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A review of the importance of high resolution SSTs: Application to a Coastal Upwelling Region

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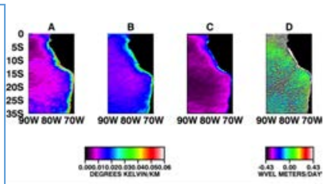
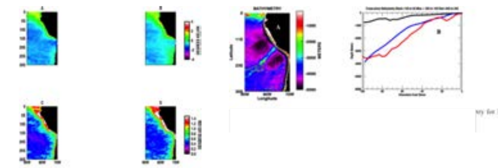
ABSTRACT:

The availability of higher resolution sea surface temperatures (SST) has allowed for new applications in coastal regions. An example is given by reviewing the application of the Multi-Scale Ultra-High-Resolution Sea Surface Temperature Data (MUR) to coastal upwelling region off Peru. Two versions of the MIT General Ocean Circulation Model are used to both compare the SST gradients and at the same relate the gradients to upwelling strength as defined by the vertical velocity.

As a first step in validation, a comparison between SST observations is performed, which indicates that the 1 km gridded multi-scale ultra-high-resolution (MUR) SST data set is defining a zone of maximum SST gradients closer to shore than the lower-resolutions. Two model versions, at nominal resolutions of 2 km and 4 km, of the Massachusetts Institute of Technology general circulation model are analyzed. A high-resolution version at 2 km is examined for the period 13 September 2011-23 January 2012, while a 4 km version is examined for 6 March 2011-22 April 2013. MUR shows maxima SST gradients in the range of 0.03 +/- 0.02 K km (-1) while the model showed higher gradients around 0.05 +/- 0.02 K km (-1). Based on coherence spectra, the relationship between upwelling rate (as inferred from the vertical velocity) and SST gradient is documented in the model from intraseasonal to annual timescales. It suggests that changes in SST gradient magnitudes are related to changes in the intensity of coastal upwelling off Peru and Chile. Such a relationship between SST gradients and vertical velocity would allow for the use of satellite-derived SSTs to monitor the intensity of coastal upwelling.





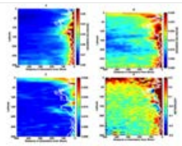


Figure 4. A) Mean magnitude of SST gradient versus cross-shore distance for LLC2160 B) Mean magnitude of SST gradient versus cross-shore distance for MUR C) Mean magnitude of SST gradient versus cross-shore distance for NCEI D) Mean Vertical Velocity WVEL from LLC2160 versus cross-shore distance. Straight line is the 500 meter isobath. Dashed line is the 2000 meter isobath.

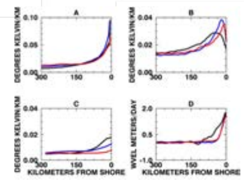
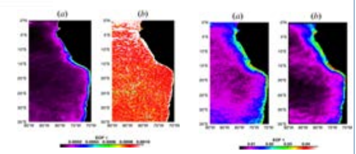


Figure 5. Mean magnitude of SST Gradient averaged for three latitude bands 35°S to 25°S (red), 25°S to 15°S (blue) and 15°S to 5°S (black) for A) LLC2160, B) MUR C) NCEI D) WVEL.



First EOF SST gradients LLC2160, LLC2160 WVEL, MUR, AVHRR_OI

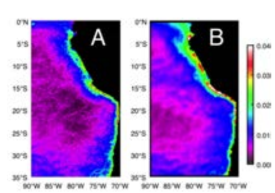


Figure 7. First EOF for /SSTG/ derived from A) MUR and B) NCEI.

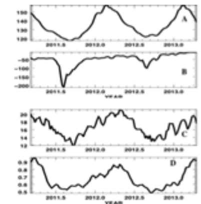


Figure 8. First principal component A) /SSTG/ derived from LLC2160 B) WVEL from LLC2160 C) /SSTG/ derived from MUR and D) /SSTG/ derived from NCEI.

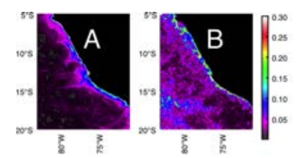


Figure 9. EOF 1 for the Northern region for /SSTG/ derived from A) LLC4320 and B) WVEL derived from LLC4320.

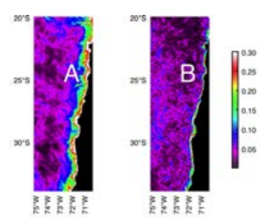


Figure 10. A) EOF 1 for the Southern region for /SSTG/ derived from LLC4320 B) EOF 1 for the Southern Region for WVEL derived from LLC4320.

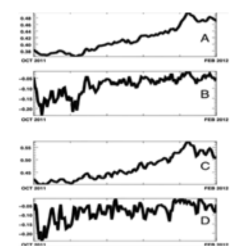


Figure 11. A) First principal component for Northern region for /SSTG/ derived from LLC4320 and B) first principal component for WVEL derived from LLC4320. C) First principal component for Southern Region for /SSTG/ derived from LLC4320 and D) first principal component for WVEL form LLC4320.

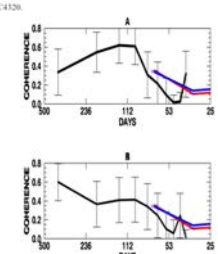


Figure 12. A) Coherence Spectra between MUR derived /SSTG/ and WVEL. B) Coherence Spectra between LLC2160 derived /SSTG/ and WVEL. Purple is coherence spectra for LLC4320 derived /SSTG/ and WVEL for purple (Northern Region) and red (Southern Region)

Cross-Shore Upwelling Scale

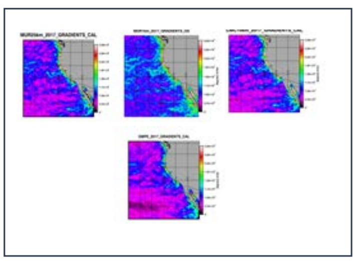
A simple methodology based on the magnitude of SST gradients is used to identify the cross-shore extent of the zone of maximum /SSTG/. Results indicate overall the zone of maximum /SSTG/ is related to local topography. Both LLC2160 and MUR show the zone of maximum /SSTG/ decreases to less than 20km with increasing latitude South. South of 25°S the zone of maxima SST gradients aligns with the zone of maxima in WVEL. MUR and vertical velocities (WVEL) from LLC2160 compare best with the shelf width in showing a decrease in the zone of maximum /SSTG/ with distance South from the equator, as well as identifying scales of approximately less than 20km between 35°S and 25°S. NCEI shows a broader scale of maxima /SSTG/, most likely due to the lower gridding resolution. WindSat indicates very little changes in SST gradients. In general SST gradients derived from the microwave WindSat satellite, indicate that lower resolution data sets are not resolving upwelling scales. South of 20° both NCEI and WindSat have limitations in identifying the coastal upwelling. Comparisons with only SST gradients from WindSat indicate high resolution infrared derived SSTs are adding critical information for identifying the coastal upwelling, especially as the cross-shore upwelling scale decreases to less than 50 kilometers, the Nyquist wavelength of the microwave derived SSTs (WindSat).

Parameter/Data Set	Latitude Band	Upwelling Scale
Shelf	35°S-25°S	20km
Shelf	25°S-15°S	49km
Shelf	15°S-5°S	76km
MUR	35°S-25°S	14km
MUR	25°S-15°S	37km
MUR	15°S-5°S	38km
LLC2160	35°S-25°S	10km
LLC2160	25°S-15°S	20km.
LLC2160	15°S-5°S	20km
NCEI	35°S-25°S	51km
NCEI	25°S-15°S	50km.
NCEI	15°S-5°S	47km
WVEL	35°S-25°S	15km
WVEL	25°S-15°S	16km
WVEL	15°S-5°S	55km

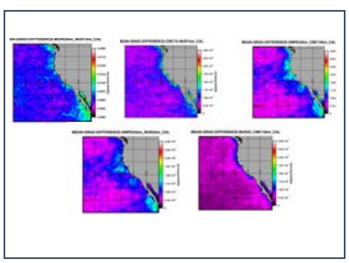
CONCLUSIONS:

The major focus of the work was to determine if the magnitude of the SST gradient (/SSTG/) could be used as an indicator of upwelling intensity and variability. The coherent spatial scale associated with the coastal upwelling was extracted by applying EOFs to LLC2160, LLC4230, MUR and NCEI. To examine the intraseasonal dependence the eigenmodes were extracted for the /SSTG/ for LLC4320, MUR and NCEI. In all cases the first eigenmode accounted for over 80% of the total variance. The first eigenmode of the /SSTG/ was compared with the first eigenmode of WVEL. Correlations between the first principal components (PC) of the /SSTG/ for LLC4320 and MUR were significant between 0.6 and 0.7. A similar procedure was applied using LLC2160 to identify the annual signal. The phase of the annual cycle was consistent for /SSTG/ derived from LLC2160, MUR and NCEI. In all cases maxima were found in the late Austral summer early fall time frame. Similar results were found for WVEL. Coherence spectra calculated between the first principal components of LLC2160/MUR SST gradient magnitudes and vertical velocity WVEL indicate a statistically significant relationship exists for the annual cycle. Similar coherence spectra for LLC4320 indicates the relationship between SST gradients and WVEL is also significant at intraseasonal time scales, but at 0.3 to 0.4. Results indicate that there is a statistically significant relationship between /SSTG/ and upwelling intensity, at least over the intraseasonal to annual time scales. Lower coherences at the intraseasonal time scale could be due to mesoscale to submesoscale variability.

Mean SST Gradients for 2017



Mean Differences of SST Gradient for2017



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