Satellite Observations

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Outline

- Some of the satellite data sets in use by ECCO
- Issues related to satellite data use as constraints in the state estimates (e.g., defining errors, choosing products,…)
- Other data sets for possible future use
- Some upcoming satellite systems (GRACE Follow-On, SWOT,…)


Observing the oceans from space...

NASA Earth Science Missions: Present through 2023

ISS Instruments
OCO-3, LIS, SAGE III, TSIS-1, ECOSTRESS, GEDI, CLARREO-PF, EMIT

JPSS-2 Instruments
OMPS-Limb

InVEST/CubeSats
RAVAN, IceCube, MiRaTA, HARP, TEMPEST-D, RainCube, CubeRRT, CIRIS, CSIM
Global coverage, fast repeat

Dependent on

- Orbit types
- Instrument footprint
- Retrieval methods

- Aside from gravity missions, measurements restricted to “surface” variables
Current satellite data constraints

- **Sea level altimetry**
  - From TOPEX/Poseidon to current constellation of altimeters

- **Space gravimetry**
  - GRACE (Gravity Recovery And Climate Experiment) but also GOCE

- **Sea surface salinity**
  - Aquarius

- **Sea surface temperature**
  - AVHRR

- **Sea ice concentration** (treated by Ian and An)
Sea surface salinity (SSS)

- Soil Moisture Ocean Salinity (SMOS, 2009-present)
- Aquarius (2011-2015)
- Soil Moisture Active Passive (SMAP, 2015-present)

(all available from different distribution centers)
Common retrieval issues

- Measuring skin vs. bulk properties
- Weakly sampling and effects of temporal aliasing
- Various footprints and horizontal sampling patterns
Valuable characteristics

- Good data coverage, even compared to Argo
- Large footprint averages out short spatial scales

Srokosz and Banks (2019, Weather)
Estimating errors

- $D = s + d'$, $M = s + m'$, $\text{var}(d') = \text{var}(D) - \text{cov}(D,M)$

- 3-way collocation (when possible)
- Mean bias (e.g., compare to in situ)
- Assess against errors provided with data (when available)

Vinogradova et al. (2014, J. Geophys. Res.)
Assess costs and the potential value as a constraint

Vinogradova et al. (2014, J. Geophys. Res.)
Satellite altimetry

- From TOPEX/Poseidon to current constellation

(courtesy of J. Benveniste)
Spatial coverage

Ground tracks of 4 missions:
Jason-2
Cryosat-2
Saral/Altika
HY2A
A complex measurement...

- Orbit determination
- Wet and dry tropospheric delay
- Sea state bias
- Ionospheric effects
Instrument noise

- Leveraging a few months of tandem flight from TOPEX and Jason-1

Ponte et al. (2007, *J. Atmos. Oce. Tech.*)
Representation noise

- Dealing with signals not represented in models

Ponte et al. (2007, *J. Atmos. Oce. Tech.*)

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Common issues

- Temporal aliasing (includes tidal and non-tidal signals)... typical repeat cycles of 10 days or longer

- Inhomogeneous spatial resolution (relatively finer along-track, coarse across-track)

- Poor coverage of coastal regions

- Static signals (largest is mean geoid)
Anomalies vs. mean state

Mean Sea Surface (mapped by satellite altimeters)

- Separate constraints for time mean and anomalies from mean typically done.
Mean dynamic ocean topography (DOT)

- Usually obtained by subtracting estimate of marine geoid (GRACE/GOCE) from altimetric mean sea surface.

Some considerations:

- Merging different spatial scales
- Omission errors
- Purely geodetic DOT
Comparing DOTs

- Evolving estimates with accumulation of data
- Effects of constraints dependent on noise estimates
Global mean sea level

- Average of GMSL curves from different centers (NOAA, AVISO, CSIRO)…spread gives measure of data noise

- Cost term based on sum of global mean steric height and net real freshwater fluxes

Masters et al. (2012, Marine Geodesy)
Space gravimetry

- Tracking changes in gravity field by microwave ranging between two satellites
- Complex retrieval of changes in ocean mass/bottom pressure
- Nominal monthly sampling at a few hundred km

(available from various processing centers, PO.DAAC @JPL)
Constraining to GRACE

- Different inversion methods
- Different temporal resolutions (submonthly fields available)

Error estimates

- Differences between model and various products
- Comparisons with errors provided by data centers

Global mean bottom pressure

- Constraining global mean mass, net freshwater flux into ocean
- Remove global mean atmospheric pressure effects
- Similar treatment of errors (mixture of methods)
Some other satellite data sets

- Global coverage, 0.1°, daily, since 2014
- Constraining, validating a most uncertain forcing field
Some other satellite data sets

- Cross-Calibrated Multi-Platform (CCMP) gridded surface vector winds produced at Remote Sensing Solutions
- Combination of satellite-derived, in situ, and analyses winds, 6-hourly, 0.25°x0.25°
NASA's OceanColor Web is supported by the Ocean Biology Processing Group (OBPG) at NASA's Goddard Space Flight Center. Our responsibilities include the collection, processing, calibration, validation, archive and distribution of ocean-related products from a large number of operational, satellite-based remote-sensing missions providing ocean color, sea surface temperature and sea surface salinity data to the international research community since 1996.

Ocean Color Feature

Benguela Upwelling Ecosystem

https://oceancolor.gsfc.nasa.gov/
GRACE Follow-On

- Launched May 2018
- First data products about to be released
- Similar to GRACE design but includes experimental laser ranging system
- Continuing GRACE record of ocean bottom pressure, global mean ocean mass, land ice…
Surface Water Ocean Topography (SWOT)

- Tentative launch date September 2021
- 21-day repeat cycle, average revisit time ~10 days
- Resolving mesoscale and submesoscale (15 km)
- Better look at coastal regions
- Land hydrology…better river runoff
Summary

- Satellites offer global coverage and relatively fast repeat cycles for mostly surface variables but retrievals and sampling are complex.

- Currently used data includes all altimetry, bottom pressure from GRACE, geodetically derived dynamic ocean topography, Aquarius, SST, ice concentration.

- Assessment of errors, including representation errors, often difficult and subjective but essential for state estimation.

- Data choices involve issues of consistency with model physics/forcing, quality, and convenience of use.

- Keeping up with new data versions, new missions and incorporating more available data is a major challenge.