Towards quantifying structural uncertainties in climate models

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July 8, 2013

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Overview

1. Tuning error or structural error?
2. Exploring parameter space

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Tuning error or structural error?

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AMOC discrepancy workshop

At our workshop in Durham last September we identified a number of key processes affecting the physics of the AMOC, thought to have "structural errors" in HadCM3.

1. Overly strong ACC transport
2. Subpolar gyre in the wrong place
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4. Separation of the gulf stream
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Are these really structural errors or are they really tuning errors?

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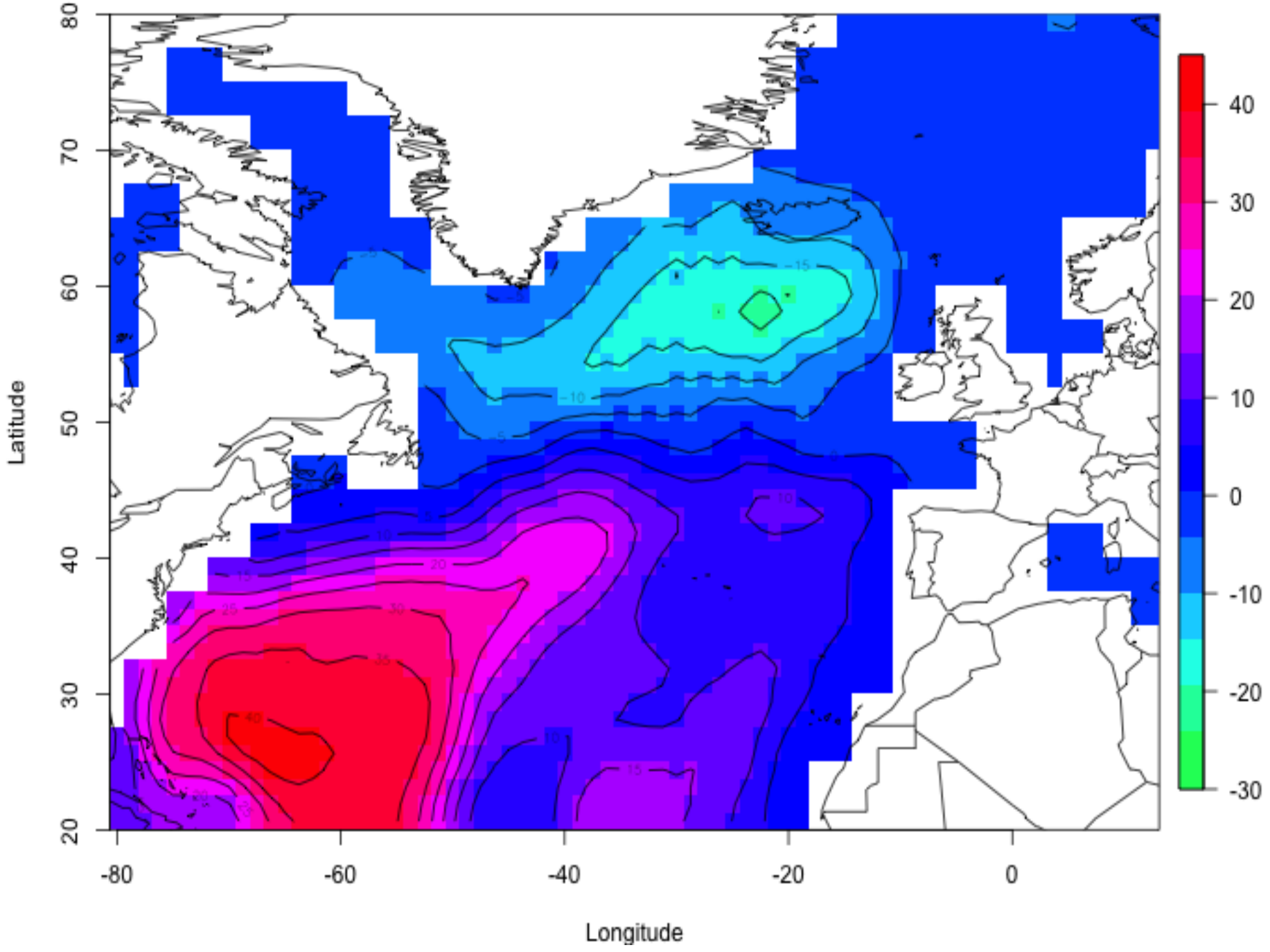
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History Matching: Brief Overview

- History matching is a statistical tool for cutting out parameter space that is implausible given observations of the real climate.

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- Distance is defined by implausibility measure $\mathcal{I}(x_0) = \max_i\{\mathcal{I}_i(x_0)\}$

$$\mathcal{I}_i(x_0) = \frac{z - \mathrm{E}\left[f(x_0)\right]}{\sqrt{\mathrm{Var}\left[z - \mathrm{E}\left[f(x_0)\right]\right]}}$$

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- We call the left over space **Not Ruled Out Yet** space (NROY).

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History Matching: (Very) Brief Overview

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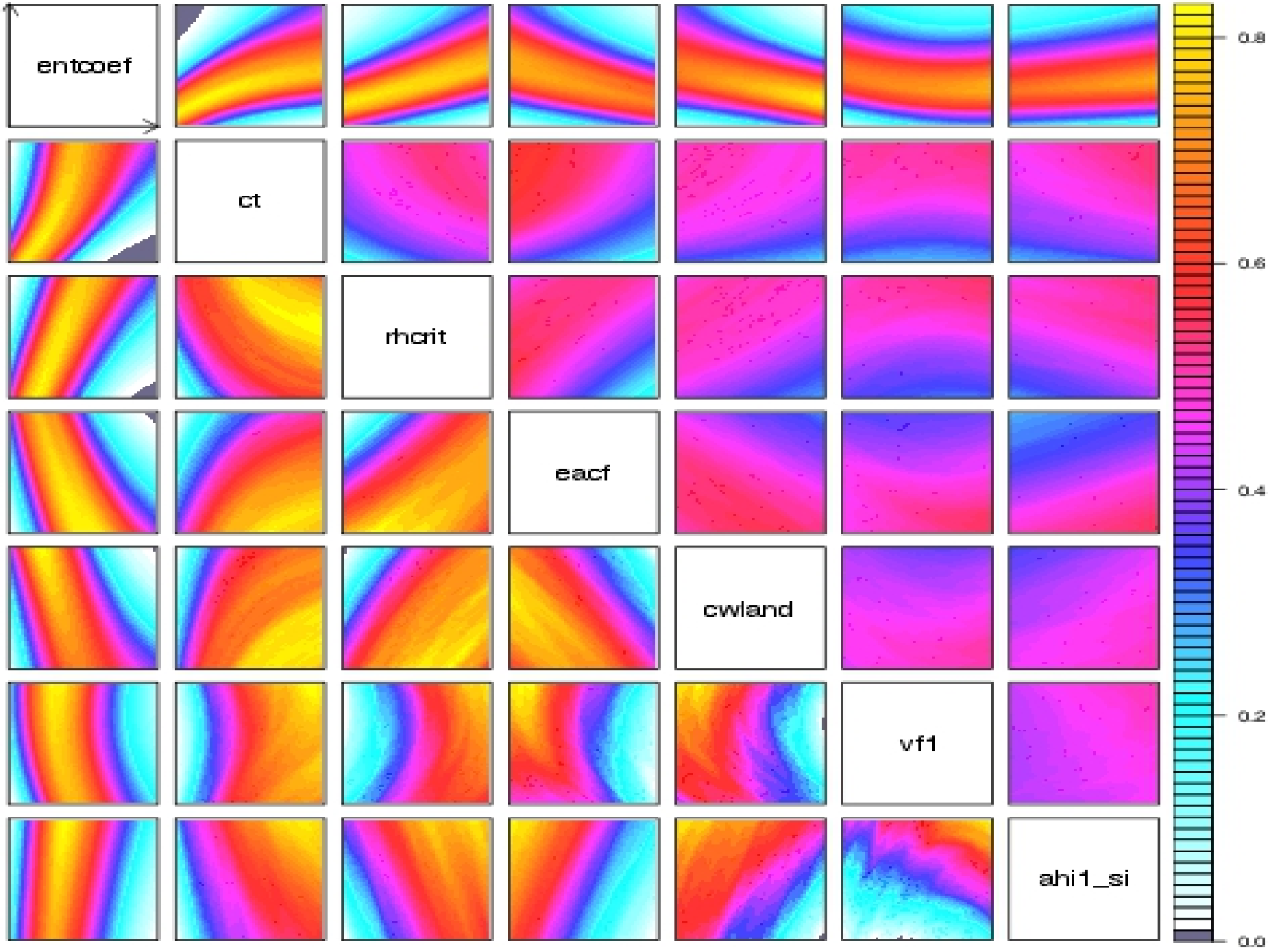
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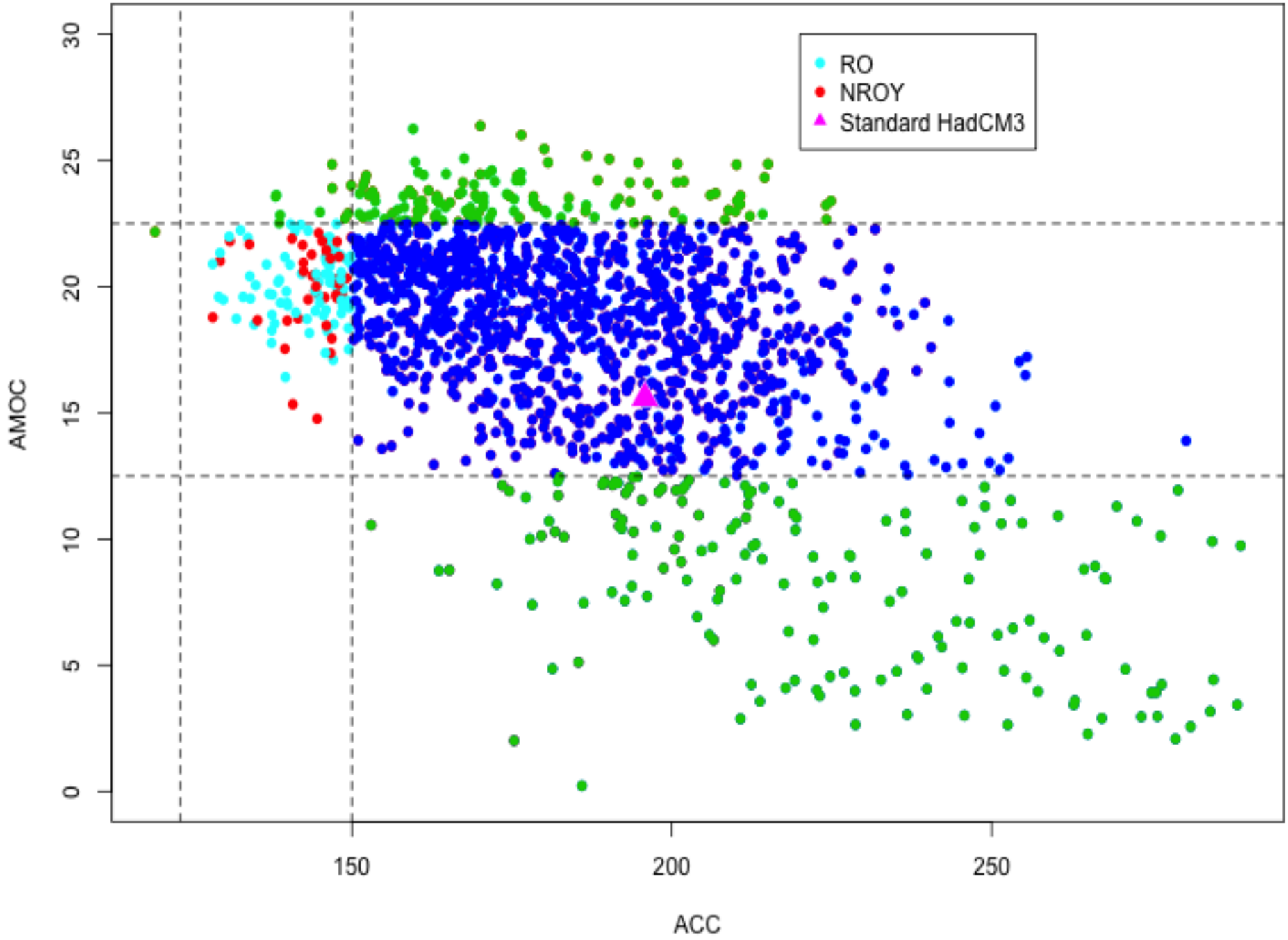
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NROY
Standard HadCM3
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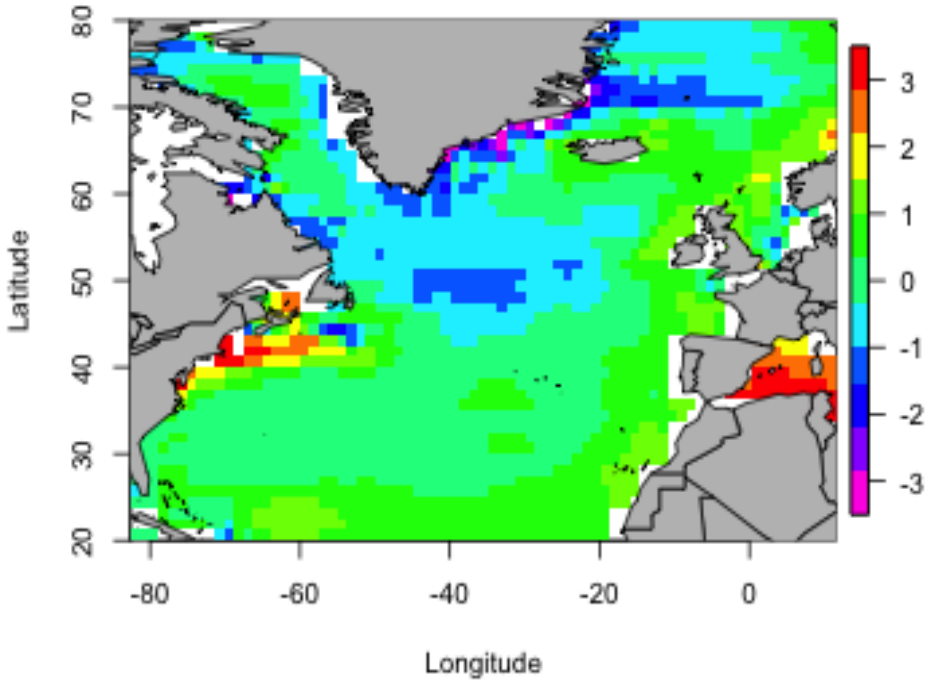
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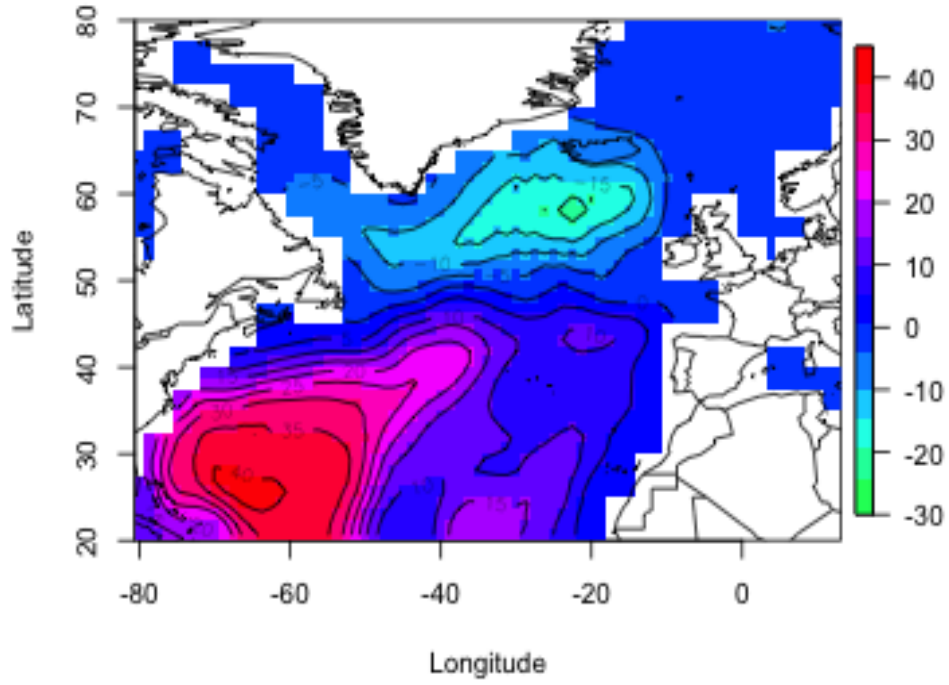
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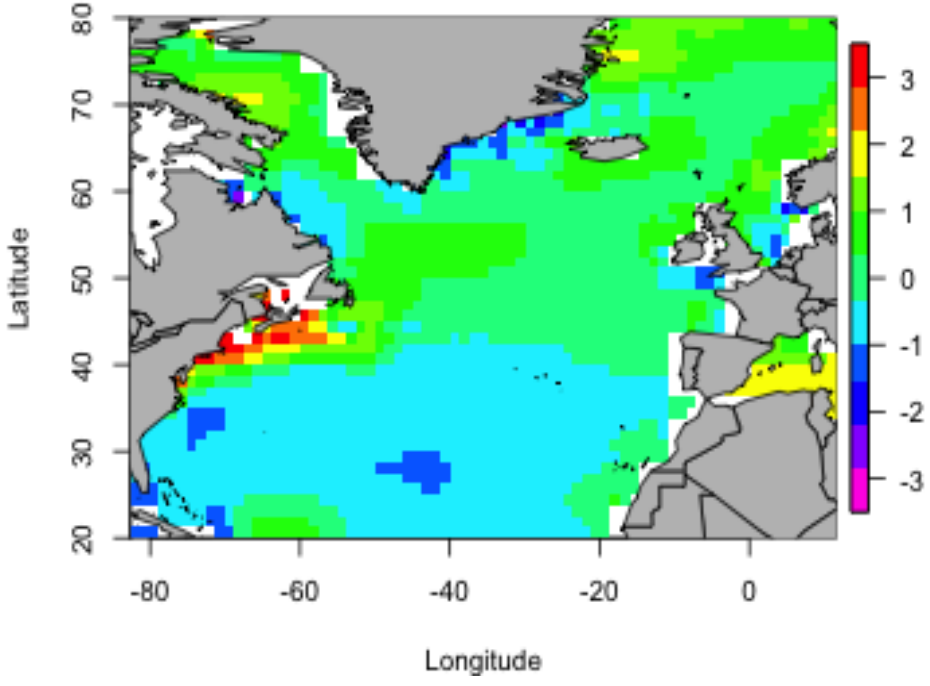
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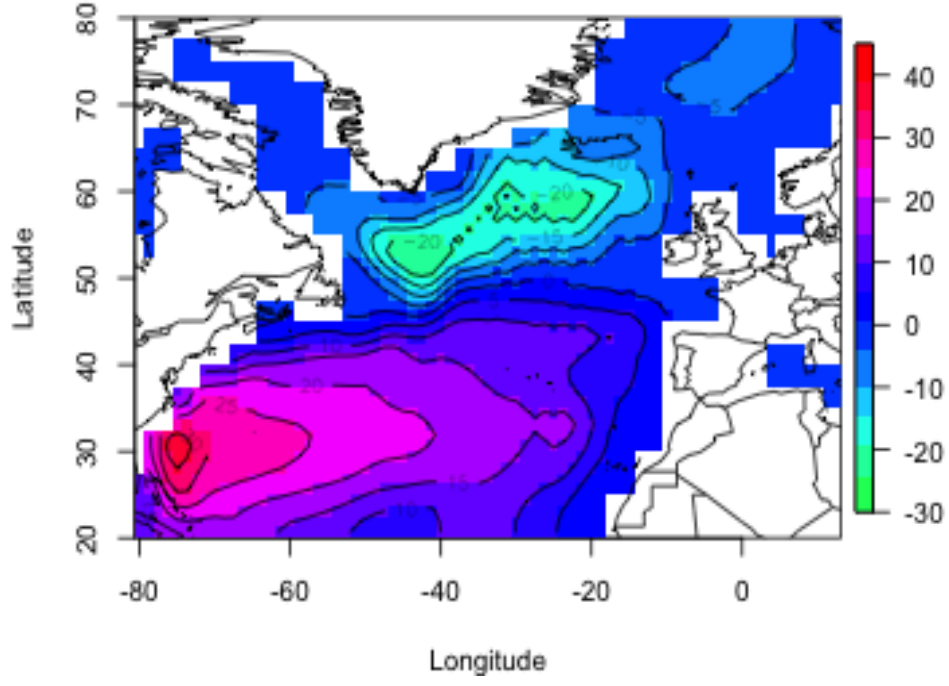
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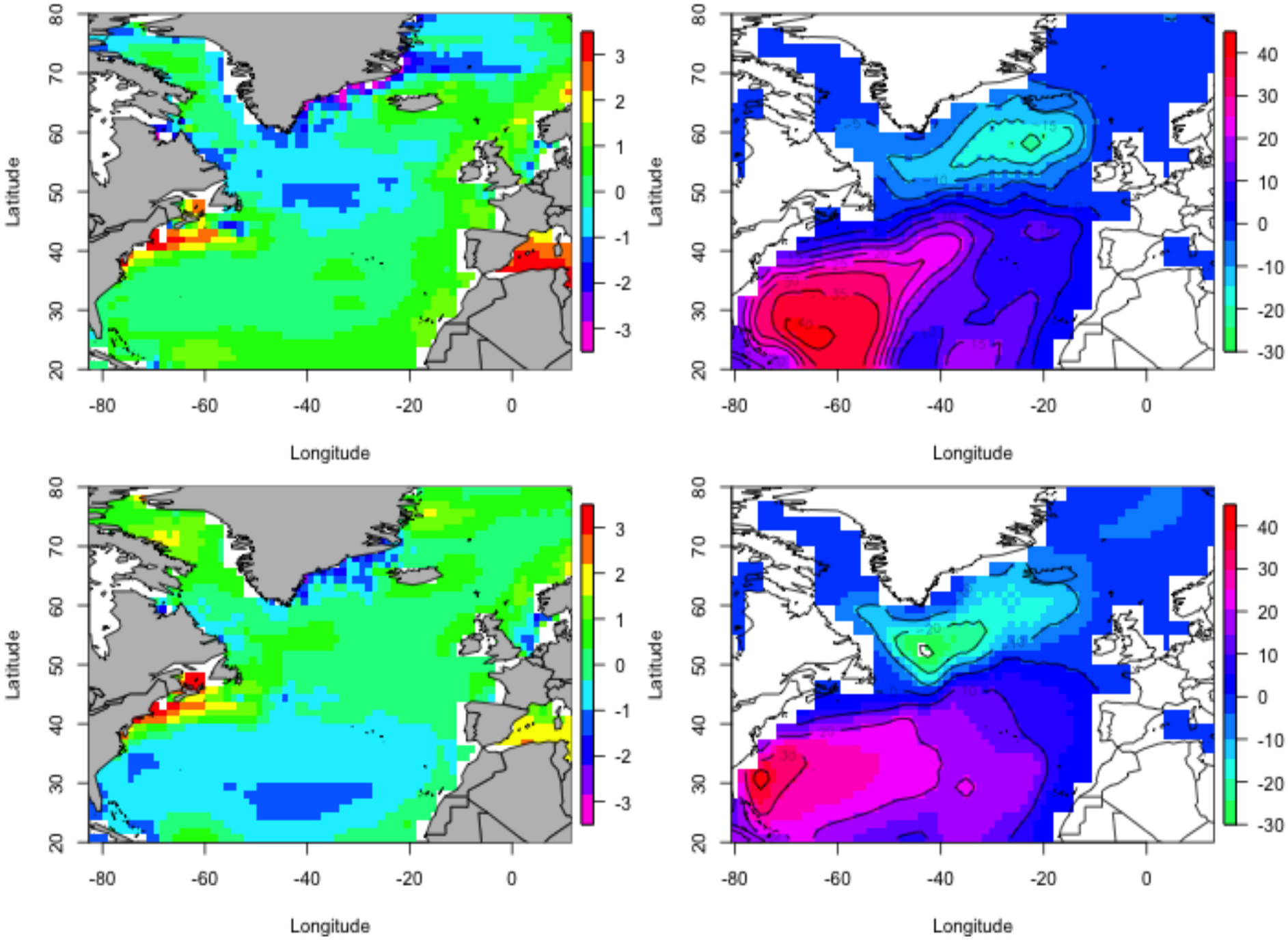
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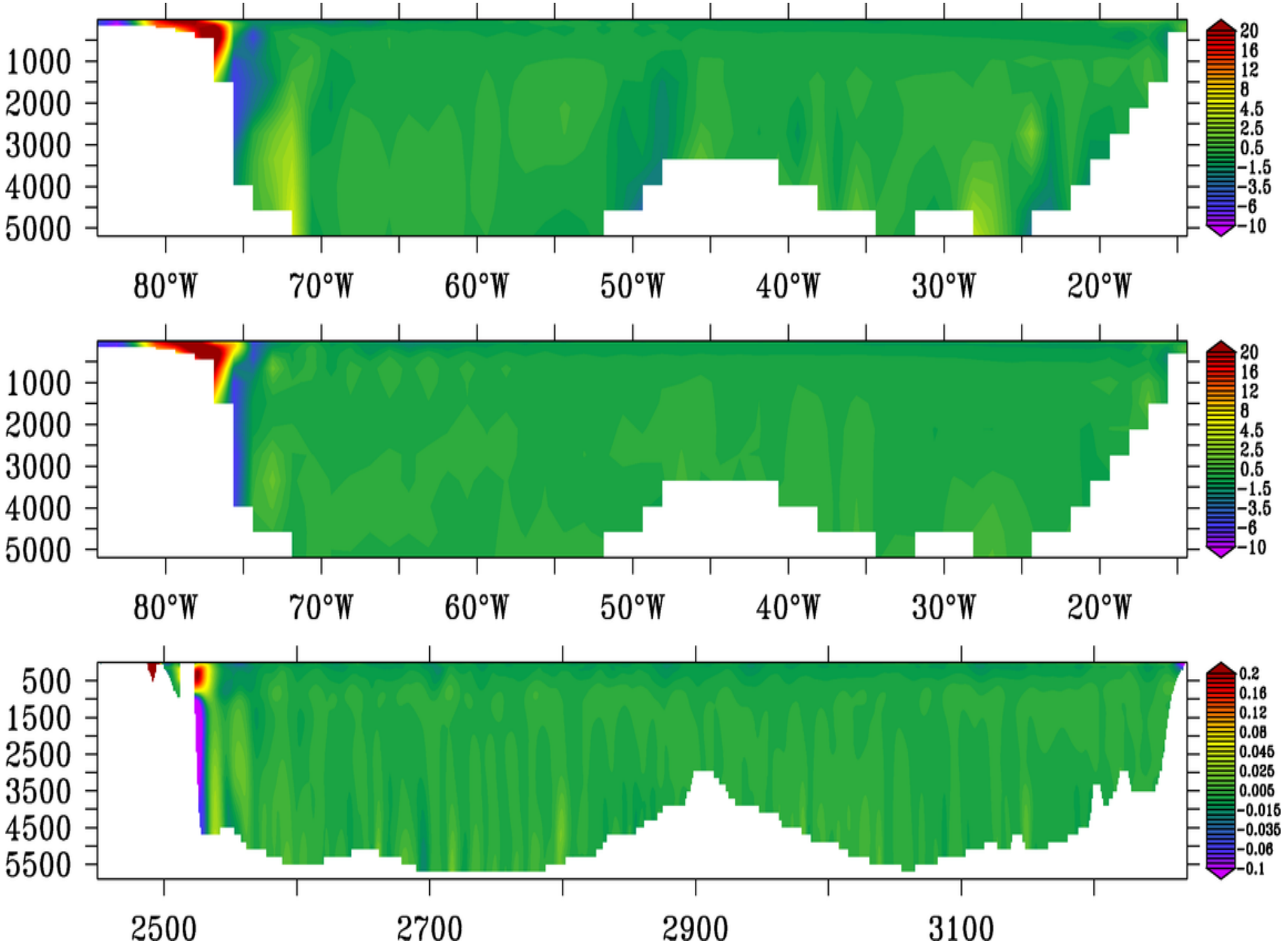
1000
2000
3000
4000
5000
80°W
70°W
60°W
50°W
40°W
30°W
20°W
20
16
12
8
4.5
2.5
0.5
-1.5
-3.5
-6
-10
1000
2000
3000
4000
5000
80°W
70°W
60°W
50°W
40°W
30°W
20°W
20
16
12
8
4.5
2.5
0.5
-1.5
-3.5
-6
-10
500
1500
2500
3500
4500
5500
2500
2700
2900
3100
0.2
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0.12
0.08
0.045
0.025
0.005
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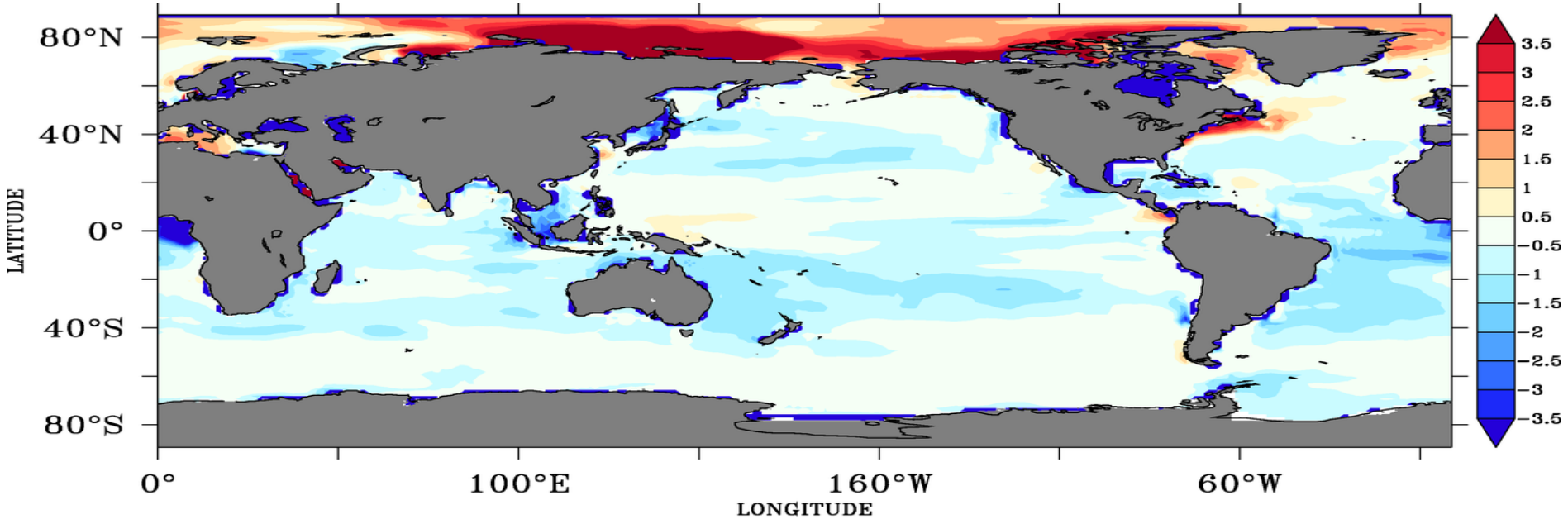
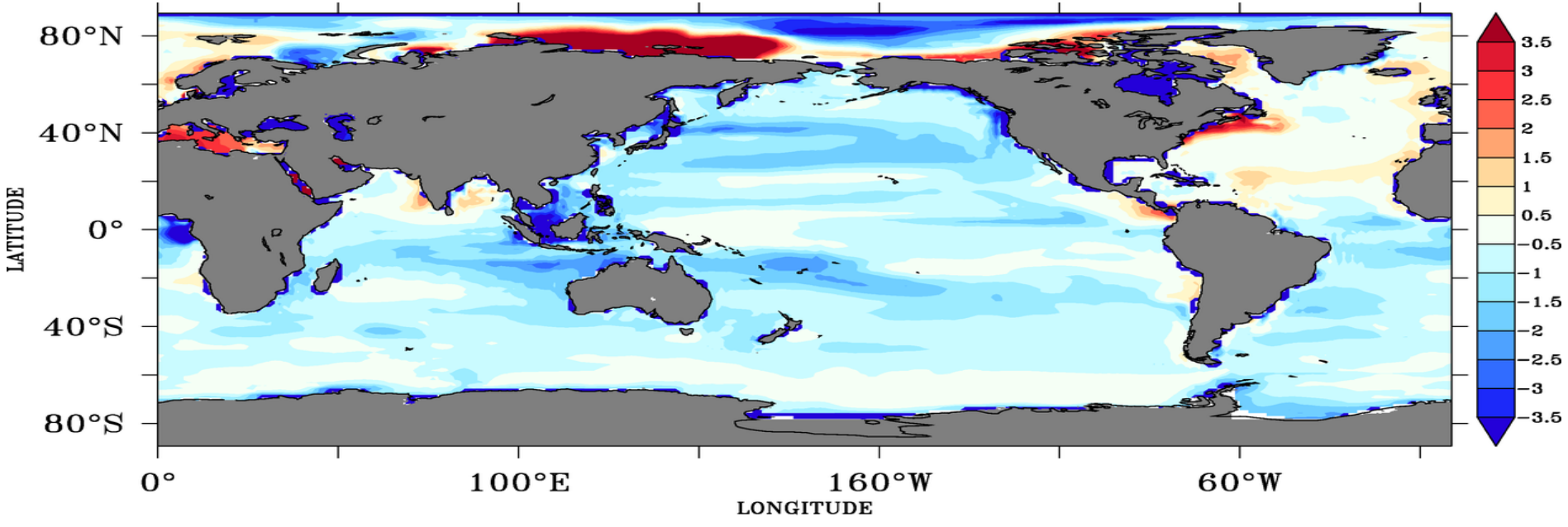
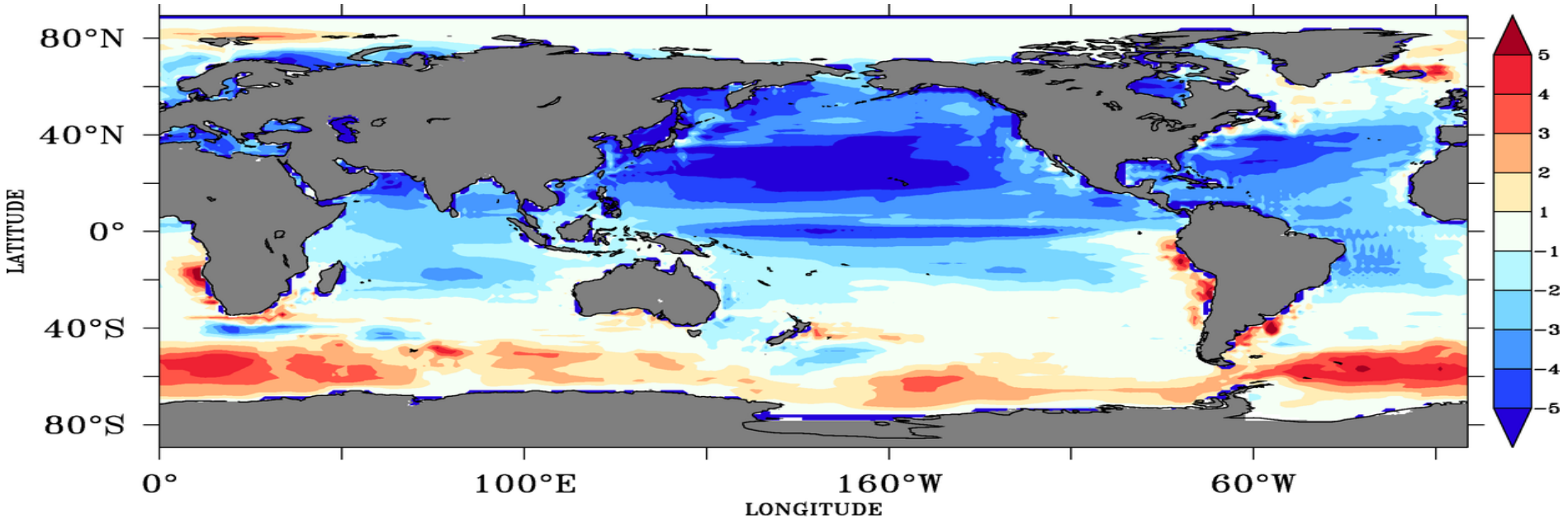
-0.035
-0.06
-0.1



Correct ACC HC3 S bias



Standard HC3 S bias



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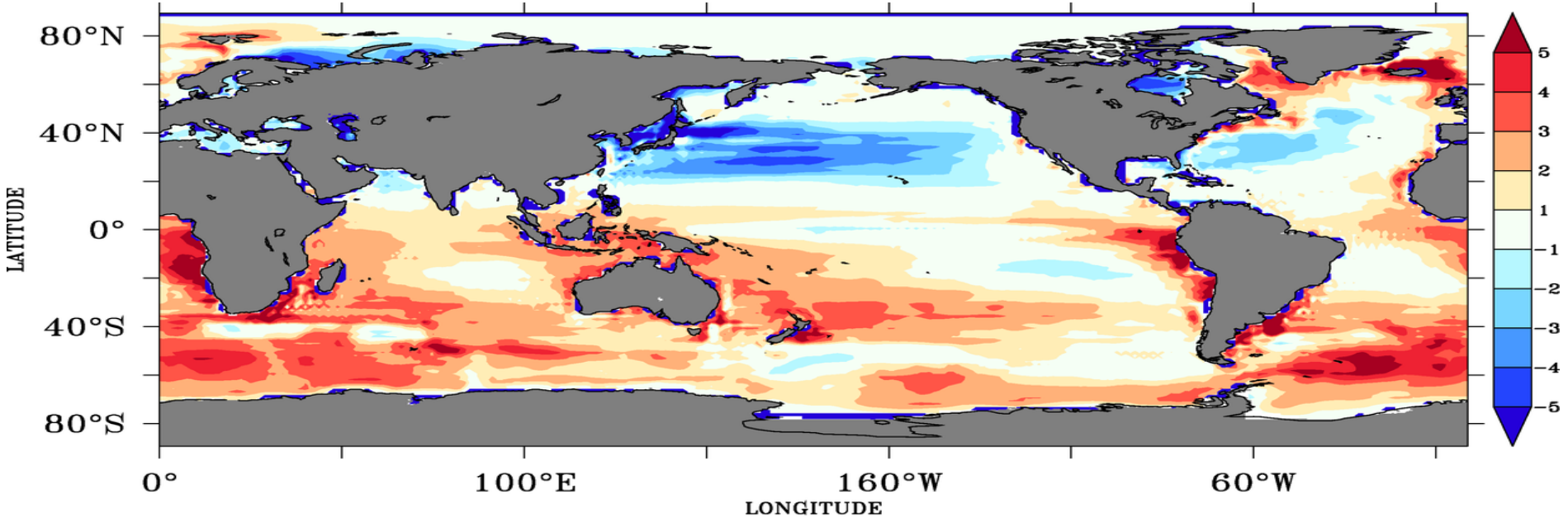
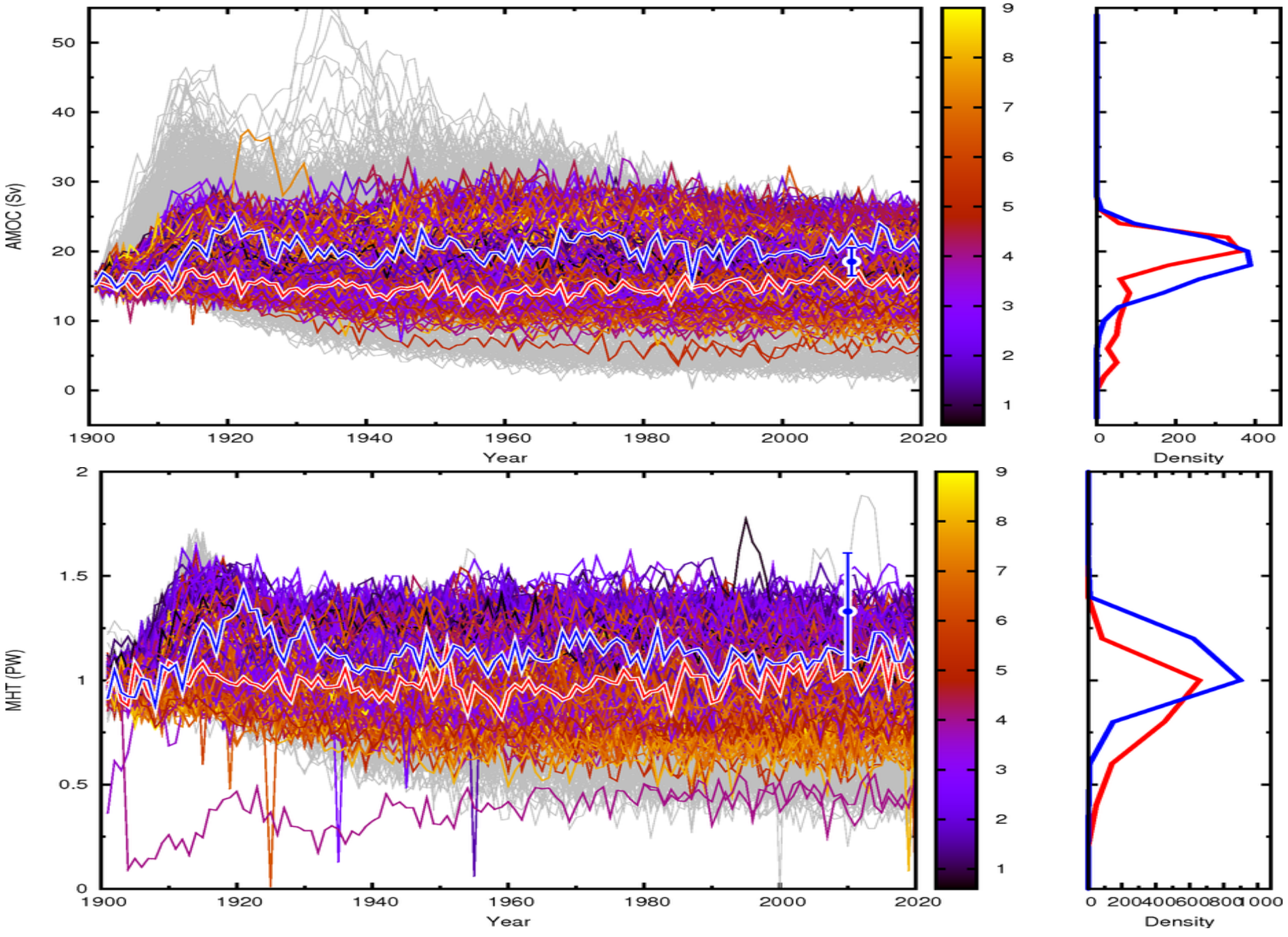


Standard HC3 T bias


AMOC (Sv)
50
40
30
20
10
0
1900
1920
1940
1960
1980
2000
2020
Year
9
8
7
6
5
4
3
2
1
0
200
400
Density
MHT (PW)
2
1.5
1
0.5
0
1900
1920
1940
1960
1980
2000
2020
Year
9
8
7
6
5
4
3
2
1
0
200
400
600
800
1000
Density

Exploring parameter space

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Constraining the ocean circulation

We impose 6 further constraints on NROY space:

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5. Not implausible that the SPG is 1.5 times stronger in the labrador sea than to the west of Greenland.
6. Not implausible SST around iceland.

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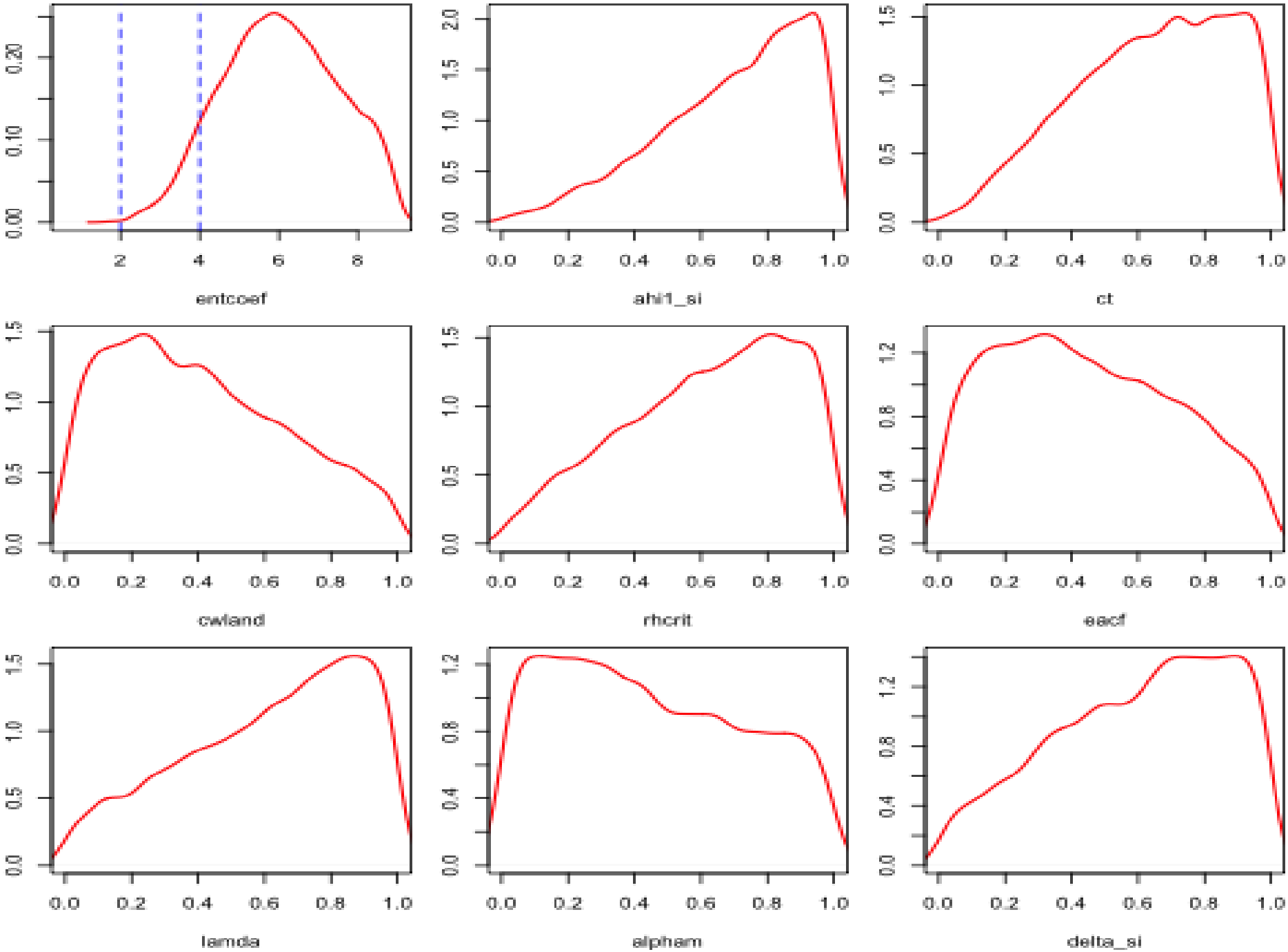
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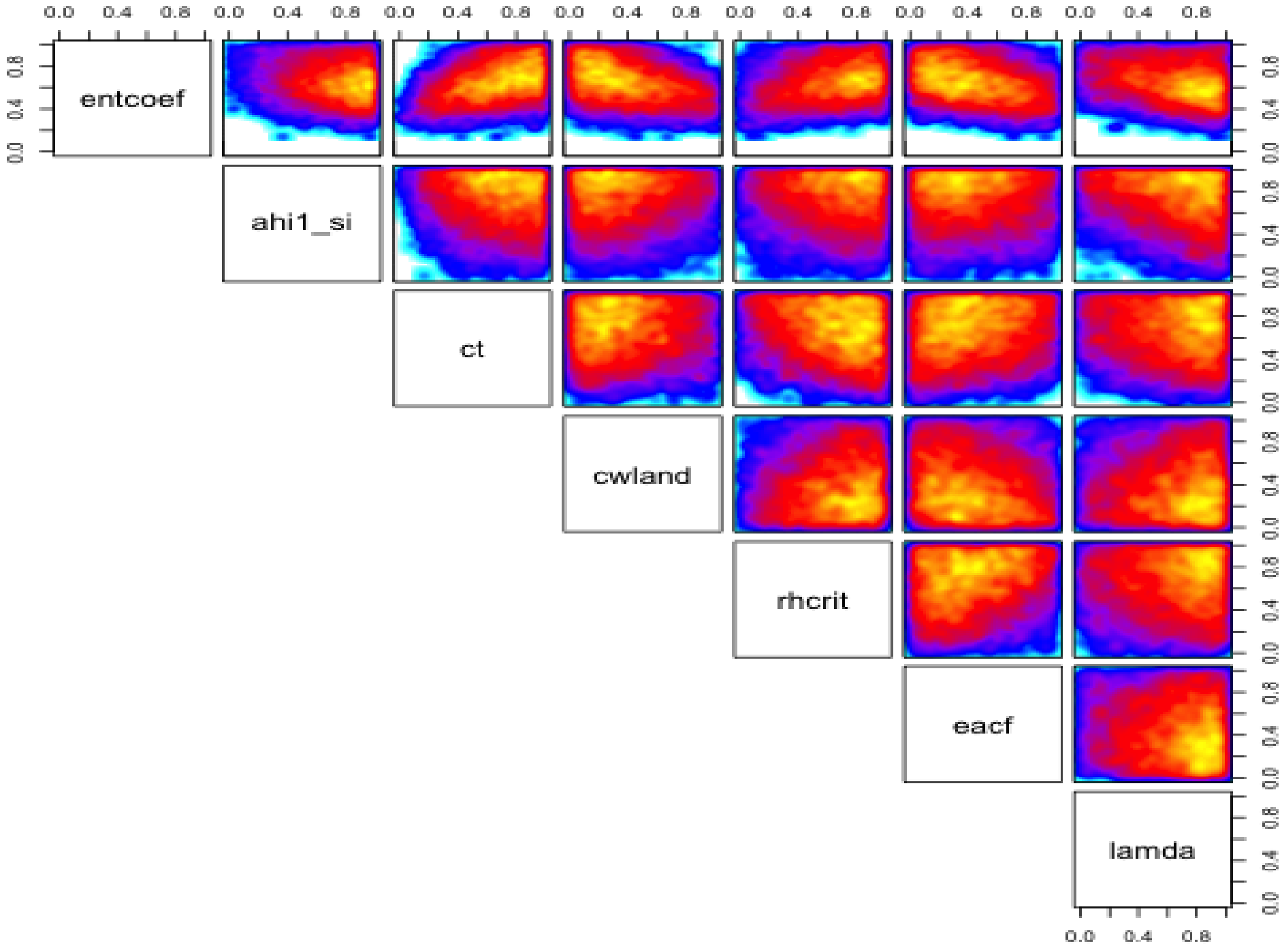
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Summary

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- They identified a number of supposed "structural errors" in the coupled HadCM3.
- We have showed that some of these errors are not structural at all, but are "tuning errors".
- We used History matching to find a region less than 1% of the volume of the HadCM3 parameter space where ocean circulations are predicted to be not implausible.

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- These results illustrate that good experimental design is essential (and not currently present) during the development and "tuning" of climate models.

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- These results illustrate that good experimental design is essential (and not currently present) during the development and "tuning" of climate models.
- Climate model tuning has implications for any one-run based study including those based on multi-model ensembles and data assimilation.
- Designs geared towards multiple waves of history matching would dramatically improve the current generation of climate models without improving resolution or including more realistic physics.

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References

Contact d.williamson@exeter.ac.uk for more info or for copies of papers

Williamson, D., Goldstein, M., Allison, L., Blaker, A., Challenor, P. Jackson, L., Yamazaki, K. (2013),

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