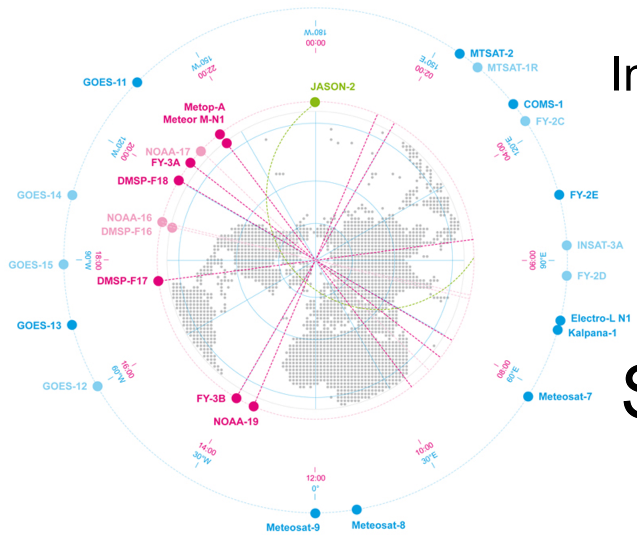

CGMS-47 IOC-WP-01 (Plenary Session 3.3.1)
In Response to CGMS-46 Plenary Action 46.12 (HLPP 3.6)

Satellite Data Requirements for UN Decade of Ocean Science for Sustainable Development 2021-2030

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Joint Technical Commission on Oceanography and Marine Meteorology

Coordination Group for Meteorological Satellites

CGMS

Abstract

The United Nations (UN) Decade of Ocean Science for Sustainable Development 2021-2030 intends to enhance the system of ocean observing systems at local, regional and global dimensions, known as the Global Ocean Observing System (Fischer et al., 2019). Societal applications include three UN instruments: Sendai Framework on Disaster Risk Reduction, Agenda 2030 Sustainable Development Goals (SDG), and Paris Climate Agreement (PCA). This paper provides examples of the critically important role of satellite data in the successful implementation of research and services for forecasting hurricane intensification, storm surge, and tsunami inundation related to Sendai; ship routing forecasting and sea level trend related to PCA; and coastal ocean eutrophication related to SDG 14 known as Life Below Water. Accurate ocean forecasts are a foundational element of progress of ocean science, technology and services for the UN Decade of Ocean Science for Sustainable Development. The paper demonstrates that generation of new knowledge and improved forecast/prediction skill will require sustained, high-spatial and temporal resolution satellite ocean observations for ocean exploration and scientific discovery and for initialization and verification of forecast/prediction schemes. A recommendation is made to establish a joint CGMS – WMO-IOC (via JCOMM) coordination mechanism to mutually enhance CGMS weather-and-climate activities with activities of the UN Decade for Ocean Science for Sustainable Development.

History of JCOMM Ocean Satellite Data Activity (1/2)

- JCOMM-4 Assembly, 28-31 May 2012, Yeosu (Republic of Korea)
  - SFSPA* established Task Team on Satellite Data Requirements (TT-SAT)
    - Annual guidance on satellite oceanography to CGMS (2011-2018)
      - CGMS-46 (2018) Halpern, D., C.-Y. Chung, M. Kachi, Y. Kurihara, T. Kitajima, S. Omori, R. Kumar, S.-S. Picart and H.-M. Zhang. Geostationary Satellite Measurements of Essential Ocean Variables.
      - CGMS-45 (2017) Halpern, D., S. Abdalla, J.-R. Bidlot and K. Ichikawa. Satellite Measurements of Ocean Surface Waves.
      - CGMS-44 (2016) Halpern, D., M. Drinkwater, W. Meier and H. Melling. Satellite Sea Ice Measurements in the Arctic Ocean.
      - CGMS-43 (2015) Halpern, D., J. Font and G. Lagerloef. Aquarius and SMOS Sea Surface Salinity Measurements: A Review of Initial Results.
      - CGMS-42 (2014) Halpern, D., E. Bayler and T. Dickey. Ocean Biology Impacts on Weather Forecasting and El Niño Prediction.
      - CGMS-41 (2013) Halpern, D. and L.-L. Fu. Satellite Global Ocean Surface Topography Measurements: Challenges and Opportunities.
      - CGMS-40 (2012) Halpern, D. Ocean Surface Vector Wind: Research Challenges and Operational Opportunities.
      - CGMS-39 (2011) Halpern, D. Sea Surface Temperature for Numerical Weather Prediction.
  - JCOMM TT-SAT disbanded itself in 2017

* SFSPA = Services and Forecasting Systems Program Area

History of JCOMM Ocean Satellite Data Activity (2/2)

- JCOMM-5 Assembly, 25-29 October 2017, Geneva
  - ➢ SFSPA established JCOMM Satellite Data Coordinator with two ToR
    - ❖ Coordinate such activities within JCOMM and act as a JCOMM liaison with WMO CBS ET-SAT and IPET-SUP and with CEOS and CGMS
    - ❖ Report to the chair of the SFSPA Coordination Group
  - ➢ May 2018 – WMO appointed David Halpern to be JCOMM Satellite Data Coordinator
- JCOMM Satellite Data Coordinator
  - ➢ Establish annual projects
    - ❖ 2019 – Satellite data requirements for UN Decade of Ocean Science for Sustainable Development
      - Jun 2018 – CGMS-47 concurred
      - Jul 2018 – IOC Albert Fischer concurred
      - Sep 2018 – SFSPA CG concurred

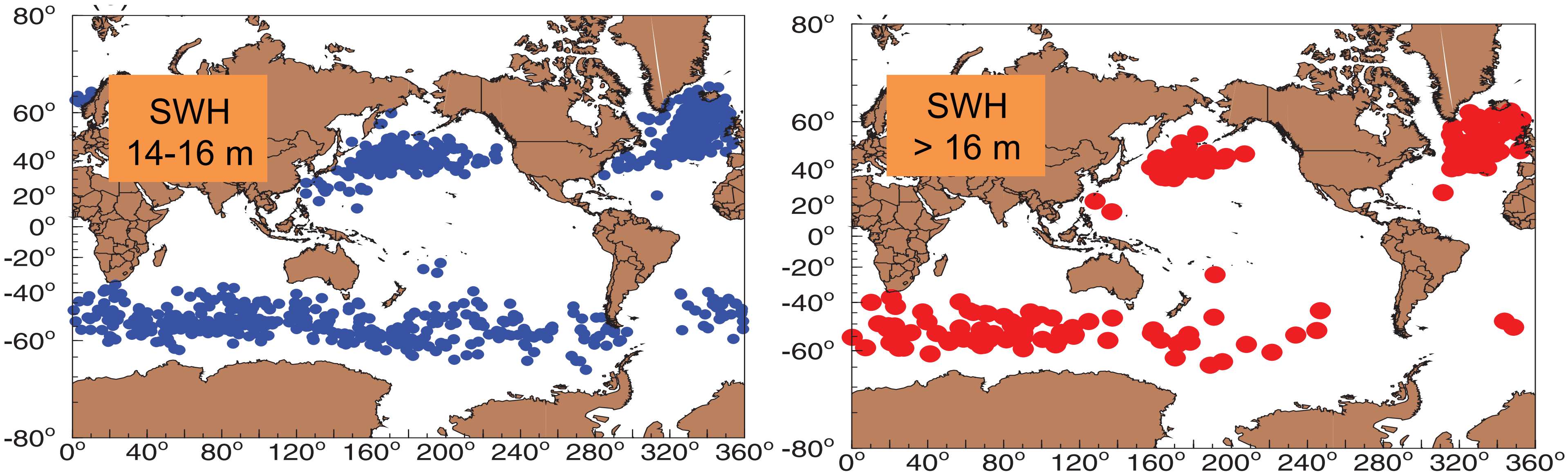
Organizational Themes

- UN Sendai Framework for Disaster Risk Reduction (Mar 2015)
  - ➢ Reduce disaster risk
    - Marine transportation
    - Storm surge forecasting
    - Tsunami forecasting

- UN Agenda 2030 Sustainable Development Goals (Sep 2015)
  - ➢ Goal 14 – Life below water
    - Coastal ocean eutrophication

- UNFCCC Paris Agreement (Dec 2015)
  - ➢ Mitigation and adaptation actions
    - Ship routing forecasting
    - Sea level trend

Sendai Framework DRR (1/4): Marine Transportation

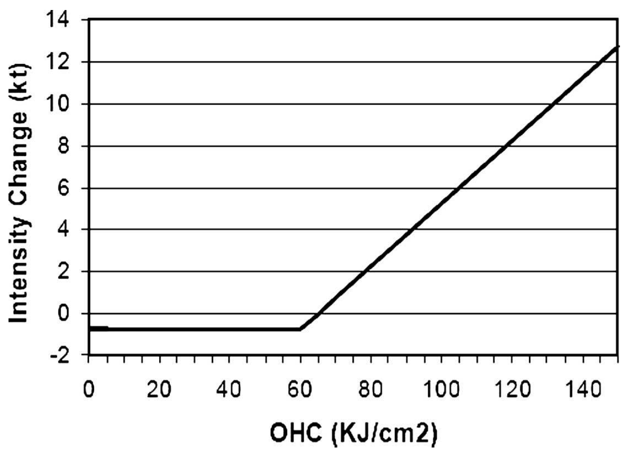


- JCOMM project to describe very extreme sea state (VESS)
- VESS = significant wave height (SWH) > 14 m
- SWH = mean trough-to-crest height of the highest third waves = 4 times standard deviation of surface height = 4 times integral of wave spectrum
- VESS climatology 1991-2010 with satellite altimeters (Σorbits > 5000)
  - ➢ could **not** be achieved with in-situ data because ships avoid heavy seas
  - ➢ SWH(18-20 m) occurred 17 times; SWH(> 20 m), 3 times; SWH(max) = 20.6 m
  - ➢ GlobWave archive: ERS-1, ERS-2, ENVISAT, GFO, Jason-1, Jason-2, TOPEX
- Heavy seas cause ~30% of major ship problems

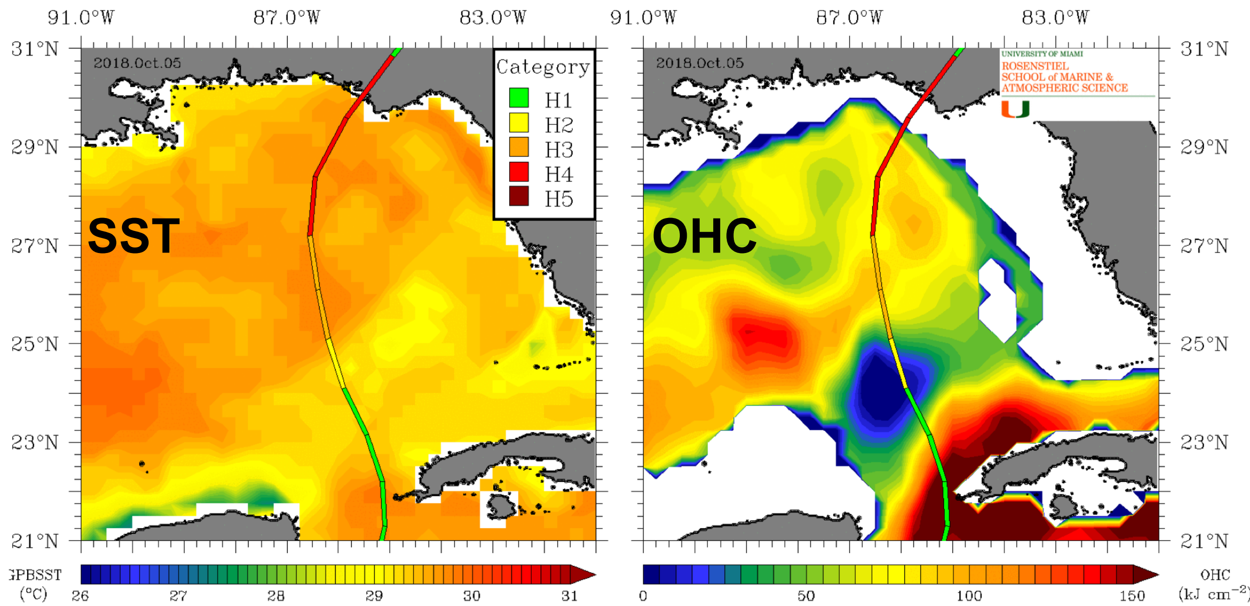
Cardone et al. (2015)

Sendai Framework DRR (2/4): Hurricane Forecast

- OHC = $\int c_p \, \rho \, T(z) \, dz$ from z=0 to z=depth of isotherm, e.g., 26°C
- High OHC (thick ocean mixed layer) beneath hurricane = large heat reservoir, which reduces SST cooling from thermocline
- Sparse real-time in-situ data requires satellite ocean surface topography data, combined with climatological-mean depth of specific isotherm



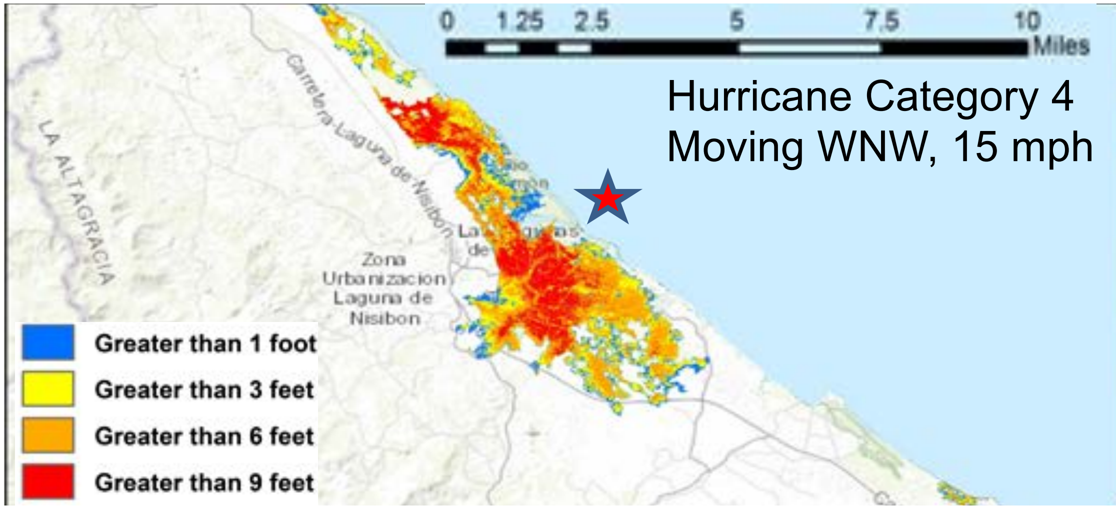
Assimilation of OHC: Increased wind speed of NOAA National Hurricane Center 72- to 96-h forecasts of Cat 5 hurricanes Emily, Isabel, Ivan, Katrina, Rita and Wilma (2003-2005)



Hurricane Michael 2018

Mainelli et al. (2008)
Lynn Shay (pers. comm., November 2018)

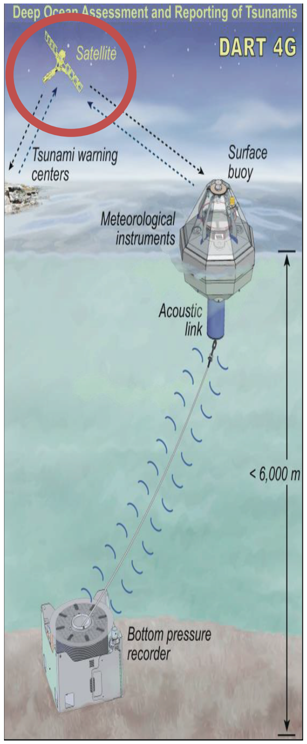
Sendai Framework DRR (3/4): Storm Surge Services

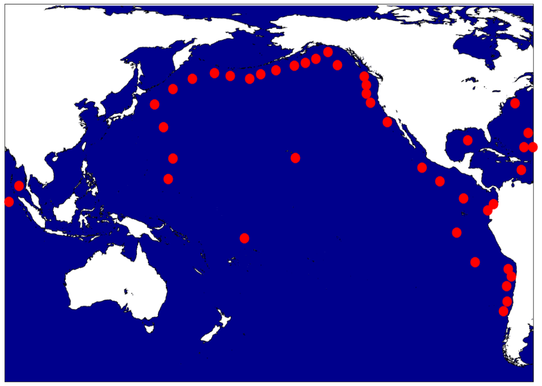


- Coastal Inundation Forecasting Demonstration Project (CIFDP)
  - JCOMM + WMO Commission for Hydrology
  - Hispaniola (Haiti and Dominican Republic) + 3 other regions
  - Forecast providers worked with end-user community
  - Developed easy-to-use early warning system for coastal flooding
    - Computed *a priori* maximum envelopes of coastal flooding
      - ALOS, ASTER, SRTM, & TANDEM-X measurements of height for DEM
      - Simulated ~ 16,000 hypothetical storm surges from hurricane category 1-5 moving at different speeds in a variety of directions

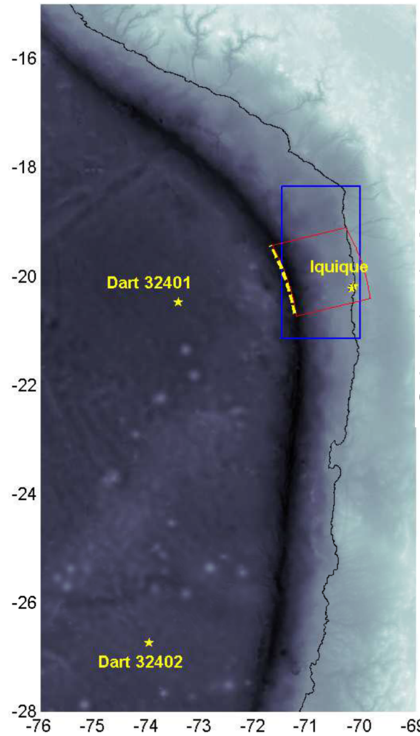
WMO (2018), WMO Media News (2018, 2019), Zhang et al. (2019)

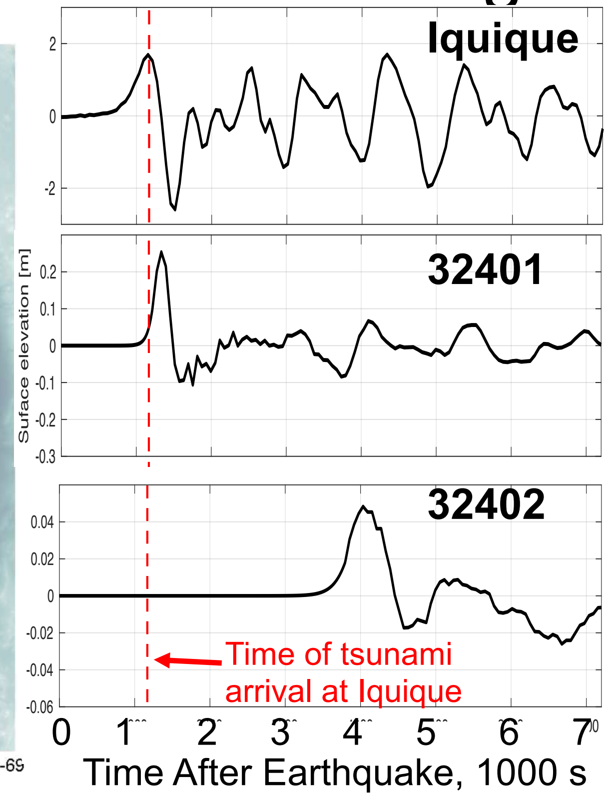
Sendai Framework DRR (4/4): Tsunami Forecasting





- Satellites – data relay communicator & locator
- **DART**
  - ➢ Located offshore of earthquakes
  - ➢ Missing opportunity for ocn-met data

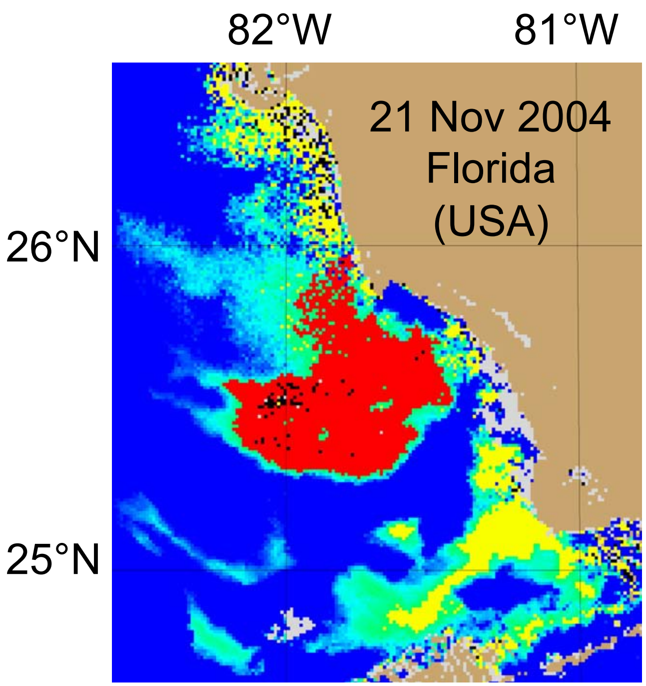




- t_0 – Earthquake occurs
- ~ 10 min – U.S. Geological Survey provides earthquake location and magnitude
- National tsunami warning centers predict tsunami arrival time and magnitude
  - ➢ DART data constrain shallow-water model prediction for far-field response
  - ➢ DART sites are too far from coastline for useful near-field prediction

An et al. (2014)
Ignacio Sepúlveda (pers. comm., March 2019)

SDG 14.A: Increase Knowledge of Ocean Health



- Locate offshore presence of potential harmful algal bloom (HAB) with ocean color sensors (SeaWiFS, MODIS, MERIS, …)
  - Period of occurrence = August - January
  - **Blue** = no Chl-*a* anomaly
  - **Cyan/Green** = Chl-a anomaly > 0 mg m^{-3}
  - **Yellow** = Chl-*a* anomaly > 1 mg m^{-3}
- Chl-*a* anomaly = observed Chl-*a* at a specific time minus average Chl-*a* over previous 60 days
- **Red** = HAB prediction
  - Chl-*a* > 1 mg m^{-3}
  - In-situ determination of *Karenia brevis* cells
  - Wind-generated transport at the coast
    - Upwelling brings *K. brevis* to surface
    - Downwelling brings *K. brevis* to coast
  - Patch > 30 km^2, not coast-wide
- Predictive skill 1-3 days
  - 65% - 85%
- Coastal respiratory irritation forecast
  - HAB & surface wind

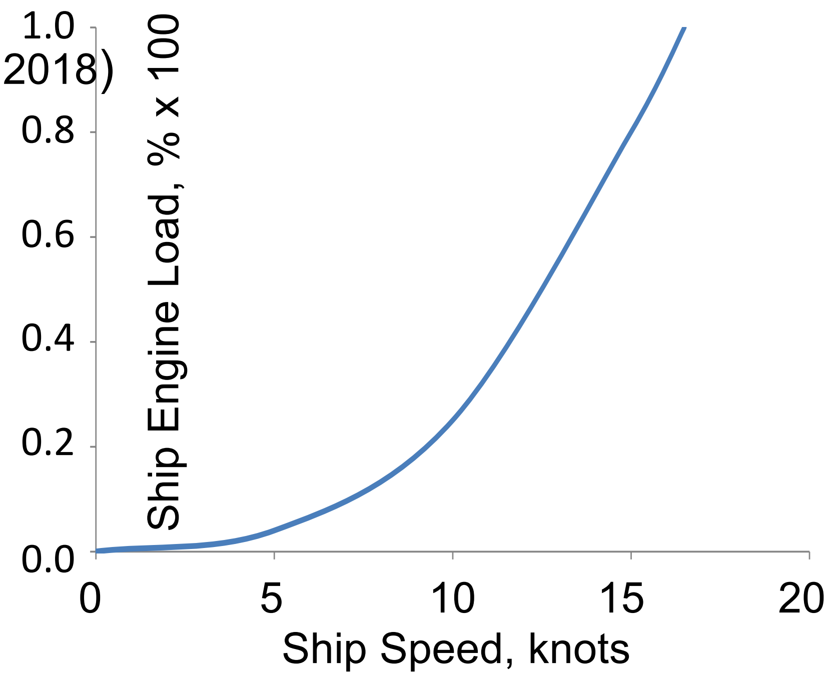
Coordination Group for Meteorological Satellites

Stumpf et al. (2009), Tomlinson et al. (2004)
Richard Stumpf (pers. comm., April 2019)

CGMS

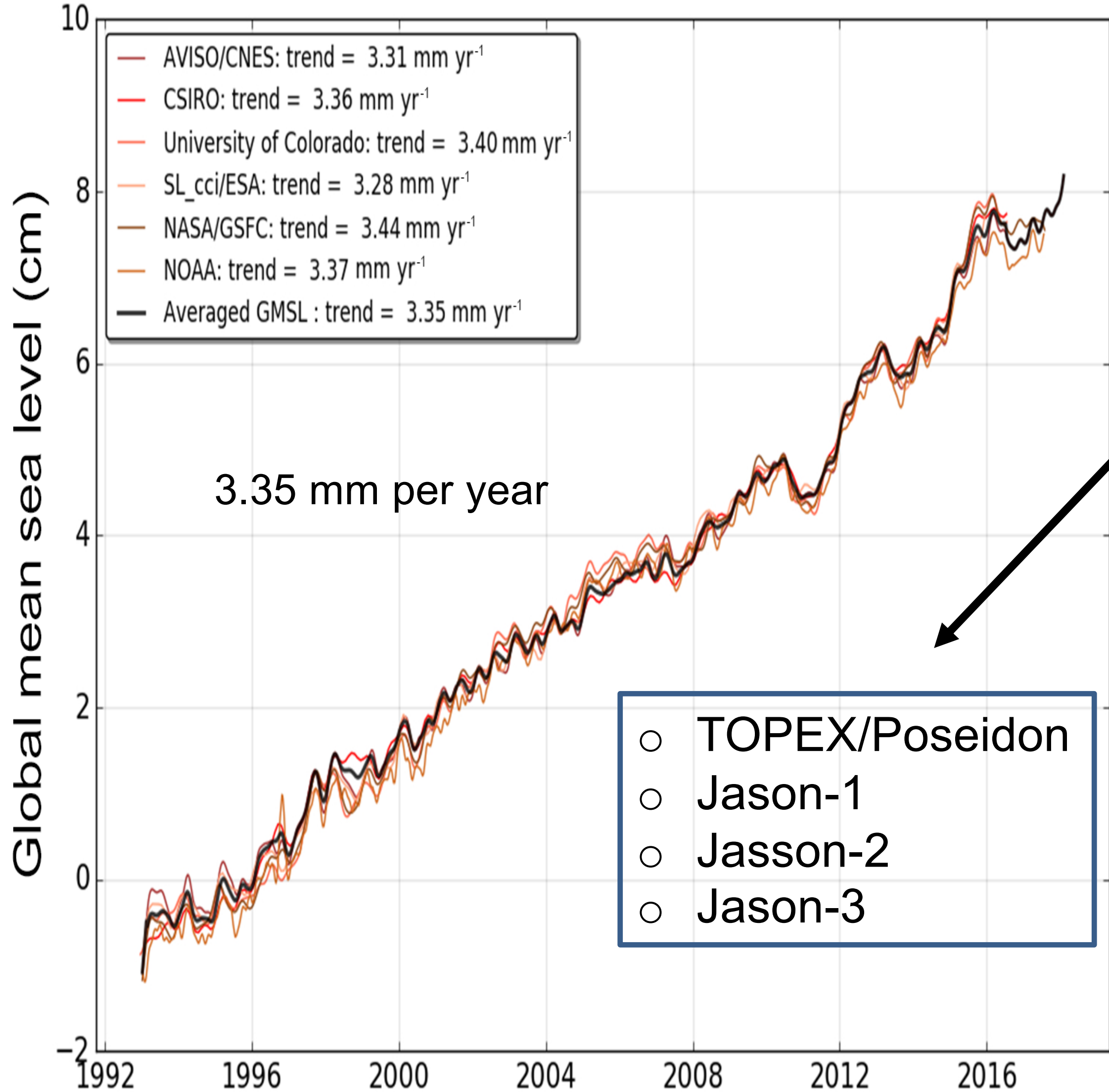
Paris Agreement (1/2): Ship Routing Forecasting

- Optimal strategy (Arslan et al., 2015)
  - ➢ Wind, wave and current forecasts
    - o Reduce voyage costs (BAMS 1982)
    - o 2-4% fuel & GHG reduction (Motorship, 2018)
  - ➢ Ship motion performance
  - ➢ Maximize safety
  - ➢ Minimize fuel consumption
    - o 50-60% of ship operating cost
  - ➢ Minimize GHG emissions (IMO 2018)
    - o Shipping - 3% of global emissions
    - o Tripling of shipping expected by 2050
  - ➢ Maximize profits
  - ➢ Maximize certainty of arrival time
    - o Port berth, loading, unloading



- Dynamic routing strategy (Andersson and Ivehammar, 2016)
  - ➢ Ship alters route based on shared information on movements of other ships

Paris Agreement (2/2): Global Mean Sea Level Trend



- Satellite observing systems
  - ➢ Reference missions provide the most accurate long-term stability at global and regional scales and are all on the same T/P ground track
  - ➢ Additional mission data poleward of 66° and increased resolution
    - ERS-1, ERS-2, Envisat, Sentinel-3A, Geosat Follow-on, SARAL/AltiKa

Cazenave et al. (2018)

Key issues of relevance to CGMS

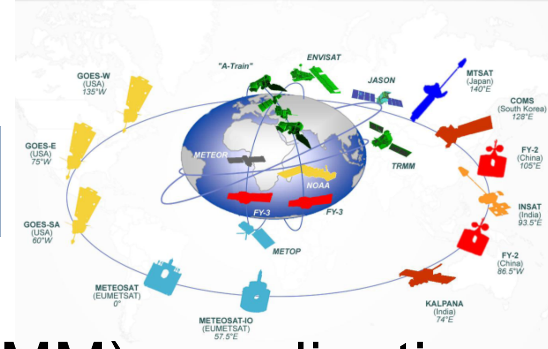
- Ocean economy generates US$3 trillion for world economy.
- CGMS satellite data providers are critically important for a successful UN Decade of Ocean Science for Sustainable Development to accelerate enhanced ocean science for:
  - Healthy ocean
  - Predicted ocean
  - Safe ocean
  - Productive ocean
  - Responsible ocean stewardship
  - Accurate, transparent and accessible ocean information
  - New era of ocean science for a better world

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

- UN Decade will significantly accelerate contributions to CGMS weather-and-climate themes.

Pendleton et al. (2019)

To be considered by CGMS



- Establish joint CGMS – WMO-IOC (via JCOMM) coordination mechanism to mutually enhance CGMS weather-and-climate activities with activities of the UN Decade for Ocean Science for Sustainable Development
  - Receive annual briefing on the UN Decade of Ocean Science for Sustainable Development
  - Sustain satellite and in situ system of ocean observing systems
  - Utilize geostationary meteorological satellites for ocean observations
  - Enhance data acquisition for special observing periods
  - Add CGMS-relevant ocean measurements to tsunami watch infrastructure
  - Add HAB toxic aerosols to coastal air pollution forecasts

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CGMS-48 IOC-WP-01 (2020)

- Annual guidance on satellite data requirements for improved coastal ocean prediction and services
  - Contribution to UN Decade of Ocean Science for Sustainable Development
  - Challenges and opportunities of utilizing satellite data to enhance coastal ocean science and services