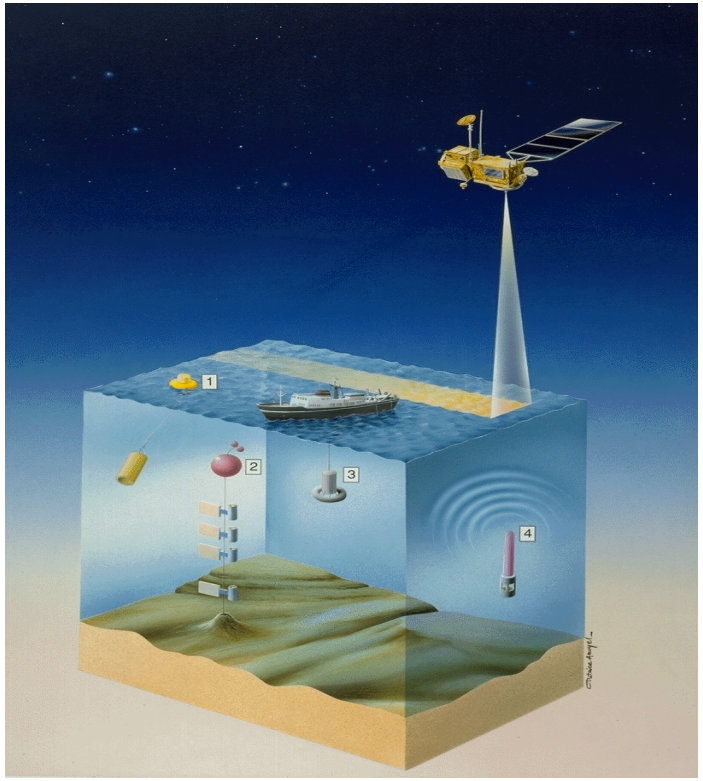
OceanObs19 Overview : Observing Technology Innovation-Satellite

Our OceanObs breakout session addressed **satellite innovation and enhancement** in the coming decade 2020-2030

Integration : All satellite innovation is accompanied by modelling/assimilation advances and requires matching in-situ innovation for CalVal and for understanding the ocean vertical structure

Continuity : Important transition from satellite innovation/enhancement to continuity and operational systems



Six sub-sessions were presented and discussed :

- Sea surface temperature/salinity:
- Sea-level Altimetry
- Ocean mass and bottom pressure changes
- Ocean vector winds currents waves
- Ocean color, polarimetry and lidar for biogeochemistry
- Synergy between multiple sensors

Intermediate recommendations were available from each sub-session

Session leads & discussion process :
Observing Technology Innovation-Satellite

Review & discuss **major satellite innovation for different parameters & multiple sensors**

Six sub-sessions were presented for satellite innovation, with the following session leads :

- **Sea surface temperature/salinity**: N Vinogradova, J. Boutin, A. O'Carroll, J. Hoyer, J. Vasquez
- **Sea-level Altimetry** : R. Morrow, L.L. Fu, P.Y. Le Traon, A. Cazenave, G Chen
- **Ocean mass and bottom pressure changes** : V. Zlonicki, F. Landerer, C. Boening
- **Ocean vector winds currents waves** : E. Rodriguez; F. Ardhuin; M. Bourassa, C. Gommenginger
- **Ocean color, polarimetry and lidar for biogeochemistry** : E. Boss, S. Groom, C. Jamet
- **Synergy between multiple sensors :** E. Boss, M. Bourassa, PY Le Traon, J. Boutin

OceanObs Process (2h session) :

a. Review major satellite innovation for different parameters & for multiple sensors (6 talks x 10 mins)
b. Discuss recommendations for each component using sli.do
c. Discuss final recommendations using sli.do

SSS & SST recommendations

Observing Technology Innovation-Satellite

1. Continuity, Higher resolution, Better Accuracy
    a. New technology (eg CIMR (Conical Imaging Microwave Radiometer), SMOS-HR (Soil Moisture Ocean Salinity High Resolution), AMSR2 follow-on (in Phase A by JAXA))
    b. Resilience to RFI
    c. Multi-frequency, Multi parameters synergy
2. Improved satellite stability / uncertainty & error estimation / validation
    a. Enhanced Fiducial Reference Measurements,
    b. Enhanced validation methodologies:
        a. Enhanced knowledge of SSS & SST variability (e.g. sub-pixel)
        b. Enhanced physics of measurements (e.g. radiometric models)
3. Emphasis on Arctic and coastal ocean
4. International collaboration

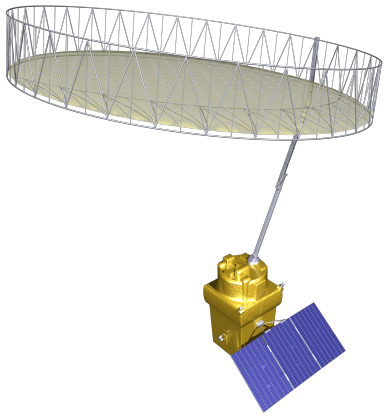


Image : CIMR

Fine-scale surface topography recommendations :

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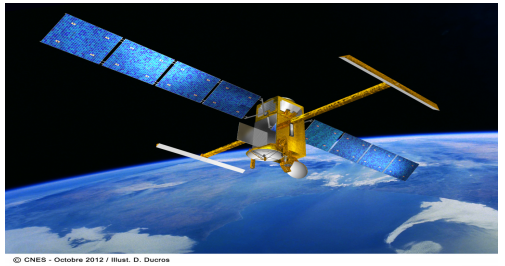
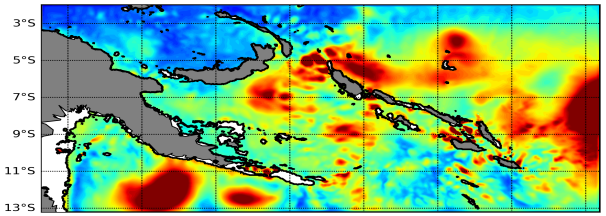
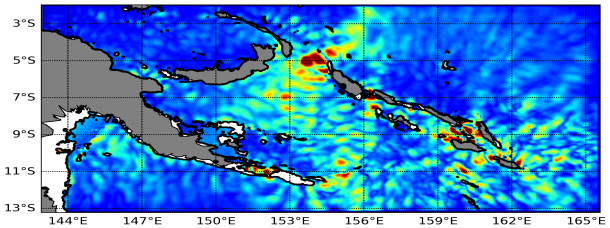


- **Continuity :** Maintain the precise altimetric time series for global and regional **mean sea level monitoring**
- **Enhancement** : Extend the time series of high-resolution SAR and wide-swath altimeter observations in the **coastal zone, marginal seas** and **high-latitude regions**
- Encourage **co-ordinated** space-time sampling from **multiple missions**/agencies, platforms (incl. cubesats) & **sensors**
- Combine wide-swath and nadir altimeters with other sensors to better observe the **2D ocean mesoscale and submesoscale** circulation (smaller, rapid scales), for ocean climate studies, coastal sea level rise, shoreline retreat & erosion studies
- Maintain some non-sun-synchronous missions to observe well **coastal/estuarine dynamics and tides, and high-latitude tides and internal tides**, important in the ocean's energy budget, and for ocean mixing & dissipation



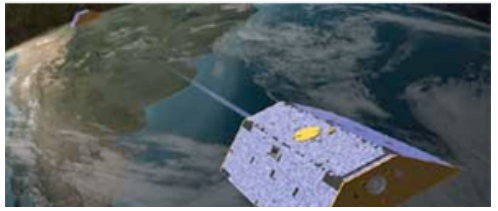


- **Uncertainties** : Continued investment into **Fiducial Reference Measurements** with known uncertainties for traceability and long-term assessment of SSH stability

Satellite Gravimetry Recommendations

Observing Technology Innovation-Satellite

- Accurately measure regional to global ocean heat content over decades combining gravimetry, altimetry, and in-situ floats.
- Ensure continuity of mass change/OBP measurement after GRACE-FO, as recommended by the 2018 US NASEM Decadal Survey.
- Consider technologies to enhance signal to noise ratio and spatial resolution < 300 km
- Reduce aliasing of fast signals by coordinating satellites (pairs) in complementary orbits, implemented by different space agencies/ partners.
- Implement a robust set of ocean bottom pressure stations with long deployments both for validation of global satellite OBP and for local studies in their own right.



Sea-ice topography recommendations :

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During the period 2020-2030 no high-latitude/ long-repeat altimetry, i.e. CryoSat-2 and ICESat-2 will not be operational and no successor will be in orbit. Main gaps :

1. **Sampling above 81.5 N/S, and dense ground tracks sampling elsewhere.** These gaps have major implications for monitoring Arctic sea ice (latitudinal limit), for Antarctic sea ice (ground track spacing), for the Antarctic ice sheet (both), and for the Greenland ice sheet (ground track spacing). (SWOT covers to 78° for 3.5 years)

2. Gap in knowledge of **snow loading on sea ice,** & **firn height changes** over the polar ice sheets (compacted snow). No established satellite retrieval and few in situ observations. Dual frequency (e.g. laser + radar or ka + ku radar) system could help - more work is required.

Ice & Sea-Ice Recommendations

Any altimeter observations in a near polar long repeat orbit first (eg launch Sentinel 3c in a different orbit), secondly a duel frequency system.

Note : Recommendations made in pre-conference email discussions : Sea-Ice community not present in Sensor Innovation session discussions

Ocean surface winds, currents, waves recommendations :

Observing Technology Innovation-Satellite

- Observations of microwave radar Doppler/phase have been demonstrated to be related to ocean surface currents.
  - **Airborne demonstrators**: AirSWOT, DopplerScatt, KaRADOC, KuROS, Wavemill
  - **Key advance**: separation of surface currents from wind-wave contamination
- Use of rotating pencil-beam or squinted antenna beams to obtain ***vector*** surface currents.
- Existing mission : **S-MODE** (2019-2024) NASA Suborbital-3 Mission; Mission concept candidates: **SKIM**: ESA Earth Explorer 9; **WaCM:** NASA; **SEASTAR**: ESA Earth Explorer 10,11

Recommendations :

- **Satellite observations of ocean surface currents should be undertaken**, with space-time sampling to **resolve the ocean mesoscale, equatorial, coastal and polar currents**, and their **impact on air-sea interactions**.
- Simultaneous observations of **ocean currents and winds /waves** are highly desired

Ocean biology & biogeochemistry recommendations :

To obtain better constraints on oceanic particle composition, vertical distribution, size distribution and function (needed to constrain their role in ocean biogeochemistry – e.g. biological carbon pump), we need:

Passive scalar radiometer (OC) :

1. Multi-spectral is coming.
2. Need improved algorithms;
3. Need increased horizontal, spectral and temporal resolution for coastal and inland water (upcoming GLIMR);
4. Need improved atmosphere-ocean co-ordination.

Lidar & Polarimeters

1. Lidar and polarimeters that are optimized for ocean retrievals.
2. Improved algorithms and data to validate them.

Multi-satellite synergy recommendations :

- Dynamical processes observed by the different instruments are complementary, and the synergistic use of multiple sensors is desirable, but requires **coordinated sampling** for monitoring small-rapid dynamics, or multiple parameters/instruments on the **same platform**.

- **Coordination**: Multi-agency Co-ordinated space-time sampling (virtual constellation) of physical and biological observations from different missions is essential, and we recommend opening mission advisory groups & science teams to membership from different countries & different disciplines.

Observing Technology Innovation-Satellite : Final recommendations (255 chars)

Rosemary Morrow & co-authors

Satellite Innovation In Response to User Needs

1) Enhance high-resolution coverage in space and time of satellite observations extending into the polar regions, coastal and regional seas, and in the equatorial band, whilst maintaining long-term continuity in the satellite observing system.

2) Fly Missions to **cover Gaps in observed ocean ECVs/EOVs** where the technology exists : total surface currents, wave spectra, vertical plankton distribution, ….

3) Promote synergy and co-ordination between agencies for (1) multiple sensors, platforms and disciplines for an integrated virtual constellation to observe the ocean's small rapid scales globally, and (2) for in-situ Calval infrastructure.