Ageostrophic components in the coastal sea surface height obtained from the GPS on a ferryboat

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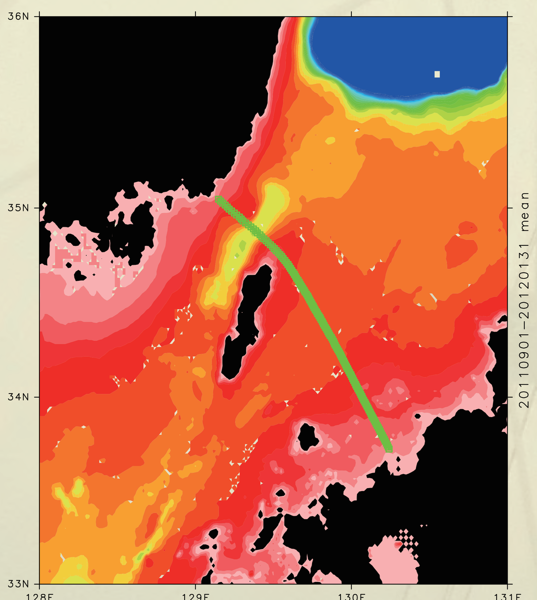
1. Introduction

High-resolution SSH will be obtained soon.

e.g. SWOT (JPL/CNES), COMPIRA (JAXA) and SAR-mode altimeters

But, how significant are ageostrophic variations in coastal areas?

Direct coastal SSH measurements by real-time kinematic **GPS** on the ferryboat *New Camellia,* crossing the Tsushima Strait between Japan and Korea everyday (Ichikawa *et al.*, 2013).



New Camellia (19,961 Gross Tons) with RTK GPS (NetR5, Trimble), and her mean route in the Tsushima Strait (bathymetry C.I. 20m).

2. Data and Method

The GPS antenna height (H_G) is observed every 30 sec with 3 fixed GEONET reference sites from September 2011. To avoid misfit of the RTK GPS analysis, the H_G should agree within 5cm diff. for at least 2 references.

By this criterion, we limit our data for only **nighttime** (from Pusan to Hakata) cruises, mainly due to errors originated from water vapor in daytime cruises.

The Sea Surface Dynamic Height (SSDH) ζ^G is determined from the H_G as;

$$H_G = \textbf{Geoid} + \textbf{Tides} + \textbf{Ship\_Motions} + \zeta_G$$

where,

Geoid; EGM2008 geoid model (Nikolaos *et al.*, 2012)

Tides; TP-Jason based local tide model (based on Morimoto, 2009)

Ship_Motions; waves & ship draft

waves; removed by along-track averaging. Due to the aliasing of wind waves at the 30-sec samplings, longer 15 min. averaging is adopted, which results in 7-10km spatial smoothing.

ship draft; determined by draft gauges installed to the ferry and ship speed. Fuel consumption causes nearly 5 cm lift during a cruise.

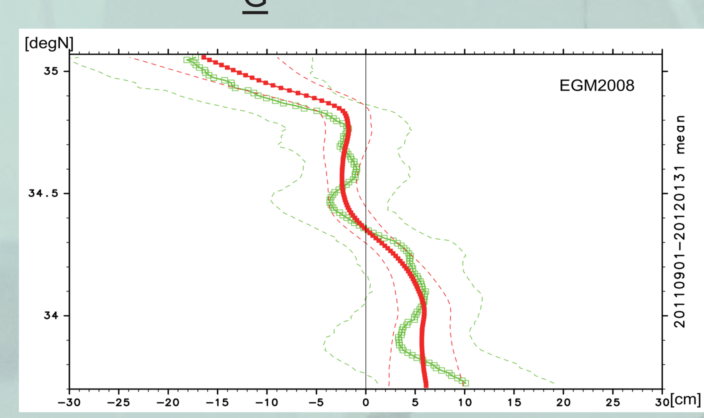
Then, ζ_G is interpolated at the standard ship route by the Gaussian smoothing with 8-km decorrelation scale; no data far from the standard route were used.

For comparison, the SSDH ζ_A is also estimated from the de-tided velocity at the top layer (**18m depth**) of the **bottom-mounted ADCP**(Fukudome *et al.*, 2010), assuming the geostrophic current.

3. SSDH determined by GPS, ζ_G

3.1 Temporal Mean SSDH ζ_G

The 5-month mean ζ_G agrees well with ζ_A, which shows accurate H_G obs., as well as good precision of the EGM 2008 geoid model.

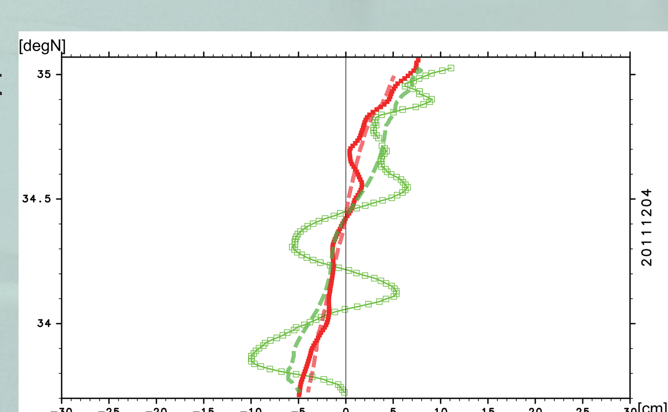


The 5-month (2011/9-2012/1) mean ADCP ζ_A profile (red line) and the GPS ζ_G profile (green).

3.2 SSDH Anomaly ζ'_G

Example of the SSDH Anomaly (SSDHA) is plotted in the right panel. Both SSDHA agree well in a larger spatial scale, but ζ'_G includes small-scale variations with ~0.1m amplitudes.

Since their scales (~20km) are less than the internal Rossby radius, they could be related with ageostrophic components.

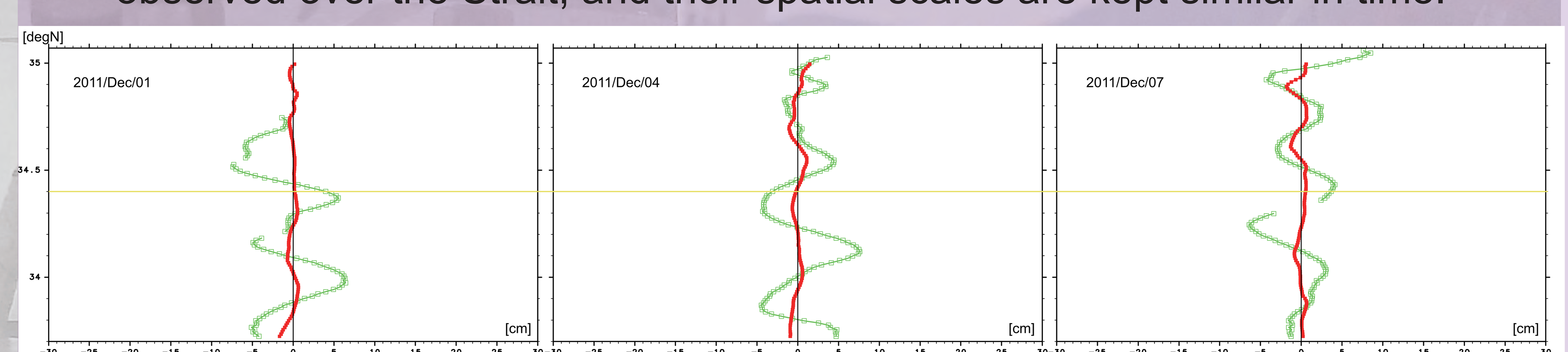


The GPS ζ'_G (green) and ADCP ζ'_A (red line) SSDHA profile on 2011/12/04. Spatially 30-km smoothed values are also plotted with broken lines.

4. Ageostrpchic SSDHA components

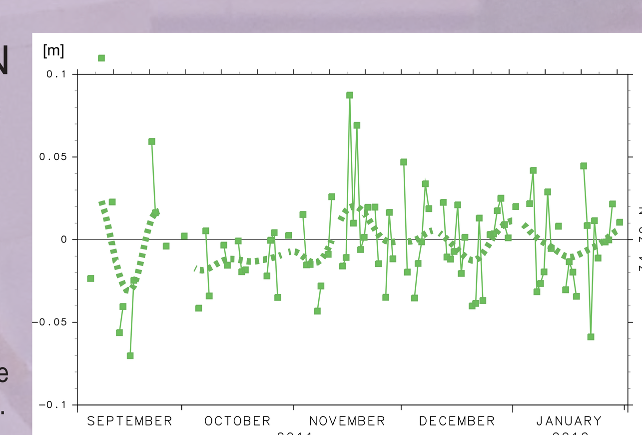
Small-scale SSDHAs on 01, 04, 07, December, 2011 are plotted in the lower panels, by subtracting 30-km smoothed SSDHA.

The samll-sacle variations, or the ageostrophic SSDHA, are commonly observed over the Strait, and their spatial scales are kept similar in time.

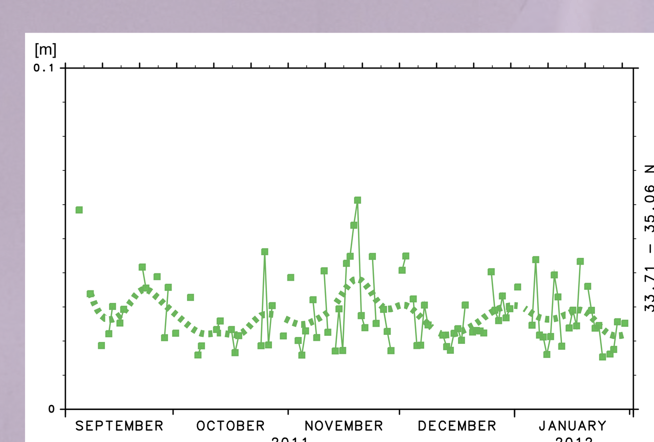


Small-scale SSDHA profile on 2011/12/01 (left), 12/04 (middle) and 12/07 (right). The colors are the as the other figures.

The time series of the ageostrophic SSDHA at 34.4N (right panel) shows that those variations are quite variable in time. When a low-pass filter by 5-day Gaussian smoothing is applied (broken line), the ageostrophic SSDHA indicates variations with periods around 20 days.



Time series of the small-scale SSDHA at 34.4N. The low-pass filterd values are plotted by the bold broken line.



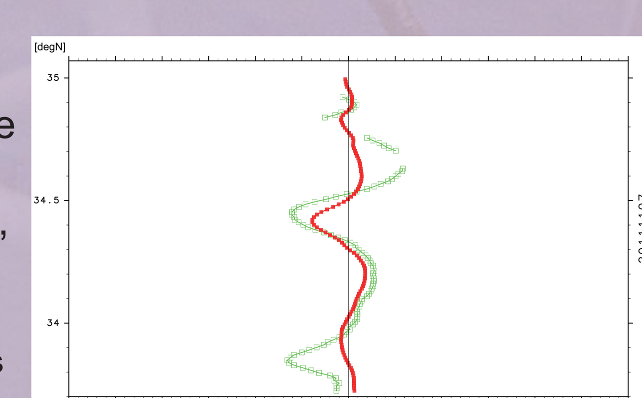
The variance of the small-scale SSDHA along the ferry track over the whole Strait, or the amplitude of the ageostrophic SSDHA, is plotted in the left panel. The amplitude modulation of the ageostrophic SSDHA occurs with 10~25 days periods.

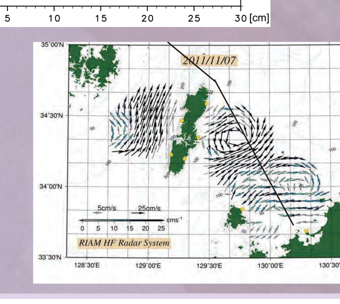
A possible candidate would be a spring/neap cycle of the internal tides in the lower layer, which may not be captured by the 18-m depth ADCP data.

Time series of the variance of the small-scale SSDHA along the ferry track.The low-pass filterd values are plotted by the bold broken line.

Note that the small-scale SSDHA is sometimes recorded in the ADCP data. Significant small-scale variation at 34.4N is recognized both in the GPS (green) and ADCP (red) SSDHAs on 7 November, 2011, which was caused by passage of a **submeso-scale eddy**.

We would need to separate the ageostrophic SSDHA components of different causes.





Small-scale GPS (green) and ADCP(red) SSDHA profile on 2011/11/07 (top). The daily-averaged surface ocean current observed by ocean radars (http://le-web.riam.kyushu-u.ac.jp/radar/daily/) with the ferry route (bottom).

Reference

Fukudome *et al.* (2010) *J. Oceanogr.*, 66(4), 539-551.

Ichikawa *et al.* (2013) ESA SP-710.

Morimoto (2009) *J. Oceanogr.*, 65(4), 477-485.

Nikolaos *et al.* (2012), *J. Geophy. Res.*, 117(B4).

5. Summary

Coastal SSDH is obtained by **GPS** on the ferryboat *New Camellia*, and compared to the ADCP velocity.

The **GPS and ADCP SSDHs agree well in larger scales.** Meanwhile, small-scale variations with ~20km scales are commonly found only in the GPS SSDHA.

Although spatial scales of the small-scale GPS SSDHA is kept similar in time, its phase at a location is complicated. Their amplitude modulation has 10~25 days period. These suggest that **internal tides** are one of the candidates.

Submeso-scale eddies also cause small-scale SSDHA variations, but they accompany the ADCP variations.