Assessing Shelf Sea Tides in Global HYCOM

Patrick G. Timko[1], Patrick Hyder[2], Brian K. Arbic[3], and Luis Zamudio[4]

1 Bangor University
2 UK Met. Office
3 University of Michigan
4 COAPS, Florida State University

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Motivation

- Performance of HYCOM in reproducing global tides has been assessed for deeper water
- Accurate Shelf Sea Tides requires:
  - accurate tides at shelf edge
  - good representation of shallow water tidal processes that influence the propagation and superposition of tidal constituents on the shelf

Objective

- First order assessment of shelf sea tides in global HYCOM
  - a regional comparison of HYCOM SSH to TPXO
  - comparison of HYCOM SSH to a regional model of NW European Shelf (NEMO)
  - comparison of SST with and without tides on the NW European Shelf
  - comparison of location of tidal mixing fronts on the NW European Shelf

Surface Tides on Shelf Seas

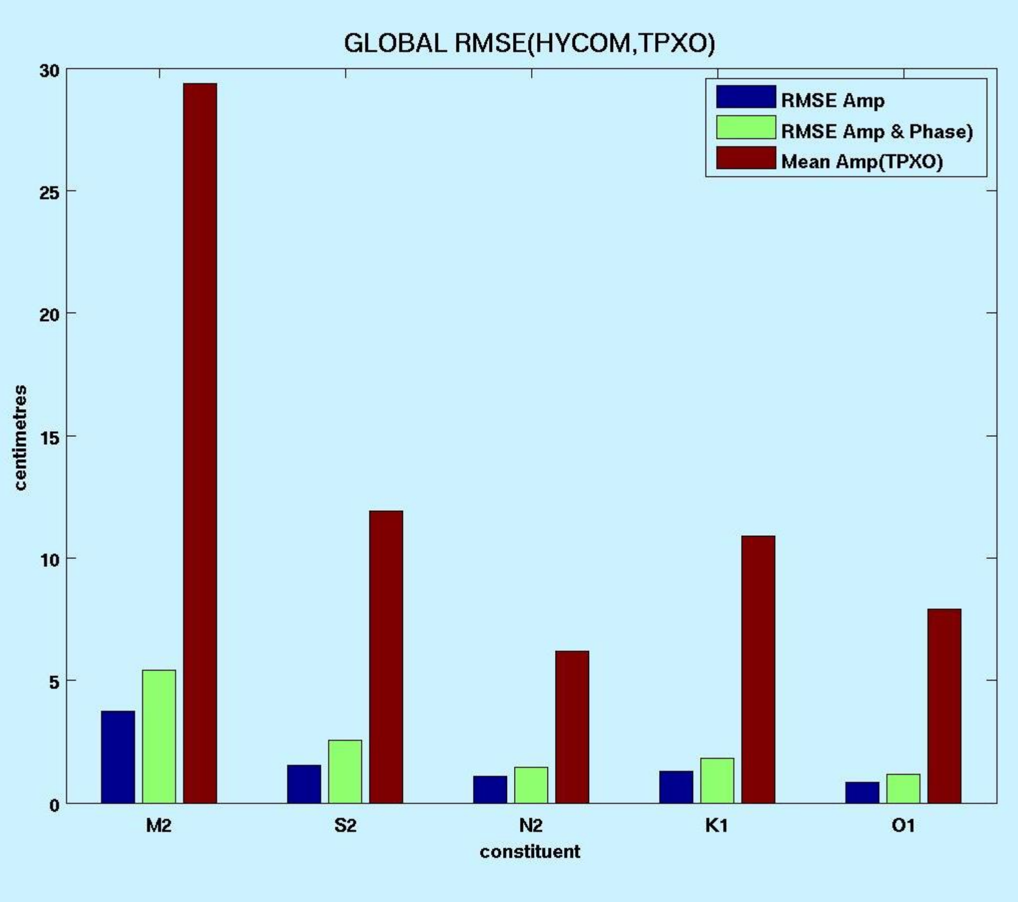
The RMSE for HYCOM compared to the altimetry constrained model TPXO (Egbert and Erofeeva, 2002) may be calculated using amplitude only or amplitude and phase (Shriver et al., 2012).

The RMSE may be calculated both globally and regionally for water column depths less than a given value.

$$RMSE(a) = \sqrt{\frac{\iint \frac{1}{2}(a_{HYCOM} - a_{altimeter})^2 \, dA}{\iint dA}}$$

$$RMSE(a,\theta) = \sqrt{\frac{\iint \left[\frac{1}{2}(a_{HYCOM} - a_{altimeter})^2 + a_{HYCOM}\, a_{altimeter}\,(1 - \cos(\theta_{HYCOM} - \theta_{altimeter}))\right] dA}{\iint dA}}$$

Global RMSE



Global RMSE HYCOM:

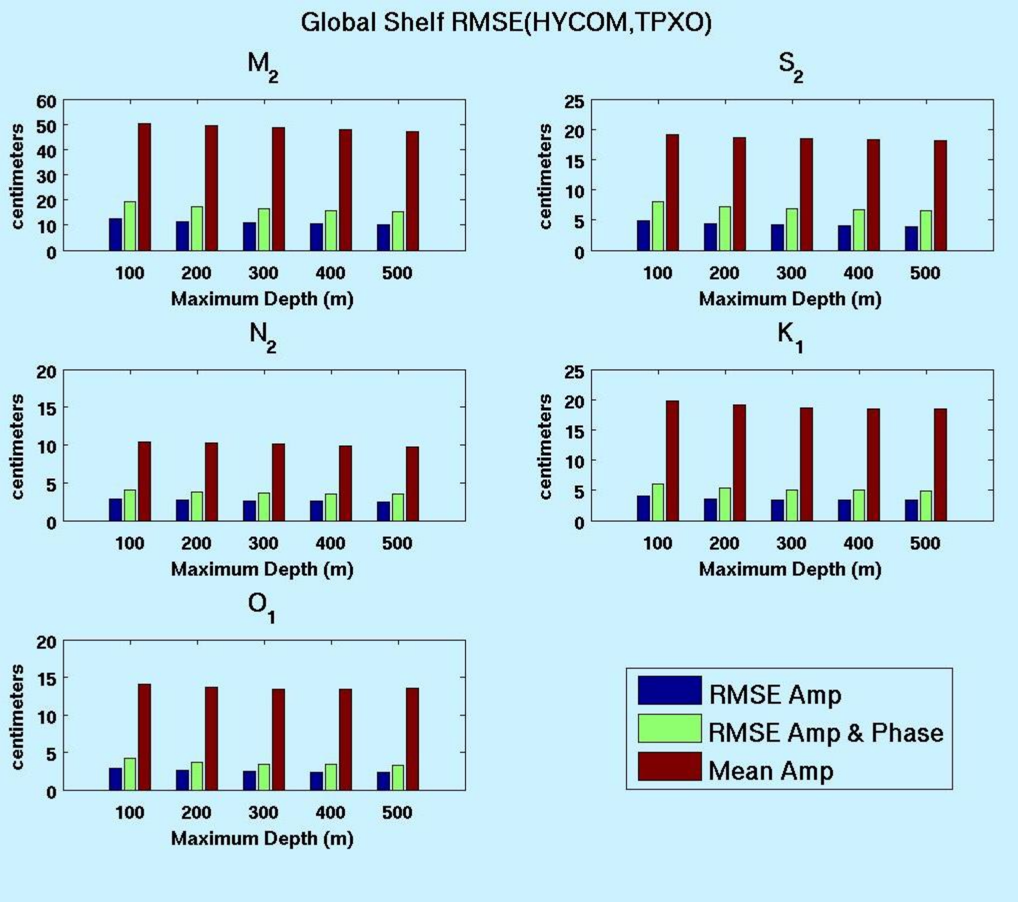
Semi Diurnal tides:

	A	A,Ɵ
M2	13%	18%
S2	13%	21%
N2	17%	24%

Diurnal tides:

	A	A,Ɵ
K1	12%	17%
O1	10%	15%

Global RMSE for shelf seas



Global RMSE HYCOM vs. TPXO (water column depth < 500 m):

20-40% for semi diurnal constituents (M2, S2, N2)

20-30% error for diurnal constituents (K1, O1)

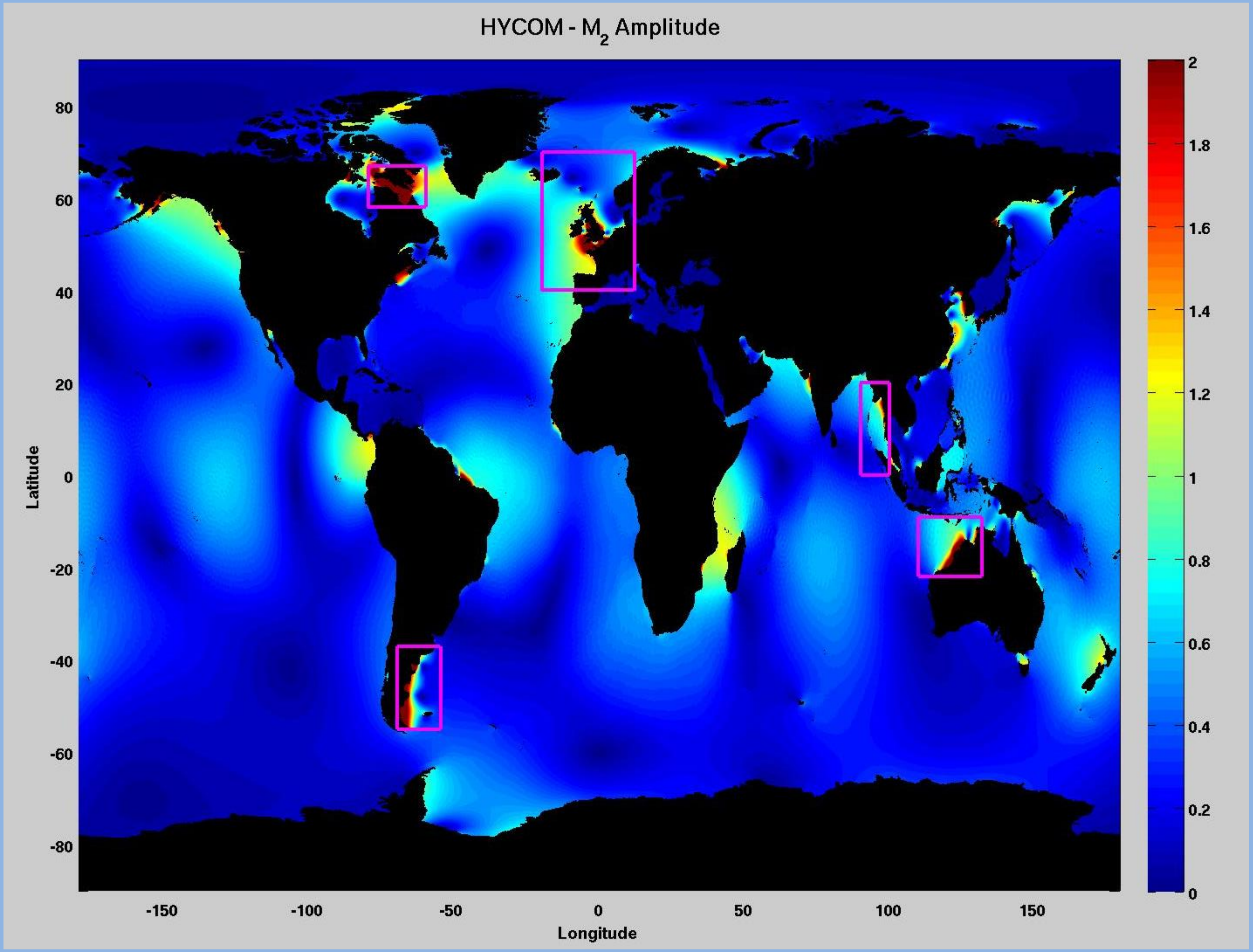
RMSE decreases as water column depth increases (as expected)

RMSE increases by 10-15% compared to signal strength when tidal phase is taken into account.

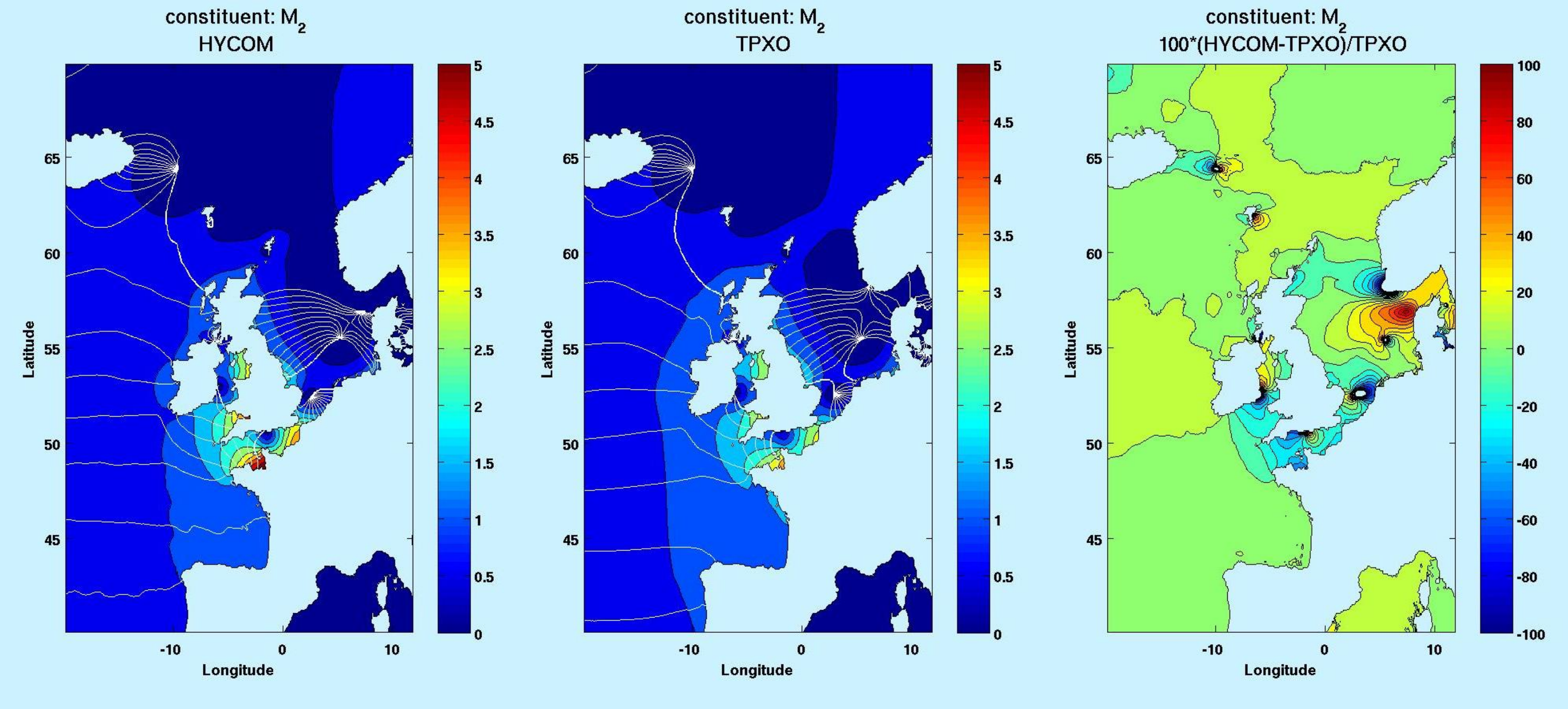
Regional RMSE

- HYCOM performance for regional shelf seas where large amplitude tides are known to exist:
  - NW European Shelf*
  - Hudson Strait
  - NW Australian Shelf
  - Patagonian Shelf
  - Andaman Sea

Regional RMSE

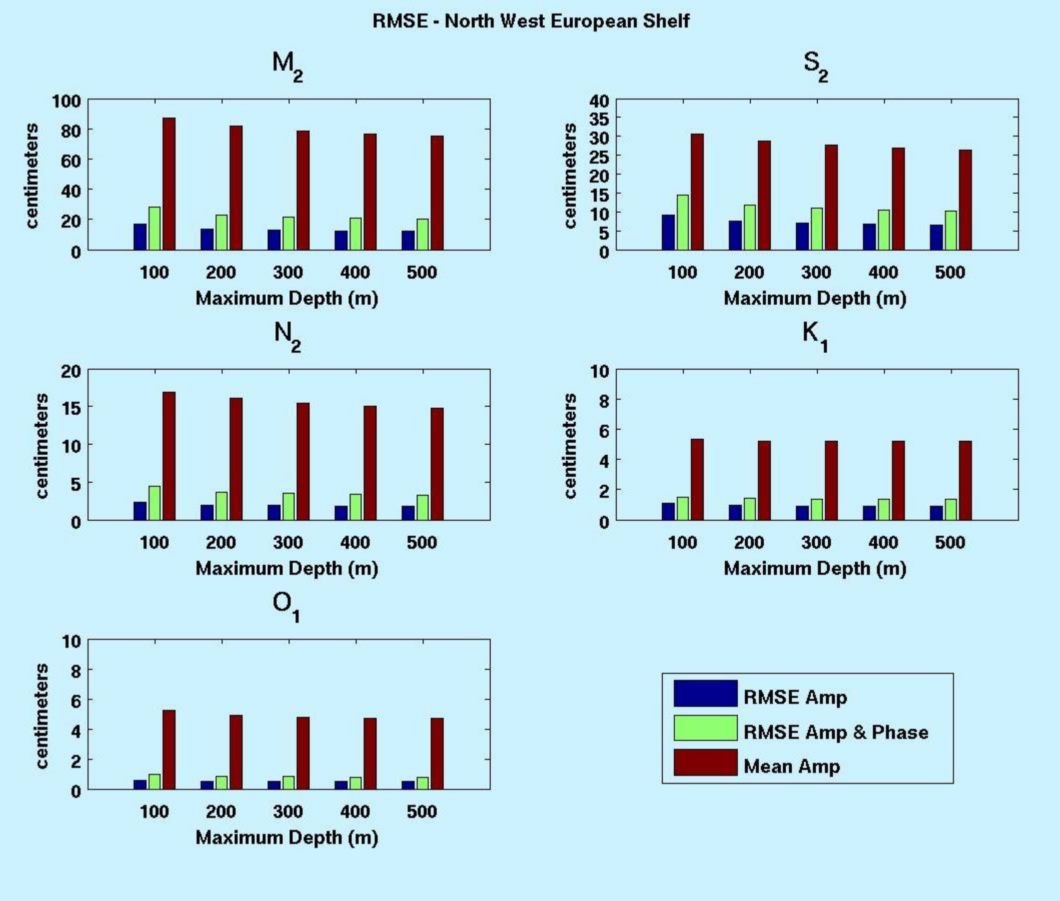


NW European Shelf



Both SSH Amplitude and Phase for M_2 are qualitatively similar but large errors (100^{+}%) in amplitudes exist along coastlines and around islands.

NW European Shelf



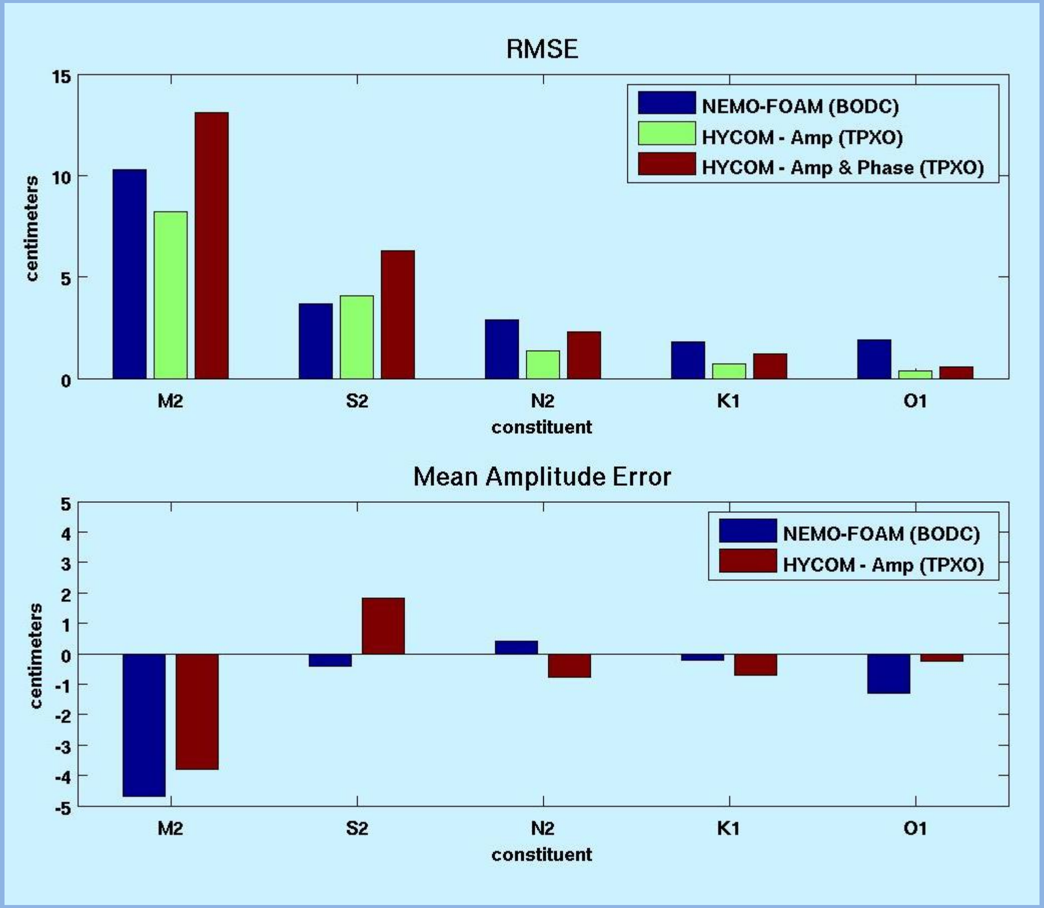
NW European Shelf RMSE

M2: 15-30% error
S2: 25-50% error*
N2: 10-25% error
K1: 15-30% error
O1: 10-20% error

percent error doubles when phase is taken into account

Tide signal is close to those given by Stammer et al. (2014)

NW European Shelf



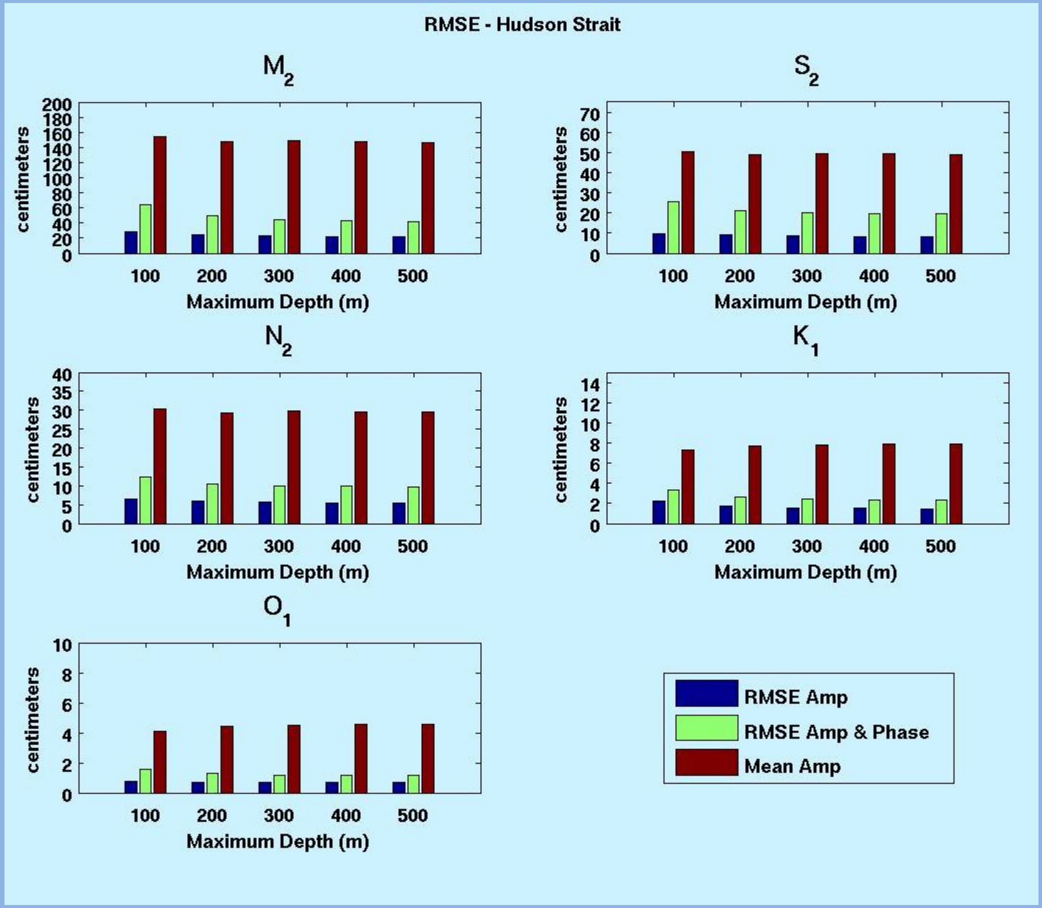
Mean Amplitude ERROR:
NEMO – BODC
HYCOM – TPXO

NEMO model is compared to tide gauge data from BODC (O'Dea et al., 2012)

HYCOM is compared to TPXO

The spatial domains may differ slightly

Hudson Strait

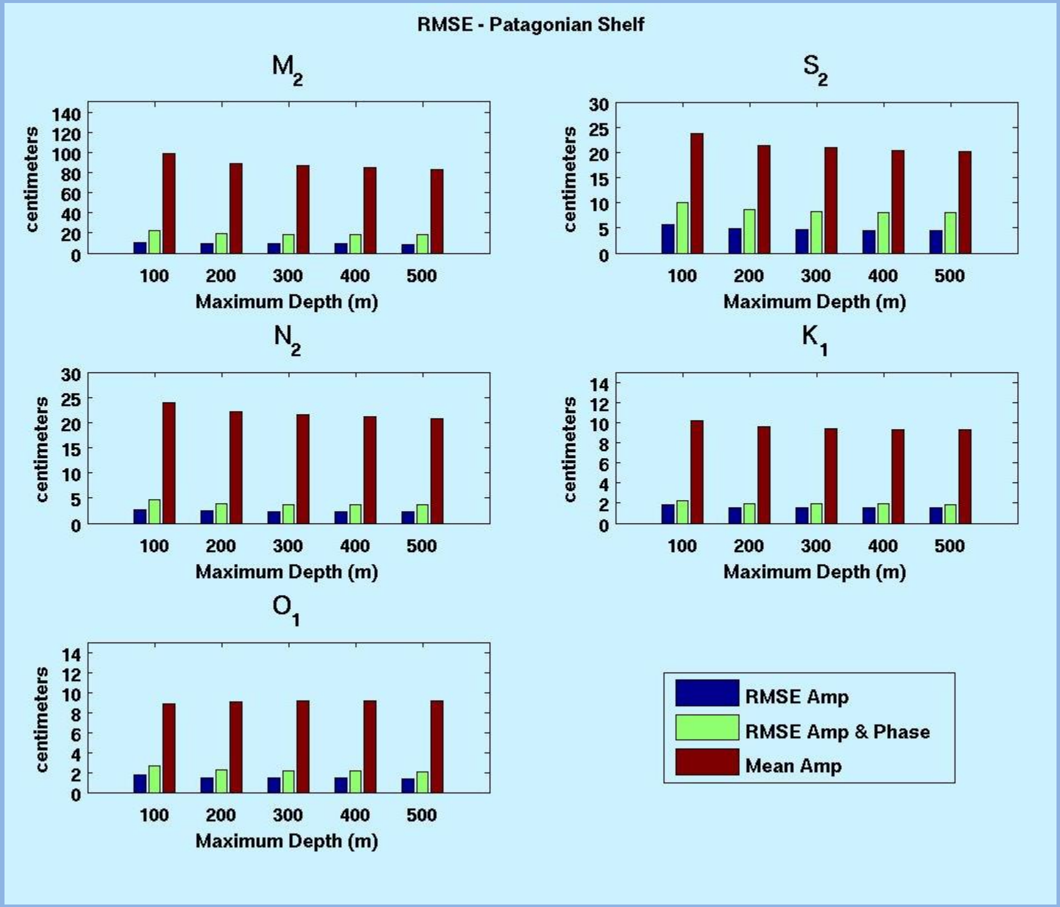


Hudson Strait RMSE

M2: 15-40% error
S2: 15-50% error*
N2: 20-40% error
K1: 20-45% error
O1: 15-40% error

Percent error increases by a factor of 2-3 when phase is taken into account

Patagonian Shelf

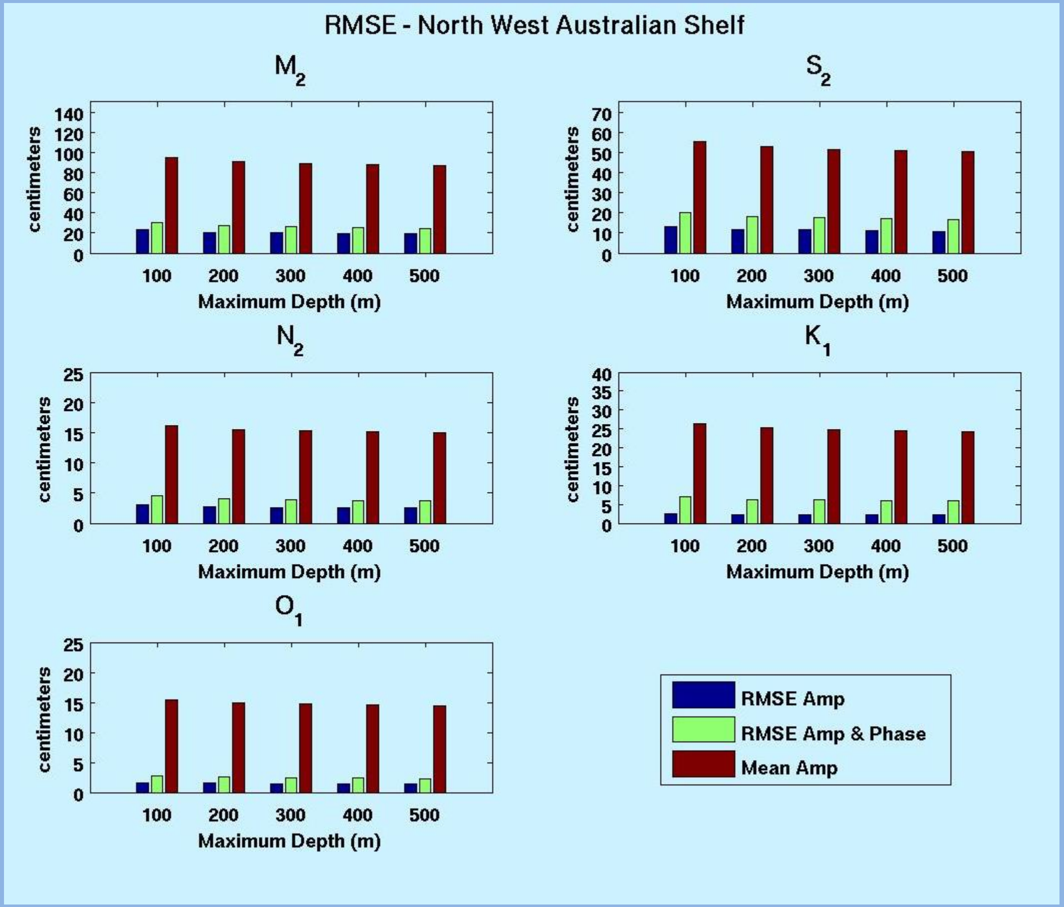


Patagonian Shelf RMSE

M2: 10-25% error
S2: 20-40% error*
N2: 10-20% error
K1: 15-20% error
O1: 15-30% error

Error increases by a factor of 2 when phase is taken into account

NW Australian Shelf

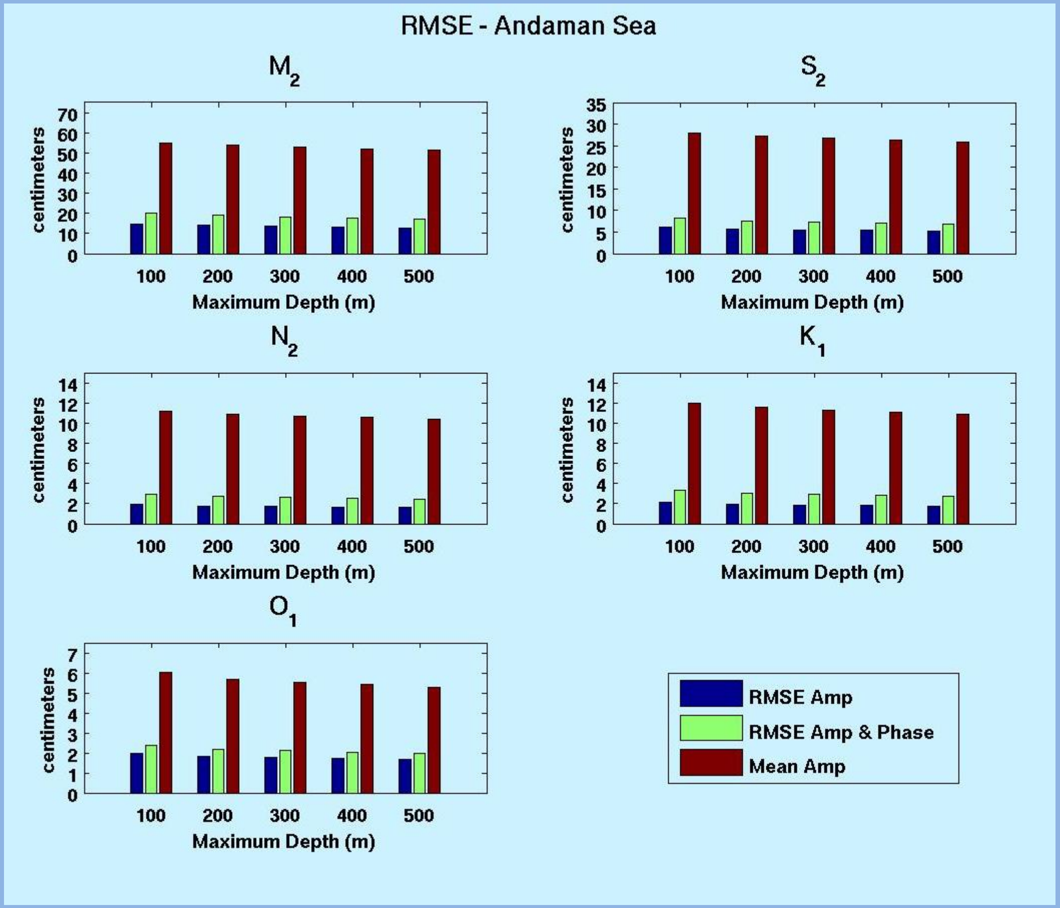


NW Australian Shelf RMSE

M2: 20-30% error
S2: 20-35% error*
N2: 20-30% error
K1: 10-25% error
O1: 10-20% error

Percent error increases by 10-15% when phase is taken into account

Andaman Sea



RMSE Andaman Sea

M2: 25-35% error
S2: 20-30% error*
N2: 15-25% error
K1: 15-30% error
O1: 30-40% error

Percent error increases by 10-15% when phase is taken into account

Tidal Mixing Fronts on the Shelf

The ratio, R, is the balance between the rate of production of potential energy due to surface heat flux, Q, and the rate of tidal energy dissipation Pingree and Griffiths,1978):

$$R = \frac{g\alpha Qh / 2C_p}{\rho C_D \left\langle |u|^3 \right\rangle} \propto \frac{h}{C_D \left\langle |u|^3 \right\rangle}$$

A simple measure for the amount of stratification is the difference between temperatures at the sea surface (SST) and near the seabed (SBT):

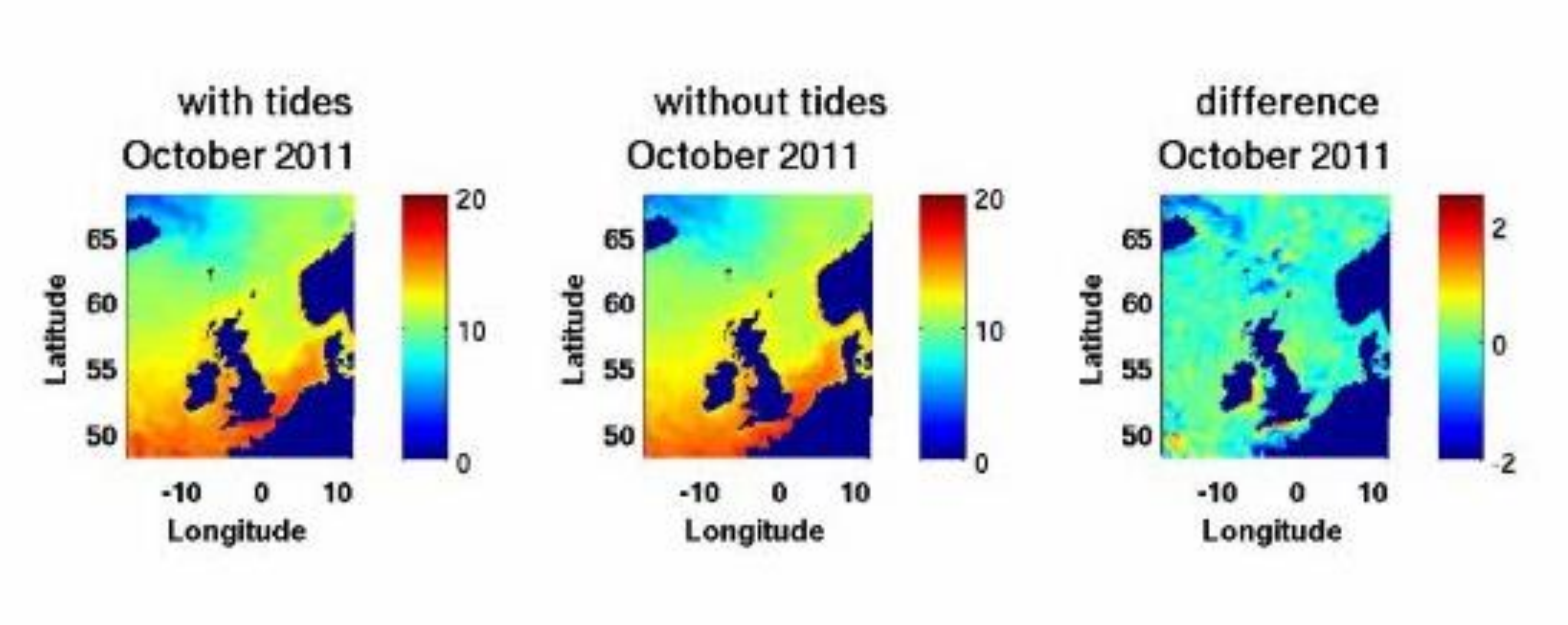
$$\Delta T = SST - SBT$$

Holt and Umlauf (2008) define the inter-annual mean frontal position with $\Delta T = 0.5°C$.

Tidal Mixing Fronts on the Shelf

- For summer months (JJA), Holt and Umlauf (2008) analysed 80,000 SST-SBT pairs from the ICES data base (http://geo.ices.dk) and interpolated ΔT onto a NEMO model grid using an inverse distance weighting and search radius of 30 km.
- For winter months (DJF) 21,000 SST-SBT pairs from CTD stations from 1990-2014 in the ICES data base were interpolated to the NEMO model grid using Delaunay triangulation separately on the SST and SBT observations.
- Objectively analysed mean temperature records (1955-2012) from the World Ocean Atlas 2013 (Locarnini et al., 2013; http:/www.nodc.noaa.gov) at 1/4° resolution are also used for comparison to model output in both summer and winter.
- NEMO model run used for comparison to HYCOM and data bases is the non data assimilative run of Odea et al. (2012) provided by the UK Met Office.

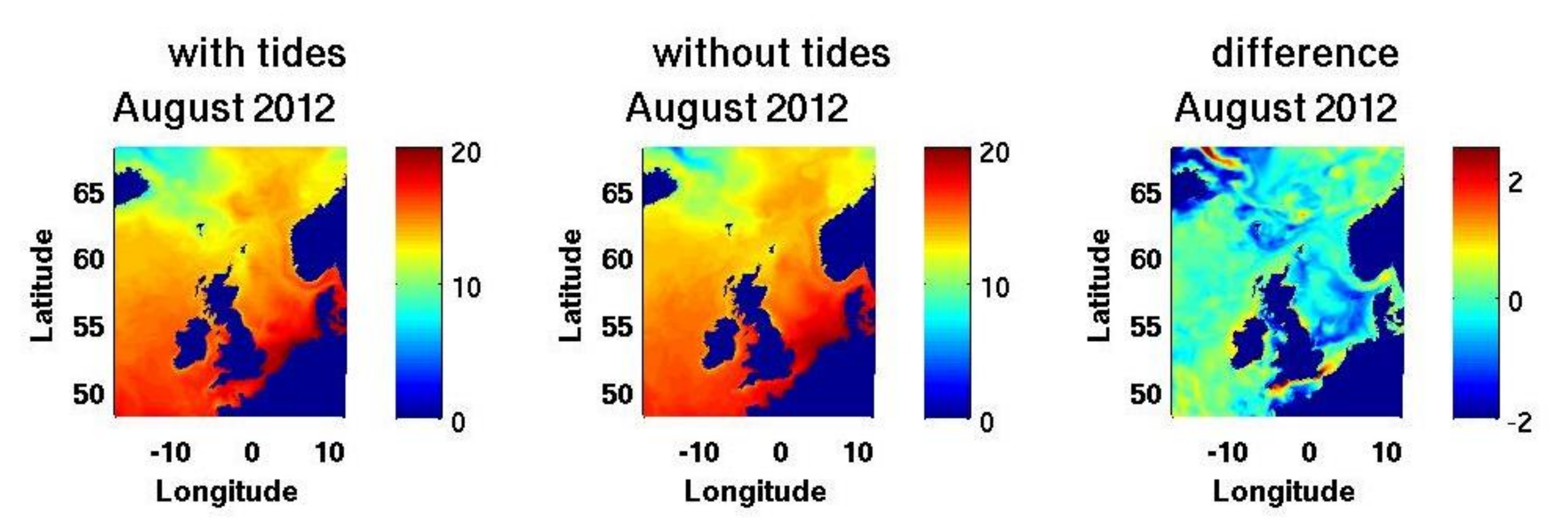
SST and Tidal Mixing Fronts



Global HYCOM with tides does produce differences in SST signatures.

Is the tidal mixing on the shelf producing frontal zones as expected?
SST Images from June, July and August indicate differences that are located in the region where we expect to see the tidal mixing front.

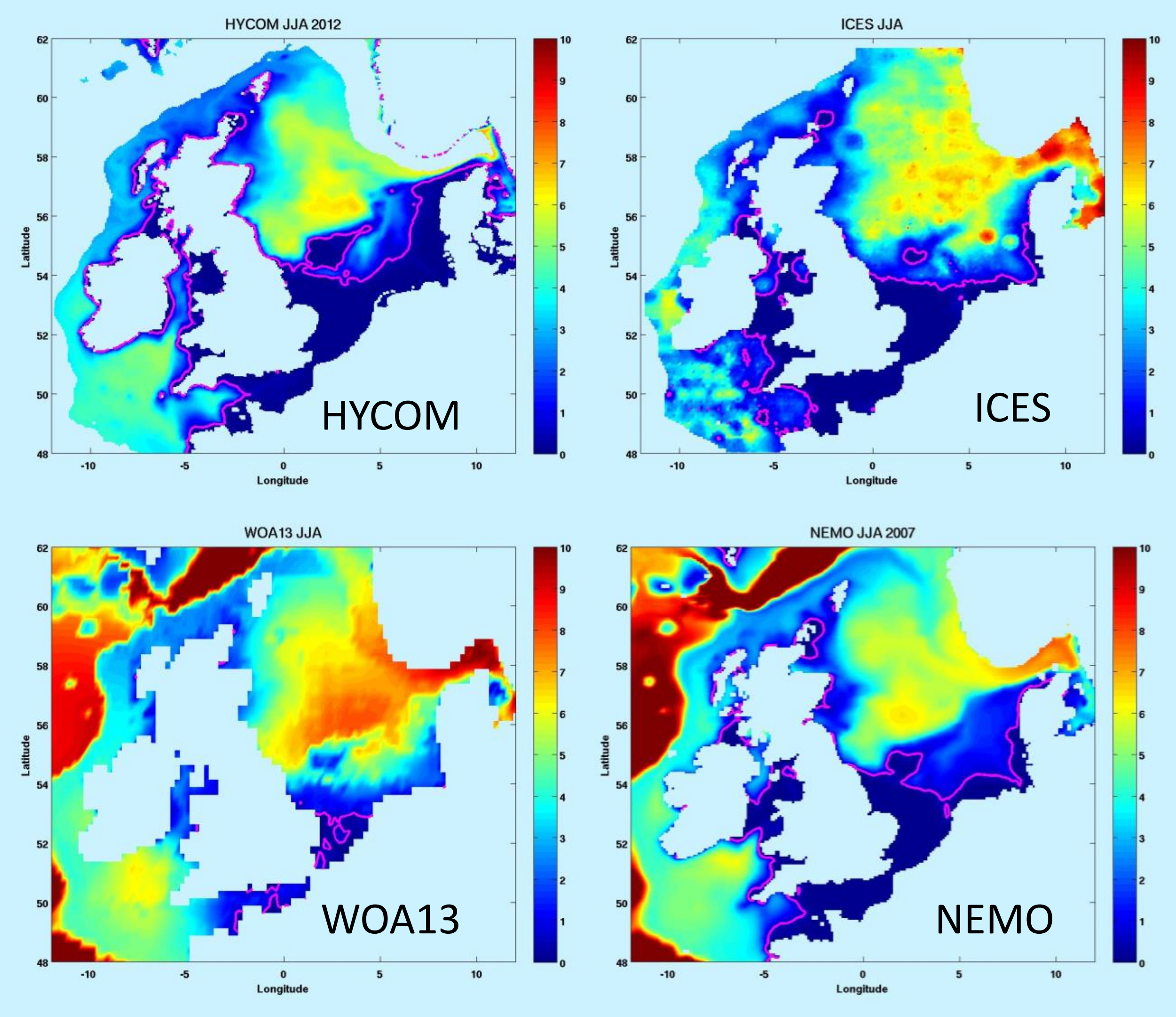
SST and Tidal Mixing Fronts



Global HYCOM with tides does produce differences in SST signatures.

Is the tidal mixing on the shelf producing frontal zones as expected?
SST Images from June, July and August indicate differences that are located in the region where we expect to see the tidal mixing front.

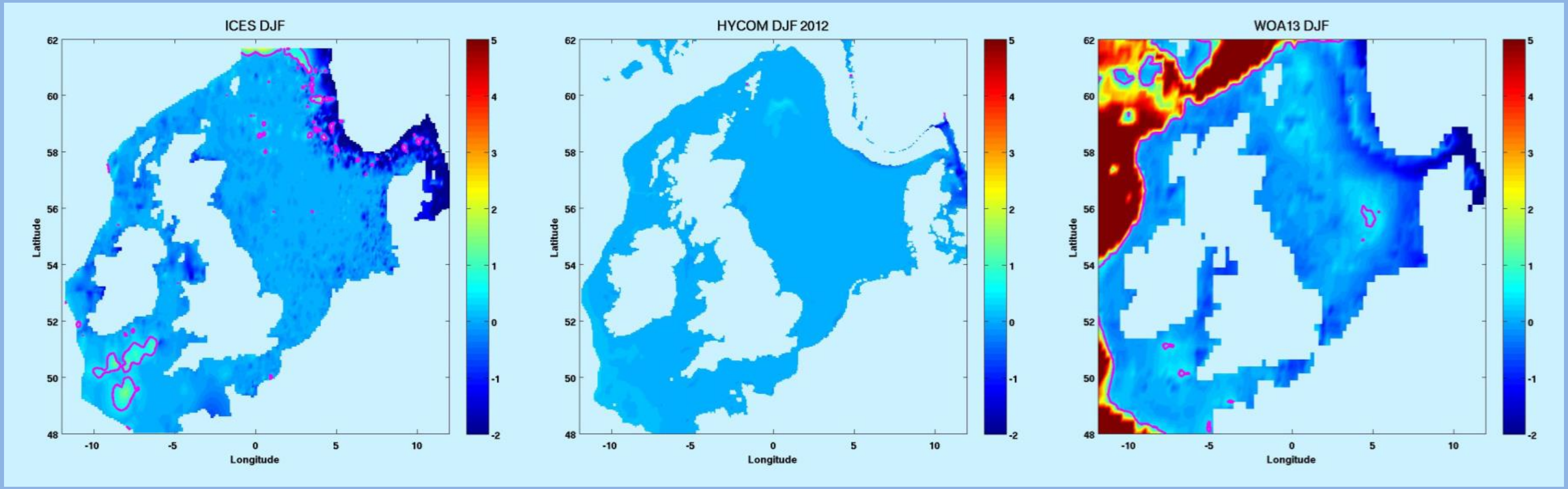
Summer (JJA) SST – Seabed temp (SBT)



SST – SBT for summer (JJA) for water column depths less than 200 m indicate that HYCOM is producing qualitatively similar surface to seabed temperature gradients when compared to a NEMO simulation of the NW European Shelf as well as compared to ICES and WOA climatalogies.

The magenta line indicates the position of the 0.5° C surface to bottom gradient which is considered to be the location of the mixing front. Waters with a gradient less than 0.5 ° C are considered to be well-mixed.

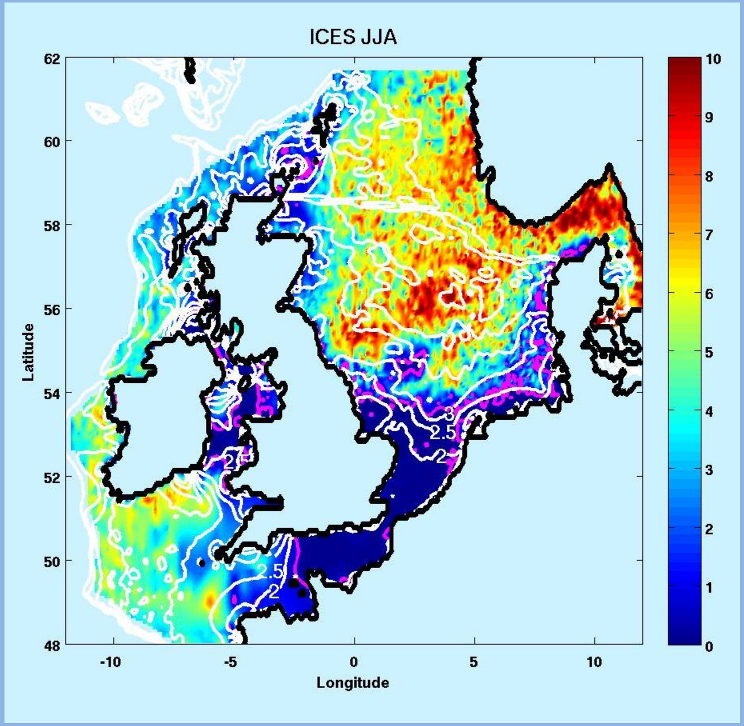
SST – Seabed temp. DJF

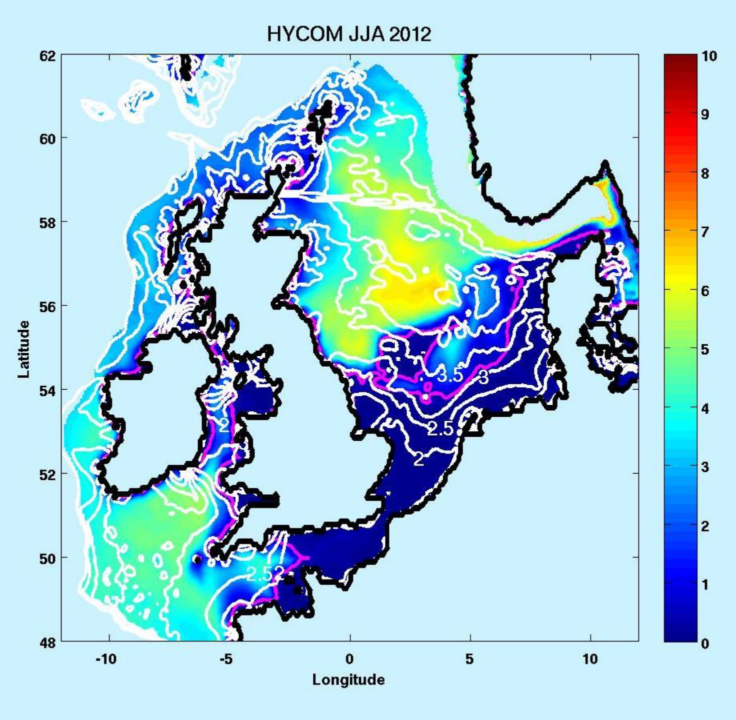


For Winter (DJF) no visible mixing fronts are found in either HYCOM, ICES or WOA for water columns depths < 200 m.

WOA indicates that the location of the mixing front appears to lie over ~200 m depth contour.

Summer (JJA)
SST – SBT vs. h/u^3





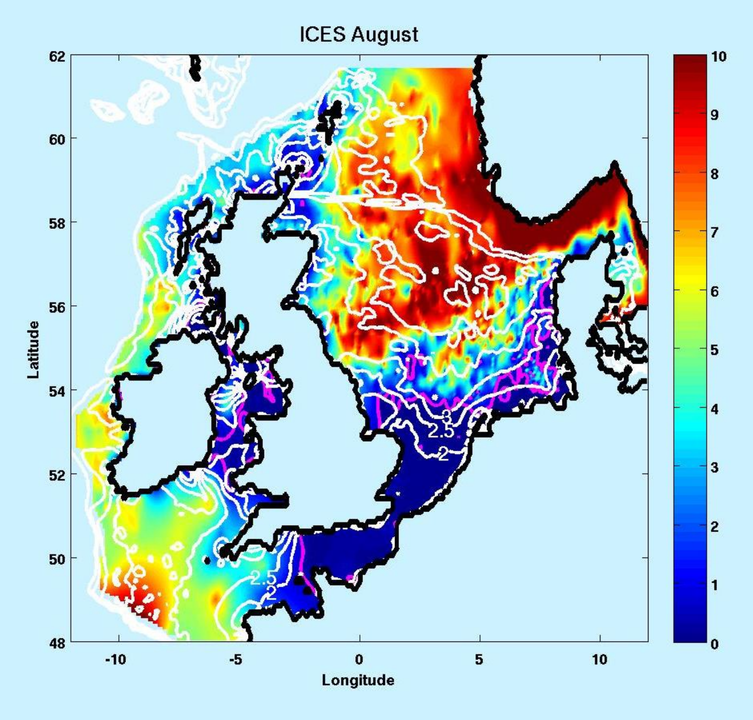
Summer ΔT = SST – SBT = 0.5 (magenta)

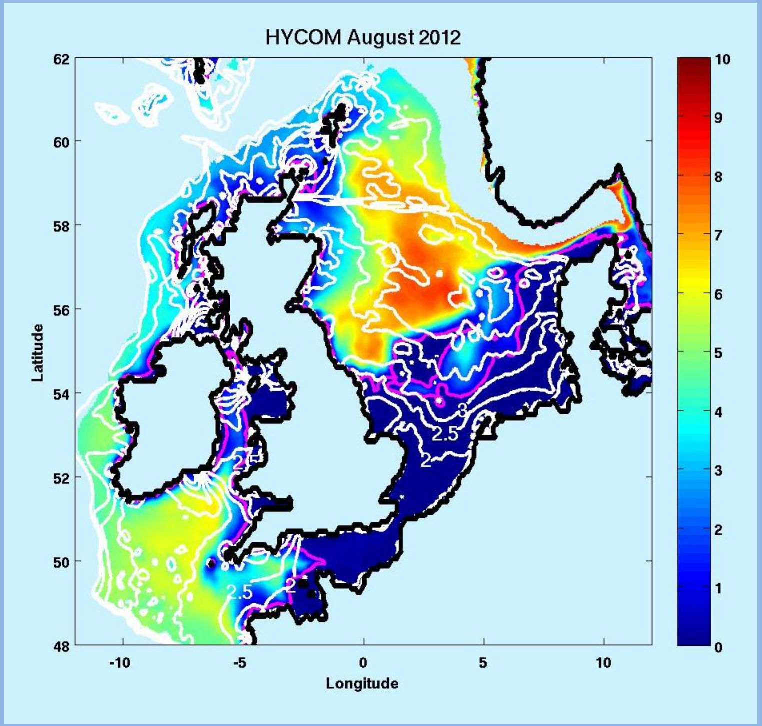
$S = \log_{10}(h/u^3)$ (white) u – M_2 semi-major axis (HYCOM)

When $\Delta T = 0.5$: ICES: S = 2.5 -3; HYCOM: S = 3; WOA: S = 2 – 2.5

Bowers and Simpson (1987) estimated a critical value of S = 2.7 ± 0.4.

Monthly (August)
SST – Seabed Temperature vs. h/u^3

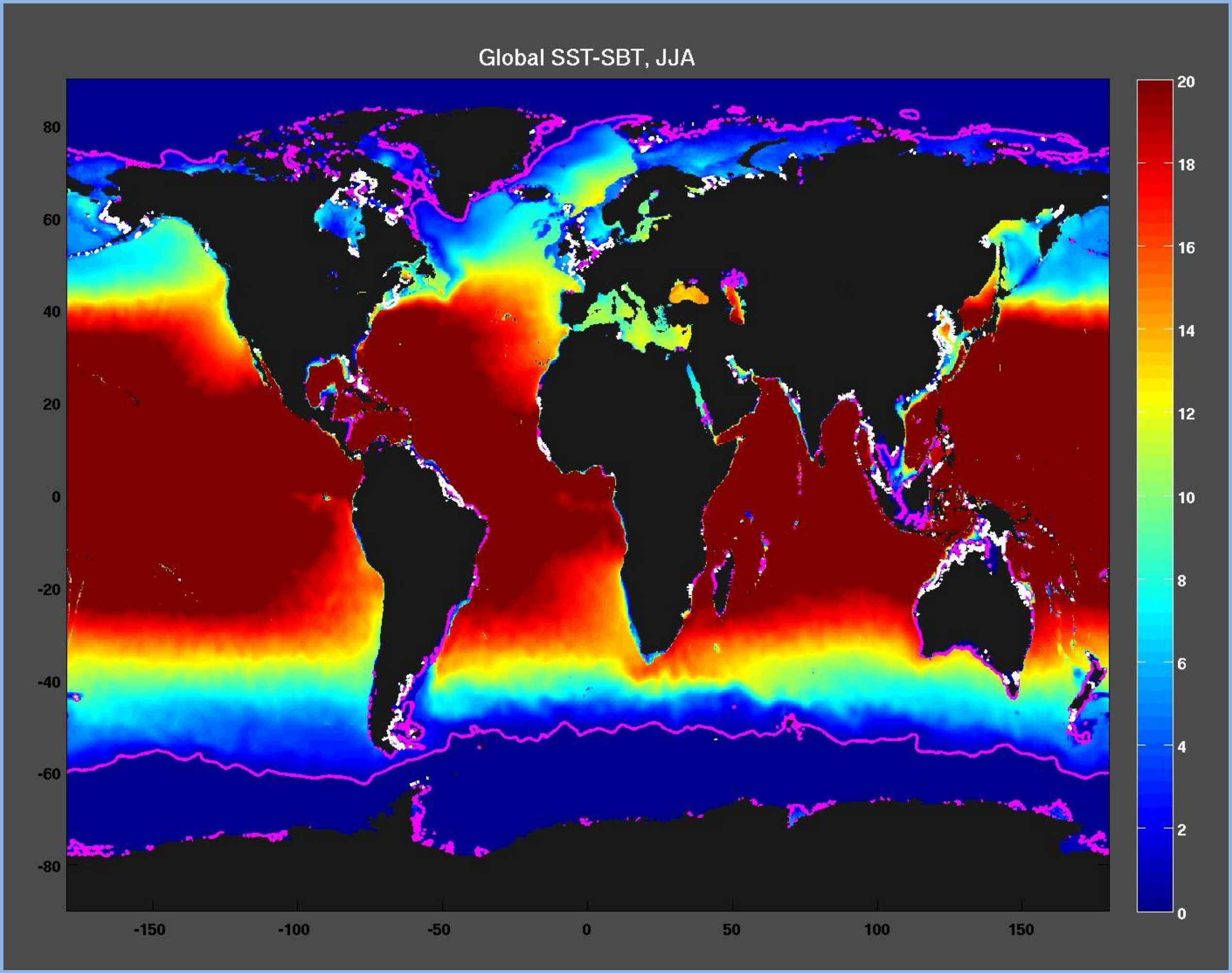




HYCOM ΔT in 2012 is lower than monthly climatology derived from ICES CTD data.

The location of the tidal mixing front shows little movement over the summer months in both ICES and HYCOM simulation

Global WOA13 ΔT = SST-SBT
HYCOM $S = \log_{10}(h/u^3)$

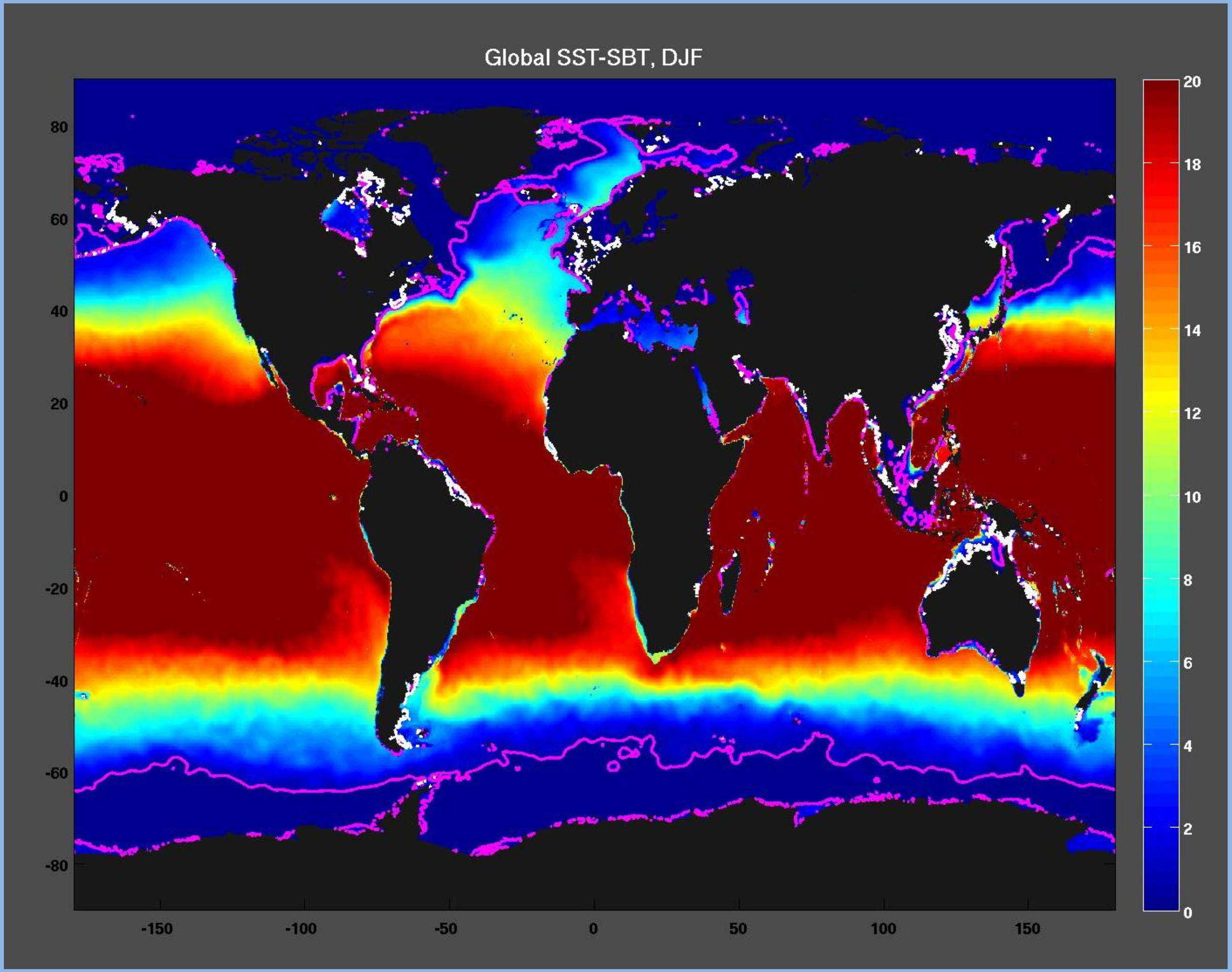


Initial comparison between WOA13 and HYCOM indicates that, globally, there exists other tidal mixing fronts on shelves with large amplitude tides that may be predicted and/or studied.

magenta:
WOA13 $\Delta T = 0.5$

white:
HYCOM $S = 2.7$

Global WOA13 ΔT = SST-SBT
HYCOM S = $\log_{10}(h/u^3)$



Initial comparison between WOA13 and HYCOM indicates that, globally, there exists other tidal mixing fronts on shelves with large amplitude tides that may be predicted and/or studied.

magenta:
WOA13 $\Delta T = 0.5$

white:
HYCOM S = 2.7

Summary

- Globally – RMSE for HYCOM surface tides in water depths less than 500 m represents approximately 20-40% error for semi-diurnal constituents and a 15-30% error for the diurnal constituents
- Regionally the RMSE for HYCOM compared to TPXO varies by region and by constituent. The largest amplitude errors (100^+%) lie close to coastlines and islands.
- Typically for semi-diurnal tidal surface heights S2 shows the largest error which may be partially due to atmospheric tides. Errors in the diurnal tides, K1 and O1, are approximately the same. When tidal phase is taken into account RMSE increases by a factor of 2-3
- Tidal mixing does influence the SST within HYCOM
- Summer time stratification on the NW European Shelf in HYCOM appears weaker than summer stratification from ICES and WOA
- Despite the weakness in the surface to seabed temperature gradient the location of tidal mixing fronts is reasonably consistent with the estimated critical value of $S = 2.7 \pm 0.4$ of Bowers and Simpson and the location of the fronts indicated by ICES observations. Both ICES and HYCOM indicate that tidal mixing fronts appear to the north of their location derived from WOA
- Globally the location of other expected tidal mixing front locations in HYCOM appear to be, at least initially, where they may be expected to occur indicating that HYCOM performance on the shelf seas is “reasonable” although the phase of the tide on shelf seas may not be correct.

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