GNSS monitoring of the Ross Ice Shelf, Antarctica

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Taking the pulse of the Ross Ice Shelf

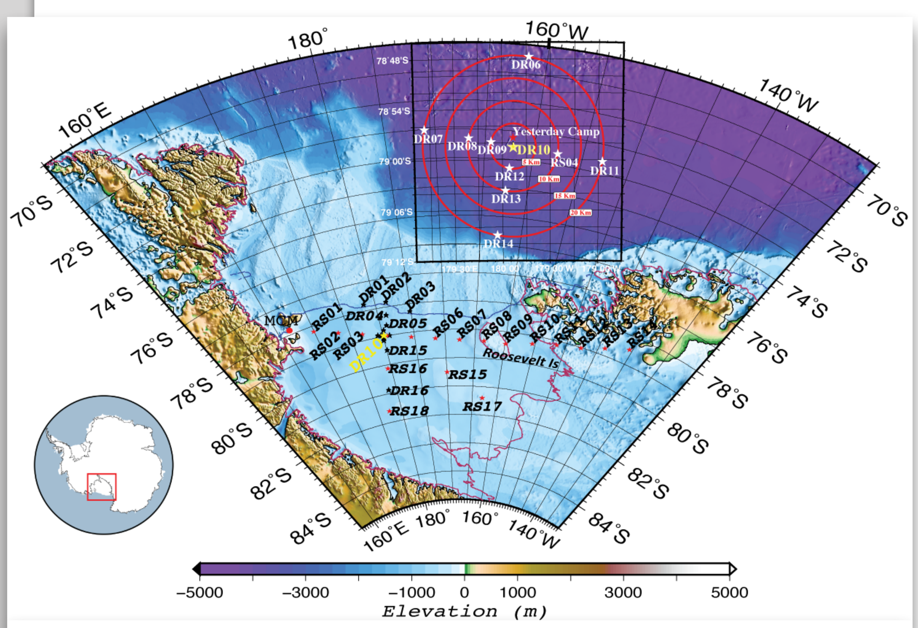


Fig.1: Location of seismic stations on the Ross Ice Shelf [1]

The *Dynamic Response of the Ross Ice Shelf to Wave-induced Vibrations* (DRRIS) project is investigating how ocean wave-induced vibrations can drive changes in ice-shelf stability. To do so, an array of broadband seismometers was deployed on the ice shelf surface starting in November 2014 (Fig.1) to measure the amplitude and speed of these vibrations along multiple paths across the Ross Ice Shelf (RIS) and to identify zones and regions of weakness.

In November 2015, a GPS array of 13 stations along 2 perpendicular transects was installed, collocated with the seismic stations. One station recorded for a full year (DR10, blue star, Fig.2), the others 12 recorded during the 2 summers only (white stars, Fig.2).

I. GPS processing and merging of daily time series

Data processing approach:
Observations at 1Hz on all stations

→ *Precise Point Positioning* (PPP) approach following [2], using final IGS orbits.

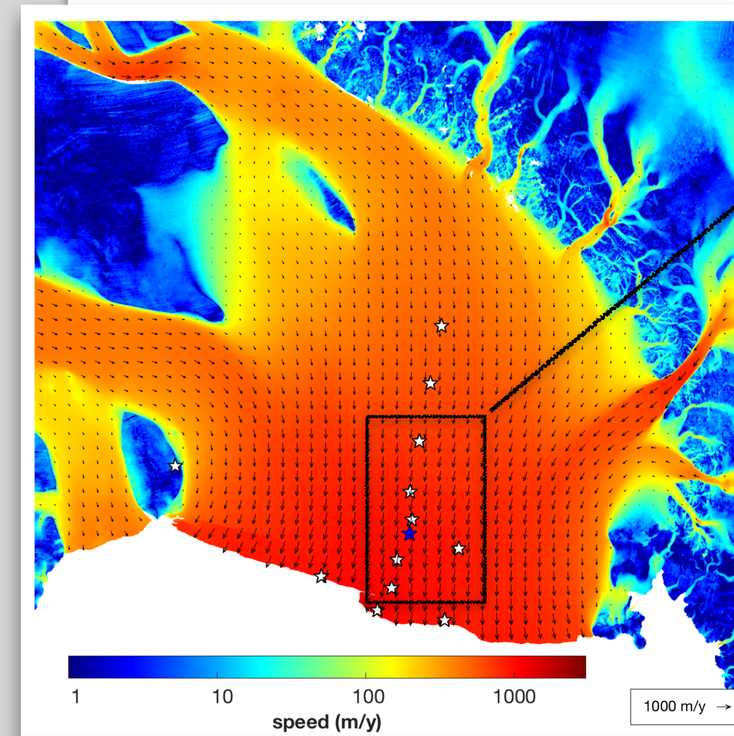


Fig.2: Horizontal velocity of the RIS depicted by the color scale (InSAR-based Ice Velocity [3]). Stars depict the GPS stations location.

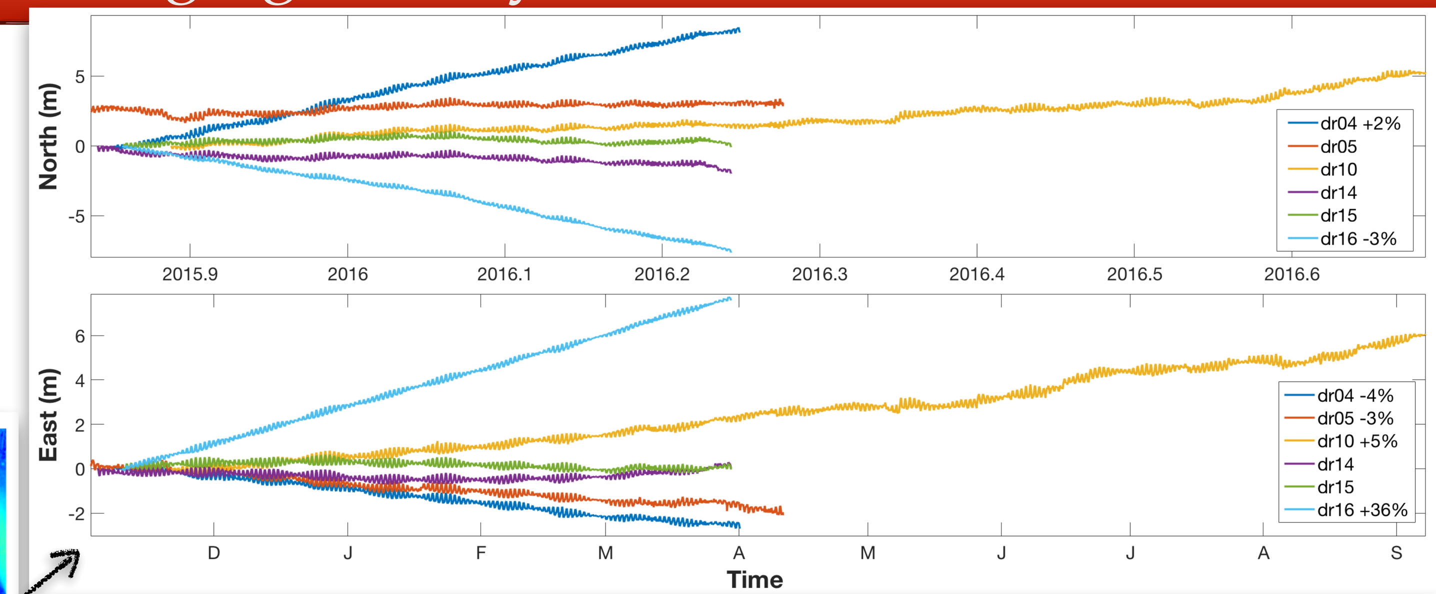


Fig.3: Time series of horizontal components (m), corrected from steady state ice velocity [3]. Notable velocity deviations are indicated in percentage on legends.

Merging of daily time series by estimation and correction of day boundary offsets:

- *Horizontal component:* Estimation of first and last 5 min trend using least squares to predict initial and final positions.
- *Vertical component:* Estimation of sin function fitting the whole day to remove outliers and predict initial and final positions

Only 5 months of observations on most stations (first summer of experiment) but allow to observe some velocity deviations from the InSAR-based ice velocity predictions ([3], Fig.2), mainly on the eastward component (Fig.3), reaching 50% on stations closest to the ice front

→ could be associated with ice shelf fragmentation.

Stations DR10 and DR14 located on both sides of a major rift on the shelf (Inset Fig.4).
On both horizontal components:

$V_{DR10} > V_{DR14}$

→ the northern wall is moving faster than the southern wall (Fig.4).

→ transient velocity change on DR10 could be associated with episodic rift motions (Fig.3).

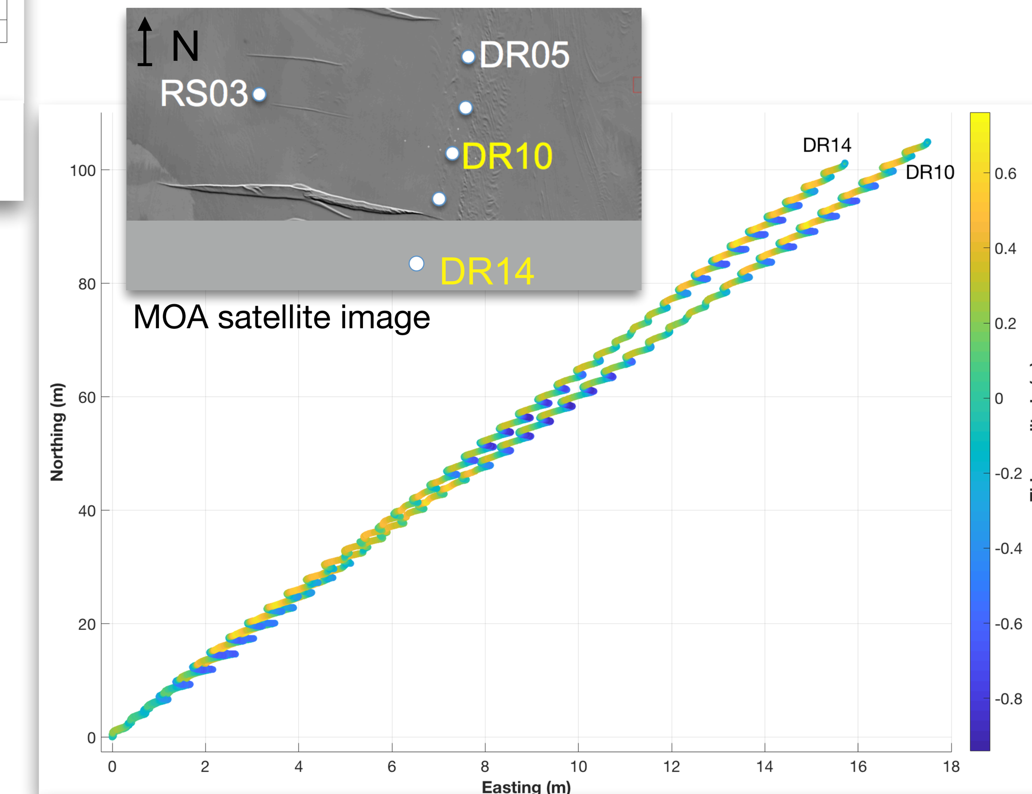


Fig.4: 3D plot of DR10-DR14 [Nov2015 - Dec2015]. The color scale depicts the tide amplitude of the vertical component.

III. Ocean tides on the ice shelf

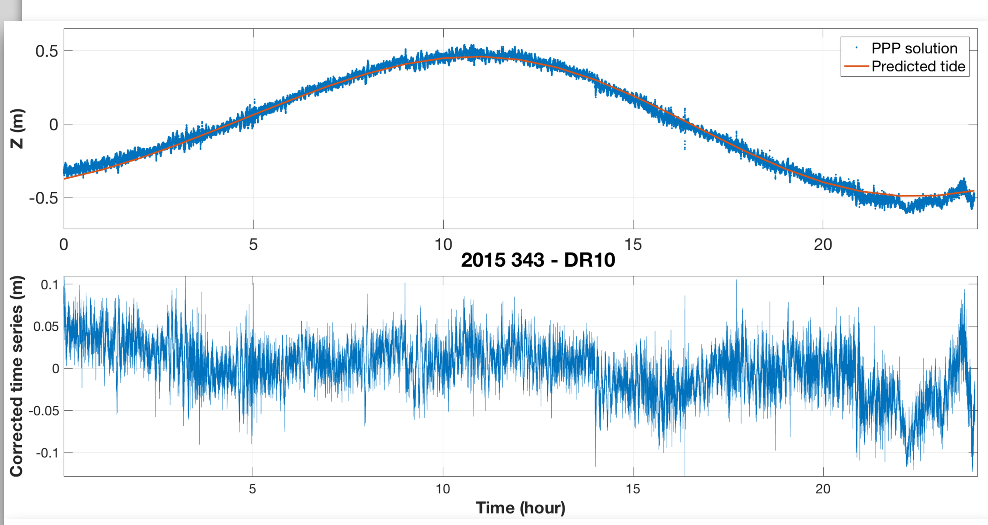


Fig.5: Up component of DR10 as function of hours (day of year 343, 2015) compared to CATS2008 prediction (red curve). Below is the residual time series after correction of tide signal.

Very strong tidal signal observed on the vertical component of time series (Fig.5), up to 1m

→ Good agreement with astronomical predicted tides from CATS2008.

Two principal tides components on the RIS [4] :

- *Principal lunisolar diurnal*
  K_1 - period = ***23.93h***
- *Principal lunar diurnal*
  O_1 - period = ***25.82h***.

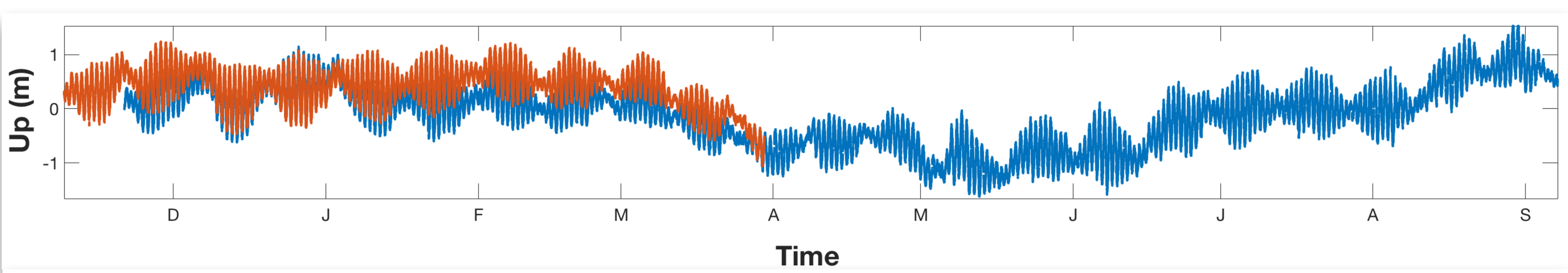


Fig.6: Vertical component (in m) of stations DR10 (blue) and DR14 (red) as function of time.

Spectral analysis of the vertical component of merged time series (Fig.6)

Two peaks of frequency extracted (Fig.7):

- ***23.7h*** in average corresponding to K_1
- ***26.1h*** in average corresponding to O_1

→ good agreement with predictions.

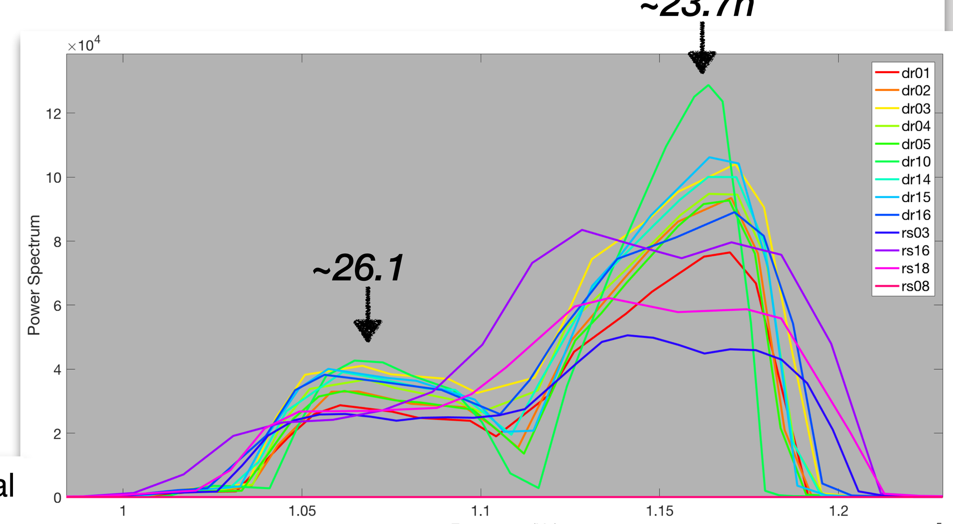


Fig.7: Spectrum analysis of vertical merged times series

IV. Vertical component evolution

Band-pass filter, based on the results of the spectral analysis, of vertical component of time series to remove the tidal signal.

→ Fig.8: Subsidence of all stations between February and April, could be associated with basal melting during the austral summer and summer-winter transition period.

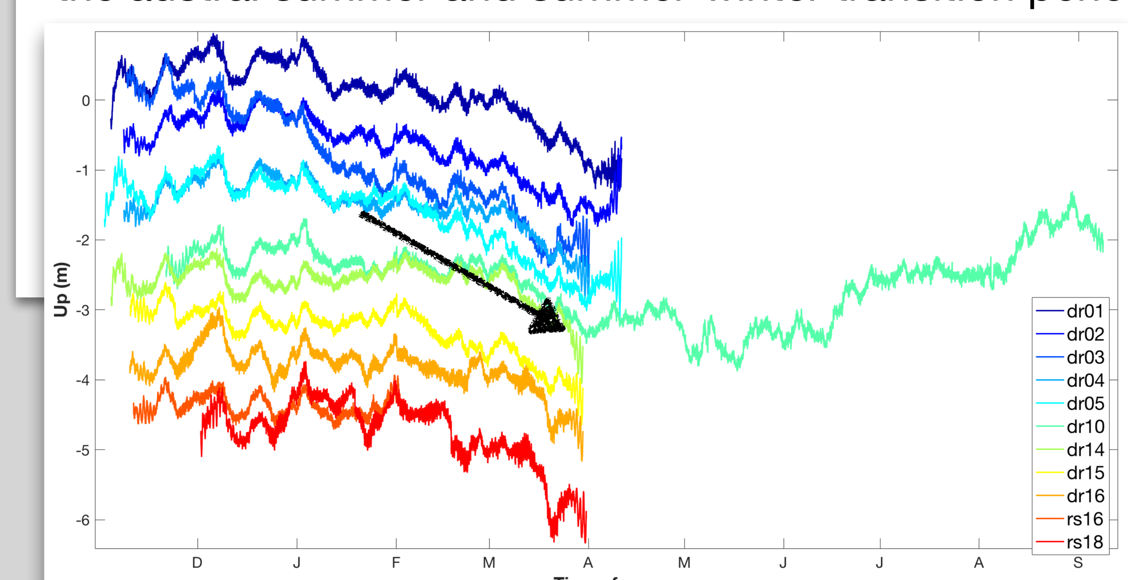
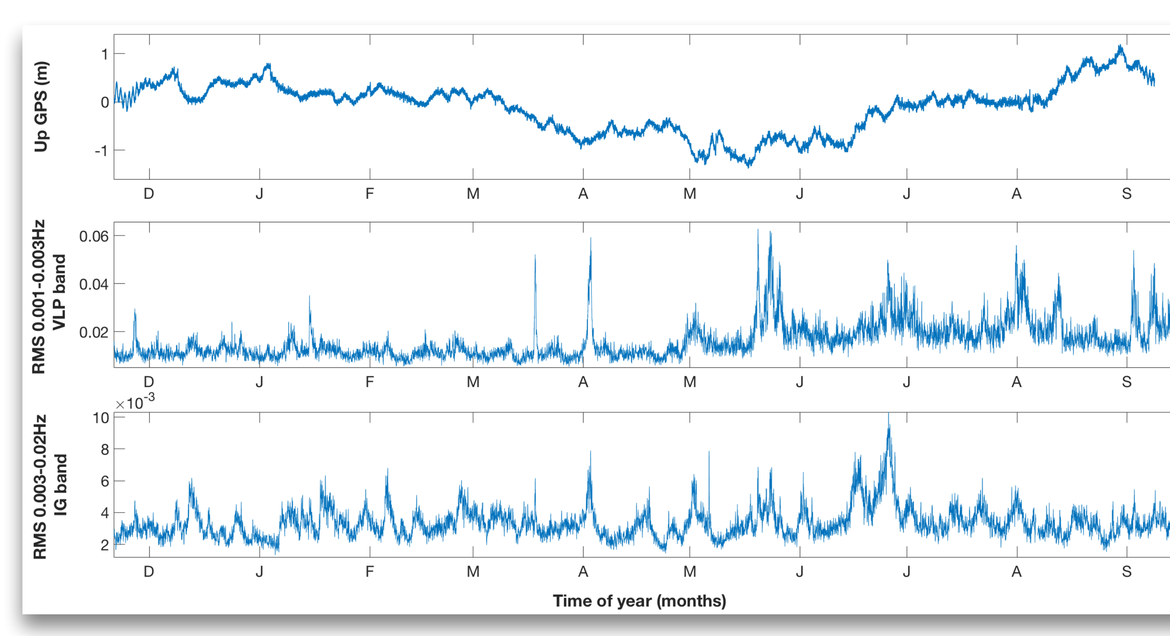


Fig.8: Time series of vertical component band-passed filtered (m)



First comparison with seismic rms displacements extracted on InfraGravity (IG) and Very Long Period (VLP) gravity wave bands

→ Fig.9: Major peak displacements observed during the summer to winter transition period.

Fig.9: Vertical component of DR10 bandpass filtered compared to RMS displacements for IG (middle) and VLP bands extracted from seismic data

References

[1] Bromirski, P. D., Chen, Z., et al. 2017. Tsunami and infragravity waves impacting Antarctic ice shelves. *Journal of Geophysical Research: Oceans*.

[2] Geng J, Shi C, et al. 2012 Improving the estimation of fractional-cycle biases for ambiguity resolution in precise point positioning *Journal of Geodesy* 86 579–89

[3] Rignot, E., J. Mouginot, and B. Scheuchl. 2017. *MEaSUREs InSAR-Based Antarctica Ice Velocity Map,Version 2*. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center.

[4] Padman, L., Siegfried, M. R., & Fricker, H. A. 2018. Ocean Tide Influences on the Antarctic and Greenland Ice Sheets. *Reviews of Geophysics*.

Conclusions & Perspectives

Broad-scale GPS array high sample rate collected on Ice Shelf.

→ First results in agreement with satellite dataset and existing models (tides and ice velocity)

→ Observations of large scale motions potentially associated with rift expansion and ice flow

→ Further investigations on elevation changes associated with the evolution at the base of the ice shelf (basal melting or re-freezing) or with snow accumulation

→ Seismogeodetic combination:

- Investigate ocean gravity waves
- Search for Icequakes

→ Are they detectable by high rate GPS ?

→ Further investigations about rifting motions

→ Complement satellite altimetry or InSAR dataset with direct observations of ice shelf dynamics