



# **INTERNAL REPORT**

## **Atlas of Tides, North West European Shelf**

### **Volume I: Tide only model**

Joanne Williams and Clare O'Neill

4th October 2024

NOC Internal Report No. 27



# Atlas of Tides, North West European Shelf

Volume I: Tide only model

*The Atlas has 2 volumes:*

*Volume I: Tide-only*

*Volume II: Tide and surge*

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4<sup>th</sup> October 2024

## Content

This Atlas contains co-phasal maps of tidal constituents' amplitudes and phases, and summary statistics for the NEMO surge model. They are derived from the AMM7 regional (North West European Shelf) ERA5-forced hindcast run of the NEMO surge and tide model. The hindcast was run by Clare O'Neill at the Met Office on behalf of NOC as part of the EA-funded project on radiational tides. All postprocessing to derive tides has been done by Joanne Williams, NOC.

This document contains figures of the maps. The data is available as netcdf files from zenodo via <https://doi.org/10.5281/zenodo.13882297>.

Volume I is derived from the tide-only run.

Volume II is from the model forced by the ERA5 hindcast. In this case although the maps are labelled eg "HAT" to be consistent with the other set, it's actually highest/lowest tide+surge. All the statistics are calculated on the full 42-year 15-minute timeseries at each grid point, rather than estimates from the tidal constituents.

All means are relative to the surge and tide model datum only and will require correcting to local chart datum or ODN.

**A 7km model cannot reproduce the tide accurately on complex coastlines, for example shallow water and estuaries can significantly change the range of the tide. These data are provided for research purposes into the spatial structure of the tides are the UK. They are not locally validated, and are not sufficient for navigation, flood forecasting or legal purposes.**

## Model

The NEMO surge model is used as the main operational surge model for the UK, for which it is run every 6 hours forced by the atmospheric pressure and surface winds from the Met Office deterministic and ensemble weather forecasts. Model surge residuals are the difference between the tide-and-surge model run and a tide-only run. This analysis is on the ERA5-hindcast forced run.

## Tidal analysis

Tidal analysis is done on the full 42-year timeseries at each grid point independently. This is done using the NOctide software, a least-squares fit method. These are harmonic tides predictions including up to 115 constituents, including the annual SA. (See Table 1). The nodal correction is within the code so constituents are unchanged between years.

The harmonic tidal prediction  $\tilde{G}$  is constructed:

$$\tilde{G}(t) = Z_0 + \sum_N A_n f_n \cos[\sigma_n t - g_n + (V_n + u_n)],$$

where  $Z_0$  is the mean of  $G$ , and the tidal constituents with frequencies  $\sigma_n$  have amplitude  $A_n$  and phase  $g_n$ .  $f_n(t)$  and  $u_n(t)$  are nodal modulations to amplitude and phase applied in order to allow for the 18.61-year nodal cycle and 8.85-year longitude of the lunar perigee cycle.  $V_n$  represents the phases of the equilibrium tide, which we take as for Greenwich, using UTC for all times.

## Statistics Maps

The statistics maps are:

HAT, Highest Astronomical Tide

LAT, Lowest Astronomical Tide

MHW, Mean High Water

MLW, Mean Low Water

MHWS, Mean High Water Springs

MLWS, Mean Low Water Springs

MHWN, Mean High Water Neaps

MLWN, Mean Low Water Neaps

MHHW, Mean Higher High Water

MLLW, Mean Lower Low Water

RangeAT, HAT - LAT, Maximum Tidal Range

MSRange, MHWS- MLWS, Mean Spring Tidal Range

MRange, MHW - MLW, Mean Tidal Range

MNRange, MHW - MLWN, Mean Neap Tidal Range

## Acknowledgements

Many people contribute directly or indirectly to the routine analysis of the tide gauge data and surge forecasting. In particular, thanks are due to:

Clare O'Neill and Andy Saulter at the Met Office, for operational surge modelling and development;

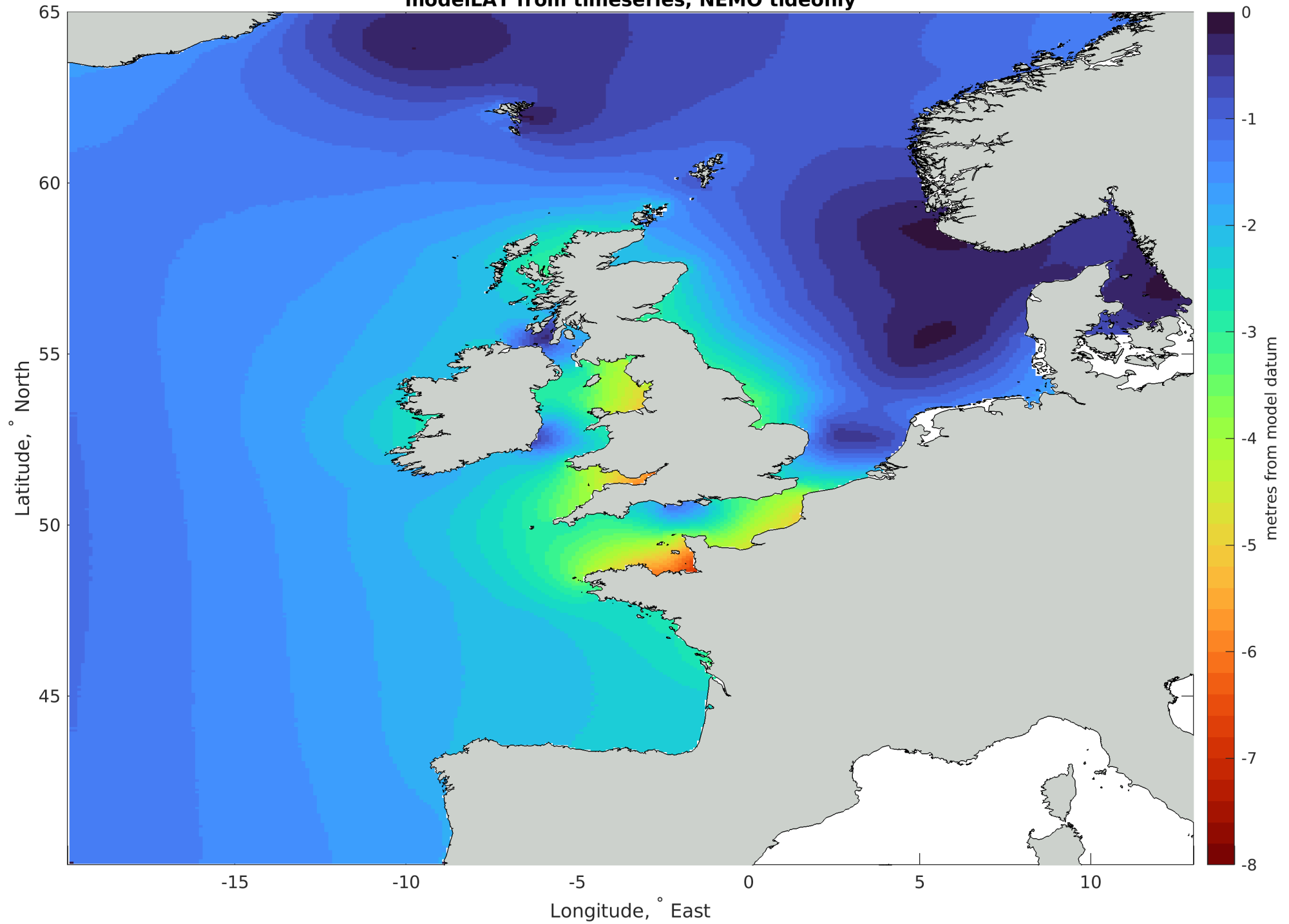
Angela Hibbert, Jeff Polton, Andy Matthews and Sveta Jevrejeva, at NOC Liverpool, for project management of this and related projects and many useful discussions;

Jenny Sansom, Roger Quinn and Philip Staley at the Environment Agency, for project management of this and related projects and many useful discussions.

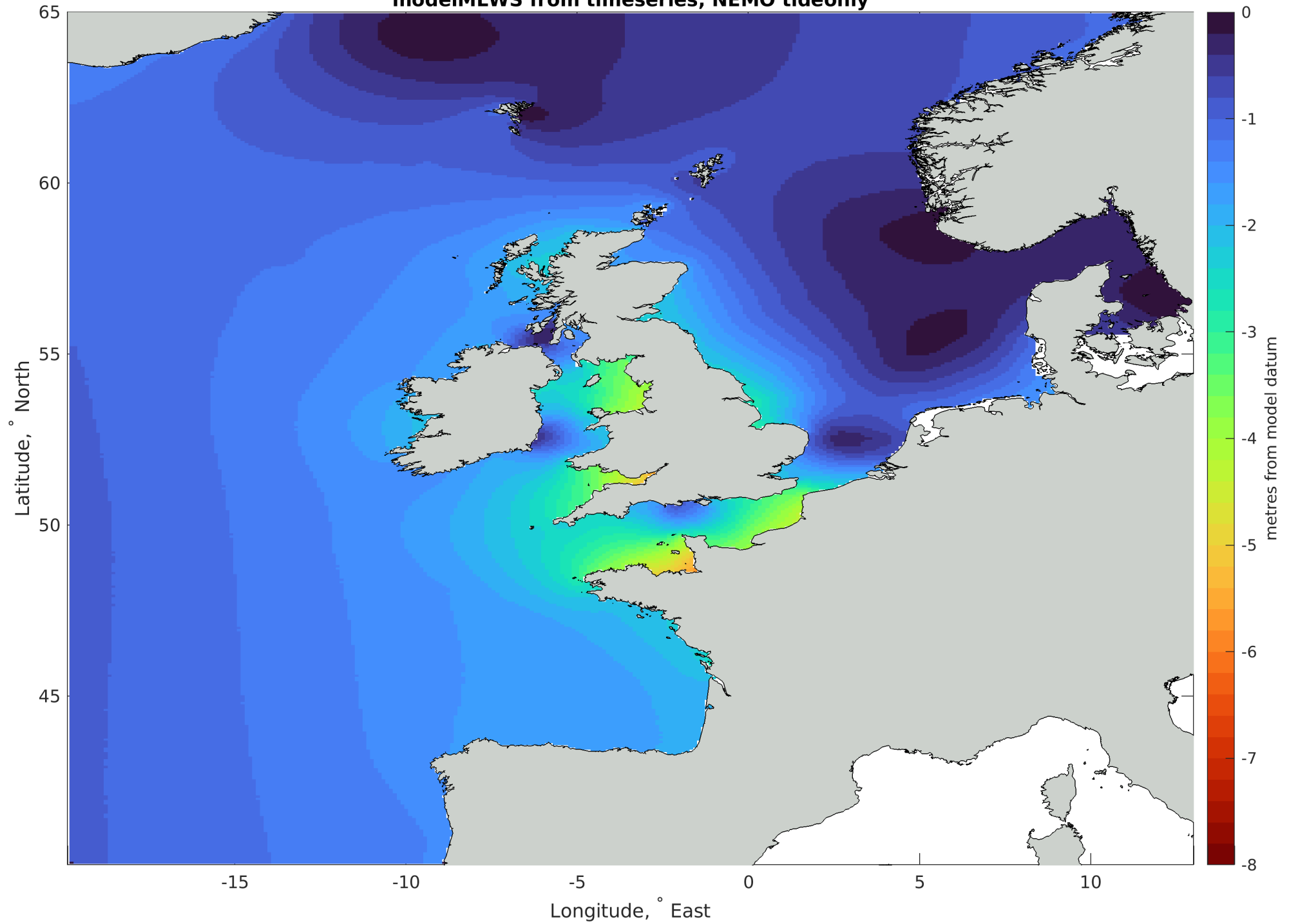
Table 1: Names and periods of 115 constituents, in the order used in the NOctide code.

<b>Name</b>	<b>Period, hours</b>	<b>Name</b>	<b>Period, hours</b>	<b>Name</b>	<b>Period, hours</b>
SA	8765.8211	KJ2	11.7545	4MK6	4.1932
SSA	4382.9052	2SM2	11.6070	4MS6	4.1891
MM	661.3092	MO3	8.3863	2MSNK6	4.1702
MSF	354.3671	M3	8.2804	2MV6	4.1628
MF	327.8590	SO3	8.1924	3MSK6	4.1441
2Q1	28.0062	MK3	8.1771	4MN6	4.1144
SIG1	27.8484	SK3	7.9927	3MSN6	4.0672
Q1	26.8684	MN4	6.2692	MKL6	4.0634
RO1	26.7231	M4	6.2103	2MN8	3.1346
O1	25.8193	SN4	6.1602	3MN8	3.1198
MP1	25.6681	MS4	6.1033	M8	3.1052
M1	24.8412	MK4	6.0949	2MSN8	3.0926
CHI1	24.7091	S4	6.0000	3MS8	3.0782
PI1	24.1321	SK4	5.9918	3MK8	3.0760
P1	24.0659	2MN6	4.1663	MSNK8	3.0637
S1	24.0000	M6	4.1402	2MS8	3.0517
K1	23.9345	MSN6	4.1179	2MSK8	3.0495
PSI1	23.8693	2MS6	4.0924	4MS10	2.4668
PHI1	23.8045	2MK6	4.0886	3M2S10	2.4498
TH1	23.2070	2SM6	4.0457	4MSN12	2.0645
J1	23.0985	MSK6	4.0419	5MS12	2.0581
SO1	22.4202	2MN2S2	13.6323	4M2S12	2.0462
OO1	22.3061	3MSK2	13.3978	MVS2	13.0925
OQ2	13.1667	3M2S2	13.3569	2MK2	12.9097
MNS2	13.1273	MNK2S2	13.0881	MA2	12.4382
2N2	12.9054	SNK2	12.6950	MB2	12.4030
MU2	12.8718	2SK2	12.0329	MSV2	11.8143
N2	12.6583	2MS2N2	11.5798	SKM2	11.5763
NU2	12.6260	MQ3	8.4940	2MNS4	6.3821
OP2	12.4559	2MP3	8.3703	MV4	6.2612
M2	12.4206	2MQ3	8.0773	3MN4	6.1525
MKS2	12.3855	3MK4	6.3302	2MSN4	6.0475
LAM2	12.2218	3MS4	6.3211	NA2	12.6767
L2	12.1916	2MSK4	6.2191	NB2	12.6401
T2	12.0164	3MK5	5.0062	MSO5	4.9364
S2	12.0000	M5	4.9682	MSK5	4.8632
R2	11.9836	3MO5	4.9309	2MN2	12.1916
K2	11.9672	2MNS6	4.2429		
MSN2	11.7861	3MNS6	4.2158		

modellAT from timeseries, NEMO tideonly

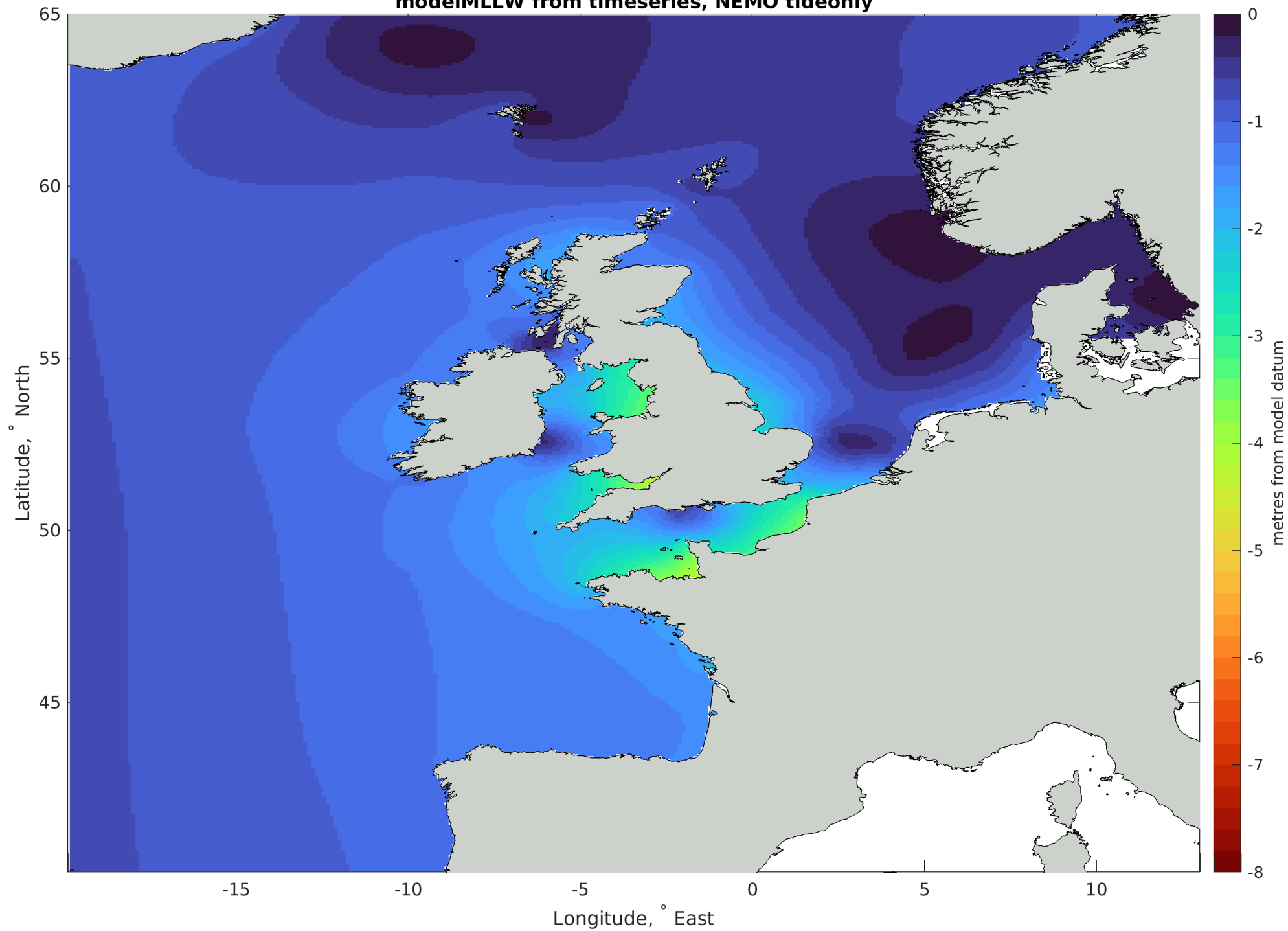


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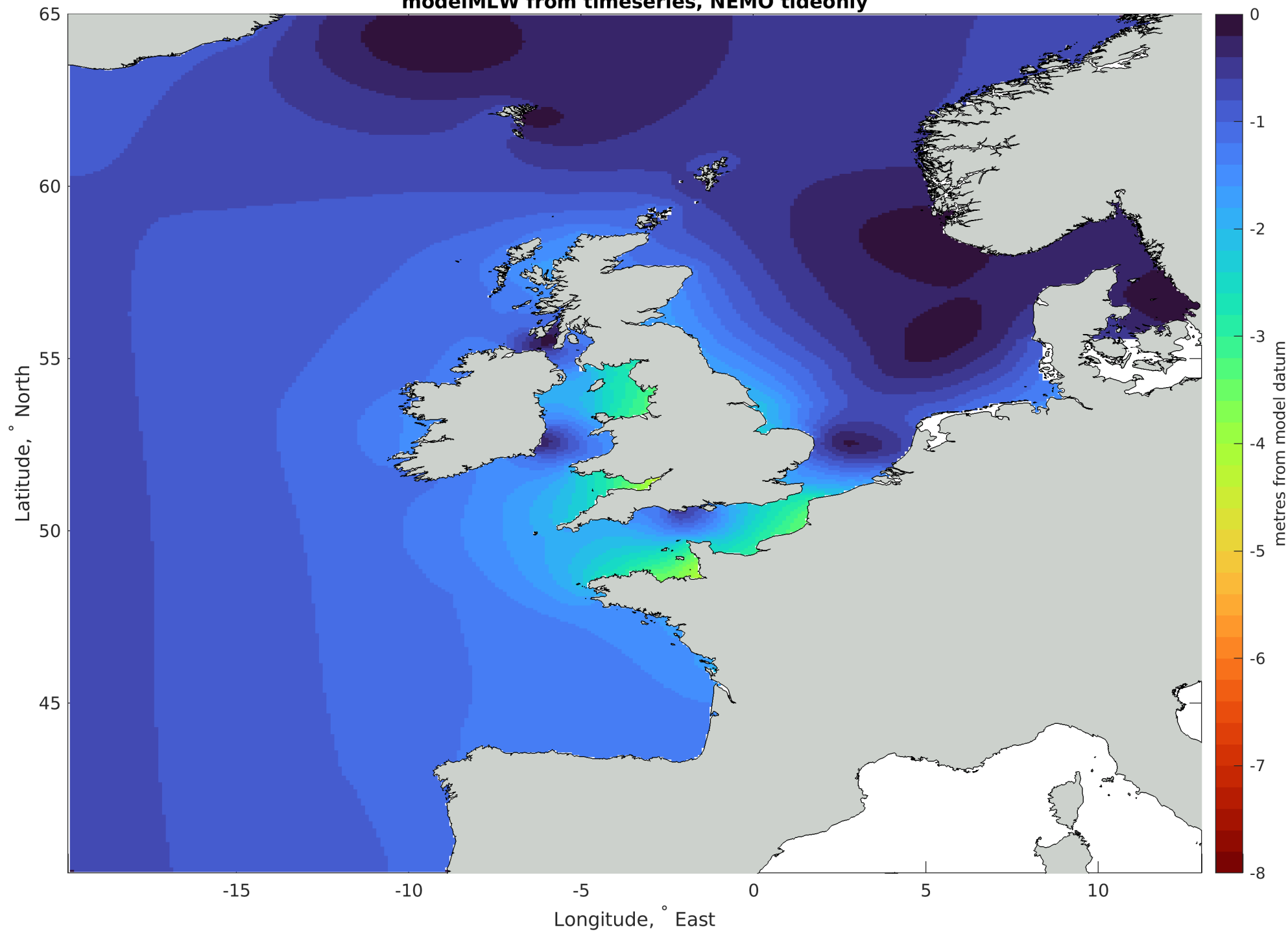




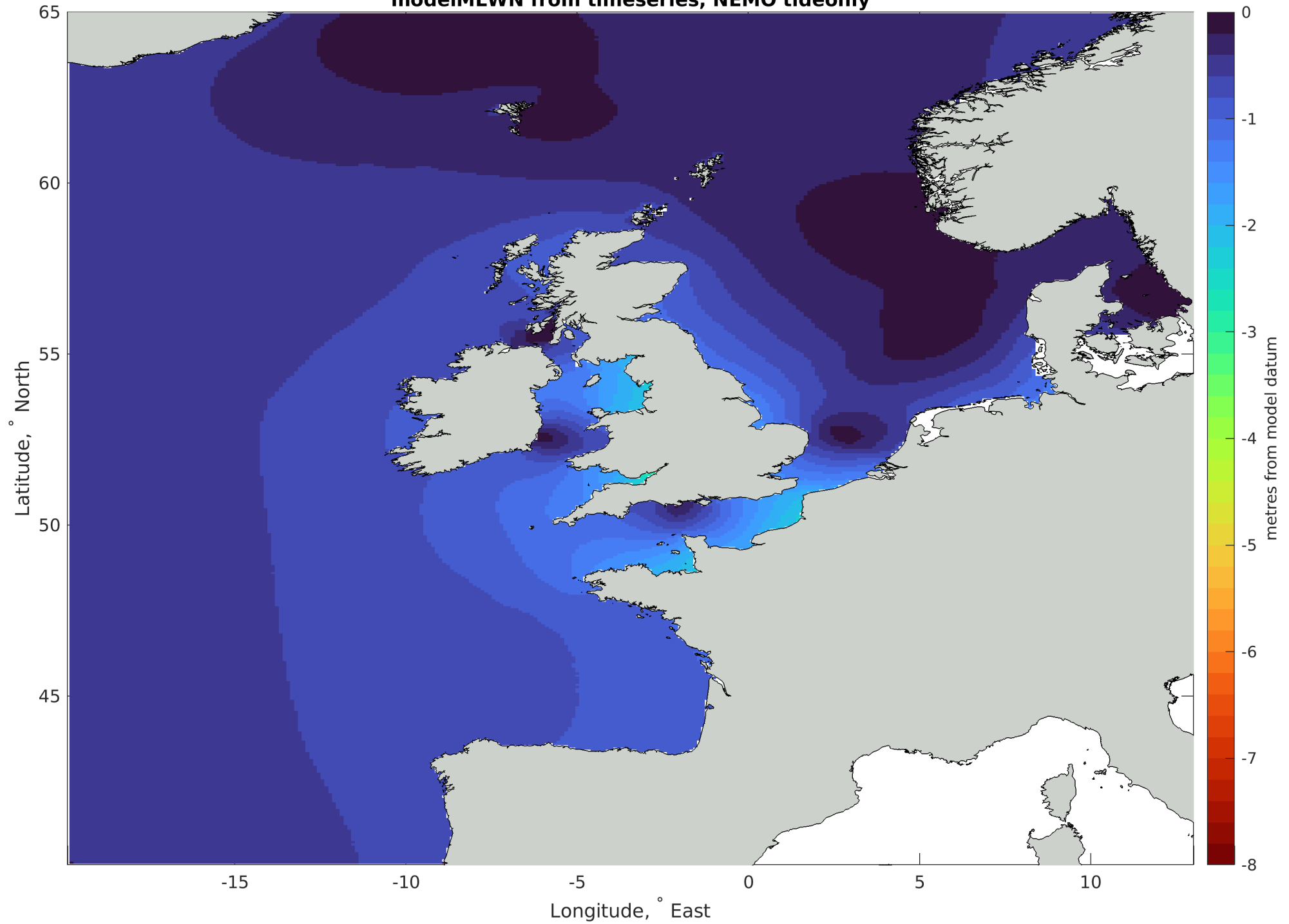
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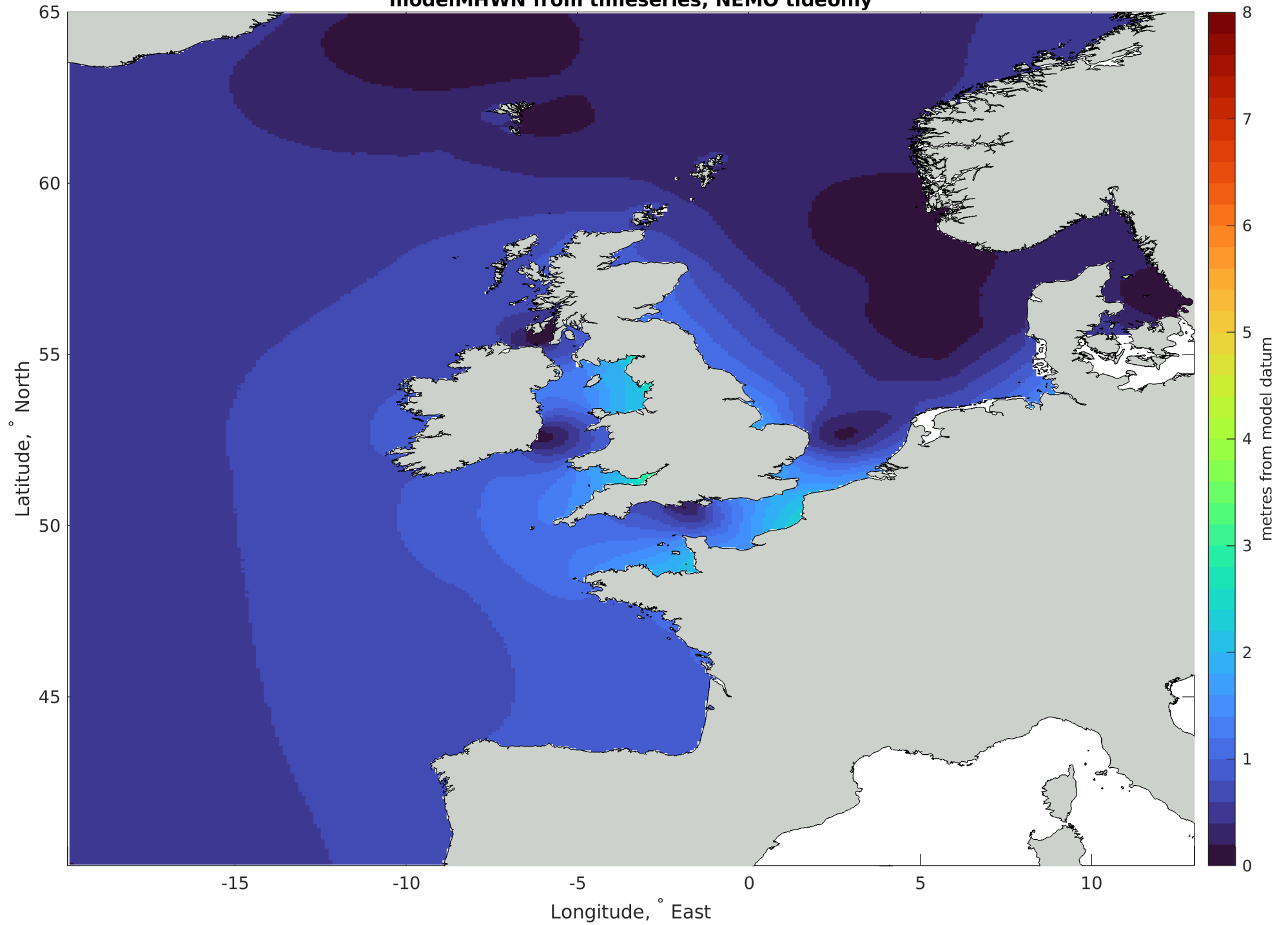
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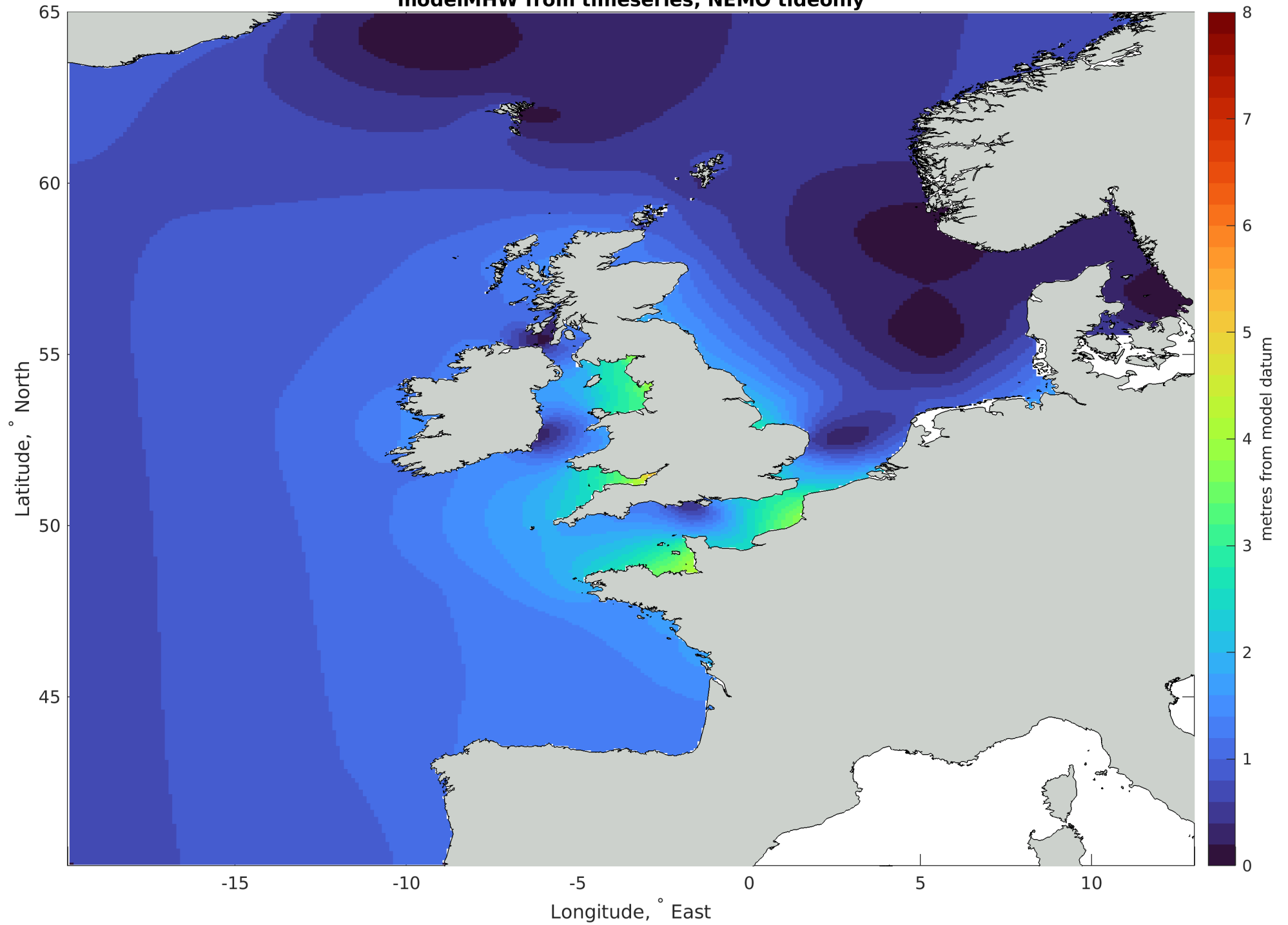
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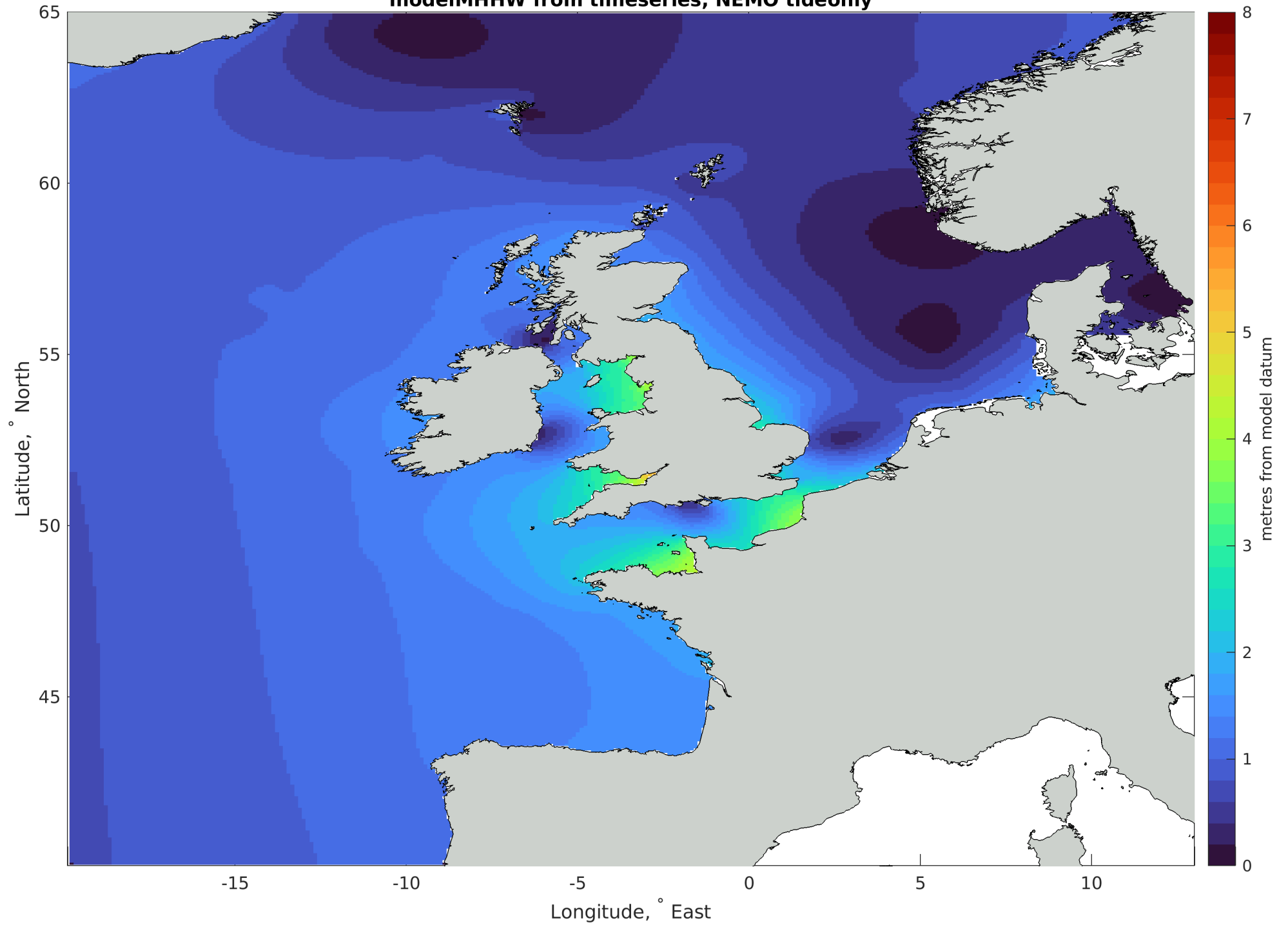
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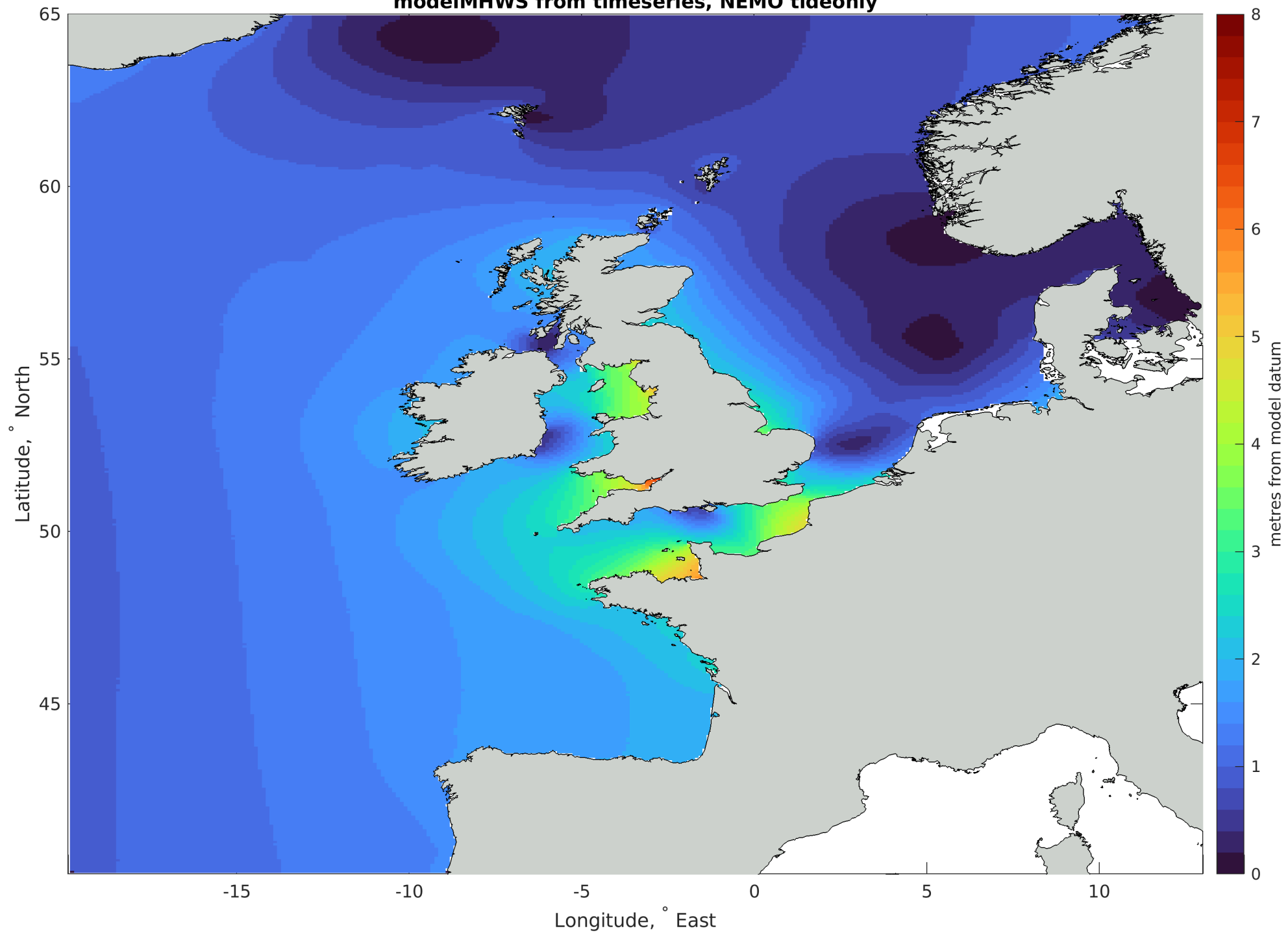
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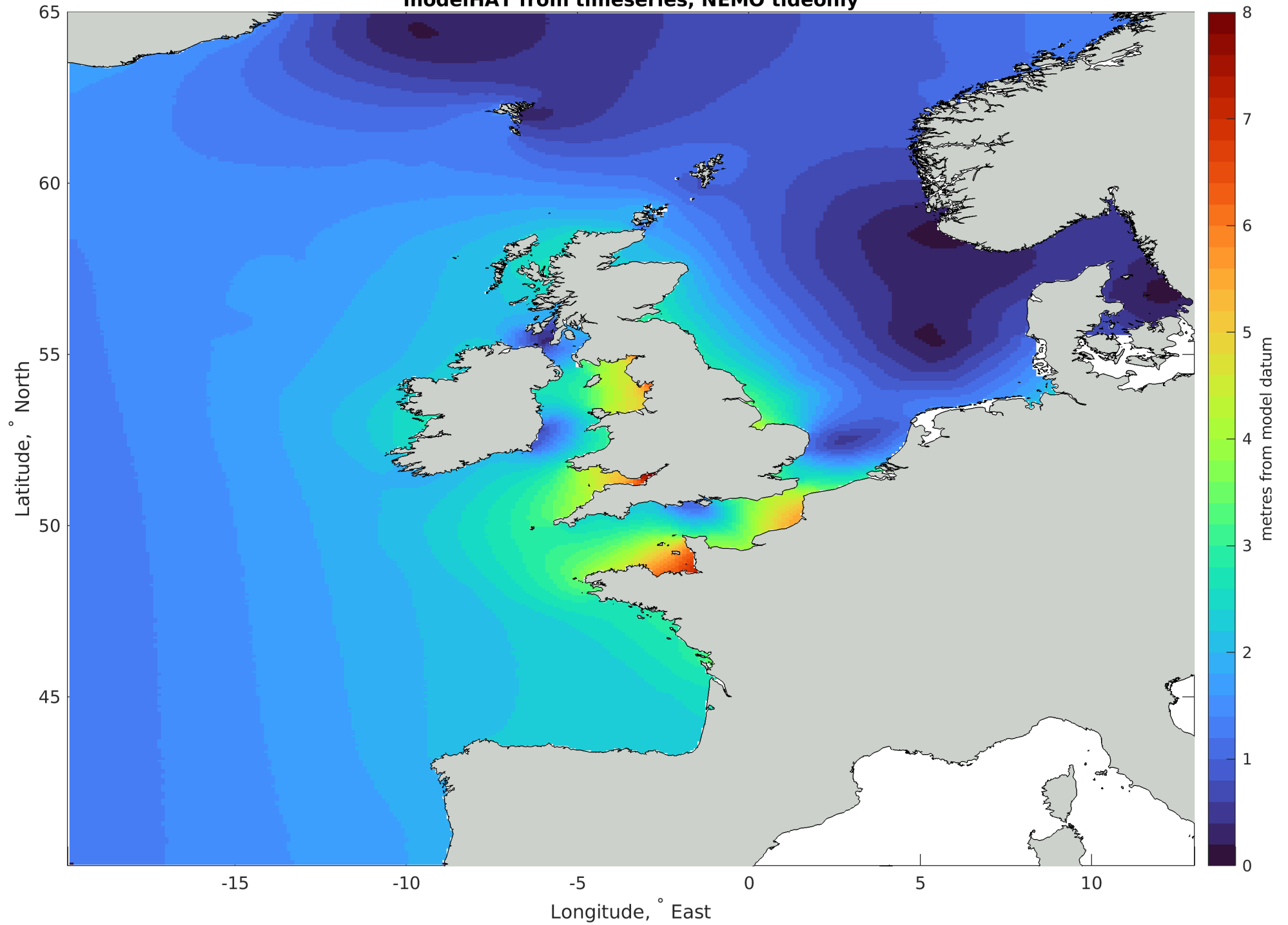
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modelMHWS from timeseries, NEMO tideonly

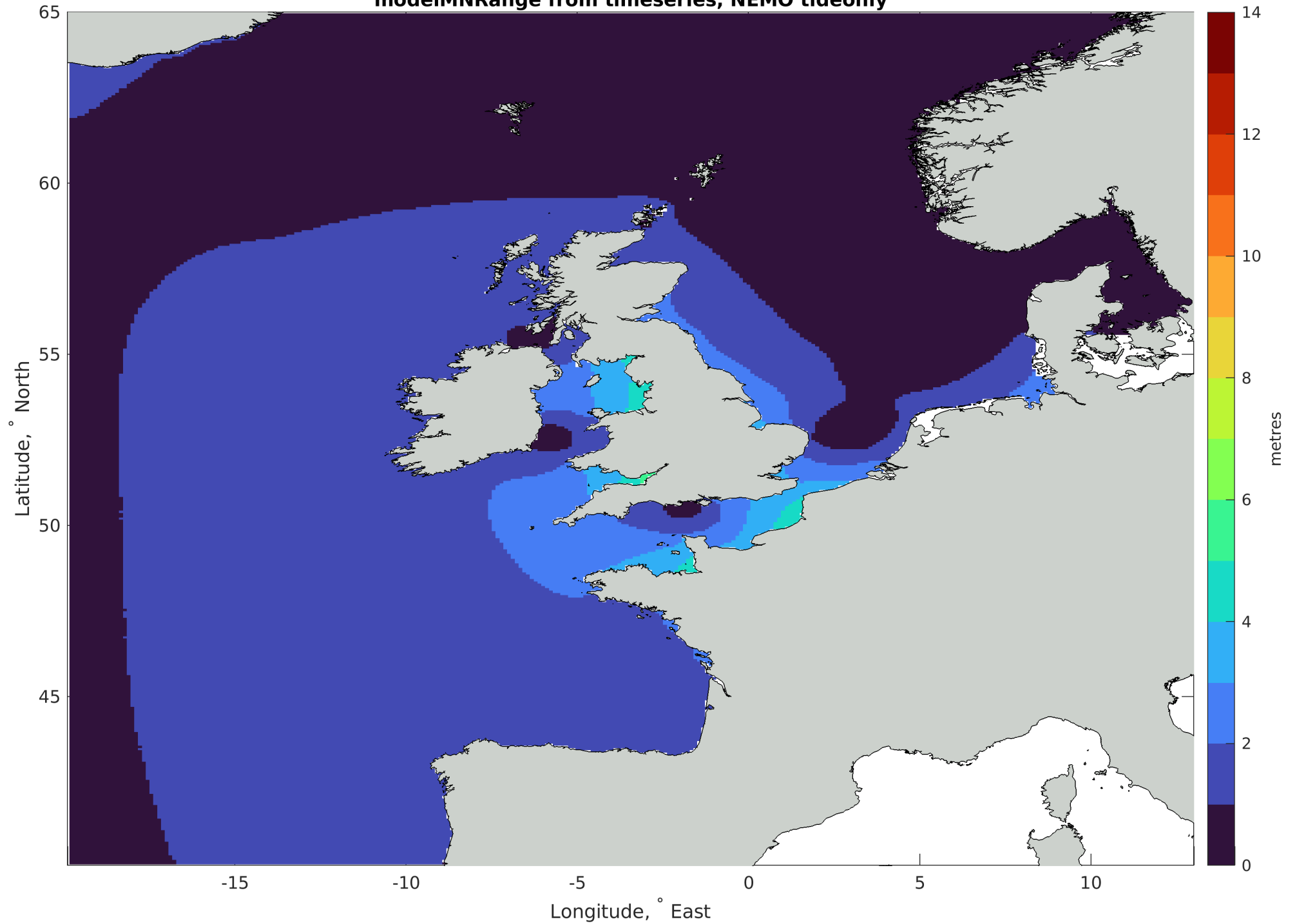


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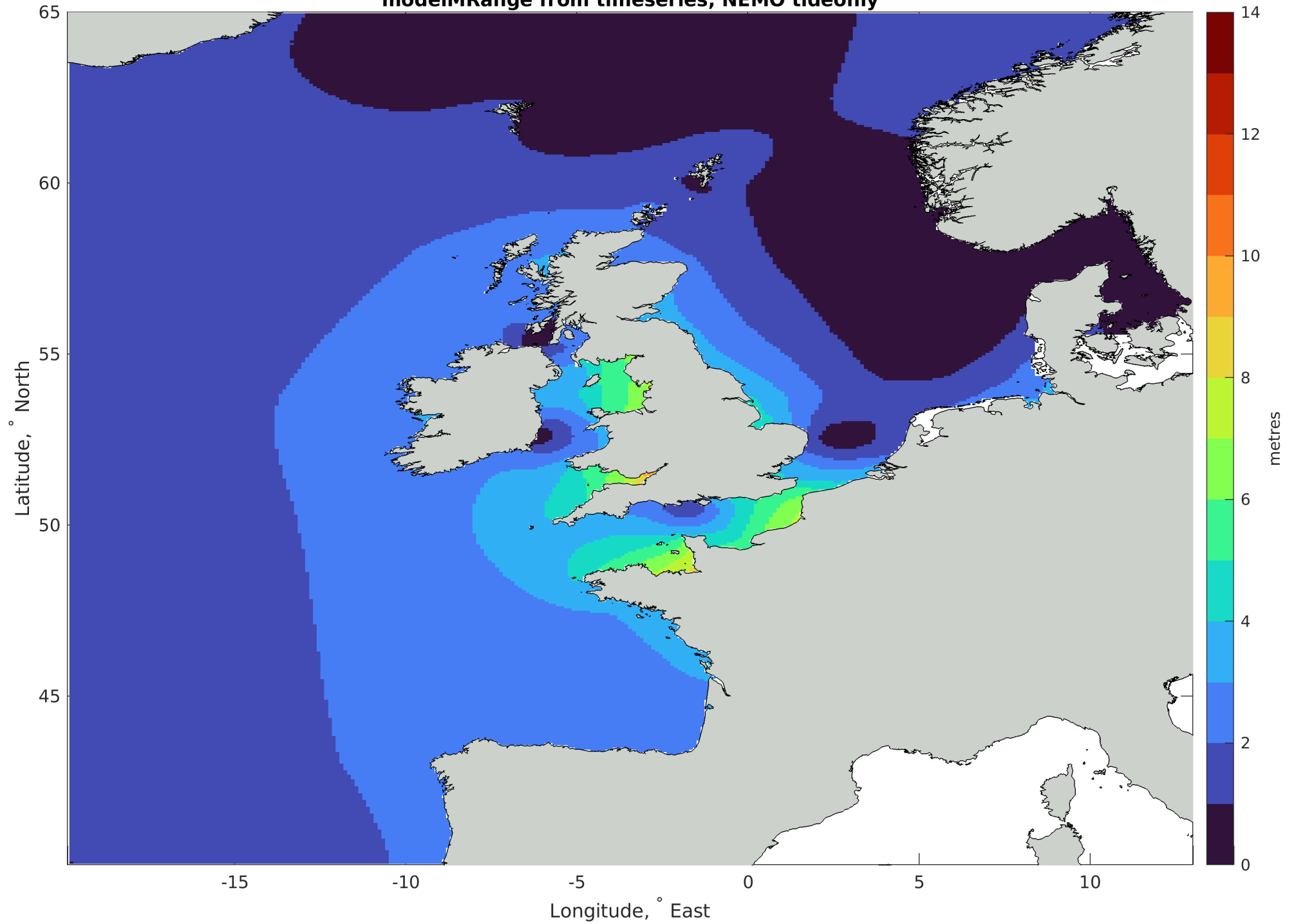




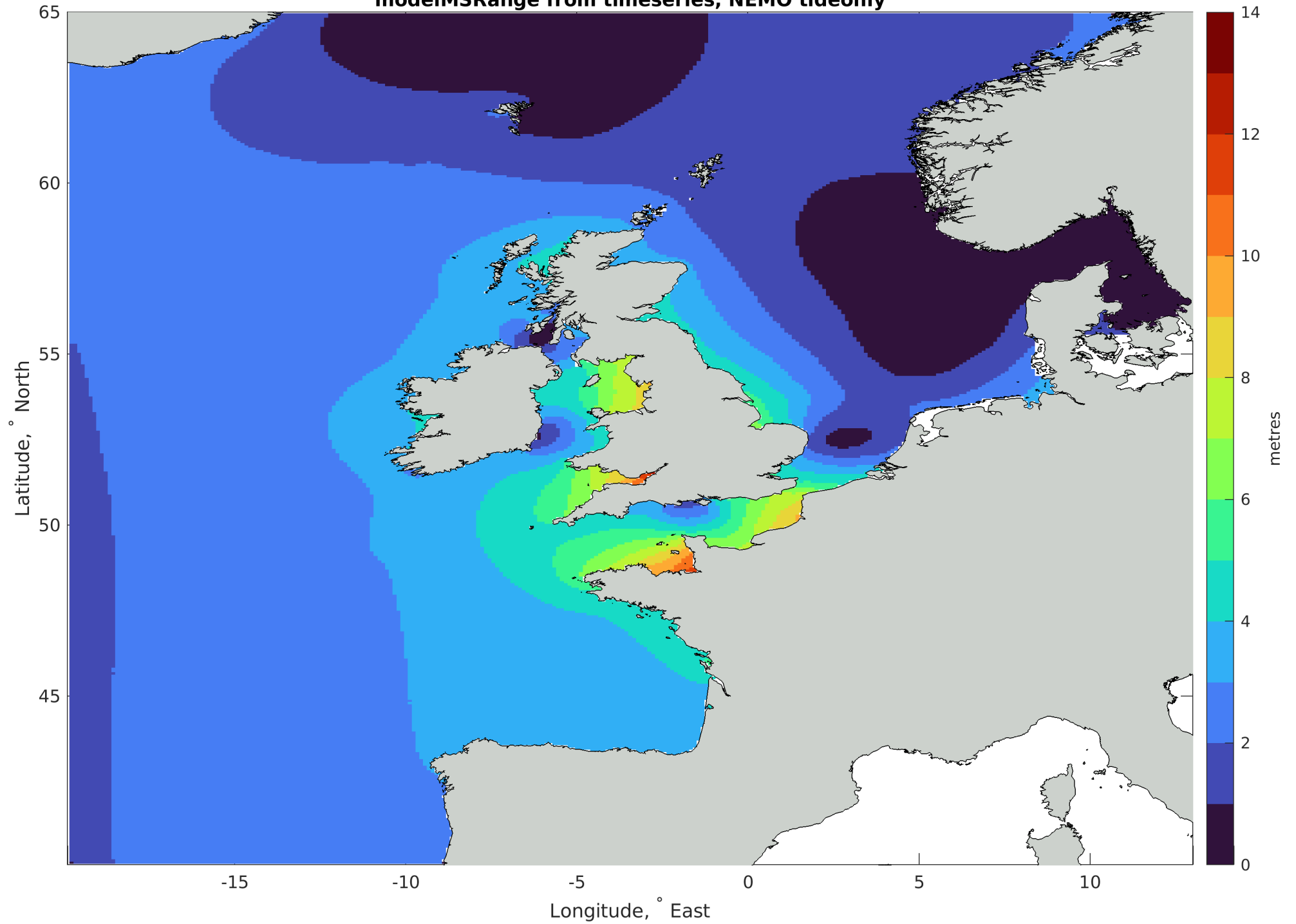
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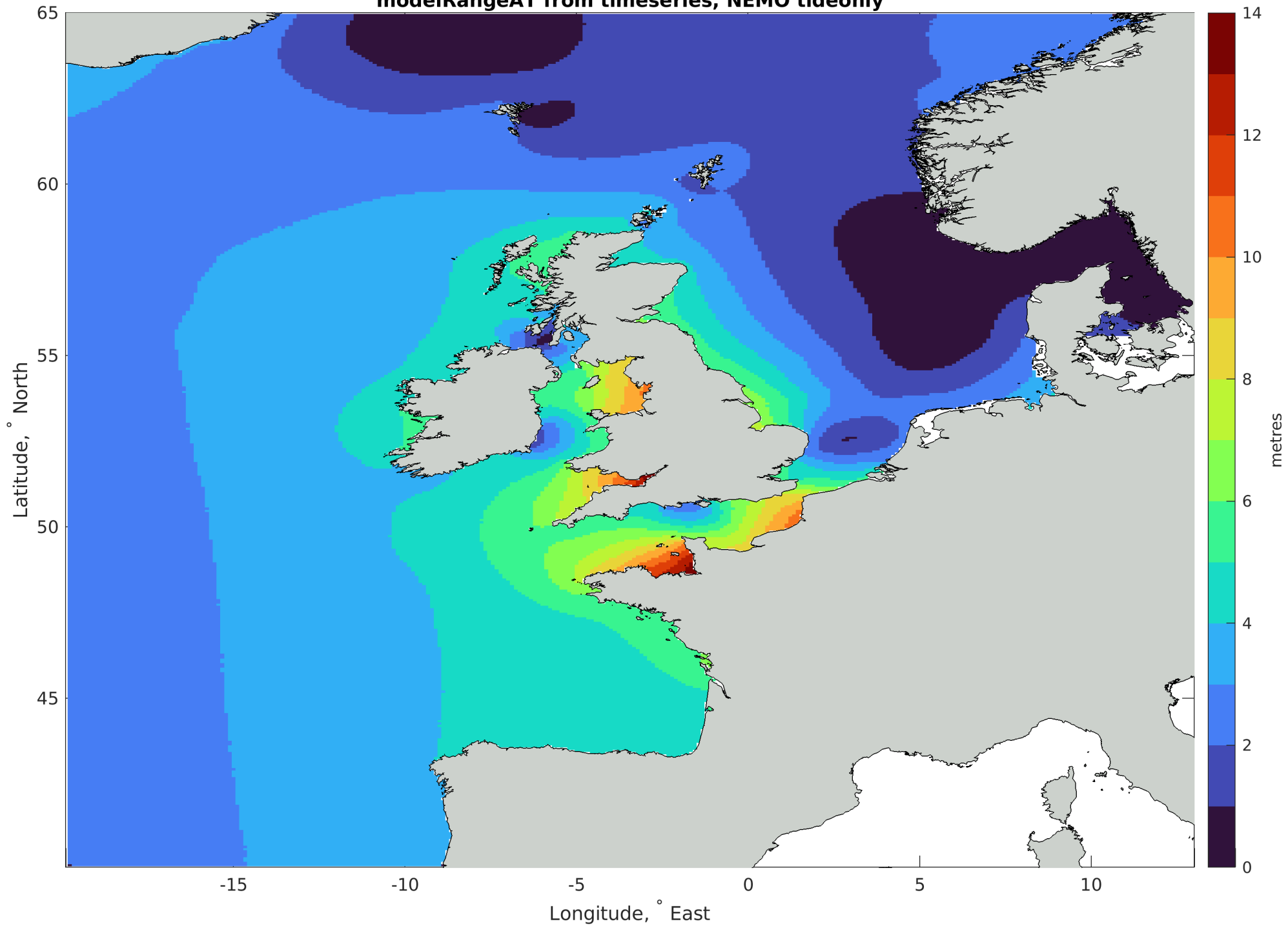
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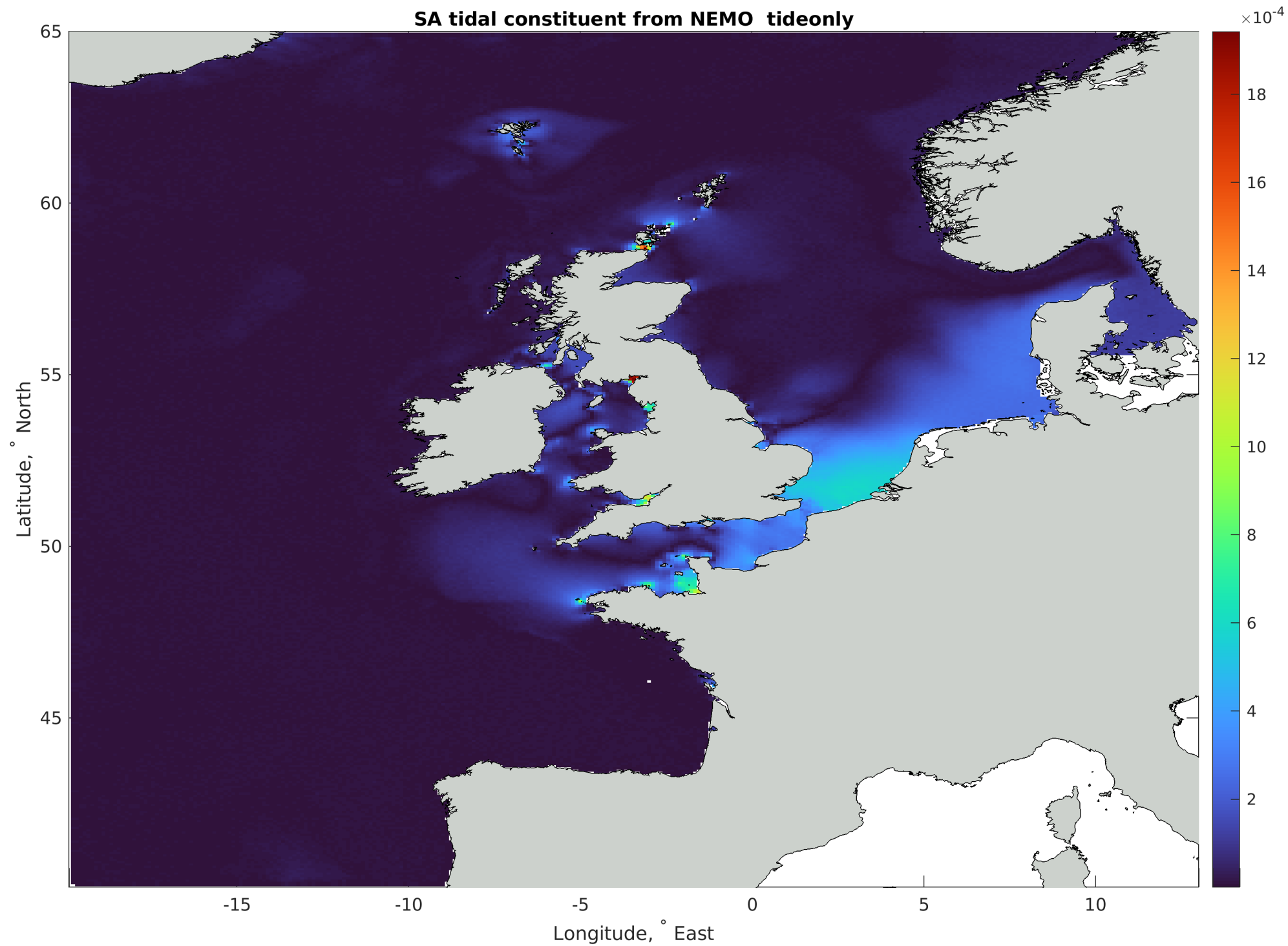
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modelRangeAT from timeseries, NEMO tideonly

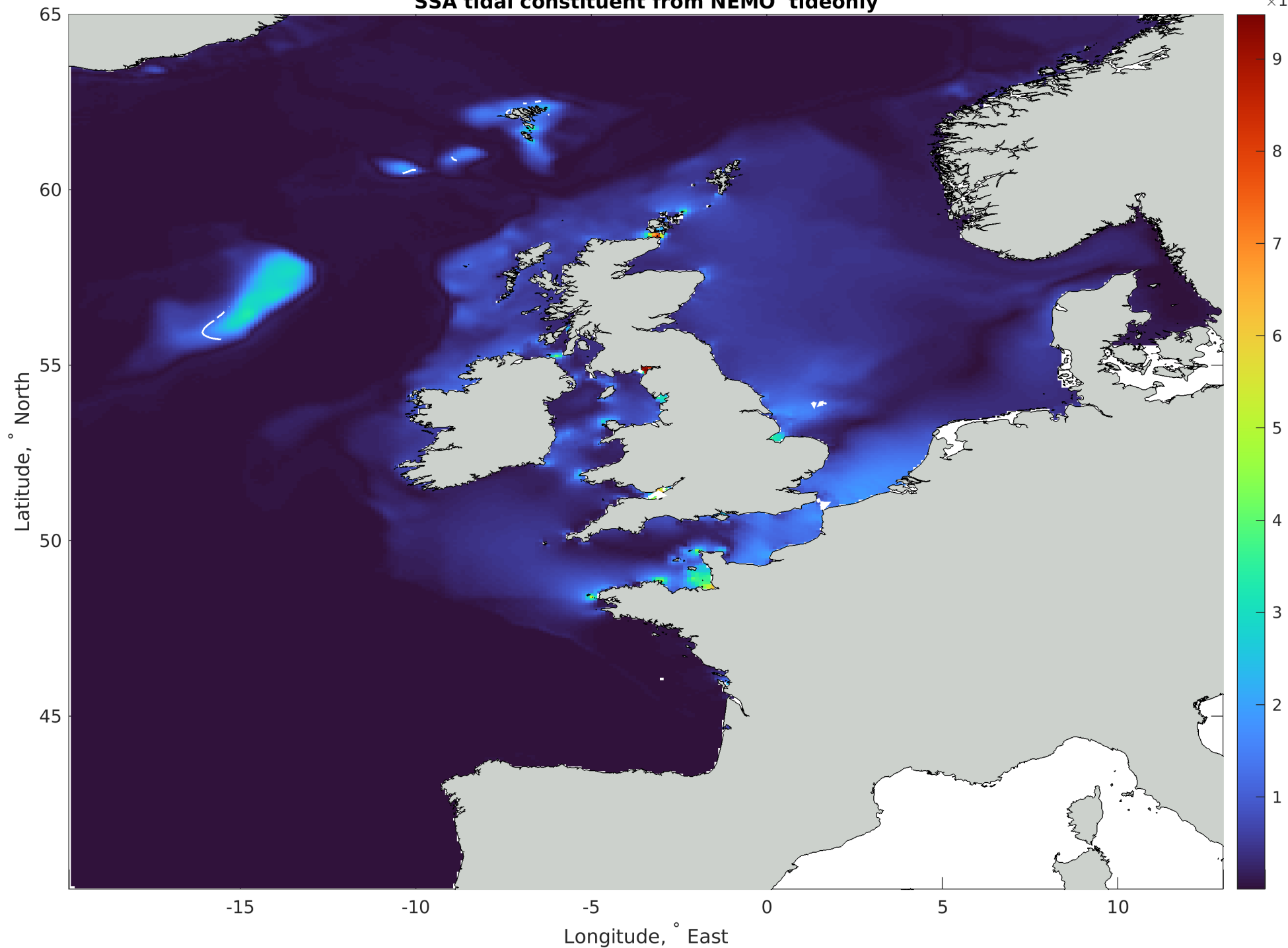


SA tidal constituent from NEMO tideonly

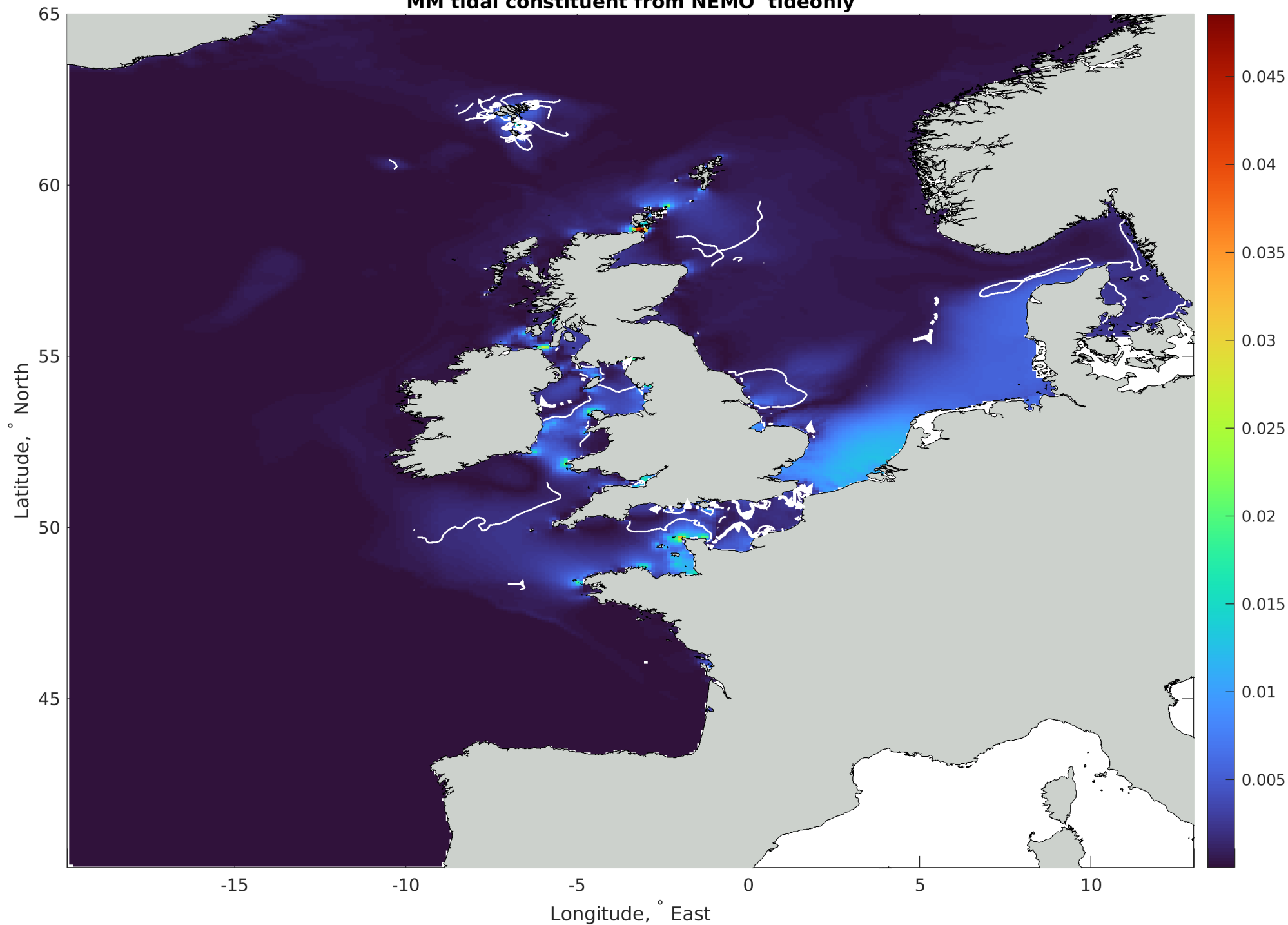


SSA tidal constituent from NEMO tideonly

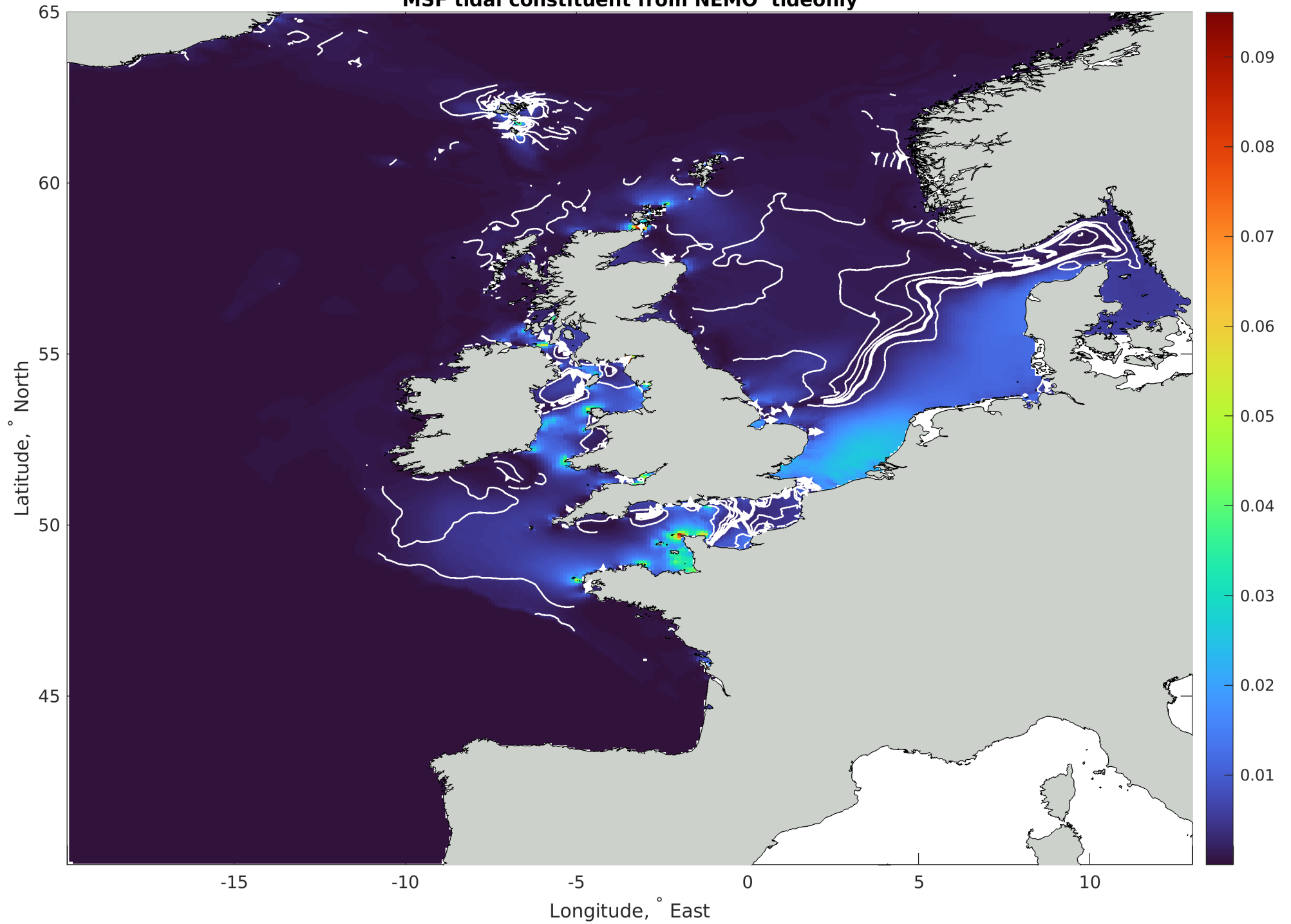
$\times 10^{-3}$



MM tidal constituent from NEMO tideonly

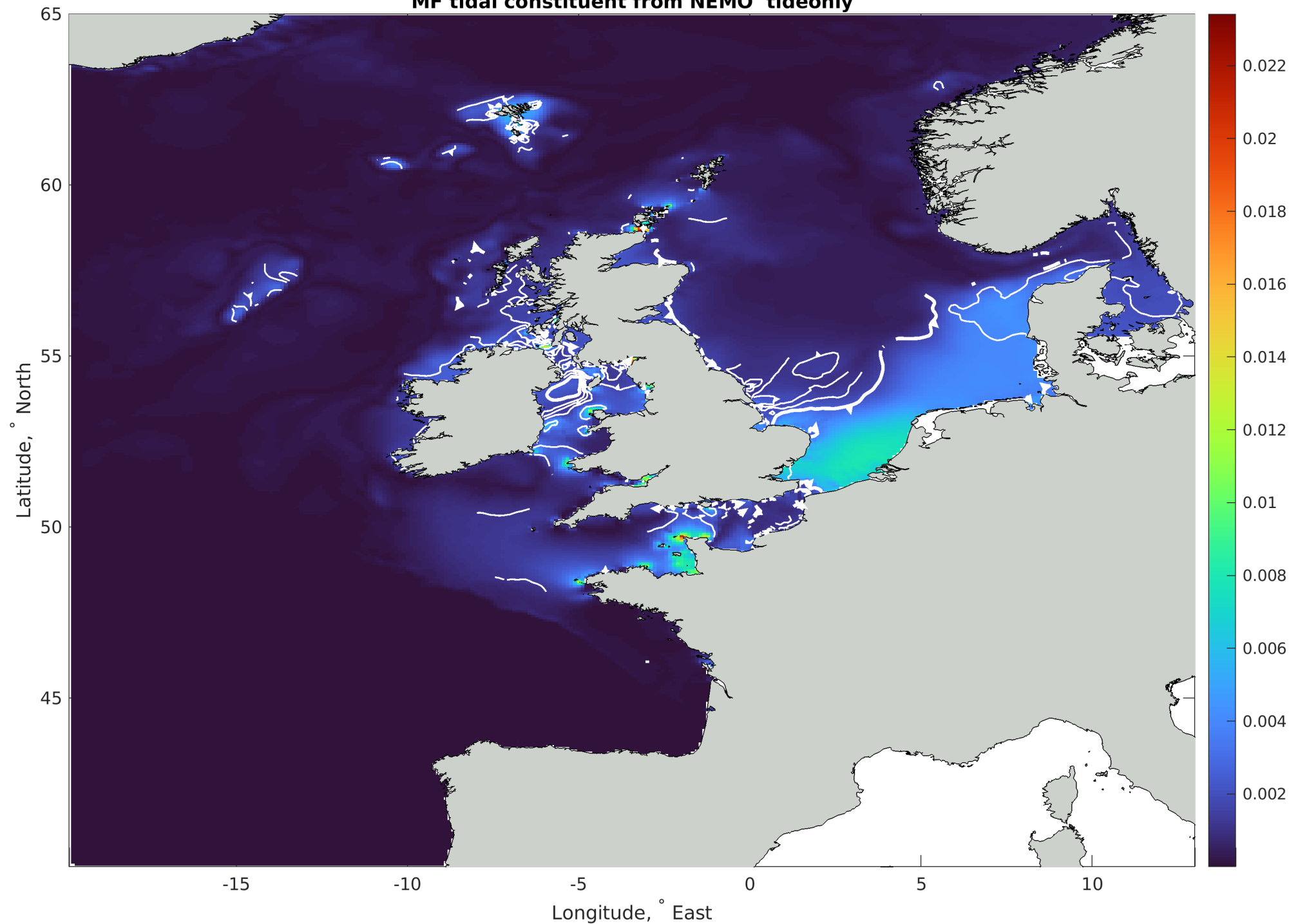


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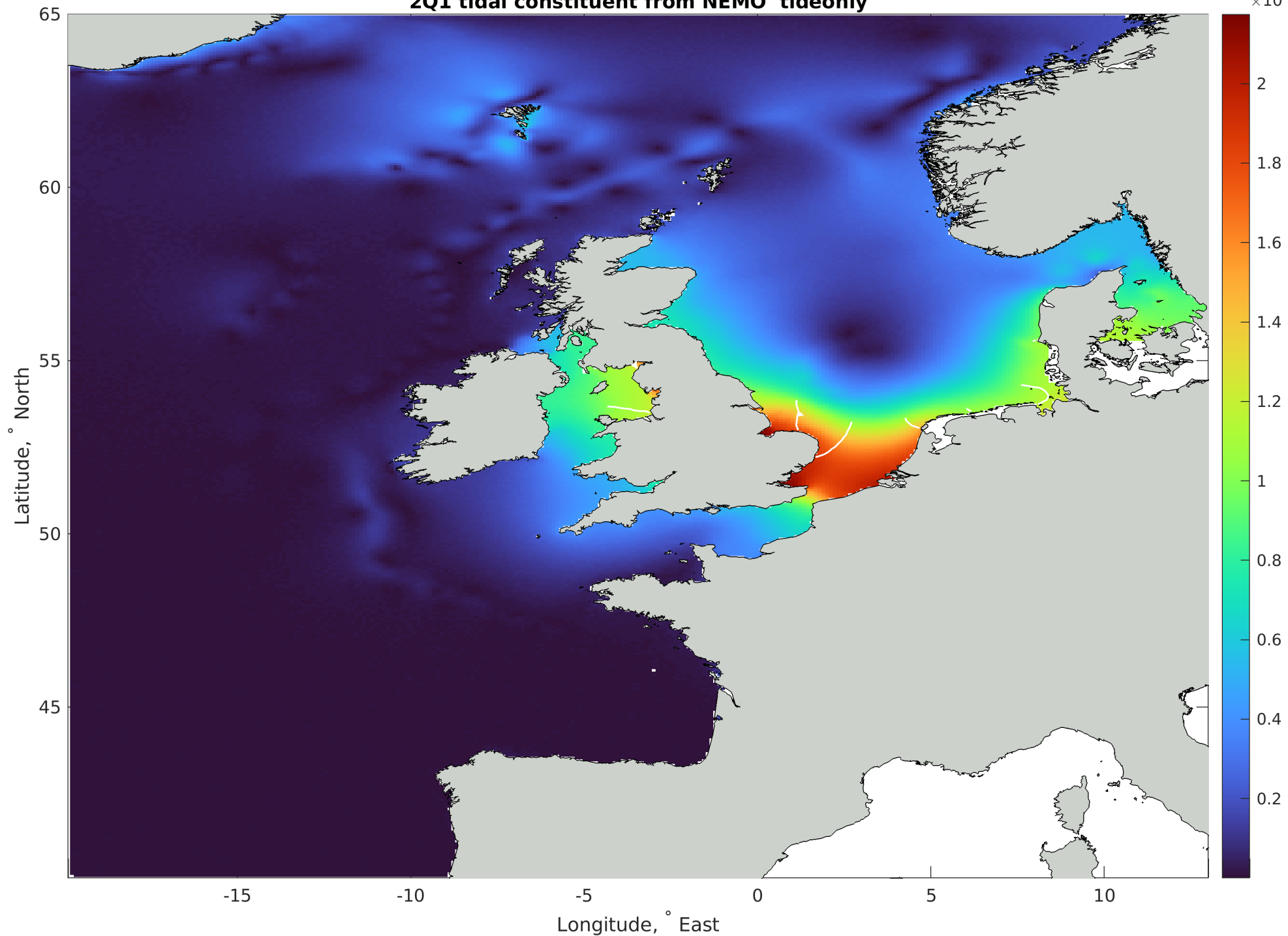


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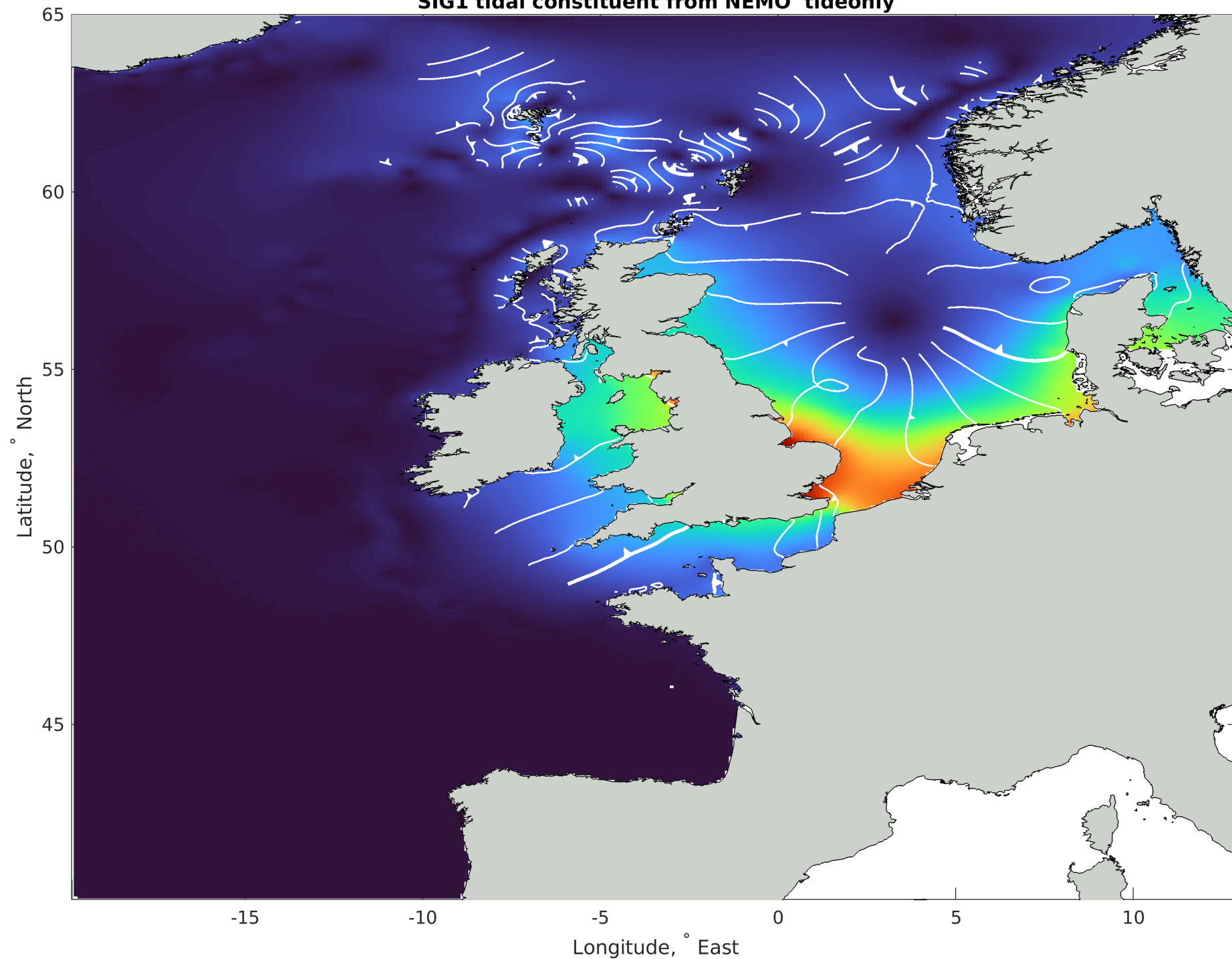
2Q1 tidal constituent from NEMO tideonly

$\times 10^{-3}$

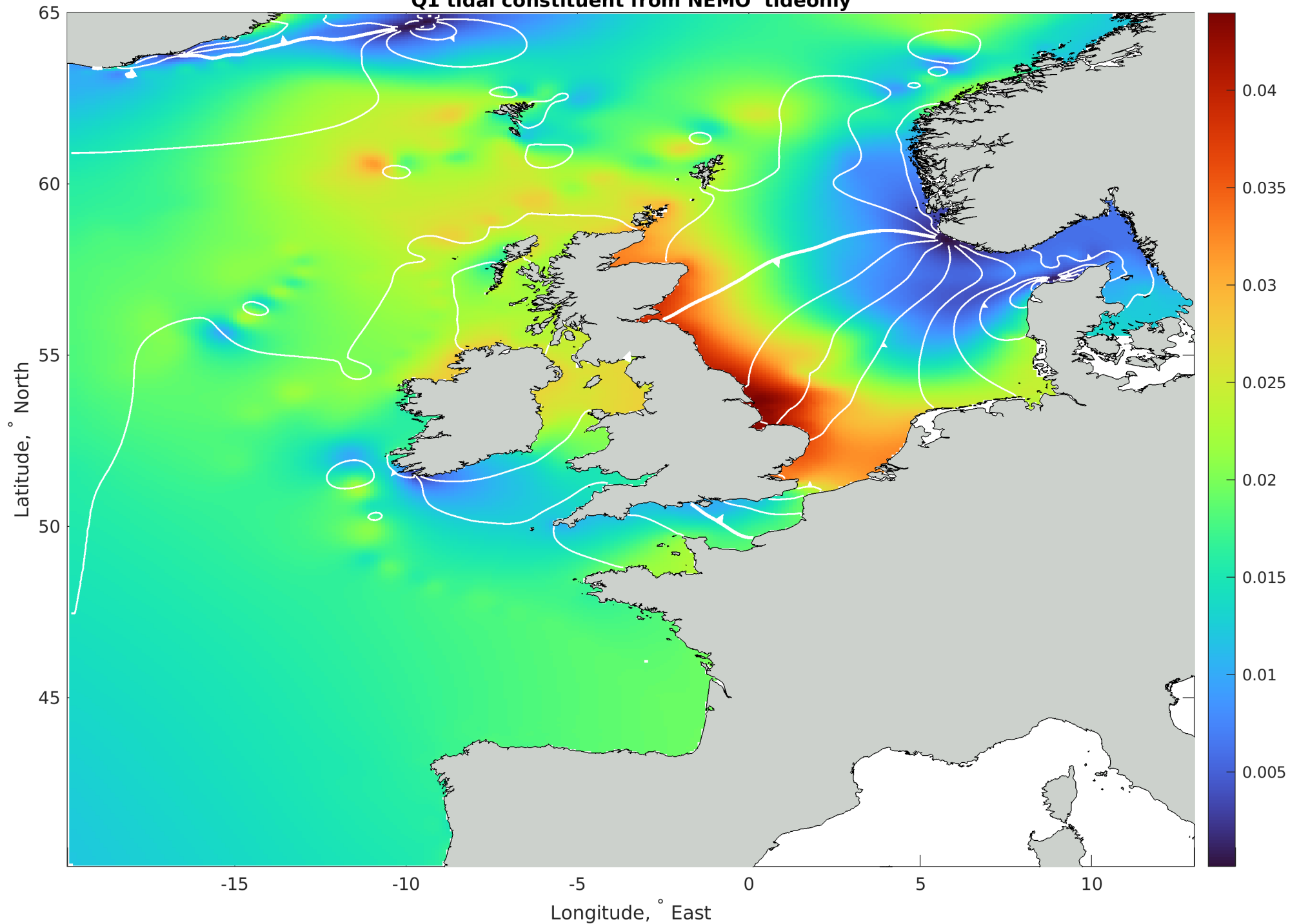


SIG1 tidal constituent from NEMO tideonly

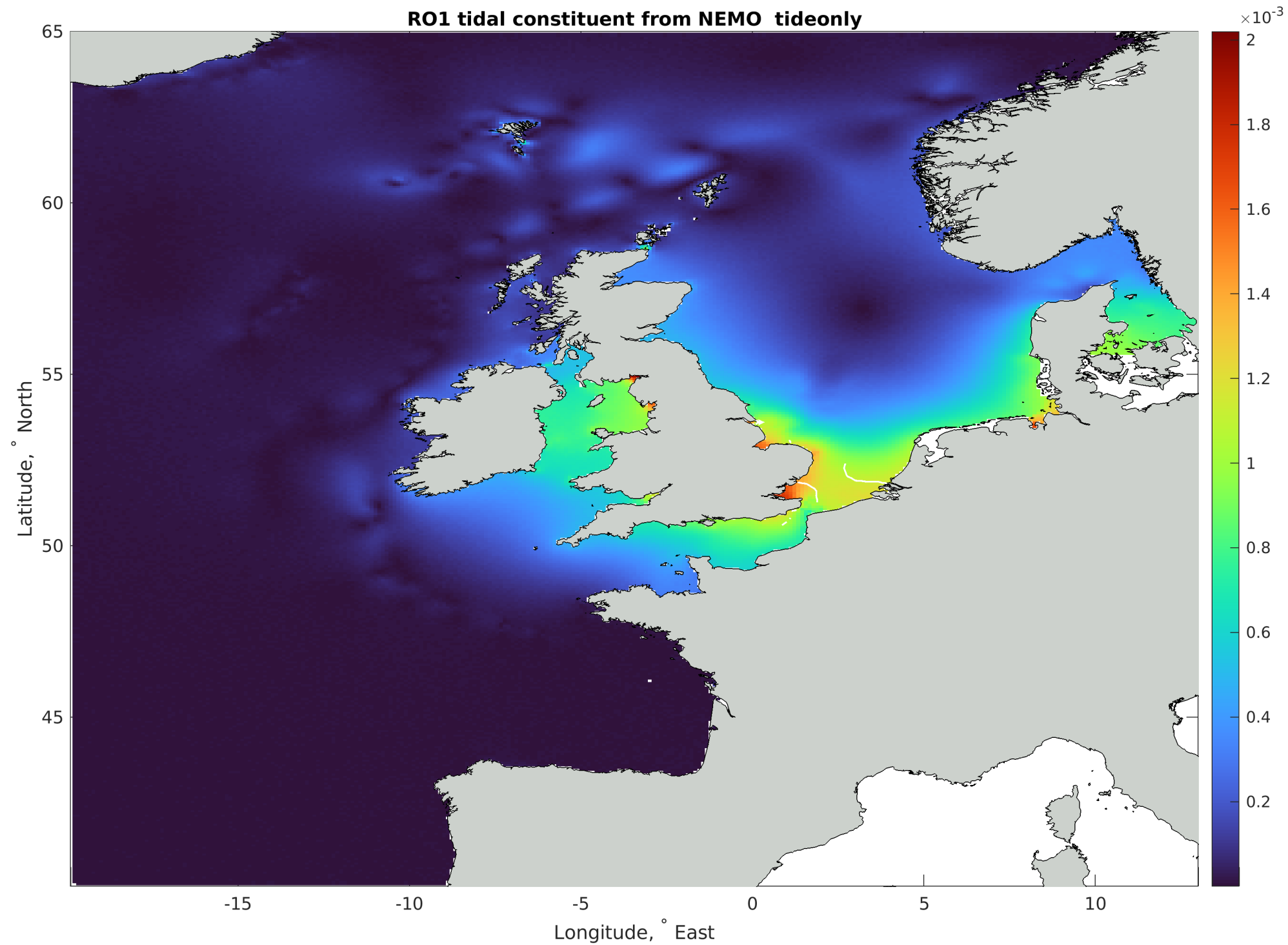
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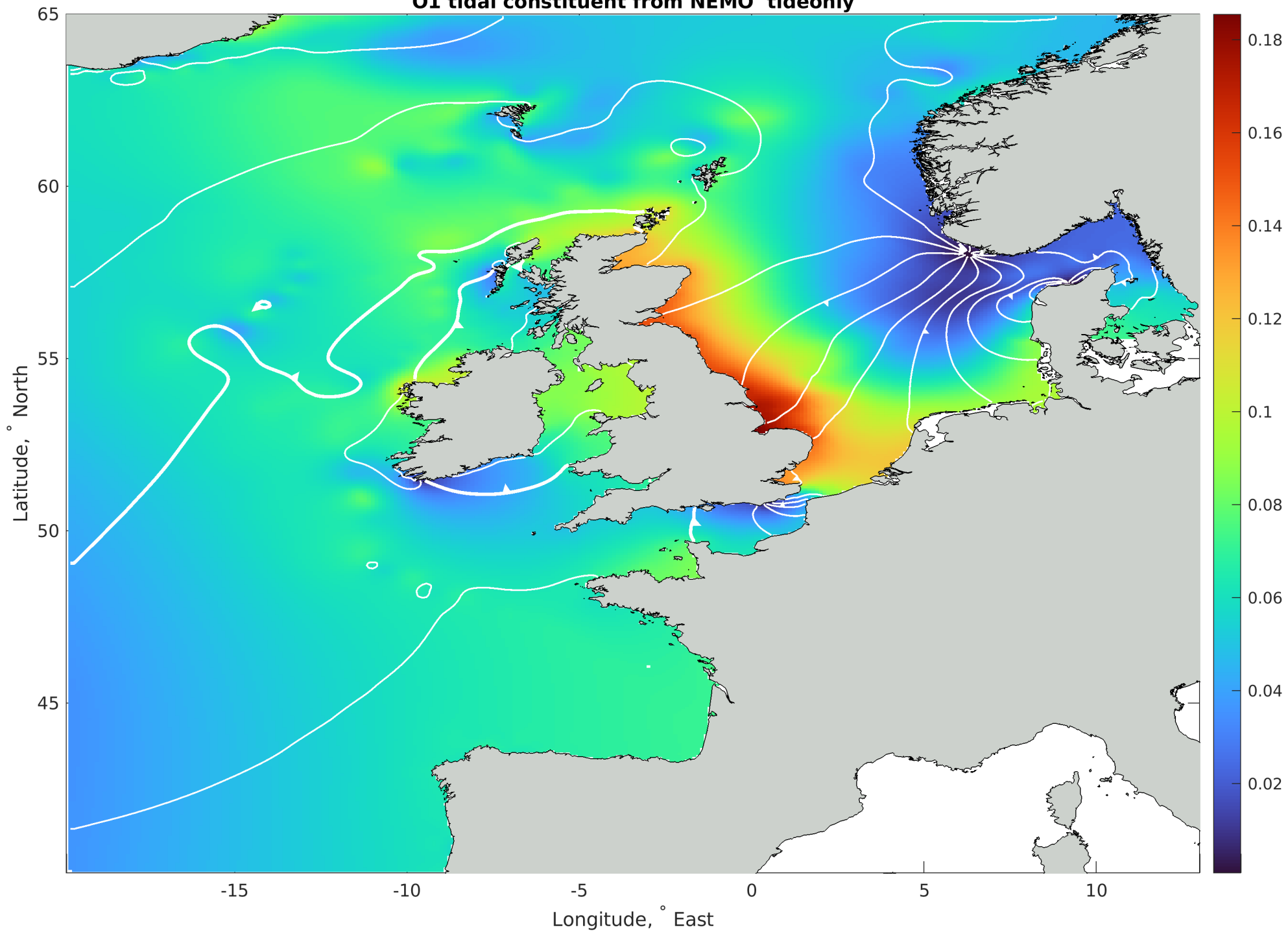
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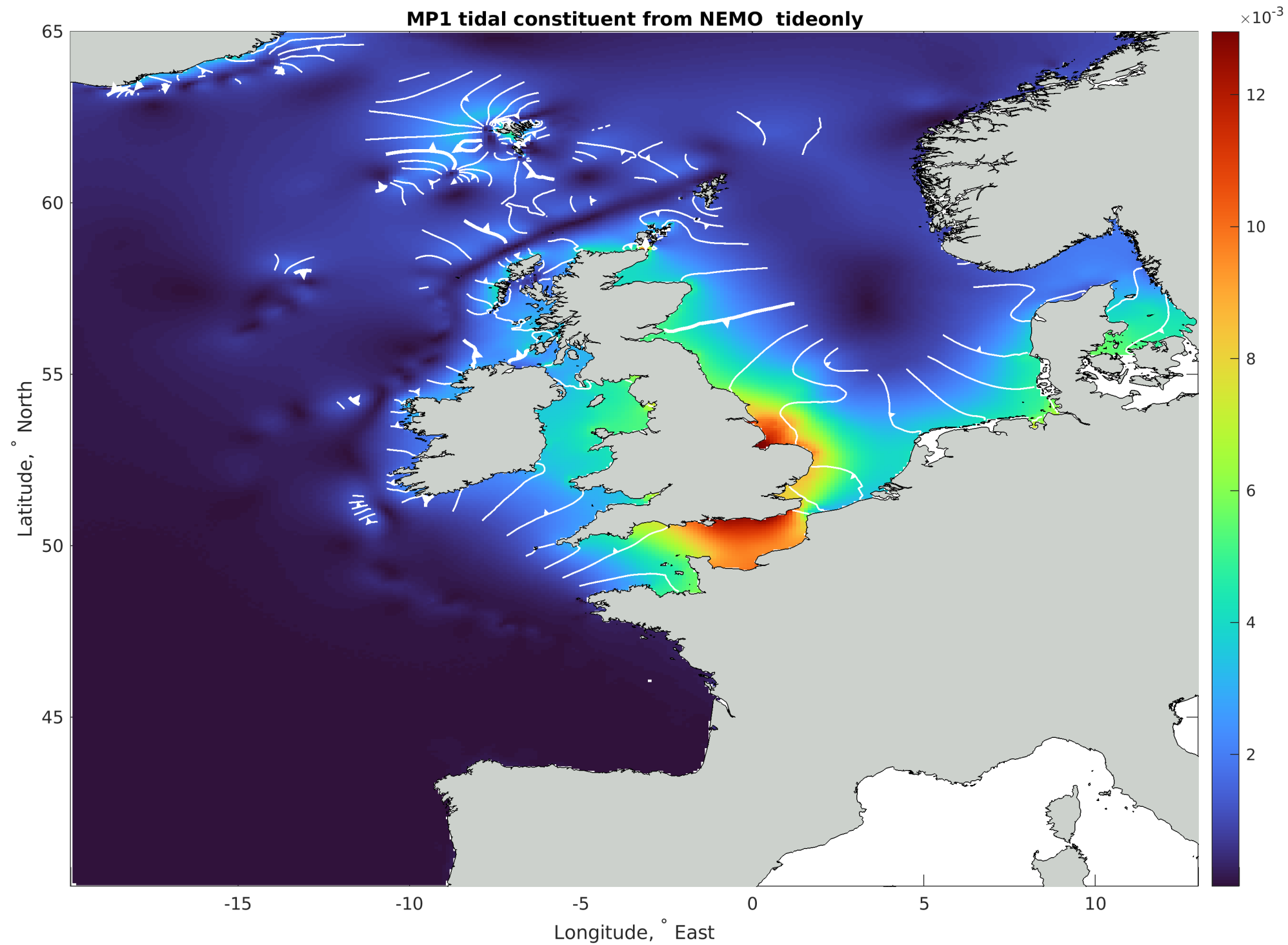
RO1 tidal constituent from NEMO tideonly



O1 tidal constituent from NEMO tideonly

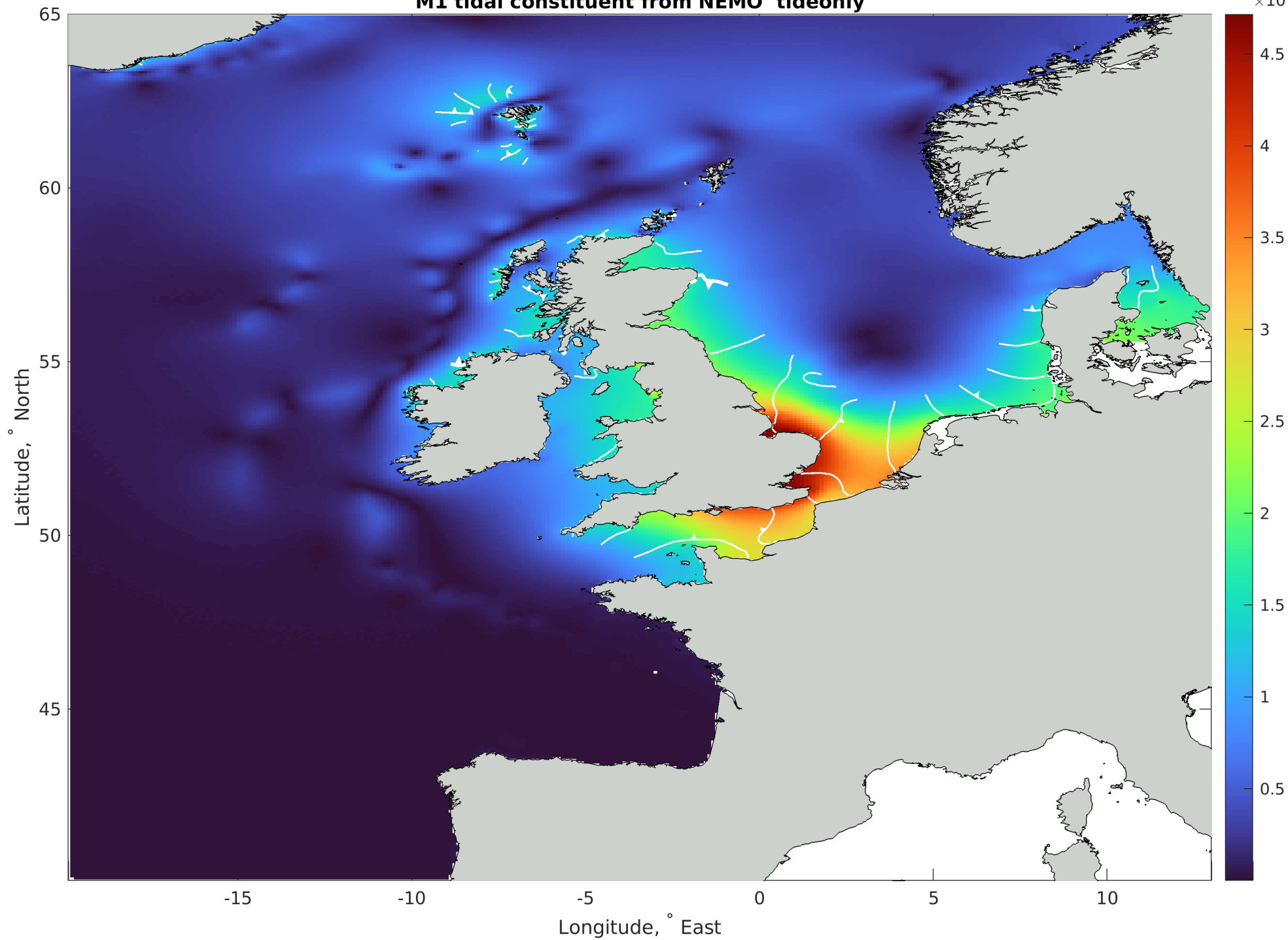


MP1 tidal constituent from NEMO tideonly



M1 tidal constituent from NEMO tideonly

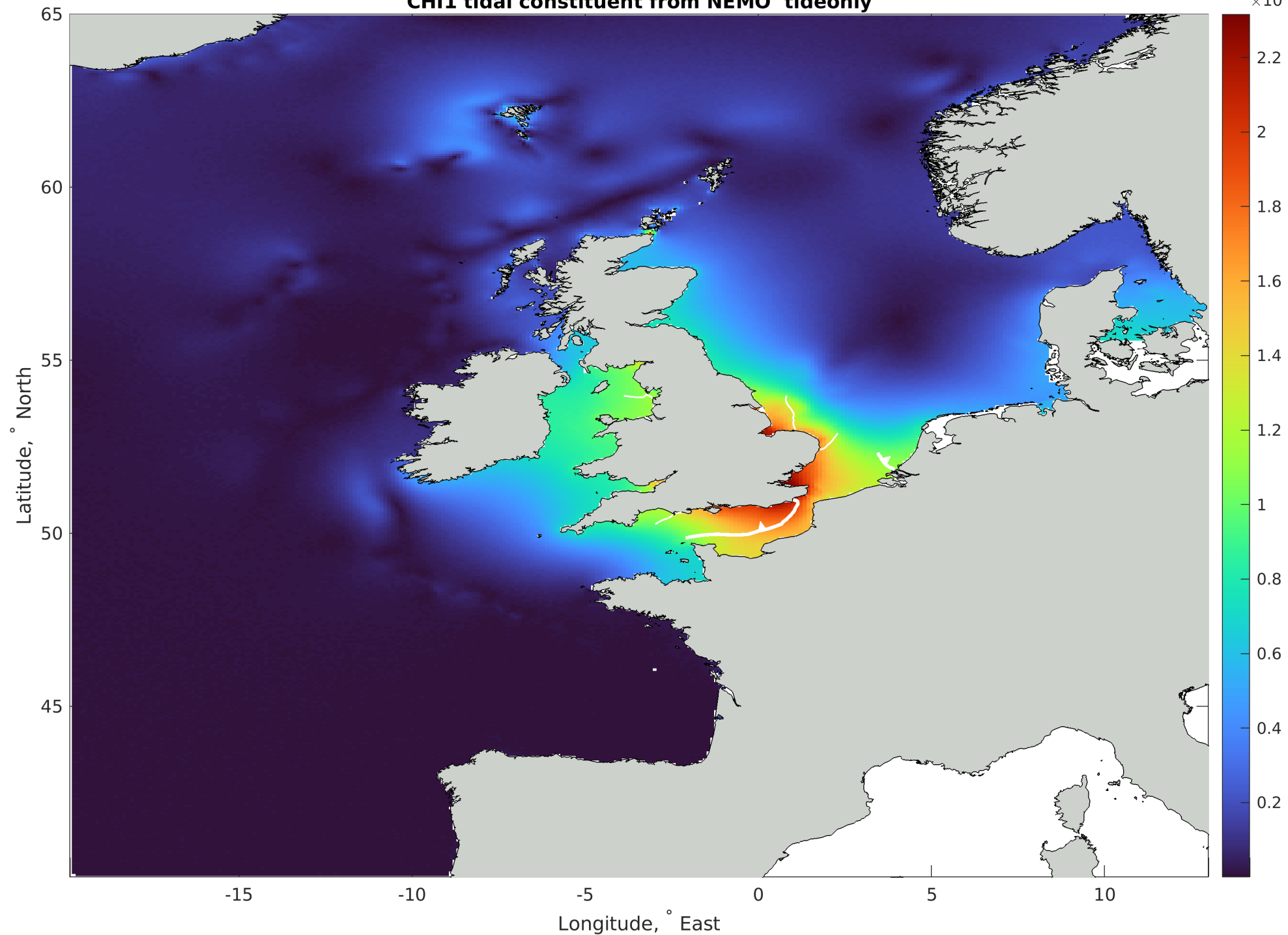
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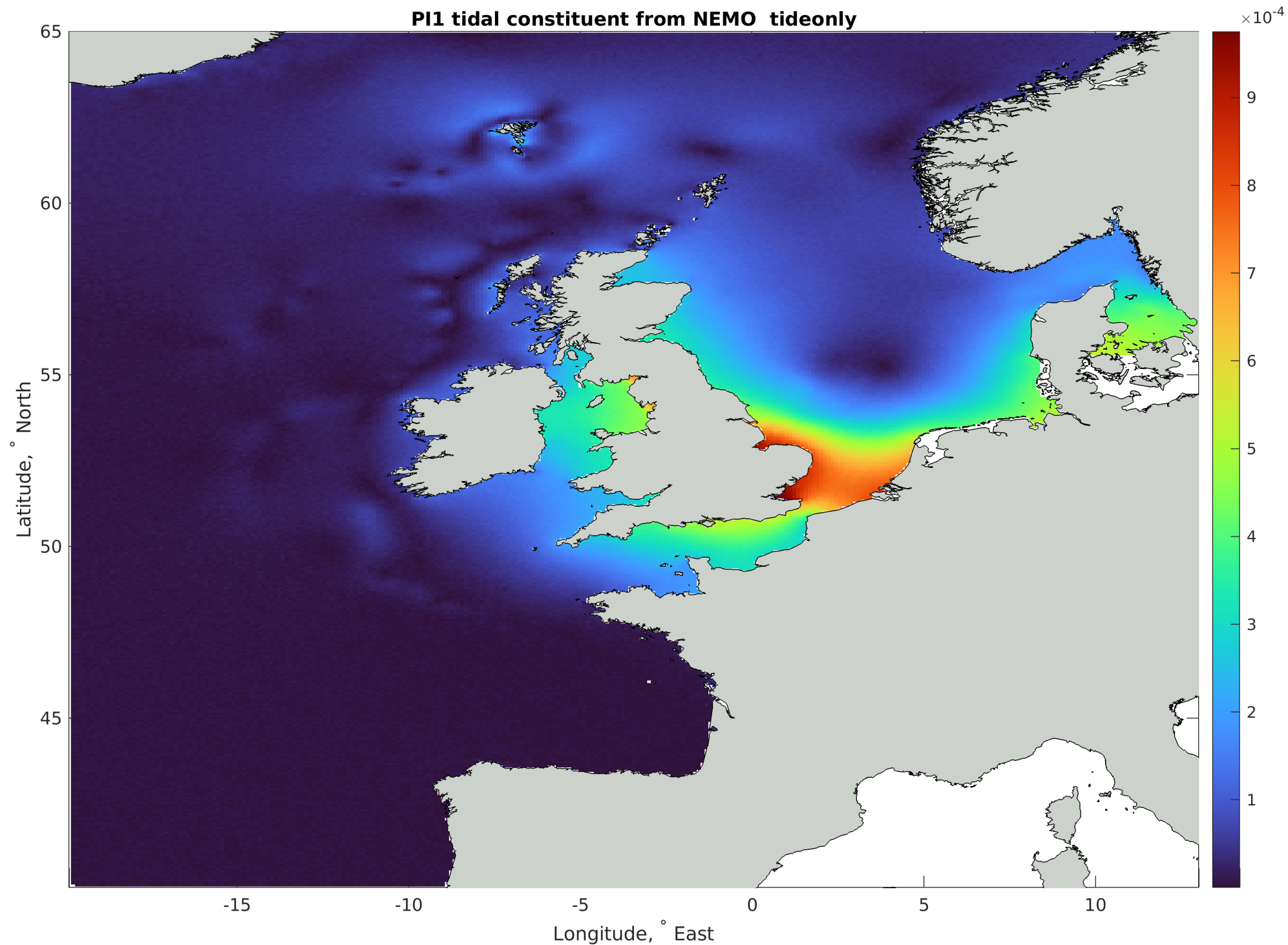


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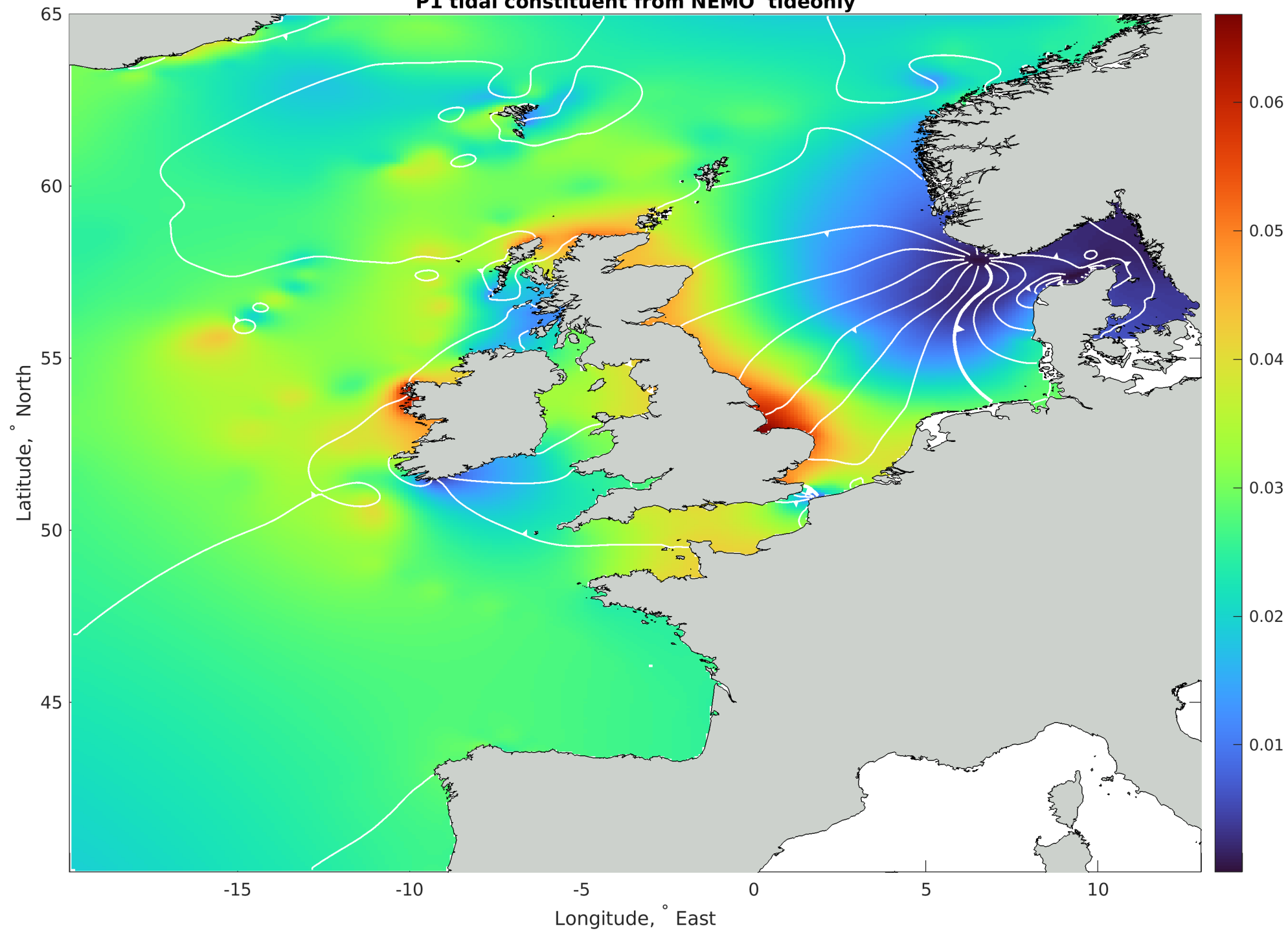
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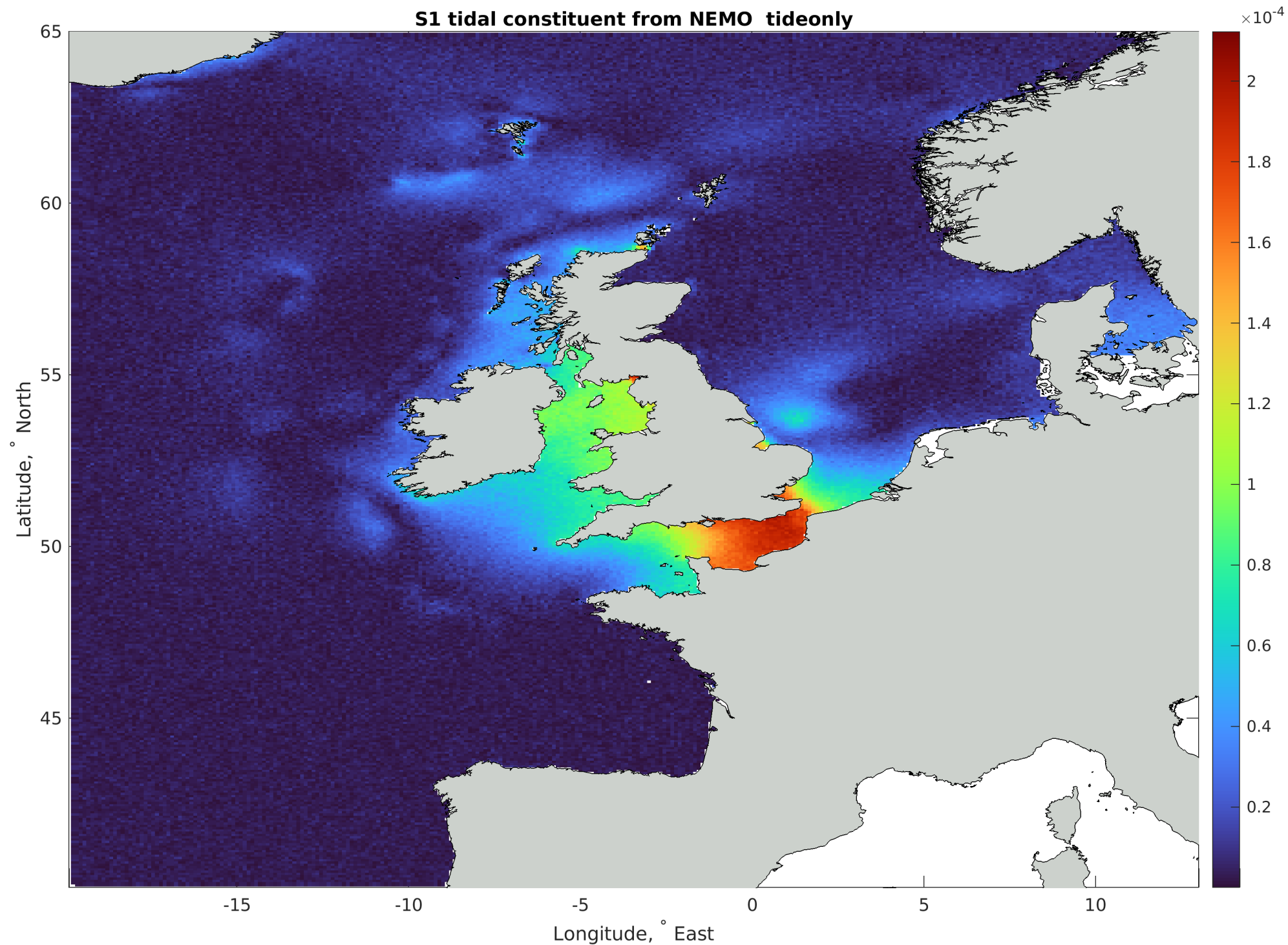
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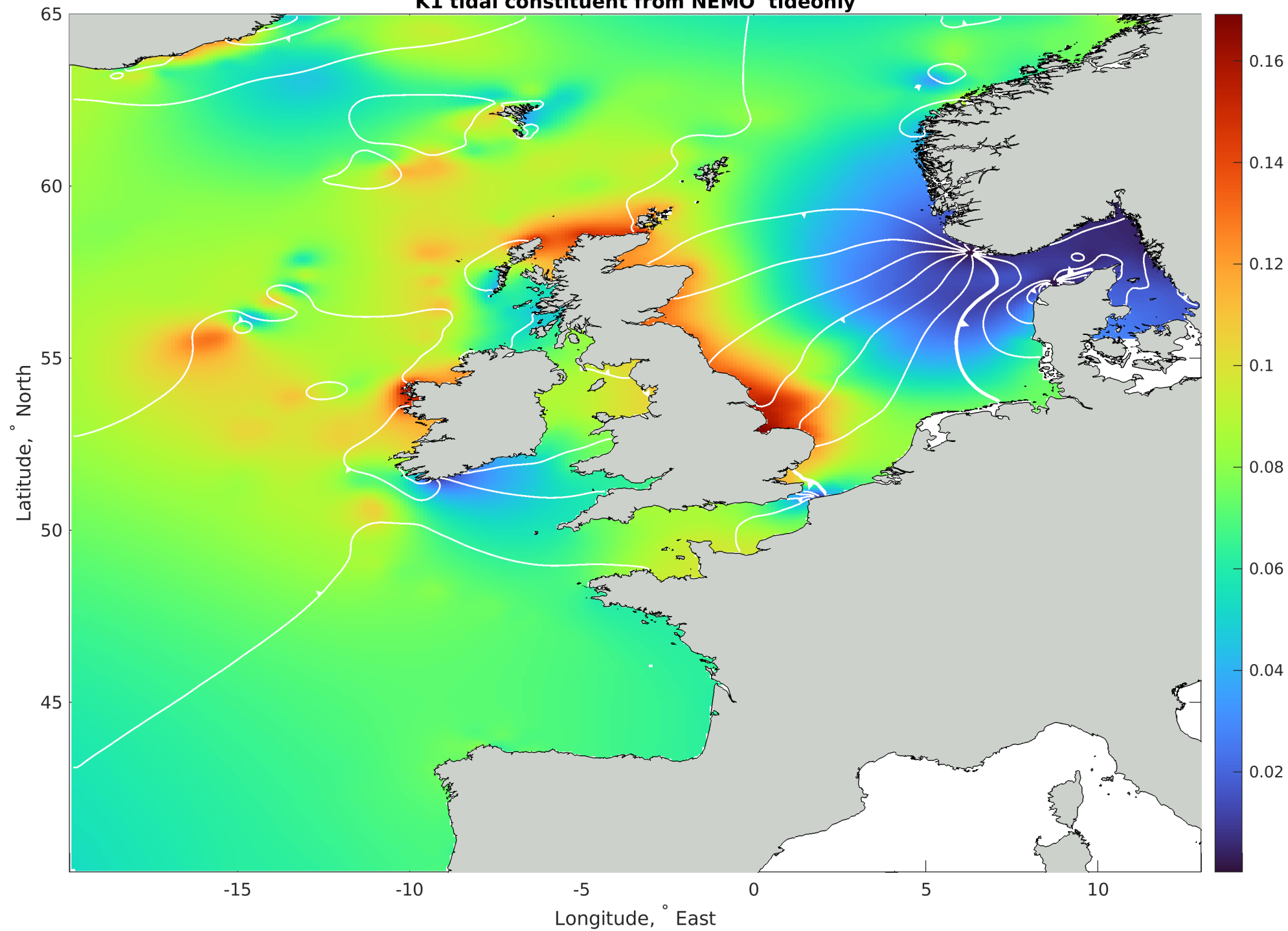
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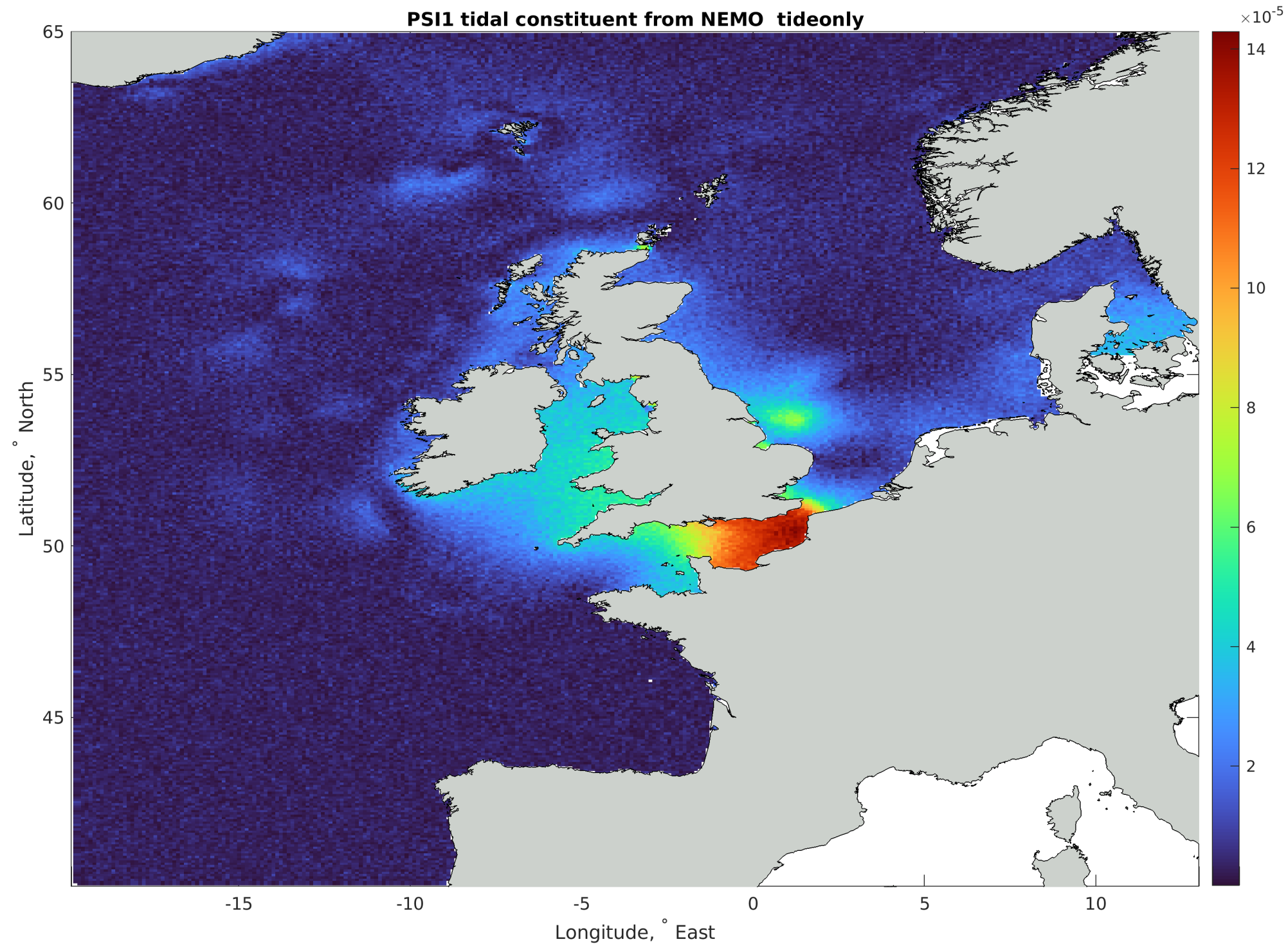
S1 tidal constituent from NEMO tideonly



K1 tidal constituent from NEMO tideonly

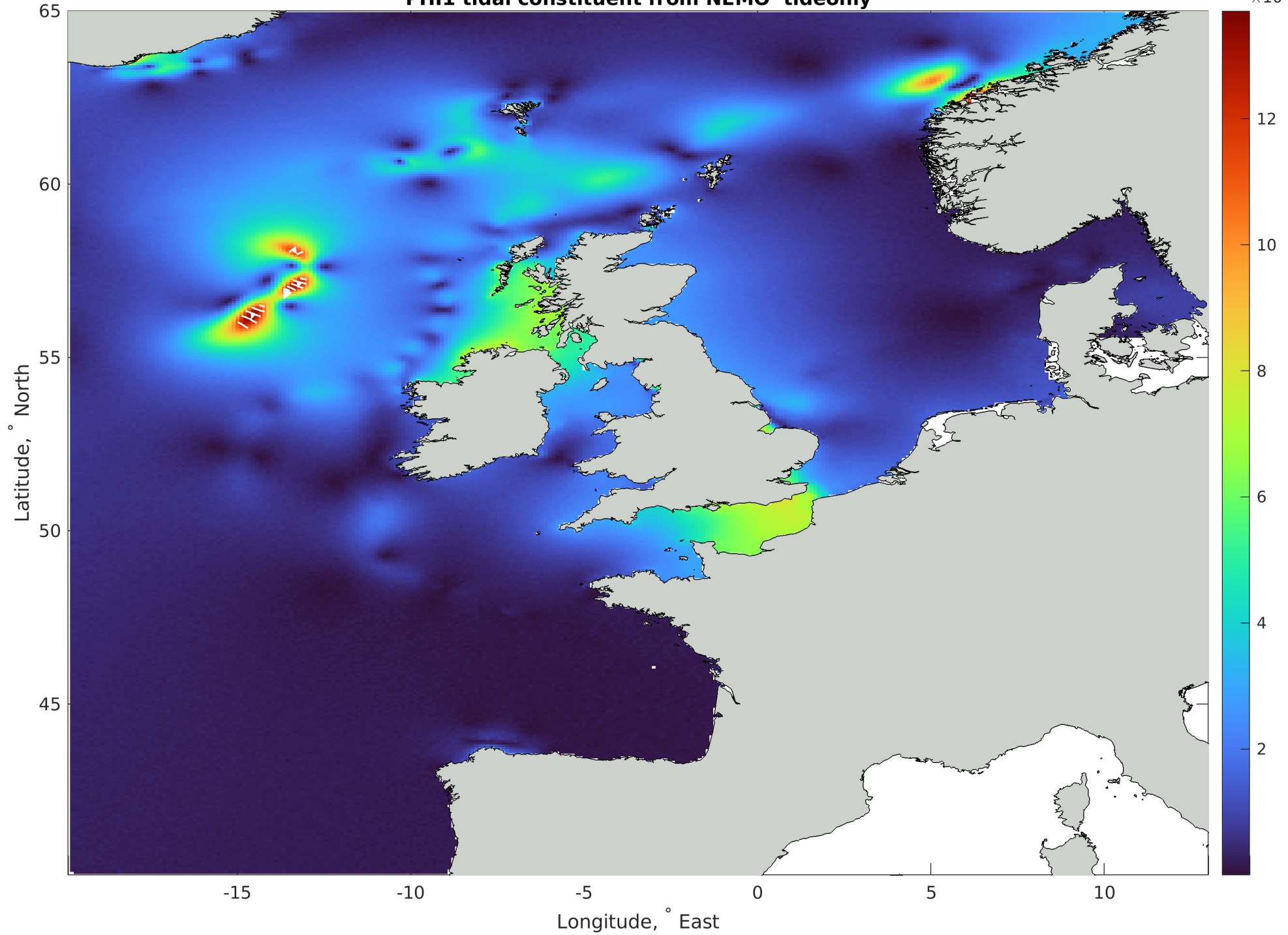


PSI1 tidal constituent from NEMO tideonly

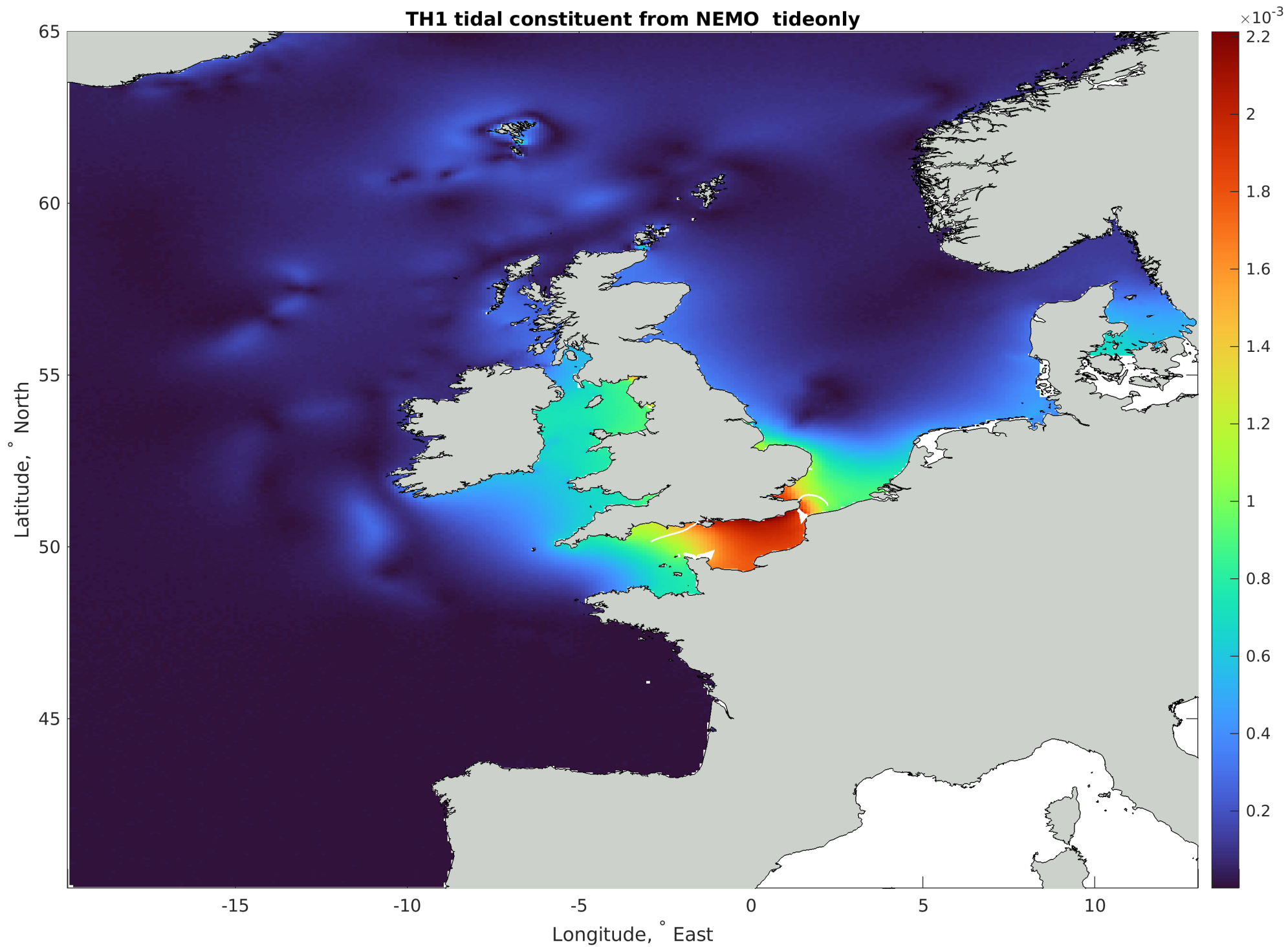


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$\times 10^{-4}$



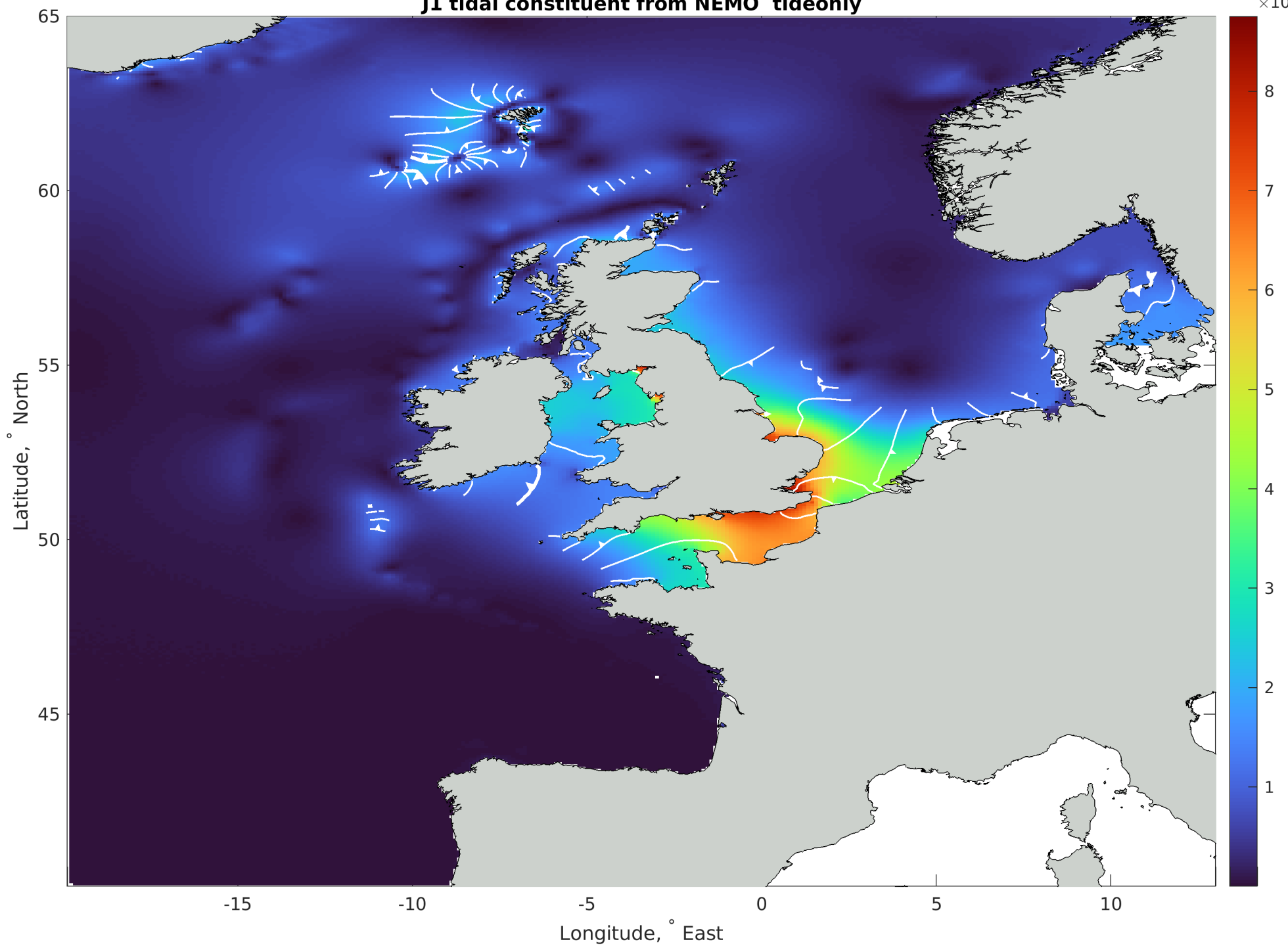
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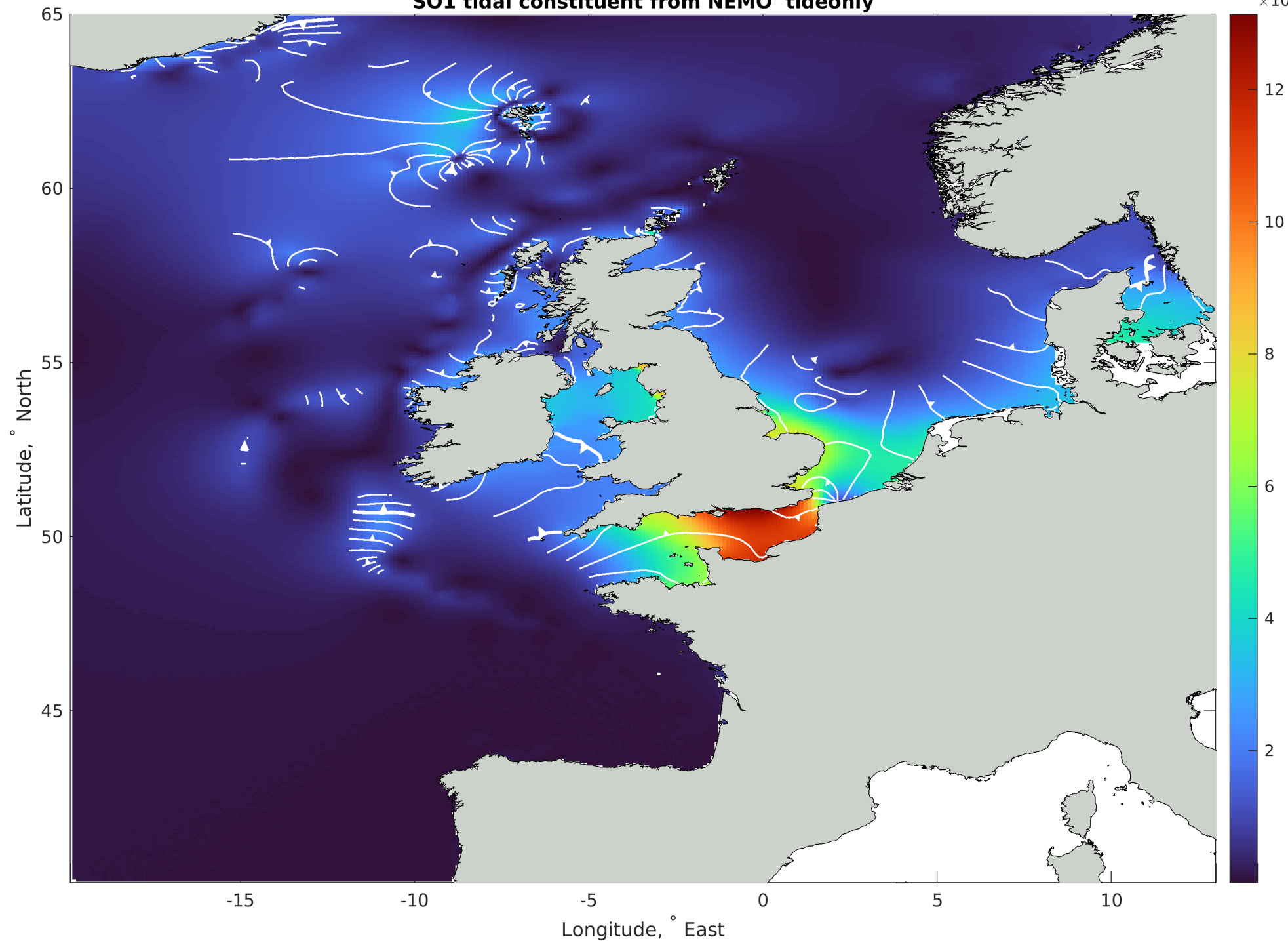
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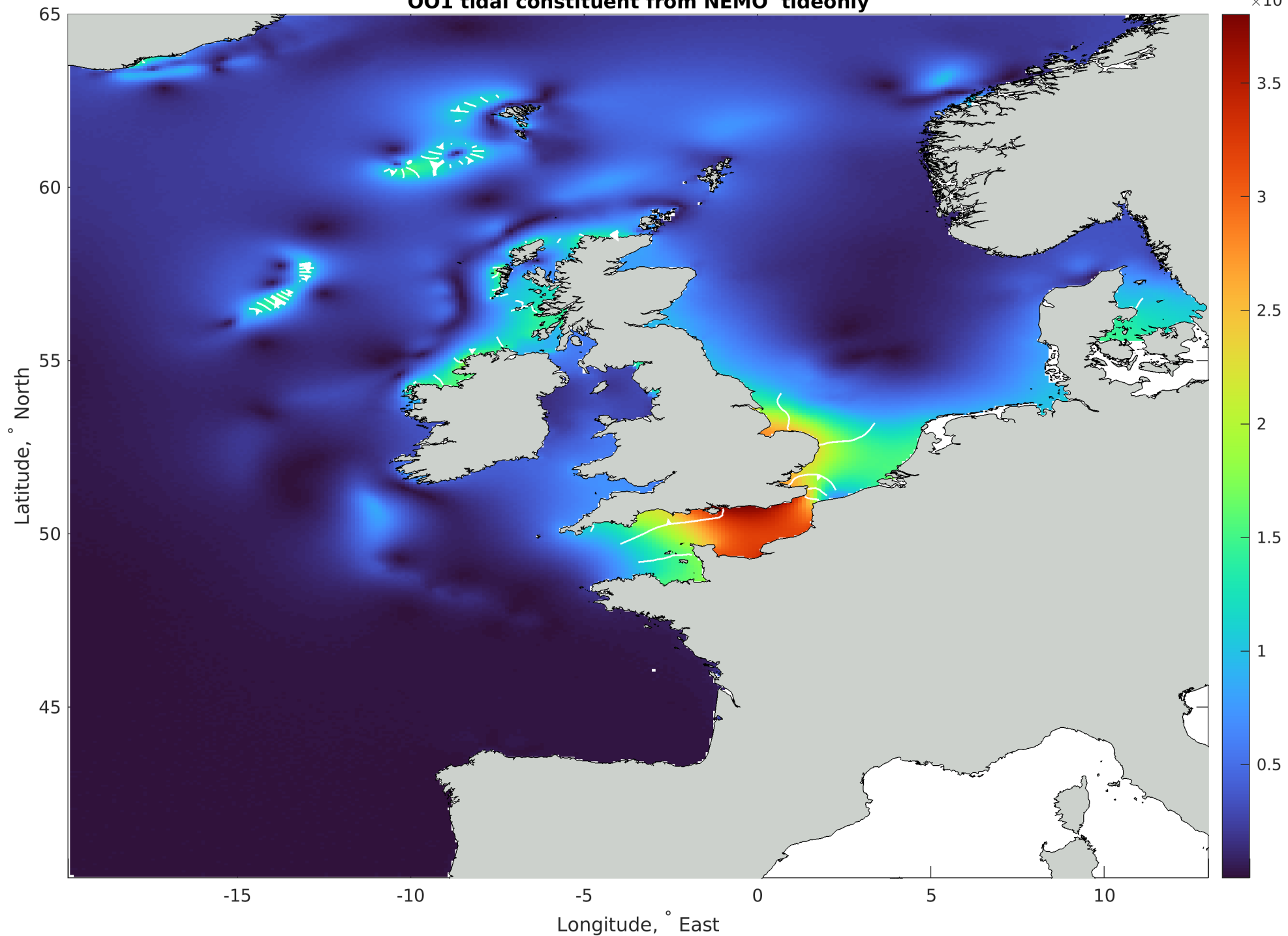
SO1 tidal constituent from NEMO tideonly

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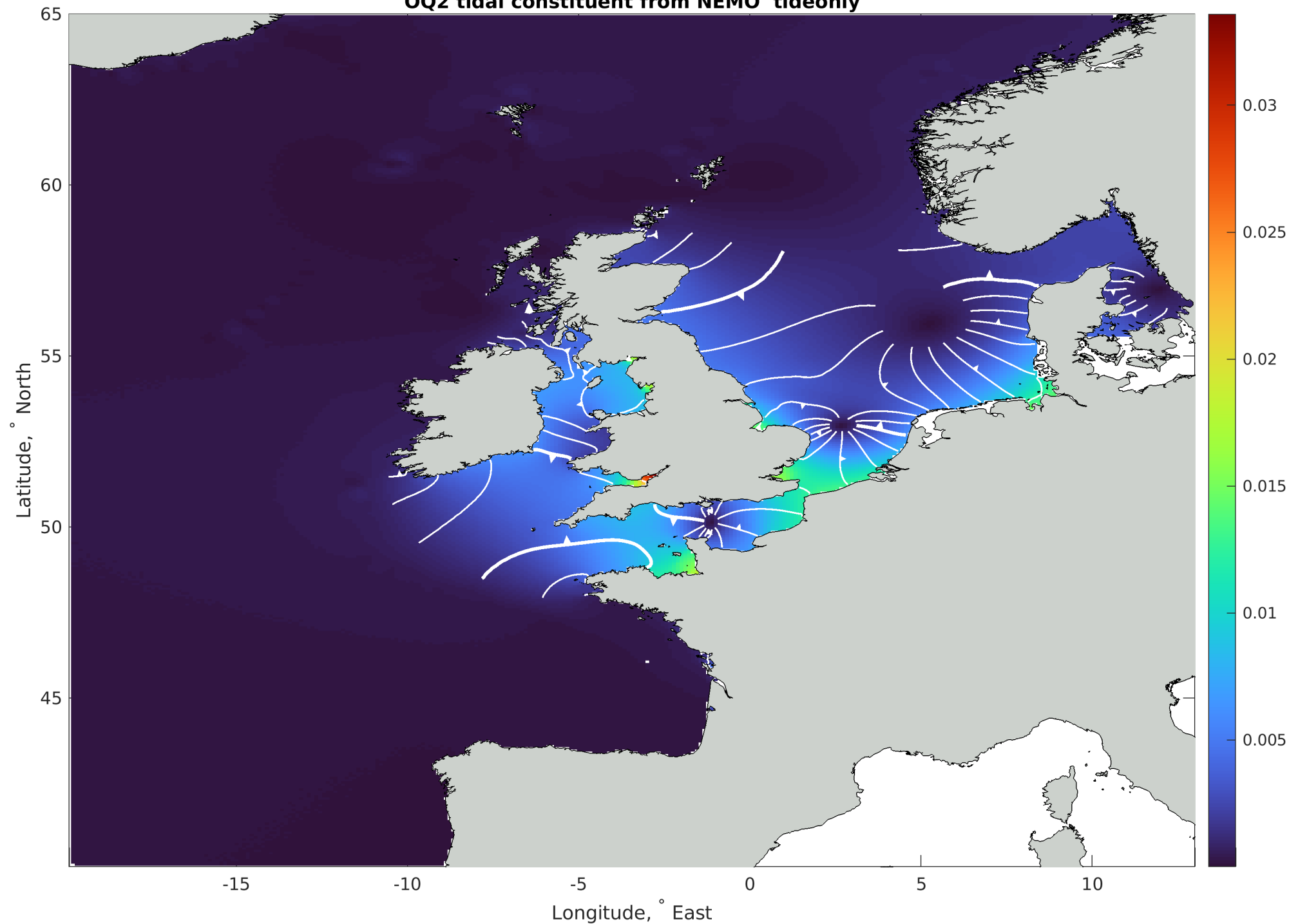


OO1 tidal constituent from NEMO tideonly

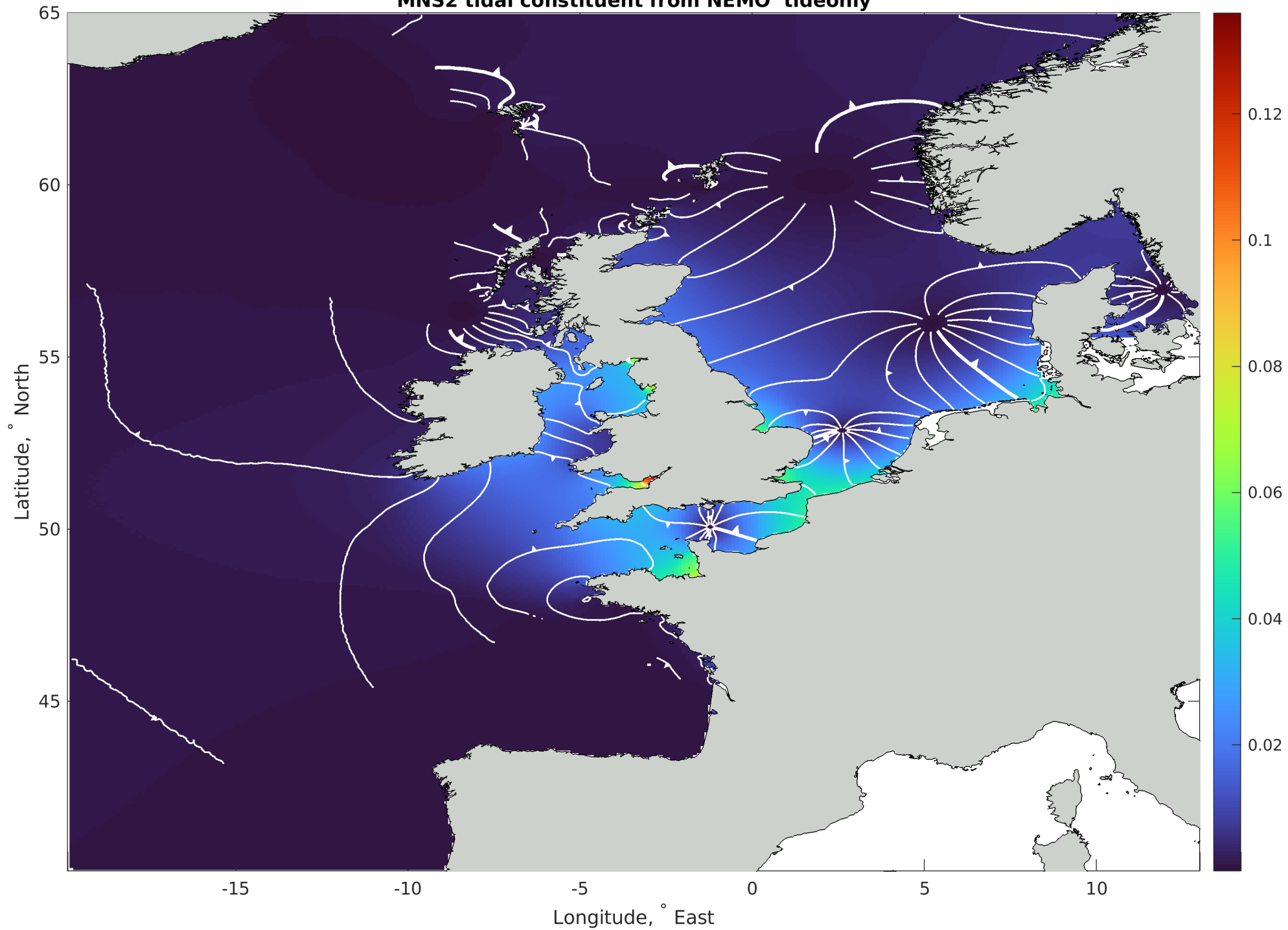
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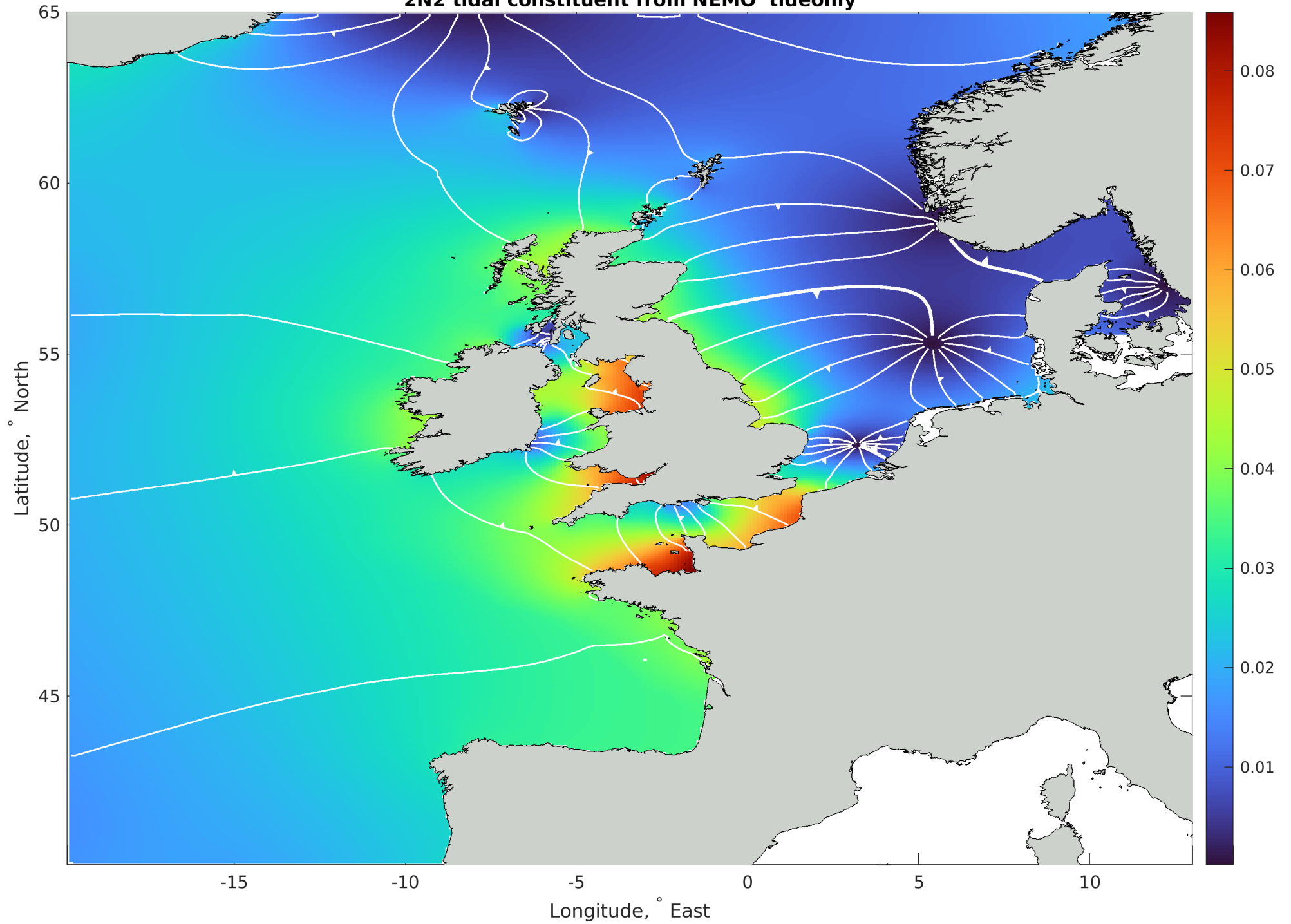
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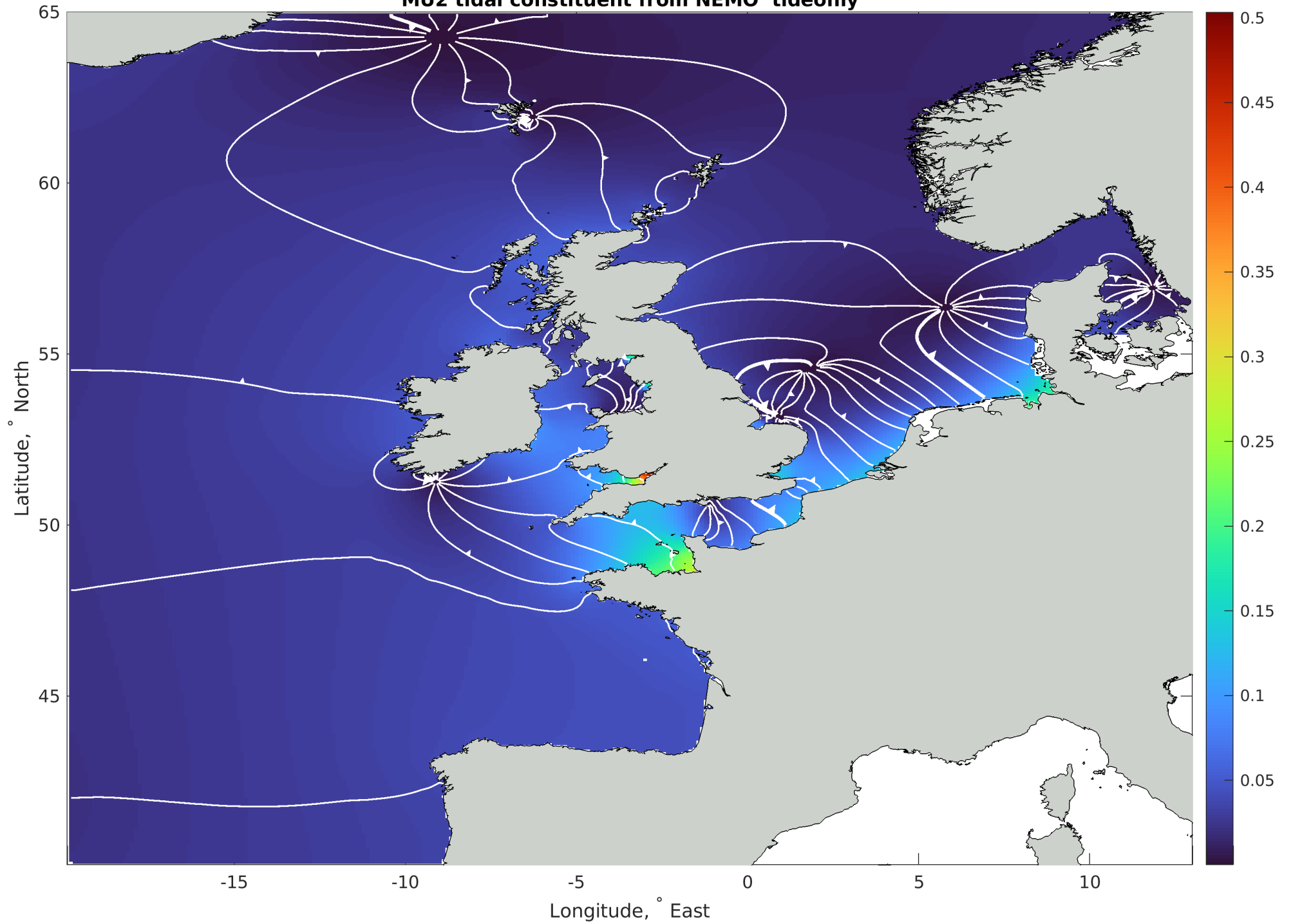
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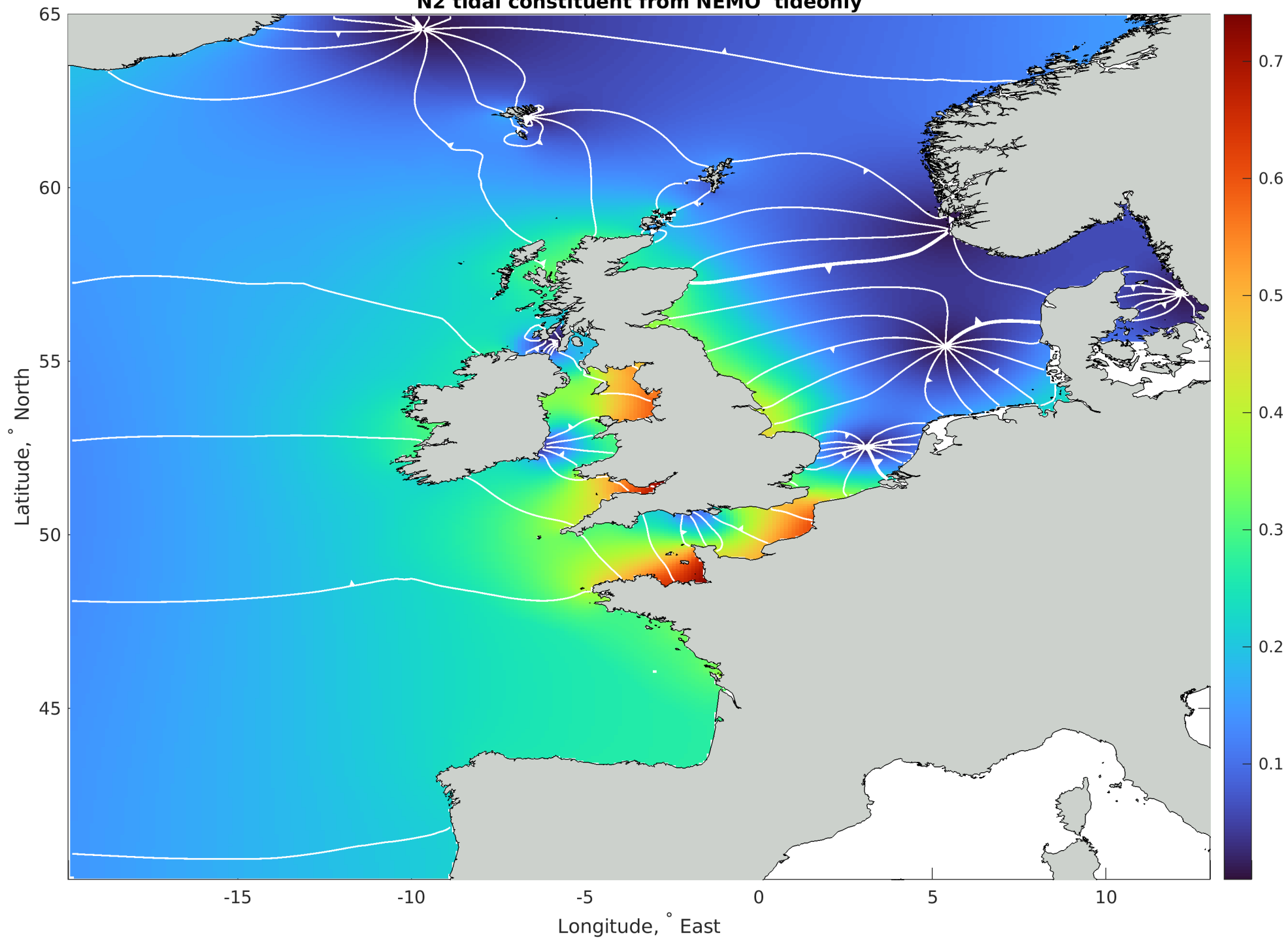
2N2 tidal constituent from NEMO tideonly



MU2 tidal constituent from NEMO tideonly

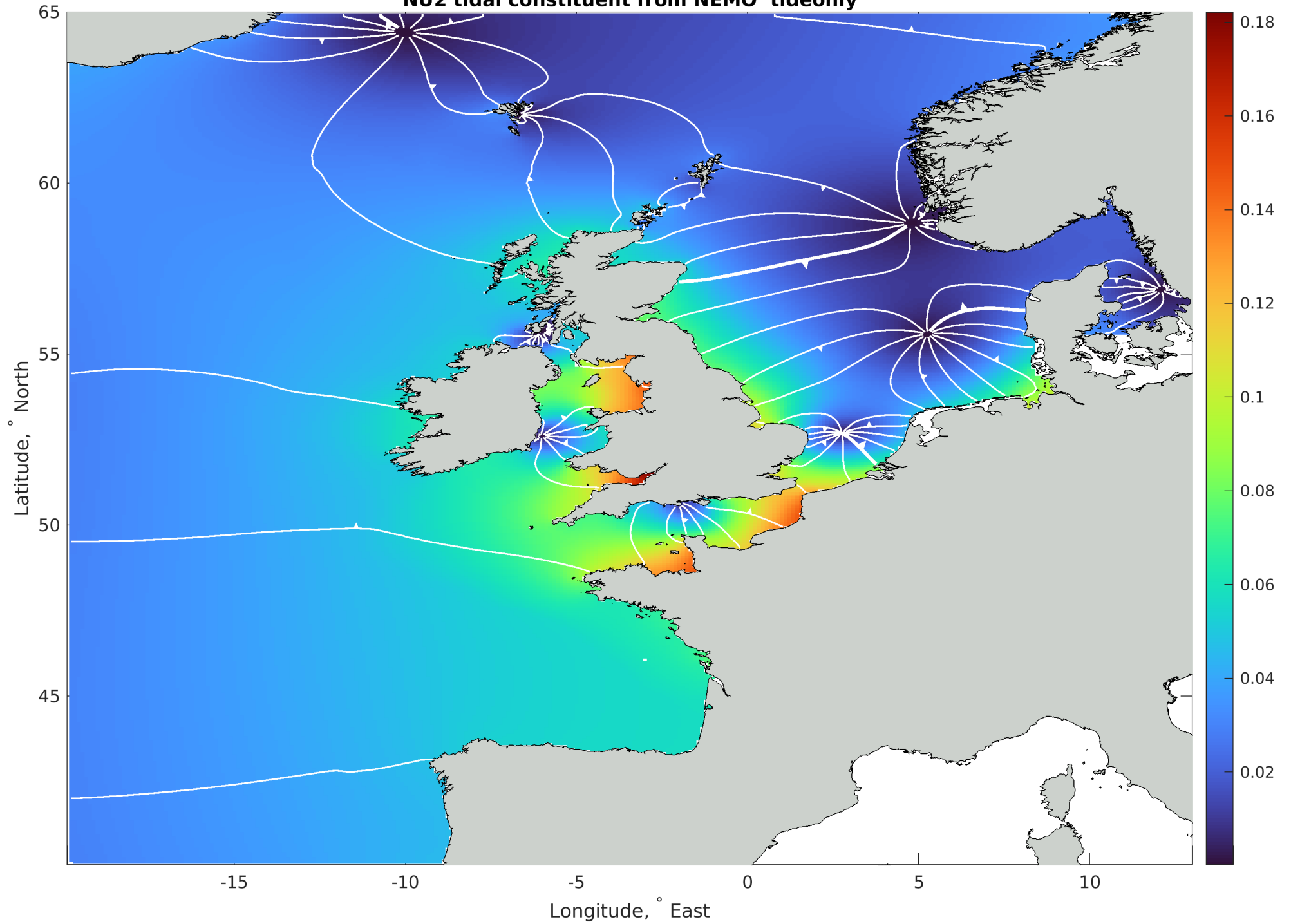


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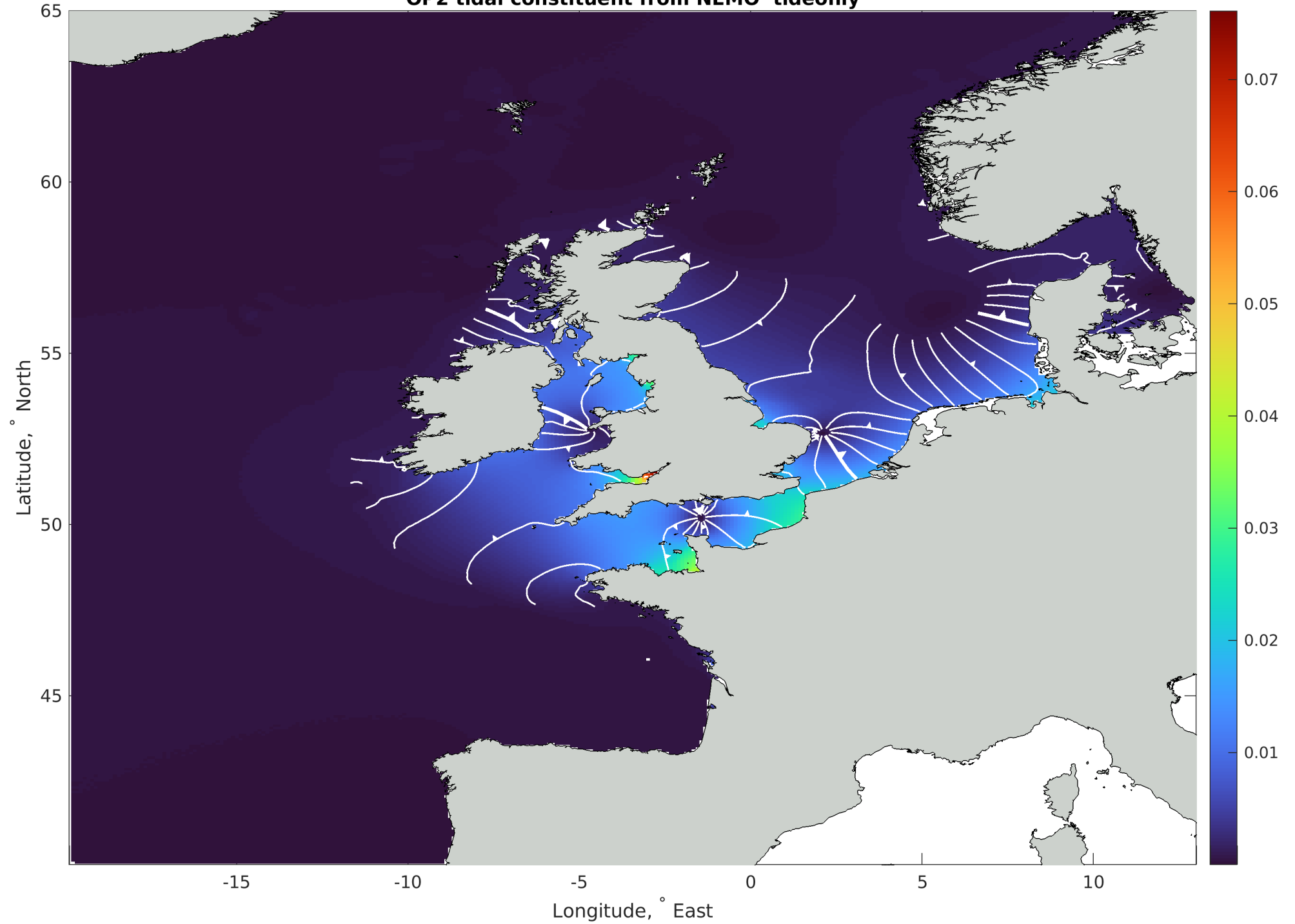




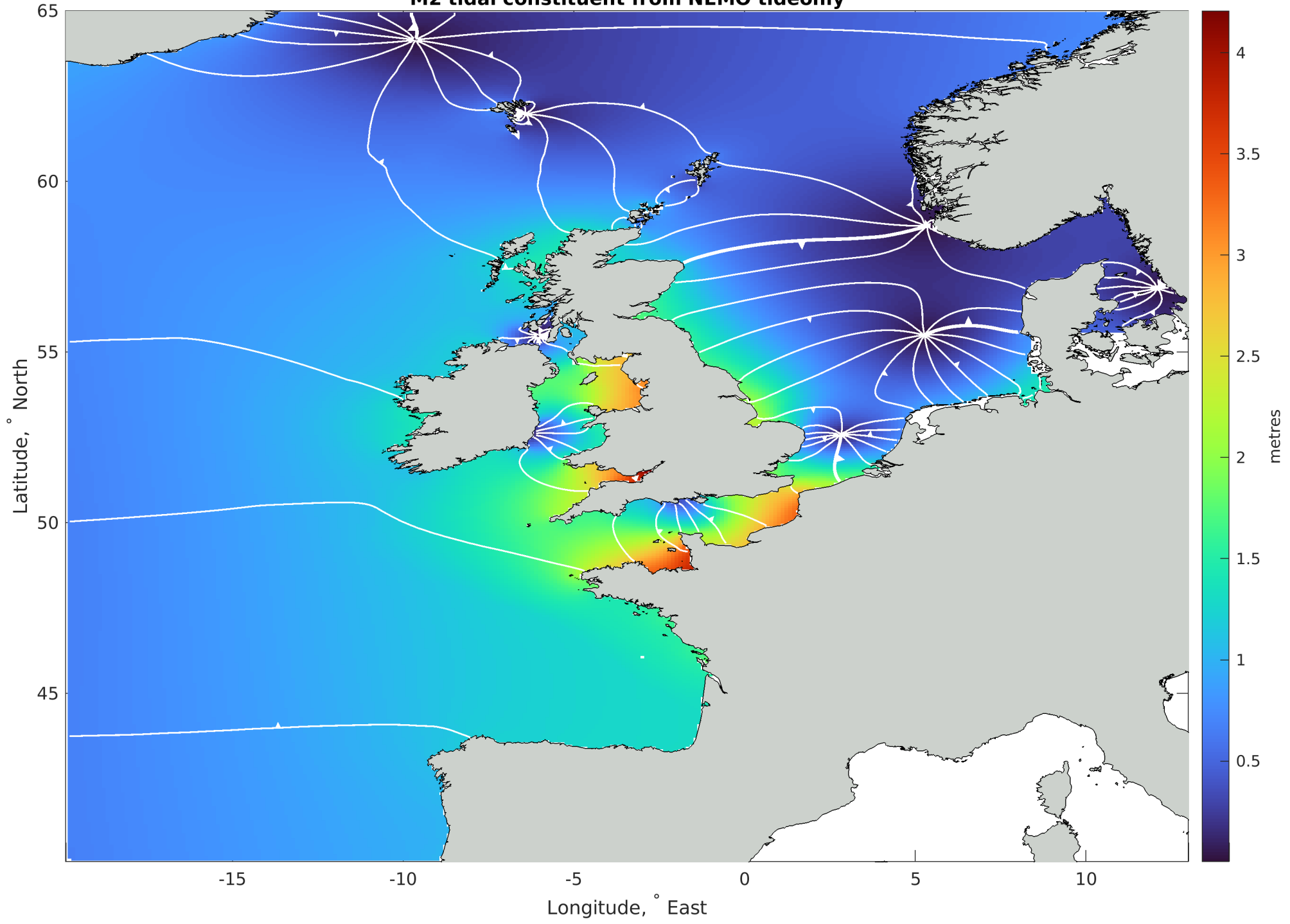
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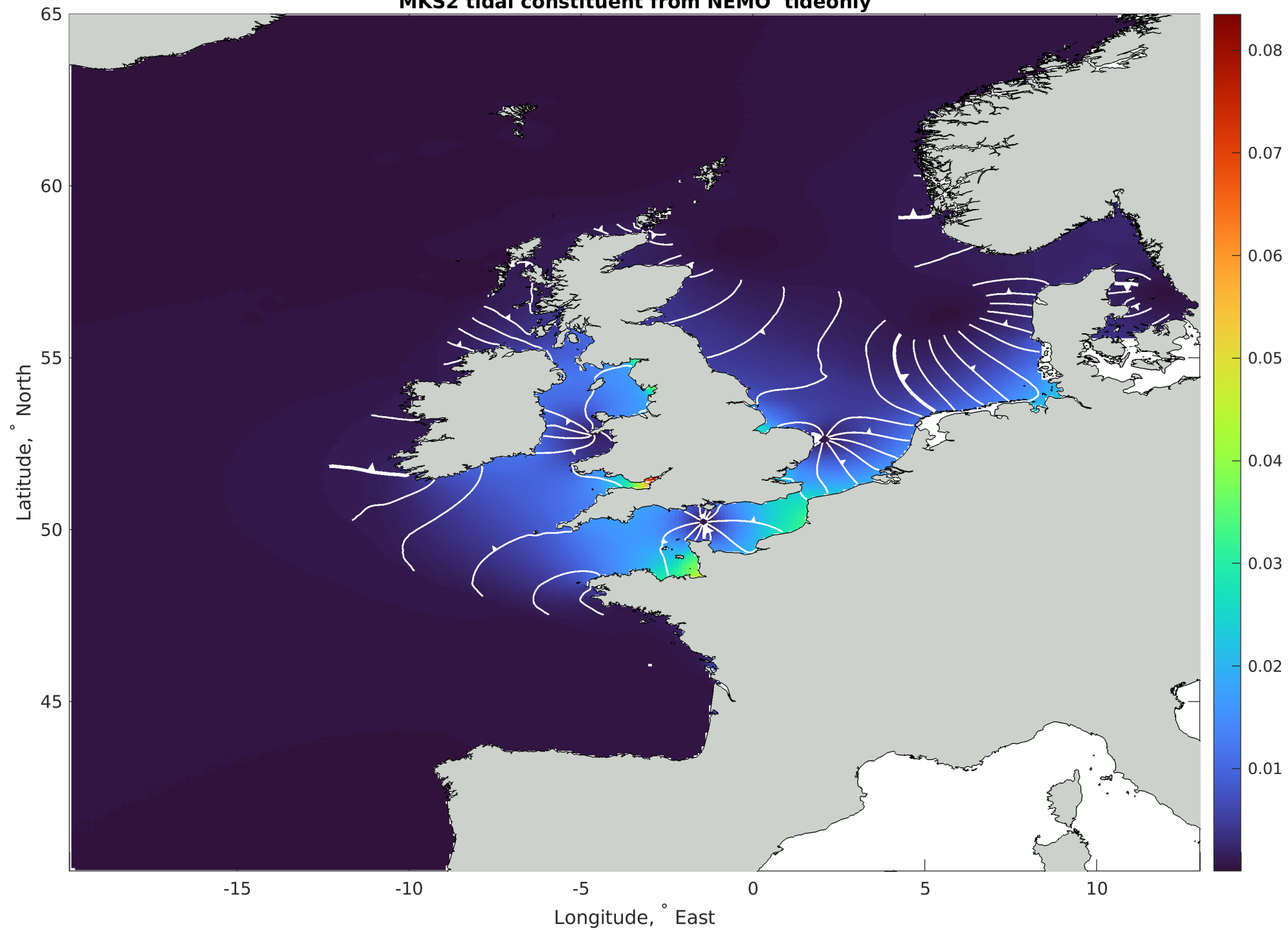
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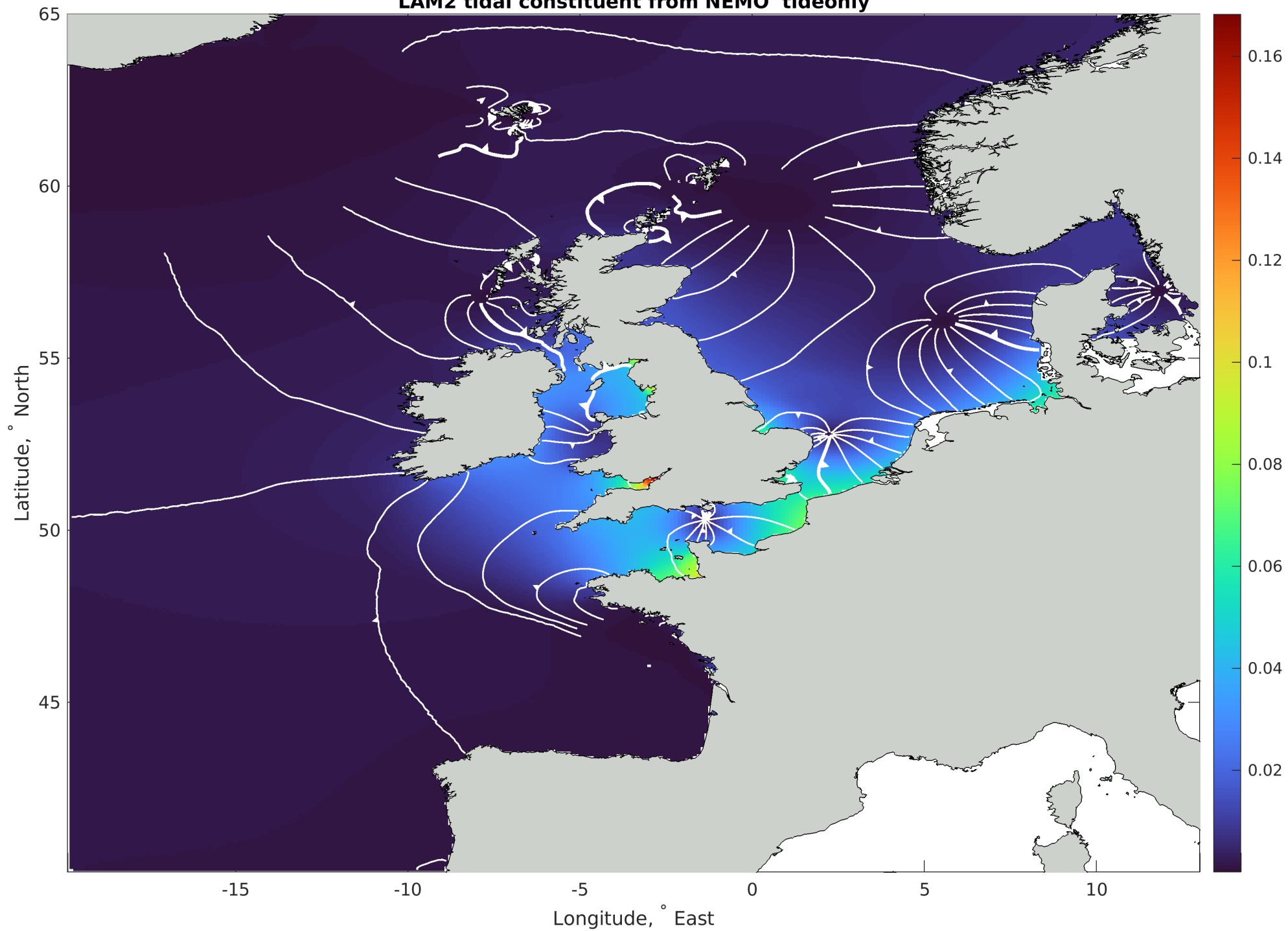
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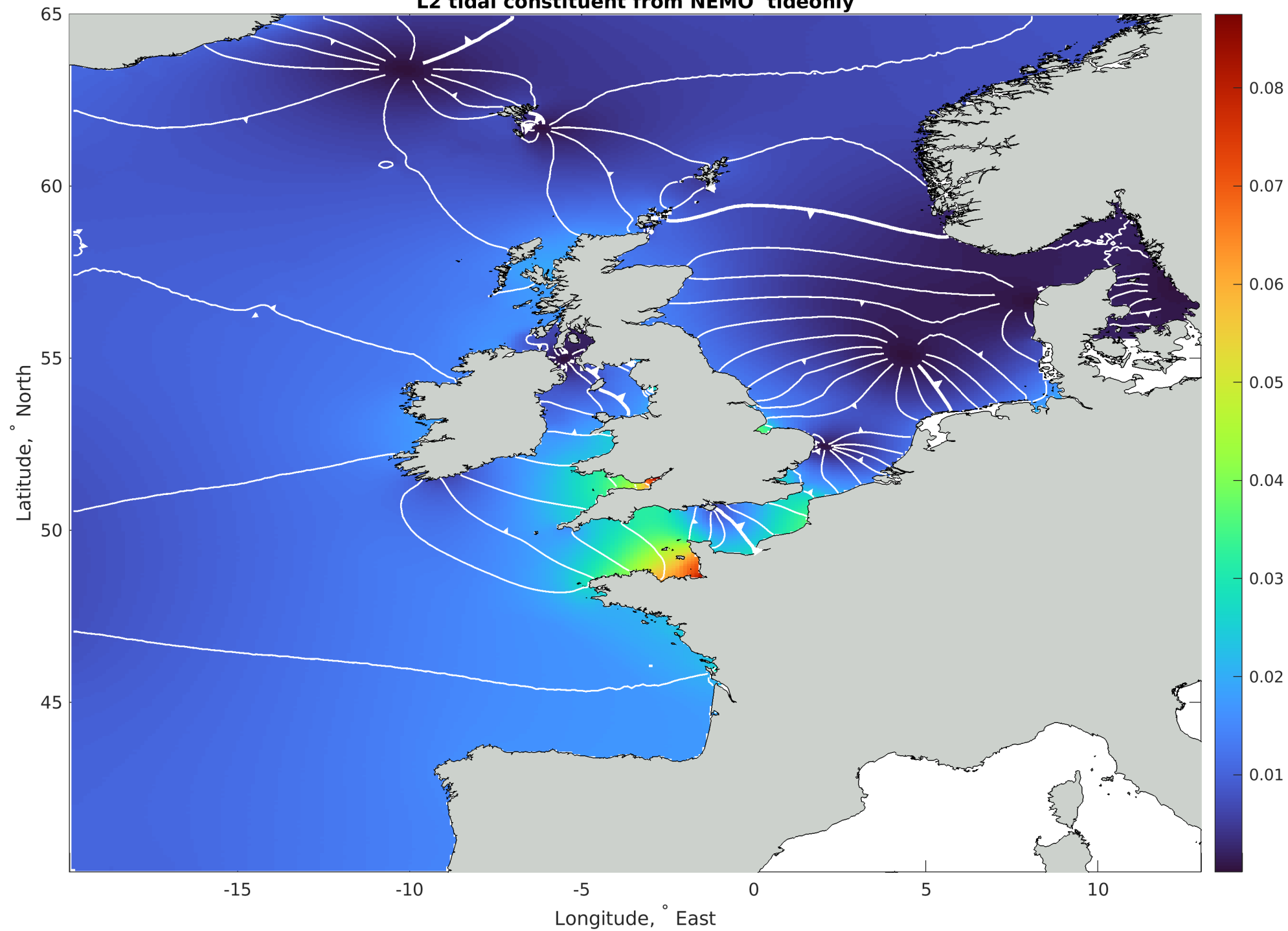
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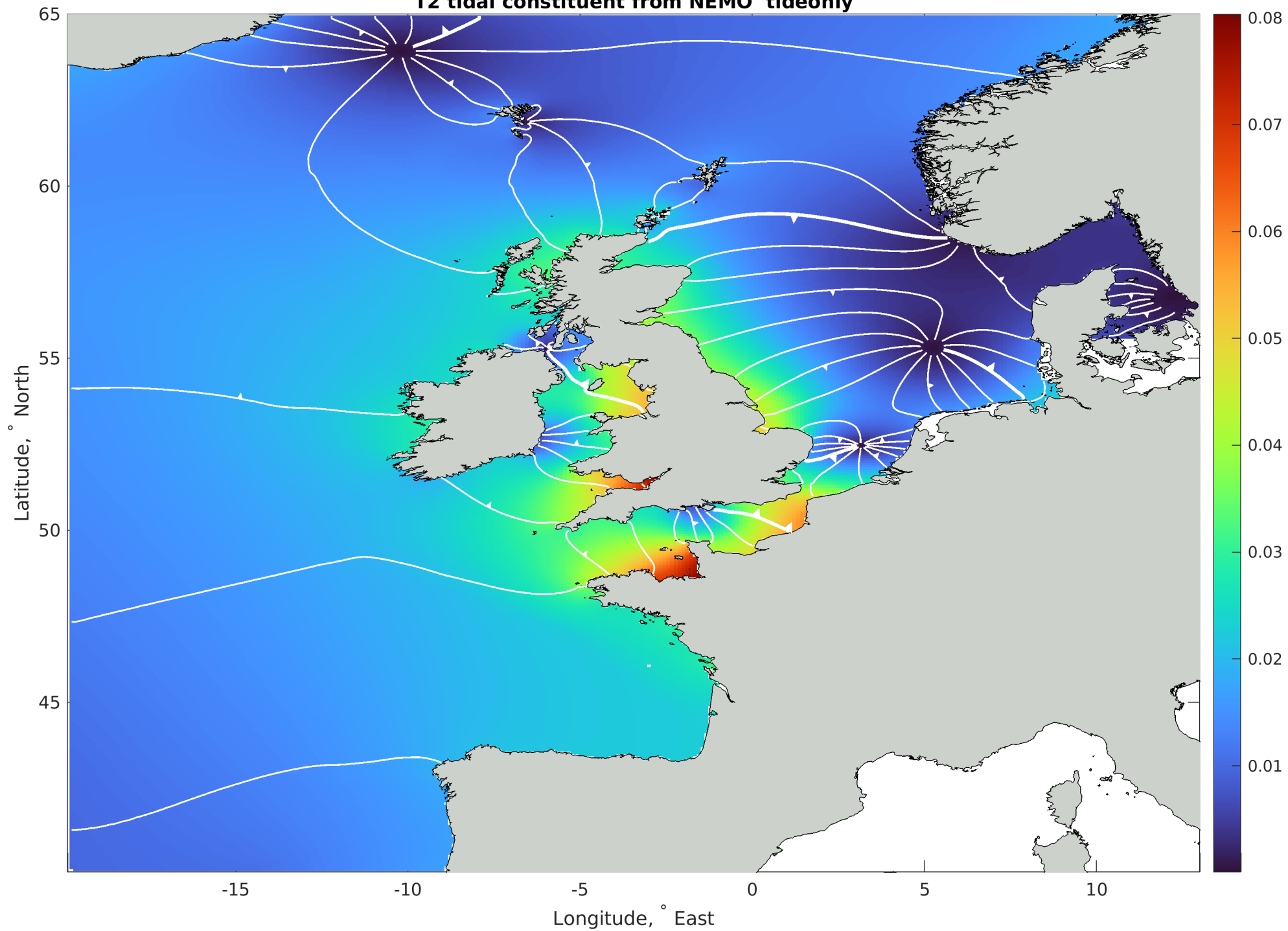
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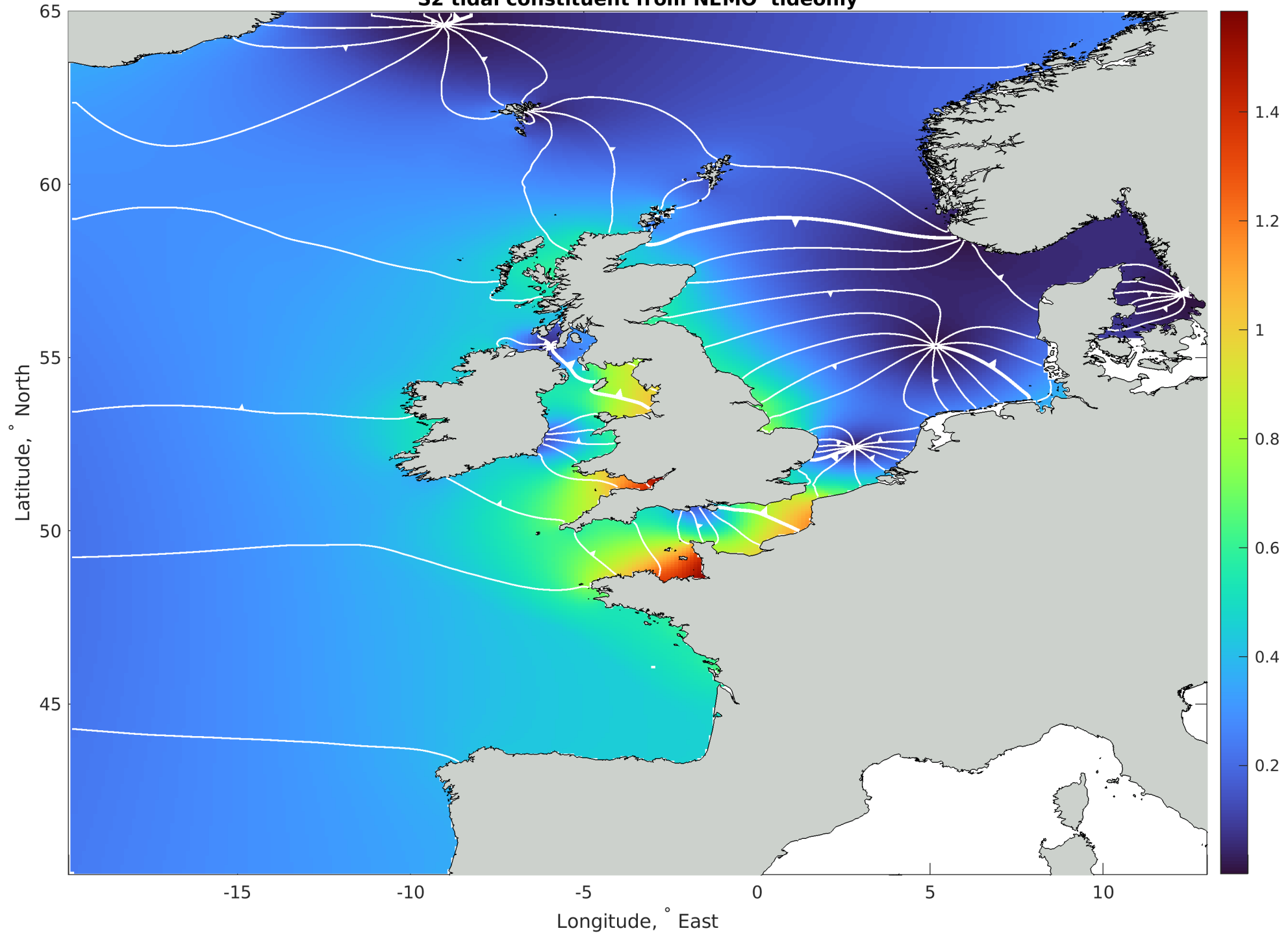
L2 tidal constituent from NEMO tideonly



T2 tidal constituent from NEMO tideonly

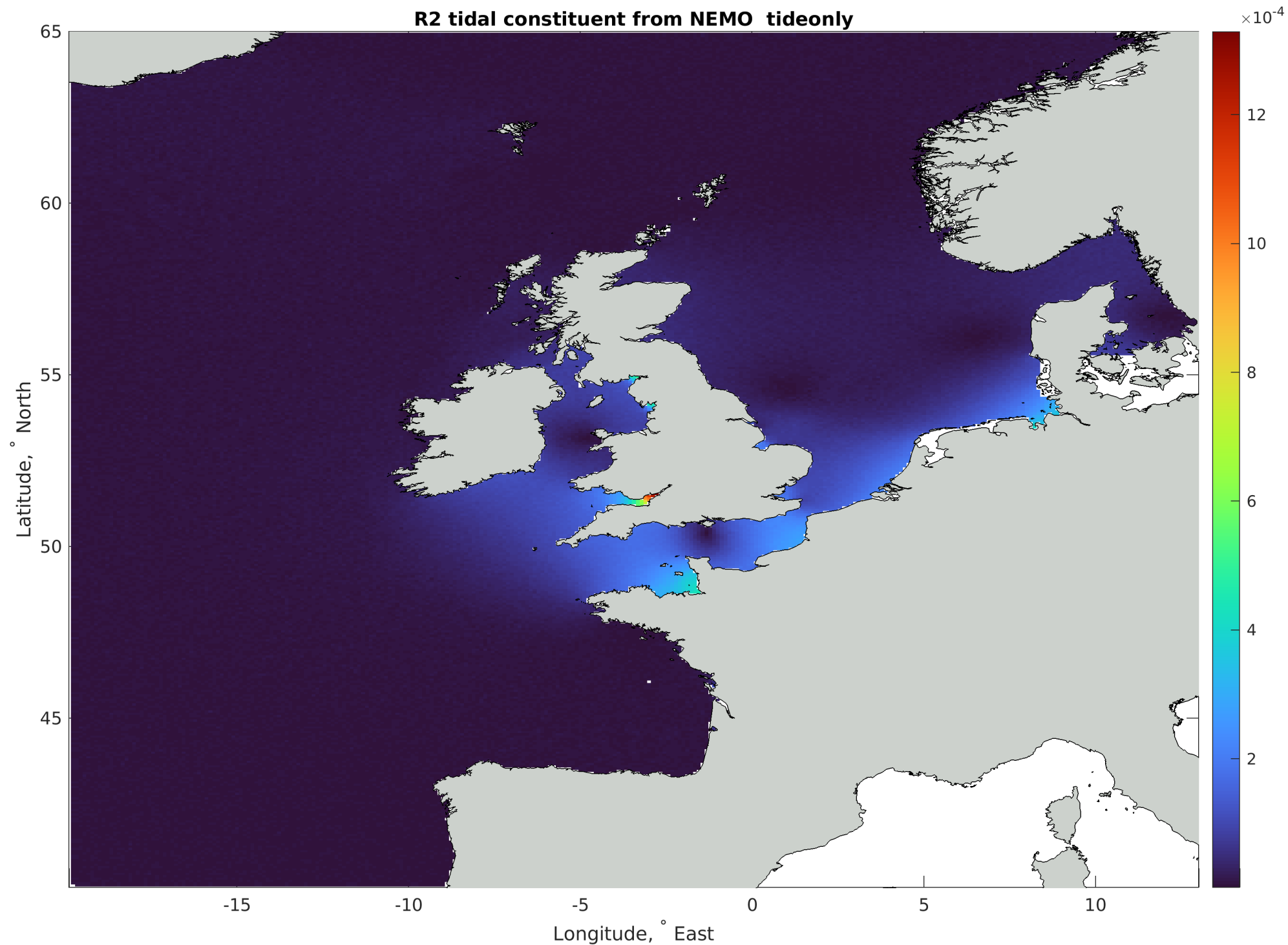


S2 tidal constituent from NEMO tideonly

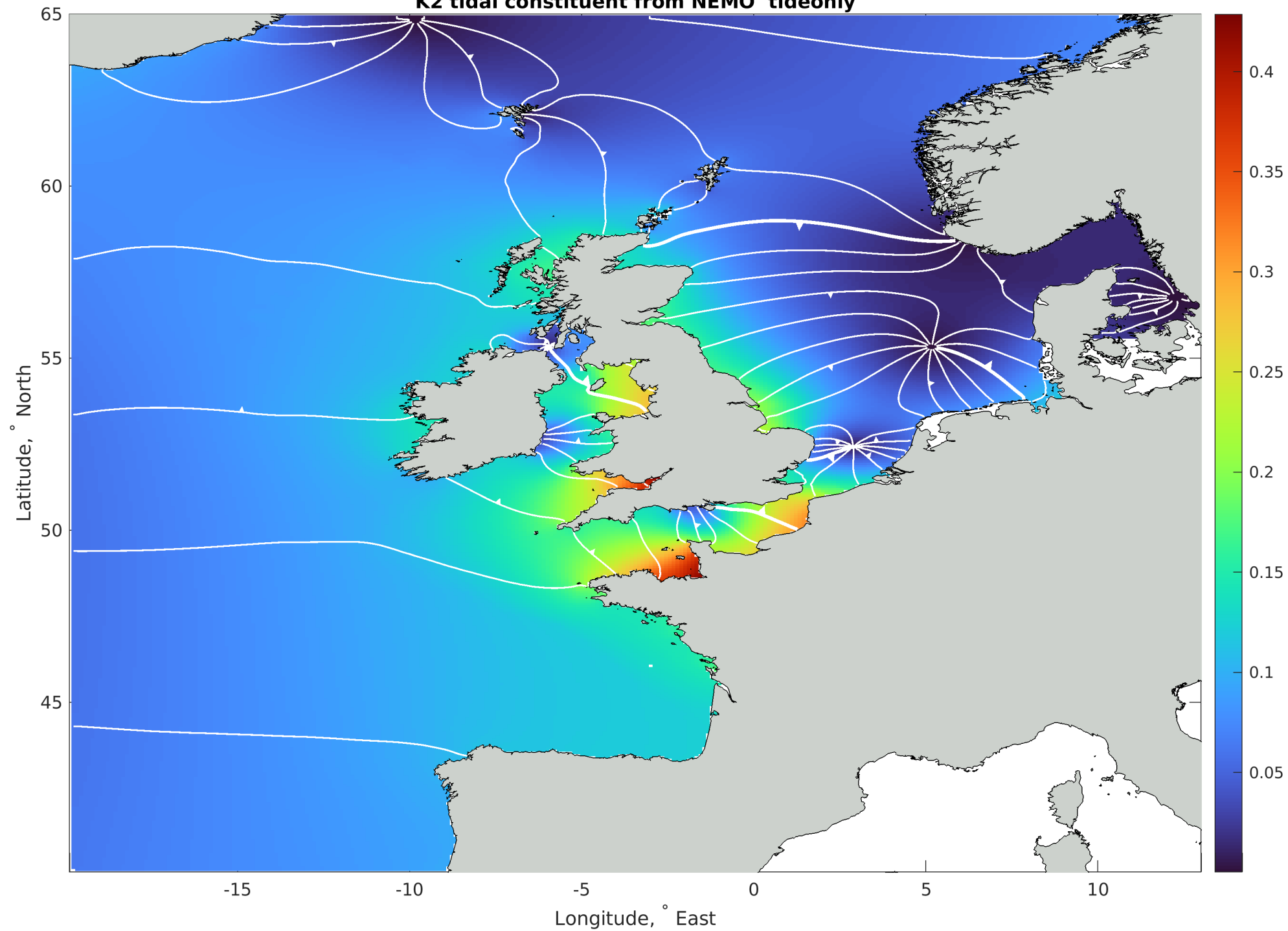




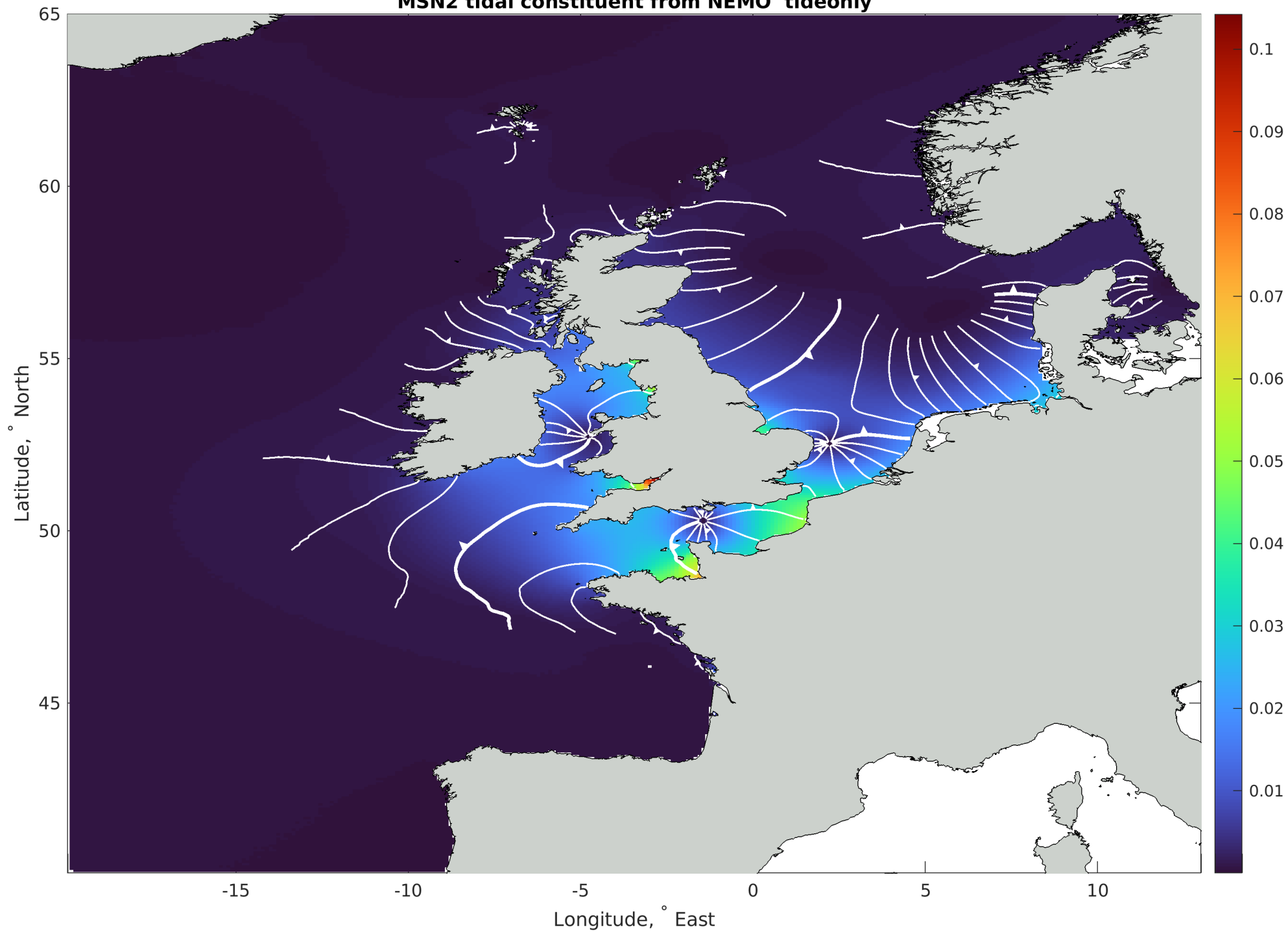
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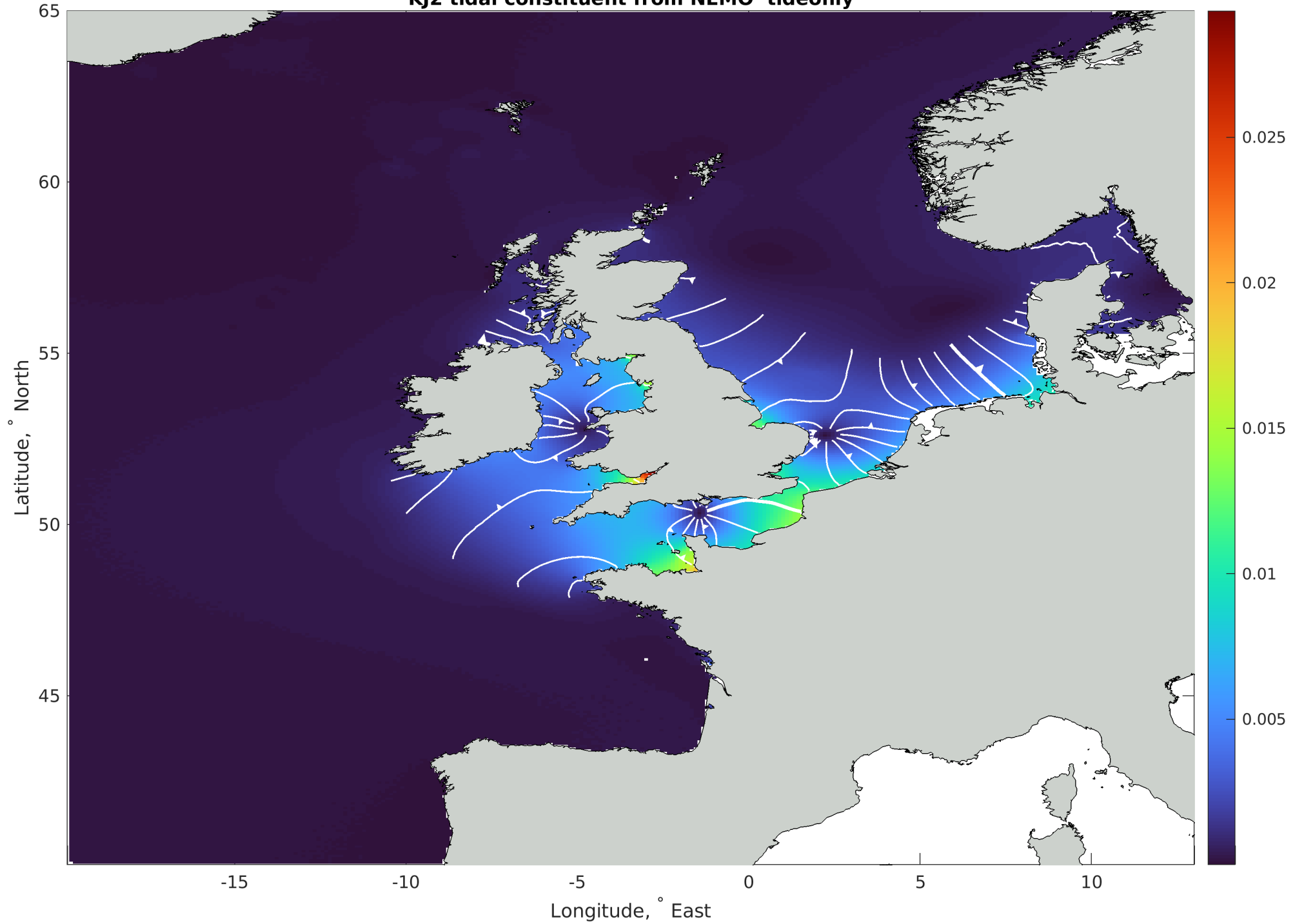
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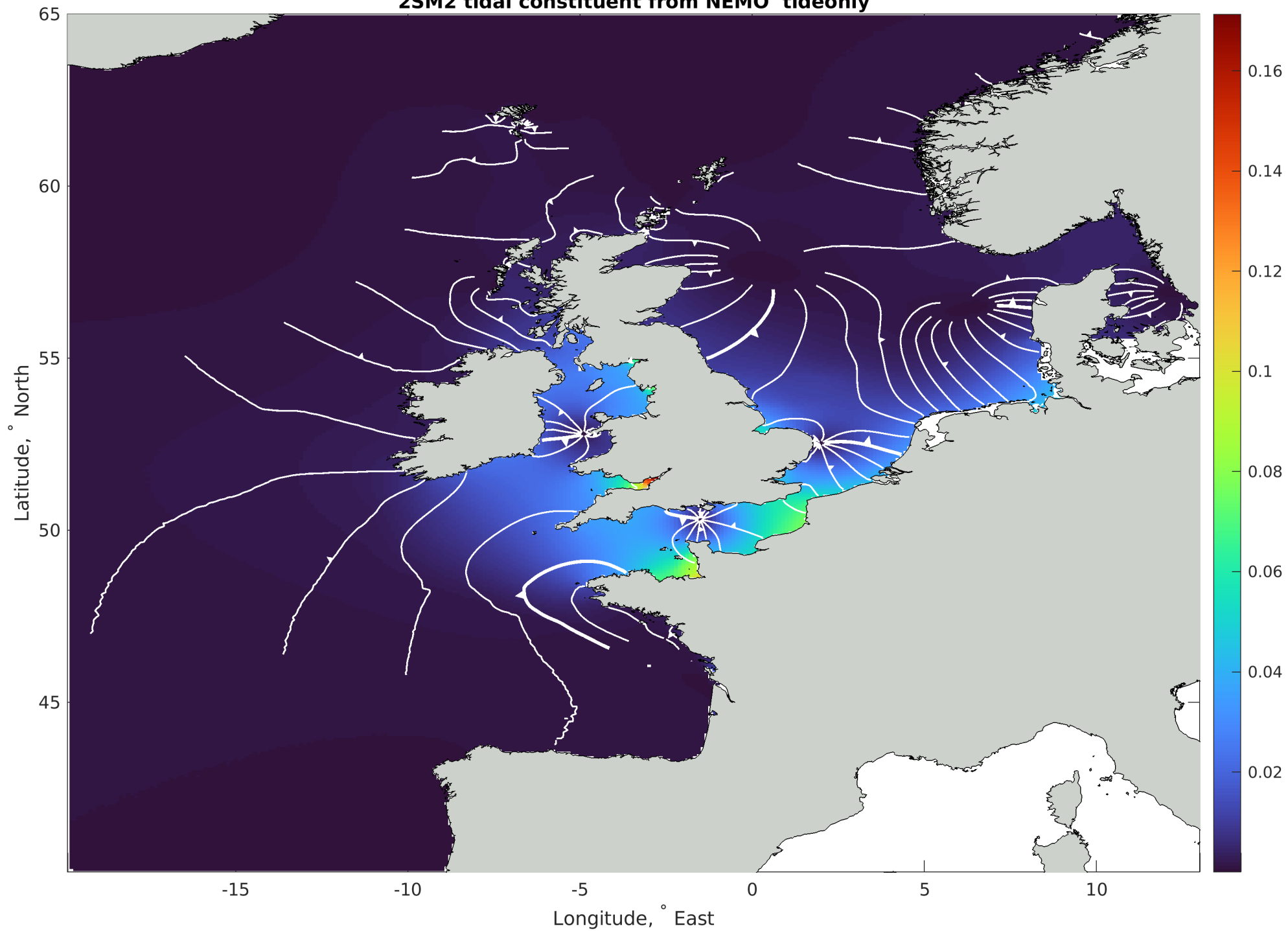
MSN2 tidal constituent from NEMO tideonly



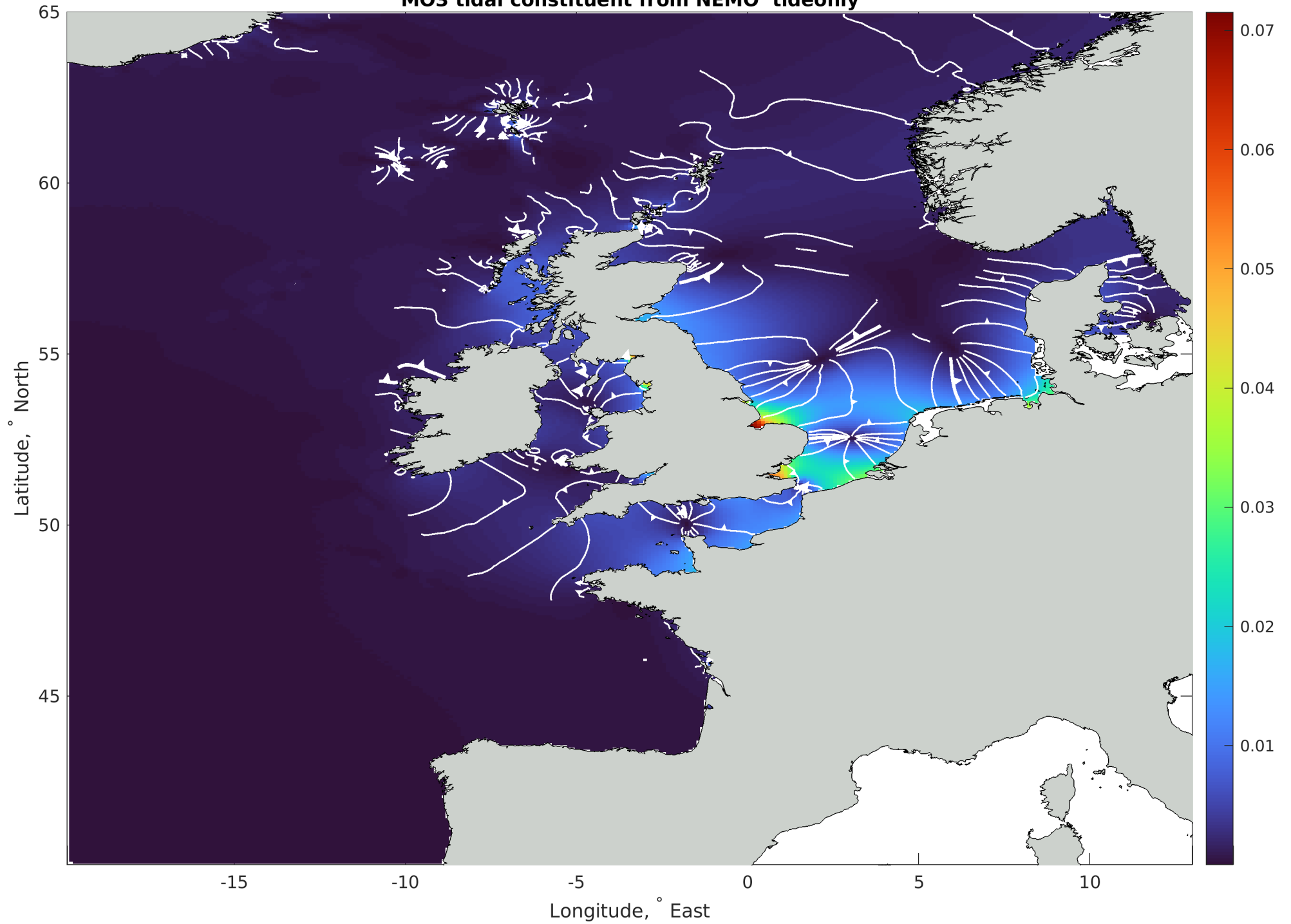
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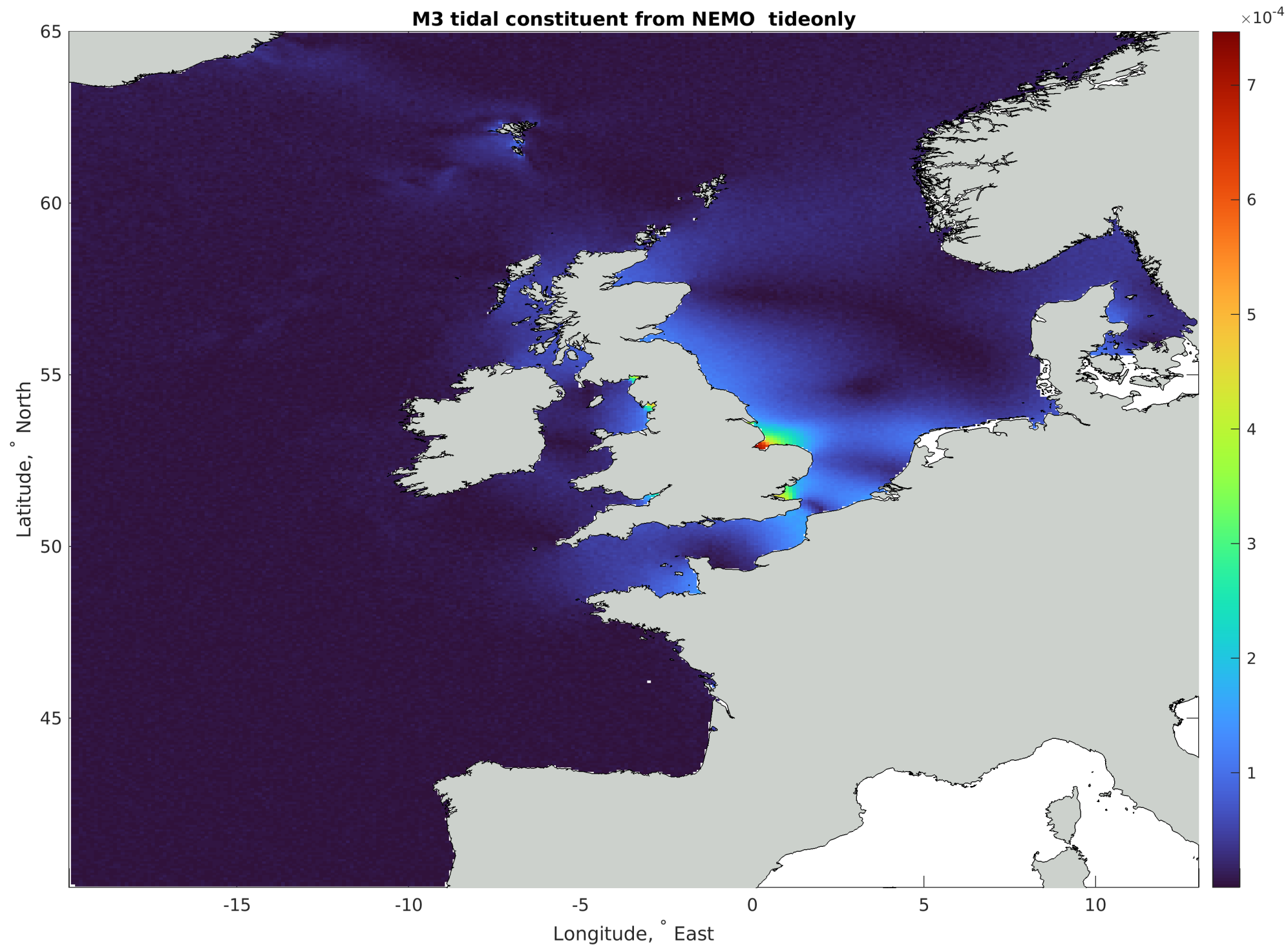
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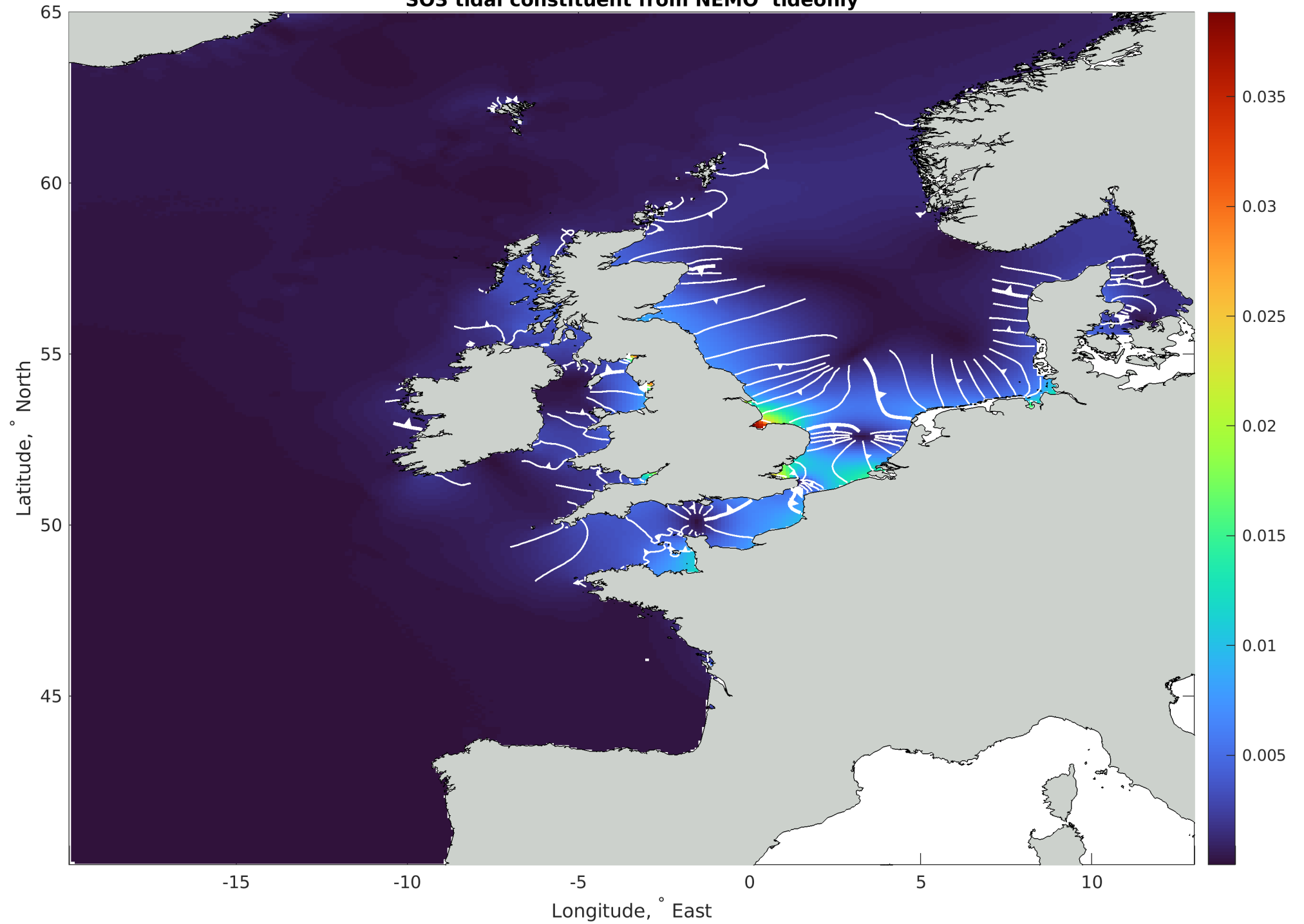
MO3 tidal constituent from NEMO tideonly



M3 tidal constituent from NEMO tideonly

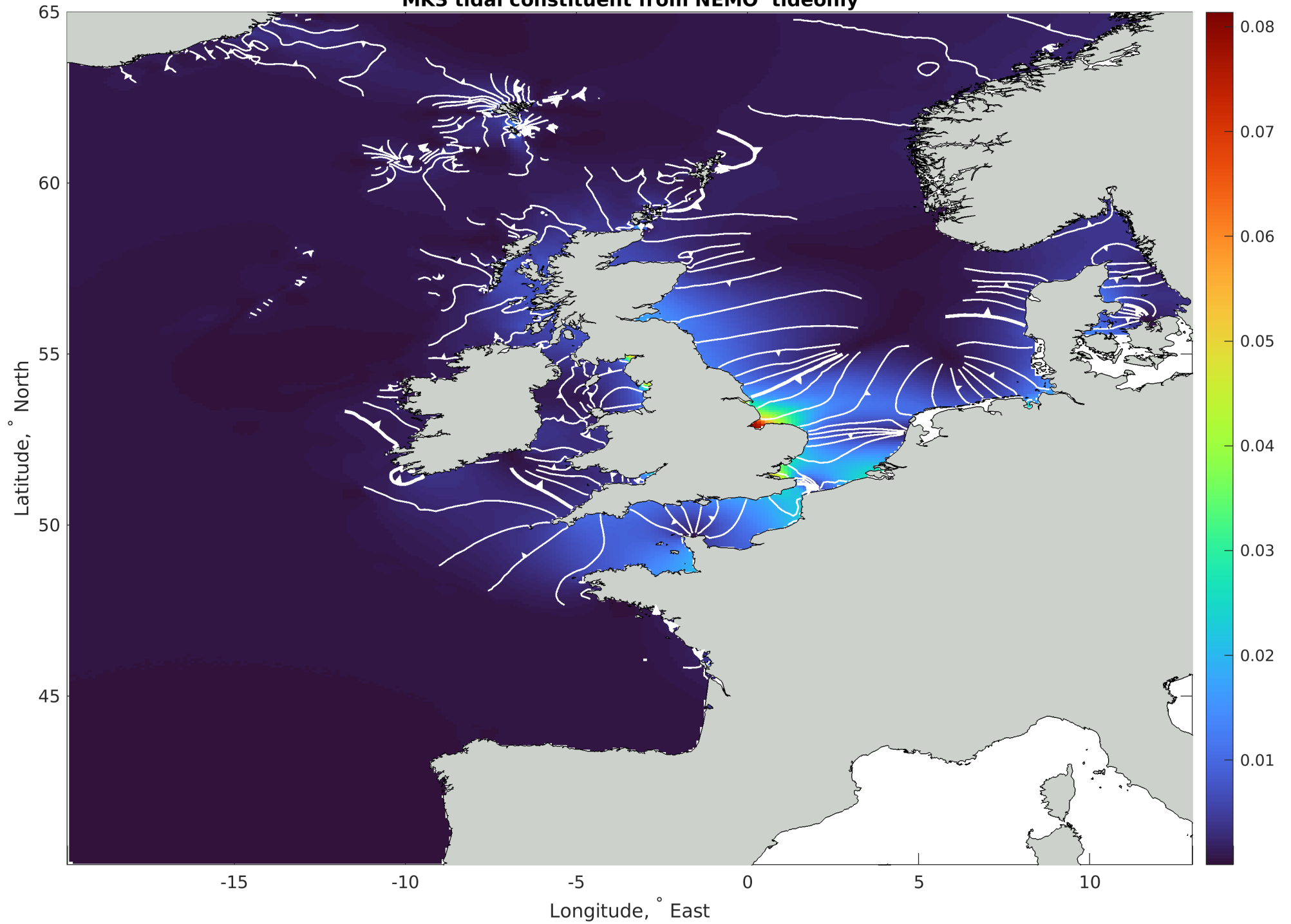


SO3 tidal constituent from NEMO tideonly

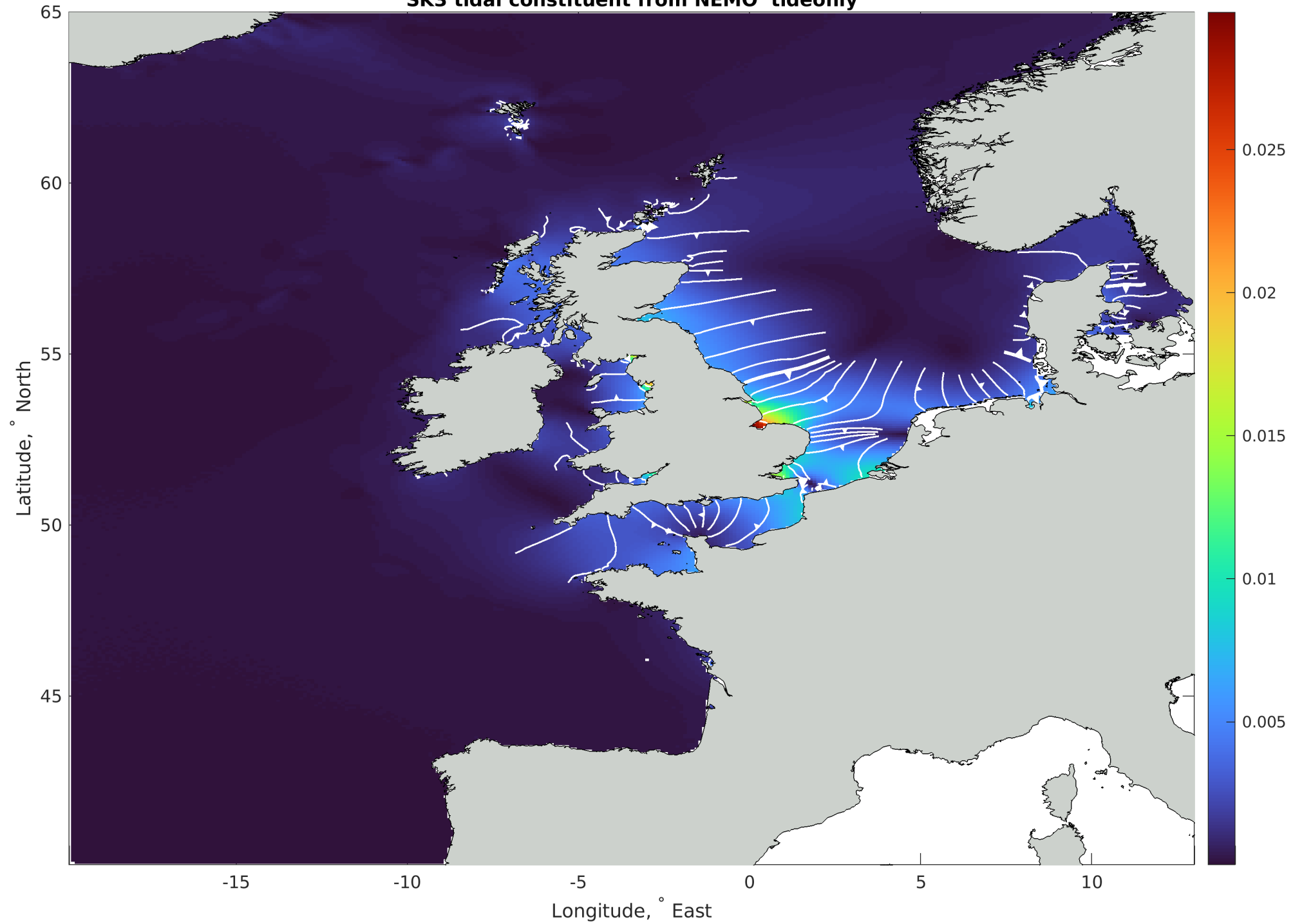




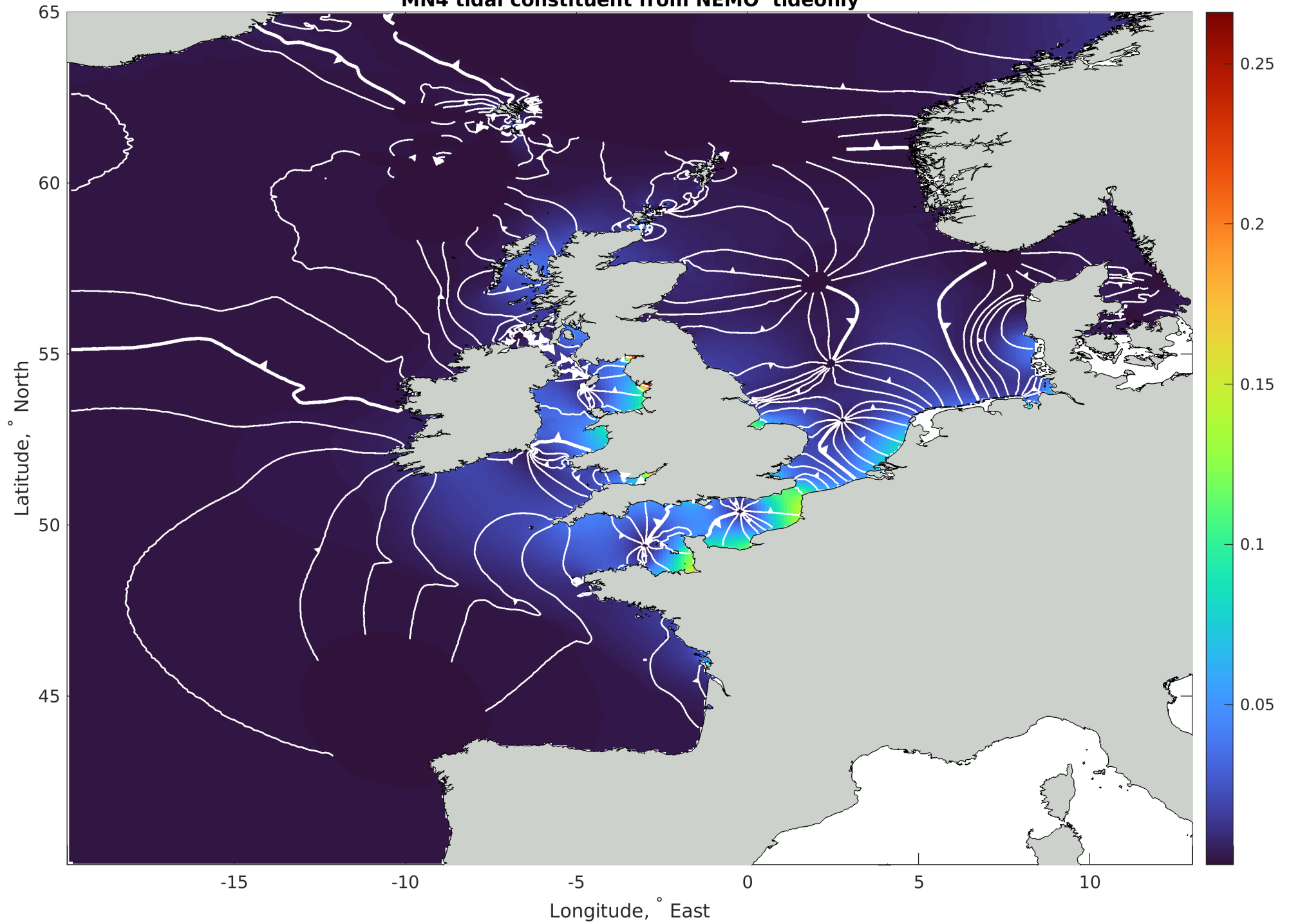
MK3 tidal constituent from NEMO tideonly



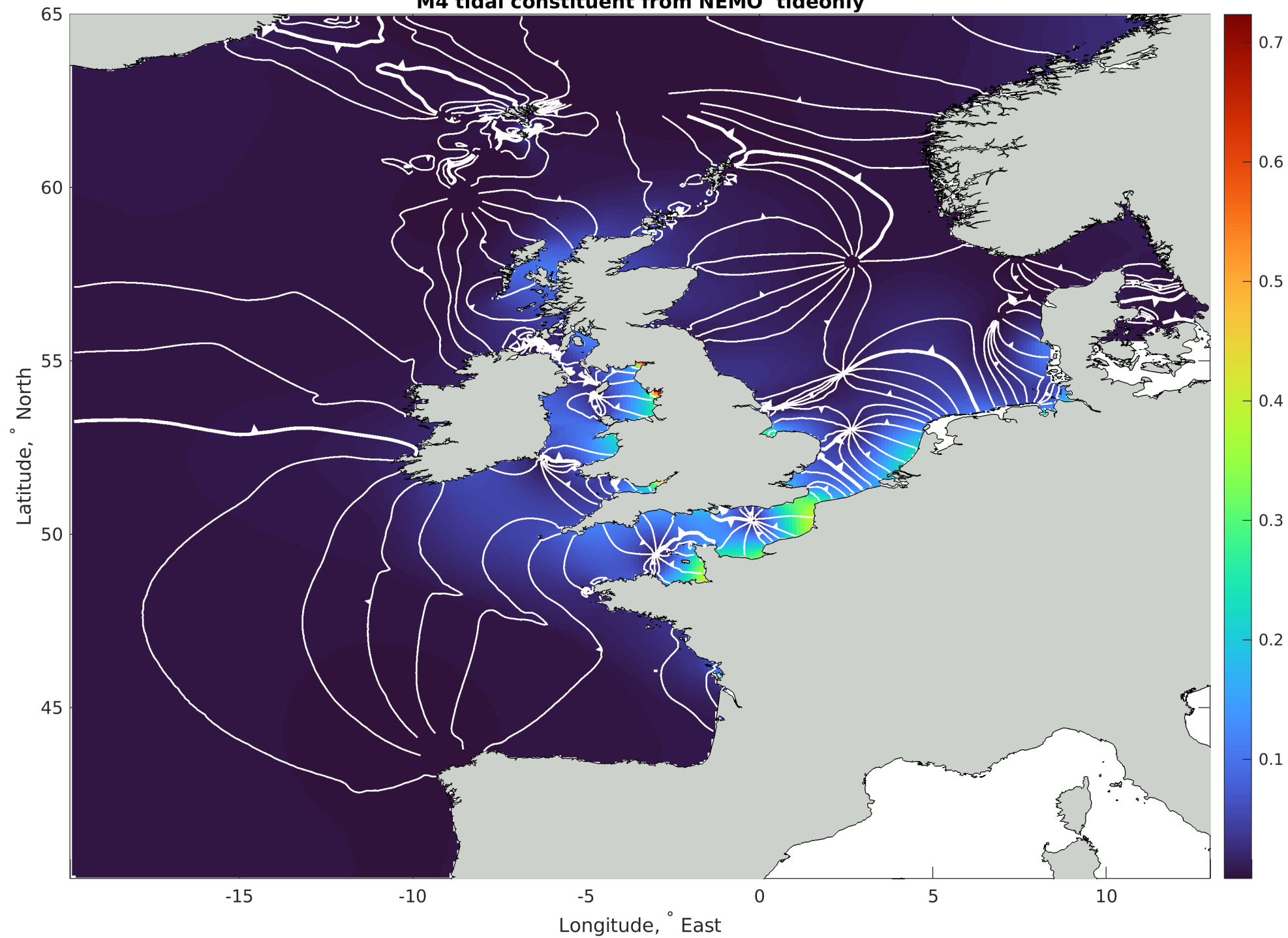
SK3 tidal constituent from NEMO tideonly



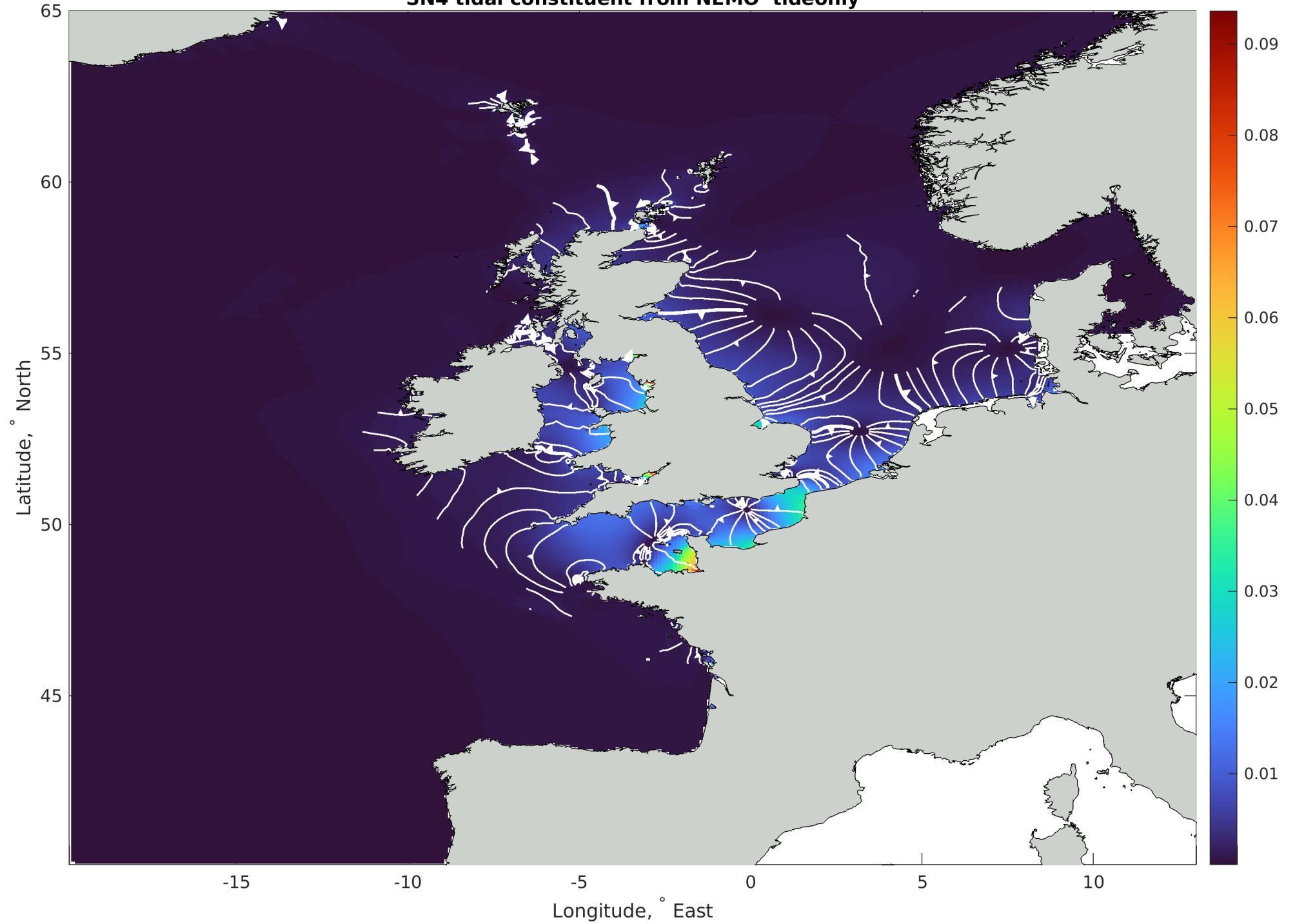
MN4 tidal constituent from NEMO tideonly



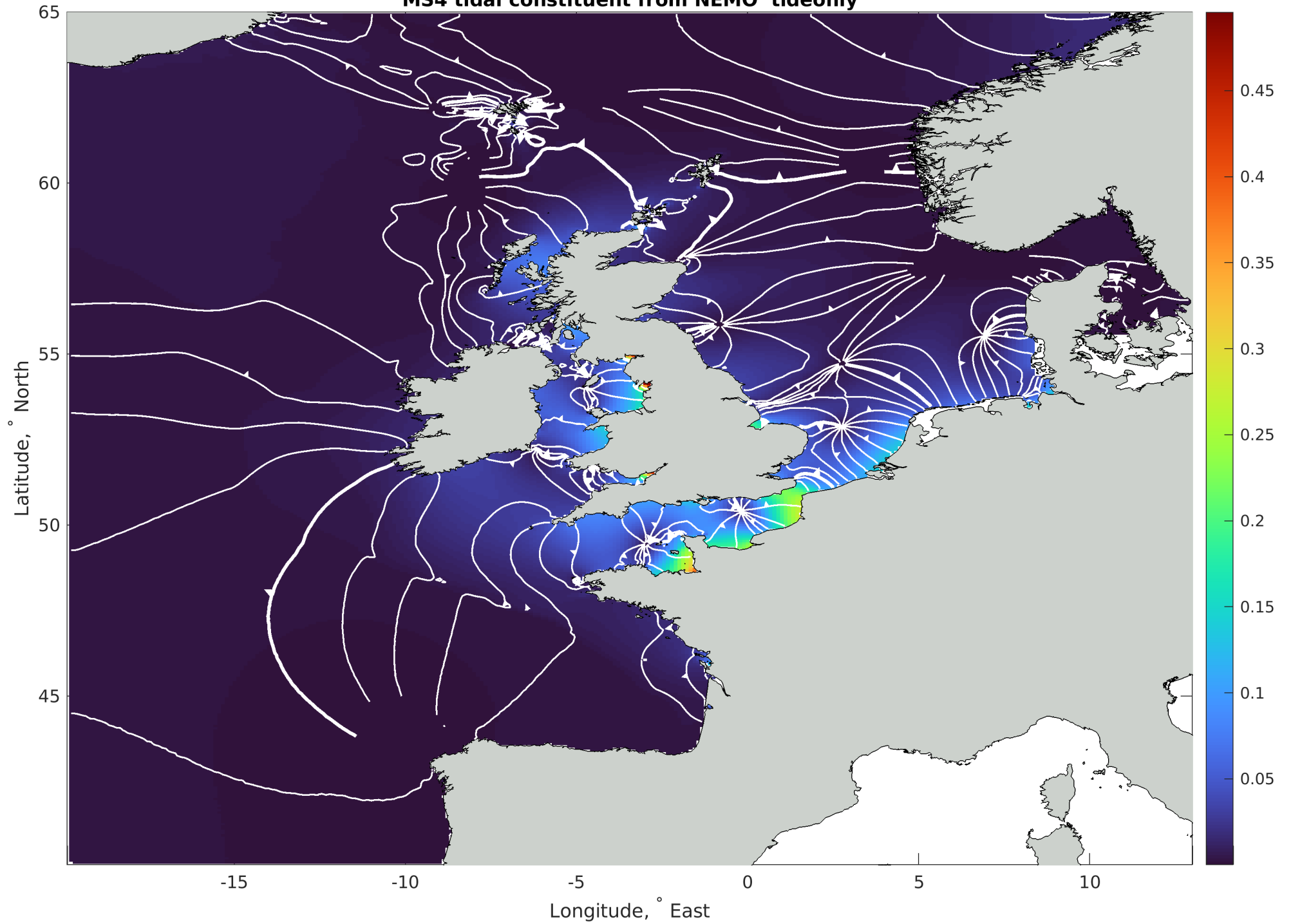
M4 tidal constituent from NEMO tideonly



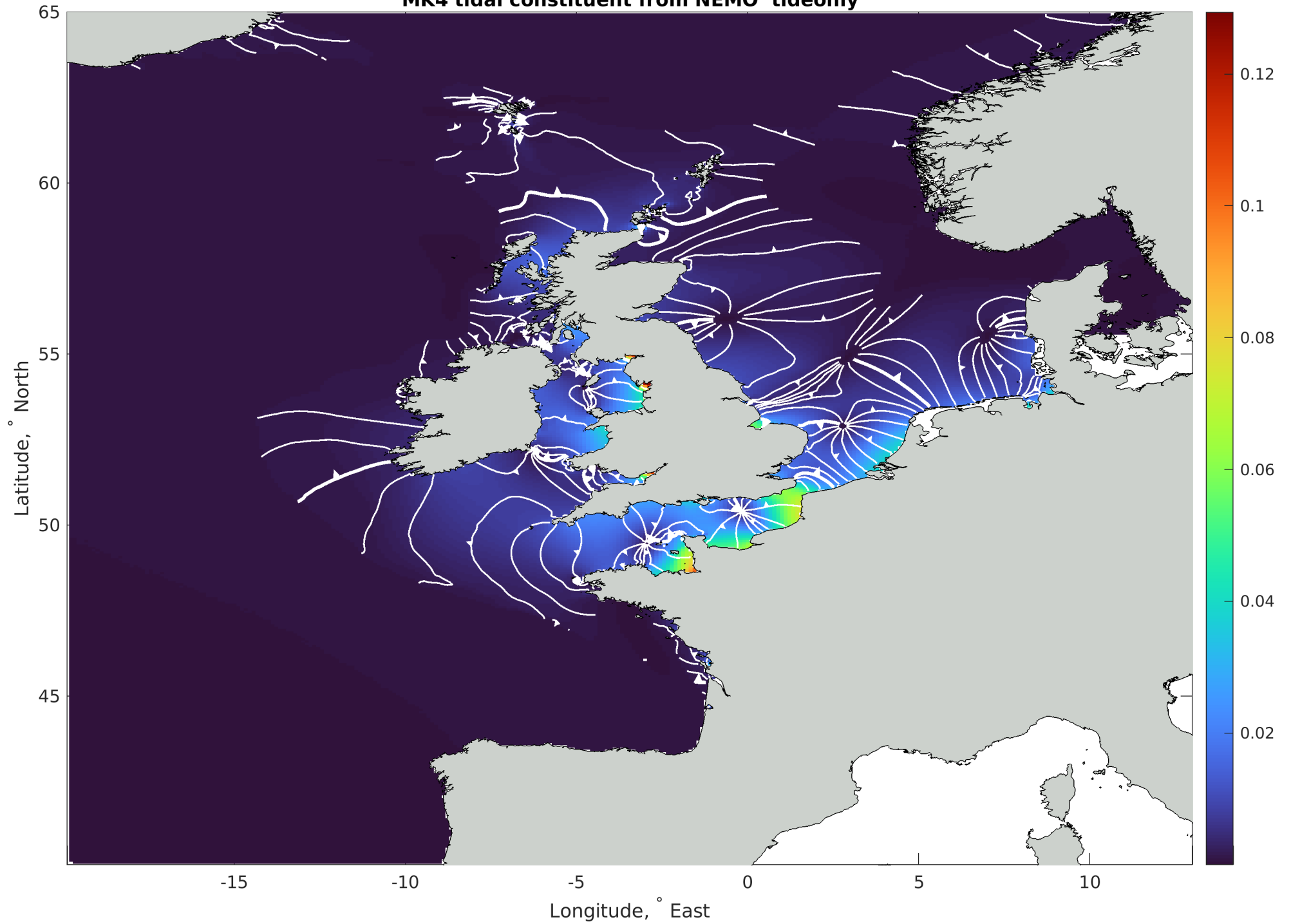
SN4 tidal constituent from NEMO tideonly



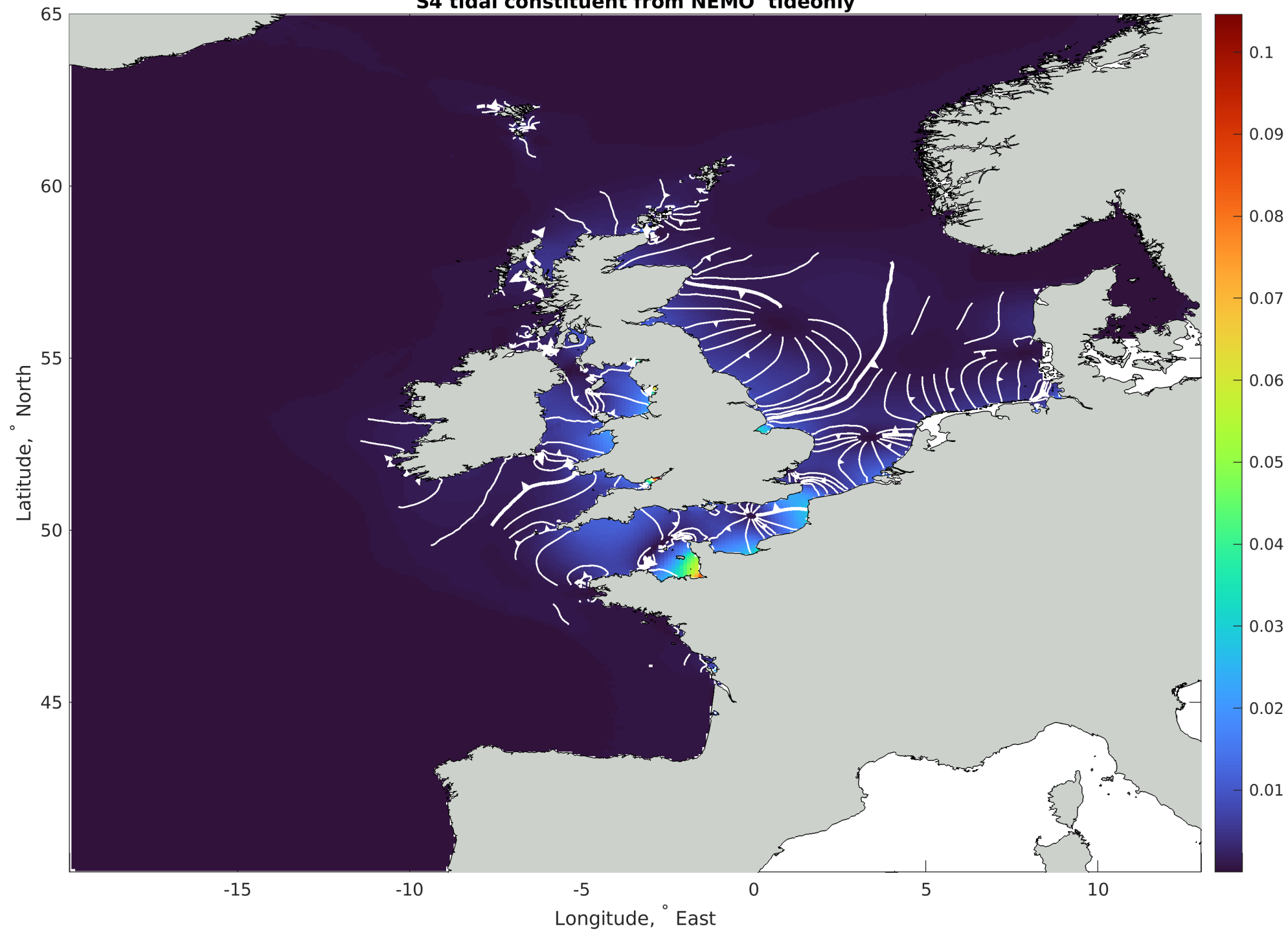
MS4 tidal constituent from NEMO tideonly



MK4 tidal constituent from NEMO tideonly

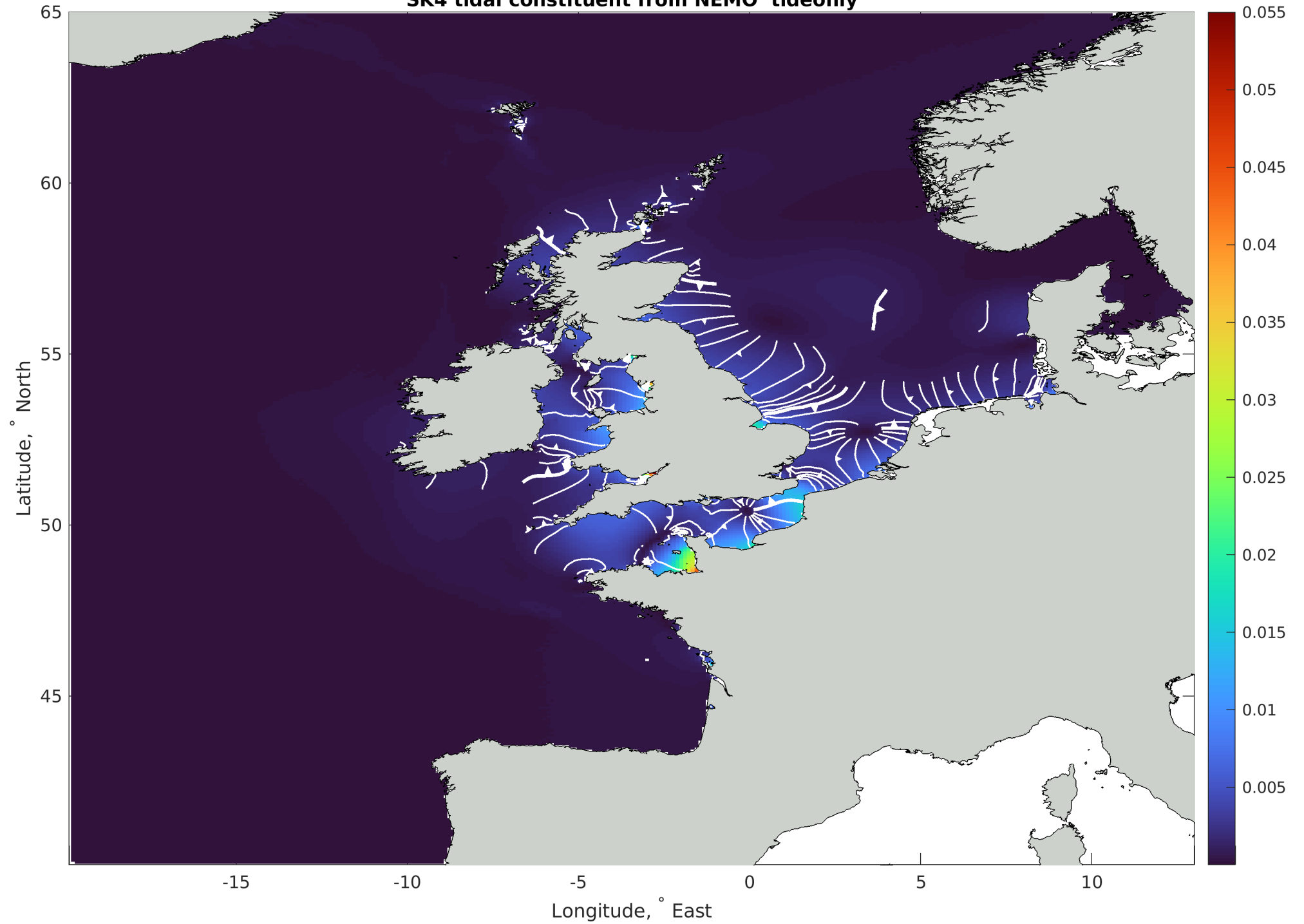


S4 tidal constituent from NEMO tideonly

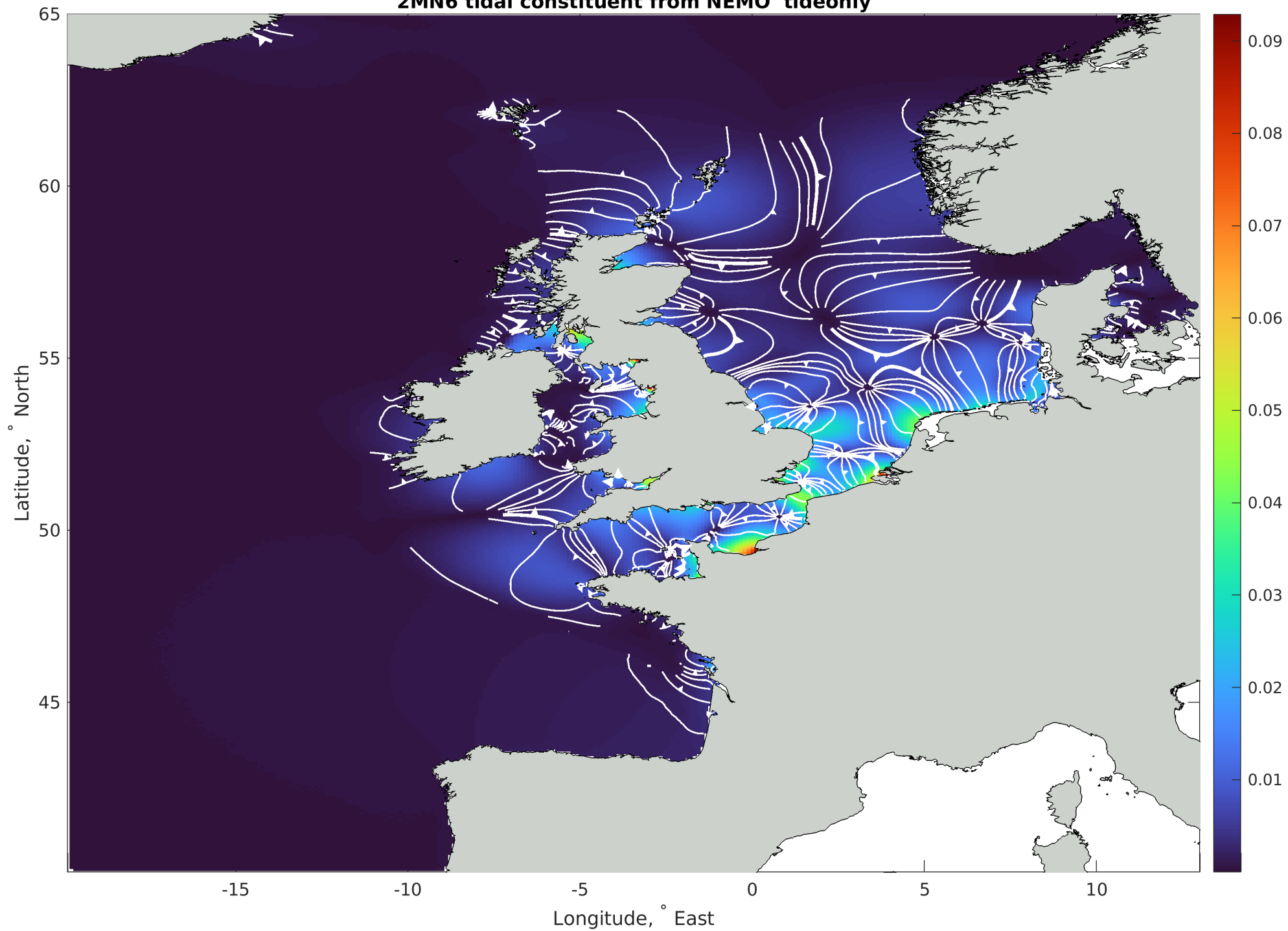




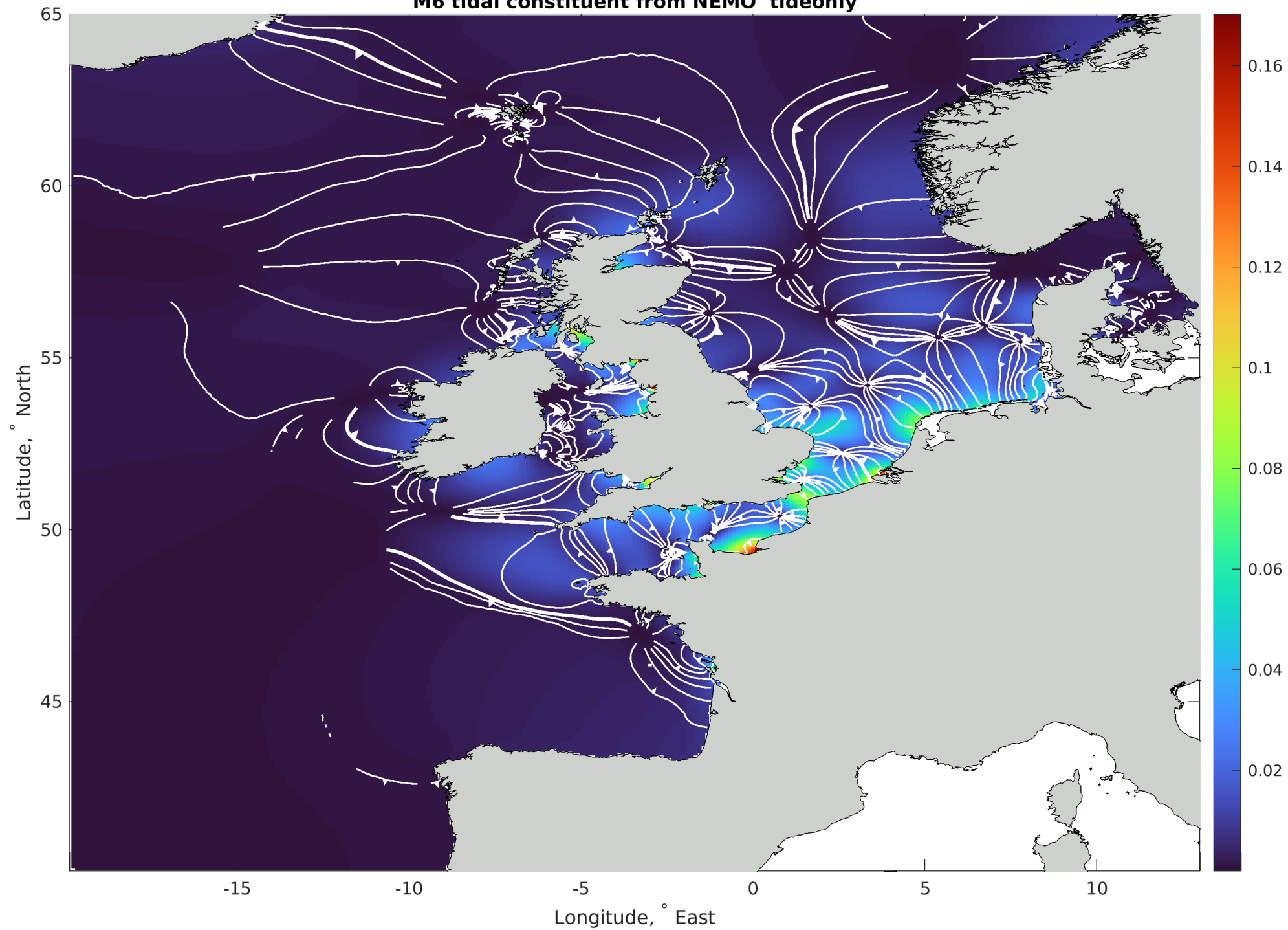
SK4 tidal constituent from NEMO tideonly



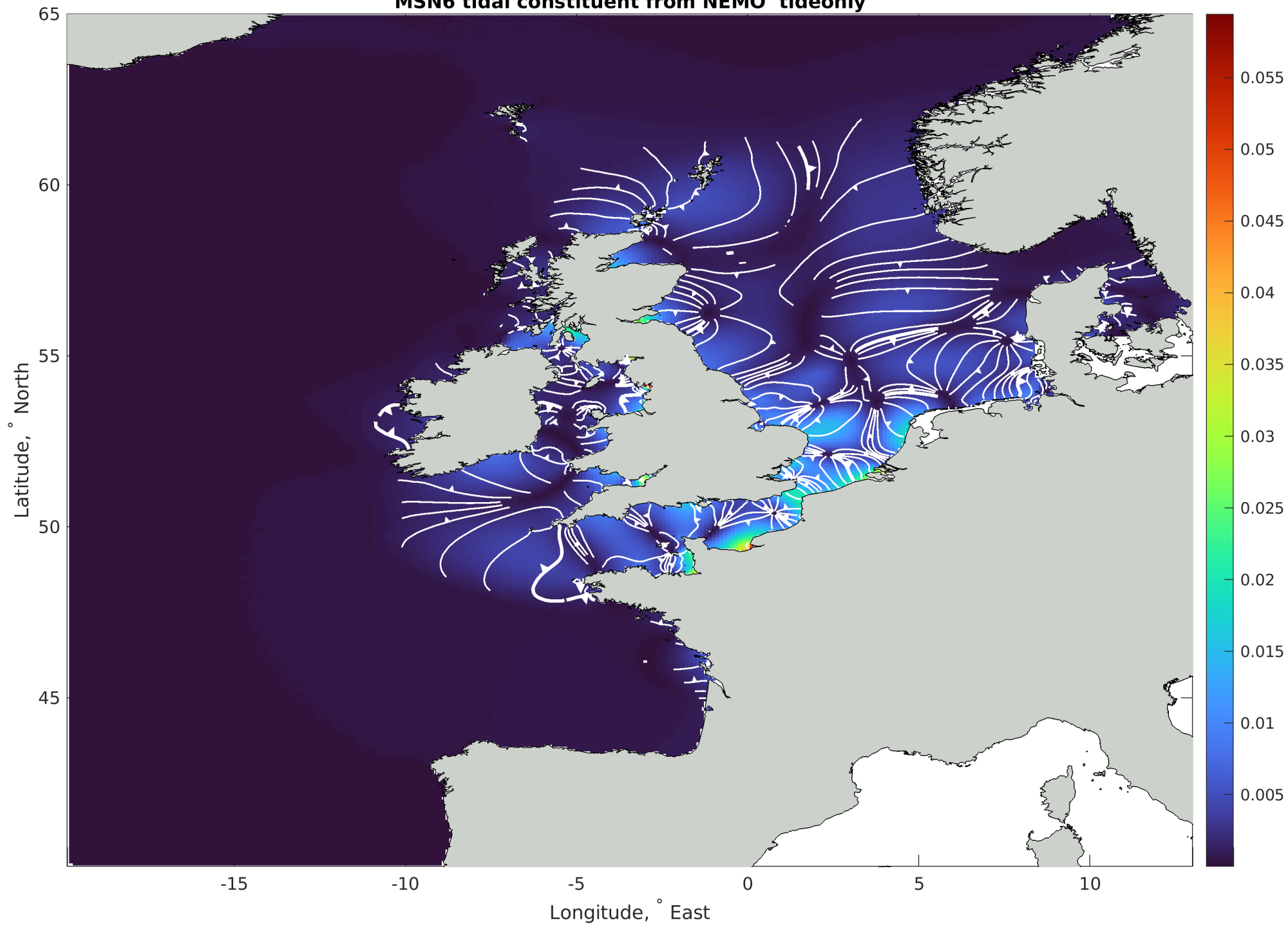
2MN6 tidal constituent from NEMO tideonly



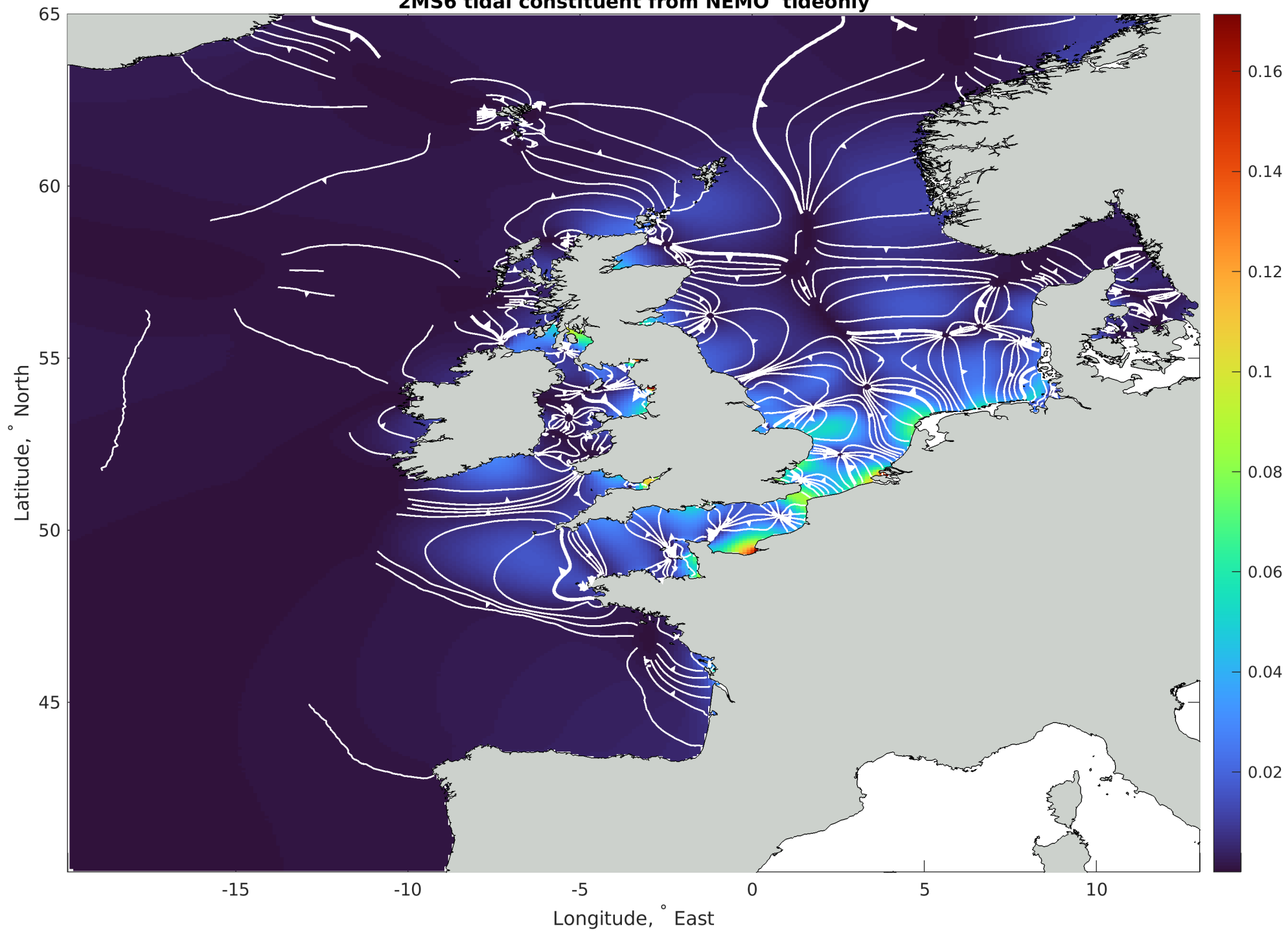
M6 tidal constituent from NEMO tideonly



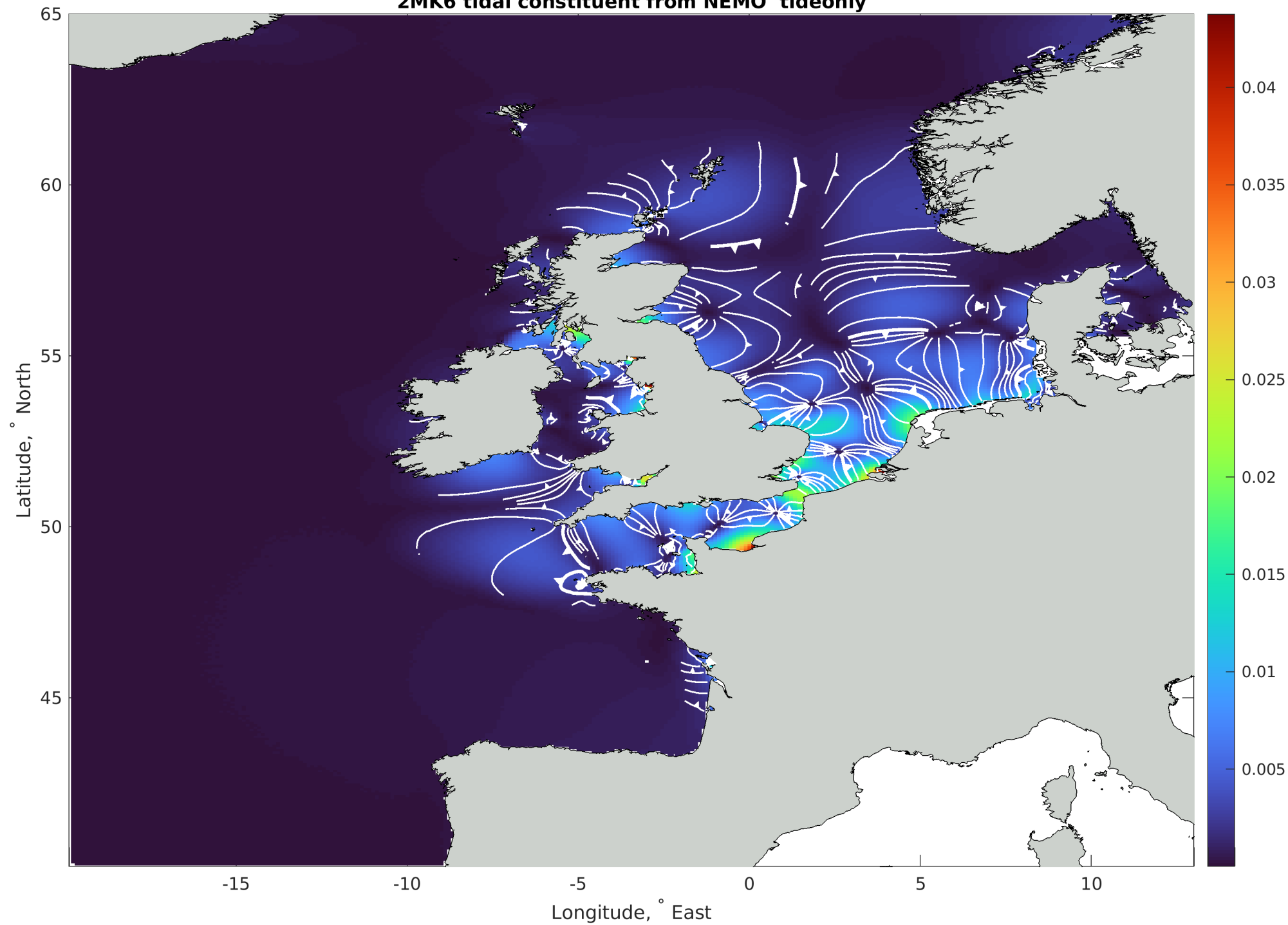
MSN6 tidal constituent from NEMO tideonly



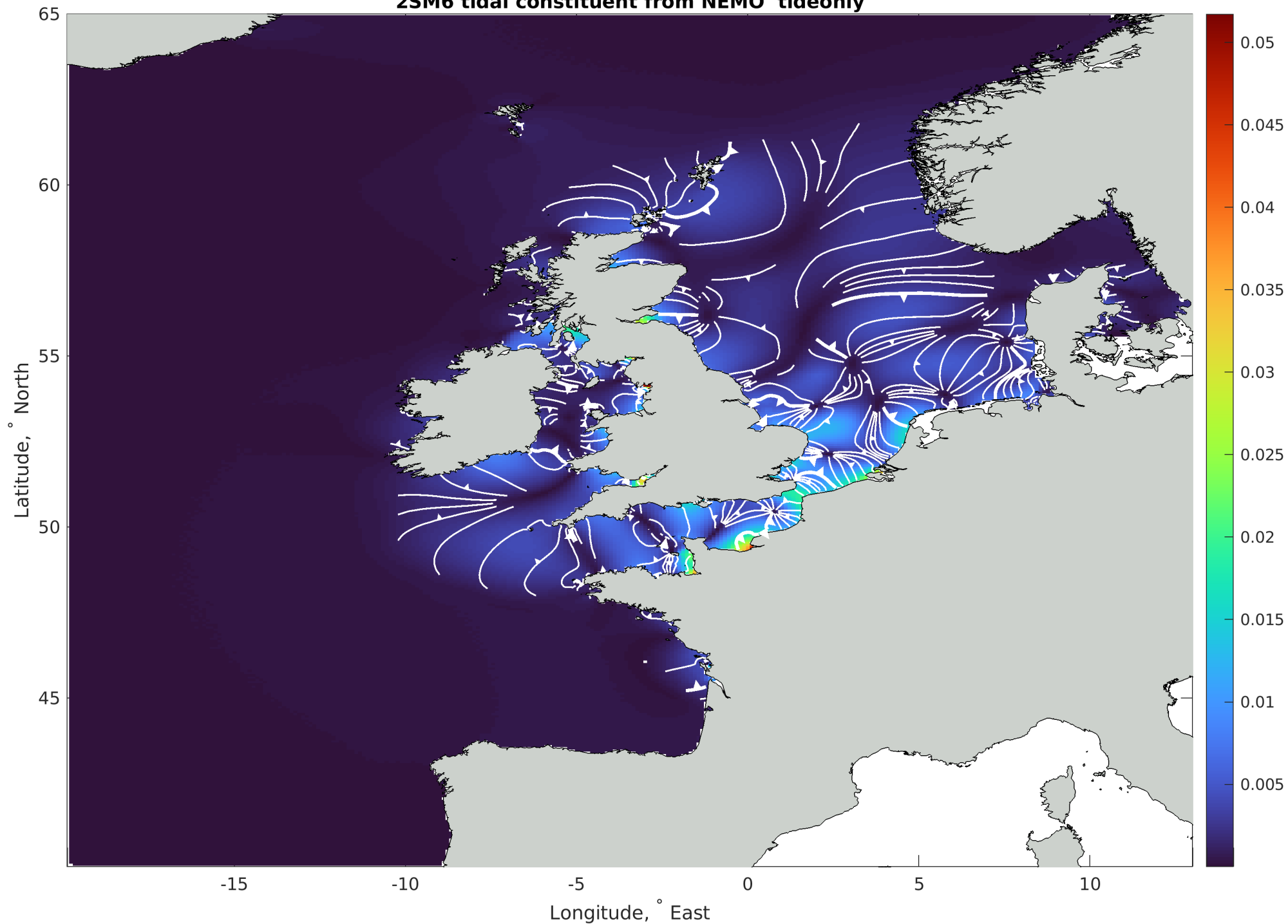
2MS6 tidal constituent from NEMO tideonly



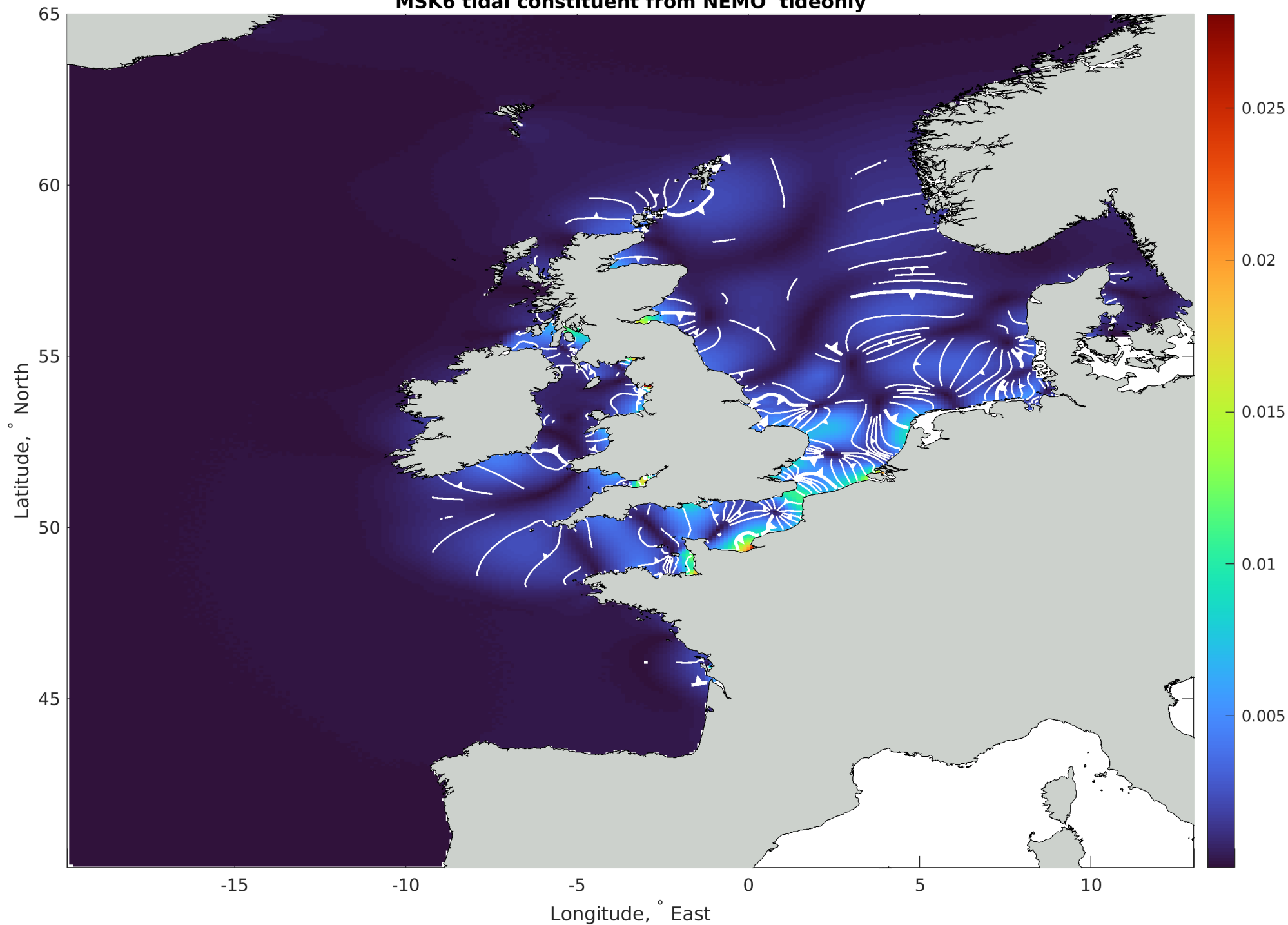
2MK6 tidal constituent from NEMO tideonly



2SM6 tidal constituent from NEMO tideonly

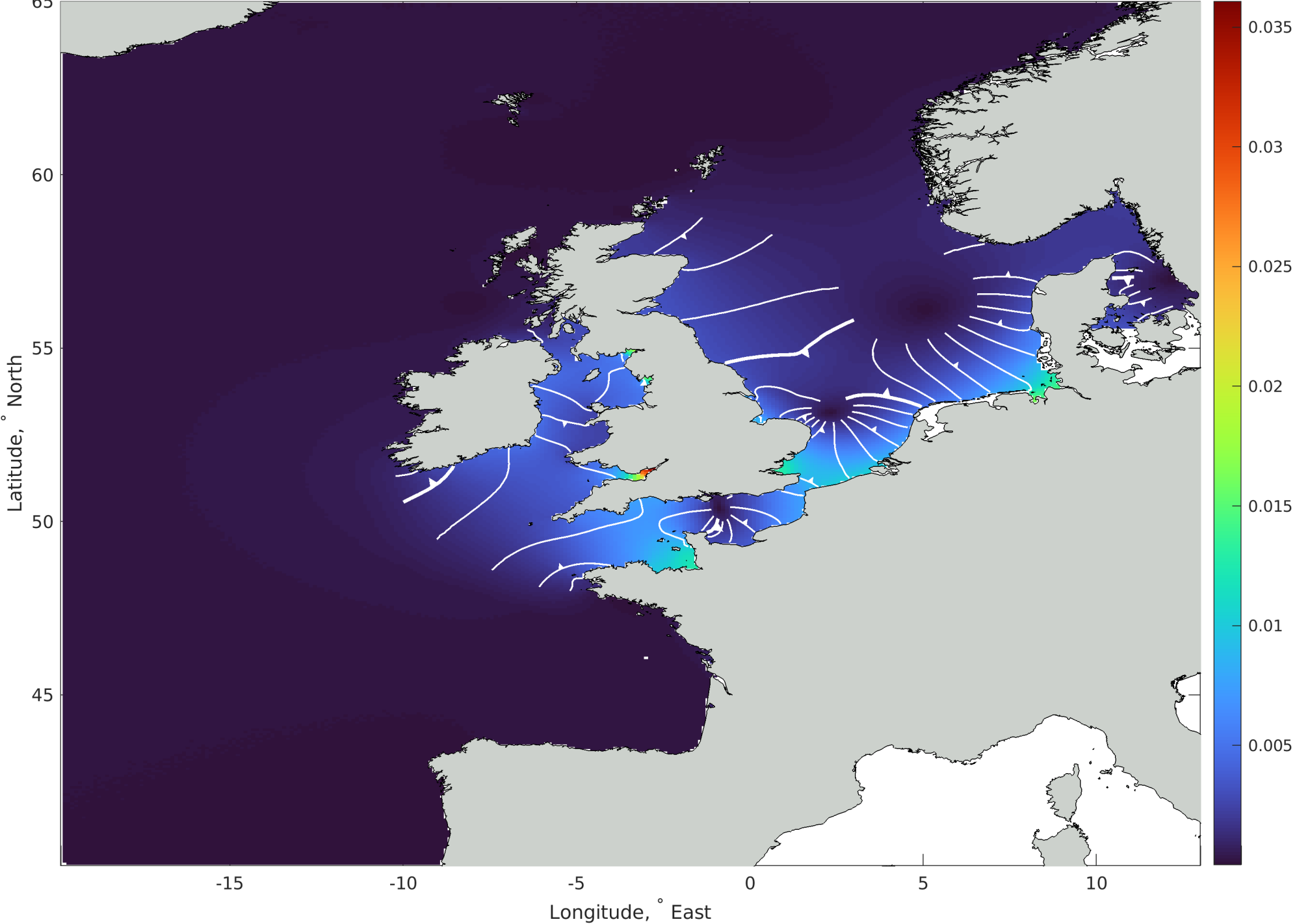


MSK6 tidal constituent from NEMO tideonly

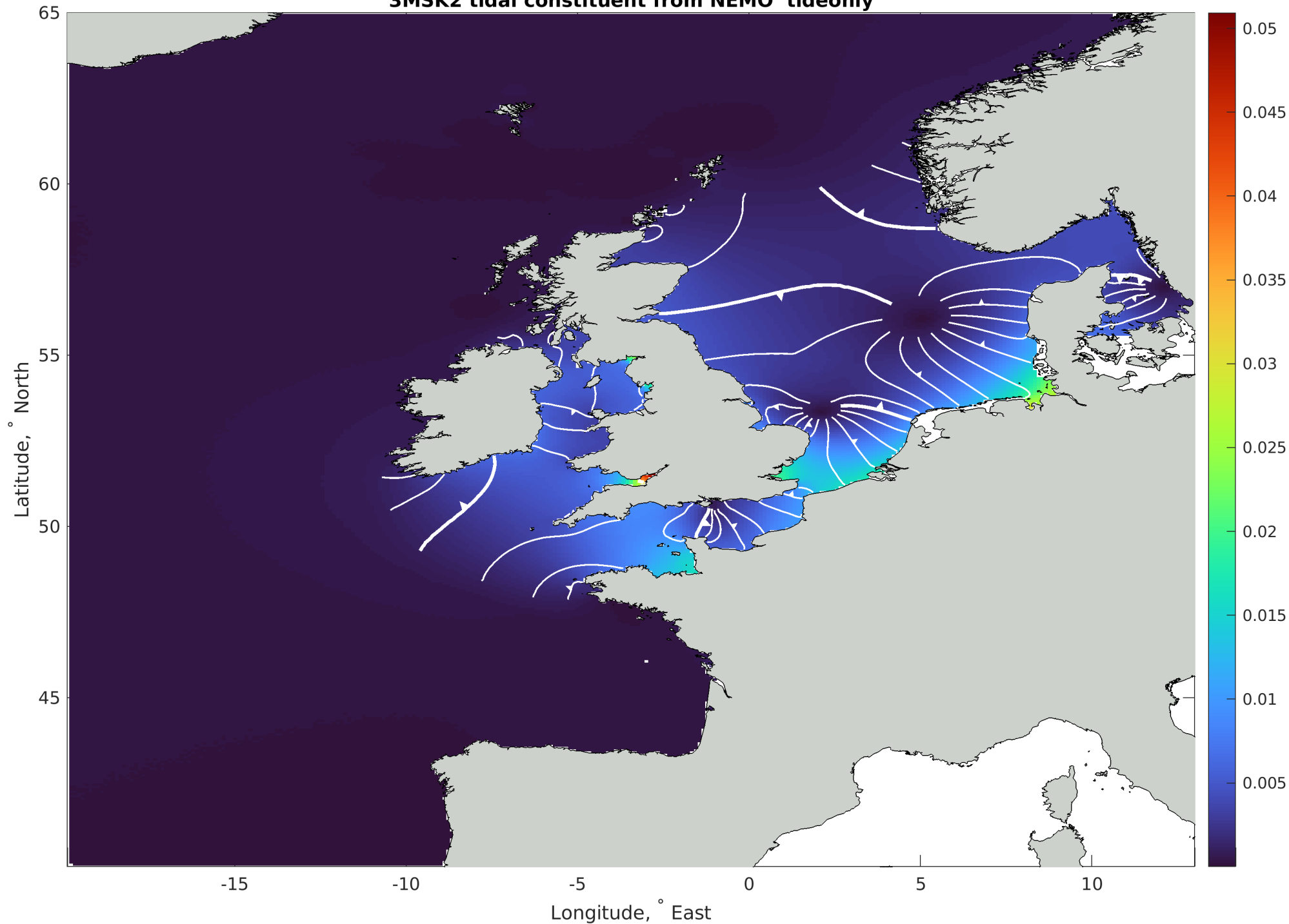




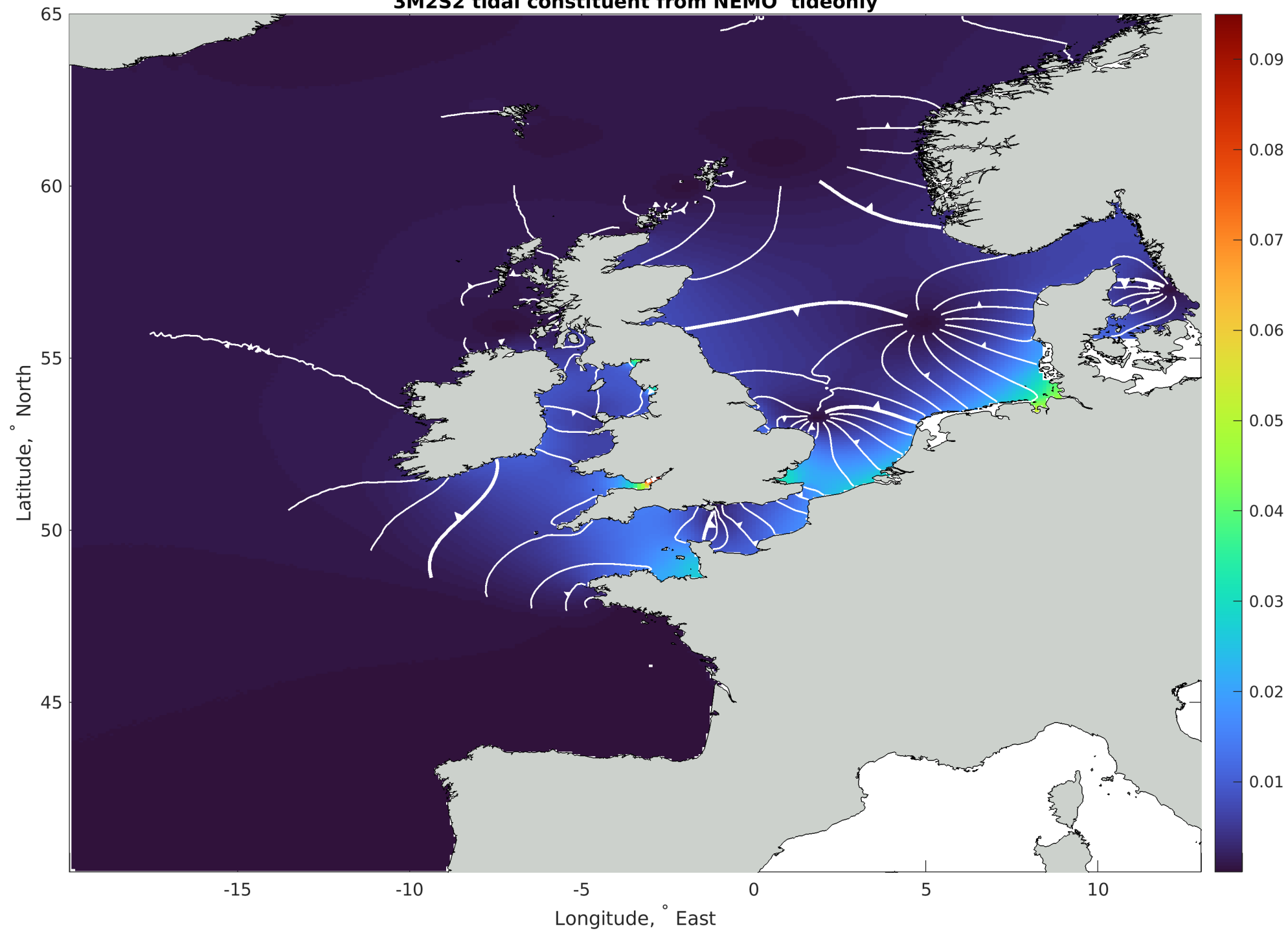
2MN2S2 tidal constituent from NEMO tideonly



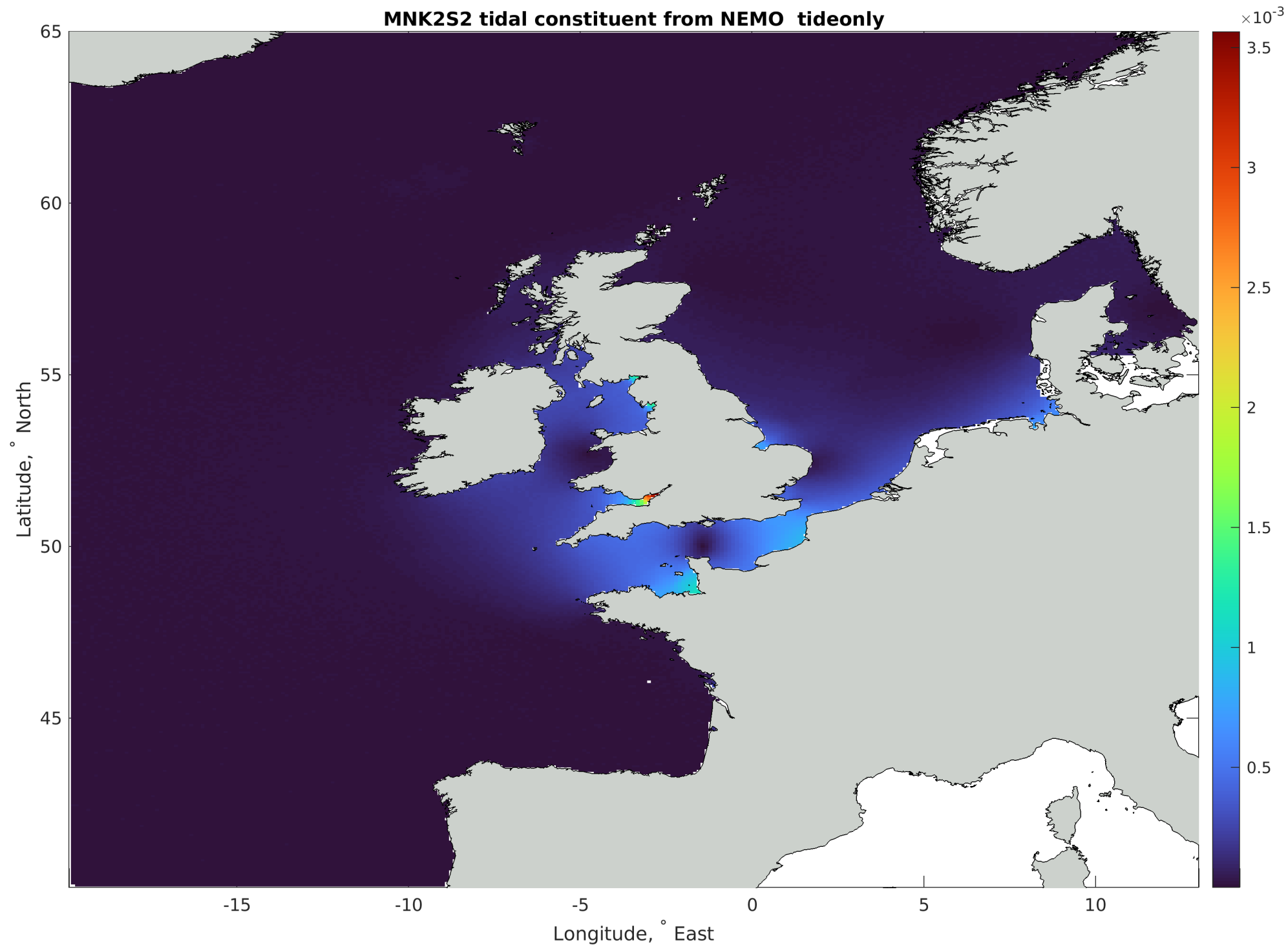
3MSK2 tidal constituent from NEMO tideonly



3M2S2 tidal constituent from NEMO tideonly

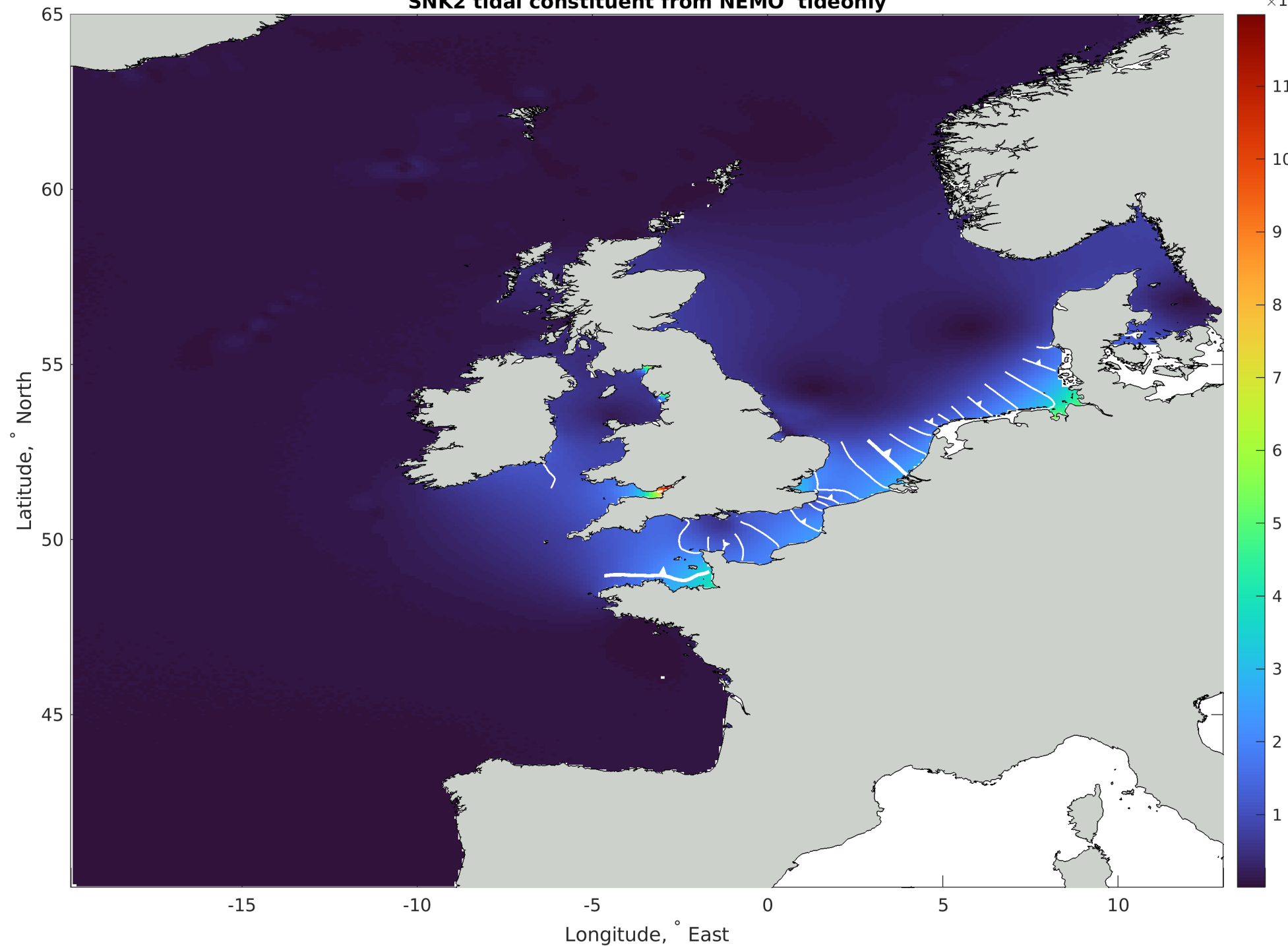


**MNK2S2 tidal constituent from NEMO tideonly**

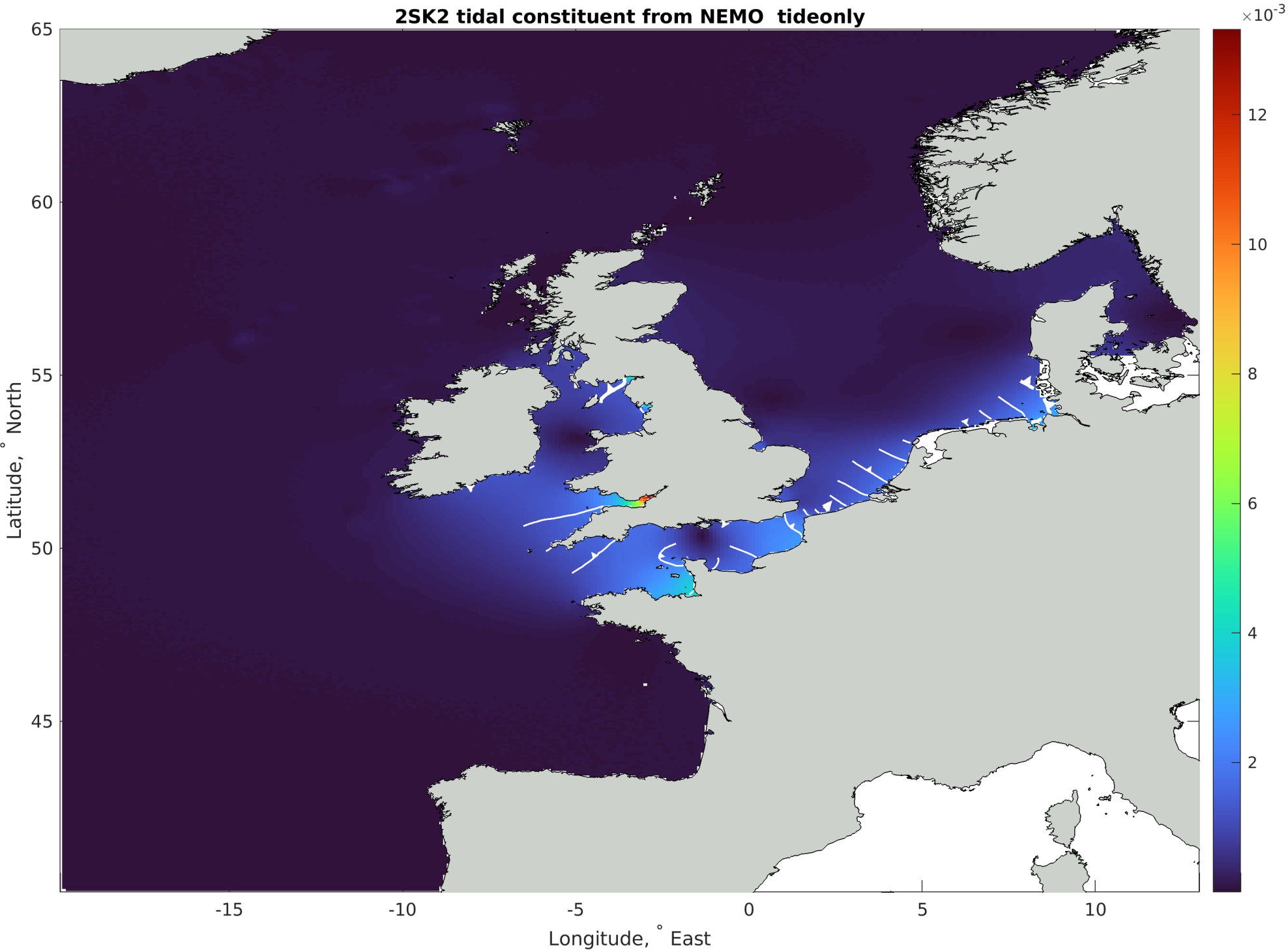


SNK2 tidal constituent from NEMO tideonly

$\times 10^{-3}$

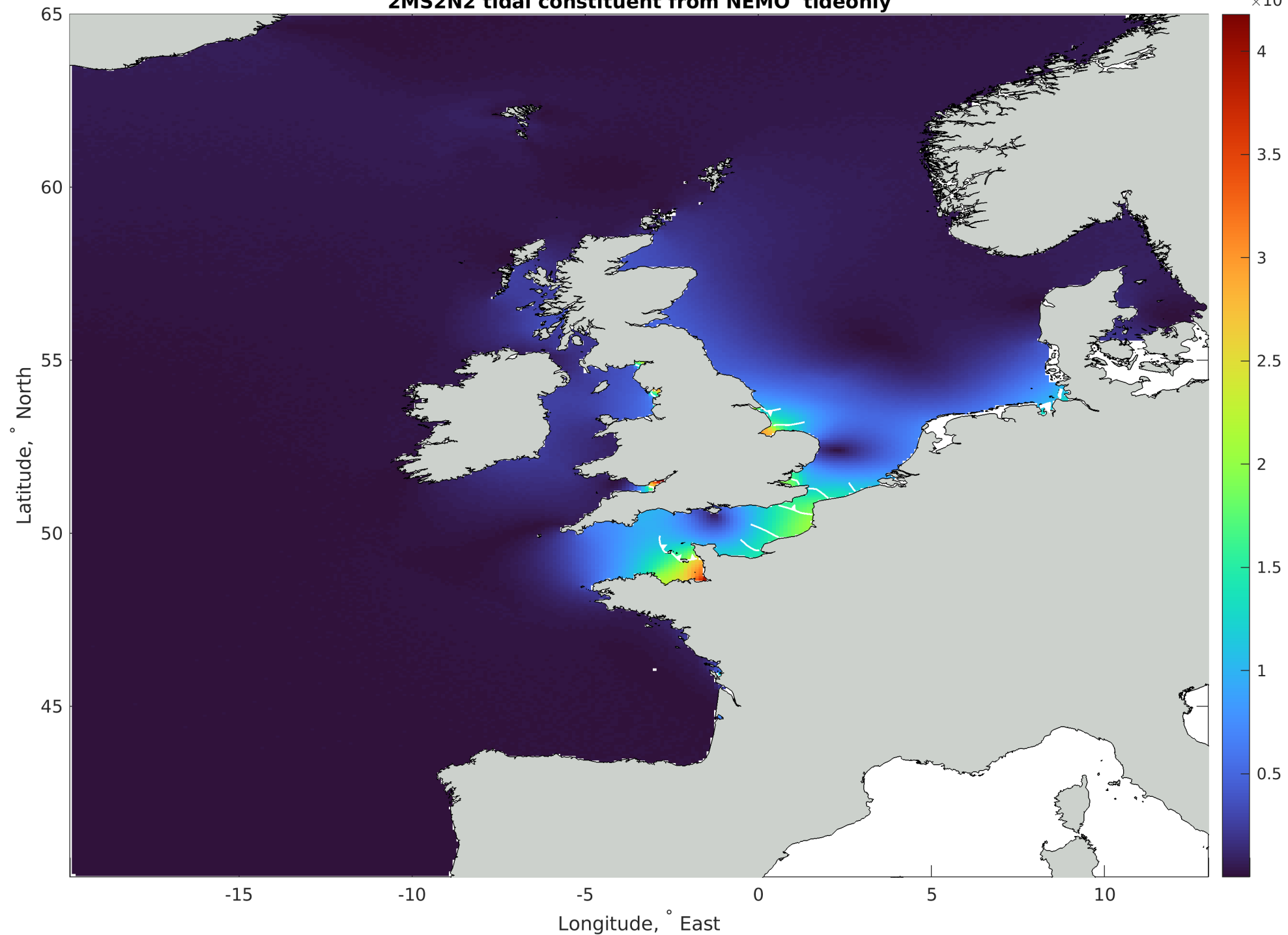


2SK2 tidal constituent from NEMO tideonly

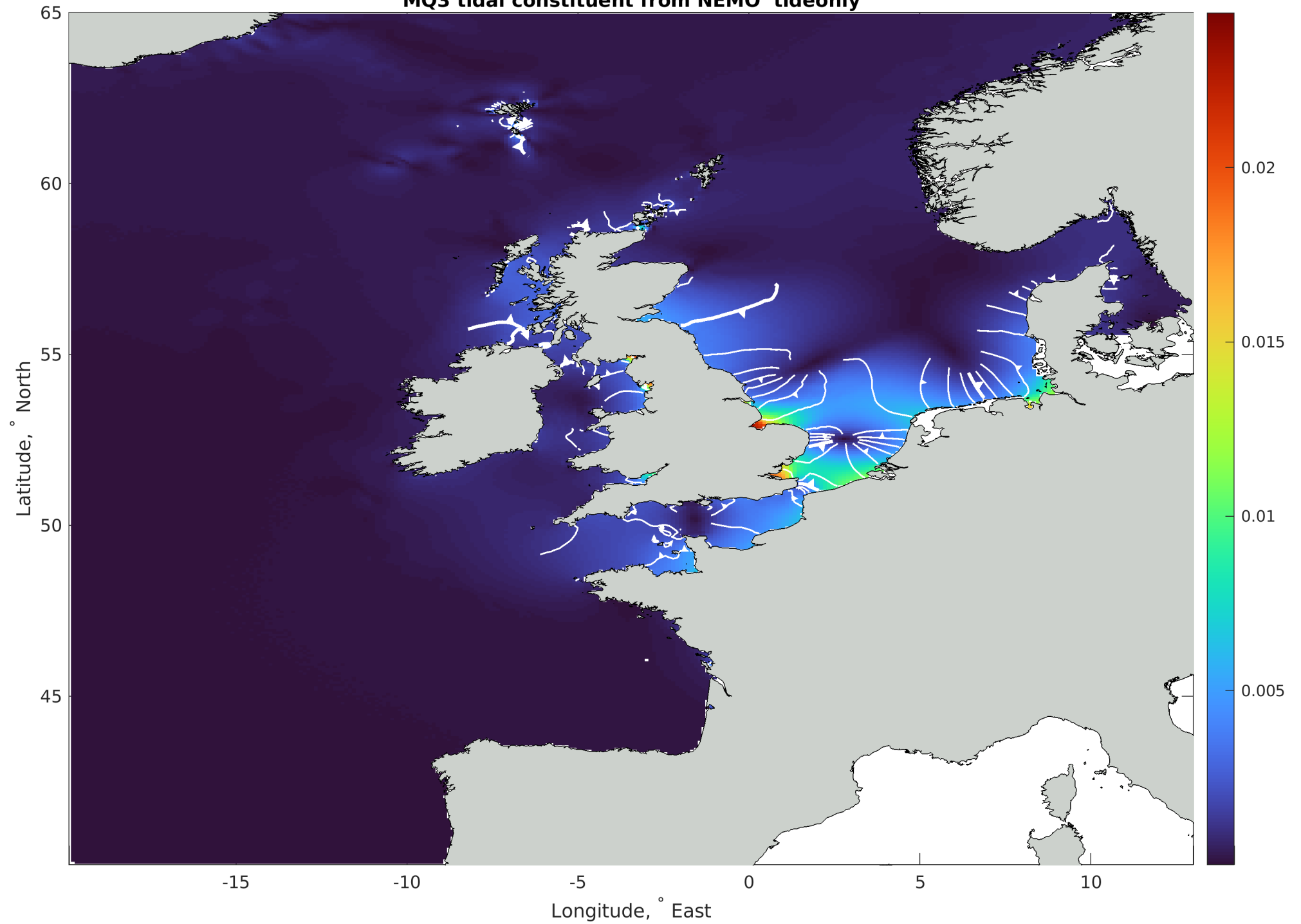


2MS2N2 tidal constituent from NEMO tideonly

$\times 10^{-3}$



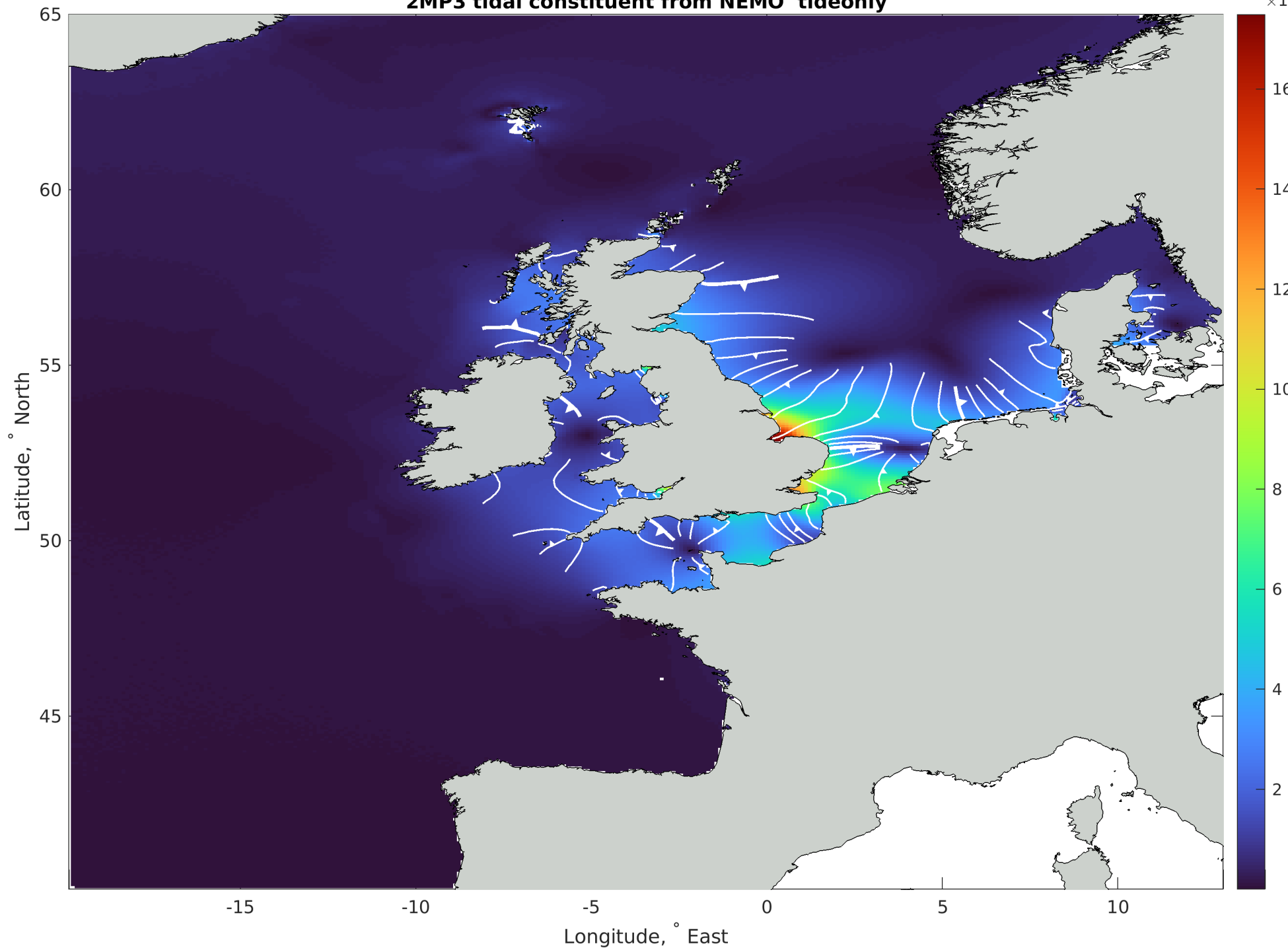
MQ3 tidal constituent from NEMO tideonly





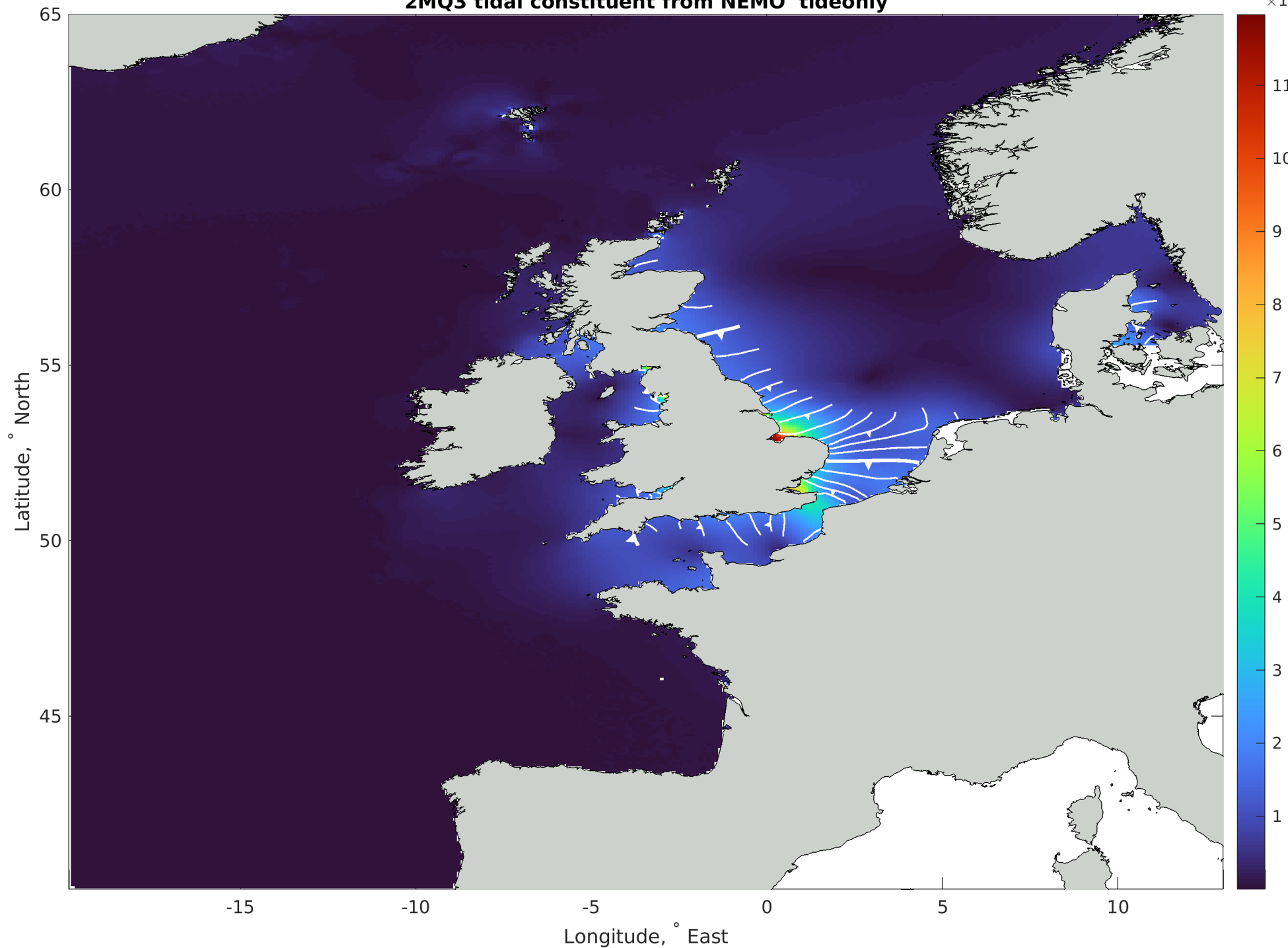
2MP3 tidal constituent from NEMO tideonly

$\times 10^{-3}$

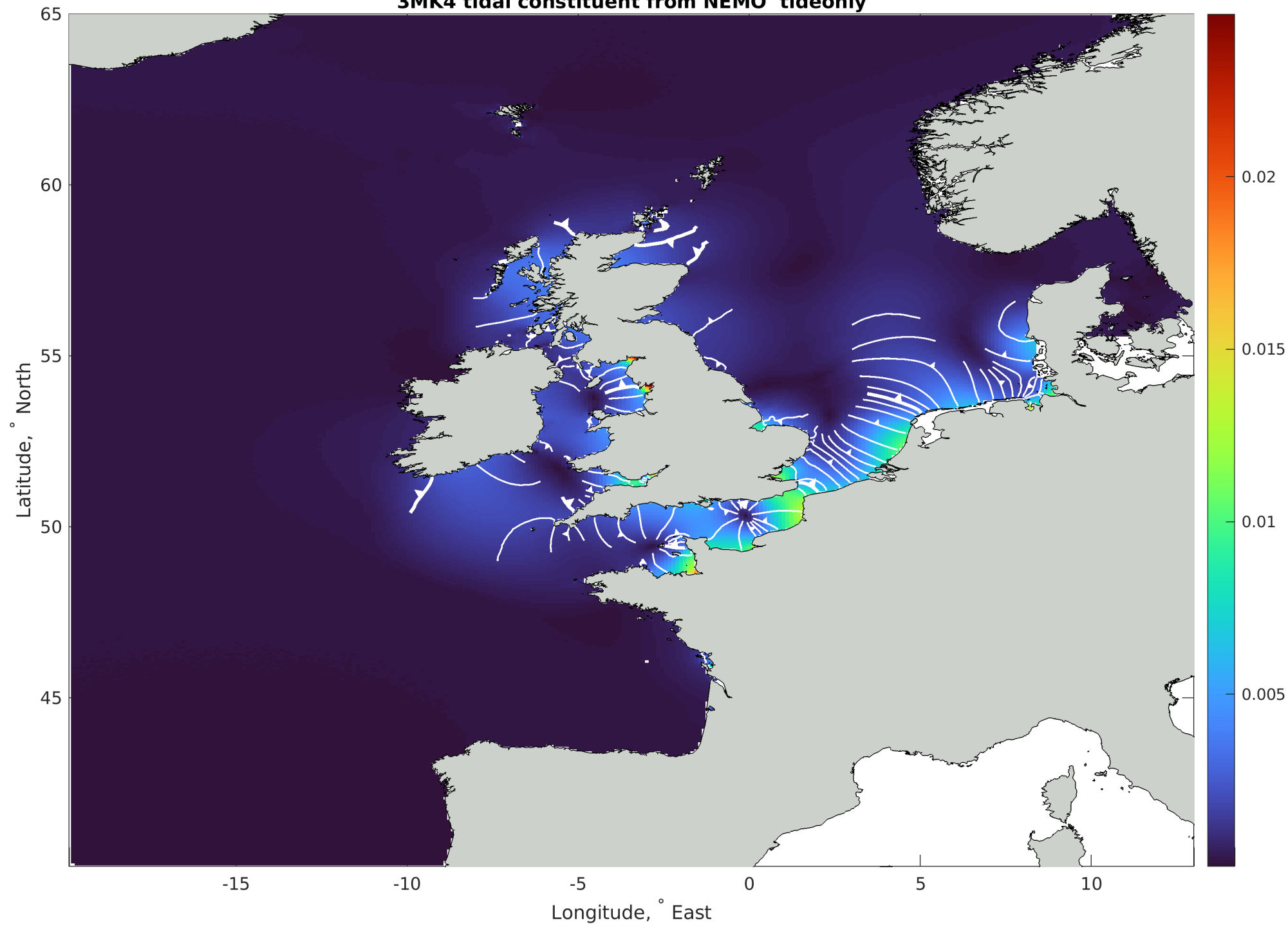


2MQ3 tidal constituent from NEMO tideonly

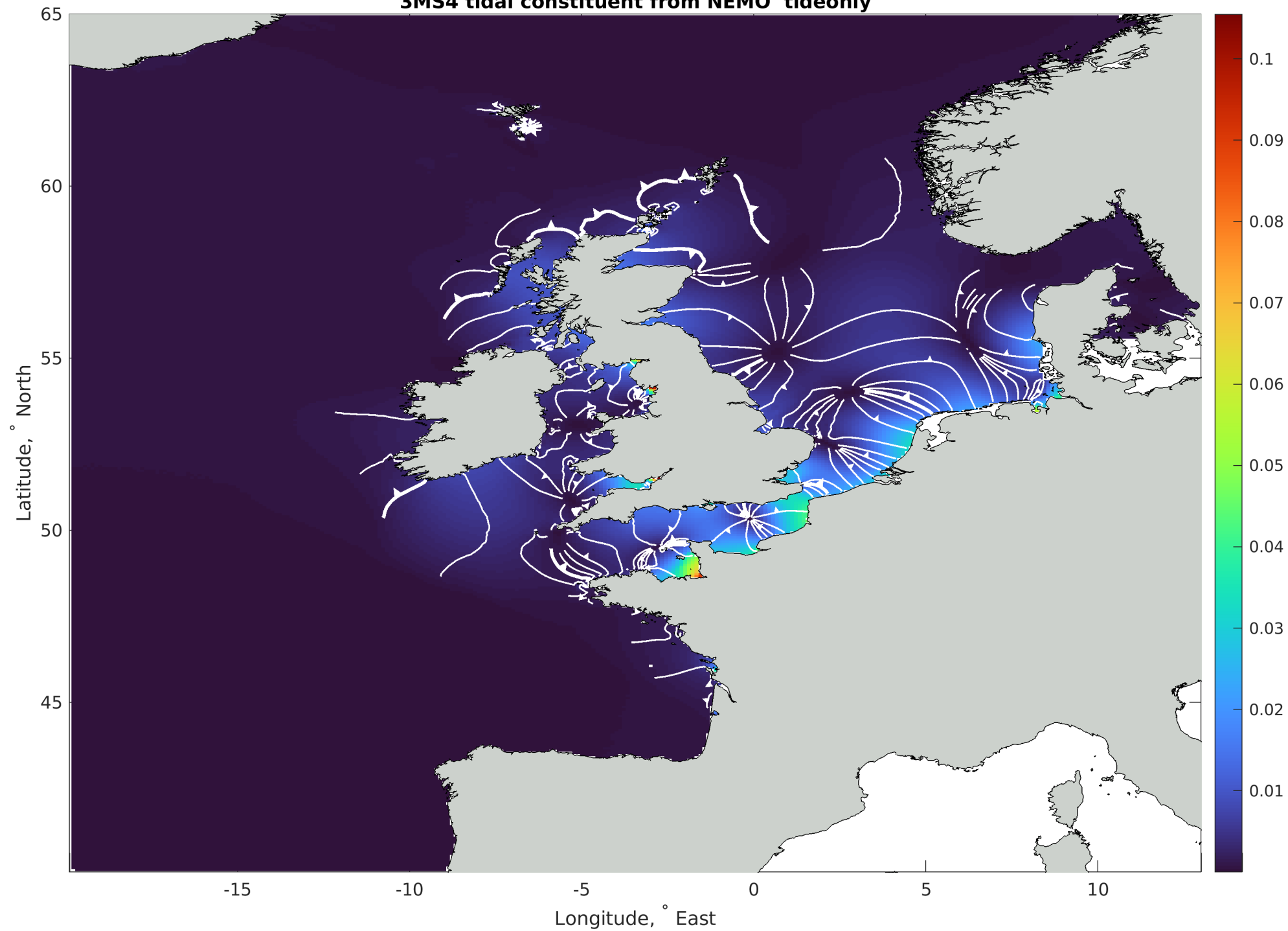
$\times 10^{-3}$



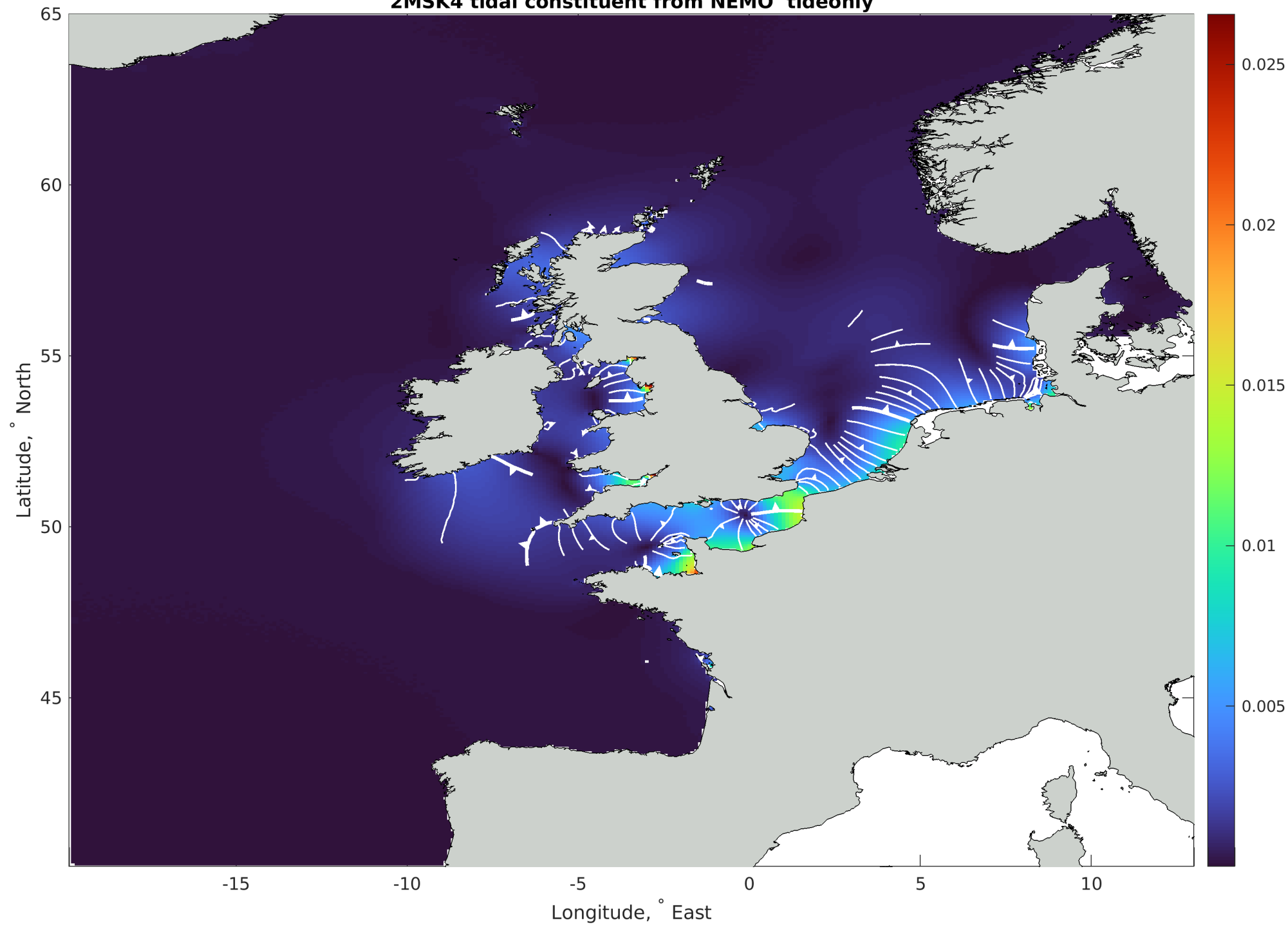
3MK4 tidal constituent from NEMO tideonly



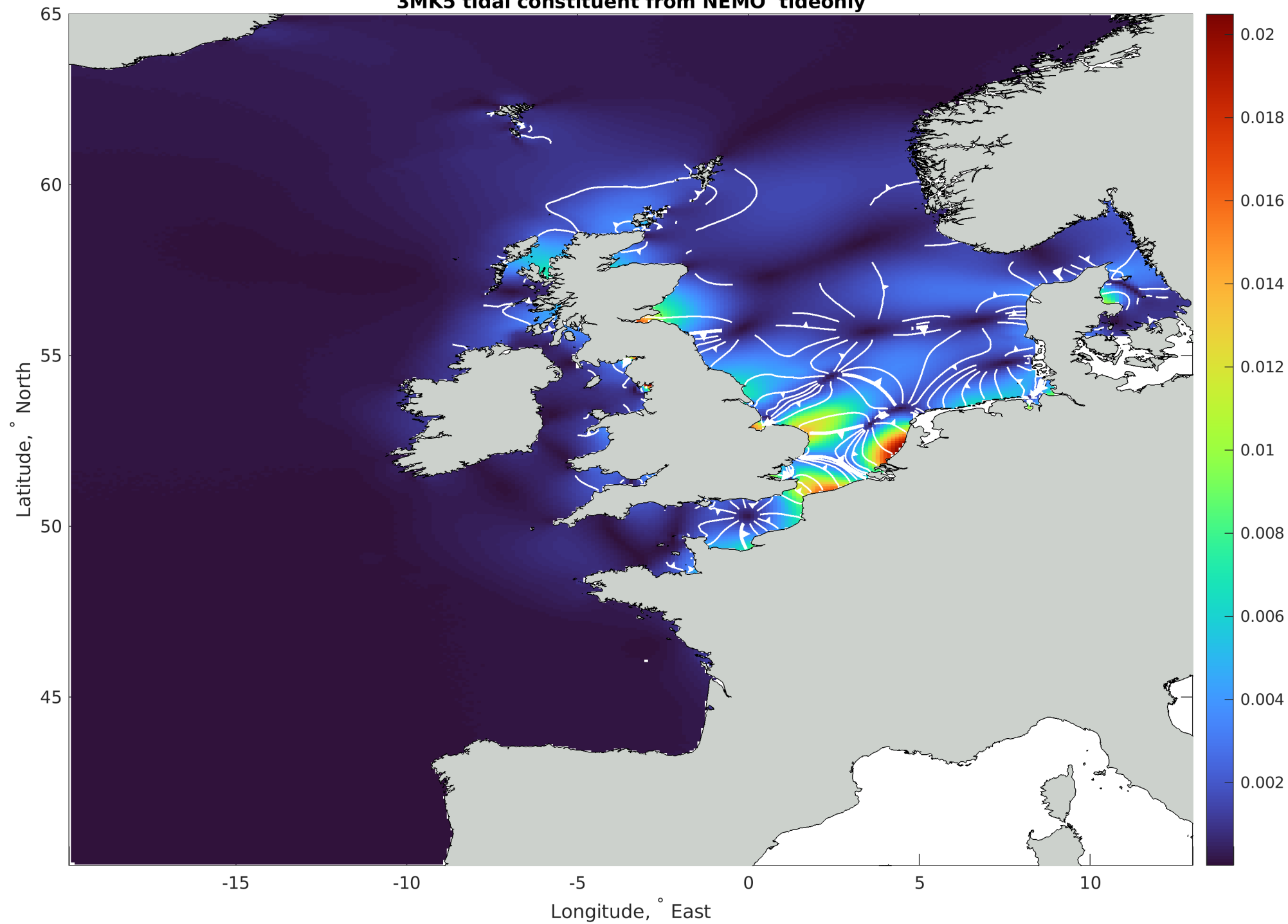
3MS4 tidal constituent from NEMO tideonly



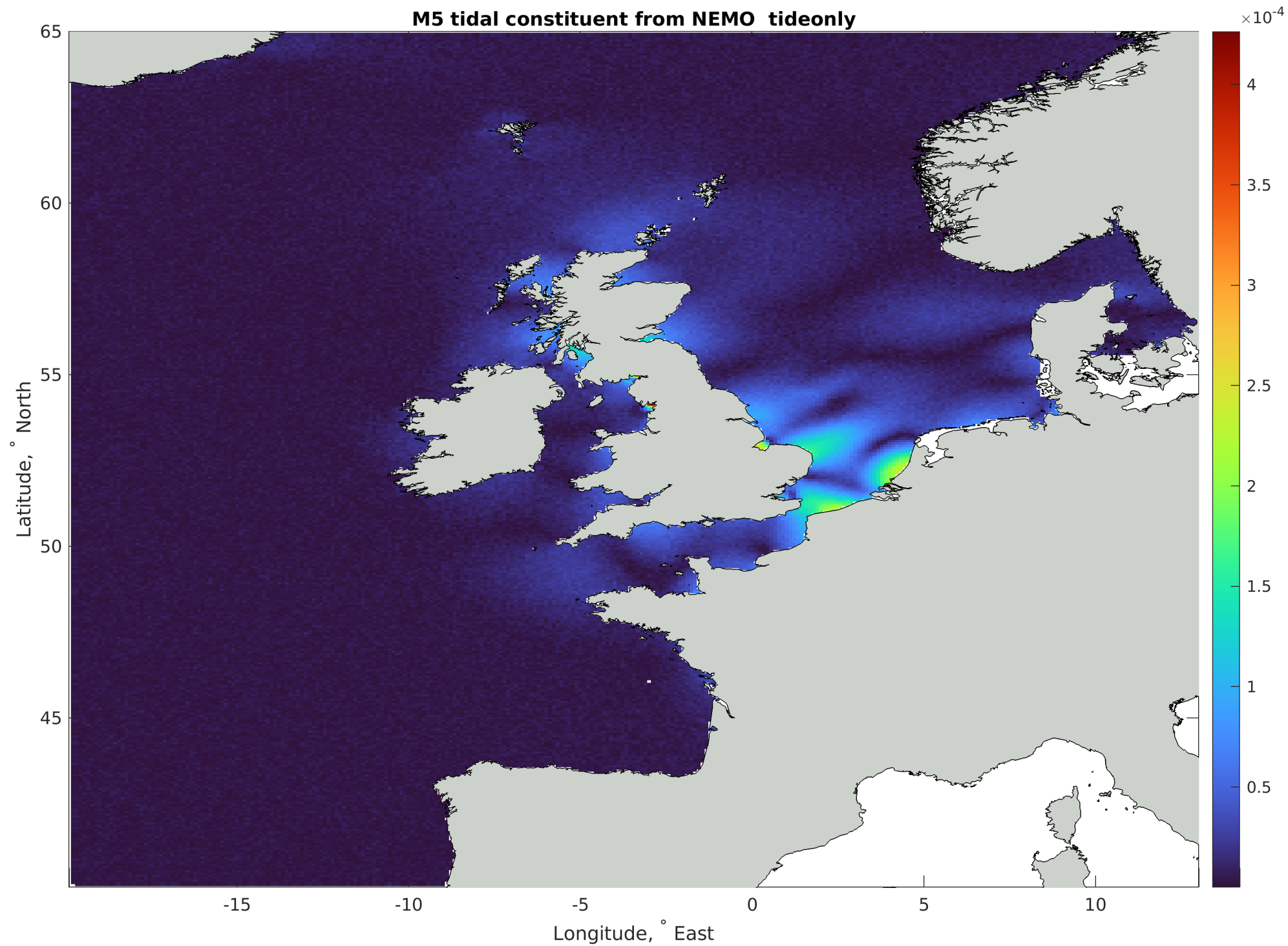
2MSK4 tidal constituent from NEMO tideonly



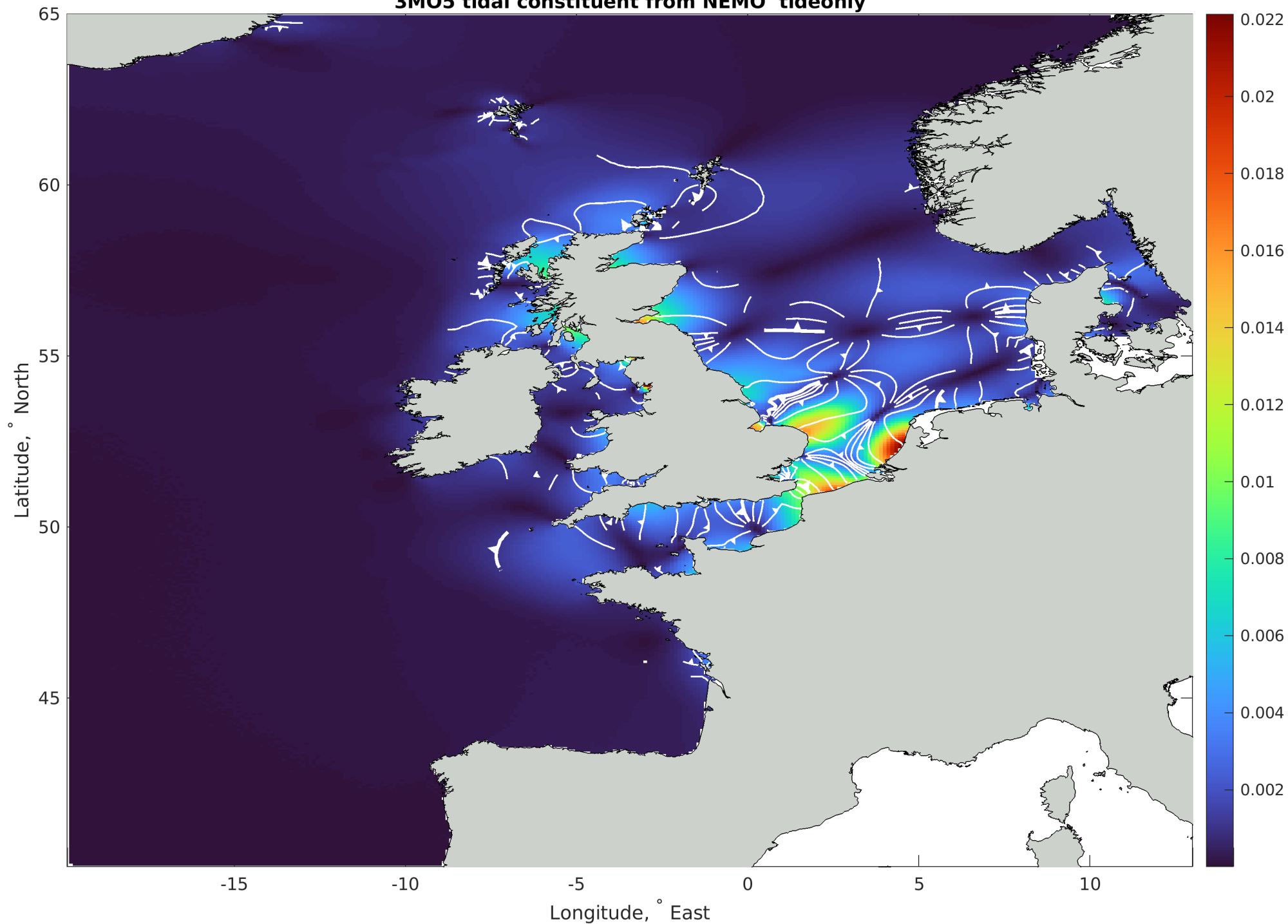
3MK5 tidal constituent from NEMO tideonly



M5 tidal constituent from NEMO tideonly

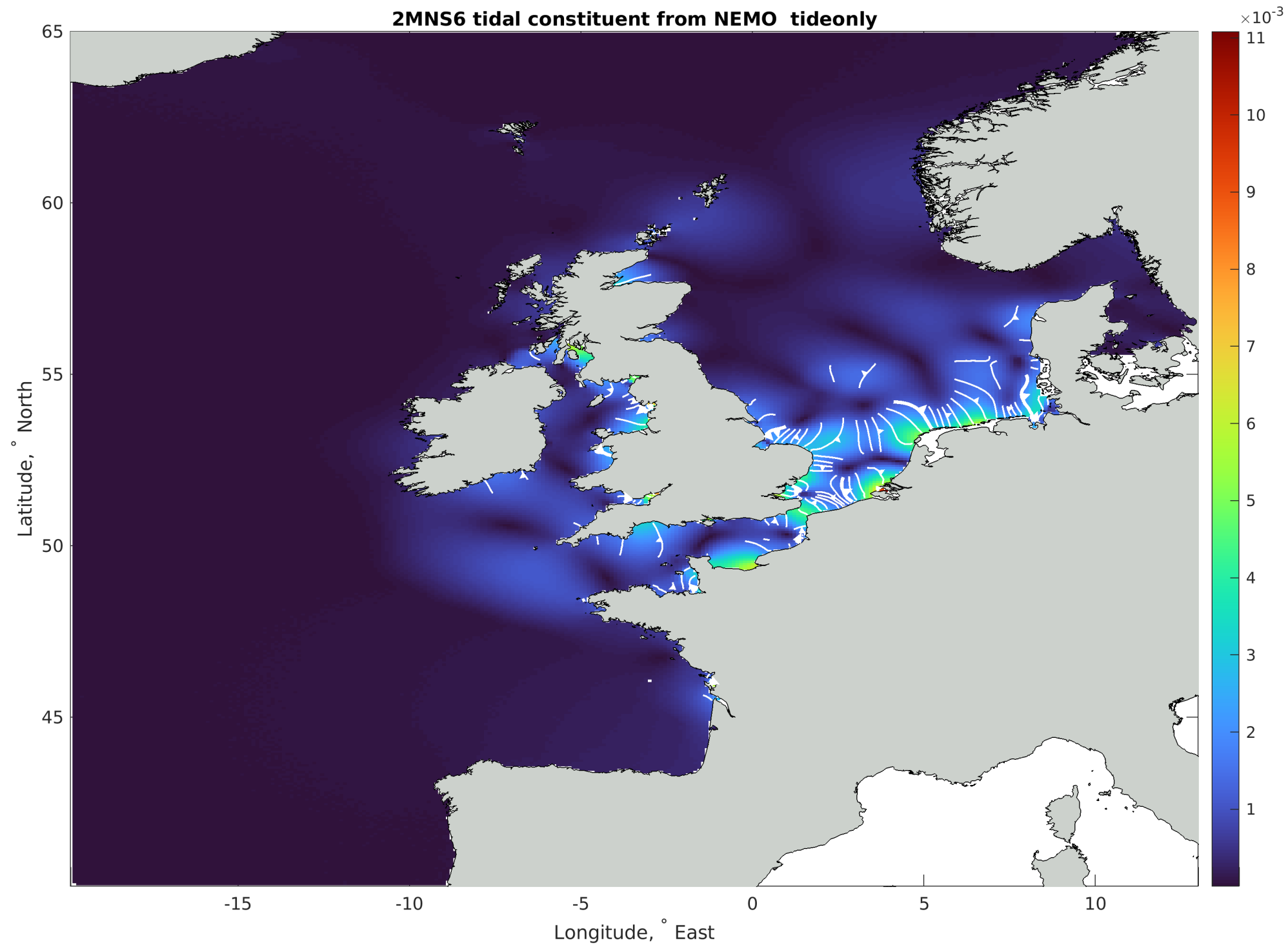


3MO5 tidal constituent from NEMO tideonly

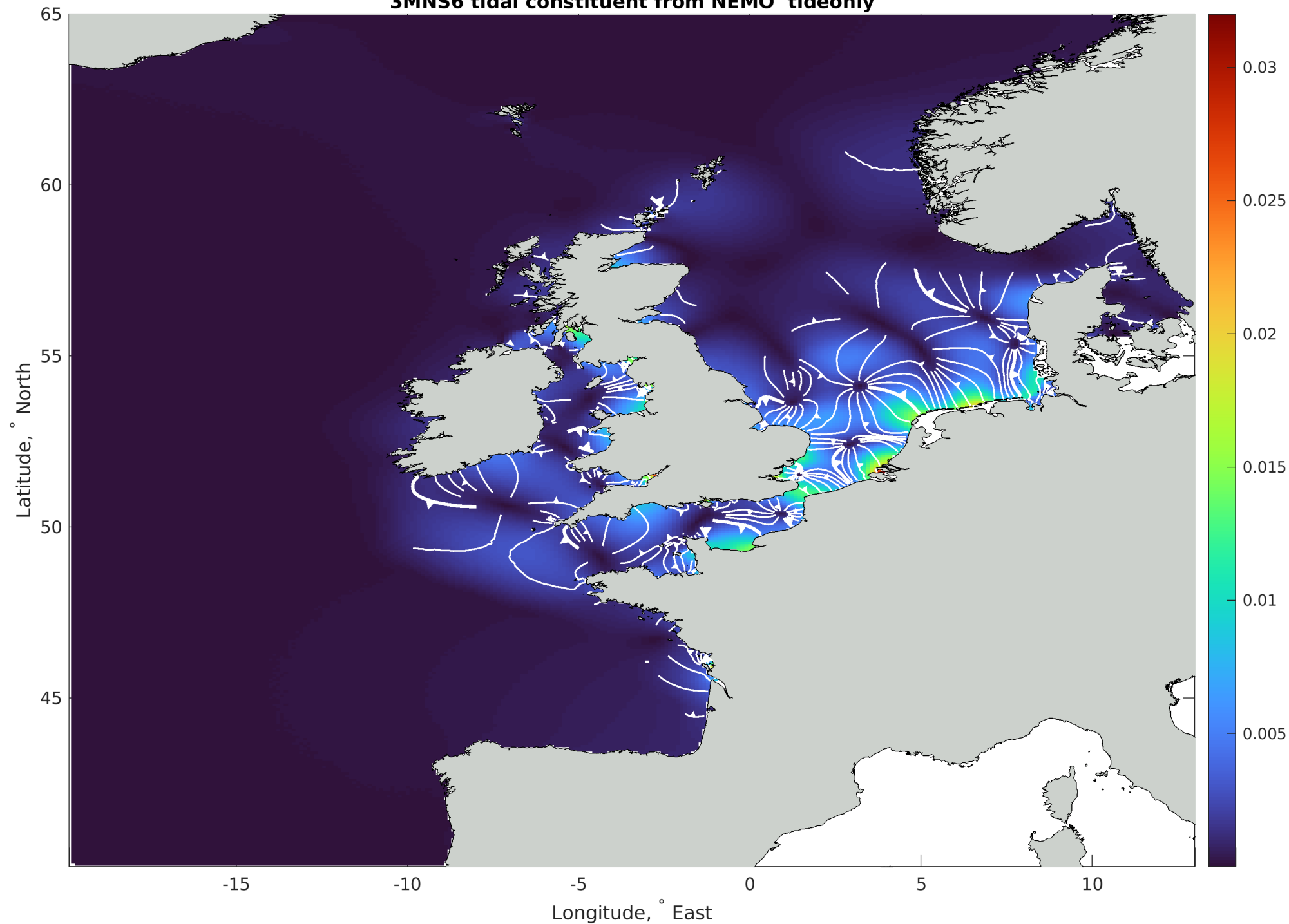




2MNS6 tidal constituent from NEMO tideonly

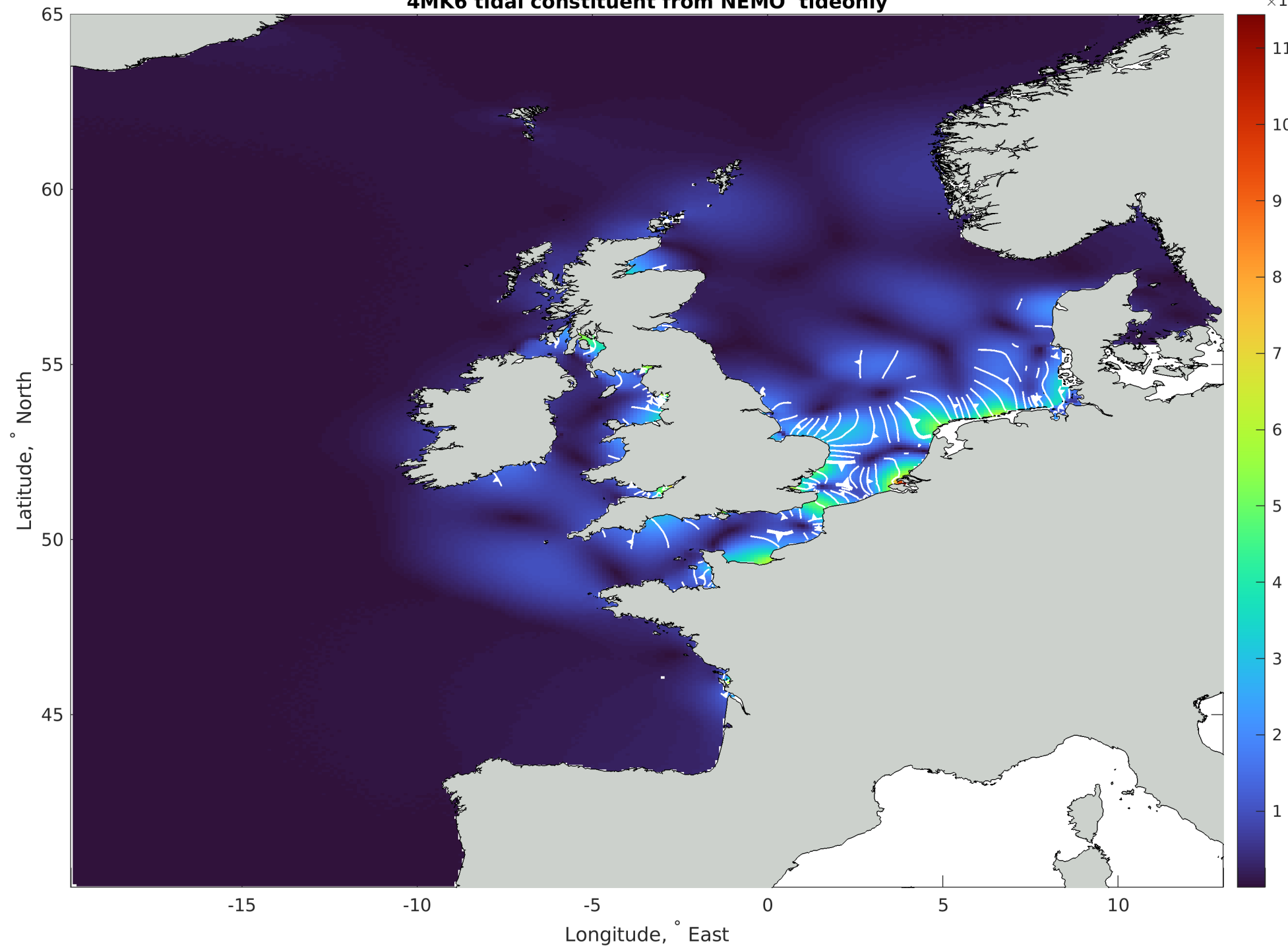


3MNS6 tidal constituent from NEMO tideonly

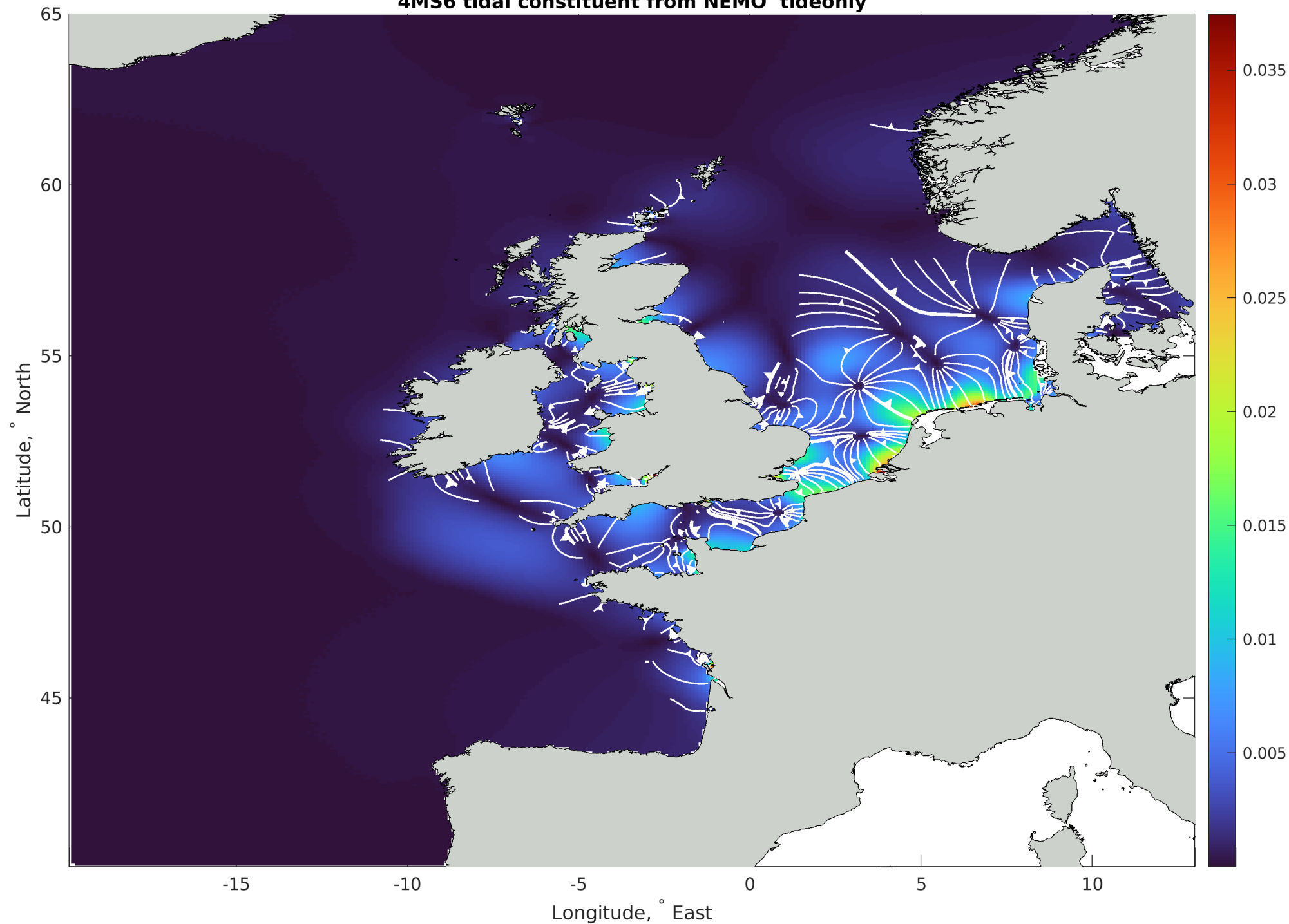


4MK6 tidal constituent from NEMO tideonly

$\times 10^{-3}$

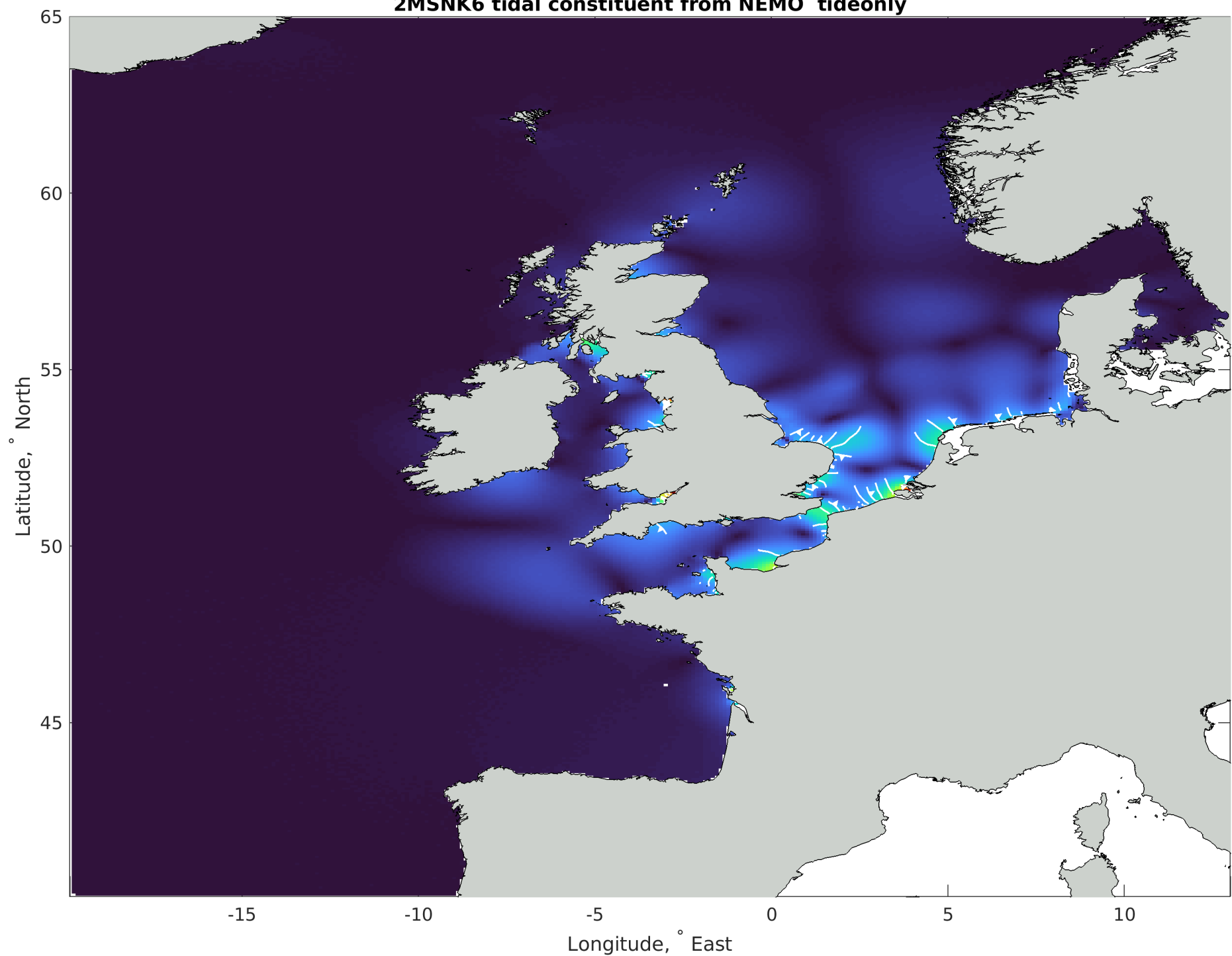


4MS6 tidal constituent from NEMO tideonly

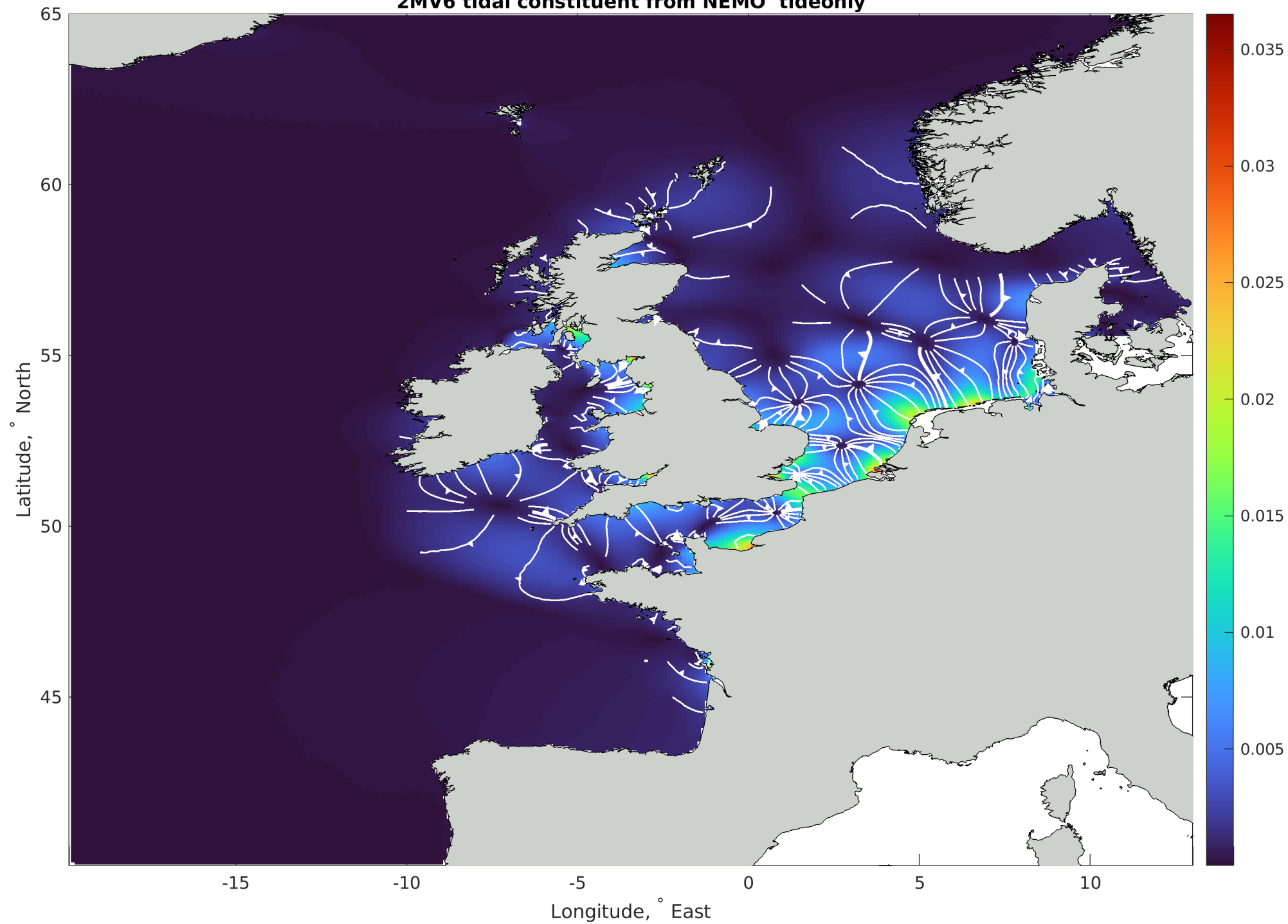


2MSNK6 tidal constituent from NEMO tideonly

$\times 10^{-3}$

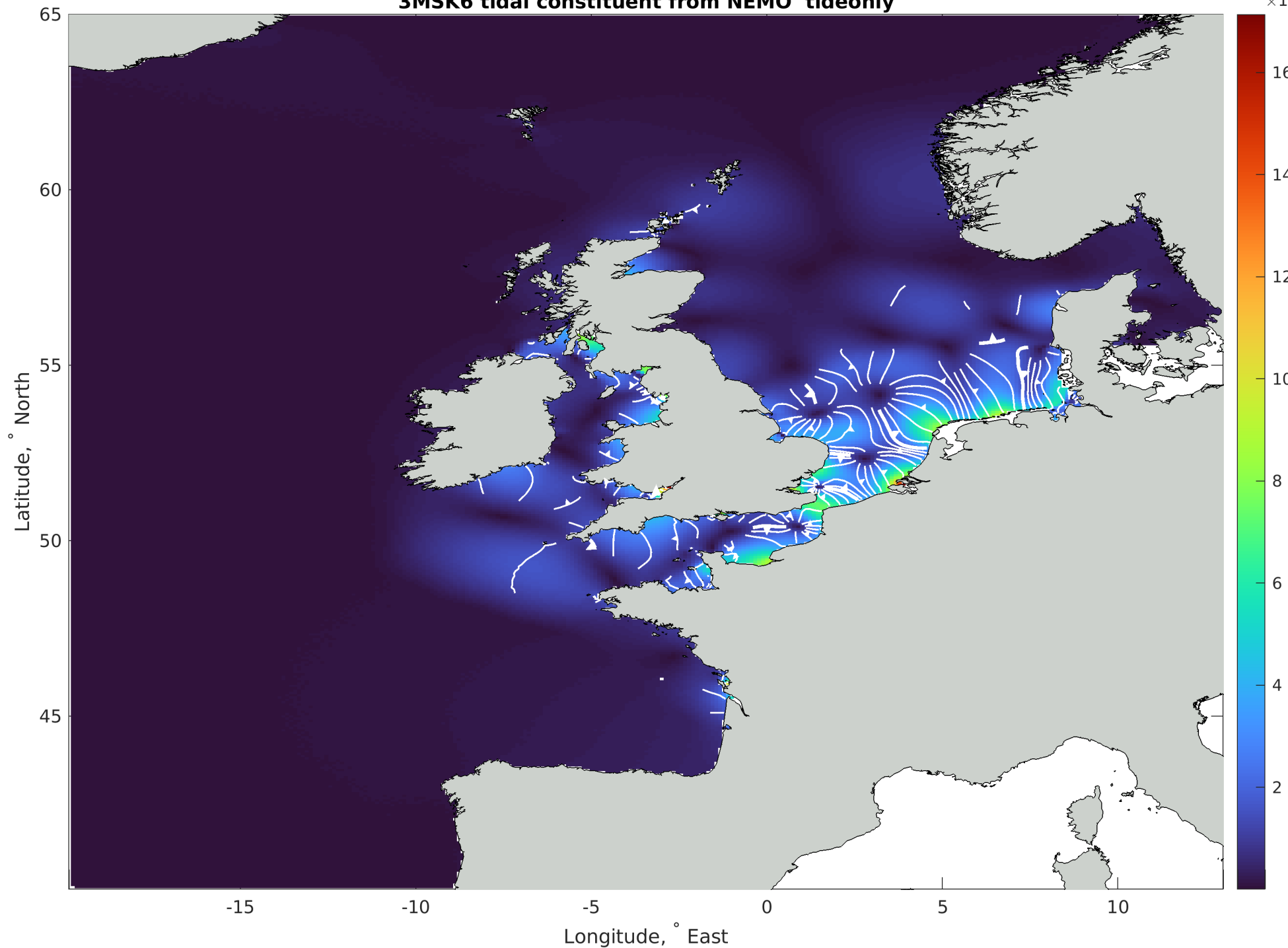


2MV6 tidal constituent from NEMO tideonly

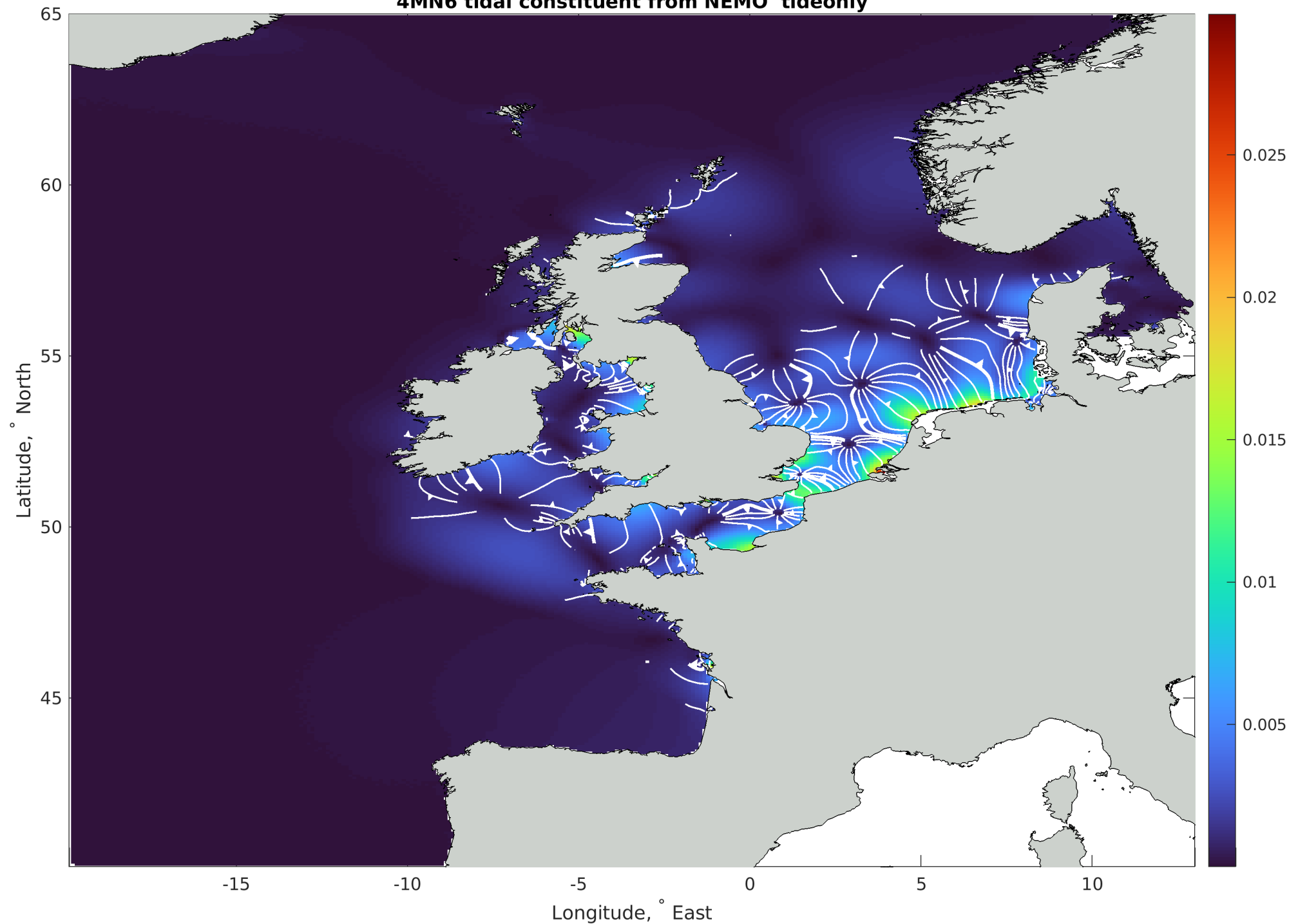


3MSK6 tidal constituent from NEMO tideonly

$\times 10^{-3}$

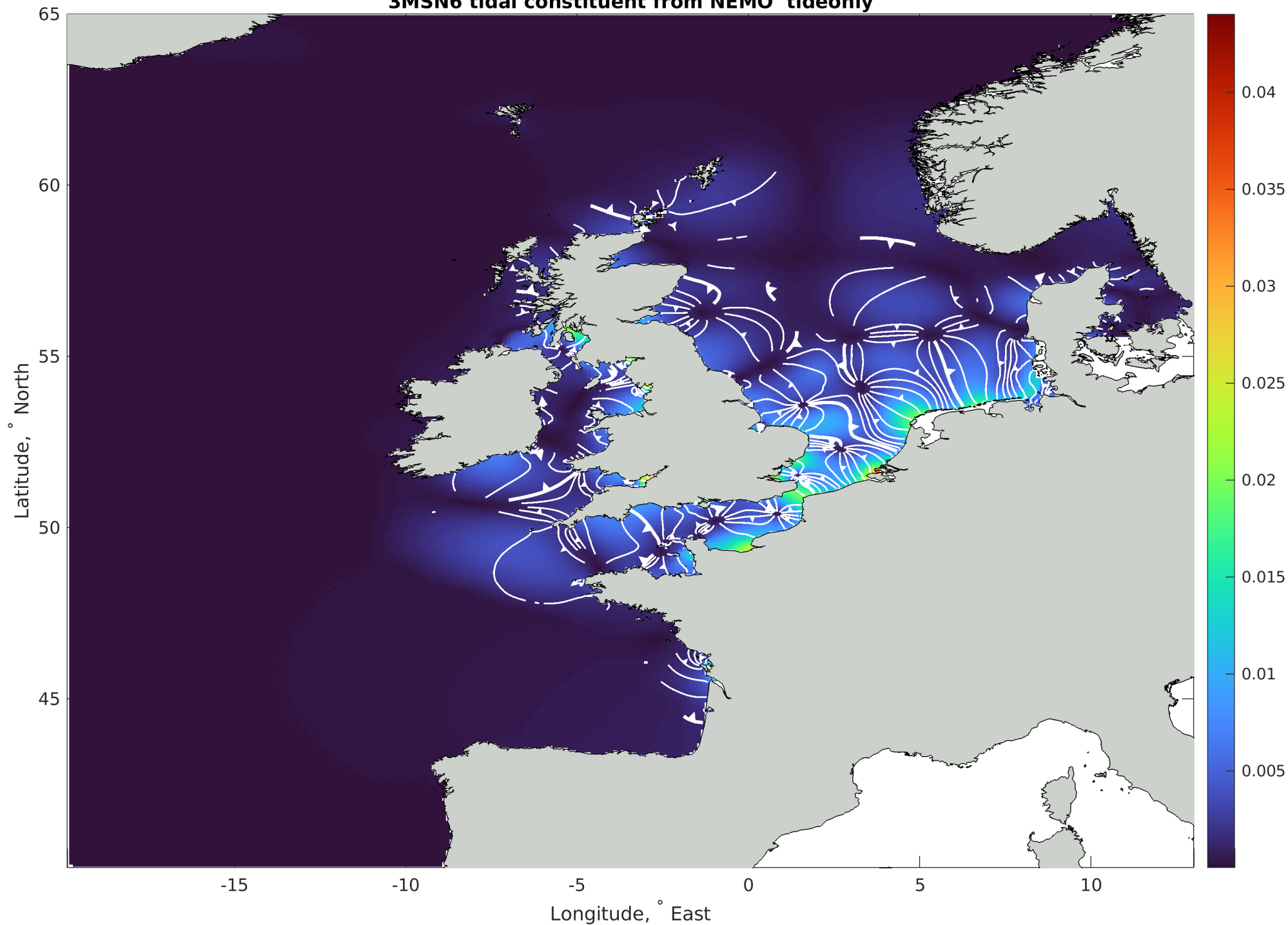


4MN6 tidal constituent from NEMO tideonly



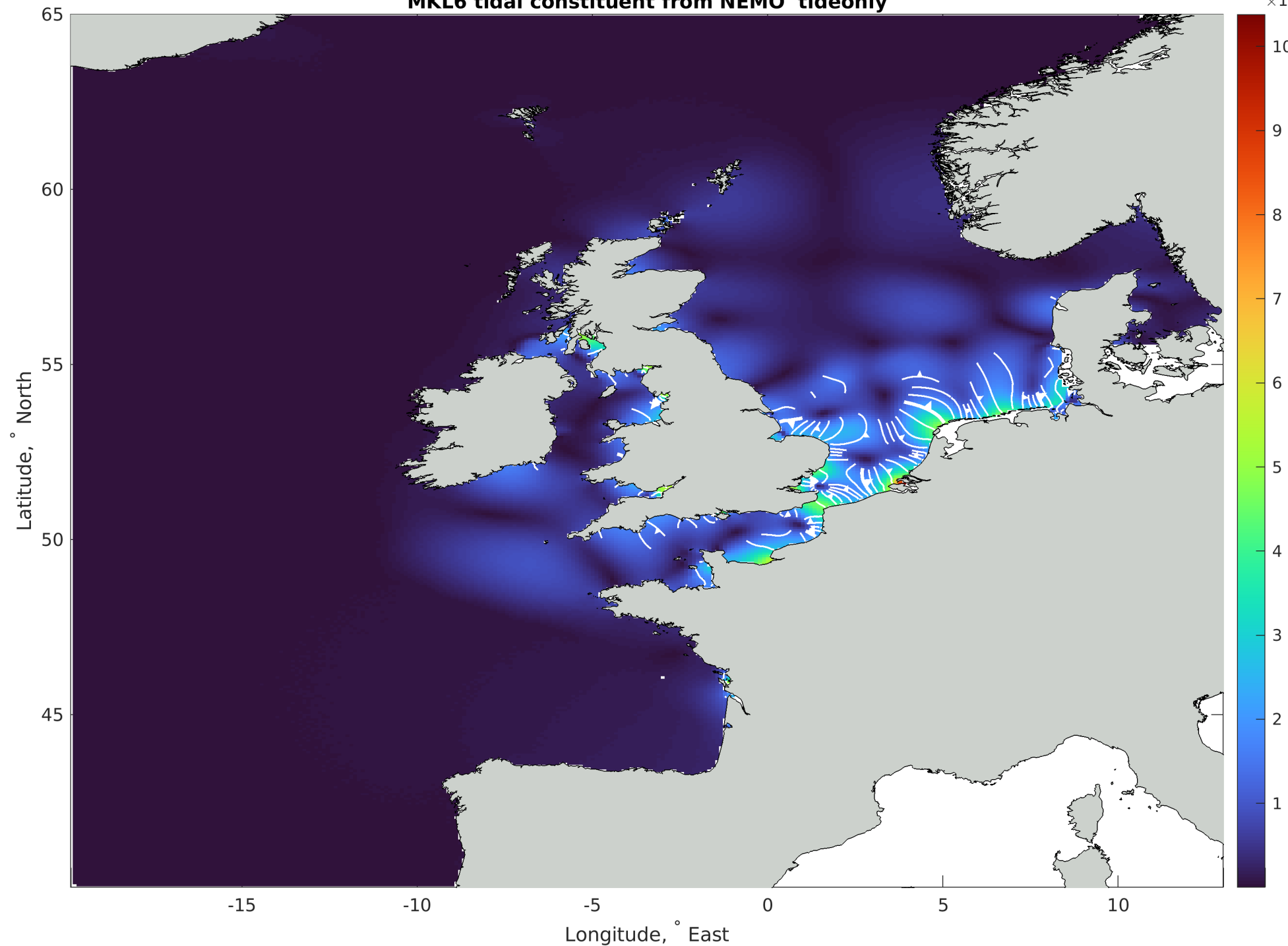


3MSN6 tidal constituent from NEMO tideonly



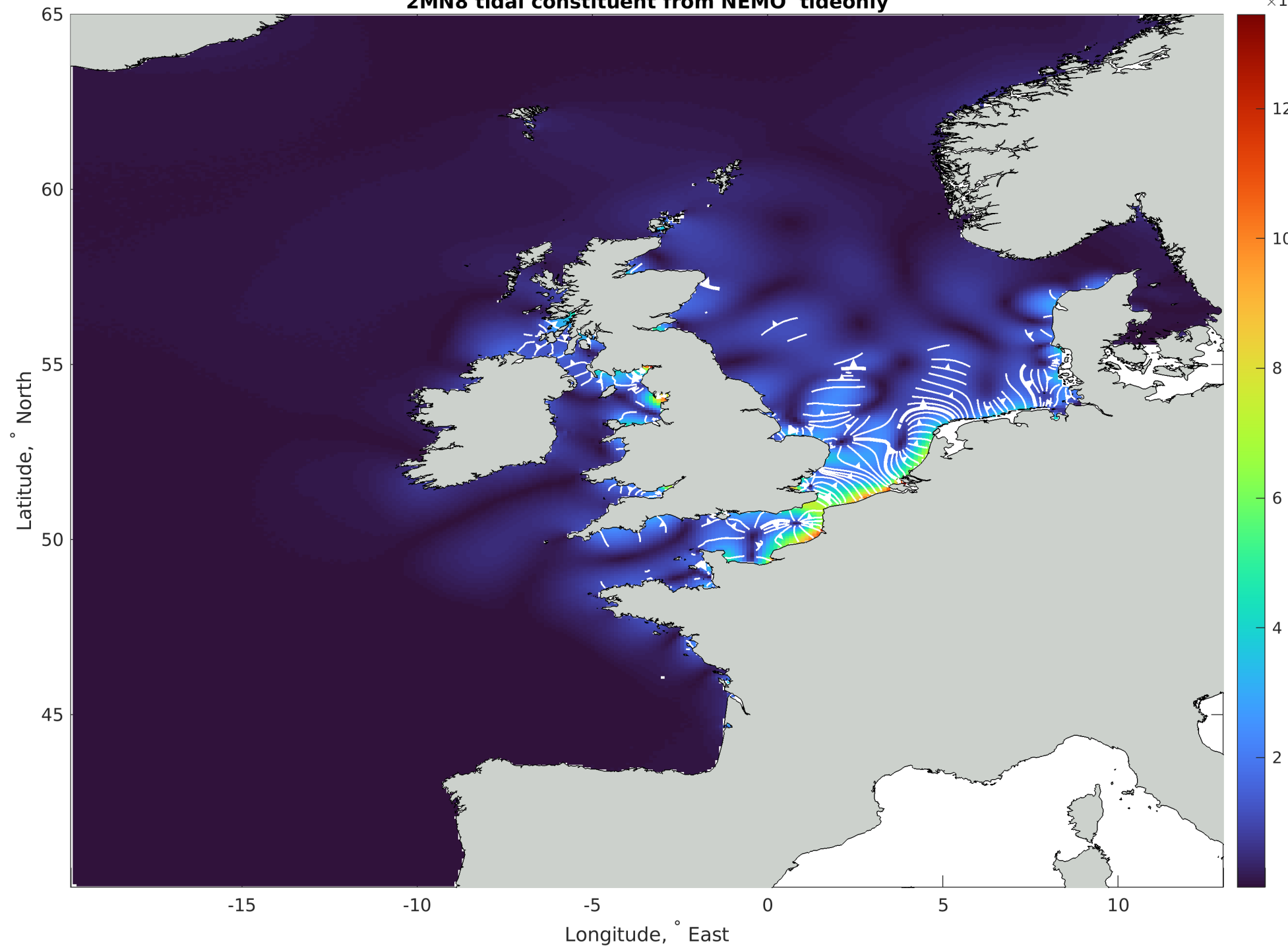
MKL6 tidal constituent from NEMO tideonly

$\times 10^{-3}$

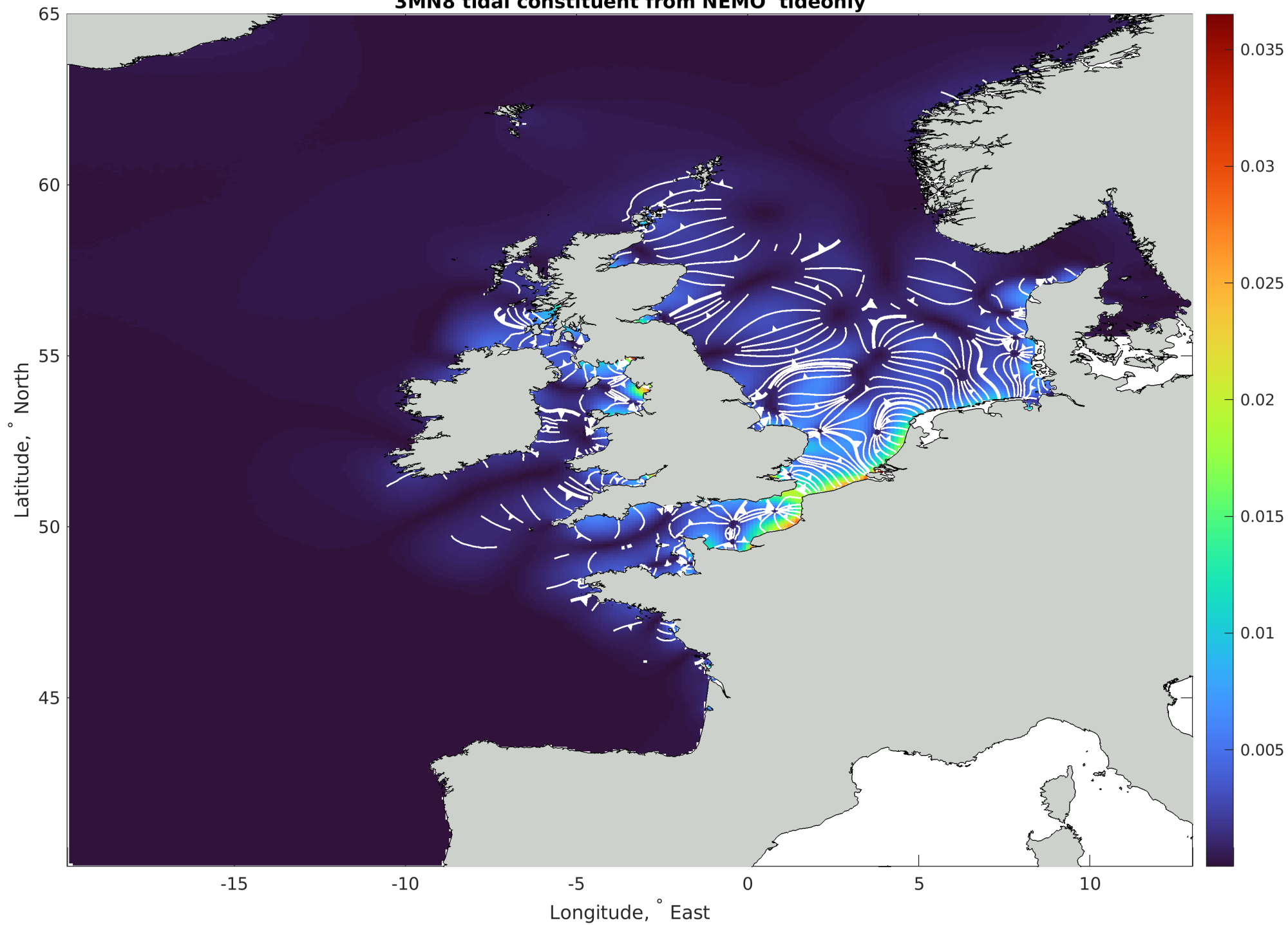


2MN8 tidal constituent from NEMO tideonly

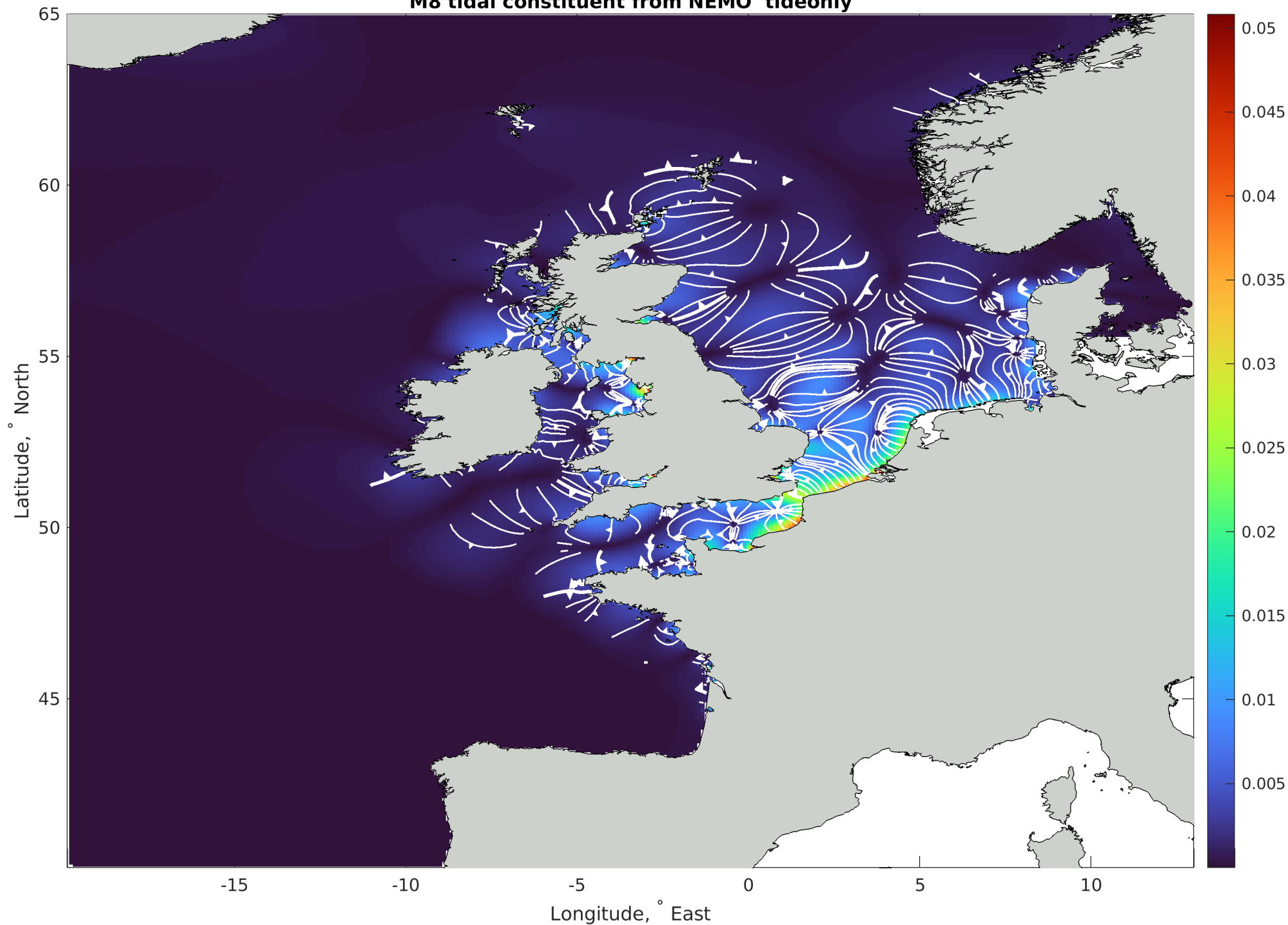
$\times 10^{-3}$



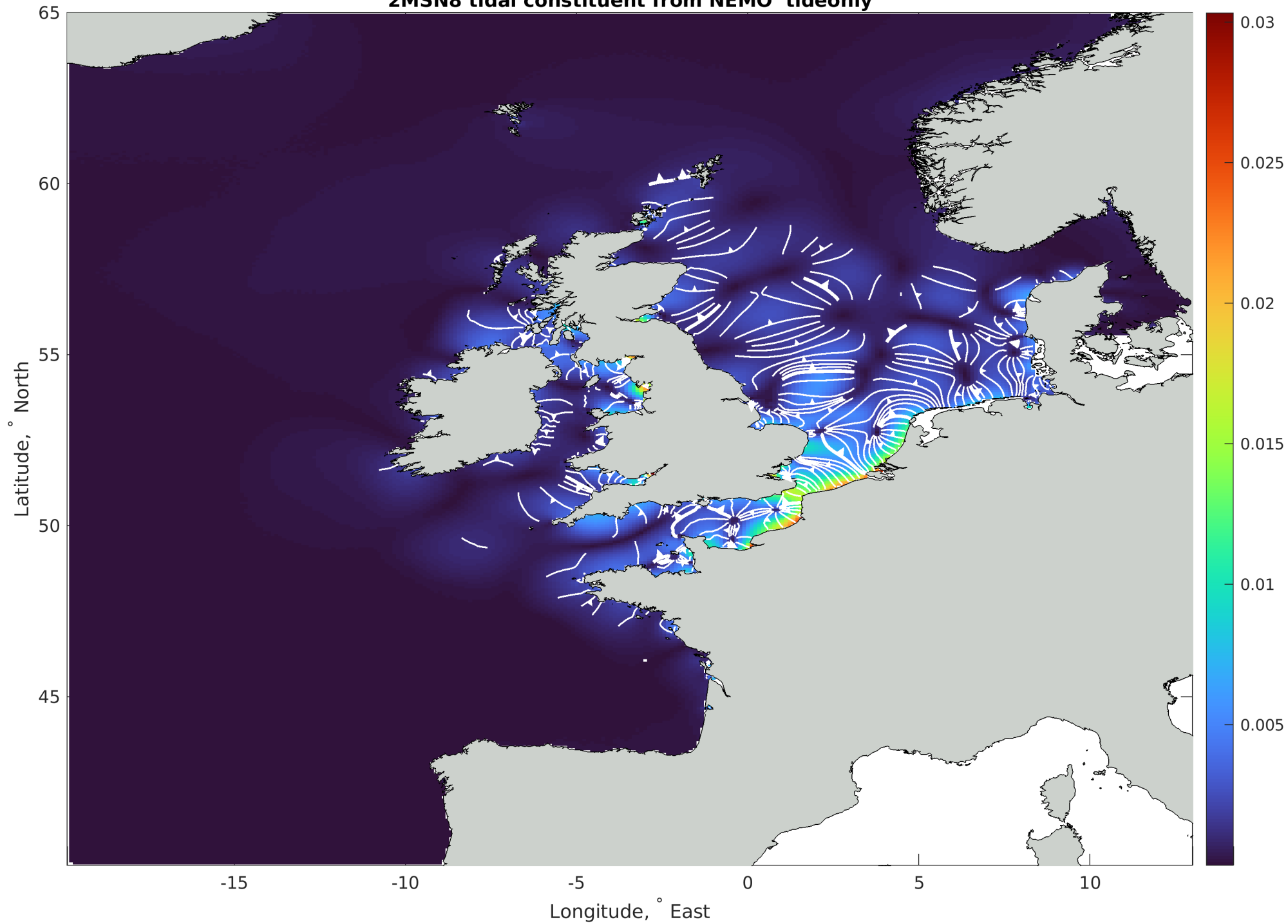
3MN8 tidal constituent from NEMO tideonly



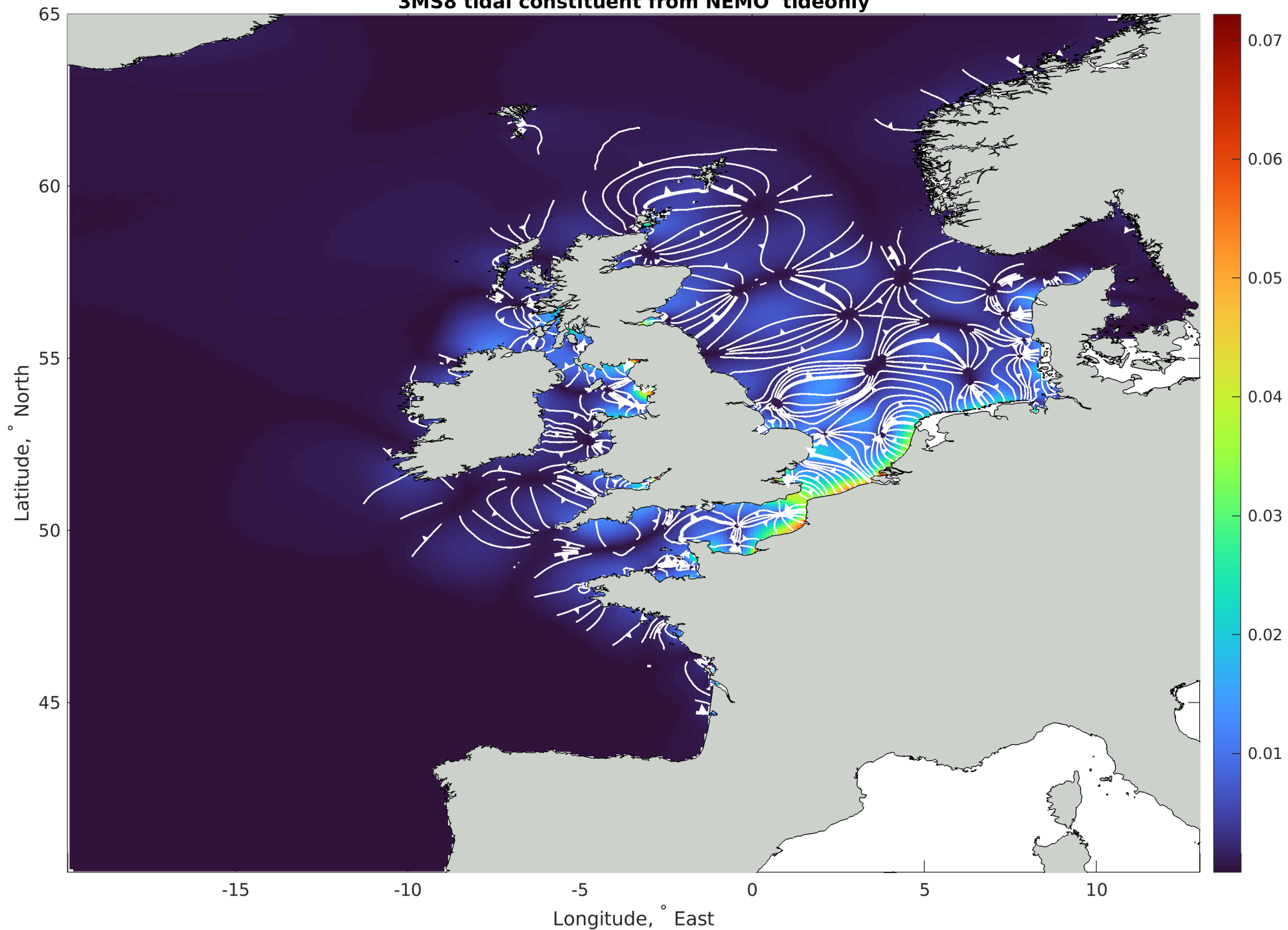
M8 tidal constituent from NEMO tideonly



2MSN8 tidal constituent from NEMO tideonly

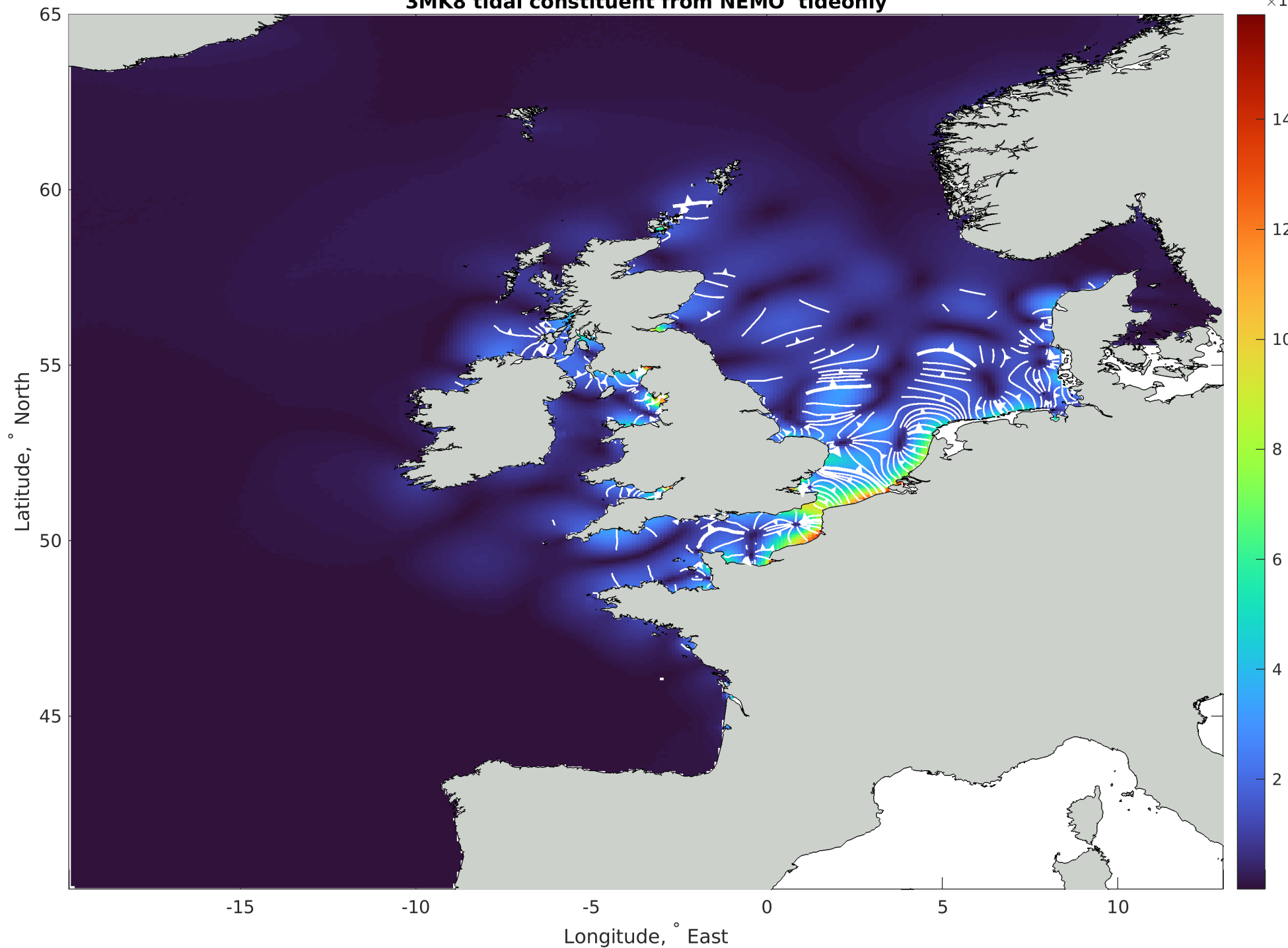


3MS8 tidal constituent from NEMO tideonly



3MK8 tidal constituent from NEMO tideonly

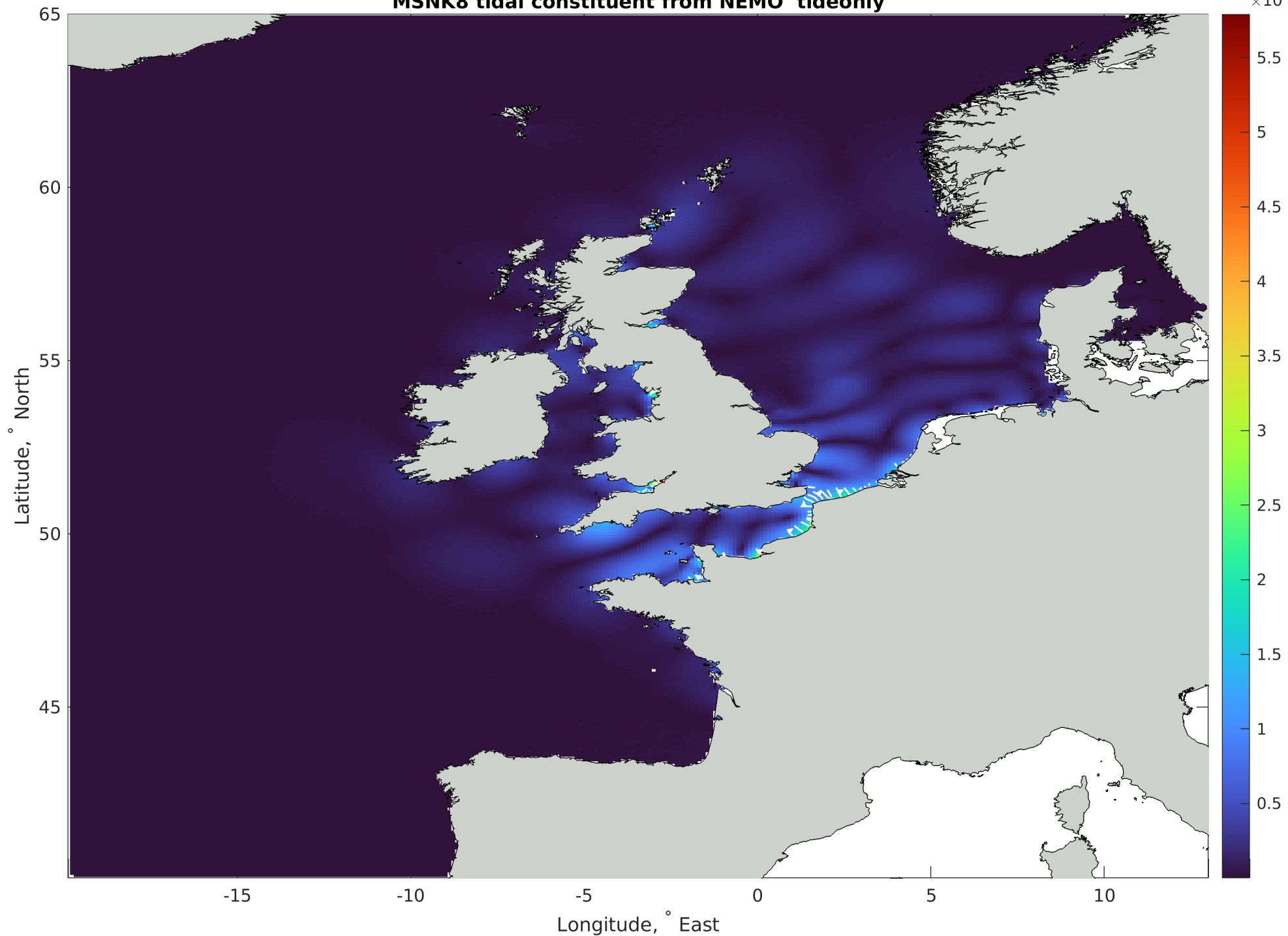
$\times 10^{-3}$



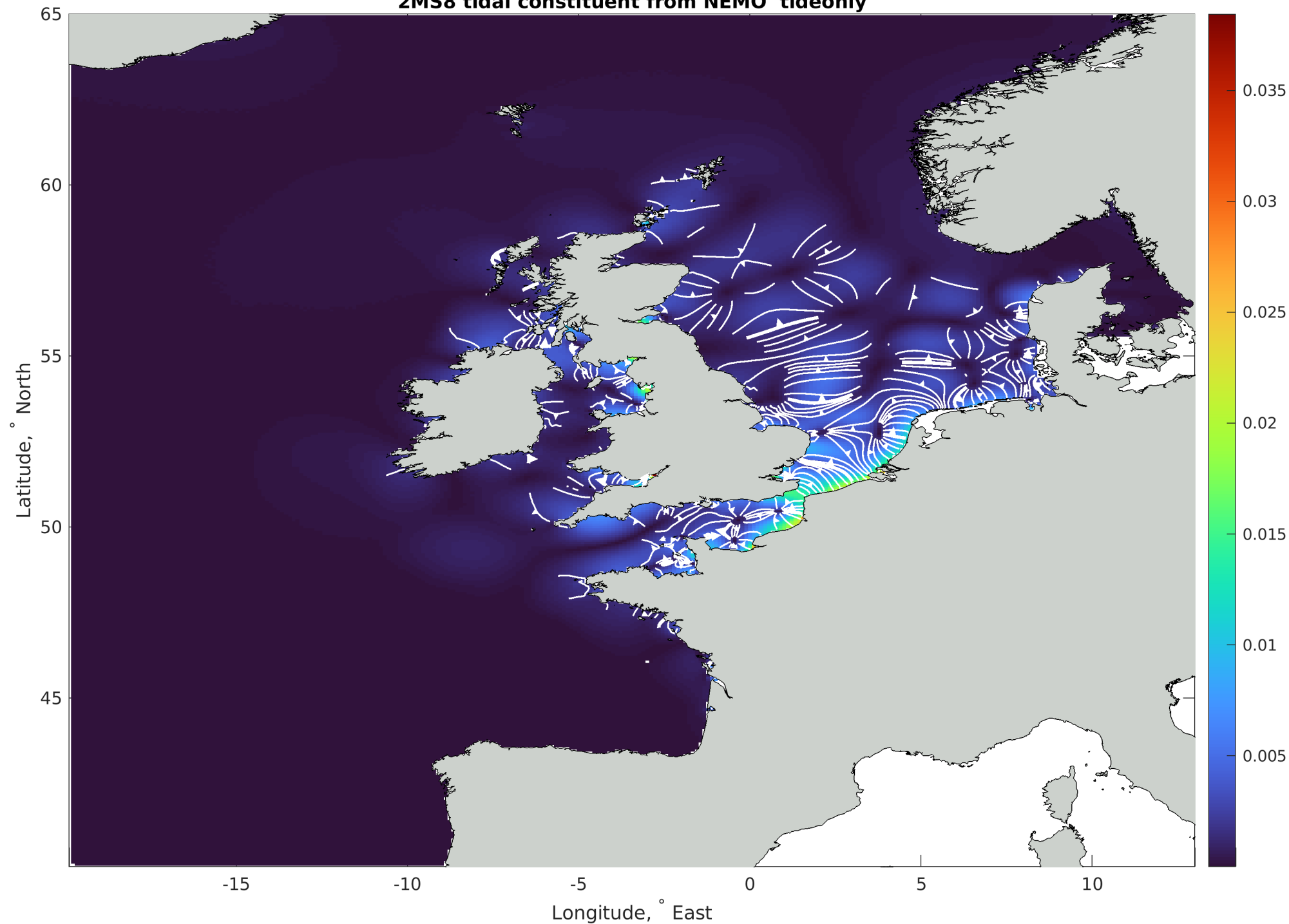


MSNK8 tidal constituent from NEMO tideonly

$\times 10^{-3}$

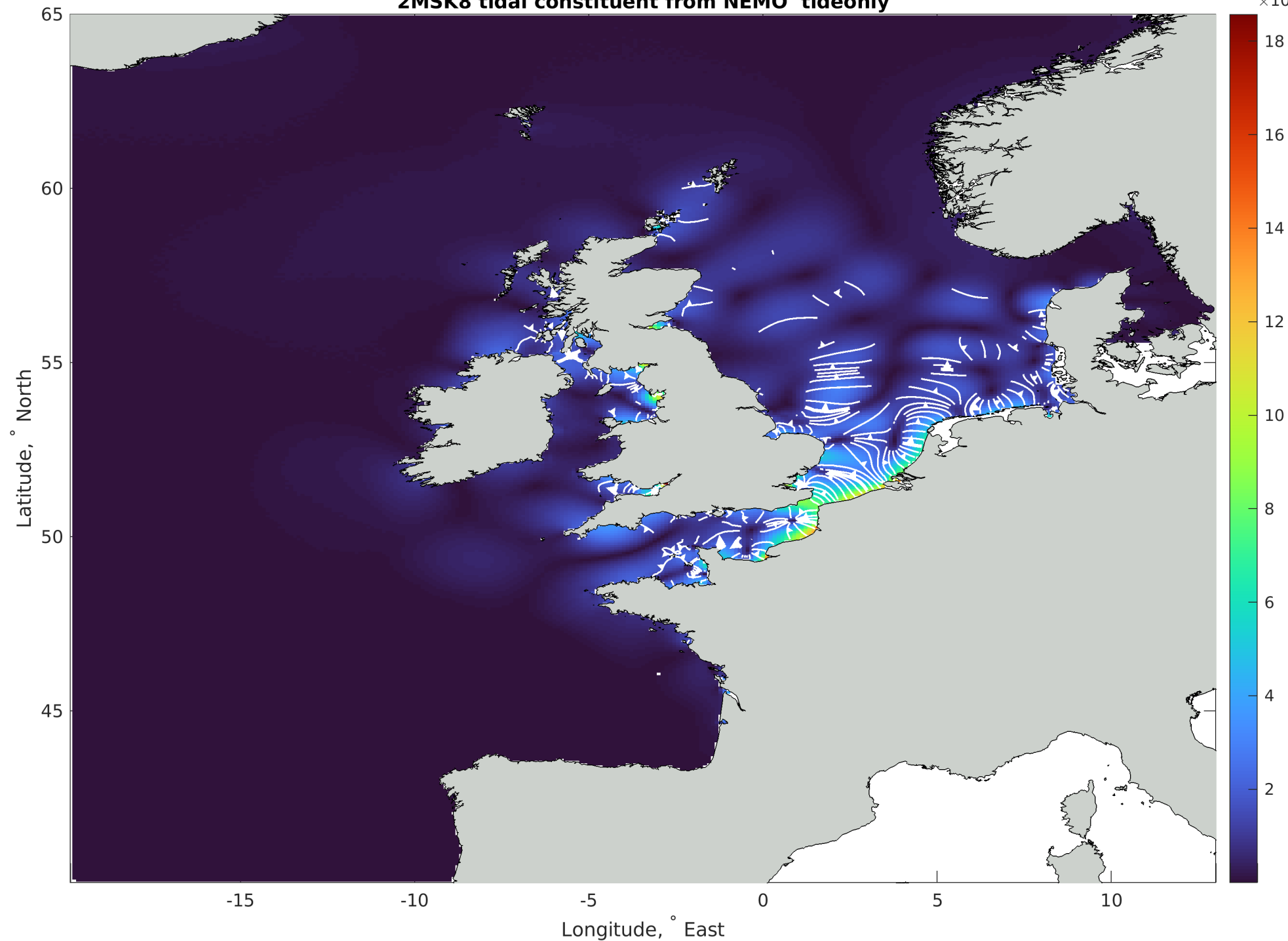


2MS8 tidal constituent from NEMO tideonly

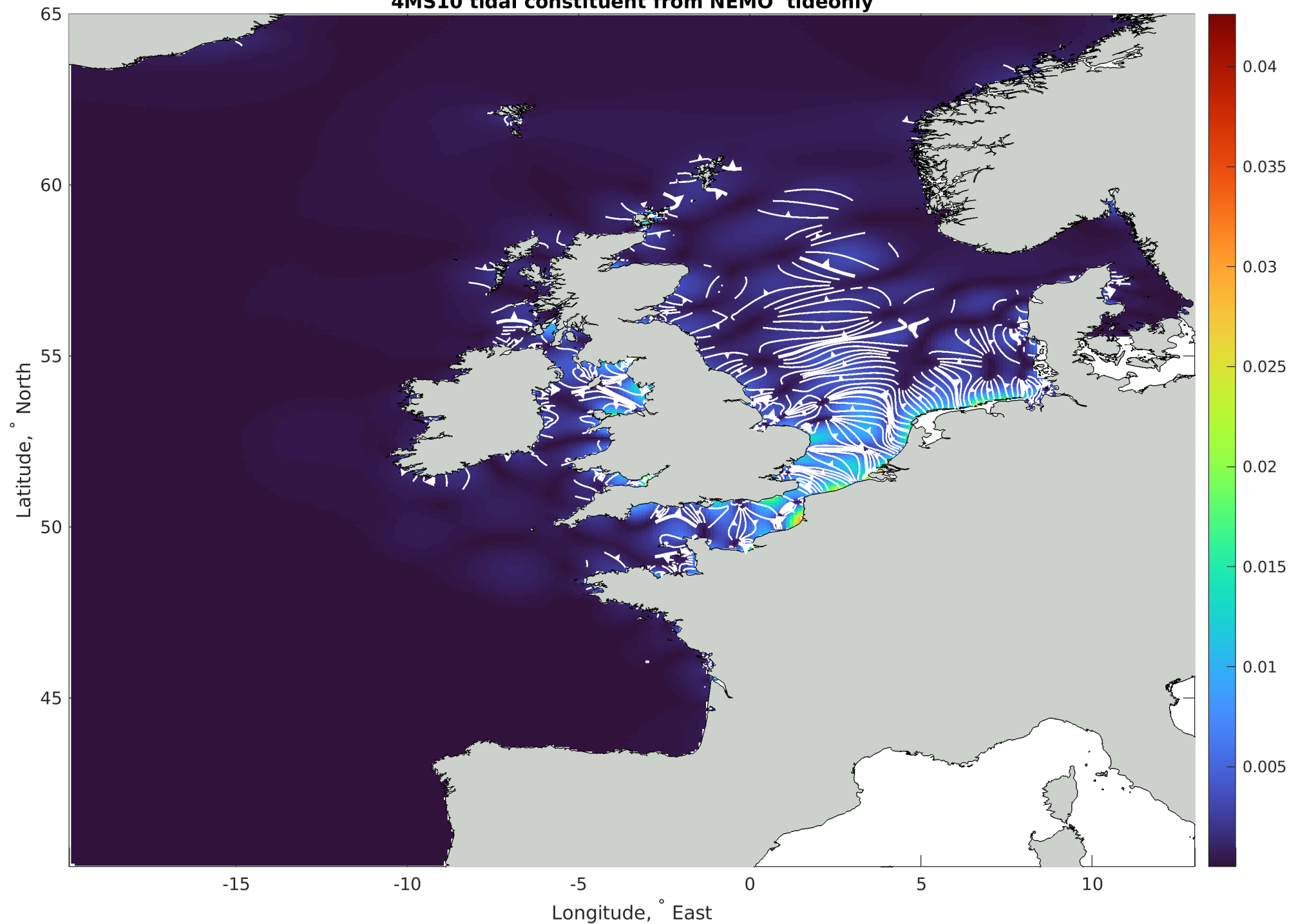


2MSK8 tidal constituent from NEMO tideonly

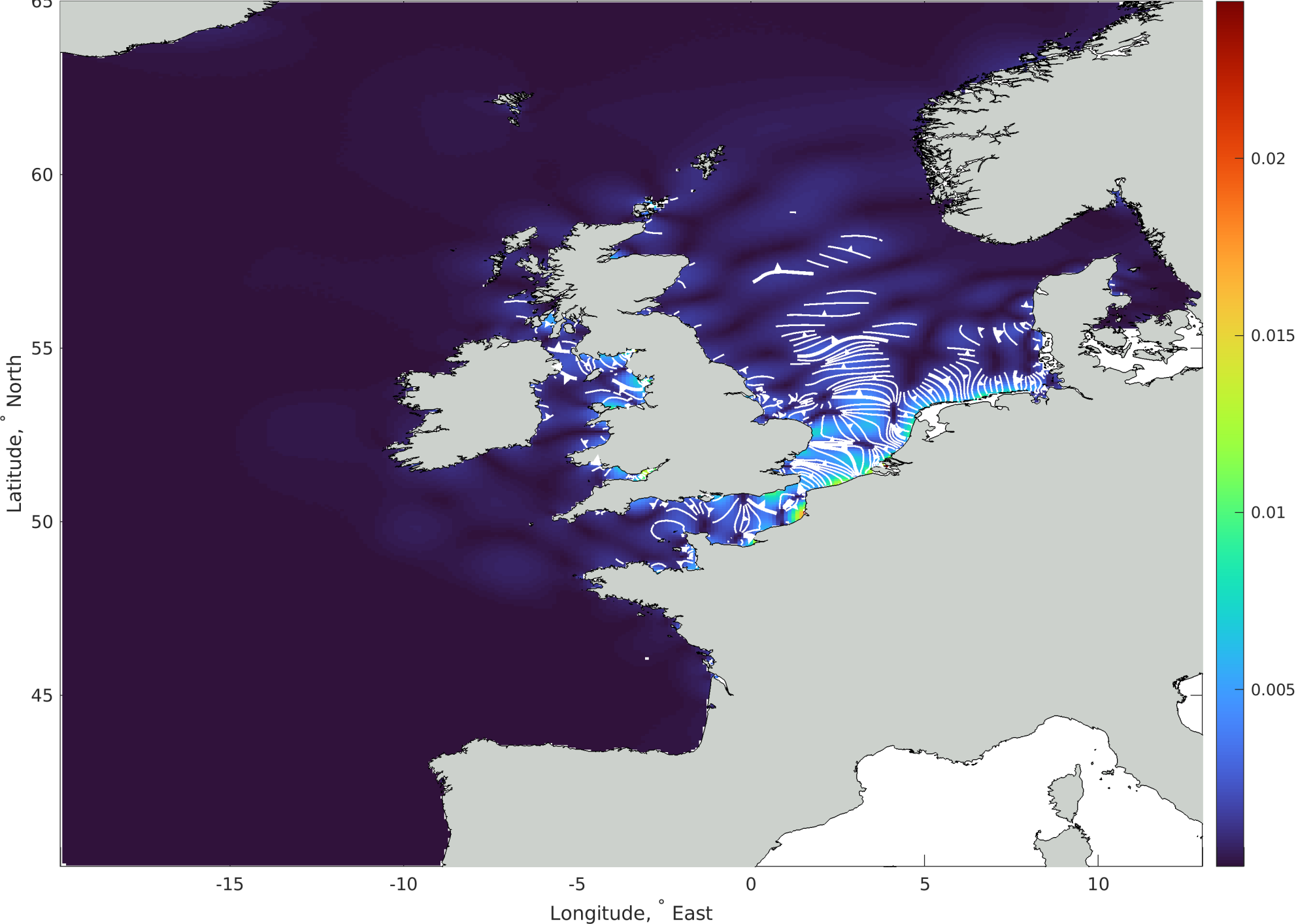
$\times 10^{-3}$



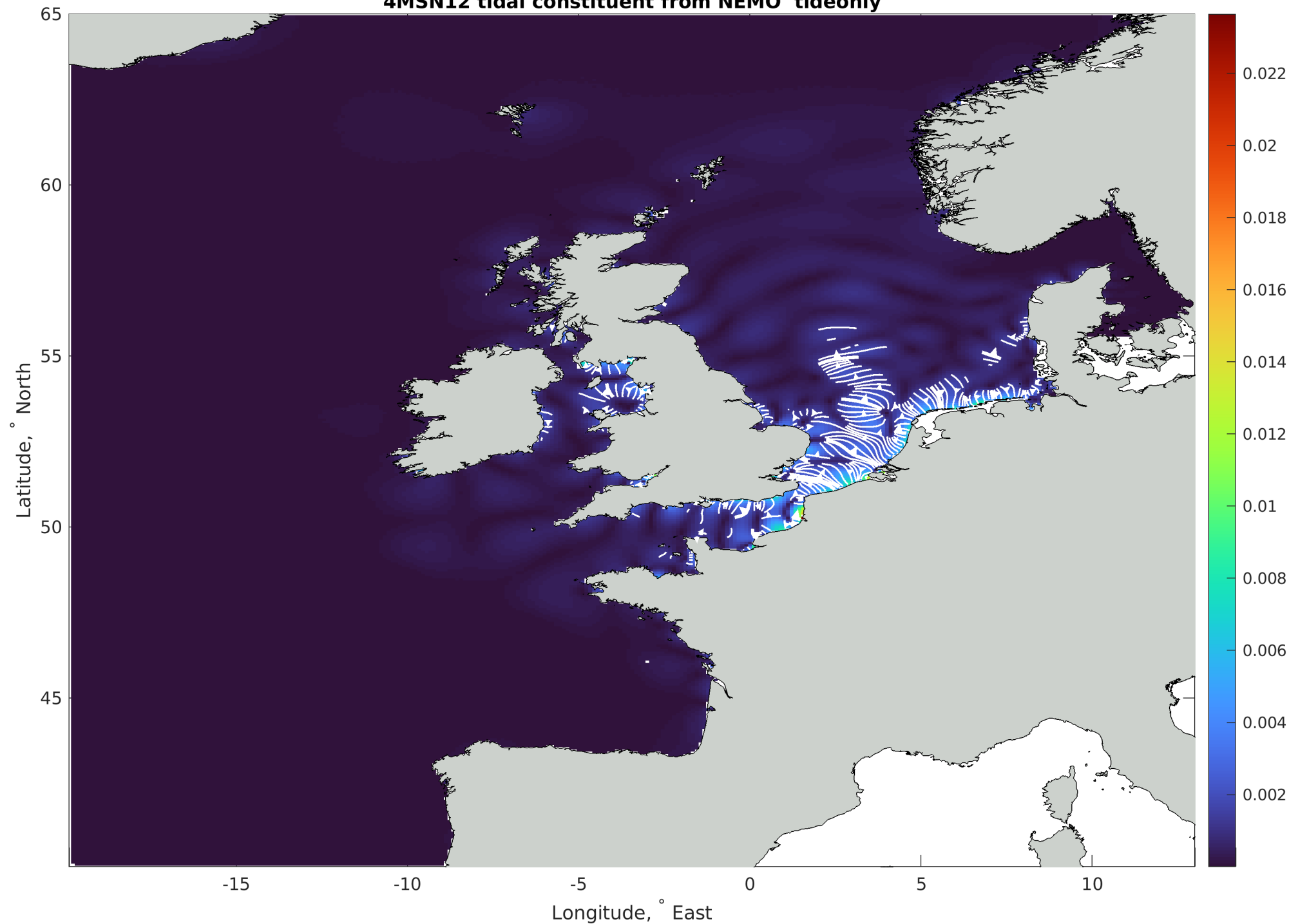
4MS10 tidal constituent from NEMO tideonly



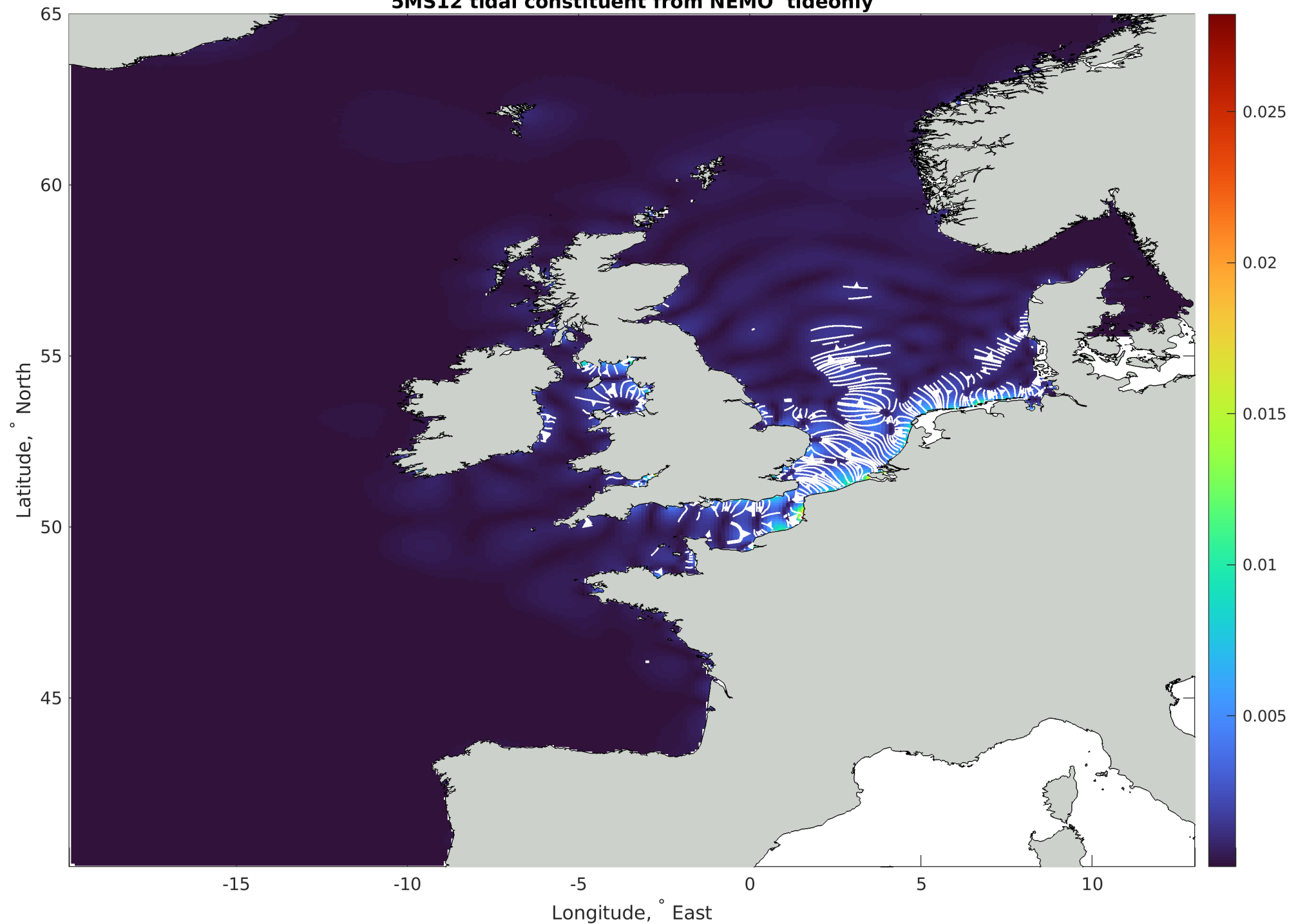
3M2S10 tidal constituent from NEMO tideonly



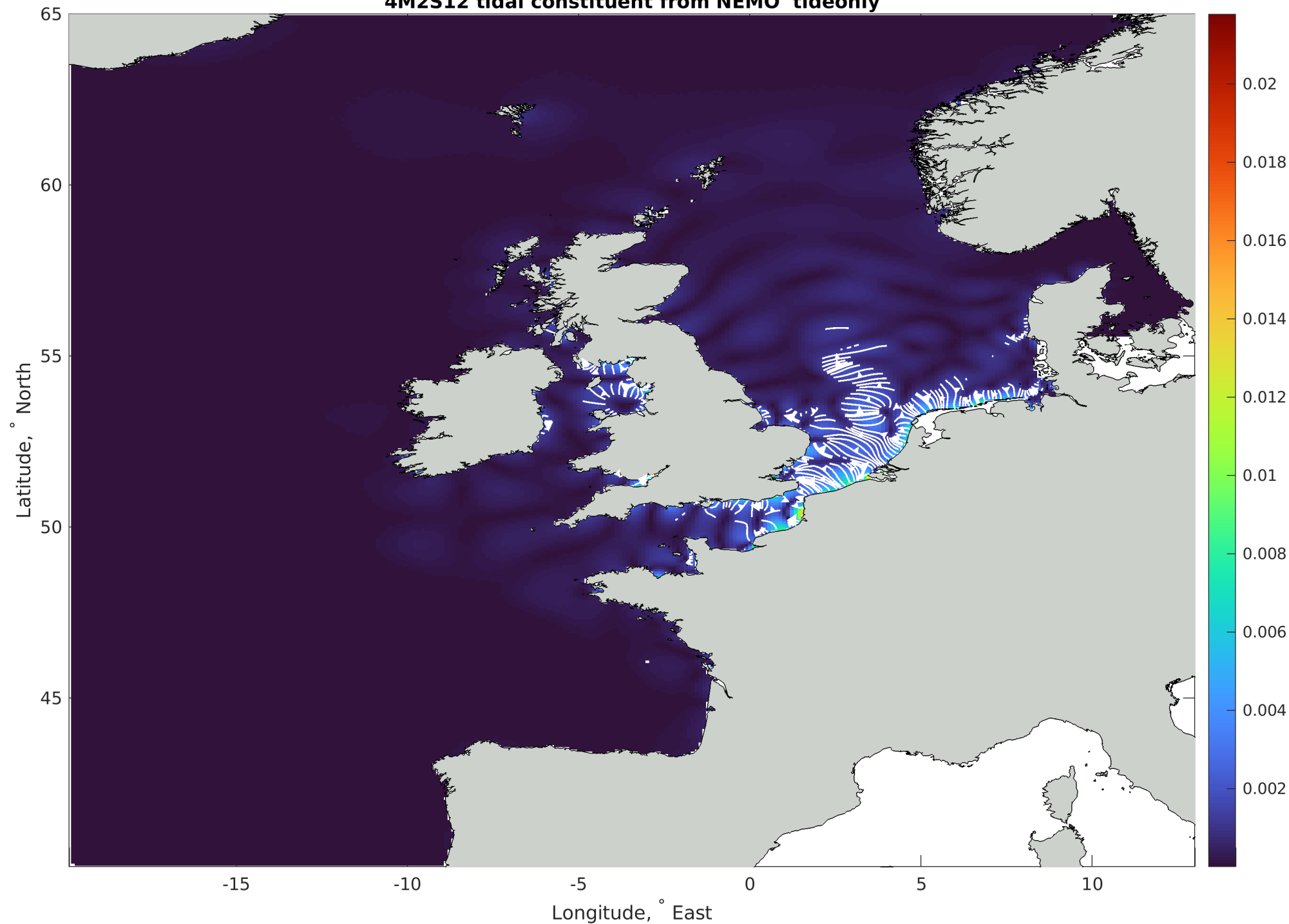
4MSN12 tidal constituent from NEMO tideonly



5MS12 tidal constituent from NEMO tideonly

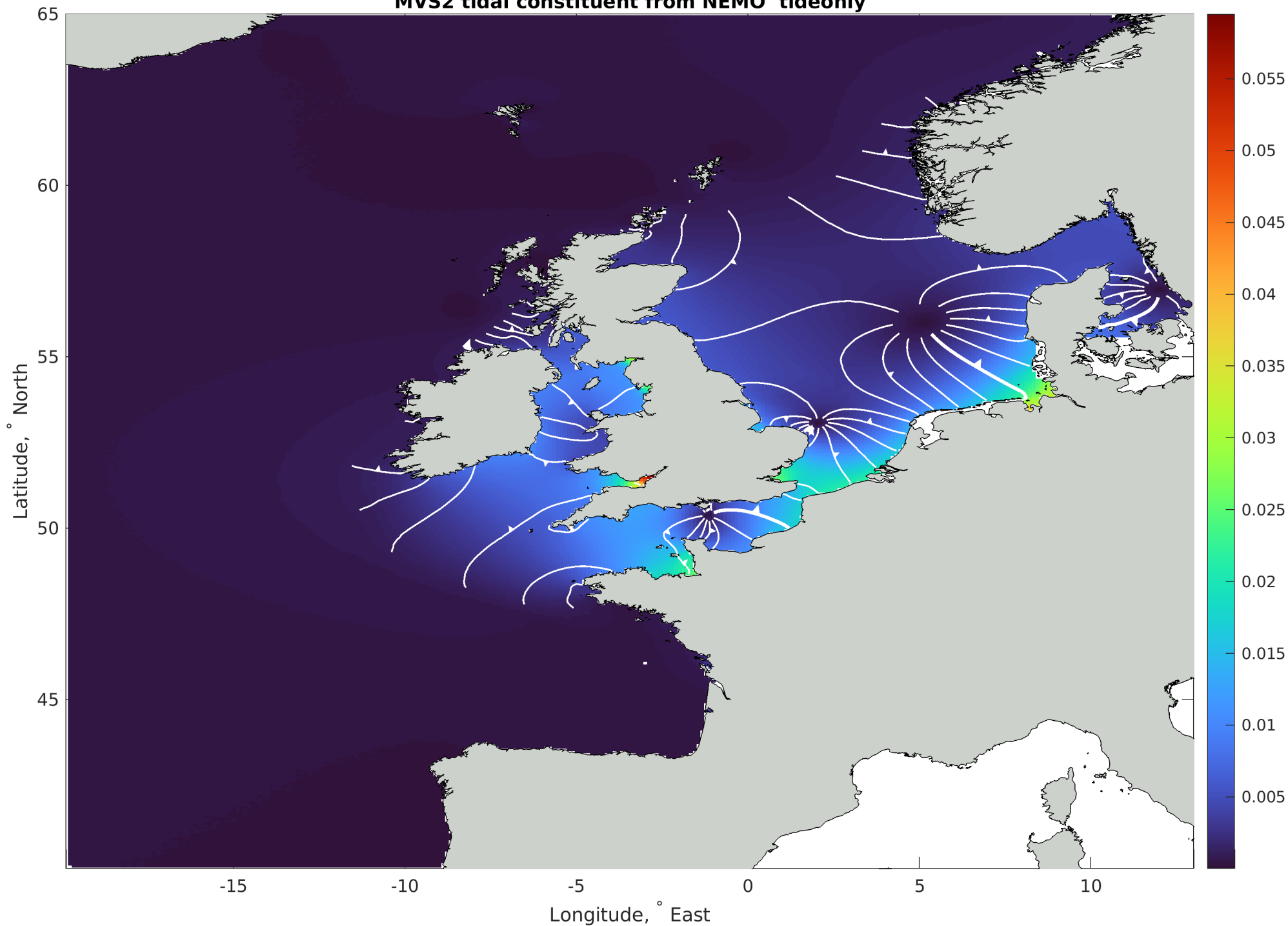


4M2S12 tidal constituent from NEMO tideonly

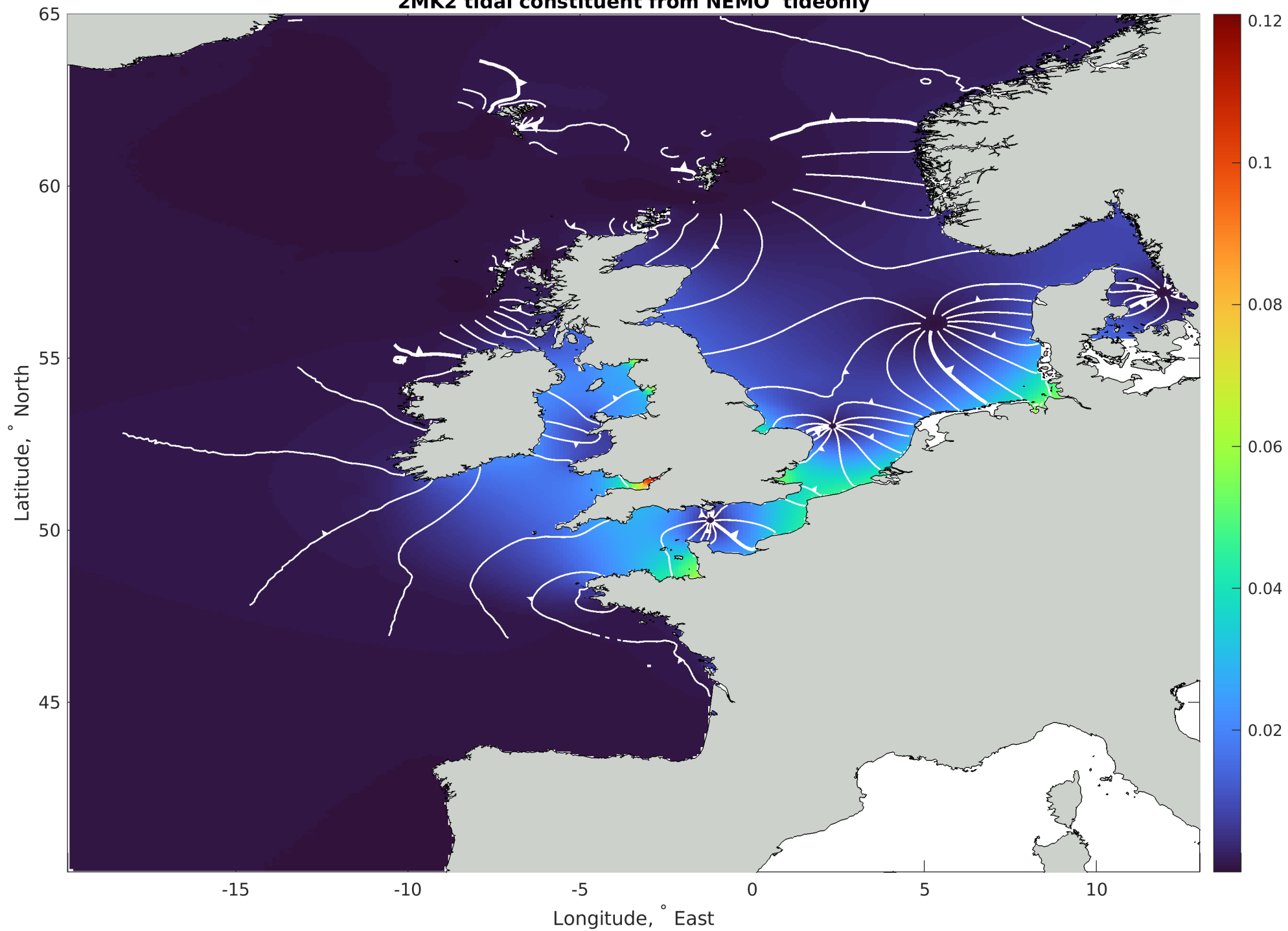




MVS2 tidal constituent from NEMO tideonly

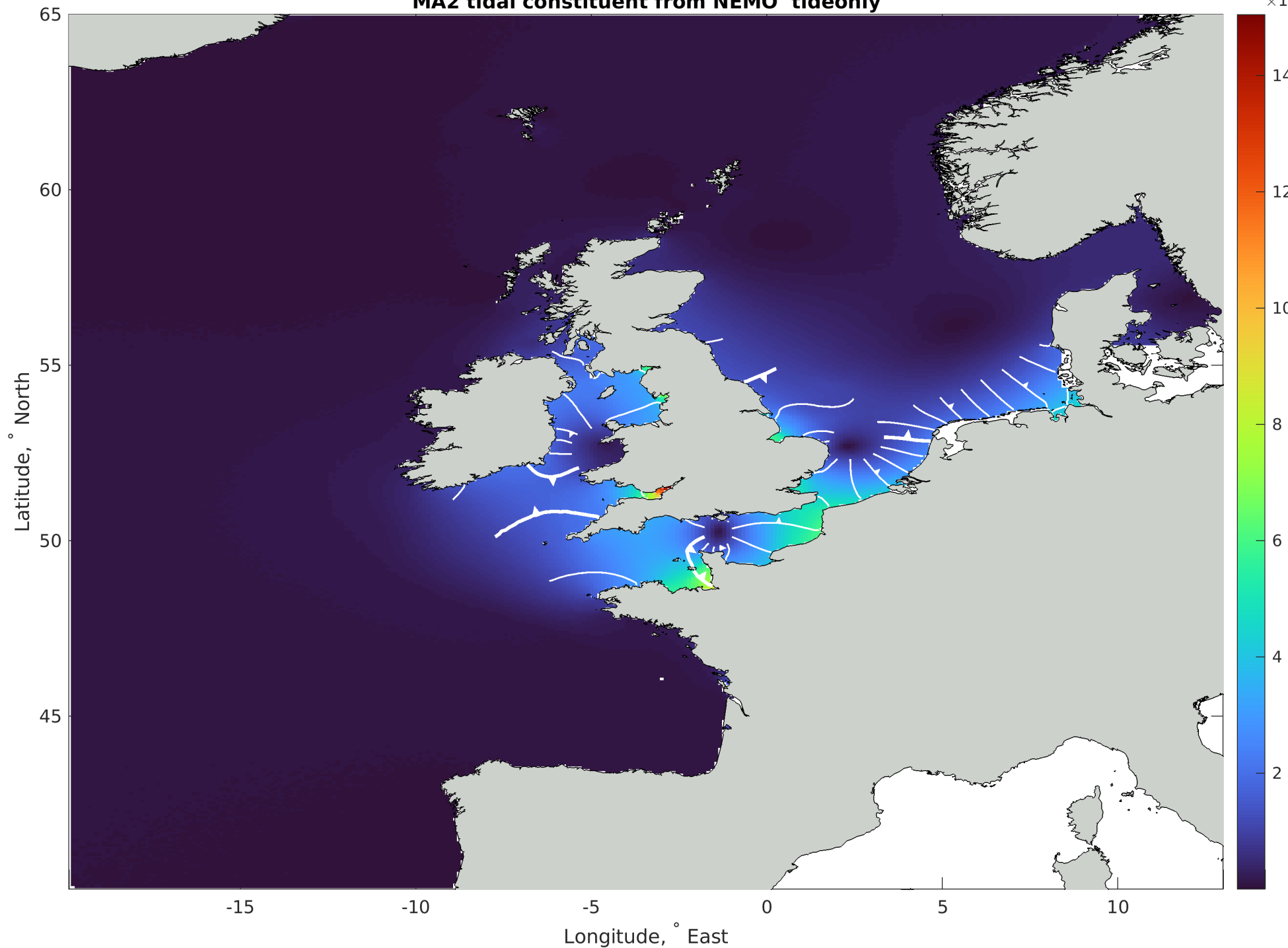


2MK2 tidal constituent from NEMO tideonly

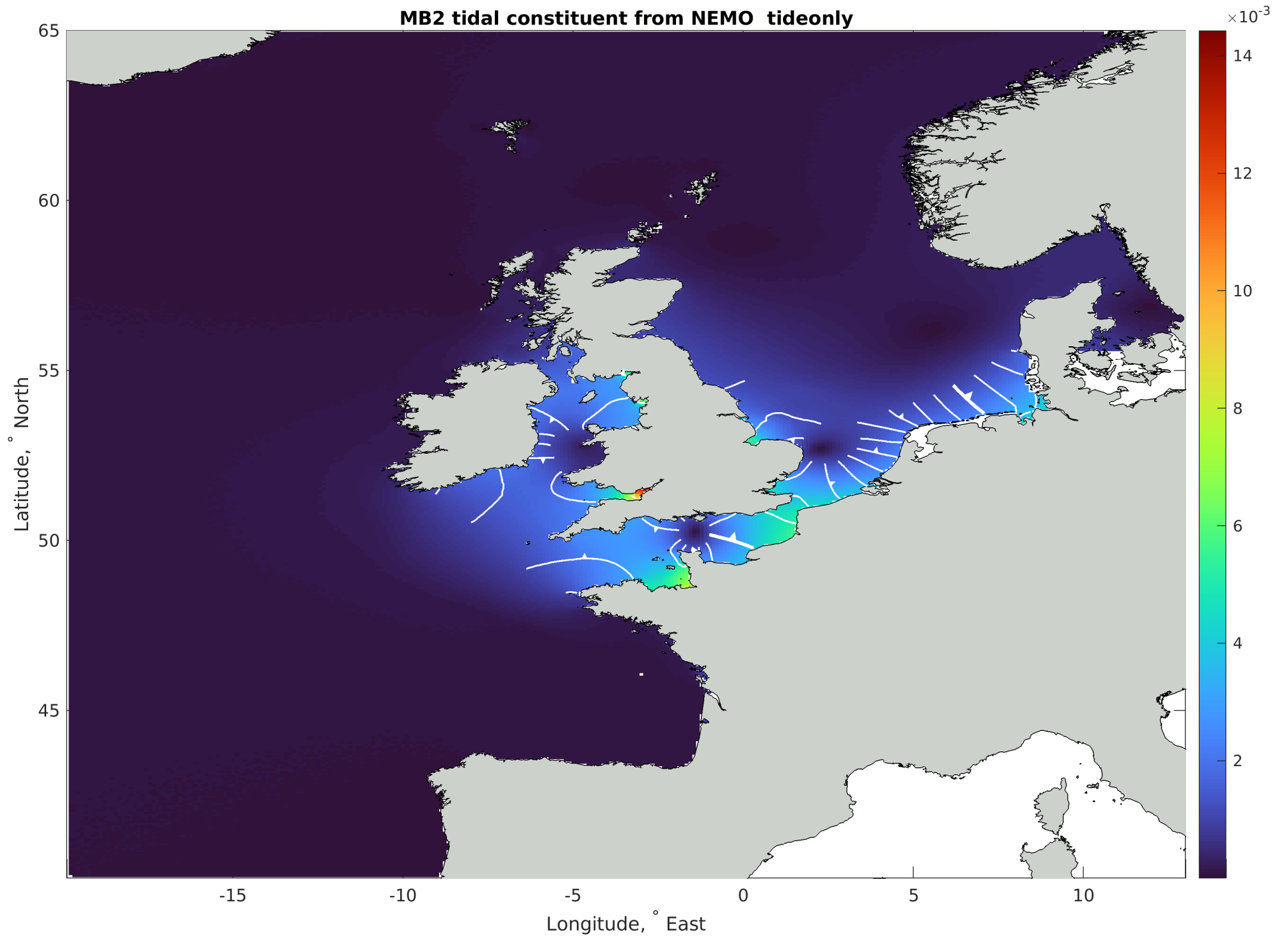


MA2 tidal constituent from NEMO tideonly

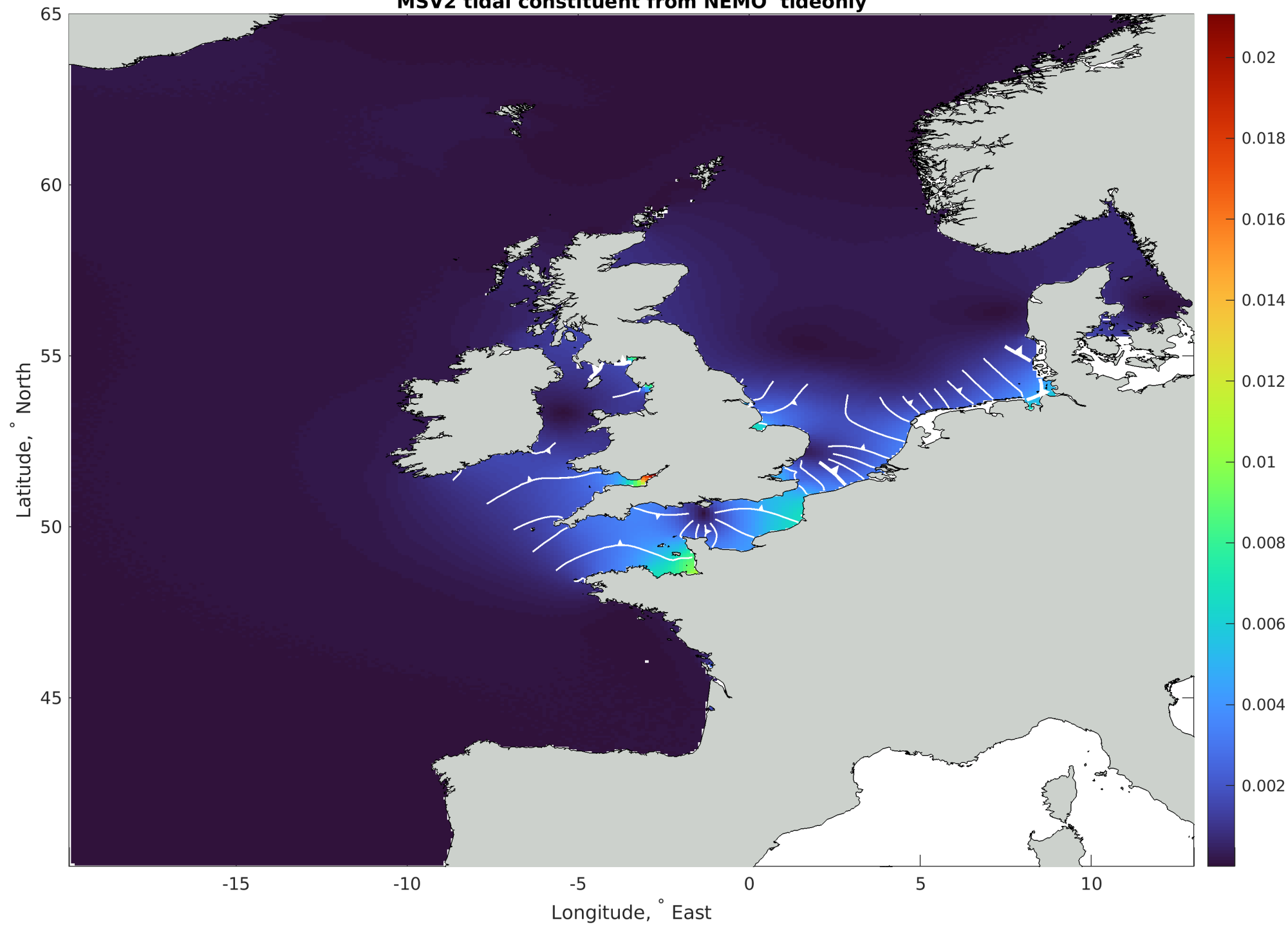
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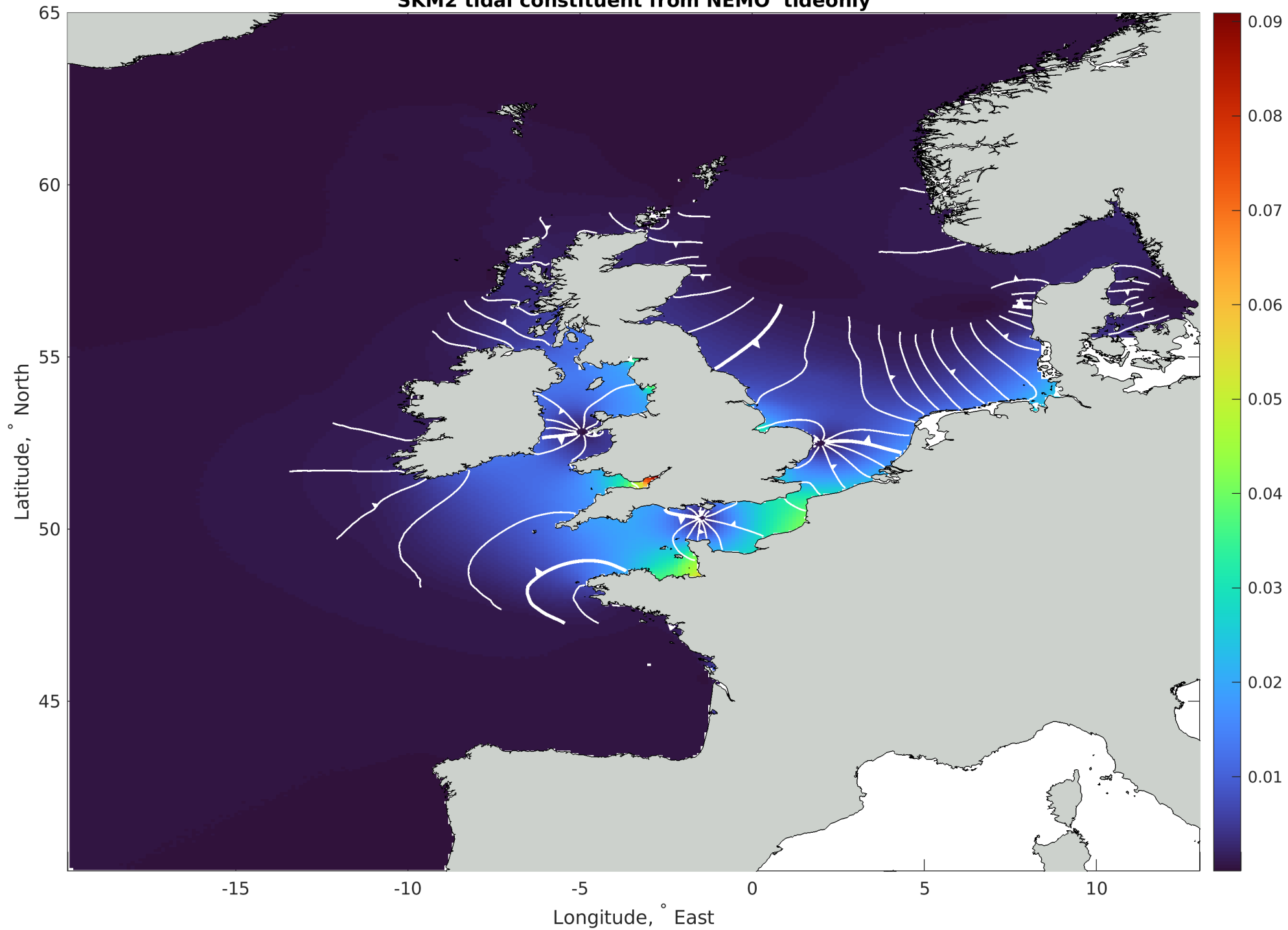
MB2 tidal constituent from NEMO tideonly



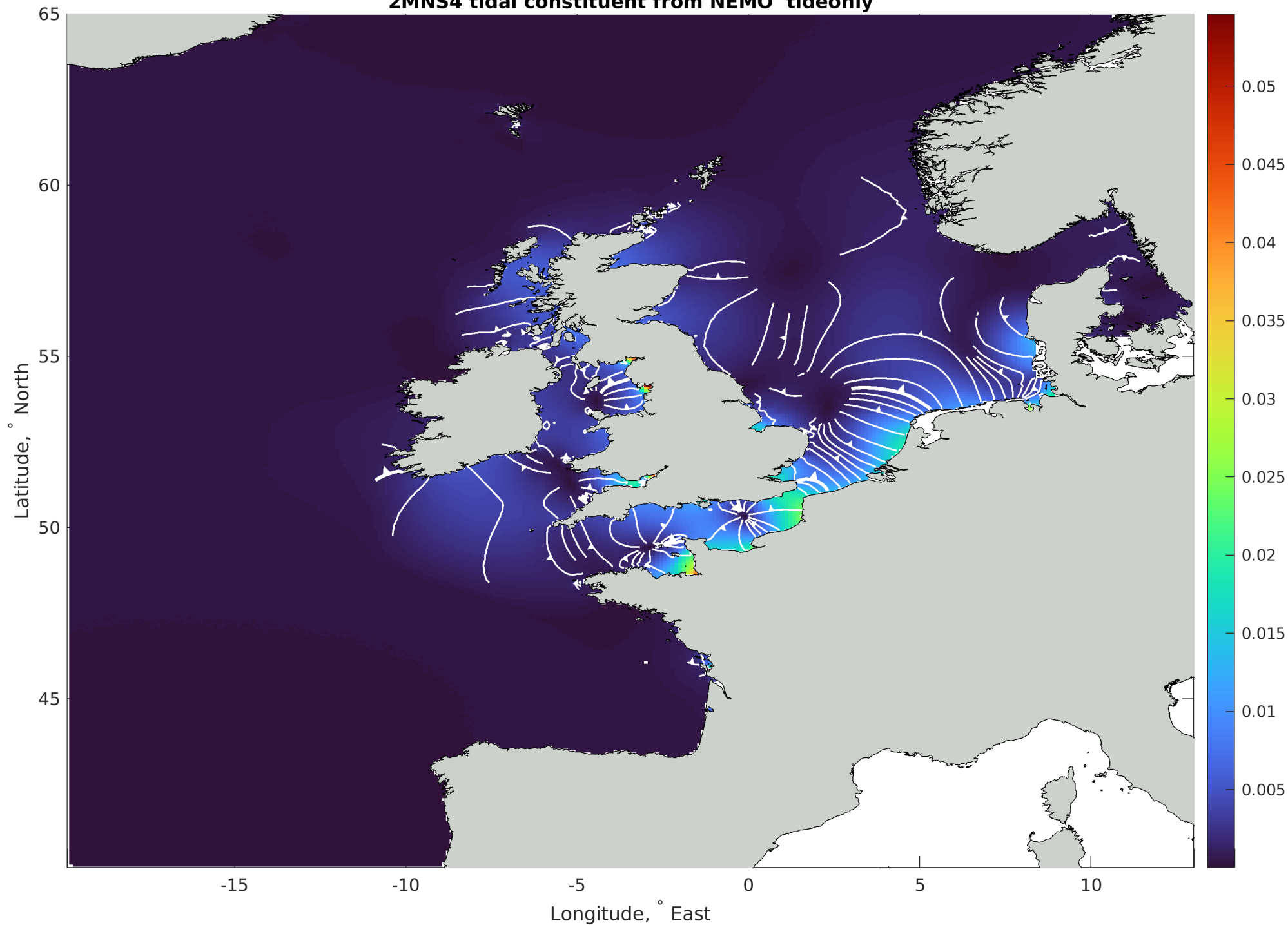
MSV2 tidal constituent from NEMO tideonly



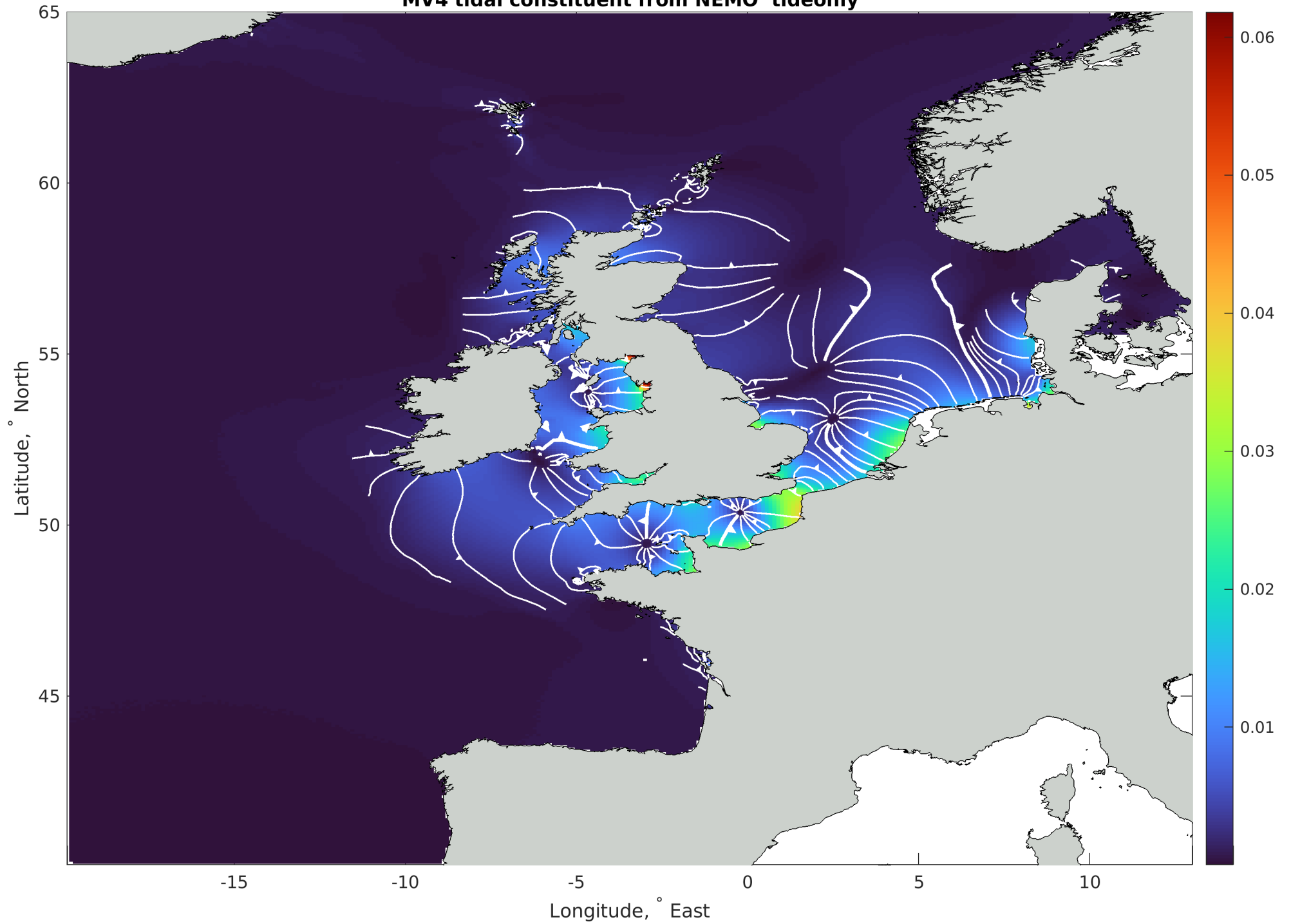
SKM2 tidal constituent from NEMO tideonly



2MNS4 tidal constituent from NEMO tideonly

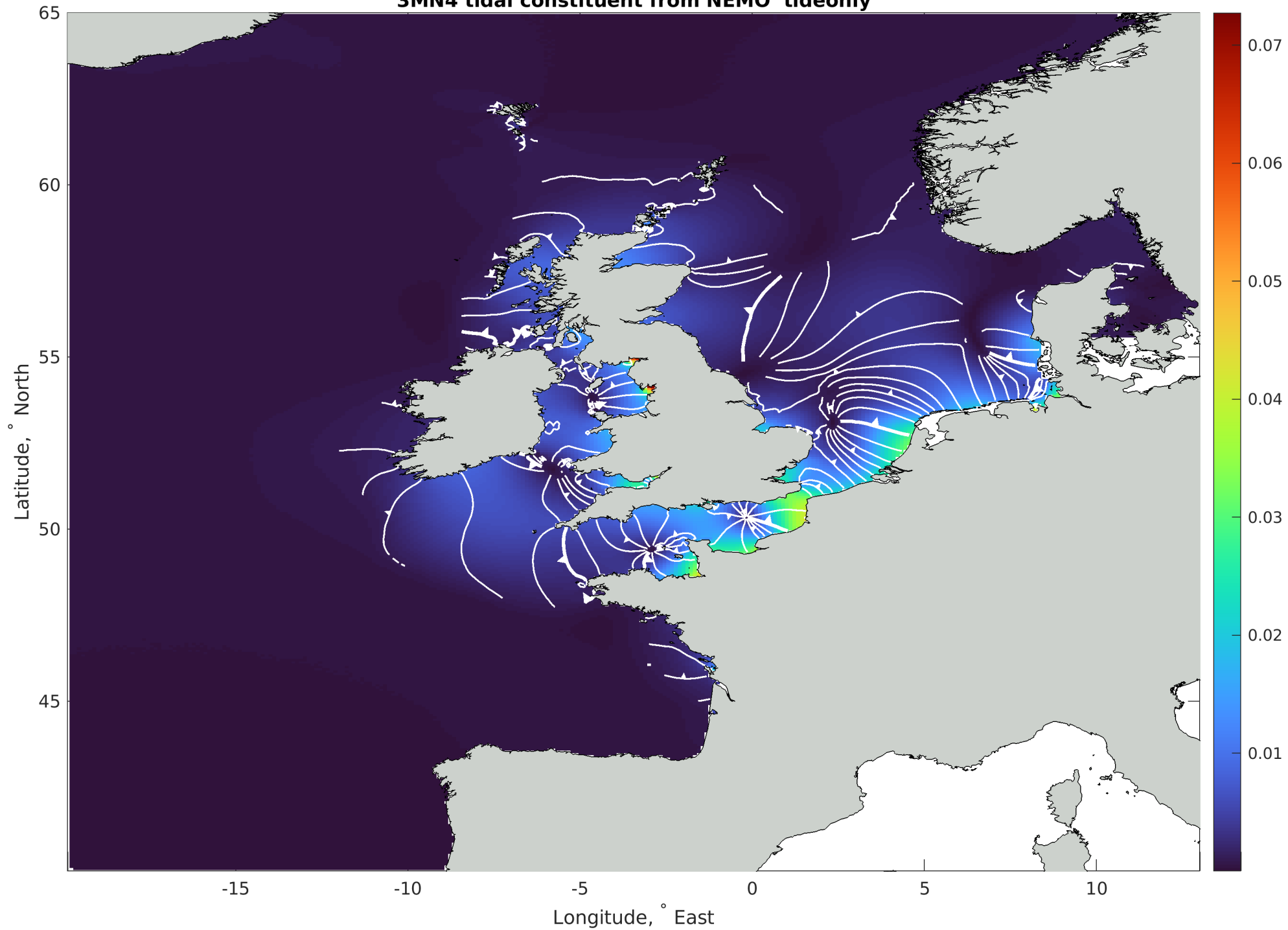


MV4 tidal constituent from NEMO tideonly

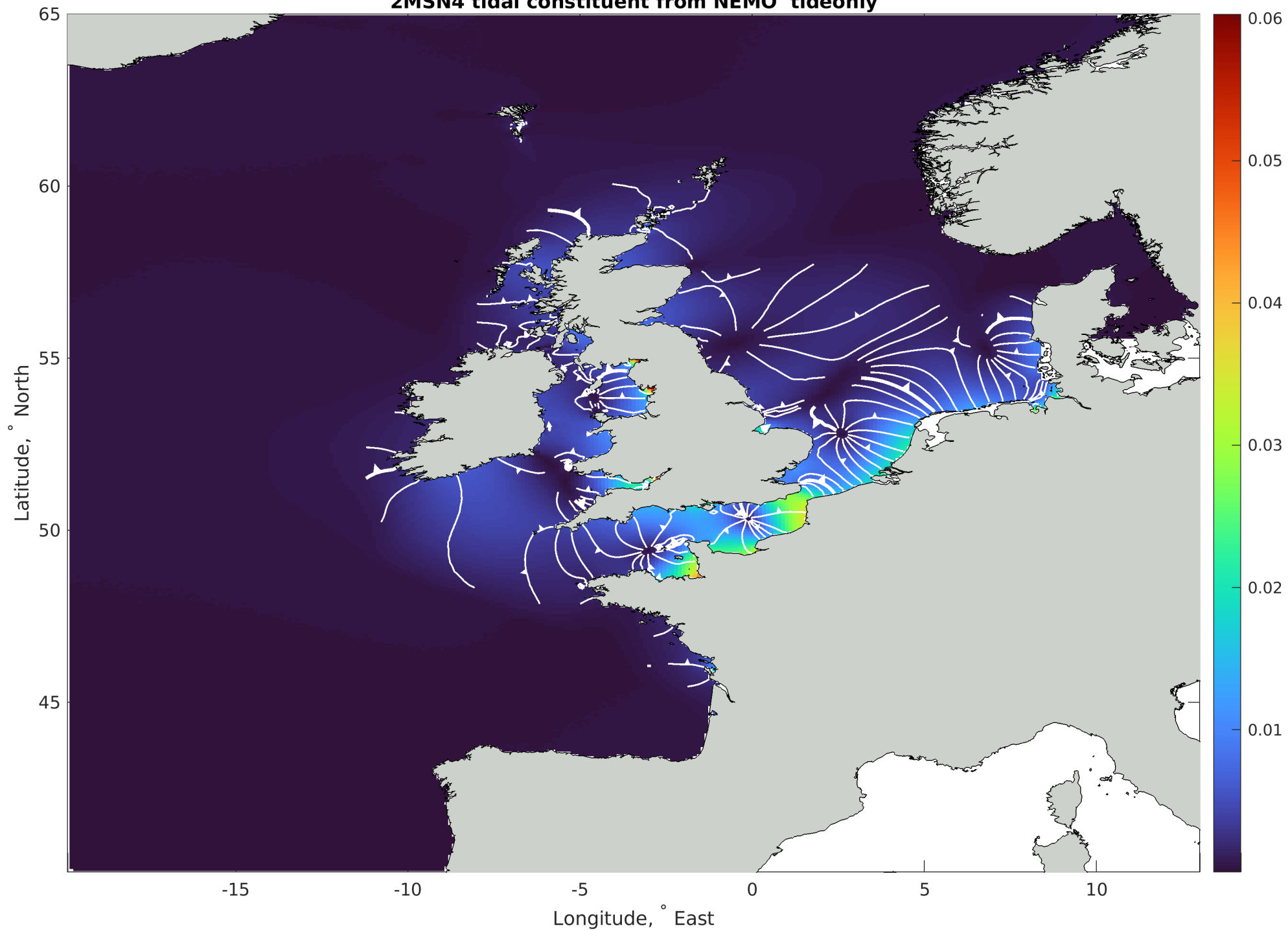




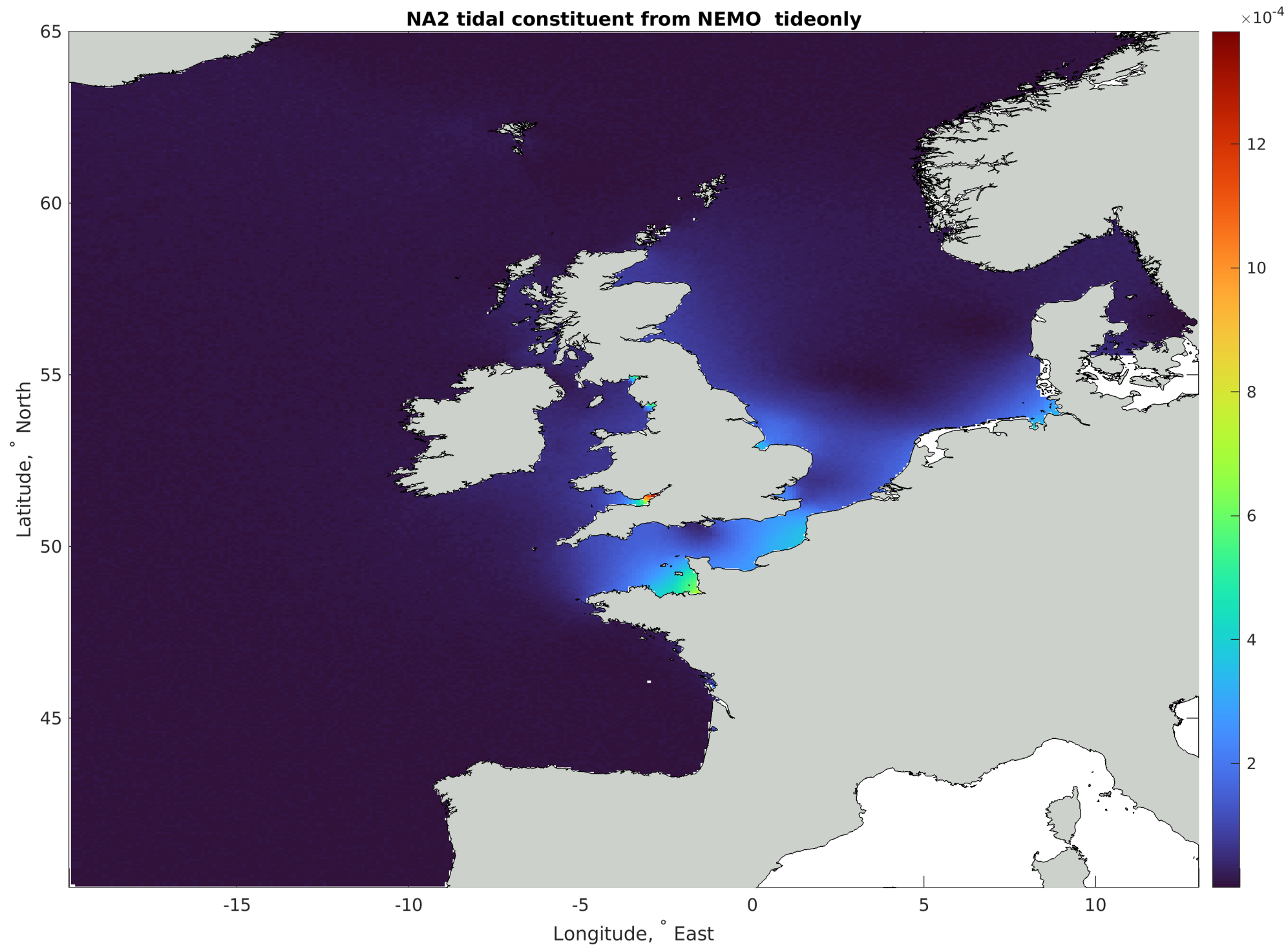
3MN4 tidal constituent from NEMO tideonly



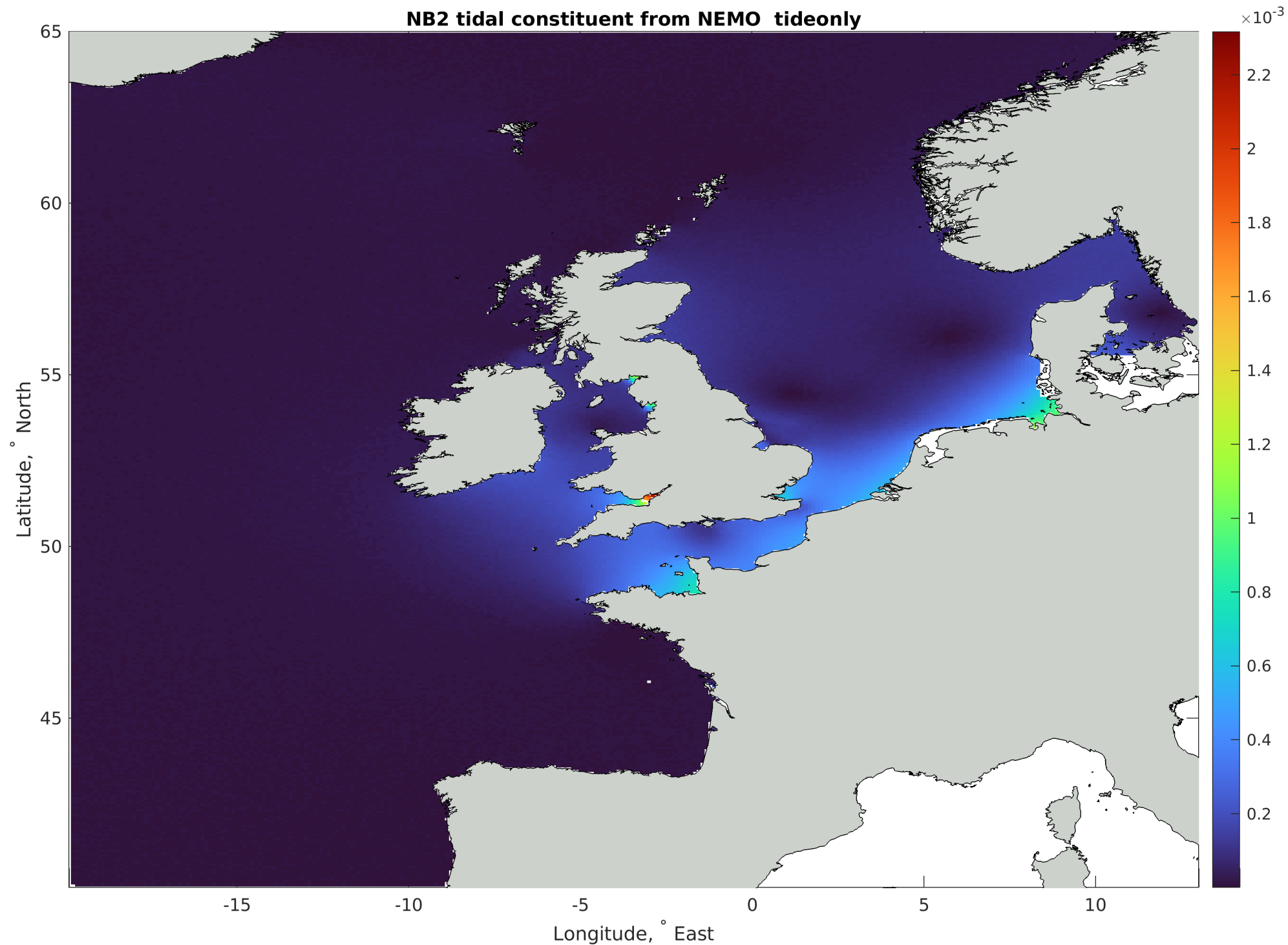
2MSN4 tidal constituent from NEMO tideonly



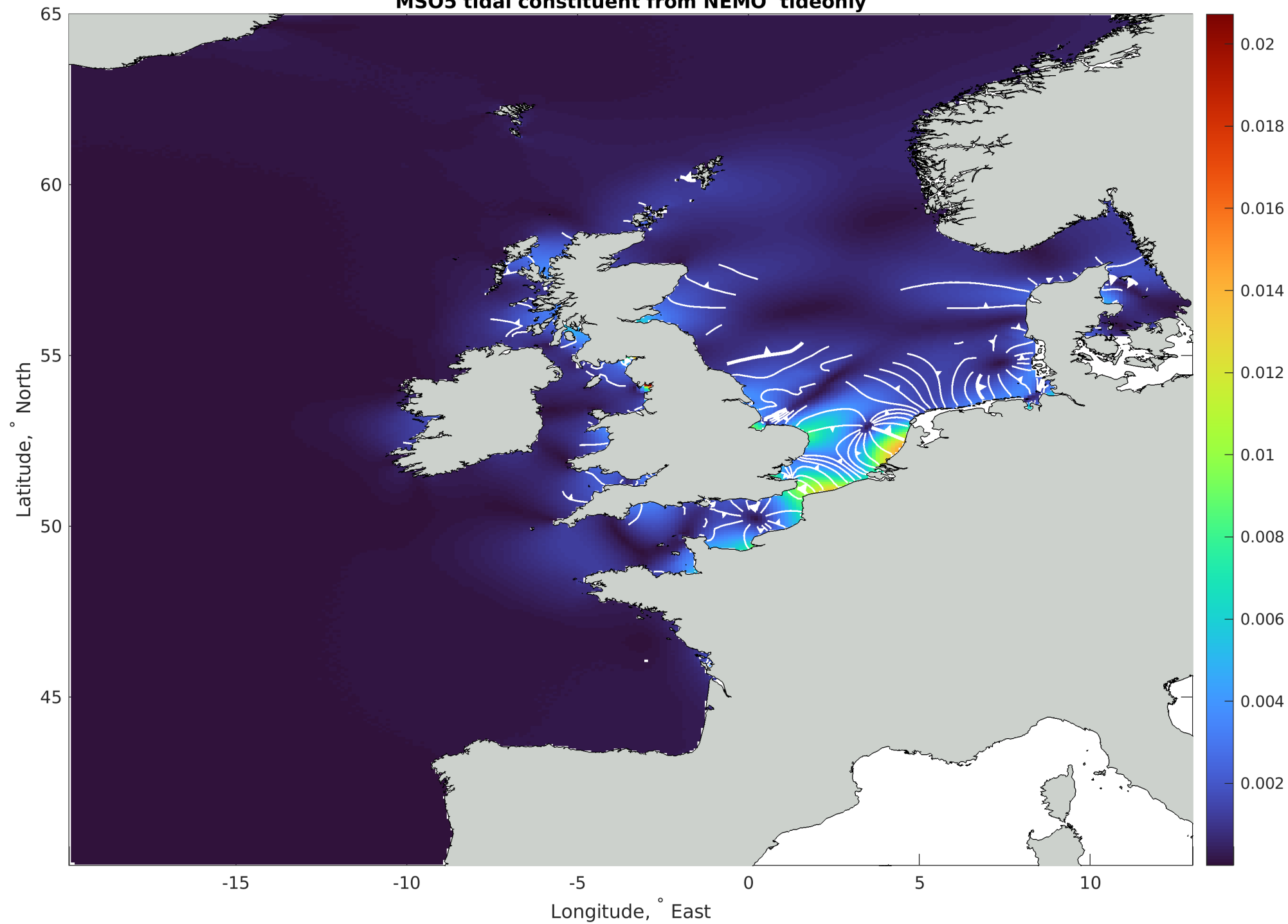
NA2 tidal constituent from NEMO tideonly



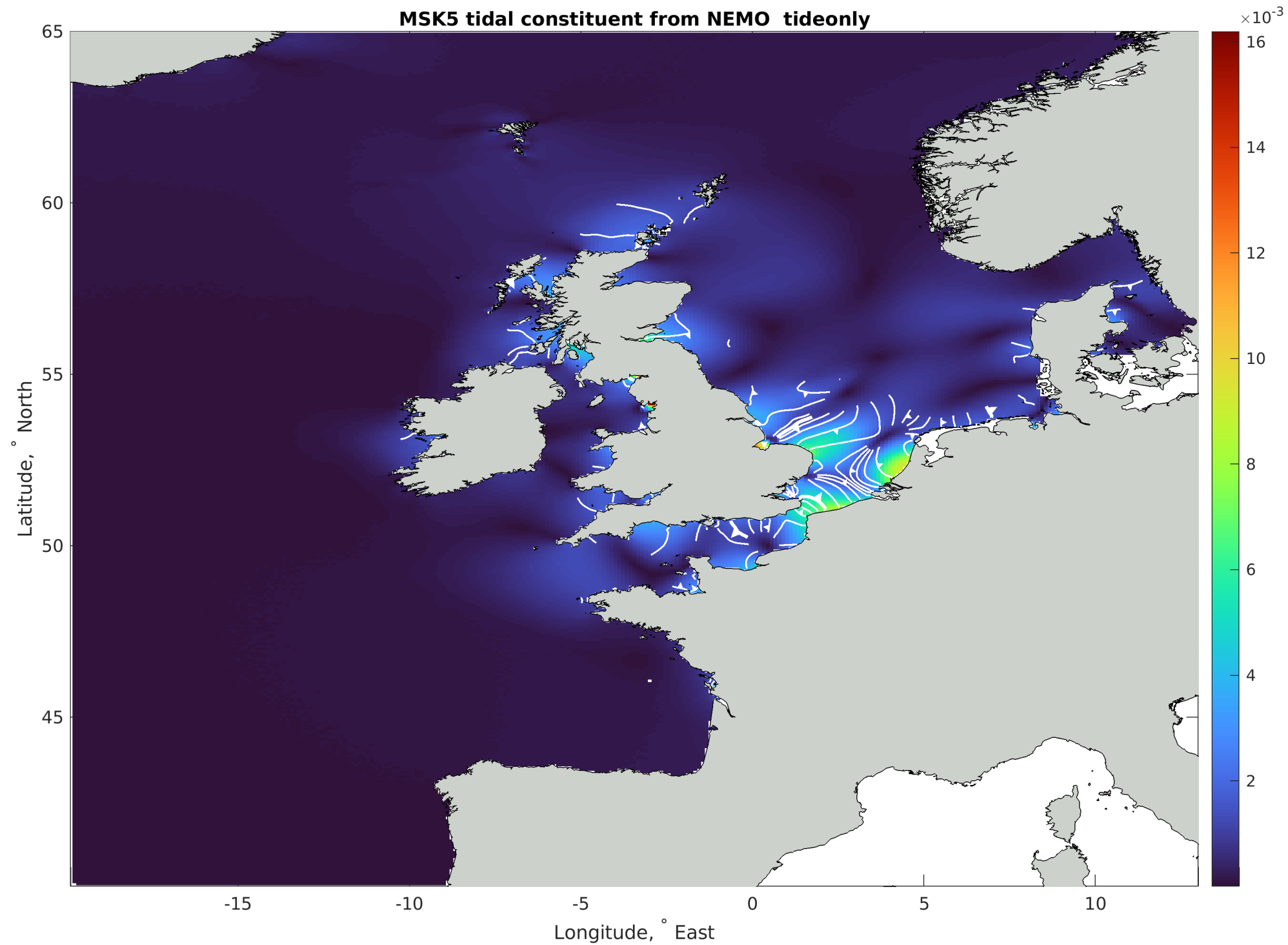
NB2 tidal constituent from NEMO tideonly



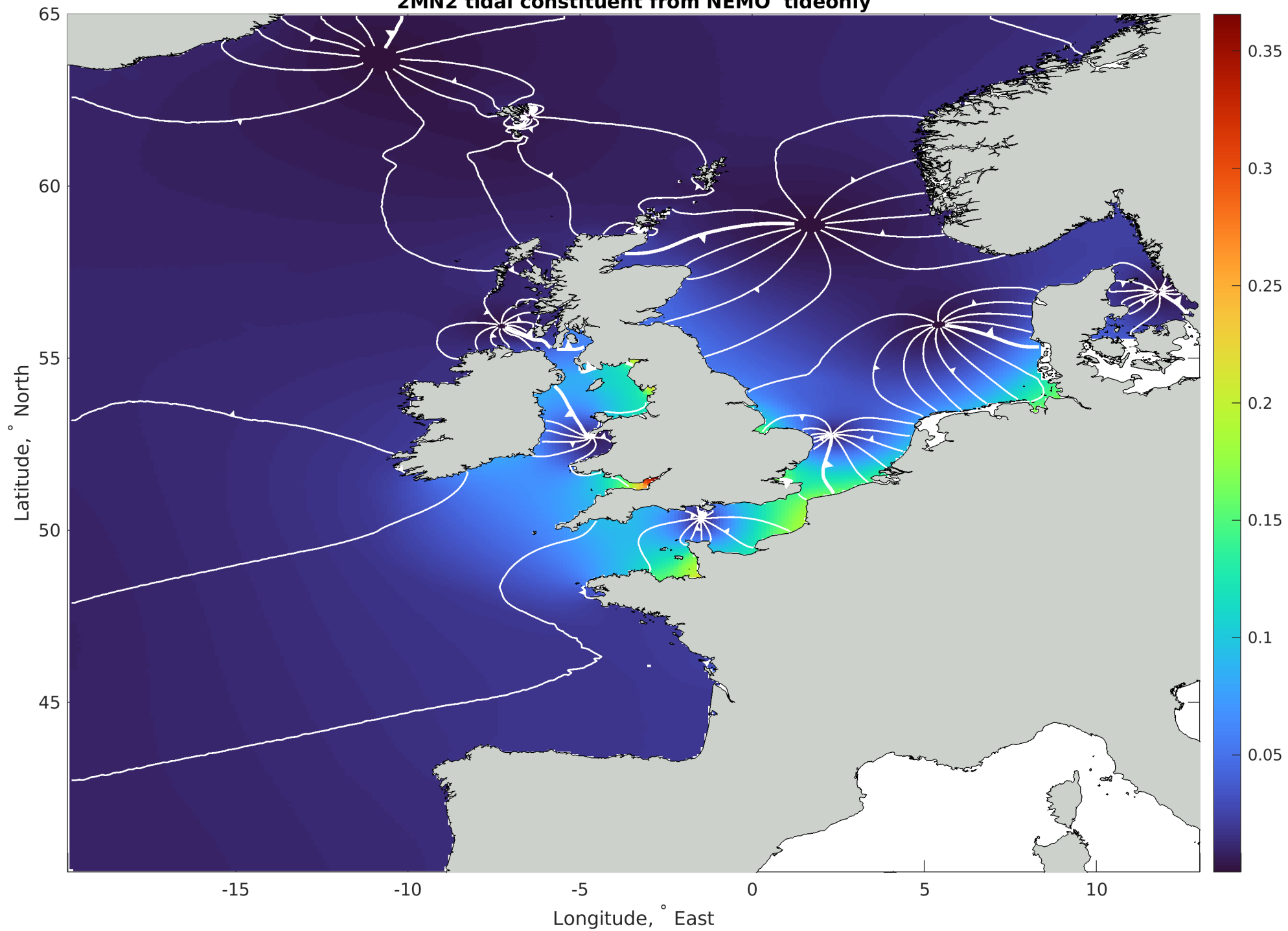
MSO5 tidal constituent from NEMO tideonly



MSK5 tidal constituent from NEMO tideonly



2MN2 tidal constituent from NEMO tideonly



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