Submesoscale Impacts on Mesoscale Agulhas Dynamics

René Schubert¹, Franziska U. Schwarzkopf¹, Burkard Baschek², Jonathan Gula³, Richard J. Greatbatch¹, Willi Rath¹ and Arne Biastoch¹

¹) GEOMAR
   Helmholtz Center for Ocean Research
   Kiel, Germany

²) HZG
   Helmholtz Center for Materials and Coastal Research
   Geesthacht, Germany

³) LOPS
   Laboratoire d'Océanographie Physique et Spatial
   Brest, France
Which impact do Submesoscale Dynamics have on Mesoscale Agulhas Dynamics?

Submesoscale dynamics drive a strong lateral exchange of Agulhas rings with their surrounding. ([Capuano et al. (2018), Sinha et al. (2019)])

What is their impact on the dynamics of the large mesoscale eddies?
The Model Configurations
(integrated 2010 – 2017 from the same 30 year spin-up)

1/4°
1/20°
~4.5 km

TVD/VI advection schemes
+ explicit diffusion
The Model Configurations
(integrated 2010 – 2017 from the same 30 year spin-up)

TVD/VI advection schemes + explicit diffusion

UBS advection schemes no explicit diffusion

INALT20_noSMS

Sep 9th, 2012

INALT20

1/4°

1/20°

~4.5 km
The Model Configurations
(integrated 2010 – 2017 from the same 30 year spin-up)

TVD/VI advection schemes
+explicit diffusion

UBS advection schemes
no explicit diffusion

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Mar 9th, 2012

INALT20_noSMS
INALT20
INALT60
The Model Configurations
(integrated 2010 – 2017 from the same 30 year spin-up)
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How can we validate the submesoscale dynamics?

Sep 9th, 2012
How can we validate the submesoscale dynamics?

Time-Mean **SST** Spectra from MODIS Swaths!

![Image of SST Spectra and resolution comparison]

1.0 km resolution

1.5 km resolution

**Effective resolutions**

8 km

25 km

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How can we validate the mesoscale dynamics?
Time-Mean SSH Spectra from JASON-2 tracks!
Time-Mean **SSH** Spectral Slope $n$ for $k^{-n}$ (79 – 150 km)

**INALT20_noSMS**

**INALT20**

**INALT60**

Surface Quasi-Geostrophy

Interior Quasi-Geostrophy

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SSH-based Eddy Detection following Chelton et al. (2011)

Anticyclones

Cyclones

Scale of the eddies ~ diameter of a circle with the same area
The improvements can be mainly attributed to a strengthening of the eddies.

**Anticyclones**

| Category | 20 cm < $A_{max}$ | 7 cm < $A_{max}$ < 20 cm | 1 cm < $A_{max}$ < 7 cm | All |
|----------|-------------------|--------------------------|--------------------------|-----|
| weak     | 2.5               | 2.2                      | 4.1                      | 8.8 |
| medium   | 1.8               | 2.8                      | 4.1                      | 8.7 |
| strong   | 2.1               | 3.3                      | 7.1                      | 9.1 |

**Cyclones**

| Category | 20 cm < $A_{max}$ | 7 cm < $A_{max}$ < 20 cm | 1 cm < $A_{max}$ < 7 cm | All |
|----------|-------------------|--------------------------|--------------------------|-----|
| weak     | 0.2               | 2.6                      | 5.7                      | 8.4 |
| medium   | 0.5               | 3.6                      | 5.2                      | 9.2 |
| strong   | 1.1               | 4.5                      | 3.8                      | 9.4 |

MAR 13, 2019 | René Schubert | Schubert et al. 2019 (in prep.)
In particular large amplitude cyclones are much better represented in INALT60.
Spatially Filtering the Navier-Stokes Equations

\[
\tilde{f}_\ell(x) = G_\ell \ast f
\]

\[
f'_\ell(x) = f(x) - \tilde{f}_\ell(x)
\]

Leonard (1974), Germano (1992)
Eyink & Aluie (2009)
Aluie et al. (2018)
Spatially Filtering the Navier-Stokes Equations

\[ \bar{f}_\ell(x) = G_\ell \ast f \]

\[ f'_\ell(x) = f(x) - \bar{f}_\ell(x) \]

Leonard (1974), Germano (1992), Eyink & Aluie (2009), Aluie et al. (2018)

\[ G_\ell \]

Circular-Shaped

2D-Running Mean

\[ l = 45 \text{ km} \]

KE Budget for Scales > \( l \)

\[ ET(x, t, l) = -\rho_0 \left[ \overline{u_x(u^2 - \bar{u}^2)} + \right. \]

\[ \left. (\overline{u_y + \bar{v}_x}) (\bar{u}\bar{v} - \overline{u\bar{v}}) + \overline{\bar{v}_y} (\bar{v}^2 - \overline{\bar{v}^2}) \right] \]
Seven times more kinetic energy transfer into the mesoscales

Mean Surface Energy Transfer 2012-2017 in mW/m³ at 100 km Scales
Seven times more kinetic energy transfer into the mesoscales.

Mean Surface Energy Transfer 2012-2017 in mW/m³ at 100 km Scales

- INALT20_noSMS
- INALT20
- INALT60

Graph showing the mean surface energy transfer with various scales and data points.
Seasonality of the energy transfer and its scale of change to upscale transfer

Surface Energy Transfer in mW/m³

Scale of Change to Upscale Transfer in km
Seasonality of the energy transfer and its scale of change to upscale transfer
Seasonality of the energy transfer and its scale of change to upscale transfer

Scale of Change to Upscale Transfer (JAS mean) in km

Kinetic Energy Spectral Slope

Scale of Change to Upscale Transfer in km

Eff. Res. INALT20 (25 km)
Eff. Res. INALT60 (8 km)
Conclusion

The representation of mesoscale eddies in the Agulhas ring path improves strongly with the resolution of submesoscale flows -

![Graph showing SSH Spectra in the Agulhas Ring Path](image_url)

Mesoscale eddies are found to strengthen - in particular the cyclones.

*Submesoscale Impacts on Mesoscale Agulhas Dynamics*  
Ocean Modelling, soon
Conclusion

The representation of mesoscale eddies in the Agulhas ring path improves strongly with the resolution of submesoscale flows -

Submesoscale Impacts on Mesoscale Agulhas Dynamics
Ocean Modelling, soon

The gap to the observations might be closed due to the full resolution of the upscale energy cascade.

Scale Energy Transfer in the Greater Agulhas region
in preparation

Mesoscale eddies are found to strengthen - in particular the cyclones.