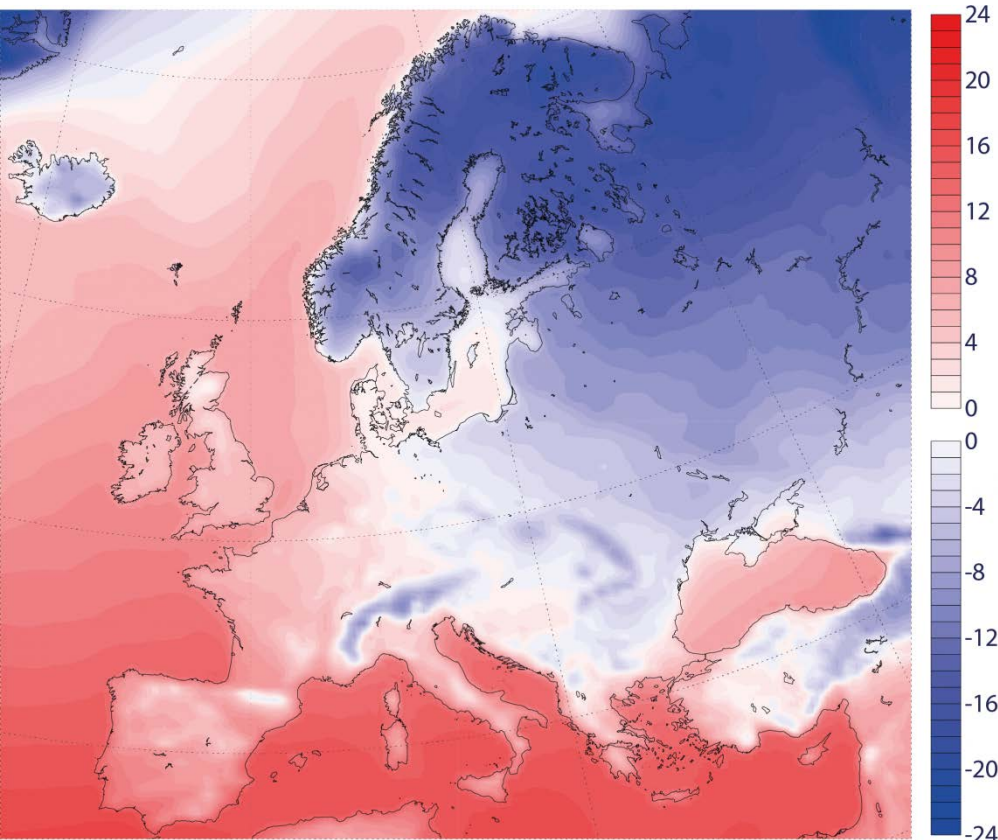# ERA5: High temporal and spatial resolution reanalyses as a tool to investigate high impact events and other natural hazards in the Baltic Earth region
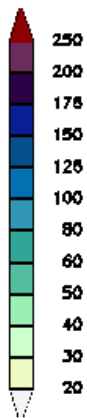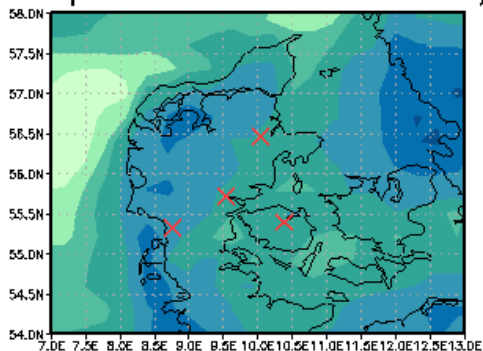
Martin Stendel
Danish Meteorological Institute

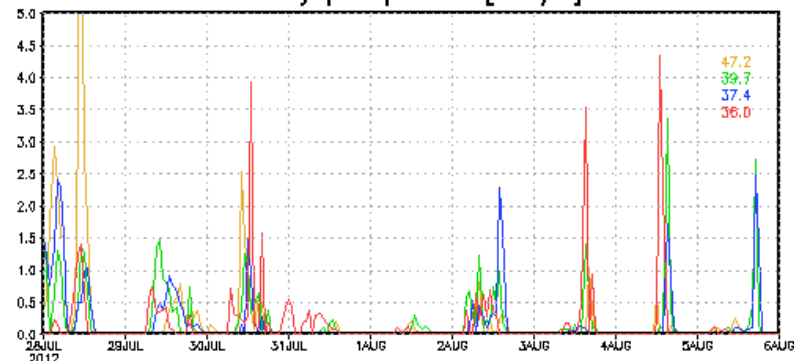- What is new in ERA5?
- Case studies:
  - Copenhagen deluge 2 July 2011
  - Storm surge "Bodil" 5/6 December 2013
  - The "quiet flood" 4/5 January 2017
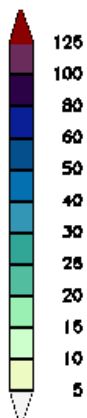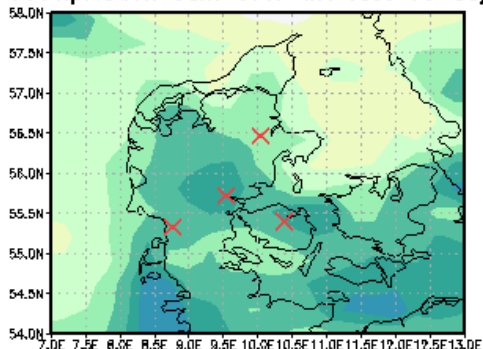
ERA5 precipitation and wind 28JUL2012−06AUG2012

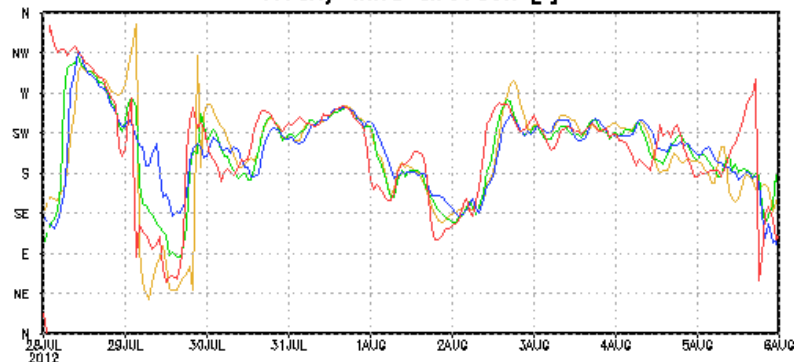## Precipitation sum over the last 30 days

Hourly precipitation [mm/h]
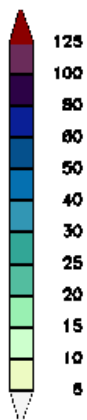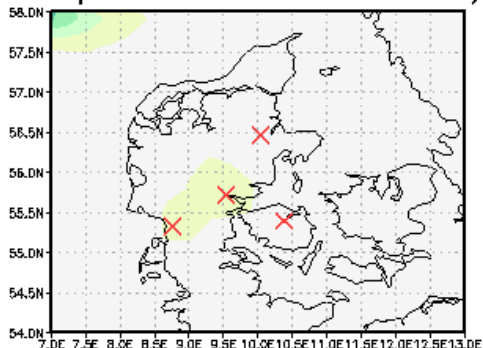

47.2
39.7
37.4
36.0

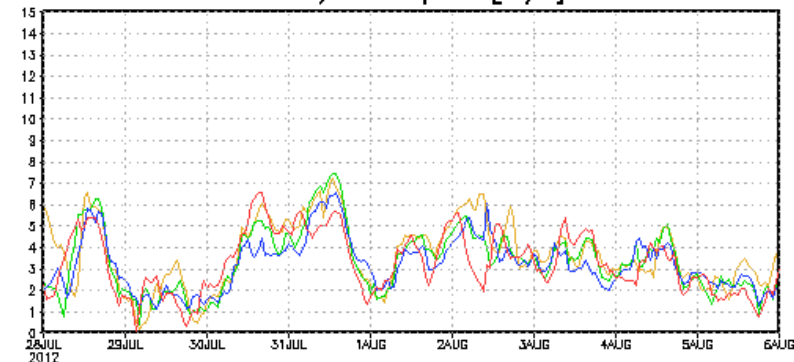## Precipitation sum over the last 10 days

Hourly wind direction [°]

Precipitation sum over the last 5 days

Hourly wind speed [m/s]

Ribe (55.32°N, 8.76°E)   Randers (56.46°N, 10.04°E)   Vejle (55.71°N, 9.53°E)   Odense (55.39°N, 10.39°E)

What is new in ERA5?

- ERA5 climate reanalysis aims to give a numerical description of the recent climate
- Atmospheric and surface parameters, including soil moisture content, sea-surface temperature and wave height.
- First reanalysis produced as an operational service - therefore considerably higher spatial and temporal resolution:
  - hourly analysis and forecast fields
  - horizontal resolution of 31 km
  - 137 levels from the surface up to 0.01 hPa (around 80 km).
- Information on uncertainties for each parameter at 3-hourly intervals and at a horizontal resolution of 62 km
- Roughly 9 petabytes of data
- Freely available

ERA5 public release plan

17 July 2017	Release 2010-2016
December 2017	ERA5 continuous updating i.e. ERA5: < 3 months after real time (final product)
by mid 2018	ERA5T: short delay (< 1 week, preliminary product)
by mid 2018	Access to ERA5 observations from 2010 onwards
Late 2018	Complete the release of 1979-2009
2019	Release 1950-1978

ERA5 compared to ERA-Interim

- Much higher spatial and temporal resolution
- Information on variation in quality over space and time
- Much improved troposphere
- Improved representation of tropical cyclones
- Better global balance of precipitation and evaporation
- Better precipitation over land in the deep tropics
- Better soil moisture
- More consistent sea surface temperature and sea ice

ERA5 compared to ERA-Interim

	ERA-Interim	**ERA5**
Period covered	1979 - present	1950 - present
Production Period	August 2006 – end 2018	Jan 2016 – end 2017, then continued in near real-time
Assimilation system	IFS Cycle 31r2 4D-Var	IFS Cycle 41r2 4D-Var
Spatial resolution	79 km globally, 60 levels to 0.1 hPa	31 km globally, 62km for the Ensemble of Data Assimilations (EDA), 137 levels to 0.01 hPa

ERA5 compared to ERA-Interim

Output frequency (temporal resolution)	6-hourly analysis fields Forecast fields on surface and pressure levels 3-hourly up to 24 hours, with reduced frequency up to 10 days	Hourly analysis fields, 3-hourly for the Ensemble of Data Assimilations (EDA) Hourly forecast fields, 3-hourly for the Ensemble of Data Assimilations (EDA), up to 18 hours, with reduced frequency up to 10 days (not in initial release)
Uncertainty estimates	None	From a 10-member Ensemble of Data Assimilations (EDA) at 63 km resolution

ERA5 compared to ERA-Interim

Model input	As in operations (inconsistent SST)	Appropriate for climate (e.g. CMIP5 greenhouse gases, volcanic eruptions, SST and sea-ice cover)
Input observations	As in ERA-40 and from Global Telecommunication System	In addition, various newly reprocessed datasets and recent instruments that could not be ingested in ERA-Interim
Variational bias scheme	Satellite radiances	Also ozone, aircraft and surface pressure data
Satellite data	RTTOV-7, clear-sky, 1D-VAR rainy radiances	RTTOV-11, all-sky for various components

ERA5 compared to ERA-Interim

Handling of accumulated parameters	Accumulated from the beginning of the forecast	Accumulated from previous post-processing
Additional innovations		Long-term evolution of CO2 in RTTOV, cell-pressure correction SSU, improved bias correction for radiosondes, EDA perturbations for sea-ice cover

Copenhagen Deluge 2 July 2011

| 44,3 | 30,5 | 42,6 | 48,9 | 41,3 | 26,8 | 44,2 | 26,2 | 12,3 | 16,9 | 15,1 | 11,1 |
28,0	41,0	46,1	36,3	66,1	41,8	50,7	37,7	20,7	17,0	24,9	46,3
27,5	32,8	30,6	38,6	47,6	59,5	84,0	100,5	60,4	57,0	53,9	48,4
43,2	42,1	39,8	31,8	75,3	88,2	80,9	87,1	96,5	95,9	161,5	50,8
39,7	71,7	91,3	61,4	60,9	104,3	78,8	155,8	123,1	115,2	101,1	73,6
18,0	63,9	62,9	78,7	56,4	76,6	91,0	177,4	121,1	90,0	79,9	55,1
36,4	99,9	109,9	99,7	62,8	78,2	73,4	148,1	163,3	91,0	44,3	58,6
49,7	92,3	94,5	76,9	78,1	80,5	100,5	99,5	84,1	58,1	38,9	65,3
89,9	131,4	87,8	84,0	62,8	43,1	58,0	61,6	55,4	36,3	36,7	37,2
101,7	118,6	75,9	44,0	37,1	39,9	35,6	33,9	32,0	50,0	40,3	28,1
65,2	78,8	65,4	33,7	33,1	33,6	31,1	26,2	28,2	45,7	51,5	28,5

Rain sum 06Z02JUL2011 – 06Z03JUL2011

Rain sum 06Z02JUL2011 – 07Z02JUL2011
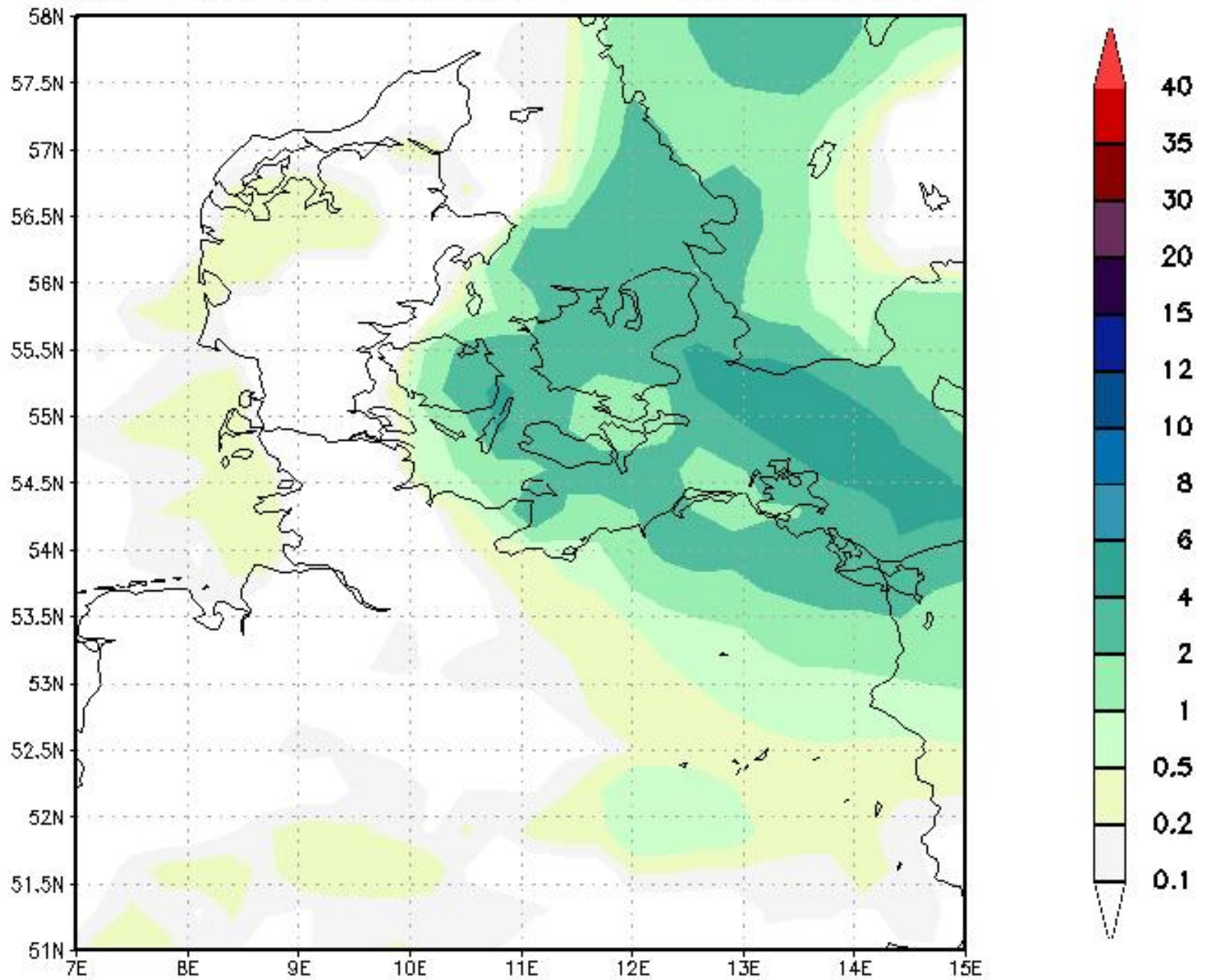
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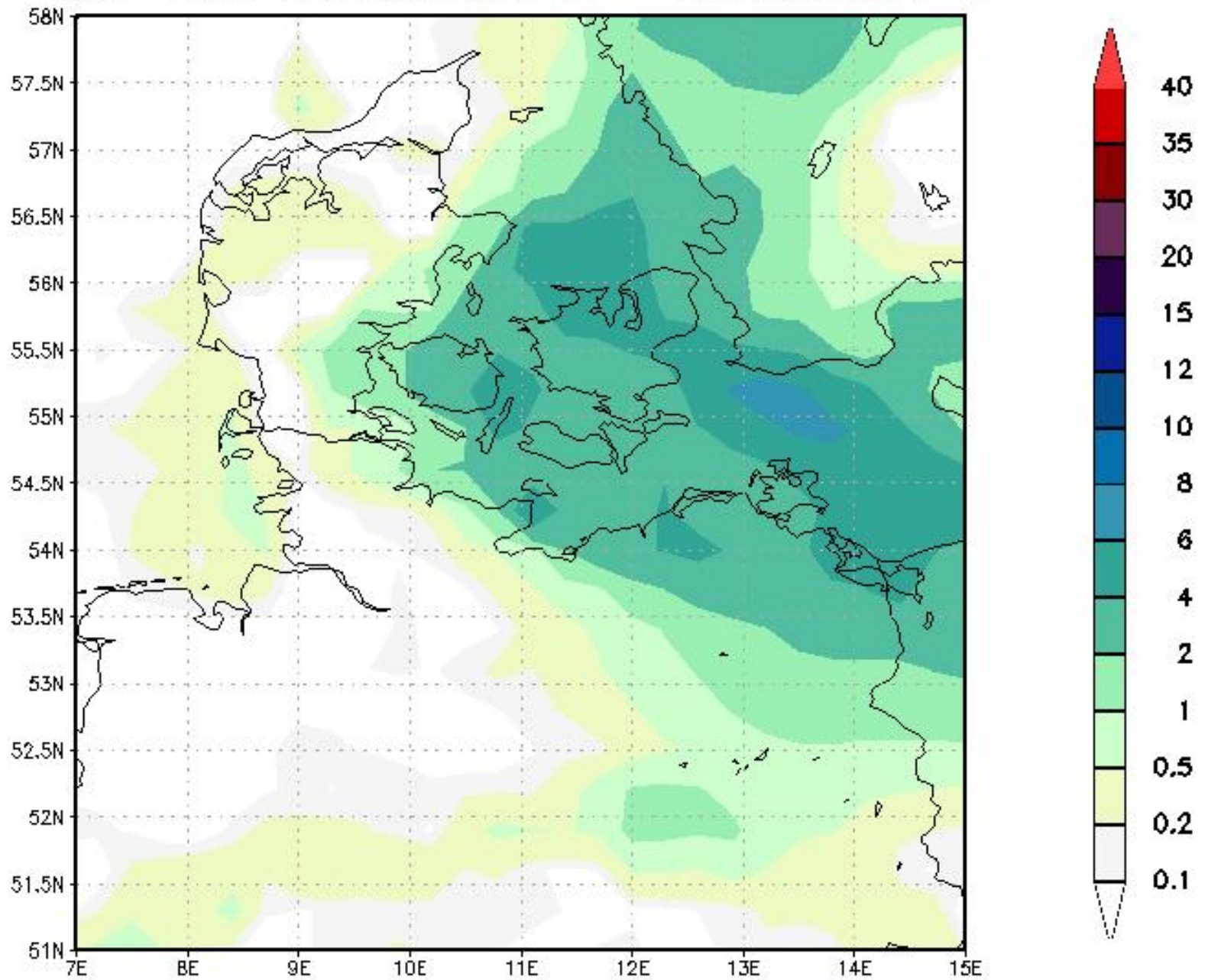
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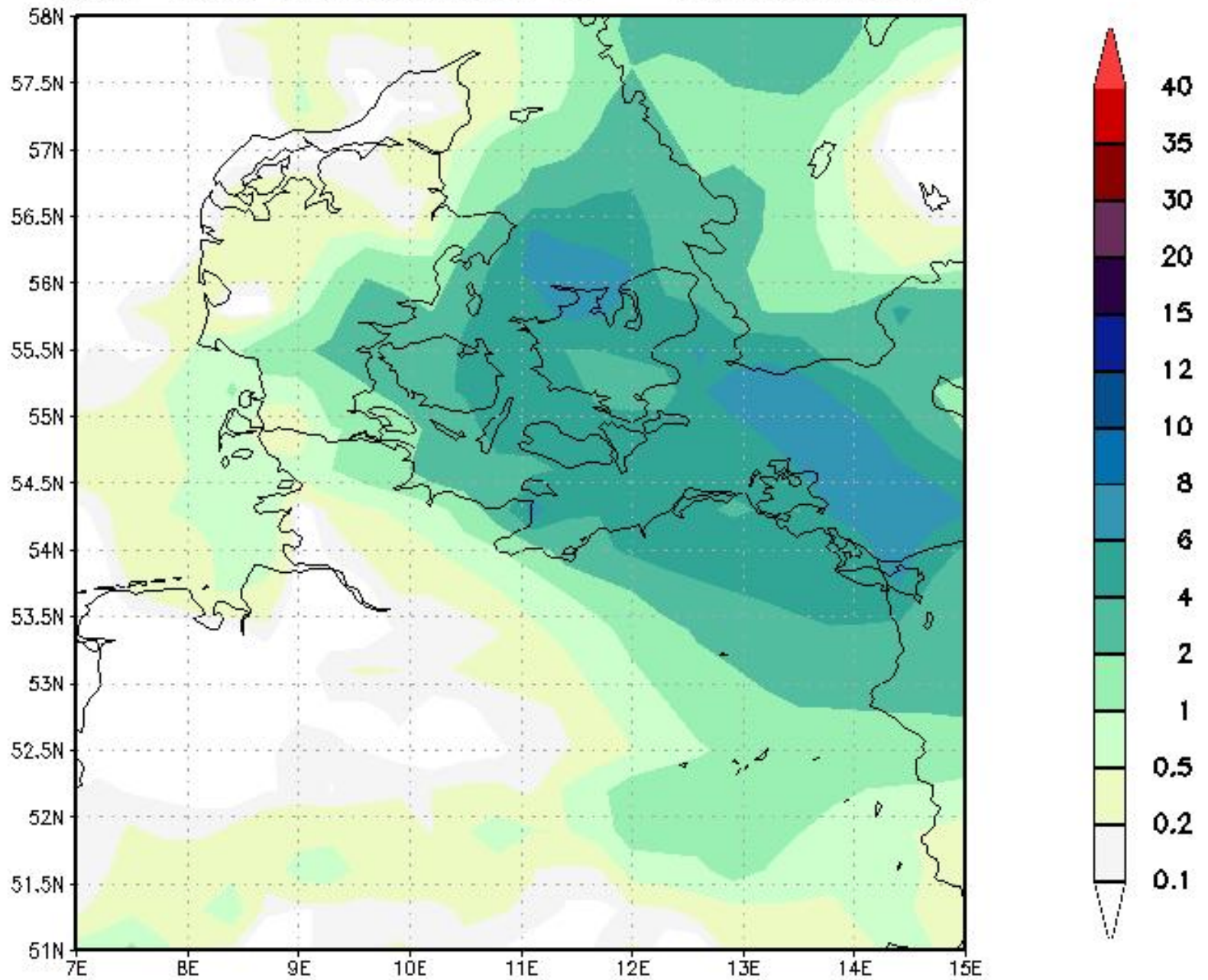
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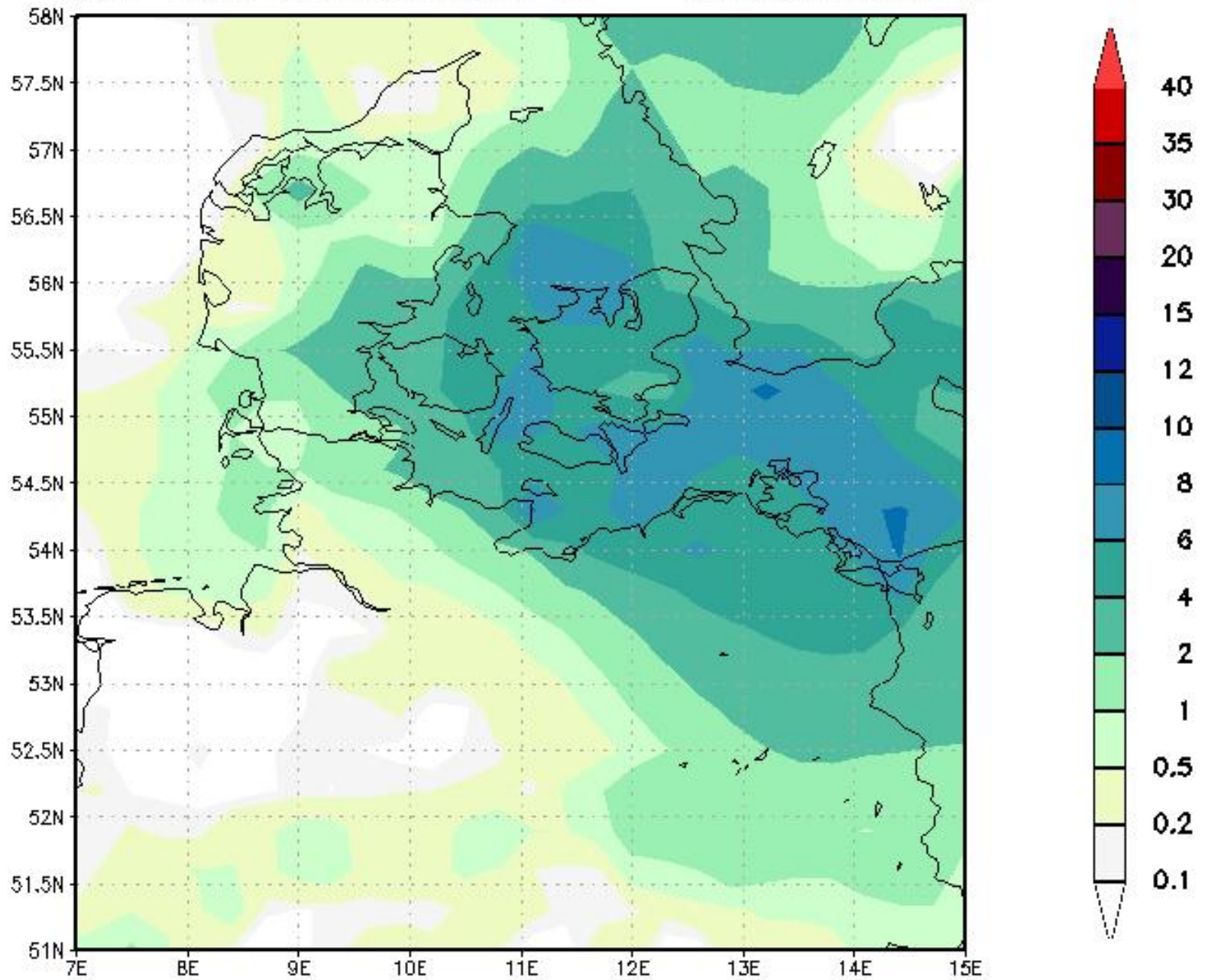
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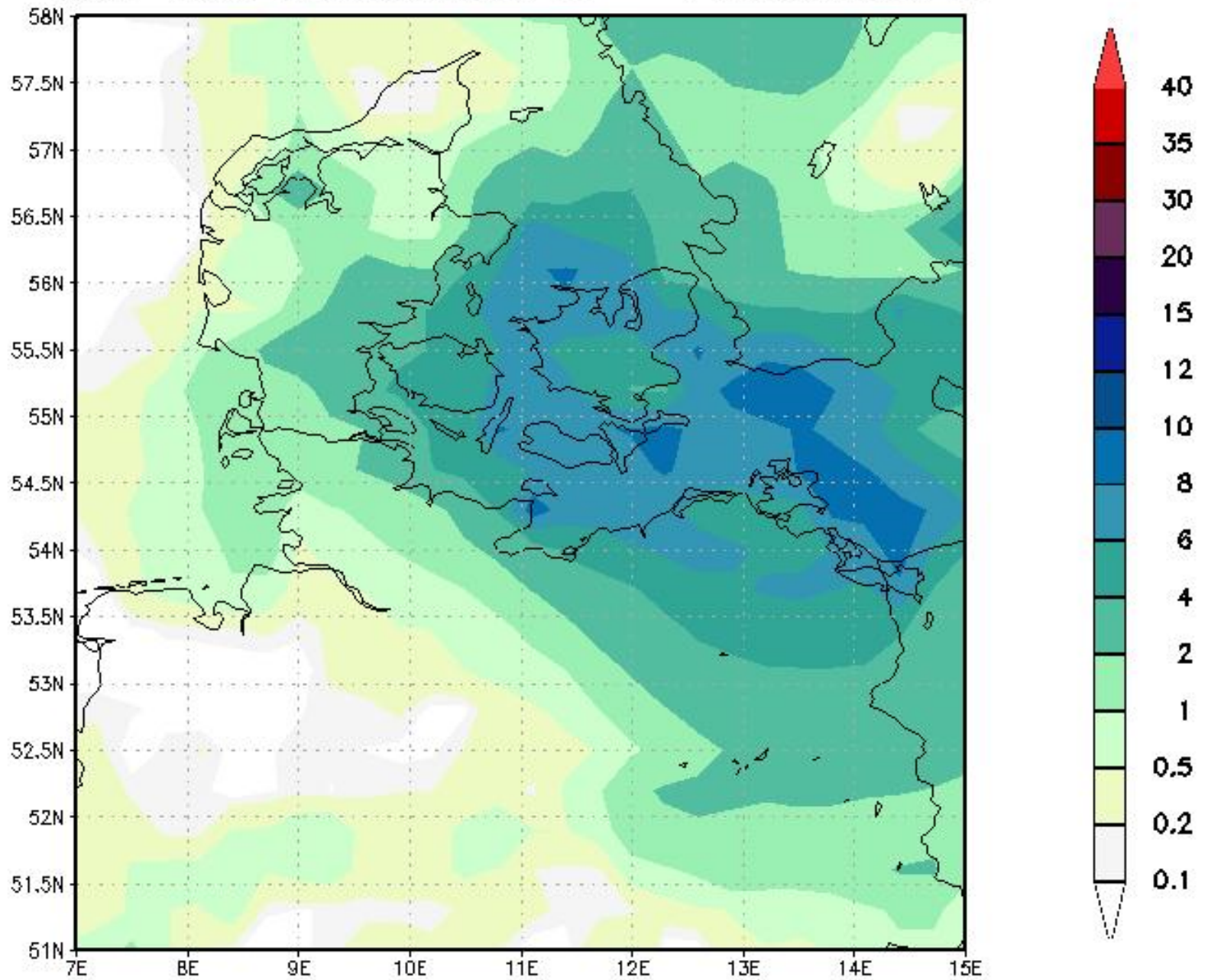
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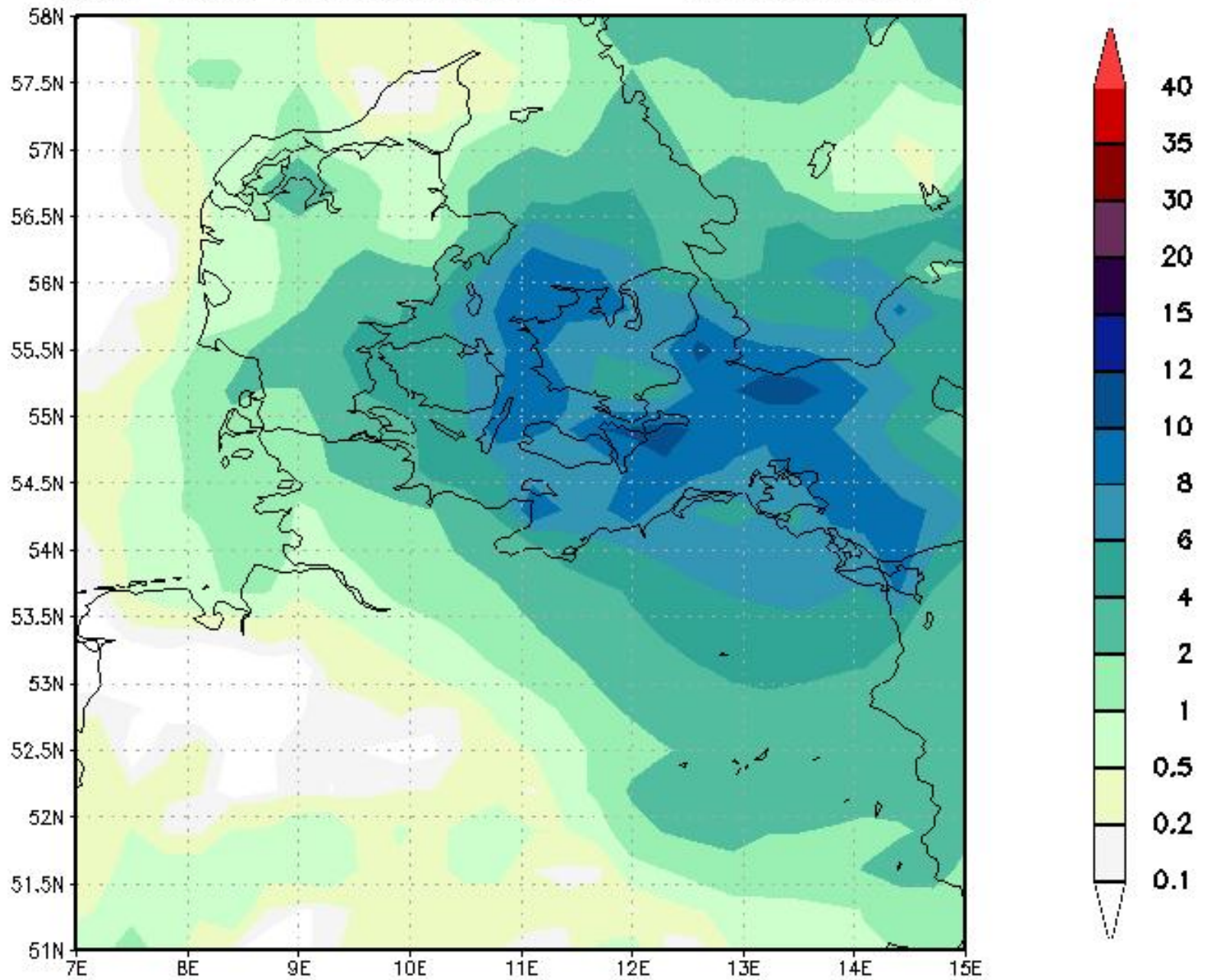
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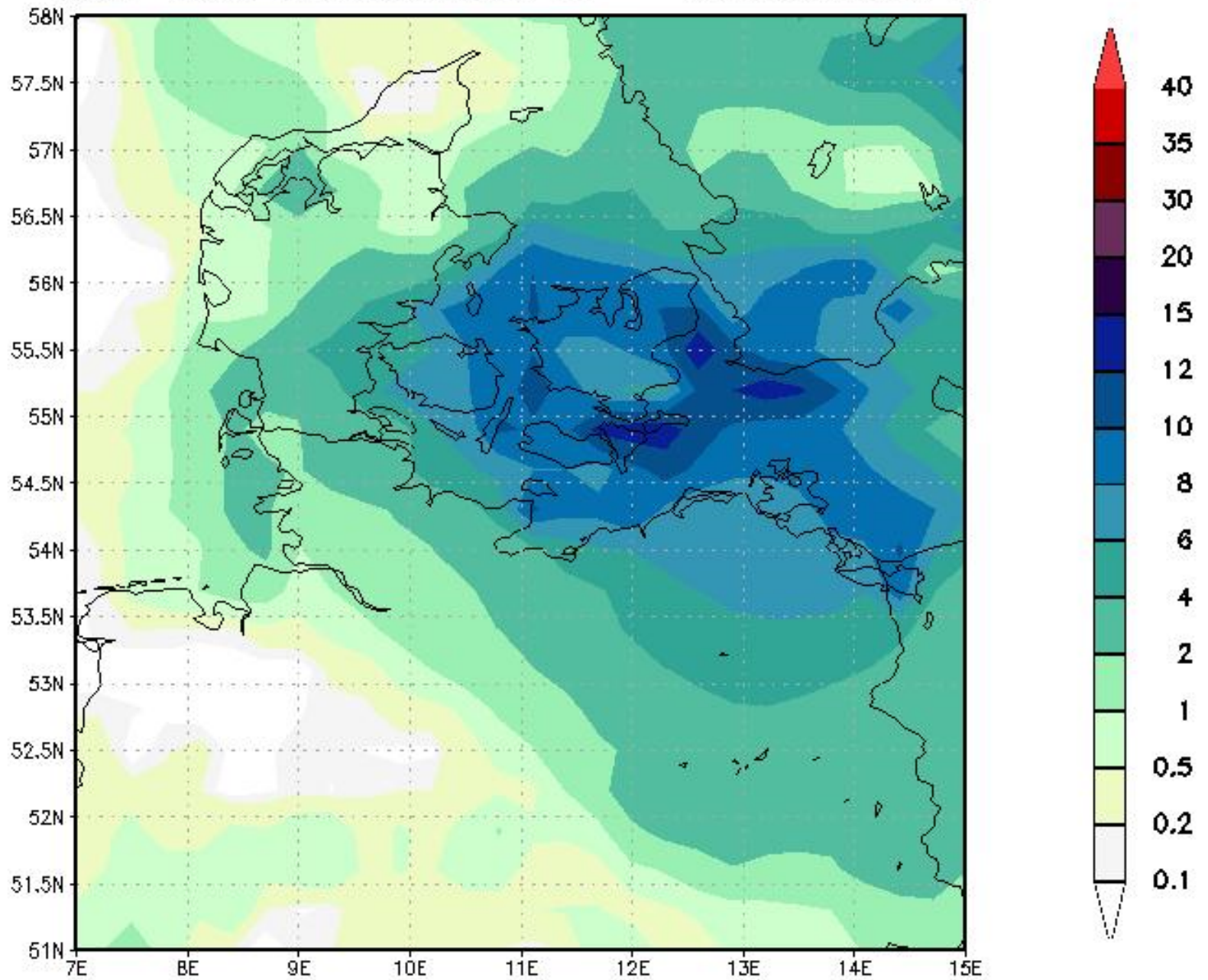
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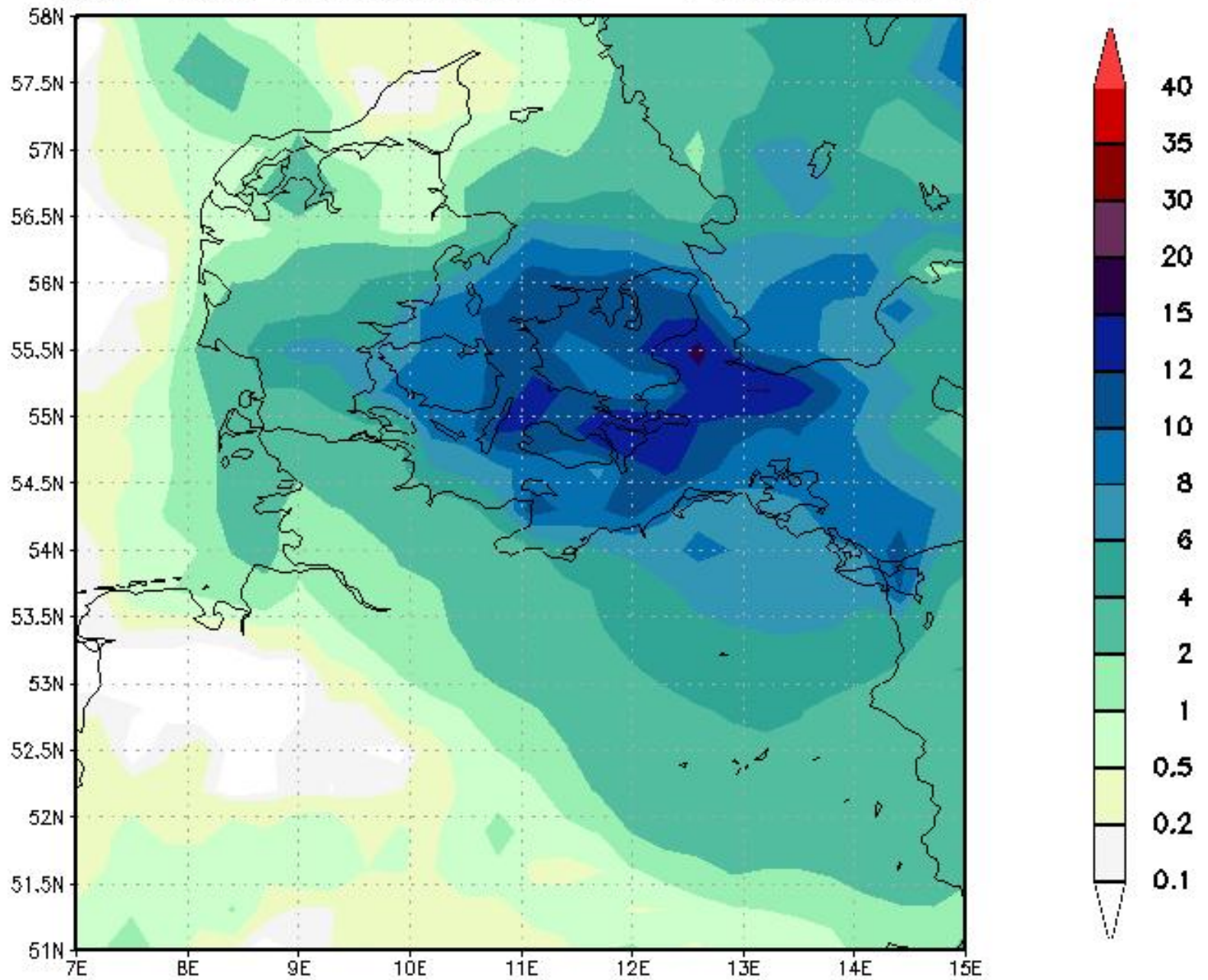
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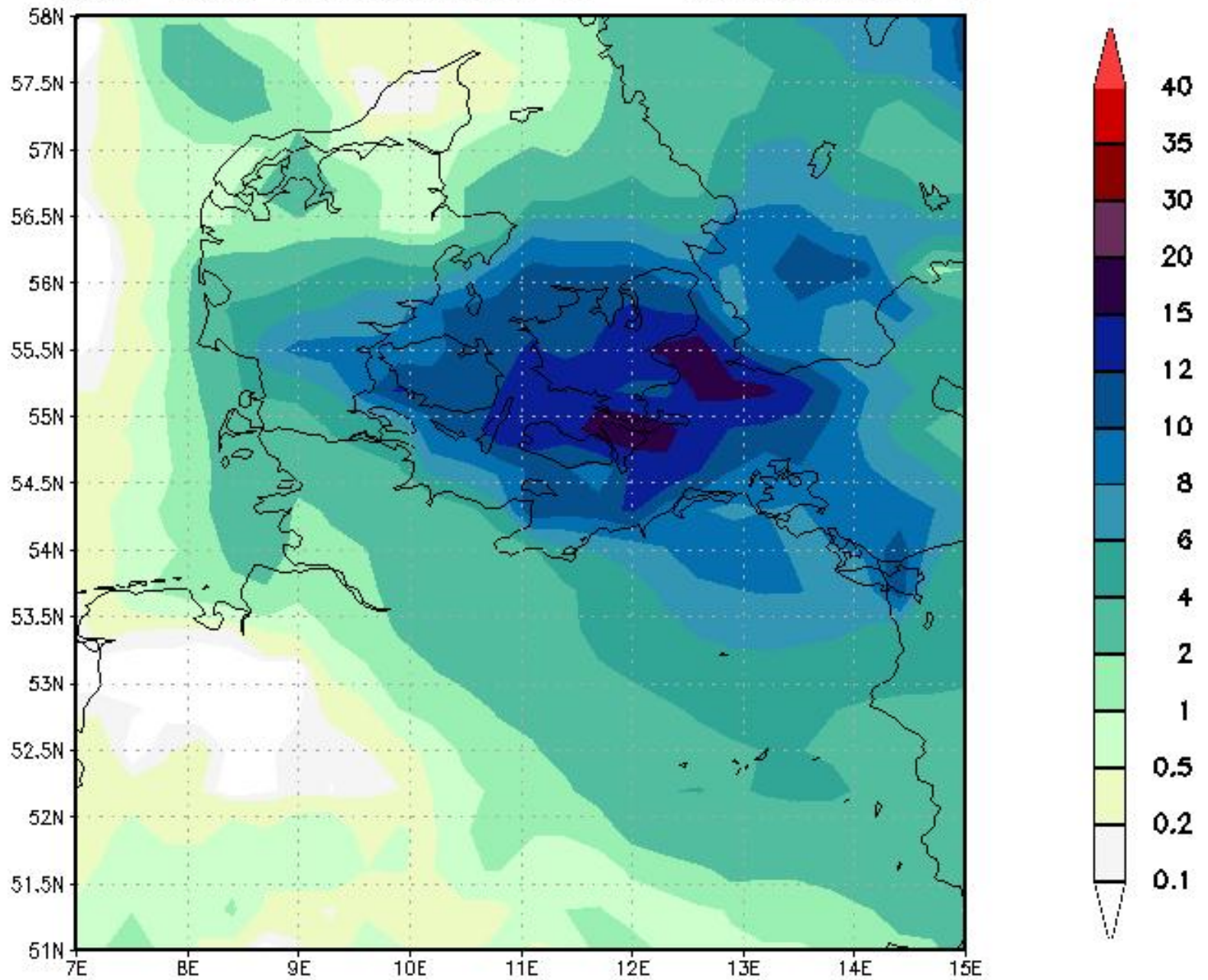
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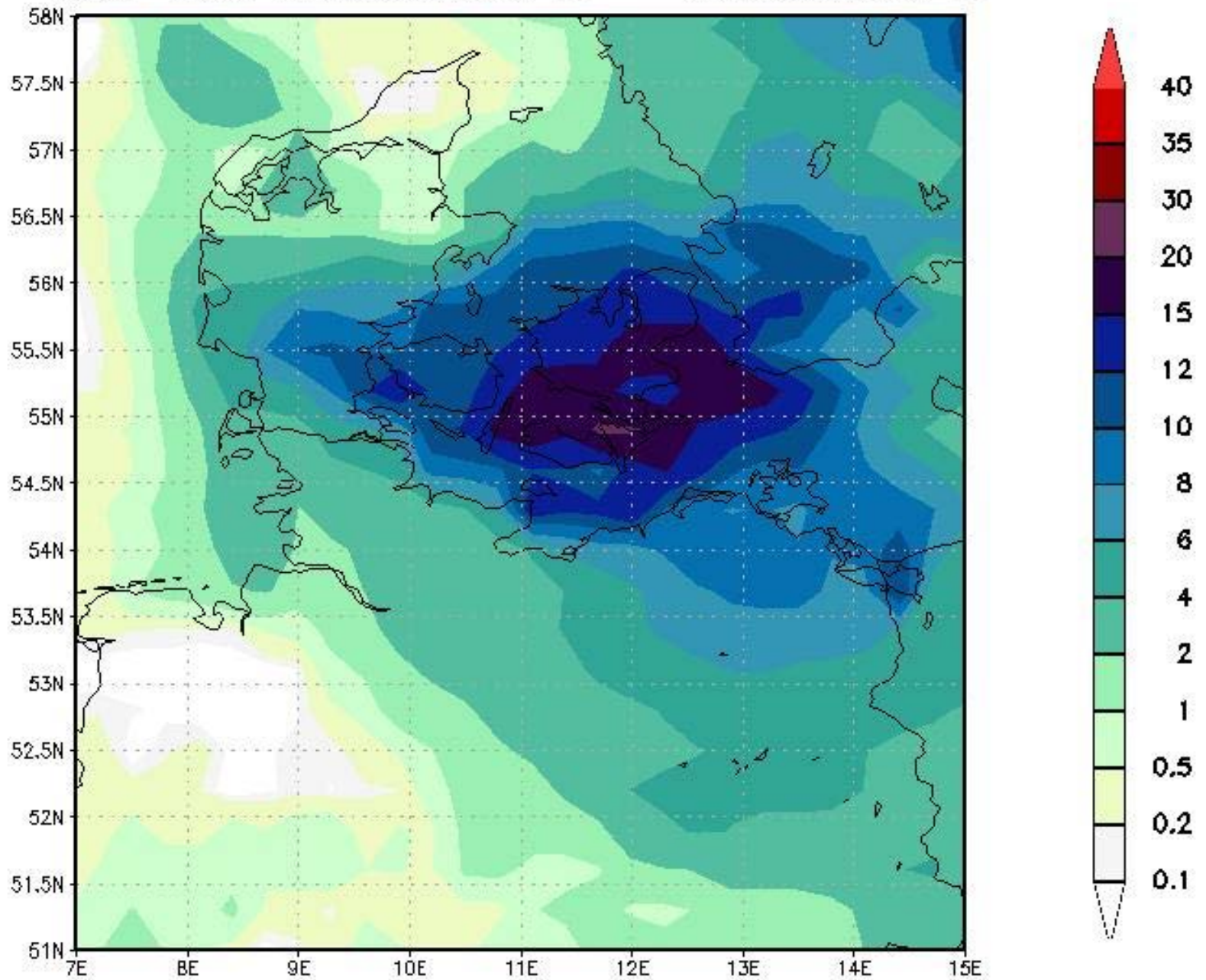
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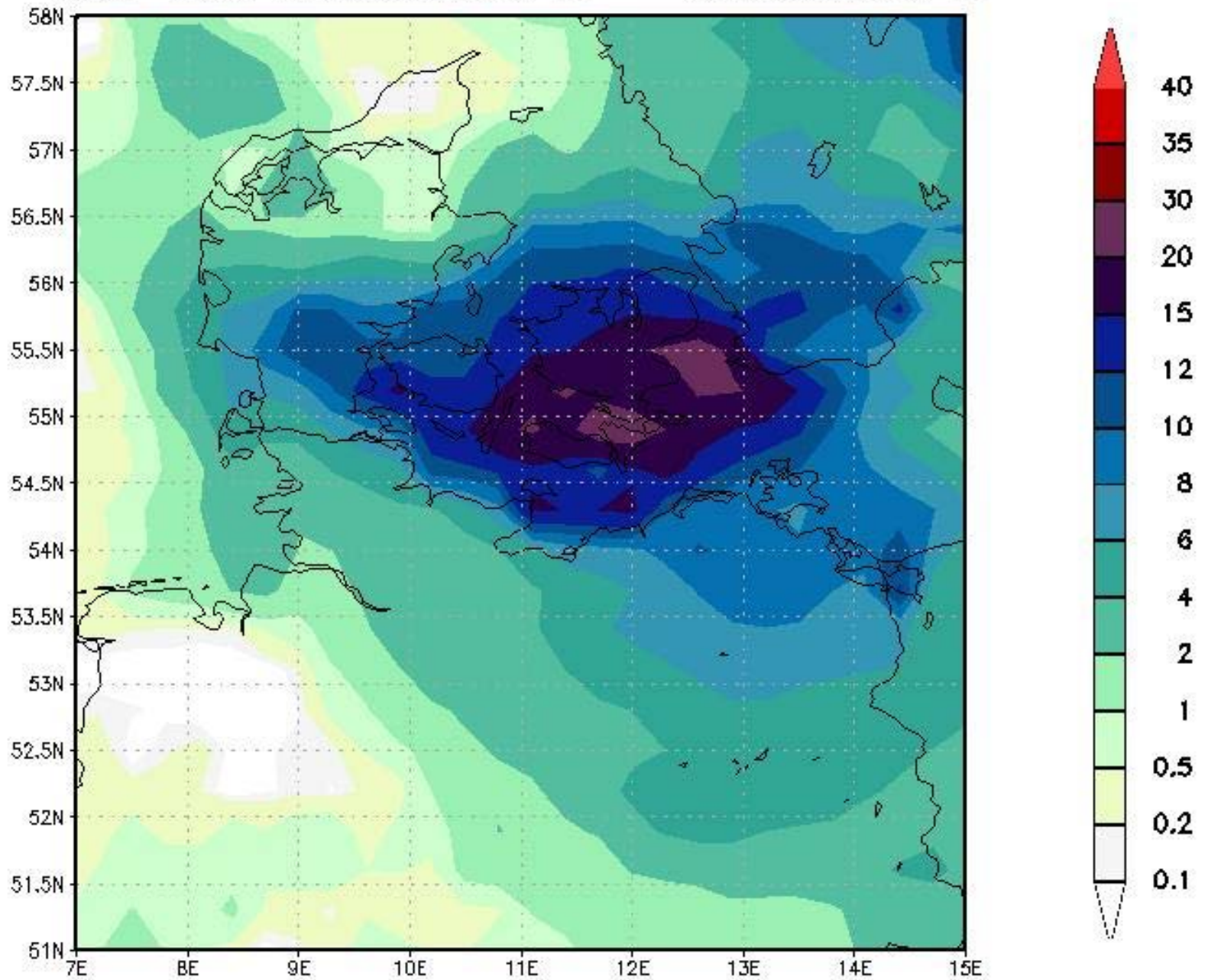
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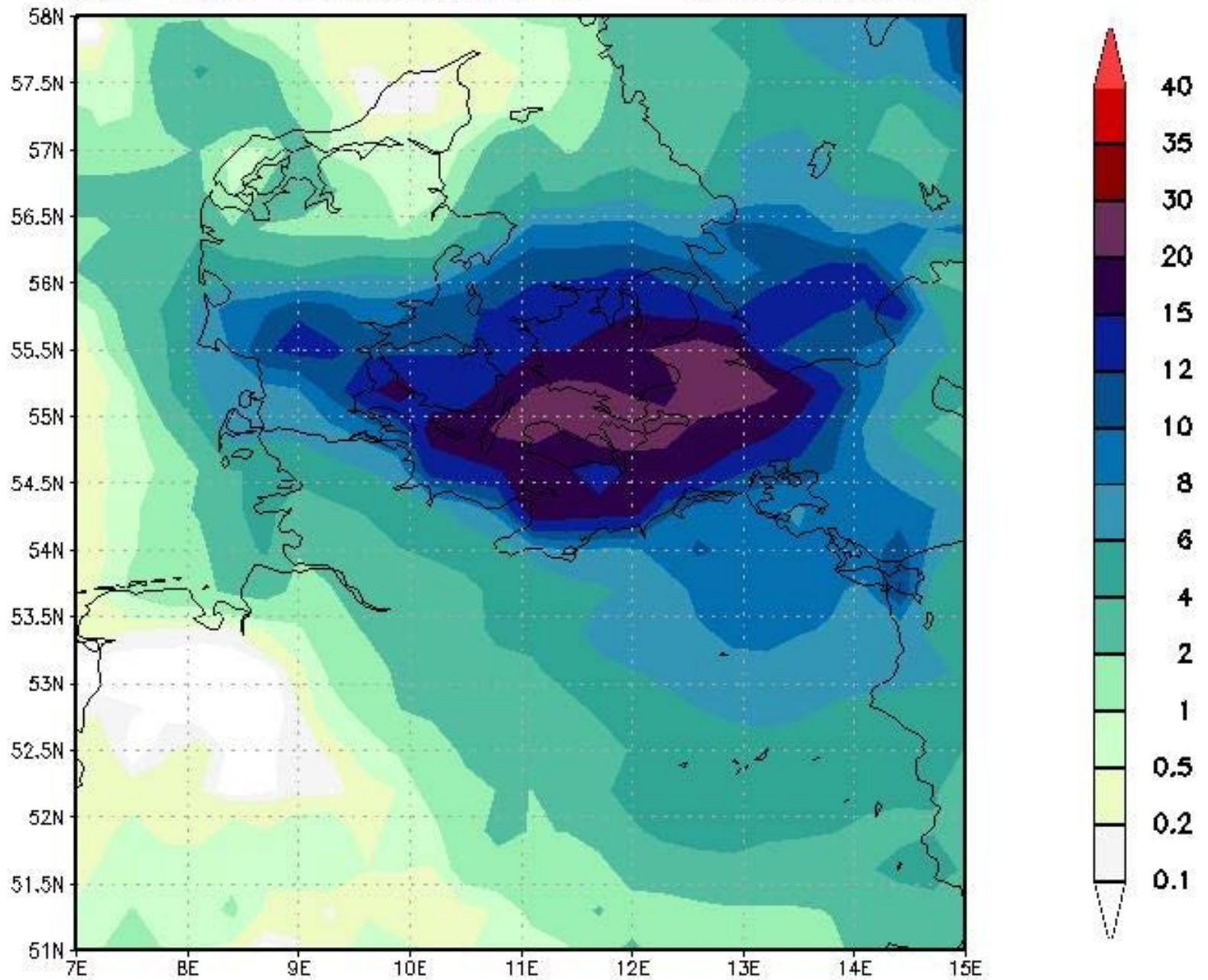
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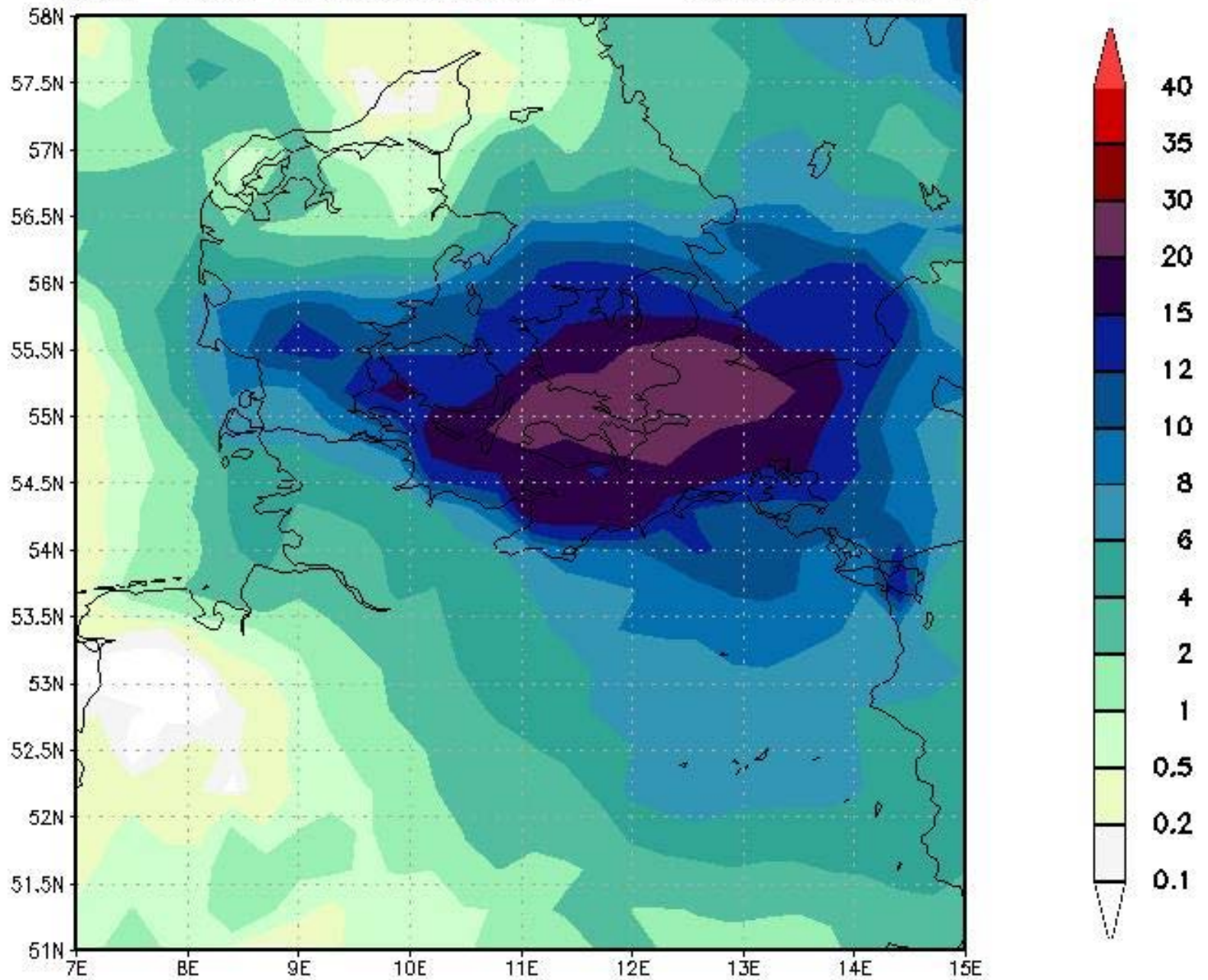
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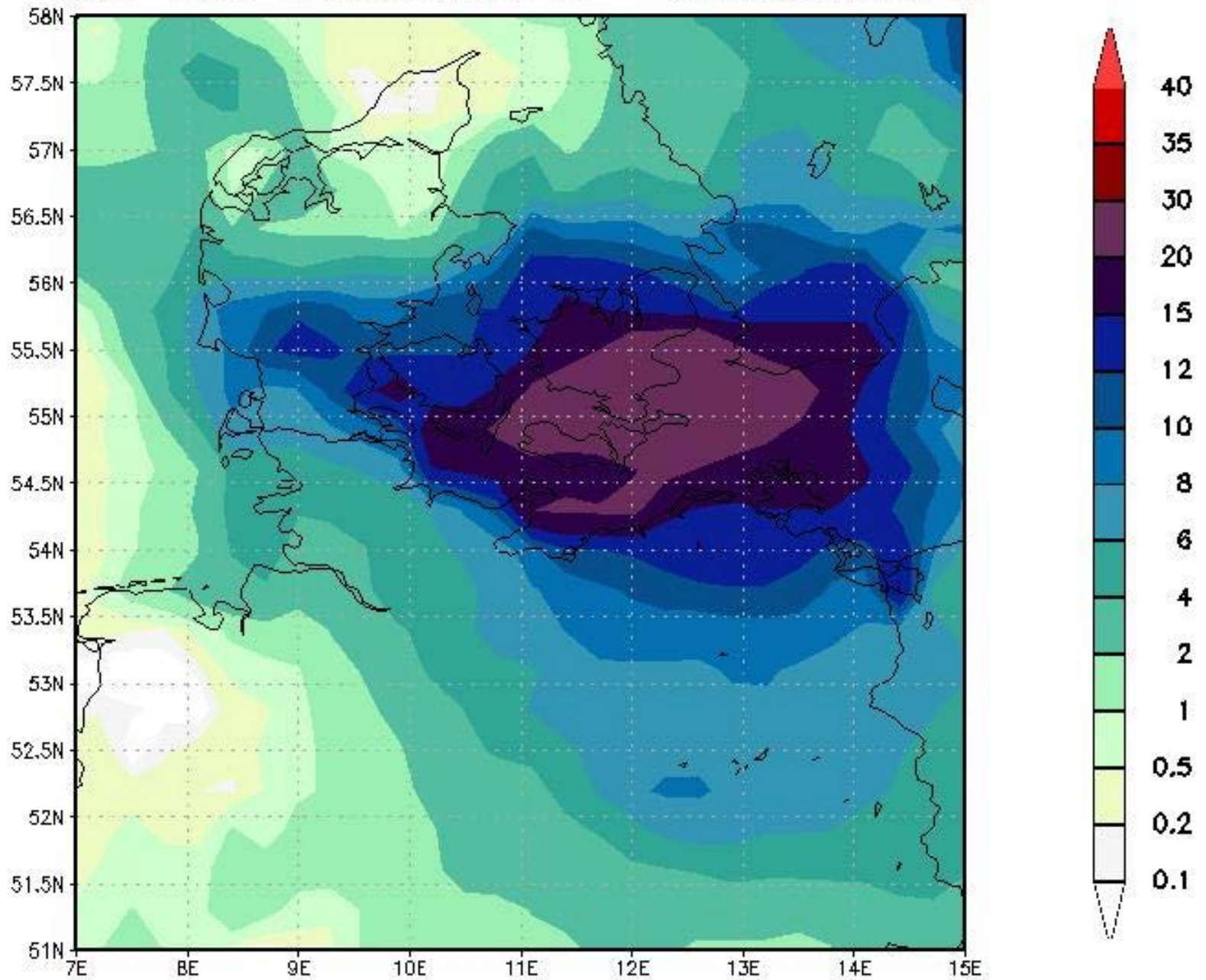
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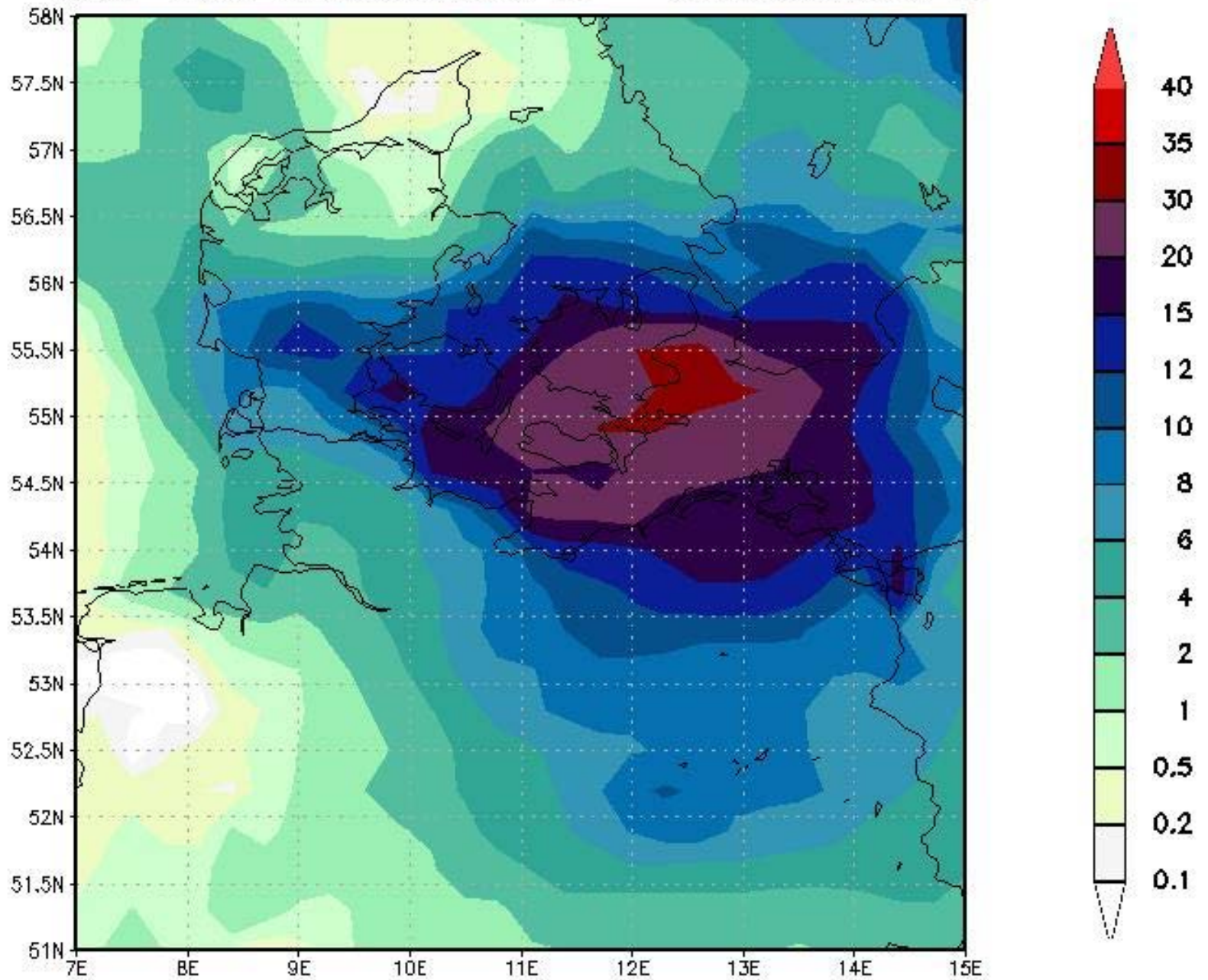
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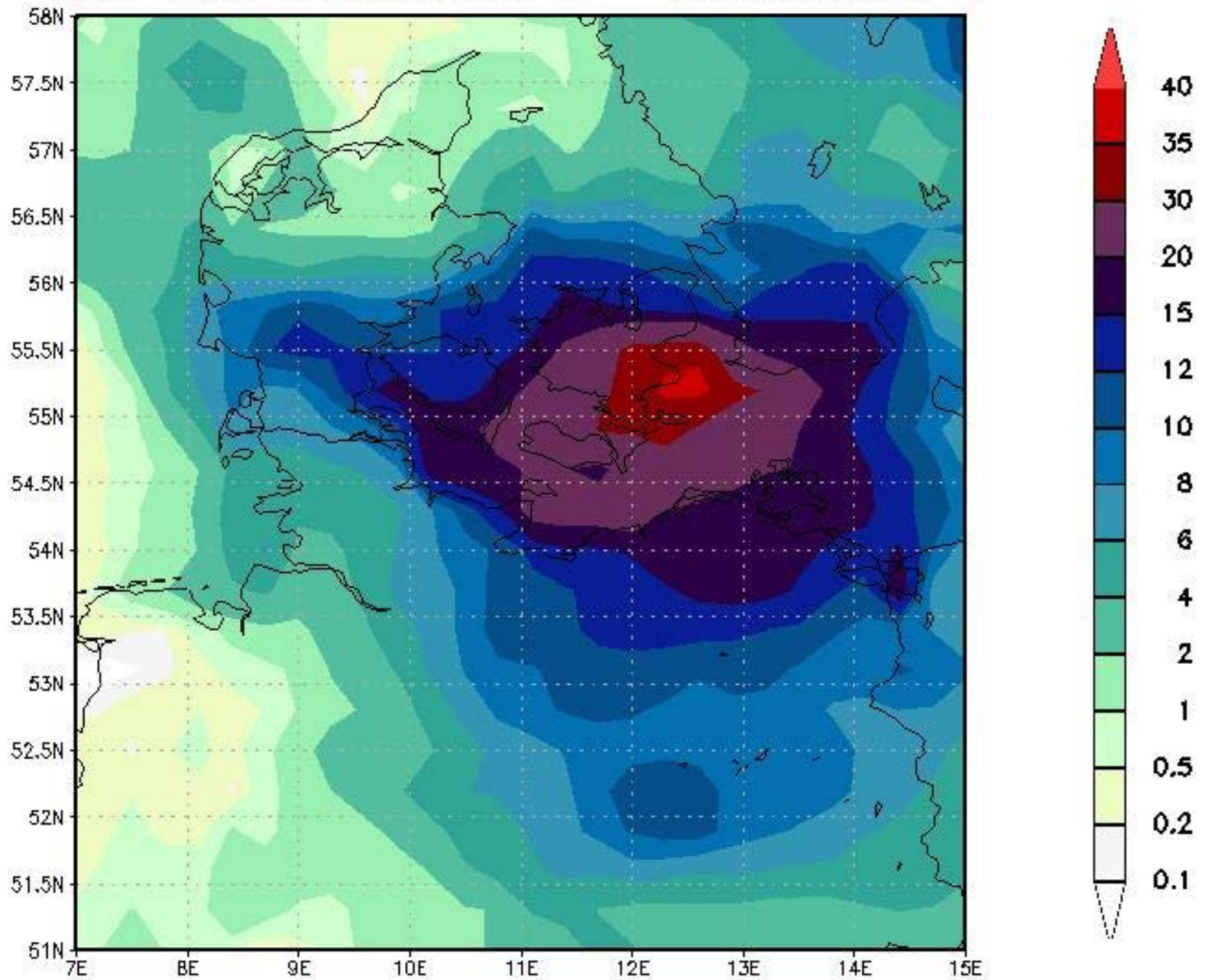
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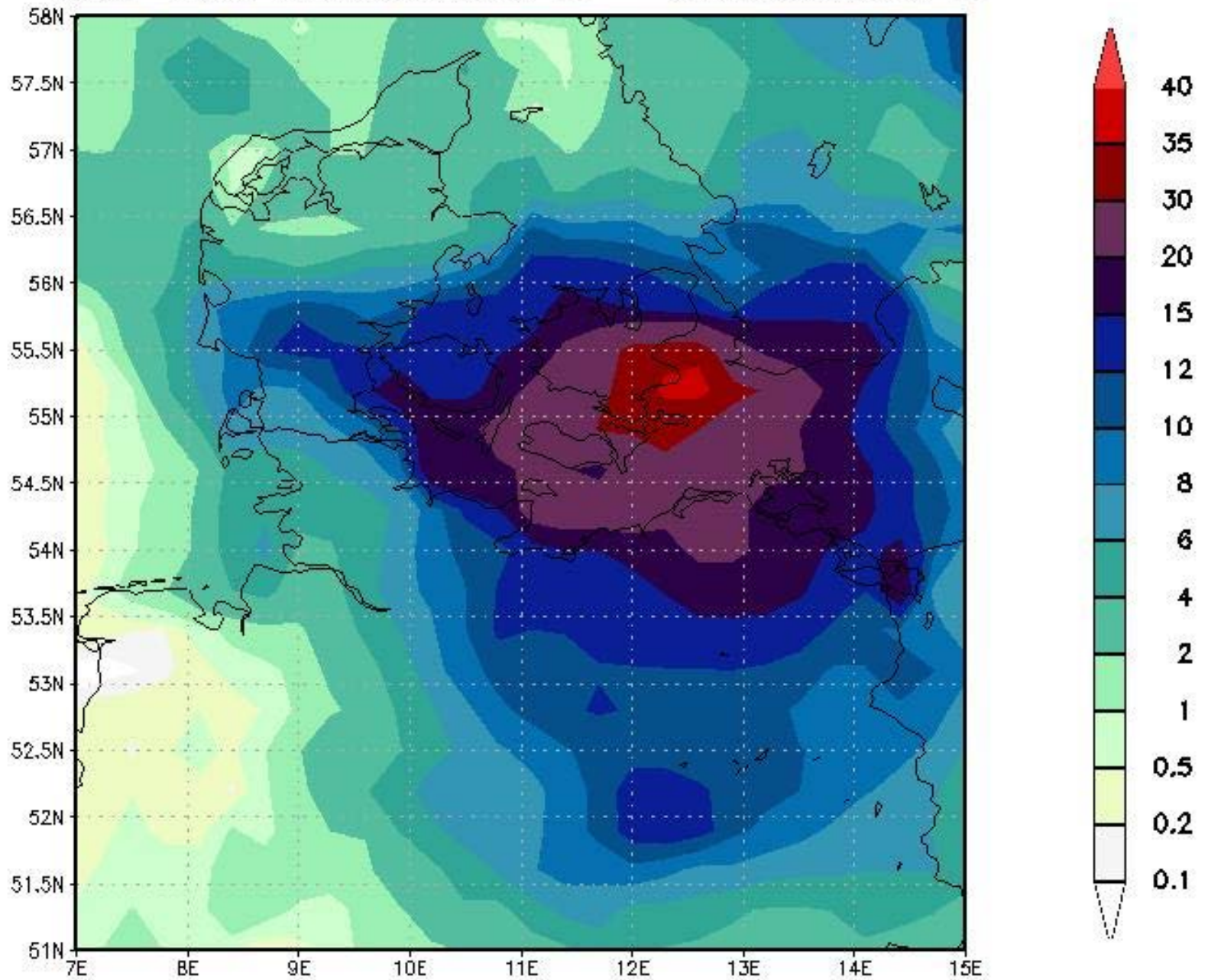
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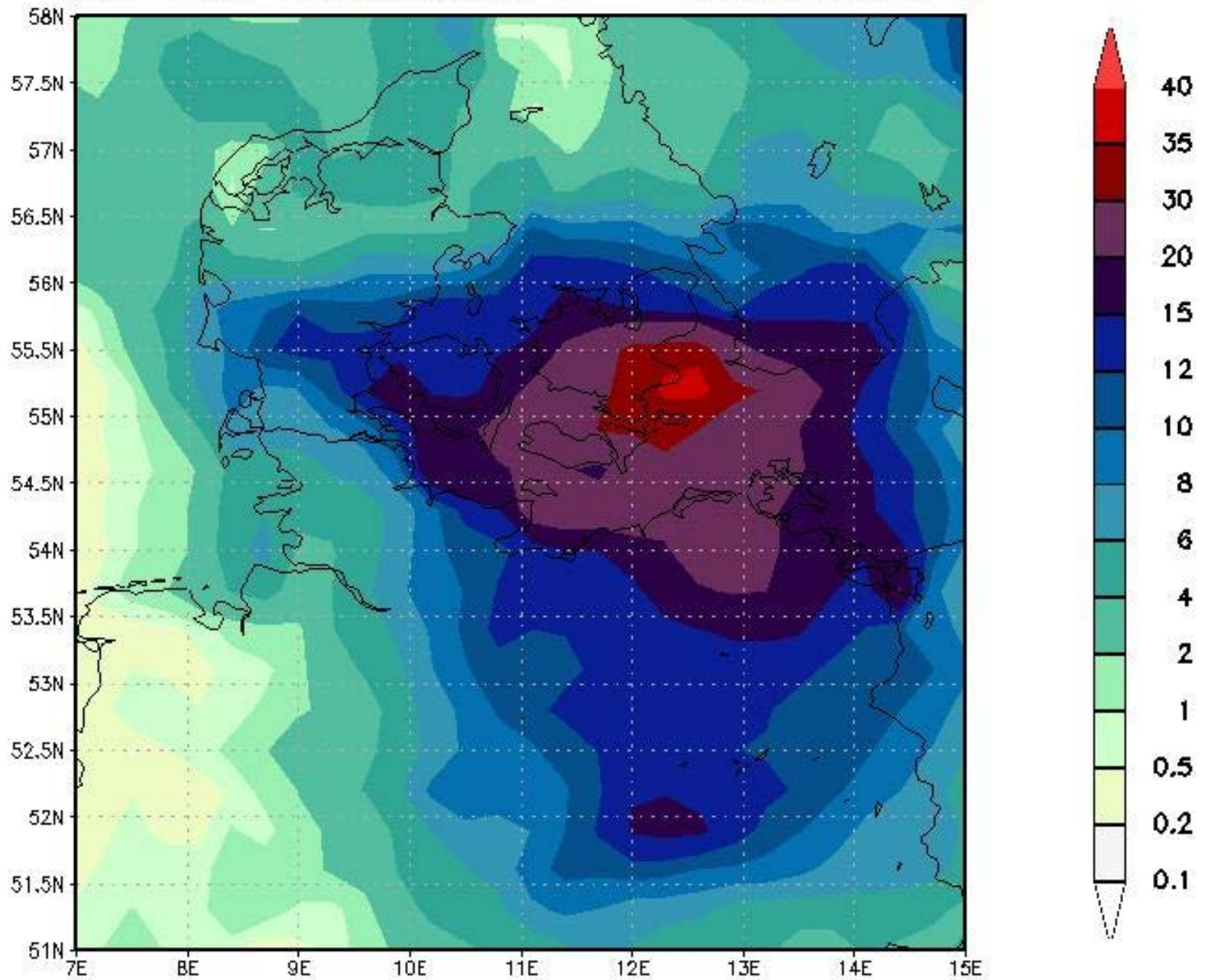
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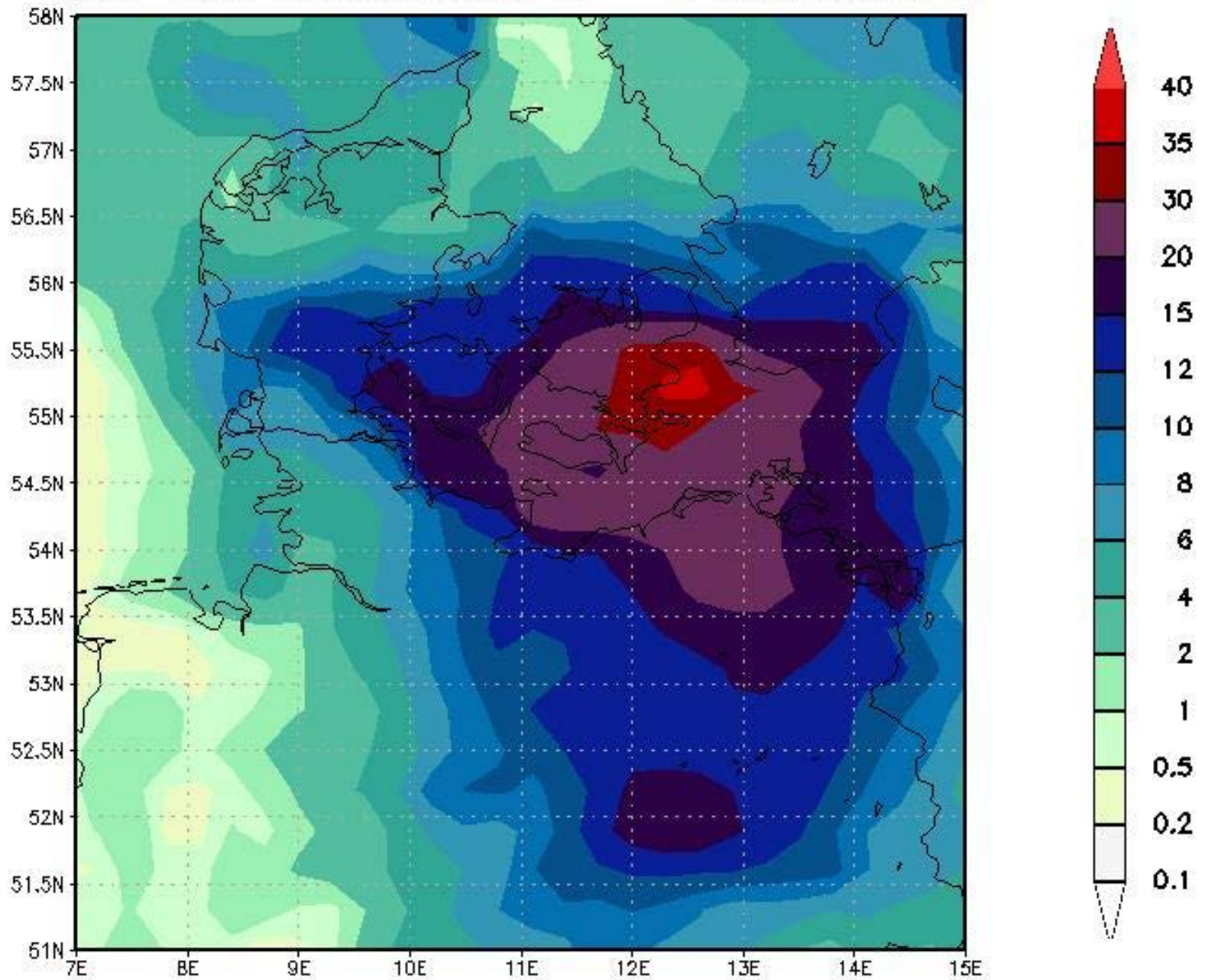
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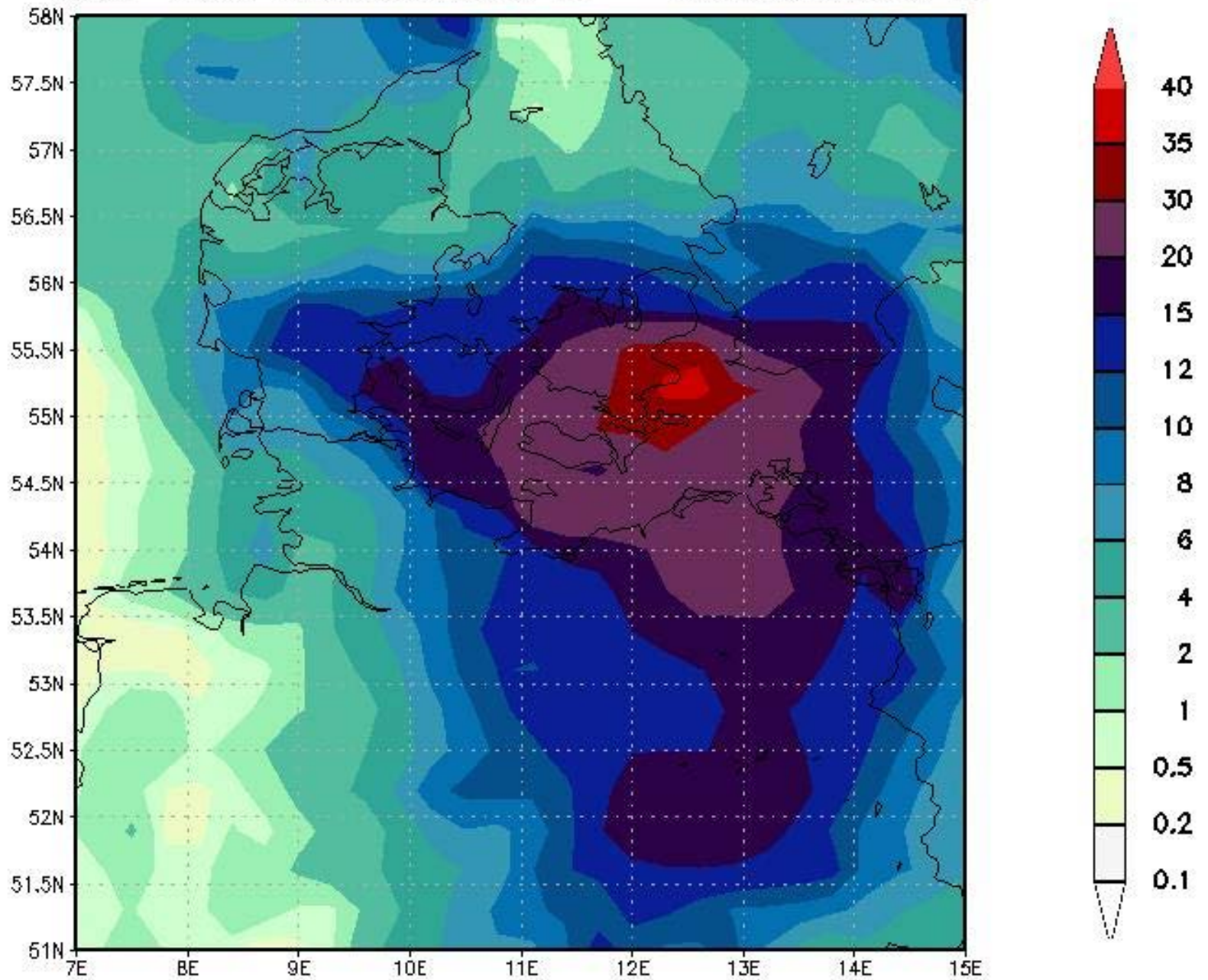
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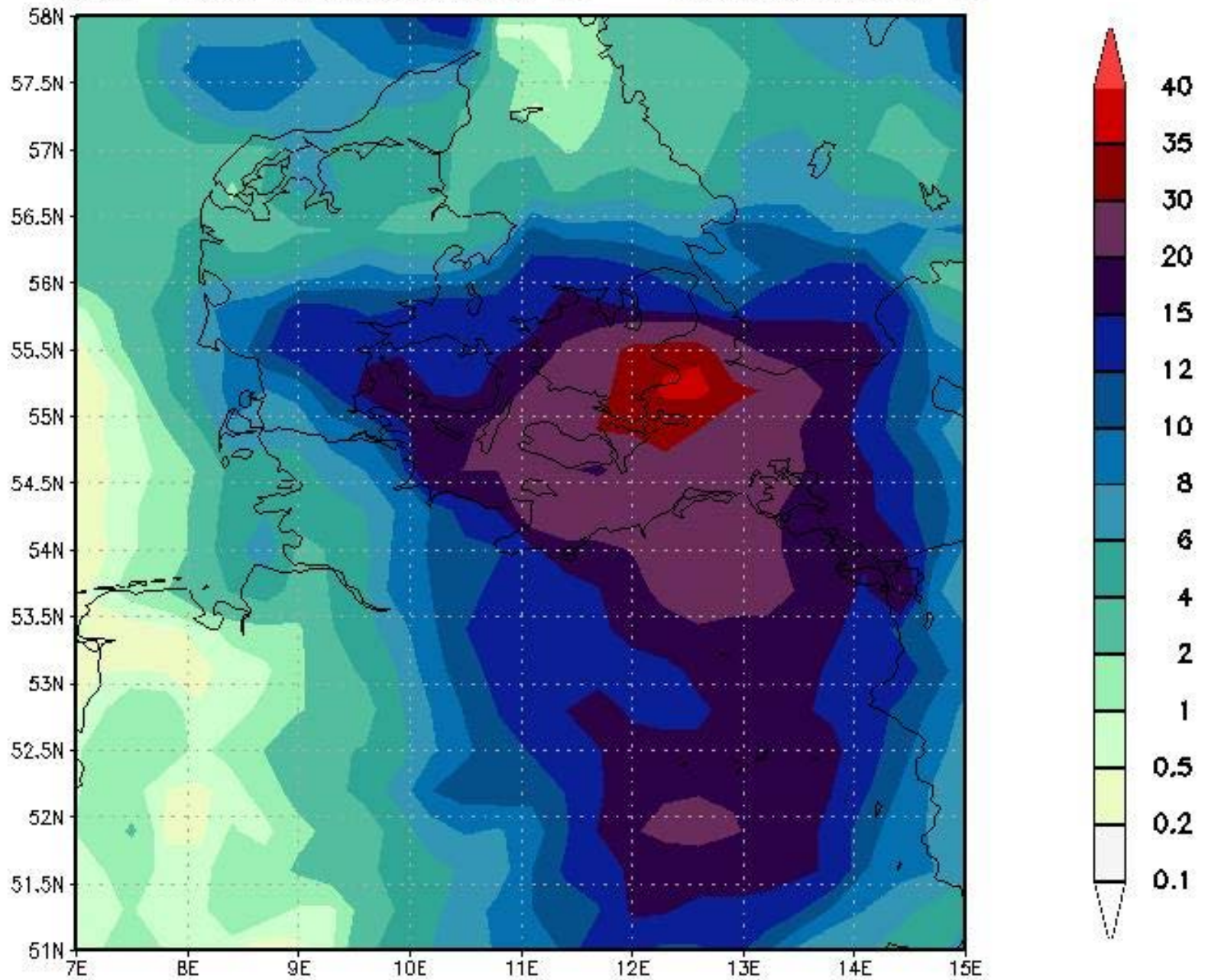
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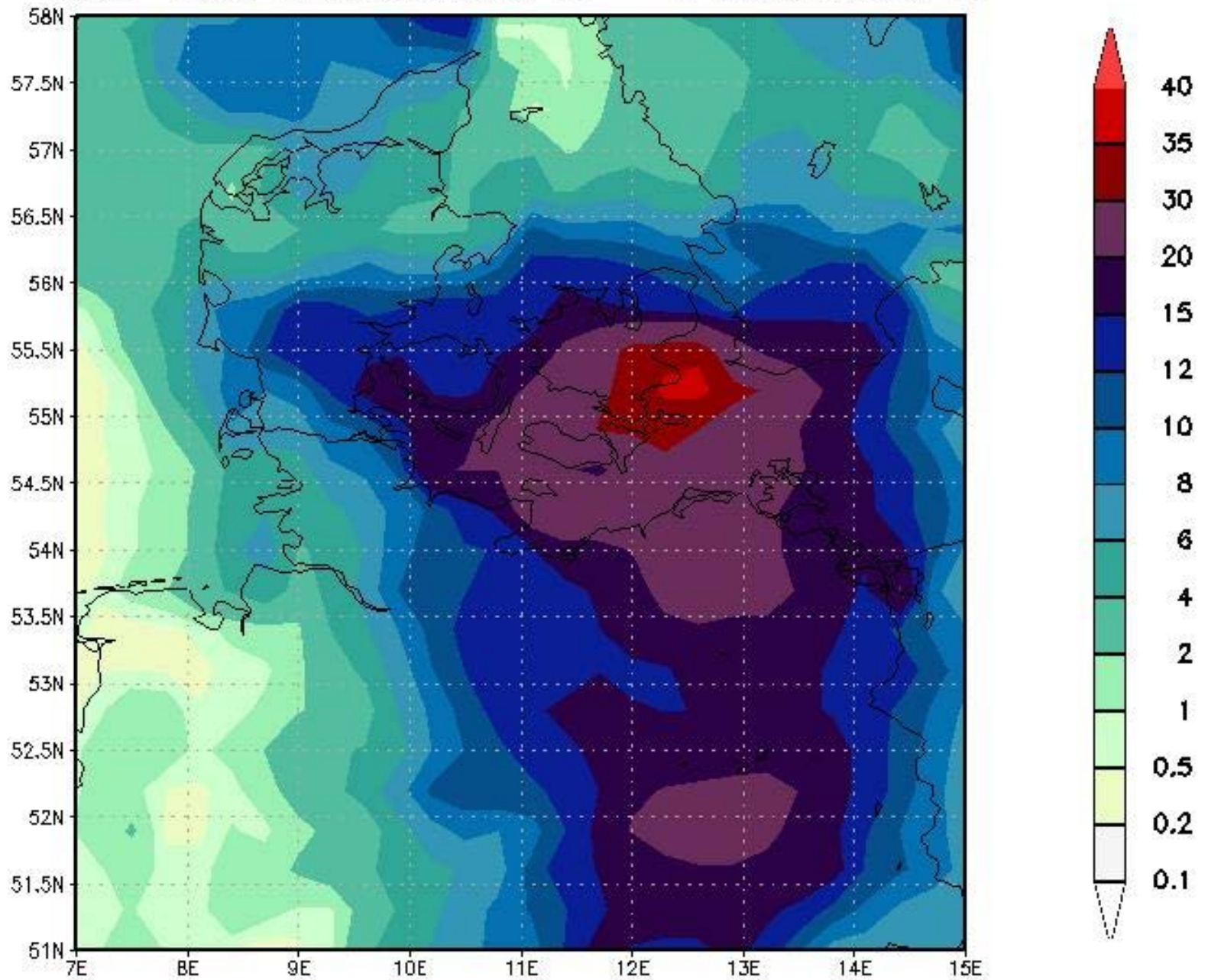
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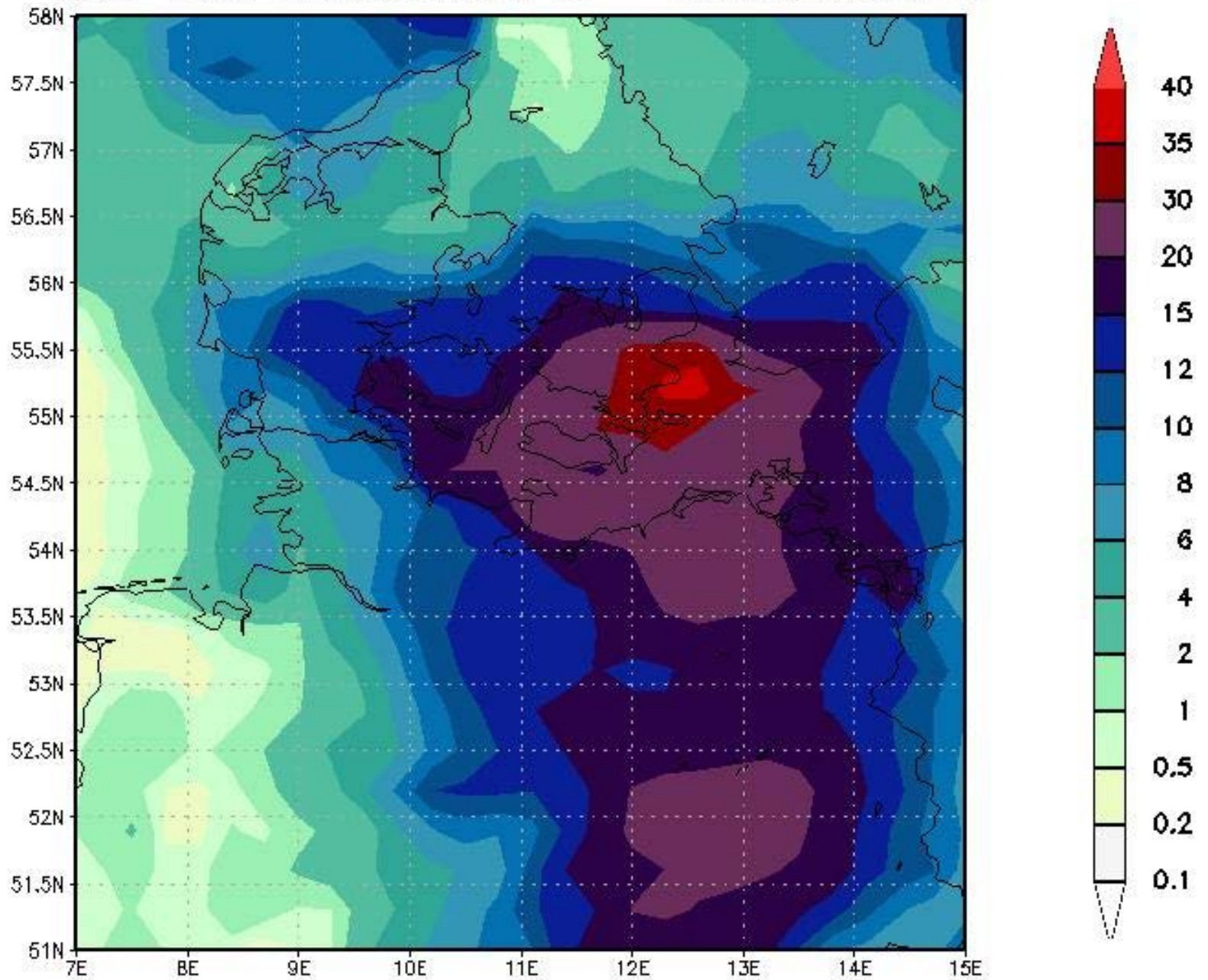
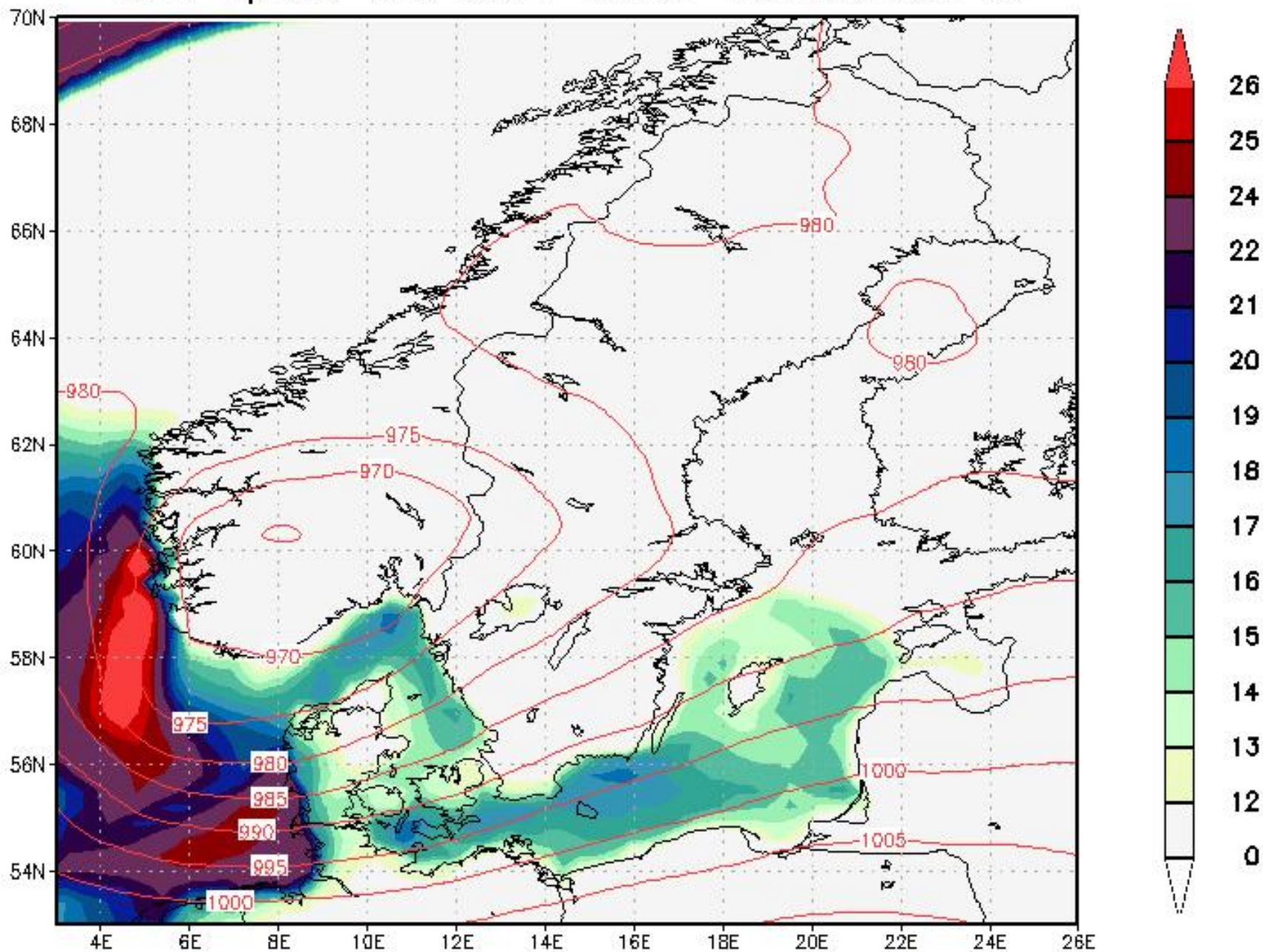Rain sum 06Z02JUL2011 – 06Z03JUL2011
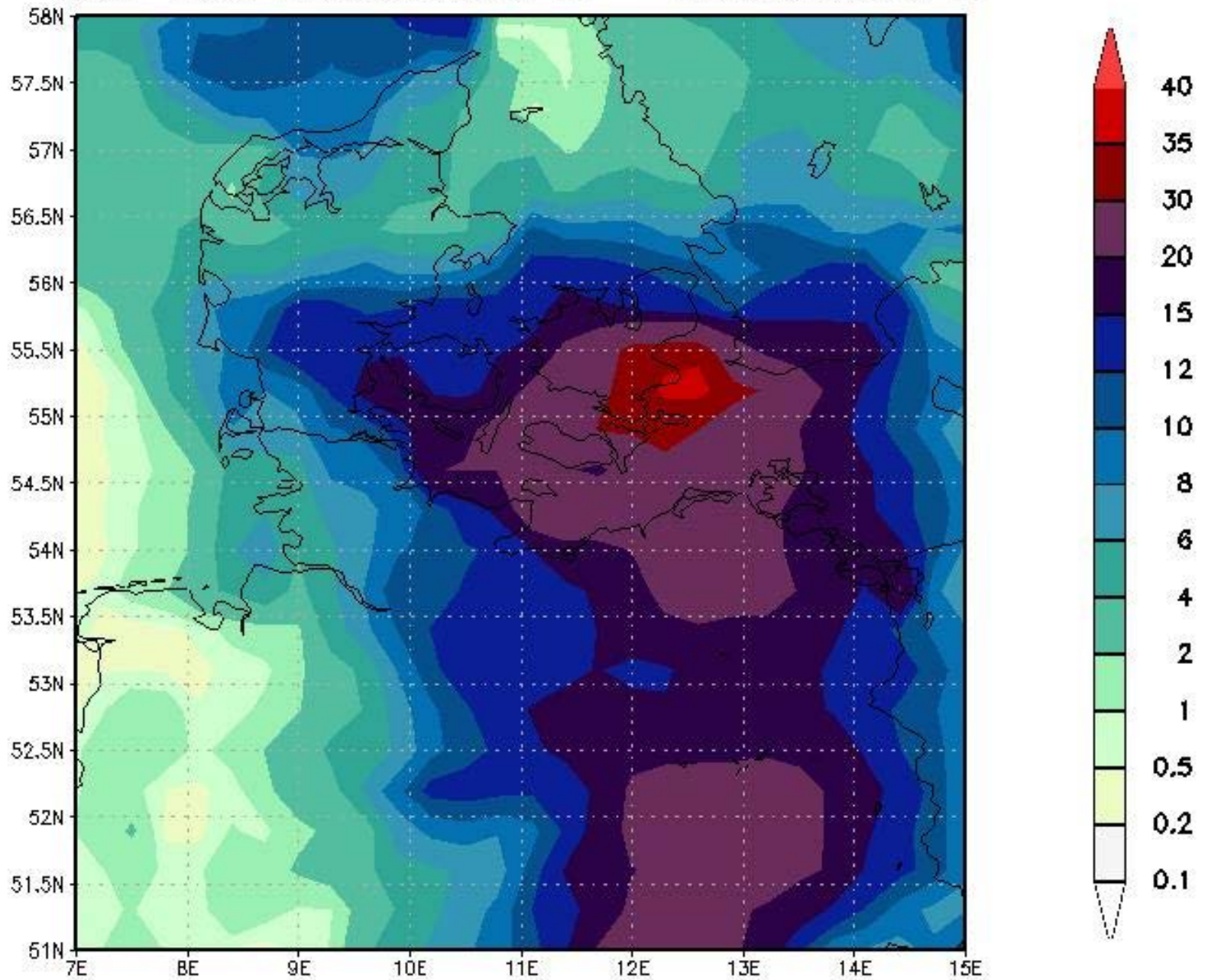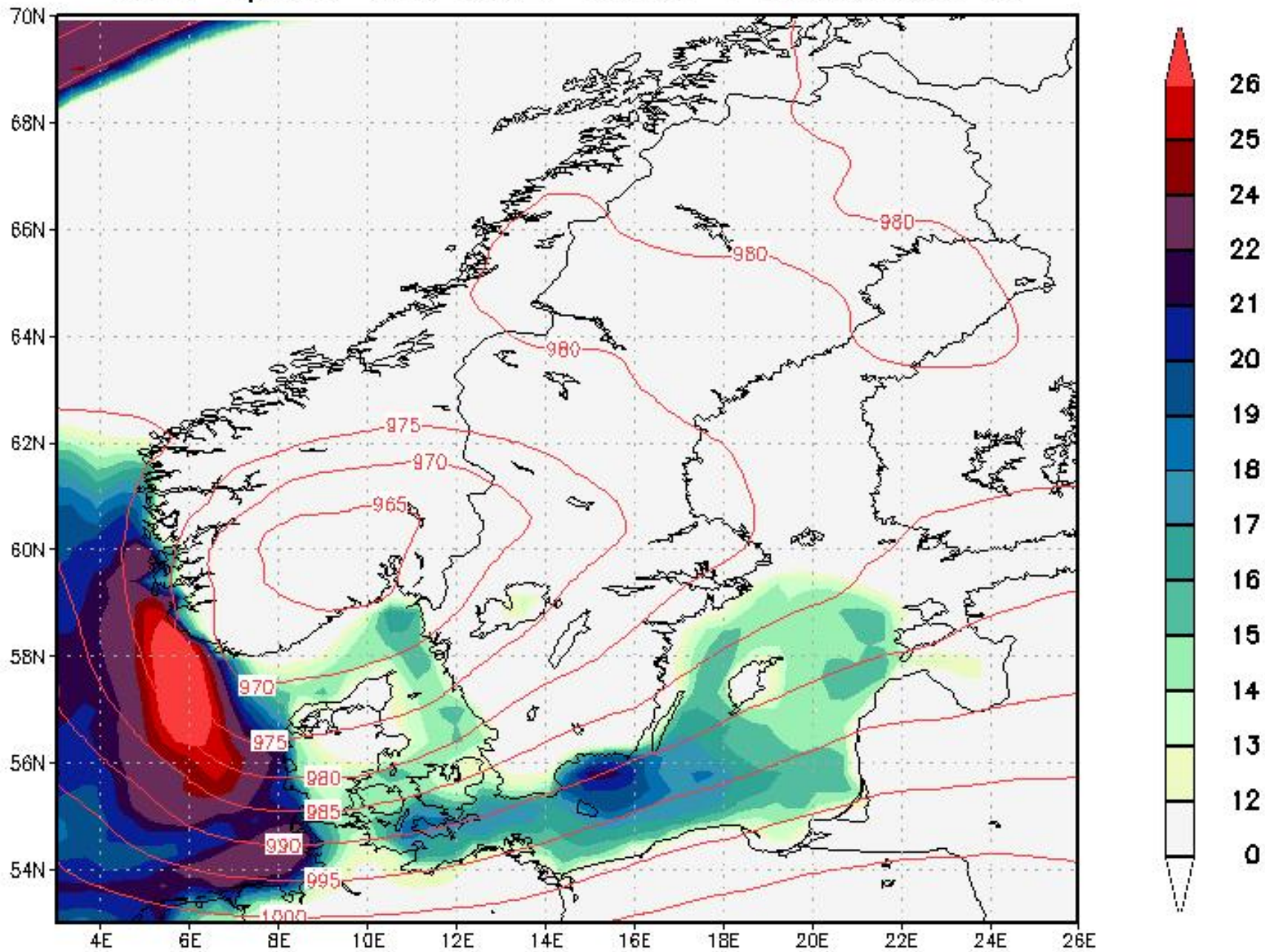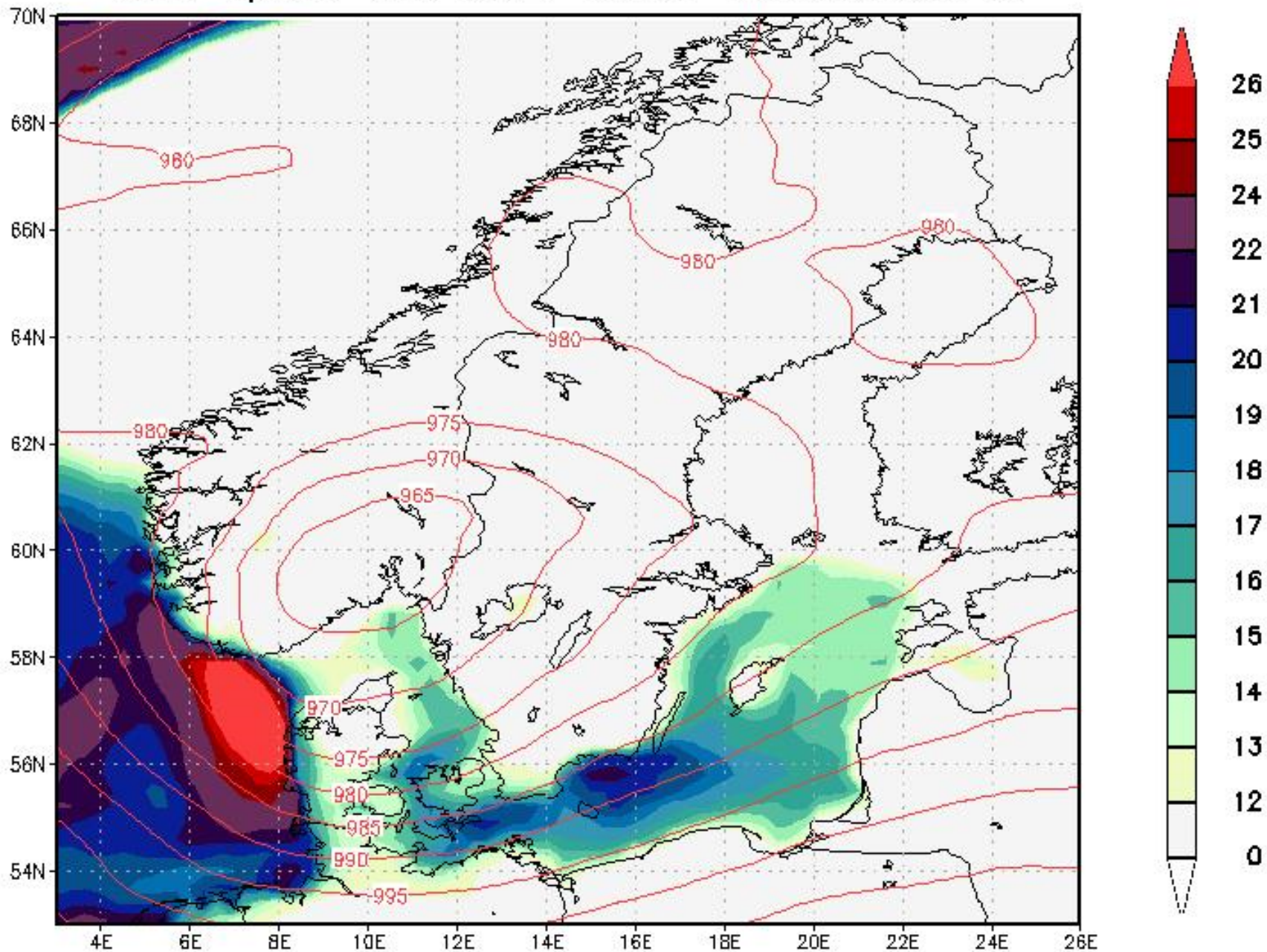
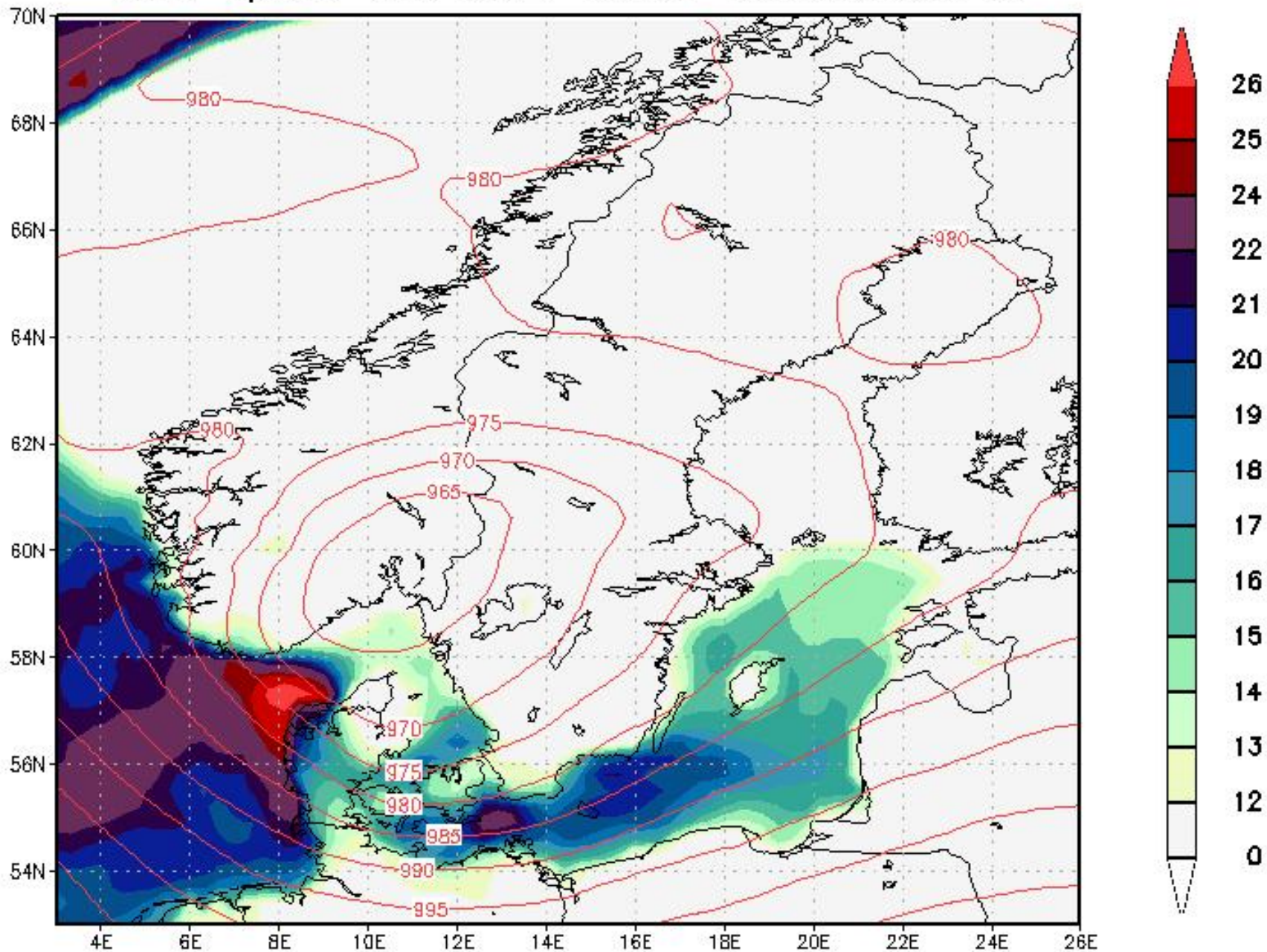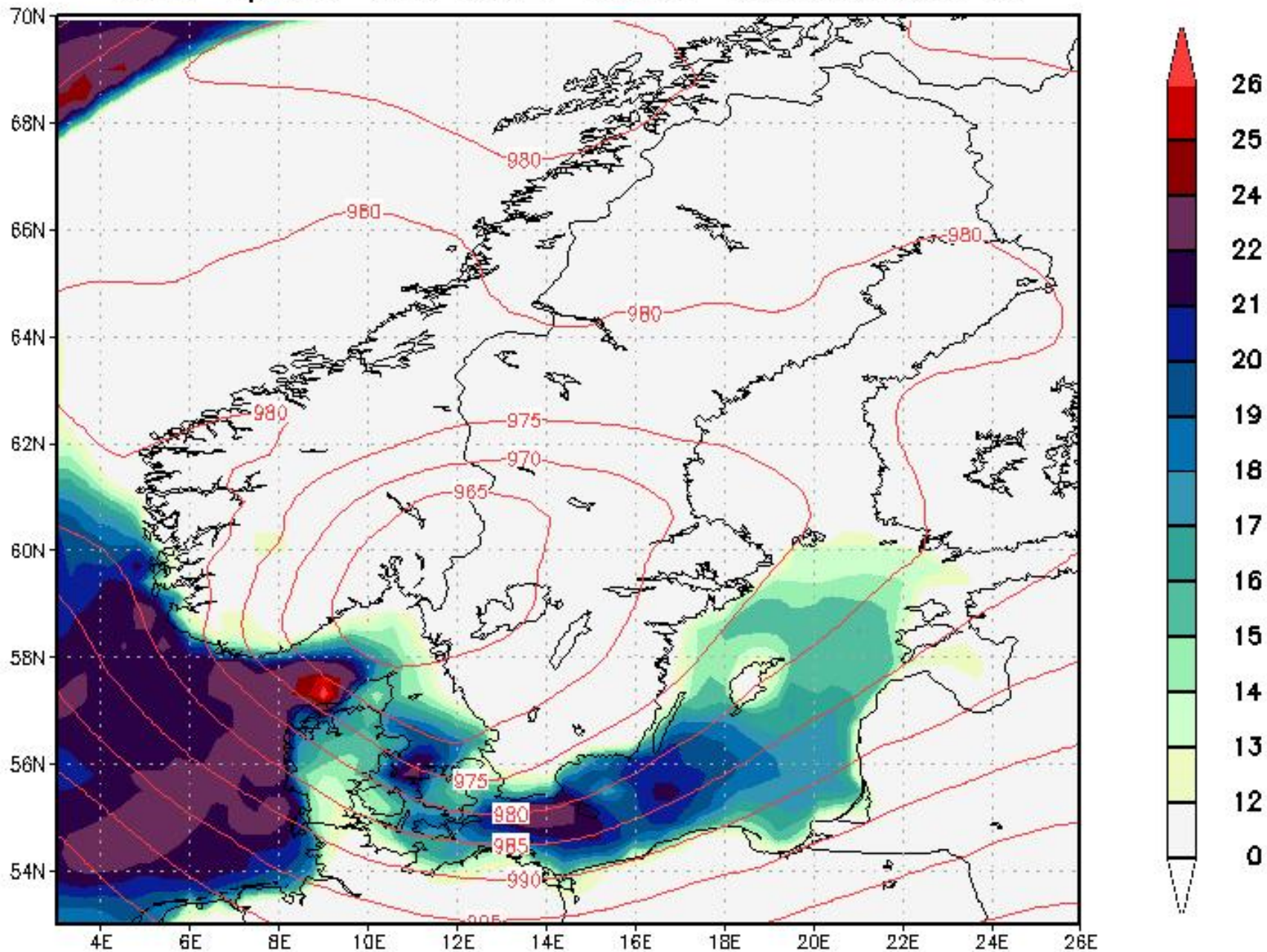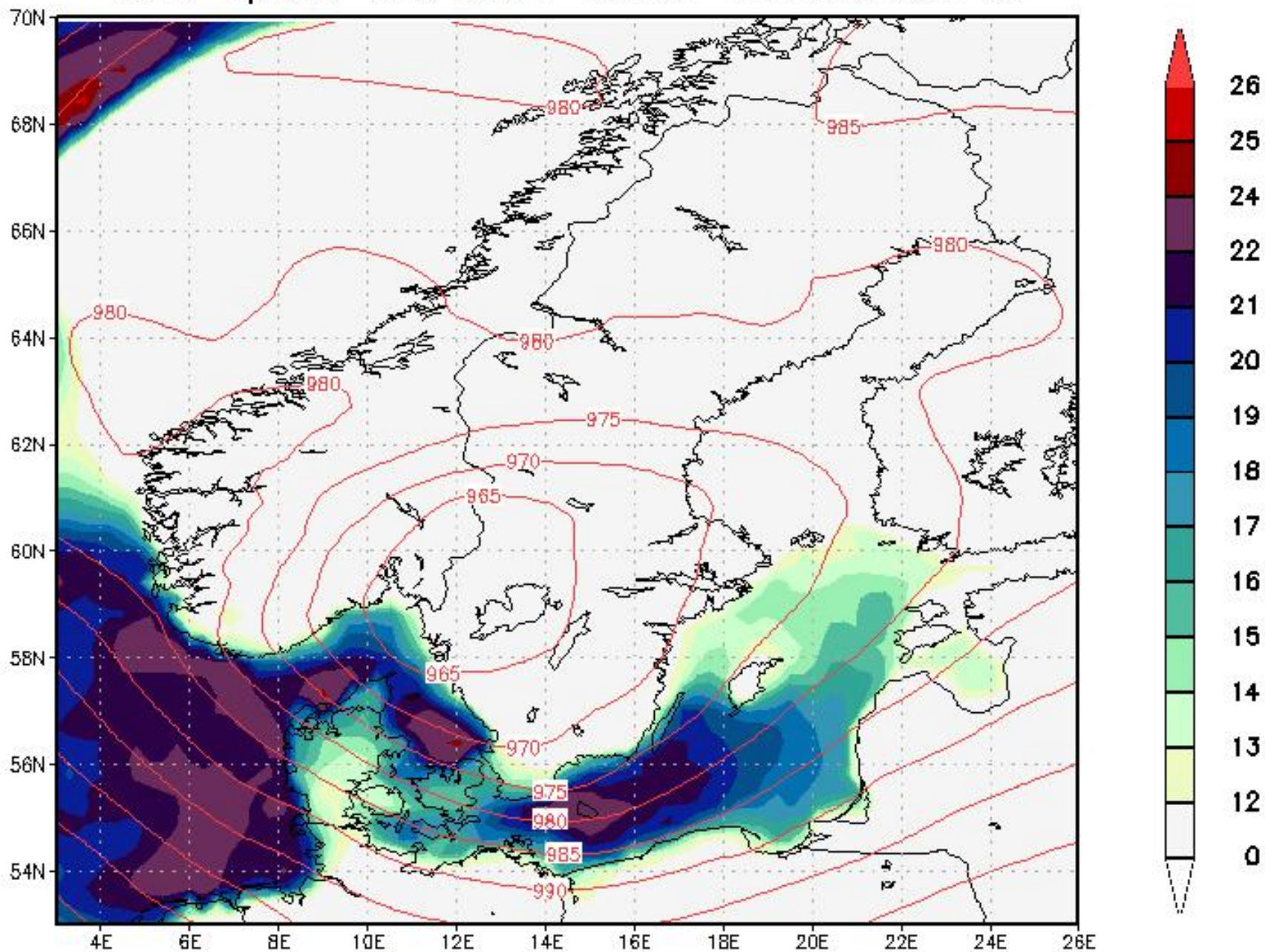# "Bodil" 5 and 6 December 2013
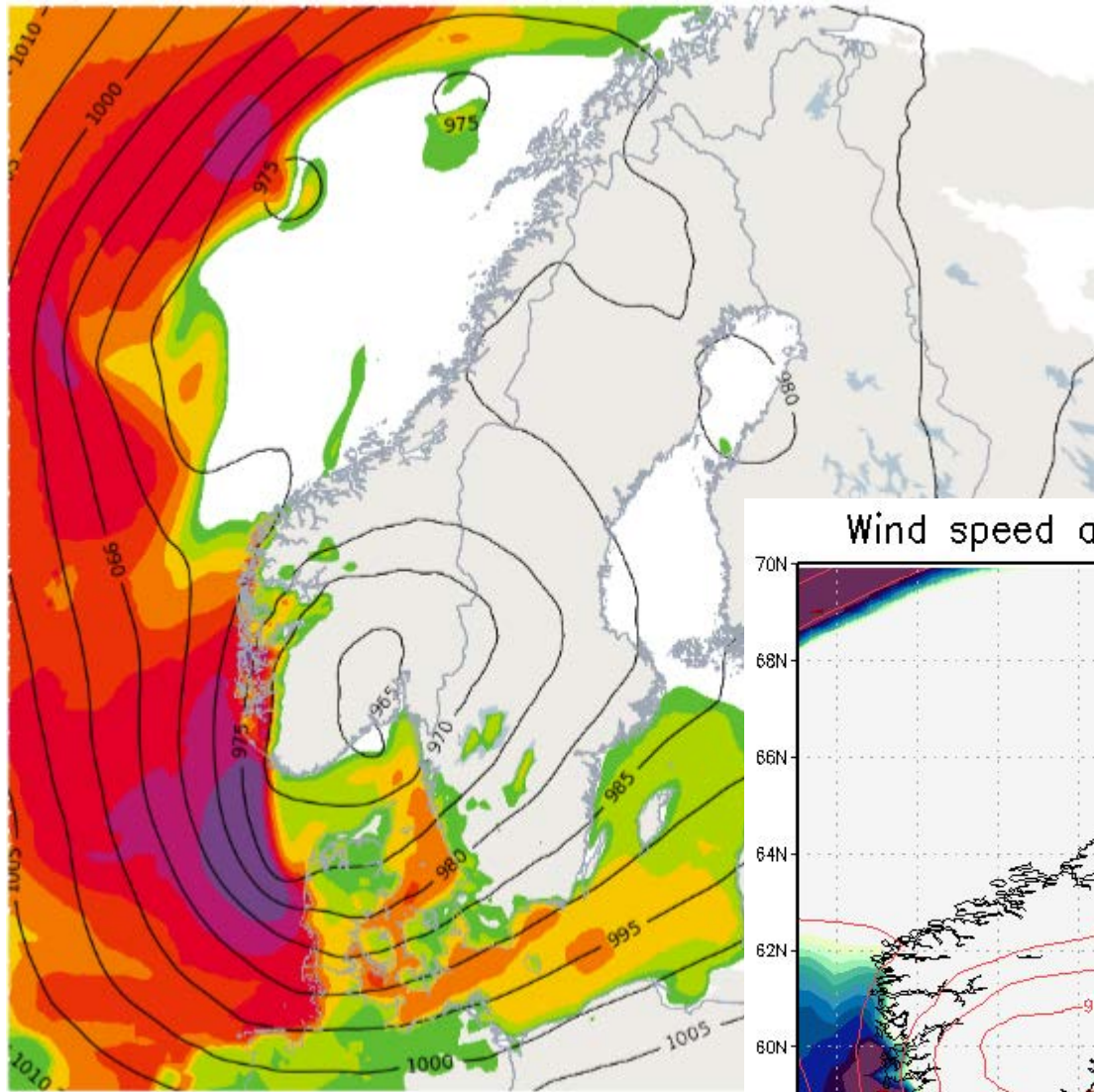
Wind speed and MSLP Bodil 14Z05DEC2013
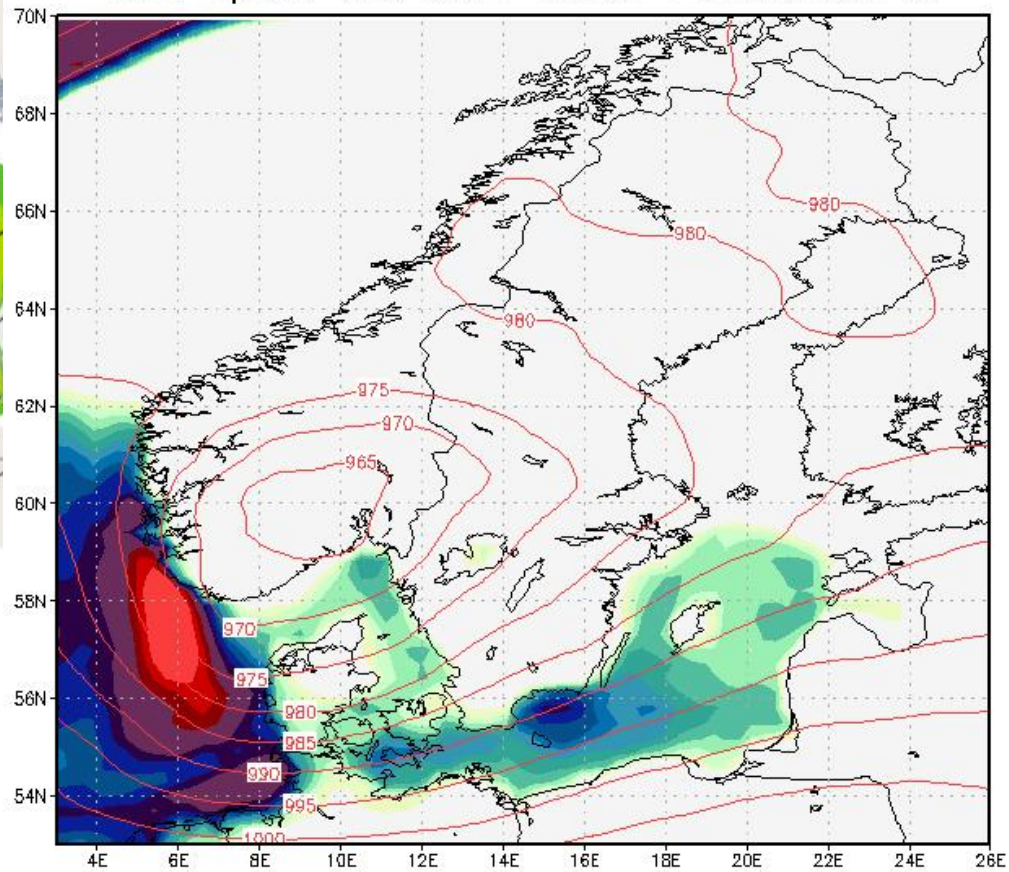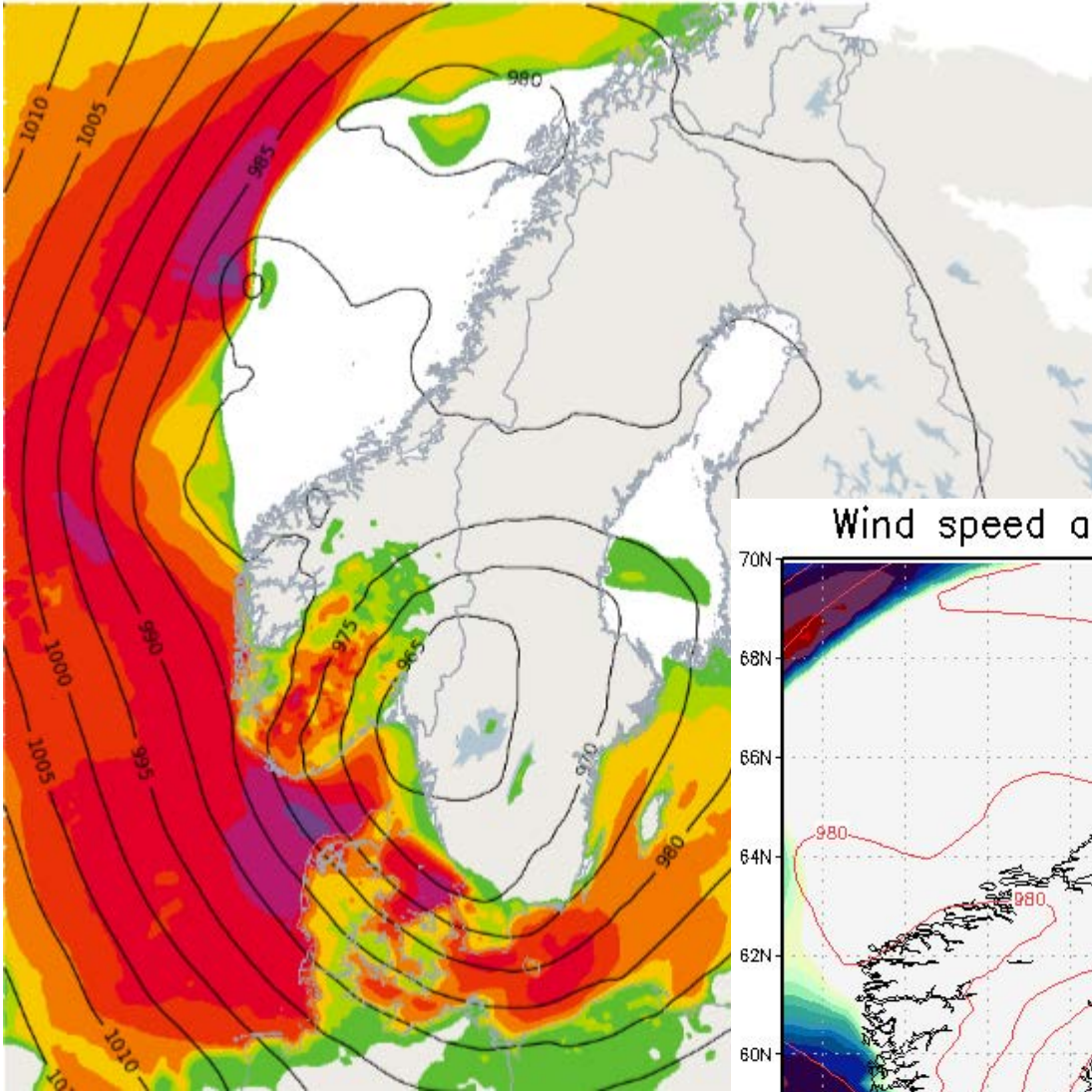
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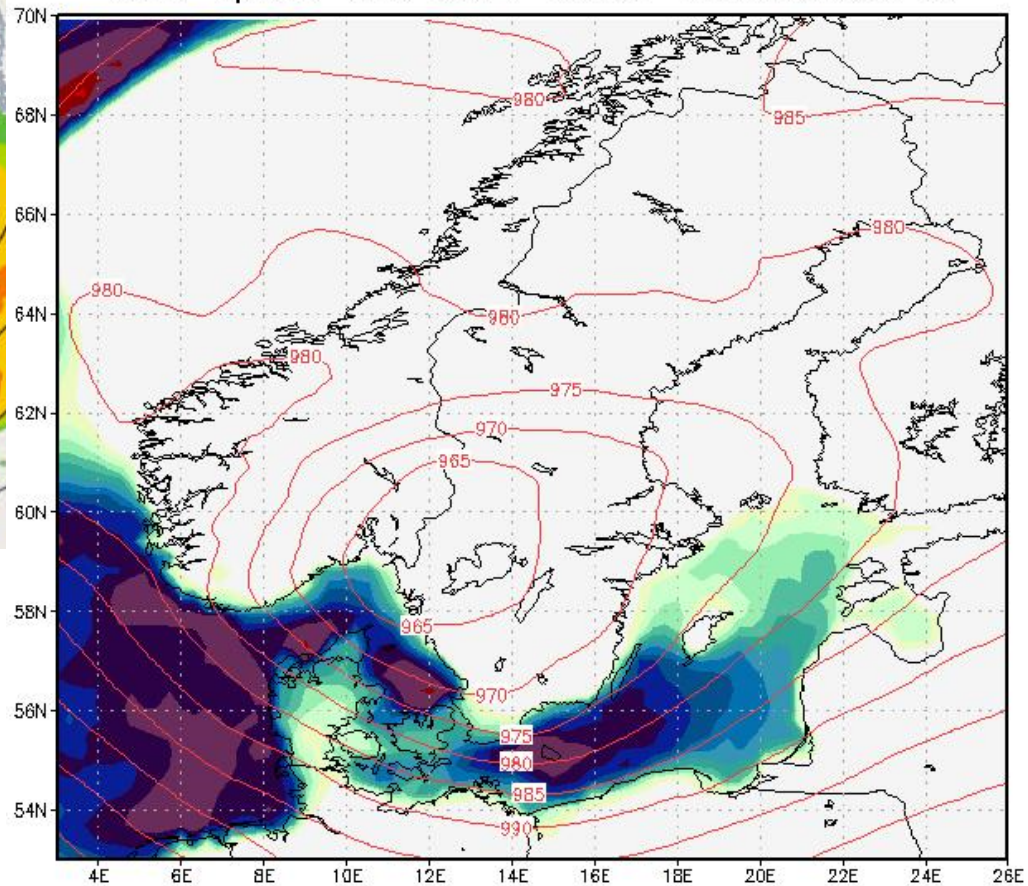
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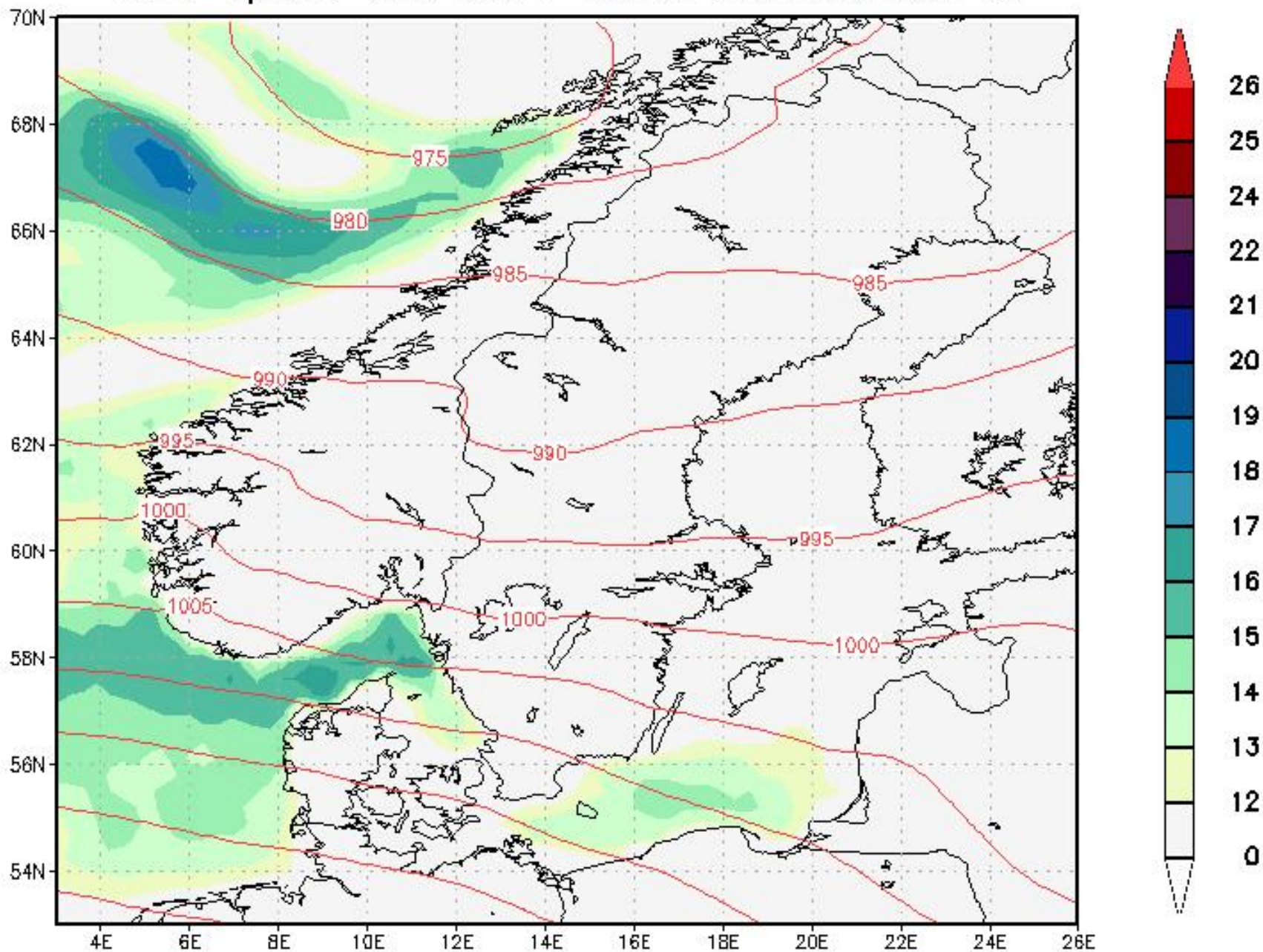
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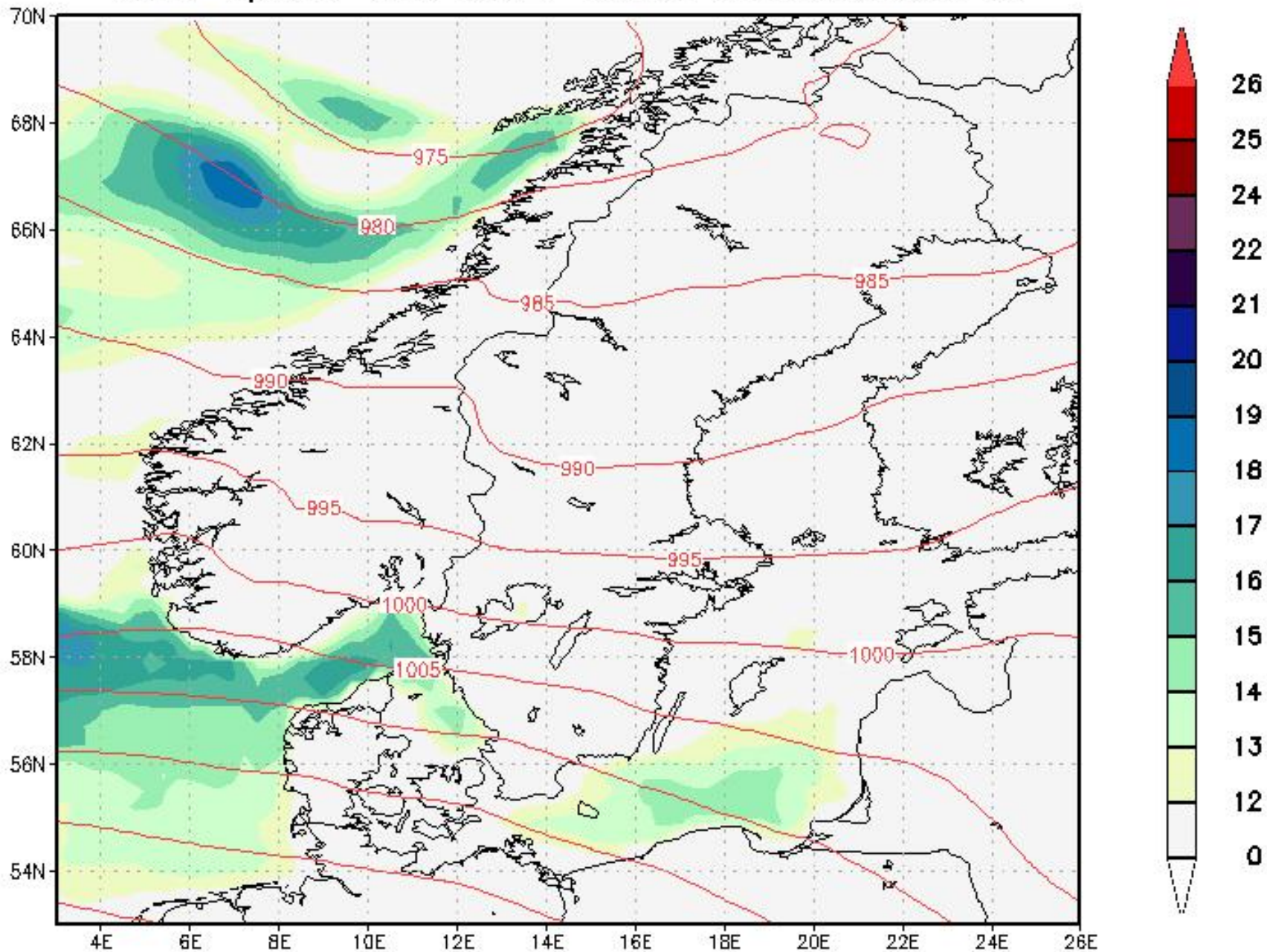
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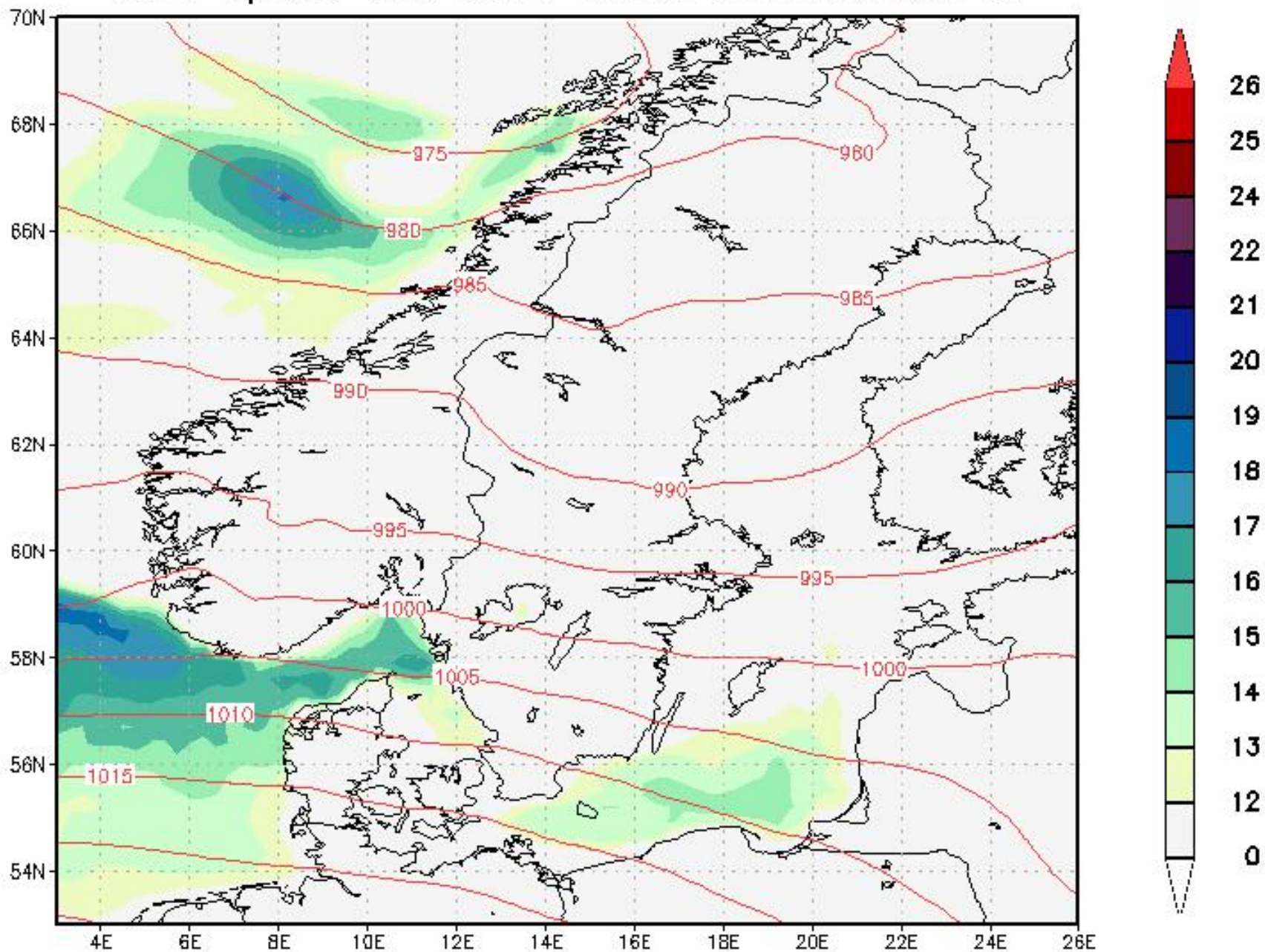
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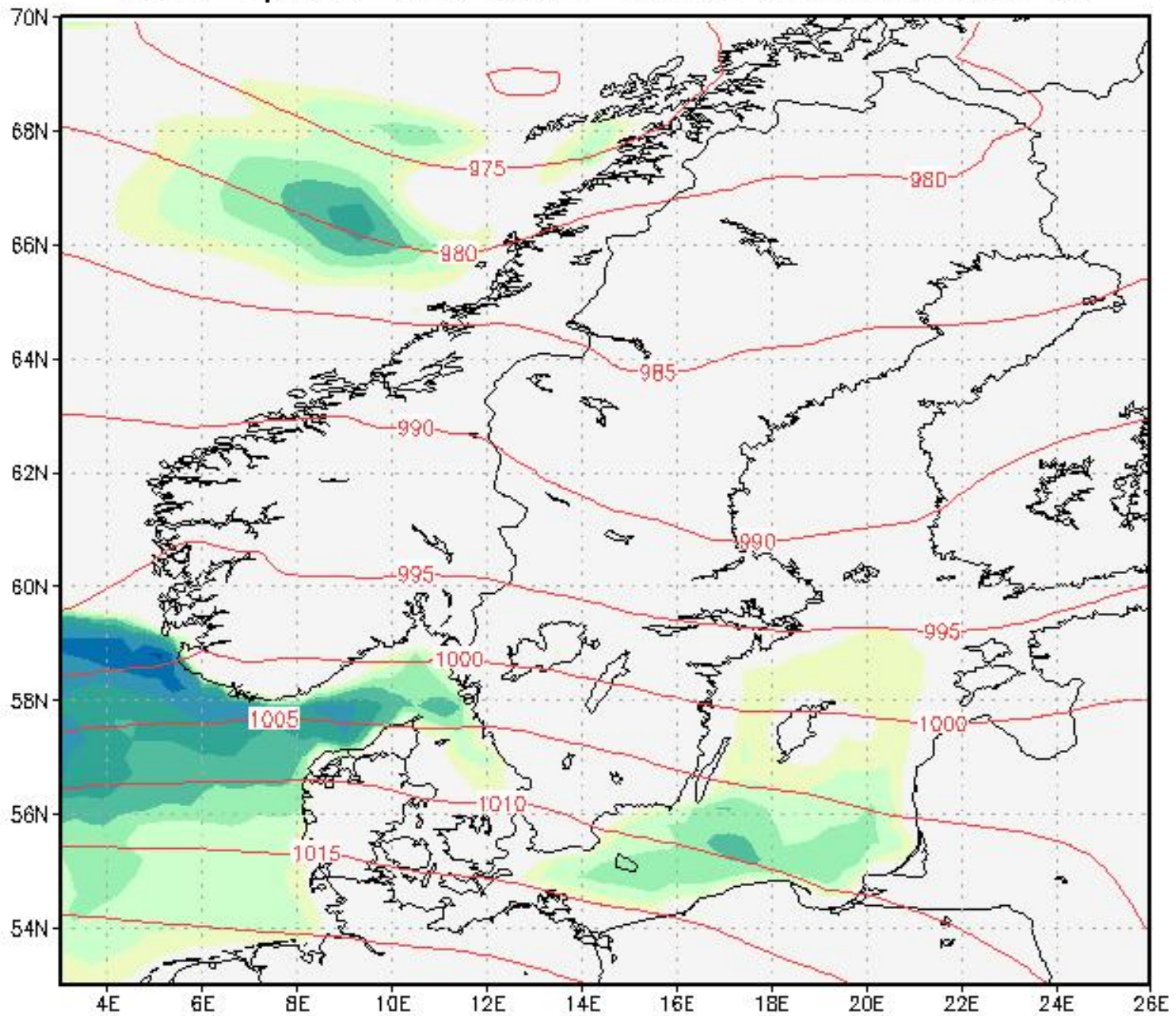
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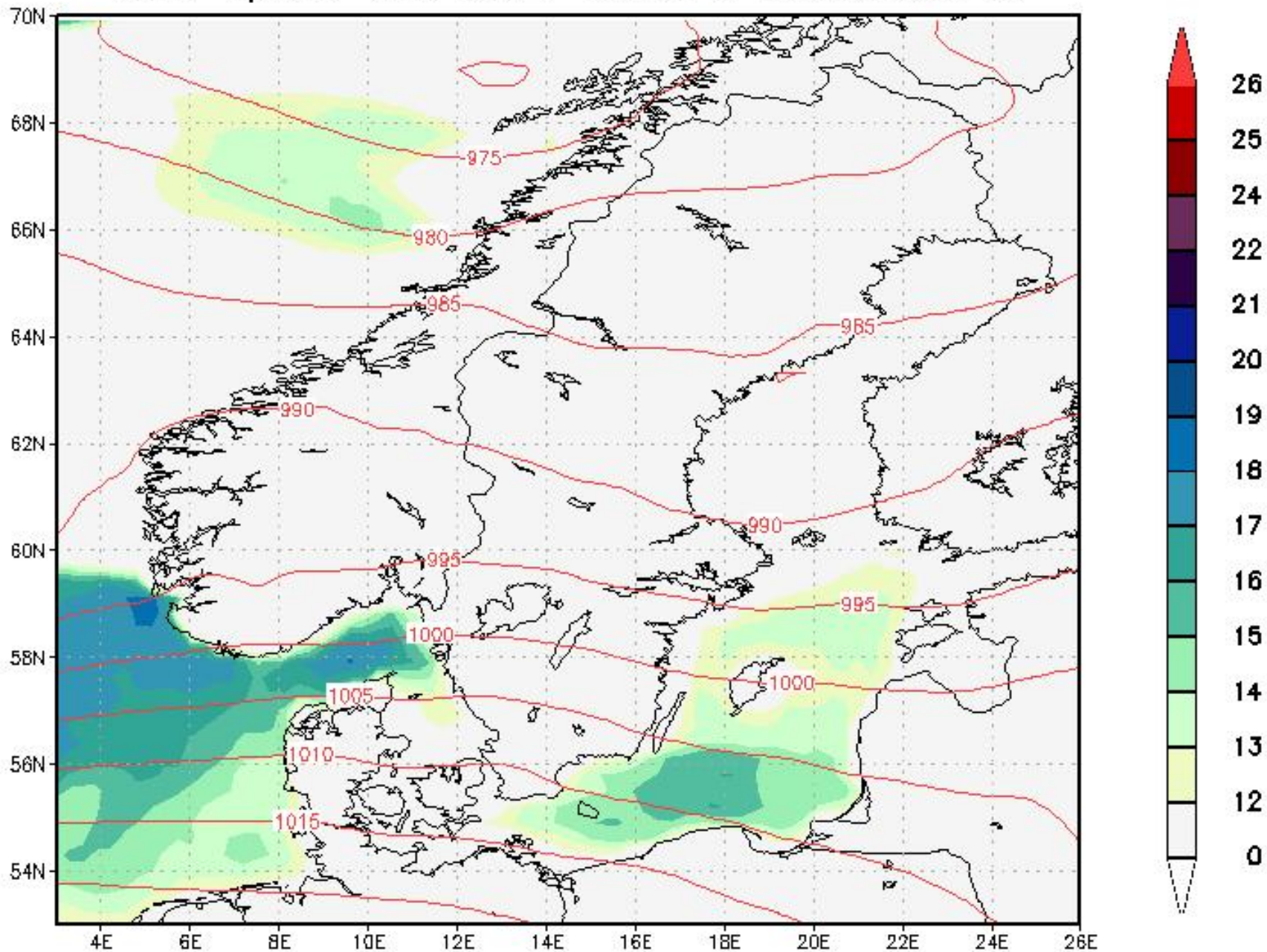
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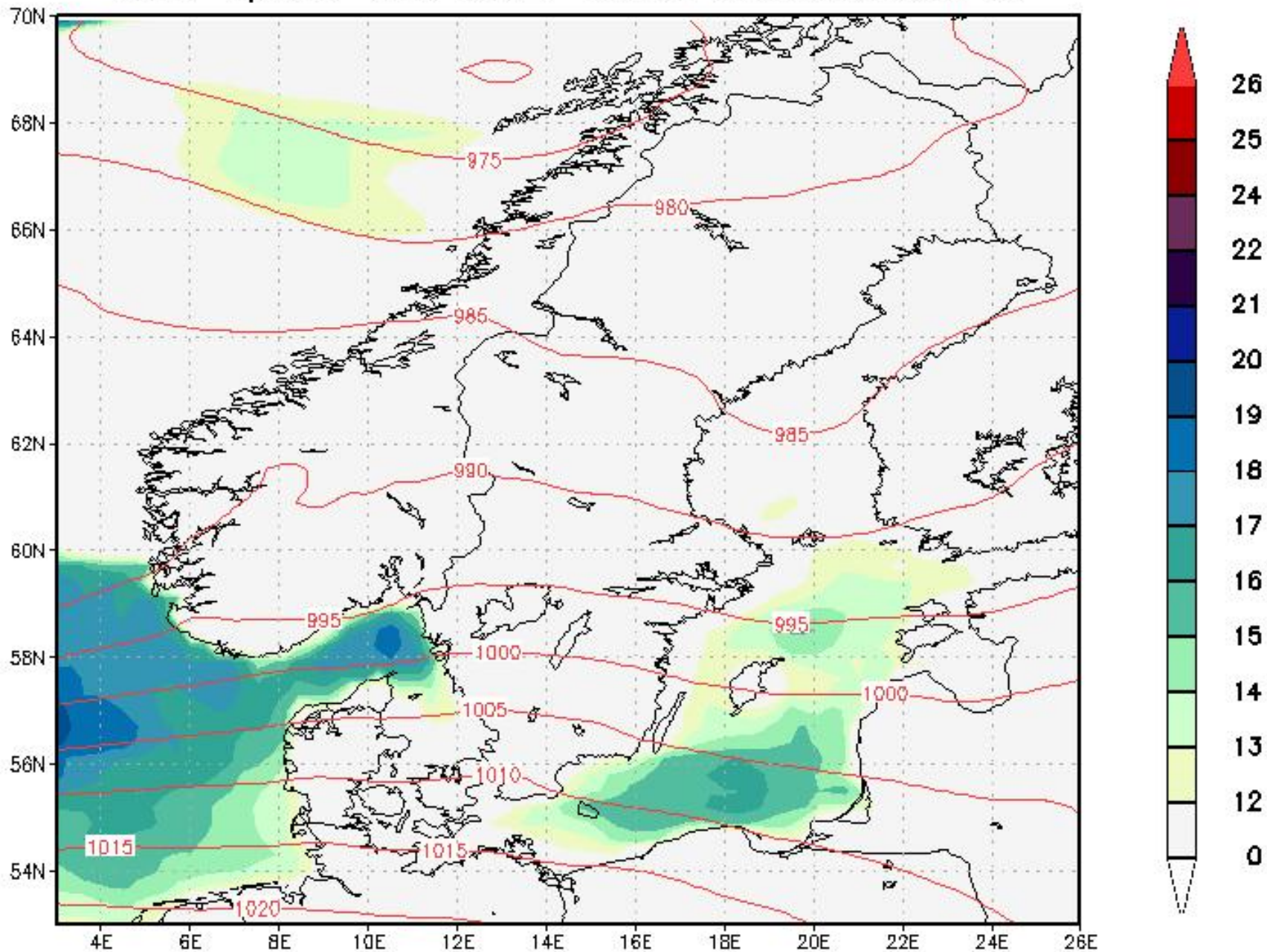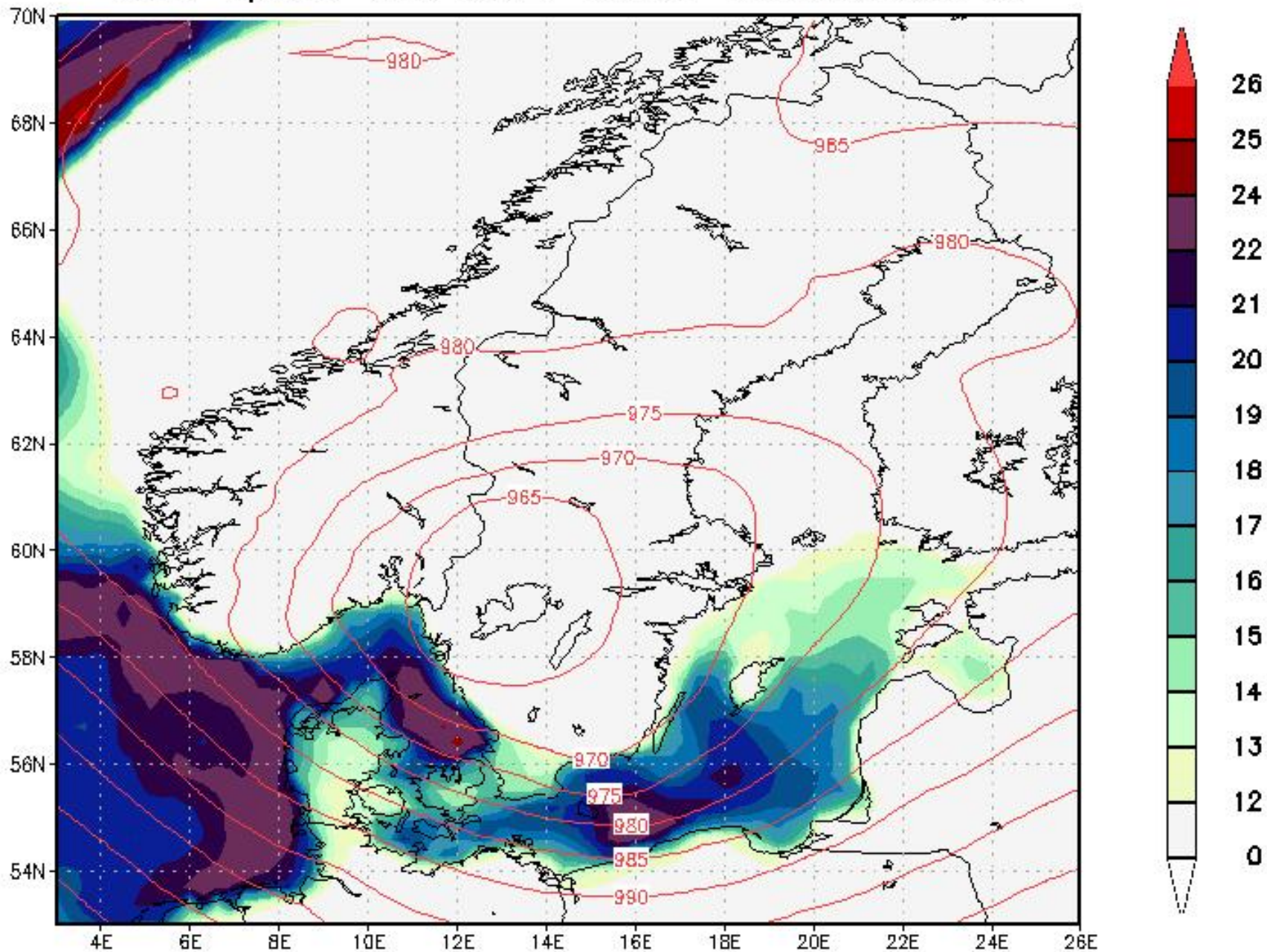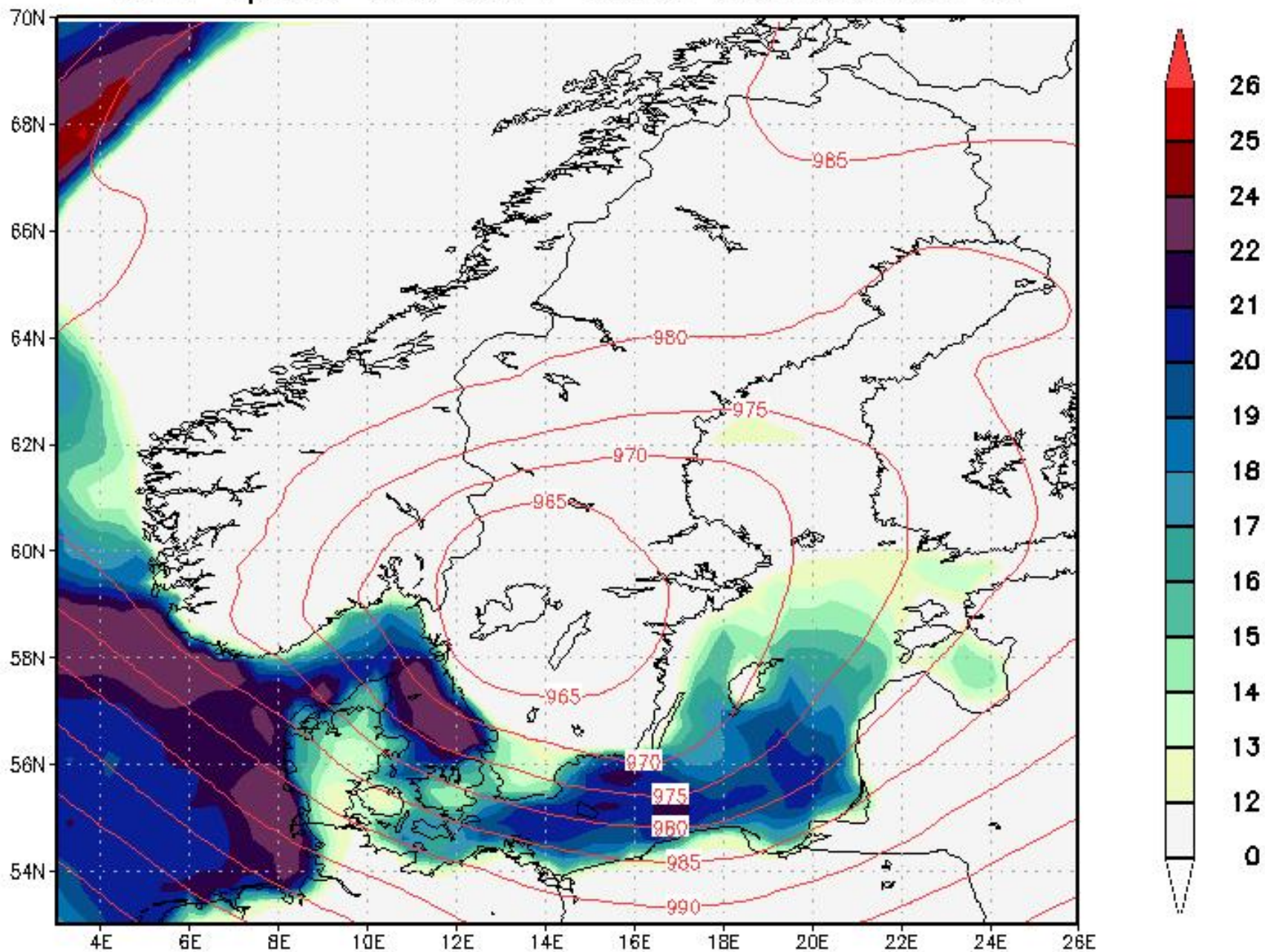
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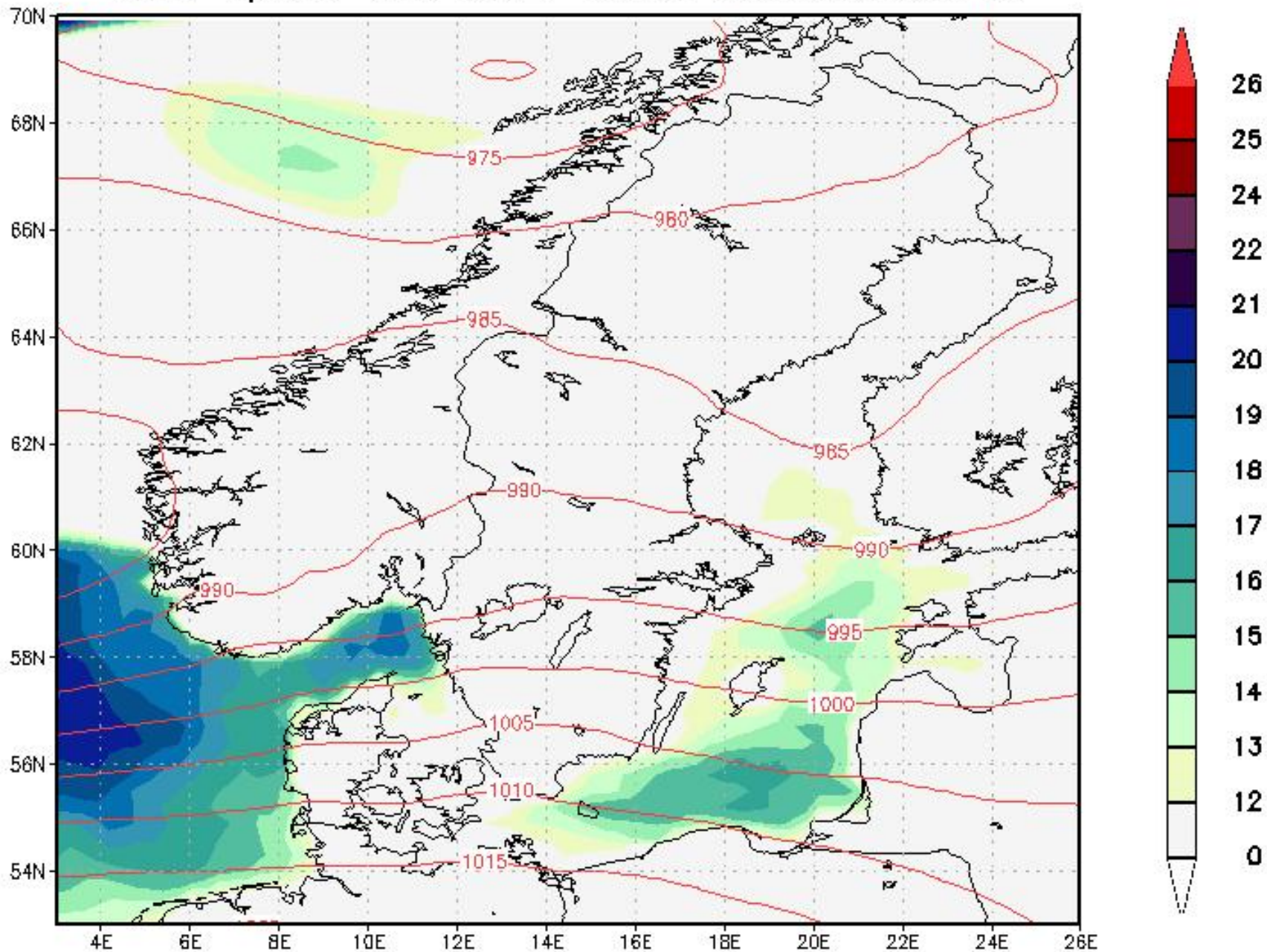
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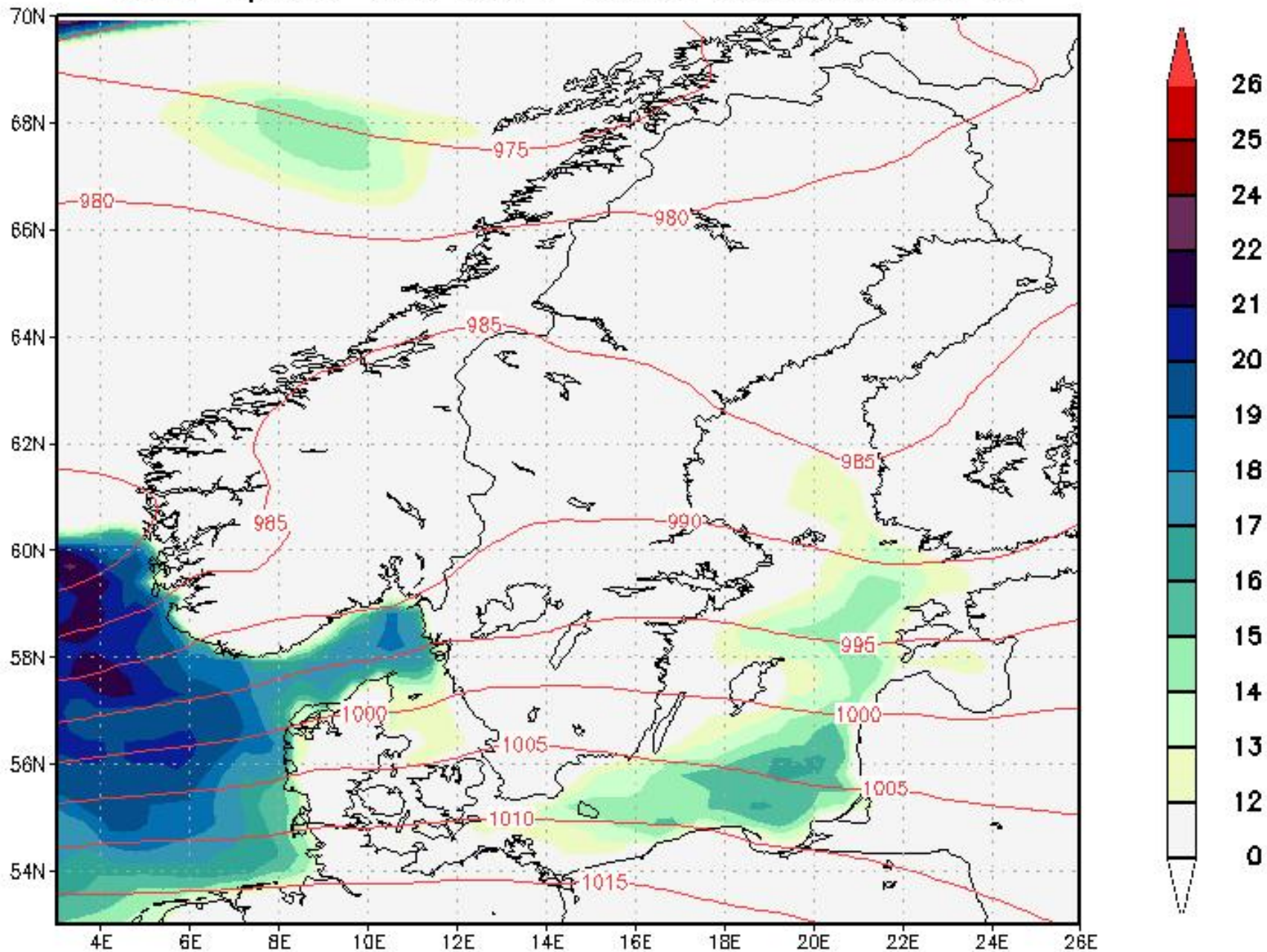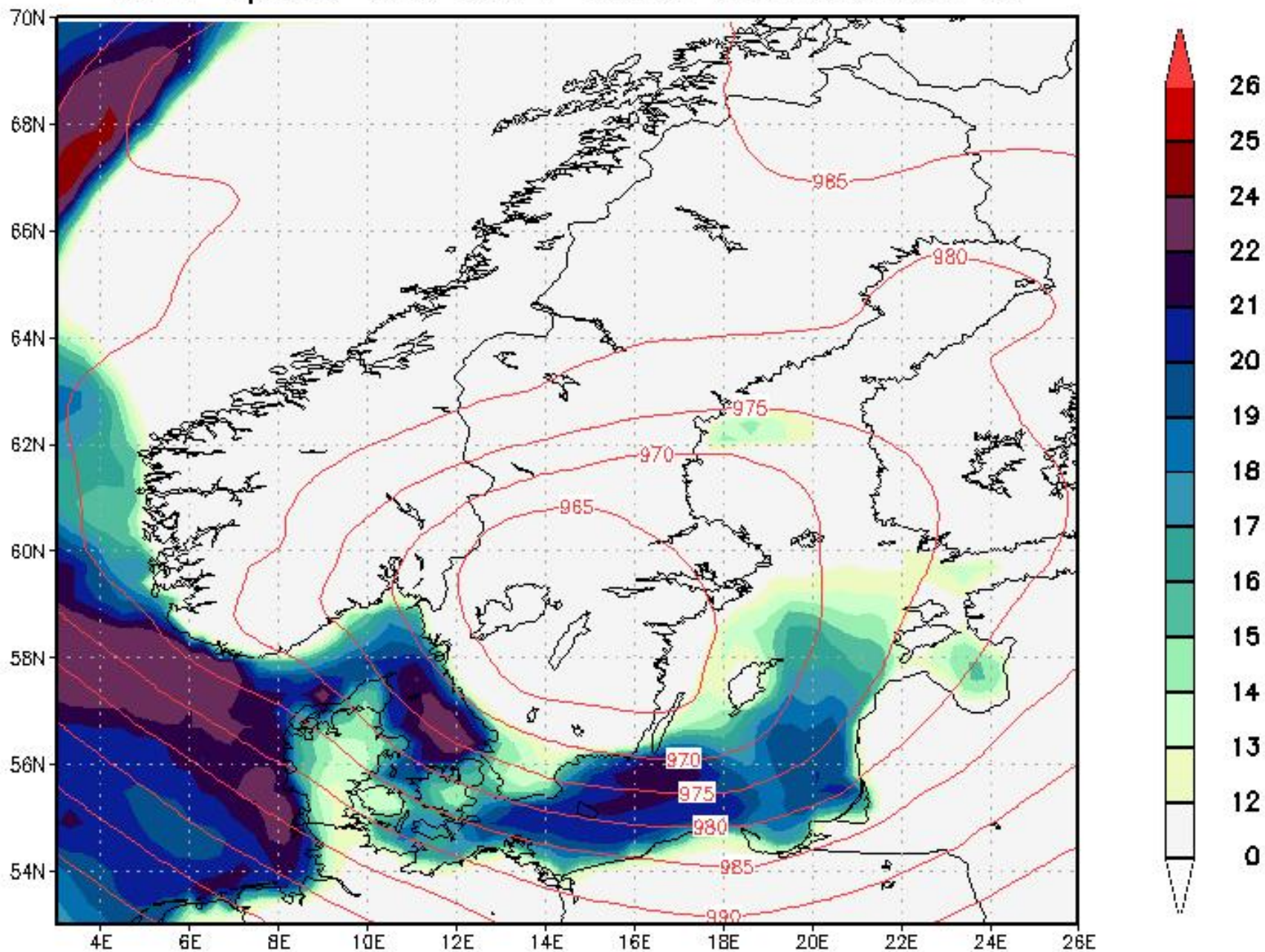
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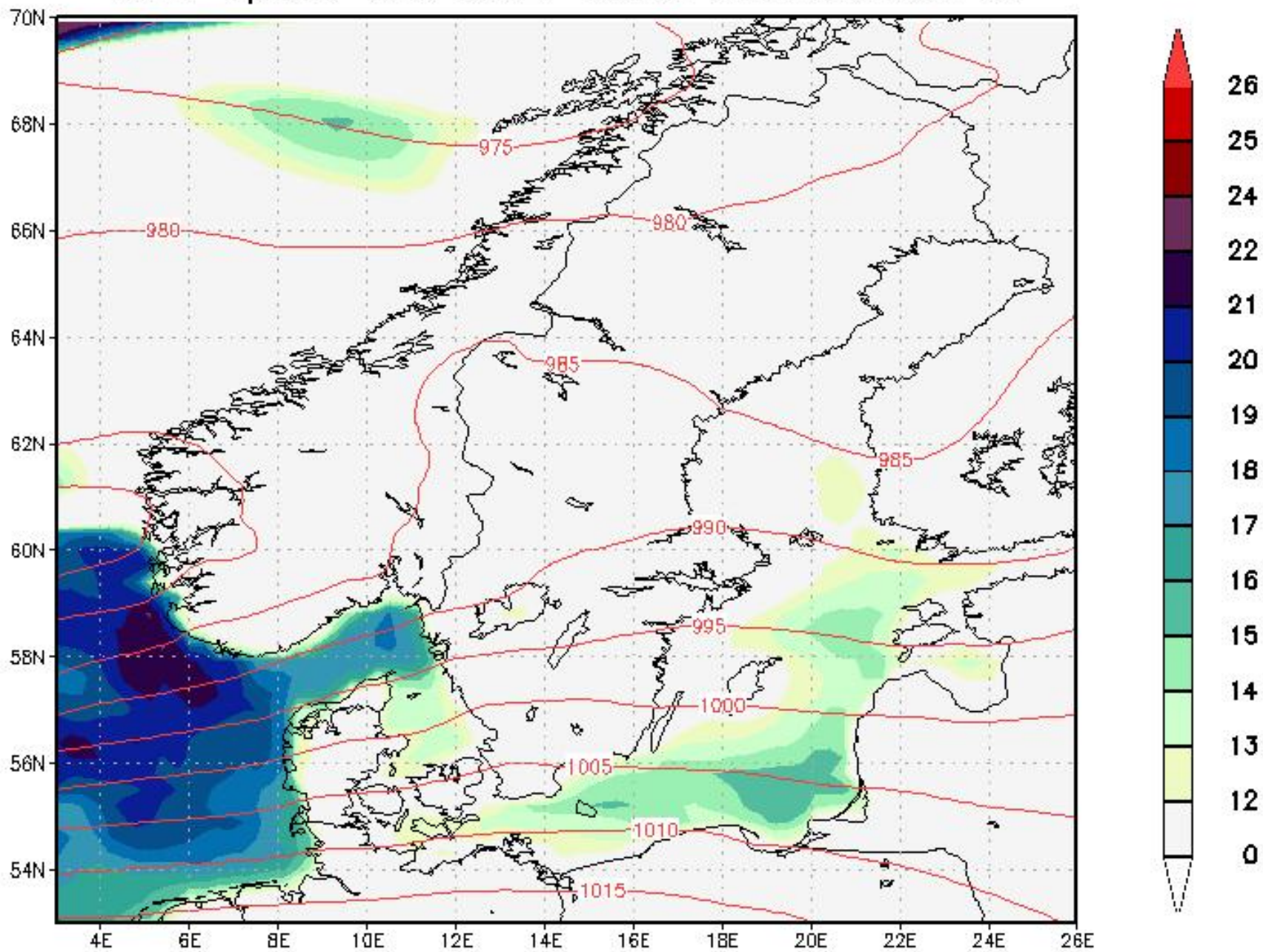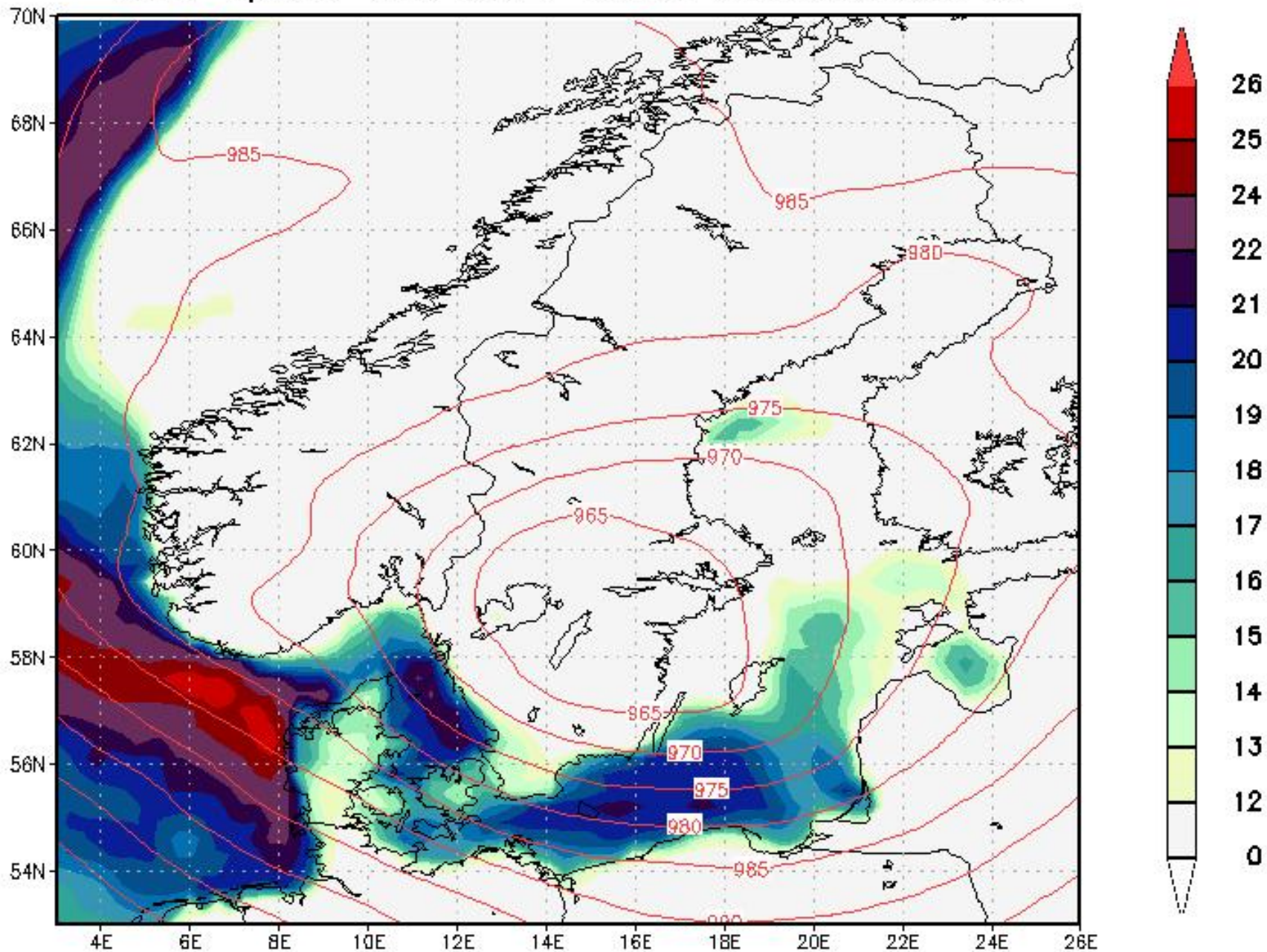
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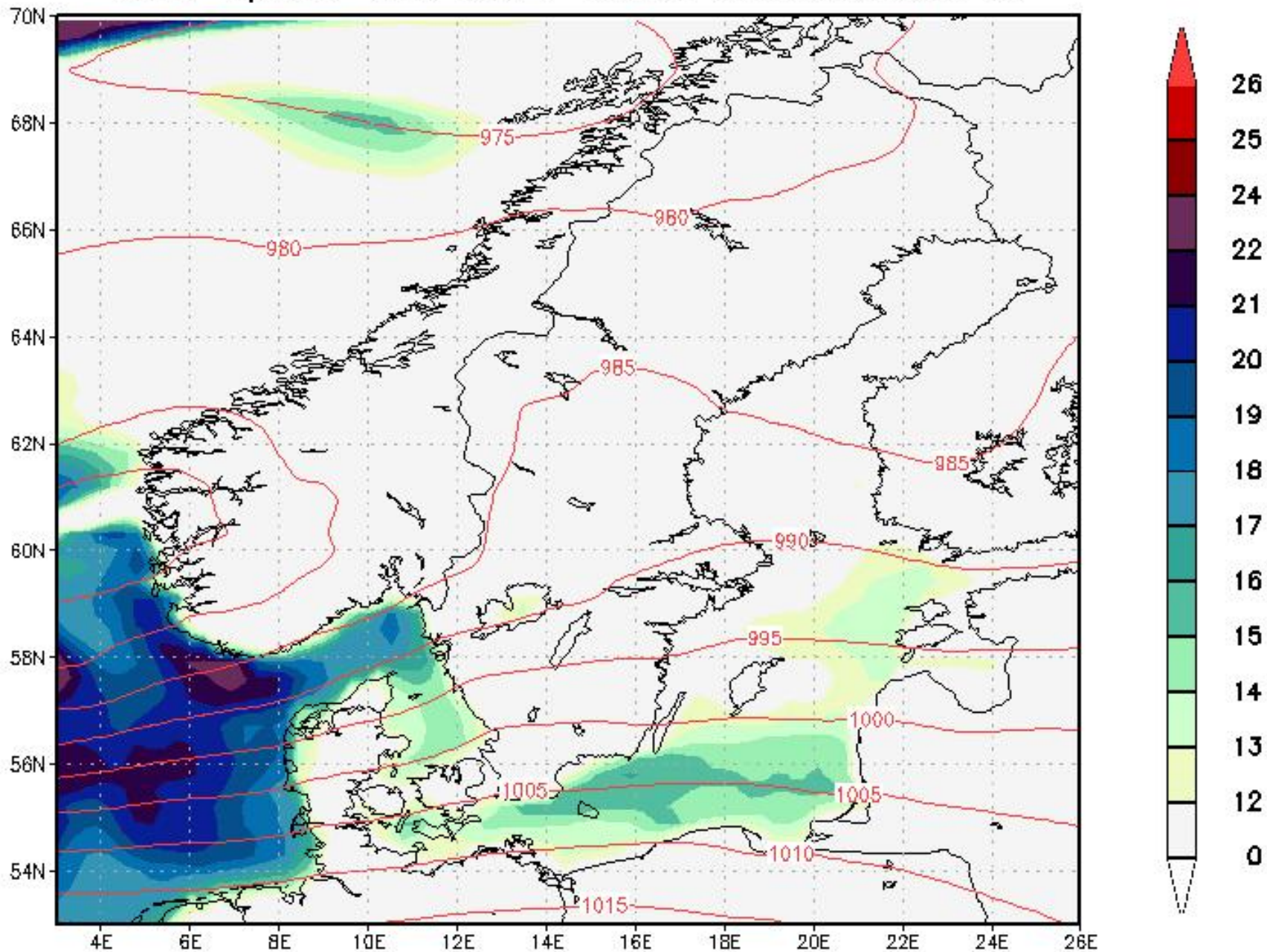
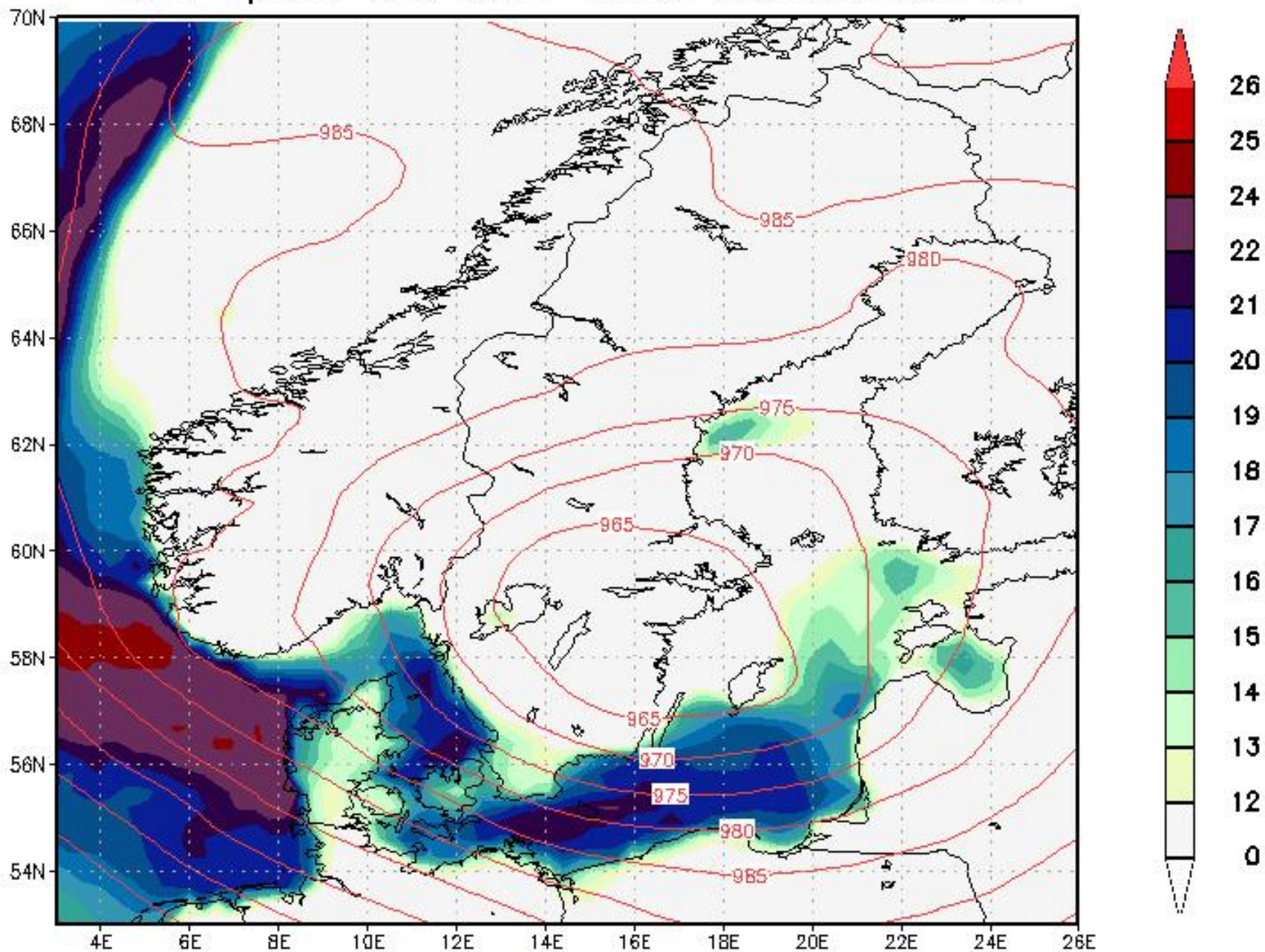Wind speed and MSLP Bodil 10Z05DEC2013
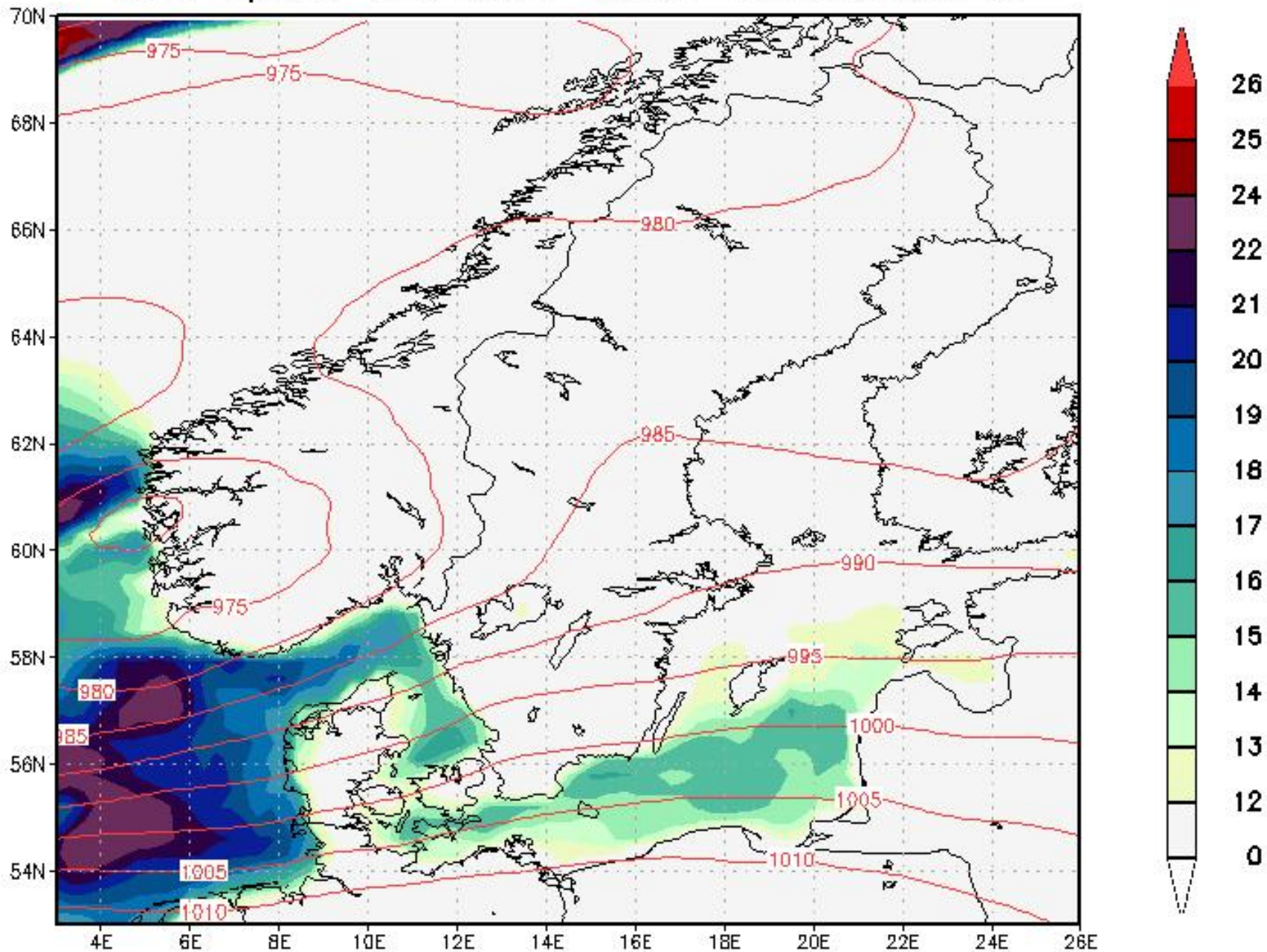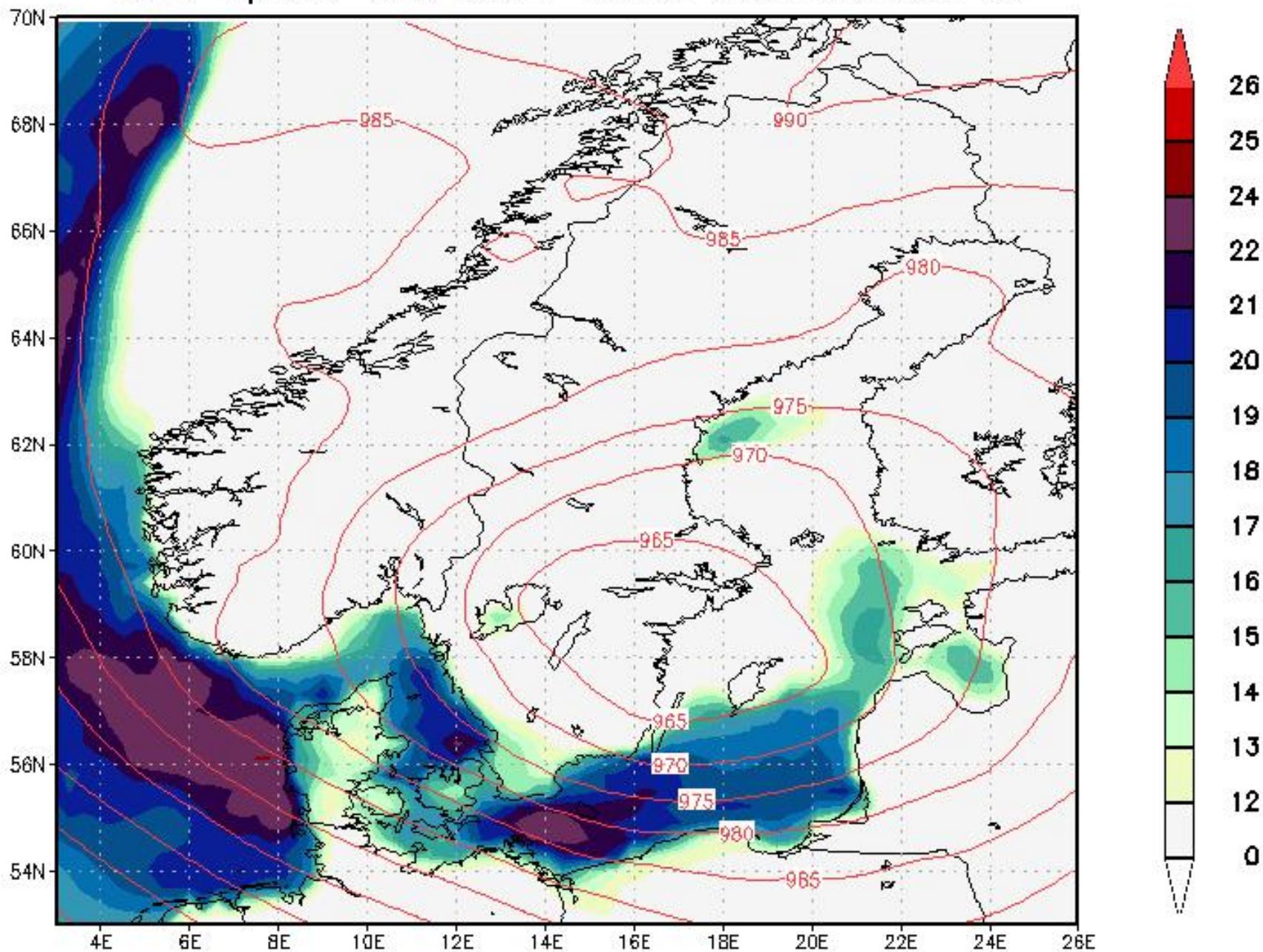
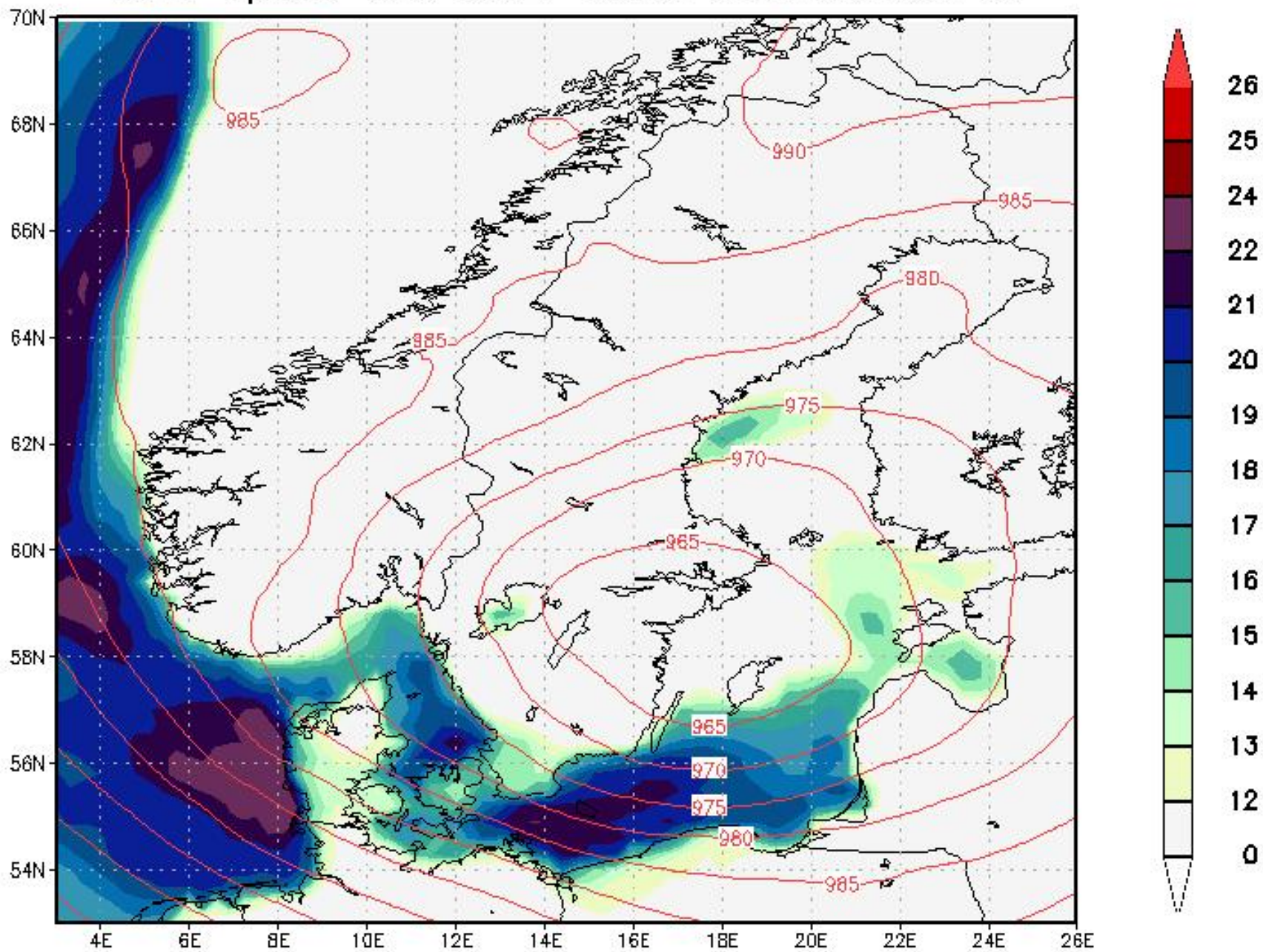Wind speed and MSLP Bodil 11Z05DEC2013
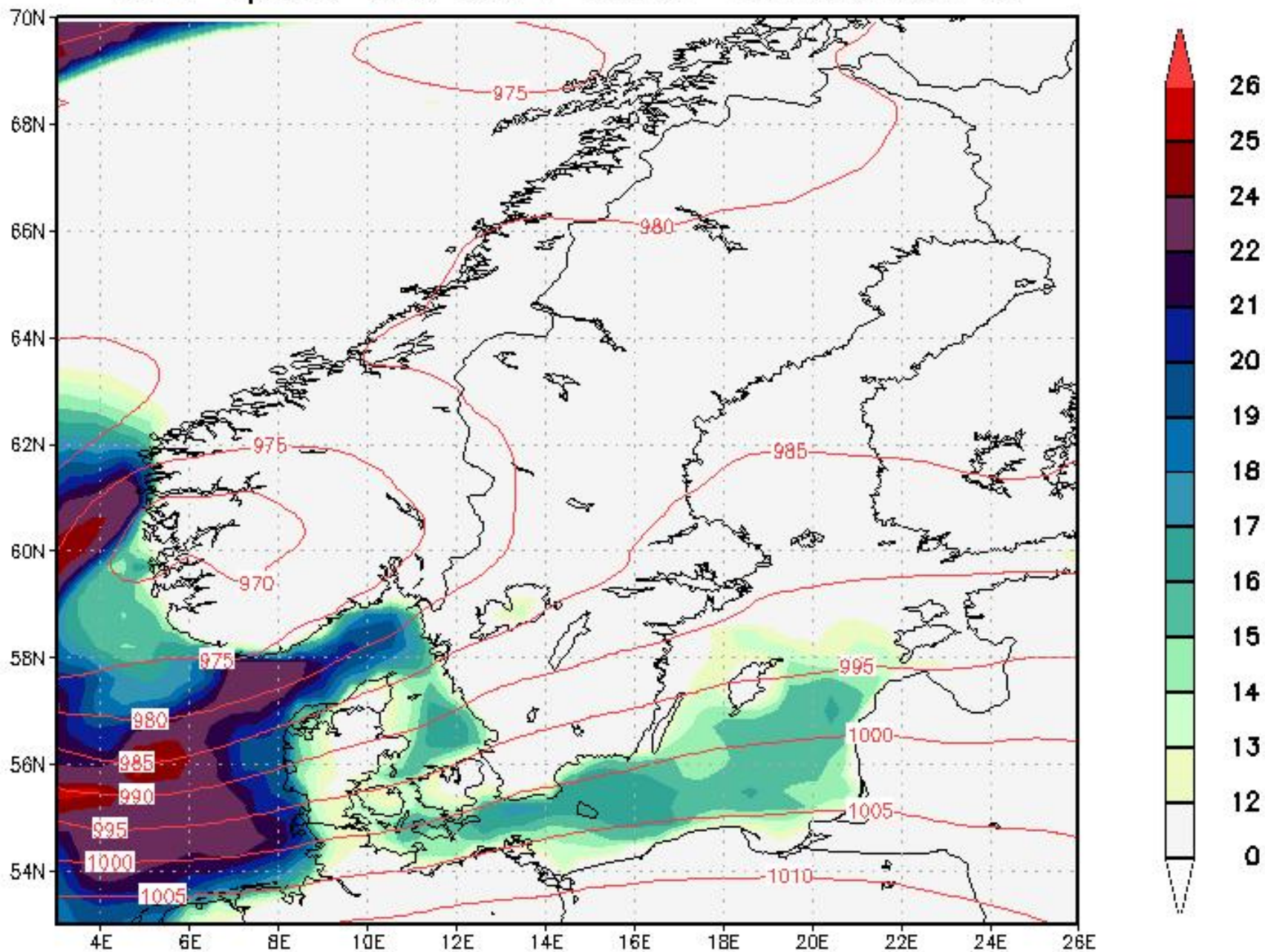
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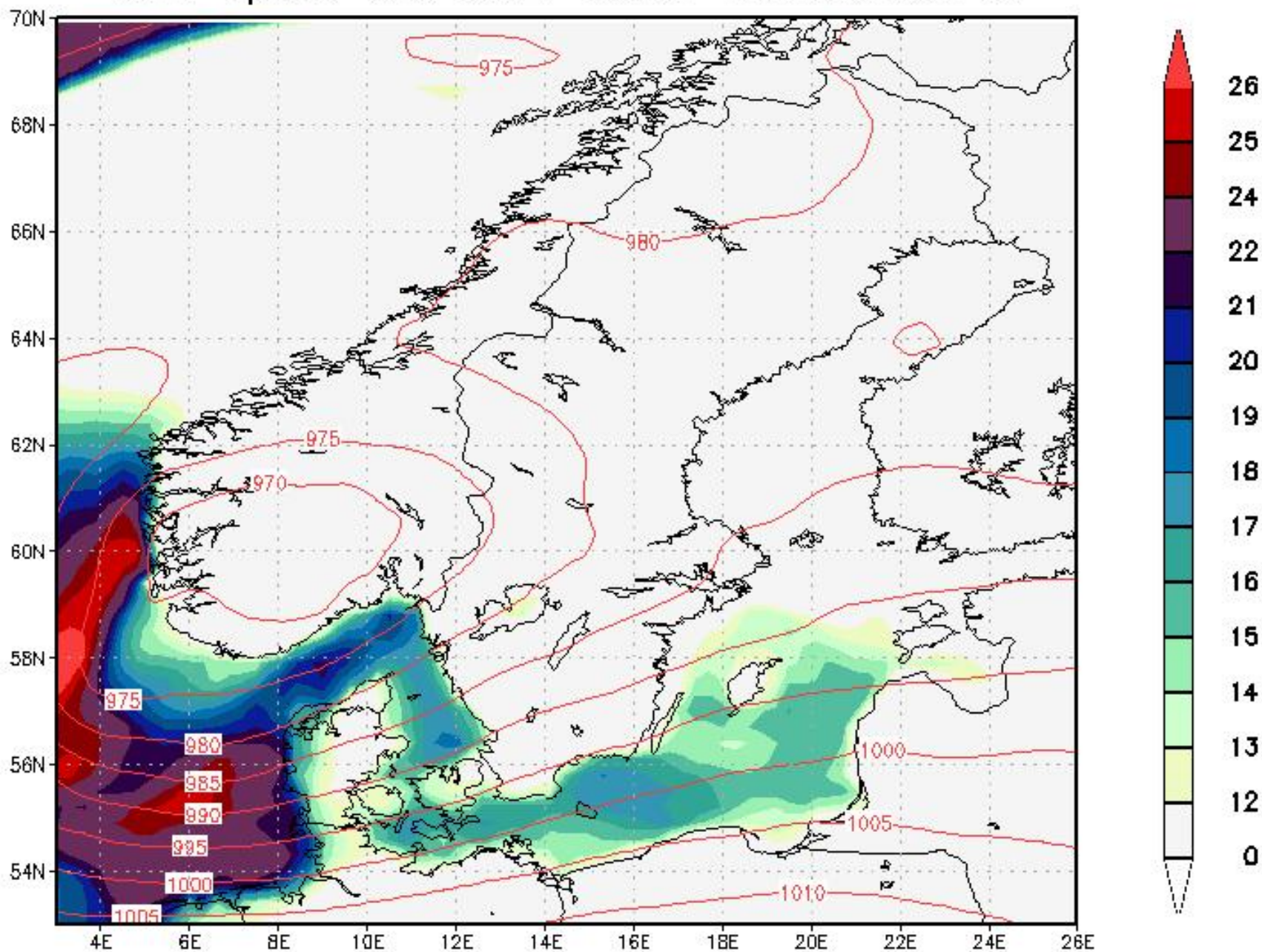
Wind speed and MSLP Bodil 13Z05DEC2013

Wind speed and MSLP Bodil 14Z05DEC2013

Wind speed and MSLP Bodil 15Z05DEC2013

Wind speed and MSLP Bodil 16Z05DEC2013

Wind speed and MSLP Bodil 17Z05DEC2013

Wind speed and MSLP Bodil 18Z05DEC2013

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Wind speed and MSLP Bodil 20Z05DEC2013

Wind speed and MSLP Bodil 21Z05DEC2013

Wind speed and MSLP Bodil 22Z05DEC2013

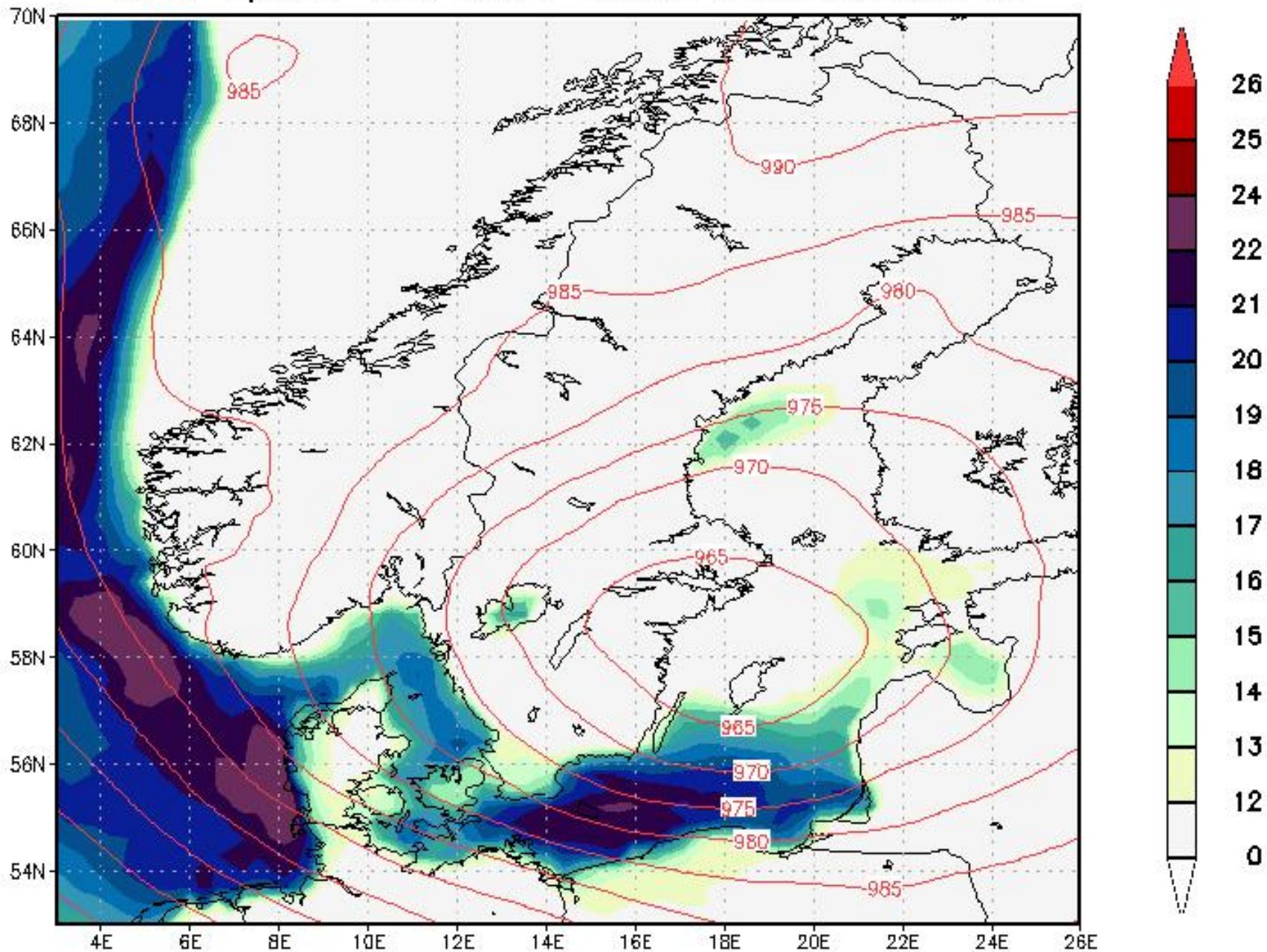Wind speed and MSLP Bodil 23Z05DEC2013
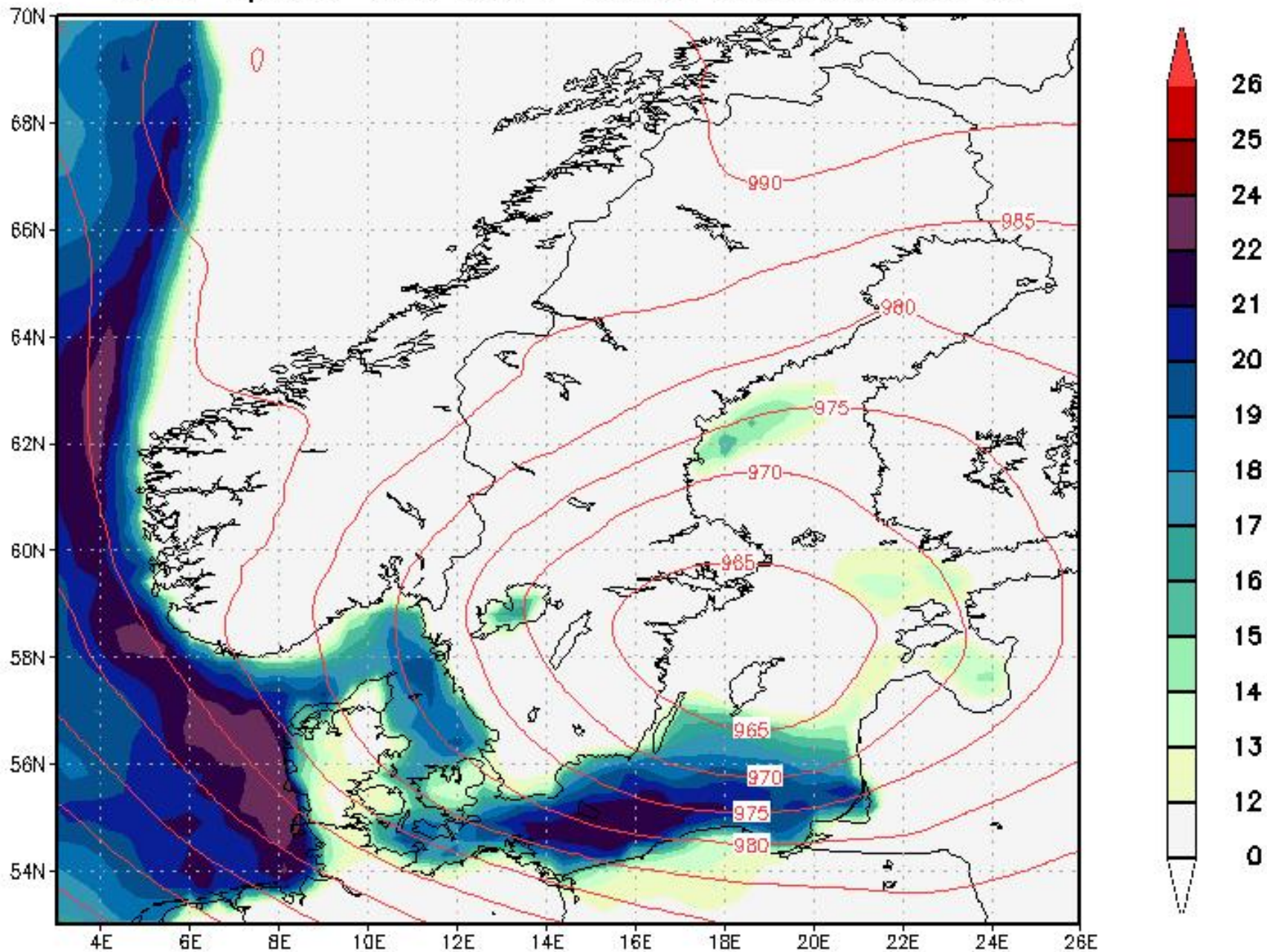
Wind speed and MSLP Bodil 00Z06DEC2013

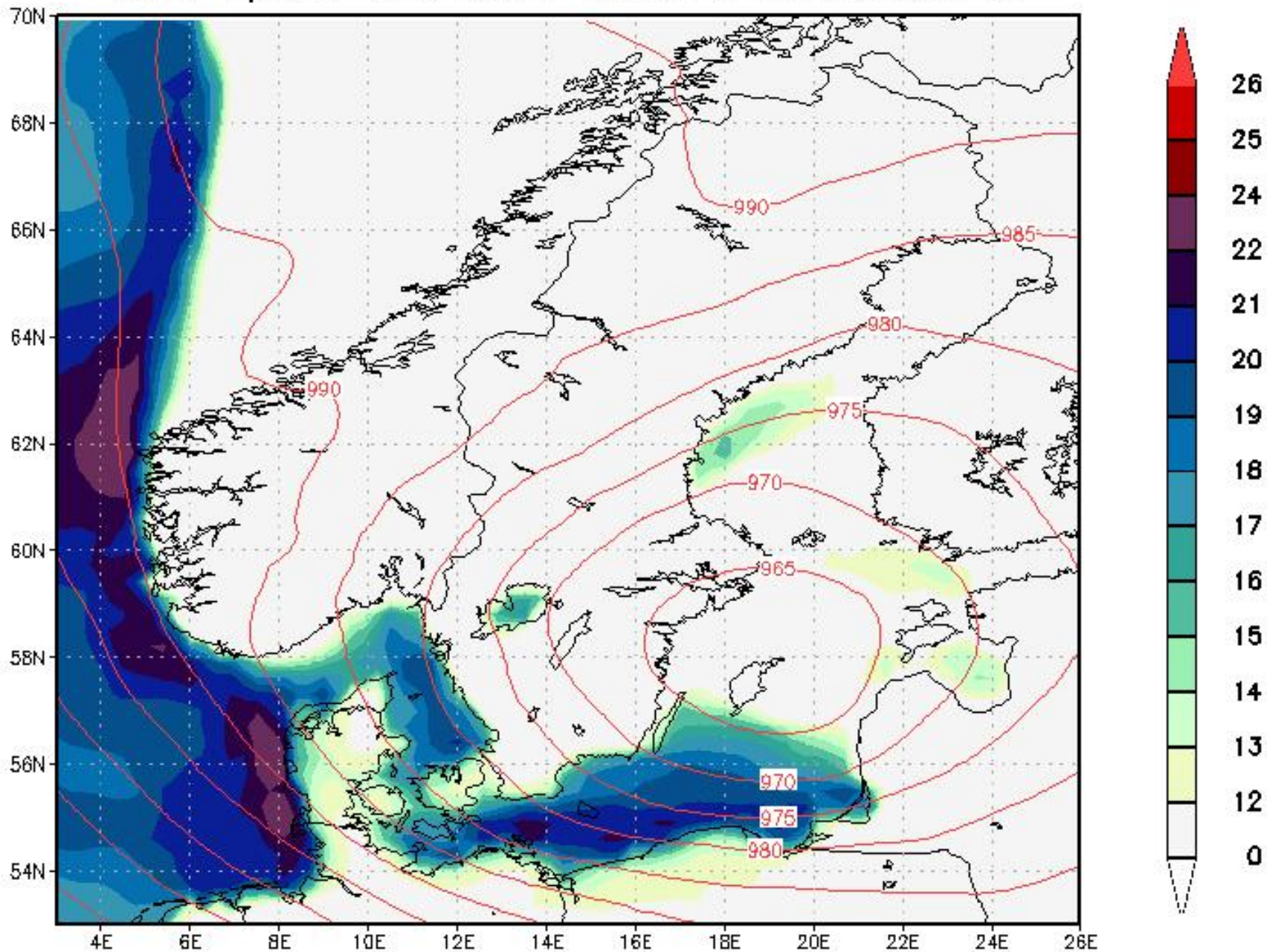Wind speed and MSLP Bodil 01Z06DEC2013

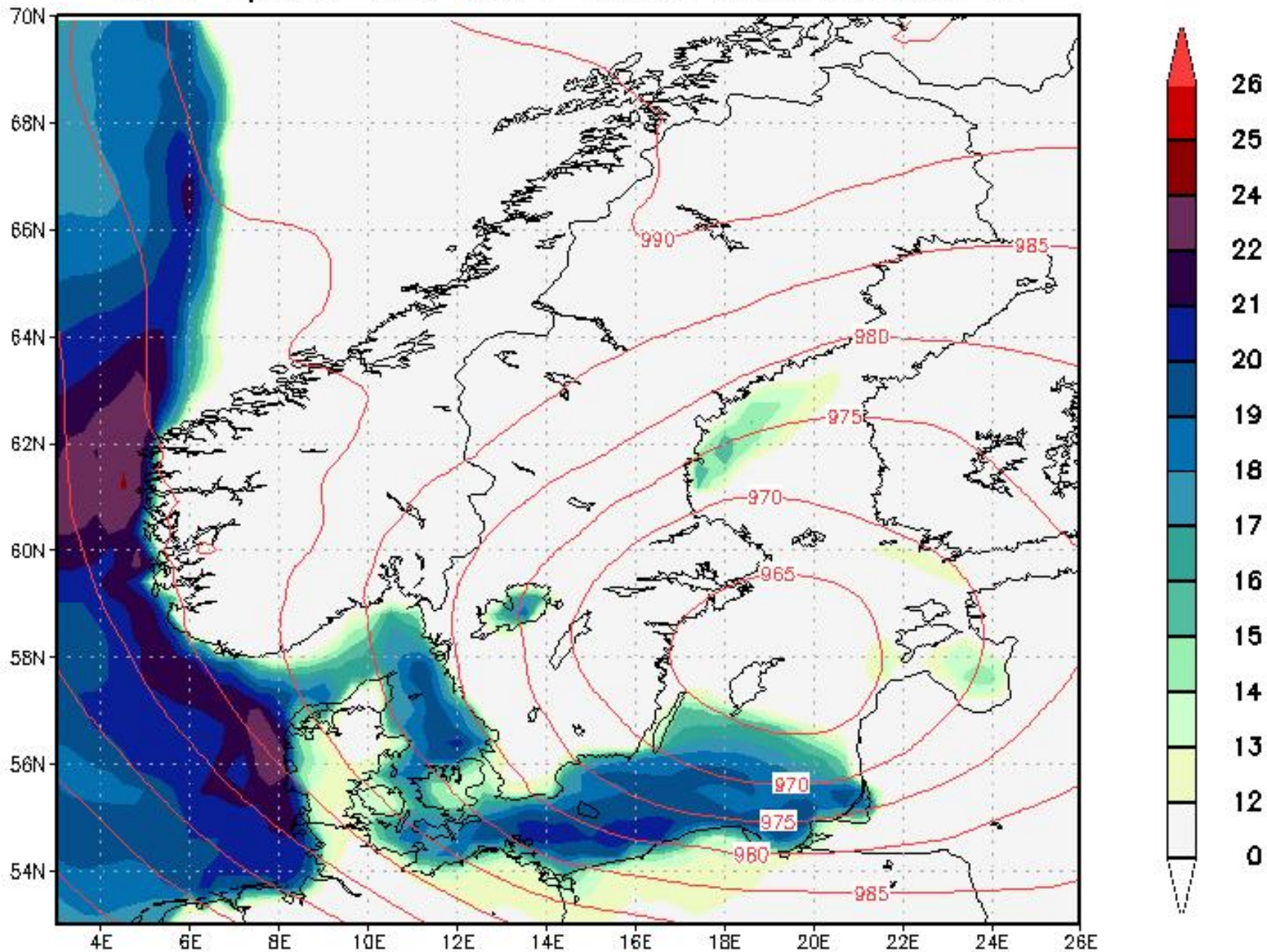Wind speed and MSLP Bodil 02Z06DEC2013
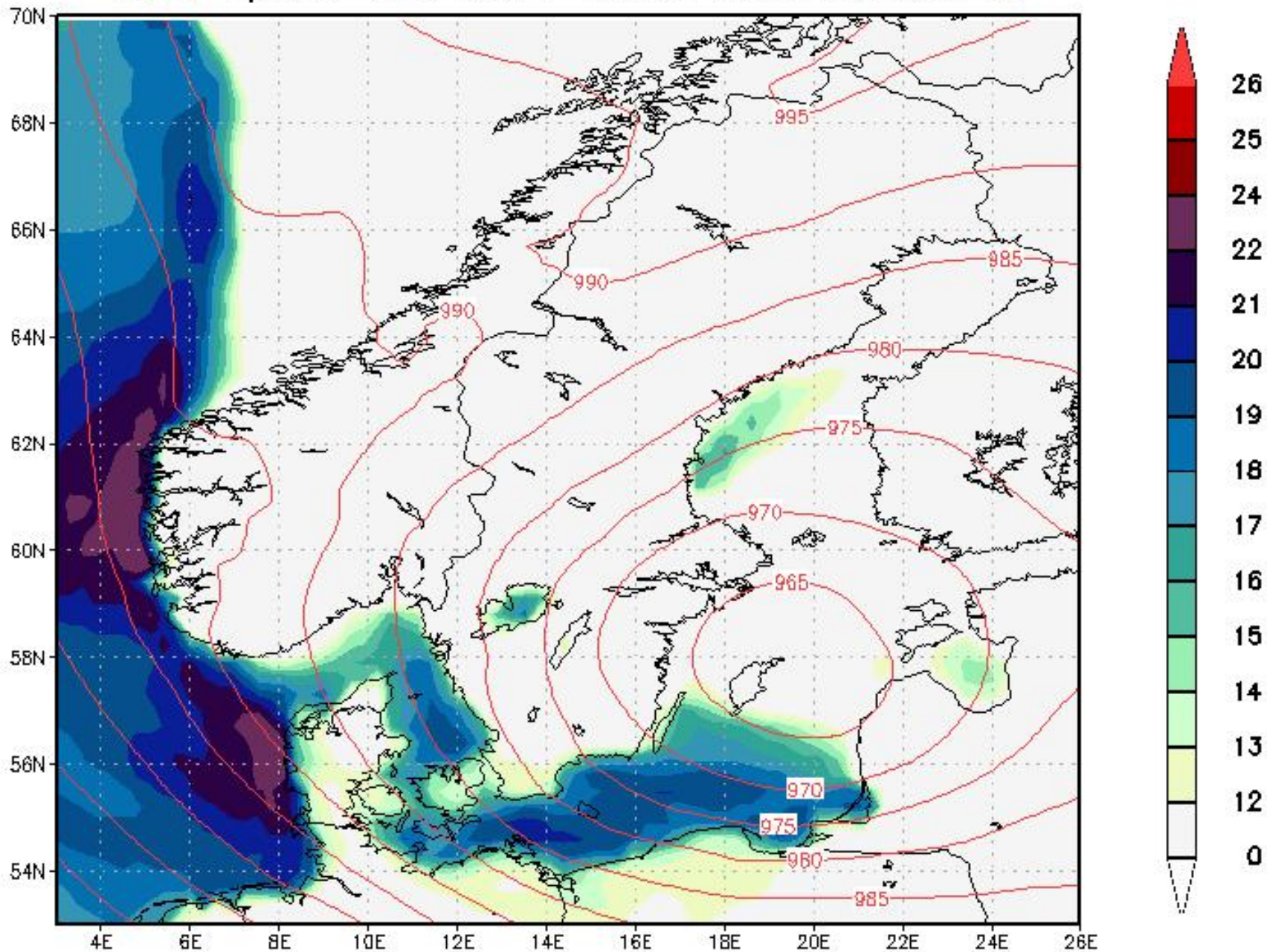
Wind speed and MSLP Bodil 03Z06DEC2013

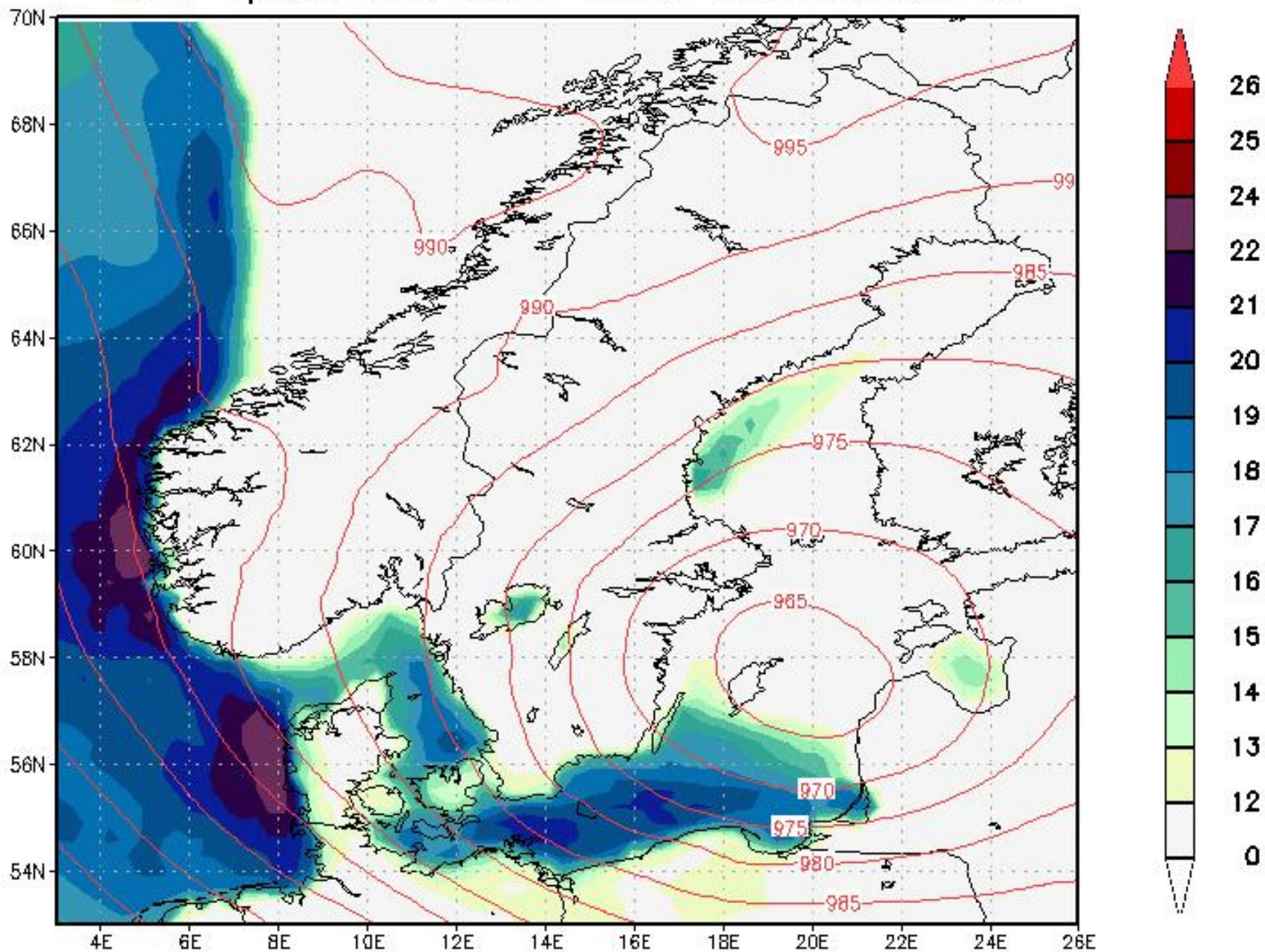Wind speed and MSLP Bodil 04Z06DEC2013

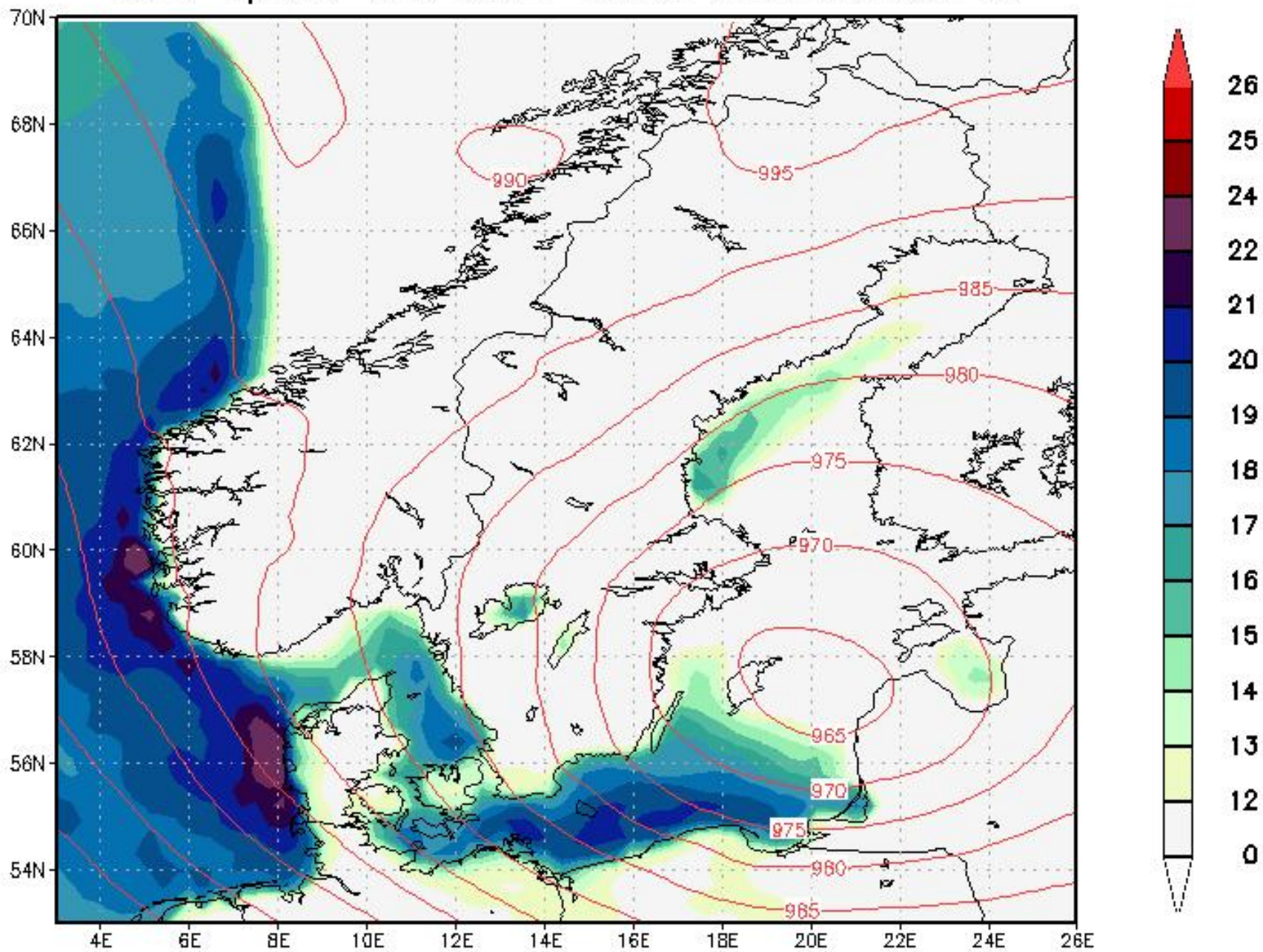Wind speed and MSLP Bodil 05Z06DEC2013
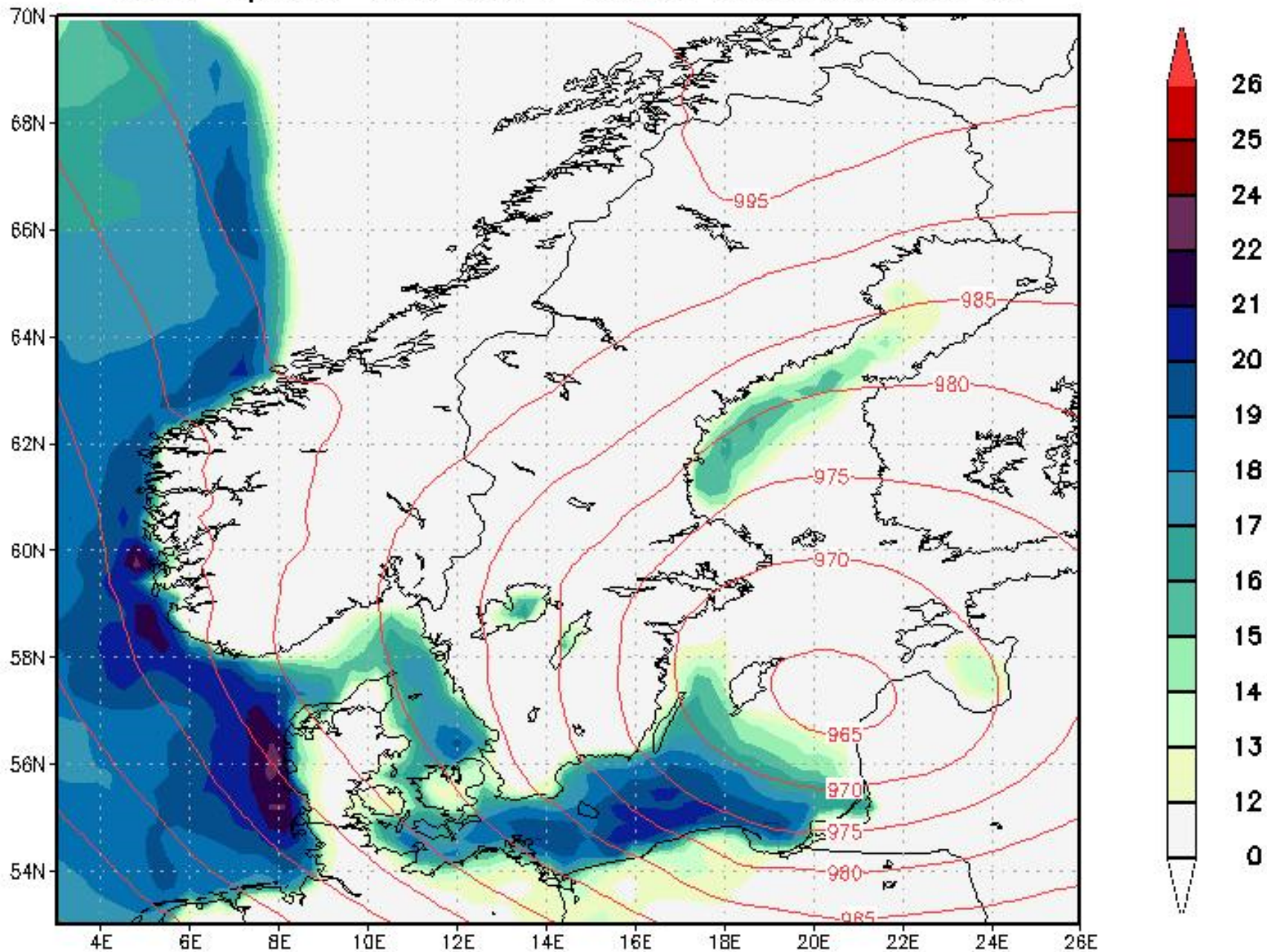
Wind speed and MSLP Bodil 06Z06DEC2013

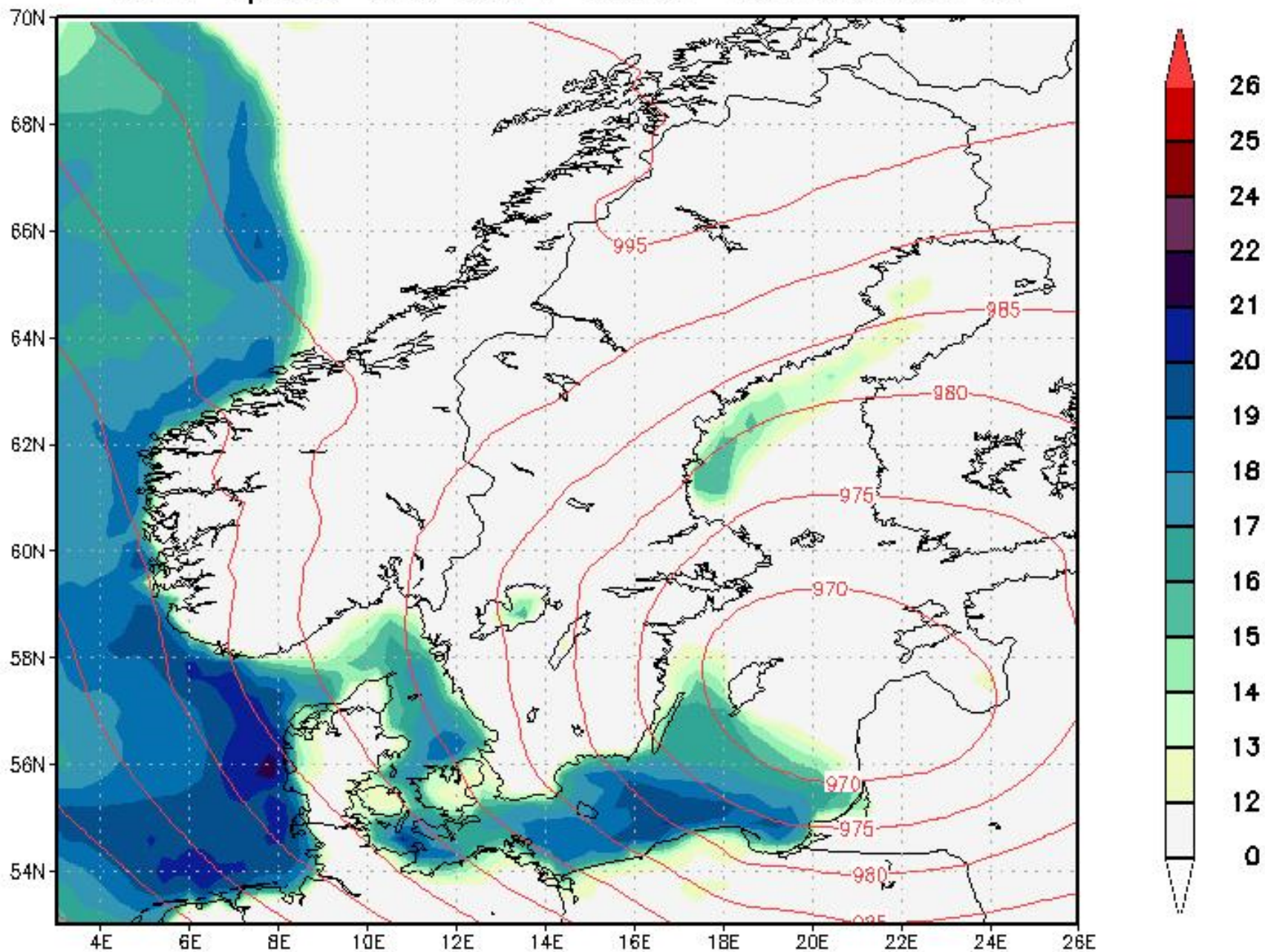Wind speed and MSLP Bodil 07Z06DEC2013

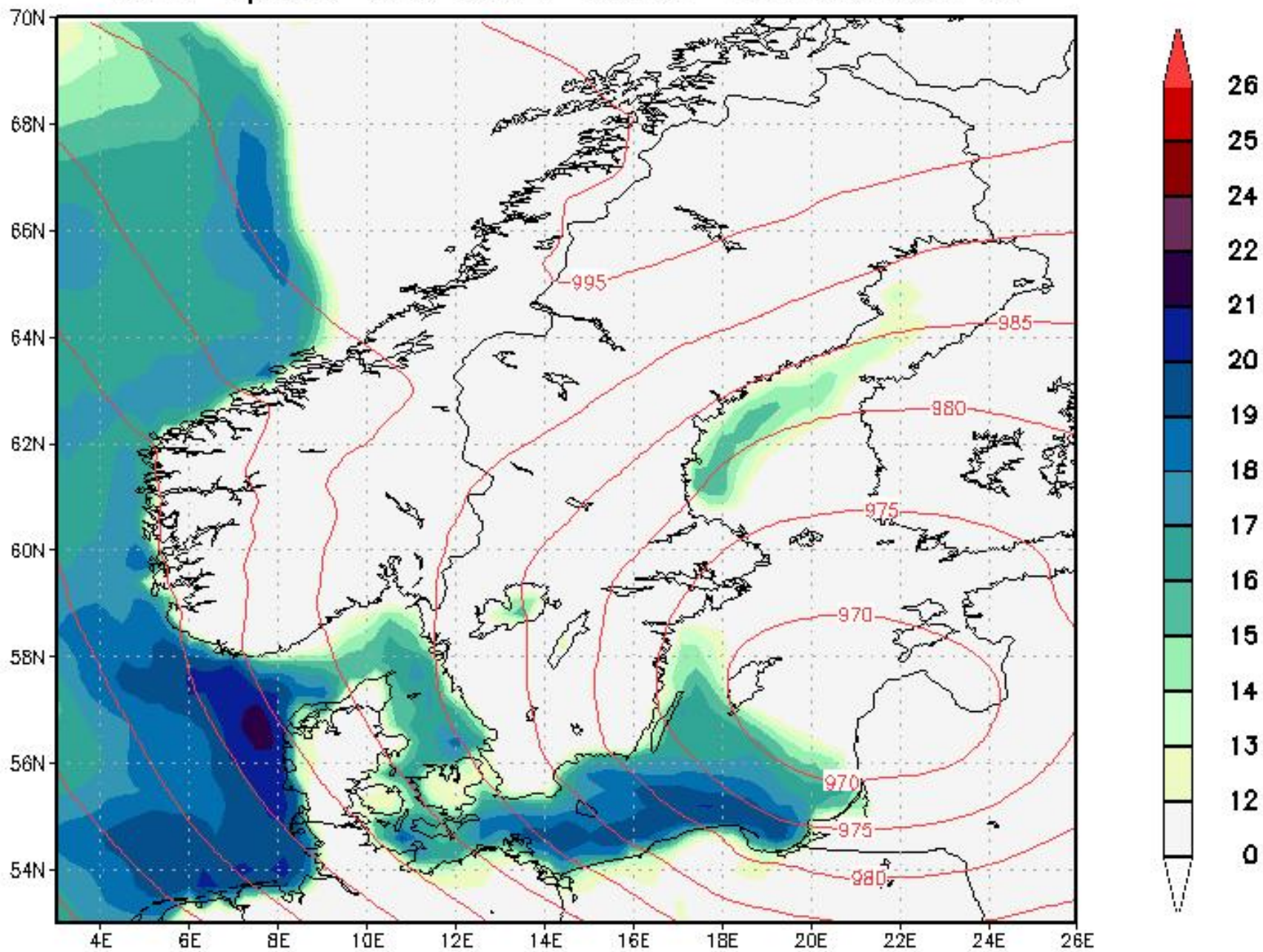Wind speed and MSLP Bodil 08Z06DEC2013

Wind speed and MSLP Bodil 09Z06DEC2013

Wind speed and MSLP Bodil 10Z06DEC2013

Wind speed and MSLP Bodil 11Z06DEC2013

Wind speed and MSLP Bodil 12Z06DEC2013

Wind speed and MSLP Bodil 13Z06DEC2013

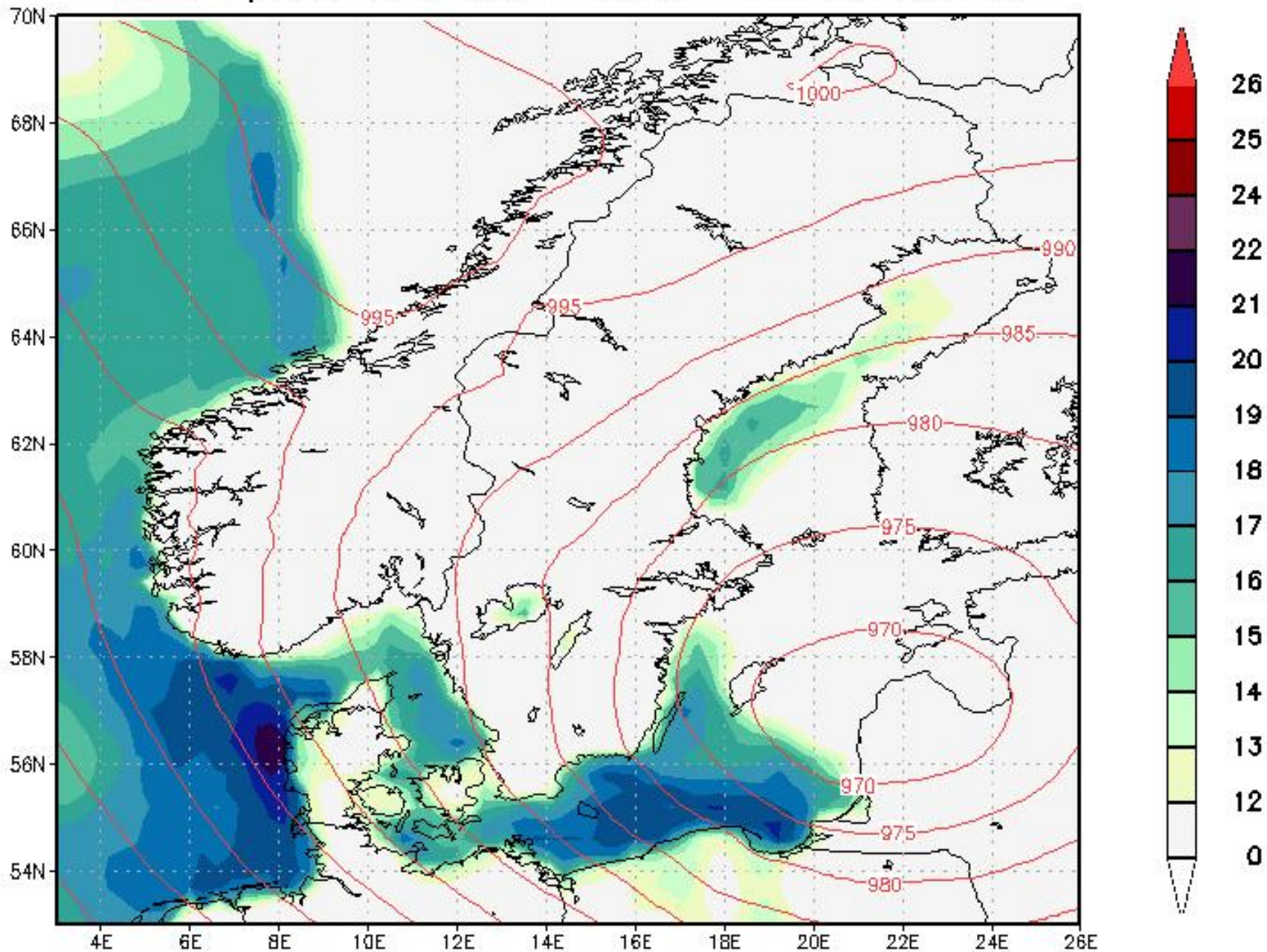Wind speed and MSLP Bodil 14Z06DEC2013

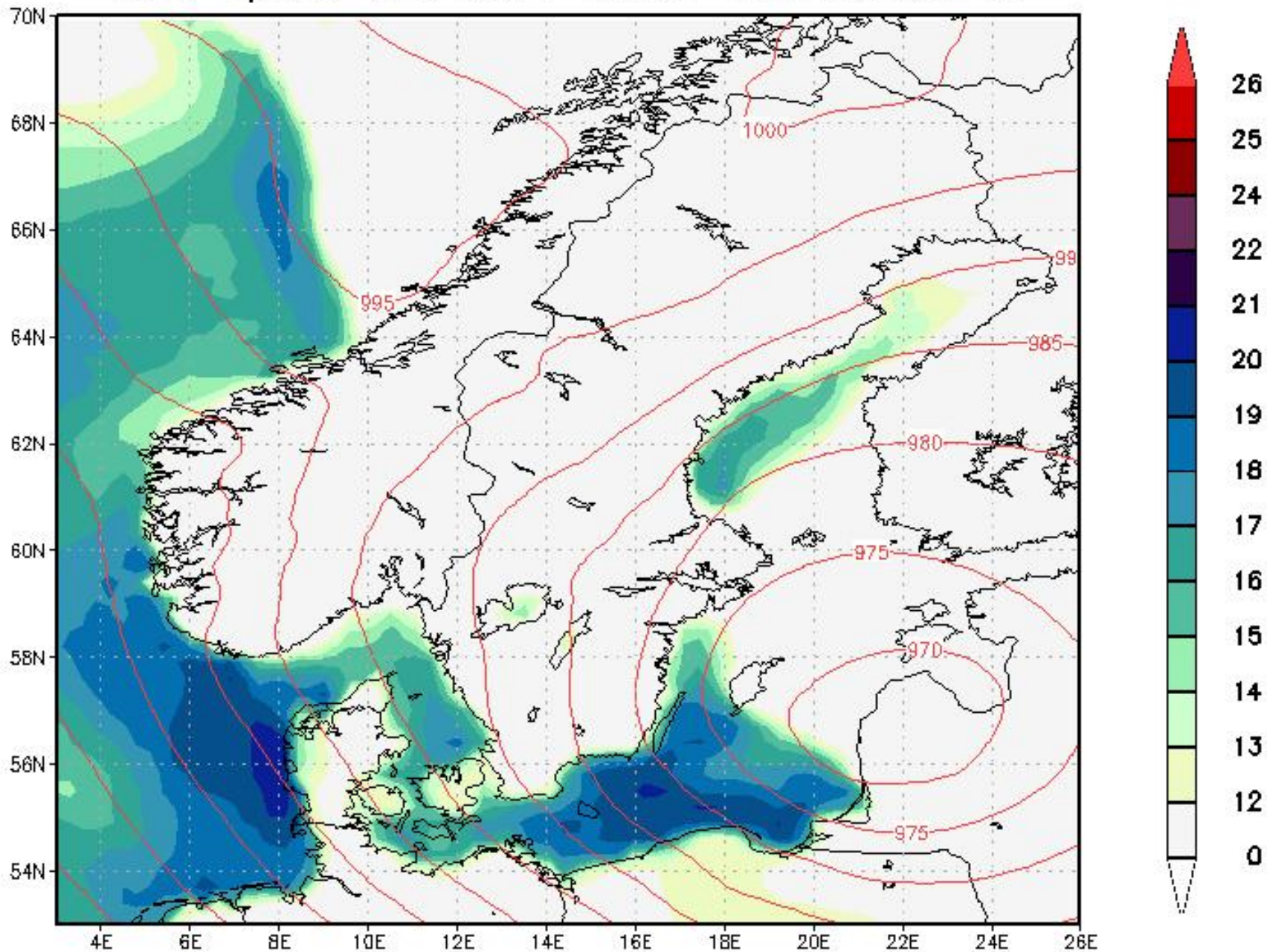Wind speed and MSLP Bodil 15Z06DEC2013

Wind speed and MSLP Bodil 16Z06DEC2013
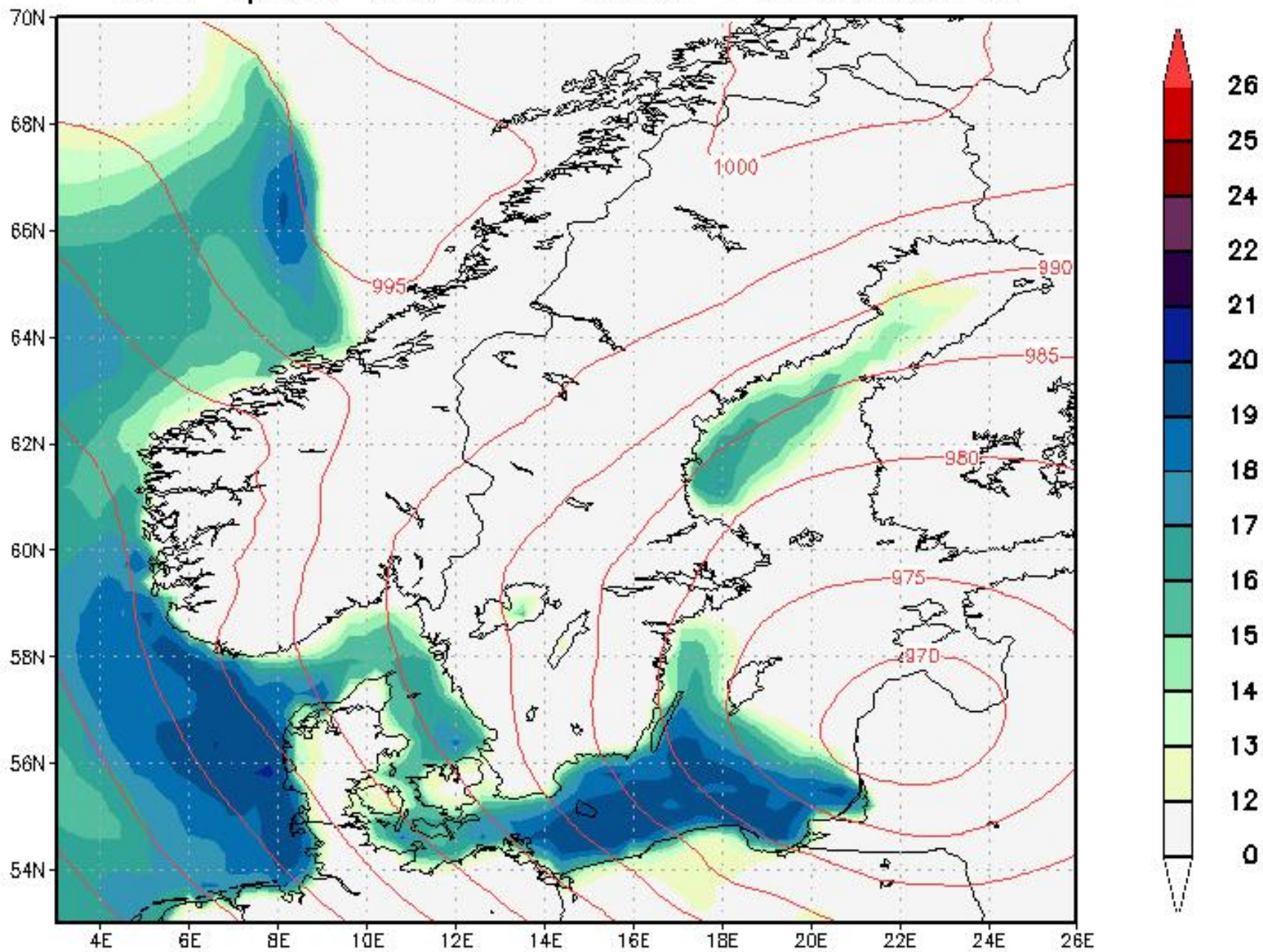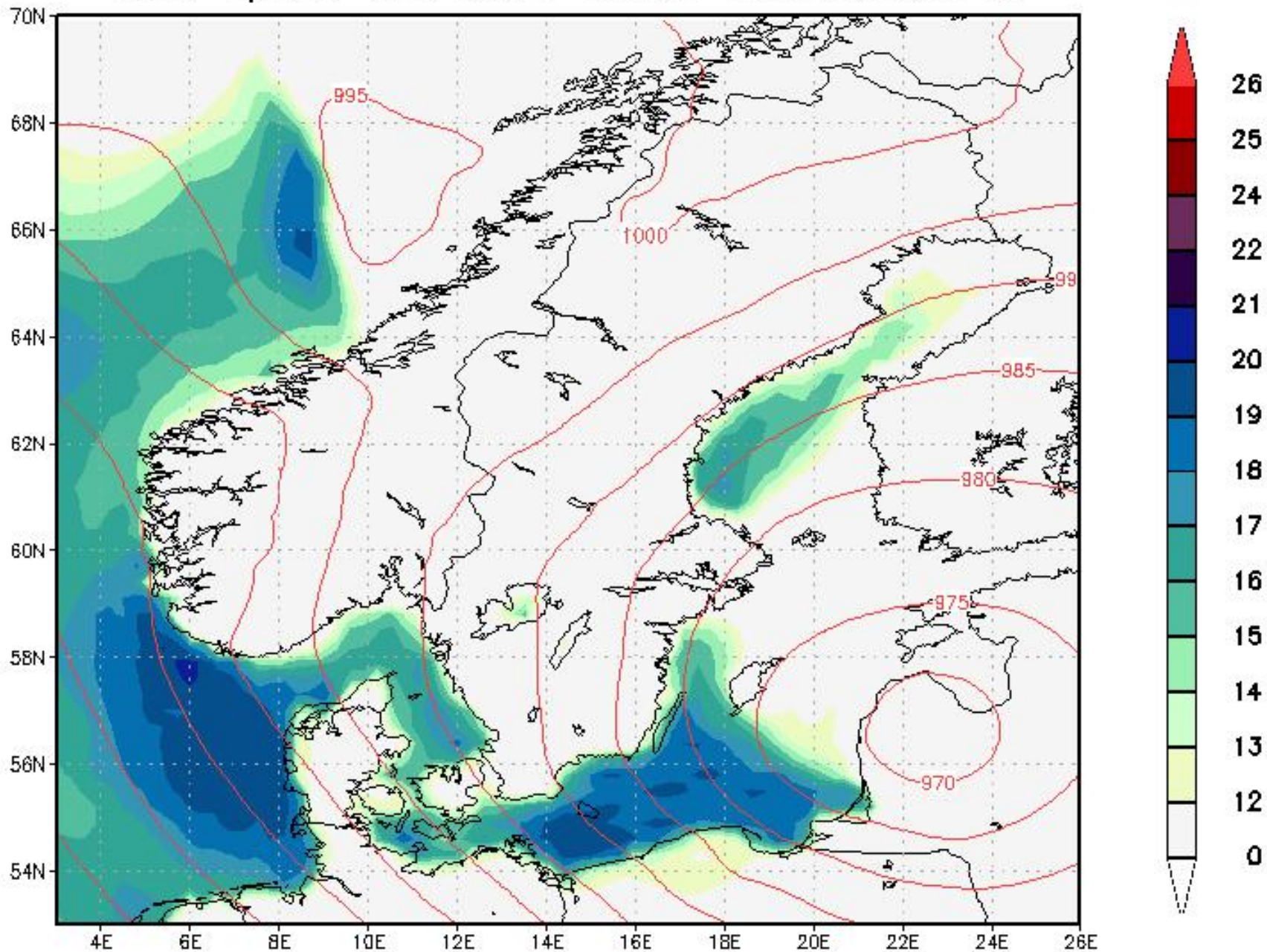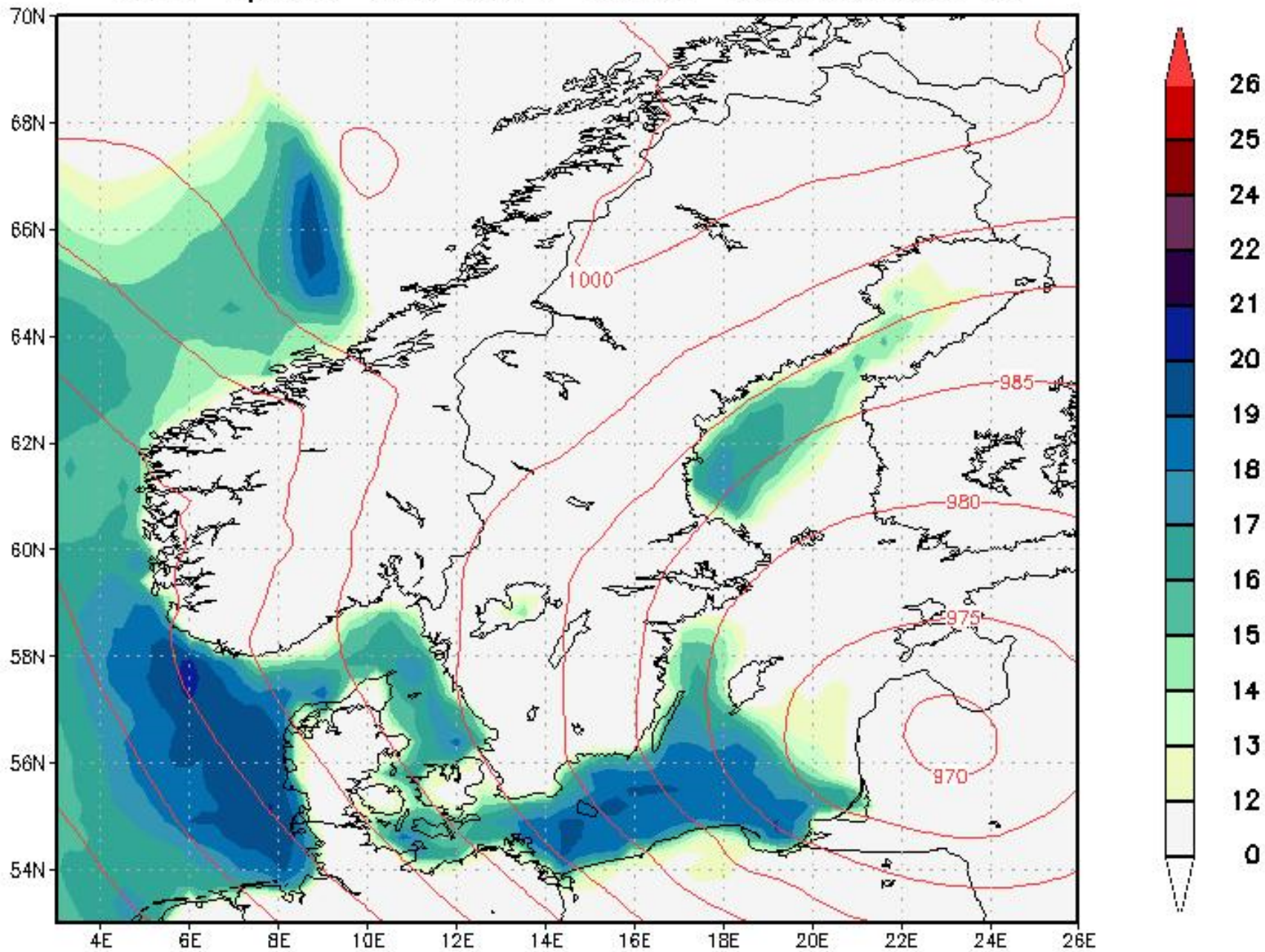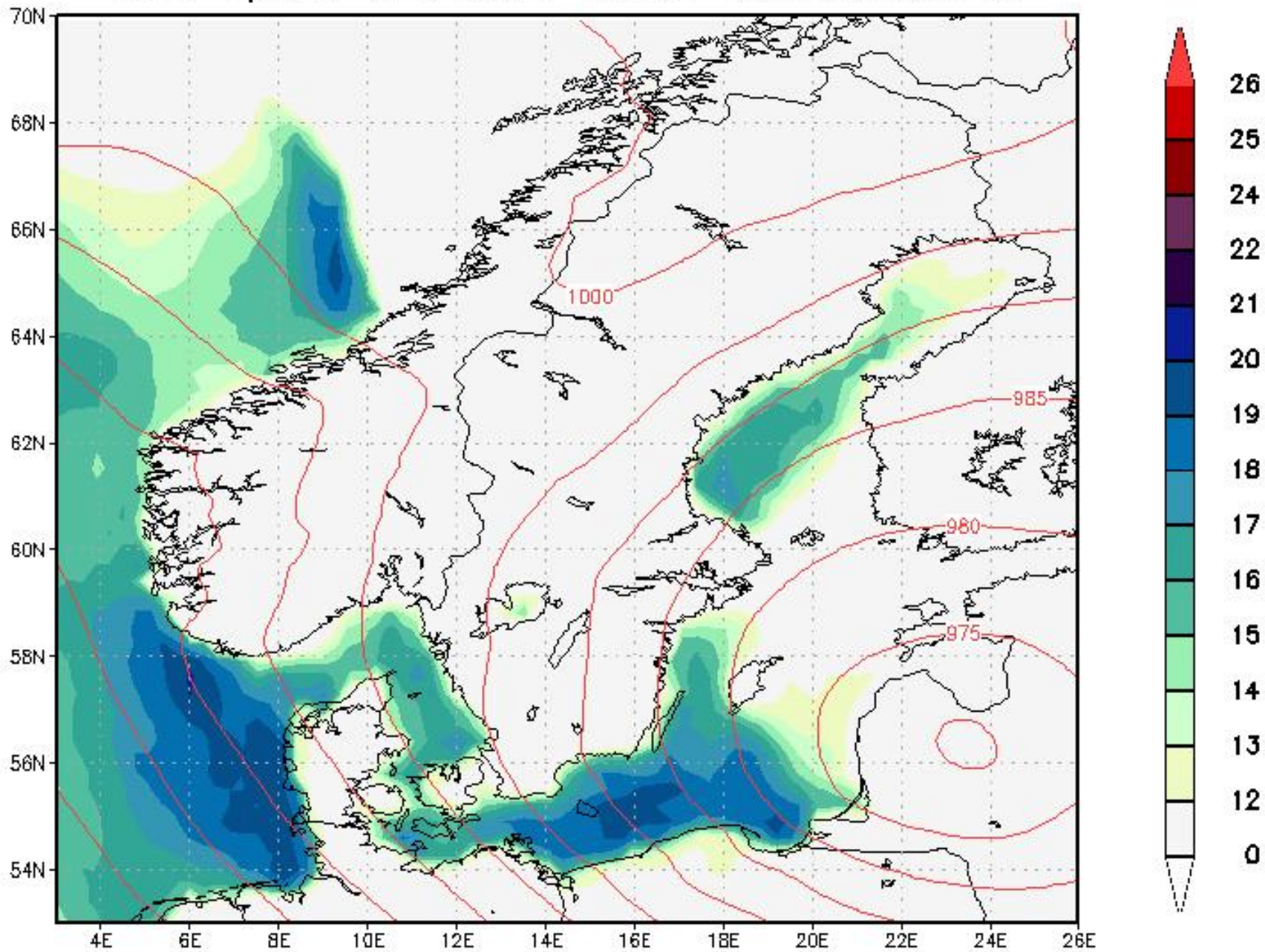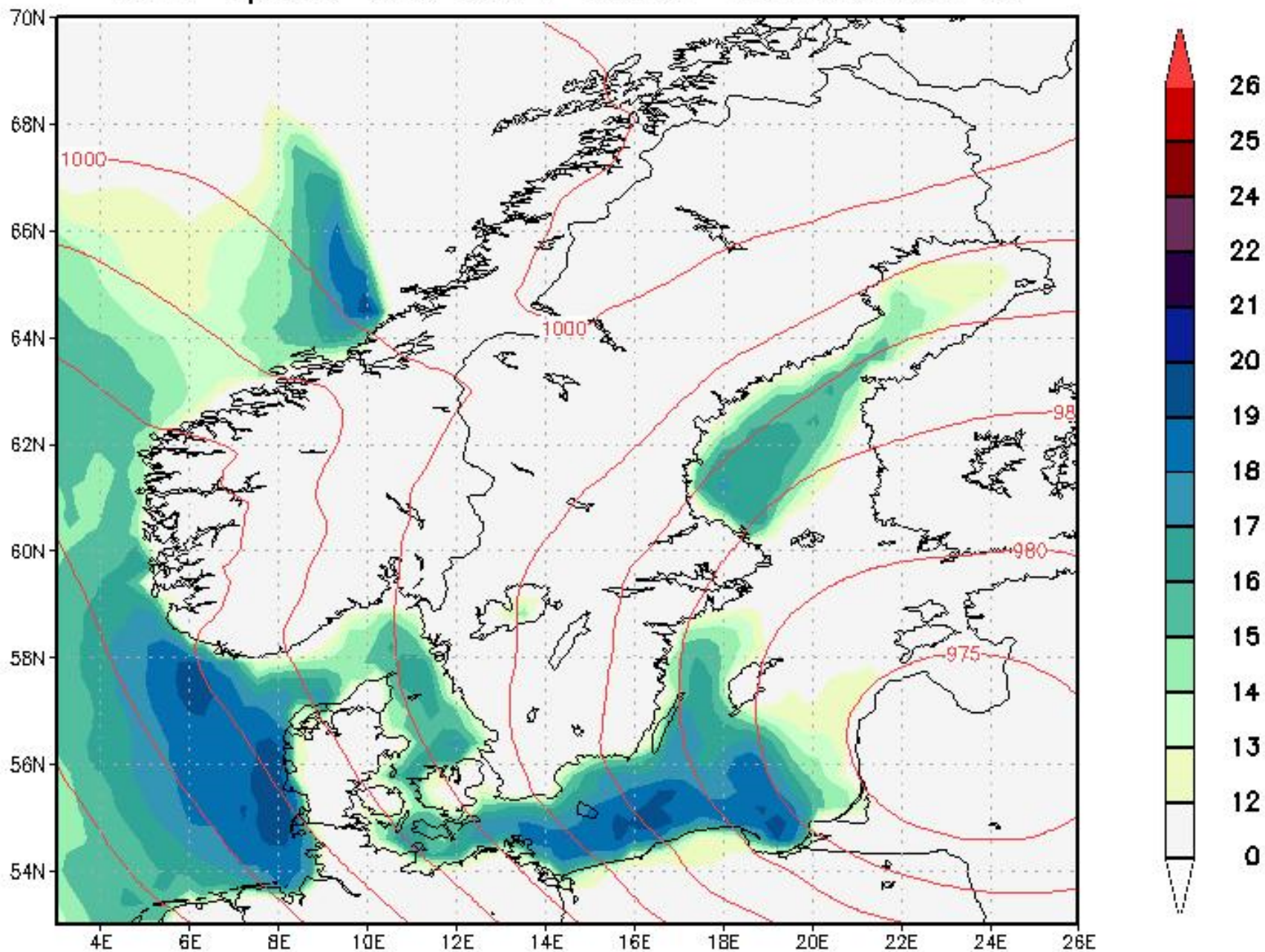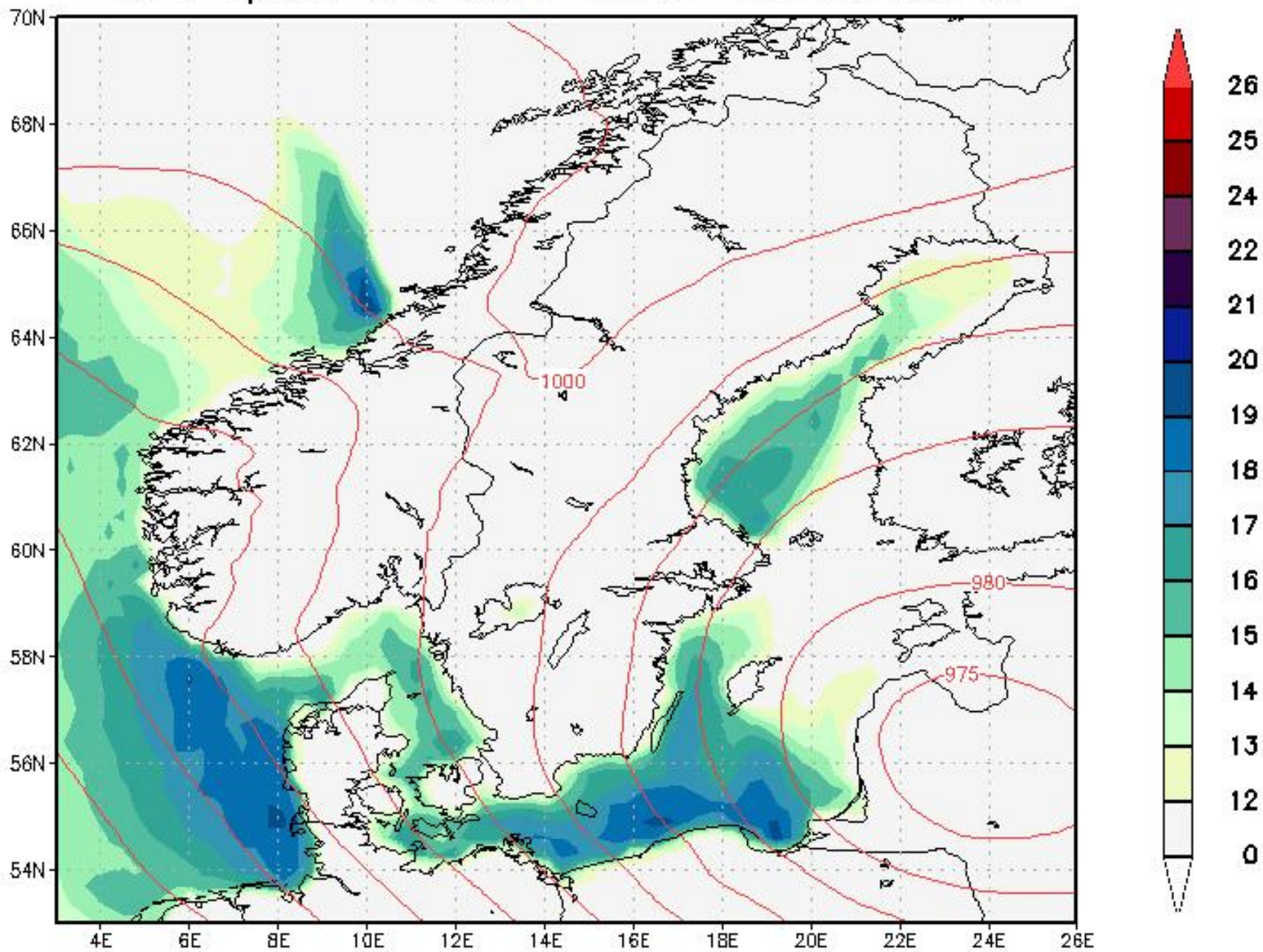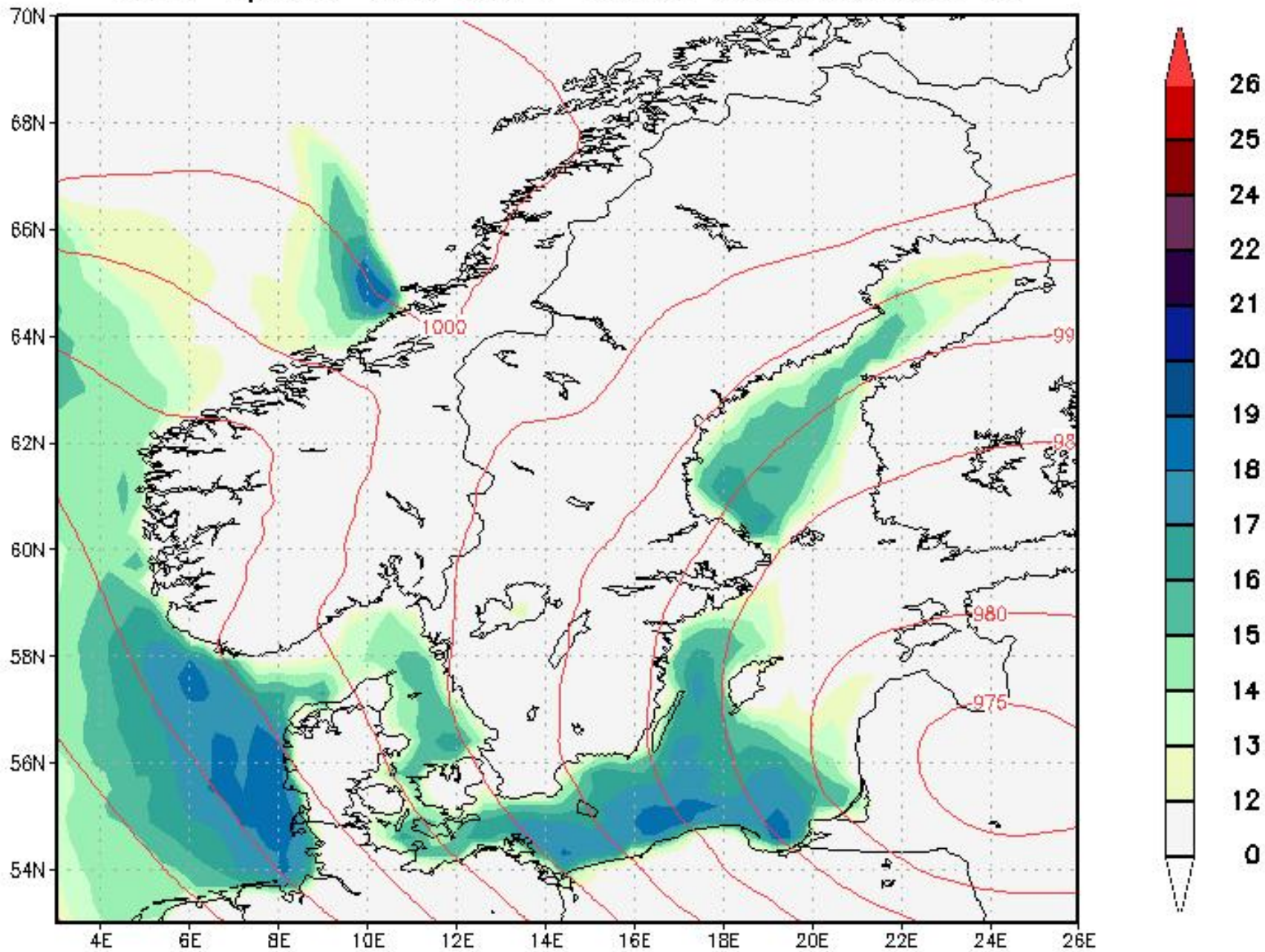
Wind speed and MSLP Bodil 17Z06DEC2013

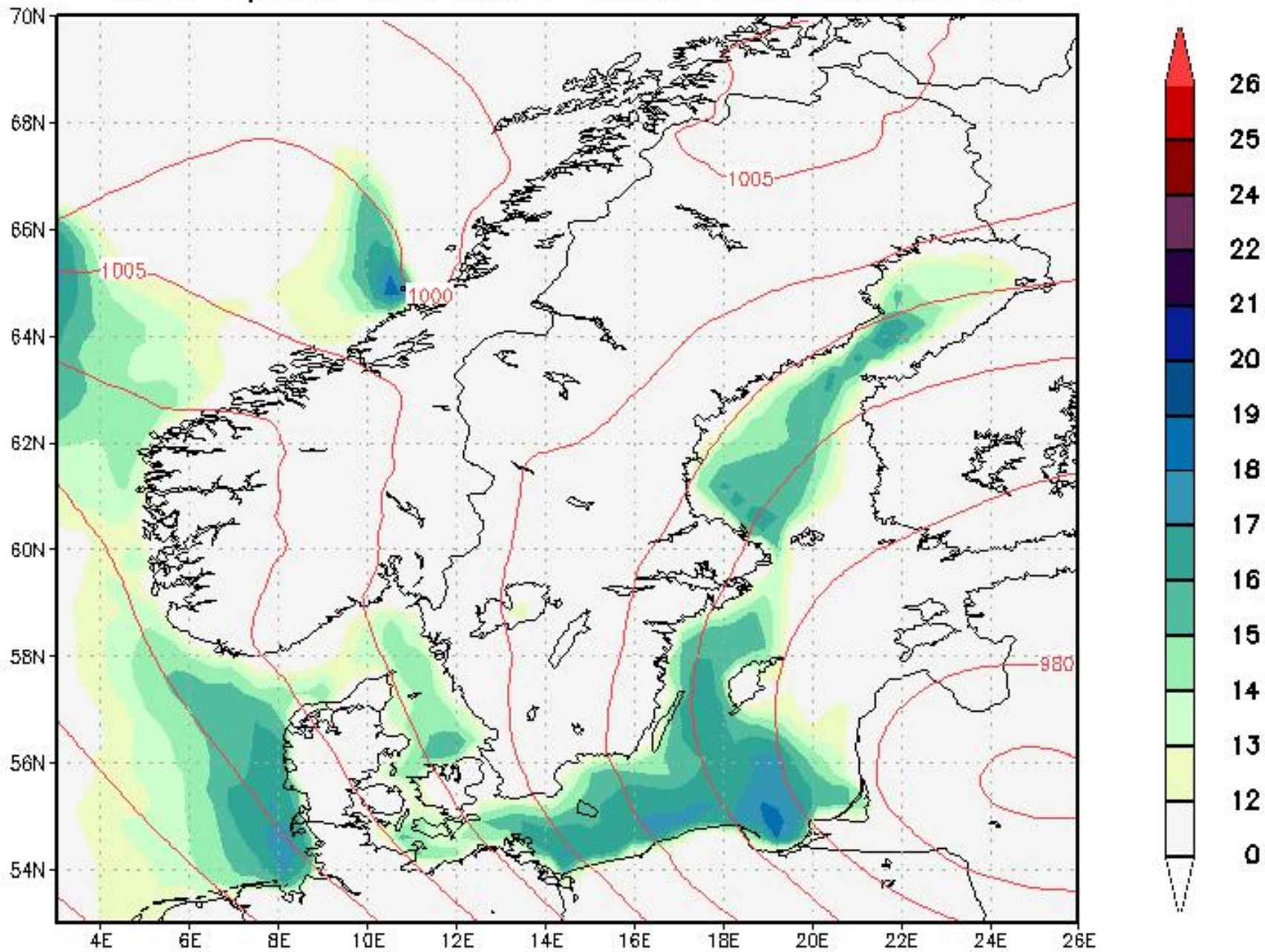Wind speed and MSLP Bodil 18Z06DEC2013
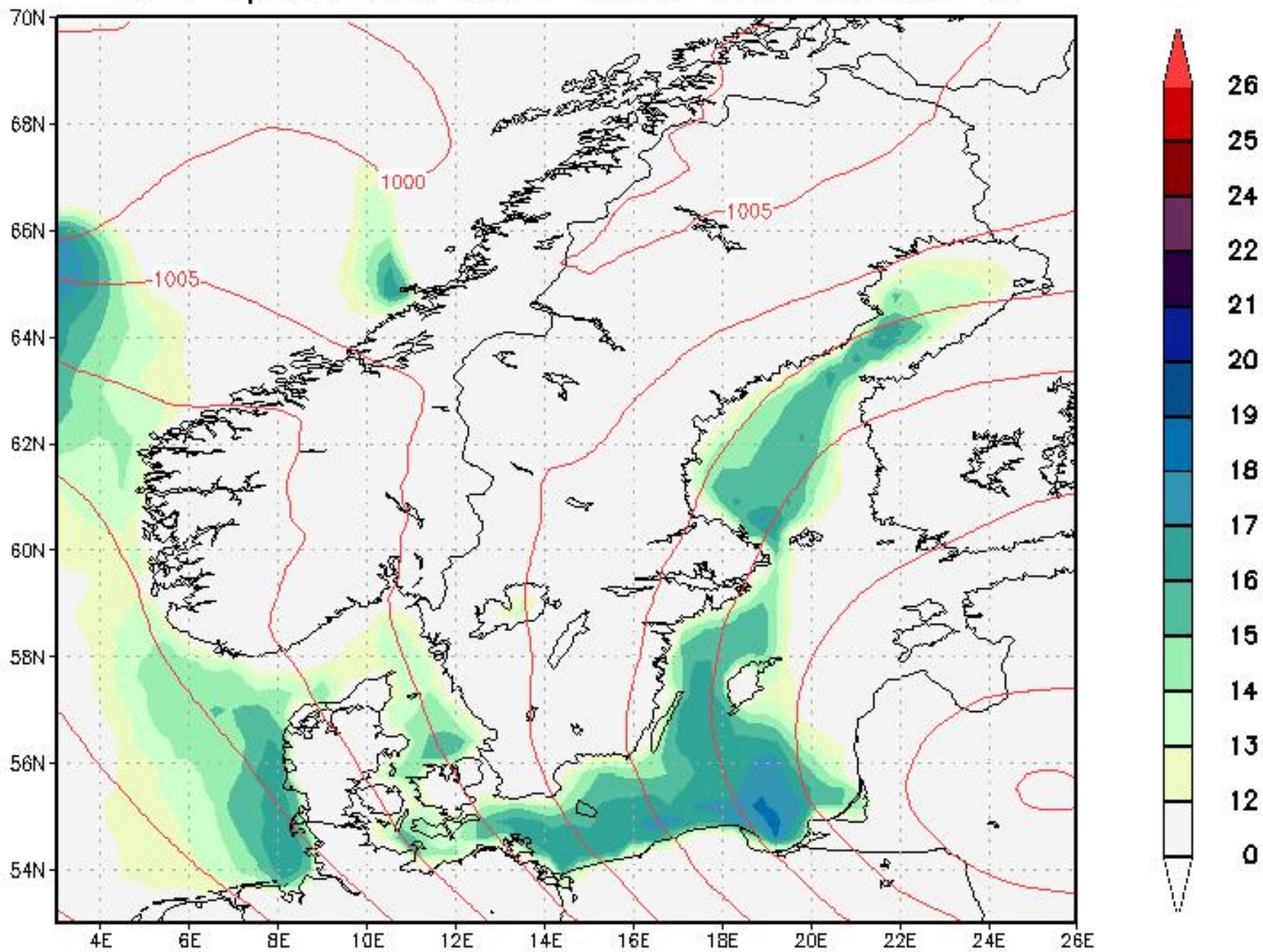
Wind speed and MSLP Bodil 19Z06DEC2013

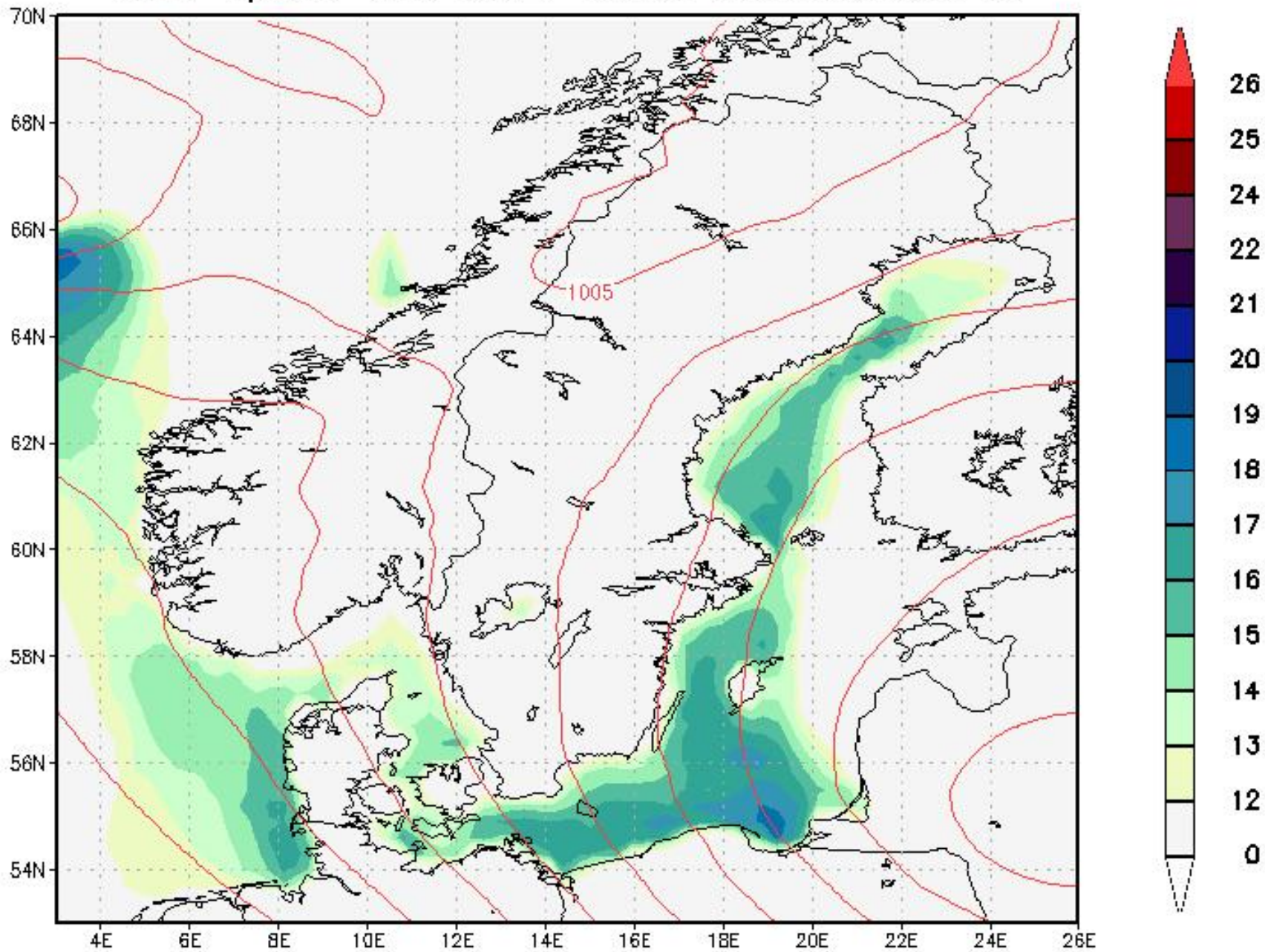Wind speed and MSLP Bodil 20Z06DEC2013

Wind speed and MSLP Bodil 22Z06DEC2013

Wind speed and MSLP Bodil 23Z06DEC2013
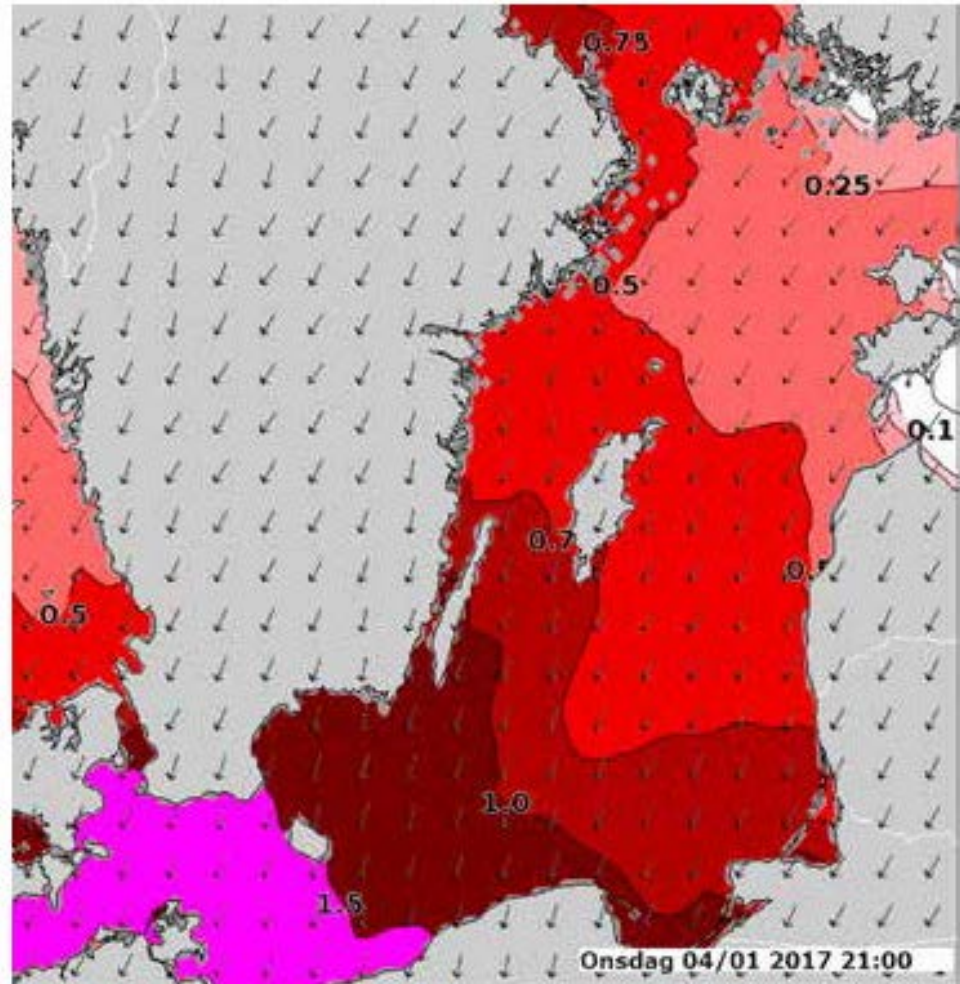
Wind speed and MSLP Bodil 00Z07DEC2013
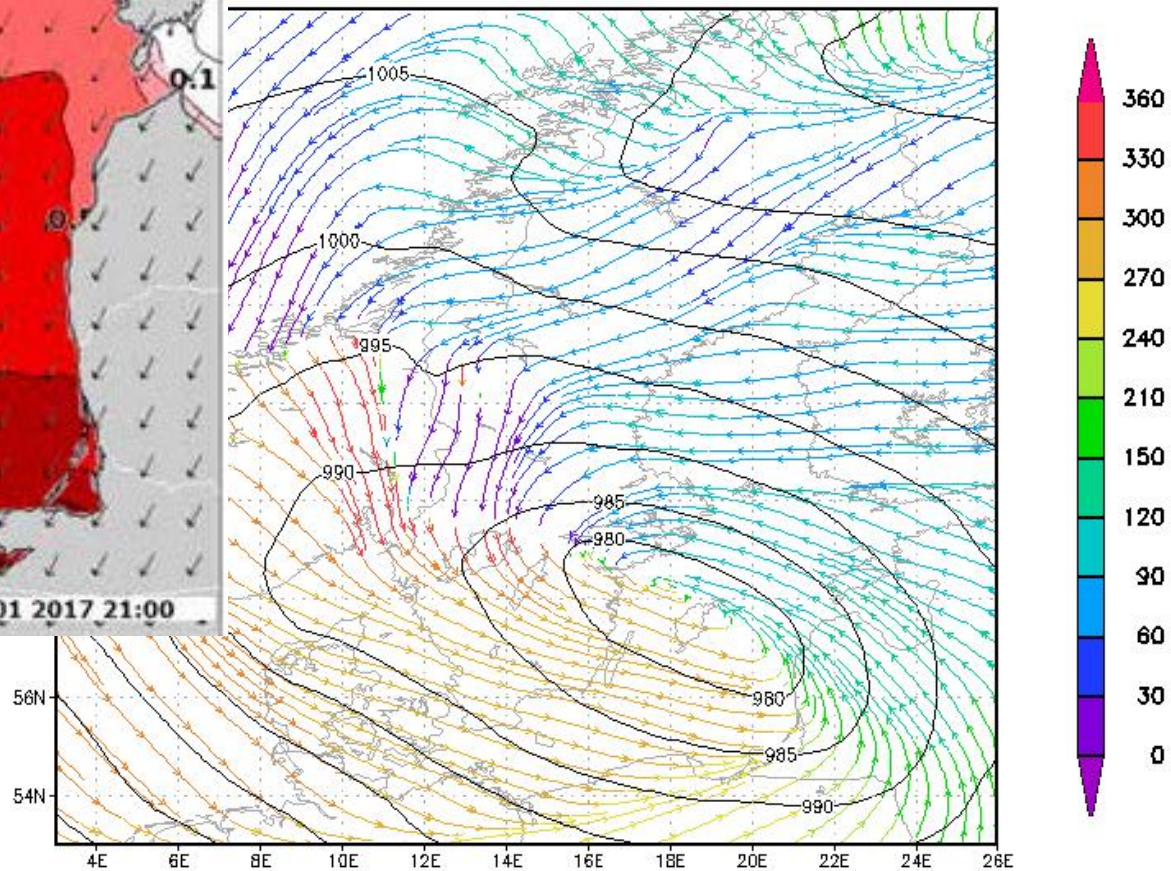
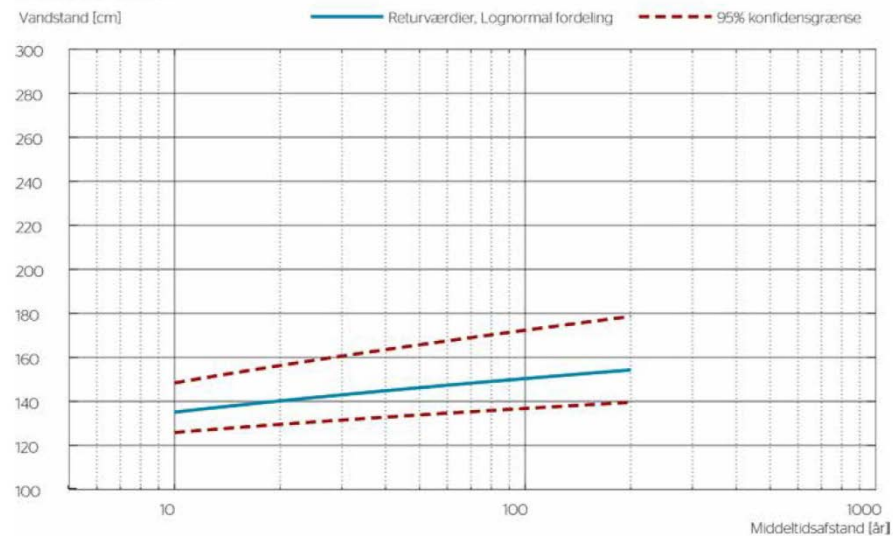# The "quiet flood" 4 and 5 January 2017

Map labels (Databladsnr., stationsnavn, 100 års middeltidsværdi (cm)):

- 22 Skagen Havn **151**
- 21 Hirtshals Havn **144**
- 23 Frederikshavn Havn **158**
- 67 Tejn Havn **121**
- 66 Rønne Havn **120**
- 20 Hanstholm Havn **172**
- 30 Nr. Sundby **141**
- 29 Attrup **150**
- 31 Hals **154**
- 28 Løgstør Havn **198**
- 27 Thisted Havn **190**
- 19 Thyborøn Havet **250**
- 26 Hvalpsund **187**
- 18 Thyborøn Havn **197**
- 24 Lemvig Havn **197**
- 25 Skive Havn **203**
- 17 Ferring **274**
- 12 Skovlund **125**
- 15 Thorsminde Havn **329**
- 16 Thorsminde Havet **274**
- 11 Kloster Havn **136**
- 32 Randers Havn **171**
- 33 Grenå Havn **171**
- 10 Ringkøbing Havn **111**
- 34 Aarhus Havn **163**
- 57 Hornbæk Havn **181**
- 53 Havnebyen/ Sjællands Odde **168**
- 13 Hvide Sande Havn **314**
- 14 Hvide Sande Havet **297**
- 56 Hundested Havn **158**
- 9 Bork Havn **136**
- 45 Ballen Havn **165**
- 58 Københavns Havn **15?**
- 54 Holbæk Havn **181**
- 35 Juelsminde Havn **162**
- 55 Roskilde Havn **175**
- 52 Kalundborg Havn **158**
- 44 Bogense Havn **172**
- 59 Drogden Fyr **14?**
- 7 Esbjerg Havn **404**
- 36 Fredericia Havn **153**
- 46 Odense Fjord (Gabet) **168**
- 60 Køge Havn **159**
- 8 Grådyb Barre **310**
- 37 Kolding Havn **172**
- 47 Kerteminde Havn **172**
- 6 Ribe Kammersluse Flyder **488**
- 51 Korsør Havn **156**
- 61 Rødvig Havn **150**
- 5 Mandø Havet **395**
- 43 Assens Havn **179**
- 48 Slipshavn **155**
- 4 Brøns Sluse Havet **443**
- 38 Haderslev Havn **175**
- 50 Karrebæksminde **160**
- 3 Ballum Sluse **453**
- 2 Havneby Havn **423**
- 42 Fåborg Havn **181**
- 62 Kalvehave **149**
- 39 Åbenrå Havn **174**
- 1 Vidåslusen-Højer I **471**
- 41 Fynshav Havn **181**
- 40 Sønderborg Havn **177**
- 63 Hesnæs Havn **162**
- 49 Bagenkop Havn **170**
- 65 Rødbyhavns Havn **172**
- 64 Gedser Havn **178**

Signaturforklaring

- Databladsnr., stationsnavn, 100 års middeltidsværdi (cm)

Middeltidshændelser

Vandstand [cm]

— Returværdier, Lognormal fordeling   - - - 95% konfidensgrænse

Middeltidsafstand [år]

Højeste registrerede vandstande i cm [trendfri]

|							
4. januar 2017	161	16. november 2001	122	23. november 2004	111	1. november 2006	109
11. april 1997	130	11. februar 2011	119	14. januar 2012	111	15. januar 2007	108
2. januar 2002	129	27. januar 2007	114	20. januar 2007	111	1. februar 2007	107
3. januar 1995	127	3. november 1997	113	24. januar 2007	111	5. februar 1993	105
3. november 1995	127	2. december 2013	112	21. februar 2002	111	8. april 1995	103

Streamlines and MSLP "Quiet Flood" 00Z03JAN2017
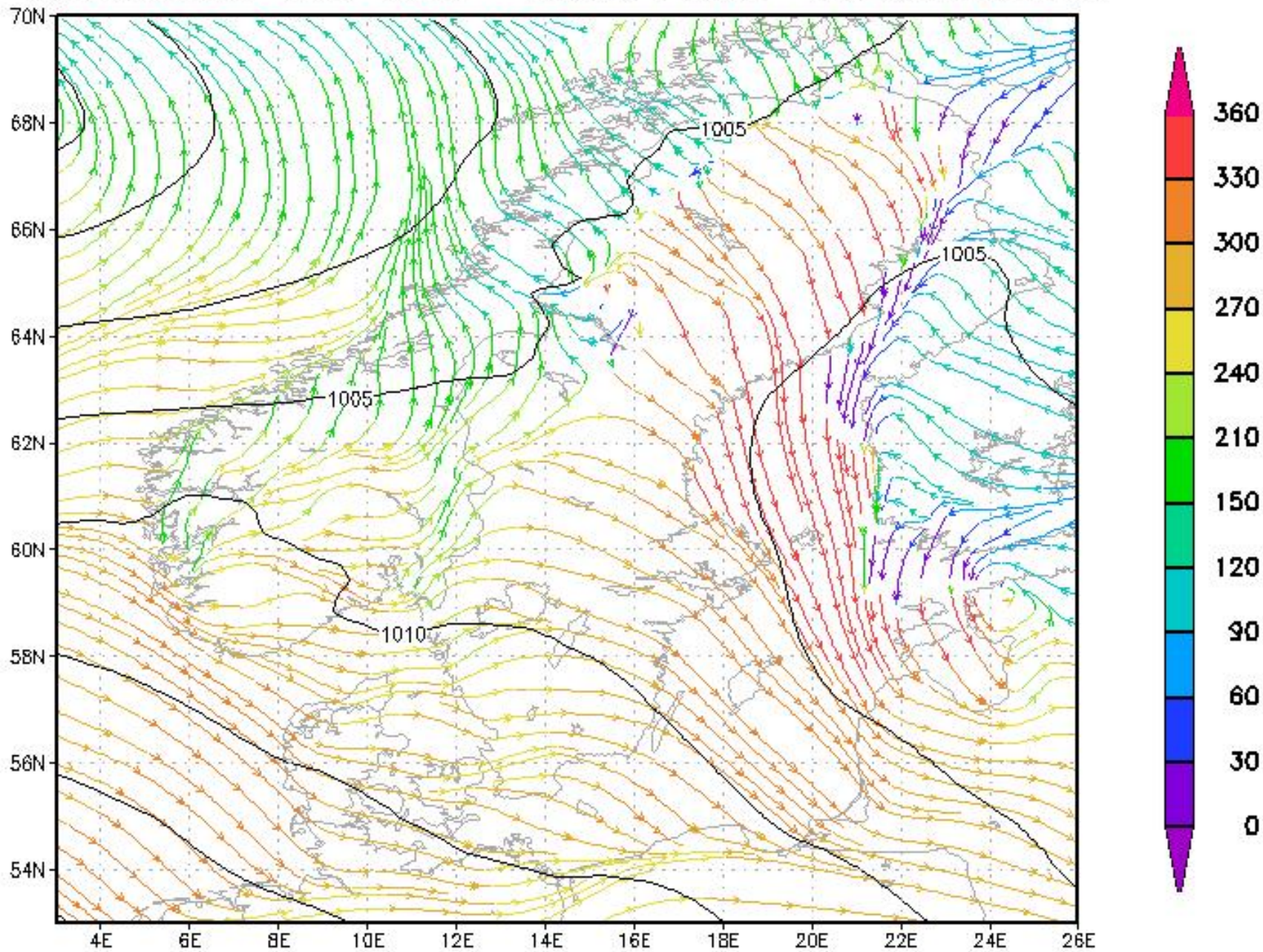
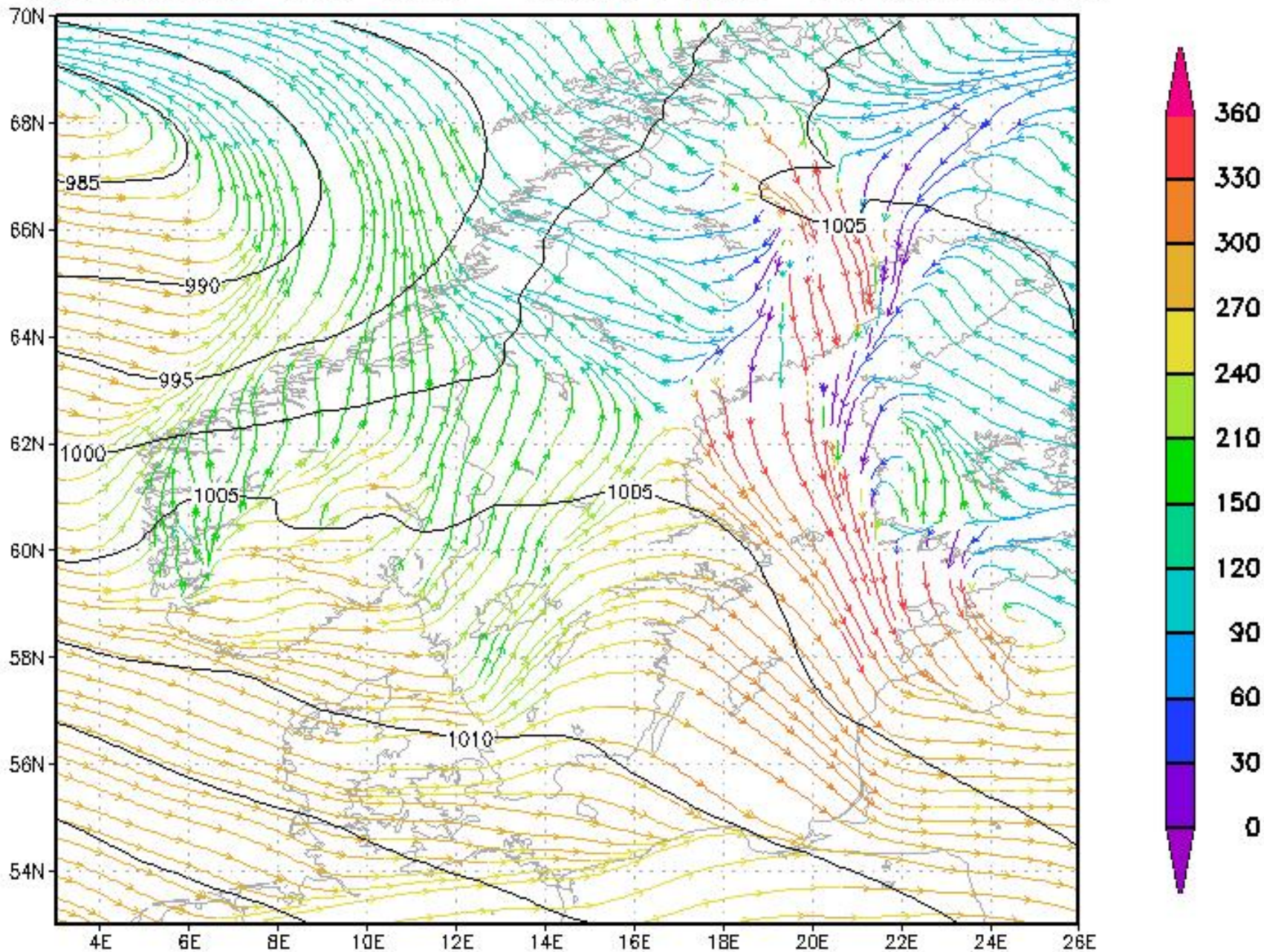Streamlines and MSLP "Quiet Flood" 01Z03JAN2017
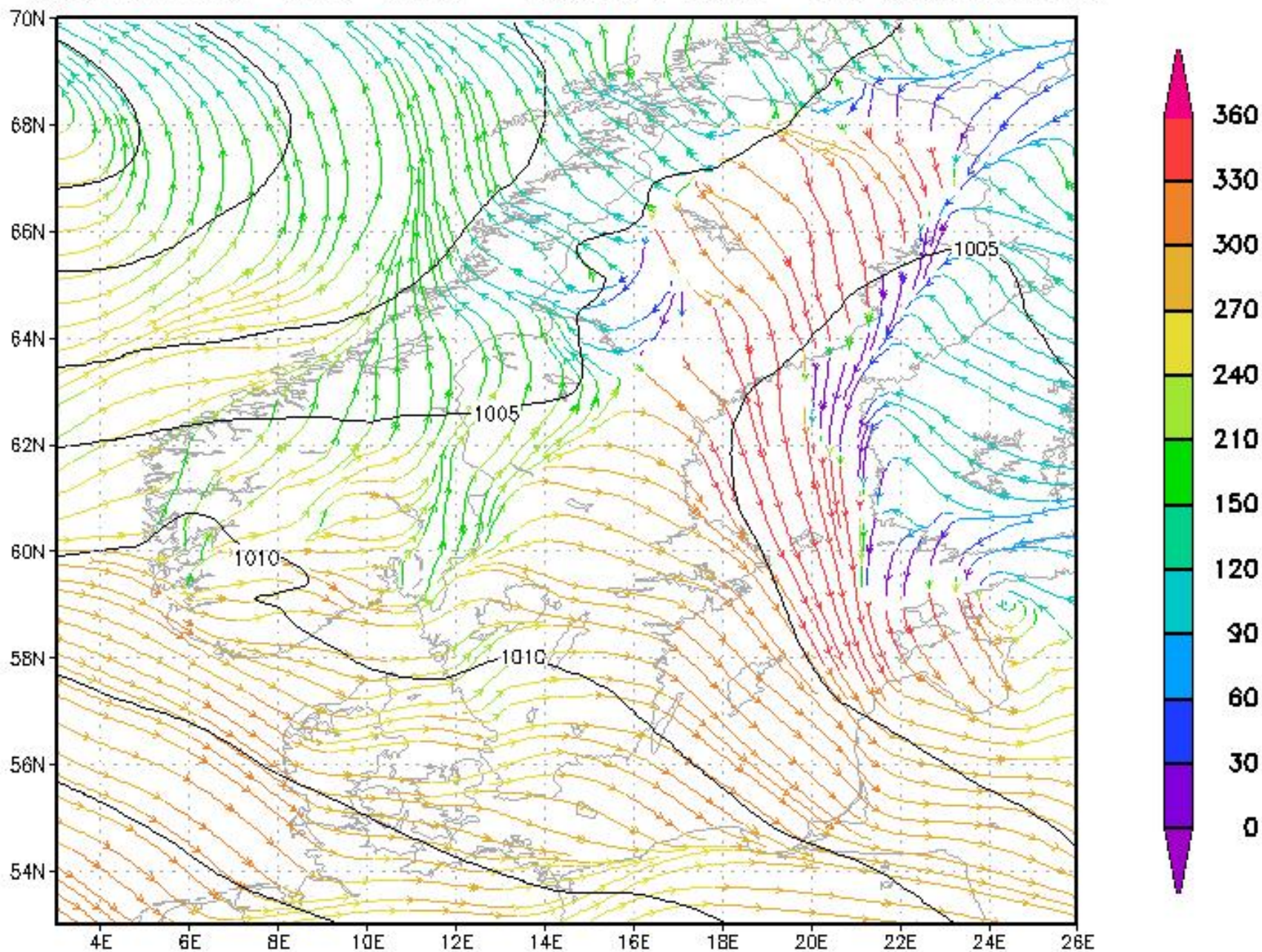
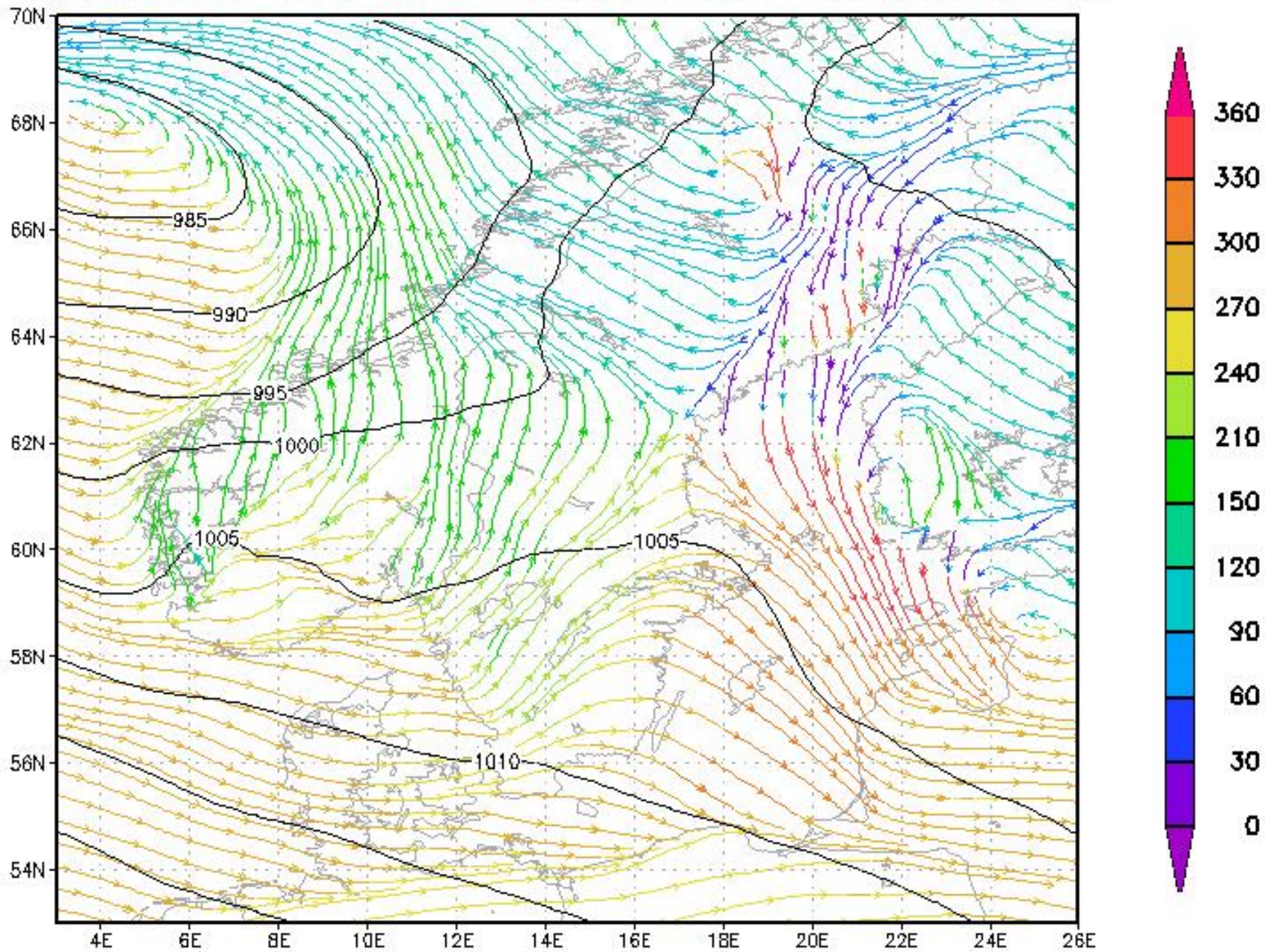Streamlines and MSLP "Quiet Flood" 02Z03JAN2017
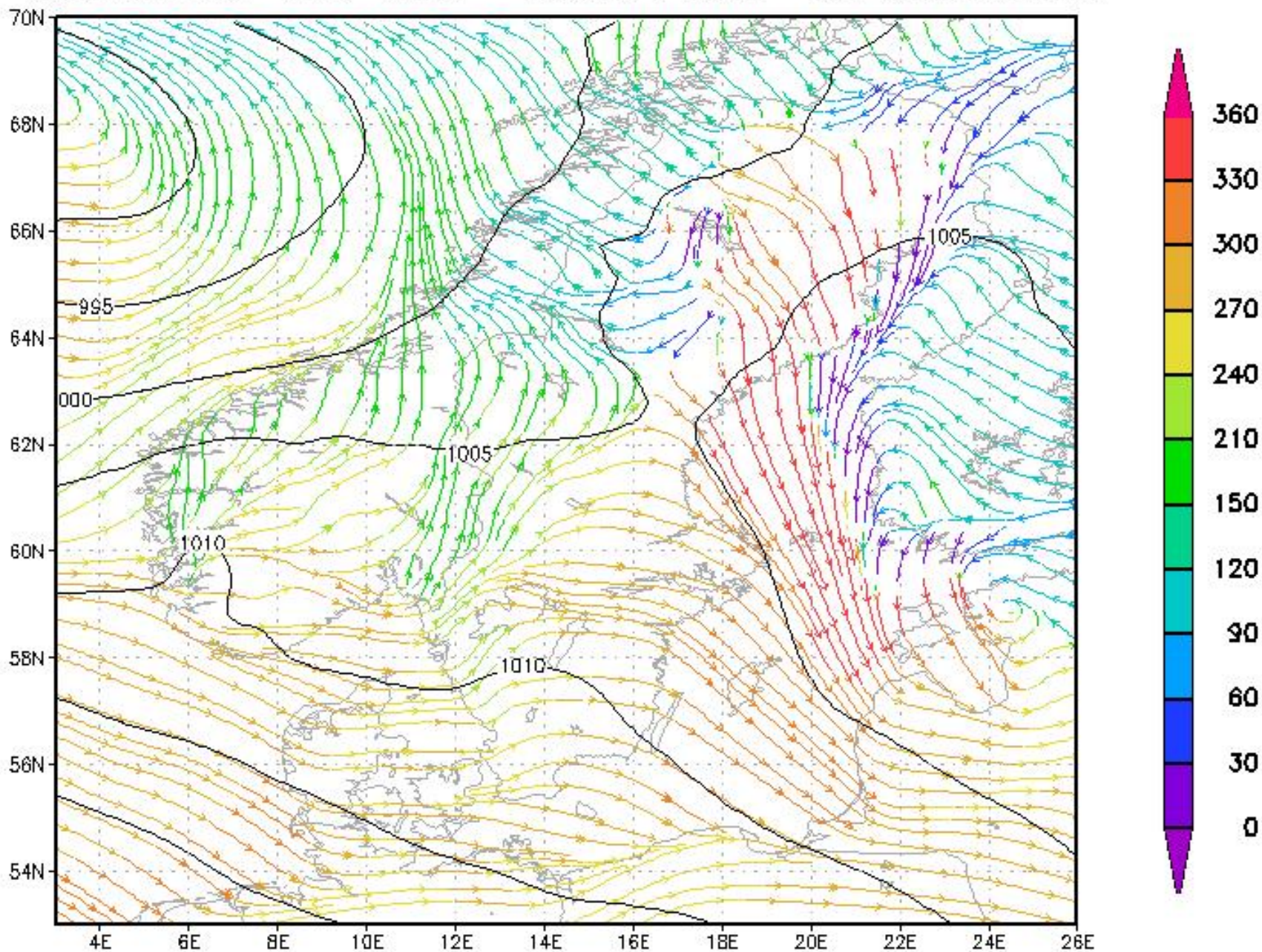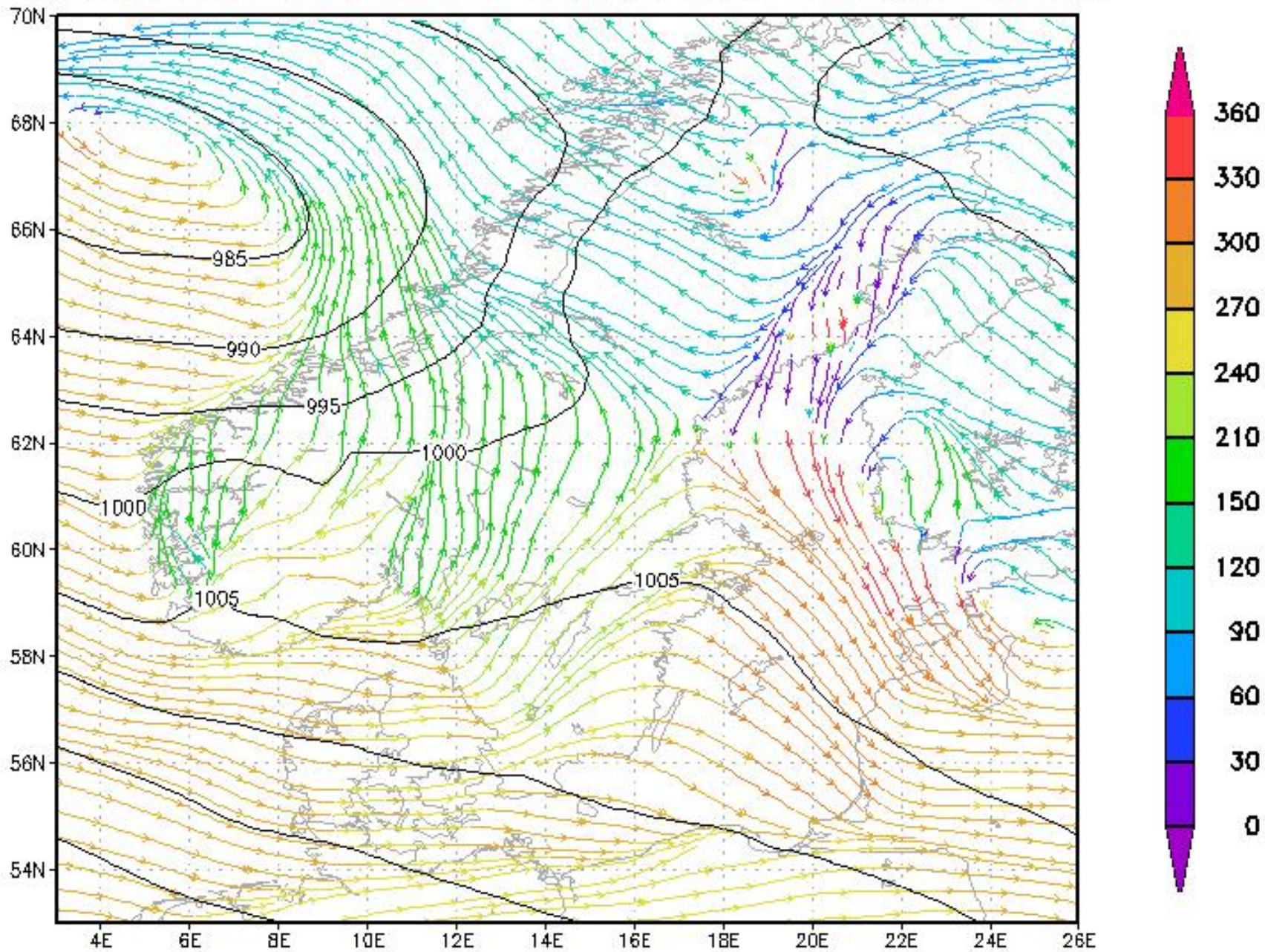
Streamlines and MSLP "Quiet Flood" 03Z03JAN2017
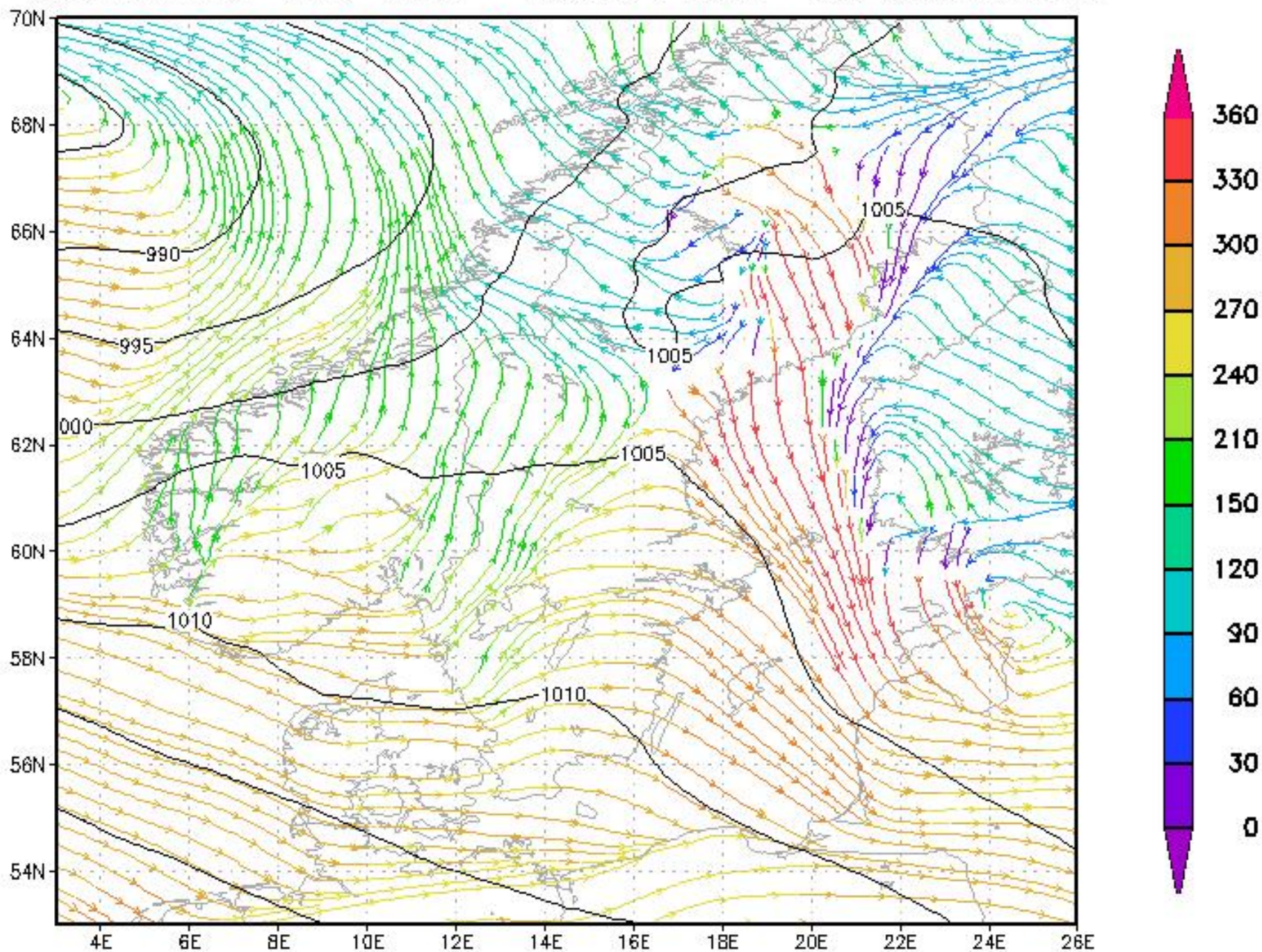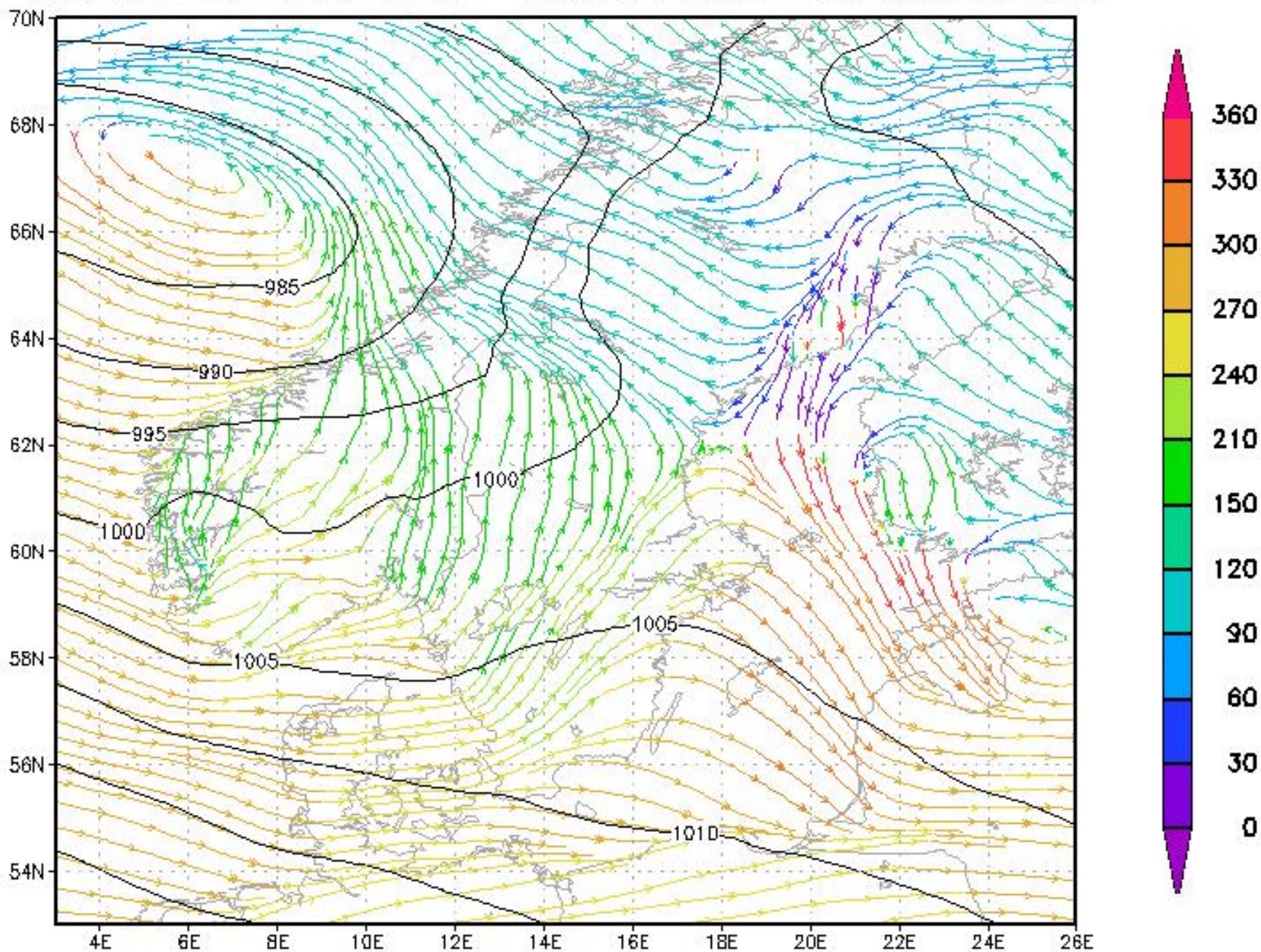
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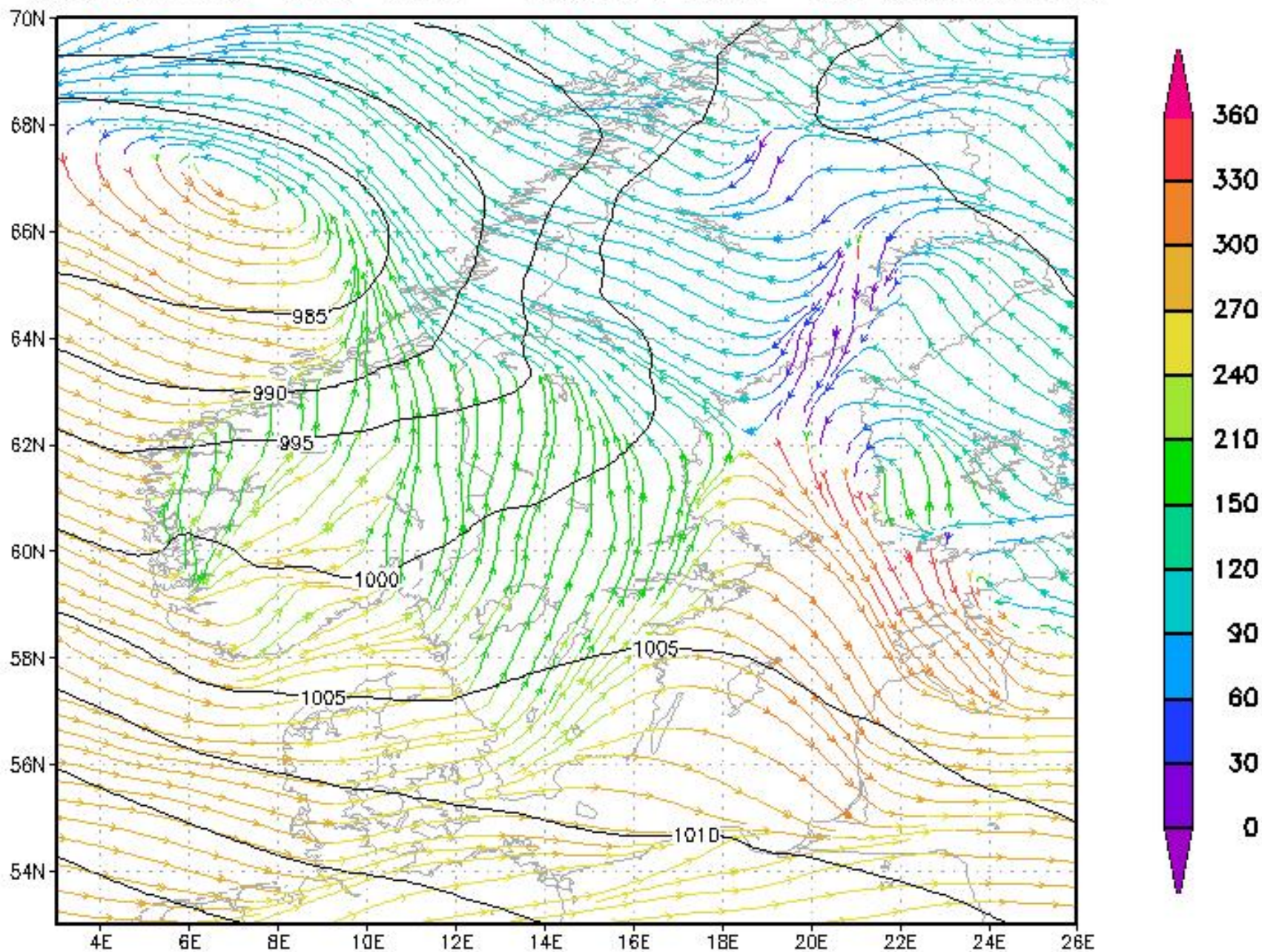
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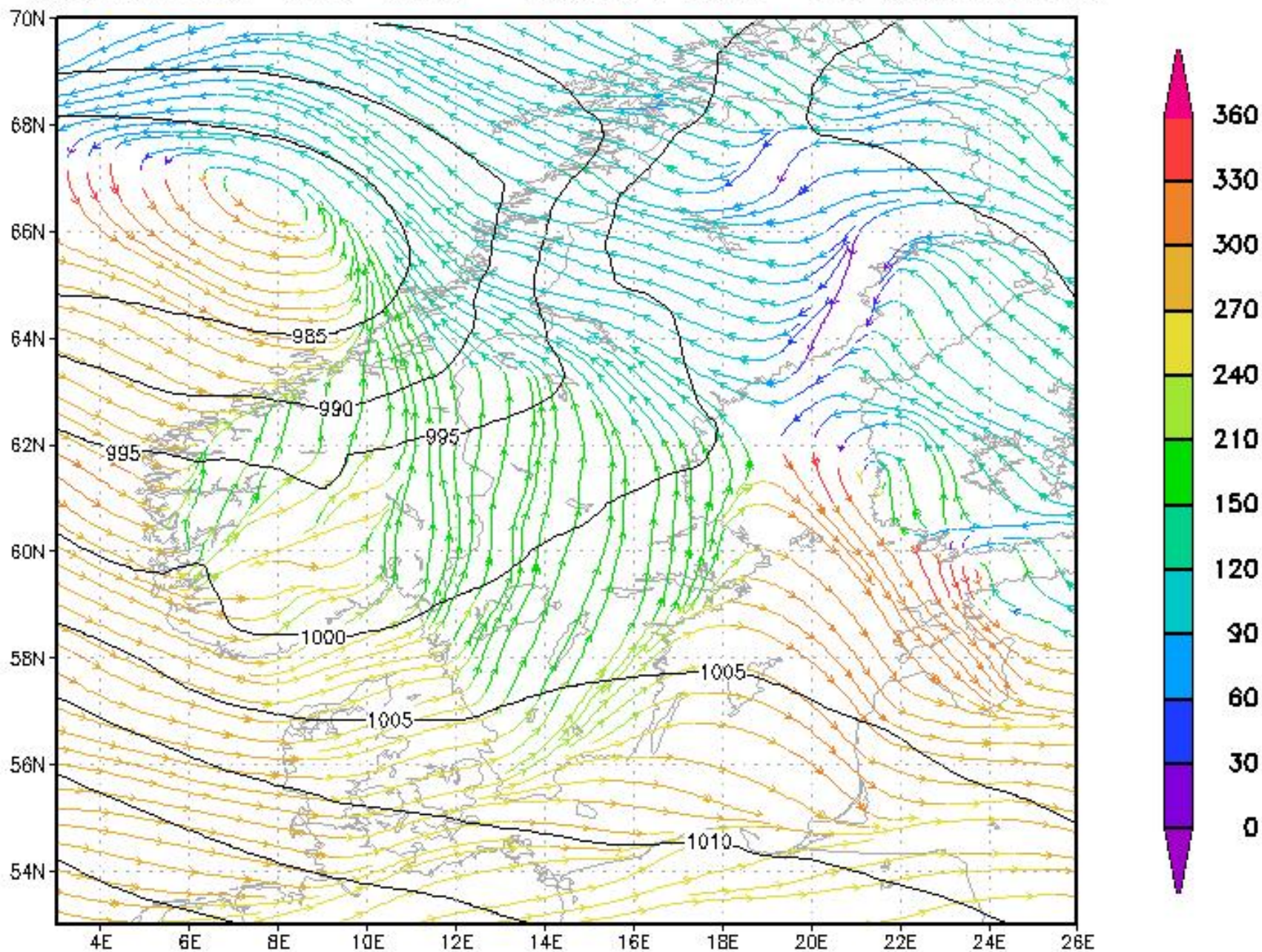
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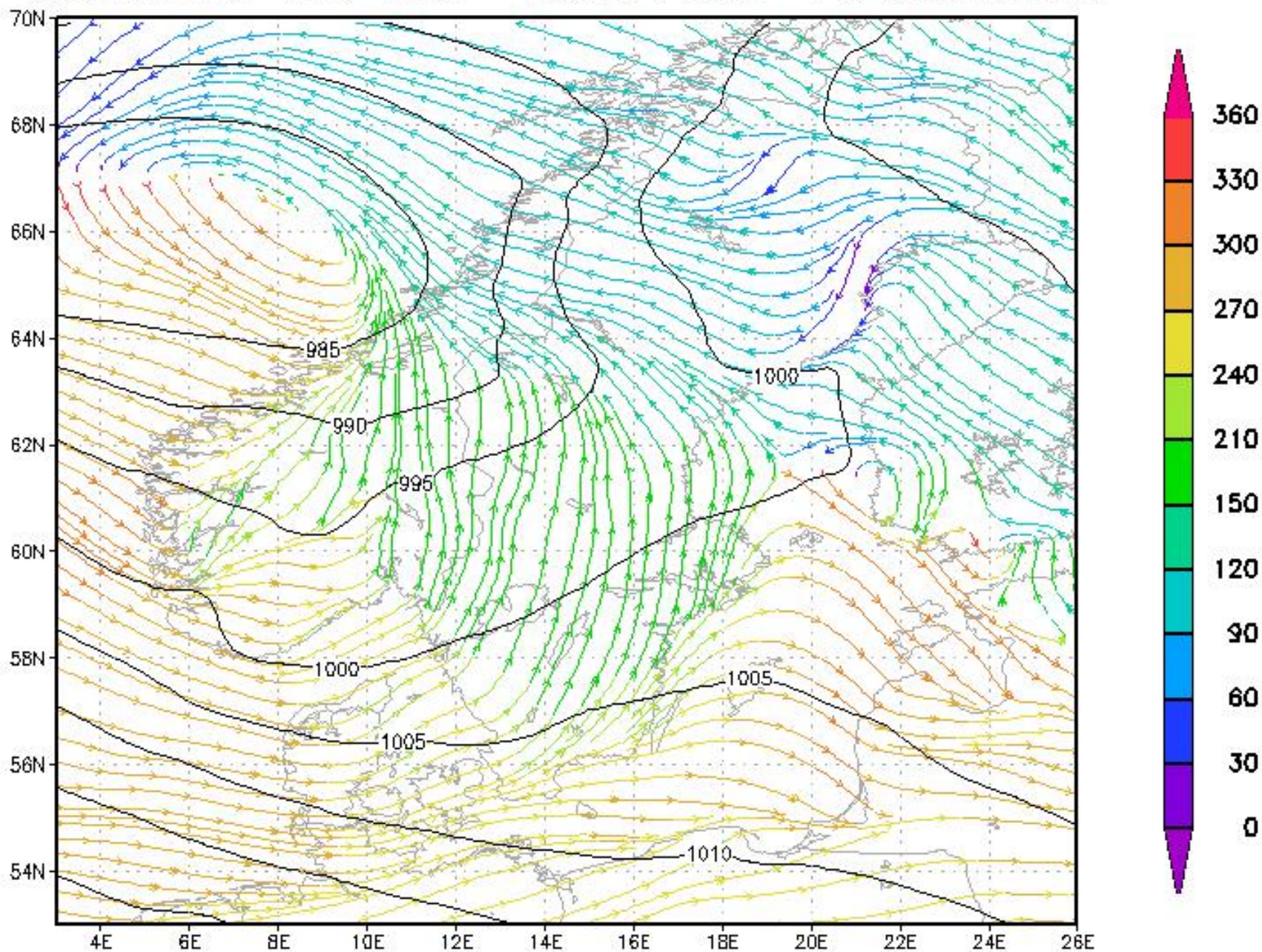
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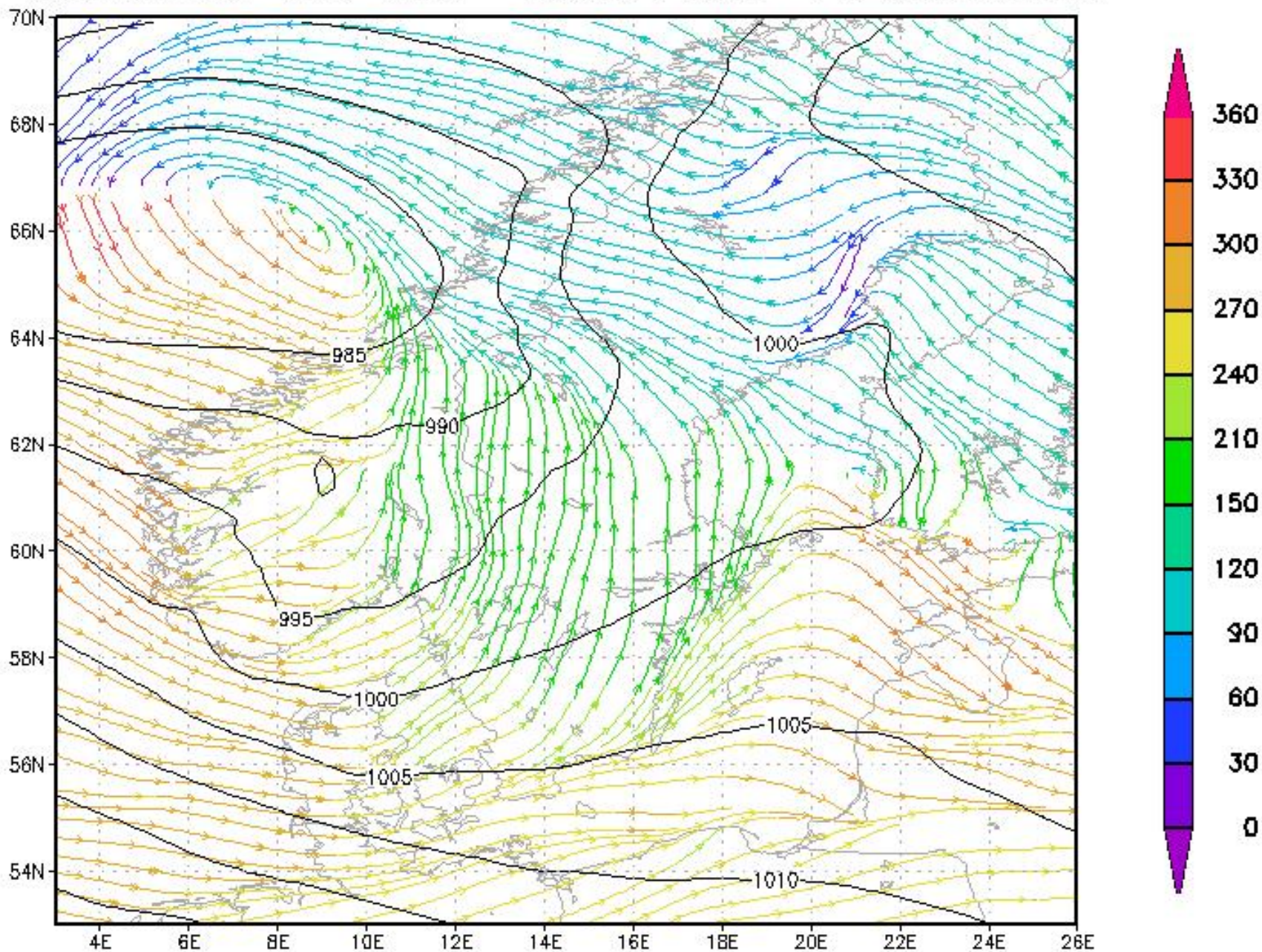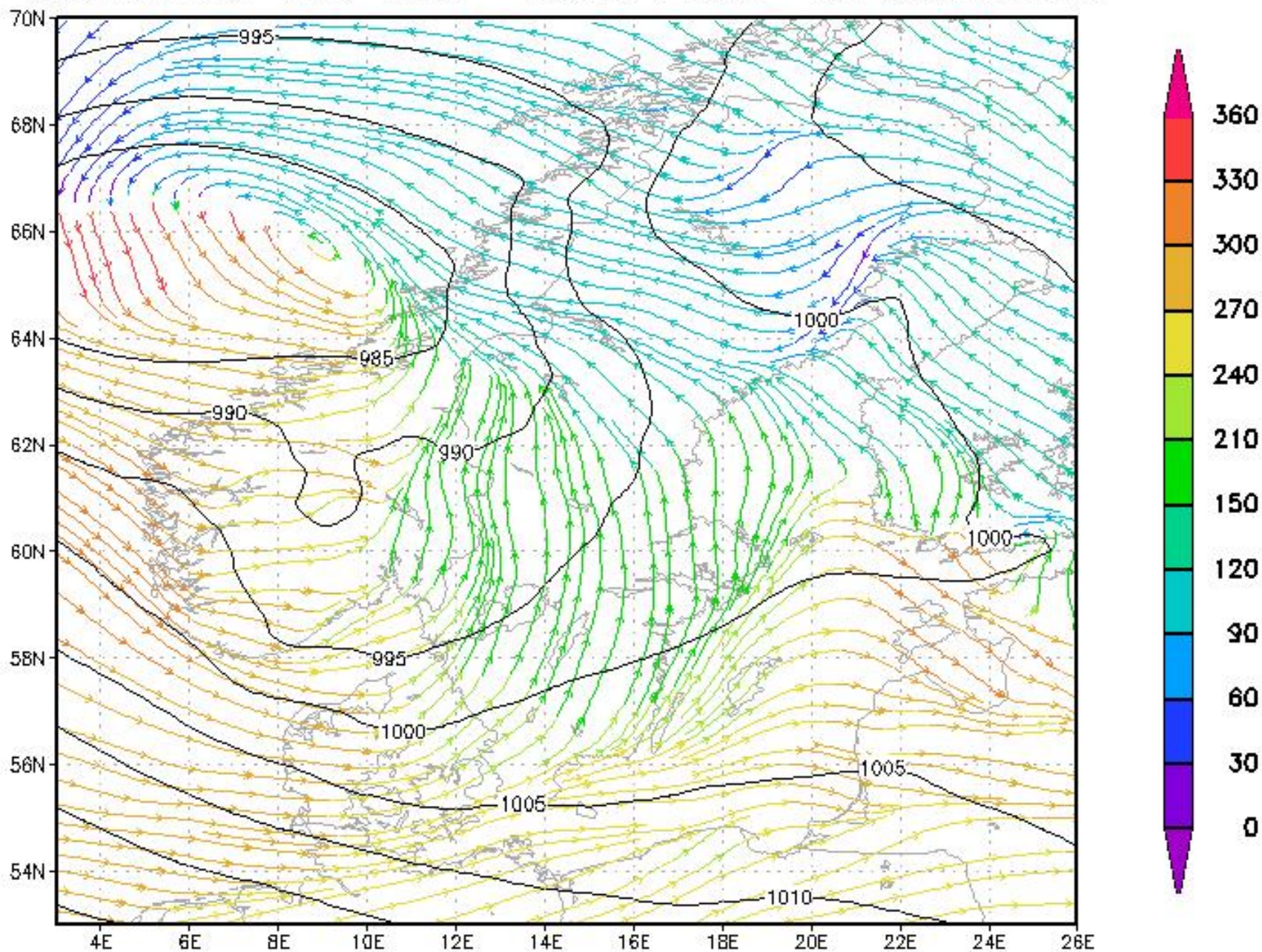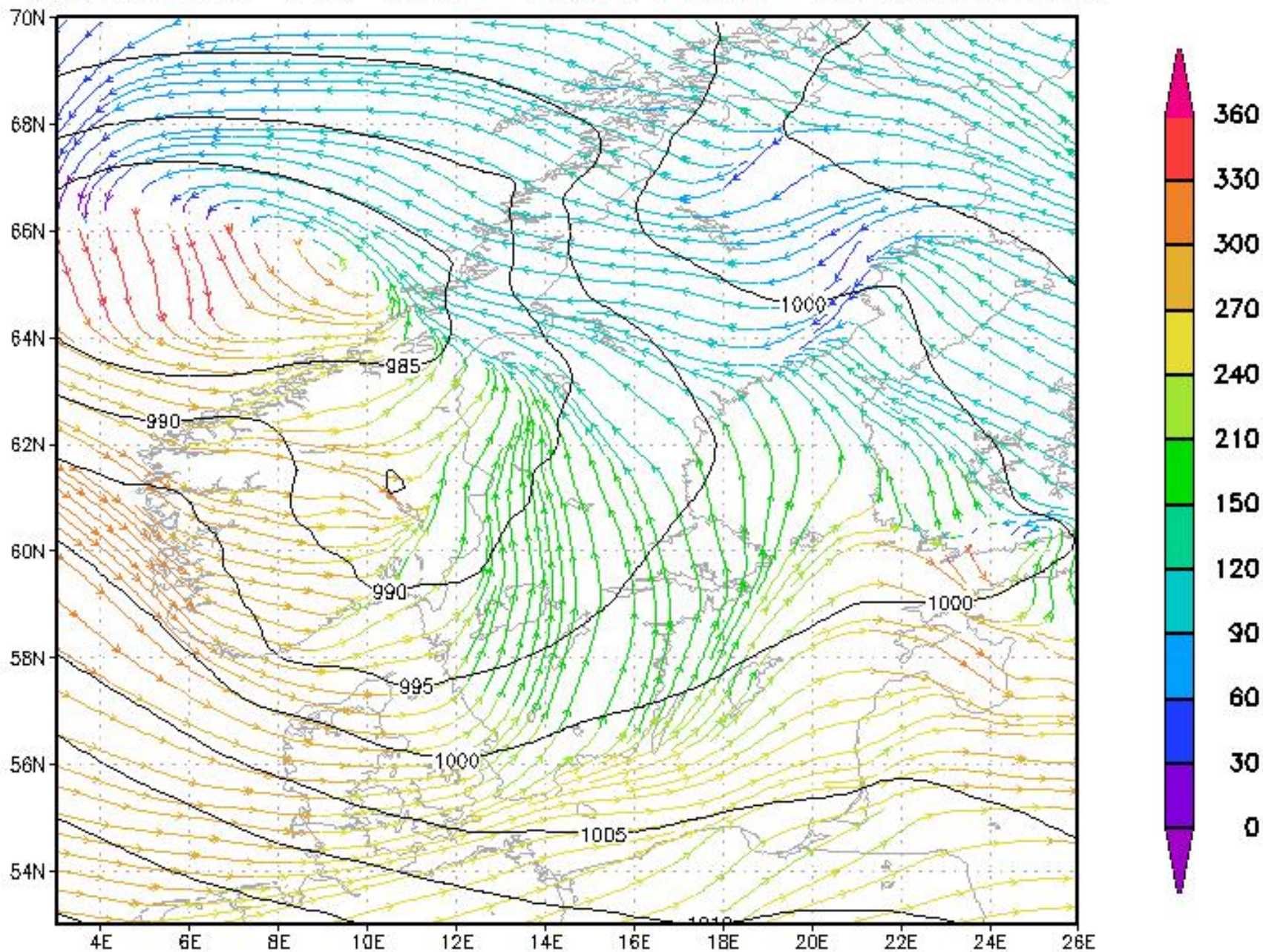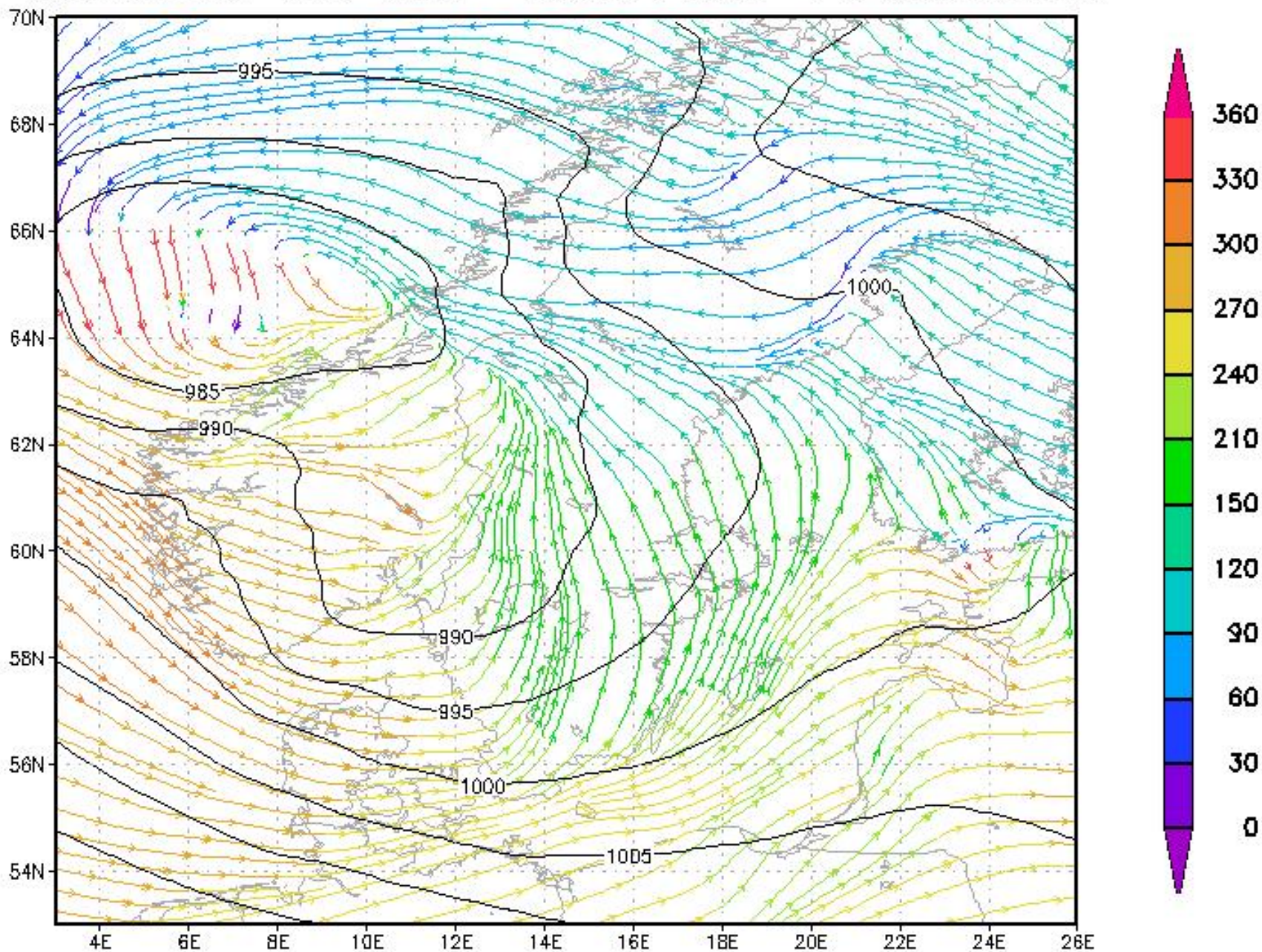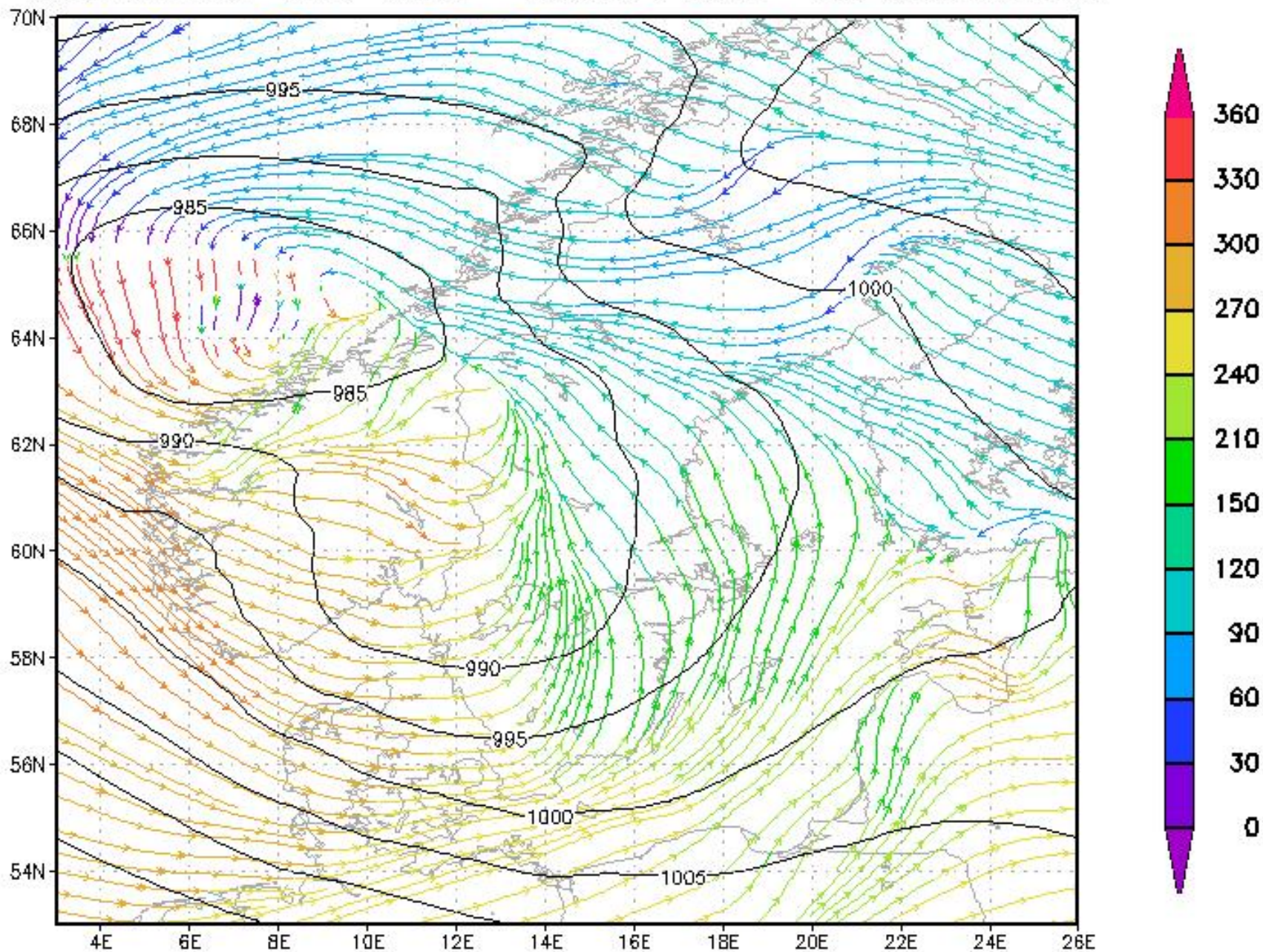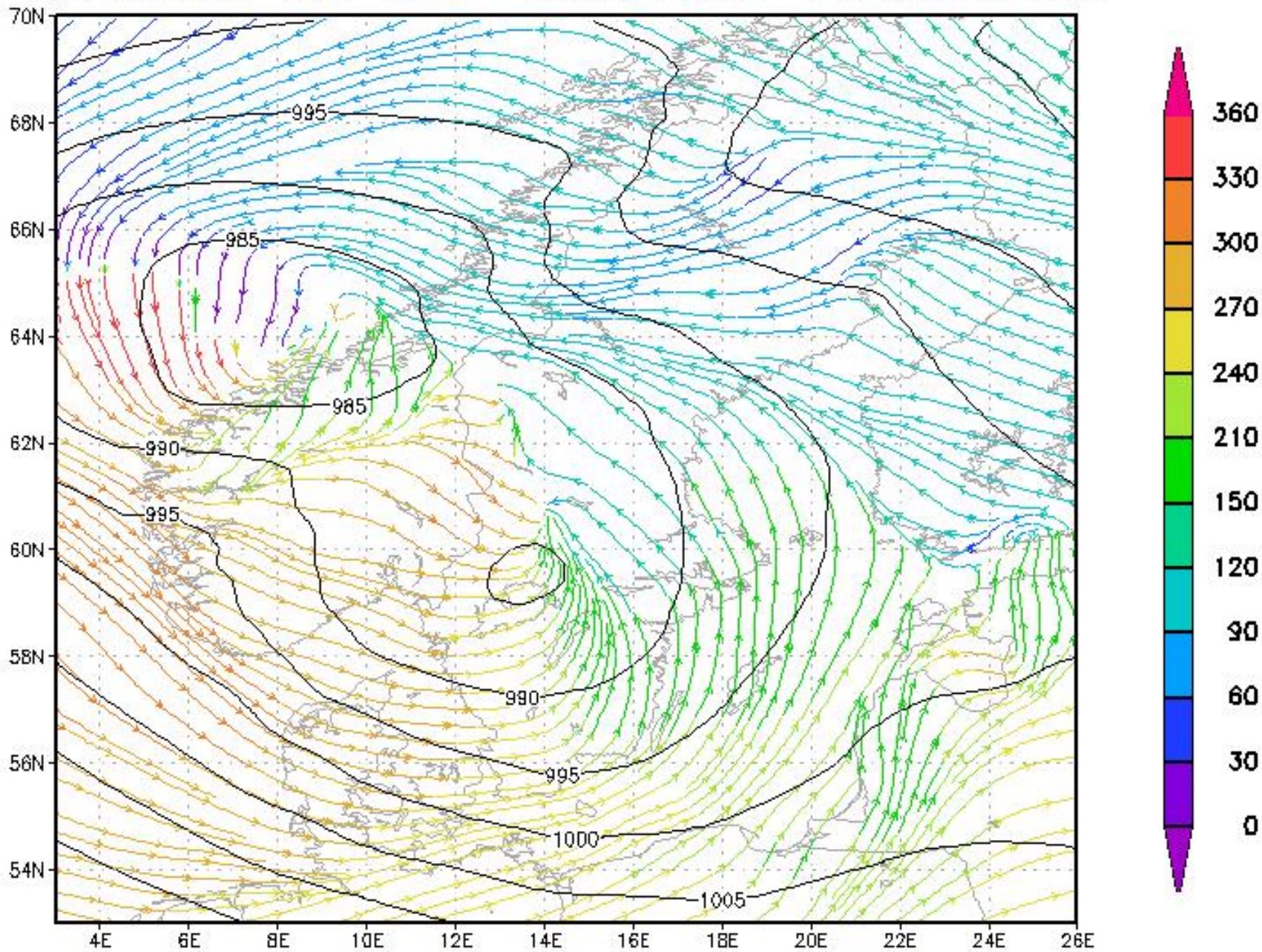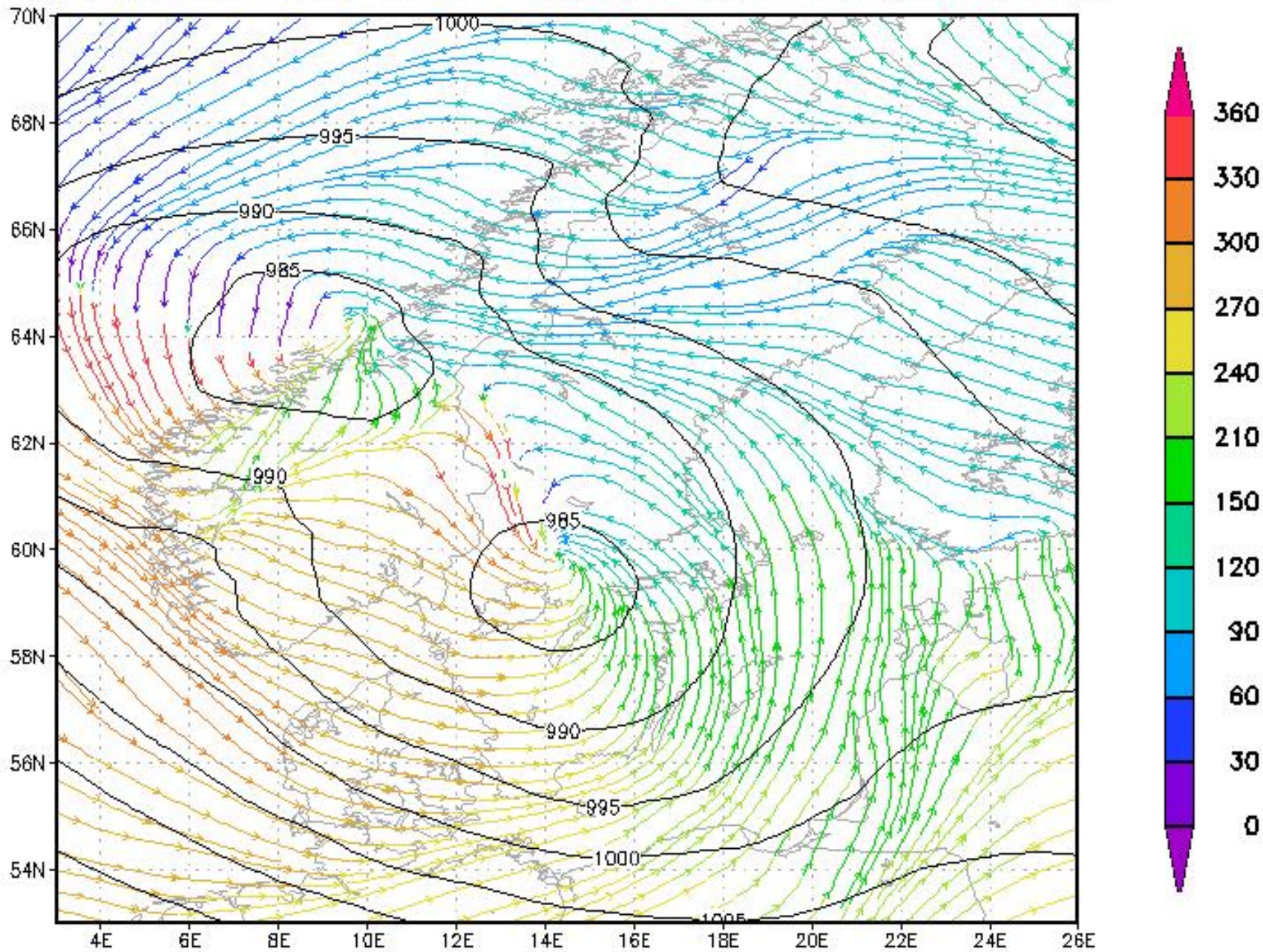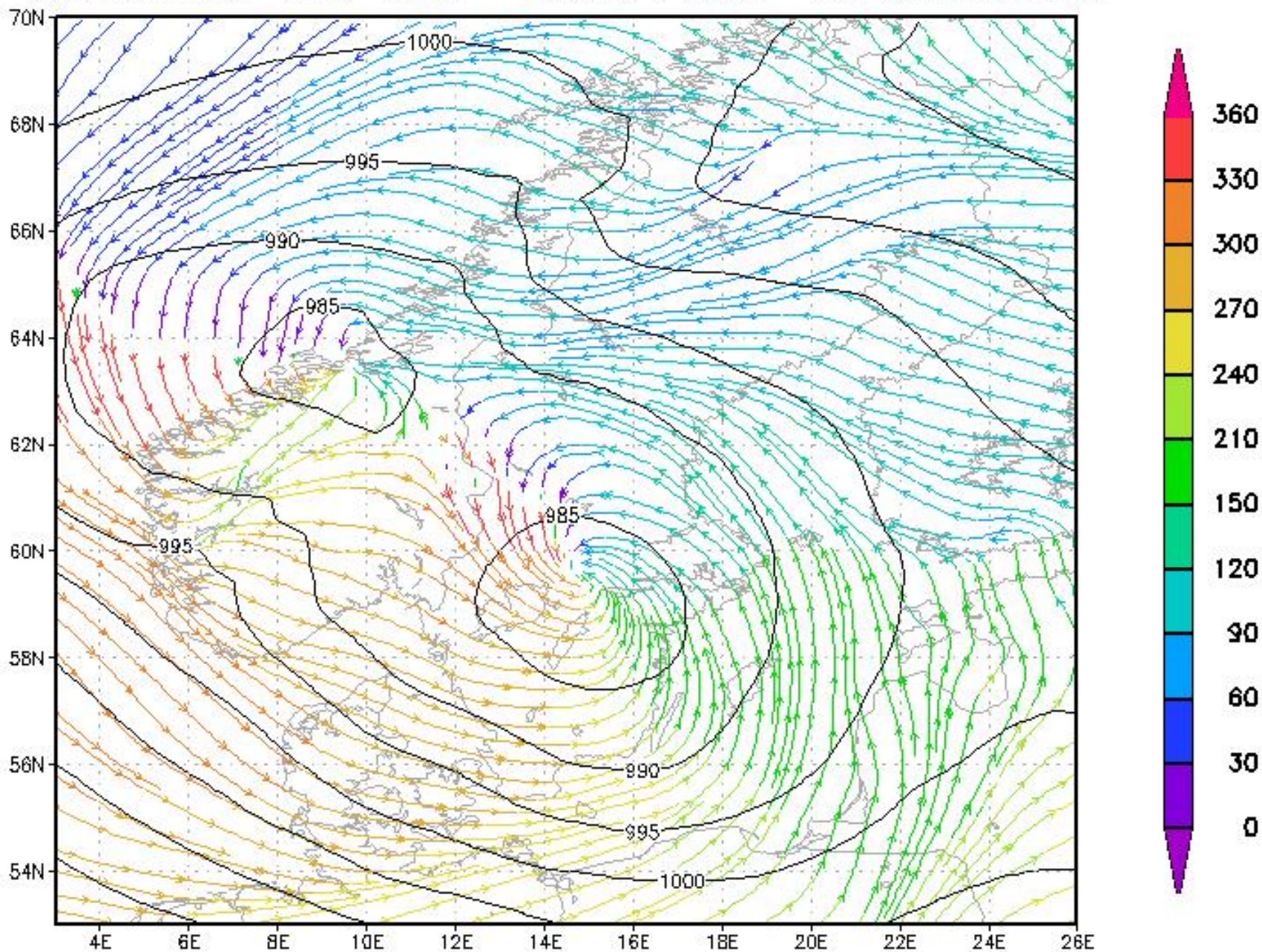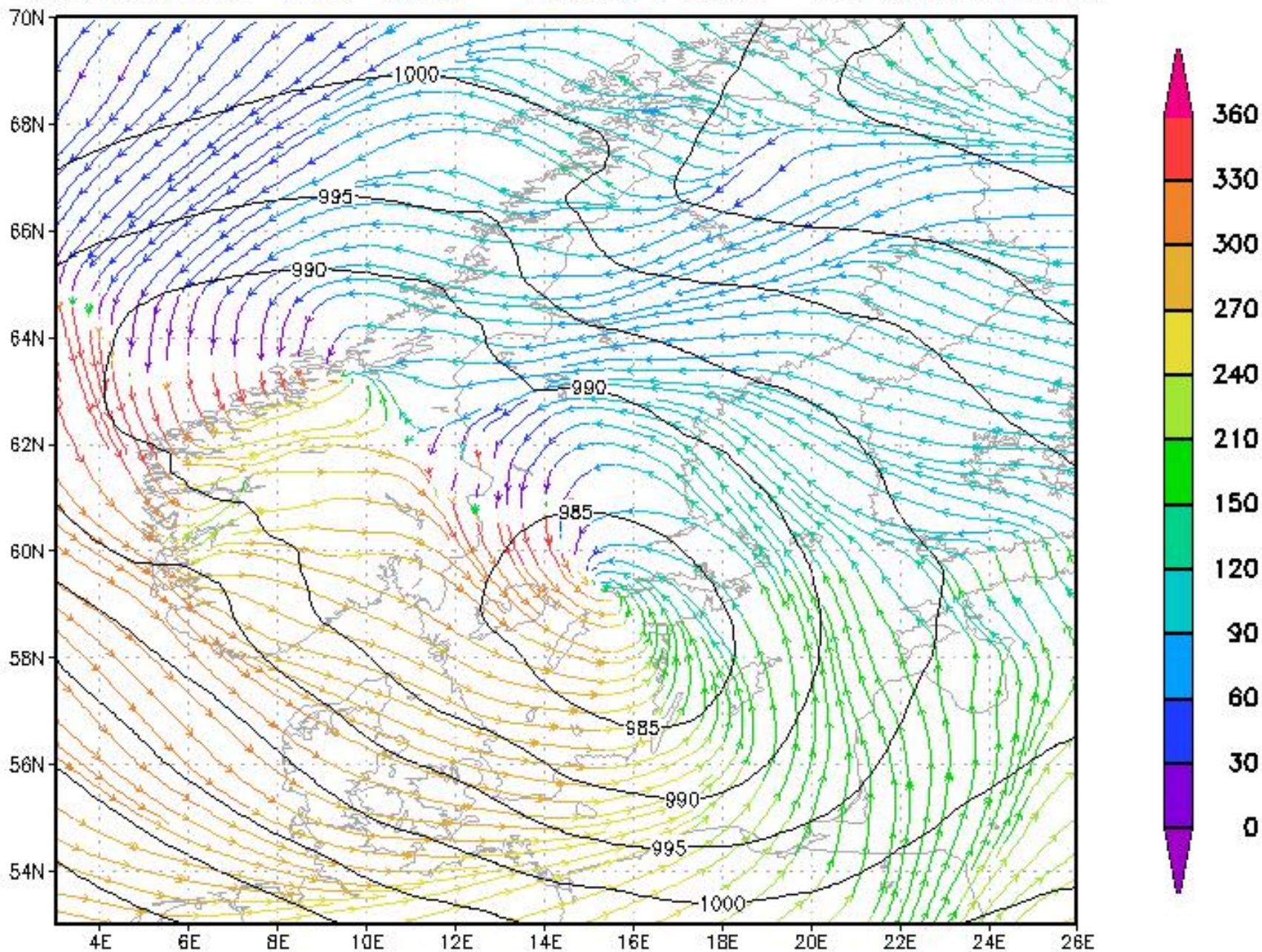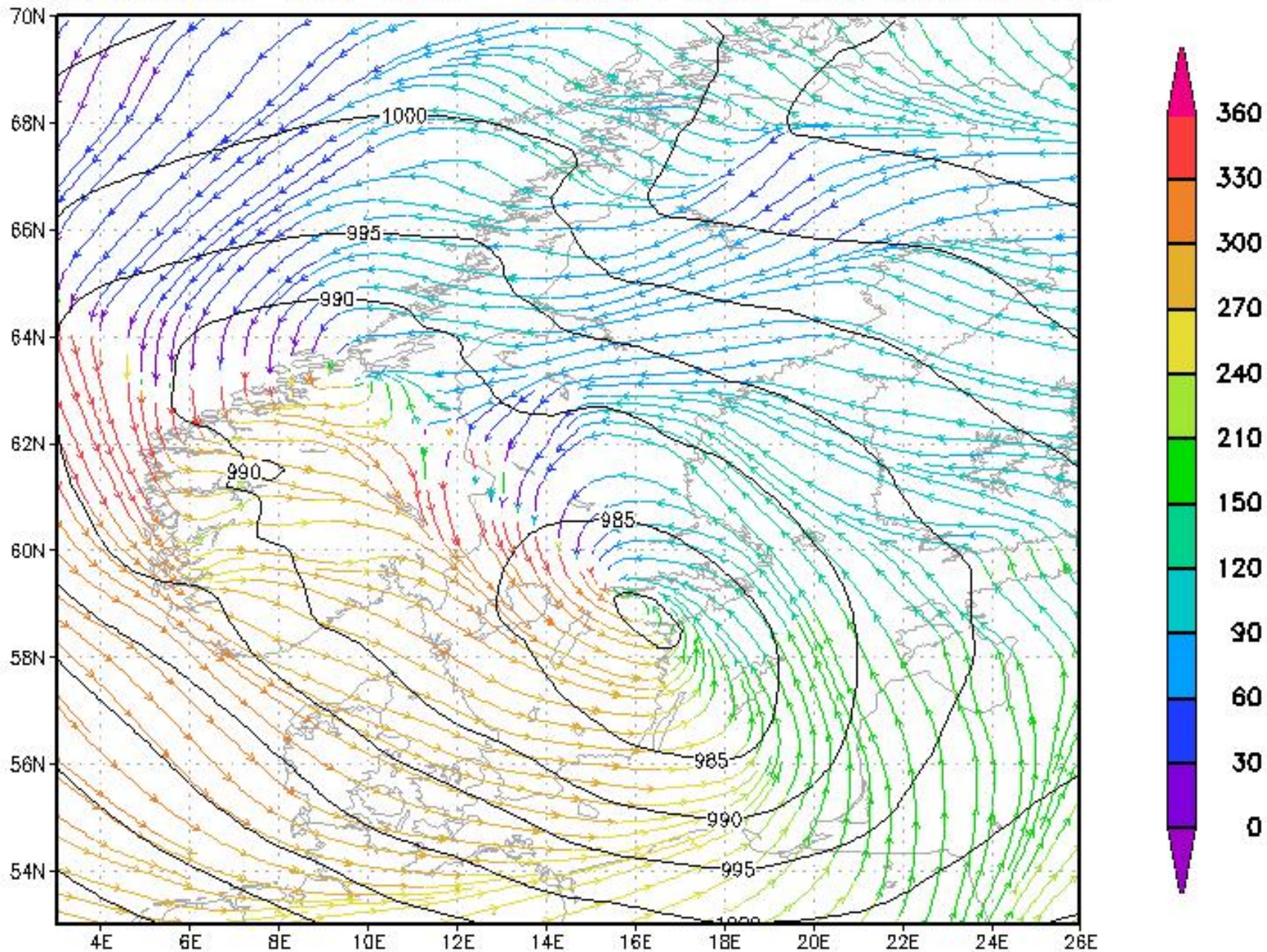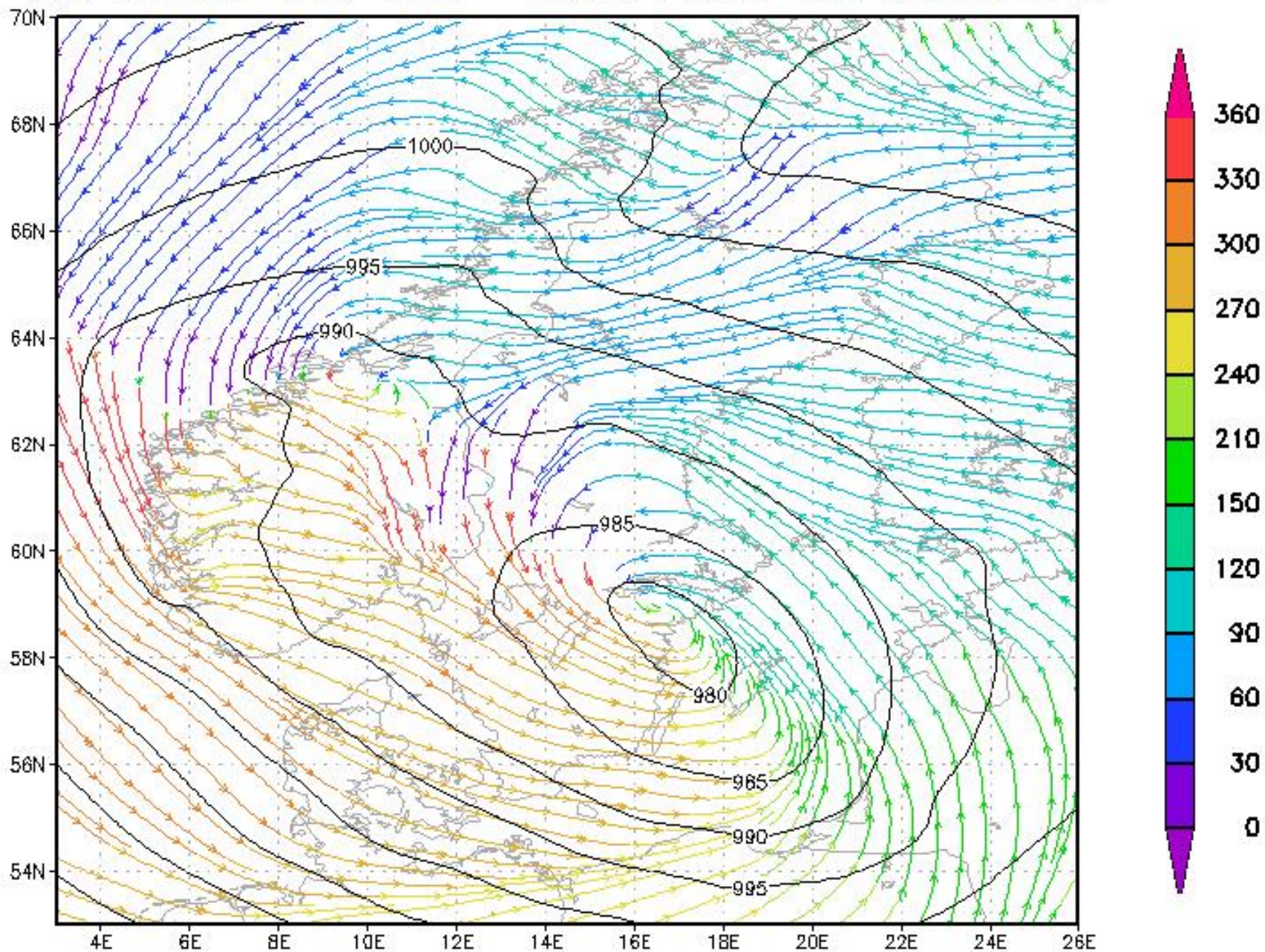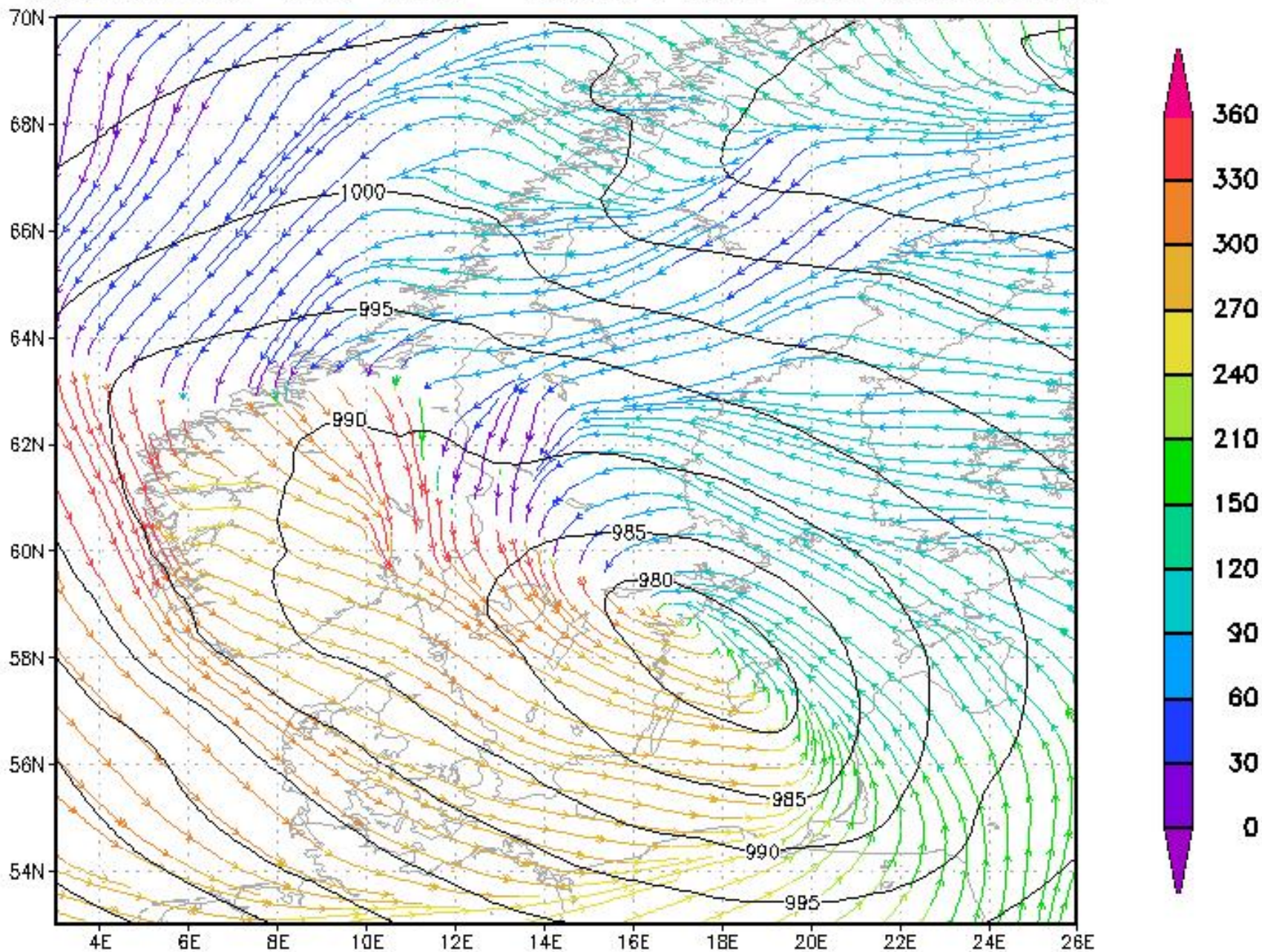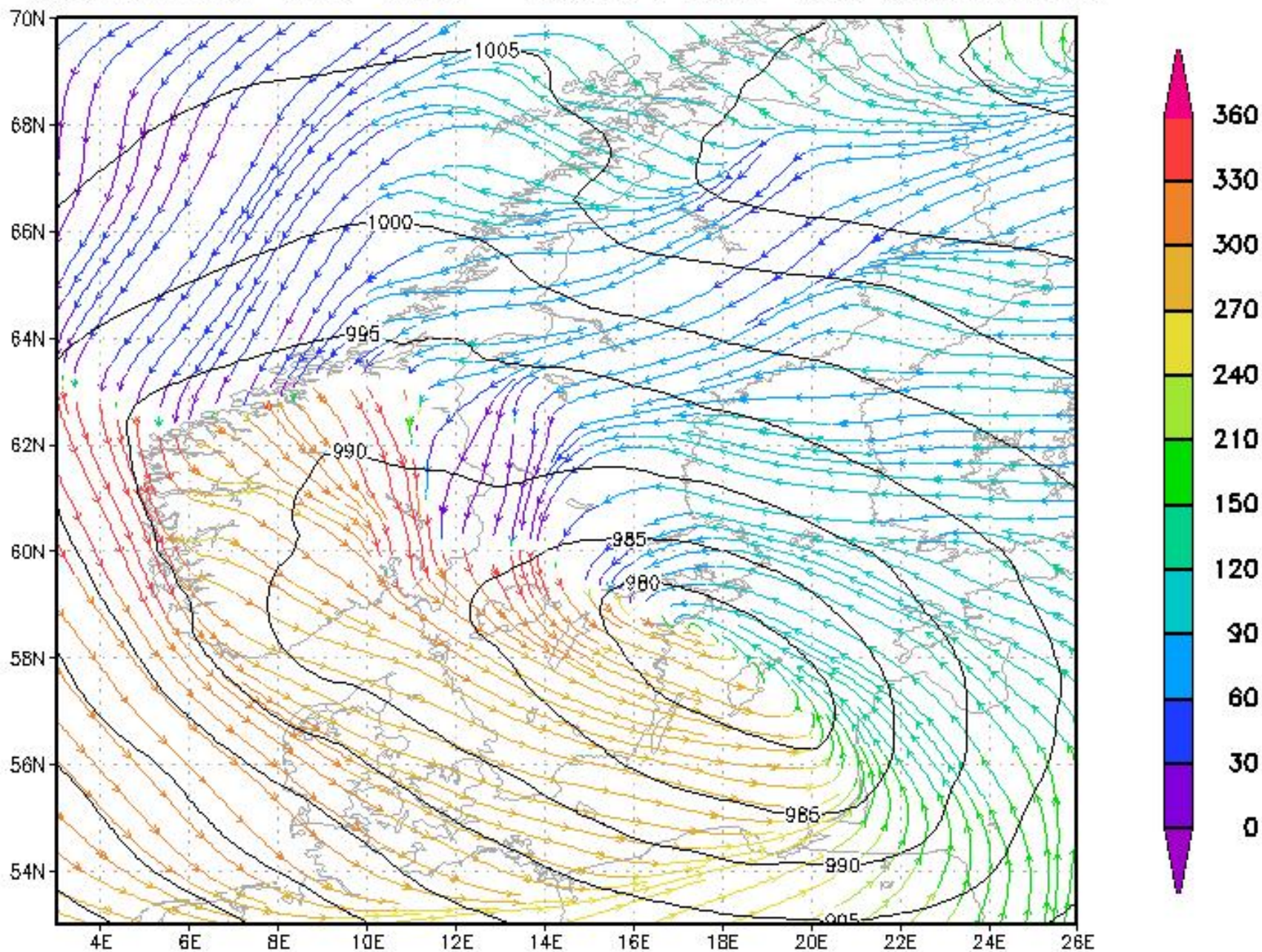
Streamlines and MSLP "Quiet Flood" 08Z03JAN2017

Streamlines and MSLP "Quiet Flood" 09Z03JAN2017

Streamlines and MSLP "Quiet Flood" 10Z03JAN2017
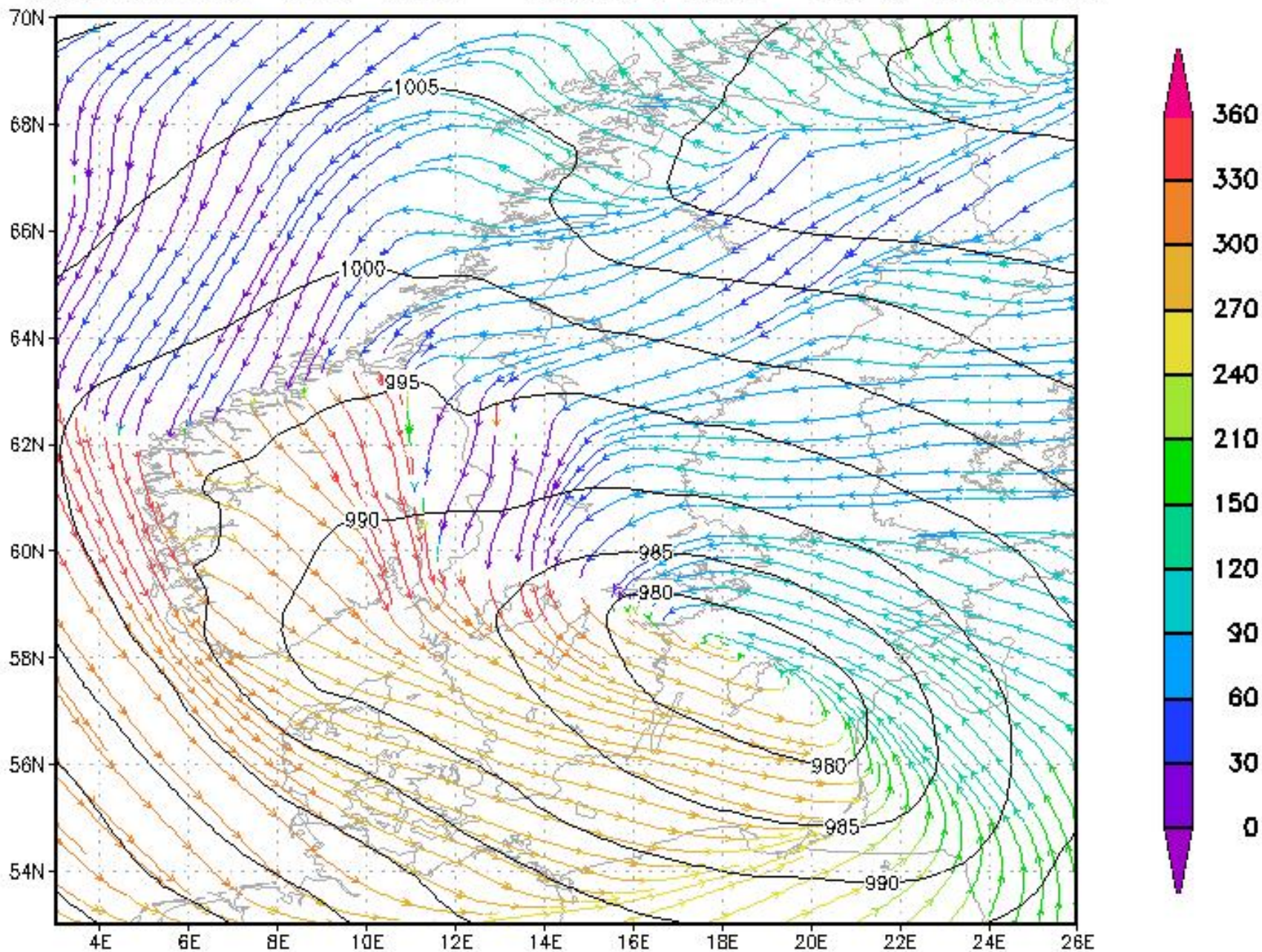
Streamlines and MSLP "Quiet Flood" 11Z03JAN2017
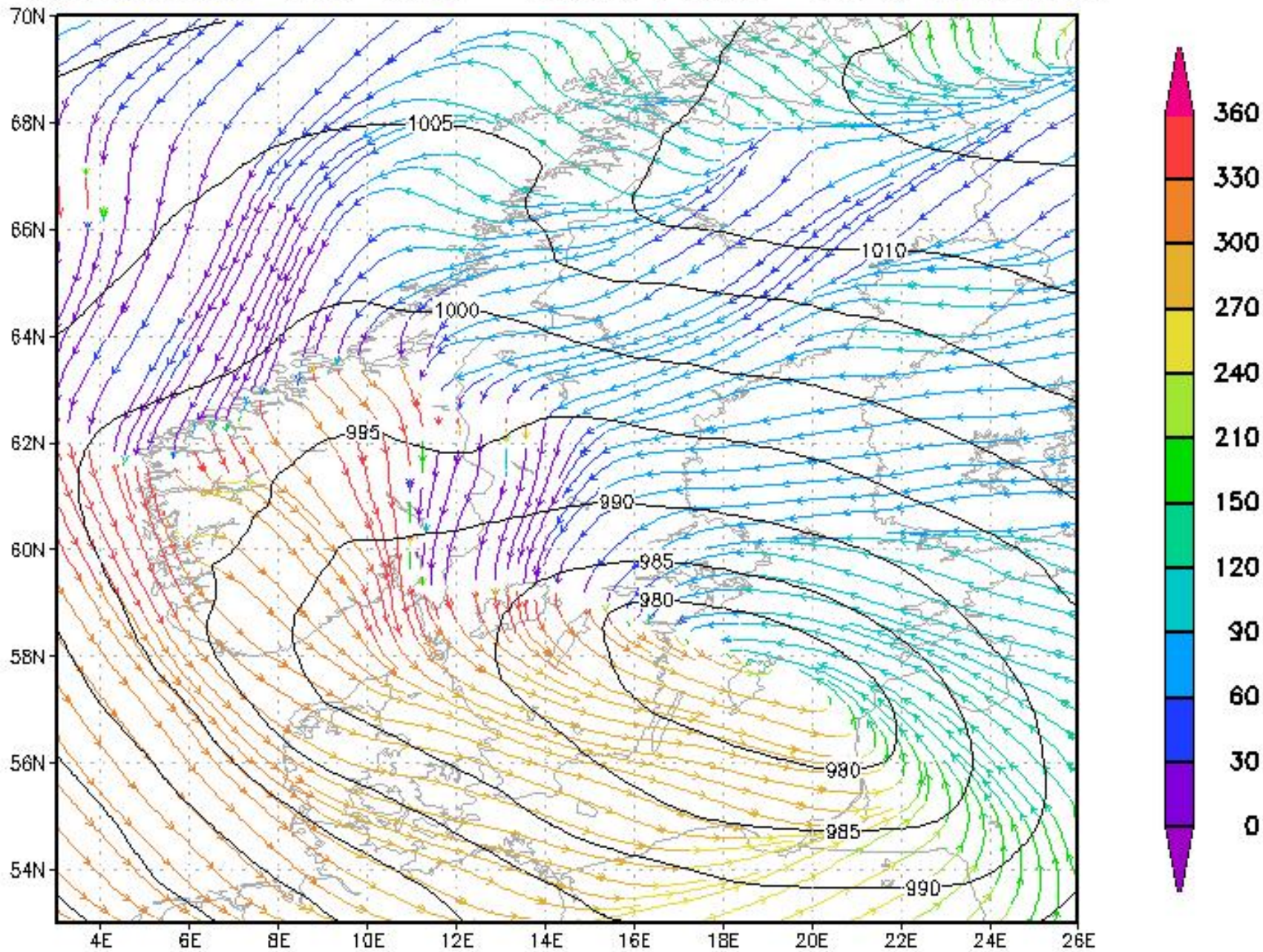
Streamlines and MSLP "Quiet Flood" 12Z03JAN2017
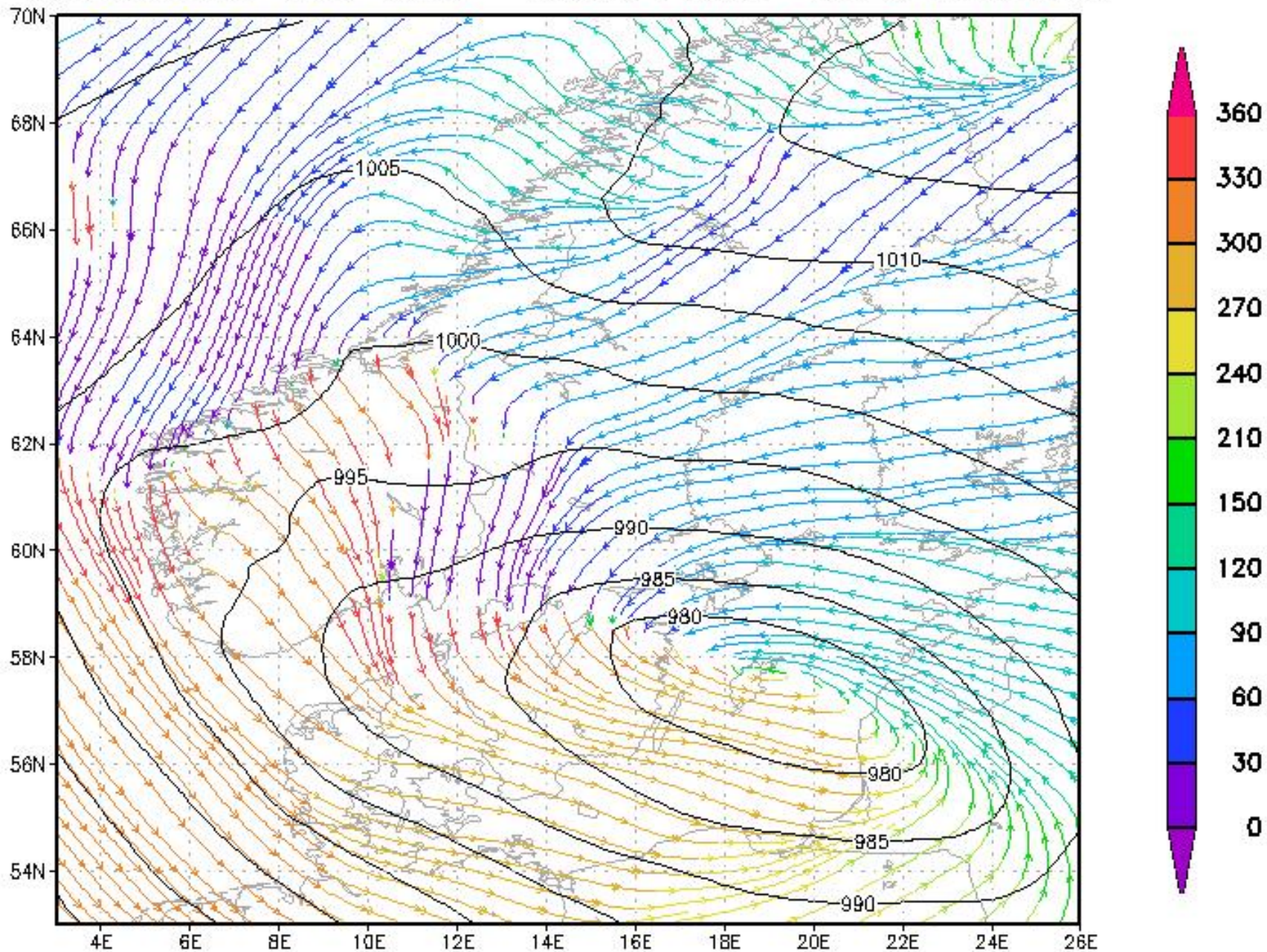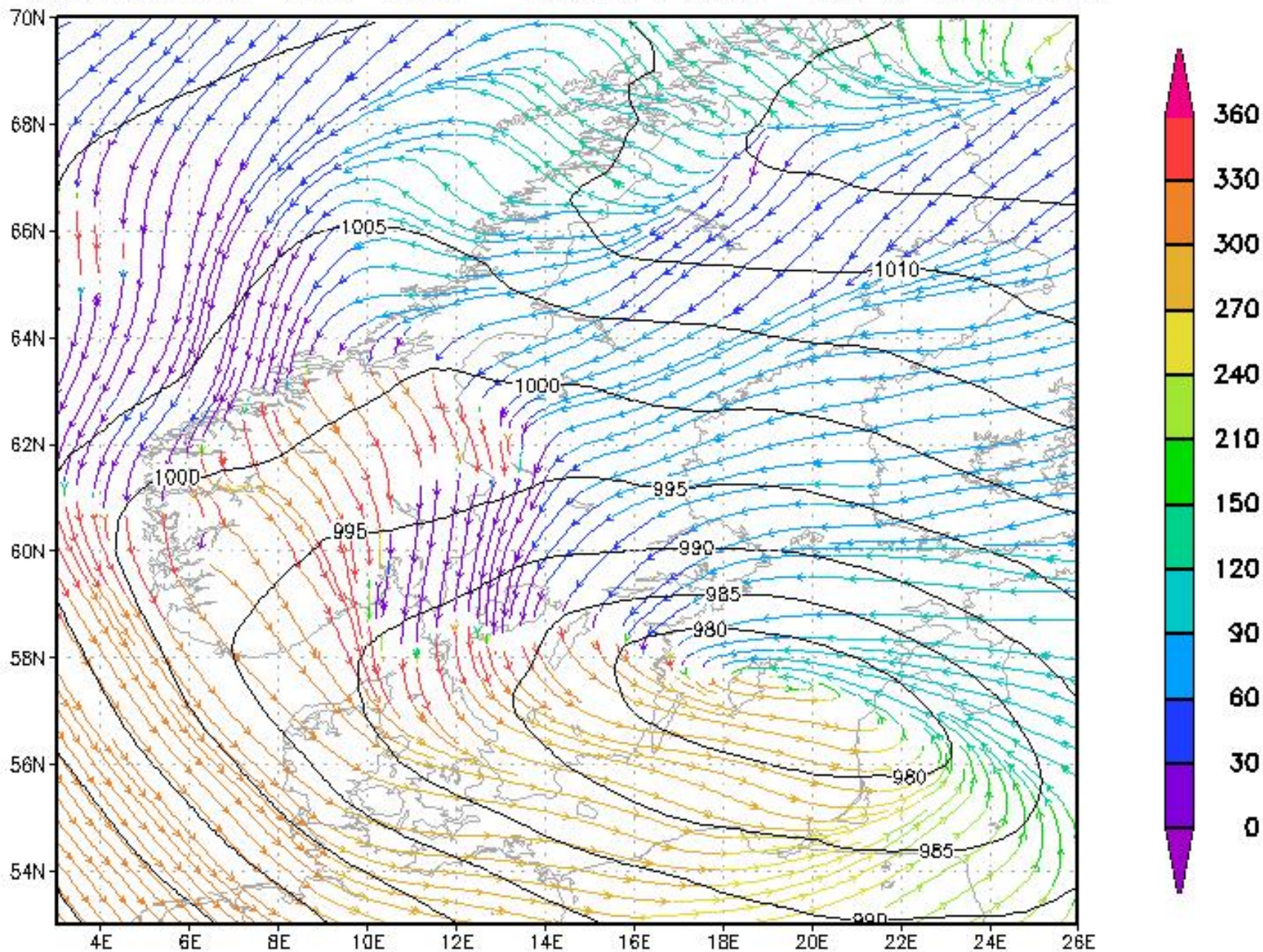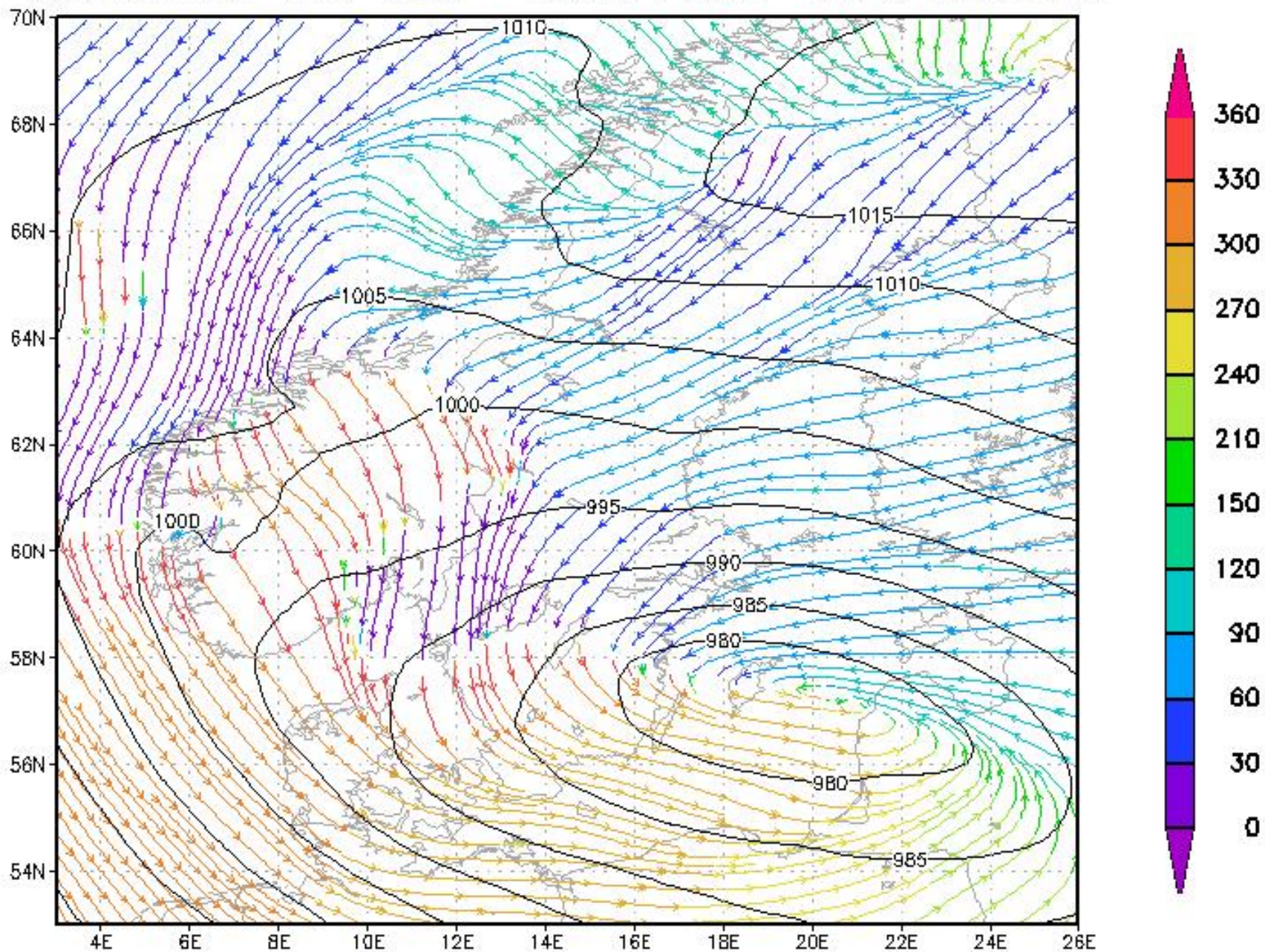
Streamlines and MSLP "Quiet Flood" 13Z03JAN2017

Streamlines and MSLP "Quiet Flood" 14Z03JAN2017

Streamlines and MSLP "Quiet Flood" 15Z03JAN2017

Streamlines and MSLP "Quiet Flood" 16Z03JAN2017

Streamlines and MSLP "Quiet Flood" 17Z03JAN2017

Streamlines and MSLP "Quiet Flood" 18Z03JAN2017

Streamlines and MSLP "Quiet Flood" 19Z03JAN2017

Streamlines and MSLP "Quiet Flood" 20Z03JAN2017

Streamlines and MSLP "Quiet Flood" 21Z03JAN2017

Streamlines and MSLP "Quiet Flood" 22Z03JAN2017

Streamlines and MSLP "Quiet Flood" 23Z03JAN2017

Streamlines and MSLP "Quiet Flood" 00Z04JAN2017

Streamlines and MSLP "Quiet Flood" 01Z04JAN2017
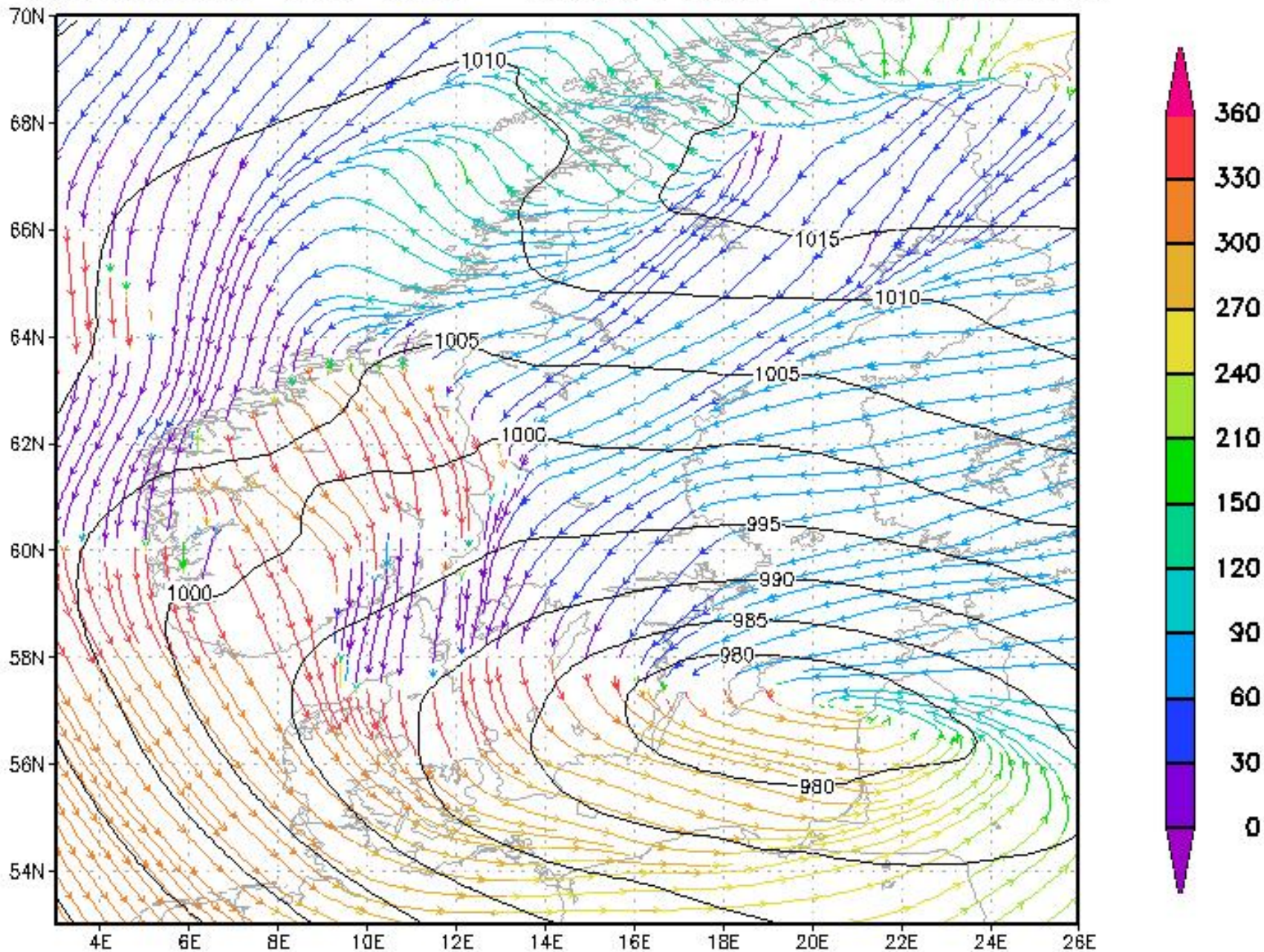
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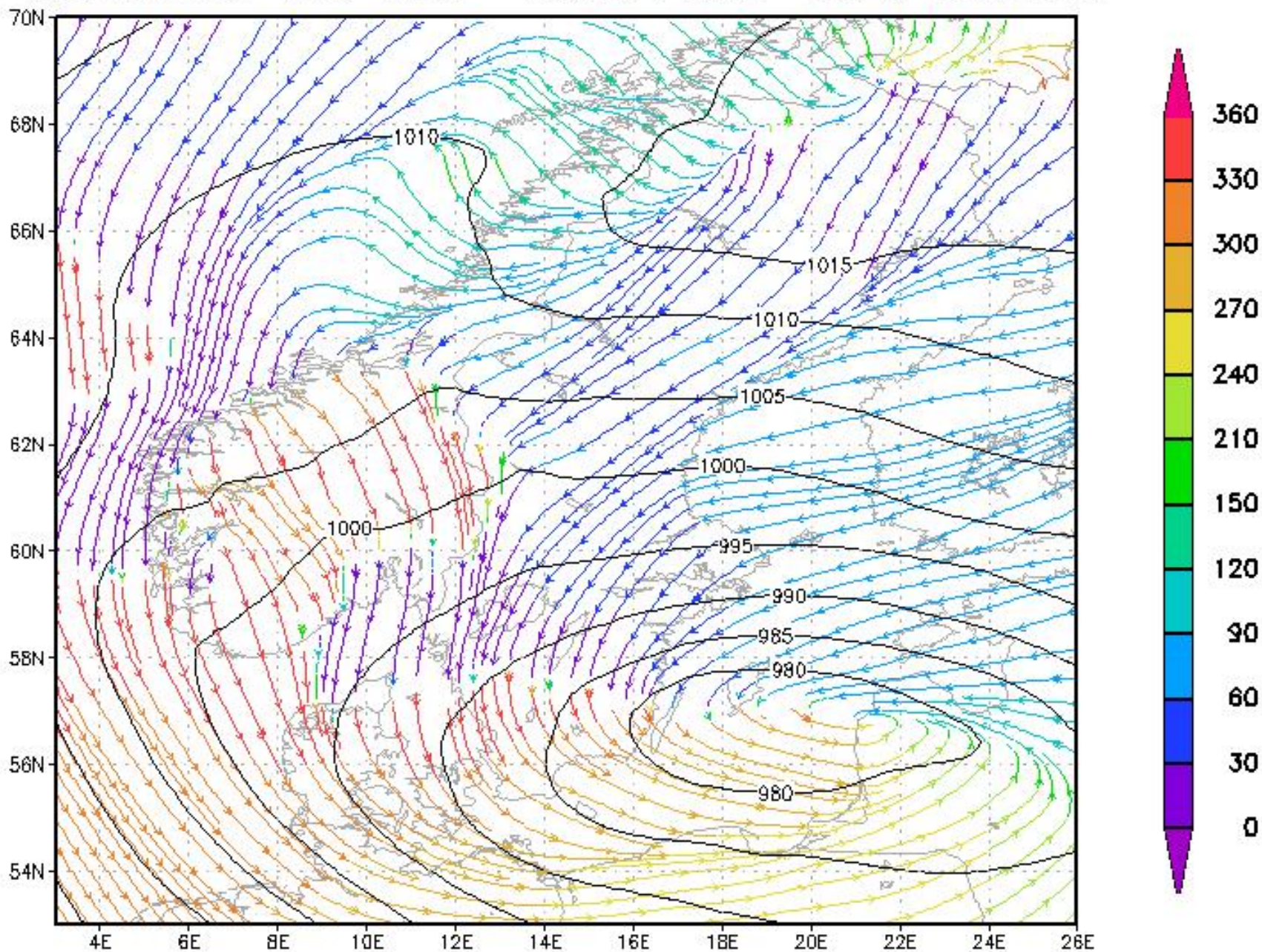
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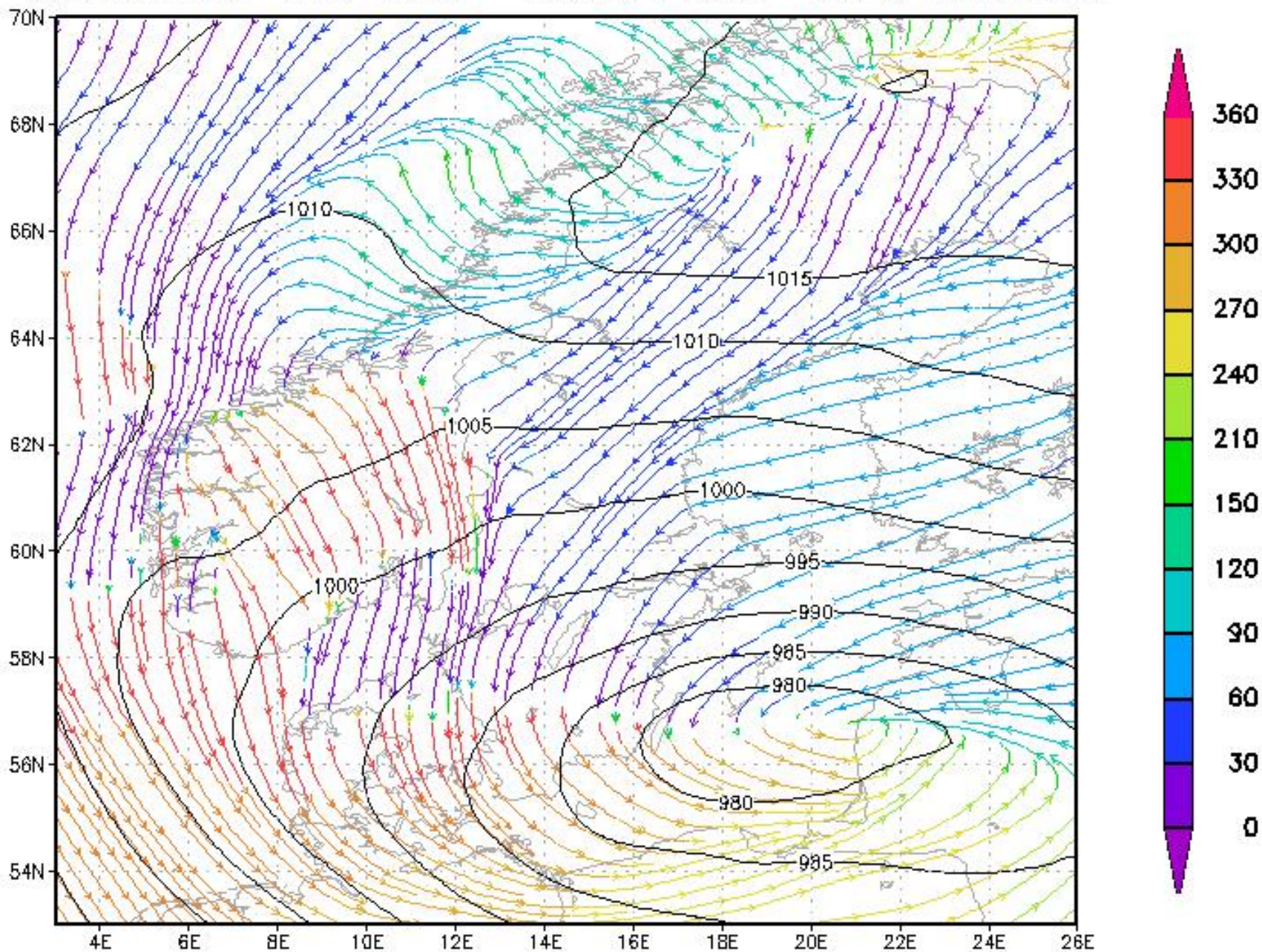
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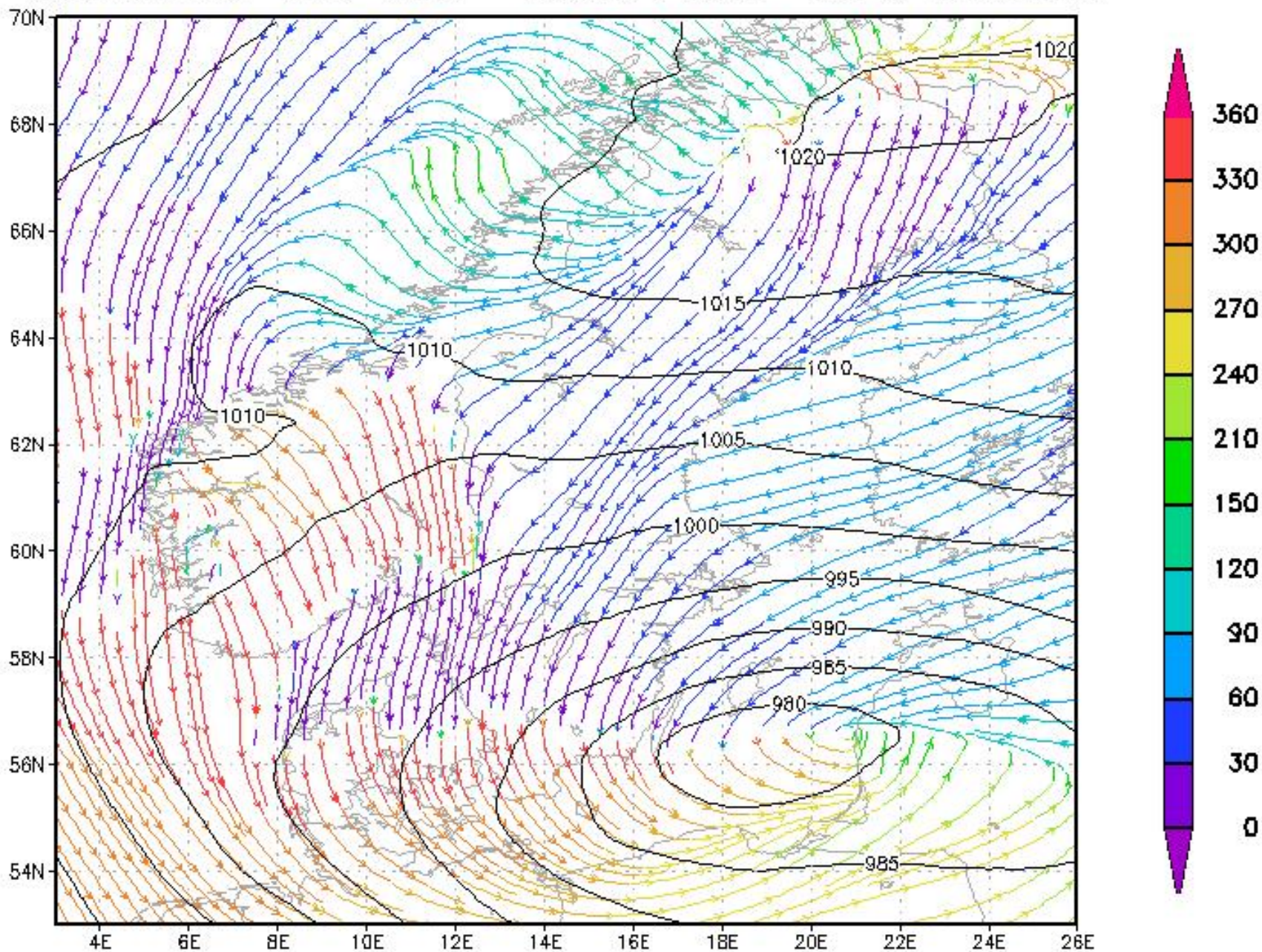
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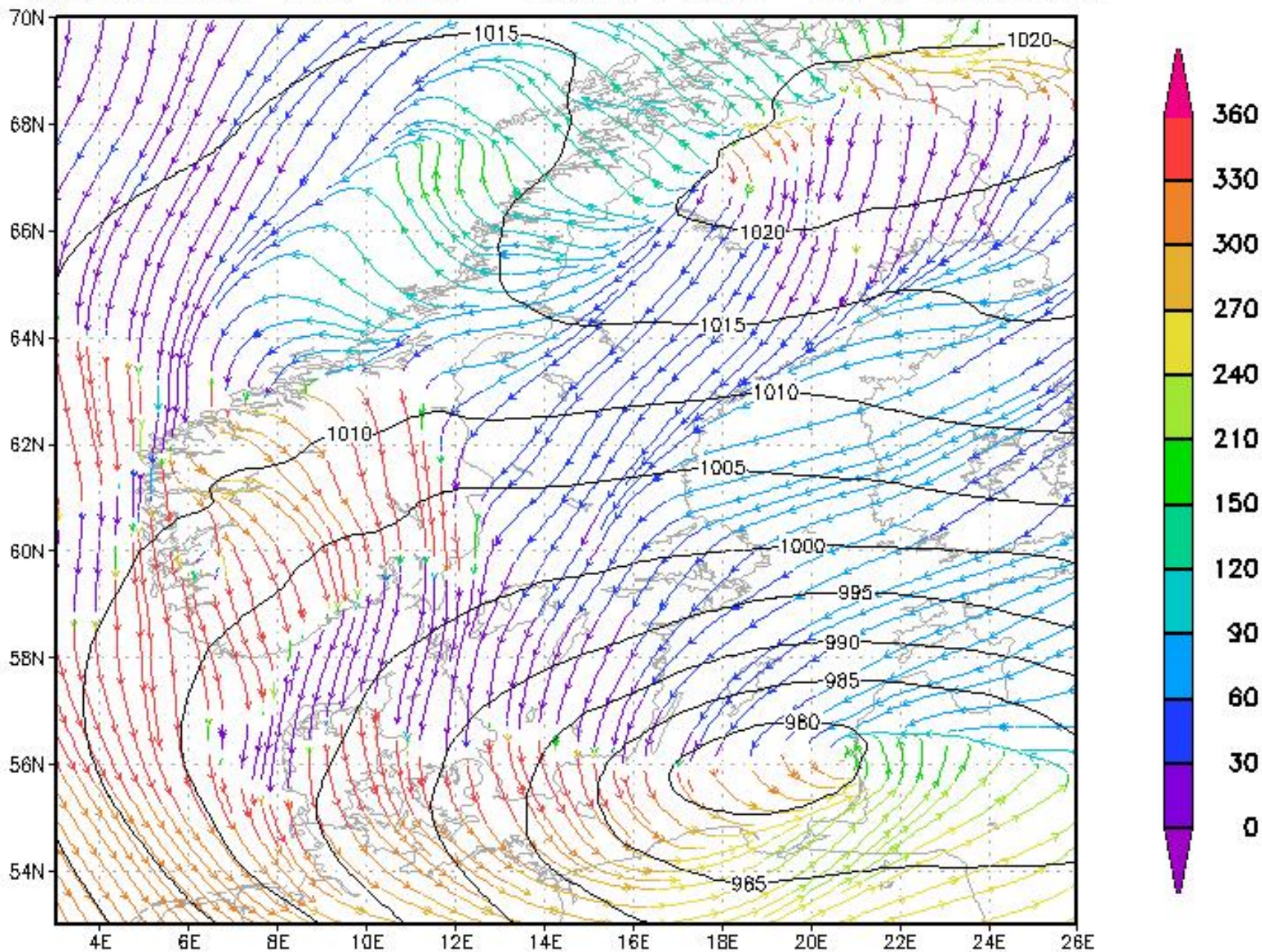
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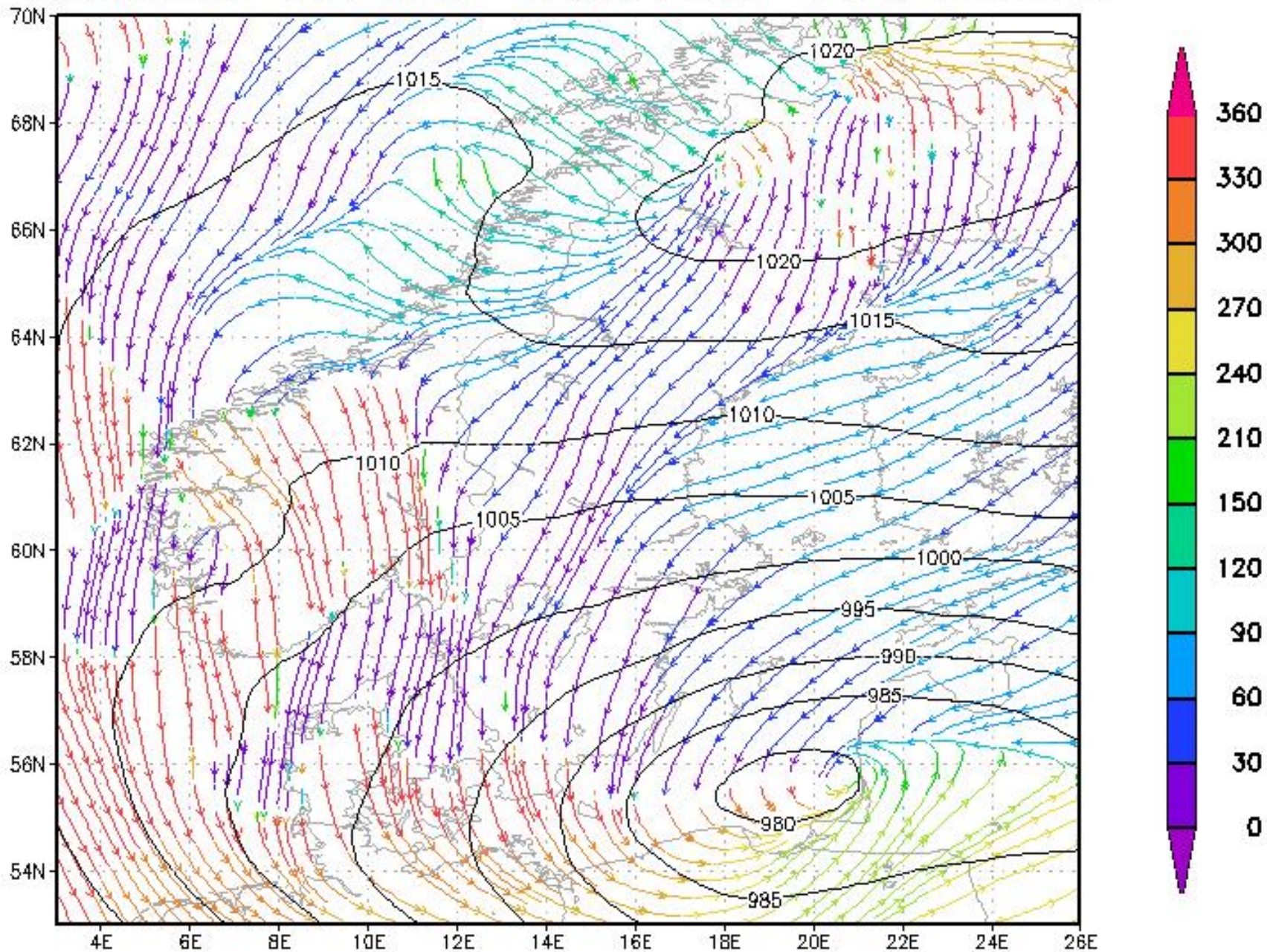
Streamlines and MSLP "Quiet Flood" 07Z04JAN2017

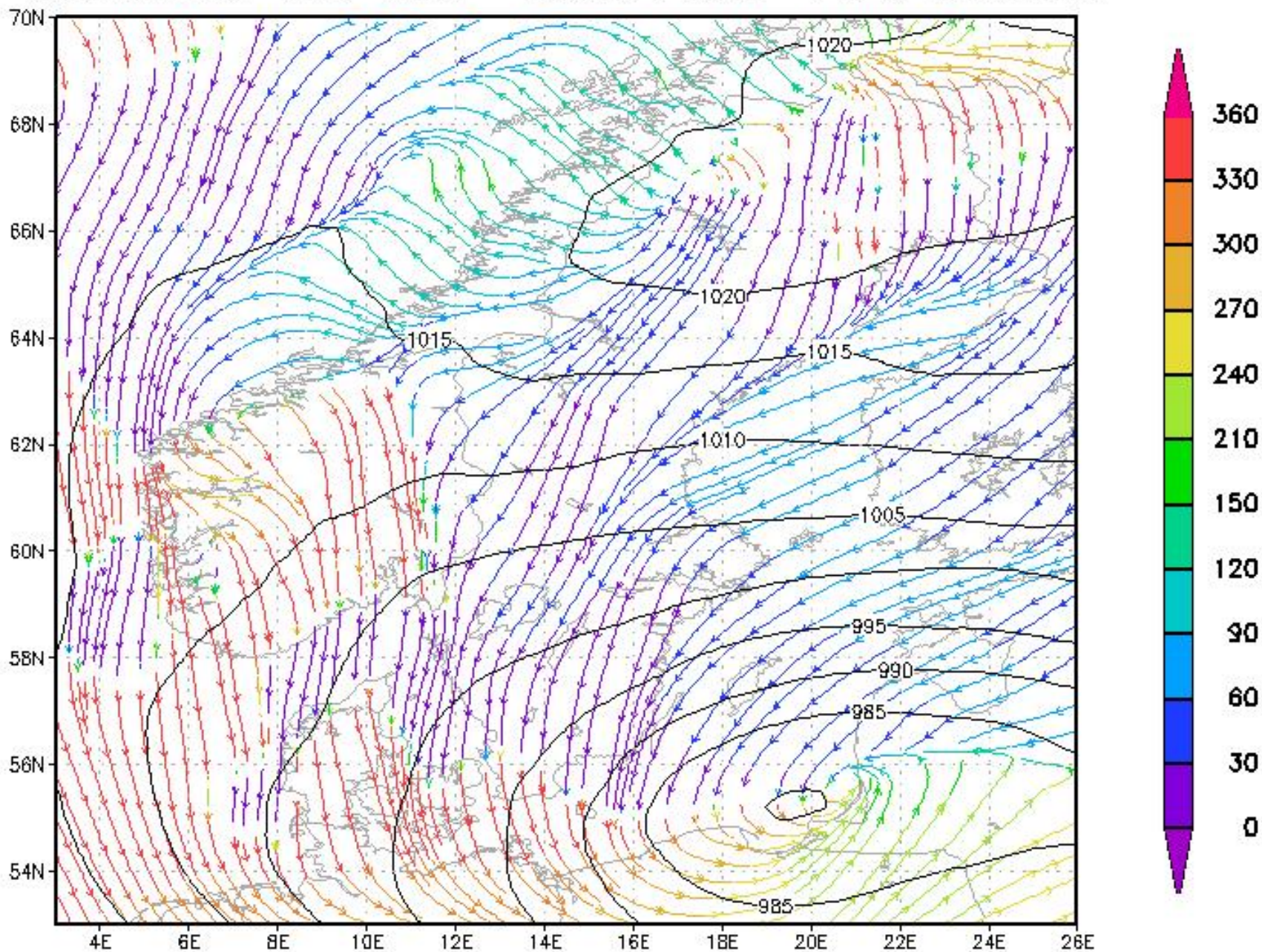Streamlines and MSLP "Quiet Flood" 08Z04JAN2017

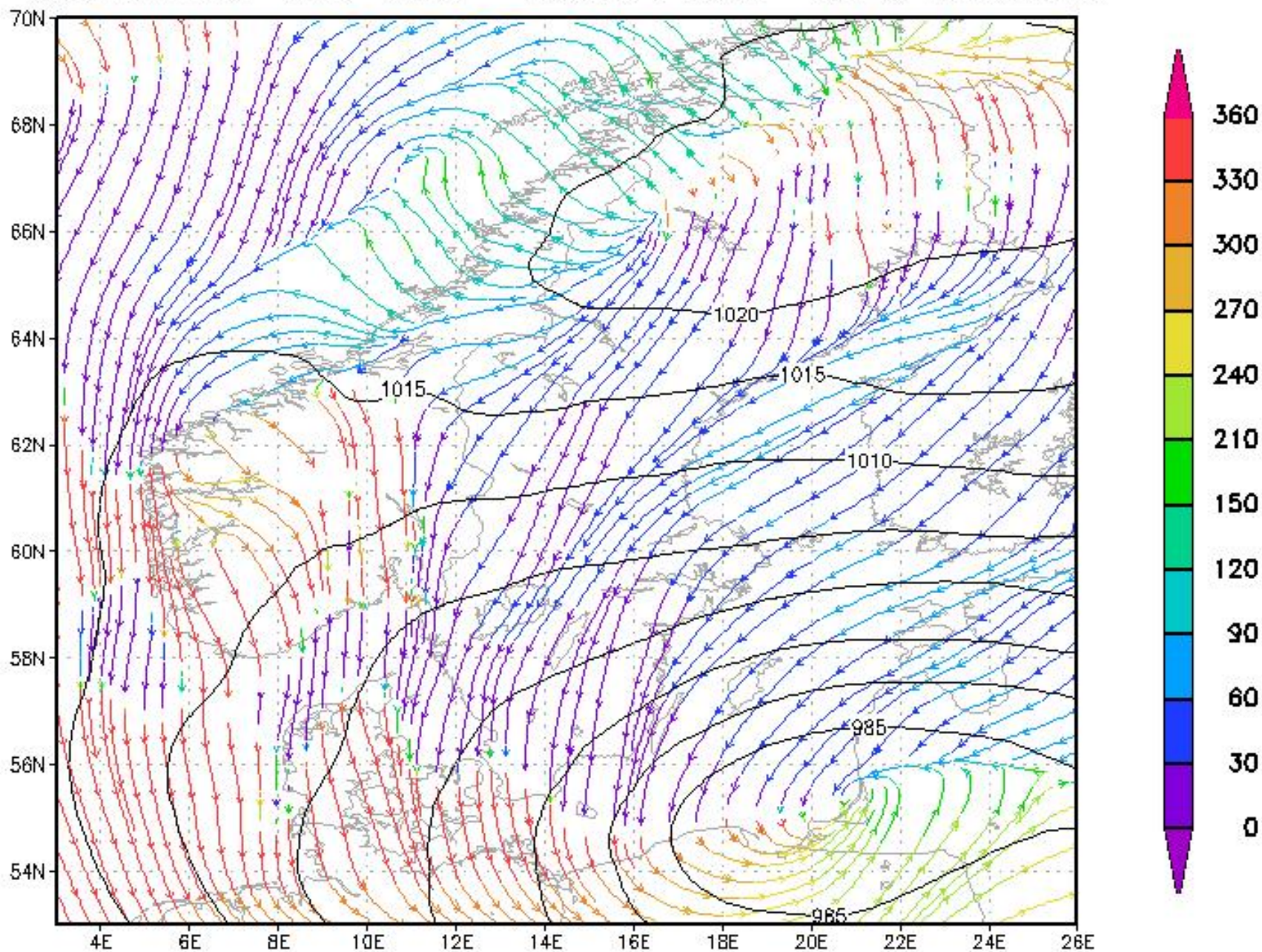Streamlines and MSLP "Quiet Flood" 09Z04JAN2017
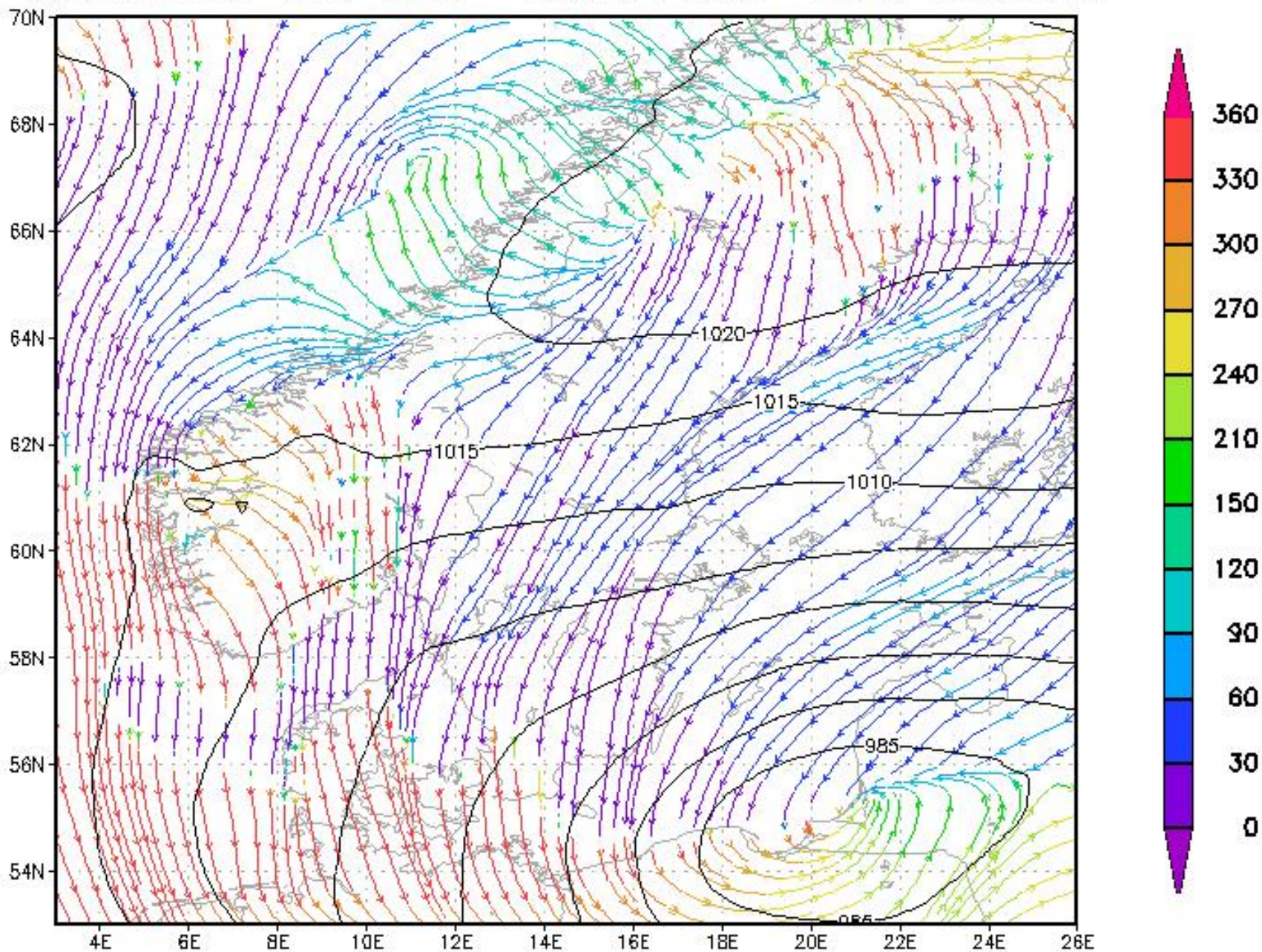
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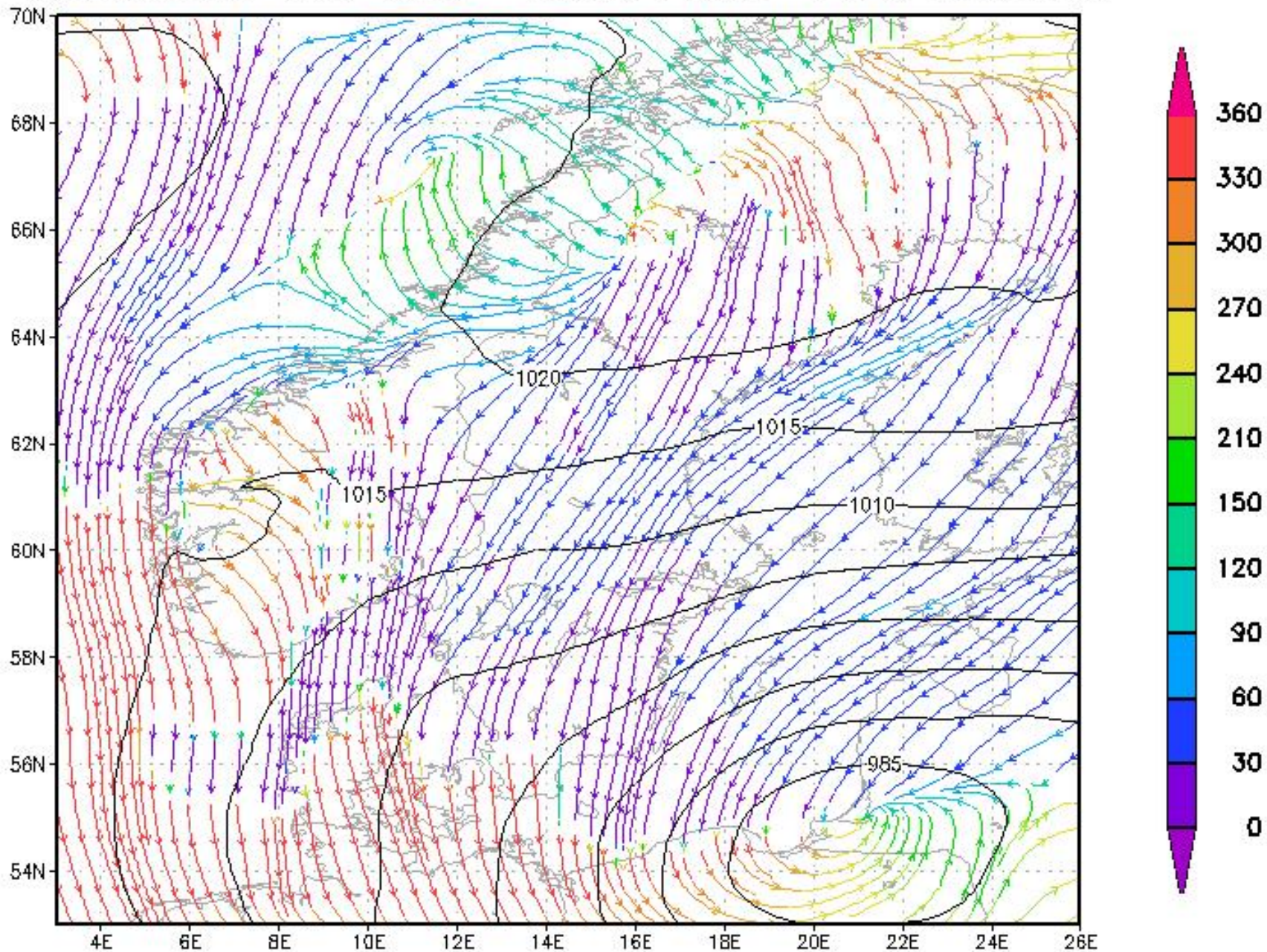Streamlines and MSLP "Quiet Flood" 11Z04JAN2017

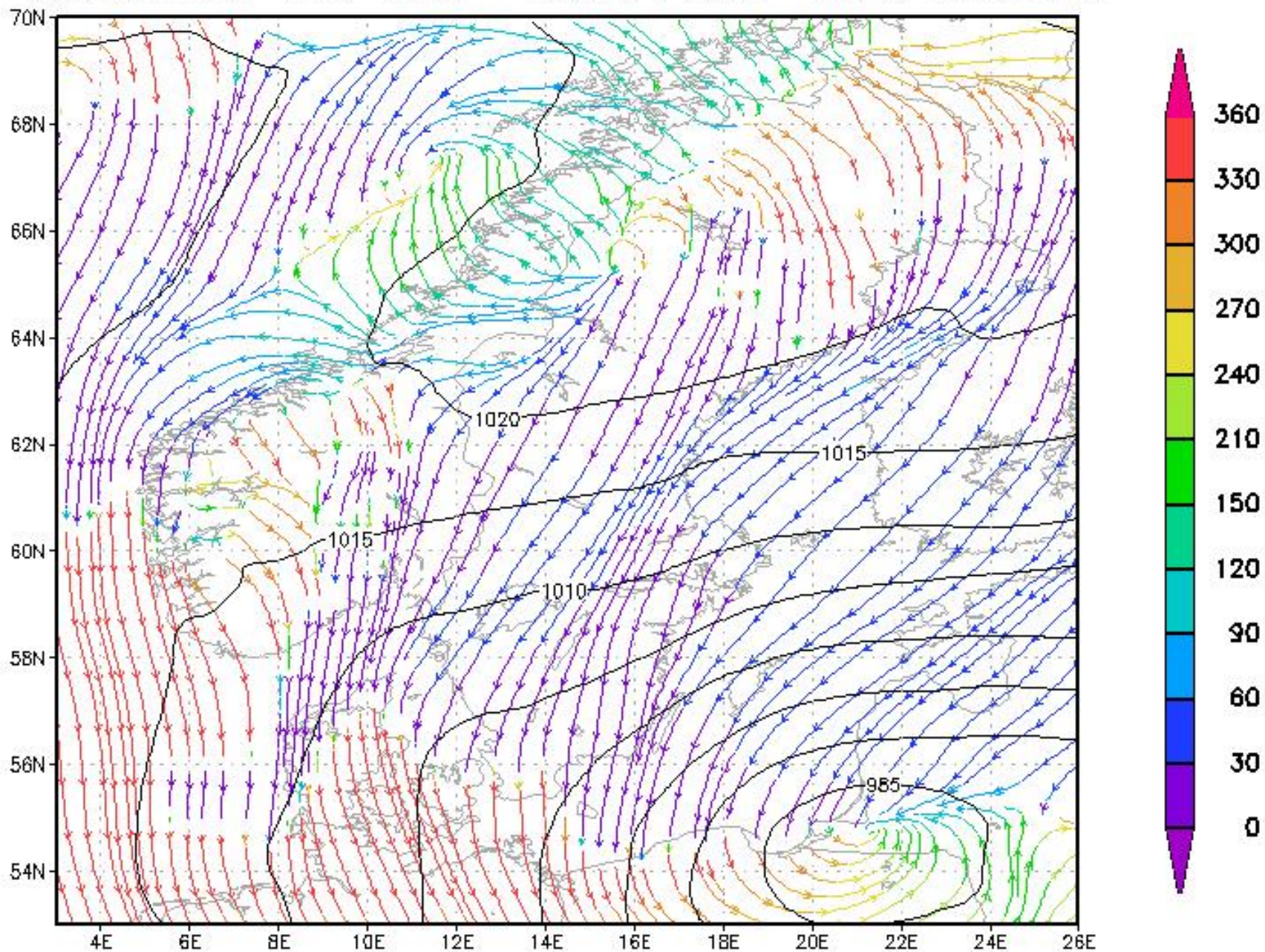Streamlines and MSLP "Quiet Flood" 12Z04JAN2017

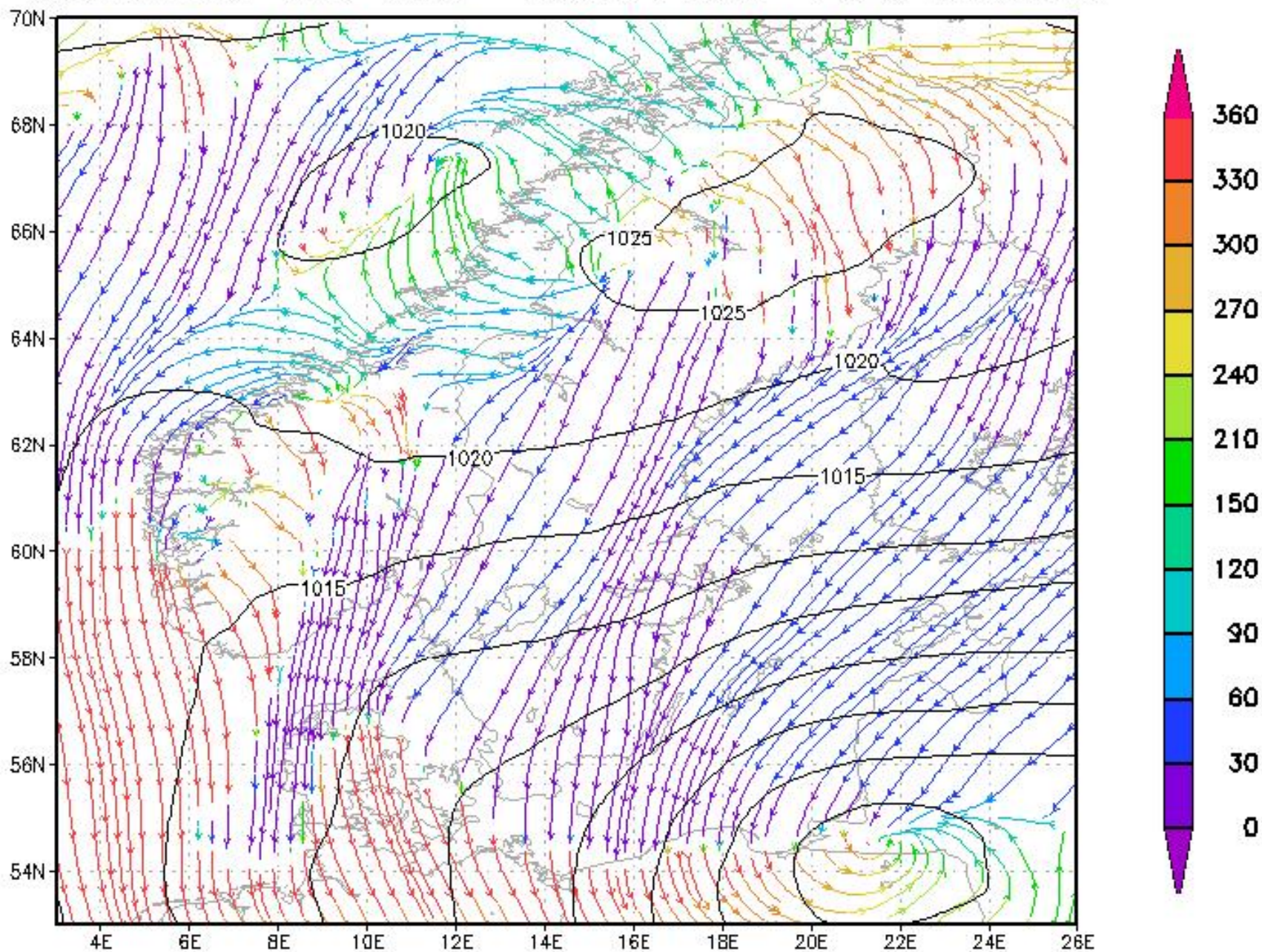Streamlines and MSLP "Quiet Flood" 13Z04JAN2017

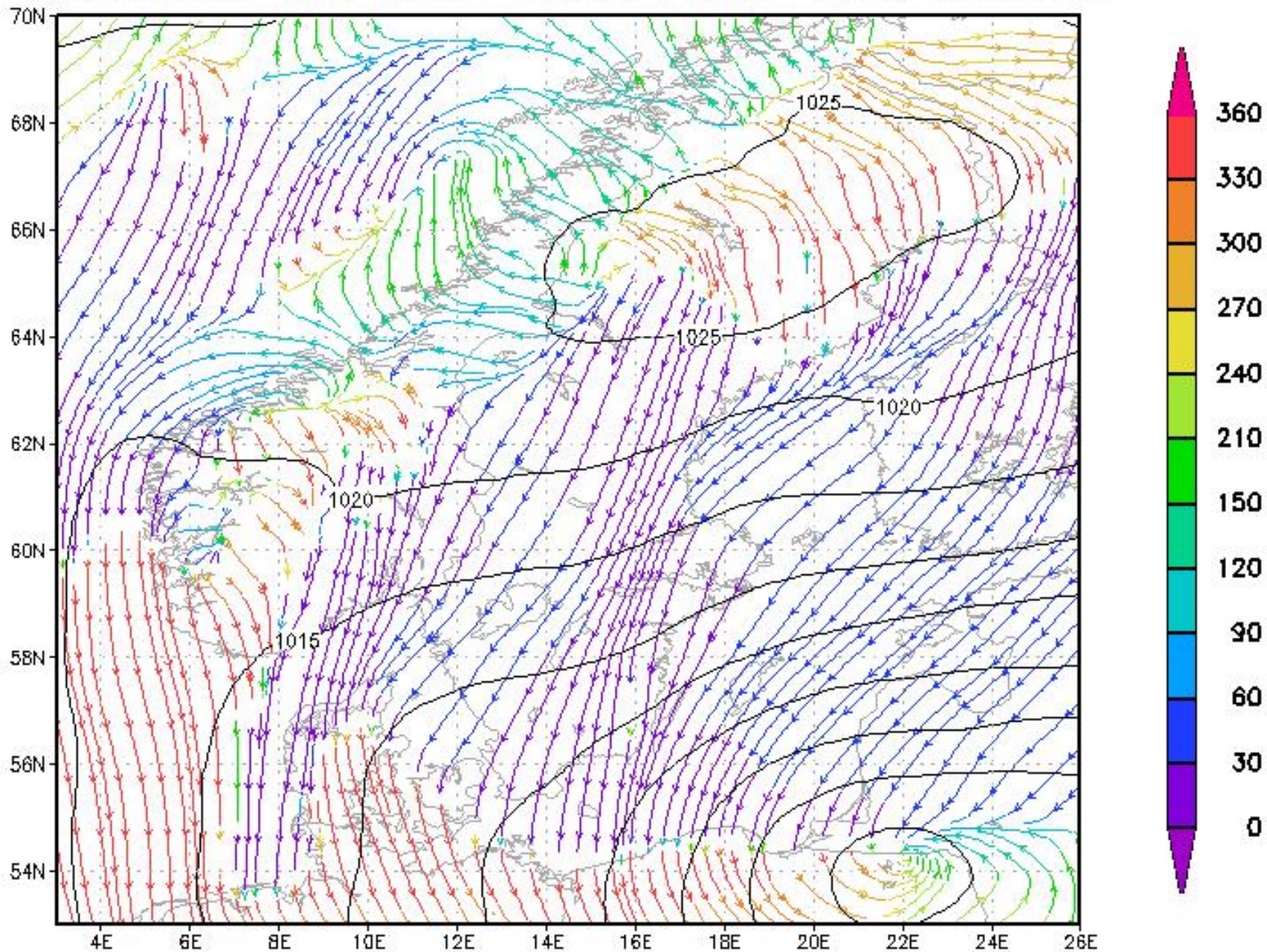Streamlines and MSLP "Quiet Flood" 14Z04JAN2017

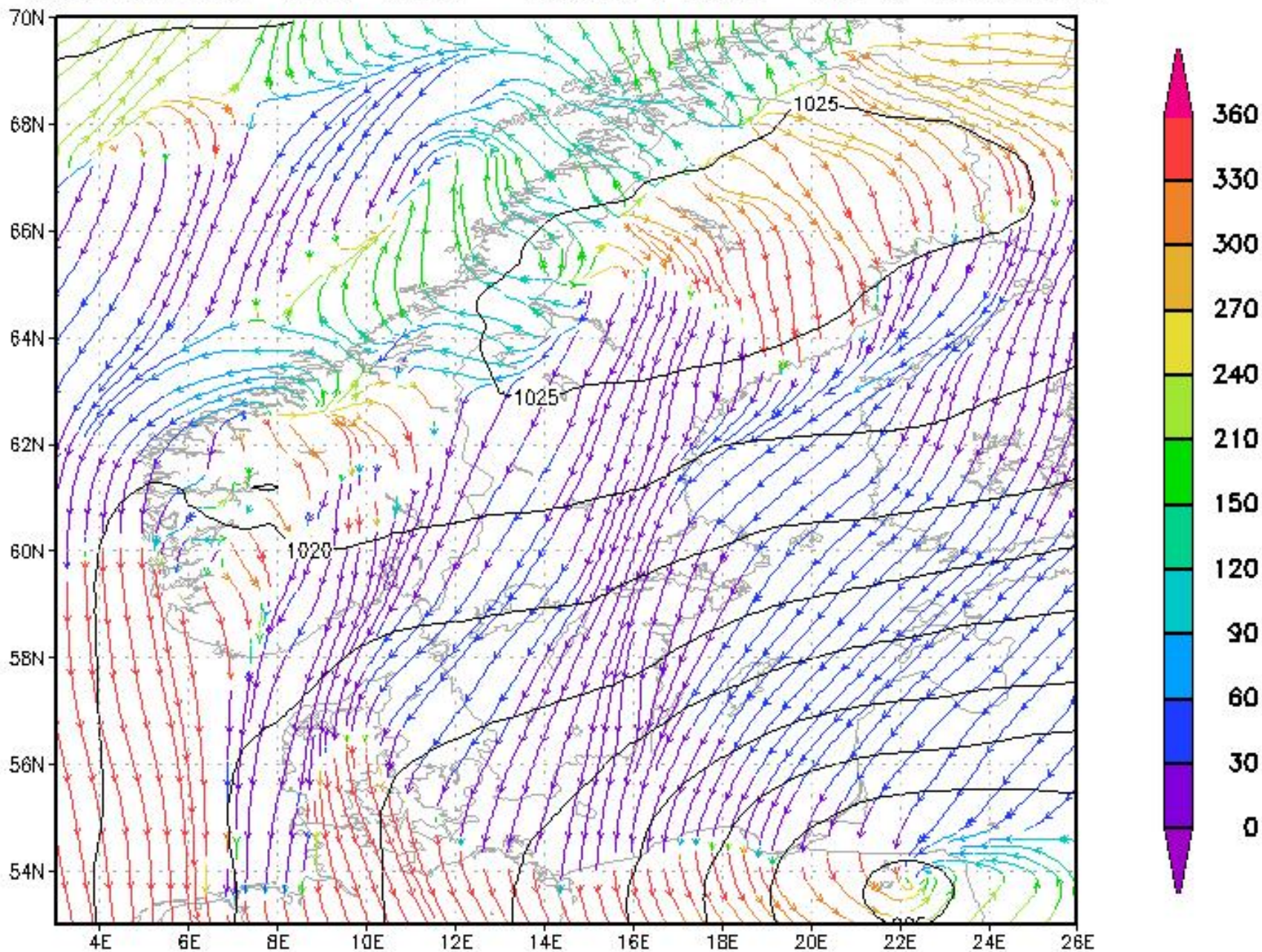Streamlines and MSLP "Quiet Flood" 15Z04JAN2017
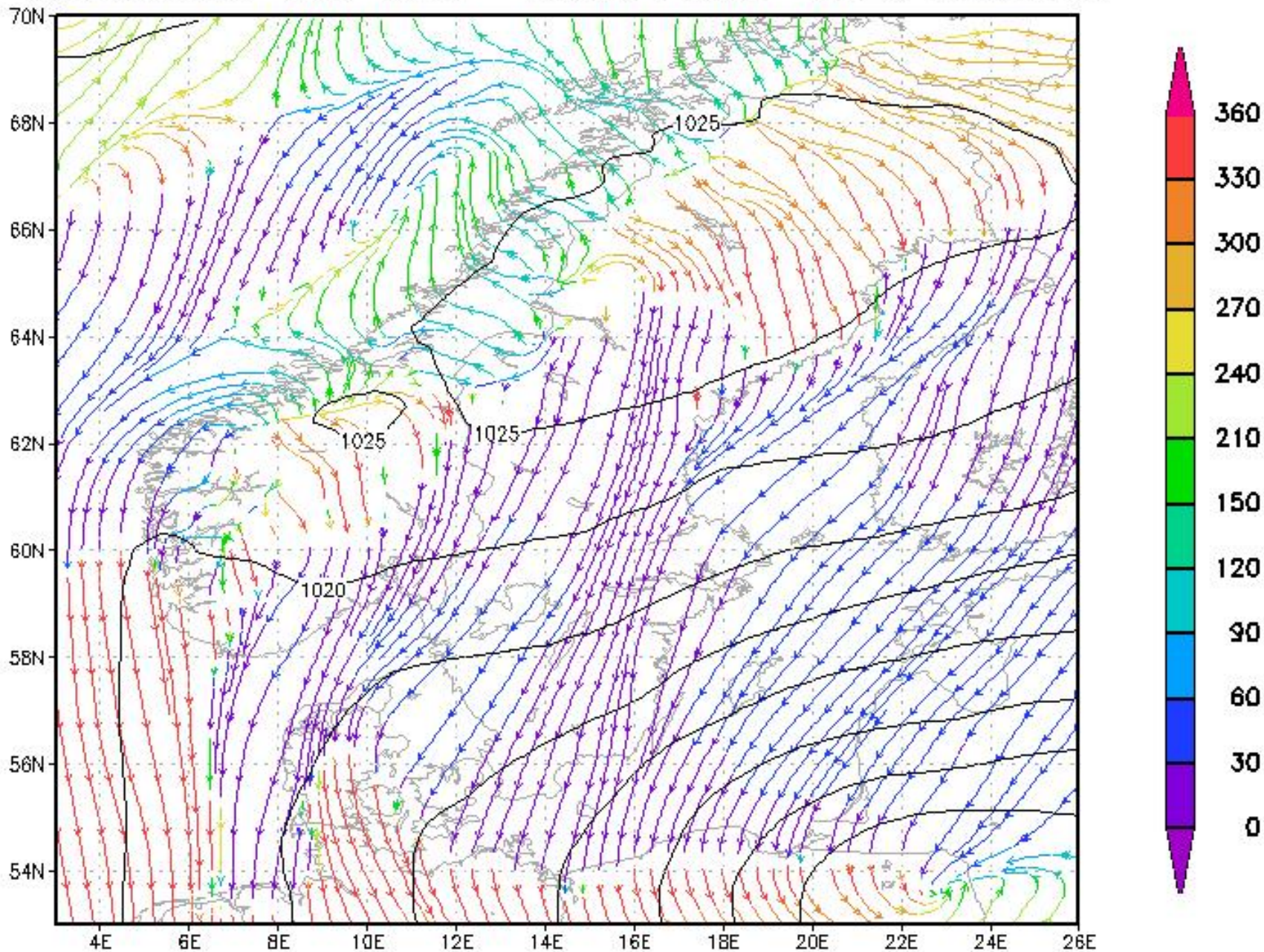
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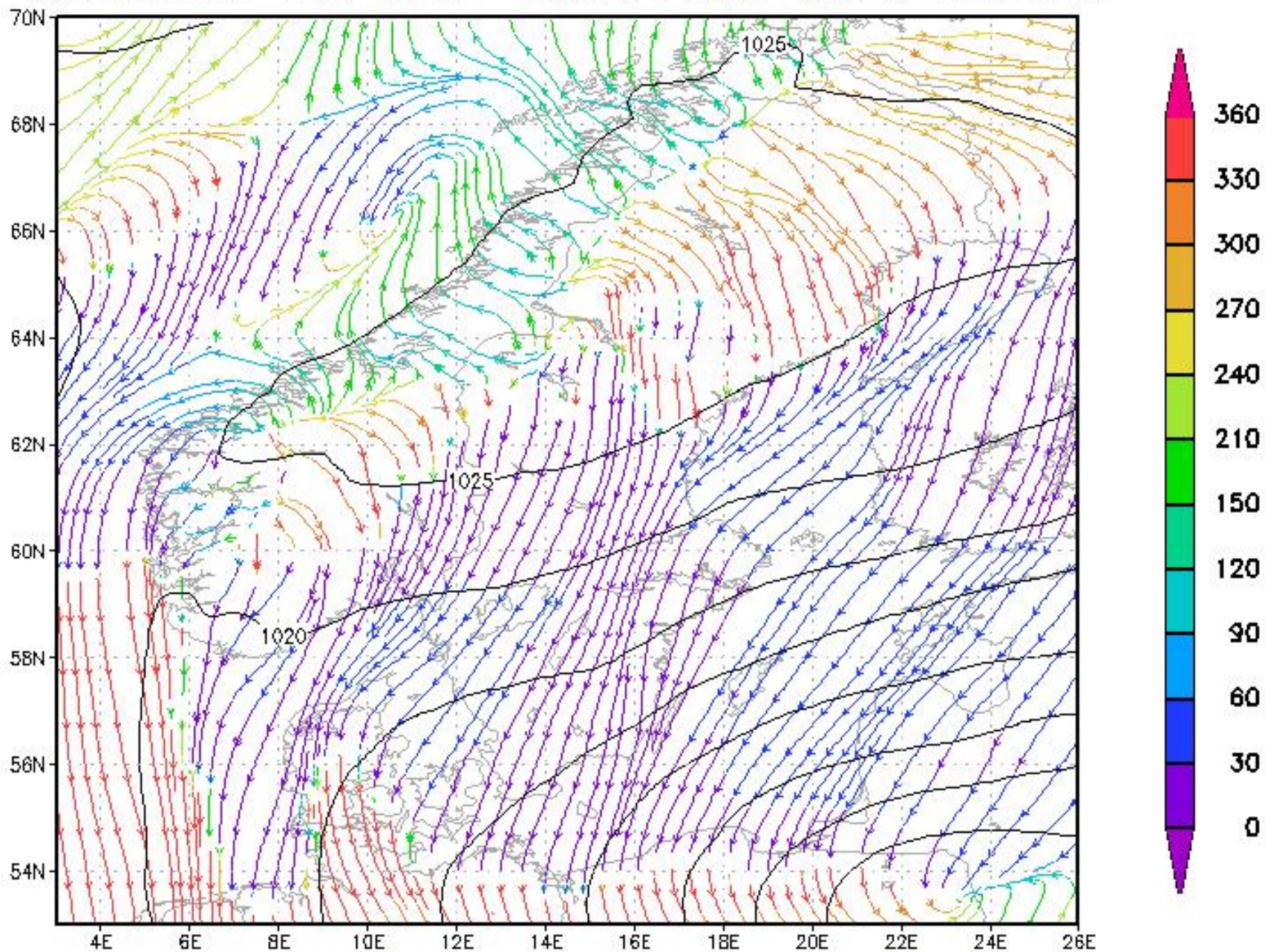
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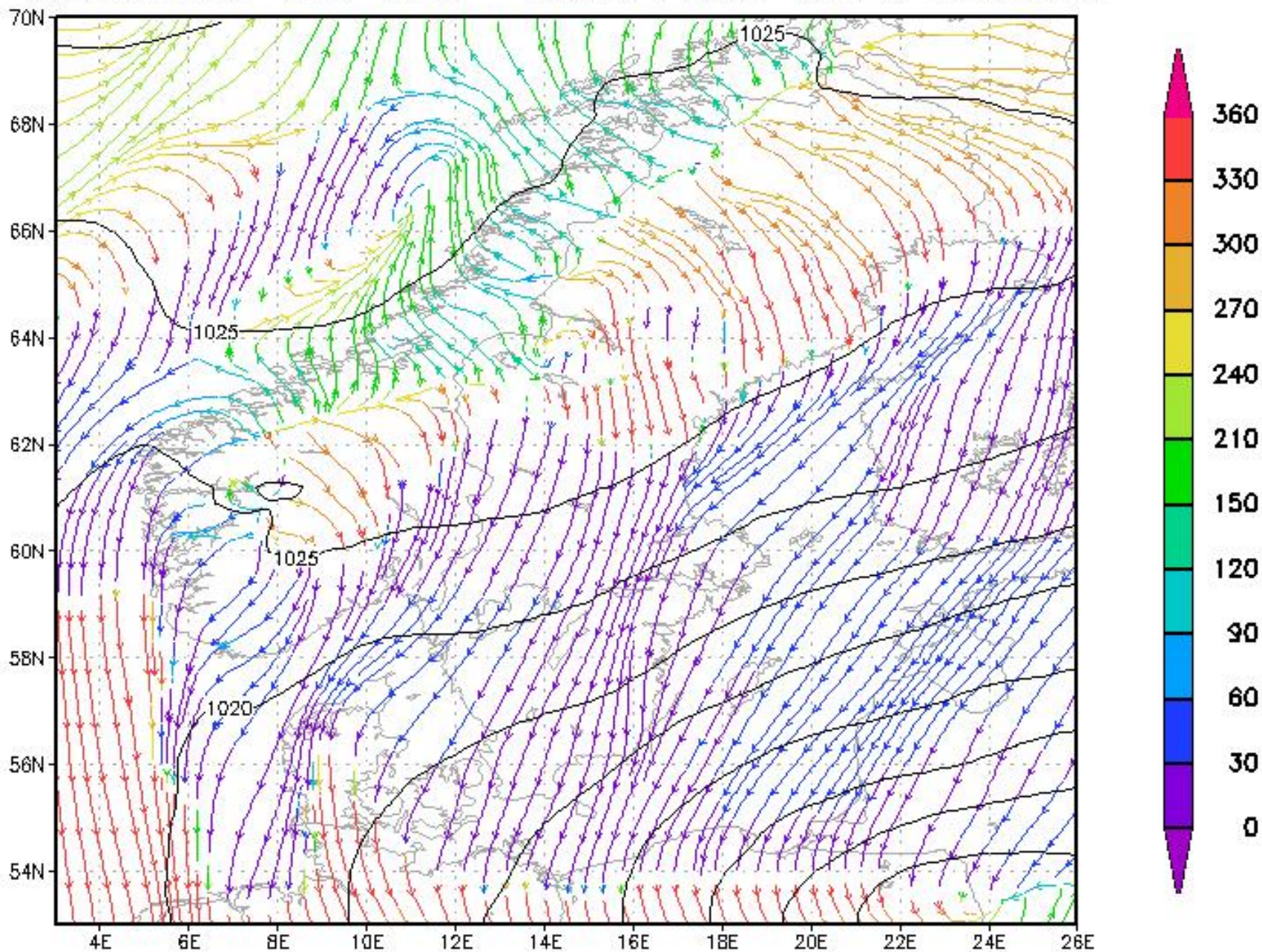Streamlines and MSLP "Quiet Flood" 18Z04JAN2017

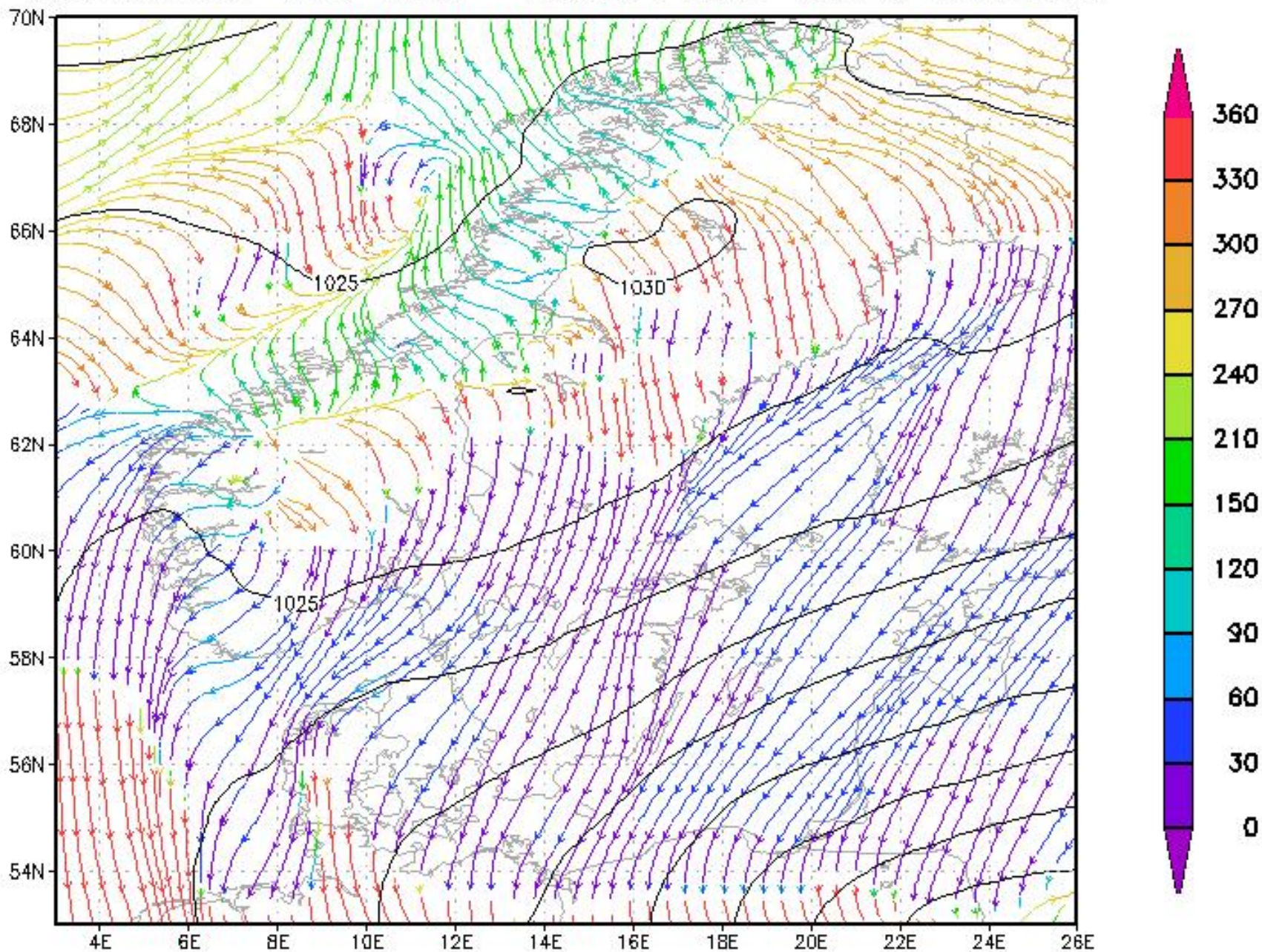Streamlines and MSLP "Quiet Flood" 19Z04JAN2017
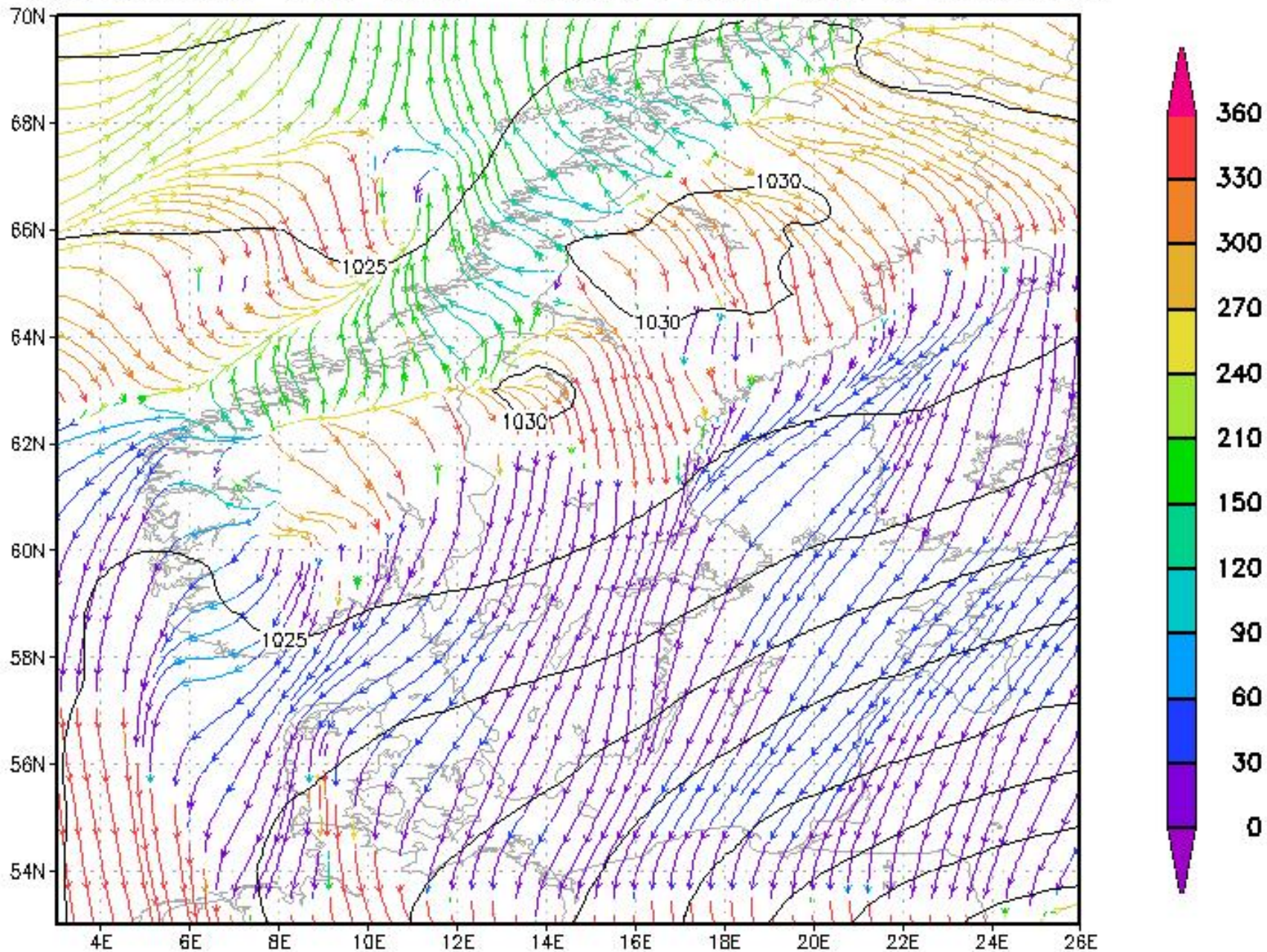
Streamlines and MSLP "Quiet Flood" 20Z04JAN2017

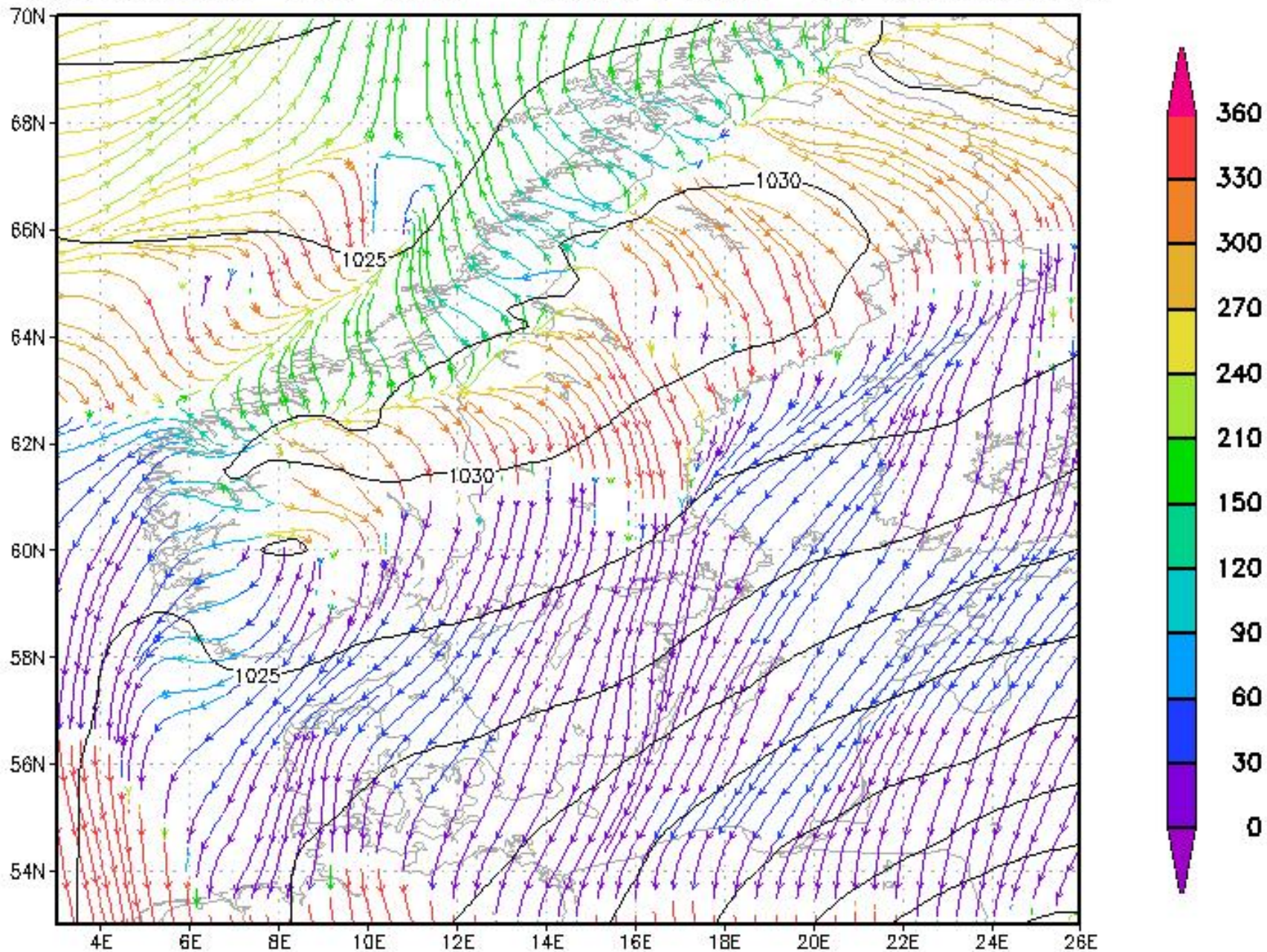Streamlines and MSLP "Quiet Flood" 21Z04JAN2017

Streamlines and MSLP "Quiet Flood" 22Z04JAN2017

Streamlines and MSLP "Quiet Flood" 23Z04JAN2017

Streamlines and MSLP "Quiet Flood" 00Z05JAN2017

Conclusions

- ERA5 is a state-of-the art reanalysis with a focus on climate
- Unprecedented spatial (31 km) and temporal (1 hour) resolution
- Well suited to study small scale features like heavy rain events or front passages
- Freely available to everybody
- Available for 2008 until present minus 2 or 3 months
- To be extended backward to 1950