How to choose the vertical resolution for ocean models

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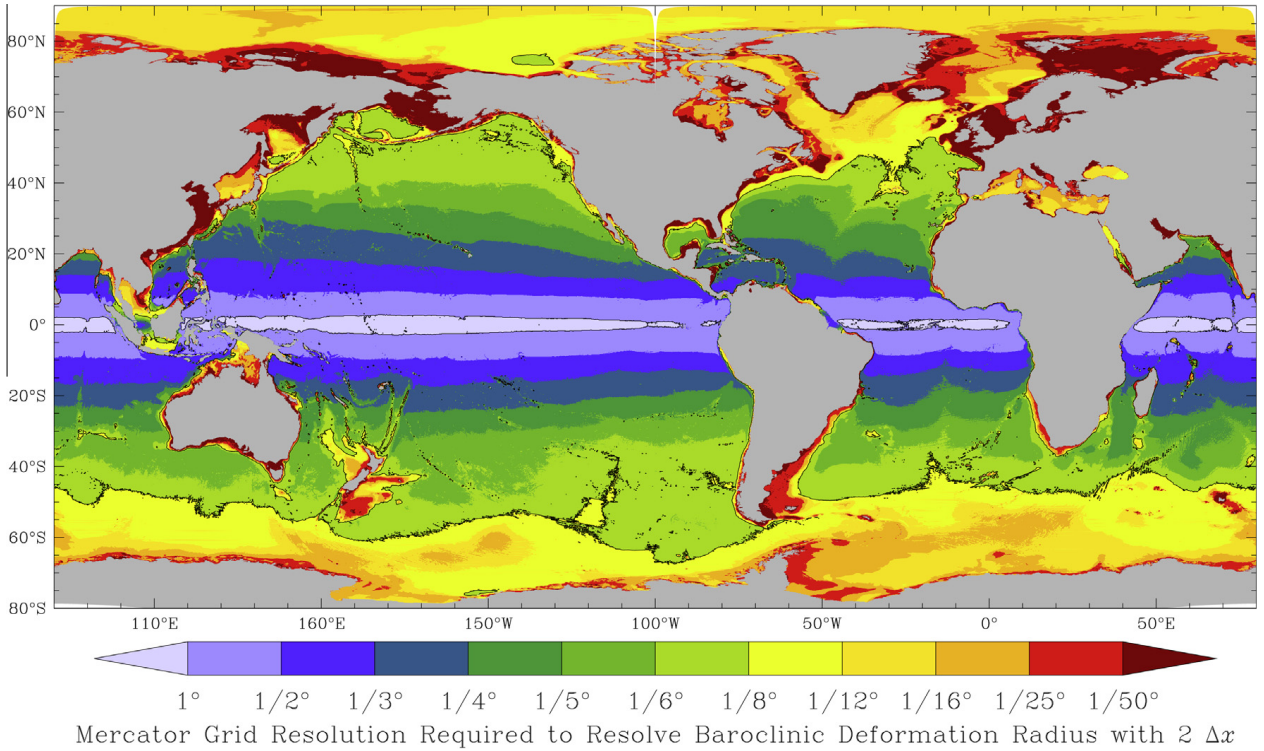
Australian National University

ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE

Motivation:
Horizontal resolution required to resolve* deformation radius of 1st baroclinic mode



***deformation radius L_{def} > 2Δx**

$$L_{def} = \sqrt{\frac{c_m^2}{(f^2 + 2\beta c_m)}}$$

Fig. 1. The horizontal resolution needed to resolve the first baroclinic deformation radius with two grid points, based on a 1/8° model on a Mercator grid (Adcroft et al., 2010) on Jan. 1 after one year of spinup from climatology. (In the deep ocean the seasonal cycle of the deformation radius is weak, but it can be strong on continental shelves.) This model uses a bipolar Arctic cap north of 65°N. The solid line shows the contour where the deformation radius is resolved with two grid points at 1° and 1/8° resolutions.

Hallberg (2013) *Ocean Modelling*

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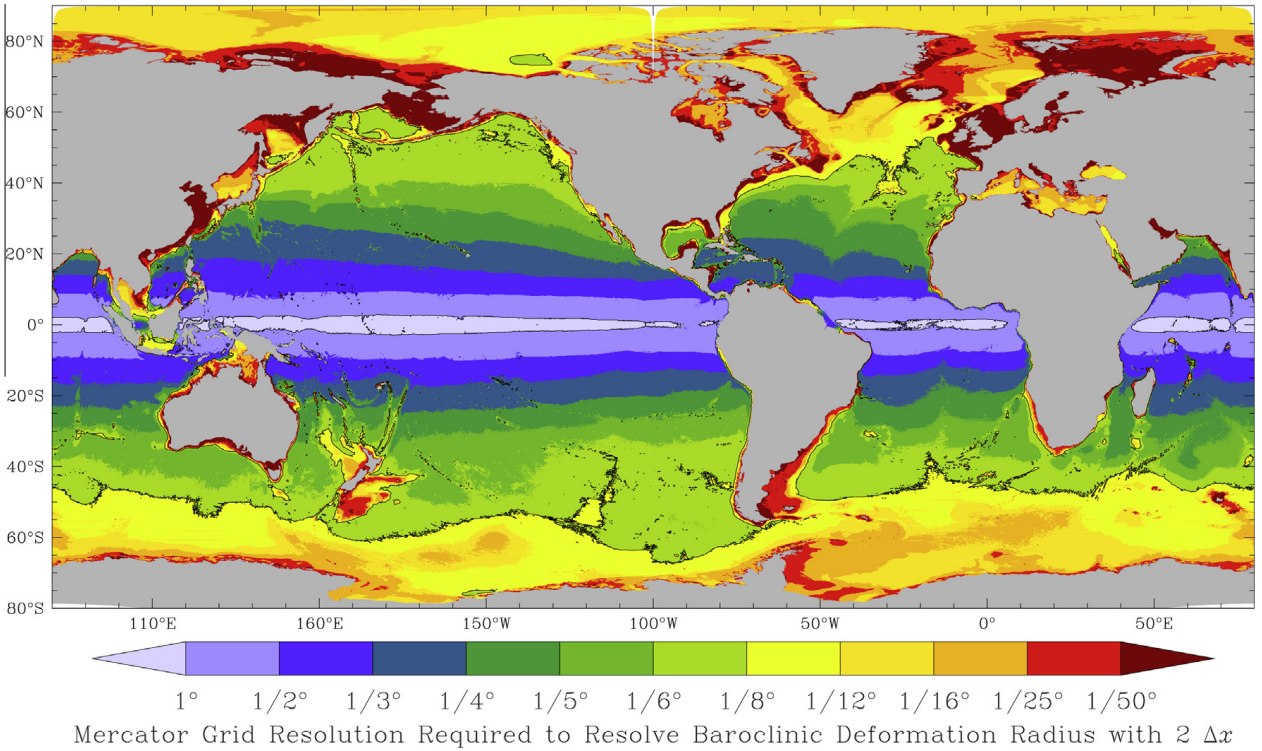

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Questions:

What vertical resolution is required for a z*-coordinate model to resolve* xth baroclinic mode?

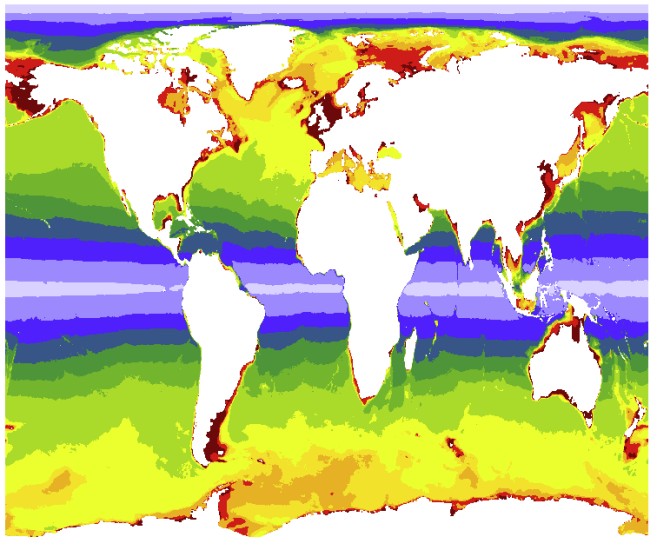
How can we quantify this?

Hallberg (2013) *Ocean Modelling*

What does it mean to resolve* a baroclinic mode vertically?

Capture the vertical structure of the horizontal flows

BC1 resolution (deg.)



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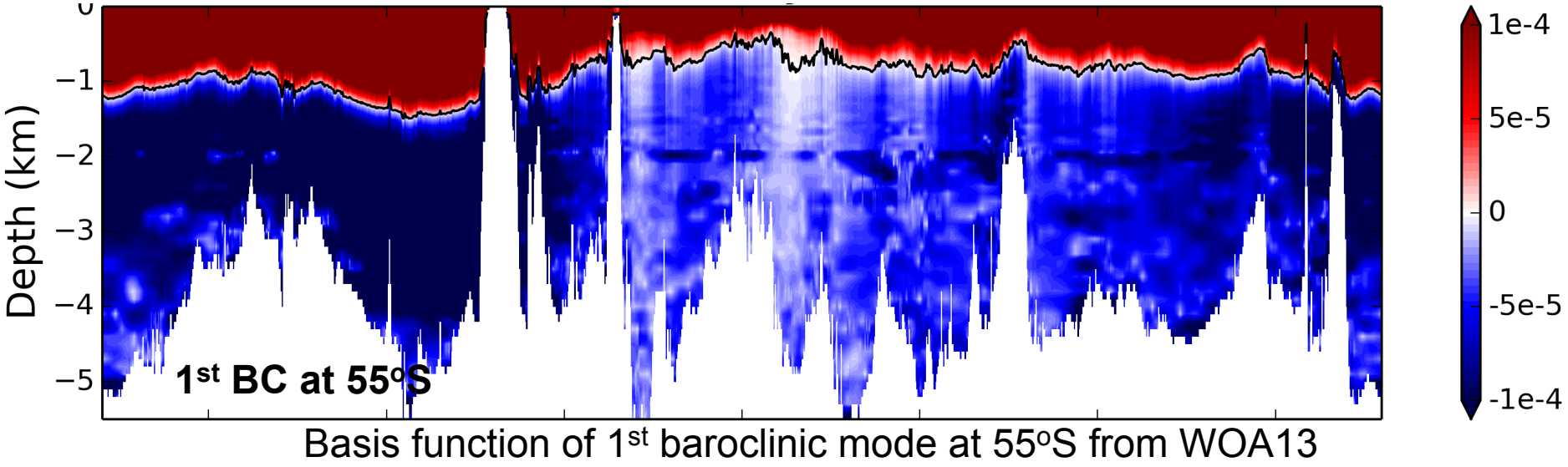

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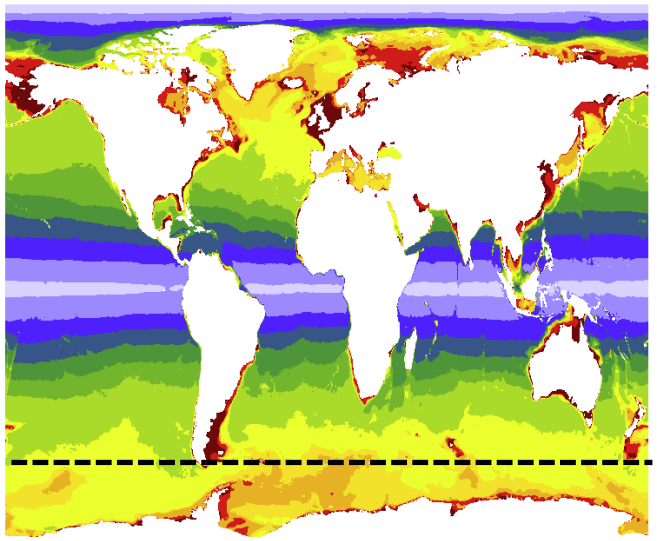

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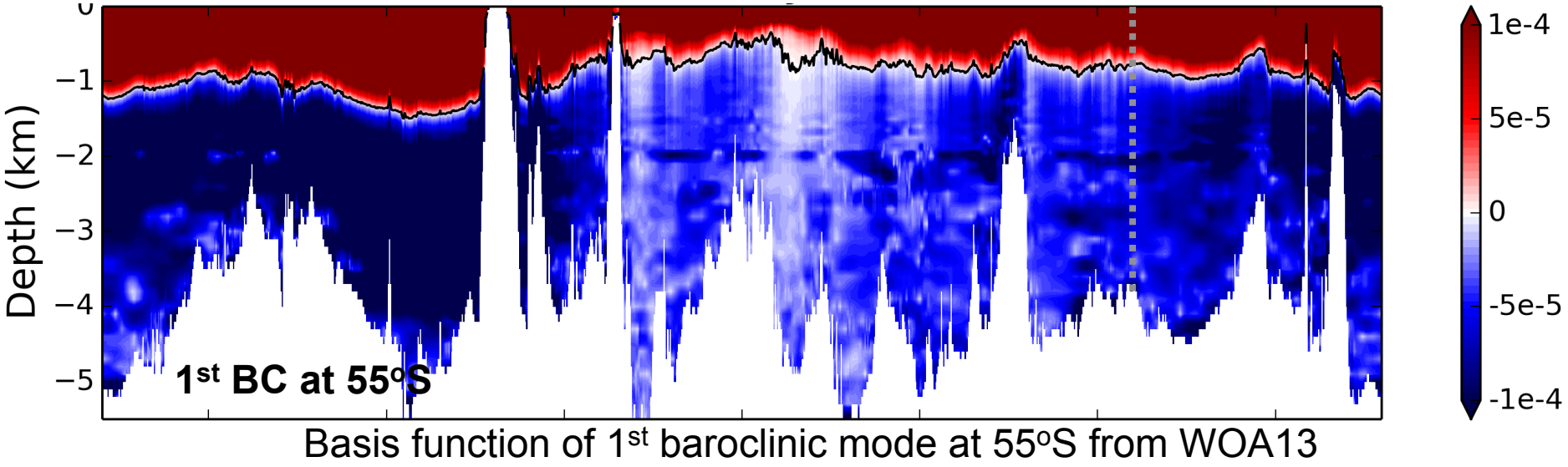

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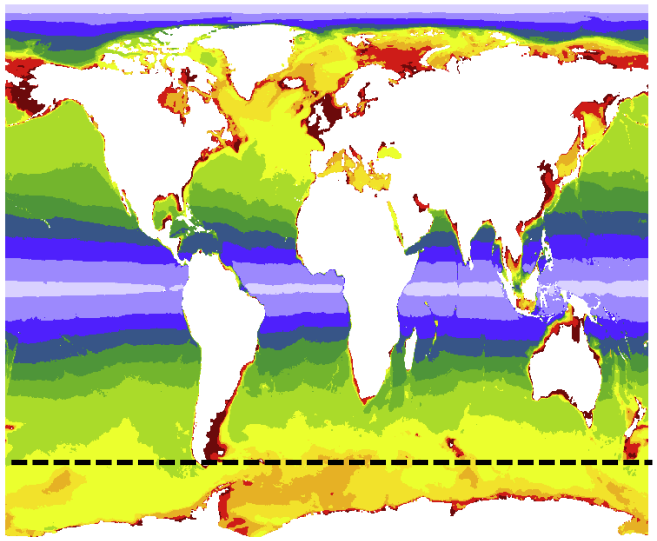

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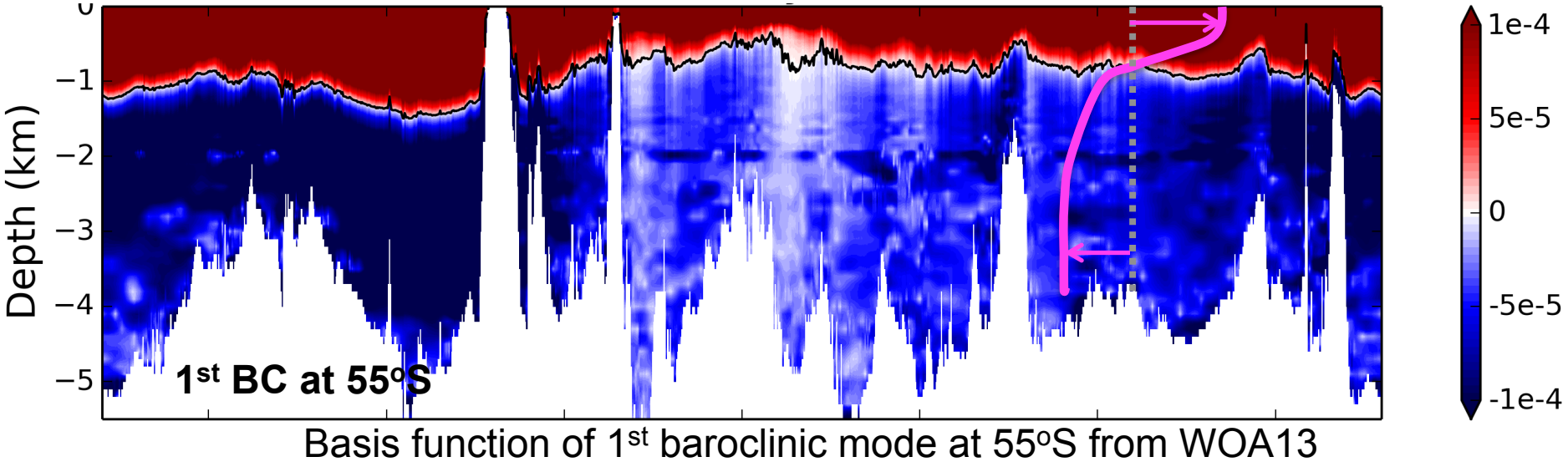

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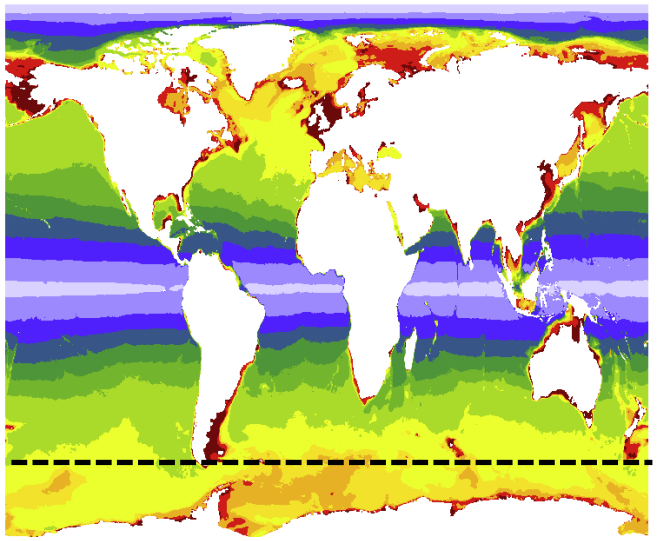

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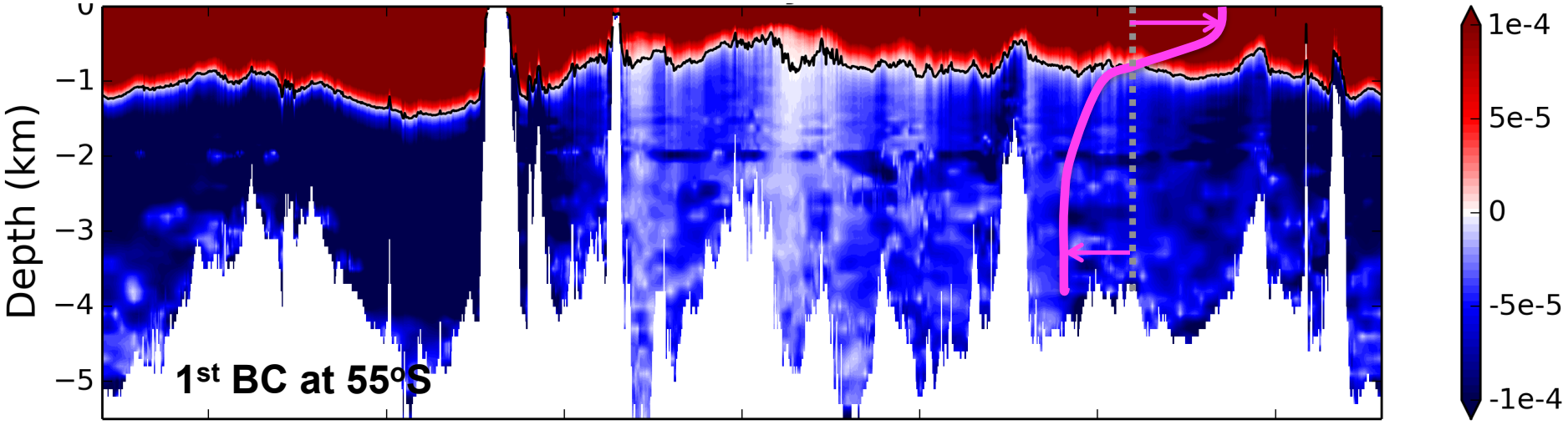

Basis function of 1st baroclinic mode at 55°S from WOA13

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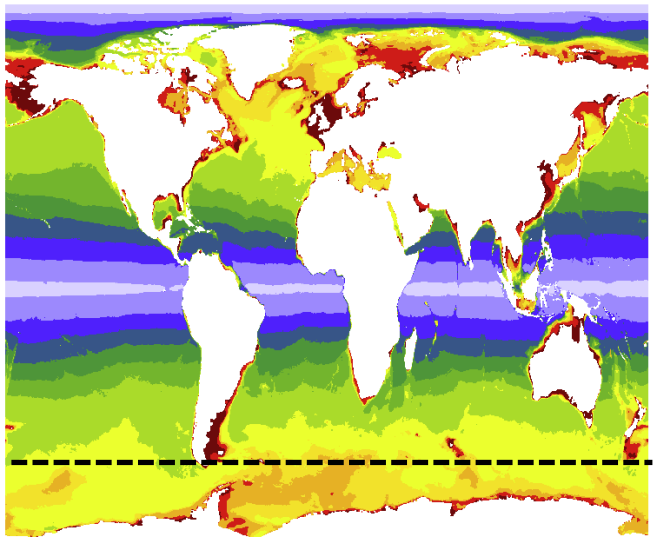

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-peaks & troughs
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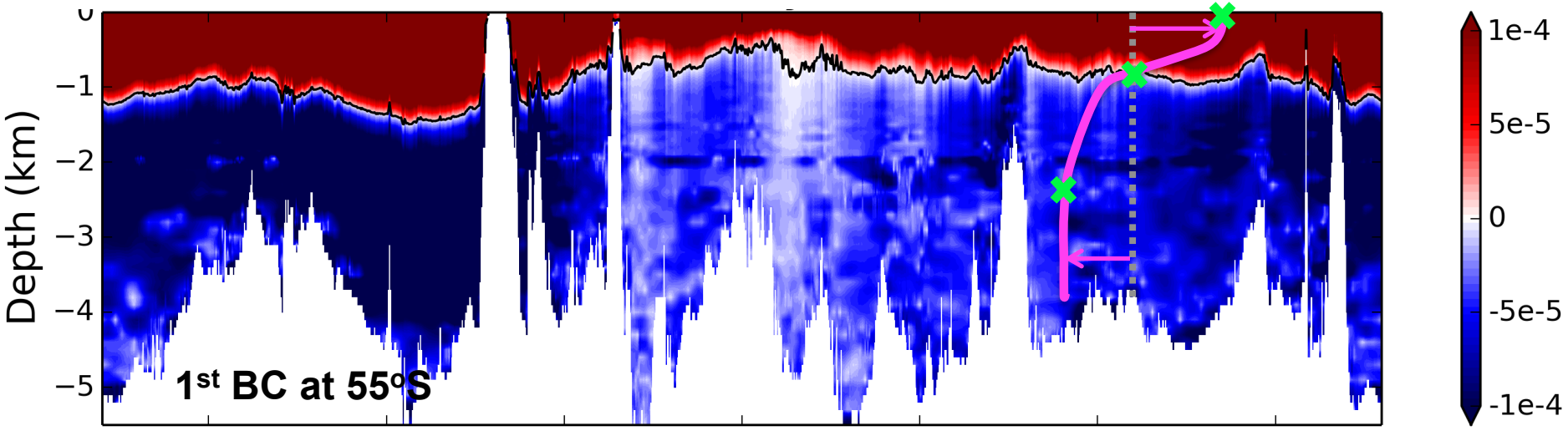

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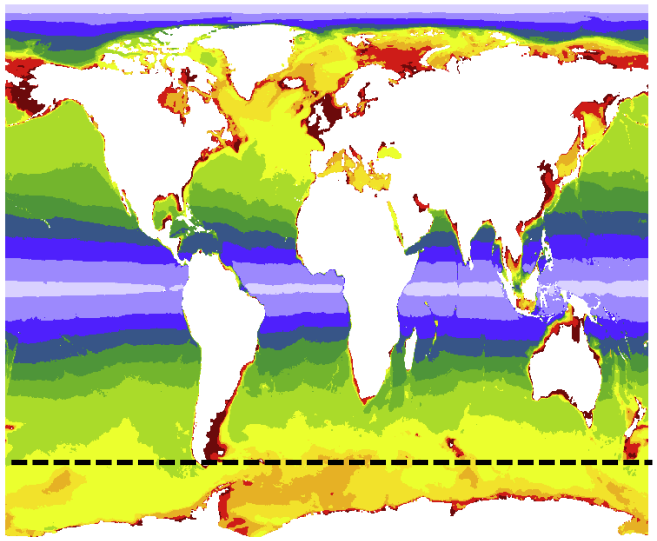

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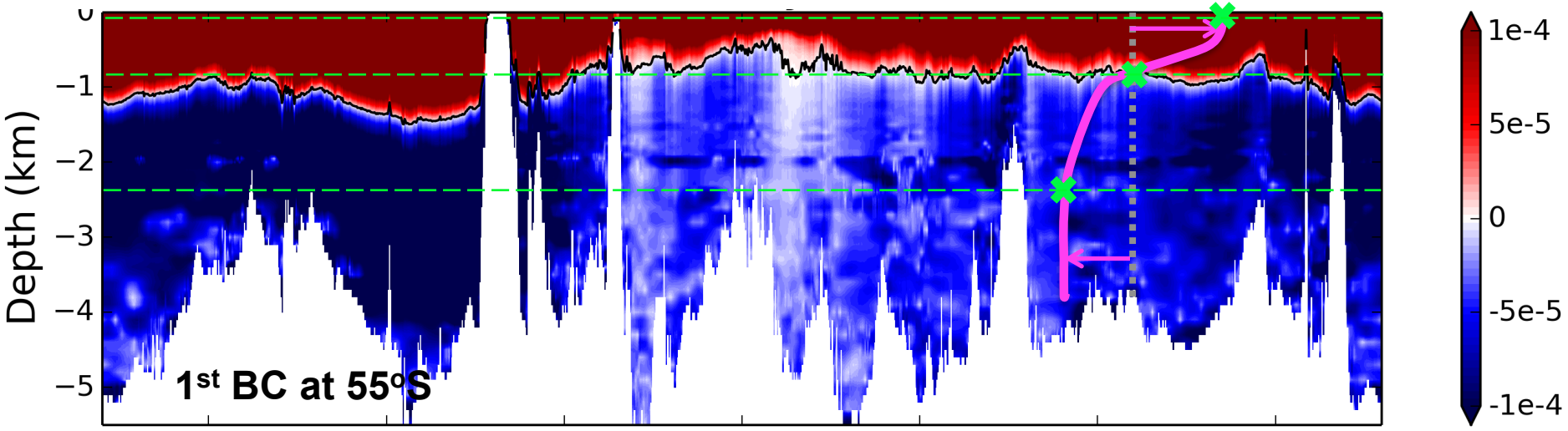

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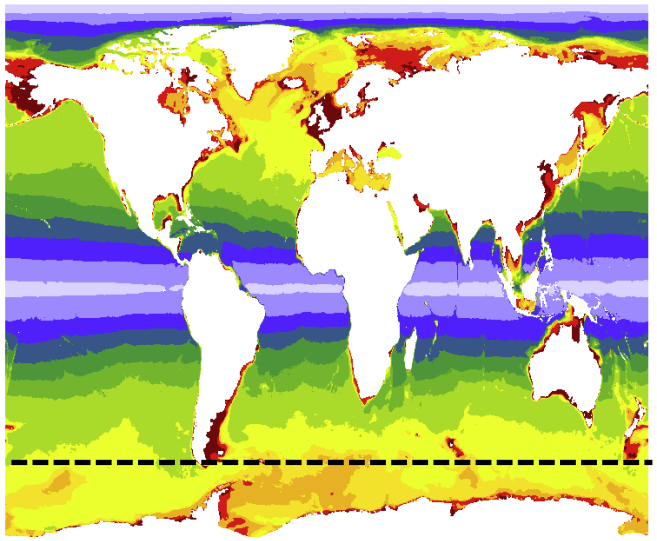

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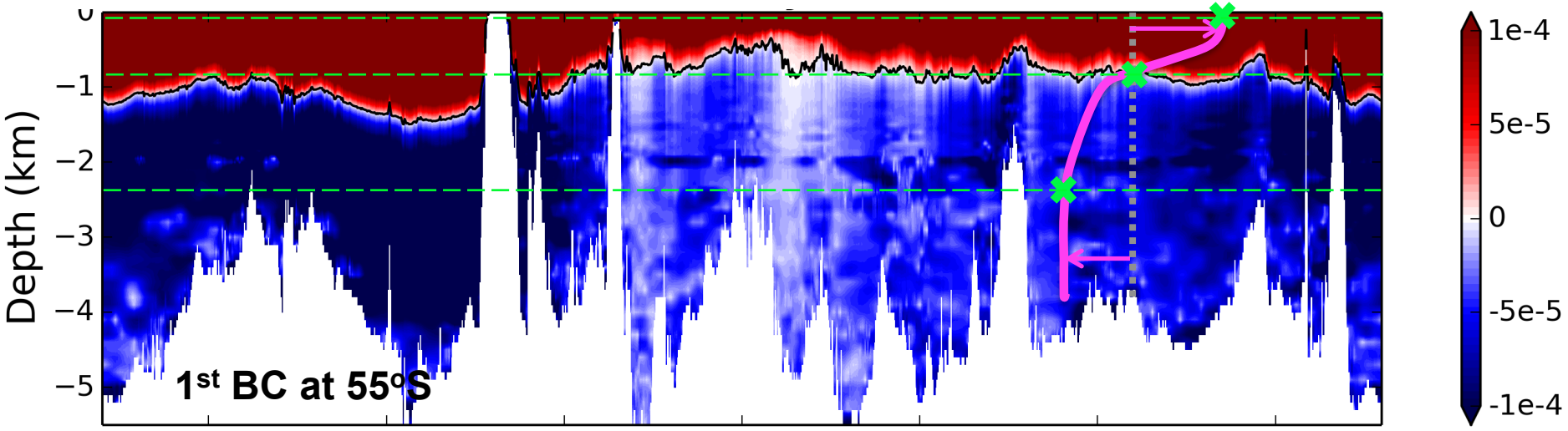

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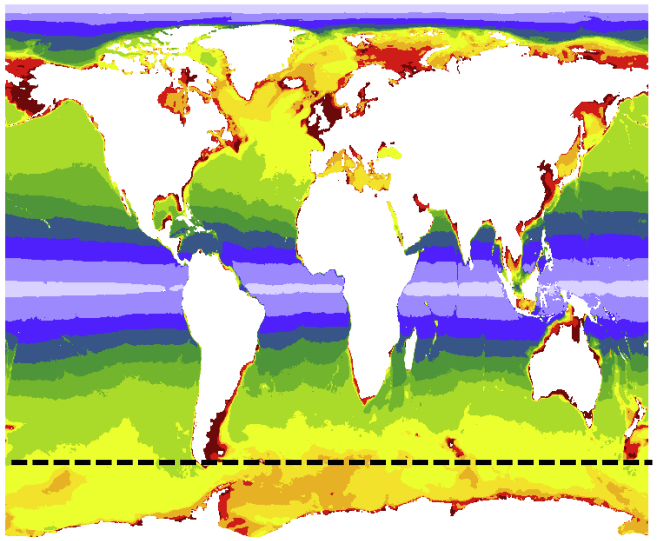

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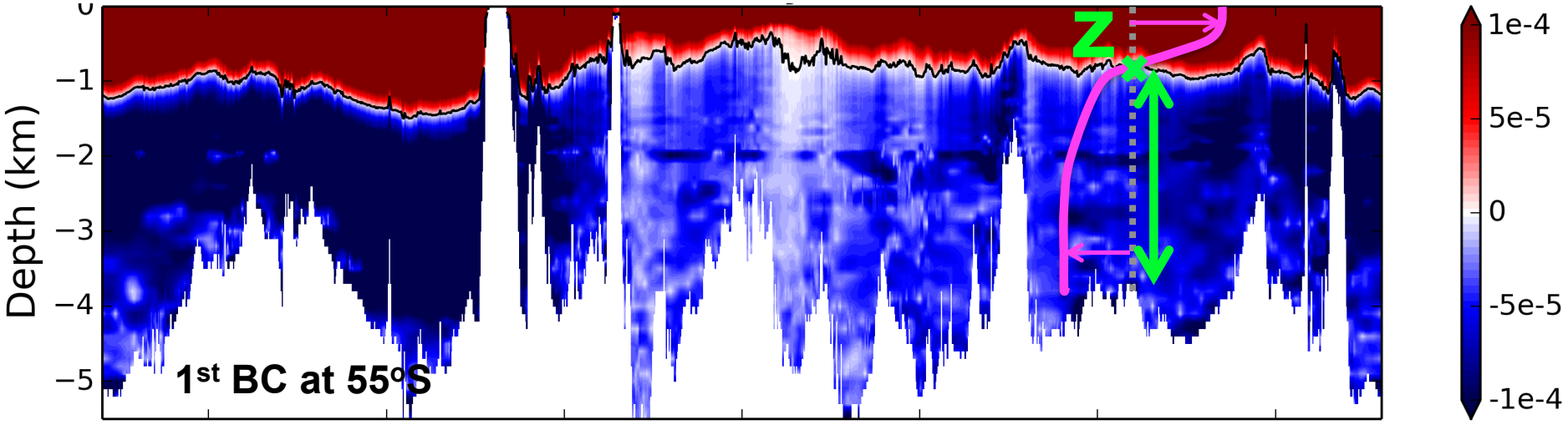

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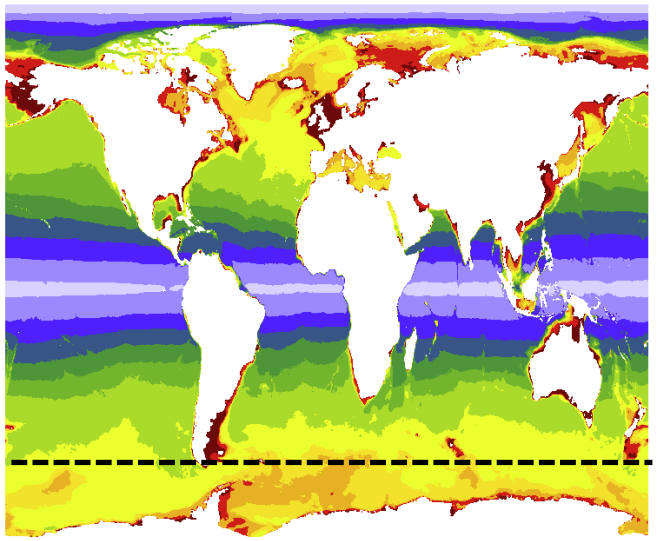

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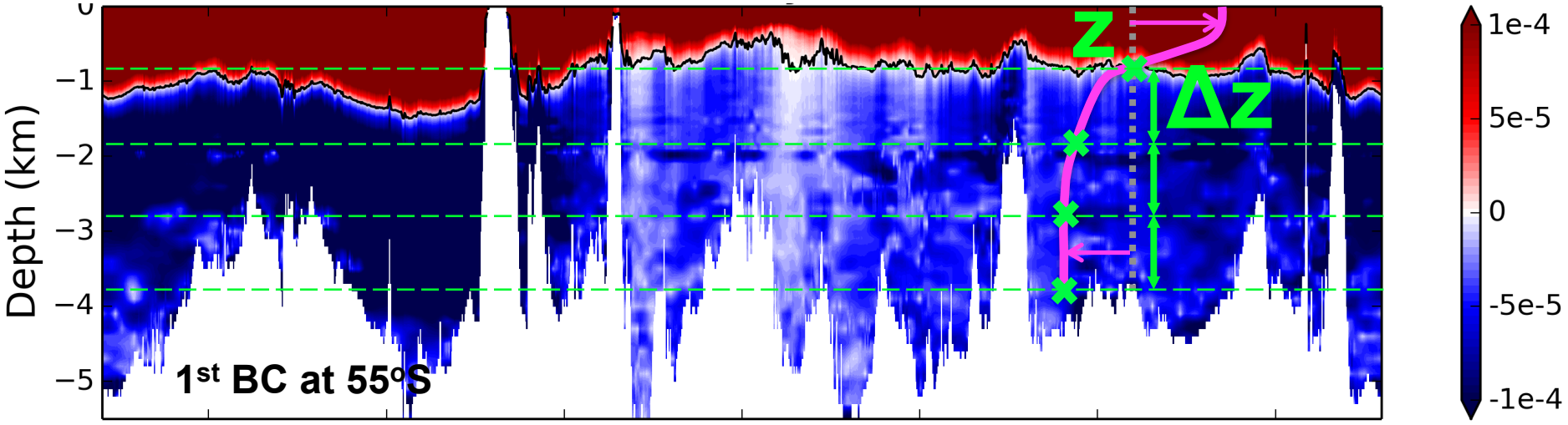

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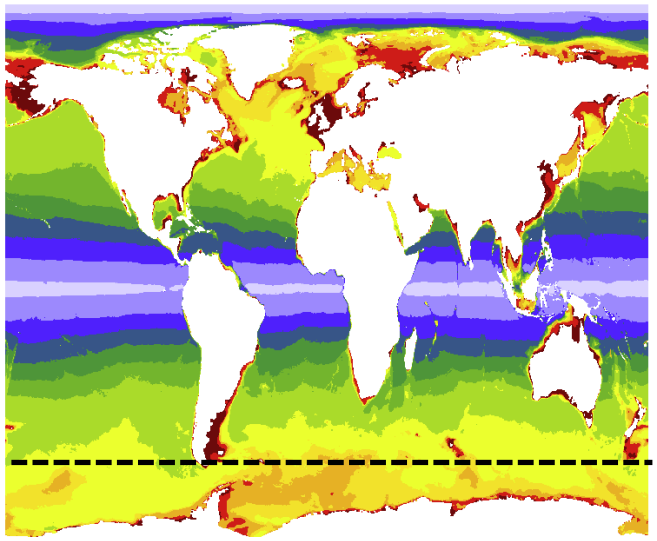

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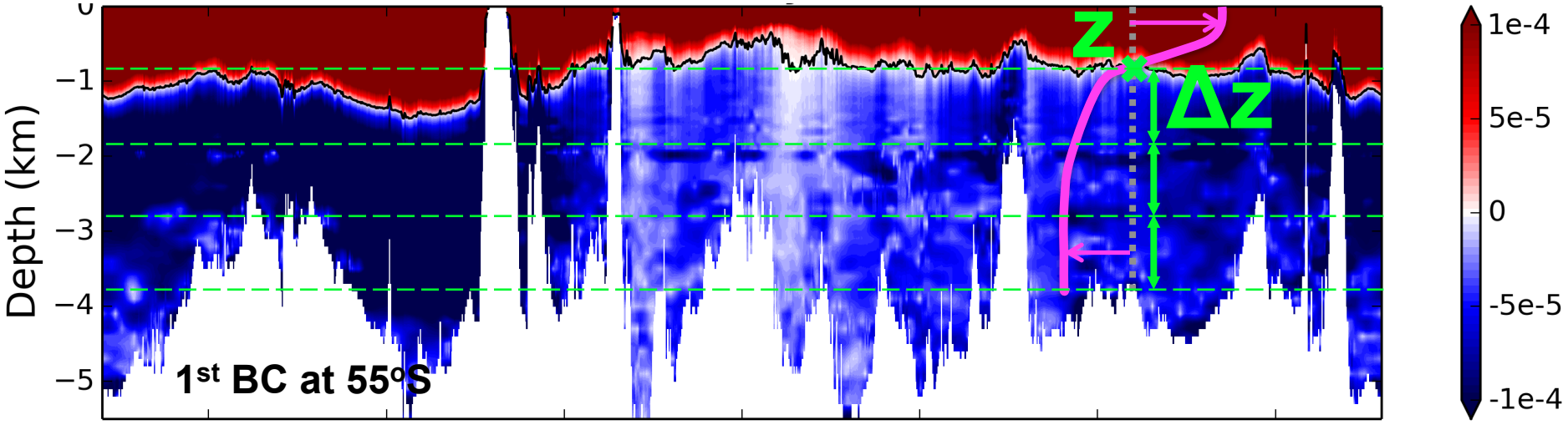

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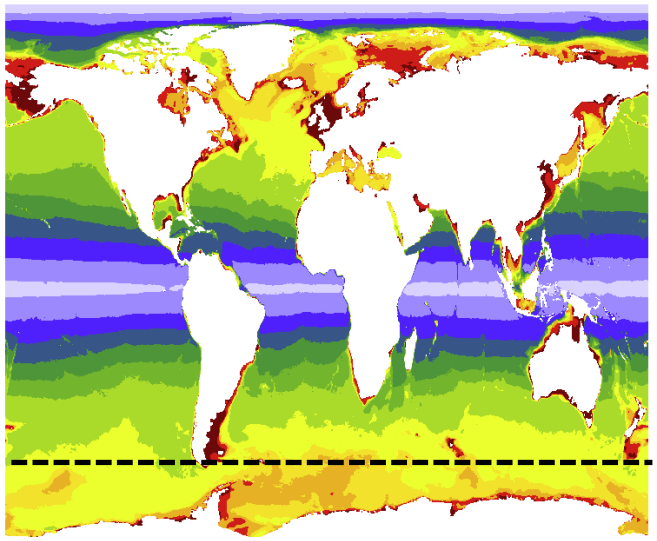

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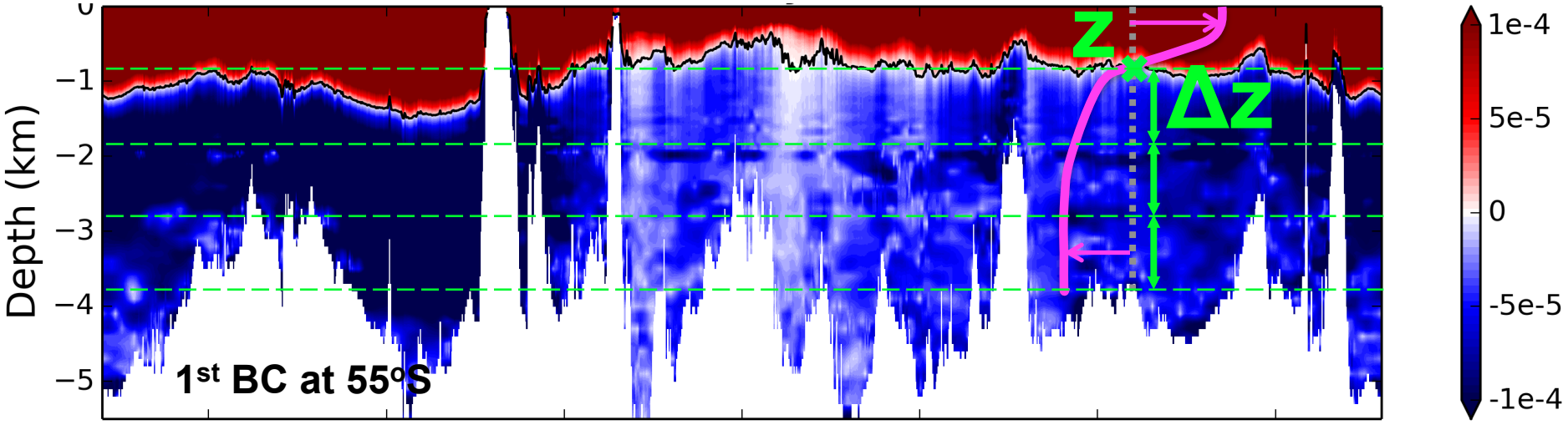

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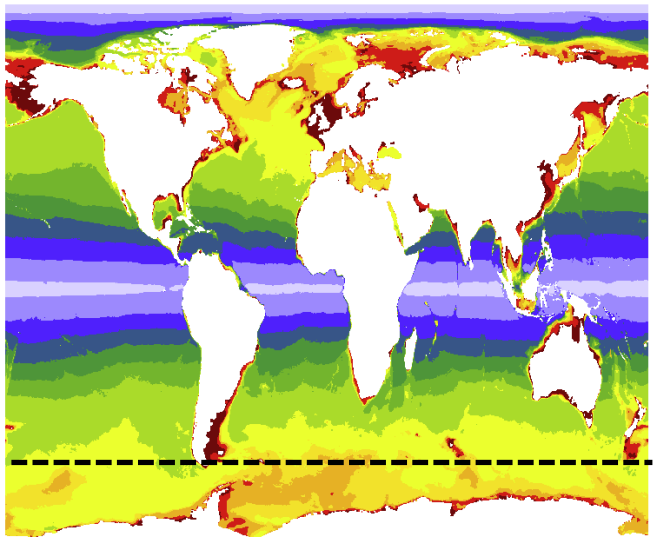

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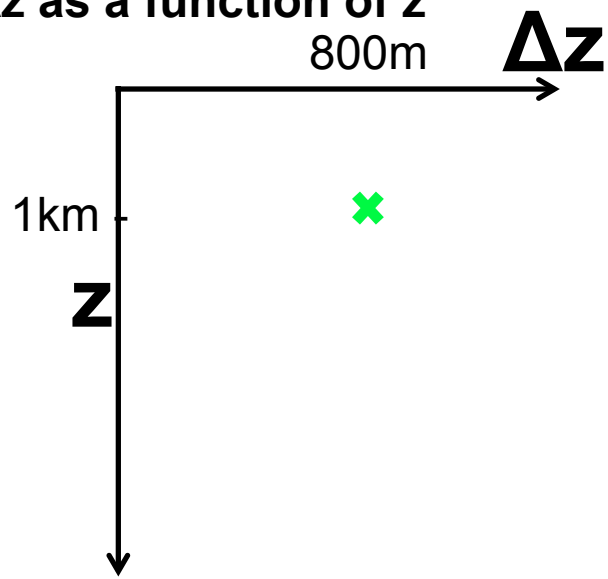

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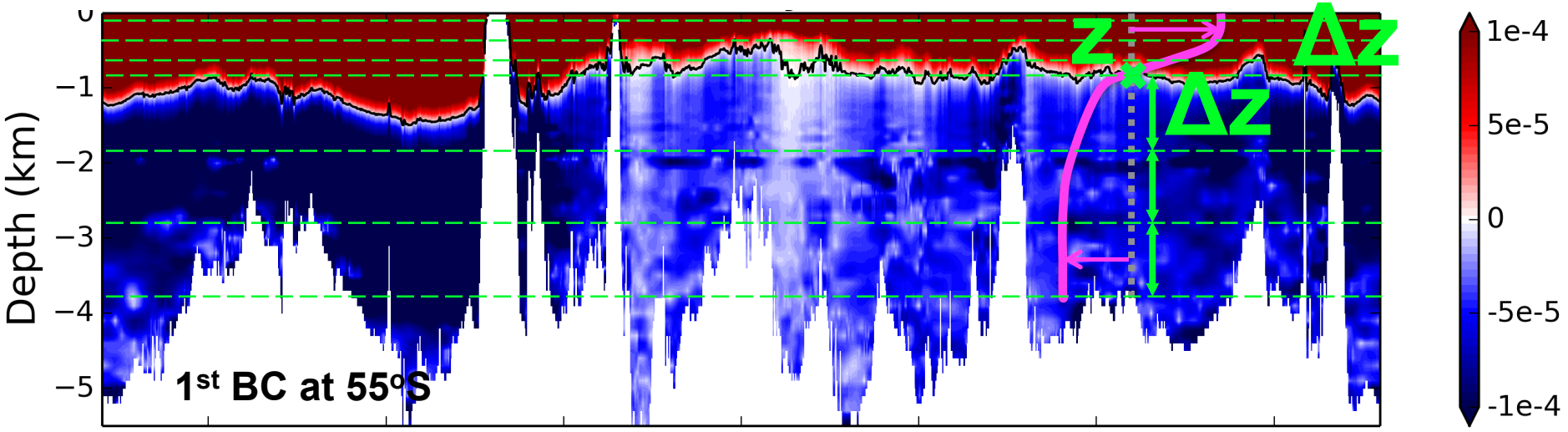

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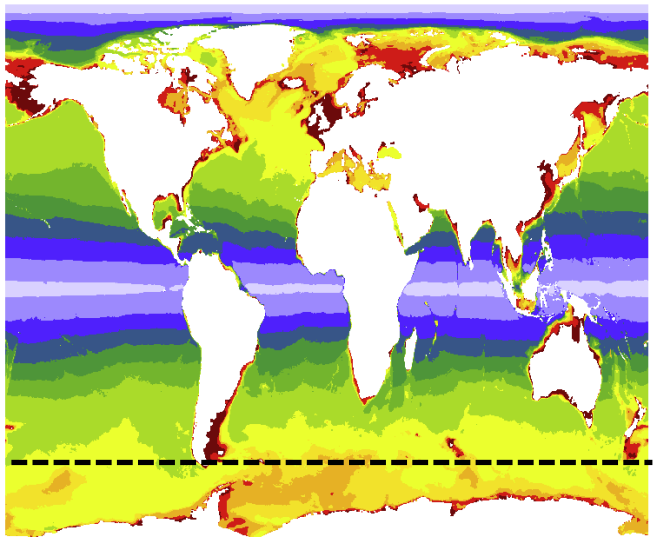

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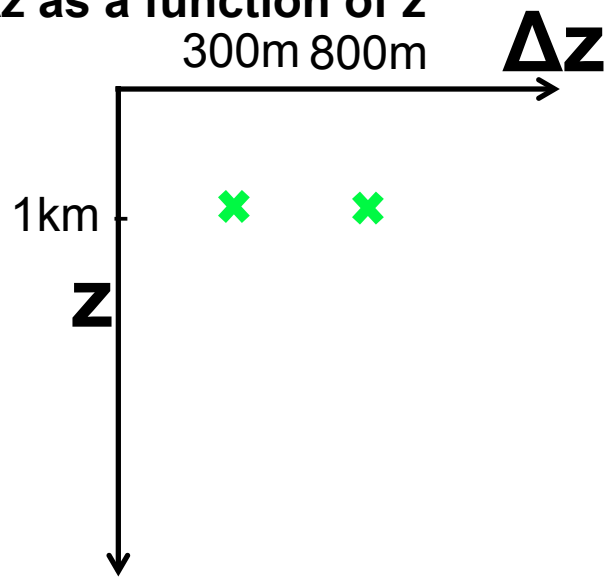

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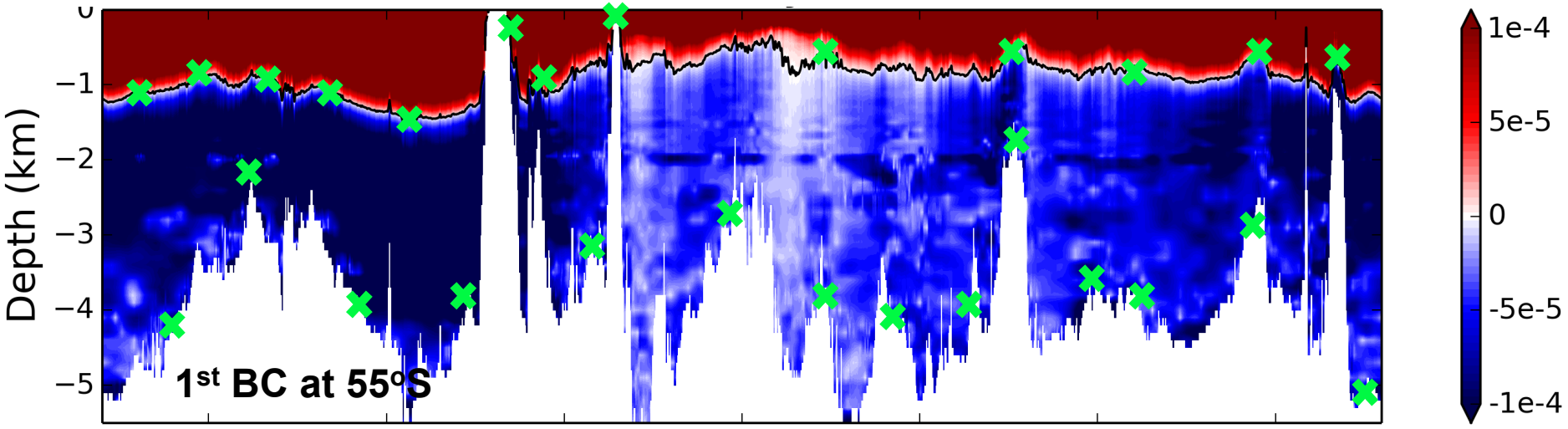

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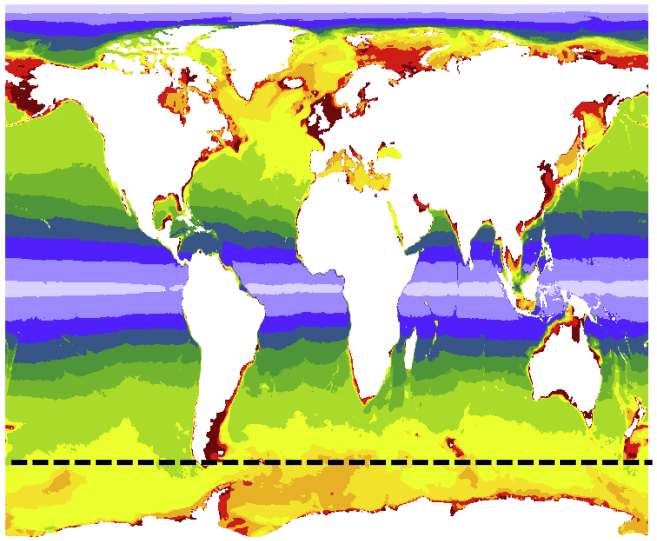

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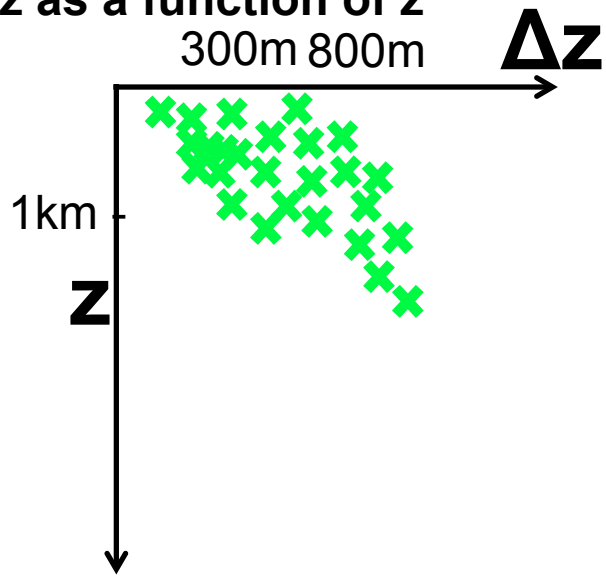

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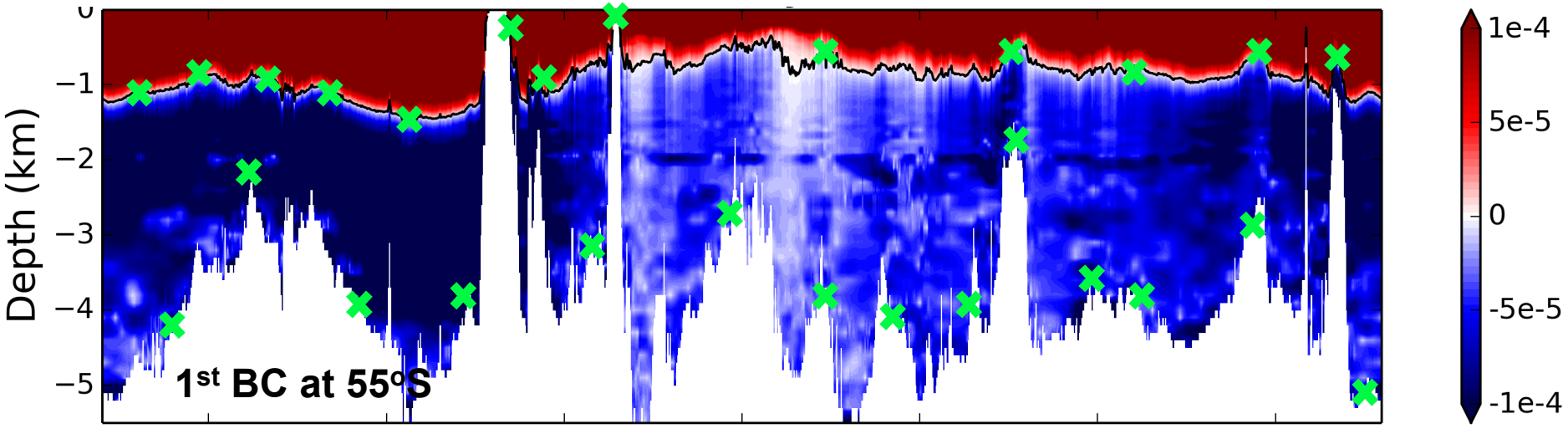

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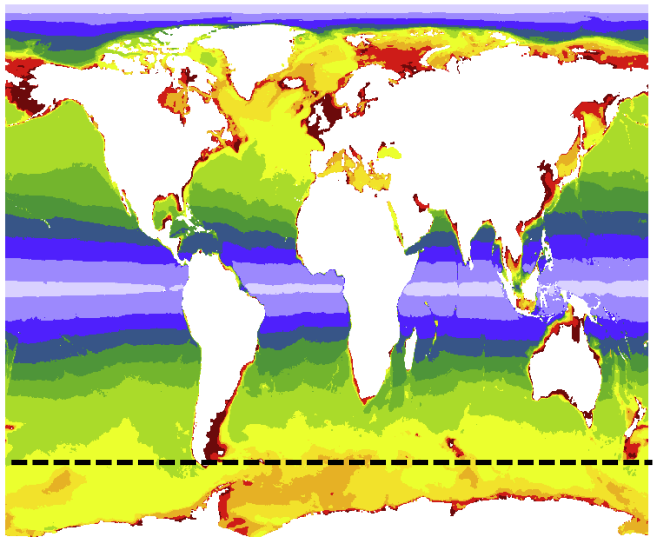

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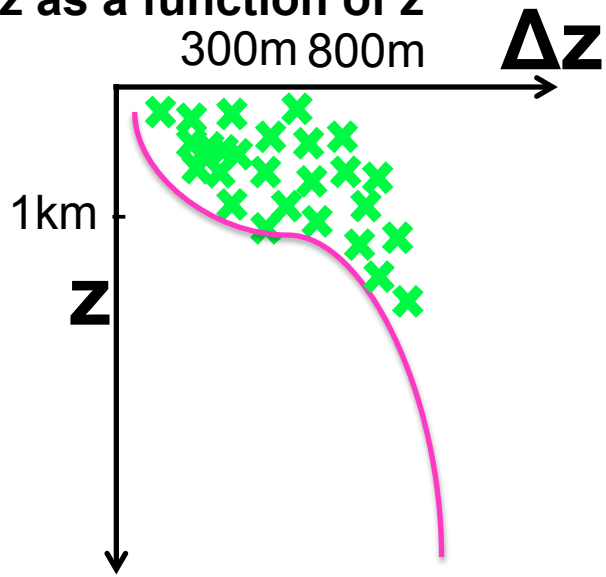

Horizontal resolution required to resolve* BC modes 1-4 (WOA13)

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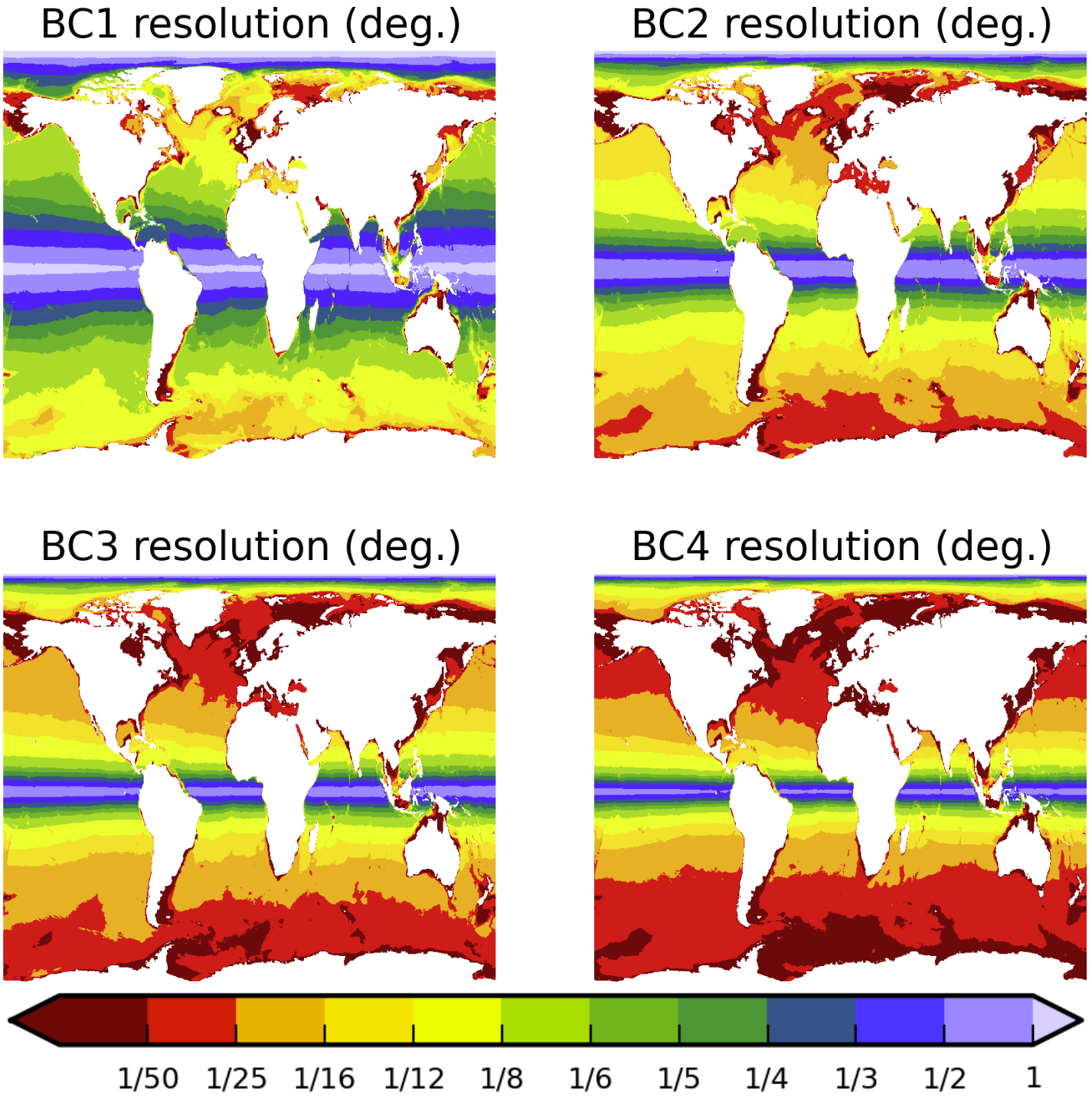

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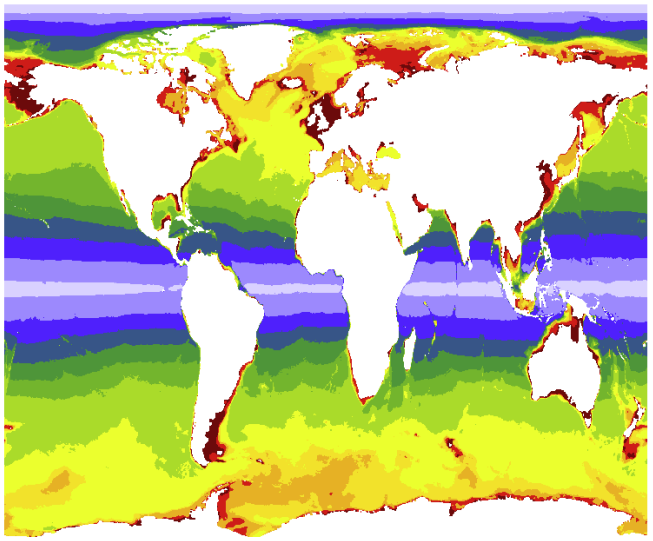
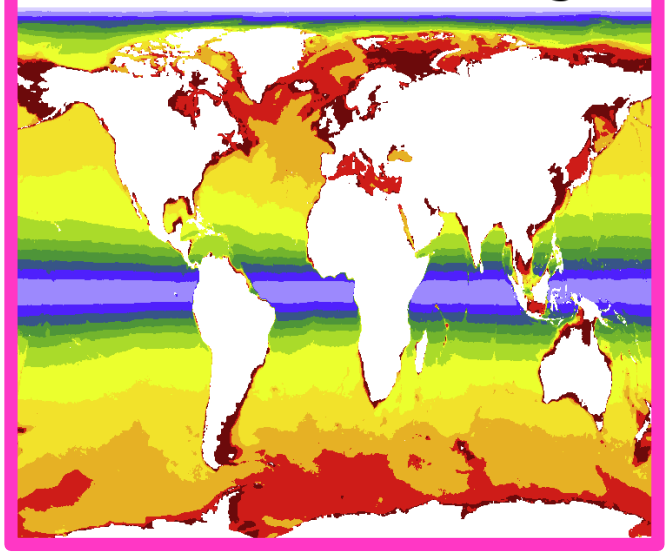


BC2 resolution (deg.)



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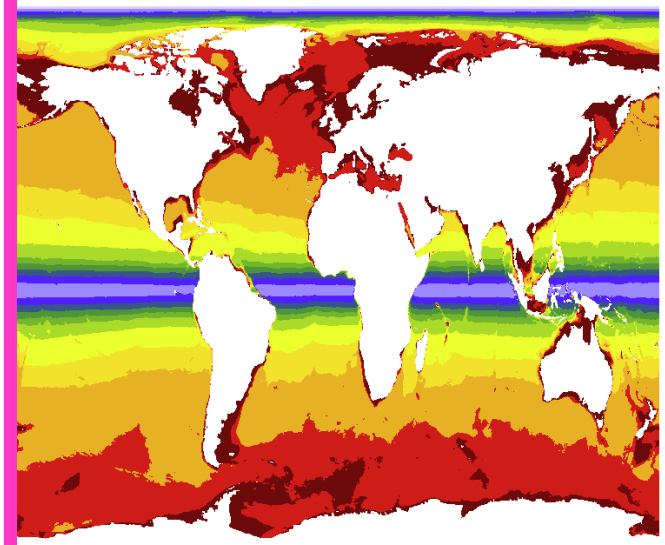

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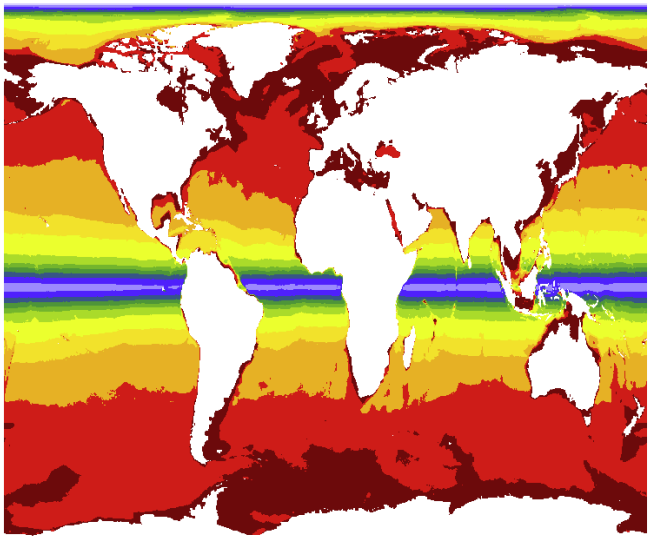

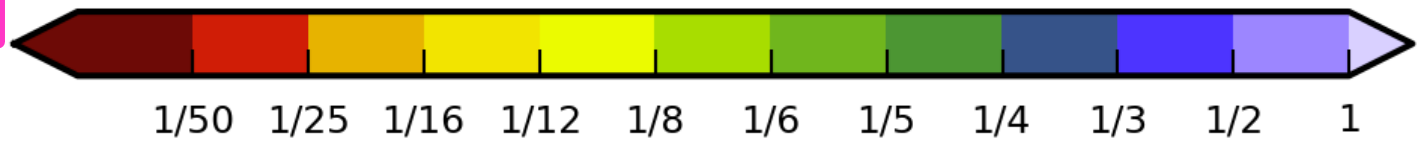

For a 1/10° model, target BC2 and develop a vertical grid that is *at least as good* as the horizontal grid for BC2.

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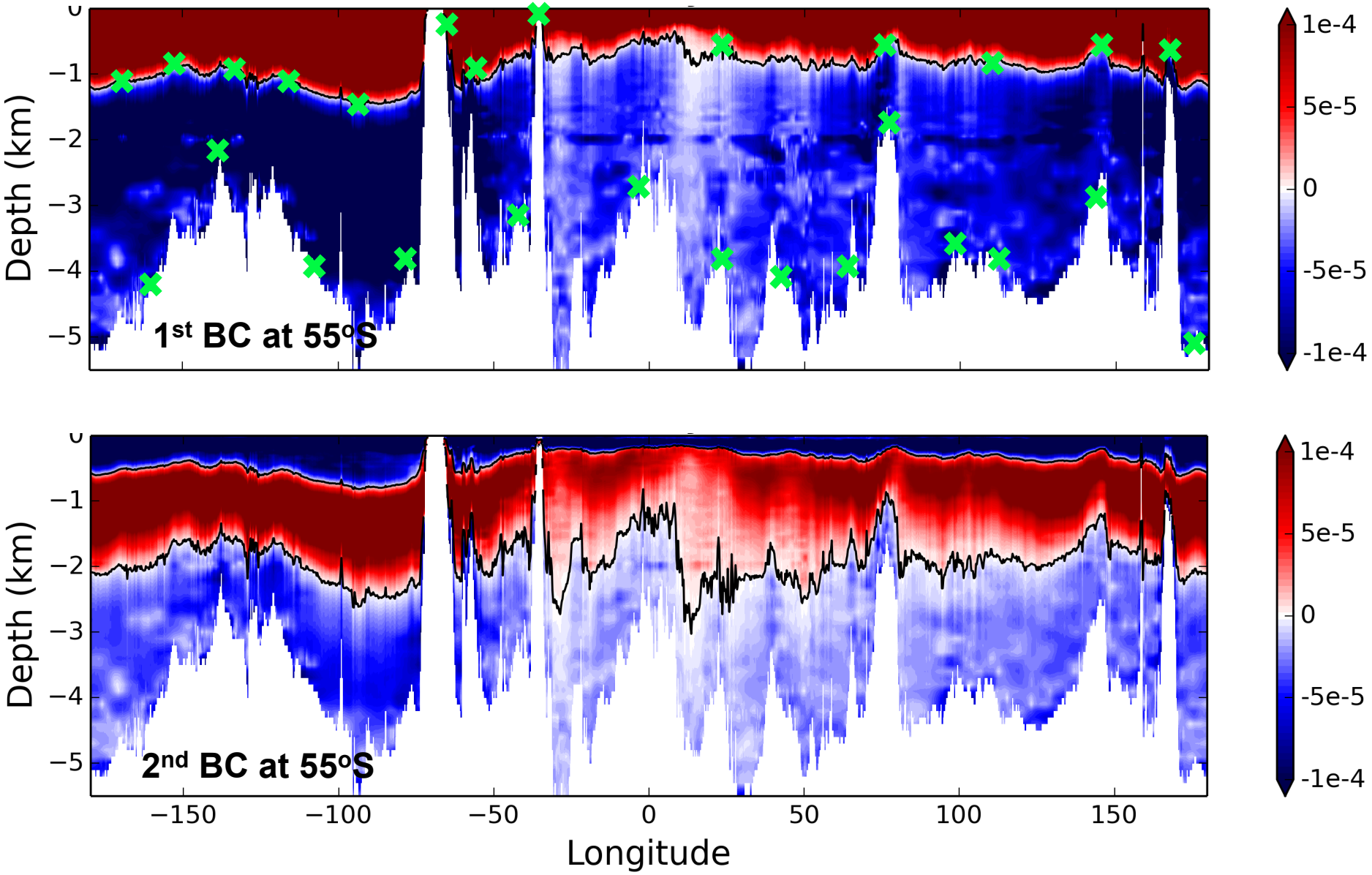

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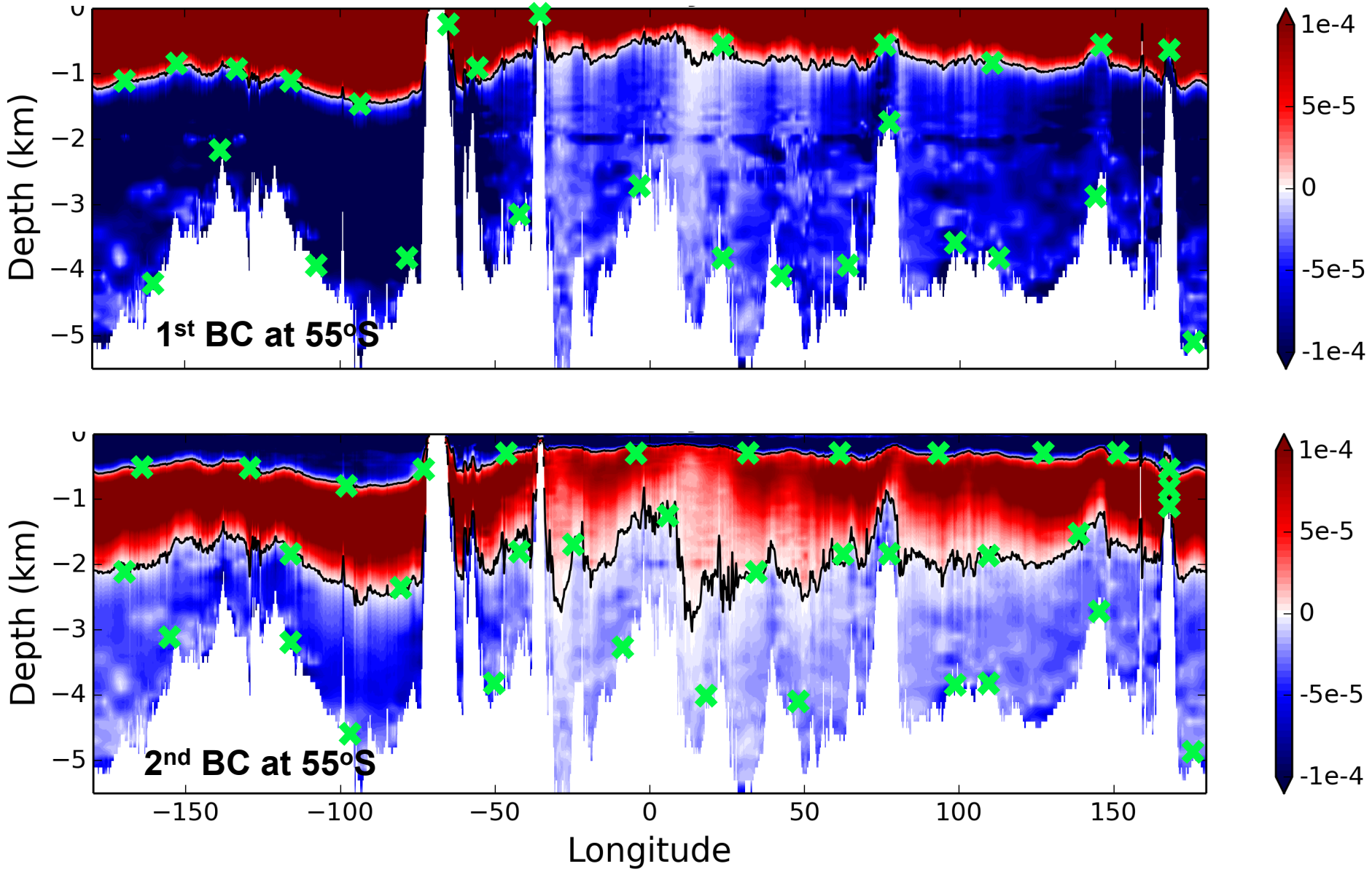


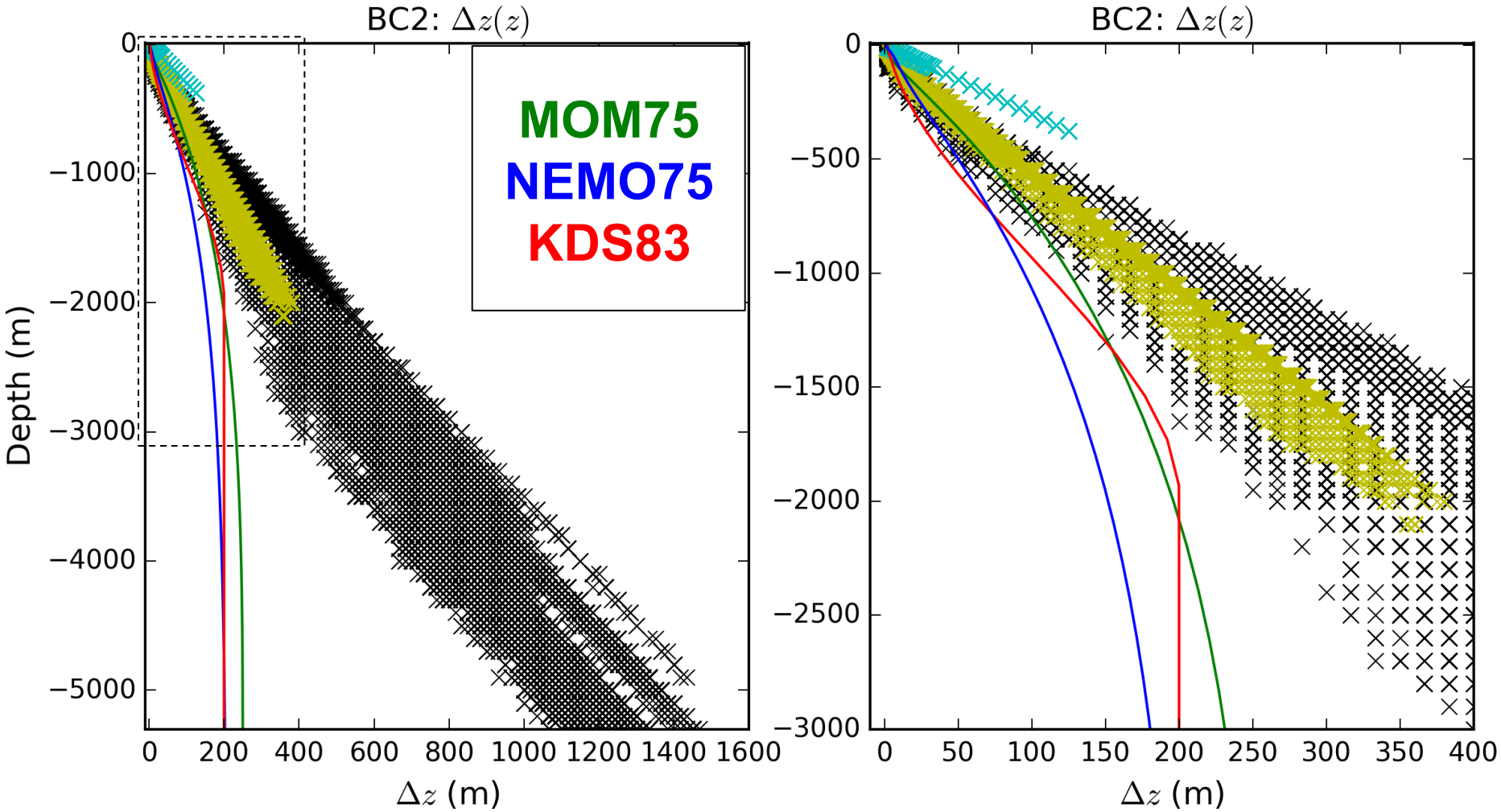
WOA13

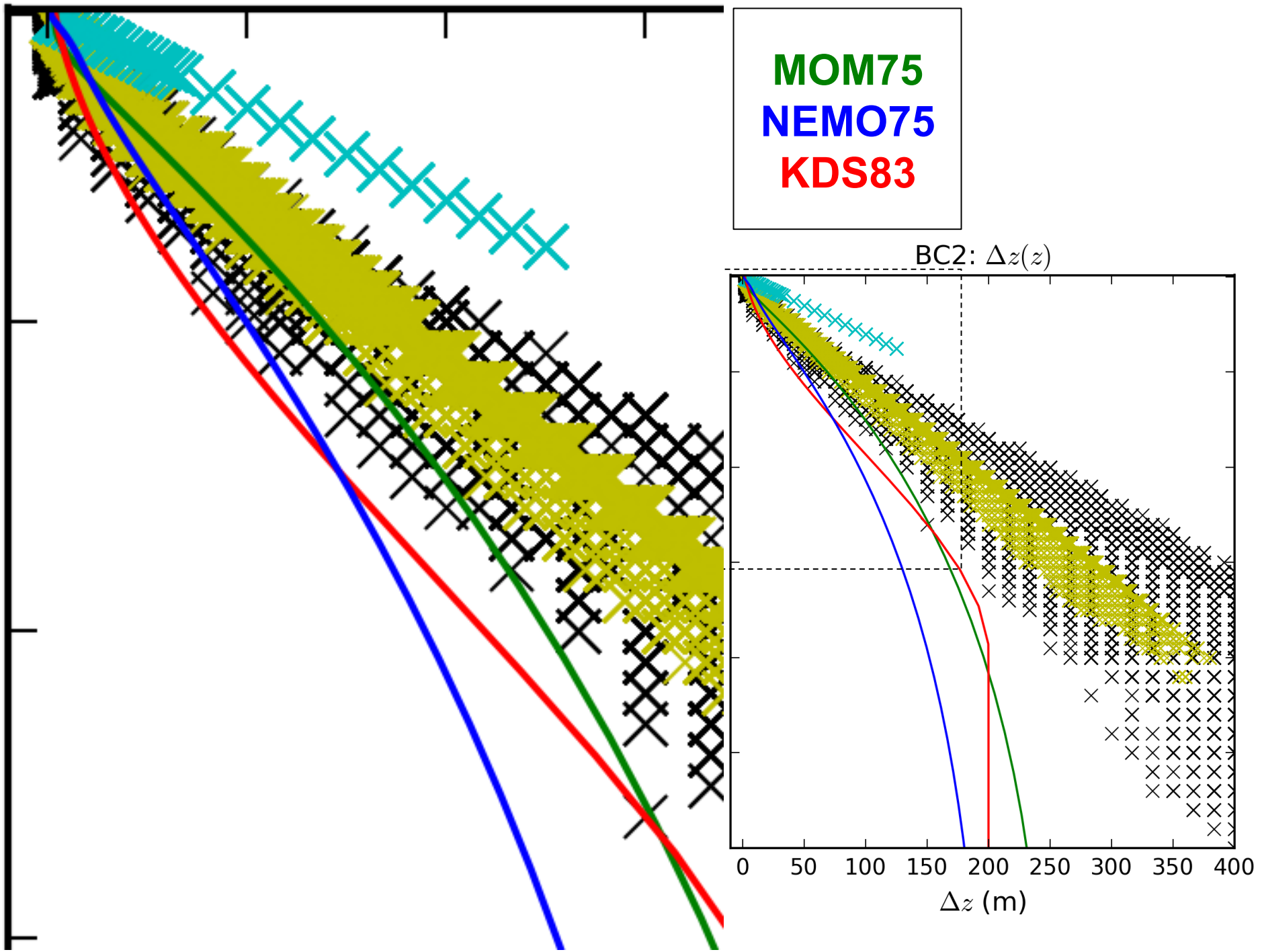
-calculate basis function of 2nd baroclinic mode

-find the depth (**z**) of the zero crossings and the depth between (**Δz**) zero crossings

-scatterplot of (**z**, **Δz**)

-develop a smooth curve to envelop (**z**, **Δz**)




MOM75
NEMO75
KDS83
BC2: $\Delta z(z)$
0
50
100
150
200
250
300
350
400
Δz (m)

How to quantify if the x^{th} baroclinic mode is resolved by a given vertical grid?

Build a horizontal velocity field that is representative of the x^{th} mode, and see how well the vertical grid resolves this…

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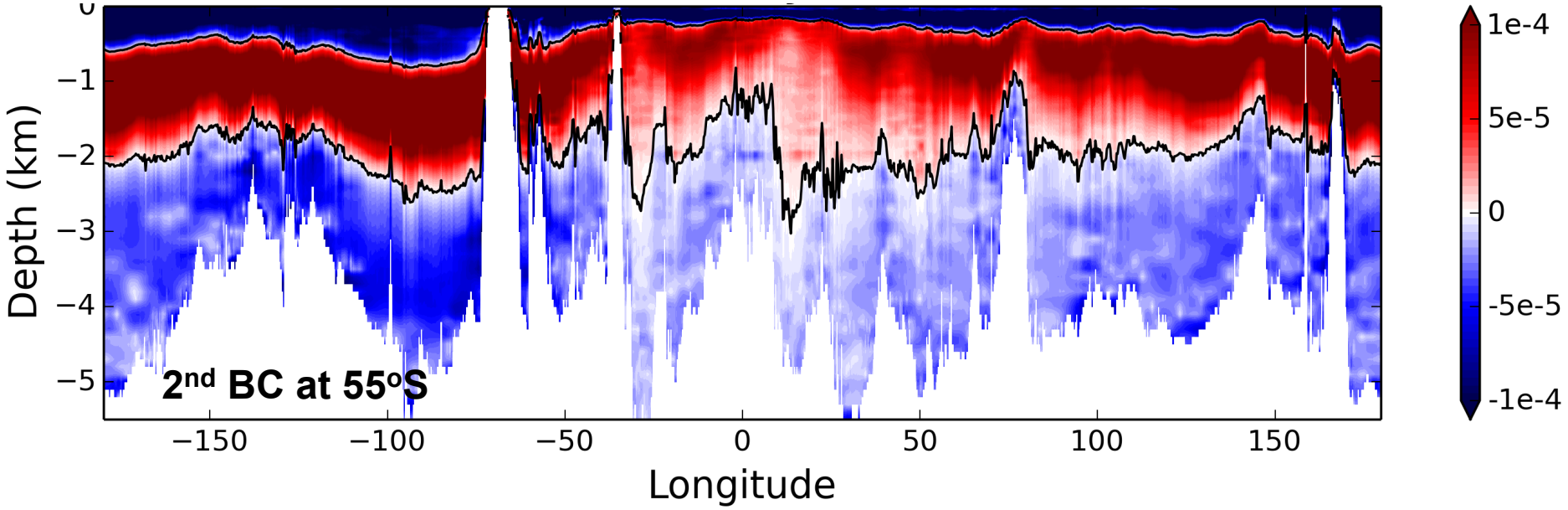

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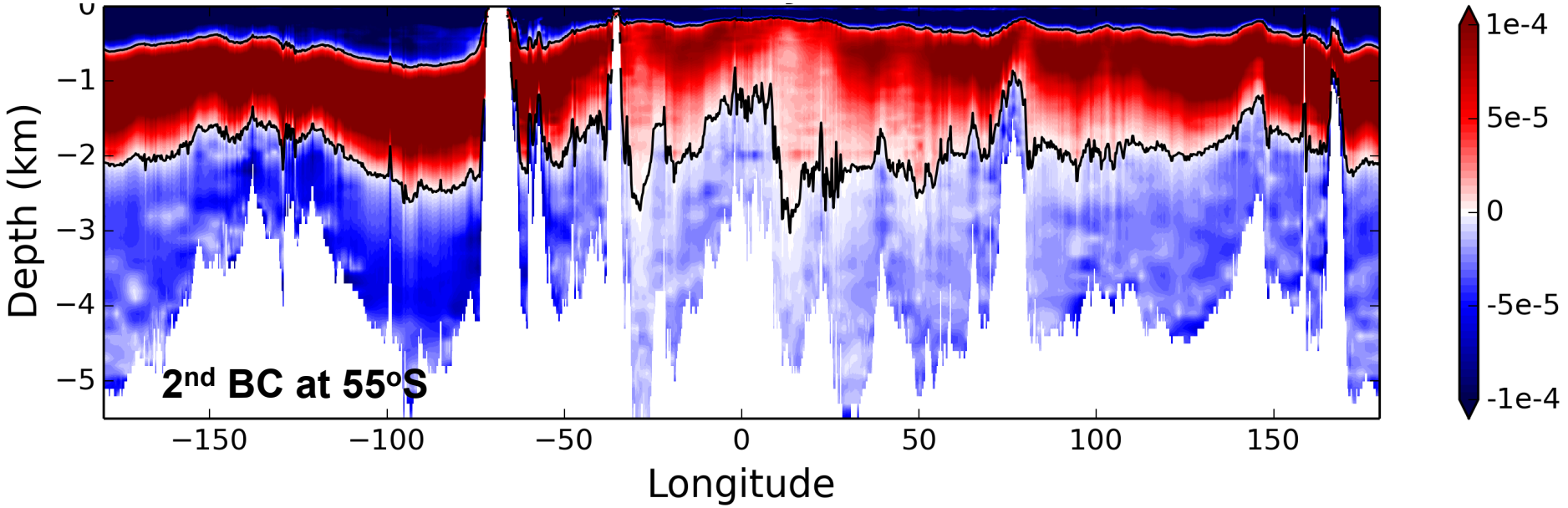
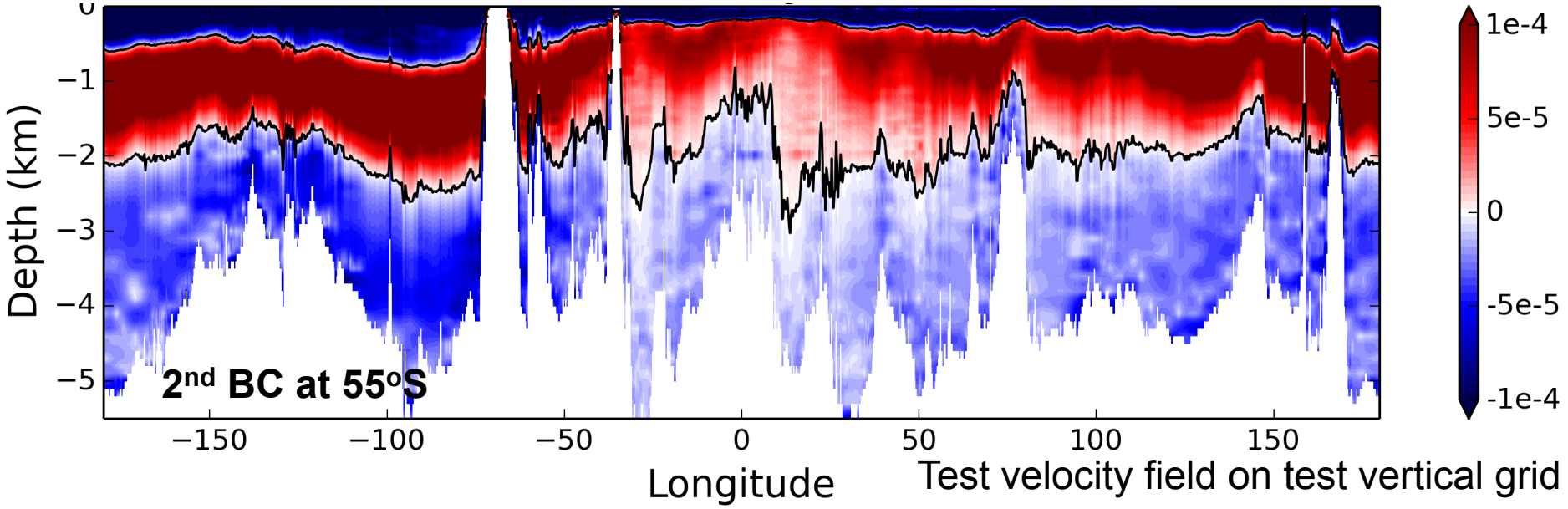


"Truth" velocity field on WOA13 grid

Get N^2 from WOA13 T & S on WOA13 grid.
Calculate the x^{th} baroclinic basis function
Multiply by a scalar
= "Truth" horizontal velocity field

How to quantify if the xth baroclinic mode is resolved by a given vertical grid?

Build a horizontal velocity field that is representative of the xth mode, and see how well the vertical grid resolves this…



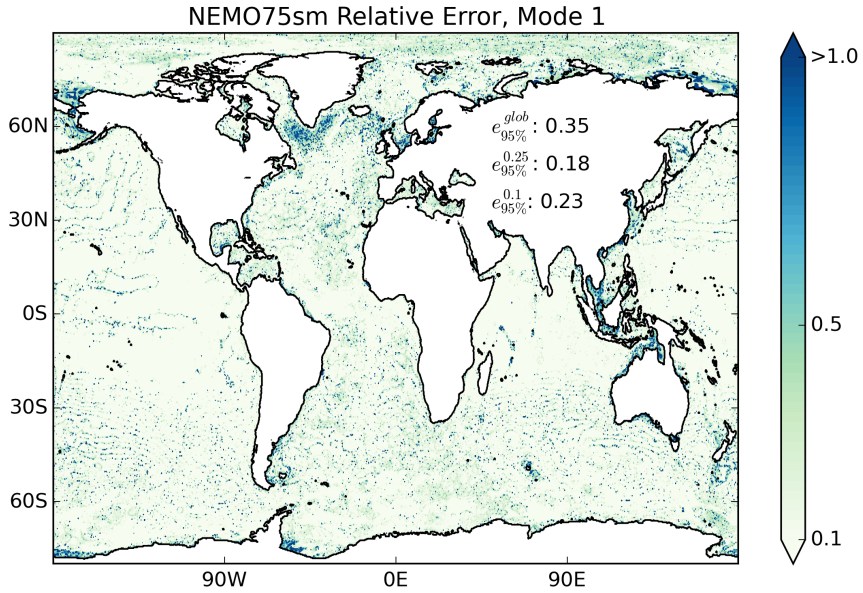
"Truth" velocity field on WOA13 grid

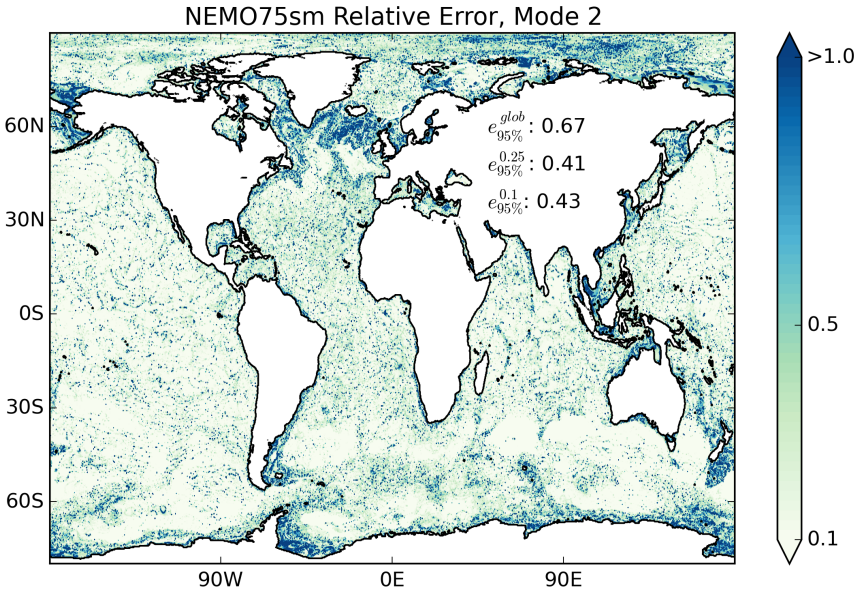
Get N^2 from WOA13 T & S on WOA13 grid.
Calculate the xth baroclinic basis function.
Multiply by a scalar.
= "Truth" horizontal velocity field

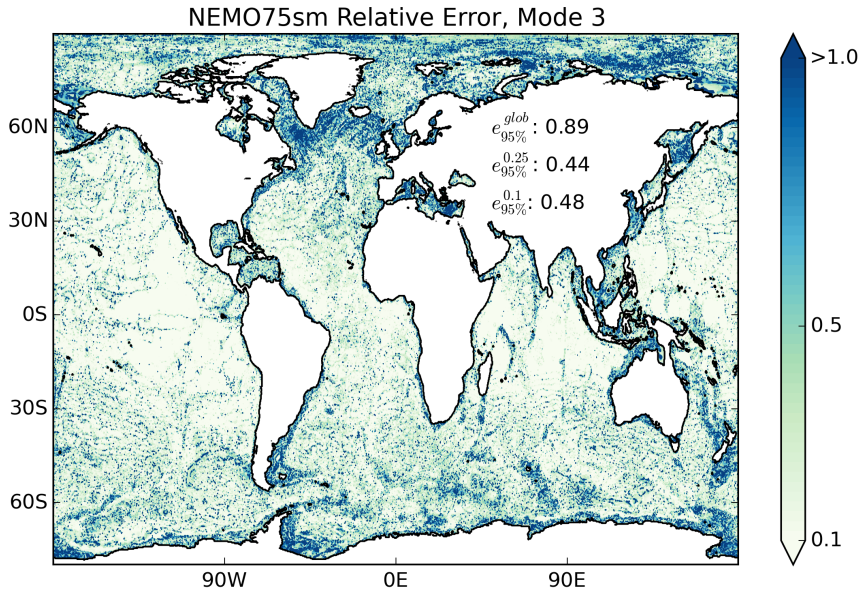
Test velocity field on test vertical grid

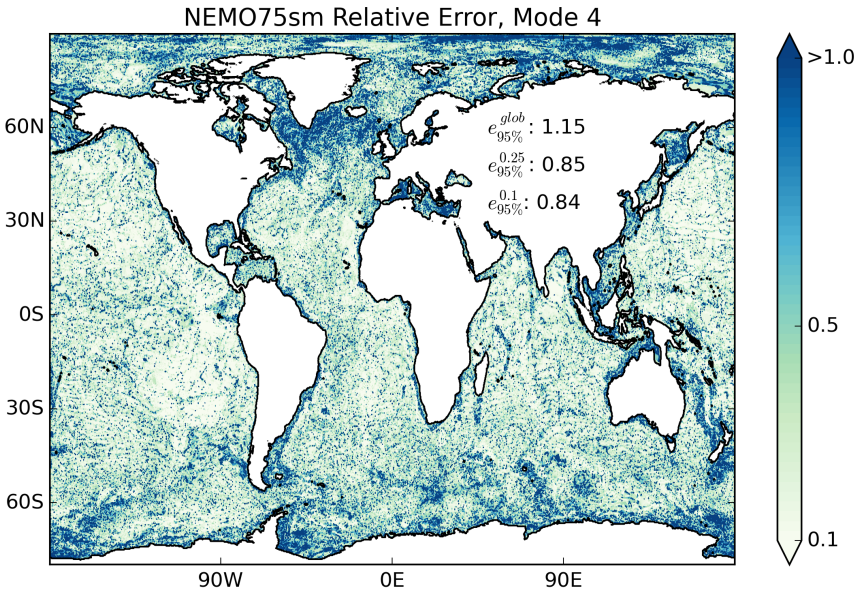
Interpolate WOA13 T & S onto test vertical grid
Get N^2 on test grid.
Calculate the xth baroclinic basis function.
Multiply by scalar for a test velocity field.
Re-interpolate back onto WOA13 grid and compare with "Truth" velocity field

How to quantify if the xth baroclinic mode is resolved by a given vertical grid?









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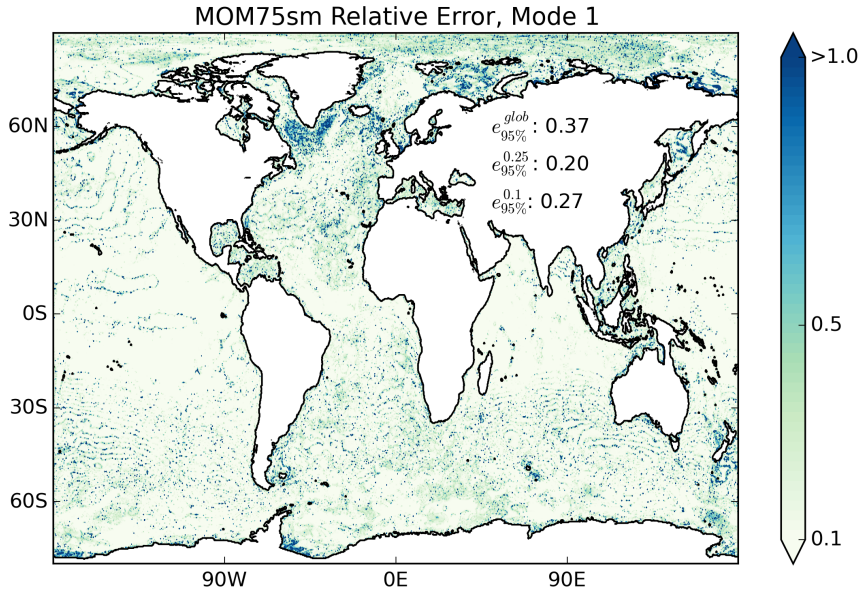

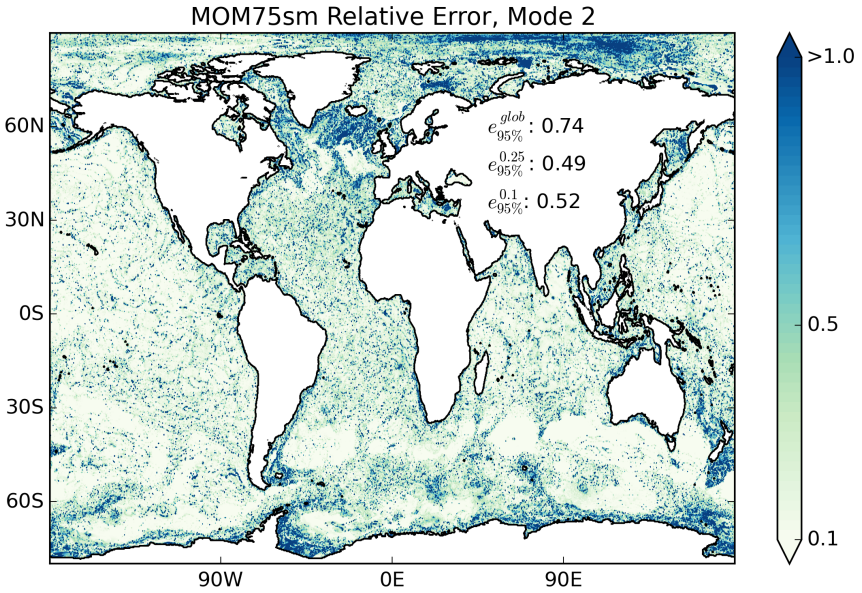

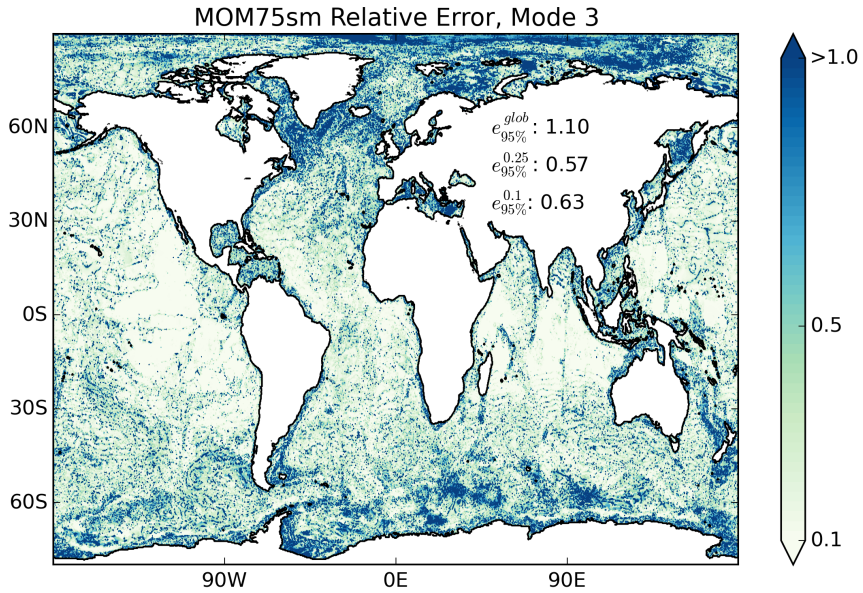

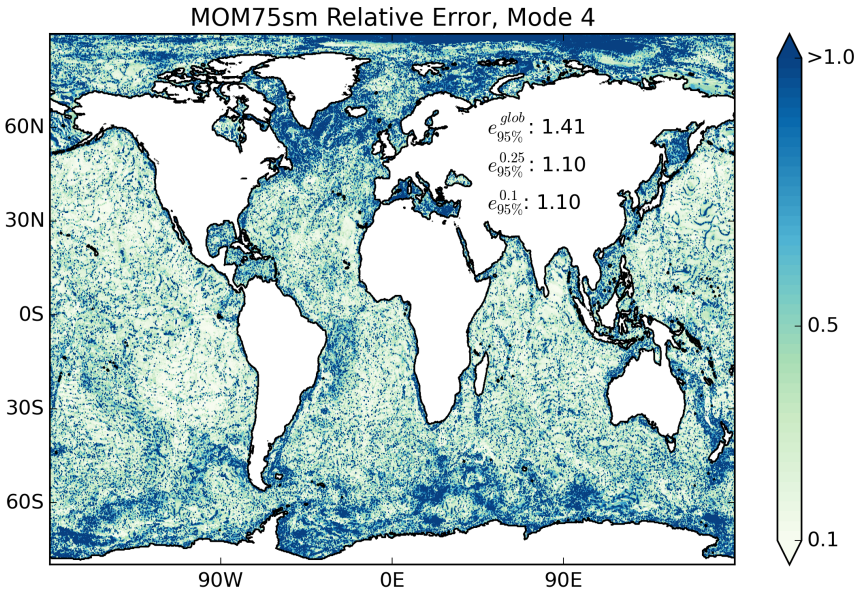

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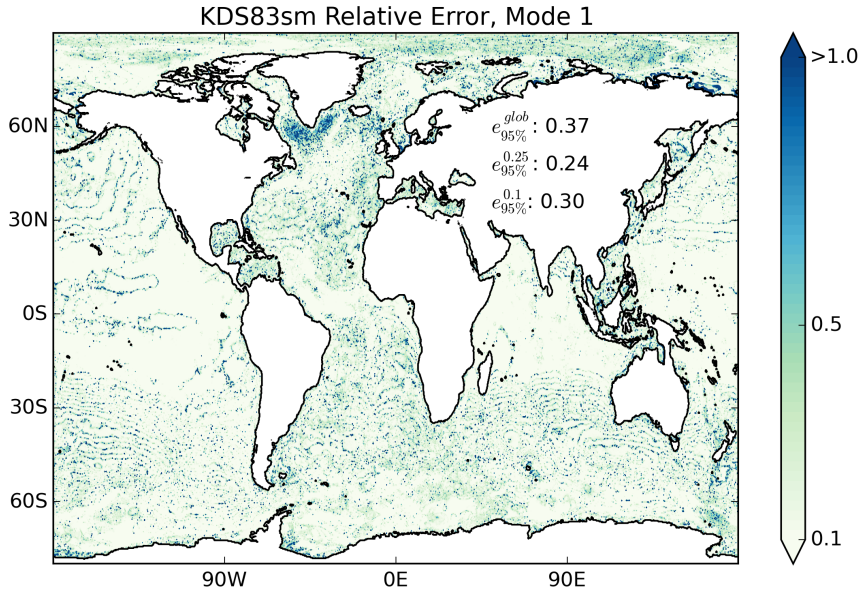
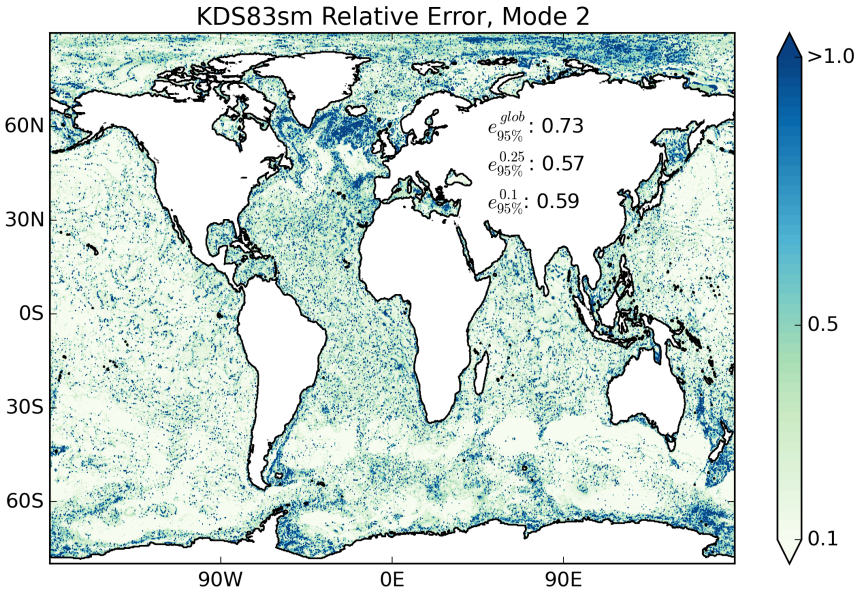
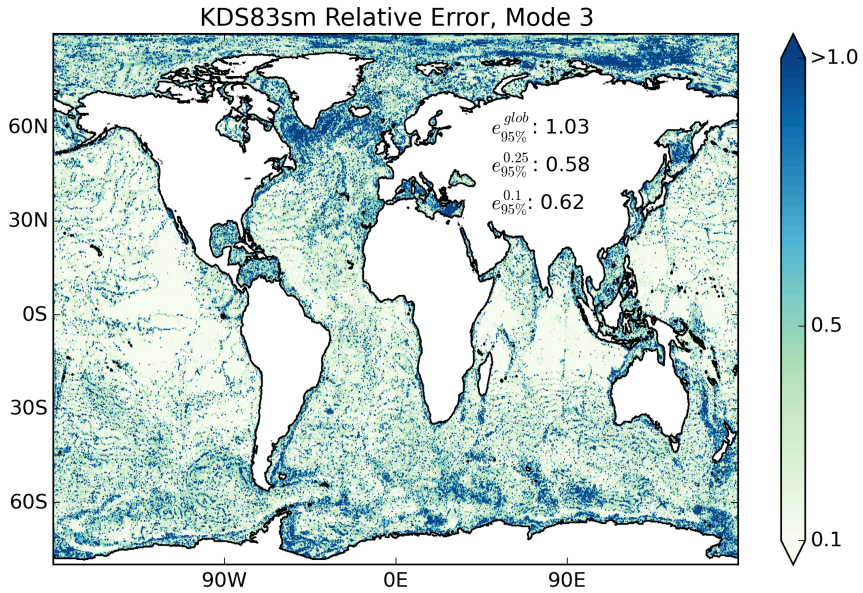
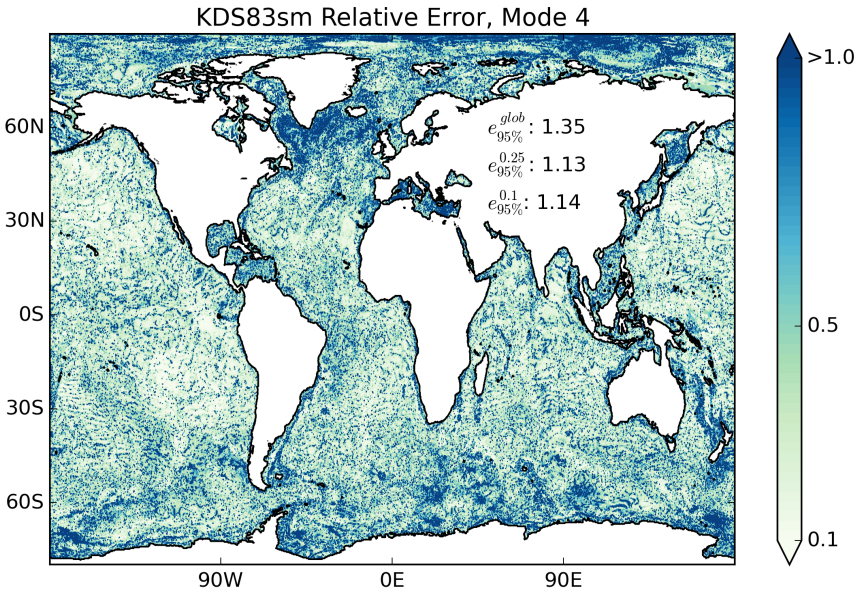
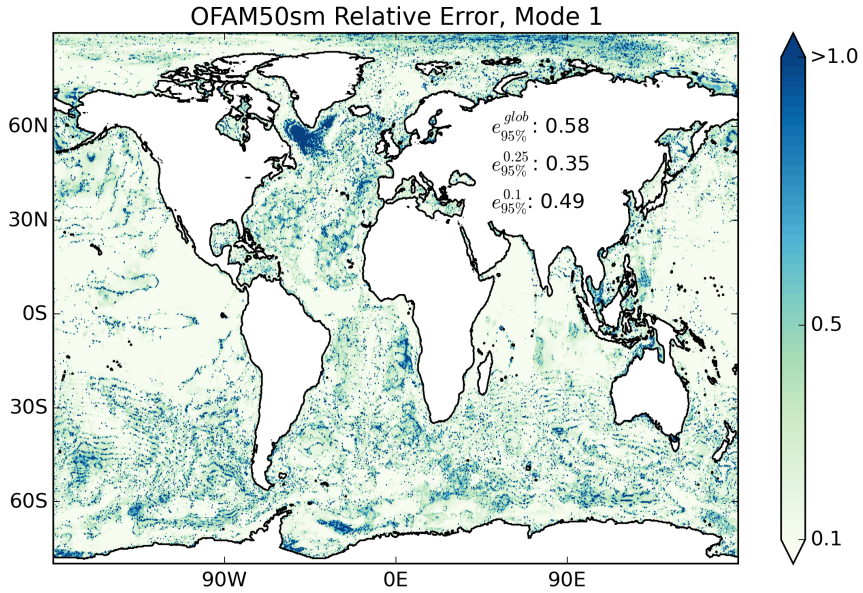


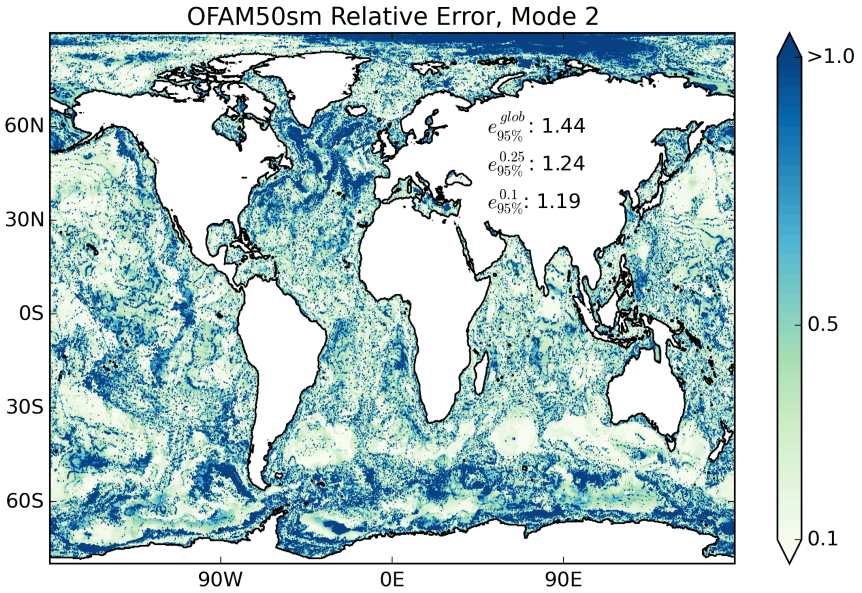


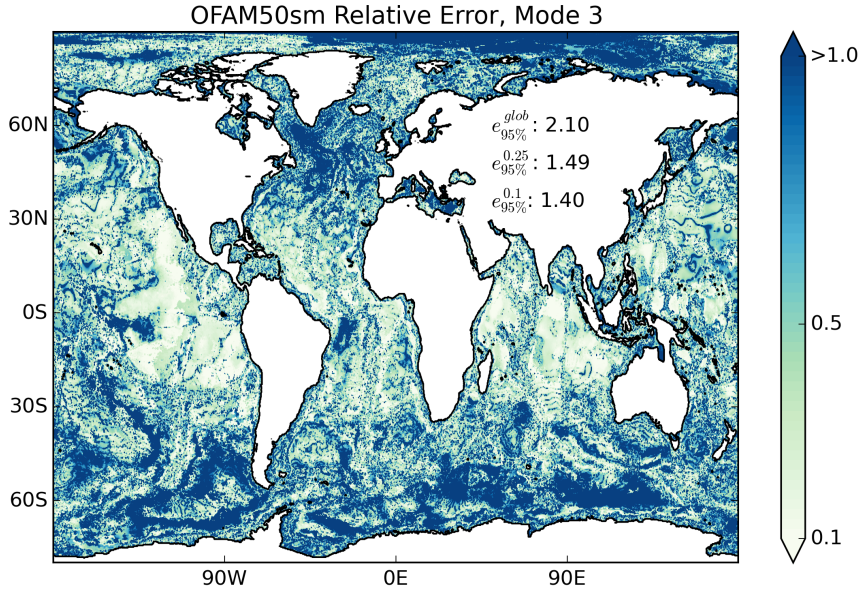


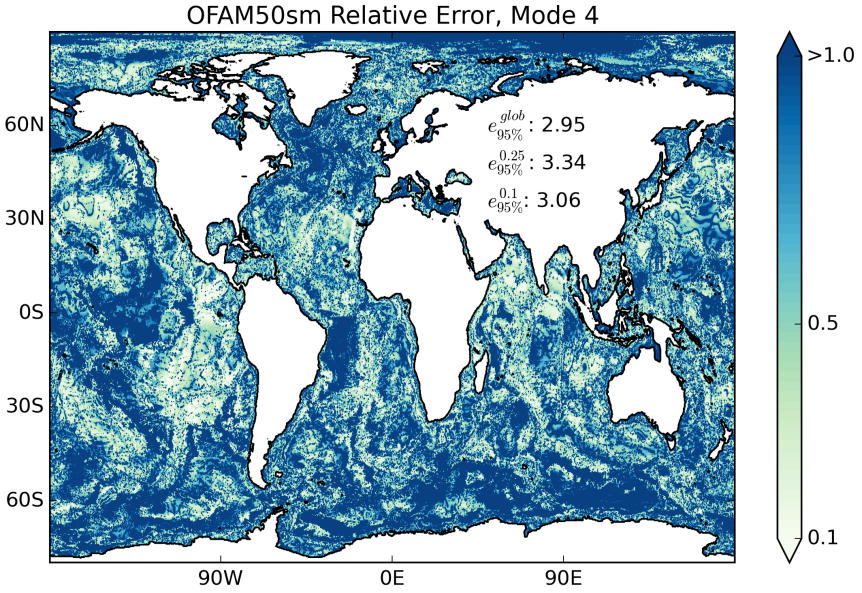


How to quantify if the xth baroclinic mode is resolved by a given vertical grid?

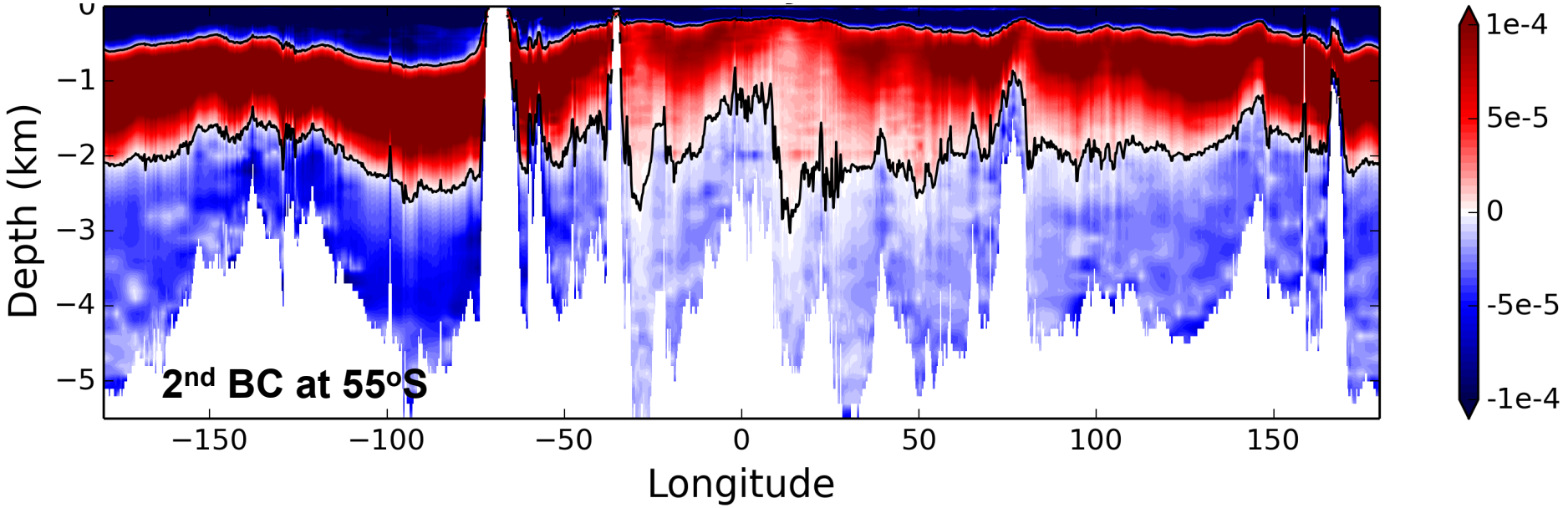








Summary



-The vertical grid needs objective consideration

-Metrics exist for comparing vertical grids

-Many, many other dynamical processes to consider