Feature resolution in OSTIA L4 analyses

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Talk outline

- Introduction – NEMOVAR in OSTIA
- Methods
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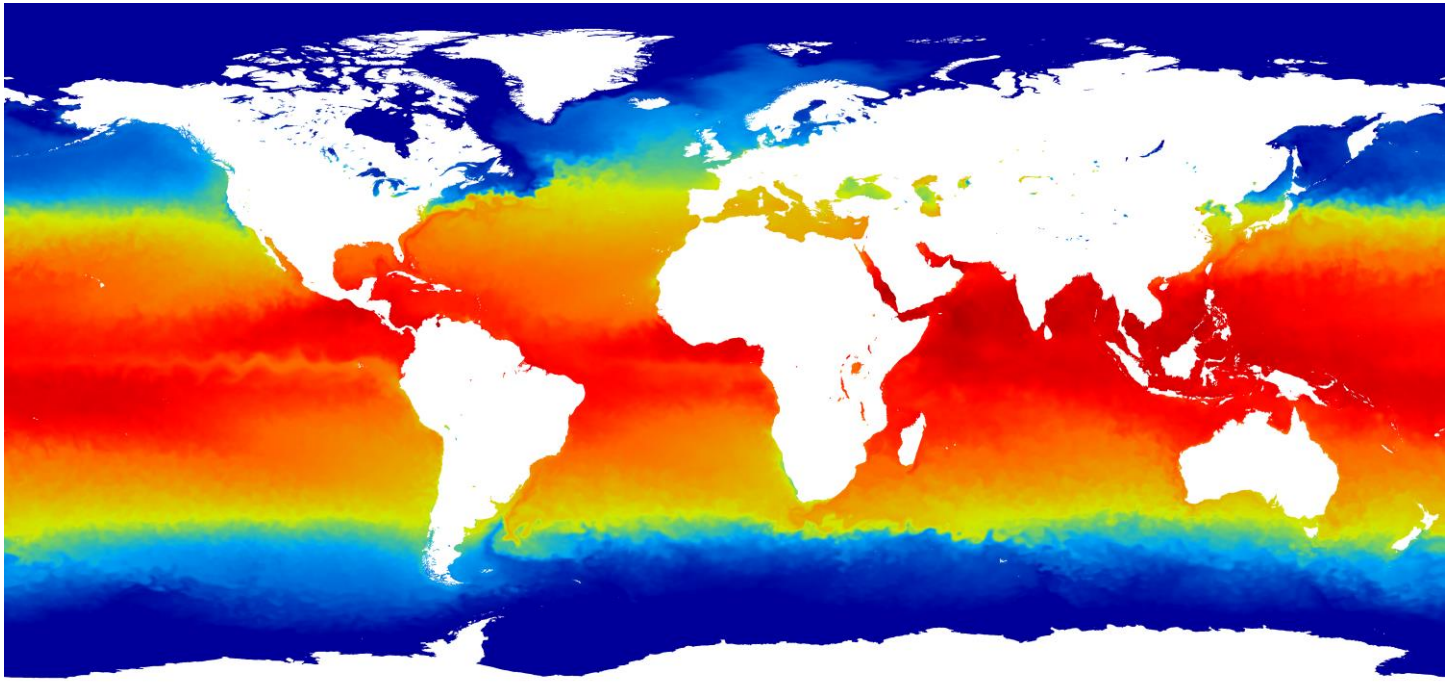
  - Spectral Analysis
- Improvements in feature resolution
  - OI vs. NEMOVAR OSTIA
  - Compared to other analyses
- Validation of NEMOVAR OSTIA
  - Argo statistics
  - NWP trials
- Conclusions
- Update on SLSTR in NEMOVAR OSTIA

About OSTIA

- Operational Sea Surface Temperature (SST) and Ice Analysis system
- Produces L4 (globally complete, gridded) analyses of SST and sea ice using observations from satellite and in situ platforms
- Near-real-time, diurnal and reanalysis configurations, developed at Met Office



NEMOVAR in OSTIA

Currently being transitioned from using an OI (Optimal Interpolation) type assimilation scheme to NEMOVAR, a variational assimilation scheme

- NEMOVAR OSTIA system will be used for new ESA SST CCI reanalysis (production begins shortly)
- Aim to replace OI OSTIA operationally in late 2017
- NEMOVAR data assimilation scheme developed with international collaboration for use with the NEMO ocean model
- Already used in Met Office in FOAM (Forecasting Ocean Assimilation Model) system
- Uses a diffusion method to model the background error correlation length scales

NEMOVAR in OSTIA

- The NEMOVAR dual length scale correlation operator (developed by Isabelle Mirouze) was implemented for NEMOVAR in OSTIA:

Short Length scale (40 km)

+

Long Length scale (300 km)

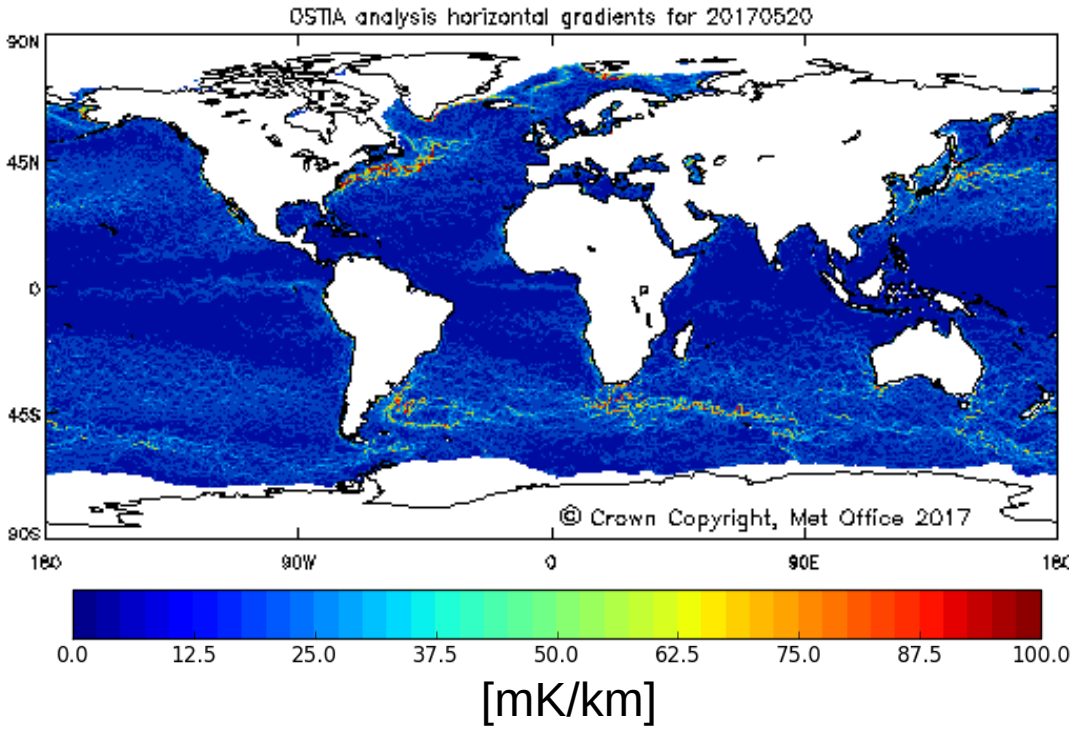
Ratio of short and long background error variances → Effective Length scale

- However, the pre-defined background error variances vary spatially and seasonally, but not on shorter timescales. If derived length scales applied to the analysis are too long, genuine SST features may be smoothed out.

Example horizontal gradient of an SST field

- Therefore a flow-dependent component determining the length scale ratio has been developed under the ESA SST CCI project. The total horizontal gradient of the background SST field is used to identify highly variable regions, where the effective background error covariance length scale should be shortened.

- The flow-dependence method linearly changes the ratio of the two length scales where SST gradients are between 20 and 50 mK/km, and sets the shortest length scale (40 km) above 50 mK/km.



Methods

The feature resolution capabilities of three OSTIA configurations were compared:

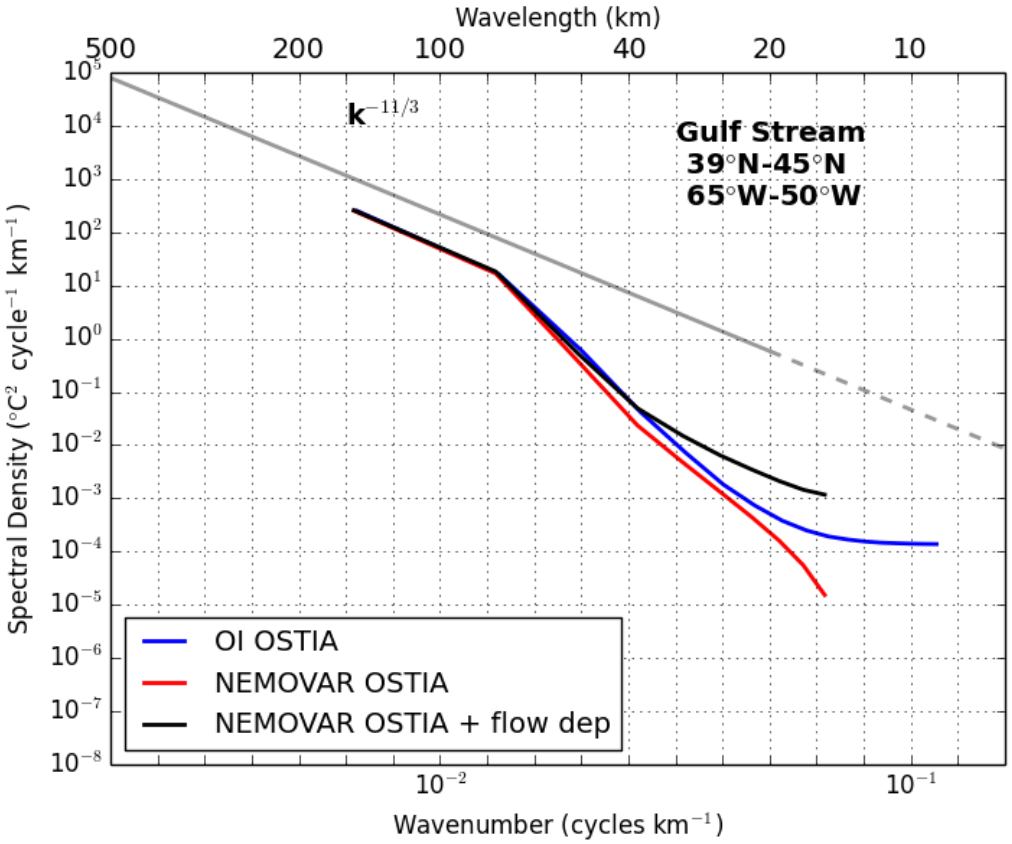
- OI OSTIA
- NEMOVAR OSTIA
- NEMOVAR OSTIA + flow-dependence

- Three runs over the period from June 2016 to March 2017
- The analysis focus on periods Jul – Sep 2016 and Jan – Mar 2017, with June 2016 as spin-up
- Results shown here are hemispherical winter in the Gulf Stream (GS, 39° - 45° N, 50° - 65° W, March 2017) and the Agulhas Current Retroflection (ACR, 25° - 45° S, 10° - 50° E, September 2016)

Methods

- Spatial power spectral analysis is used to assess the results
  - Daily power spectra are calculated for each latitude (latitudes with land grid points are excluded), then average to get the regional daily power spectra
  - Average over the daily power spectra to get monthly power spectra
  - Results for NEMOVAR OSTIA are calculated on the ORCA12 grids
- The power spectra are then compared against power law gradients that explains the theoretical decay of power spectra [Le Traon et al., 2008 JPO]:
  - K^{-5} power law demonstrates the quasi-geostrophic (QG) turbulence at longer wavelengths
  - $K^{-11/3}$ power law demonstrates the surface quasi-geostrophic (SQG) theory

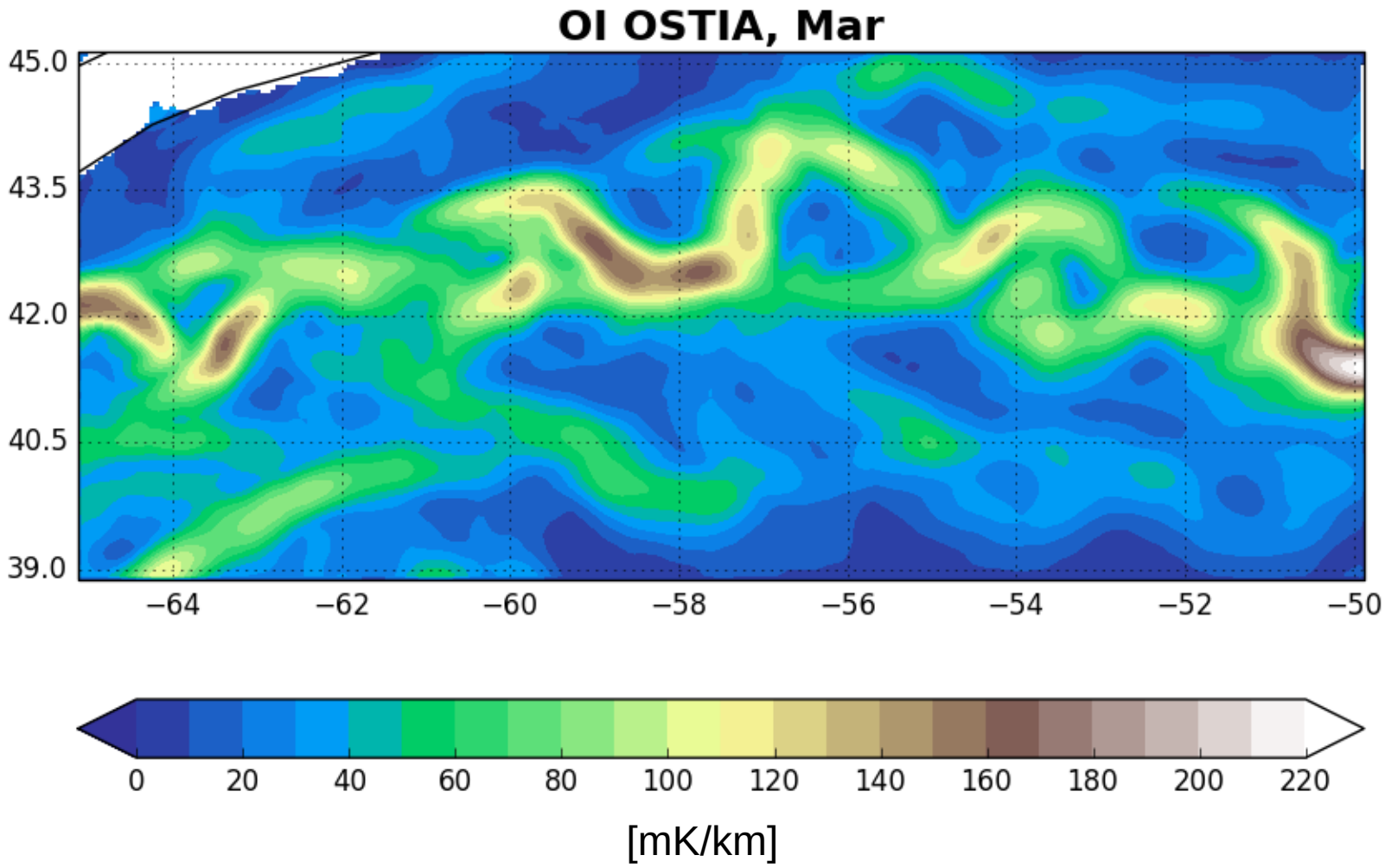
Improvements in feature resolution – Power Spectra



- All three OSTIA runs follow the $k^{-11/3}$ power law between ~150 – 75 km
- NEMOVAR OSTIA falls off faster than the other two runs
- OI OSTIA and NEMOVAR + Flow Dependent OSTIA separate at ~40 km (the short length scale in NEMOVAR OSTIA) and NEMOVAR version maintains higher power at lower wavelengths
- The power law for shorter scales is still under debate, especially those below the Rossby radius, which is ~20 km for this latitude[1]

[1] Chelton et al., 1998: Geographical variability of the first-baroclinic Rossby radius of deformation, JPO, 28, 433-460

Improvements in feature resolution – Horizontal Gradient



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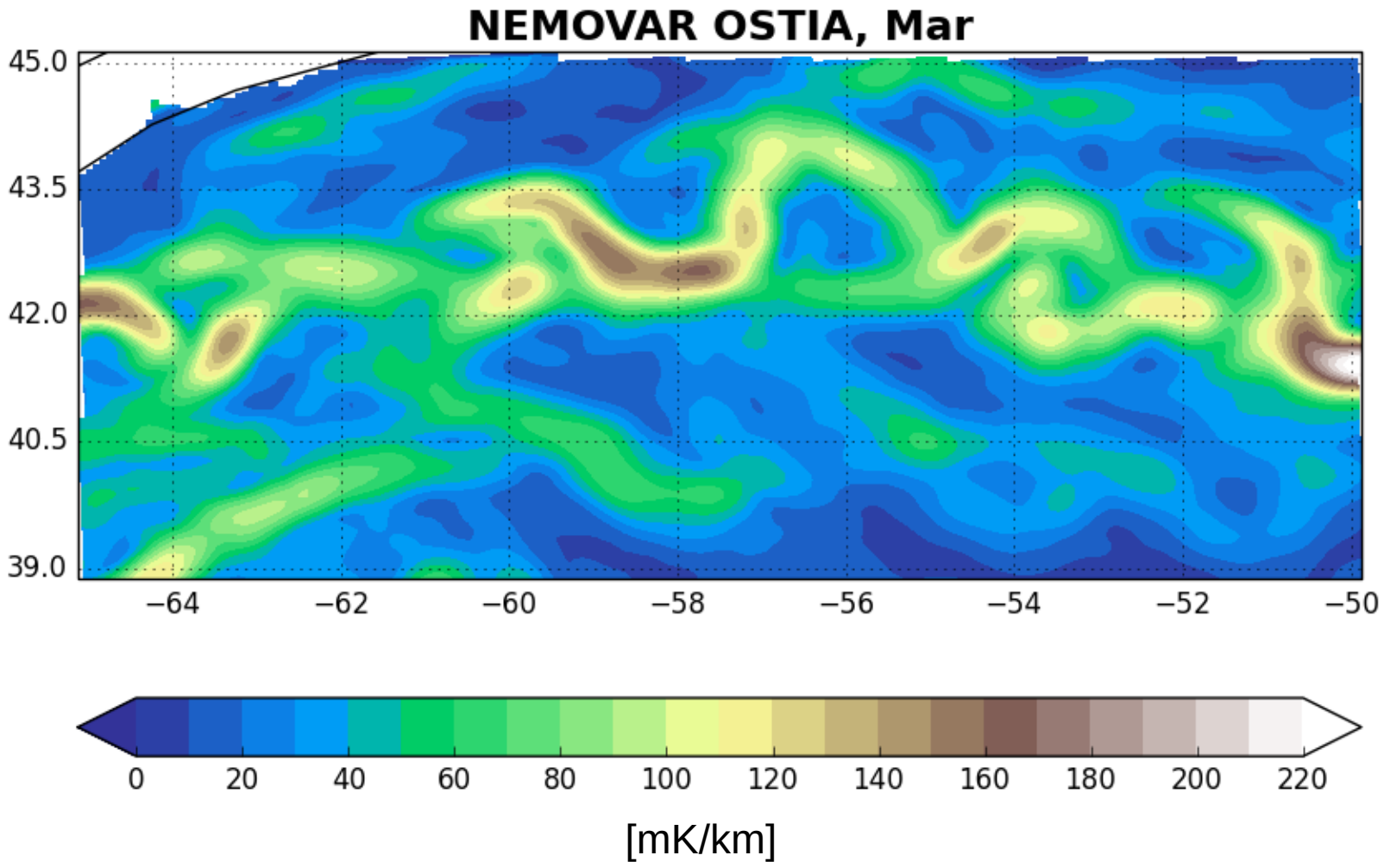

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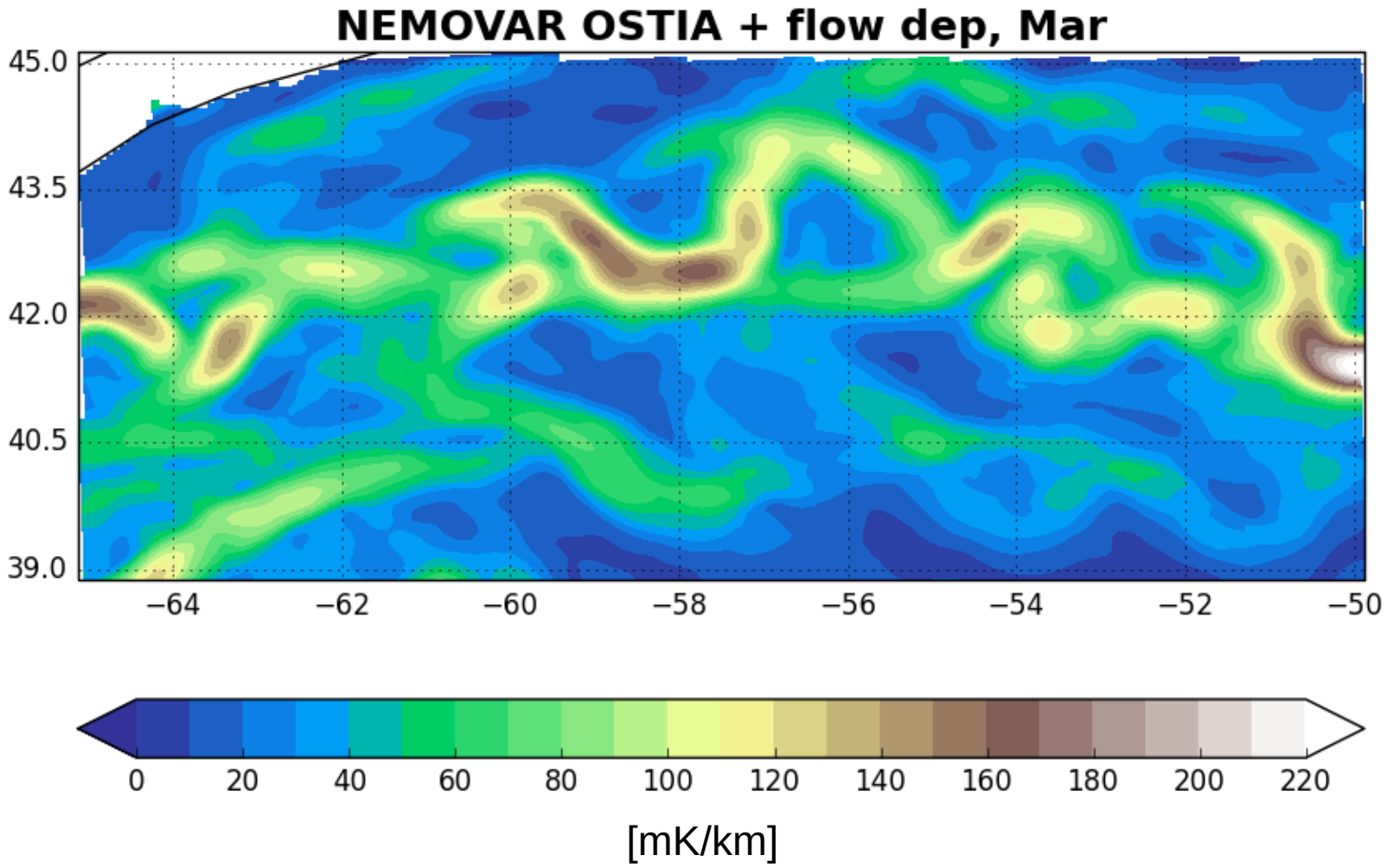
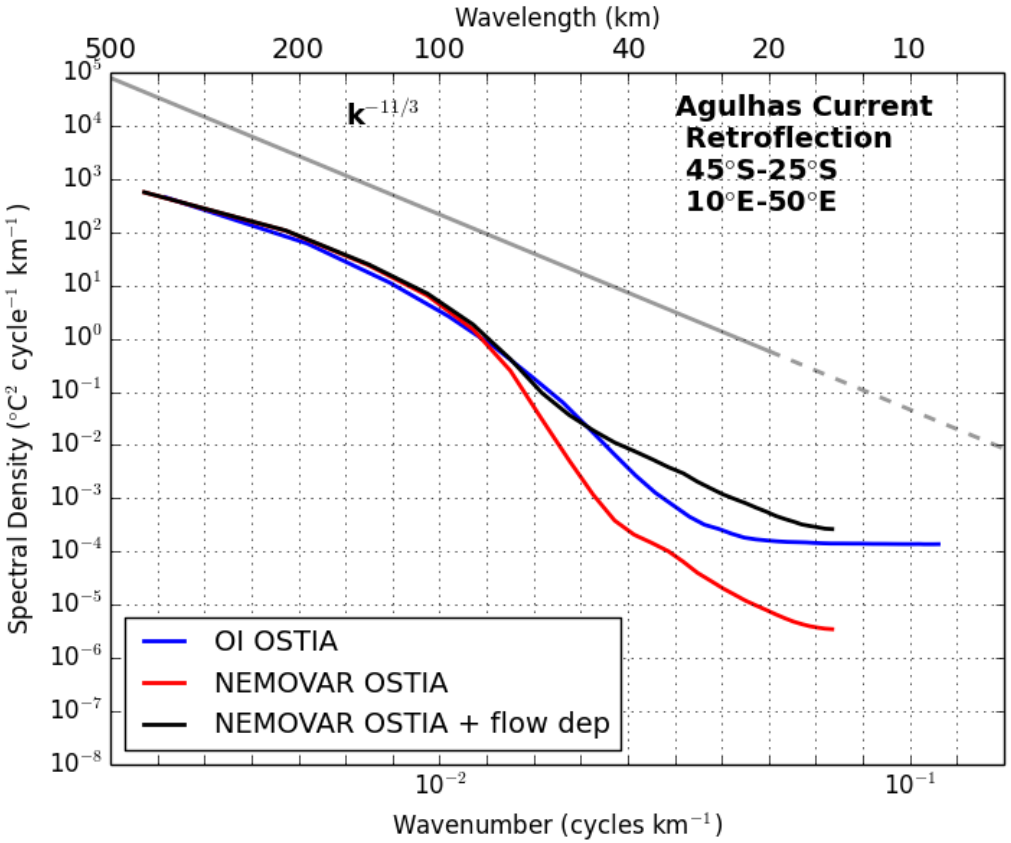


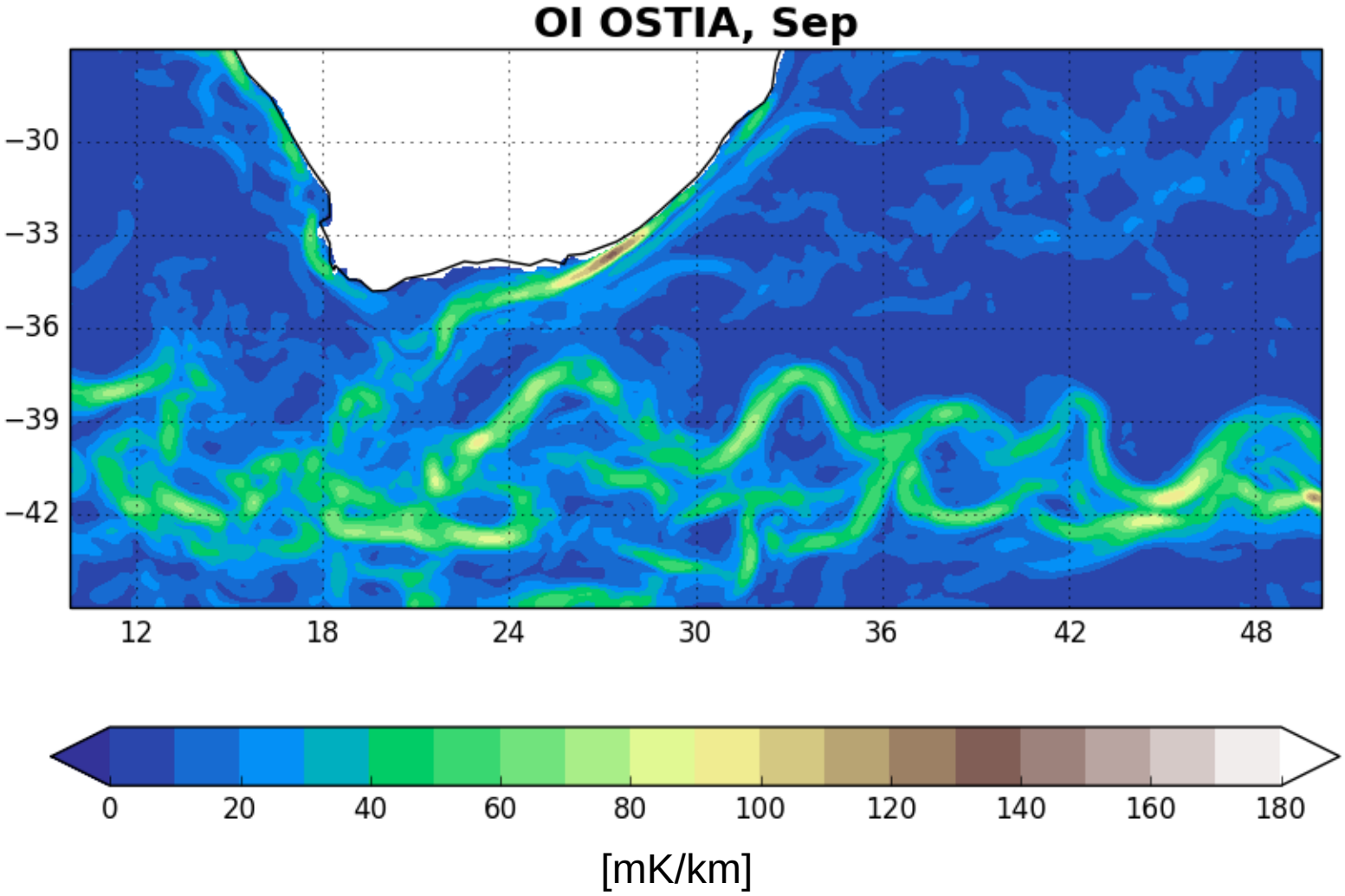
Improvements in feature resolution – Power Spectra

- Similar to the Gulf Stream, all three OSTIA runs agree well and follow the $k^{-11/3}$ power law between ~200 – 75 km and the slope is flatter than $k^{-11/3}$ for wavelength > 200 km
- The power spectrum for NEMOVAR OSTIA drops faster than the other two runs
- The flow dependent component increases the power spectrum for wavelengths shorter than 40 km

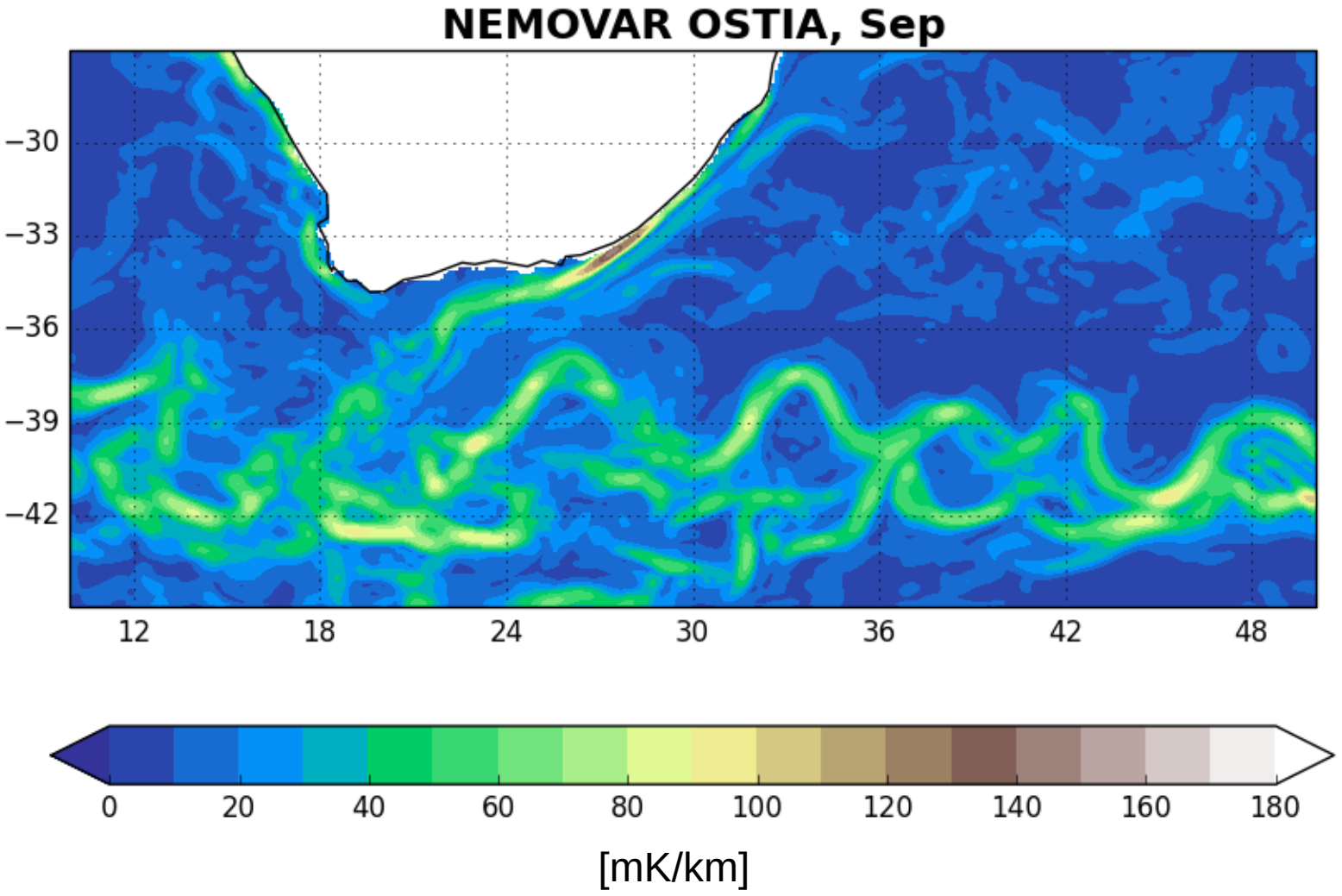


NEMOVAR with additional flow-dependent adjustment of background error covariance length scales captures the most power at shorter wavelengths compared to NEMOVAR OSTIA and OI OSTIA, without the introduction of spurious noise

Improvements in feature resolution – Horizontal Gradient



Improvements in feature resolution – Horizontal Gradient



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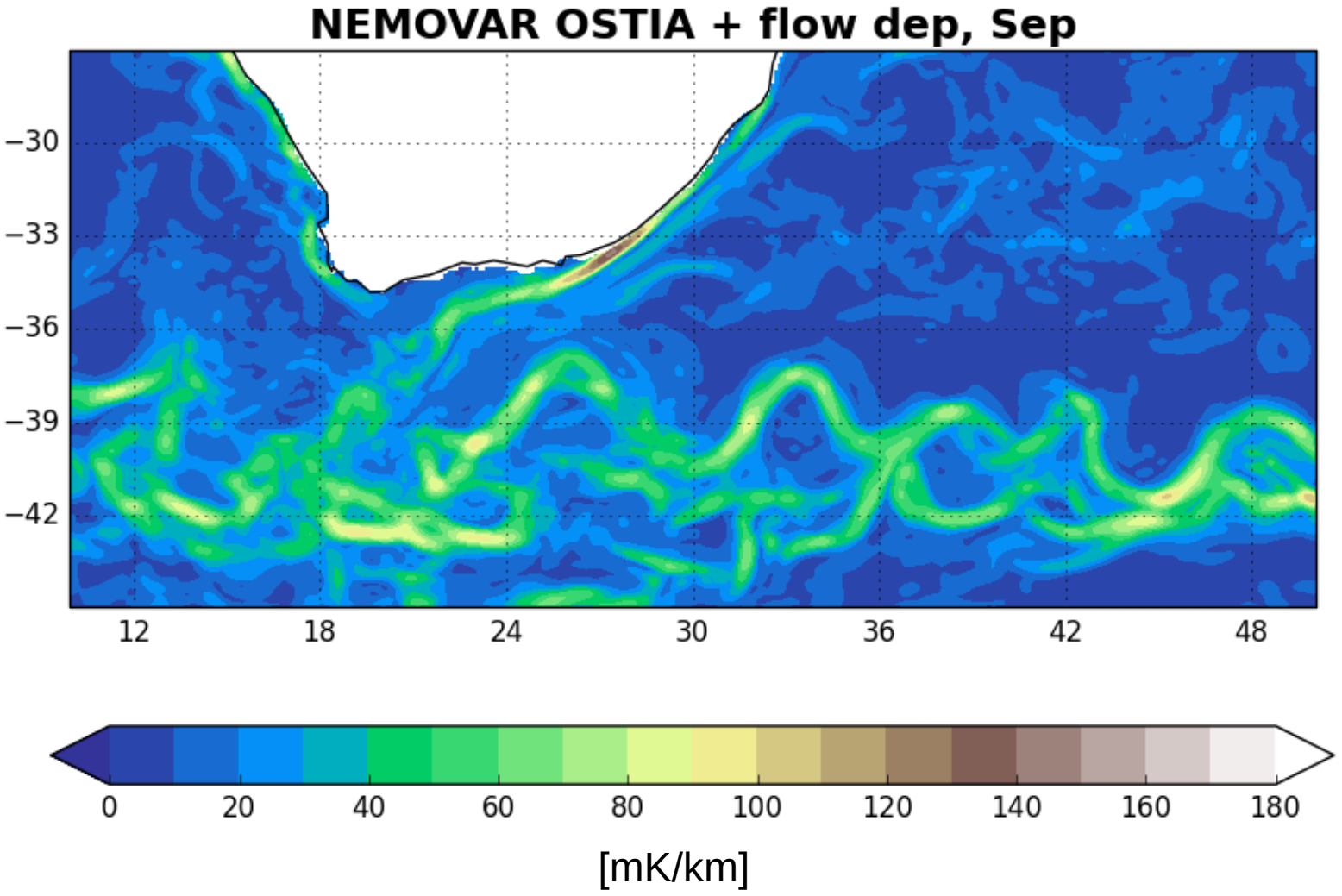
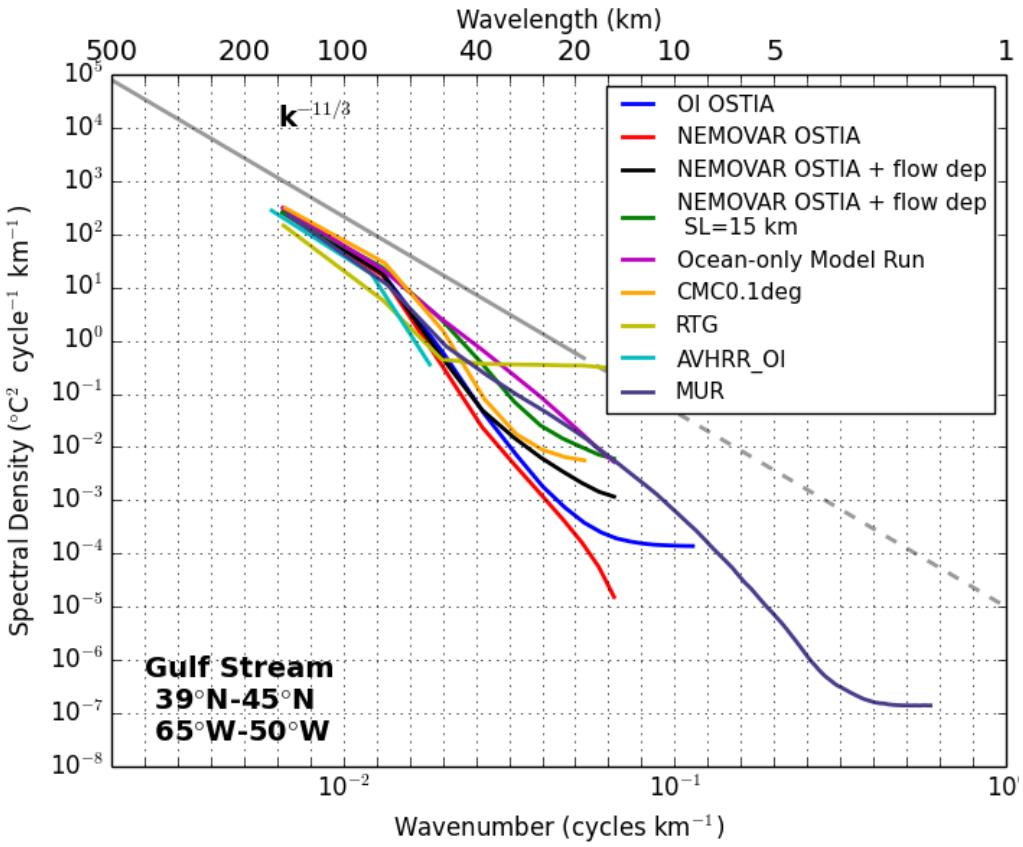


Improvements in feature resolution

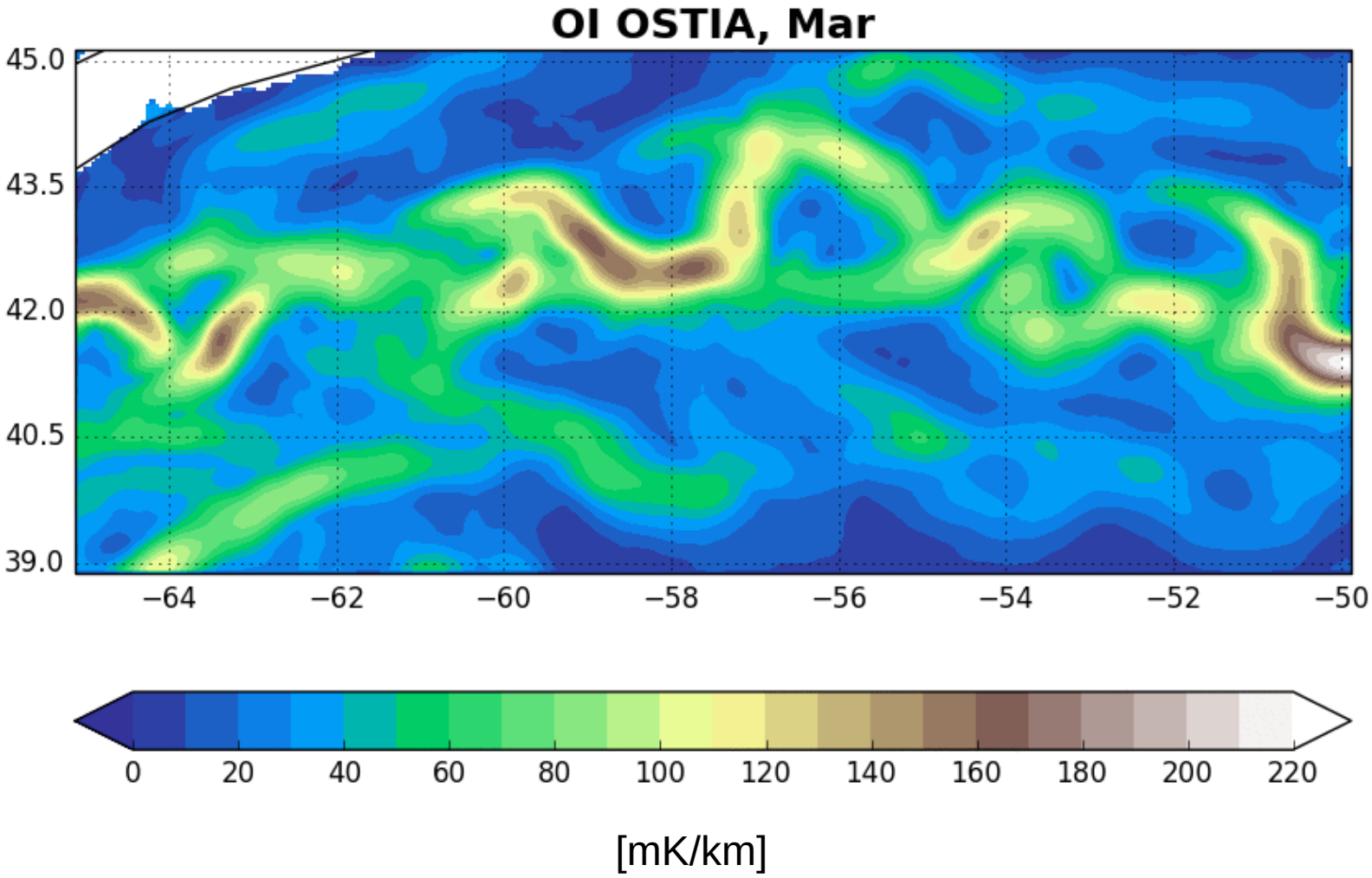
- The three OSTIA runs are then compared to other analyses:
  - NEMOVAR OSTIA + Flow dependent with shortest length set to 15 km
  - CMC 0.1º produced by the Canadian Meteorological Centre
  - Real Time Global (RTG) SST data from NCEP, produced on 0.5º grid
  - AVHRR_OI analysis
  - Multi-scale Ultra-high Resolution (MUR) SST data from JPL, on 1 km resolution
  - Ocean only model run with no observation assimilation on ORCA12 grid, data from the last year (1995) of a climatology run
- Spectral analysis is applied to all data on their original grid over the same region of interest as the three OSTIA runs
- Results shown here are September 2016 in ACR and March 2017 in GS region

Improvements in feature resolution

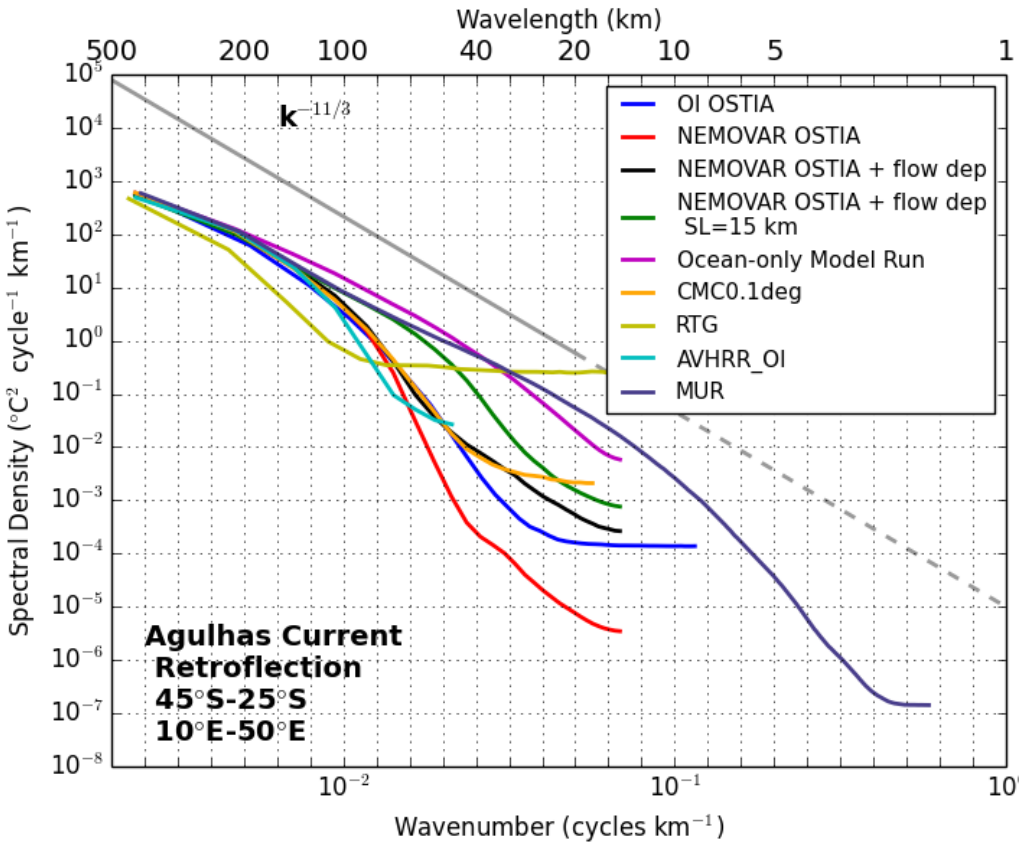


- For wavelength between ~65 km and ~150 km, all analyses except RTG show similar power spectra
- NEMOVAR + Flow Dependent with short length scale set to 15 km increase the power spectra at wavelengths below 40 km
- The model run has more power than the rest between wavelengths ~50 km – ~20 km
- The power spectrum for MUR follows $k^{-11/3}$ power law in GS for wavelength > 10 km, where it rolls off and flattens at ~5 km
- A flat power spectrum suggests noise in data, e. g. OI OSTIA at wavelengths < ~30 km

Improvements in feature resolution

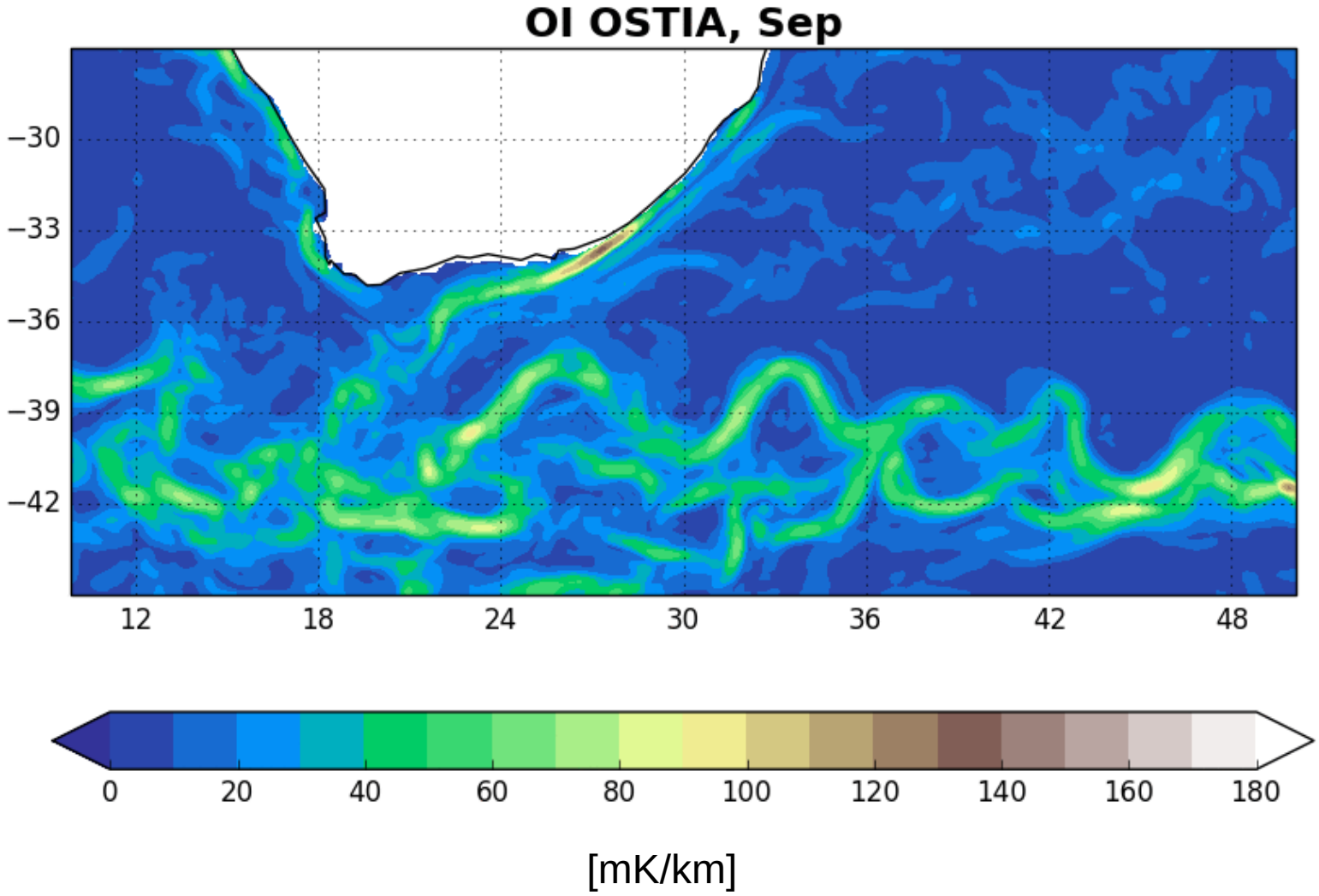


Improvements in feature resolution



- For wavelength above 100 km, all analyses except RTG show similar power spectra
- NEMOVAR + Flow Dependent with short length scale set to 15 km increases the power spectra between 40 – 100 km, which is close to that for the Ocean-only model run and MUR
- The power spectra for MUR and the Ocean-only model run are flatter than the $k^{-11/3}$ power law at wavelengths > 40 km, with model run having slightly higher power
- In both regions, AVHRR_OI does no reveal signals below 40 km

Improvements in feature resolution



Validation of NEMOVAR OSTIA: Argo

Comparison of OI OSTIA, NEMOVAR OSTIA and NEMOVAR OSTIA plus flow-dependent component (short length scale is set to 40 km) with independent near-surface Argo temperature observations. Results shown here are for the Global Ocean over the period of Jul – Sep 2016 and Jan – Mar 2017.

Analyses	Mean Diff, Argo – OSTIA (K)		Standard Deviation, Argo – OSTIA (K)		Num of Obs	
	Jul – Sep	Jan – Mar	Jul – Sep	Jan – Mar	Jul – Sep	Jan – Mar
OI	0.06	0.05	0.43	0.41	28832	30644
NEMOVAR	0.05	0.06	0.42	0.40		
NEMOVAR + FlowDep	0.05	0.06	0.42	0.40		

Compared to the OI OSTIA system, NEMOVAR OSTIA shows modest, but consistent global improvements using Argo as the validation reference.

Validation of NEMOVAR OSTIA: NWP trials

OSTIA is used as a boundary condition for NWP (Numerical Weather Prediction). Tests demonstrate that NEMOVAR OSTIA with flow-dependence improves NWP compared to the OI OSTIA analysis, particularly for longer range forecasts. This is most likely due to improvements in SST feature resolution. Results shown here are for July – September 2016

NWP Index	Compared to observations (NEMOVAR OSTIA+flow dep minus OI OSTIA)	Compared to analyses (NEMOVAR OSTIA+flow dep minus OI OSTIA)	Compared to observations (NEMOVAR OSTIA minus OI OSTIA)	Compared to analyses (NEMOVAR OSTIA minus OI OSTIA)
Global NWP Index change (RMS % change)	0.29 (0.29%)	0.40 (0.31%)	0.13 (0.13%)	0.25 (0.20%)

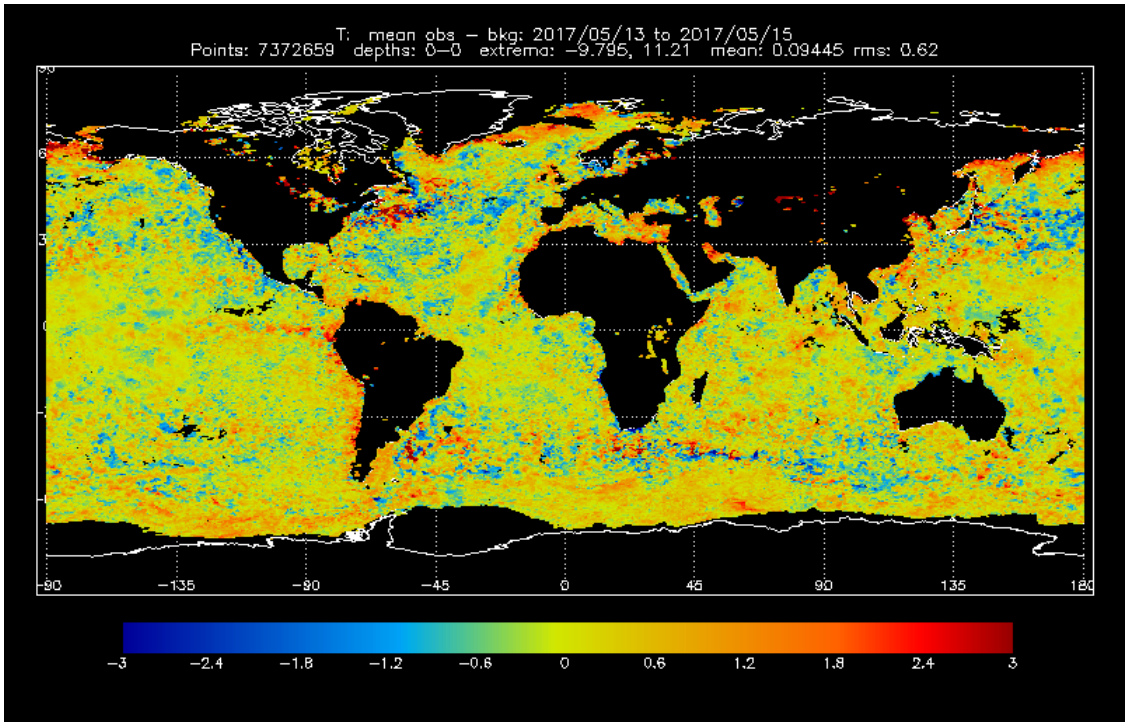
The typical total annual improvement in NWP index is ~1.0-2.0. Note that results can be very dependent on time period investigated.

Conclusions

- The NEMOVAR OSTIA system demonstrates modest improvements in accuracy compared to the OI system, but improved feature resolution. It improves NWP performance, particularly when using a flow-dependent component for the background error covariance length scales
- The latest NEMOVAR OSTIA system with short length scale set to 15 km improves the power spectrum of the analysis, especially for wavelengths between 40 – 100 km
- The spectral analysis suggests that the dominating signal in the Gulf Stream and Agulhas Current Retroflection regions follow the $k^{-11/3}$ power law at wavelengths over 100 km, demonstrating surface quasi-geostrophic (SQG) turbulence
- Further study is required to understand the power spectra at shorter wavelengths

SLSTR in NEMOVAR OSTIA

- Quality Level in the files seemed to be fixed around 16 May 2017
  - Lead to significant improvement of SLSTR field and SST analysis, especially for RMS
- 5º C background check against the OI OSTIA analysis from previous day
- Loses half of the tracks from 17 May 2017, seems to be related to the QL fix



- Analysis date: 20170514
- Mean Difference (Obs-Bkg): 0.09
- RMS (Obs-Bkg): 0.62

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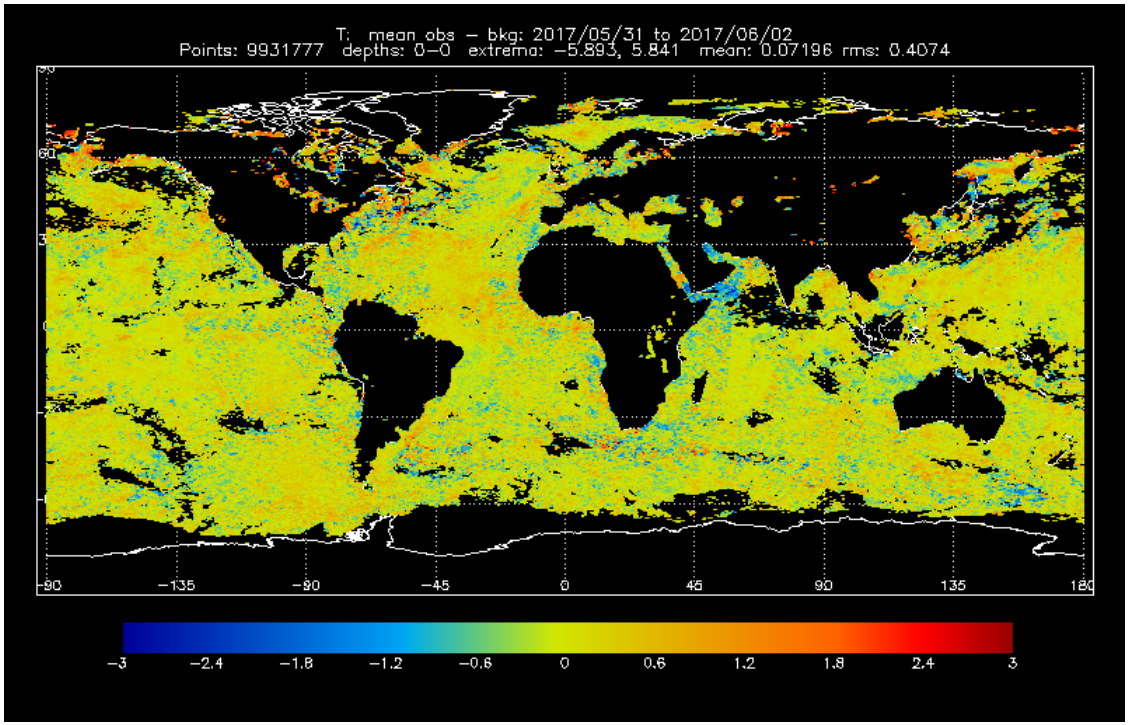

- Analysis date: 20170601
- Mean Difference (Obs-Bkg): 0.07
- RMS (Obs-Bkg): 0.41

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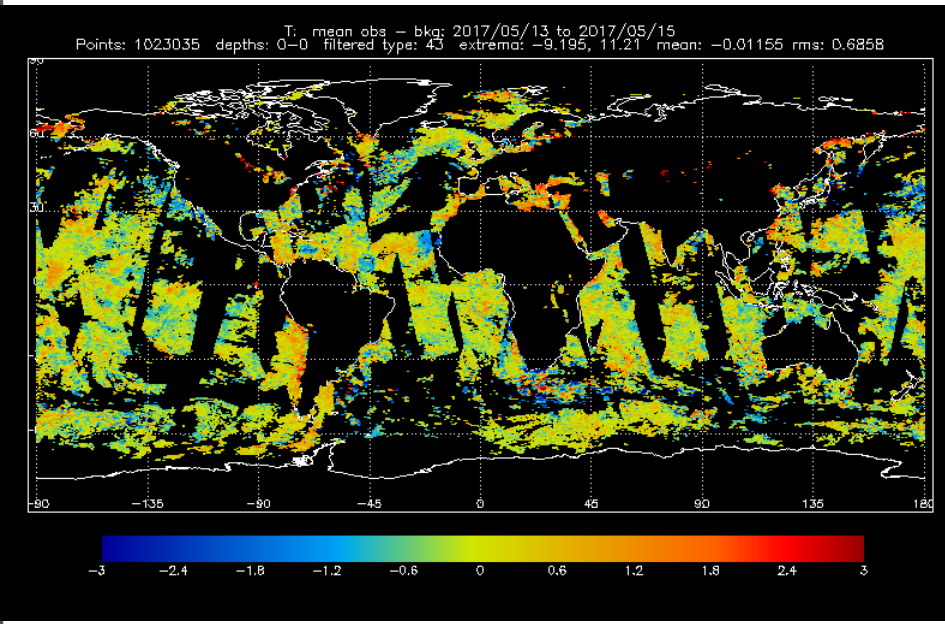
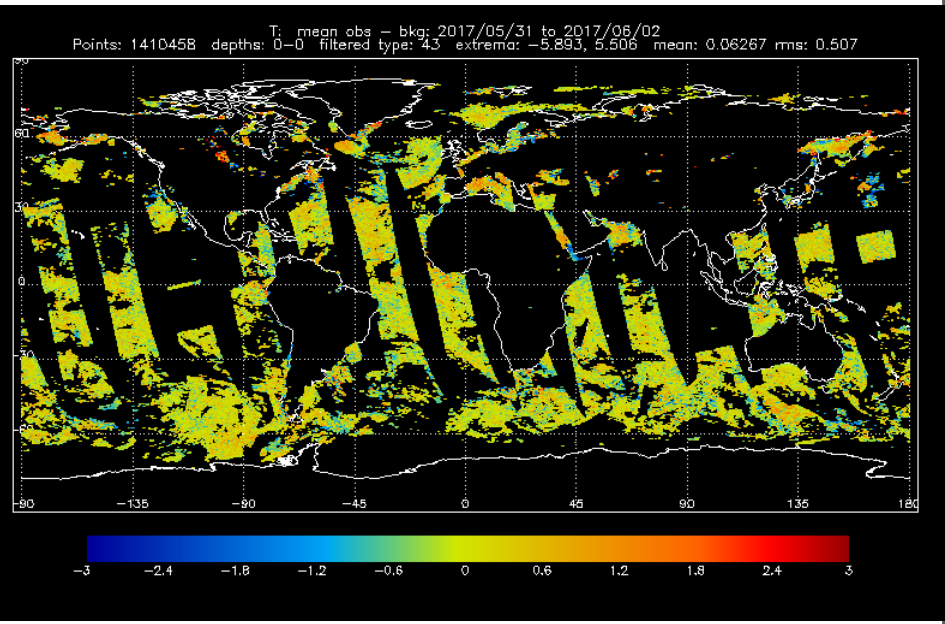


Analysis date 20170601



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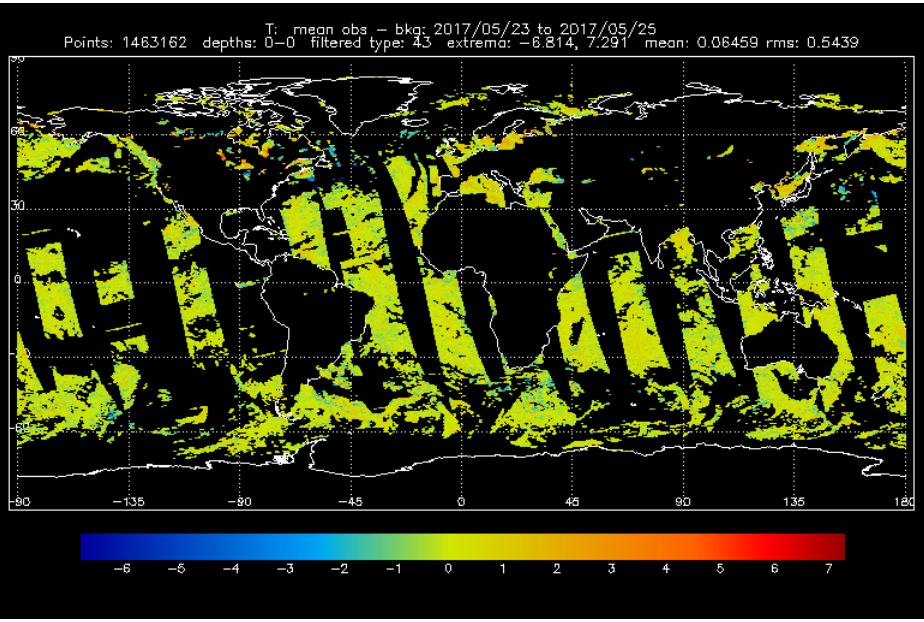
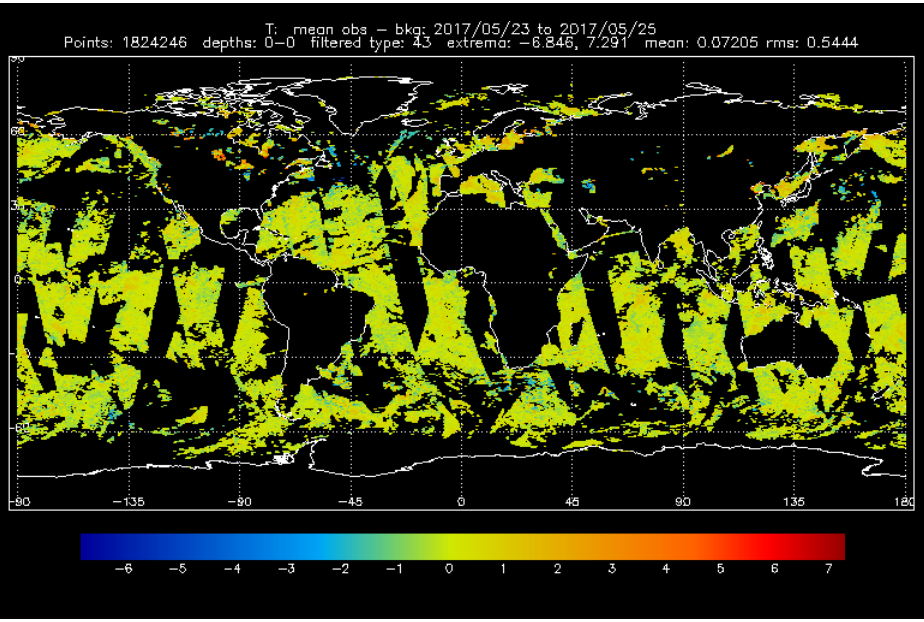
Control (Ingest QL 4+)



Ingest QL 2+



Met Office

Questions?