Ocean tides under the Larsen C and Filchner-Ronne Ice Shelves: Comparison of observations and models

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Introduction

The ocean tides under the Larsen C and Filchner-Ronne Ice Shelves are some of the least well observed on Earth. Data to validate, or assimilate into, ocean tide models is sparse. Tide model errors alias into measurements of ice shelf elevation from satellite altimetry and ice mass change estimates from the Gravity Recovery and Climate Experiment (GRACE). To address this shortcoming, ten geodetic-quality GPS receivers were deployed on Filchner-Ronne Ice Shelf and three on Larsen C Ice Shelf during the period Nov. 2007-Jan. 2009 – see **Figures 1** and **2**. About half of these were in place for the 2008 austral winter. Here, we report on the tidal analysis of data from this preliminary record and compare it to a range of global and regional ocean tide models. To increase the coverage, we also considered tide gauge records.

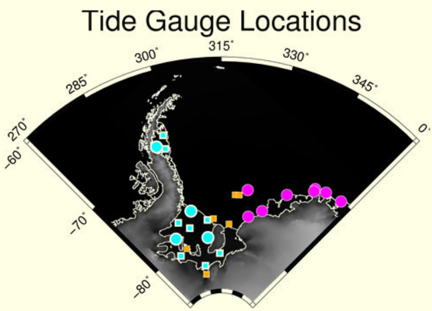

Figure 1: Tide gauge locations. Circles and squares indicate long (>186 days) and short records, respectively. Cyan symbols show the new GPS records.

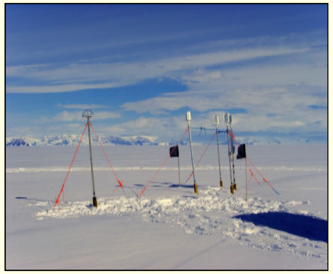

Figure 2: Over-winter GPS site setup on the Larsen C Ice Shelf in 2007/8, powered by a wind/solar system.

Methods

◈ Three-dimensional coordinate time series were determined from the GPS data with a precise point positioning approach using the GIPSY software. In this preliminary assessment, ocean tide loading displacements were modelled using the TPXO6.2 global tide model. Formal errors are 2-3mm per constituent, with systematic errors of up to 4mm for solar related constituents (the GPS constellation repeats with period ~K1).

◈ Tidal analysis was performed using the Matlab™ t_tide package. For short records, K1/P1 and K2/S2 were separated by inference using nearby long-term records or modelled relationships. We compared the constituents to those from the 5 recent global/regional ocean tide models listed in **Tables 1** and **2**. Where a tide record was outside a model domain, we either moved the point slightly or excluded the point from the statistics for that model.

Results

Figure 3 shows vector magnitudes of the observation-minus-model residual for 4 major constituents for FES2004, used in current GRACE analyses, and CATS2008a. Varying amounts of the tidal data were assimilated into some of the models, although the new data (shown with yellow outlines) are completely independent. **Tables 1** and **2** show summary statistics for the 13 long records and 14 short records (not generally assimilated), respectively. **Tables 3** and **4** show the same statistics but after removing the two worst records for each model.

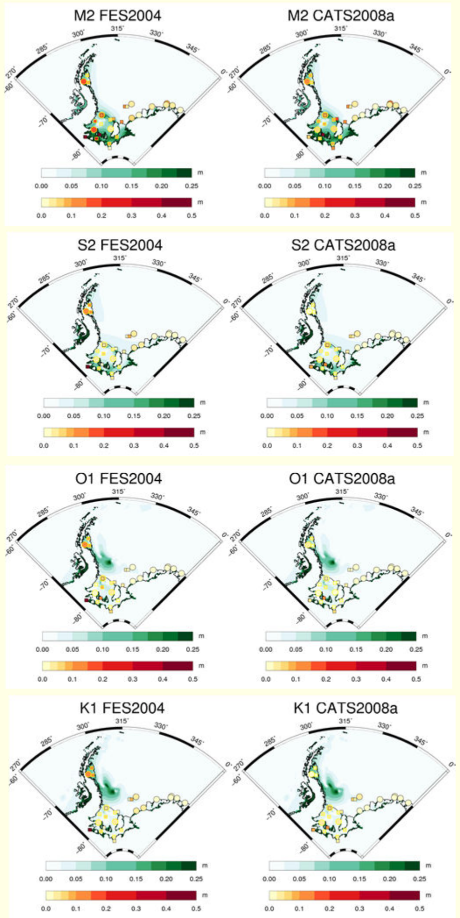

Figure 3: Maps showing residual vector amplitudes for M2, S2, O1 and K1 for FES2004 and CATS2008a. The background shading represents the amplitude of the vector difference between FES2004 and CATS2008a evaluated on a 0.25°x0.25° grid.

Table 1	M2	S2	O1	K1	All
TPXO6.2 (13)	5.9	4.4	6.0	4.3	10.4
TPXO7.1 (13)	7.1	4.5	7.5	6.2	12.9
FES2004 (13)	6.0	4.3	3.1	3.5	8.7
CATS2008a (13)	**4.4**	**3.7**	**0.9**	**1.7**	**6.1**
GOT4.7 (13)	5.2	4.1	5.8	4.1	9.7

Table 3	M2	S2	O1	K1	All
TPXO6.2 (11)	**2.1**	2.0	2.1	2.7	4.5
TPXO7.1 (11)	4.4	**1.7**	1.7	1.6	5.2
FES2004 (11)	3.0	2.1	1.0	1.8	4.2
CATS2008a (11)	2.6	1.9	**0.6**	**1.0**	**3.4**
GOT4.7 (13)	**1.8**	2.1	1.7	2.5	4.0

Table 2	M2	S2	O1	K1	All
TPXO6.2 (14)	16.0	10.0	8.5	7.4	22.0
TPXO7.1 (14)	17.4	10.5	9.4	8.0	23.8
FES2004 (14)	12.7	6.4	4.1	4.2	15.4
CATS2008a (14)	12.5	7.9	**3.0**	**3.8**	15.6
GOT4.7 (14)	**9.8**	**5.0**	7.5	7.0	**15.0**

Table 4	M2	S2	O1	K1	All
TPXO6.2 (12)	5.9	4.1	5.7	5.8	10.9
TPXO7.1 (12)	8.4	5.2	5.2	3.5	11.7
FES2004 (12)	5.7	4.4	2.9	2.5	8.1
CATS2008a (12)	5.7	4.4	**1.6**	**2.4**	**7.8**
GOT4.7 (12)	**5.1**	**3.4**	5.3	5.8	9.9

Tables 1-4: RMS (cm) of observation minus each model, for long records only (Tables 1&3) and only short, unassimilated, records (Tables 2&4). Tables 2&4 have the worst two sites for each model removed. All statistics exclude two often problematic sites near the Rutford Ice Stream grounding line. Highlighted values are "winners" within the errors of the data (taken here to be 0.4 cm).

Conclusions

◈ The Antarctic regional 4-km CATS2008a model is currently the most accurate ocean tide model for the Weddell Sea, followed closely by global models FES2004 and GOT4.7.

◈ The relative accuracy of CATS2008a and GOT4.7 comes largely from their focus on high latitudes, including improved coastline/grounding-lines and bathymetry, and assimilation of new data sets including ICESat elevations over FRIS (CATS2008a). The new GPS records have **not** been assimilated to date.

◈ TPXO7.1 does not represent an improvement over TPXO6.2 in this region. All RMS values should improve if CATS2008a were used for the GPS ocean tide loading displacement corrections instead of TPXO6.2.

◈ GRACE analyses, which now typically make use of FES2004, could be improved in this region with CATS2008a or GOT4.7. Notably, CATS2008a is more accurate for K1, which aliases to ~7 year periods in GRACE analyses. This is particularly evident under the Larsen C ice shelf where K1 errors would affect Antarctic Peninsula ice mass balance estimates from GRACE.

◈ New models CATS2009 and GOT4.8 will be released this year. These will be improved by assimilation of new GPS records, model geometry improvements, and better assimilation of satellite altimetry and/or GRACE gravity.

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