Reanalyses in Support of Fisheries and Marine Ecosystem Modeling

US CLIVAR Workshop
Future U.S. Earth System Reanalysis
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Use of ocean reanalyses in fisheries applications is increasing rapidly

Two products are currently used most in west coast fisheries applications:

<table>
<thead>
<tr>
<th>CCSRA</th>
<th>GLORYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produced by</td>
<td>UC Santa Cruz</td>
</tr>
<tr>
<td></td>
<td>Mercator Ocean</td>
</tr>
<tr>
<td>Domain</td>
<td>US West Coast</td>
</tr>
<tr>
<td></td>
<td>Global</td>
</tr>
<tr>
<td>Resolution</td>
<td>1/10° (~10 km)</td>
</tr>
<tr>
<td></td>
<td>1/12° (~8 km)</td>
</tr>
<tr>
<td>Time period</td>
<td>1980-2010, 2011-present</td>
</tr>
<tr>
<td></td>
<td>1993-present</td>
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</tbody>
</table>

Other reanalyses have been used intermittently or indirectly (e.g., as forcing for regional ocean models)
Near-real-time monitoring: Impacts of El Niño

Jacox et al. (2016)
Near-real-time monitoring: Upwelling indices

Coastal Upwelling Transport Index (CUTI): Upwelling strength

Biologically Effective Upwelling Transport Index (BEUTI): Nutrient supply

Upwelling is a dominant driver of ecosystem productivity and variability in eastern boundary currents, including the California Current System, which runs along the U.S. west coast. Given the importance of upwelling in these regions, estimates of upwelling strength (i.e., upwelling indices) are often used to help understand fluctuations in ecosystem properties ranging from temperature and density all the way to distributions and abundances of top predators.

The Coastal Upwelling Transport Index (CUTI), pronounced "cutie," and the Biologically Effective Upwelling Transport Index (BEUTI), pronounced "beauty," are two new upwelling indices that leverage state-of-the-art ocean models as well as satellite and in situ data to improve upon historically available upwelling indices for the U.S. west coast.

CUTI provides estimates of vertical transport near the coast (i.e., upwelling/downwelling). It was developed as a more accurate alternative to the previously available 'Bakun Index.'

Explore CUTI

BEUTI provides estimates of vertical nitrate flux near the coast (i.e., the amount of nitrate upwelled/downwelled), which may be more relevant than upwelling strength when considering some biological responses.

Explore BEUTI

CUTI and BEUTI were developed in the Environmental Research Division of NOAA's Southwest Fisheries Science Center, in collaboration with the UC Santa Cruz Ocean Modeling Group.

Further information, guidance, and downloads:

How is CUTI calculated?

How is BEUTI calculated?

How are CUTI and BEUTI different from the Bakun Index?

Which index should I use?

Download indices

Jacox et al. (2018)
Near-real-time monitoring: Coastal trapped wave index
Ecological modeling: Species distributions

Species tracking and observer data

Environmental data from ocean models

Species Distribution Models
Ecological modeling: Species distributions

Species tracking and observer data

Environmental data from ocean models

Brodie et al. (2018)
Ecological modeling: Species distributions

Becker et al. (2019)

Hazen et al. (2018)
Welch et al. (2019)

Muhling et al. (2019)
Ecological modeling: Groundfish recruitment

Hypothesized environmental drivers

**Female preconditioning (50–1,200 m)**

\(-\) \(DD_{pre}\)

Cold water is associated with higher system productivity and lower metabolic costs making more energy available for reproduction

**Eggs (300–825 m)**

\(+) \ CST_{egg}\)

Onshore transport maintains larvae near settlement habitat

\(+) \ DD_{egg}\)

Faster development in warm water

**Yolk-sack (1000–1200 m)**

\(+) \ LST_{yolk}\)

Transport to the north results in better feeding later on northern zooplankton

**Pelagic larvae (surface waters)**

\(-\) \(DD_{larv}\)

Cold water is associated with higher system productivity and lower chance of starvation

Time series from reanalysis

Sablefish recruitment estimates

Tolimieri et al. (2018)
Boundary conditions for regional ocean models

**Ocean**
- Sea surface height
- Temperature (3D)
- Salinity (3D)
- $u$ and $v$ currents (3D)

**Atmosphere**
- Near-surface temperature
- Near-surface winds
- Sea level pressure
- Humidity
- Shortwave radiation
- Longwave radiation

Many different ocean and atmospheric reanalyses have been used for regional downscaling.
Forecast initialization and verification
Forecast initialization and verification

Jacox et al. (in prep)
Forecast initialization and verification

Jacox et al. (in prep)
To what extent can reanalyses be treated as observations?

Sea surface height anomaly (cm)

- Neah Bay, WA (48.37°N, 124.61°W)
- Willipa Bay, WA (46.71°N, 123.97°W)
- South Beach, OR (44.63°N, 124.04°W)
- Port Orford, OR (42.74°N, 124.5°W)
- Humboldt Bay, CA (40.77°N, 124.22°W)
- Arena Cove, CA (38.91°N, 123.71°W)
- Monterey, CA (36.61°N, 121.89°W)
- Santa Monica, CA (34.01°N, 118.5°W)
- La Jolla, CA (32.87°N, 117.26°W)

$r = 0.74-0.84$ (daily)  \hspace{1cm}  $r = 0.84-0.91$ (monthly)
To what extent can reanalyses be treated as observations?

Surface temperature anomaly (°C)

Stonewall Bank (44.7°N)  
- $r > 0.9$

Farallon Islands (37.7°N)  
- $r > 0.9$

Newport Beach (33.6°N)  
- $r = 0.7-0.9$

Bottom temperature anomaly (°C)

Newport Line (44.7°N)  
- $r = 0.4-0.7$

Line 66.7 (36.8°N)  
- $r = 0.4-0.5$

Line 80 (34.5°N)  
- $r = 0.4-0.7$

Amaya et al. (submitted)
Considerations for future reanalyses: A marine ecosystems perspective

Concerns
Fidelity to nature: which variables can we trust, and where

Discontinuities/inconsistencies between historical products or between delayed time and near real time products

Reliable delivery, especially for near real time applications

Dynamical consistency is less of a concern at present, but there is interest in e.g., heat budgets during marine heatwaves

Desires
Resolution: daily, O(10 km) or better

Multi-decadal historical coverage

Near-real-time availability

Ocean variables for physical and ecological applications (e.g., 3D temperature, SSH, mixed layer depth, upper ocean stratification)

Atmosphere and ocean variables for regional model boundary conditions

Biogeochemistry