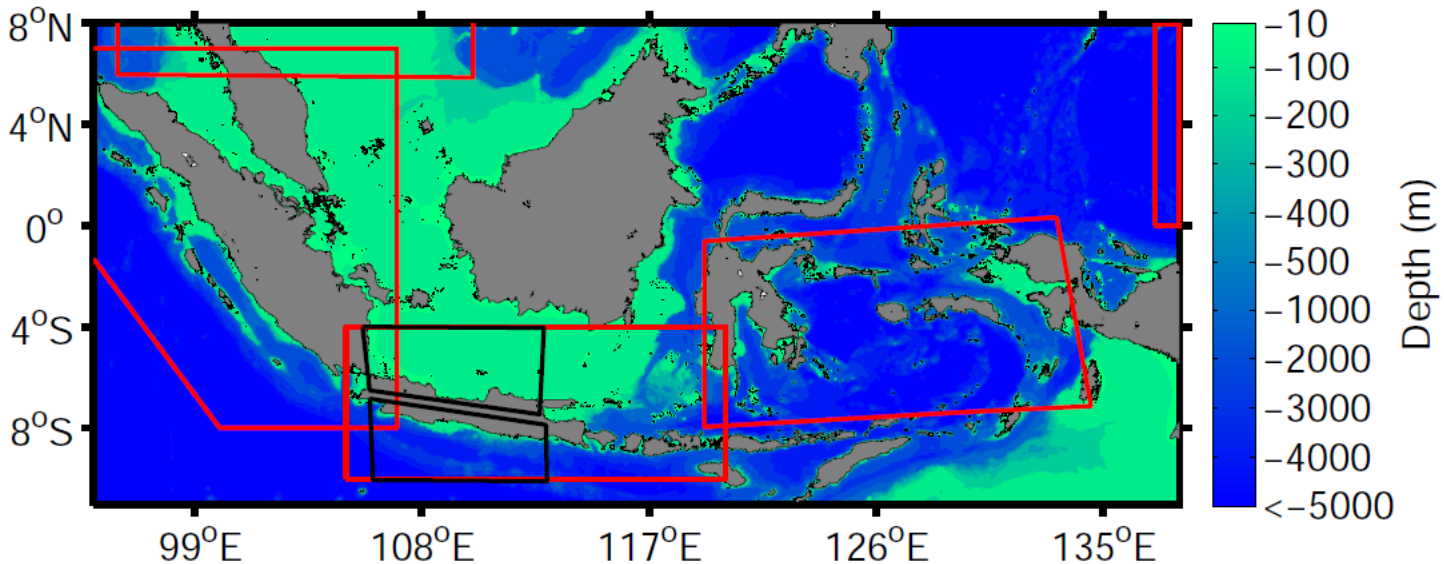
Sub-basin	ALES (m)	SL_cci Env (m)	SL_cci (m)	RADS (m)
Kattegat	0.012	0.019	0.006	0.023
Norway Skagerrak	0.014	0.022	0.023	0.028
Denmark Skagerrak	0.008	0.008	0.006	0.012
Sweden Skagerrak	0.008	0.010	0.007	0.013
West Arkona	0.004	0.031	-0.018	0.024
East Arkona	0.005	0.016	0.006	0.773
Belts	0.006	0.008	0.000	[illegible]

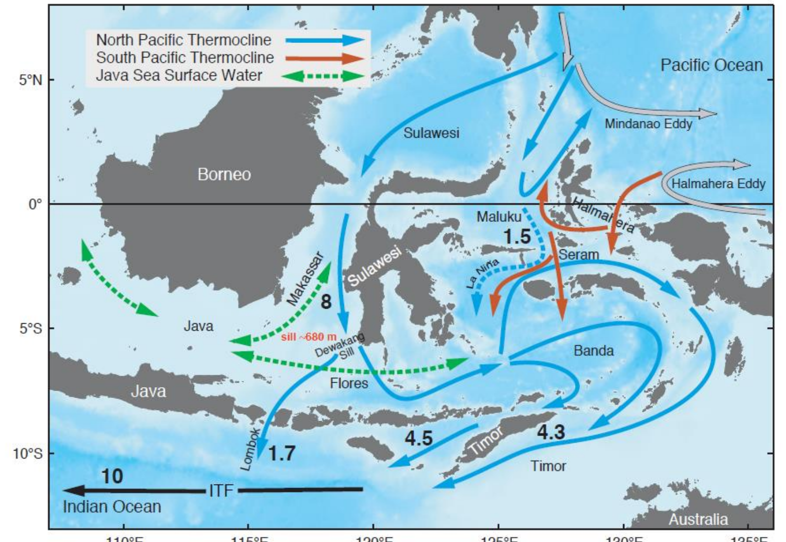
Altimetry data within 15 km of the coast!

TOTAL SIGNAL (annual sinusoids)
ALES THE ONLY DATASET WITH LESS THAN 1.5 cm RMS error w.r.t TIDE GAUGES



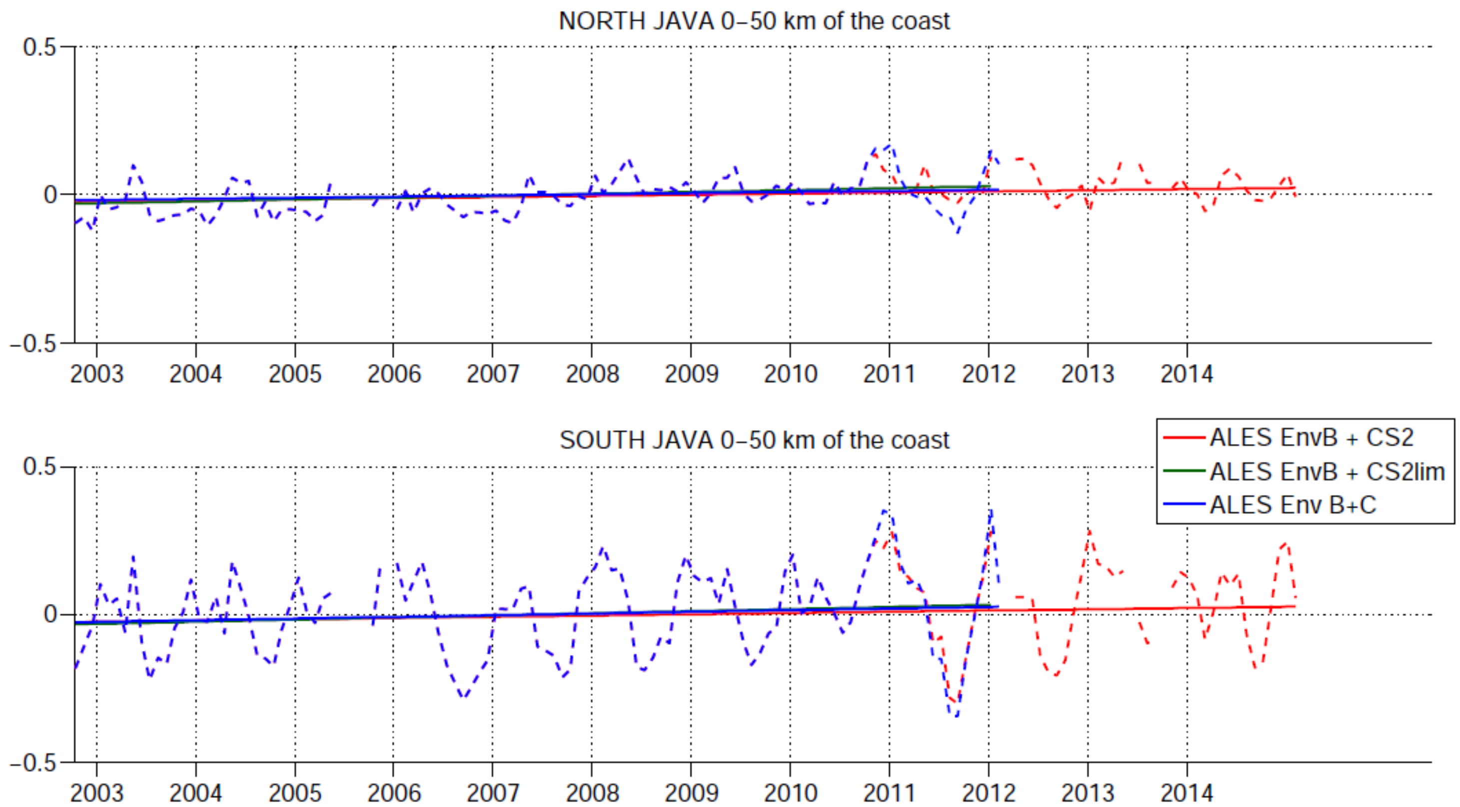
Interpreting the seasonal signal





From Gordon, A. L. (2005). The Indonesian Seas. Oceanography, 18(4), 14.

Interpreting the seasonal signal



Extension of the time series: new Cryosat-2 data cross-calibrated with Envisat

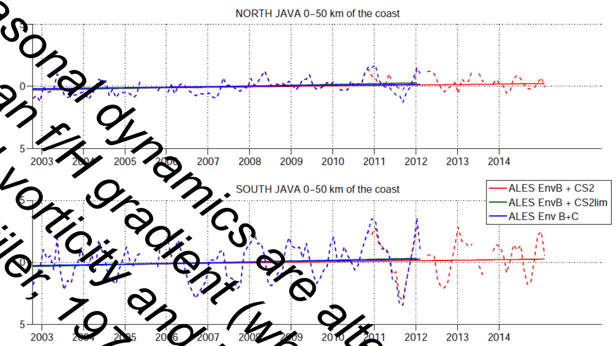
Interpreting the seasonal signal

	0-50 km	50-100 km	100-150 km
Trend (mm/y)	3.8±2.6	3.4±1.8	3.2±1.6
Ann Ampl (mm)	25.3±10.9	18.8±10.9	26.2±10.9
Semi Ampl (mm)	27.6±8.4	33.6±8.1	33.3±8.2

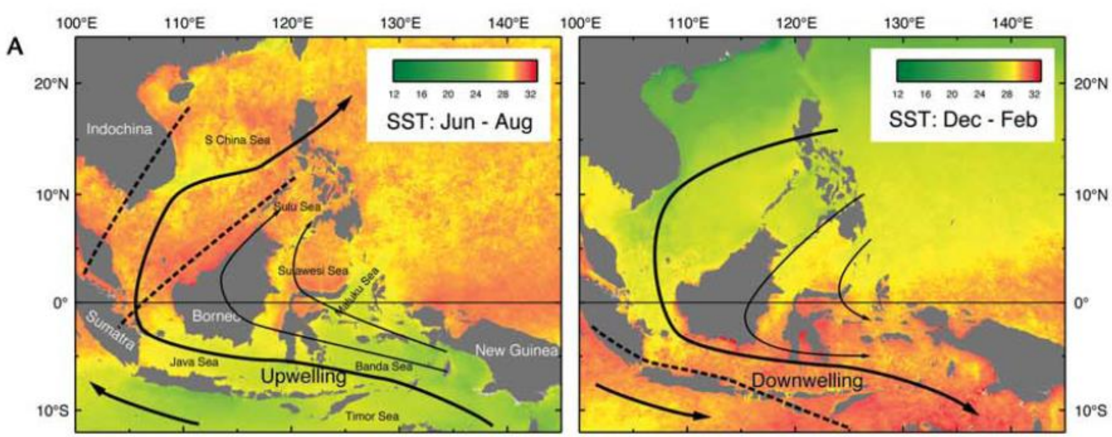
Table 7: Trend, annual amplitude and semiannual amplitude of the multimission EnvB+CS2 time series, using data at different distances from the coast of NJ.

	0-50 km	50-100 km	100-150 km
Trend (mm/y)	4.2±4.3	3.4±4.3	3.3±4.1
Ann Ampl (mm)	130.5±24.5	112.3±22.0	96.8±18.7
Semi Ampl (mm)	57.8±17.7	49.2±14.4	36.8±11.7

Table 8: Trend, annual amplitude and semiannual amplitude of the multimission EnvB+CS2 time series, using data at different distances from the coast of SJ.



'Seasonal' dynamics are altered along an f/H gradient (where f is the potential vorticity and H is the depth) [Gill and Niiler, 1973]



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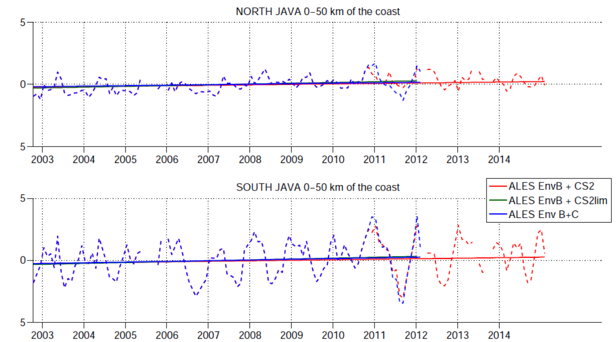

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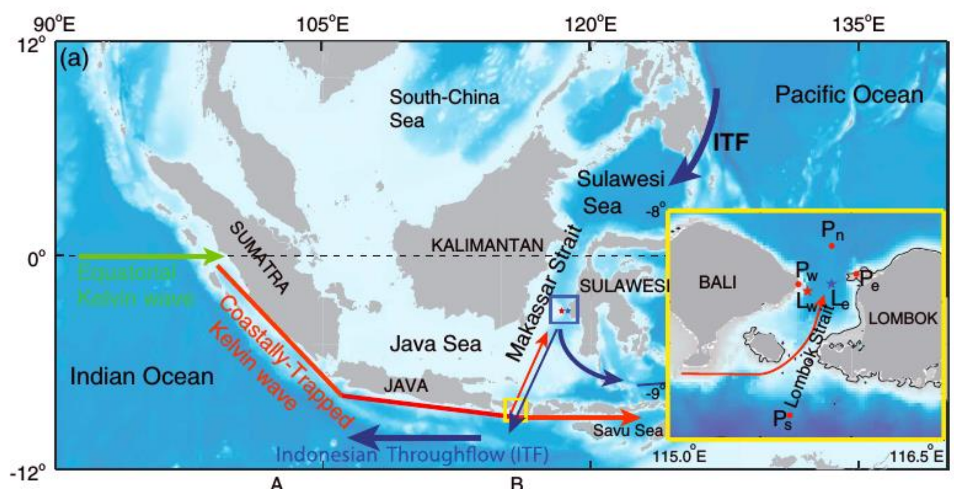
PUJIANA ET AL.: KELVIN WAVES IN MAKASSAR STRAIT

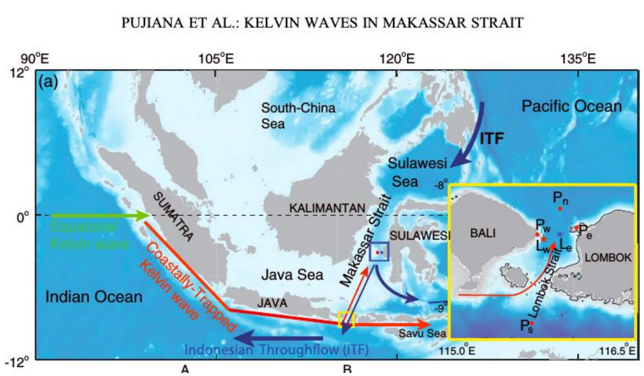


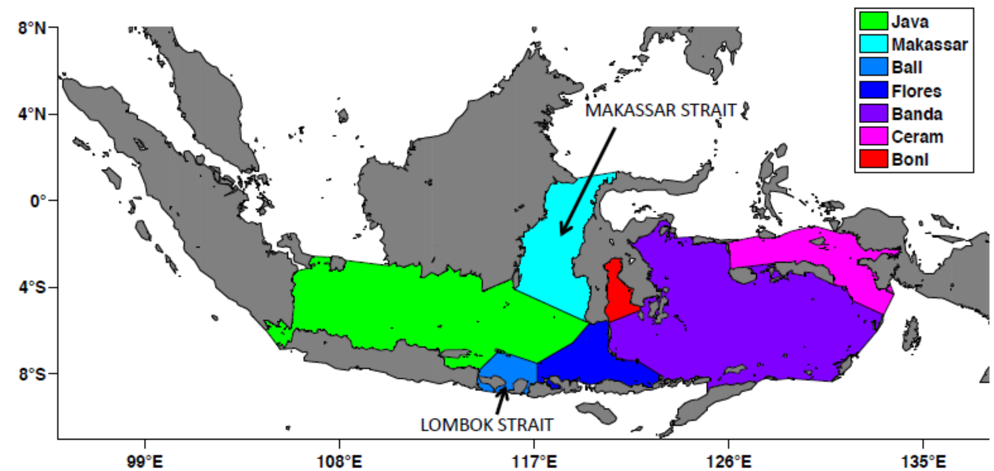
Pujiana, K., Gordon, A. L., and Sprintall, J. (2013). Intraseasonal Kelvin wave in
Makassar Strait. J. Geophys. Res.-Oceans, 118(4), 2023–2034.

Interpreting the seasonal signal

	Java	Flores	Banda	Ceram
Trend (mm/y)	2.9±2.0	2.9±2.4	1.7±4.2	3.3±3.2
Ann Ampl (mm)	52.3±10.6	59.1±10.1	79.1±10.1	78.4±11.8
Semi Ampl (mm)	26.7±6.8	4.2±6.3	2.8±5.9	6.3±7.4

Table 9: Trend, annual amplitude and semiannual amplitude of the multimission EnvB+CS2 time series for Java, Flores, Banda and Ceram seas.





Area of influence of the Kelvin Wave detected! (Moorings detected Kelvin wave path from Lombok to Makassar Strait [Pujiana et al. 2013]

Conclusions

The ALES coastal altimetry product:

- Improves the quality and the quantity of coastal measurements w.r.t. standards

- Reduces the measurement gaps between tide gauges and open ocean

The coastal sea level analysis:

- Hints to a stronger annual sea level variability along the coastal currents under study

- Reveals the path followed by the semiannual Kelvin Wave

Next steps:

TREND UNCERTAINTY -> Longer time series needed (ERS ALES coastal reprocessing foreseen)

Thanks for your attention

ELSEVIER
Advances in Space Research
Available online 28 April 2016
In Press, Accepted Manuscript — Note to users

Cross-calibrating ALES Envisat and CryoSat-2 Delay-Doppler: A coastal altimetry study in the Indonesian Seas

Marcello Passaro[a, b, c], Salvatore Dinardo[d], Graham D. Quartly[e], Helen M. Snaith[f], Jérôme Benveniste[g], Paolo Cipollini[h], Bruno Lucas[i]

SARvatore dataset:
https://gpod.eo.esa.int/

ALES dataset:
ftp://podaac.jpl.nasa.gov/allData/coastal_alt/L2/ALES/

AGU PUBLICATIONS
JGR
Journal of Geophysical Research: Oceans
RESEARCH ARTICLE
10.1002/2014JC010510

Annual sea level variability of the coastal ocean: The Baltic Sea-North Sea transition zone

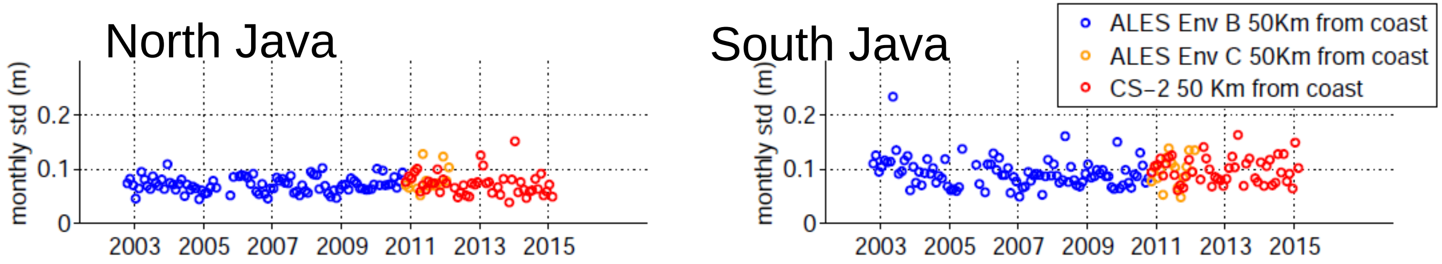
M. Passaro[1,2], P. Cipollini[3], and J. Benveniste[2]

[1]Graduate School National Oceanography Centre Southampton, University of Southampton, Southampton, UK, [2]European Space Research Institute, European Space Agency, Frascati, Italy, [3]Marine Physics and Ocean Climate Research Group, National Oceanography Centre, Southampton, UK

Key Points:
- Coastal altimetry is able to analyze the annual sea level on a subbasin scale
- Wind is the main driver of the annual cycle in the whole area of study

SPARE SLIDES

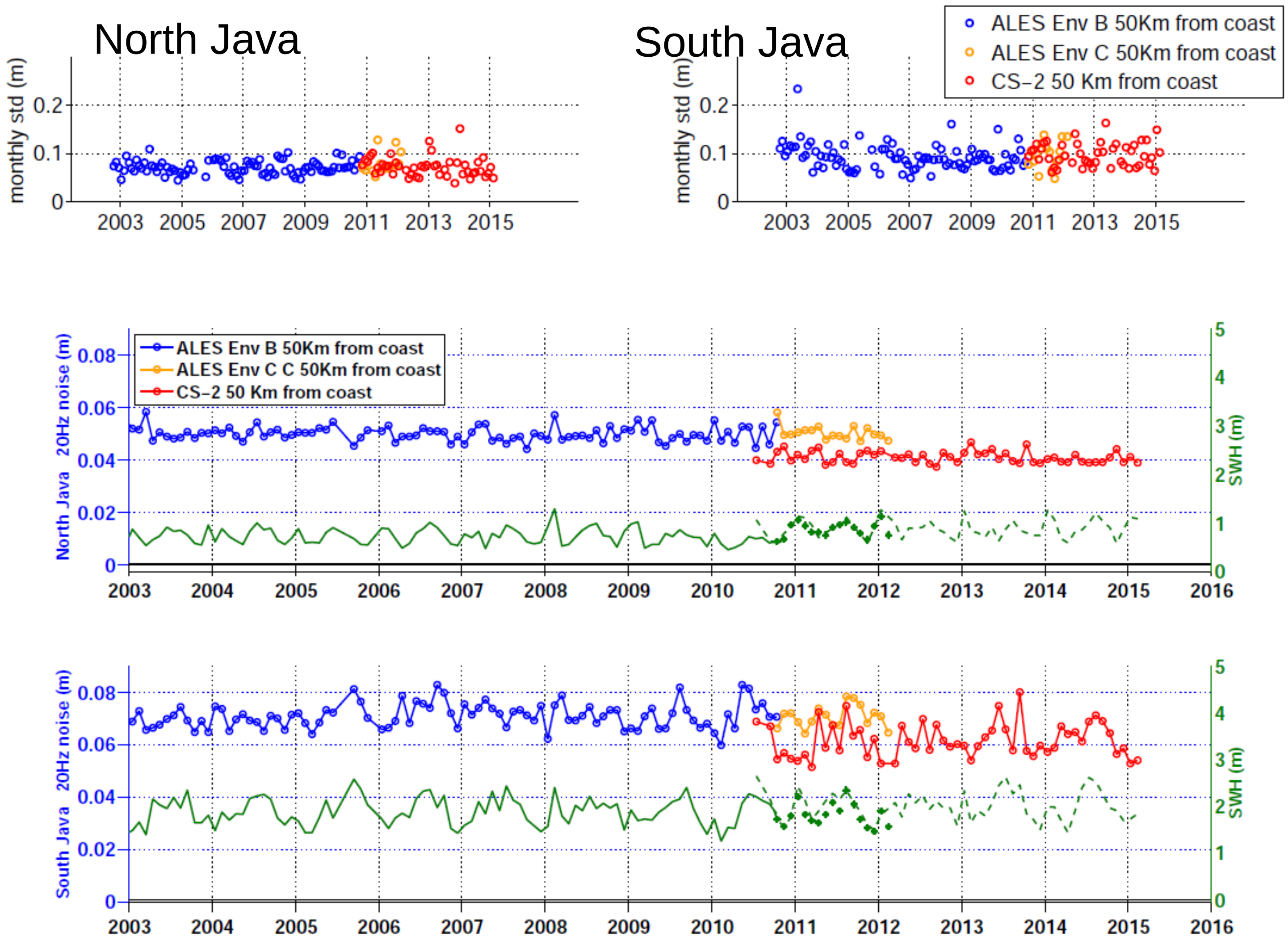
The altimetric dataset



Consistent coastal sea level variability from mission to mission

Spikes -> high variability at monsoon transition (Kelvin wave, see later…)

The altimetric dataset



SAR precision improvement -> 0.3 cm w.r.t. Envisat at 1 Hz

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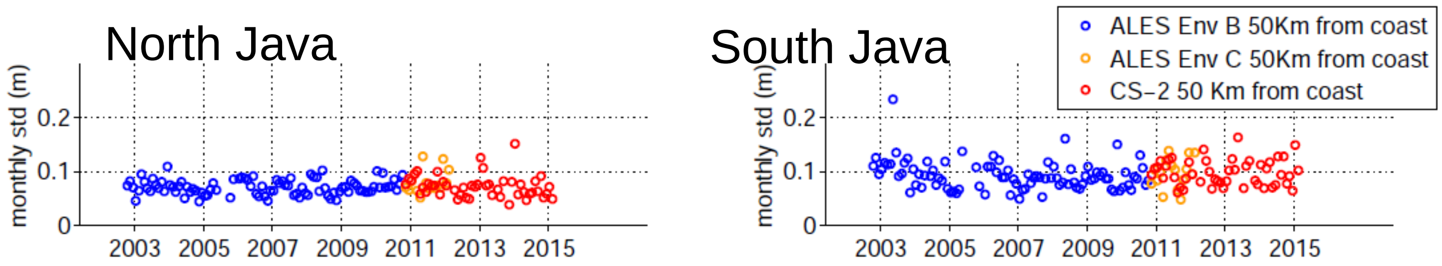

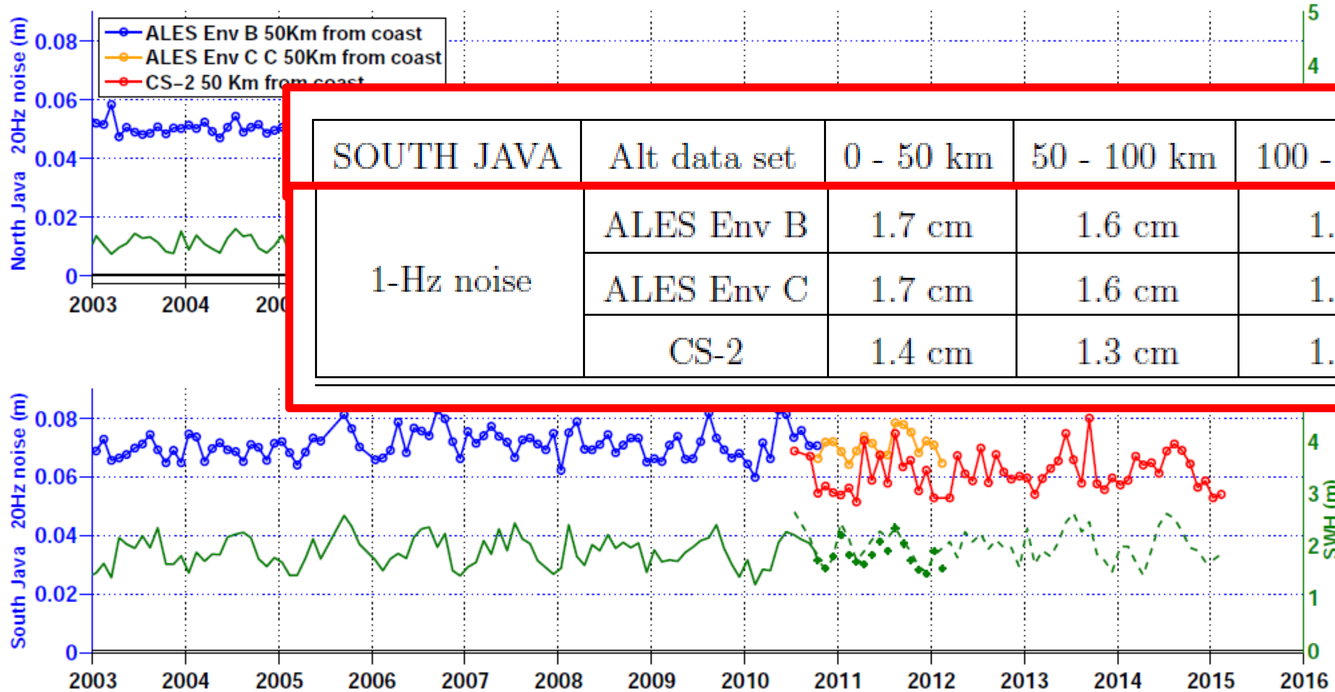

SOUTH JAVA	Alt data set	0 - 50 km	50 - 100 km	100 - 150 km
1-Hz noise	ALES Env B	1.7 cm	1.6 cm	1.6 cm
	ALES Env C	1.7 cm	1.6 cm	1.6 cm
	CS-2	1.4 cm	1.3 cm	1.3 cm

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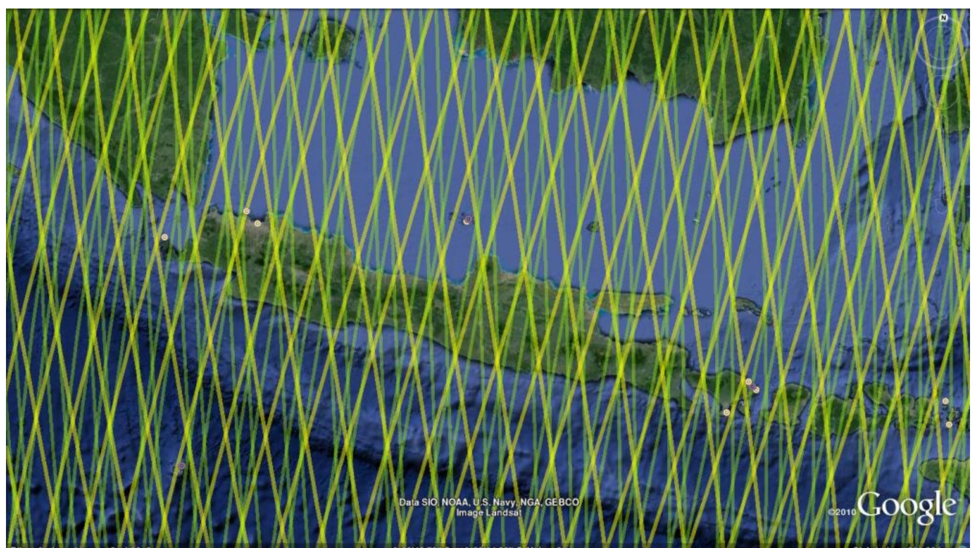
SCIENTIFIC QUESTION:
Can we combine coastal reprocessed standard altimetry and Cryosat-2 for sea level studies?



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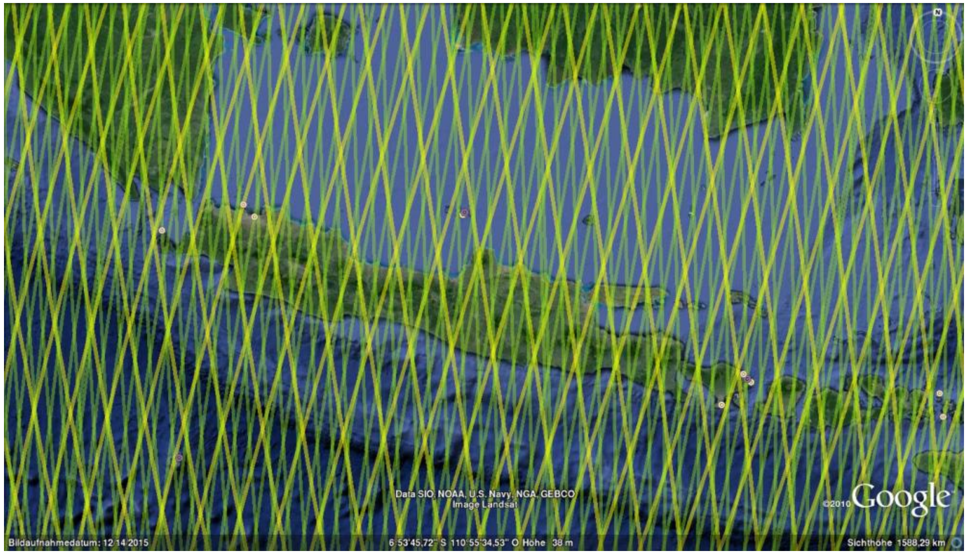

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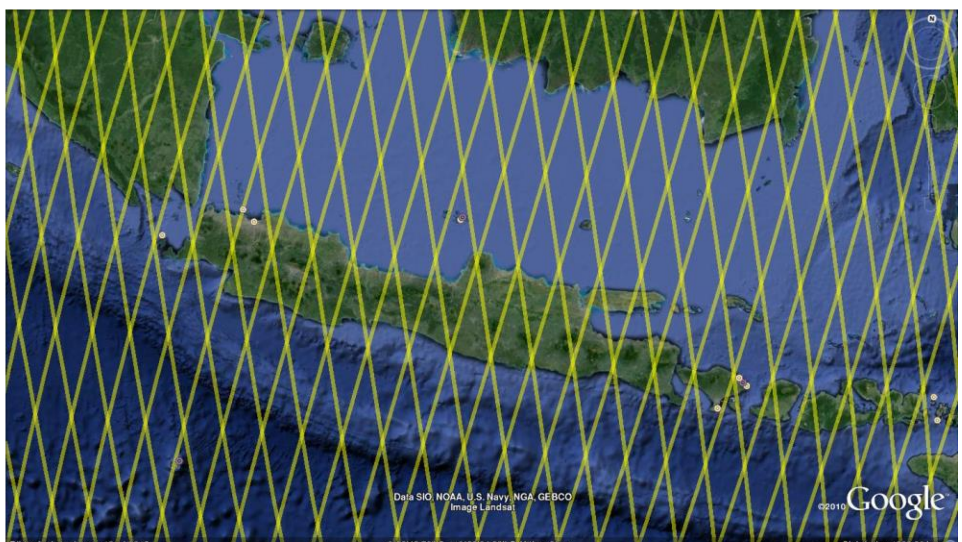

Interpreting the seasonal signal

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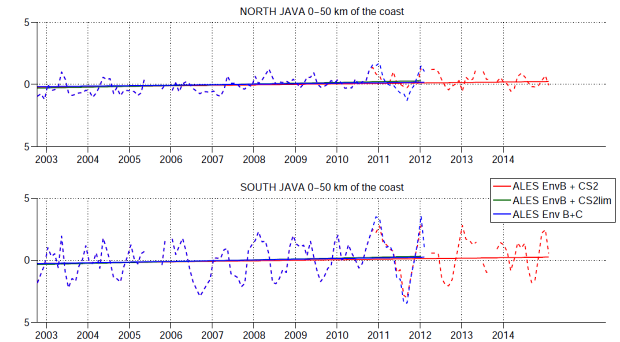

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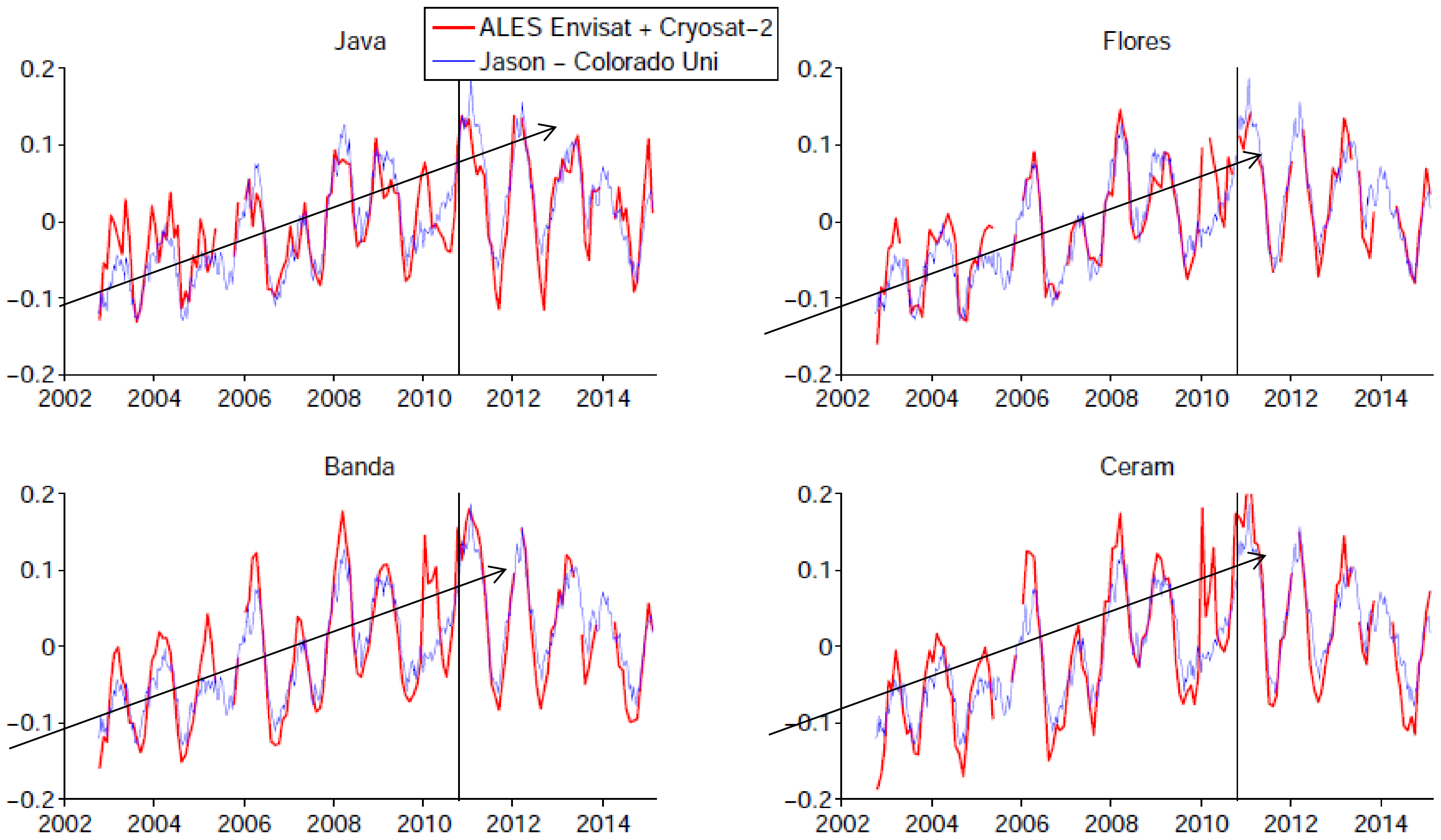
BE AWARE WHEN TRYING TO INTERPRETE TRENDS:

- UNCERTAINTY IS TOO HIGH
- DOMINATED BY INTERANNUAL VARIABILITY (El Niño, see later)

Interpreting the seasonal signal



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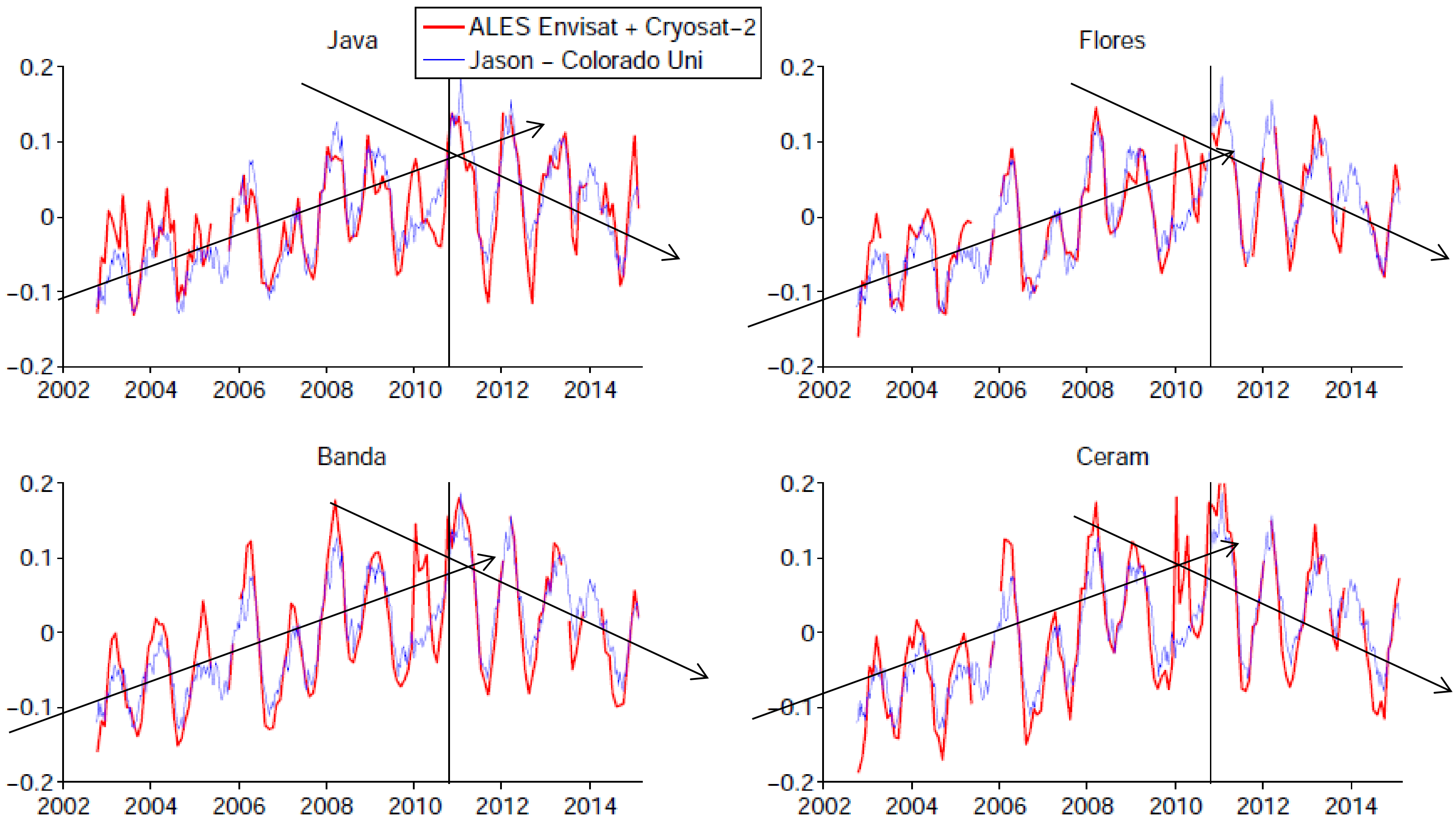

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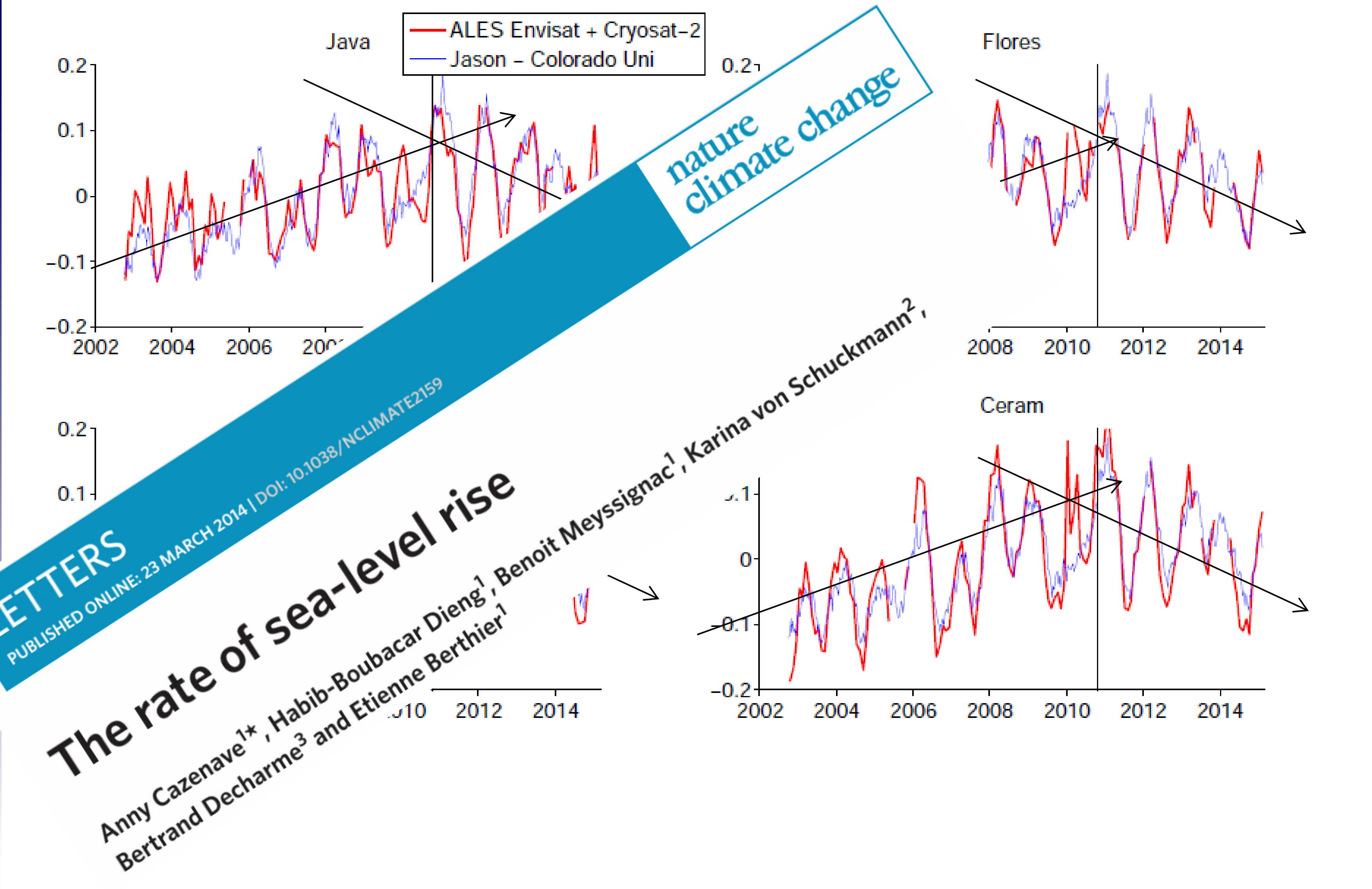

Interpreting the seasonal signal