Altimetry 3 - Altimetry and Oceanography (measuring ocean processes)
All the processing seen so far is to get a good SSH=orbit-range.
Interpreting Ocean Surface Topography

Geoid (~100 m)
- Time invariant
- Not known to sufficient accuracy
- To be measured independently (gravity survey)

Tides (~1-2 m)
- Apply a tidal prediction
- New tidal models derived from altimetry
- Choose orbit to avoid tidal aliasing

Atmospheric pressure (~0.5 m)
- Apply inverse barometer correction (1 mbar ~ 1 cm)

Dynamic topography (~1 m)
- The intended measurement

Some of these we want to correct for – or not, depending on the application!!!
Atmospheric pressure (the “Inverse Barometer” Correction)

- When air pressure changes the ocean acts like a barometer (in reverse). High air pressure depresses the sea surface, low air pressure raises it.
- $1 \text{ mbar (hPa)}$ change in air pressure is approximately equal to a $1 \text{ cm}$ change in the sea surface.
- Good in mid and high latitudes not in Tropics.
- Also, not very accurate in enclosed basins (like the Mediterranean).
• An alternative to an IB correction is to use a correction from a barotropic model of the ocean
• Barotropic (non-depth dependent) motions move very quickly and can be aliased by the altimeter ground tracks
• Barotropic models are quick to run but have proved hard to validate
The problem of the Geoid

- The geoid is the surface of equal gravity potential on the Earth’s surface (the shape of the Earth)
- The ellipsoid is an approximation to the shape of the Earth
- We know the ellipsoid - we do not know the geoid with the accuracy we would like!!!
The Geoid

Scale: magenta (-107 m) to red (84.5 m)
The Geoid

- The geoid is usually expressed in terms of spherical harmonics (sine curves on the sphere). These have degree and order
  - Degree and order 360 is a resolution of approx. 1°
- Sea surface pressure and hence geostrophic currents are in terms of sea surface height relative to the geoid
- We measure sea surface height (and hence slopes) relative to the ellipsoid.
Removing the Geoid

• The geoid is time invariant (approximately)
• So if we subtract a mean sea surface we will remove the geoid
• But we lose ...

... the mean circulation
SSH residuals

• The sea surface height residual (or Sea Surface Height Anomaly - SSHA) is what remains after removing the mean in each location (Mean Sea Surface)
• Any constant dynamic topography (from steady currents) will have been removed!
• Contains only the **time-varying** dynamic topography
• May still contain time varying errors
  • Un-removed tidal or barometric signal
  • Orbit error
• With new independent accurate geoid models (from GRACE and the new ESA GOCE mission) we are starting to be able to subtract the geoid and work with **absolute dynamic topography** (much better for oceanographers!)
Tides

• If we are going to use altimetry for oceanographic purposes we need to remove the effect of the tides
• Alternatively we could use the altimeter to estimate the tides - tidal models have improved dramatically since the advent of altimetry!
• In general we use global tidal models to make predictions and subtract them from the signal
The up and down of the ocean tides

Atlantic Ocean

South Indian Ocean

Pacific Ocean

New Amsterdam

Gascogne Gulf

Funafuti

Cophase lines drawn with a 30° interval (0° phase has a larger drawing)

Centimeters

Source: IMG/LEGI, Grenoble 1995
More tides!

• As well as the ocean tide we have to consider
  • the loading tide (the effect of the weight of water). This is sometimes included in the ocean tide
  • the solid earth tide
  • the polar tide

• On continental shelves the global models are not very accurate and local models are needed

• Any residual tidal error is going to be aliased by the sampling pattern of the altimeter
## Aliasing Periods

<table>
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<th>Tide</th>
<th>Period (h)</th>
<th>Alias (days)</th>
<th>T/P wave length (°)</th>
<th>ERS wave length (°)</th>
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</table>
Example over a pass

Orbit path

Orbit Height (modelled)

Altimeter Range (measured)

Sea Surface

Geoid: Time Constant

Dynamic Topography Caused By Ocean Currents:
Mean + Time variant

Reference Ellipsoid
The Geoid

Scale: magenta (-107m) to red (84.5m)
Ionospheric Correction

Sea Surface Height: Ionospheric Correction Applied
Dry Tropospheric Correction

Sea Surface Height: Dry Tropospheric Correction Applied
This is what most oceanographers want: dynamic topography
Example of interpolated data and data in space and time