Operational Implications of Higher Resolution Sea Surface Salinity (NOAA)

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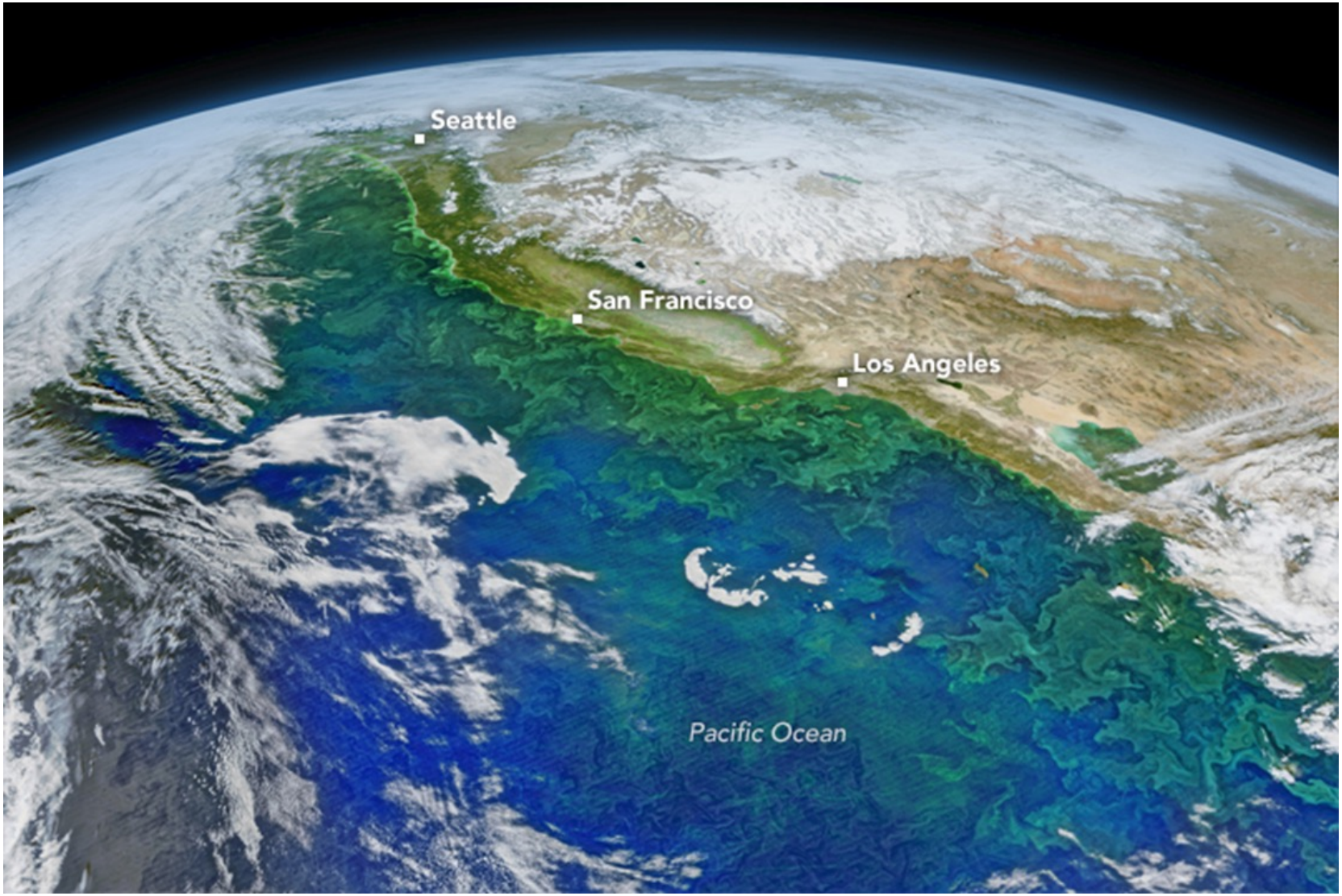
Resolution: Key Enabler



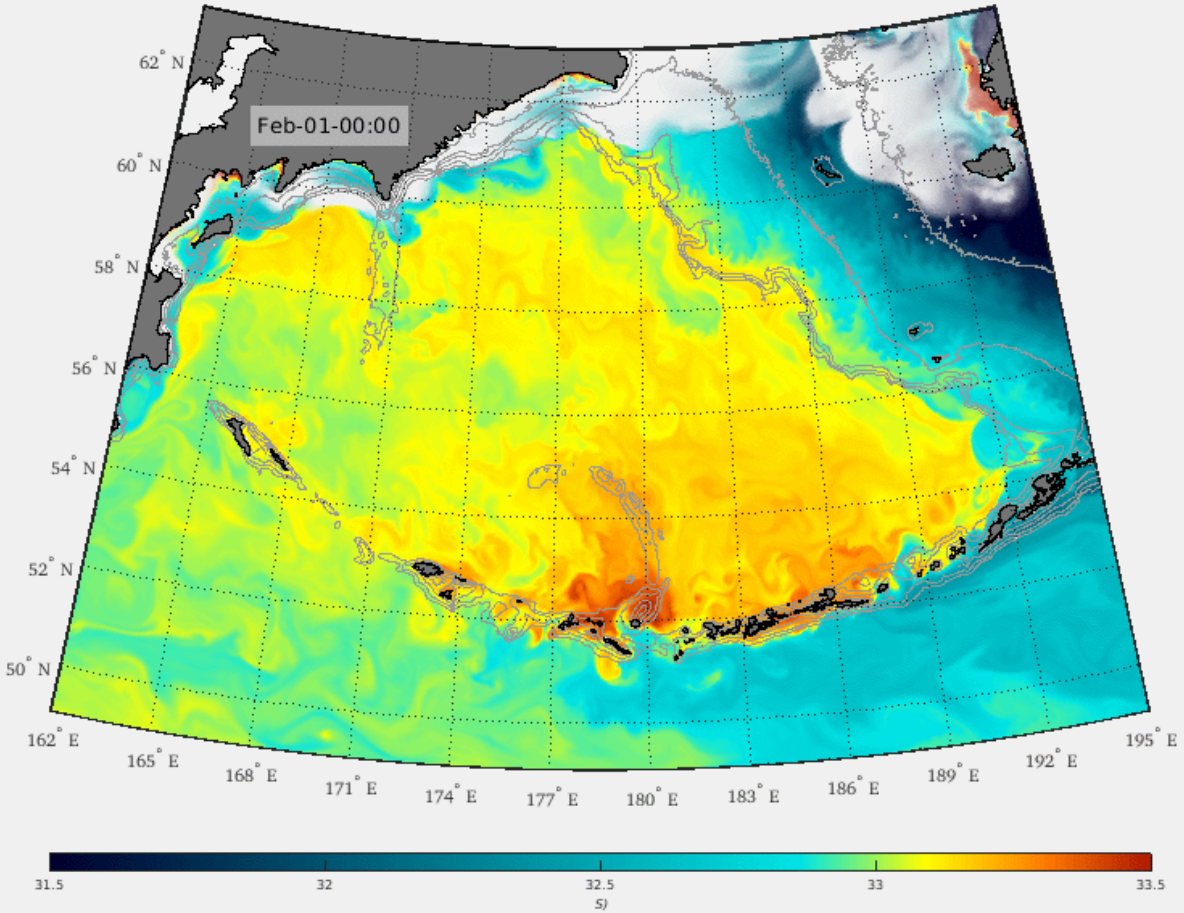
NASA image by Norman Kuring, NASA's Ocean Color Web. Data acquired February 8, 2016

Resolution: Key Enabler

NASA OSST Project

Ocean Salinity Variability influenced by shelf-interior ocean interactions

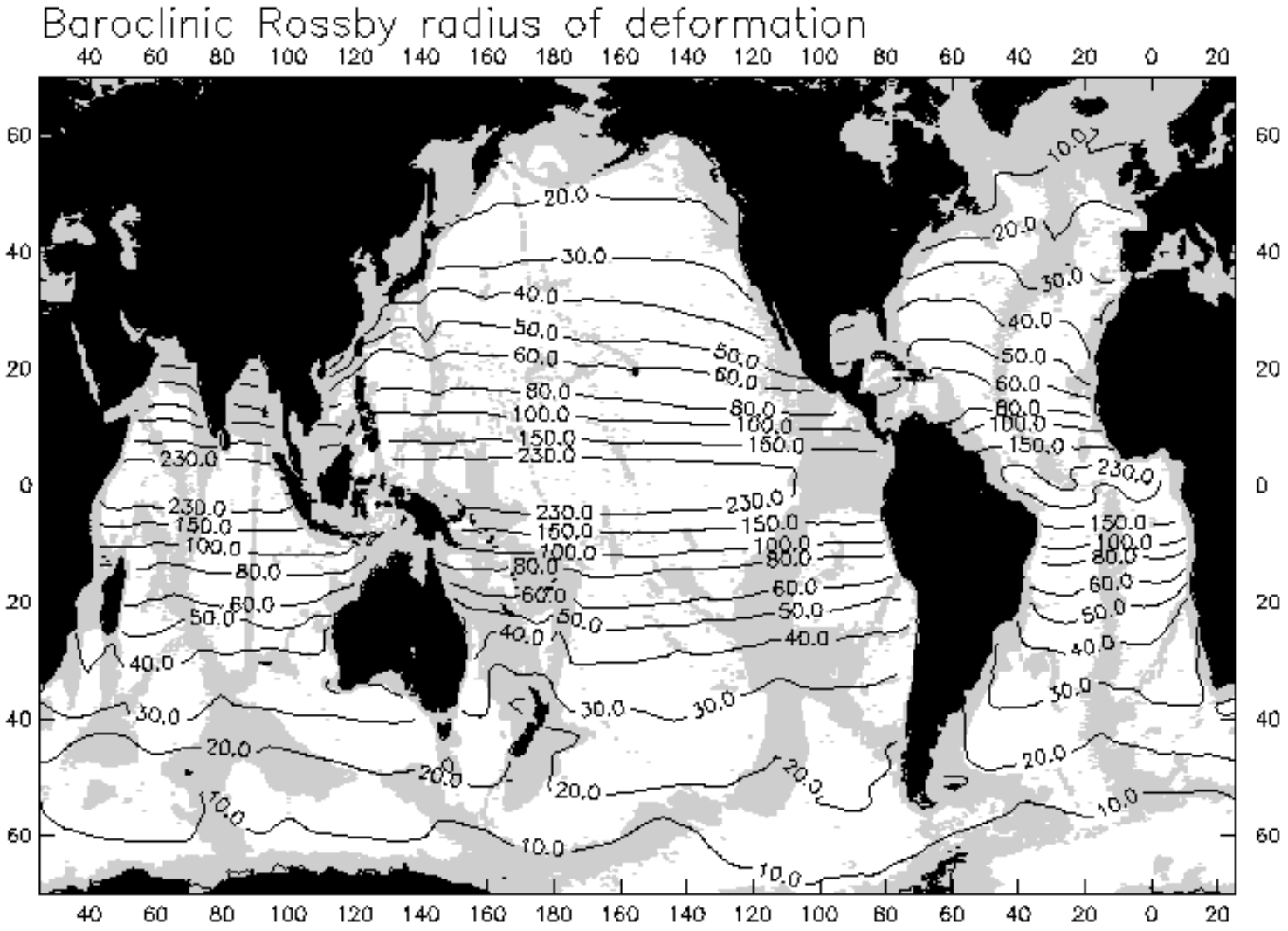
Durski & Kurapov



2km-resolution model, 1 Feb 2019 – 31 Mar 2019

Salinity range 31.5-33.5

Resolution: Key Enabler



Chelton, D. B., R. A. deSzoeke, M. G. Schlax, K. El Naggar and N. Siwertz, 1998: Geographical variability of the first-baroclinic Rossby radius of deformation. J. Phys. Oceanogr., 28, 433-460.

Rossby Radius of Deformation

- The length scale at which the geostrophic balance (between the Coriolis and the horizontal pressure gradient forces) will become important.
  - The length scale at which rotational effects become as important as buoyancy or gravity wave effects in the evolution of the flow about some disturbance.
  - Defines the length scale of baroclinic variability longer than which internal vortex stretching is more important than relative vorticity.

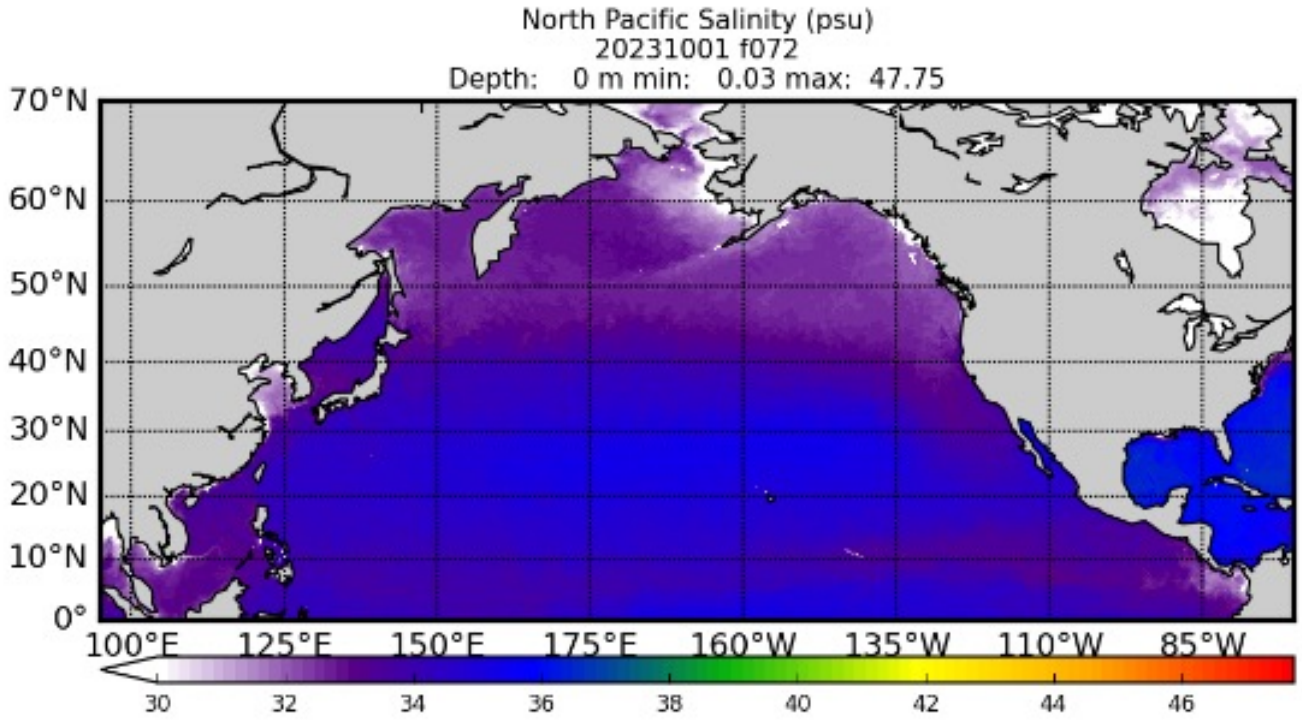
NOAA Context

- NOAA's operational Unified Forecast System (UFS)
  - Coupled ocean-atmosphere-sea ice forecast modeling
  - Near-real-time (NRT) and subseasonal-seasonal (S2S) time scales
  - For numerical modeling, refresh needs to be no more than 24 hours for oceanographic applications, ideally less, particularly for regional/coastal models
  - Latency greater than 24 hours negatively impacts utility for data assimilation.

- SSS characterizes water masses
  - Gradients and fronts important
  - Thermohaline stability/dynamics
  - Ecological habitat

- Sea-surface density (SSS + SST) necessary for assessing, representing, and constraining model values:
  - Heat and moisture fluxes with the atmosphere
  - Thermohaline circulation
  - Near-surface convective mixing
  - Assimilation of satellite altimetry and the projection of values into the modeled ocean interior
    - Ocean heat content → Tropical cyclone intensification

Operational Modeling & Prediction: Global



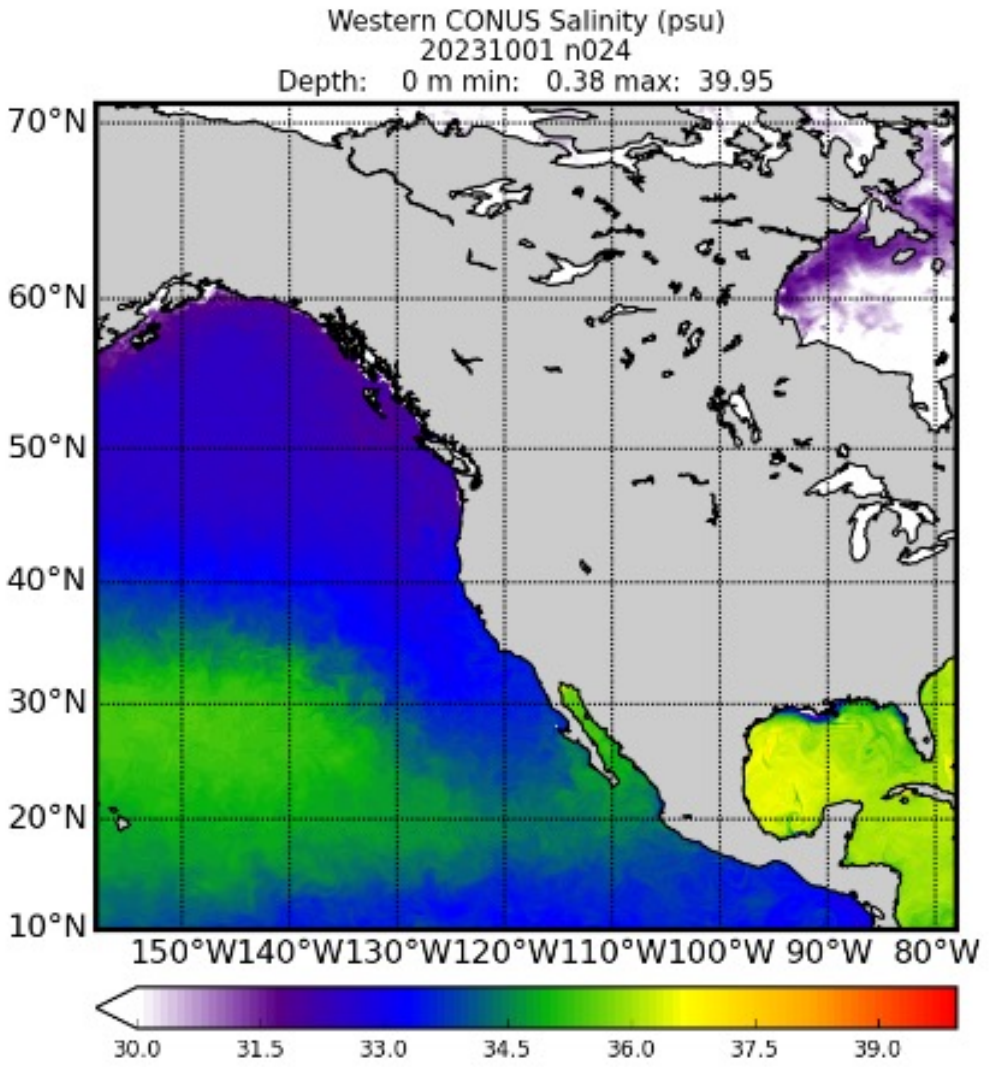
NOAA Unified Forecast System (UFS):
Global Real-Time Ocean Forecast System (RTOFS)

- **Grid resolution = 1/12th degree (~ 8 km)**

NCEP/EMC/Verification Post Processing Product Generation Branch

02 Oct 2023 *on Hera*

Operational Modeling & Prediction: Global



UFS Global RTOFS: grid resolution = 1/12th degree

NCEP/EMC/Verification Post Processing Product Generation Branch

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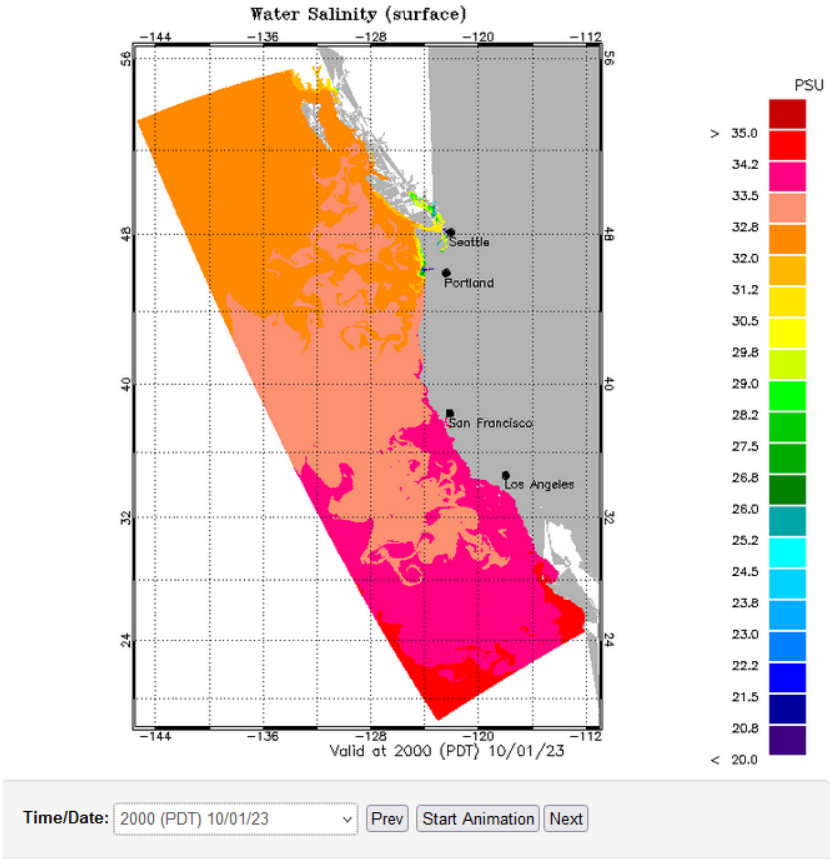
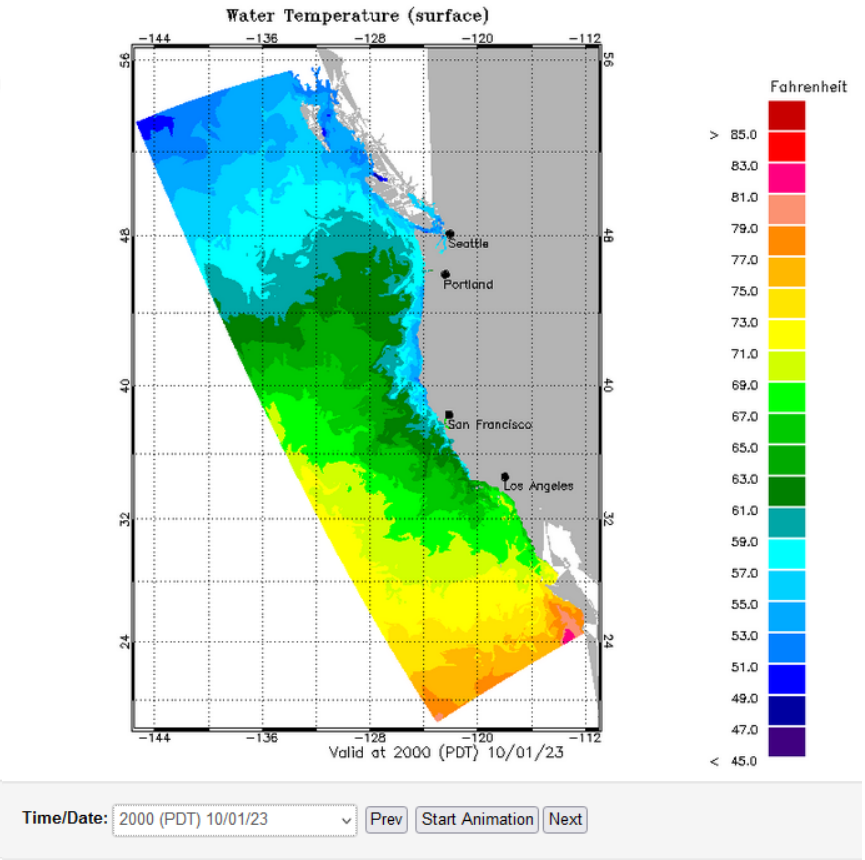
Operational Modeling & Prediction: Regional





NOAA West Coast Operational Forecast System (WCOFS)

- **Grid resolution: 4 km (~ 1/24th degree)**
- Target resolution: 2 km
- In development: East Coast Operational Forecast System (ECOFS)

NOAA Context

- Increased societal use of the Arctic Ocean
  - Critical NOAA missions: environmental prediction and marine navigation

- Cryosphere increasingly important as NOAA completes development and implements an operational coupled ocean-atmosphere-sea ice model (target 2025 Q2)
  - Sea-ice thickness is the most sought observational parameter for data assimilation in NOAA's operational ocean modeling
  - Impacts radiance-based modeling and data assimilation

NOAA Context: High latitudes

Increased societal use of the Arctic Ocean

- **Sea-surface salinity (SSS)**
  - SSS influences/drives cryospheric processes and resulting impacts on coupled ocean-atmosphere-cryosphere operational modeling.
    - Salinity notably drives the density-driven stratification/circulation, unlike at lower latitudes, where temperature more strongly drives the thermohaline circulation
  - Arctic becoming more ice free; consequently, SSS data for the Arctic is critical
    - Ice formation/melt
    - Surface stratification
    - Ocean-atmosphere fluxes (heat, moisture)
  - Ecosystem considerations
    - Salinity driven stratification and overturning circulation strongly influences the availability of nutrients, etc.
    - NOAA's Climate-Ecosystems-Fisheries Initiative
      - Arctic domain

NOAA Context: High latitudes

Increased societal use of the Arctic Ocean

- **Sea-ice Thickness (SIT)**
  - Critical for NOAA's environmental modeling and marine navigation missions.
  - Increasingly important for coupled ocean-atmosphere-sea ice modeling and prediction
    - Dramatically affects the coupling between the ocean and the atmosphere.
    - Sea ice serves as an on-off switch for surface reflectance/absorption
    - Sea-ice thickness observations for NOAA's data assimilation:
      - Initiated providing infrared-based satellite sea-ice thickness (SIT) observations for assimilation – **resolution nominally 1 km**
      - Altimetry SIT have a minimum-thickness threshold, precluding thin SIT measurements. Expect operational implementation soon.
      - **L-band SIT measures thin SIT, providing complementary methodology to IR and altimetry**

10-km L-band

- ***New Capabilities***
  - Increased assimilation accuracies, improved model constraints, and reduced uncertainties for NOAA analyses and forecasts
    - Reduce potentially substantial disparities and approximation errors from spatial displacement and resolution.
    - Enhanced resolution of gradients and fronts, important for thermohaline dynamics and ecosystem considerations
      - Improved habitat characterization for NOAA EcoCast and associated fisheries exclusion areas
    - Notably reduce contamination from near-coast and near-ice observations, permitting better representation of coastal processes and modeling
  - Enhanced operational observations for the cryosphere
    - Assessing sea-ice thickness (SIT)
    - Radiative properties impacting measurements and atmospheric response.
  - Enhanced skill at discerning ocean, atmosphere, and sea-ice components and examining complex phenomenologies

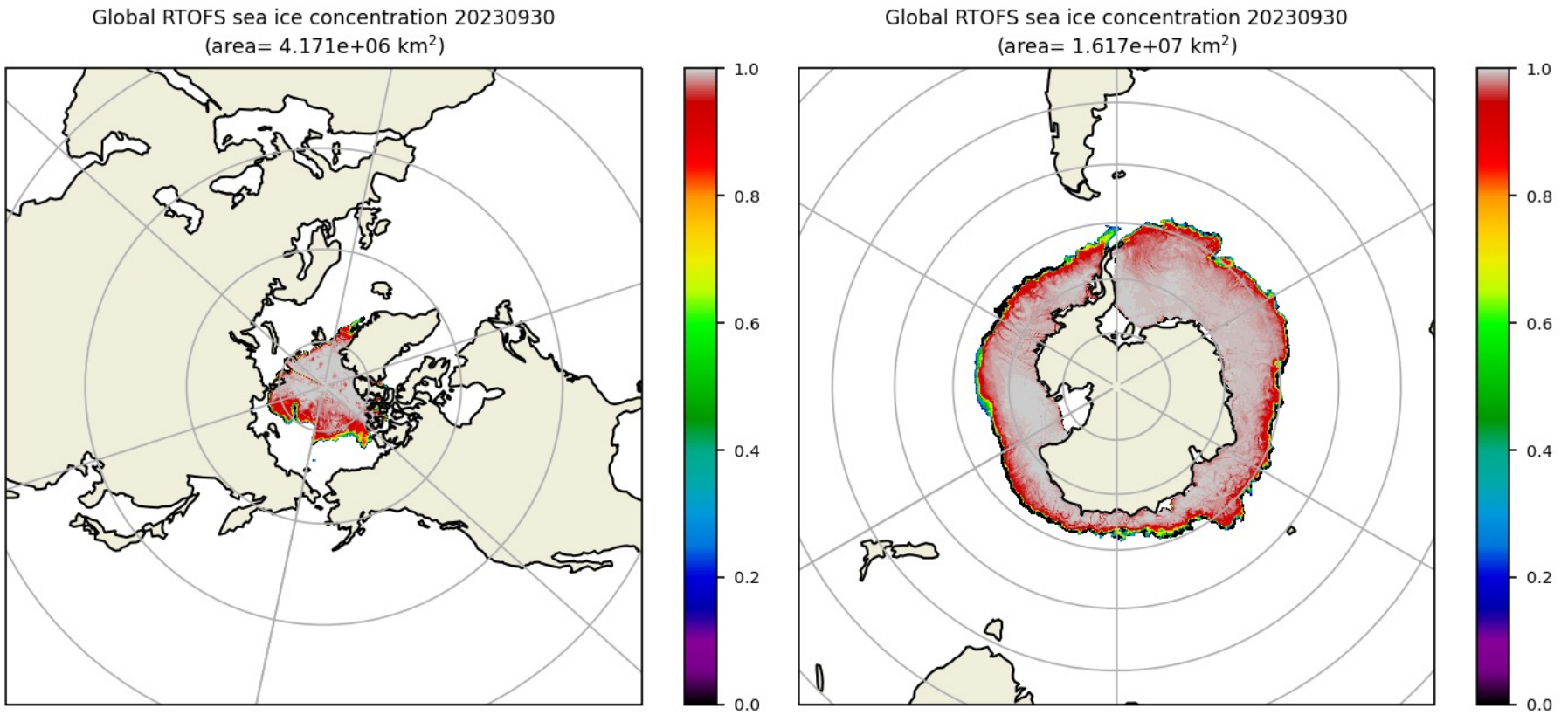
10-km L-band

Applications

- Modeling and prediction
  - Simultaneous ocean, land, cryosphere, and atmosphere observations directly enable NOAA's operational global coupled Unified Forecast System (UFS).
  - Water cycle observation and modeling
    - Drought, agriculture, energy, fish habitat, …
    - Enhanced ocean and ecology nowcasts/forecasts.
  - Planetary boundary layer characterization
  - Sea ice
    - Observing and modeling the thickness of sea ice
    - Planetary boundary layer characterization
    - Potential ramifications for mid-latitude weather to subseasonal forecasting.
- Ocean acidification
  - Salinity correlation/dependency
    - Total alkalinity (TA), dissolved inorganic carbon (DIC), partial pressure of CO_2 (pCO_2)
  - CO_2 absorbed at the ocean-atmosphere interface
    - Skin SSS observations important; although, increased accuracy is needed.

Backup

Operational Modeling & Prediction: Regional



Sea-ice thickness (SIT) = most sought observation for high-latitudes

- Arctic basin model resolution: RTOFS <4 km, UFS Coupled Model ~10 km
- Max measurable thickness = f(SSS)
  - Thicker SIT can be measured for fresher sea ice
  - Sea ice formed in nominal open-ocean SSS → max measurable SIT ~ 0.5 m
- Important for radiance-based assimilation

Atmosphere

- ***NOAA Context***
  - Improved hurricane intensity forecasting, an explicit NOAA priority (2017 Weather Act), directly connects to critical decision-making for public safety, e.g., the timing and extent of evacuation orders.
    - L-band PMW is better able to assess such extreme winds, a critical capability for hurricane intensity forecasting.
    - Operational capability being examined for L-band extreme winds (NASA's SMAP mission and ESA's SMOS mission)
- ***New Capabilities***
  - Ability to infer peak intensity in tropical cyclones.
- ***Applications***
  - Extreme wind speeds
  - Water cycle
  - Planetary boundary layer characterization

Land

- ***NOAA Context***
  - NOAA's Unified Forecast System (UFS) needs to address land coupling in order to extend forecast skill.
  - Critical parameters include surface emissivity, heat flux, and moisture flux.
  - Land surface emissivity needed, particularly as it relates to the hydrological cycle (e.g., soil moisture, water vapor, snow cover), and exploiting such measurements for enhanced, insight, assessments, and forecast skill.
  - Soil moisture observations have high value for assessments/forecasts for the agriculture and emergency response sectors
  - Observations under all-weather conditions needed to support operational assessments/forecasts
- ***New Capabilities***
  - Higher-resolution soil moisture measurements will better align with variability
- ***Applications***
  - Soil moisture (drought, agriculture, fire risk) assessment