WATER HM and Aliasing Issues

R. D. Ray
NASA Goddard Space Flight Center

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Sea Level Spectrum at Canton Island

Nyquist frequency
ERS  T/P

Spectral density (cm²/cpy)

Frequency (cpy)
T/P Aliasing – Semidiurnal Band

Spectral density (cm²/cpy)

Frequency (cpy)

Alias period (d)

Spectral density (cm²/cpy)

Frequency (cpy)

Alias period (d)
ERS Aliasing – Semidiurnal Band

Table 1: Primary alias periods for ERS orbit

<table>
<thead>
<tr>
<th>Constituent (°/hr)</th>
<th>Frequency</th>
<th>35-day Alias (d)</th>
<th>3-day Alias (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q₁</td>
<td>13.39866</td>
<td>132.8</td>
<td>9.4</td>
</tr>
<tr>
<td>O₁</td>
<td>13.94304</td>
<td>75.1</td>
<td>14.2</td>
</tr>
<tr>
<td>P₁</td>
<td>14.95893</td>
<td>365.2</td>
<td>365.2</td>
</tr>
<tr>
<td>S₁</td>
<td>15.00000</td>
<td>∞</td>
<td>∞</td>
</tr>
<tr>
<td>K₁</td>
<td>15.04107</td>
<td>365.2</td>
<td>365.2</td>
</tr>
<tr>
<td>J₁</td>
<td>15.58544</td>
<td>95.6</td>
<td>25.6</td>
</tr>
<tr>
<td>2N₂</td>
<td>27.89535</td>
<td>392.5</td>
<td>7.1</td>
</tr>
<tr>
<td>N₂</td>
<td>28.43973</td>
<td>97.4</td>
<td>9.6</td>
</tr>
<tr>
<td>M₂</td>
<td>28.98410</td>
<td>94.5</td>
<td>14.8</td>
</tr>
<tr>
<td>S₂</td>
<td>30.00000</td>
<td>∞</td>
<td>∞</td>
</tr>
<tr>
<td>K₂</td>
<td>30.08214</td>
<td>182.6</td>
<td>182.6</td>
</tr>
</tbody>
</table>
How does this picture change for a wide-swath altimeter?

Solar tides are always aliased to long periods.
The precession rate of the satellite orbit plane determines which frequency gets aliased to zero.
To avoid unfavorable aliasing requires a precession rate $\leq -2^\circ/d$ (cf., Topex), which limits satellite inclination.
We must study tradeoffs.

Four main solar diurnal tides are separated in frequency by 1 cpy.
What’s so bad about sun-synchronous altimetry?

For many applications, absolutely nothing. For these, T/P solved the “tide problem.” But for others....

I. It prevents serious tide studies.

Shallow-water tides; tides polewards of 66°; open-ocean internal tides

II. It maps “diurnal” errors to undesirable periods.

— into the mean sea surface.
— into long (climate-like) periods.
— into the annual and semi-annual cycles.

Question: How large are the tide effects in (II.)?
Answer: Generally ~1 cm or smaller at basin scales (excl. polar seas);
~5 cm at short scales in shallow water.
~5 cm—but usually smaller—at internal-tide scales;
BUT.....

It’s not just tides! ...

diurnal ionospheric delay errors
diurnal pressure oscillations (IB / dry trop)
diurnal rain contamination (ITCZ)
thermal effects on spacecraft & tracking stations
atm. drag / radiation pressure errors
Three Examples

1. Atmospheric tides ($S_1$ and $S_2$)
2. Topex-Jason altimeter bias
3. Internal tides ← most critical for WATER ?
Atmospheric Tide Errors

Dry\_trop (mm) = \sim 2.3 \text{ Pressure (mb)}

Also affects IB-type corrections.
Mean Jason – Topex Sea-surface Height Differences as Function of Local Time

Jason-1 cal/val period    Feb–July 2002

What is the cause?

Note: Results are independent of tide corrections!
Mean Jason – Topex SSH Differences as Function of Local Time

In T/P and Jason, these errors map mostly into ~60-day periods.

Sun-synch maps them into long periods.
Internal Tides & Topex/Poseidon

T/P observes tiny surface waves from internal tides in deep ocean.

T/P allows global mapping of sources and sinks of internal tides.

Internal tides are generated when surface tides impact ocean ridges and seamounts. They contribute energy for deep-ocean mixing, and thereby help power the ocean's large-scale thermohaline circulation.

Internal tides are usually studied in situ; T/P provides a unique global view.

Warning: Not every "wiggle" here is from internal tides!
WATER and Deep-Ocean Internal Tides

Properties of ITs:

— Altimetry most sensitive to mode-1 (~5 cm, ~100 km), and some mode-2 signals (~1 cm, ~50 km).
— ITs are not predictable via numerical modeling.
— Low-mode ITs are temporally varying. How much??
  – small (1 cm) year-to-year variations are common.
  – seasonal variations seen in places.

IT errors wrongly interpreted as geostrophic currents:

— A slope error of 1 cm over 100 km generates
  O(1 cm/s) velocity errors.

\[
 u = \frac{g}{f} \frac{\Delta \eta}{\Delta x} \approx \frac{10}{10^{-4}} \times \frac{10^{-2}}{10^5} = 1 \text{ cm/s}
\]

Is this error acceptable?
M2 Internal Tide Signals  (Hawaiian Ridge)
M2


Summer // Winter

In-phase (cm)

Quadrature (cm)

Latitude (deg)

Track 24    South China Sea
How to correct WATER data for ITs?

— Initial data cannot be corrected. We will rely on pre-WATER tide models.

— After several years of good data, the temporally coherent IT signals can be removed by use of empirical models. (Seasonal terms maybe).

— The temporally incoherent IT signals cannot be corrected.

Therefore, we must ensure that these signals are aliased to “uninteresting” frequencies. Implies no sun-synch orbit.

Impact of sun-synch orbits

— S2 signals cannot be corrected; they will map into mean SSH.

— Seasonal S2 variations will corrupt true annual sea-level signal.

— Interannual S2 variations will corrupt true climate signals.

Note: S2 amplitudes are ~ half M2.