The Global Ocean Observing System
www.ioc-goos.org

MERCATOR OCEAN INTERNATIONAL

Ocean Observations in support of Ocean prediction

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OceanPredict'19, Halifax, Canada 6-8 May 2019.

UNESCO IOC WMO UN environment International Science Council

Outline

- GOOS 2030 Strategy
- In situ observations and forward directions
- Observing system development and review

- Satellite observations: status and plans
- Impact of satellite and in situ observations for ocean prediction
- Concluding thoughts:
  - Observation challenges for the next decade
  - The GOOS-OceanPredict partnership

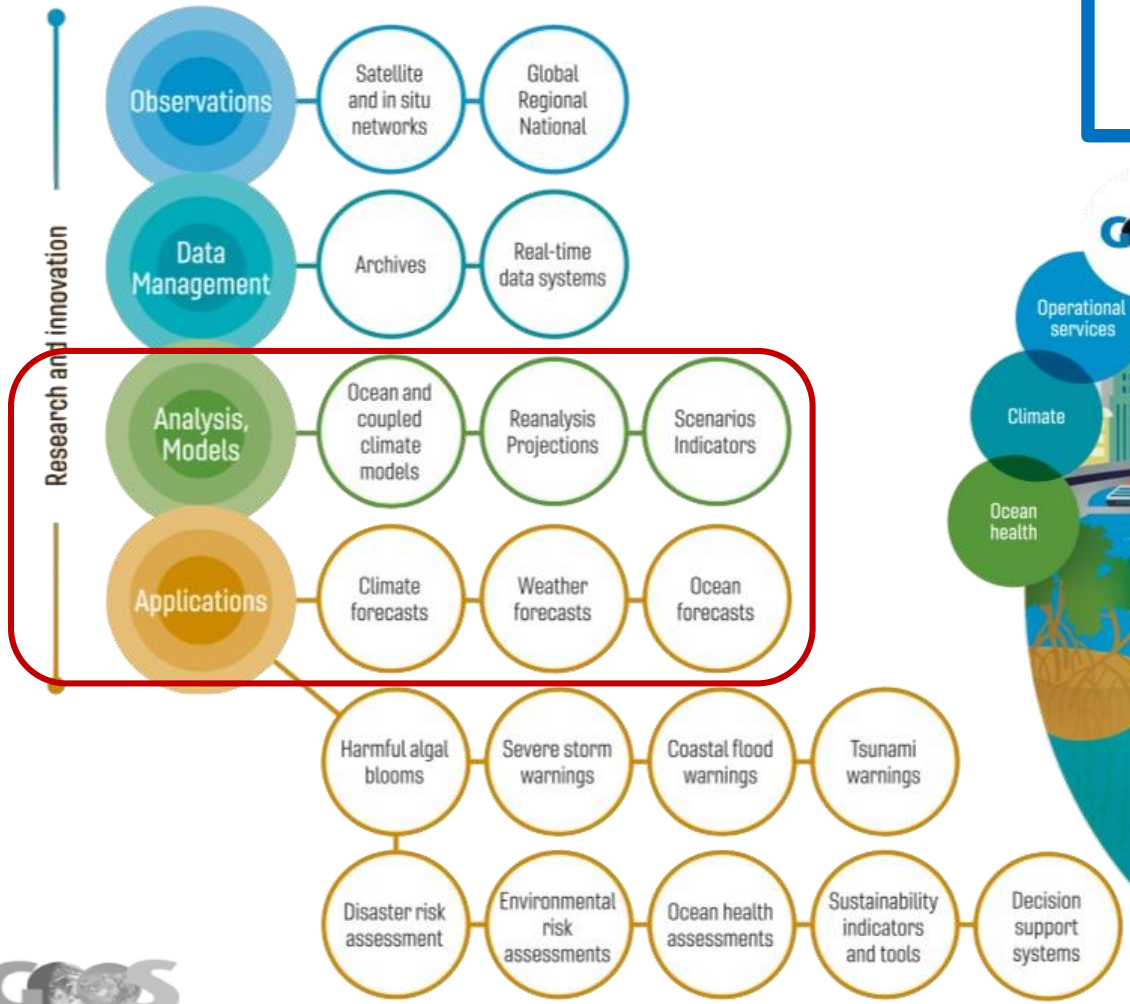
Vision

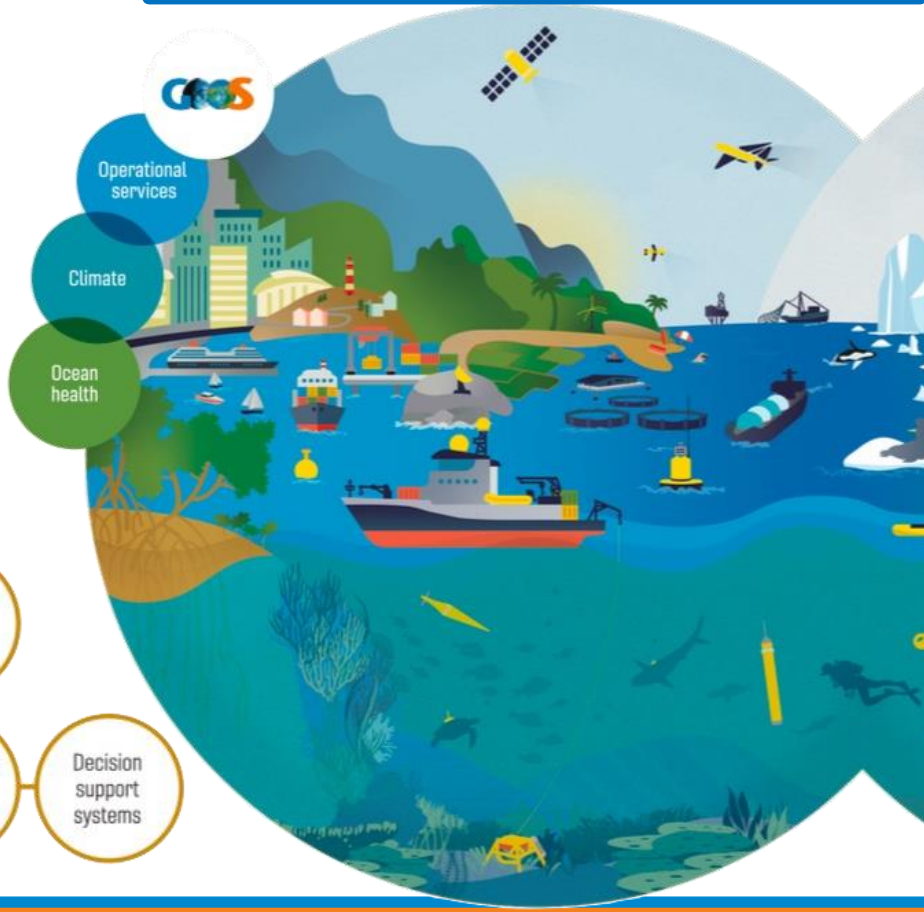
A truly global ocean observing system that delivers the essential information needed for our sustainable development, safety, wellbeing and prosperity

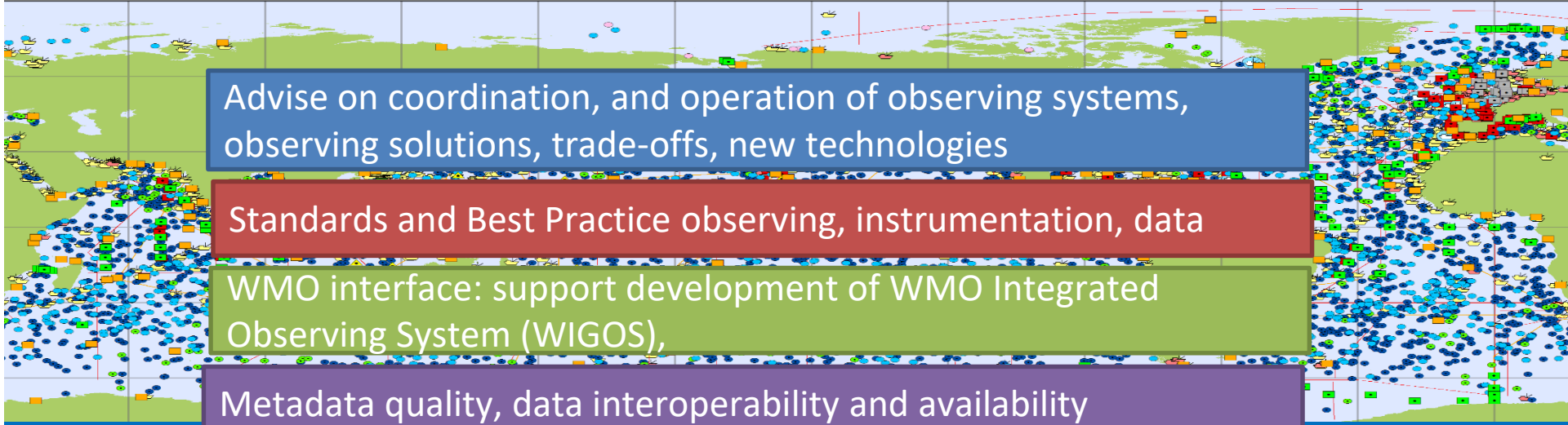
Mission

To lead the ocean observing community and create the partnerships to grow an integrated, responsive and sustained observing system

Partnerships for delivery







Advise on coordination, and operation of observing systems, observing solutions, trade-offs, new technologies

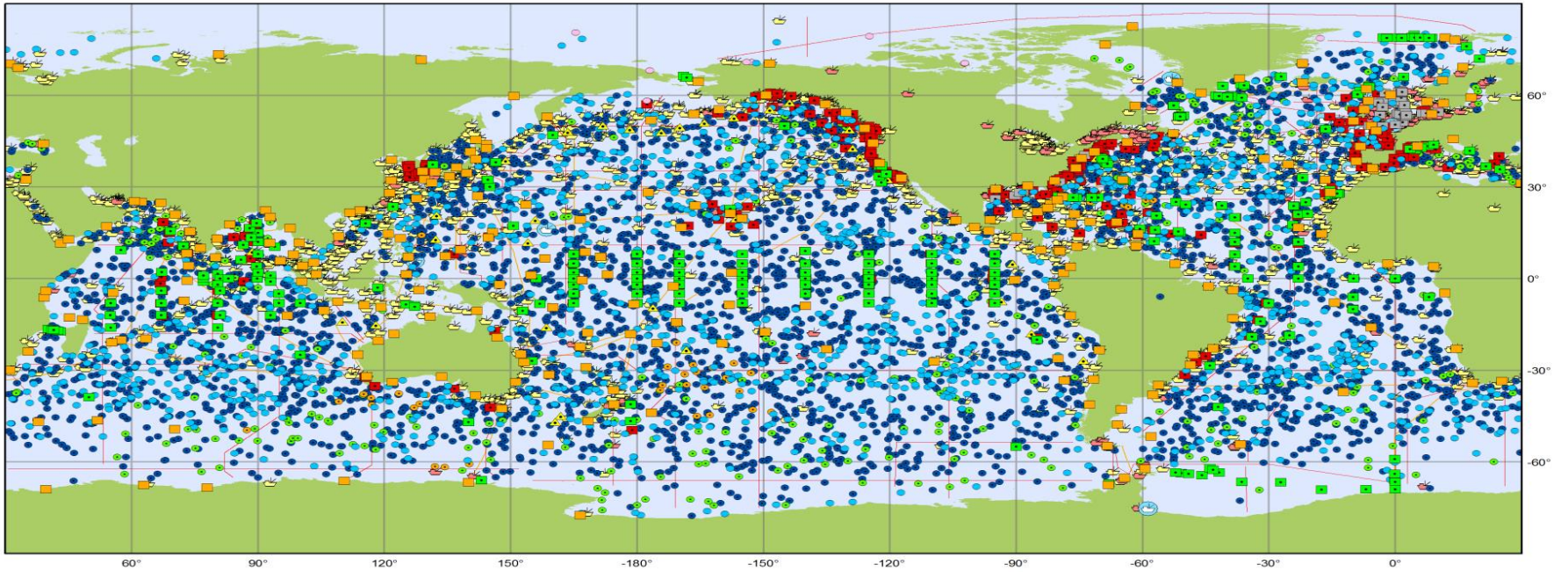
Standards and Best Practice observing, instrumentation, data

WMO interface: support development of WMO Integrated Observing System (WIGOS),

Metadata quality, data interoperability and availability

THE OBSERVING NETWORKS (THE OBSERVATIONS COORDINATION GROUP)

The Global Ocean Observing System



Main in situ Elements of the Global Ocean Observing System

January 2018

Profiling Floats (Argo)
- Core (3895)
- Deep (44)
- BioGeoChemical (314)

Data Buoys (DBCP)
- Surface Drifters (1410)
- Offshore Platforms (102)
- Ice Buoys (12)
- Moored Buoys (370)
- Tsunameters (33)

Timeseries (OceanSITES)
- Interdisciplinary Moorings (333)

Repeated Hydrography (GO-SHIP)
- Research Vessel Lines (61)

Sea Level (GLOSS)
- Tide Gauges (252)

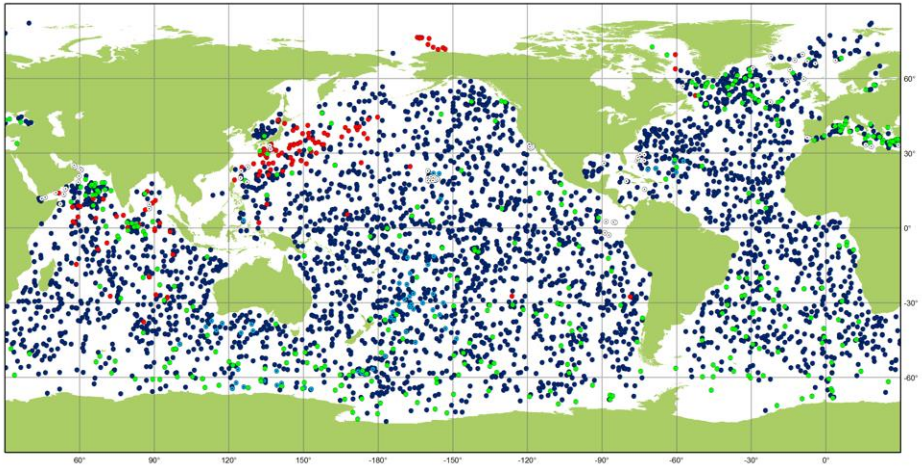
Ship based Measurements (SOT)
- Automated Weather Stations (261)
- Manned Weather Stations (1745)
- Radiosondes (14)
- eXpendable BathyThermographs (37)

Generated by www.jcommops.org, 15/02/2018

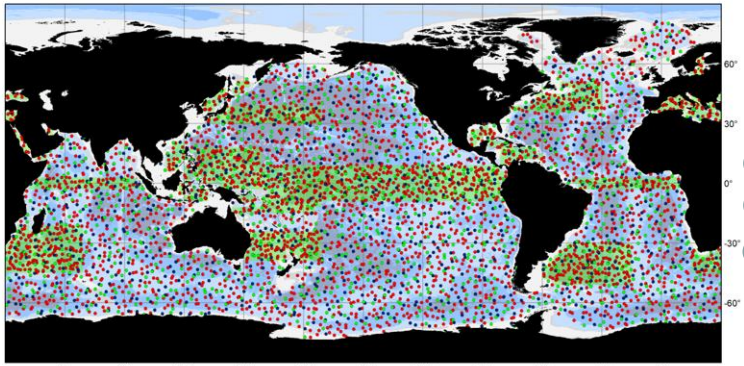
Attributes: maturity level

	Global	Sustained	Community	EOV / ECV	Data Flow	Mission / targets	Best Practices
Argo							
DBCP moorings							
DBCP drifters							
SOT VOS							
SOT SOOP							
GLOSS							
OceanSITES							
GO-SHIP							
OceanGliders							
HF Radar							
Animal Borne Sensors							

Status and plans for the Argo array – March 2019



Core + Equivalent (3501)
Deep (378)
BGC (347)
Non-Argo (71)

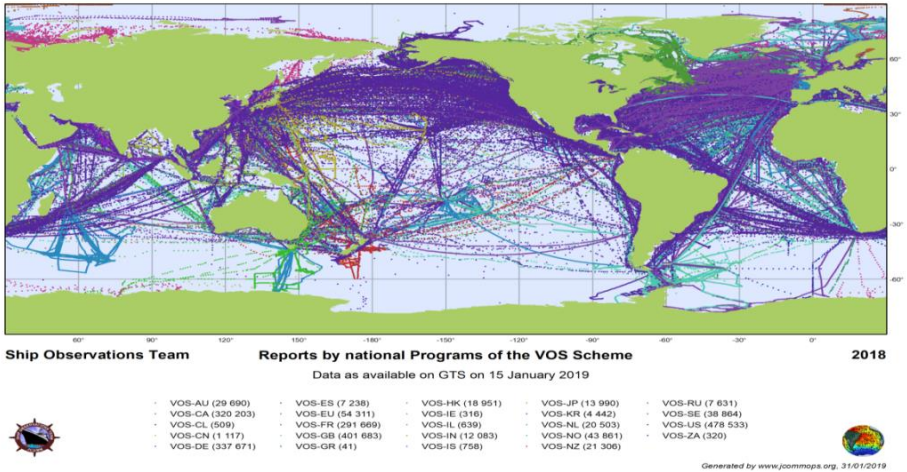


Concept Map
4700 floats

Core (2500)
BGC (1000)
Deep (1200)
Double density

- Core Argo continues to deliver over 95% of data to the GTS and Argo GDACs within 24 hours of measurement … underpinning ocean forecasting services
- It's time to enhance the Argo array for greater impact. BGC and Deep Argo pilot projects have been successful, and will become part of the global array
- The new Argo array design, adopted by the Argo Steering Team in 2019, is:
  - Global (including ice + marginal seas),
  - Multidisciplinary (including BGC),
  - Full Depth (including deep),
  - With enhanced coverage in the tropics and **western boundary currents**.

Ship Observations Team

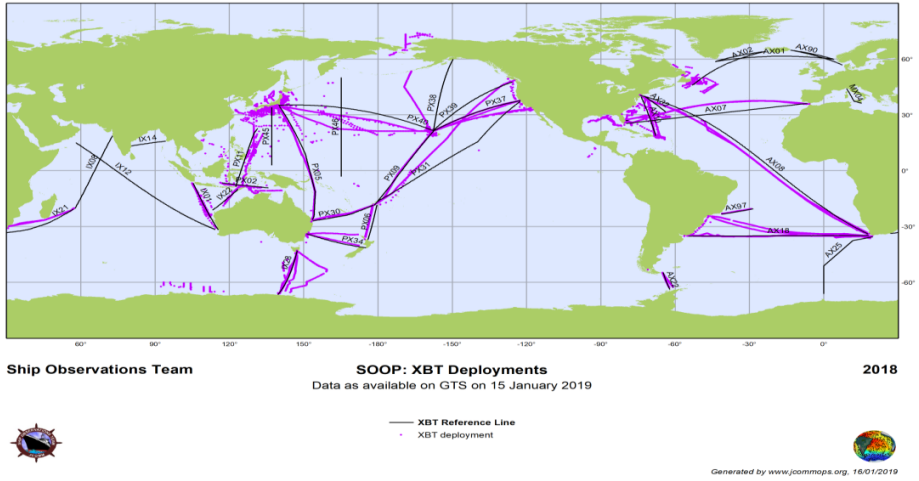


Voluntary Observing Ships (VOS)

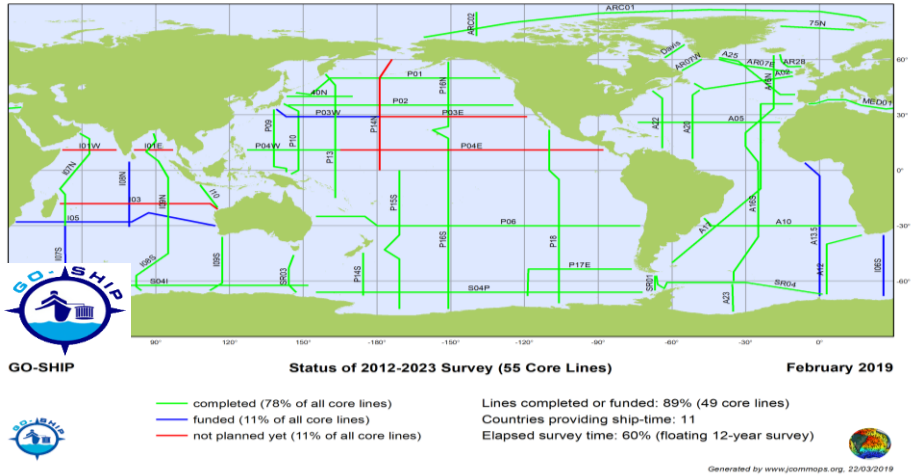
- **Approx. 2500 active vessels**
- 24 active national VOS programmes
- Increasing Automatization
- Opened high-level dialog with Maersk to address recruitment of whole fleet (approx. 300 vessels)
- **Coverage depends on existence of shipping lines**
- **Future: Autonomous surface vehicles could be a game changer..**

Ships of Opportunity (SOOP)

- **~70 active XBT ships (33/34 lines)**
- **~50 ships with underway CO_2 systems**
- Supports VOS and GOSUD data acquisition and Argo and surface drifter deployments.
- **Incorporation of CO_2 network into SOOP** continues (for air-sea flux in CO_2 and quantification of surface ocean acidification).
- **Research on boundary currents** and trans-basin meridional heat transports



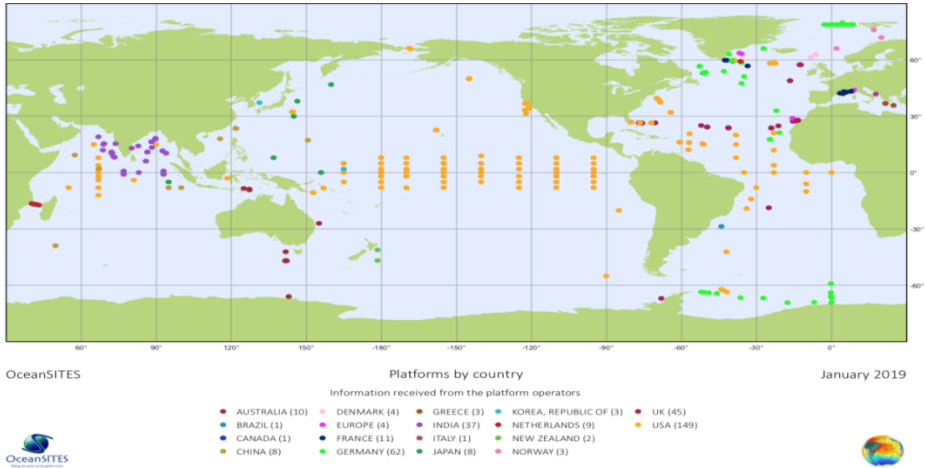
Reference observations: GO-SHIP and OceanSITES.



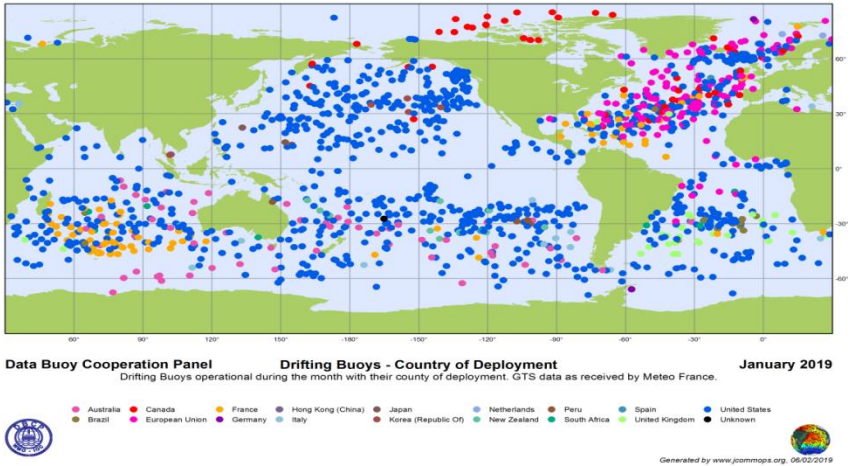
- 16 GO-SHIP reference lines completed in 201[illegible]
- 4 cruises on reference lines planned for 2019 **including new line I7S**
- **Major Contributor to Argo, BGC/Deep Argo deployment and Cal/Val, deployments of other networks, testing and piloting of new sensors.**
- Working on sustainability (key reference role, best practices).

- **Global Comprehensive High Quality Reference network**
- **Anchors' the rest of the Observing System.**

- Active sites at **415** Countries: **21**
- Discoverable Variables: **physics, air/sea flux, biogeochemistry (pH, oxygen, particle, pCO2)**
- **Flux sites generally not on GTS.**
- **Working on identifying 'missions' and 'targets' for OceanSITES (e.g. Flux sites, Transport Arrays, multidisciplinary timeseries sites, tropical Moored Array)**

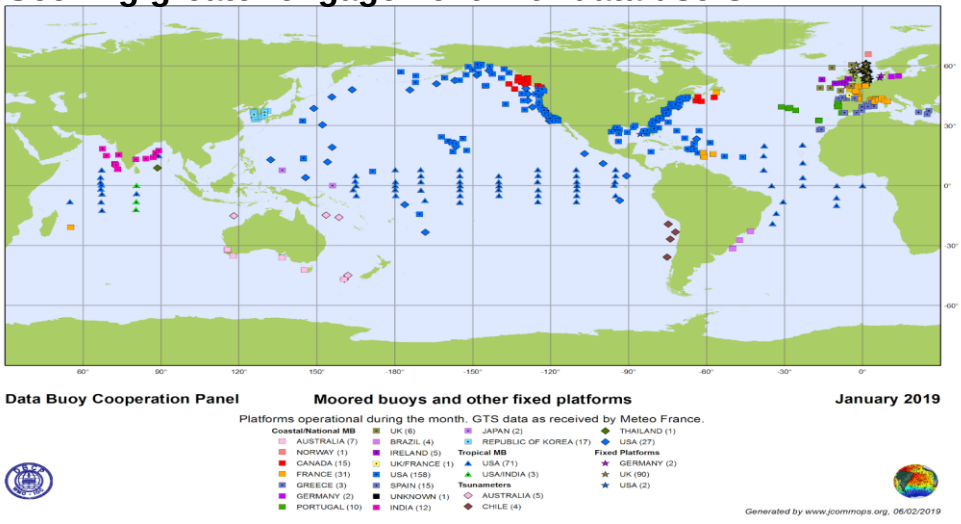


DBCP – Drifters and Metocean moored buoys

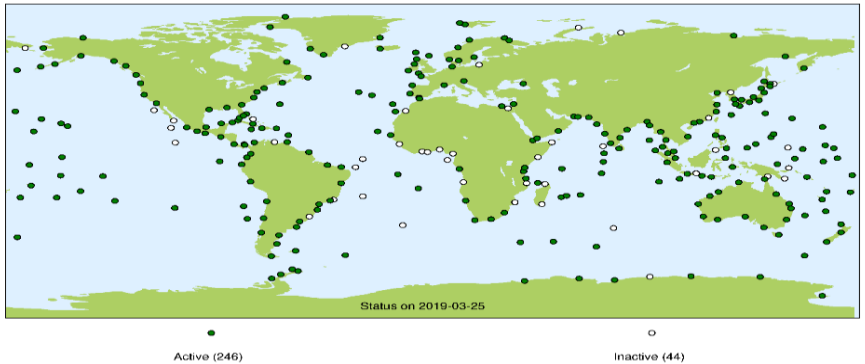


- 1319 drifting buoys between 60N and 60S providing data to the GTS
- 100 buoys in Arctic (>60N) and 78 in Antarctic (>60S)
- 51%, respectively reporting air pressure to GTS
- More than 85% using Iridium
- **Increase the number of drifters with surface pressure (for NWP)**
- **Testing drifters with wave measurements**
- **Seeking greater engagement with data users**

- 279 coastal/national operational (63% delivering met data, 46% ocean data, 88% wave data)
- 74 tropical moored buoys operational, 37 tsunami buoys ~ 35% of moored buoys (coastal/ national and tropical) reporting data to GTS in BUFR format
- **Need to identify a GDAC for moored buoy data.**
- **Seeking greater engagement with data users**

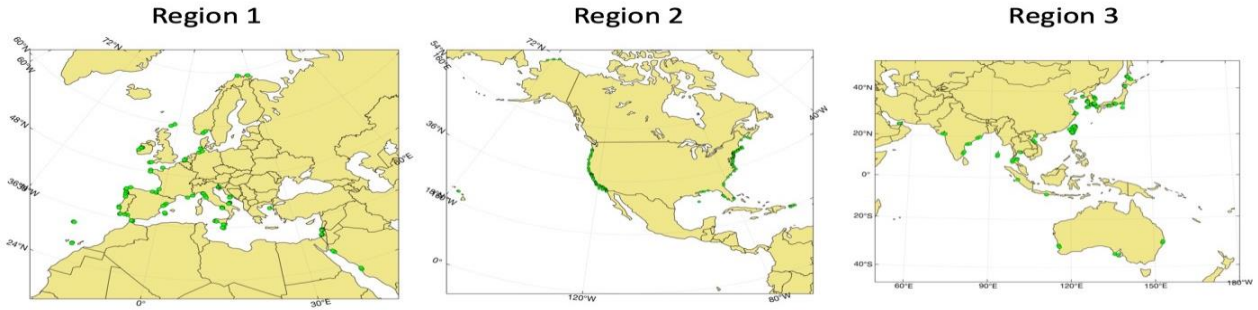


Tide Gauges (GLOSS) + HF Radar

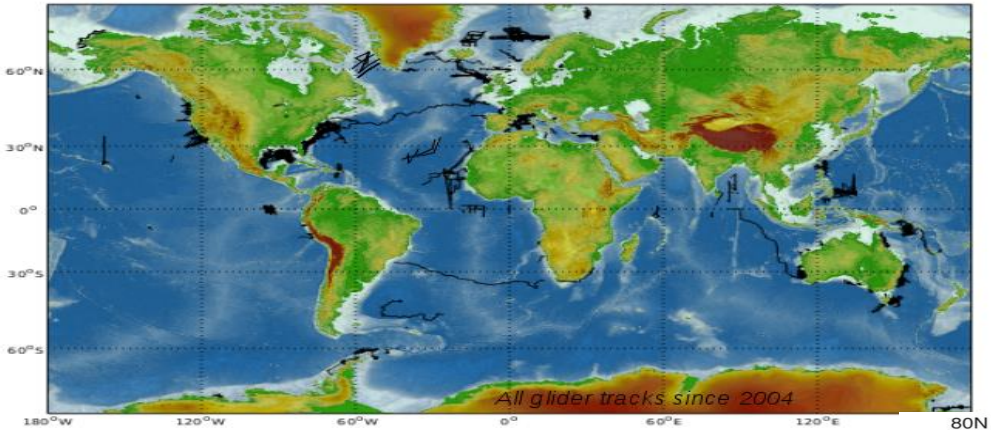


- Map shows stations reporting via at least one GLOSS data pathway
- 246 stations yes, 44 stations no
- New Sea Level Explorer tool compares altimetry to tide gauge data
- **Working on scoping set of missions, and targets for range of applications.**

- 400 radars making real time measurements of surface currents
- 34 countries making measurements of their coastal waters
- 10 countries sharing data via global network http://global-hfradar.org/
- **Developing metrics and targets**
- **Encouraging sharing data**



OceanGliders and Animal Tagging

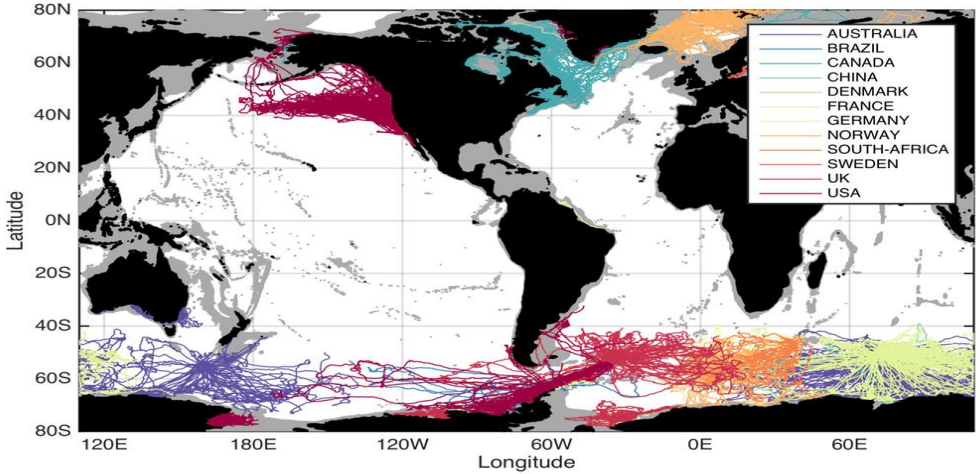


Ocean Gliders

- ~30 (BGC) gliders active at any time
- 50-100,000 profiles per year
- **Storms, boundary systems, convective regions: Developing missions, design targets and KPIs.**
- 25 countries involved
- OceanGliders Technical Coordinator at JCOMMOPS
- OceanGliders V1.0 data format.
- **Pushing for improved data availability.**
- **Considering role in polar, biogeochemical applications.**

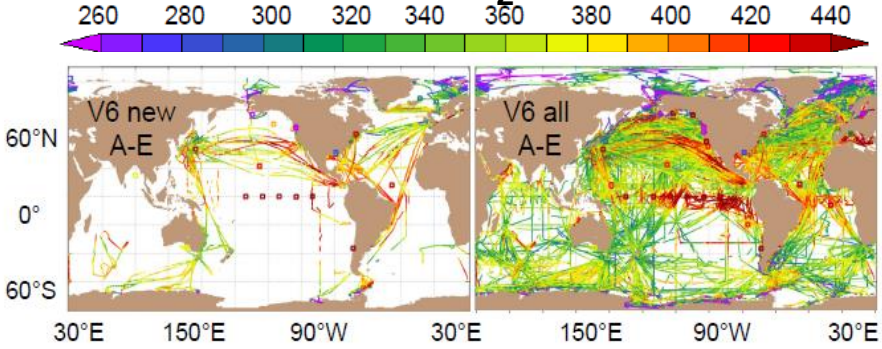
Animal Tagging

- 13 countries actively deploying CTDs on seals (NZ in 2019
- 543 735 CTD profiles from 1273 tags are available to the global community - http://www.meop.net/
- Near real-time observations are available through the GTS to the operational community
- Moving towards more proactive global coordination
- **Need greater engagement with data users**

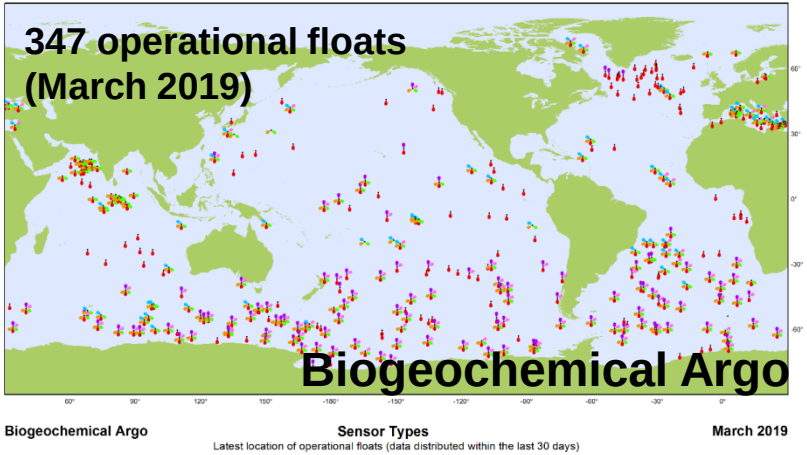


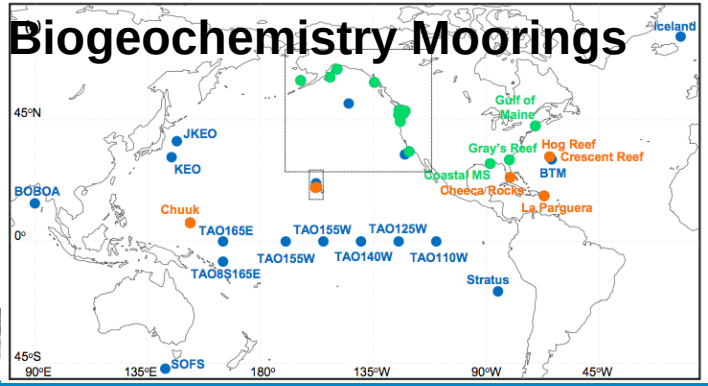
Biogeochemical Observations

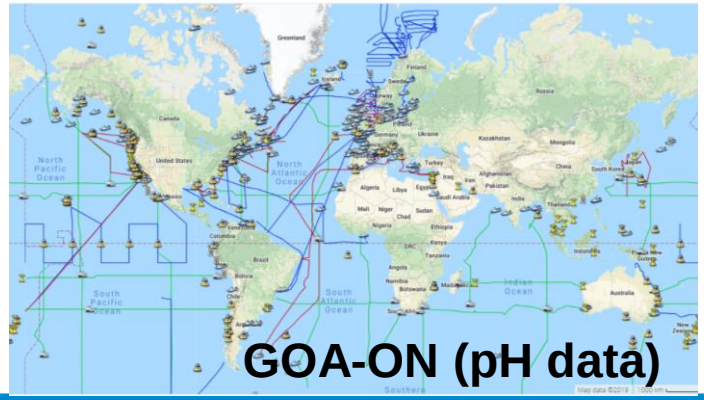
Surface ocean CO_2 observations



Newly added (left) and all quality controlled (right) surface water fCO_2 observations (uatm) in SOCAT version 6. Squares indicate moorings.



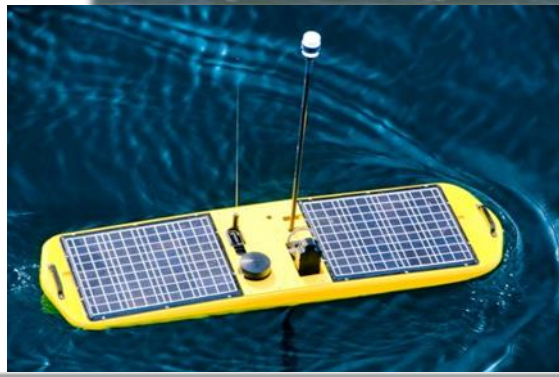




Looking forward to next decade: New Technologies……

- Developments in
  - platforms (closing spatial, temporal gaps)
  - sensors (enabling obs of new variables)
  - communications systems.
- Modular, ‘plug and play’ equipment, enabling broader participation.
- Rapid, event based sampling (e.g. Cyclones).
- Increased role and influence of private sector..

- We need to guide technological developments for optimum impact, in partnership with modelling and forecasting communities (co-design).



Reviews and evaluations to inform

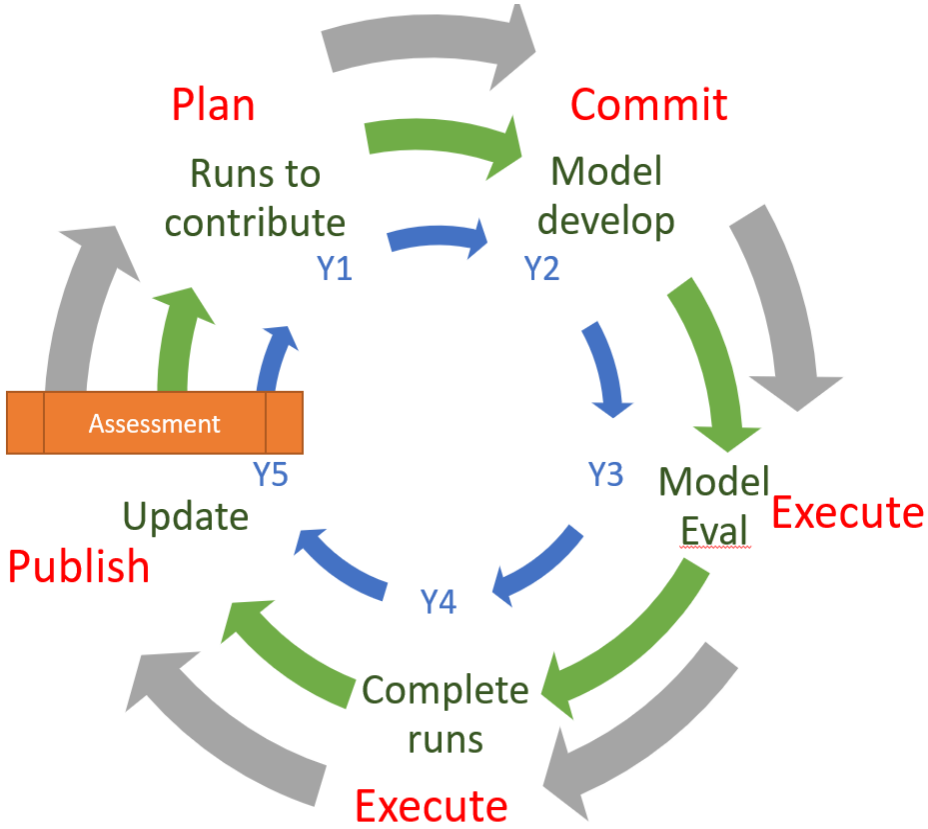
OBSERVING SYSTEM DEVELOPMENT

The Global Ocean Observing System

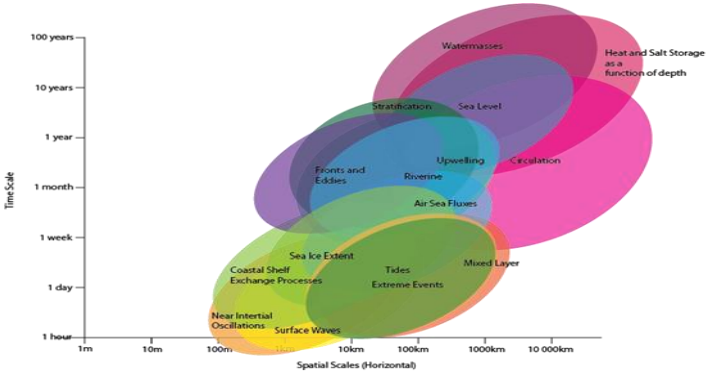
- 2nd Report published soon (following review)
- Coverage by variable assesed.
- Integrated approach:
  - Model-Data Integration
  - Satellite-In situ integration
  - Data integration

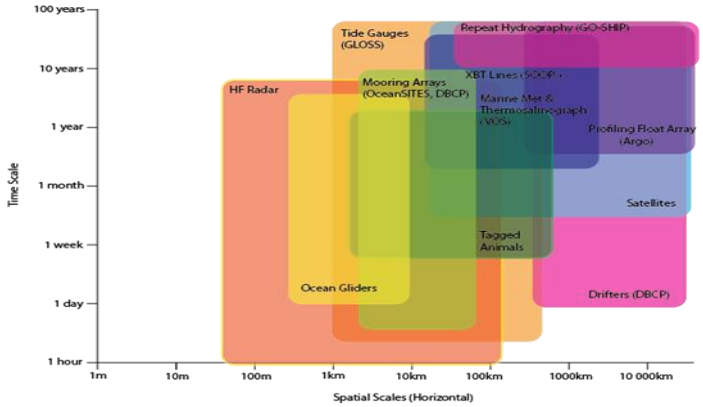
- If forecasts don't improve, TPOS 2020 won't be seen as a success.

- Recommendations:
  - Systematic cycle of work and assesment for seasonal forcast systems
  - Support for observing system simulation and sensitivity experiments

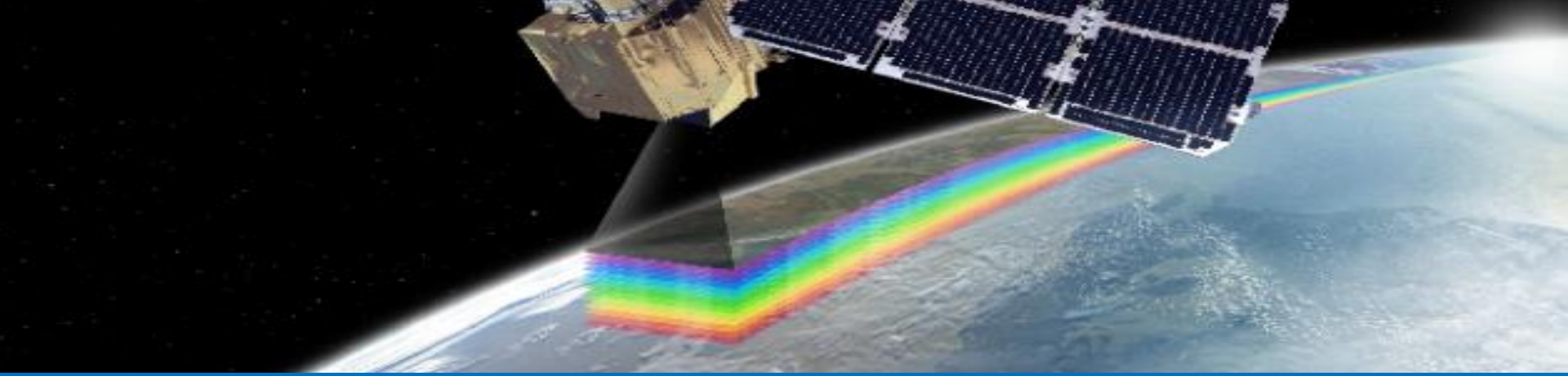


Observing System Design and Evaluation





- GOOS Expert Panels responsible for overseeing the multiplatform design and evolution of the observing system, with e.g. the Observations Coordination Group. Observing System Reviews and development projects, e.g.
  - Ocean Heat and Freshwater Storage
  - Air Sea Fluxes
  - **Boundary Systems (**R. Todd presentation)**
  - Variability in the Oxycline
- Partnership with model and forecast systems essential to ensure observing systems and modelling systems in combination advance our ability to understand, monitor and predict the ocean system **(**J. Wilkin presentation**)
- Seeking engagement!

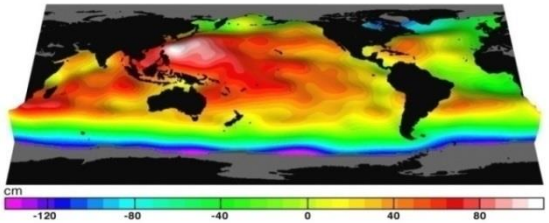


Status and plans for

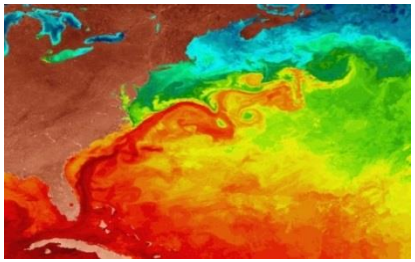
SATELLITE OBSERVATIONS

Contribution of satellite observations / ocean forecasting

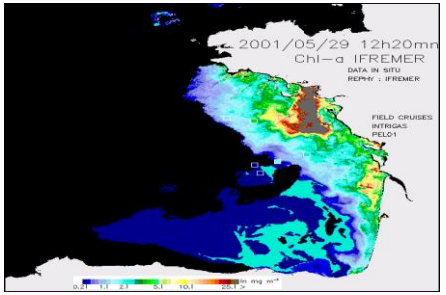
Key Ocean Parameters : Sea level and ocean currents, sea surface temperature, ocean colour, sea ice, winds, waves, sea surface salinity



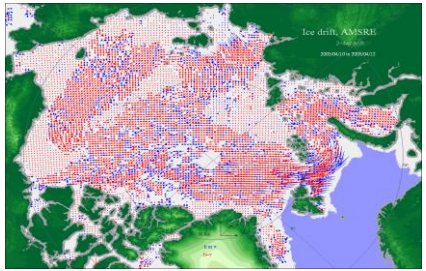
Altimetry and gravimetry
(sea level and ocean currents)



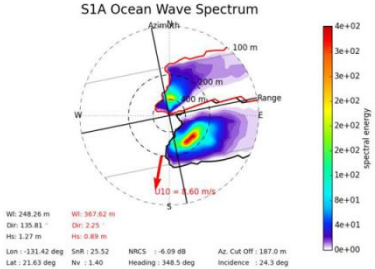
Sea Surface Temperature

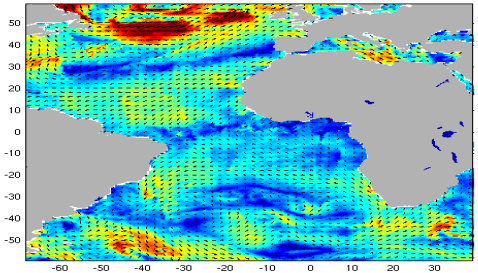


Ocean Colour (Chl-a, SPM)



Sea Ice (concentration, drift, thickness)

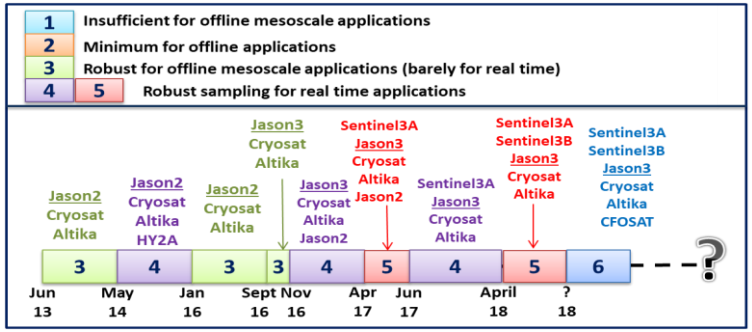


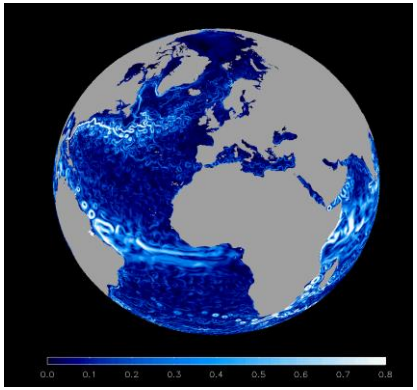


Waves (SWH, spectra) & Winds (speed and direction)

Satellite altimetry

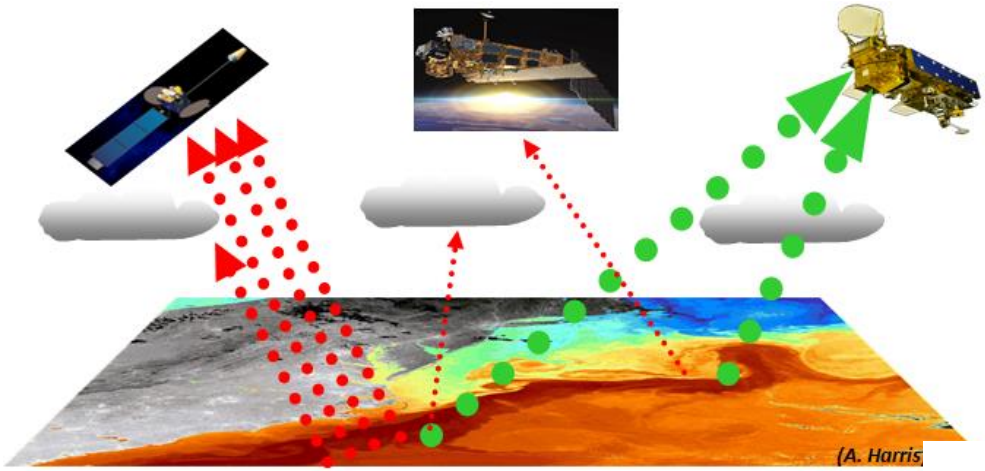
- **Unique role and contribution**: global coverage, all weather, high resolution (mesoscale), real time.
- Sea level is a **strong constraint for inferring the 4D ocean circulation** through data assimilation.
- Excellent **complementarity with Argo**.
- Need a **reference mission** (climate, intercalibration) (Jason series, S6).
- Most of applications require forecasts at high resolution (e.g. marine safety, transport, coastal). **At least 3 complementary missions** (e.g. S3A&B, Alti-Ka, Jason-2, Cryosat-2).
- Important role of **gravimetry** (e.g. GRACE, GOCE) (MDT/ADT). **Major impact for data assimilation**.





GOV systems use high resolution models (e.g. 1/12° global, 1/36° regional, 1 km coastal) => strong requirements for the altimeter constellation.

Sea Surface Temperature



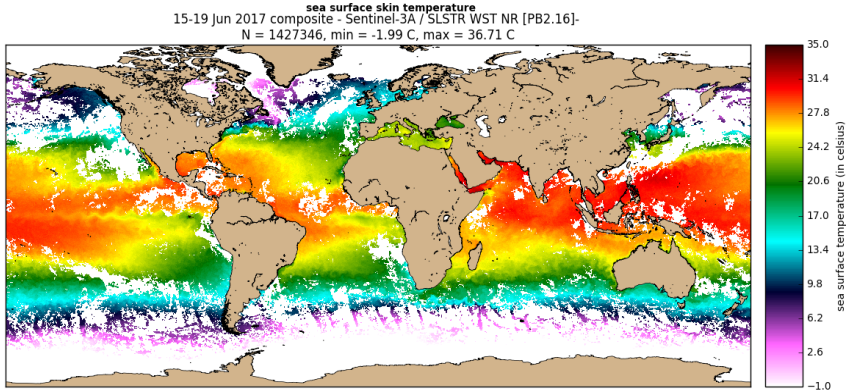
Polar Orbiting infrared: ***high accuracy - spatial resolution***

Microwave Polar orbiting: ***all-weather capability***

Geostationary infrared: ***high temporal resolution***

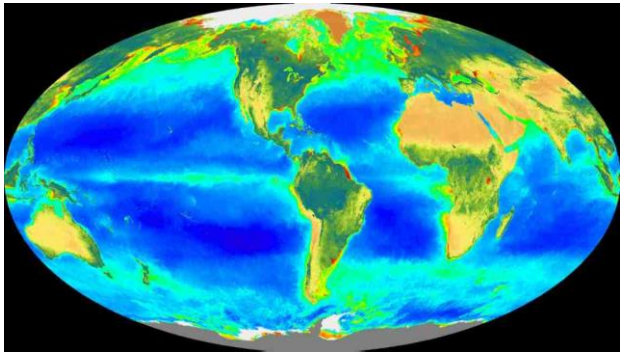
Status of passive microwave SST missions is fragile.

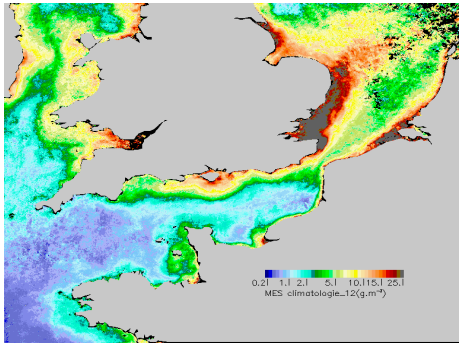
Improved DA schemes are needed to make a better use of high space/time resolution SST observation (e.g. diurnal cycle, mixed layer dynamics, mesoscale).



Ocean colour

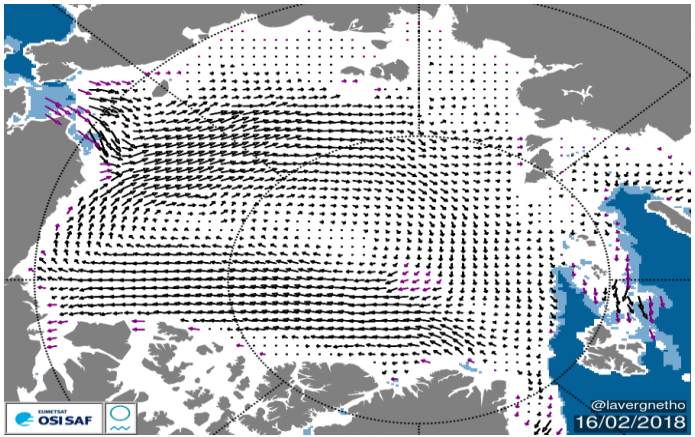
- OC missions provide essential observations for applications (e.g. water quality, eutrophication, Harmful Algae Bloom).
- Reduced number of OC missions has been a major issue. Improvement with S3A&B together with MODIS and VIIRS.
- Higher resolution/specialized OC products are required for coastal areas (Case II waters).
- **Potential of OC data to improve BGC models is large.** High priority R&D topic. Issues include: error characterization, observation operator (bio-optical models), observability and complementarity with in-situ data (BGC Argo).
- Future missions: geostationary (GOCI-II, others ?) and hyperspectral missions (e.g. PRISMA, PACE).



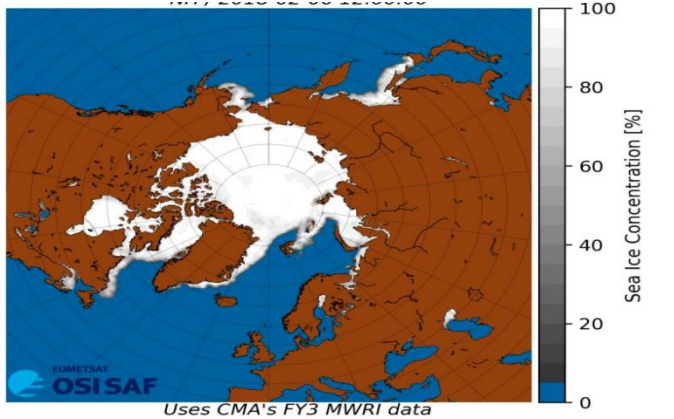


Sources of ocean color
Phytoplankton (Case I & Case II)
Dissolved organic material (Case II)
Suspended particulate matter (Case II)

Sea ice measurements from satellites

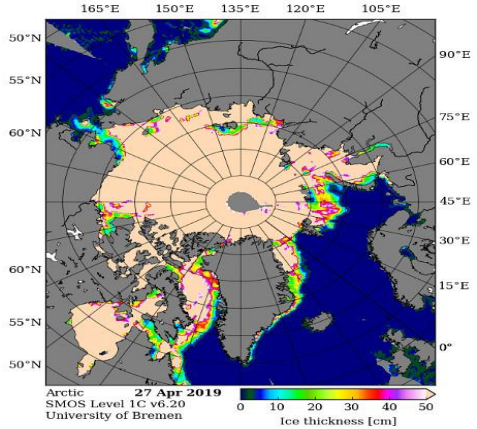


Ice drift



Ice concentration

- Sea-ice concentration (microwave)
- Sea-ice type (microwave, scatterometer, SAR)
- Sea-ice drift (microwave, scatteromer, SAR)
- Sea Ice thickness (altimeter, SAR, microwave – L band)
- Operational ice monitoring from SAR



Ice thickness

Sea Surface Salinity

Complementary missions
L-band radiometers (f = 1.4 Ghz)
SMOS launched in 2009
- Synthetic Aperture Radiometer

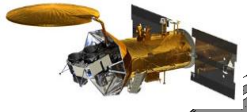
Aquarius (2011-2015)
- L-band radiometer and scatterometer

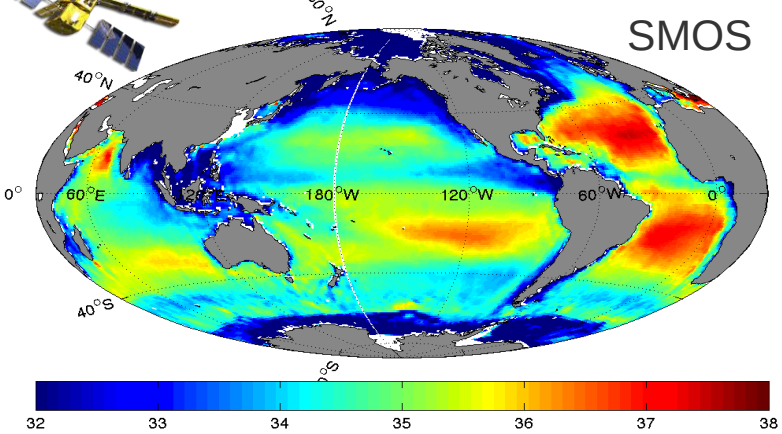
SMAP launched in 2015

Satellite SSS have demonstrated the value added to existing observations to improve understanding of ocean processes, linkages with the water cycle, seasonal-to-interannual prediction.

Positive (but slight) impact in ocean DA systems (in addition to Argo)

Planning for **future missions unclear** at this stage (Copernicus Imaging Microwave Radiometer).

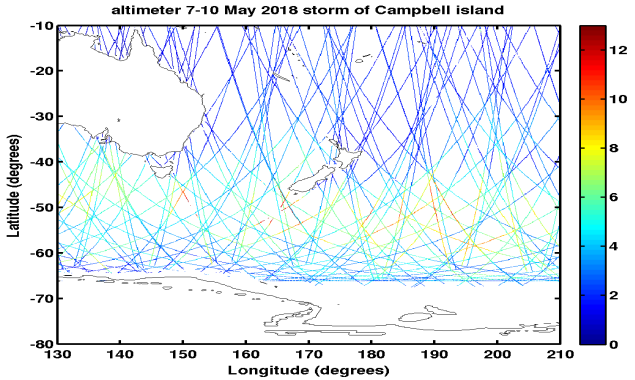


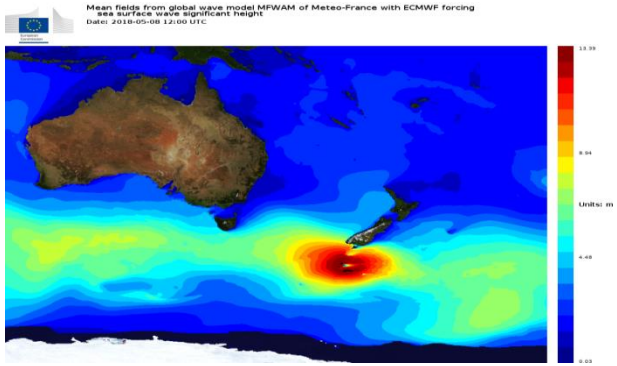


www.godae-oceanview.org/projects/smos-nino15/

smos+ niño15 support to science element

Waves

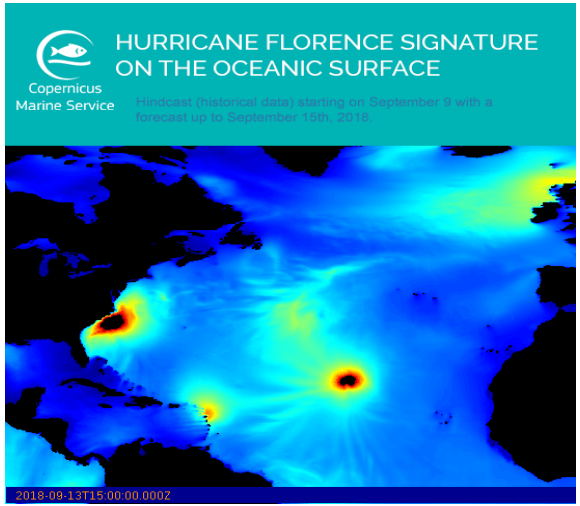




Important role of SWH observations from the altimeter constellation

Wave spectra (Sentinel 1) assimilation (CFOSAT, SKIM)

+ SLA altimeter observations for waves/currents coupling



Copernicus Marine Service global wave model with altimeter SWH and SAR data assimilation (Meteo France, L. Aouf)

Perspectives / evolution of satellite observing capabilities

Continuity, improvements (space/time resolution, accuracy), new variables

SAR altimetry (on going)

Swath altimetry (SWOT) and Copernicus (long term) (WISA) (constellation)

Wave (spectrum): CFOSAT, SKIM

Surface Currents (SKIM, WaCM)

Microwave SST/ Sea Ice mission at high resolution (CIMR)

Sea Ice thickness (CRYOSAT/CRISTAL, IceSat-2)

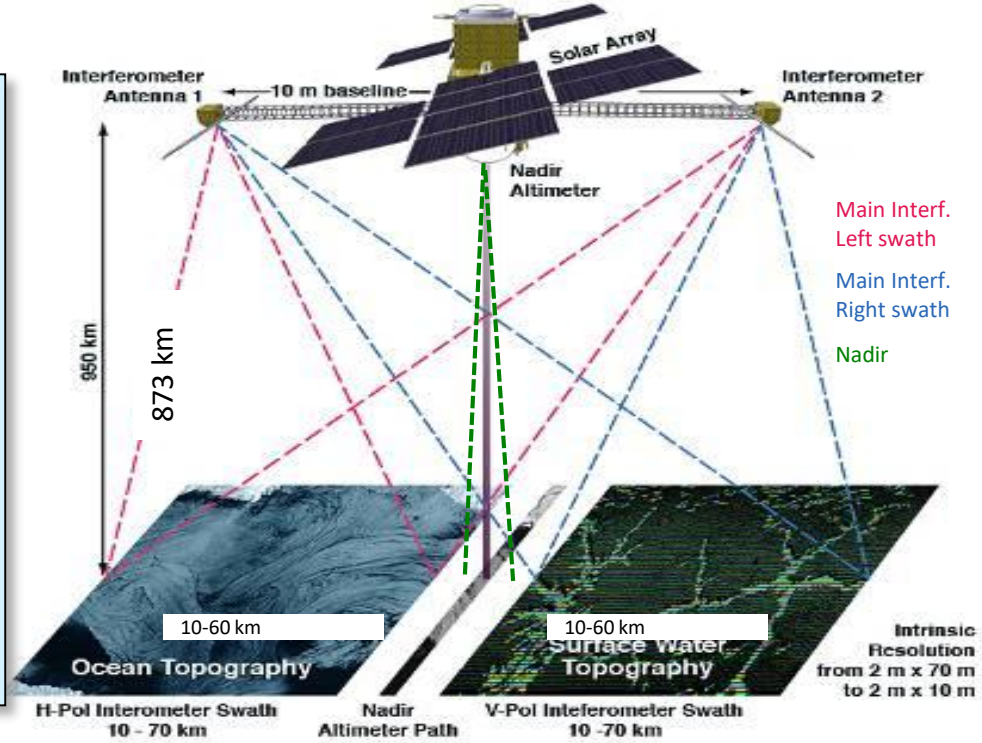
Gravimetry / mass change (GRACE FO, new missions)

Ocean colour (hyperspectral) (PRISMA, PACE), geostationary (GOCI-II)

SWOT (Surface Water Ocean Topography) Mission

Mission Architecture

- Ka-band SAR interferometric (KaRIn) system with 2 swaths, 60 km wide
- Produces heights and co-registered all-weather SAR imagery
- Intrinsic HR resolution : 5,5 m x 10-70 m grid
- HR over land to detect 100 m wide rivers, 250 m^2 lakes and onboard processor gives 250 m^2 / 1-2 km^2 grid over oceans
- Interferometry will reduce noise by 1 order of magnitude : 2.4 cm^2/cycle/km^2
- Use conventional Jason-class altimeter for nadir coverage, radiometer for wet-tropospheric delay, and GPS/Doris/Laser ranging for orbit determination.



Effective resolution over the ocean (swath) : 15 km (wavelength).

- Partnered mission NASA, CNES & CSA & UKSA
- Mission life of 3.5 years
- 890 km Orbit, 78º Inclination, 21 day repeat
- Launch: Oct 2021

Direct measure of total surface currents from space

SKIM EE9 Candidate (Courtesy F. Ardhuin, PI)

The Sea-surface Kinematics Multiscale monitoring (SKIM) mission is built around a Ka-band instrument combining:

radar altimeter, **disco ball**, and **speed gun** …

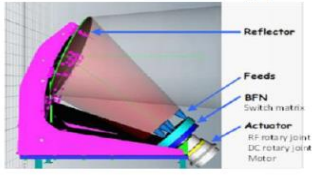

+

+

=

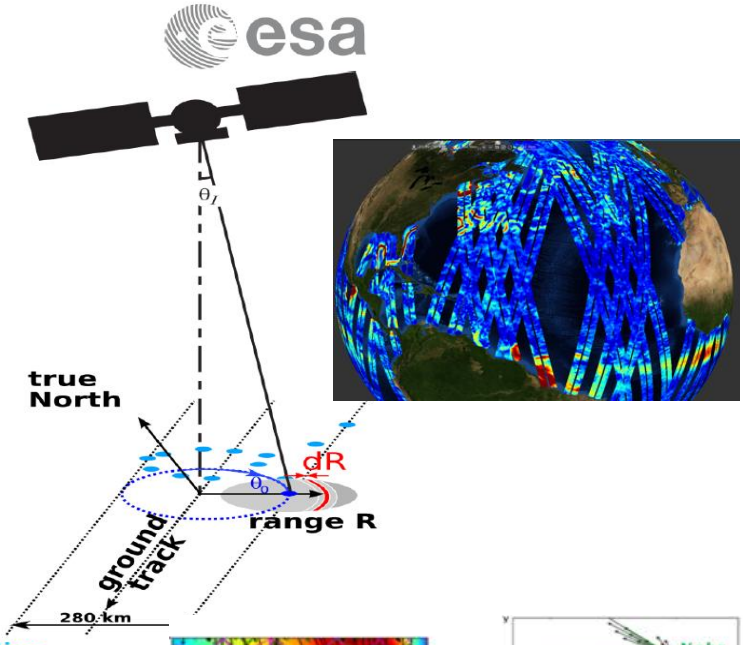
Altimeter: 32 Khz PRF, 200 MHz bandwidth, SAR unfocused
→ very low noise for **sea level**, **wave height**, **ice freeboard** …

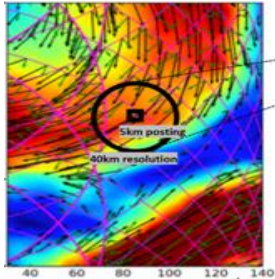
disco ball: a rotating plate with 8 horn feeds : one **nadir** beam (classical altimeter)

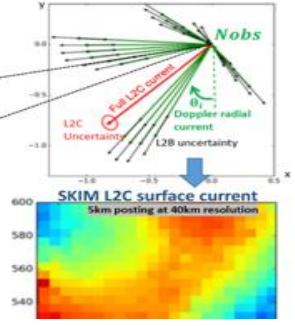


7 **other beams**
at 6 and 12° incidence
4 m range resolution

speed gun: Doppler analysis → **surface currents**, **ice drift** & **wave orbital velocities**.

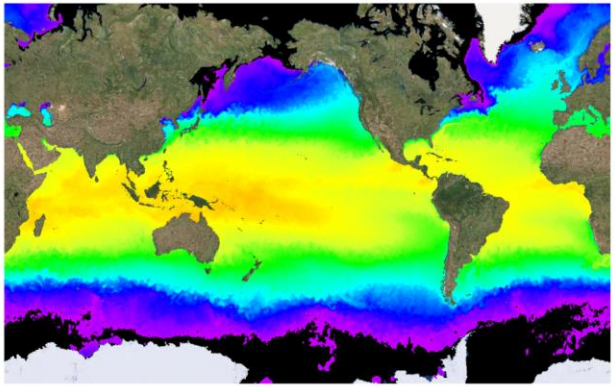






M. Dinkwater, C. Donlon
Ardhuin et al. (2018)

Expected accuracy of 10 cm/s for 100 km wavelength



First International Operational Satellite Oceanography Symposium

The Executive Steering and Programme Committees are pleased to invite community members from all levels of the value chain (data providers to users) of operational satellite oceanographic data, products and applications to attend the first international Operational Satellite Oceanography (OSO) Symposium. **The themes to be addressed are 1) redefining the operational paradigm, 2) linking data providers to information providers, 3) helping users find the information they need, and 4) facilitating the end-to-end value chain.** Participants can also elect to attend a day of training on Monday, 17 June 2019 at the same location.

MEETING DATES: 18 – 20 JUNE 2019
OPTIONAL TRAINING DAY: 17 JUNE 2019
REGISTRATION DEADLINE: 10 MAY 2019
ABSTRACT SUBMISSION DEADLINE: 29 MARCH 2019
REGISTRATION AND ABSTRACT: OSOS WEBSITE LINK

Abstract Submission Information

The focus of this first OSO symposium will be on the upstream components of the value chain, so the international community of satellite operators, information producers and high-level and intermediate users are especially encouraged to participate. Perspectives from downstream end users are important to the process and are welcome also. Poster abstracts may be submitted for consideration. Oral presentations are invited only. Abstracts (both submitted poster abstracts and invited oral abstracts) received by the deadline will be considered for placement into the Programme Abstract document assembled for the meeting. The Programme Committee will organize all accepted abstracts into interactive sessions based upon potential contribution to the symposium content and relevance to session themes.

18 - 20 June 2019
with Optional
Training Day
17 June 2019

NOAA Center for
Weather and
Climate Prediction

College Park, MD
USA
Convenient Access
From Washington DC

Abstract Submission
Deadline:
29 March 2019

Registration
Deadline:
10 May 2019

Registration and
Abstract Submission:
OSOS Website Link

(Registration Opens
Mid-February 2019)

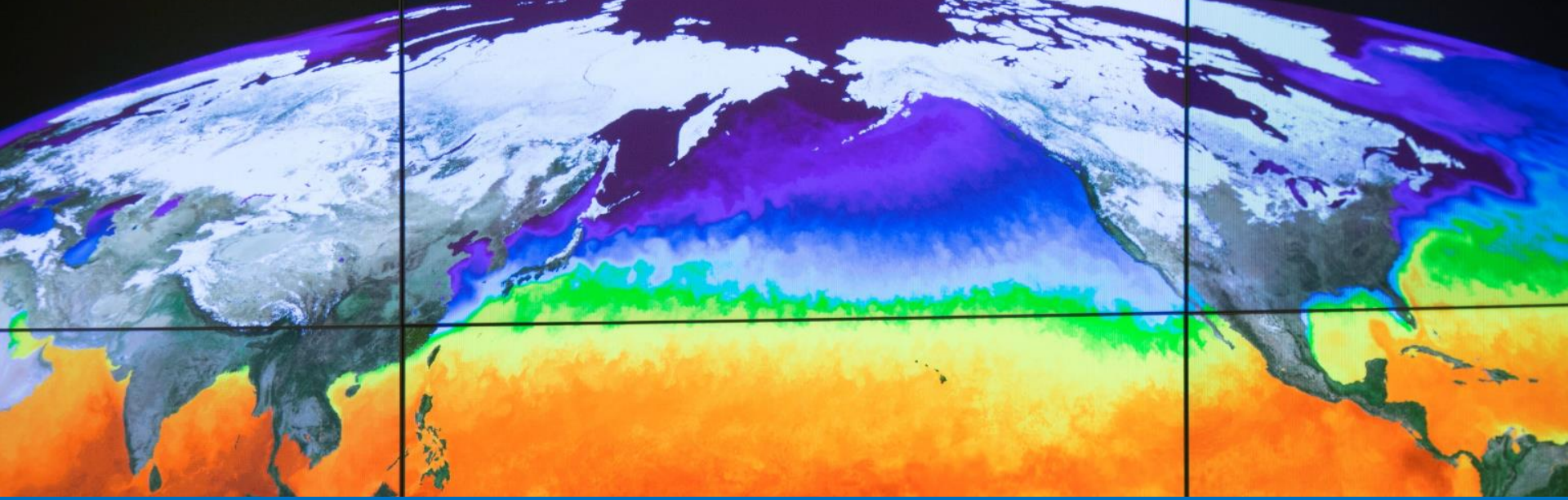
NOAA EUMETSAT

Posted 7 February 2019

First International Operational Oceanography Symposium

18-20 June 2019
College Park, MD USA

Go to coastwatch.noaa.gov
for further information



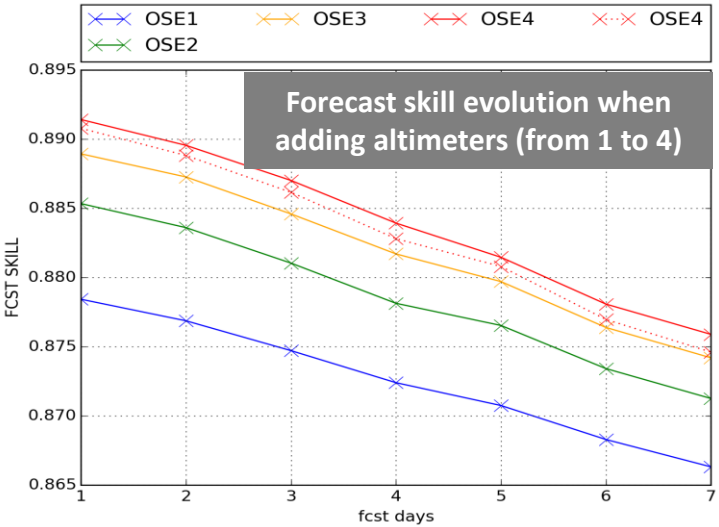
The impact of present/future satellite and in situ

OBSERVATIONS FOR OCEAN PREDICTION

Impact on the altimeter constellation on global ocean forecasts

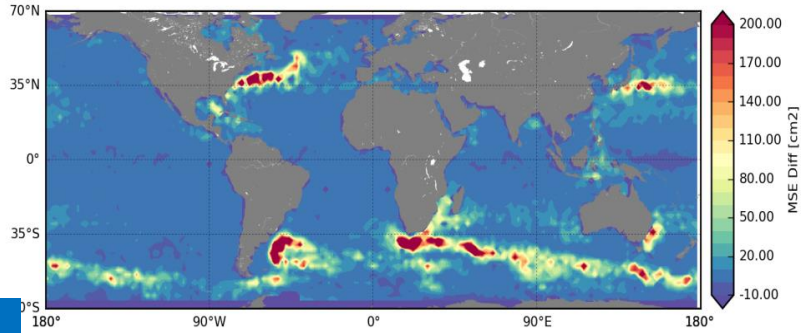
Impact of the number of altimeters on the quality of Mercator Ocean global ocean analyses and forecasts.

Hamon et al., J. Atmos. Tech. (2019)

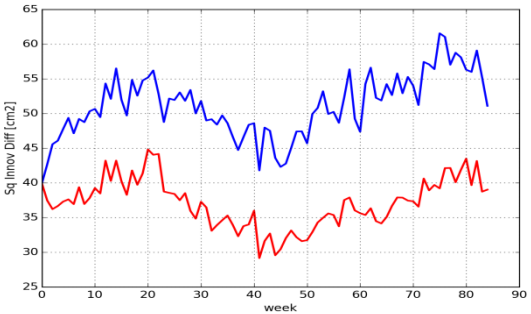


Forecast error is divided by 2 when moving from 1 to 4 altimeters.

Steady improvement of forecast skill wrt the altimeter constellation



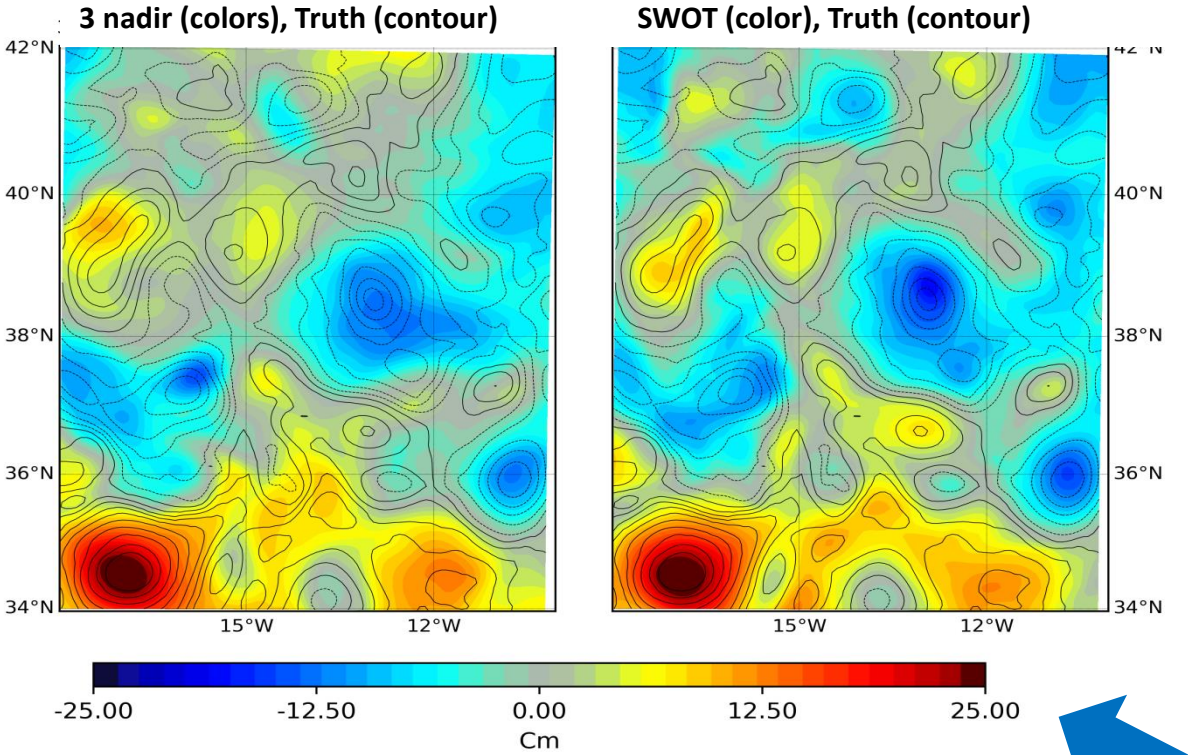
7-day sea level forecast errors : 4 versus 1



Variance of 7-day sea level forecast error : 4 versus 1

MERCATOR OCEAN INTERNATIONAL

Future of altimetry: SWOT and the revolution of swath altimetry



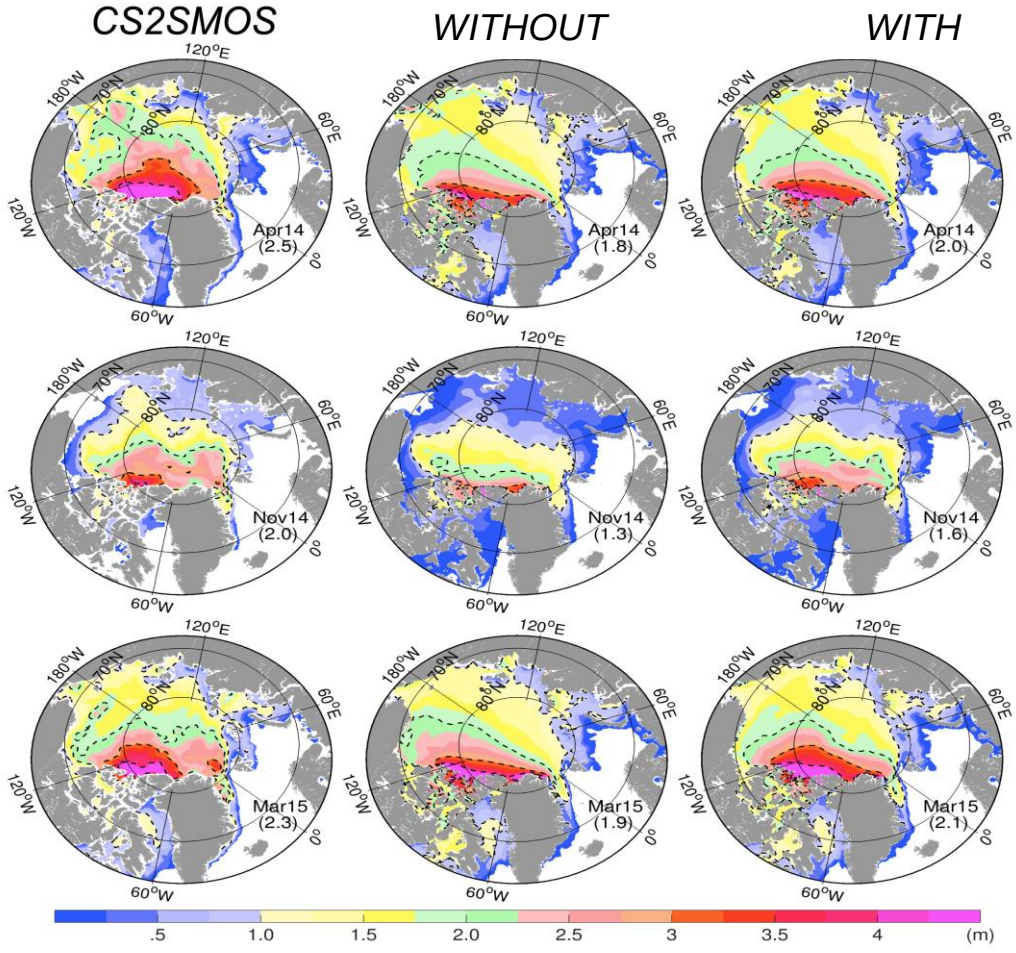
Today requirements: at least 4 altimeters. **Longer term requirements : (much) higher resolution.** Model resolution likely to increase by a factor 3 for the post 2021 time period to better represent upper ocean dynamics.

OSSEs in the IBI regional model (North East Atlantic) (SWOT/CNES study). Nature Run (truth) 1/36°assimilated in a 1/12° model (Benkiran et al., 2019).

See presentation by M. Benkiran

MERCATOR OCEAN INTERNATIONAL

Assimilating combined Cryosat-2-SMOS ice thickness data



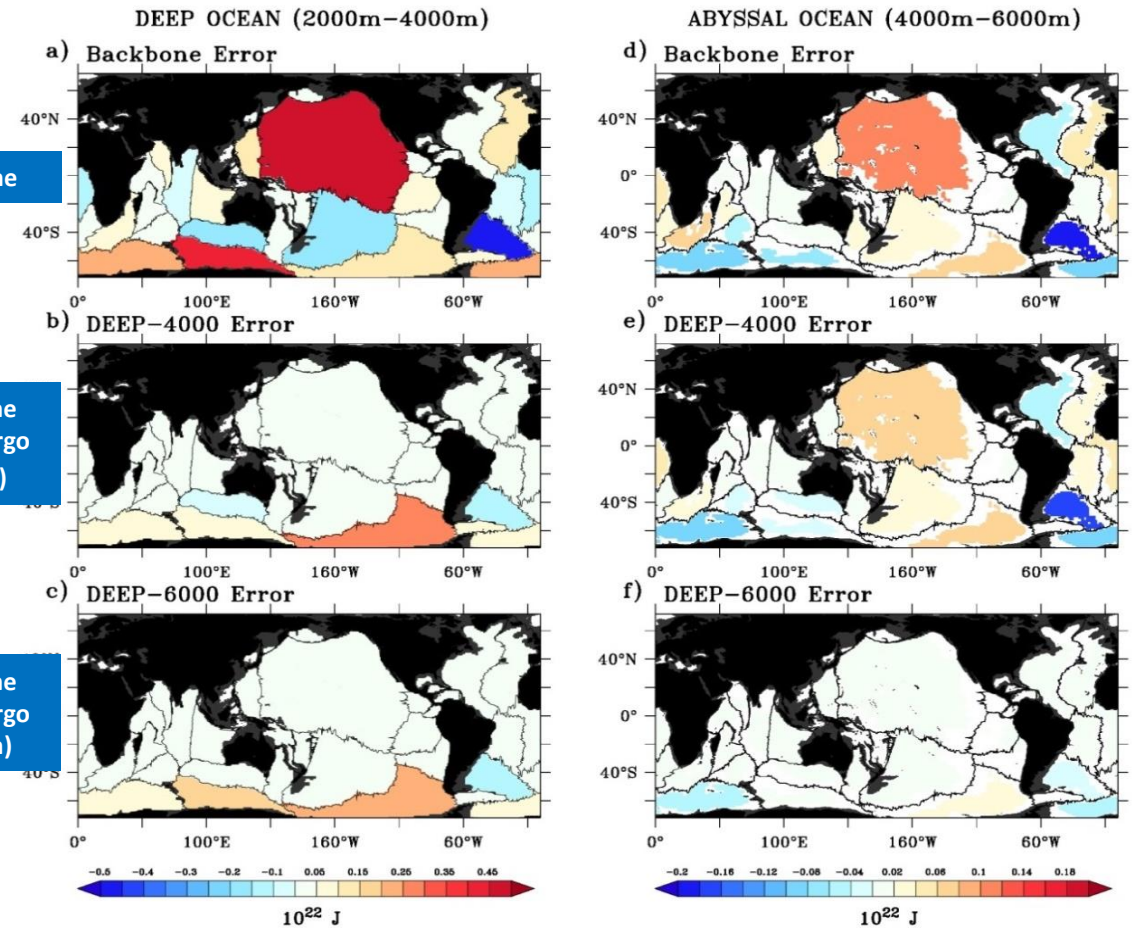
Improvements by 12% to 24% in thick ice

Xie et al. TC 2018

NERSC

L. Bertino

Deep Argo OSSEs in Atlantos (Mercator Ocean)



Backbone

Backbone + Deep Argo (4000 m)

Backbone + Deep Argo (6000 m)

2010 Ocean Heat Content error in the deep and abyssal oceans for the Backbone, DEEP4000 and DEEP6000 experiments

Impact of deep-Argo is evident on the 2010 mean in the 2000-4000m layer, the Southern Ocean remains undersampled

Compared with DEEP4000, DEEP6000 significantly reduces biases in the 4000-6000m layer

See presentation by F. Gasparin

BGC Argo OSSEs in Atlantos (Met Office, CNRS/IGE)

Perform OSSEs to assess different BGC-Argo deployment strategies

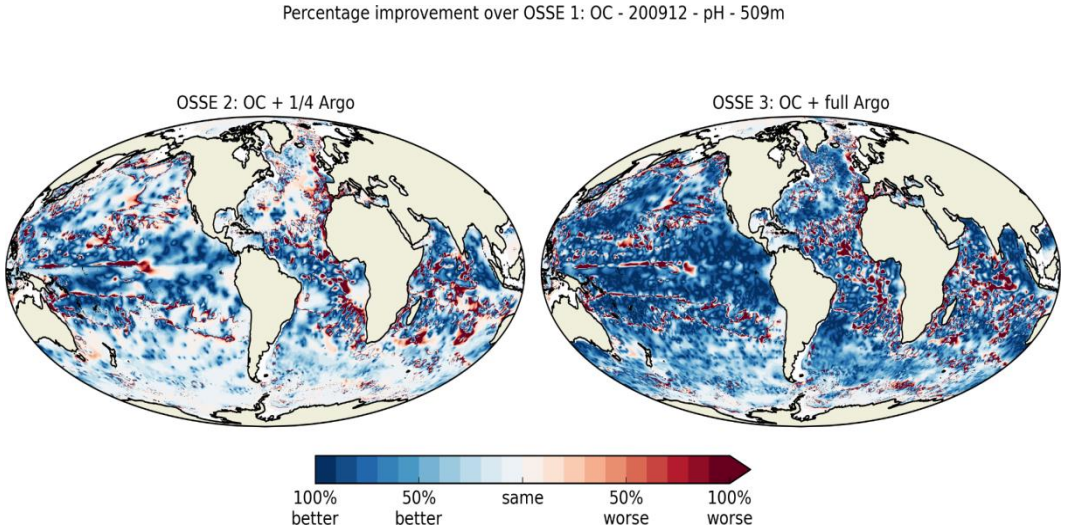
Met Office

Model runs (global ¼° NEMO-MEDUSA)

- Nature run (used to generate “ocean colour” and “BGC-Argo”)
- OSSE 1: Assimilate “ocean colour” into perturbed run
- OSSE 2: Assimilate “ocean colour” and ¼ “BGC-Argo” into perturbed run
- OSSE 3: Assimilate “ocean colour” and full “BGC-Argo” into perturbed run

Simulated observations

- Ocean colour: daily surface chlorophyll
- BGC-Argo: profiles of chlorophyll, nitrate, oxygen, pH



AtlantOS

Ford et al., 2019

Looking to the future

GOOS AND OCEANPREDICT

OceanPredict
Advancing the science of ocean prediction
The GODAE OceanView Follow-On Programme

The Global Ocean Observing System
GOOS

Ocean Observation Challenges for the next decade

Sustainability of the observing system

Evolutions to address major gaps (e.g. BGC, deep, coastal/regional, polar)

Towards an improved and more integrated (physics&biogeochemistry, in-situ&satellite, observations&models) design of a multi-purpose system (climate/ocean health/ocean services)

Demonstrating further the benefits of the observing system (beyond climate)

OCEANPREDICT
Advancing the science of ocean prediction
The GODAE OceanView Follow-On Programme

The Global Ocean Observing System
GOOS

GOOS and OceanPredict

Strong dependencies between GOOS (observations) and OceanPredict (modelling and data assimilation) programs. A **successful GOOS and successful OceanPredict require strengthened cooperation**. Joint activities are essential to:

- Improve the way observations are used in ocean forecasting systems
- Improve the impact of observations for analysis/forecasting and applications/users
- Develop an improved and more integrated design of the observing system
- Develop advocacy for the observing system based on utility and impact assessment

Way forward: stronger **alignment of GOOS and OceanPredict workplans** for the next decade (co-development & co-evolution), set up a few pilot projects on strategic/challenging issues (e.g. BGC EOVs).

OceanPredict
Advancing the science of ocean prediction
The GODAE OceanView Follow-On Programme

The Global Ocean Observing System
GOOS

An Ocean of Opportunity

OCEAN OBS'19

September 16-20, 2019
Hawai'i Convention Center
Honolulu, HI, USA

The OceanObs'19 conference is a **community-driven** conference that brings people from all over the planet together to **communicate the decadal progress of ocean observing networks** and to **chart innovative solutions to society's growing needs for ocean information** in the coming decade.

Conference Themes

- Observing System Governance
- Data & Information Systems
- Observing Technologies & Networks
- Discovery
- Ecosystem Health & Biodiversity
- Climate Change & Variability
- Water, Food, & Energy Securities
- Pollution & Human Health
- Hazards & Maritime Safety
- Blue Economy

Program Objectives

Information: how do we meet future user needs?

Interoperability: how can we better communicate among observing systems to deliver products for users that follow usability and other best practices across the globe?

Innovation: how can we spur innovation in observing technologies, products, and user services?

Integration: how can we balance user and operator needs, capabilities, and knowledge worldwide?

Attend

Regular registration for the conference is now open!

For more info: www.oceanobs19.net or info@oceanobs19.net

Thank You

www.goosocean.org

The Global Ocean Observing System