A review of the existing system for observing the US coastal climate signal

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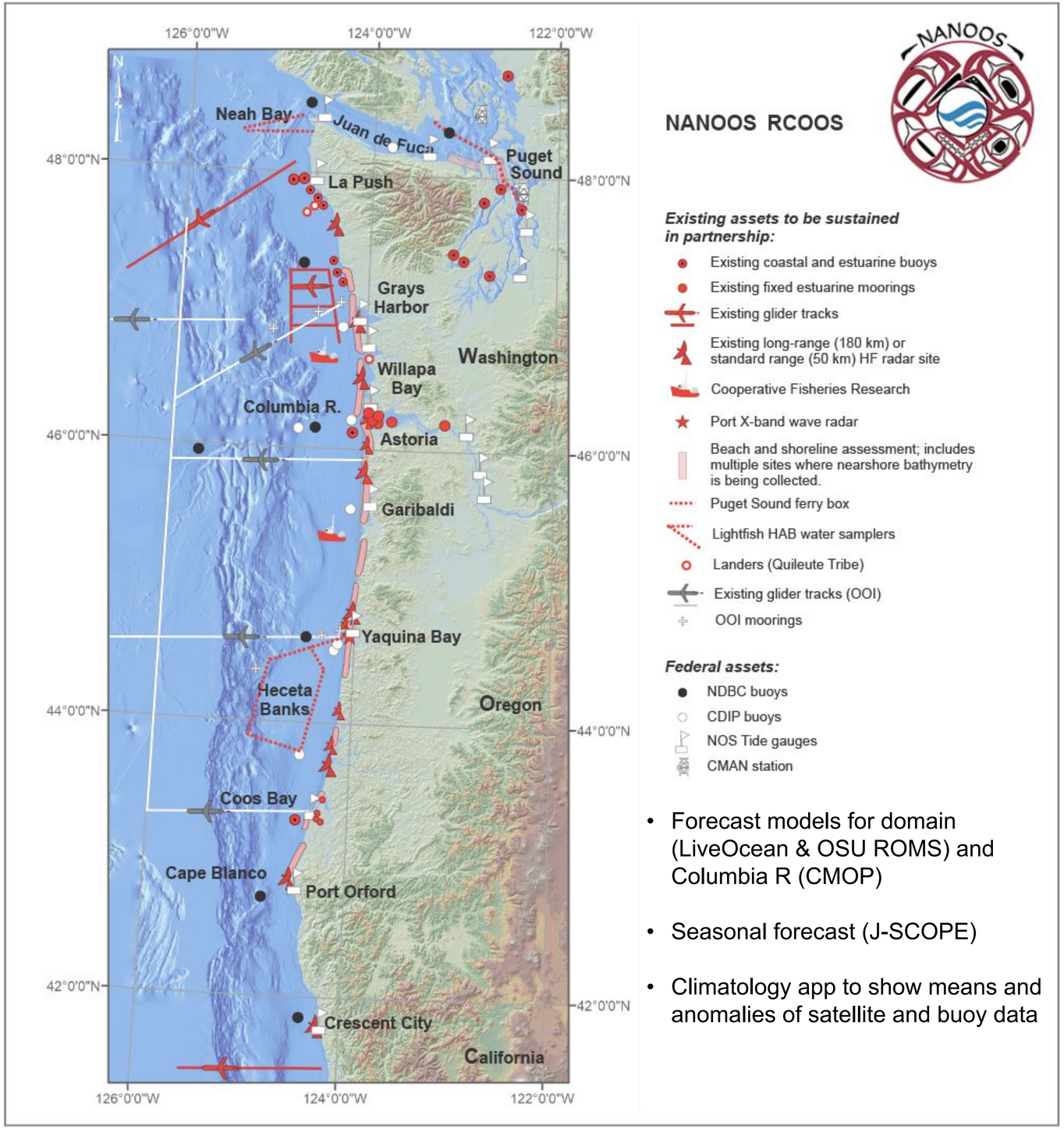
Outline

- Why measure the coastal climate signal?
- US Integrated Ocean Observing System (IOOS): a review of the regions
- The Global Ocean Observing System (GOOS): a review of the networks
- A view of the US East and West coasts
- The current observing system for the coastal climate signal is a beautiful outcome of history, not the result of an optimization

Why is the coastal climate signal important?

- Society experiences climate change through the effects in the coastal region
- Fisheries, transportation, weather, recreation, etc.
- On the US east coast, the Gulf Stream dominates the meridional transport of heat, and is a major driver of climate variability
- On the US west coast, the upwelling system is one of the most biologically productive regions in the world, and is strongly affected by El Niños at the equator
- On the US Gulf coast, the Loop Current and Eddies impact the shelf and regional ecosystems
- Pacific Islands, Alaska, Great Lakes, Caribbean …

- The IOOS contribution to observing the coastal climate signal
- A national issue
- Distinct regional approaches
- Some of these to be reviewed next



- Forecast models for domain (LiveOcean & OSU ROMS) and Columbia R (CMOP)
- Seasonal forecast (J-SCOPE)
- Climatology app to show means and anomalies of satellite and buoy data

Northwest Association of Networked Ocean Observing Systems

Important climate phenomena:

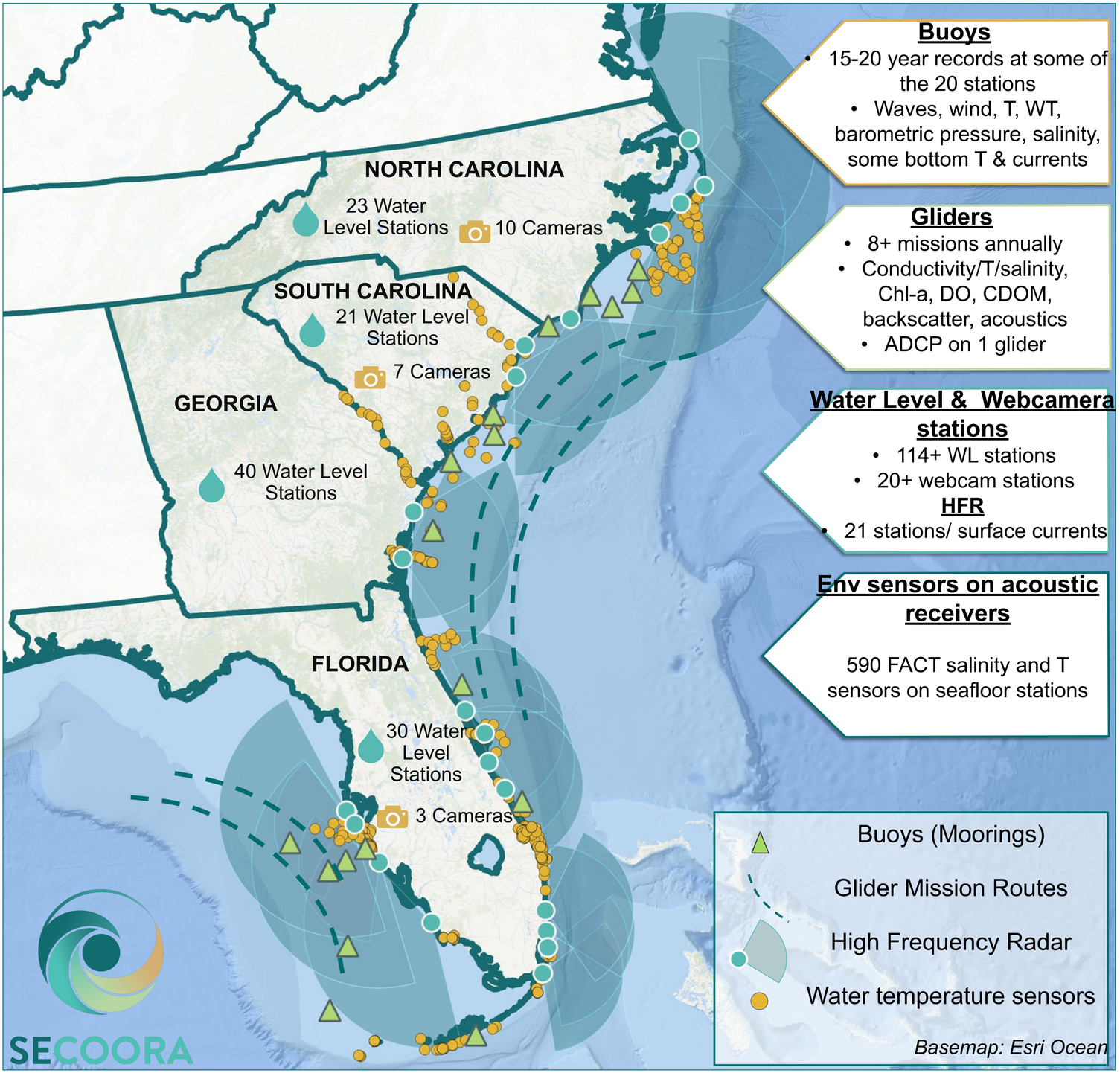
- ENSO/PDO/NPGO
- Marine Heat Waves (MHWs)
- Changes in circulation and/or stratification
- Increased CO_2 □ Ocean Acidification
- Less air-sea ventilation & mixing □ Hypoxia
- Changes in amount or timing of sunlight/stratification /mixing □ blooms and harmful algal blooms (HABs)
- Altered hydrological cycle
- Altered storminess, extreme weather, atmospheric rivers
- Sea Level Rise

Related observing platforms:

- NANOOS glider network, complemented by OOI gliders:
  - La Push, WA shelf, Trinidad (cost-shared with CeNCOOS)
- NANOOS buoys, complemented by NDBC buoys:
  - Coastal shelf off La Push, Columbia plume, Coos Bay
  - Estuarine waters of Puget Sound/Salish Sea, Columbia R, Coos Bay
- Backyard Buoys wave buoys, complemented by NDBC & CDIP buoys:
  - La Push, Taholah
- NANOOS HF radars and X-band
  - WA-OR coast for HF; Yaquina for X-band
- State and NANOOS beach and shoreline assessment
  - WA & OR coastlines
- NANOOS HAB-focused assets
  - AUVs off Neah Bay and Heceta Bank
  - Fishing fleet partners off Newport and Westport
  - ESP off La Push; tribal and state beach monitoring
- Quileute Tribe hypoxia lander moorings off La Push
- OAP funded OA buoys off La Push and Coos Bay
- NOS tide gauges; CMAN stations

Observing variables: (also meteorological variables on buoys)

- Temperature, salinity, pressure, density, ADCP currents, oxygen, optics, chlorophyll, pH, pCO_2, domoic acid, surface currents, waves, beach profiles
- Remotely collected water samples for IFCB & toxin analysis
- Soon: passive acoustics, nitrate



Southeast Coastal Ocean Observing Regional Association (SECOORA)

Important climate phenomena:

- More extreme rainfall and heat
- Rapid hurricane intensification
- Higher storm surges
- Sea level rise
- Changes in Gulf Stream / AMOC
- Harmful algal blooms
- Ocean acidification
- Marine heat waves

Related observing platforms:

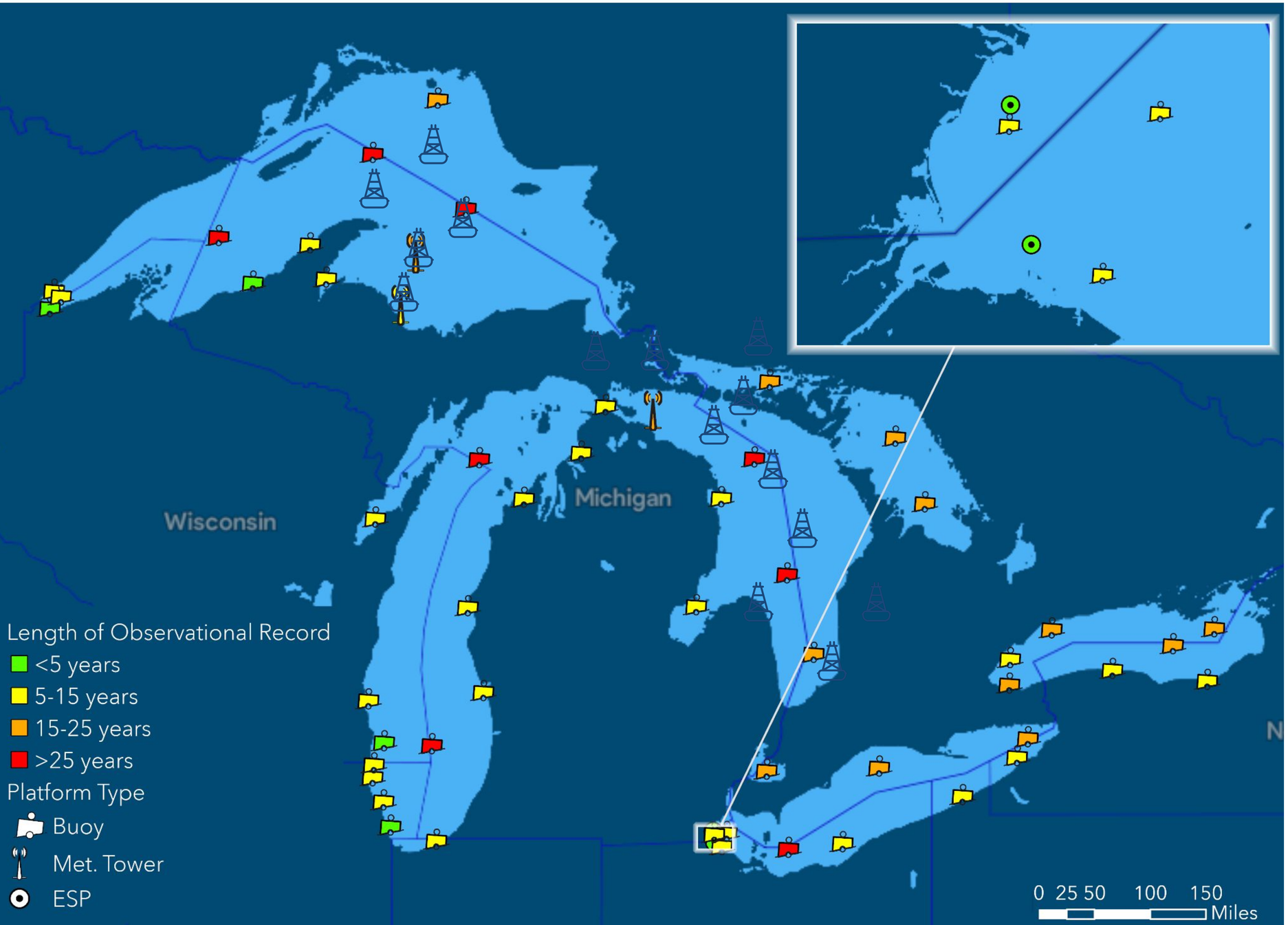
- Oceanic:
  - Buoys, HFR, gliders, seafloor environmental sensors
  - Seafloor OA station in FL Keys
- Coastal:
  - Water level stations
  - Web cameras
  - NEW: Sediment elevation tables (SETs)

Observing variables: (also meteorological variables on buoys)

- Temperature, salinity, pressure, density, ADCP currents, oxygen, optics, chlorophyll, pH, pCO_2, surface currents, waves, marsh elevation change, marine soundscapes/acoustics

Great Lakes Climate Observing Platforms

great lakes observing system



Phenomena of Interest

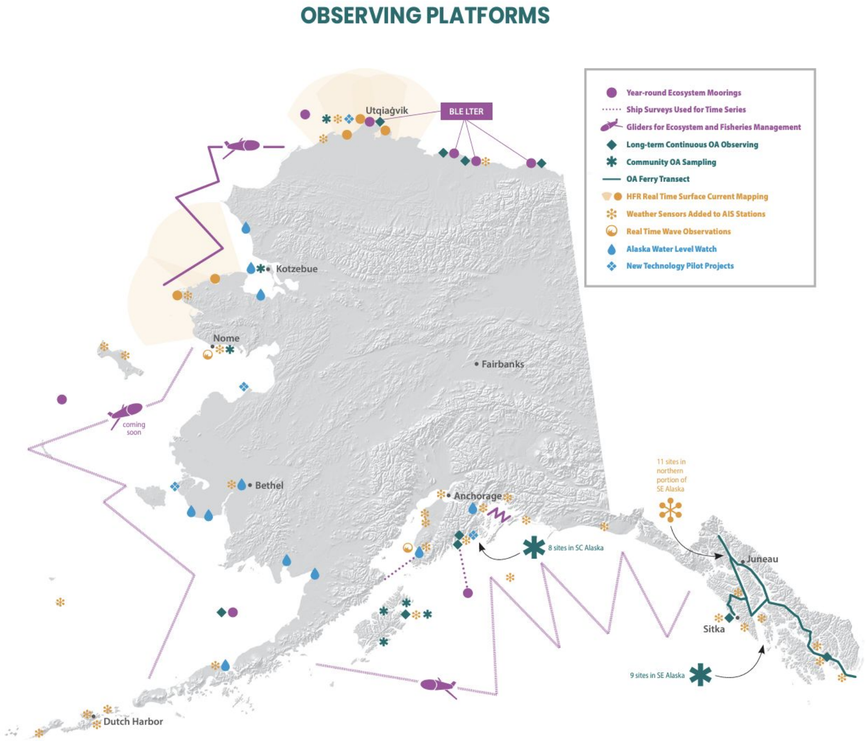
- Understanding **winter** dynamics
- Decreasing **ice** coverage
- Increasing water **temperatures** + storm intensities
- Ecosystem changes (**HABs and hypoxia**)
- **Changing** water levels, not just flooding

Technologies Used

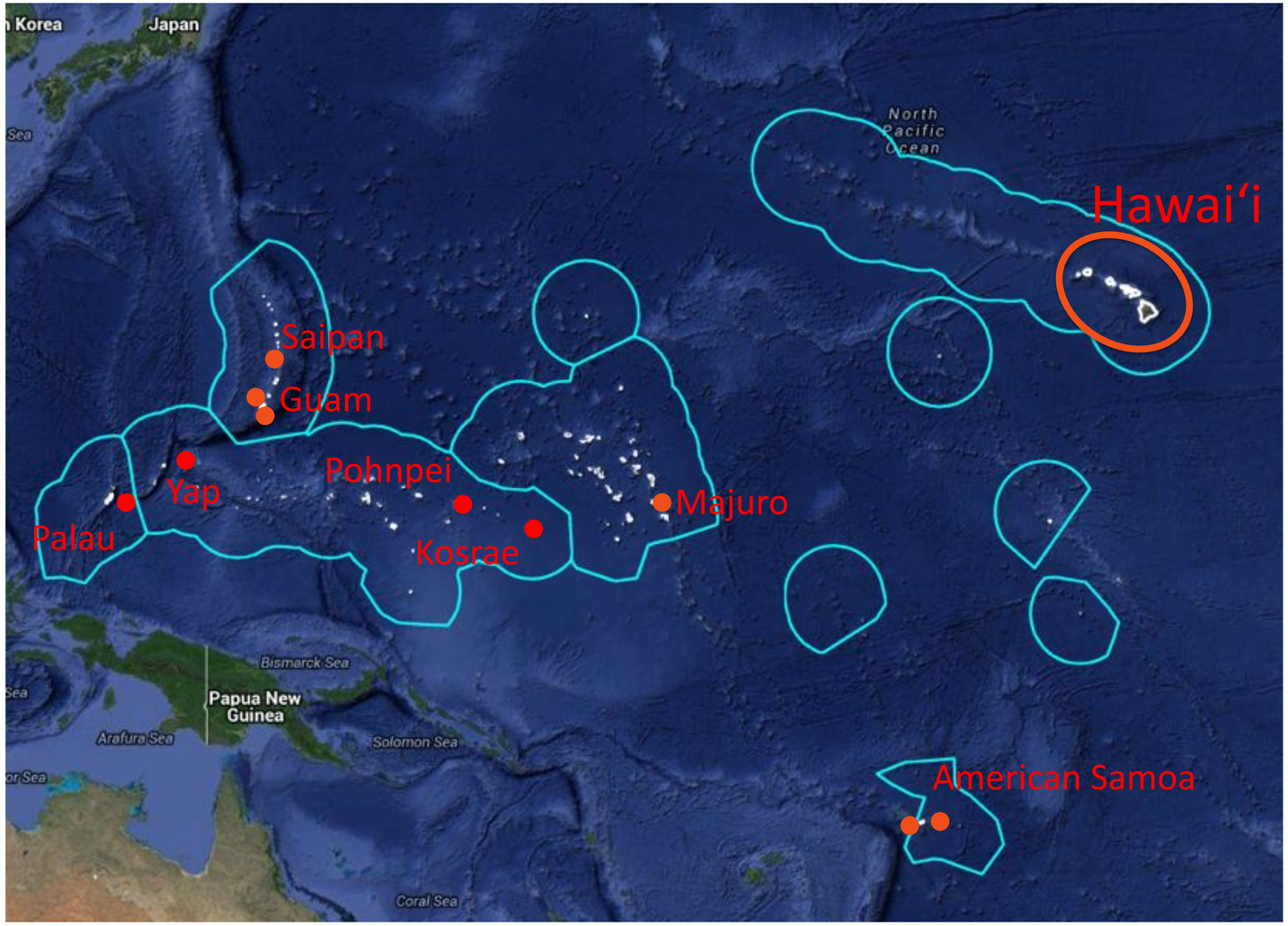
- Metocean buoys
- Met towers
- Environmental sample processors

Alaska Ocean Observing System

- Climate phenomena important in Alaska
  - Ocean acidification (OA)
  - Harmful algal blooms (HABs)
  - Storm surge, sea level rise, coastal flooding
  - Loss of sea ice
  - Marine heat wave
  - Changes in species distribution and habitat use
- Observations/Technologies to detect climate signal
  - Ecosystem moorings: long term biogeochemical oceanographic data
  - High Frequency Radars (HFRs): surface currents
  - Stationary acoustic telemetry: tagged species detection
  - Gliders
    - Marine mammal vocalization acoustic detection
    - Tagged fish/crab acoustic detection
    - Physical & chemical oceanography
  - Weather stations on AIS receivers for real-time weather
  - Water levels / Waves
    - Water pressure & acoustic sensors (where there is infrastructure)
    - GNSS-R (where there is no infrastructure)
    - CDIP wave buoys
    - Sofar Ocean Spotter buoys
  - HABS
    - Community sampling
    - Support for testing with State of Alaska lab
    - Imaging Flow Cytobots (IFCB): own two for use by partners
  - OA
    - Community sampling with Burke-o-lators
    - OA sampling on ferry (no longer active, but looking to restart)



PacIOOS & Climate Signals in the Pacific Islands



Map: Distribution of PacIOOS wave buoys as an example of the spatial extent of IOOS observational assets in the Pacific Islands

Climate-related concerns

- Tropical cyclones
- Flooding and inundation from sea level rise, waves, tides
- Water quality (driven by wildfire, drought, etc.)
- Wave impacts (safety)
- Oceanographic changes (ocean currents, marine heatwaves, coral bleaching)

Technologies / platforms

- Wave and water quality buoys
- Nearshore sensor network (CTDs)
- Forecasts – atmospheric, wave, ROMS, high sea level
- Sea Level Rise tools – with and without wave driven flooding models / visualization tools
- Seagliders

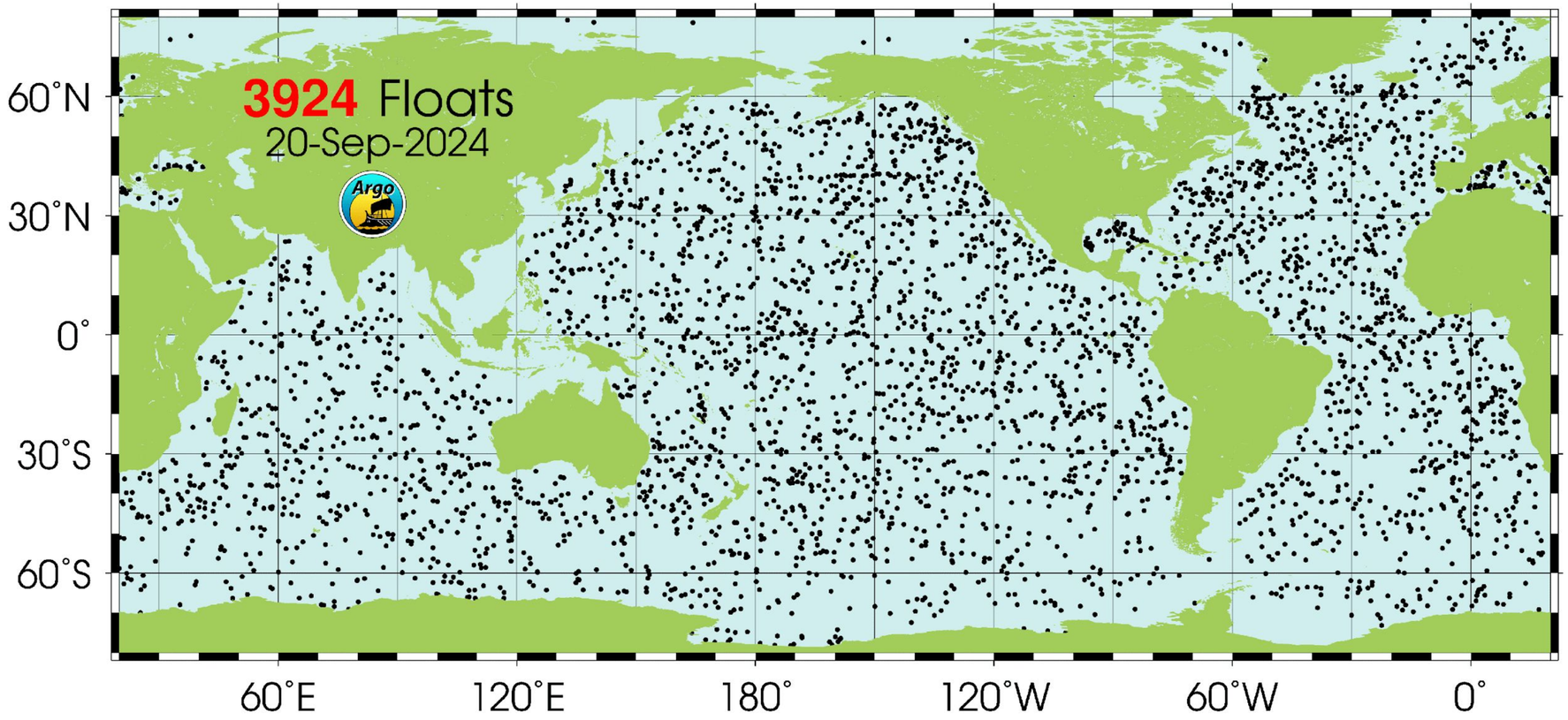
IOOS commonalities

- Climate processes
  - Marine heat waves
  - Sea level rise
  - Interannual and decadal variability
  - Ocean acidification
- Observing approaches
  - Moorings
  - Underwater gliders
  - Shore stations
  - High-frequency radar

The Global Ocean Observing System

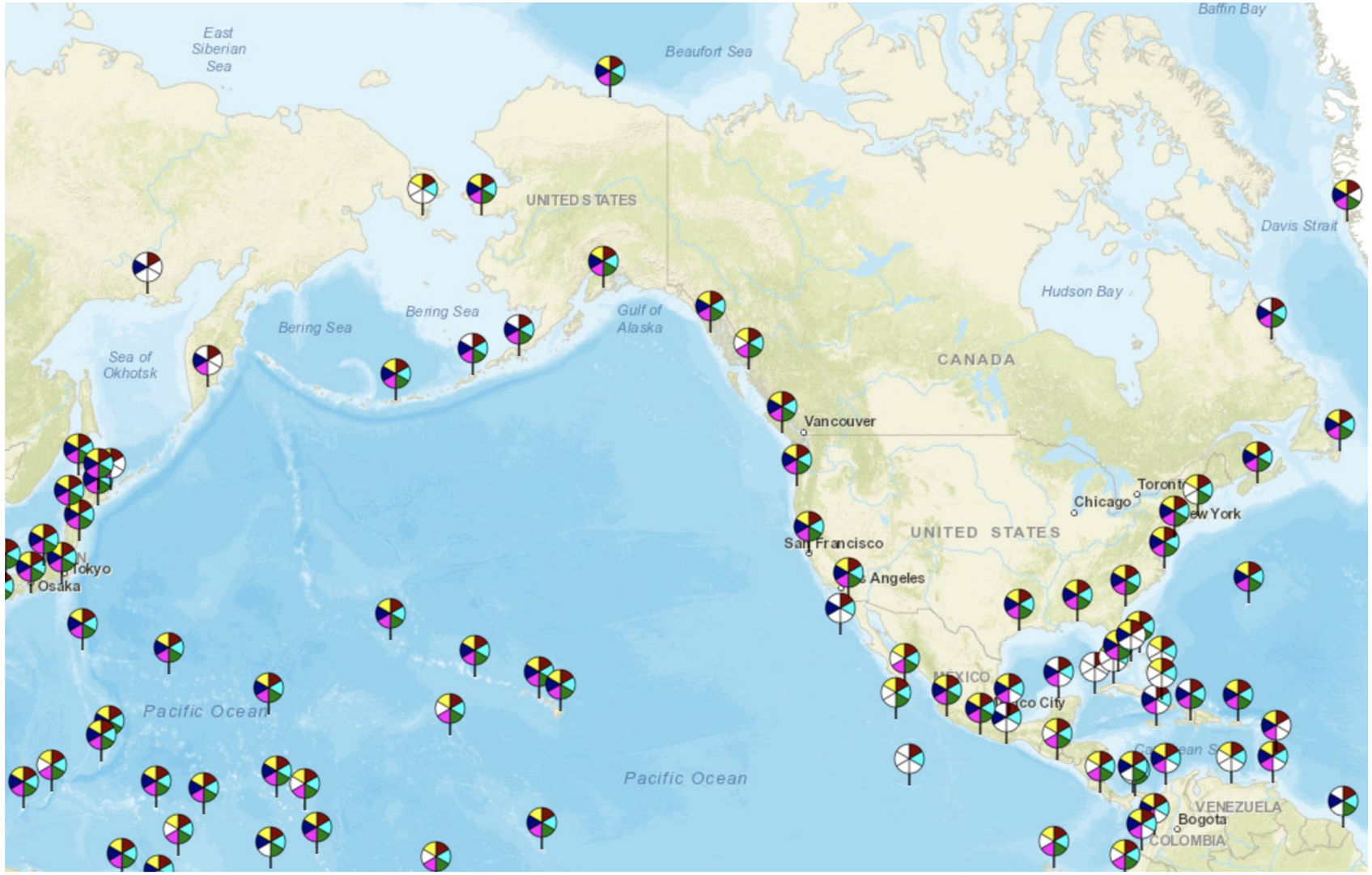
- Largely designed to observed climate variability (CLIVAR) on a global scale
- Organized primarily by platforms like floats, gliders, sea level stations, moorings, etc.
- Some of these reviewed next

Argo



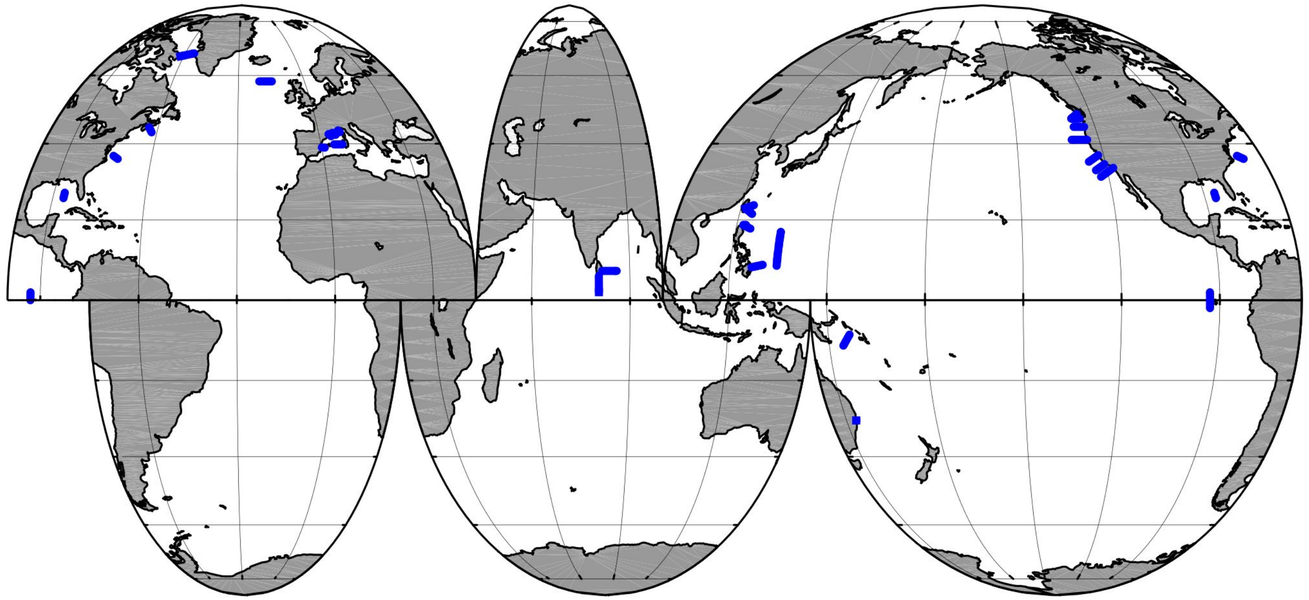
- Global coverage
- Transformational
- Profiles to 2000 m, and to 6000 m
- Growing suite of EOVs
- Remarkably uniform coverage as floats drift at a depth where currents are non-divergent

Global Sea Level Observing System (GLOSS)

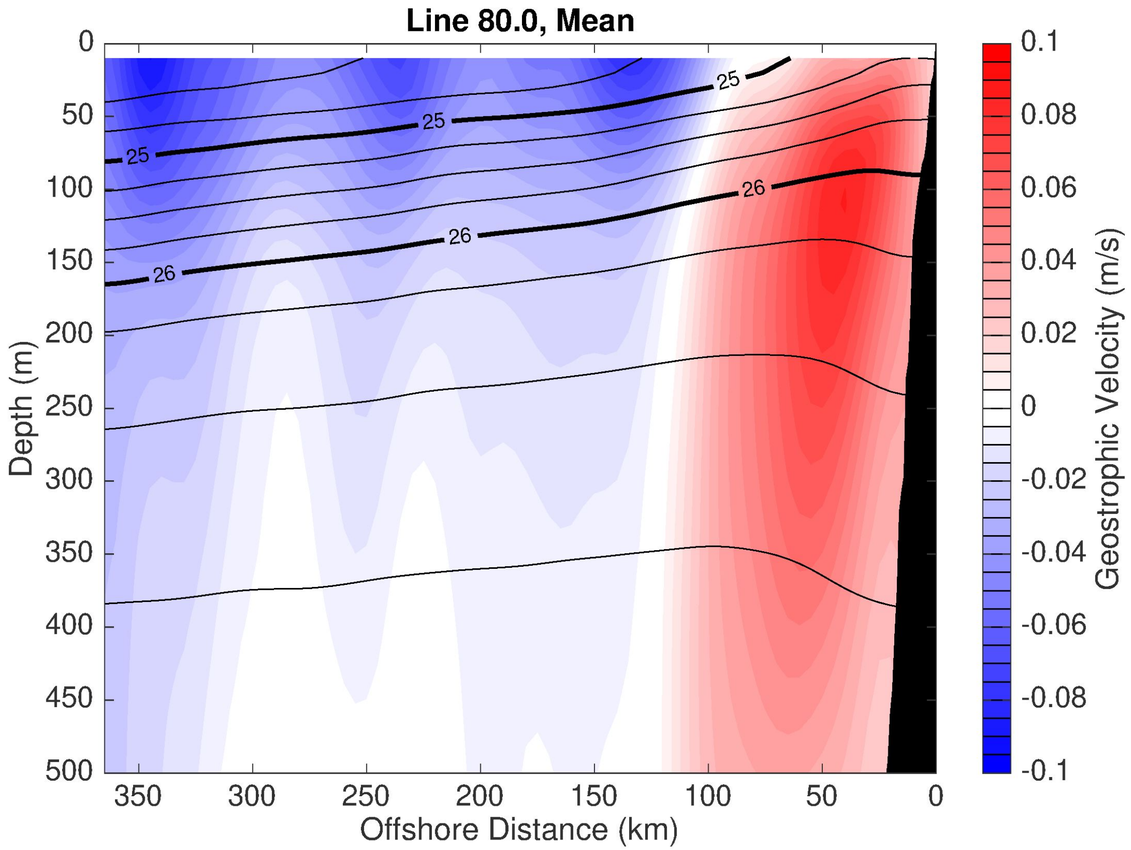


- Global coverage
- Standard reference for sea level
- Established in 1985
- Over 90 countries

OceanGliders BOON

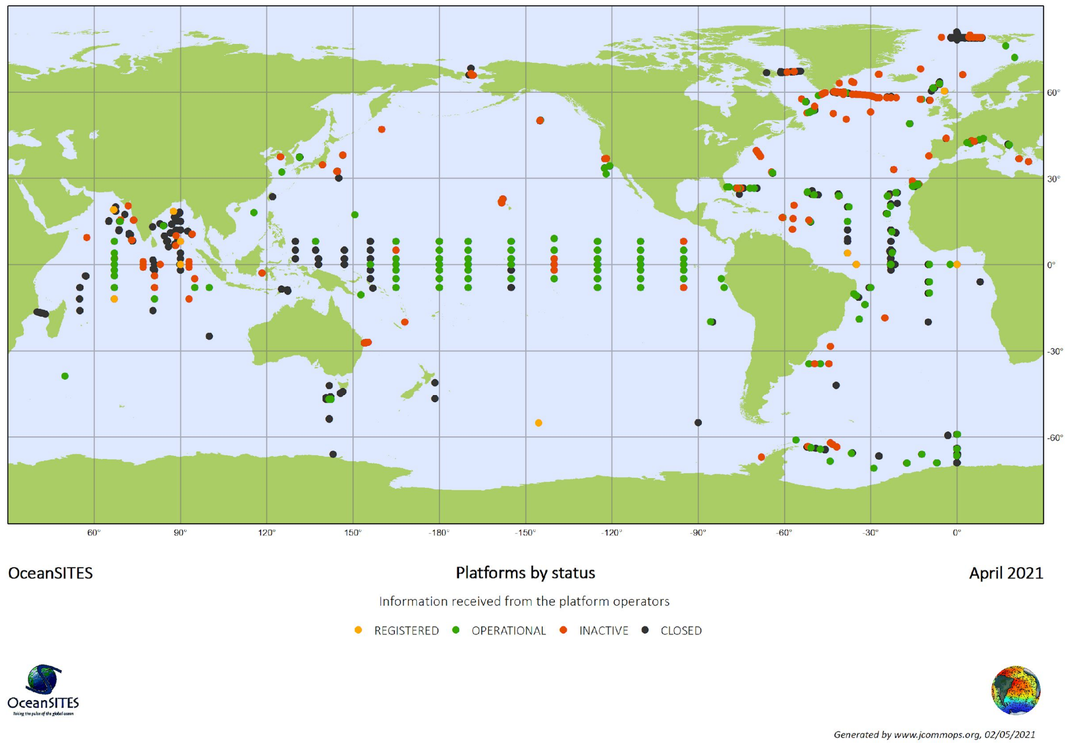


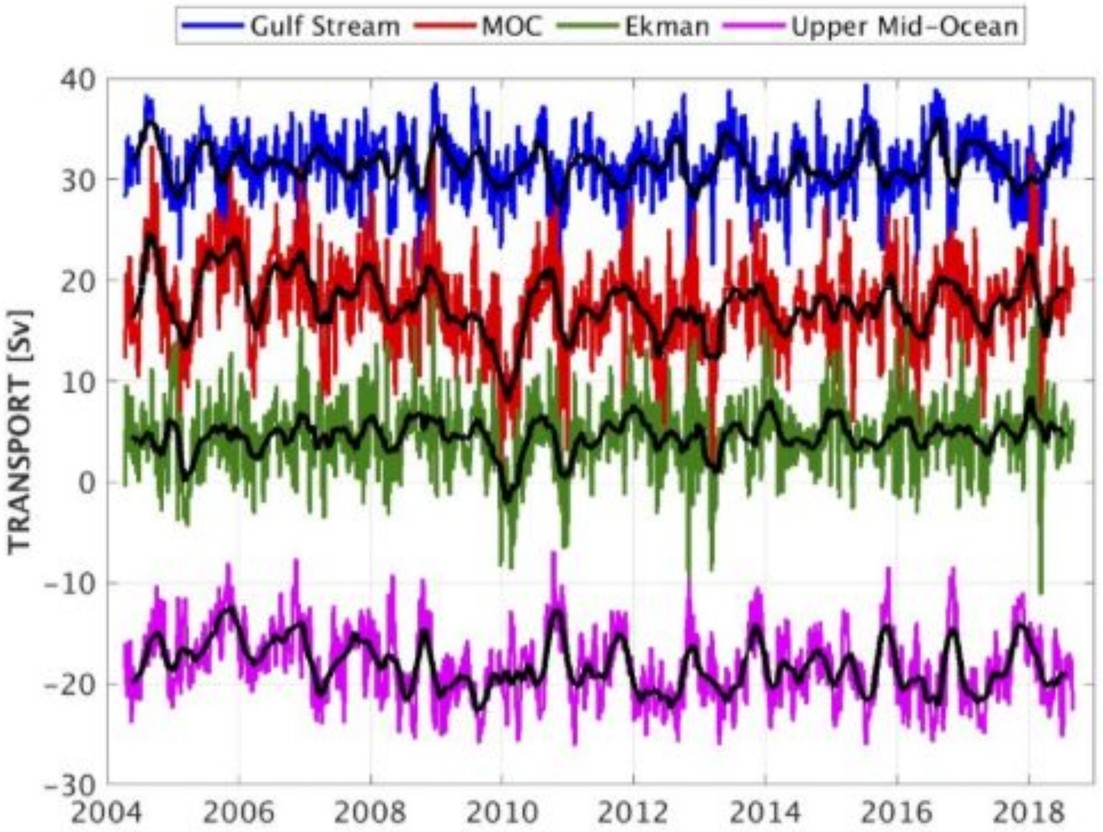
Testor et al. 2019



- Sustained observations across boundary current systems
- Gliders provide measure of absolute geostrophic velocity
- California Underwater Glider Network, 19 years, Rudnick et al. (2017)

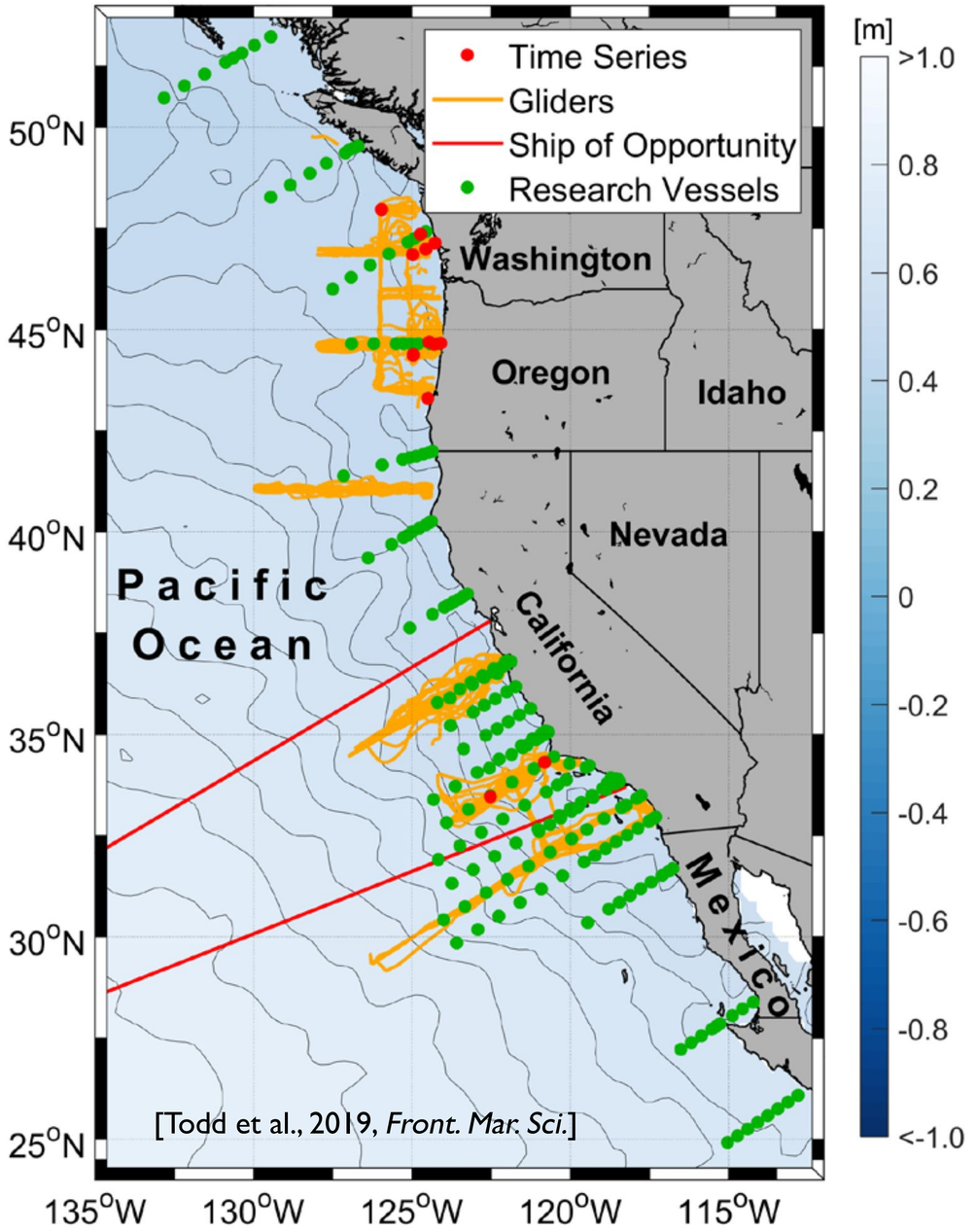
OceanSites





- Equator and boundary currents, high frequency observations at strategic sites
- RAPID/MOCHA

Observing System Status: California Current System

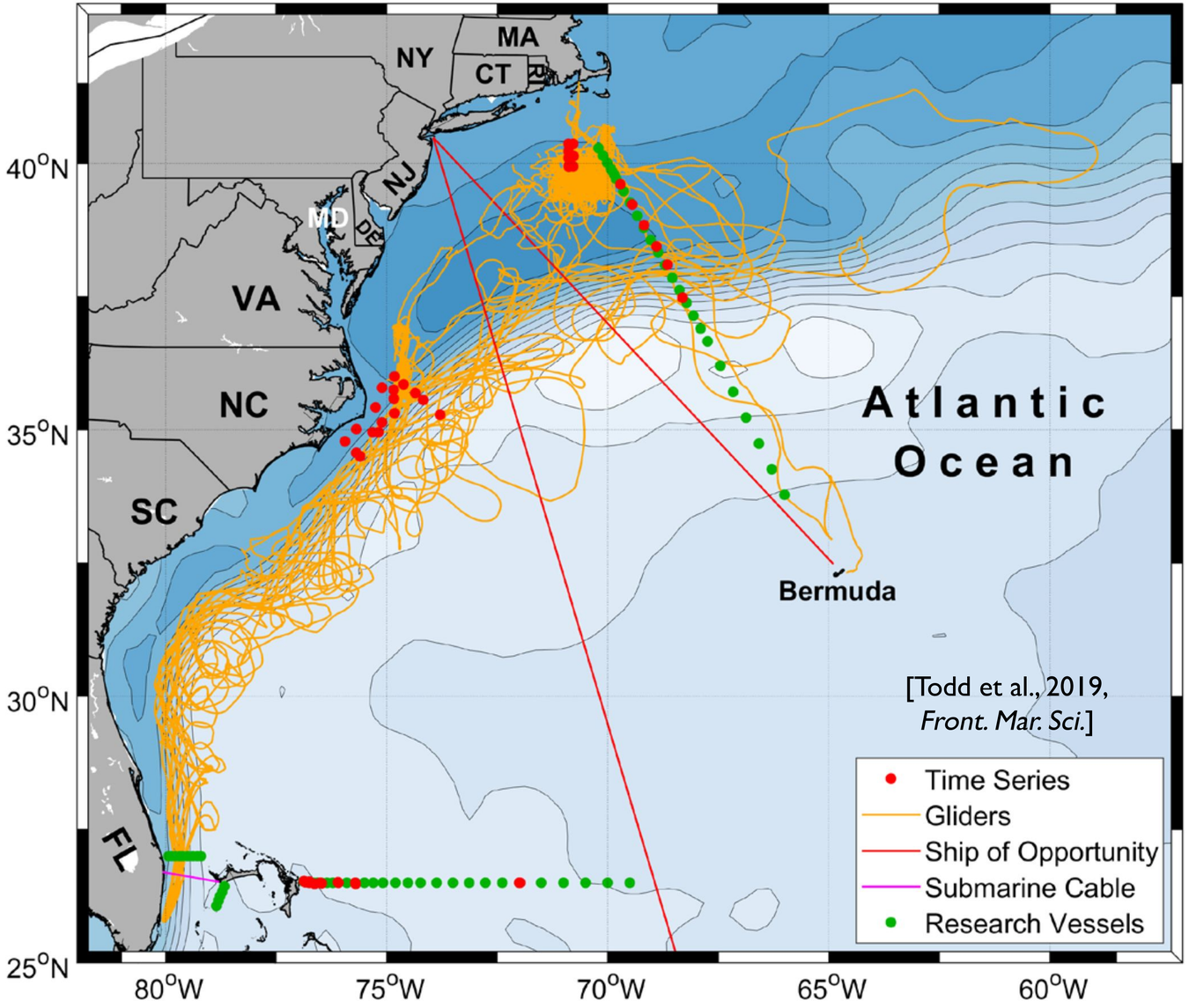


- Well-sampled boundary current system.
- Multi-disciplinary sampling routinely since 1940's.
- Many different groups/funders.

Shown: Sustained (>1 year), in situ sampling efforts during 2009-2018.

Not shown: remote sensing, drifters, Argo, short-term sampling (<1 year).

Observing System Status: NW Atlantic



- Multi-decadal measurements in Florida Strait and across Gulf Stream using submarine cable, research ships and ships of opportunity (Oleander).
- Moored arrays at strategic locations.
- Gliders since 2015.

Designing an ocean observing system for the coastal climate signal

- The current network is a beautiful outcome of history, not the result of an optimization
- A practical way forward should honor the legacy systems while taking advantage of new approaches
- National, while respecting regional priorities
- Multi-platform, multi-variable, while respecting existing global approaches

Big Hairy Audacious Goal

A purposely-designed ocean observing system for the coastal climate signal