Exploiting Satellite Observations for NOAA Ocean Prediction

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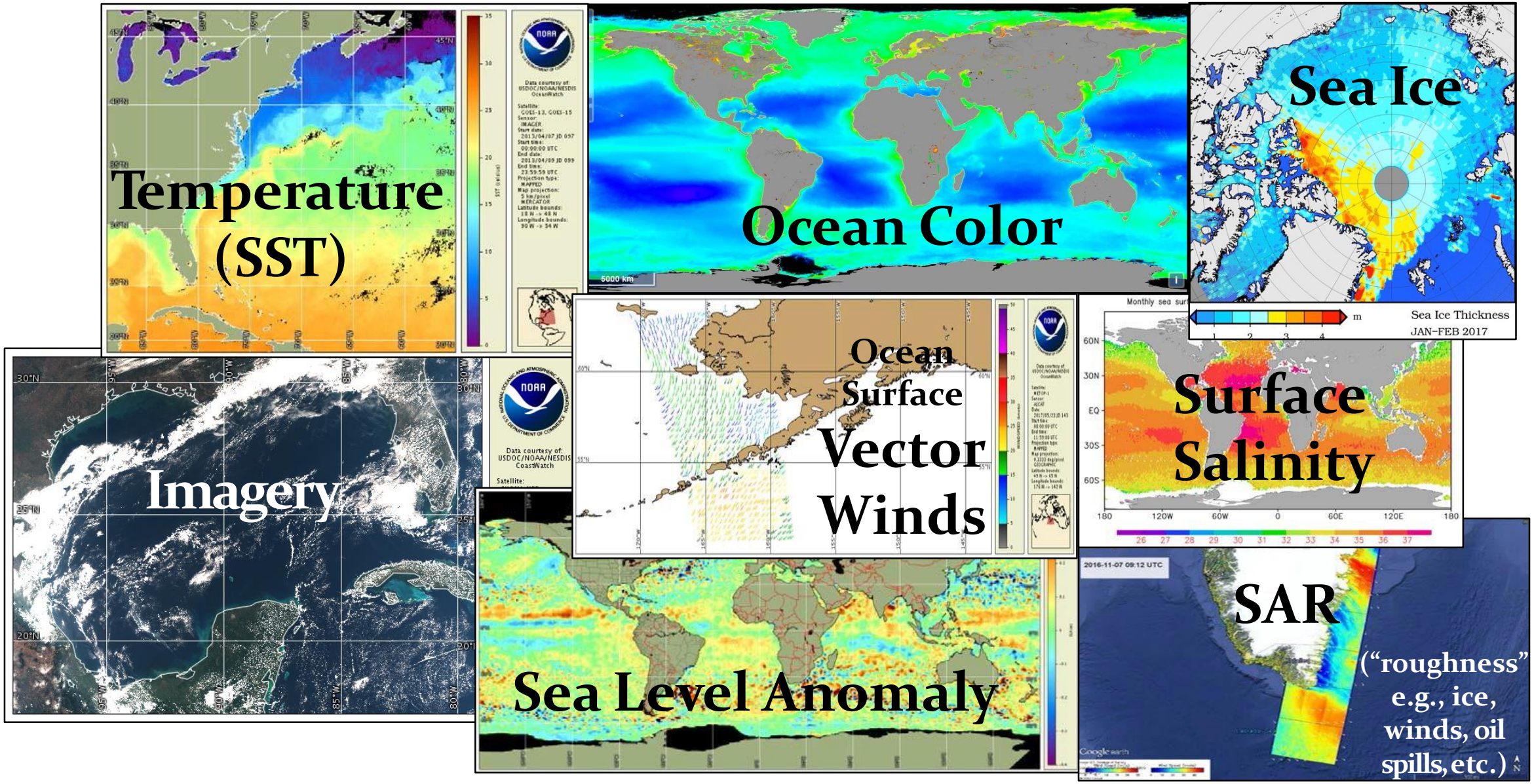
Ocean Parameters from Space



Satellite Ocean Data Maturity

Parameter	Phenomenology	Orbit	Maturity	Strengths	Constraints
Absolute dynamic topography	altimetry	LEO	developmental	homogenized, cloud penetration	temporal & cross-track resolution
Chlorophyll-a	visible	LEO	operational	spatial resolution	temporal resolution, clouds
Diffuse attenuation - PAR	visible	LEO	operational	spatial resolution	temporal resolution, clouds
Derived ocean color parameters, e.g., nLw, detritus, CDOM, sediment	visible	LEO	developmental	spatial resolution	temporal resolution, clouds
Ocean vector winds	scatterometry	LEO	operational	cloud penetration	temporal resolution
Ocean vector winds	SAR	LEO	developmental	cloud penetration	temporal resolution
Ocean vector winds	passive MW	LEO	operational	cloud penetration	temporal & spatial resolution
Ocean wind speed	passive MW	LEO	operational	cloud penetration	temporal & spatial resolution
Ocean wind speed	SAR	LEO	operational	spatial resolution, cloud penetration	temporal resolution
Ocean wind speed	altimetry	LEO	operational	along track resolution, cloud penetration	temporal resolution, cross-track resolution
Sea-surface height anomaly	altimetry	LEO	operational	exact-repeat, cloud penetration	temporal & cross-track resolution
Sea-surface salinity	passive MW	LEO	developmental	cloud penetration	temporal & spatial resolution, SST, surface roughness
Sea-surface temperature	IR	GEO	operational	temporal resolution	spatial resolution, clouds
Sea-surface temperature	IR	LEO	operational	spatial resolution	temporal resolution, clouds, precipitation
Sea-surface temperature	passive MW	LEO	operational	spatial resolution, cloud penetration	temporal resolution, precipitation
Significant wave height	altimetry	LEO	operational	exact-repeat, cloud penetration	temporal & cross-track resolution
Swell spectra	SAR	LEO	developmental	spatial resolution, cloud penetration	temporal resolution
Swell spectra	visible	LEO	developmental	spatial resolution	temporal resolution

Satellite Sea-ice Data Maturity

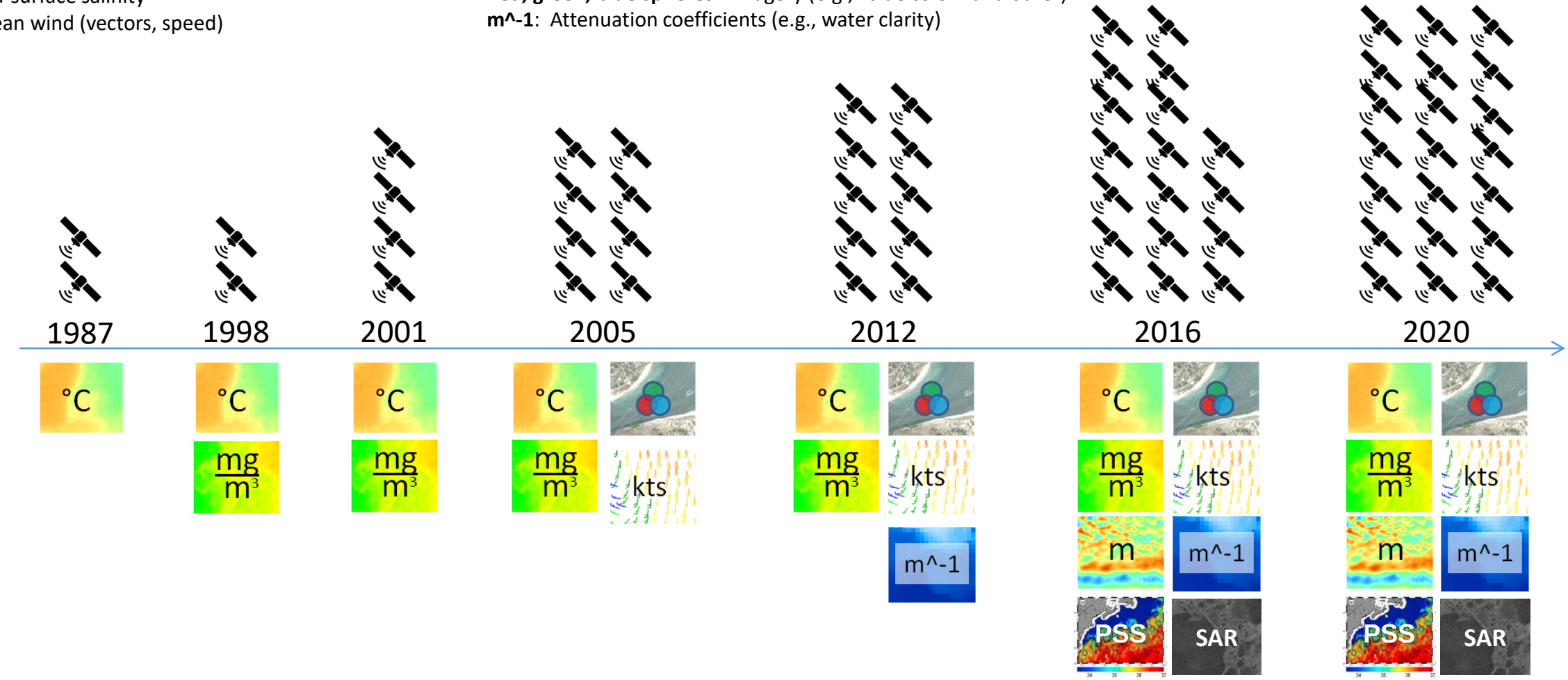
Parameter	Phenomenology	Orbit	Maturity	Strengths	Constraints
Ice edge & Ice extent	visible	LEO	operational	spatial resolution	clouds
Ice edge & Ice extent	passive MW	LEO	operational	cloud penetration	spatial resolution
Ice edge & Ice extent	SAR	LEO	operational	spatial resolution, cloud penetration	
Ice edge & Ice extent	scatterometry	LEO	operational	cloud penetration	spatial resolution
Ice type	SAR	LEO	operational	cloud penetration	temporal & spatial resolution
Ice-motion vectors	visible/IR	LEO	developmental	spatial resolution	temporal resolution, clouds
Ice-motion vectors	SAR	LEO	developmental	cloud penetration	temporal resolution
Ice-surface temperature	IR	LEO	operational	spatial resolution	clouds
Sea-ice concentration	scatterometry	LEO	operational	cloud penetration	spatial resolution
Sea-ice concentration	SAR	LEO	developmental	spatial resolution, cloud penetration	
Sea-ice concentration	Visible/IR	LEO	operational	spatial resolution	clouds
Sea-ice concentration	passive MW	LEO	operational	cloud penetration	spatial resolution
Sea-ice thickness	IR	LEO	operational	spatial resolution	clouds
Sea-ice thickness	IR	GEO	developmental	spatial resolution	clouds, max latitude ~ 75°
Sea-ice thickness	passive MW	LEO	experimental	cloud penetration	spatial resolution
Sea-ice thickness	radar altimetry	LEO	experimental	cloud penetration	temporal & spatial resolution
Sea-ice thickness	lidar altimetry	LEO	experimental	along track resolution	temporal resolution, cross-track resolution, clouds

NOAA's Operational Use of Satellite Ocean Data

Icons are intended as representative of key satellite capabilities:

°C: Sea-surface temperature
m: Sea Surface Height/ Altimetry/oceanic heat content
PSS: Sea-surface salinity
Kts: Ocean wind (vectors, speed)

SAR: Grayscale image
mg/m3: Chlorophyll (and other Ocean Color products with different units)
Red, green, blue spheres: Imagery (e.g., "true color" and other)
m^-1: Attenuation coefficients (e.g., water clarity)



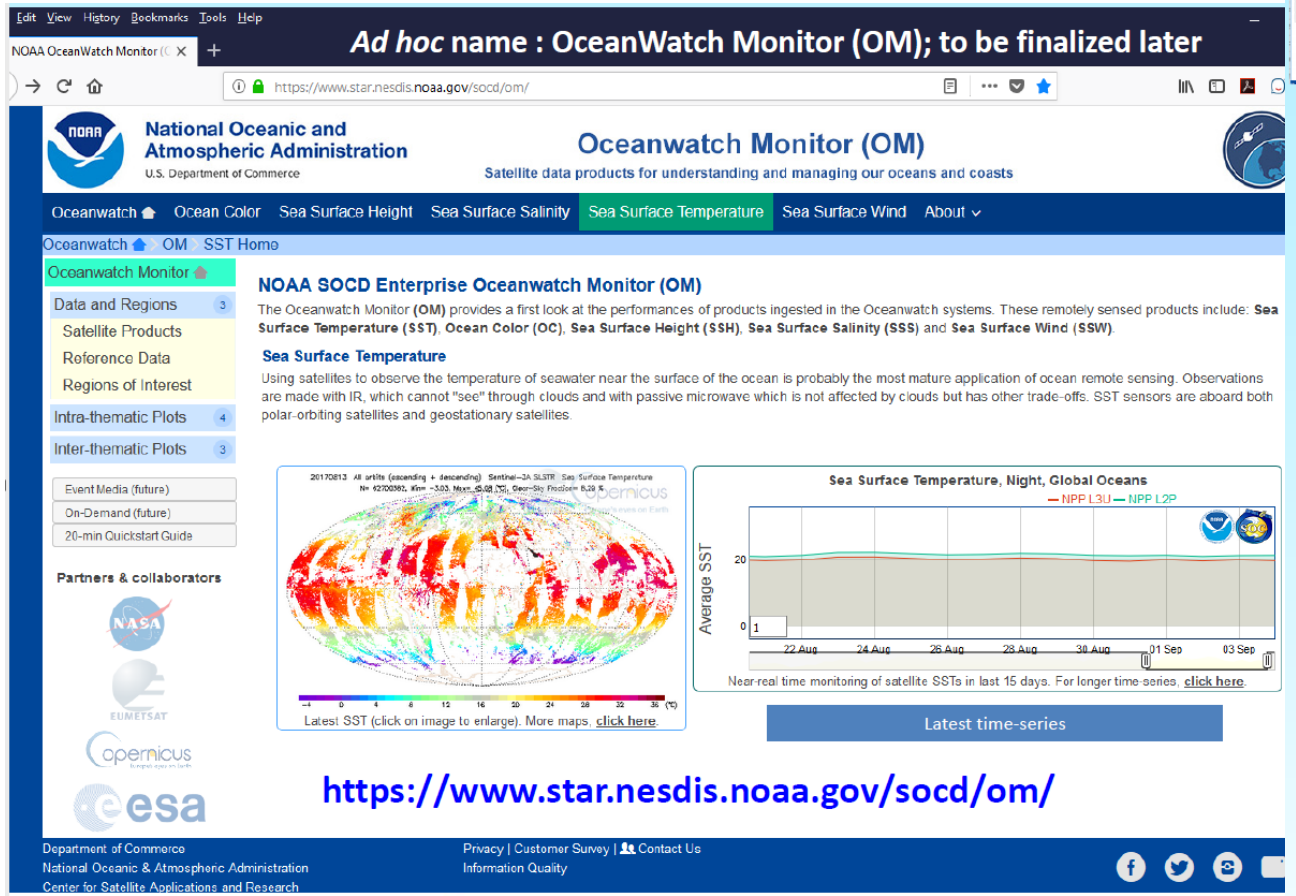
NOAA Satellite Ocean Data Sources

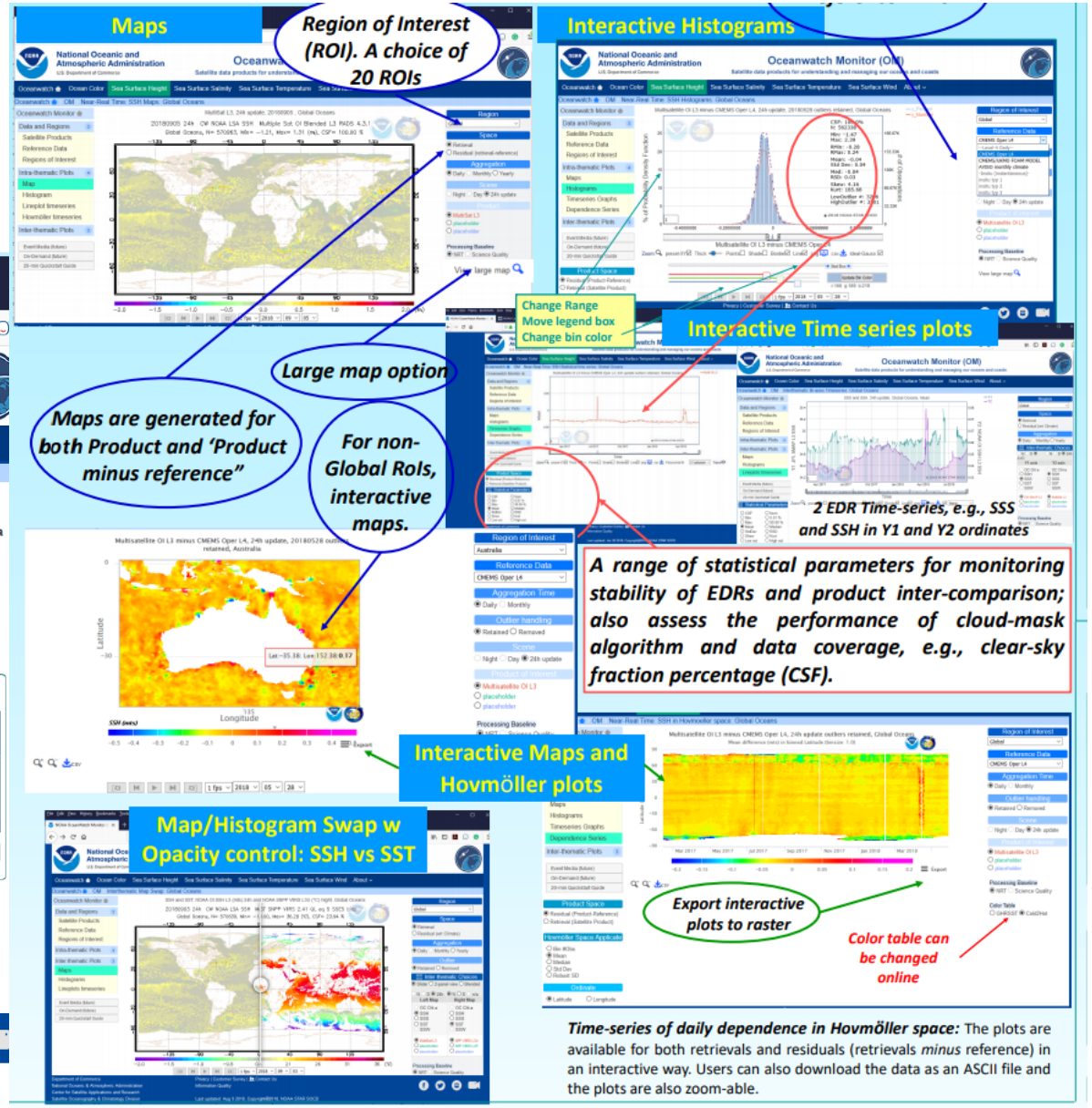
Parameter	Phenomenology	Active/Passive	Orbit	Satellites
Absolute dynamic topography	altimetry	active	LEO	Jason-2/3/CS-A/CS-B, SARAL, SWOT, Cryosat-2, Sentinel-3A/B/C/D
Chlorophyll-a	visible	passive	LEO	SNPP/NOAA-20/JPSS-2/3, Sentinel-3A,B,C,D
Diffuse attenuation - PAR	visible	passive	LEO	SNPP/NOAA-20/JPSS-2/3, Sentinel-3A,B,C,D
Derived ocean color parameters, e.g., nLw, detritus, CDOM, sediment	visible	passive	LEO	SNPP/NOAA-20/JPSS-2/3, Sentinel-3A,B,C,D
Ocean vector winds	scatterometry	active	LEO	METOP-A/B/C
Ocean vector winds	SAR	active	LEO	Radarsat-CM, Sentinel-1A/B
Ocean vector winds	MW	passive	LEO	WindSat
Ocean wind speed	MW	passive	LEO	F17/18, GCOM-W1, SMAP
Ocean wind speed	SAR	active	LEO	Radarsat-2, Radarsat-CM, Sentinel-1A/B
Ocean wind speed	altimetry	active	LEO	Jason-2/3/CS-A/CS-B, SARAL, SWOT, Cryosat-2, Sentinel-3A/B/C/D
Sea-surface height anomaly	altimetry	active	LEO	Jason-2/3/CS-A/CS-B, SARAL, SWOT, Cryosat-2, Sentinel-3A/B/C/D
Sea-surface salinity	MW	passive	LEO	SMAP, SMOS
Sea-surface temperature	IR	passive	GEO	GOES-15/16/17/T/U, Himiware-8/9, Meteosat-11, Meteosat-TG-I1/2
Sea-surface temperature	IR	passive	LEO	NOAA-15/18/19, SNPP/NOAA-20/JPSS-2/3, MetOp-A/B/C, MetOp-SG-A1, Aqua, Terra
Sea-surface temperature	MW	passive	LEO	GCOM-W1, GPM
Significant wave height	altimetry	active	LEO	Jason-2/3/CS-A/CS-B, SARAL, SWOT, Cryosat-2, Sentinel-3A/B/C/D, Sentinel-1A/B
Swell spectra	SAR	active	LEO	Sentinel-1A/B, Radarsat-2/CM, SNPP/NOAA-20
Swell spectra	visible	passive	LEO	SNPP/NOAA-20/JPSS-2/3

NOAA Satellite Sea-ice Data Sources

Parameter	Phenomenology	Active/Passive	Orbit	Satellites
Ice edge & Ice extent	visible	passive	LEO	SNPP/NOAA-20/JPSS-2/3
Ice edge & Ice extent	MW	passive	LEO	F17/18, GPM, NOAA-18/19/20/SNPP/JPSSS-2/3, MetOp-A/B/C, MetOp-SG-A1/B1, GCOM-W1
Ice edge & Ice extent	SAR	active	LEO	Radarsat-2, Radarsat-CM, Sentinel-1A/B
Ice edge & Ice extent	scatterometry	active	LEO	METOP-A/B/C
Ice type	SAR	active	LEO	Radarsat-2, Radarsat-CM, Sentinel-1A/B
Ice-motion vectors	visible/IR	passive	LEO	SNPP/NOAA-20/JPSS-2/3
Ice-motion vectors	SAR	active	LEO	Radarsat-CM, Sentinel-1A/B
Ice-surface temperature	IR	passive	LEO	SNPP/NOAA-20/JPSS-2/3
Sea-ice concentration	scatterometry	active	LEO	METOP-A/B/C
Sea-ice concentration	SAR	active	LEO	Radarsat-2, Radarsat-CM, Sentinel-1A/B
Sea-ice concentration	visible/IR	passive	LEO	SNPP/NOAA-20/JPSS-2/3
Sea-ice concentration	MW	passive	LEO	F17/18, GPM, NOAA-18/19/20/SNPP/JPSSS-2/3, MetOp-A/B/C, MetOp-SG-A1/B1, GCOM-W1
Sea-ice thickness	IR	passive	LEO	SNPP/NOAA-20/JPSS-2/3
Sea-ice thickness	IR	passive	GEO	GOES-16/17/T/U
Sea-ice thickness	MW	passive	LEO	SMOS, SMAP
Sea-ice thickness	MW	active	LEO	Cryosat-2, SWOT
Sea-ice thickness	visible	active	LEO	ICESat-2

Ocean Satellite Data Monitoring: QA/QC; *In situ* Data Match-ups



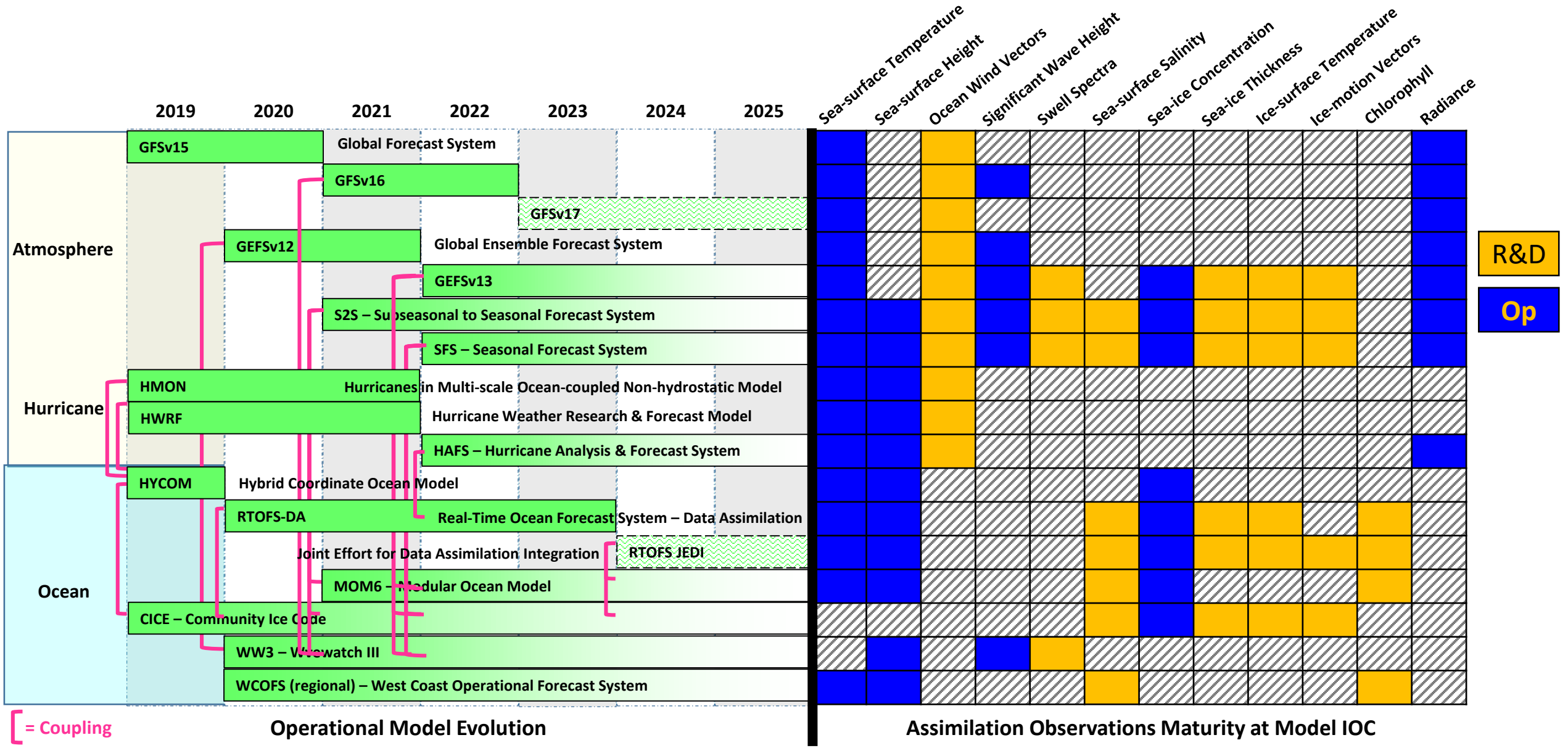


Satellite Observations in Numerical Prediction

- **Current NOAA ocean prediction operations:**
  - Sea-surface temperature
  - Sea-surface altimetry (sea-surface height anomaly)
  - Sea-ice concentration/edge
  - Sea-surface roughness (ocean vector winds, ocean wind speed)

- **Research and development (R&D) targeting ocean prediction:**
  - Sea-surface salinity
  - Sea-ice thickness
  - Ice-surface temperature
  - Ice-motion vectors
  - Ocean radiometry (color)
  - Swell spectra
  - Significant wave height
  - Radiances

Satellite Ocean Data for Operational Environmental Modeling



NOAA Satellite Ocean Data Assimilation

- Targeting coupled ocean/sea-ice/atmosphere modeling and data assimilation with development of a new operational data-assimilating modeling system

- Joint Effort for Data assimilation Integration (JEDI)
  - Partners: NOAA, NASA, Navy, Air Force
  - Concept:
    - Common observation pre-processing
    - Unified forward operators for observation types
    - High-level model-agnostic applications
    - Applicable to ocean, atmosphere, cryosphere, and land
    - Where possible/appropriate, targeting radiance assimilation to reduce uncertainties across parameters

- Community Radiative Transfer Model (CRTM) / Community Surface Emissivity Model (CSEM)
  - For exploiting radiances
  - Refining the surface emissivity components to enable/enhance use for ocean/sea-ice observations

Ecological Forecasting

- **Data Assimilation**
  - Satellite-derived chlorophyll, Kd_{PAR}, and bio-optically-active reflectance for improving HAB, biogeochemical, and SST model predictions
    - Component development effort for pending NOAA operational West Coast regional model
    - California-Harmful Algae Risk Mapping (C-HARM)
    - NOAA's EcoCast, which provides fishing guidance to minimize bycatch
  - Neural network methodology demonstrated for filling data spatial/temporal gaps and providing forecasted values
- **Habitats**
  - **NOAA Coral Reef Watch Program provides:**
    - Current and upcoming reef environmental conditions using POES-GOES Blended SST product to provide to quickly identify areas at risk for coral bleaching
    - Weekly predictions of the likelihood of coral bleaching heat stress based on NOAA's Climate Forecast System to up to four months in the future
- **Water Quality**
  - **NOAA's Ocean Service generates operational and experimental Harmful Algal Bloom (HAB) Forecasts** using satellite ocean color derived products (chl-a anomaly; cyanobacterial index) and associated wind/transport forecasts
    - Includes New product development efforts are underway to optically discriminate water mass constituents using satellite ocean color data
    - Improved detection, tracking and forecasting of coastal plumes and blooms
    - Discrimination of phytoplankton functional taxa and size in support of fisheries management and other applications
  - **NOAA CoastWatch/OceanWatch satellite ocean observations and tools support monitoring:**
    - Risk index for bacteria (multiple health issues, including seafood contamination)
    - Turbidity and visibility
    - Floating algae index
    - Ocean acidification

First Operational Satellite Oceanography Symposium

18-20 June 2019; NOAA, College Park, MD

Registration Deadline: 10 May 2019

Aims to :

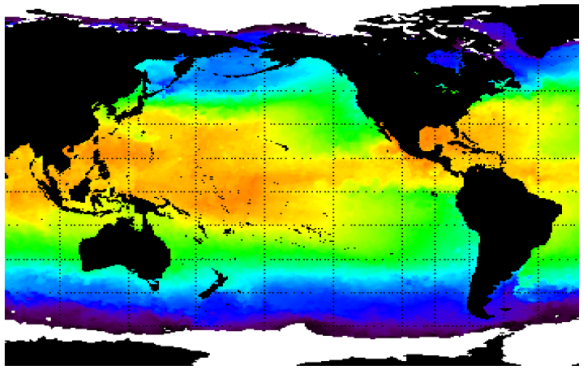
- enable the understanding of the barriers (perceived or actual) and
- facilitate the widespread incorporation of satellite ocean observations into the value chain from data to useful information across the range of operational applications.

Satellite operators, information producers and users will exchange facts and ideas to:

- understand user needs and expectations
- develop interoperability standards and establish best practices that will lead to more universal use of ocean satellite data

Themes to be addressed:

- Redefining the operational paradigm for oceans (i.e. not just NRT):
- Linking data providers to information providers
- Helping users to knowledgably shop in the “data supermarket”
- End-to-end integration: Facilitating the user-driven value-chain



18 to 20 June 2019
Washington, DC Area
FIRST INTERNATIONAL OPERATIONAL SATELLITE OCEANOGRAPHY SYMPOSIUM

Satellite remote sensing of ocean properties is a technology of continuously increasing maturity and scope. Sea surface temperature, sea surface height, ocean color, sea ice, ocean winds, roughness-derived parameters (e.g., oil spills) and other measurements are now available on a routine and sustainable basis. Some of these products are integral to operational applications for routine and event-driven environmental assessments, predictions, forecasts and management. Yet ocean satellite data are still underutilized and have a huge potential for contributing further to societal needs and the “blue economy”.

The First Operational Satellite Oceanography Symposium aims to enable the understanding the barriers (perceived or actual) and facilitate the widespread incorporation of satellite ocean observations into the value chain from data to useful information across the range of operational applications. In this symposium, an international community of satellite operators, information producers and users will exchange facts and ideas to 1) understand user needs and expectations, and 2) develop interoperability standards and establish best practices that will lead to more universal use of ocean satellite data.

Training sessions to facilitate use of satellite data products will be offered.

NOAA EUMETSAT

NOAA Center for Weather and Climate Prediction

18 to 20 June 2019
College Park, MD
USA

Convenient access from Washington DC

HTTPS://CoastWatch.NOAA.gov/OSOSymposium

STEERING COMMITTEE
Bojan Bojkov (EUMETSAT)
Christopher Brown (NOAA)
Paul DiGiacomo (NOAA)
Veronica Lance (NOAA)
Francois Montagner (EUMETSAT)

Posted 20 September 2018 with extended dates. Details to follow.

Training sessions to facilitate use of satellite data products will be offered

Summary

- The number of ocean parameters observable from space are increasing, along with their maturity for exploitation in ocean prediction efforts, notably expanding the possible types of environmental monitoring and prediction.
- Multiple satellite methodologies for retrieving a given ocean parameter provide robustness, complementary characteristics, and better spatial/temporal coverage for supporting ocean prediction.
- Ocean prediction models are becoming more complex, needing additional satellite data for initialization/assimilation to enhance skill.
- Operational coupled ocean/sea-ice/atmosphere modeling coming. Satellite observations of skin/near-surface values are critical for understanding and determining the air-sea-ice fluxes of heat, moisture, and momentum needed for proper coupling of the domains.

Abstract

The U.S. National Oceanic and Atmospheric Administration (NOAA) actively pursues exploiting satellite observations to enhance ocean prediction. NOAA engages in both numerical modeling predictions, as well as situational awareness methodologies employing derivative analyses and data fusion. Currently, NOAA operationally employs satellite observations of sea-surface temperature, sea-surface altimetry, sea-ice concentration/edge/type, sea-surface roughness (ocean vector winds, oil spills) and ocean radiometry (color). Research and development progresses for additional parameters and phenomenologies. Satellite observations targeted for research and development aimed at application to ocean prediction include ocean vector winds, swell spectra, significant wave height, sea-surface salinity, sea-ice thickness, ice-surface temperature, ice-motion vectors, ocean radiometry, and radiances. Exploiting complementary phenomenologies augments utility, for example using infrared observations, for better spatial resolution, in conjunction with microwave observations, for “all-weather” availability. An overview of the satellite observations employed in operational ocean prediction is provided, as well as a discussion of research and development foci and progress.