A new diagnostic for identifying cyclonic and anticyclonic regions and its application for combining ensembles

Nigel Roberts

UEF 2024

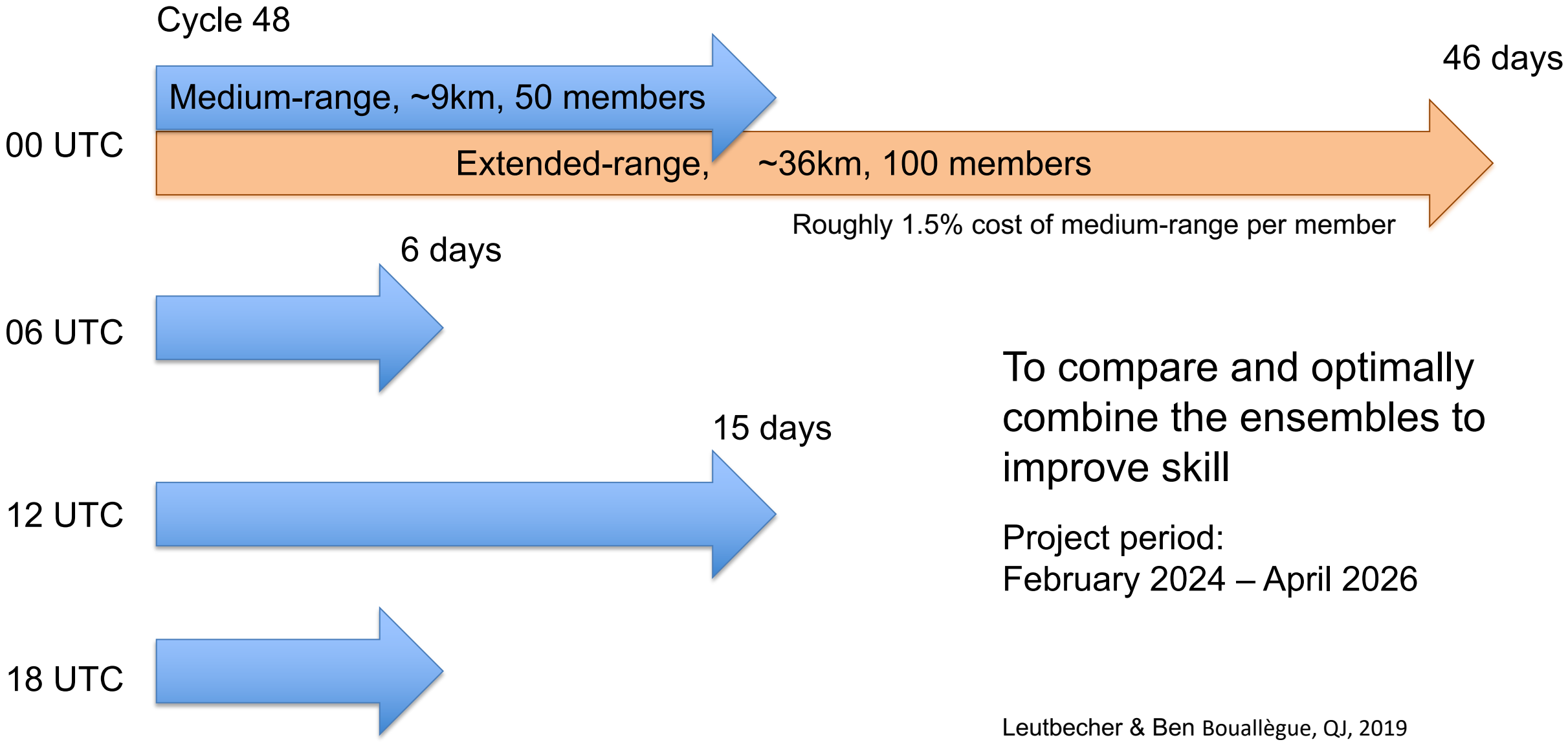
Tim Hewson, Anca Brookshaw, Matthieu Chevallier

Products Team, Evaluation Section

Thanks in various ways to:
Ivana Aleksovska, Magdalena Balmaseda, Paul Burton, Thomas Haiden, Sarah Keeley, Madhuri Khandagale, David Lavers, Martin Leutbecher, Llorenc Lledo, Fatima Pillosu, Ivan Tsonevsky, Frederic Vitart

ECMWF

Ensemble Combinations project

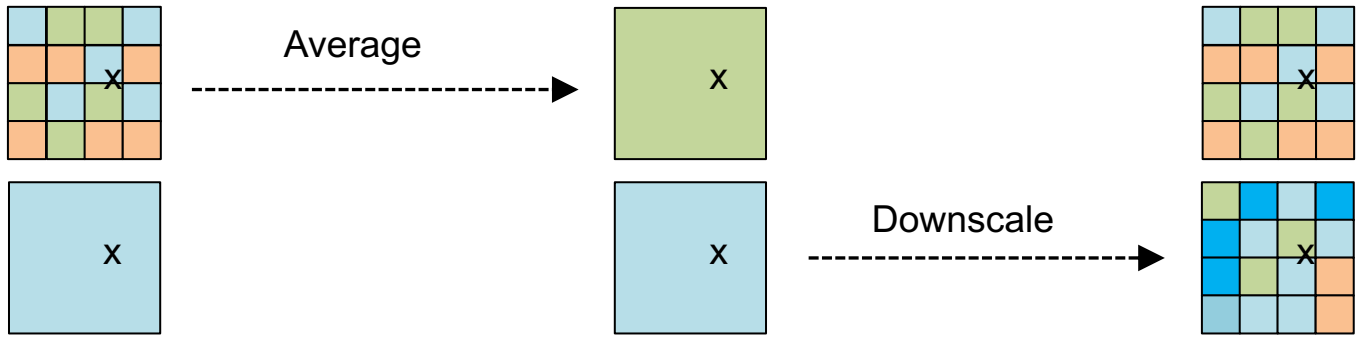


To compare and optimally combine the ensembles to improve skill

Project period:
February 2024 – April 2026

Leutbecher & Ben Bouallègue, QJ, 2019
On the probabilistic skill of dual-resolution ensemble forecasts

Approaches for comparing and blending two resolutions

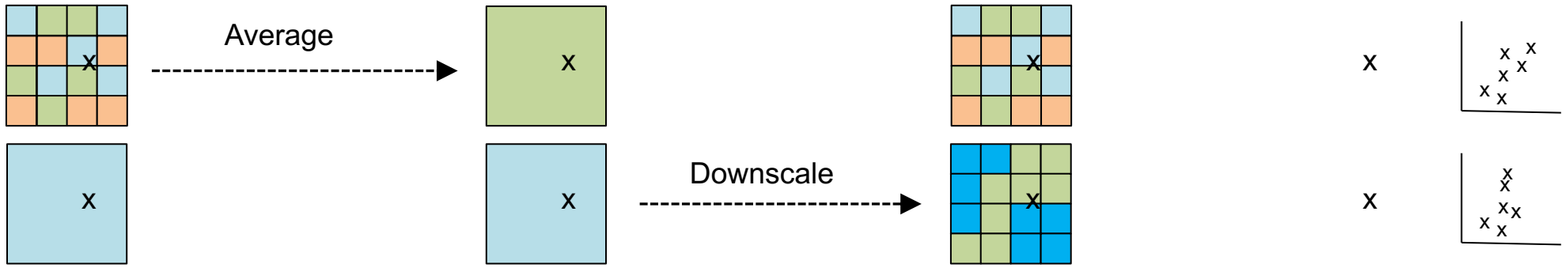


Use native grids
Most simple
Representativeness issue
Different representativeness
Compare/blend at obs only

Average to coarser grid
Relatively simple
Direct comparison / blending
Removes higher-res benefit
Representativeness issue
Compare with obs or analyses

Downscale to finer grid
Complex (physical, statistical, ML)
Distribution created from coarse res
Representativeness issue (but less)
Compare with obs or analyses

Approaches for comparing and blending two resolutions



Use native grids
Most simple
Representativeness issue
Different representativeness
Compare/blend at obs only

Average to coarser grid
Relatively simple
Direct comparison / blending
Removes higher-res benefit
Representativeness issue
Compare with obs or analyses

Downscale to finer grid
Complex (physical, statistical, ML)
Distribution created from coarse res
Representativeness issue (but less)
Compare with obs or analyses

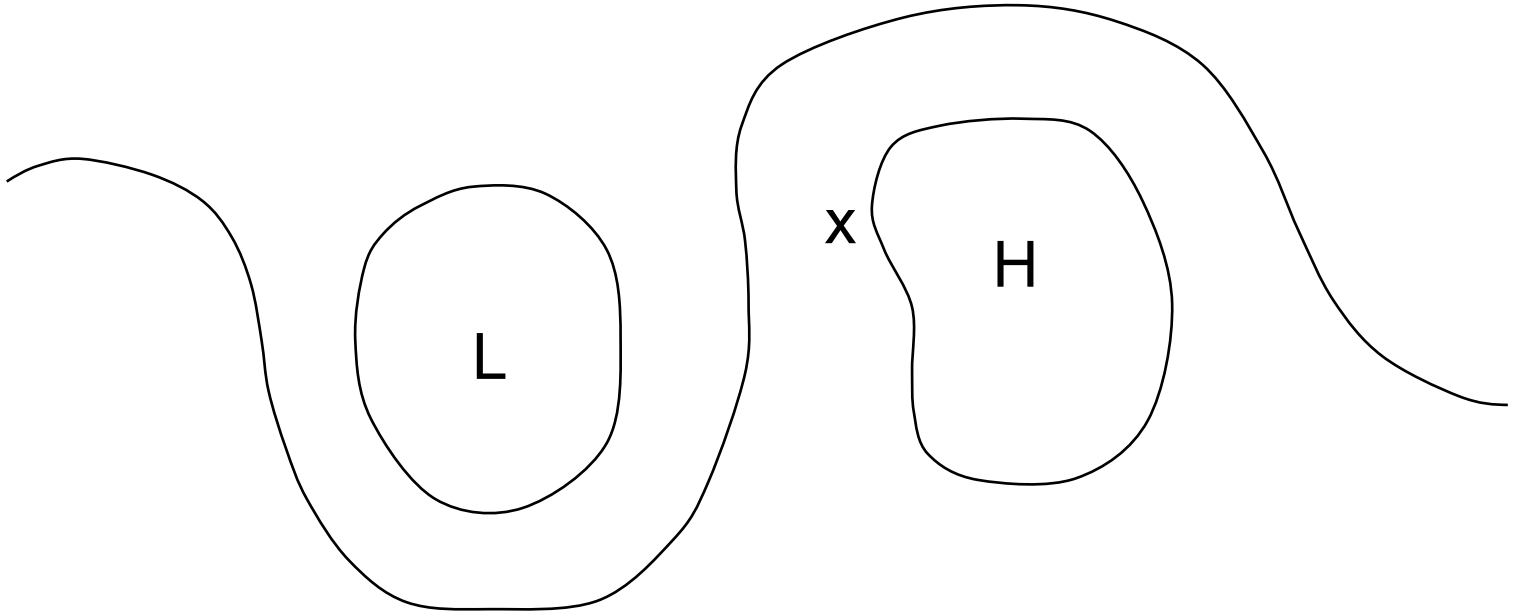
Post process to obs points
Complex (statistical, ML)
Representativeness issue removed
Biases reduced
Limited locations
Compare with obs only

Is there a different way to remove (or at least reduce) the representativeness issue simply?

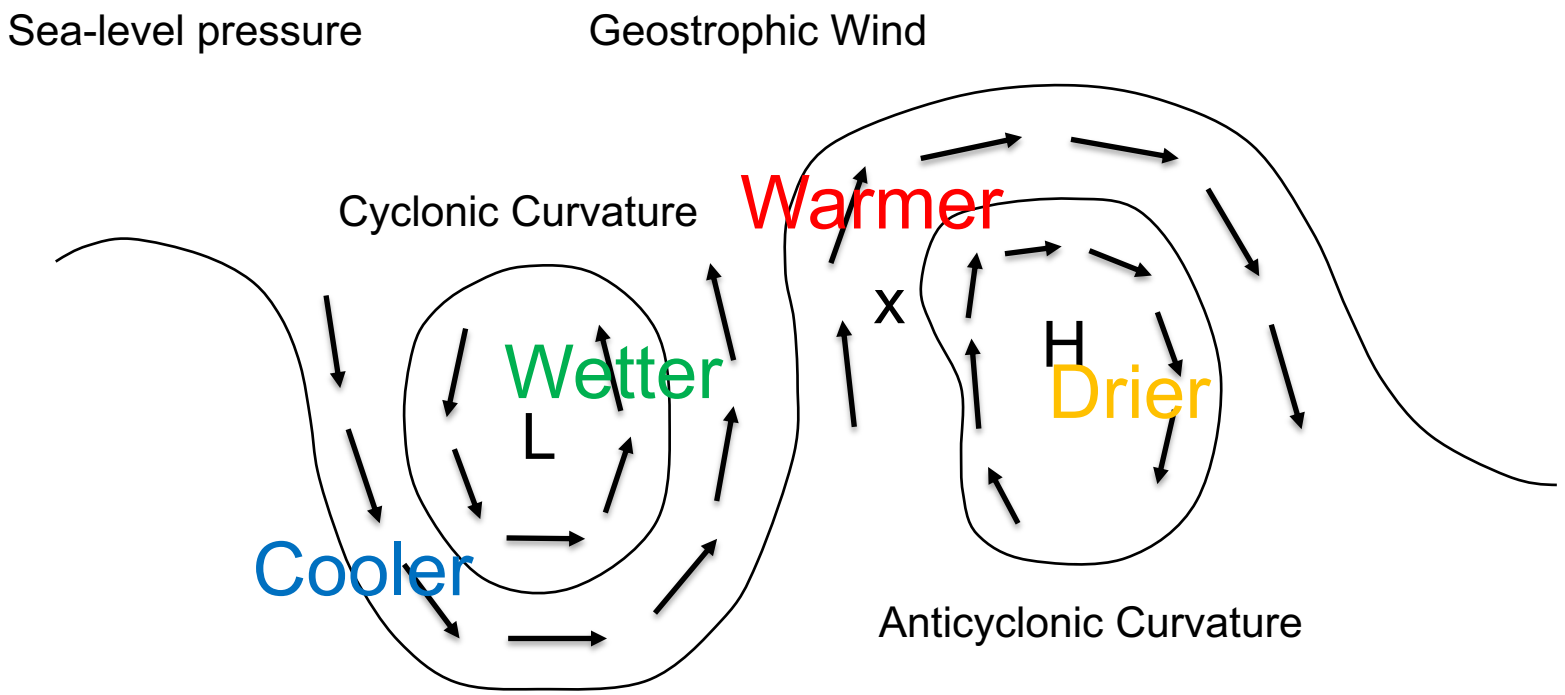
… and still compare/blend something meteorologically appropriate?

What matters in a week-2 weather forecast?

Sea-level pressure



What matters in a week-2 weather forecast?



The pressure pattern reveals the curvature of the flow
(even if the geostrophic wind isn't exactly the real wind)

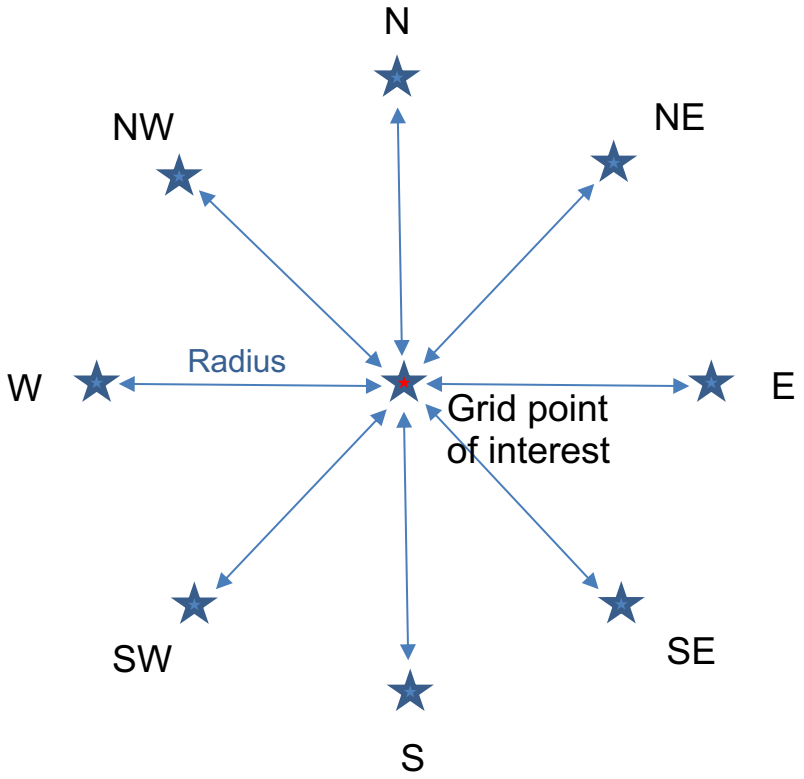
The positions of cyclones and anticyclones and the curvature of the flow greatly influence the local weather conditions. Getting that correct is crucial for a good forecast.

The curvature of the flow can be determined from the topology of the pressure (or geopotential height) pattern. New diagnostic.

The pressure itself is less useful.

A new diagnostic that measures cyclonic and anticyclonic curvature

CURV (Curvature Using Radial Variation)



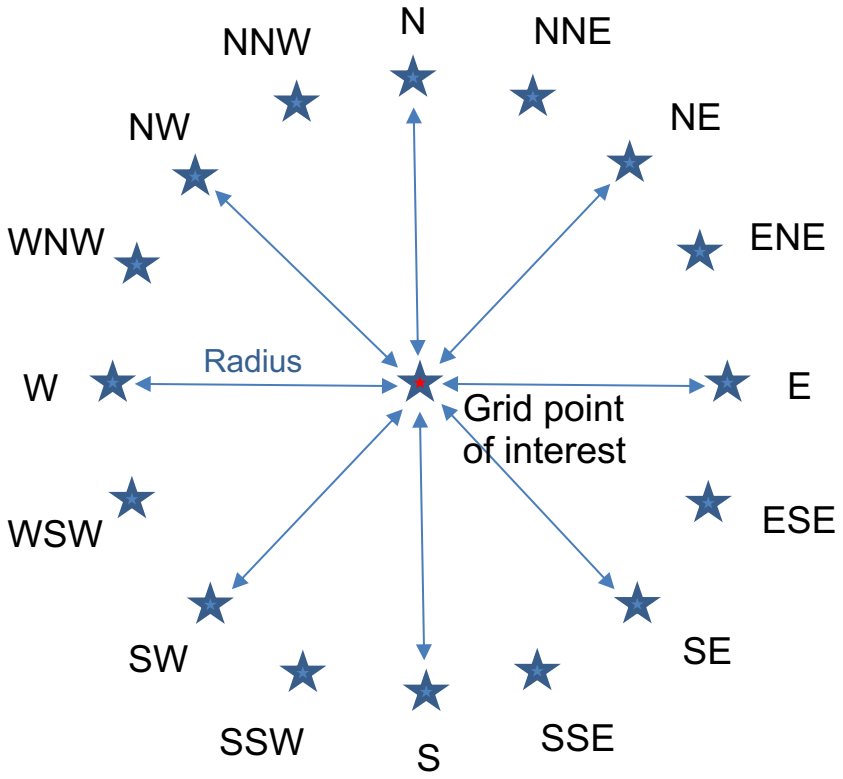
How to compute CURV

1. Take a gridded field of MSLP or geopotential height
2. For each grid point, find locations at fixed radius and fixed angles surrounding that grid point
3. Find the pressure/height values at each surrounding location (interpolation, nearest point)
4. Find the signs of differences between each grid point and its surrounding locations
5. Subtract the number of surrounding grid points with a lower value from from those with a higher value
6. Use the difference to assign the degree of cyclonic or anticyclonic curvature

If Radius >> grid spacing of each model (e.g. radius > 500km)
The different resolutions can be treated the same and representativeness differences are largely removed.
Compare forecasts with identically processed analyses.

A new diagnostic that measures cyclonic and anticyclonic curvature

CURV (Curvature Using Radial Variation)

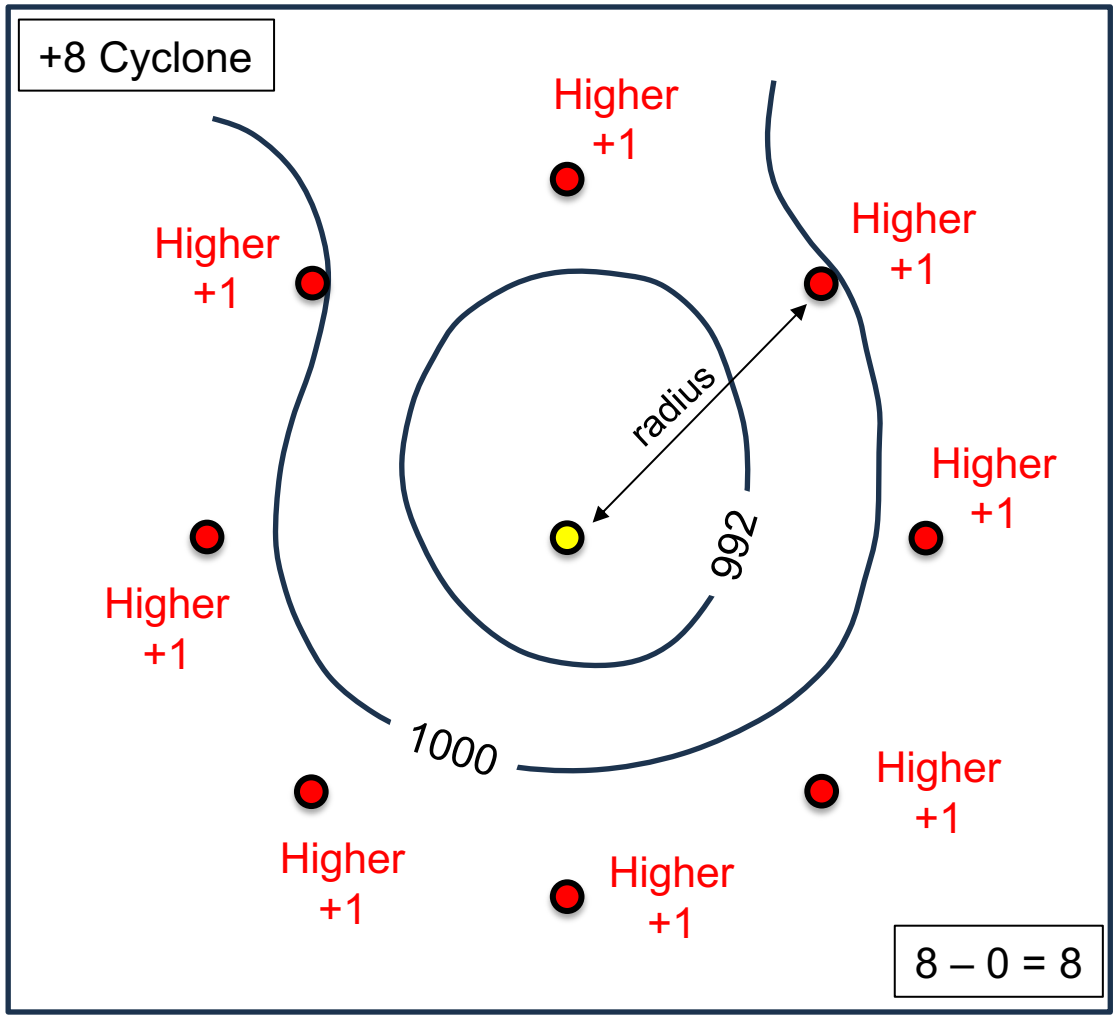


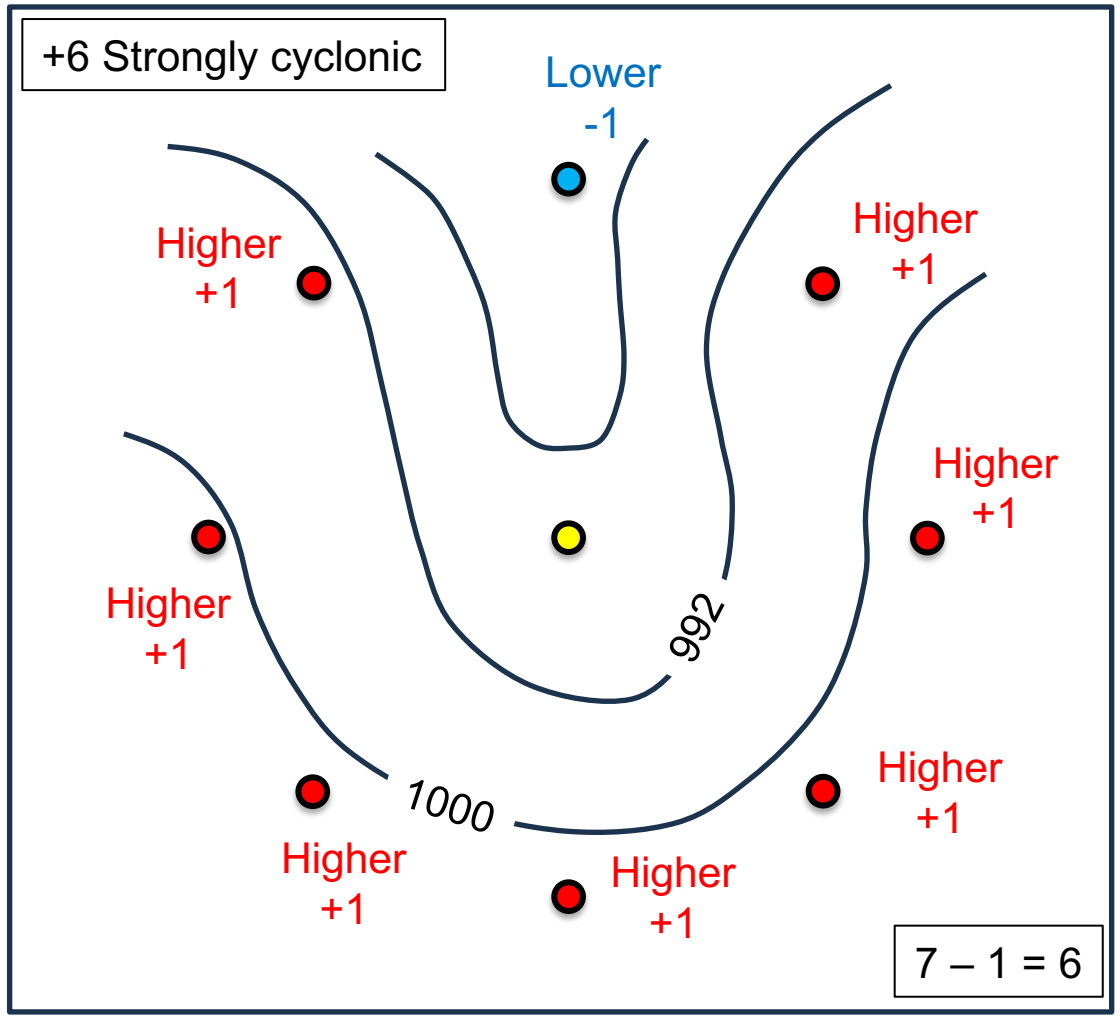
How to compute CURV

1. Take a gridded field of MSLP or geopotential height
2. For each grid point, find locations at fixed radius and fixed angles surrounding that grid point
3. Find the pressure/height values at each surrounding location (interpolation, nearest point)
4. Find the signs of differences between each grid point and its surrounding locations
5. Subtract the number of surrounding grid points with a lower value from from those with a higher value
6. Use the difference to assign the degree of cyclonic or anticyclonic curvature

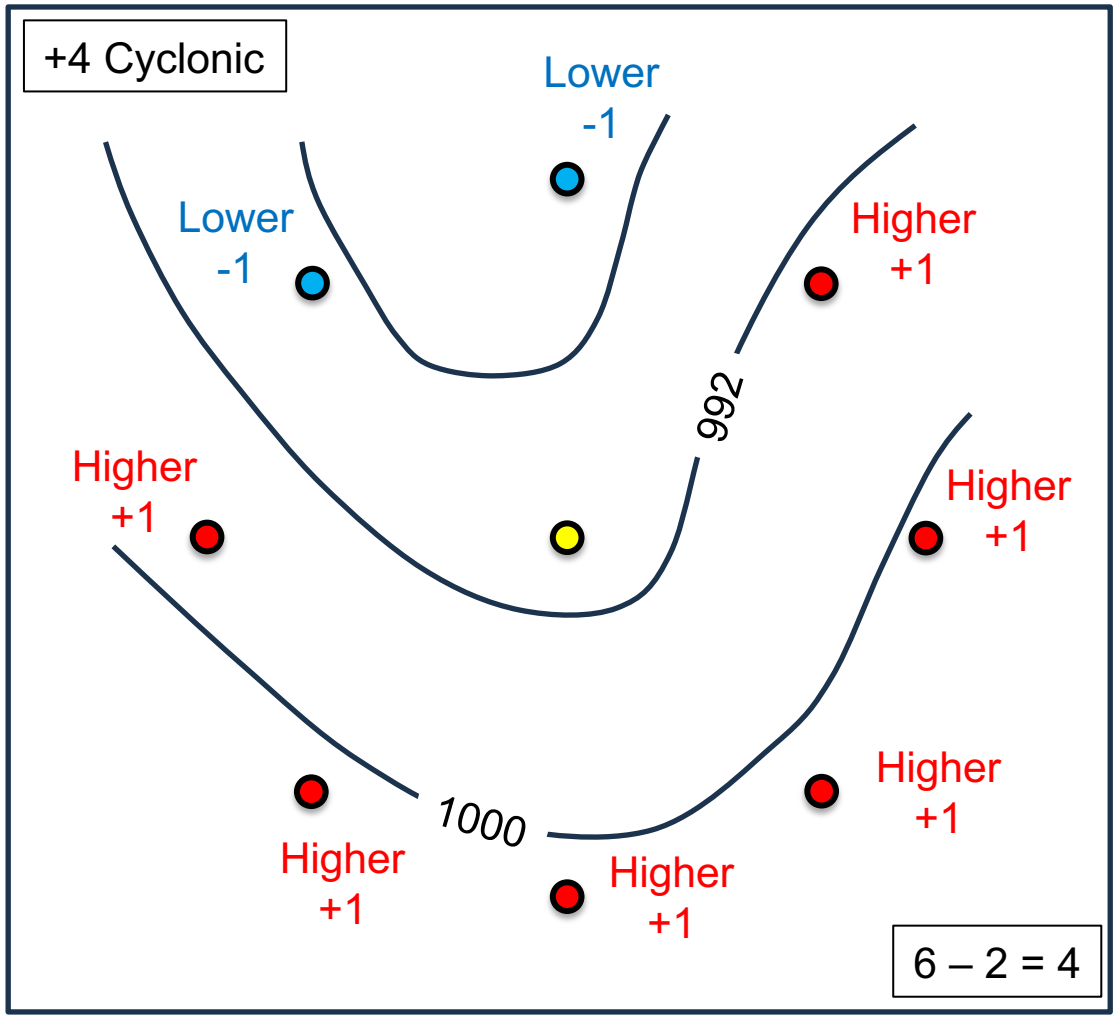
If Radius >> grid spacing of each model (e.g. radius > 500km)
The different resolutions can be treated the same and representativeness differences are largely removed.
Compare forecasts with identically processed analyses.

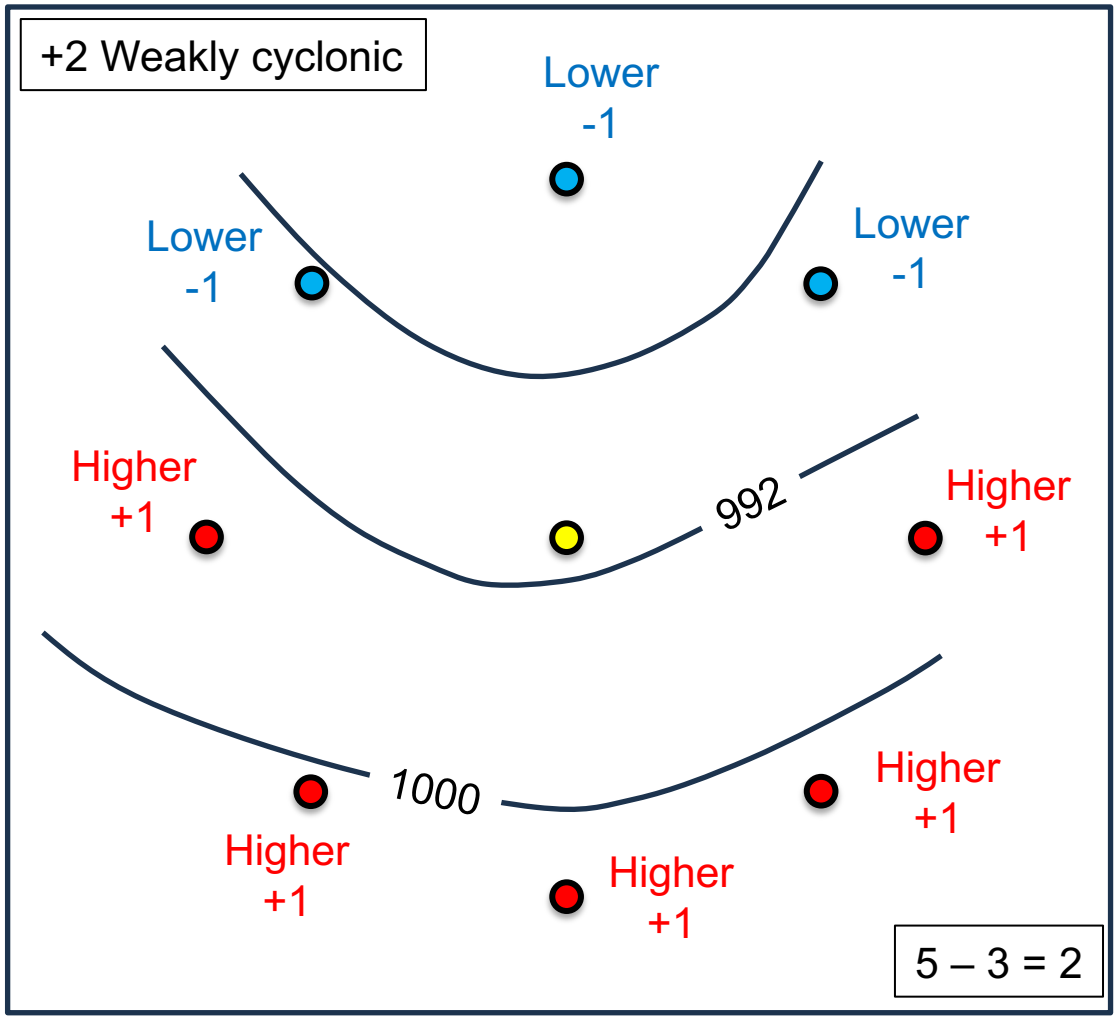
CURV schematic examples



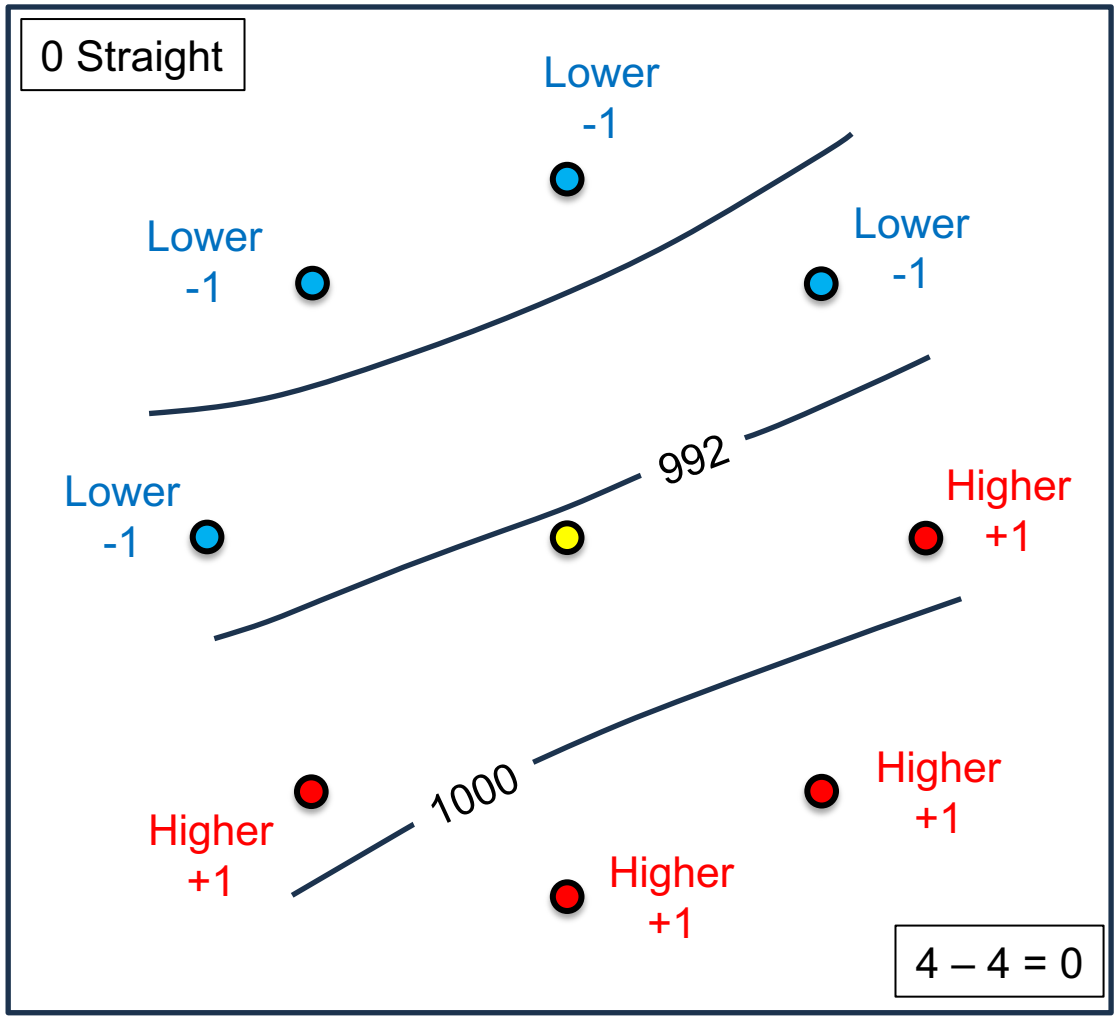


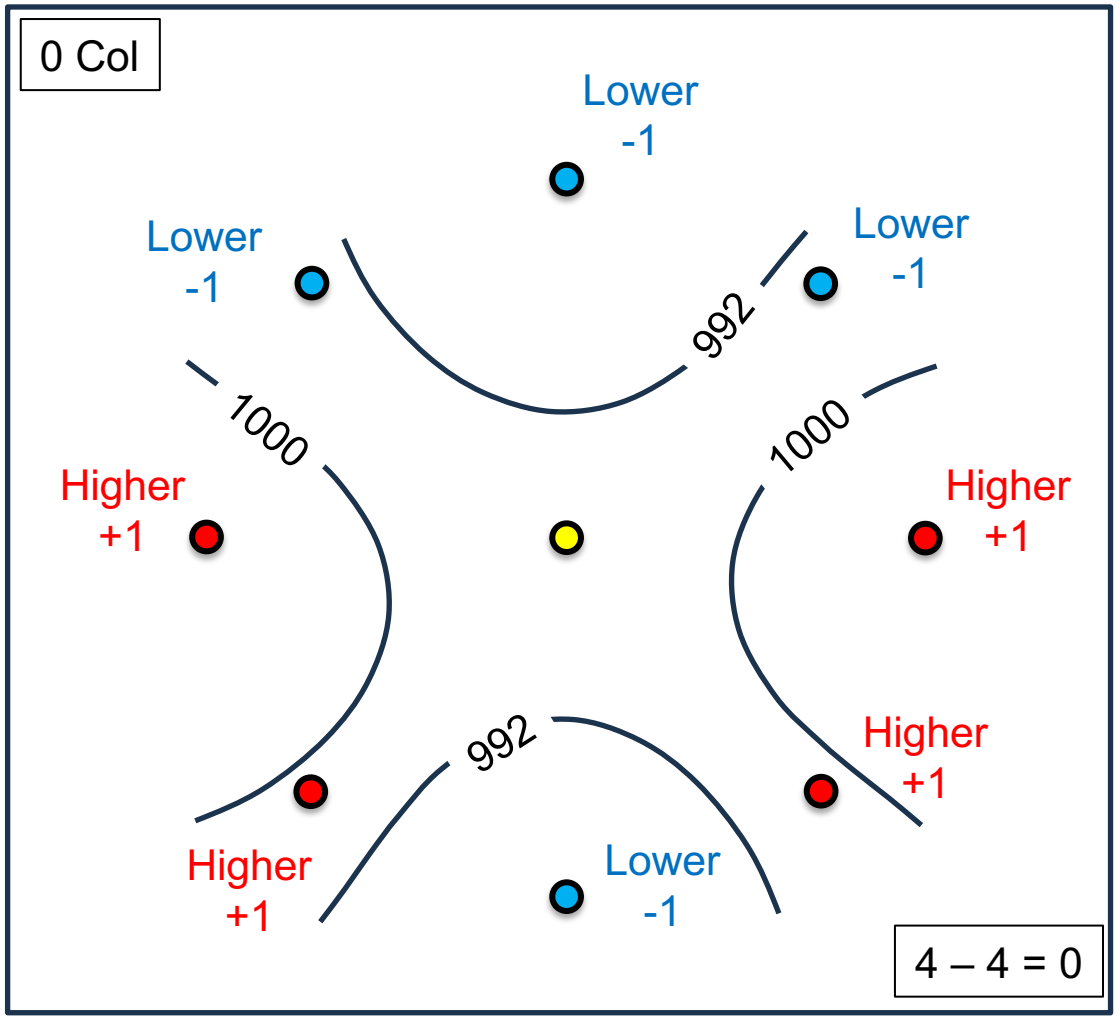
CURV schematic examples





CURV schematic examples





CURV (Curvature Using Radial Variation)

Categorise the type of flow

8 higher, 0 lower = +8 = cyclone

7 higher, 1 lower = +6 = strong cyclonic curvature

6 higher, 2 lower = +4 = cyclonic curvature

5 higher, 1 lower = +2 = weak cyclonic curvature

4 higher, 4 lower = 0 = straight flow or col

3 higher, 5 lower = -2 = weak anticyclonic curvature

2 higher, 6 lower = -4 = anticyclonic curvature

1 higher, 7 lower = -6 = strong anticyclonic curvature

0 higher, 8 lower = -8 = anticyclone

Or if using 16 points

+16 = cyclone

+12, +14 = strong cyclonic curvature

+8, +10 = cyclonic curvature

+4, +6 = weak cyclonic curvature

-2, 0, +2 = straight flow or col

-4, -6 = weak anticyclonic curvature

-8, -10 = anticyclonic curvature

-12, -14 = strong anticyclonic curvature

-16 = anticyclone

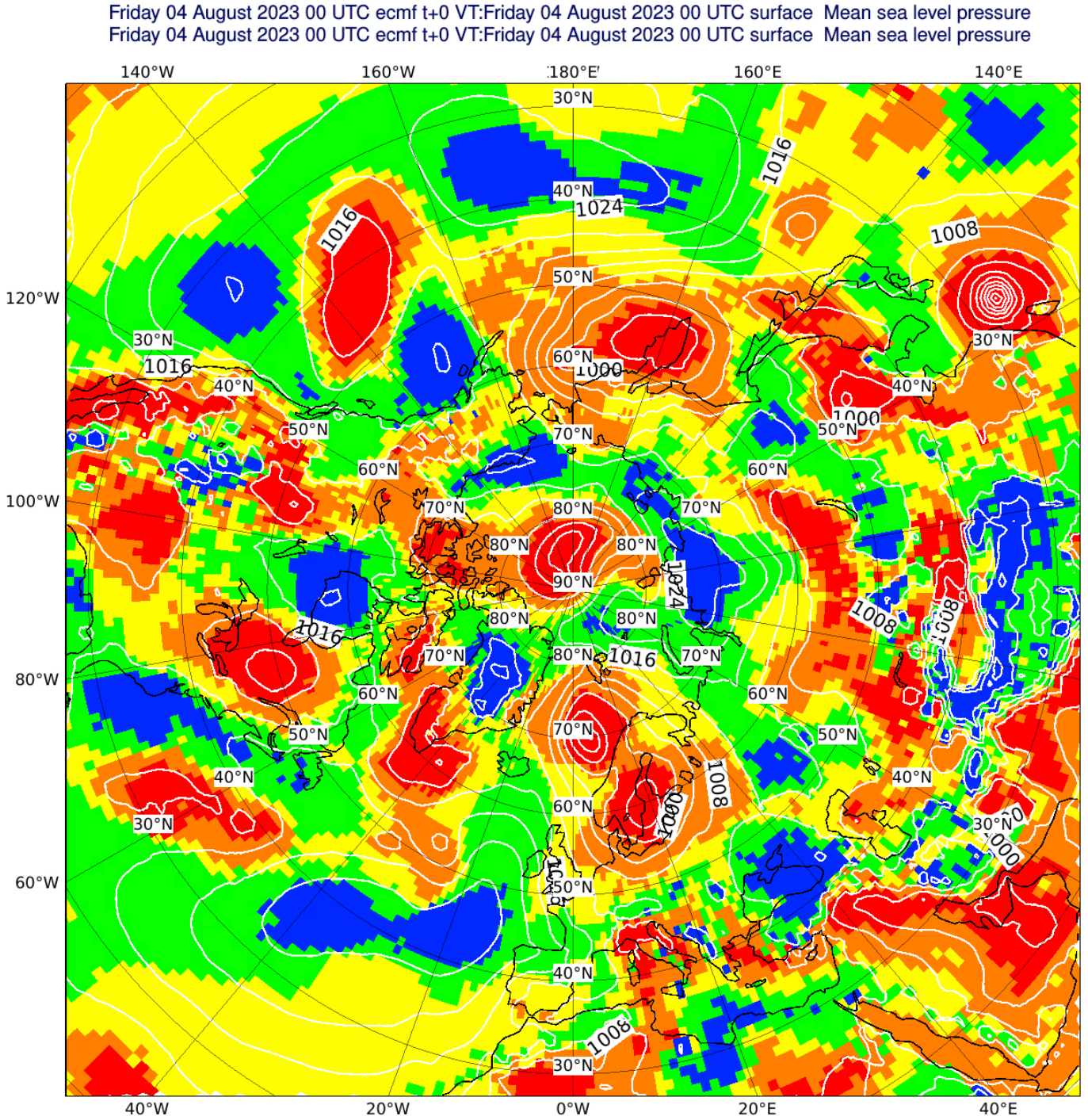
(or divide by 2)

CURV
Radius 1000 km

Northern Hemisphere

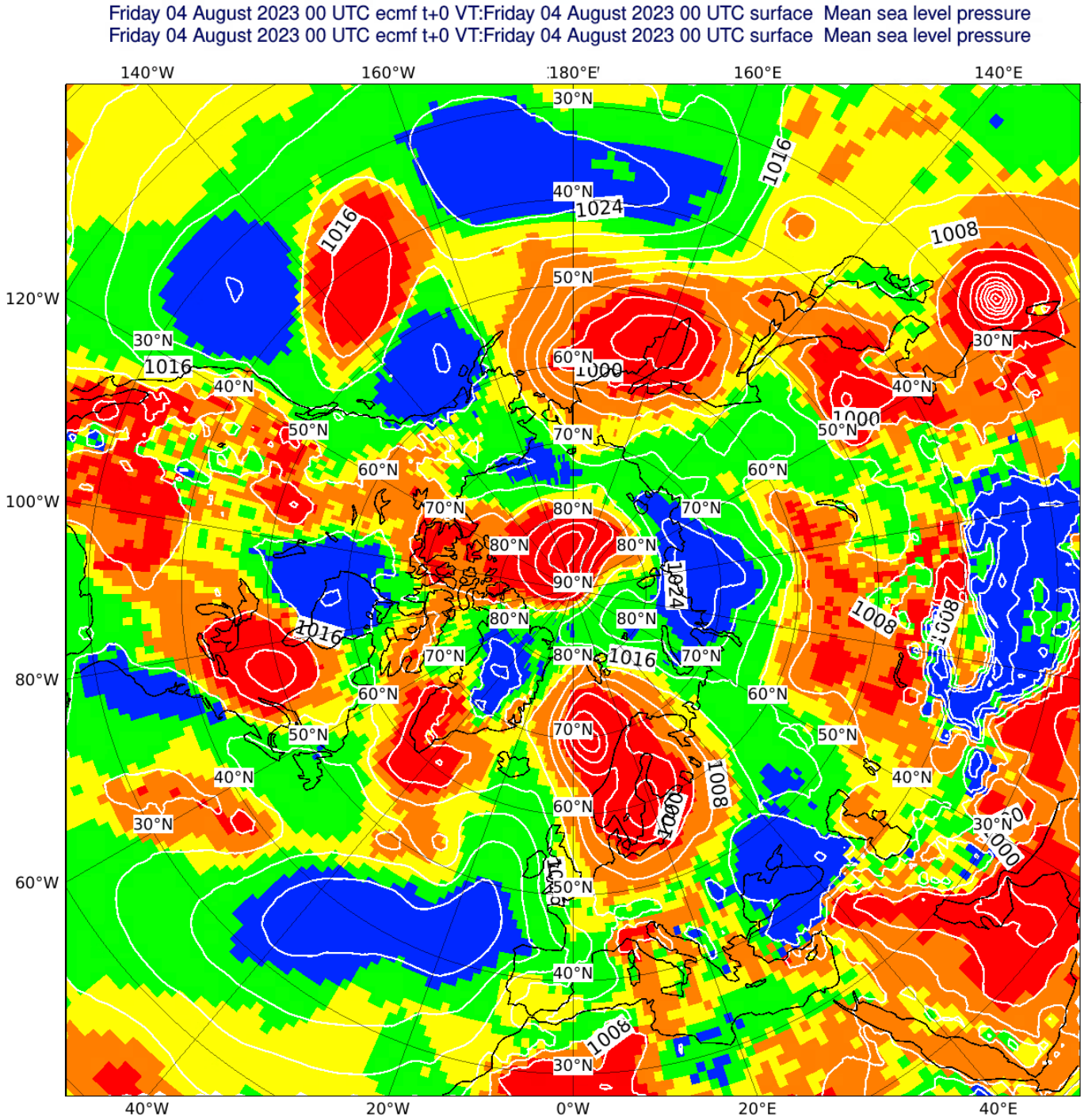
Snapshot example
04 Aug 2023

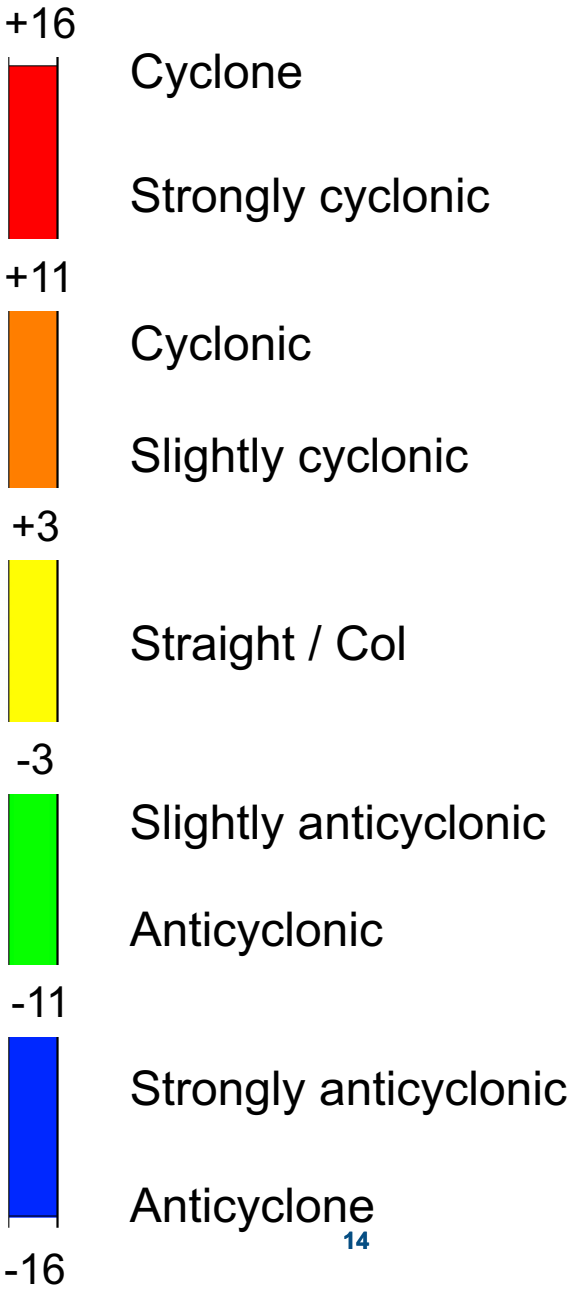
CURV has been computed on a 1-degree grid over the whole globe for both ensembles and analyses for May 2023 to April 2024 for five different radii



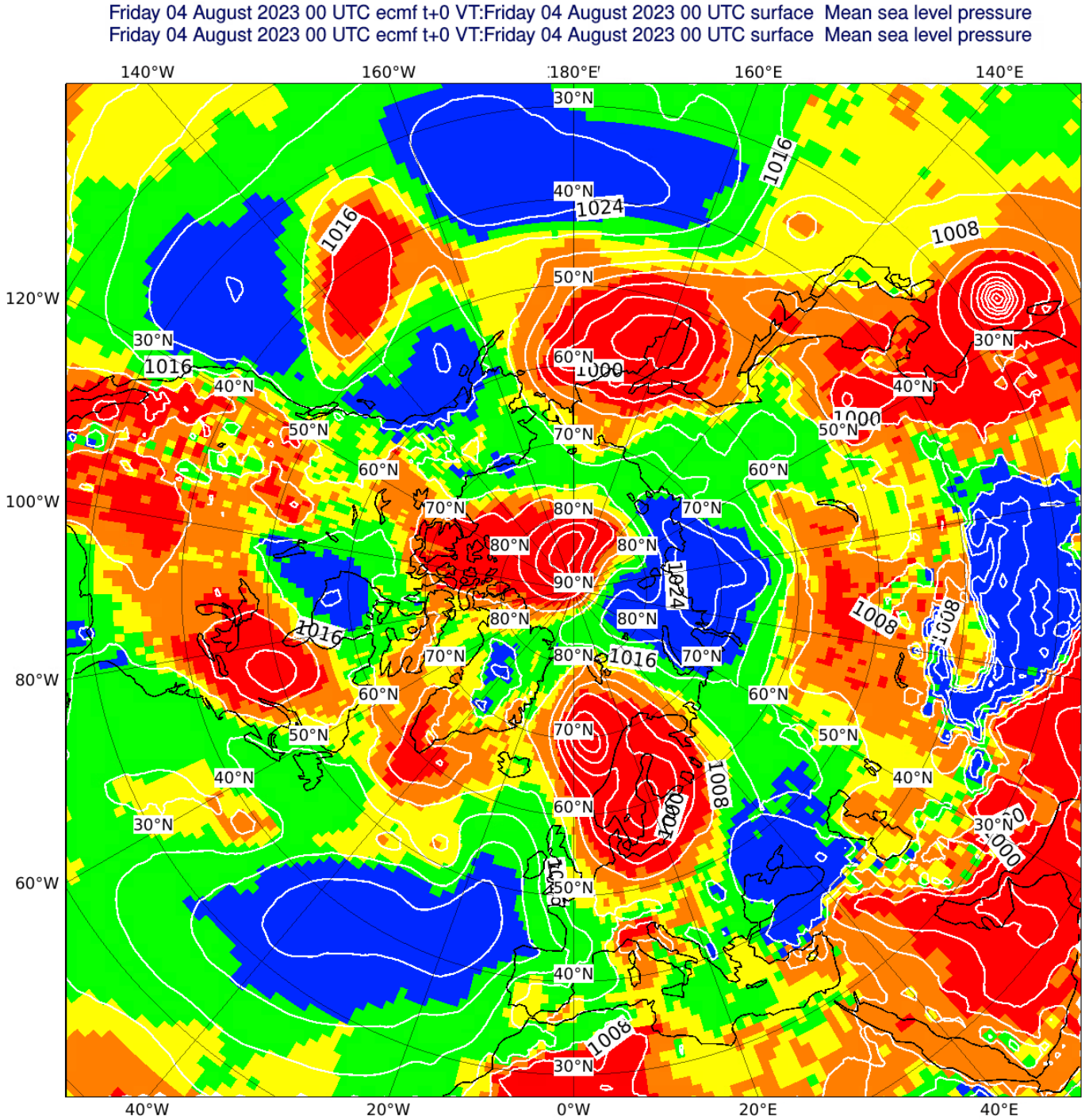
+16
Cyclone
Strongly cyclonic
+11
Cyclonic
Slightly cyclonic
+3
Straight / Col
-3
Slightly anticyclonic
Anticyclonic
-11
Strongly anticyclonic
Anticyclone
-16

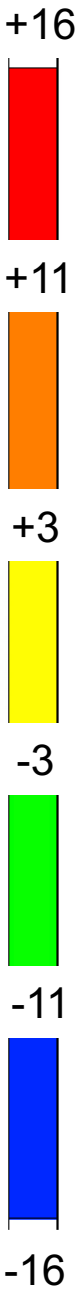
CURV
Radius 1500 km





CURV
Radius 2000 km





Cyclone

Strongly cyclonic

Cyclonic

Slightly cyclonic

Straight / Col

Slightly anticyclonic

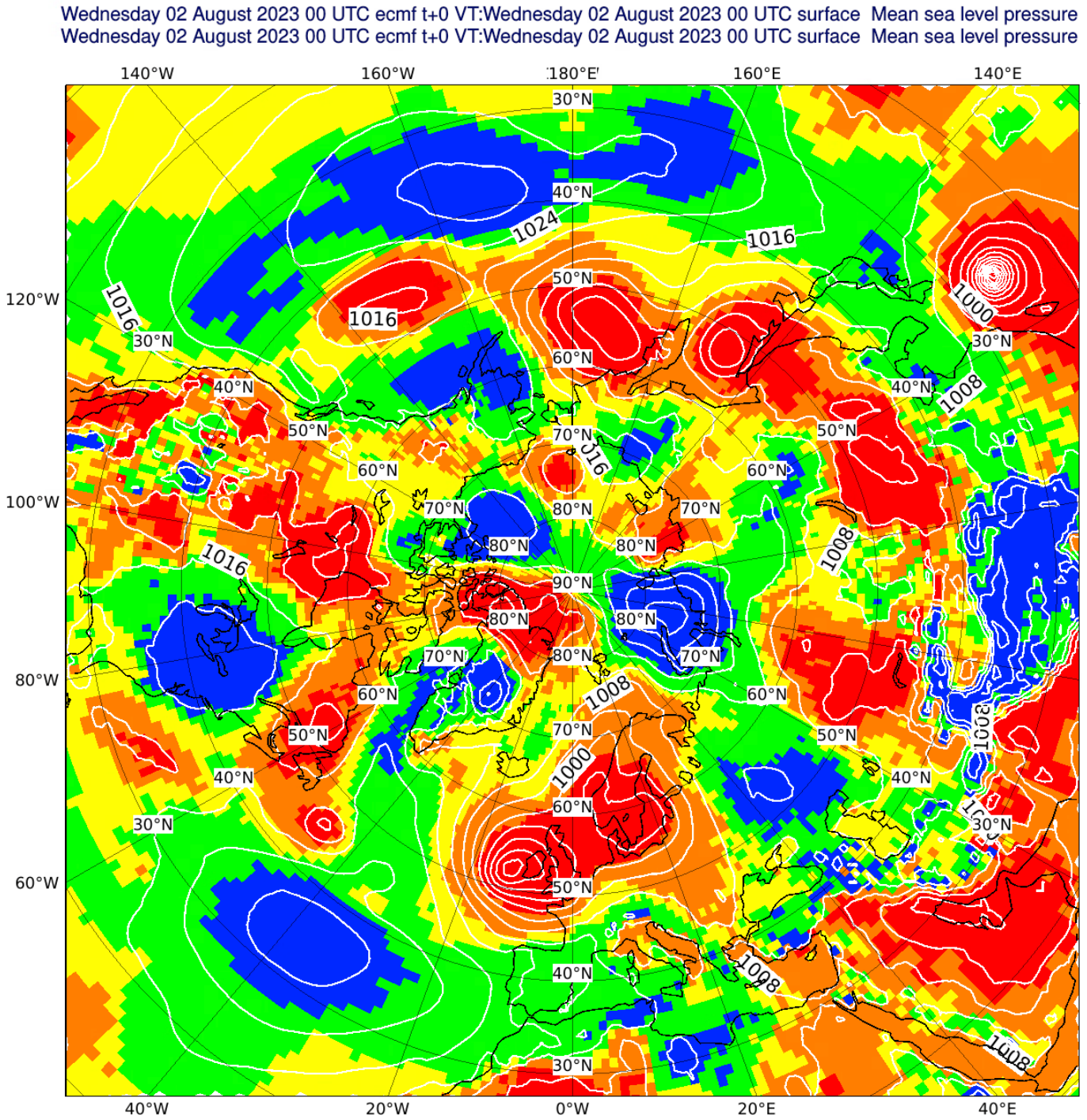
Anticyclonic

Strongly anticyclonic

Anticyclone

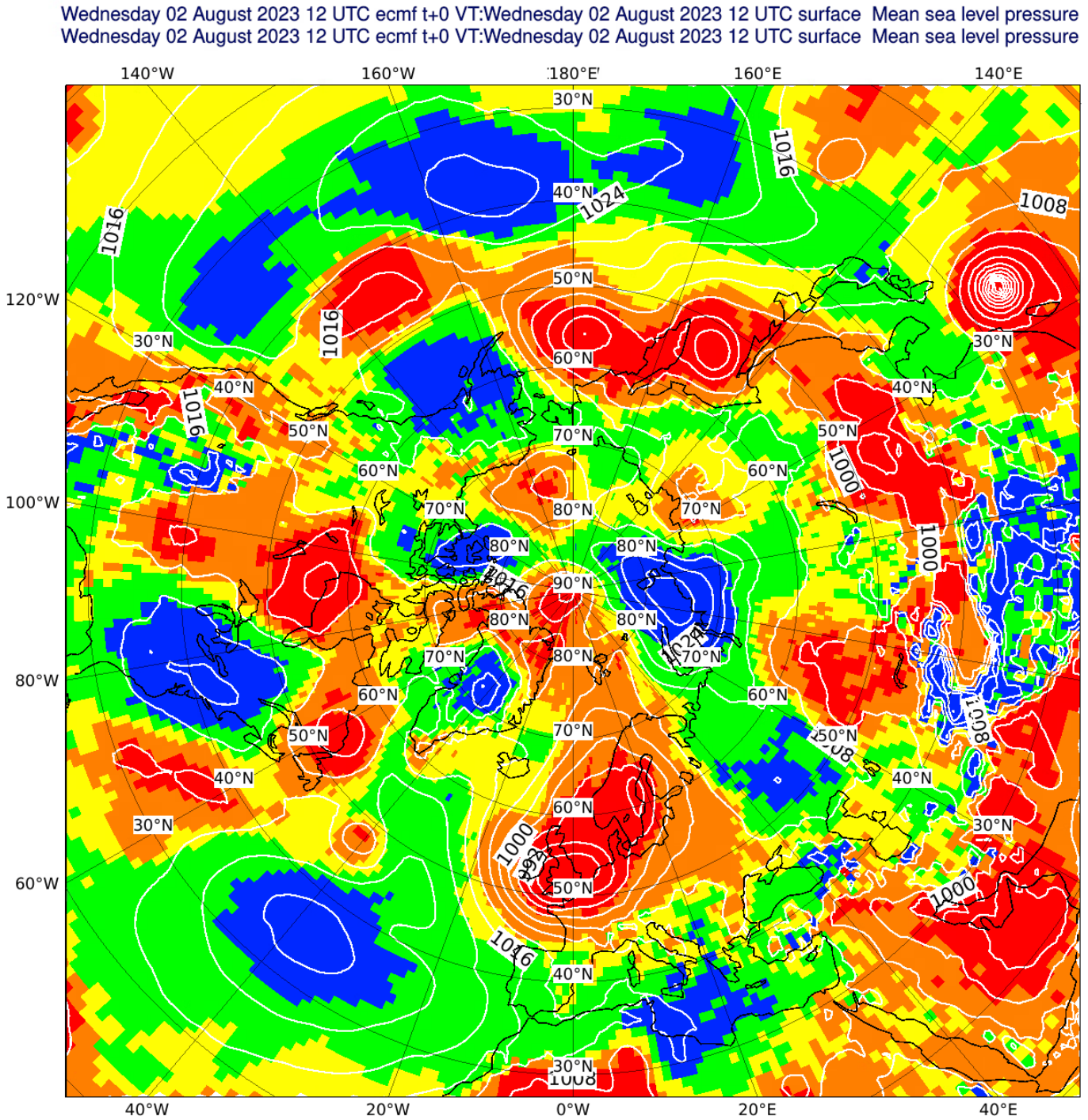
Forecast sequence

CURV
Radius 1500 km



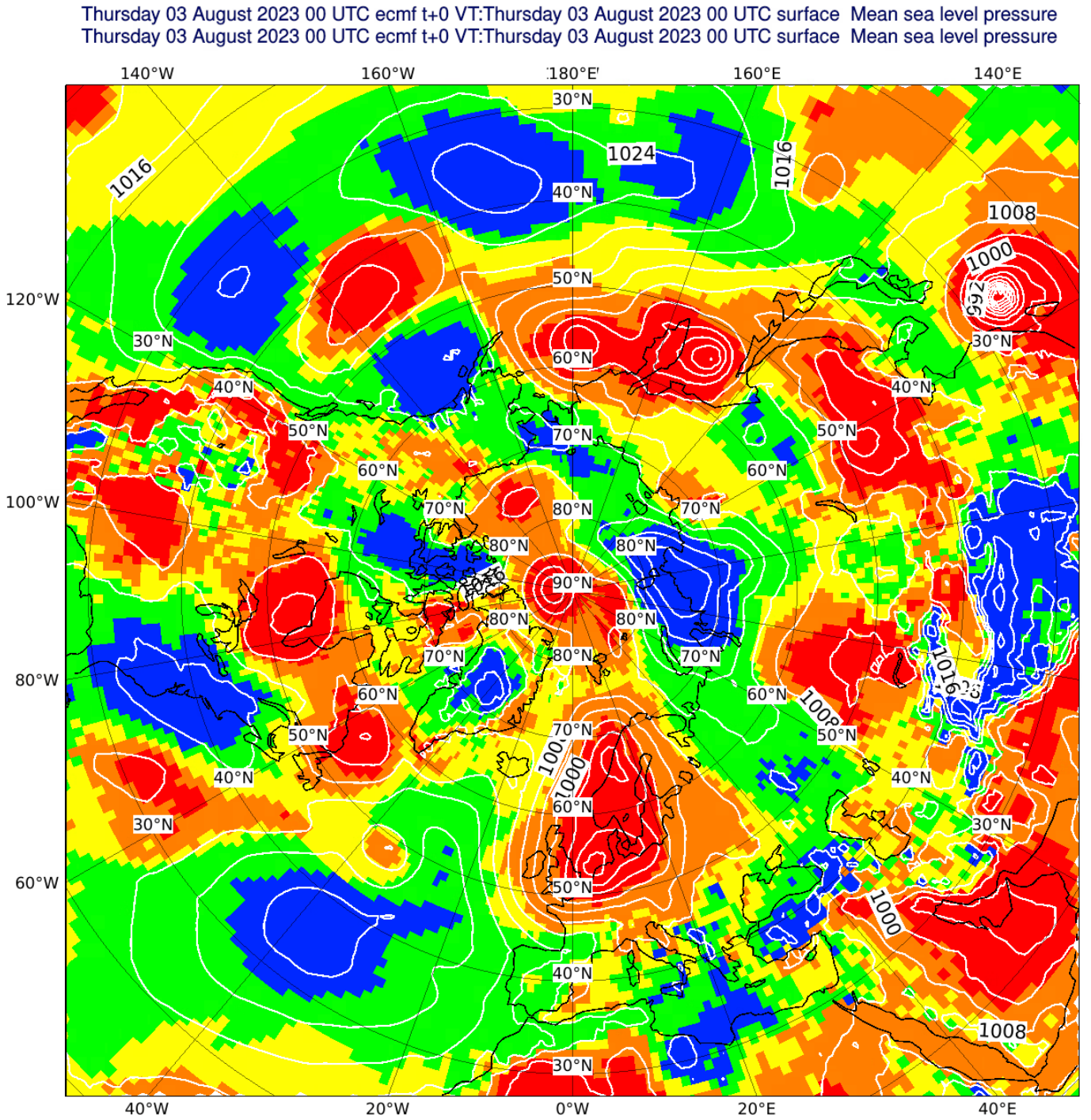
+16
Cyclone
Strongly cyclonic
+11
Cyclonic
Slightly cyclonic
+3
Straight / Col
-3
Slightly anticyclonic
Anticyclonic
-11
Strongly anticyclonic
Anticyclone
-16

CURV
Radius 1500 km



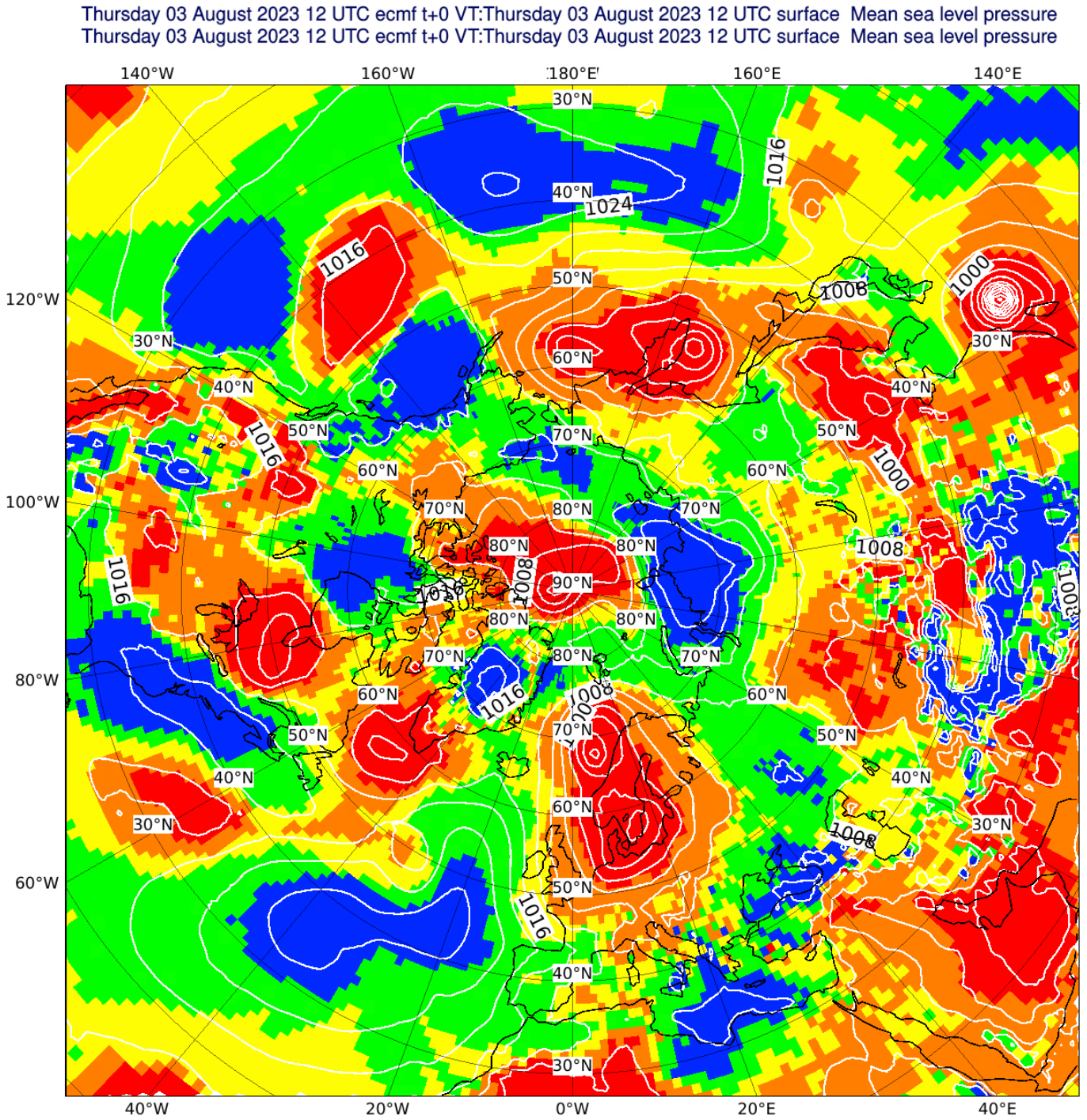
+16
Cyclone
Strongly cyclonic
+11
Cyclonic
Slightly cyclonic
+3
Straight / Col
-3
Slightly anticyclonic
Anticyclonic
-11
Strongly anticyclonic
Anticyclone
-16

CURV
Radius 1500 km



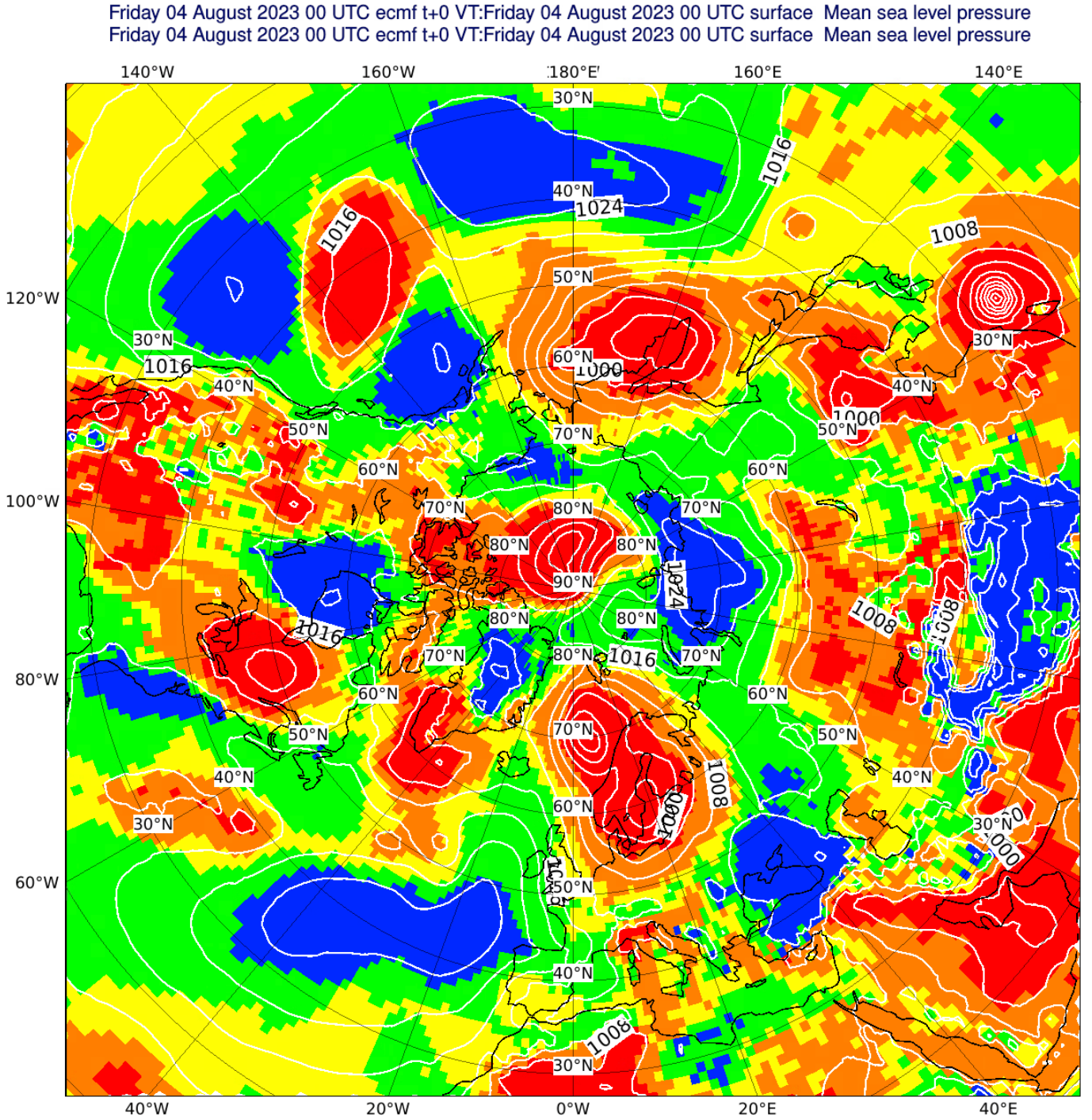
+16
Cyclone
Strongly cyclonic
+11
Cyclonic
Slightly cyclonic
+3
Straight / Col
-3
Slightly anticyclonic
Anticyclonic
-11
Strongly anticyclonic
Anticyclone
-16

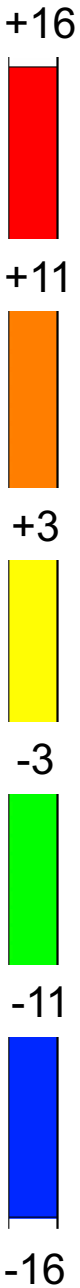
CURV
Radius 1500 km



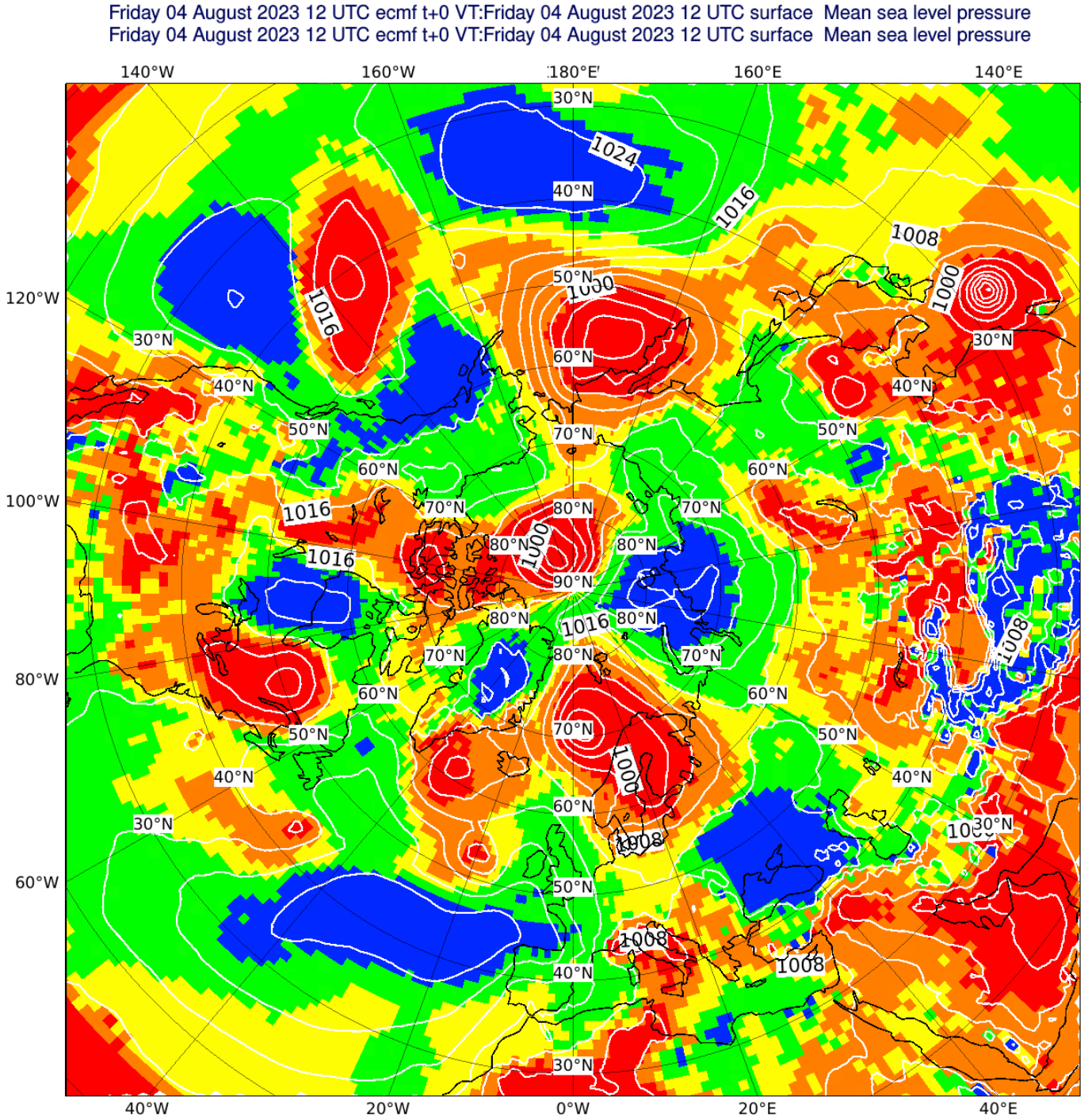
+16
Cyclone
Strongly cyclonic
+11
Cyclonic
Slightly cyclonic
+3
Straight / Col
-3
Slightly anticyclonic
Anticyclonic
-11
Strongly anticyclonic
Anticyclone
-16

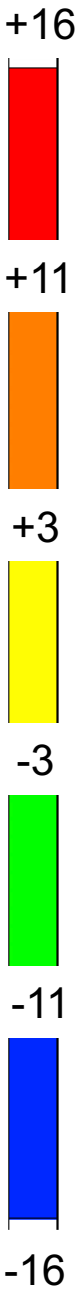
CURV
Radius 1500 km





CURV
Radius 1500 km



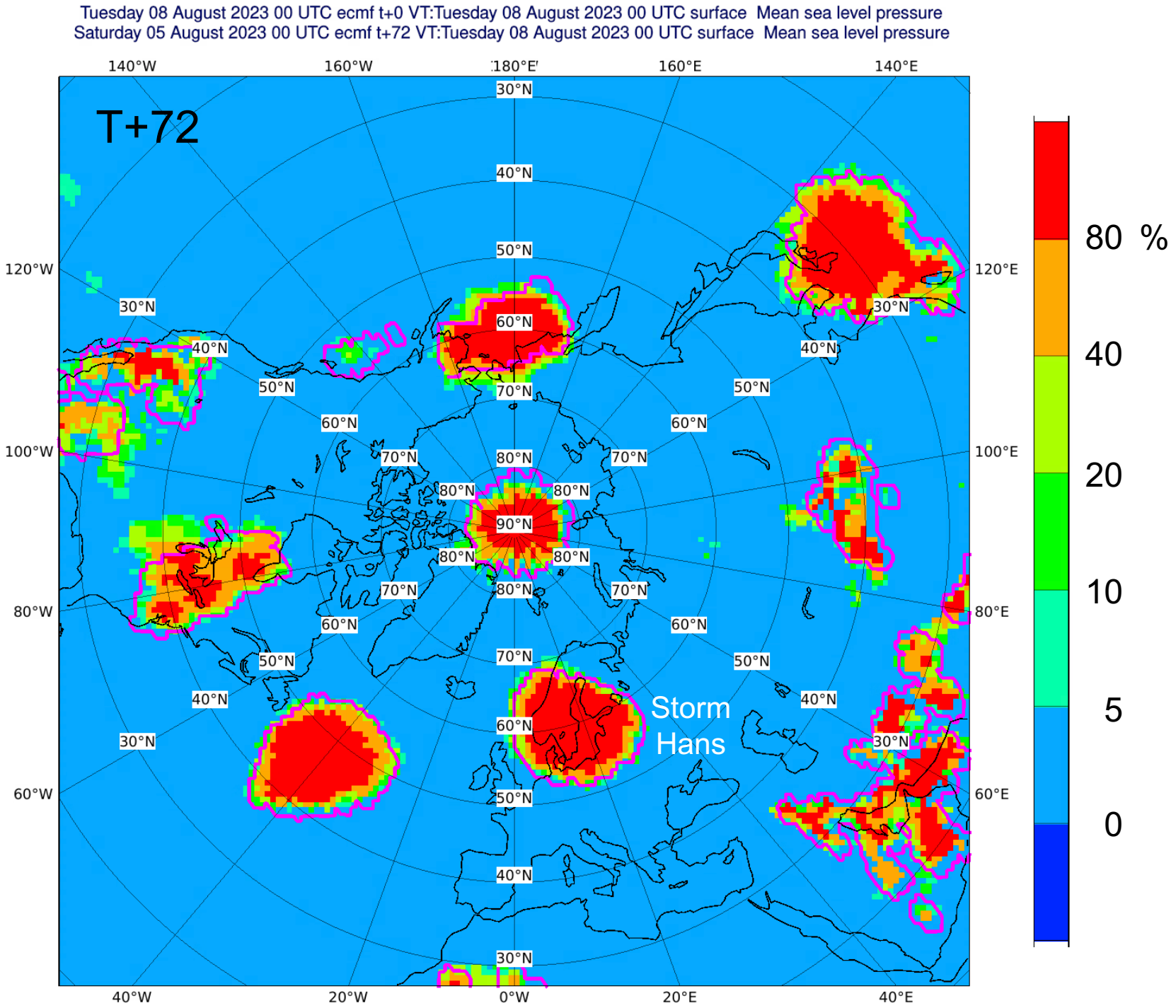


Probability of a cyclone (CURV >15)

Radius 2000 km

Medium-range ensemble

Verification time
00 UTC
08 Aug 2023

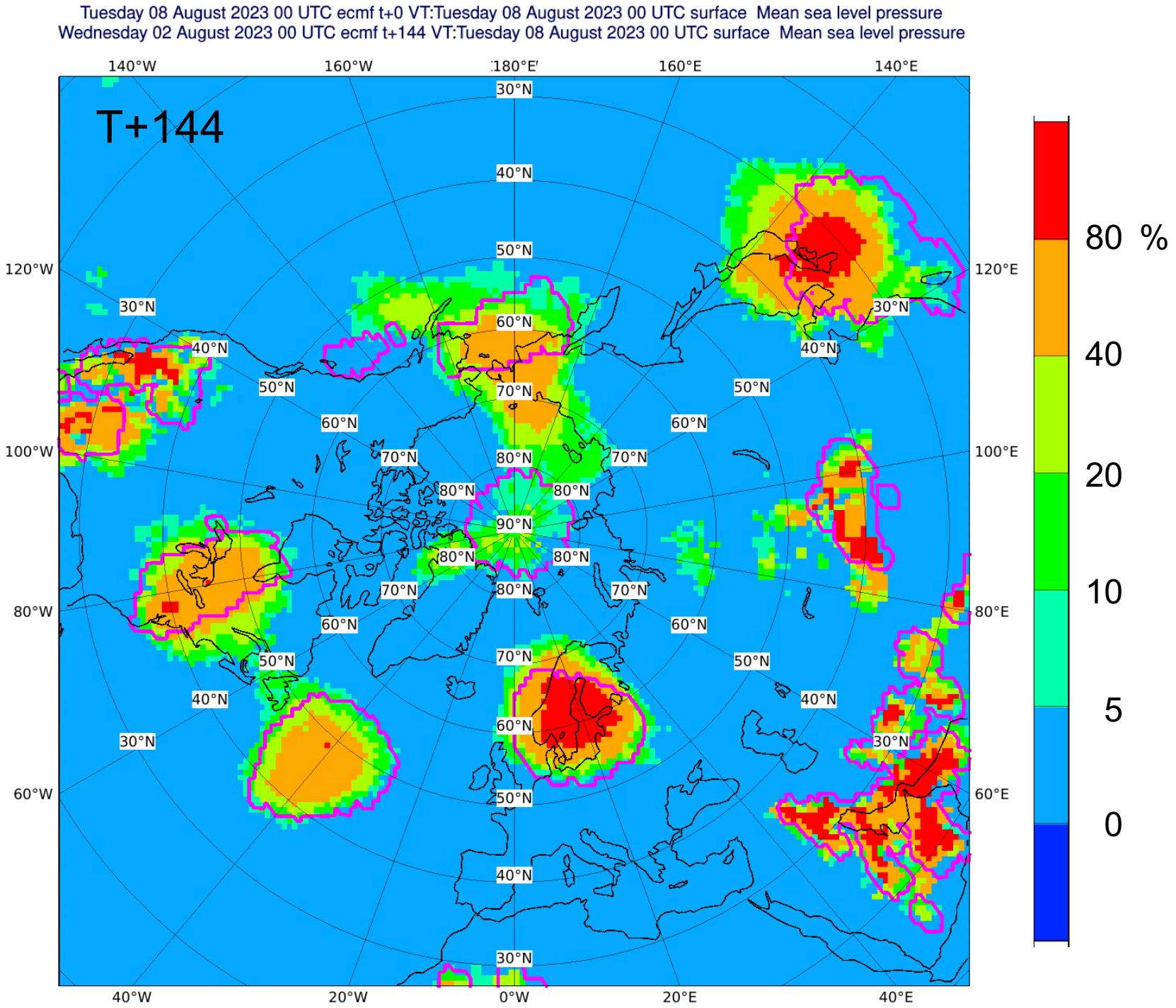


Probability of a cyclone (CURV >15)

Radius 2000 km

Medium-range ensemble

Verification time
00 UTC
08 Aug 2023

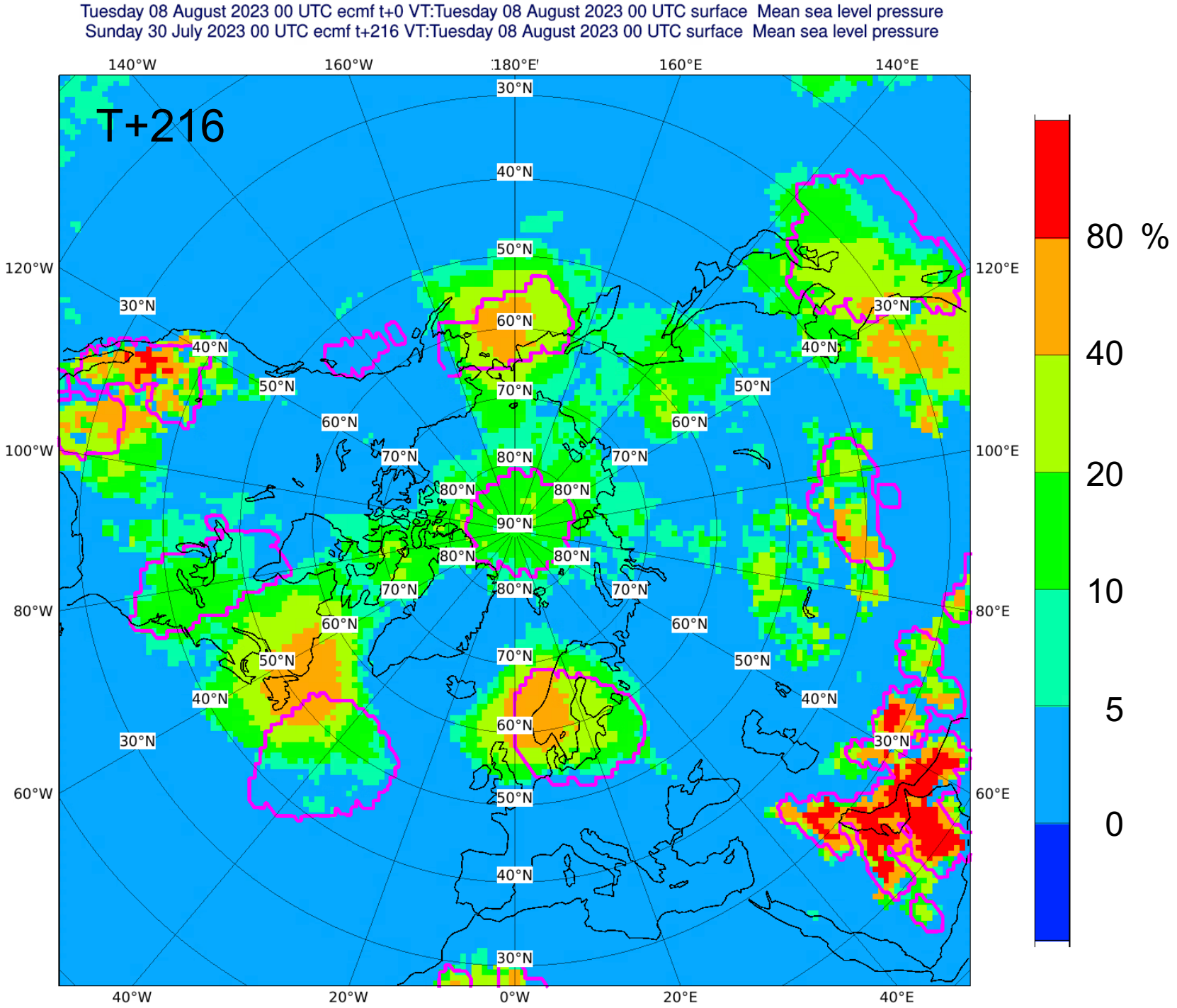


Probability of a cyclone (CURV >15)

Radius 2000 km

Medium-range ensemble

Verification time 00 UTC 08 Aug 2023

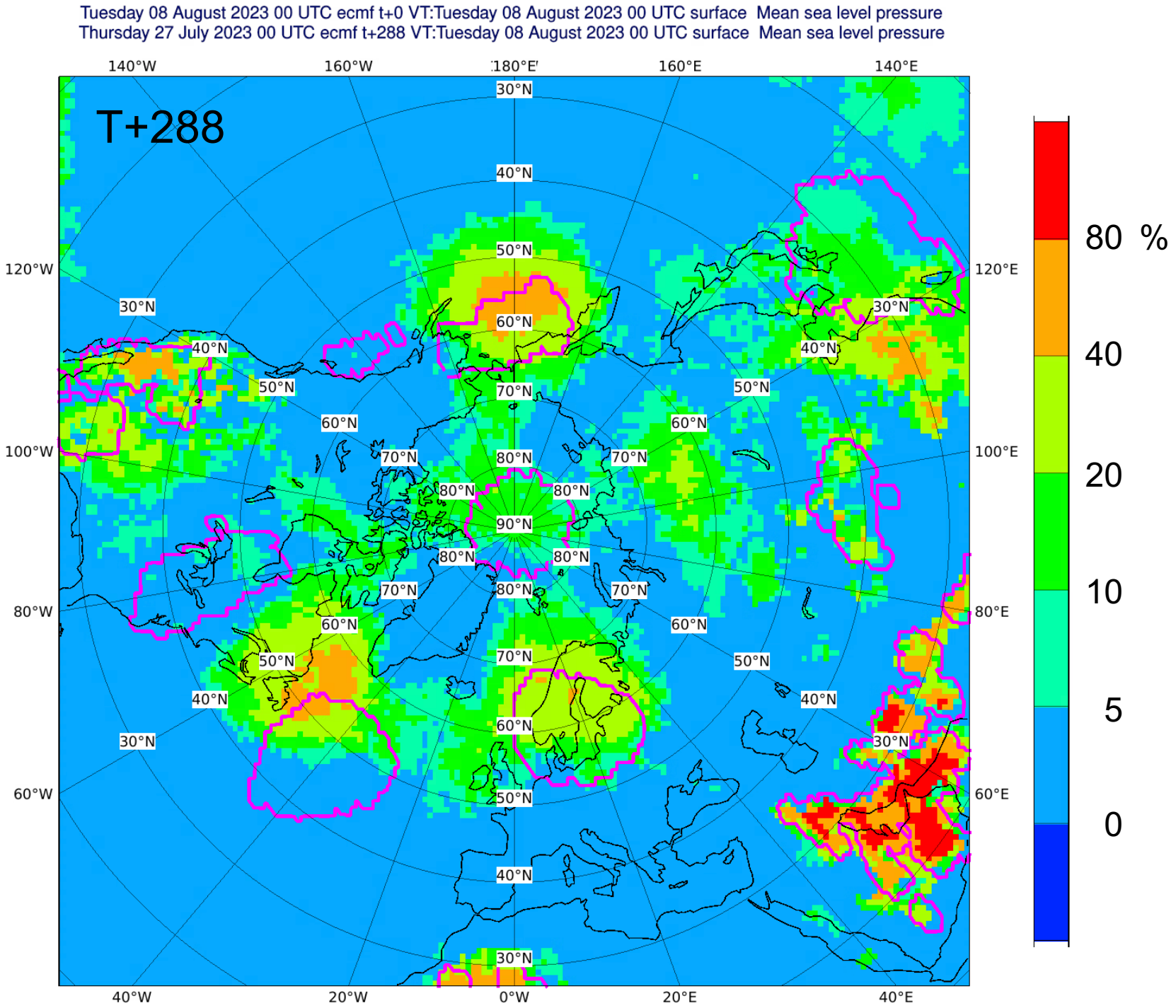


Probability of a cyclone (CURV >15)

Radius 2000 km

Medium-range ensemble

Verification time 00 UTC 08 Aug 2023

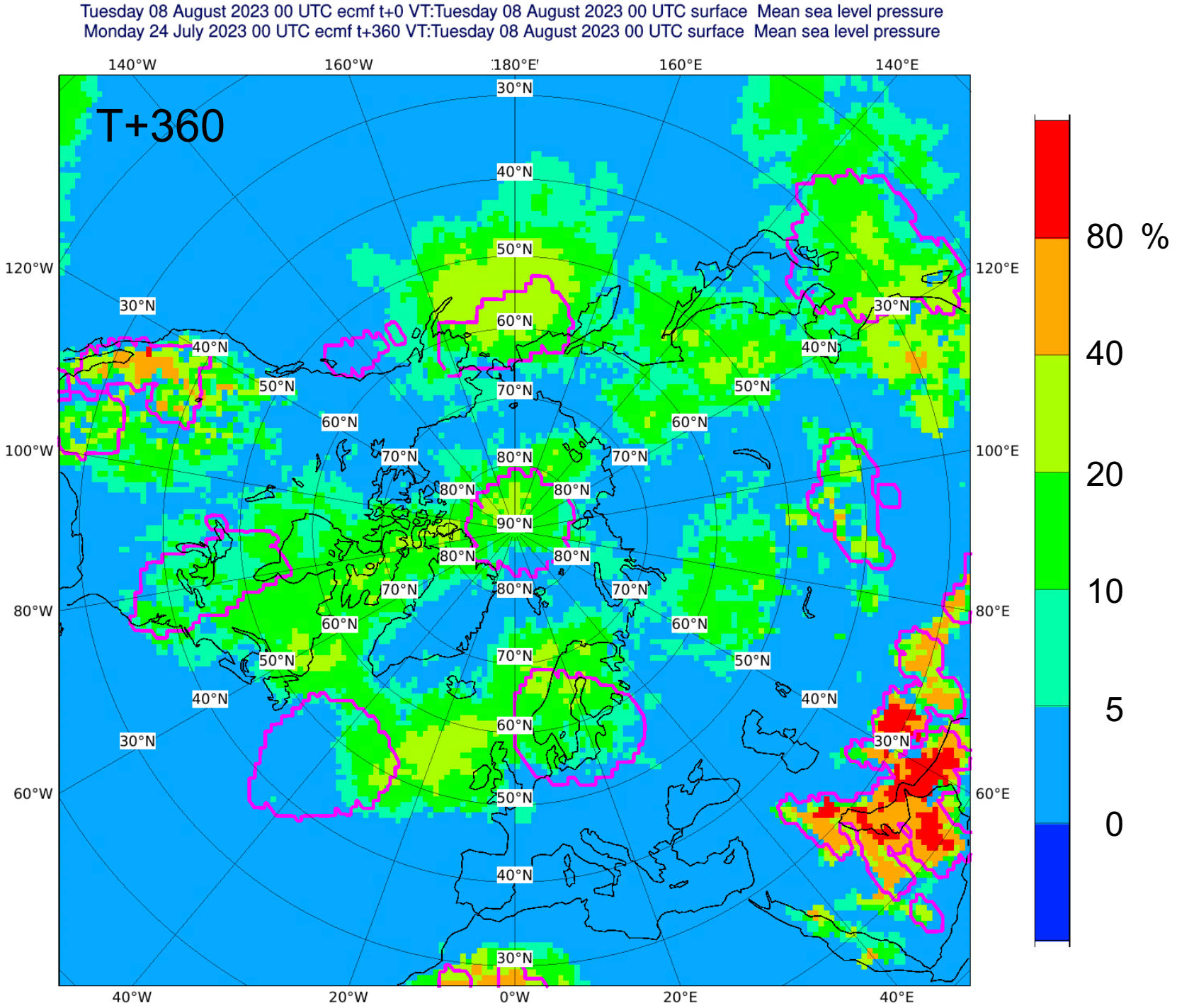


Probability of a cyclone (CURV >15)

Radius 2000 km

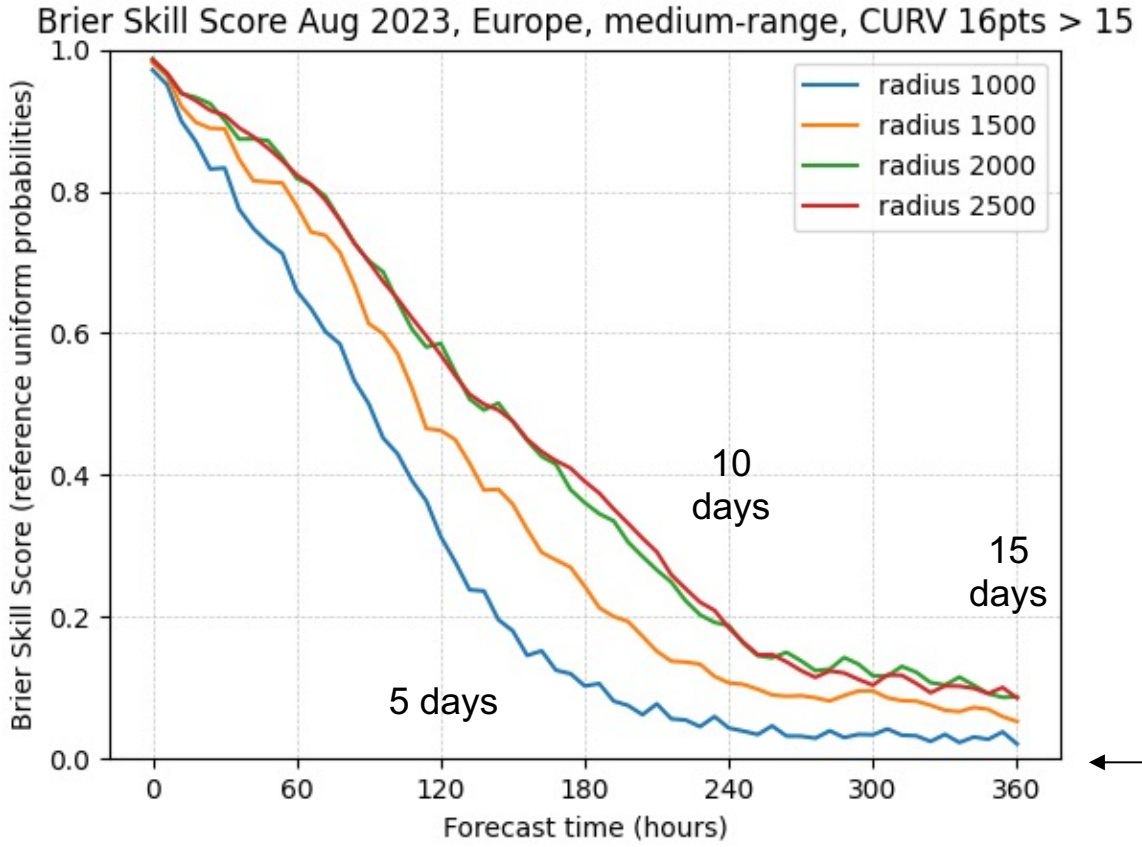
Medium-range ensemble

Verification time 00 UTC 08 Aug 2023



Medium-range ensemble Brier Skill Score for August 2023 for different CURV radii for probability of occurrence of a cyclone

Better



Probability CURV >15 against observed uniform probability is quite a stringent test

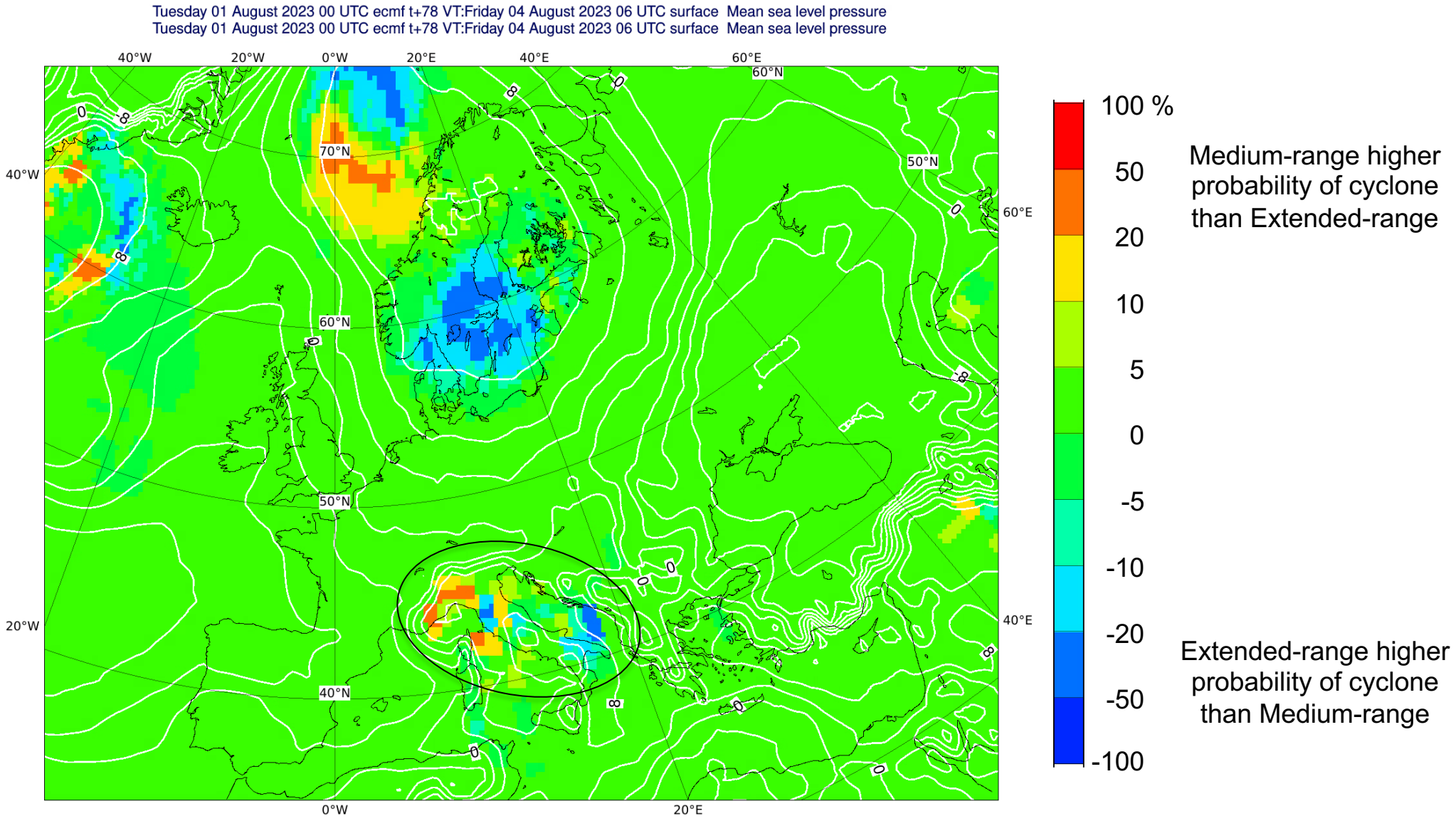
Smaller scales lose skill more quickly
Minimum scale with maximum skill ~ 2000 km

Skill of uniform domain-average probability (forecast the same probability everywhere)

Ongoing work to do this for the 12-month period and for different thresholds and different regions
Add other verification measures (e.g. CRPS or distance measures)

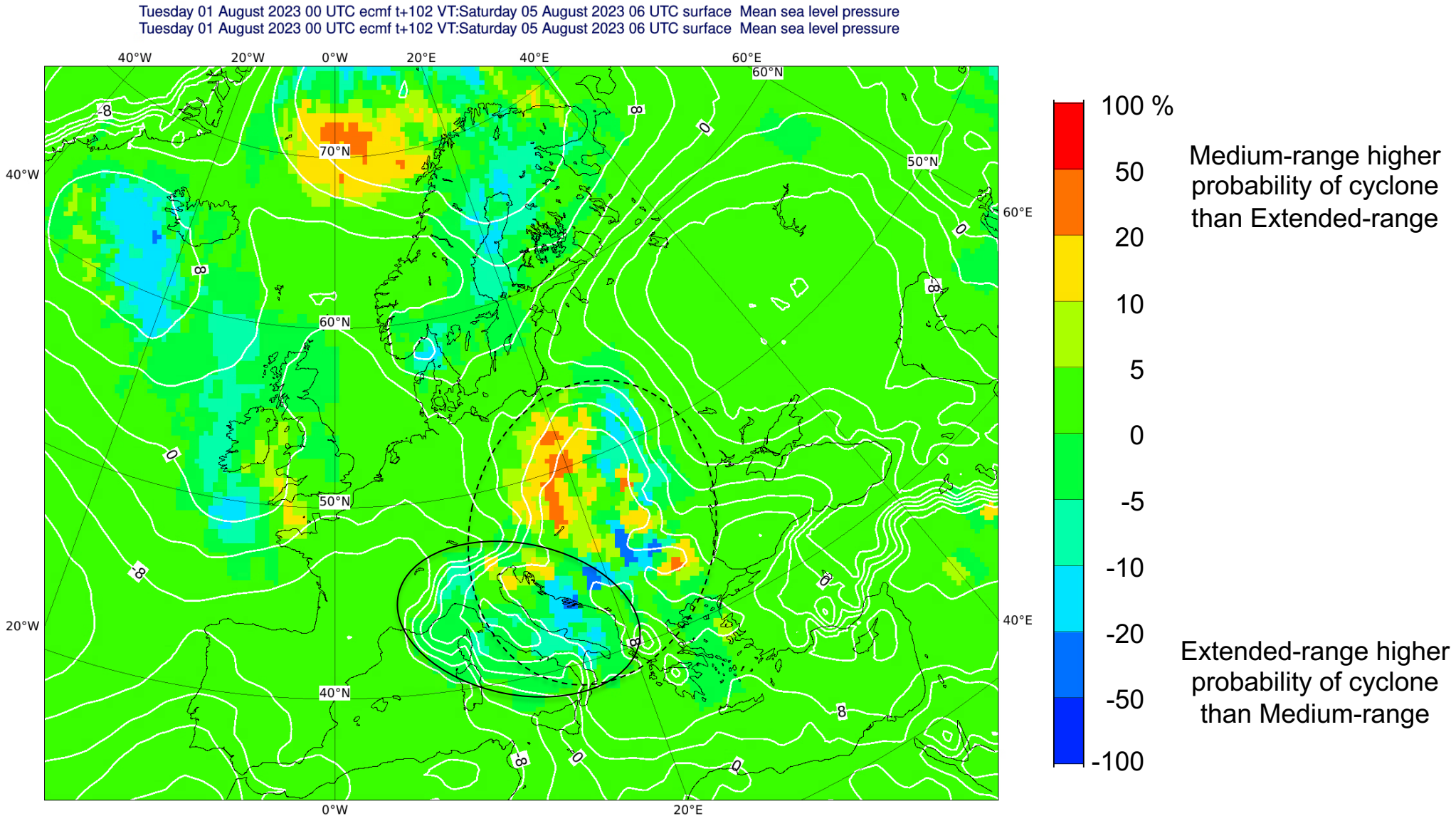
Medium 1-50 minus Extended 1-50 Probabilities T+78 from 00 UTC 01 Aug 2023 CURV 1000 km

Differences between probabilities for CURV > +15 (16 pts)



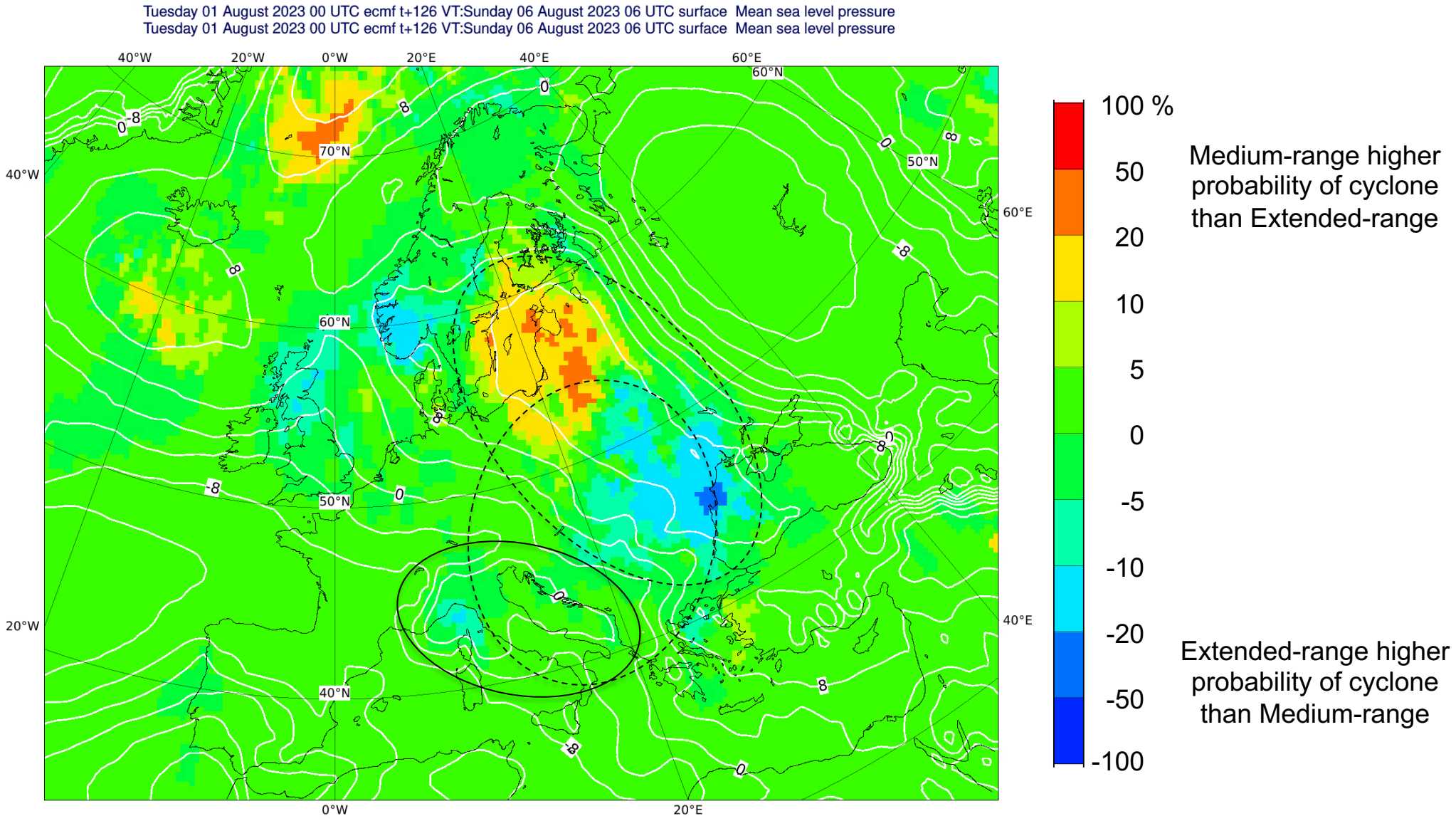
Medium 1-50 minus Extended 1-50 Probabilities T+102 from 00 UTC 01 Aug 2023 CURV 1000 km

Differences between probabilities for CURV > +15 (16 pts)



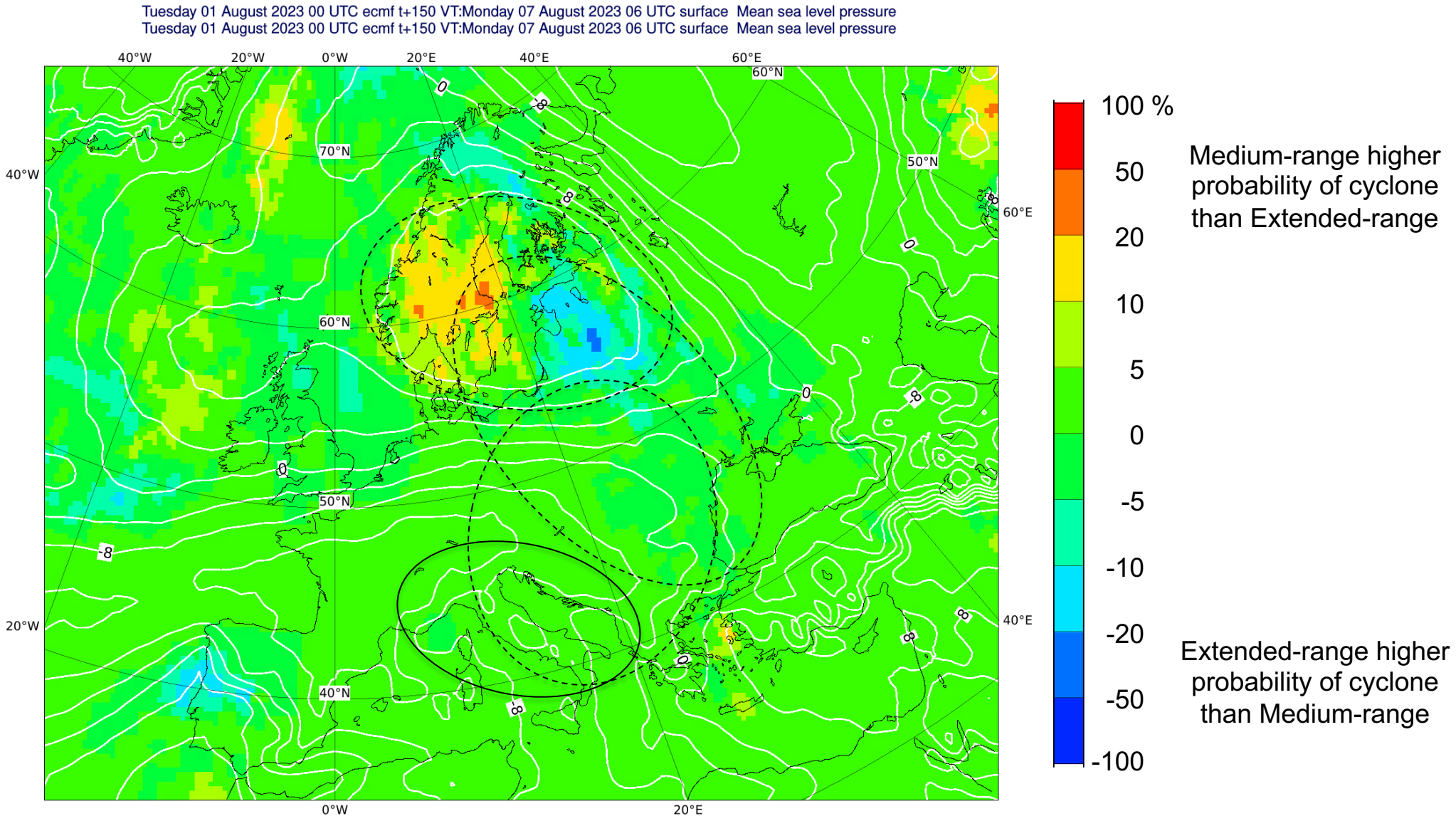
Medium 1-50 minus Extended 1-50 Probabilities T+126 from 00 UTC 01 Aug 2023 CURV 1000 km

Differences between probabilities for CURV > +15 (16 pts)



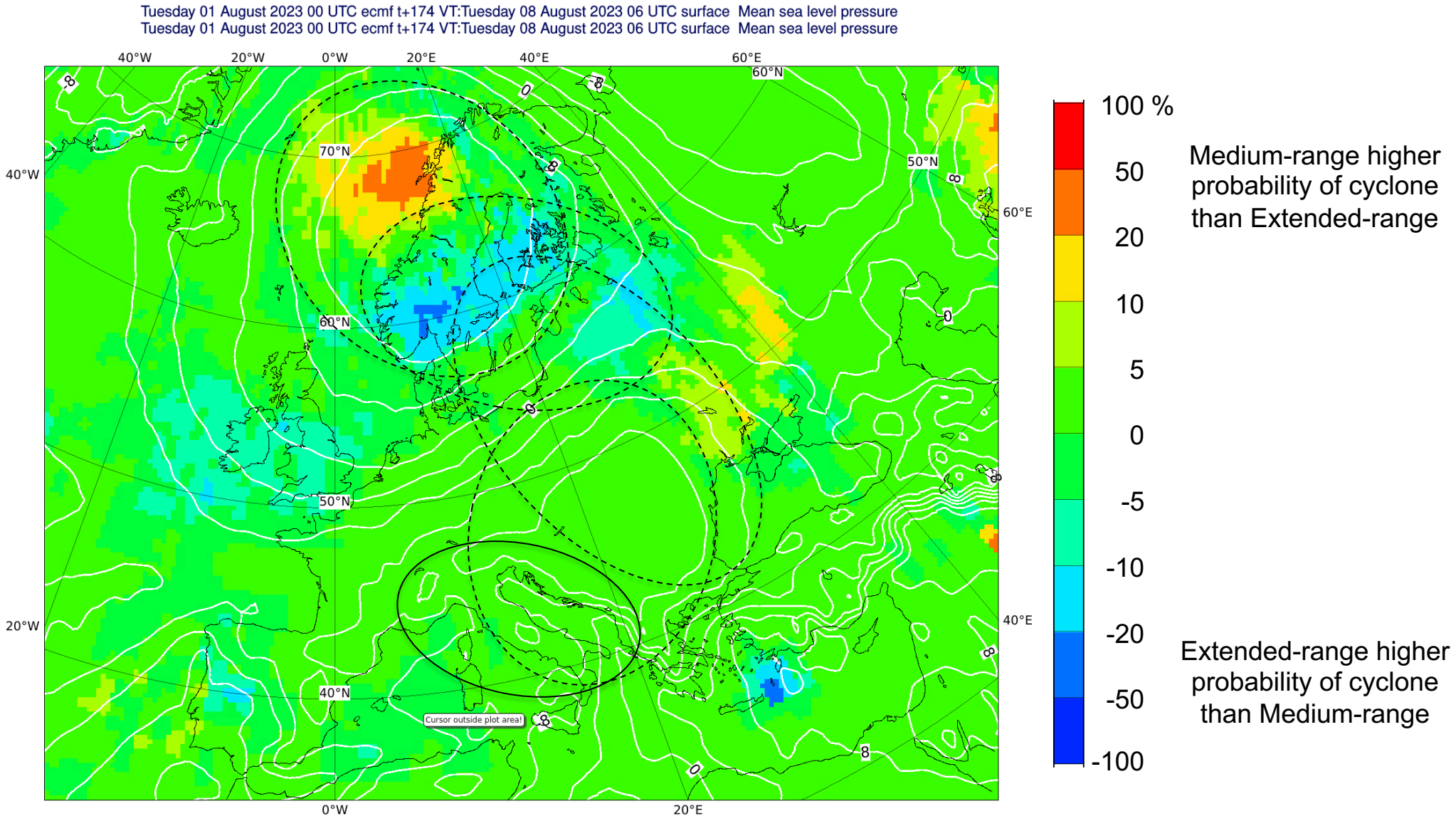
Medium 1-50 minus Extended 1-50 Probabilities T+150 from 00 UTC 01 Aug 2023 CURV 1000 km

Differences between probabilities for CURV > +15 (16 pts)



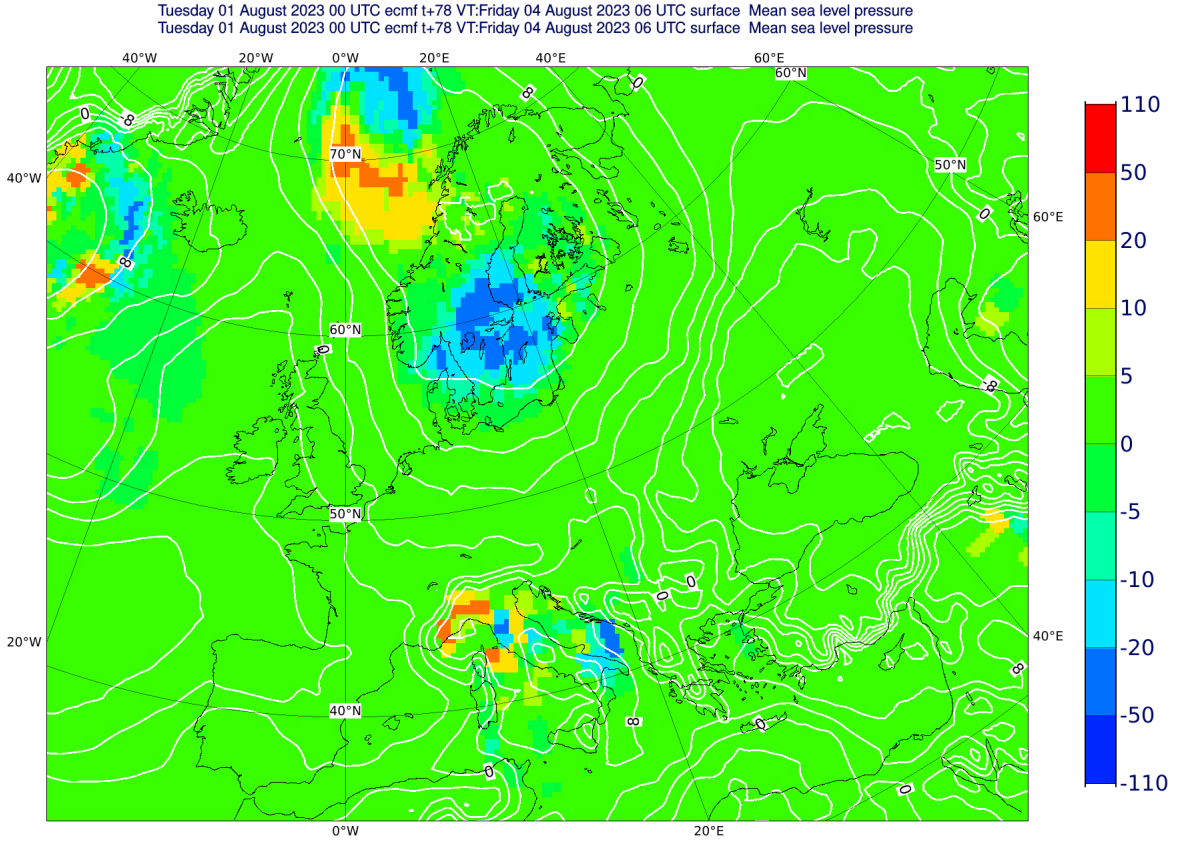
Medium 1-50 minus Extended 1-50 Probabilities T+174 from 00 UTC 01 Aug 2023 CURV 1000 km

Differences between probabilities for CURV > +15 (16 pts)

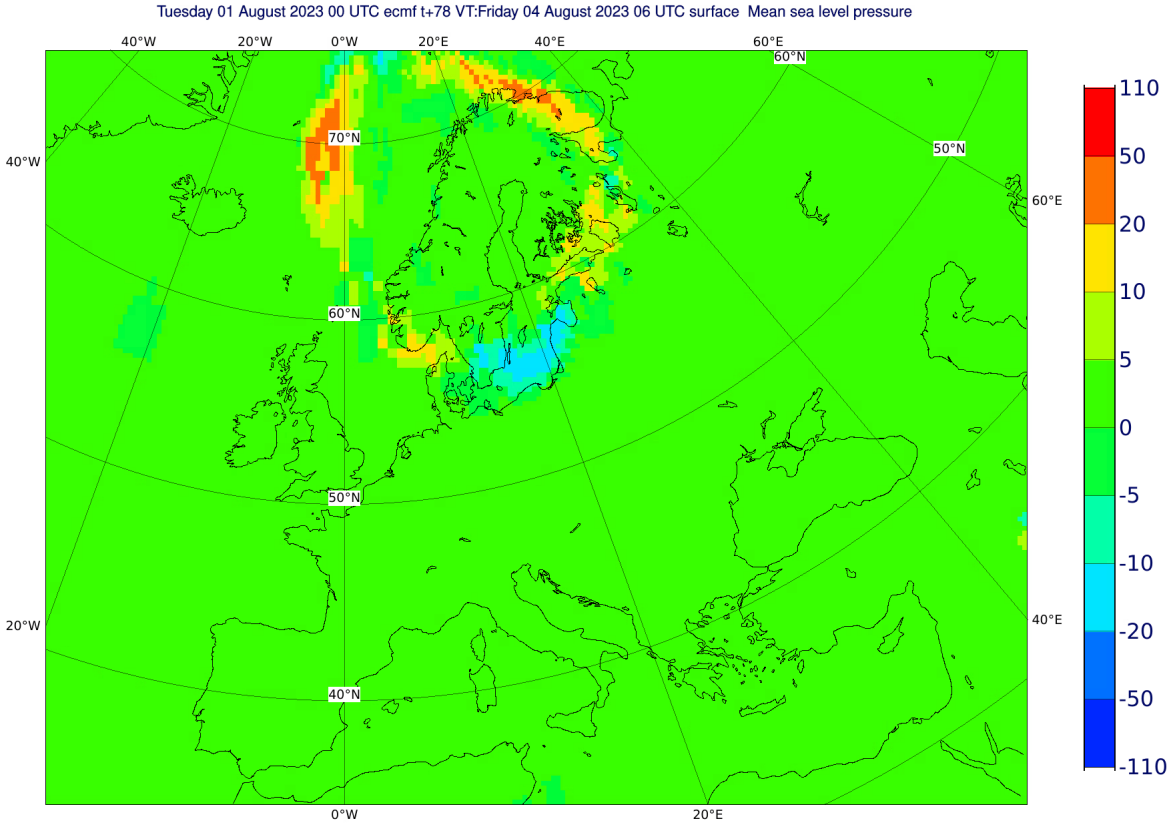


Medium 1-50 minus Extended 1-50 Probabilities T+78 from 00 UTC 01 Aug 2023

Differences between probabilities for CURV > +15 (16 pts)



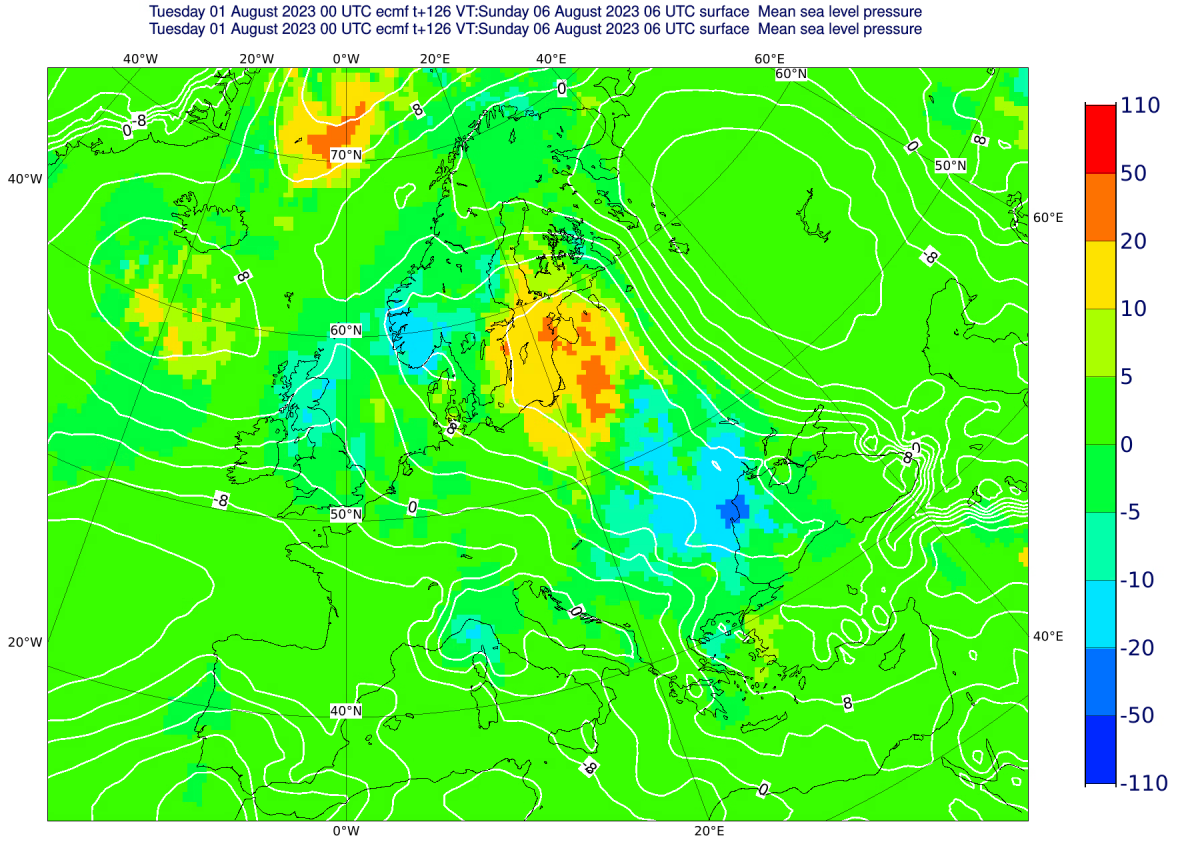
CURV radius 1000 km



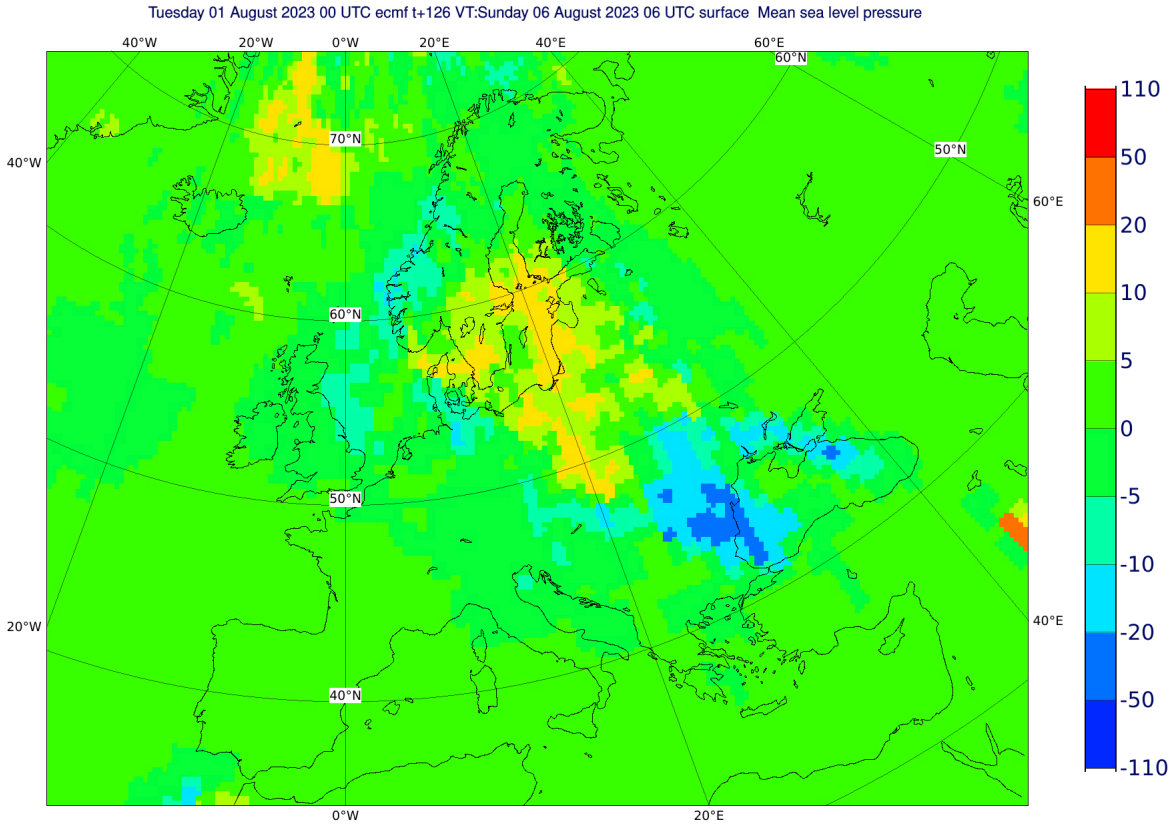
CURV radius 2000 km

Medium 1-50 minus Extended 1-50 Probabilities T+126 from 00 UTC 01 Aug 2023

Differences between probabilities for CURV > +15 (16 pts)



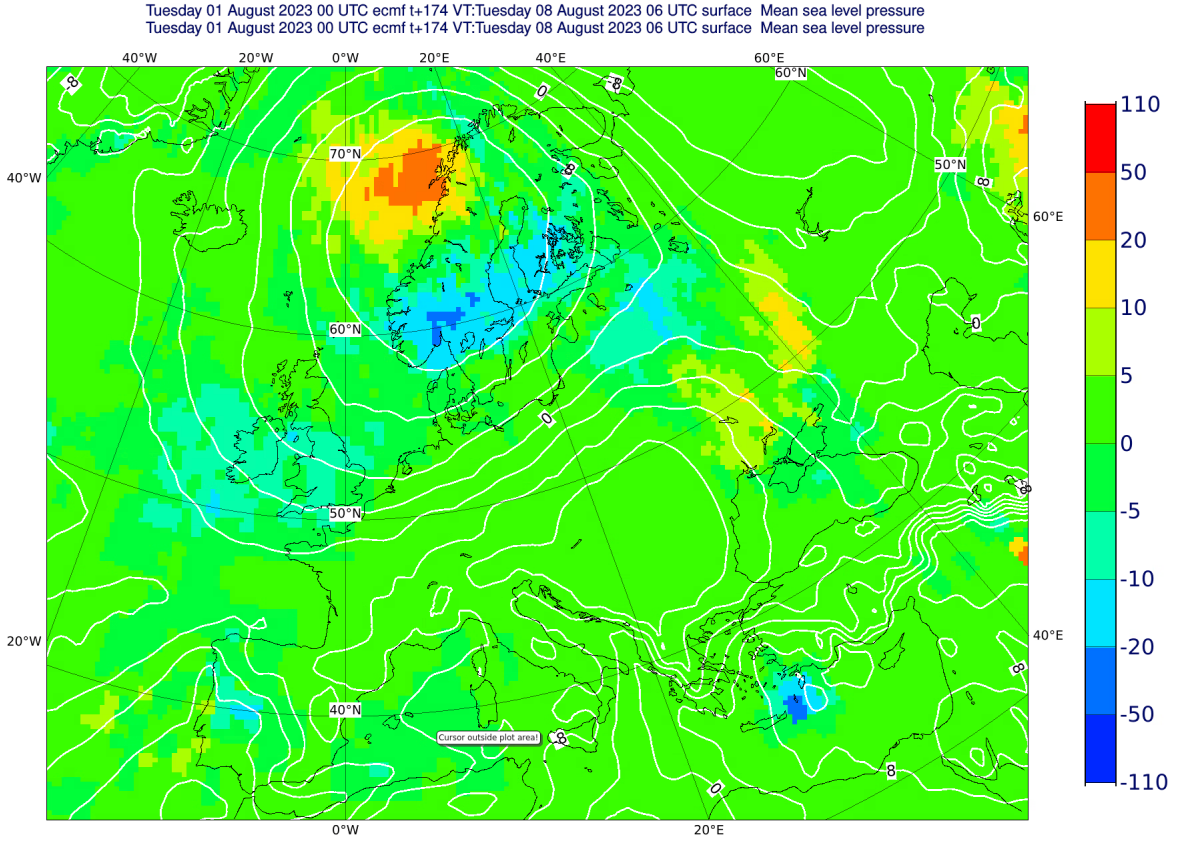
CURV radius 1000 km



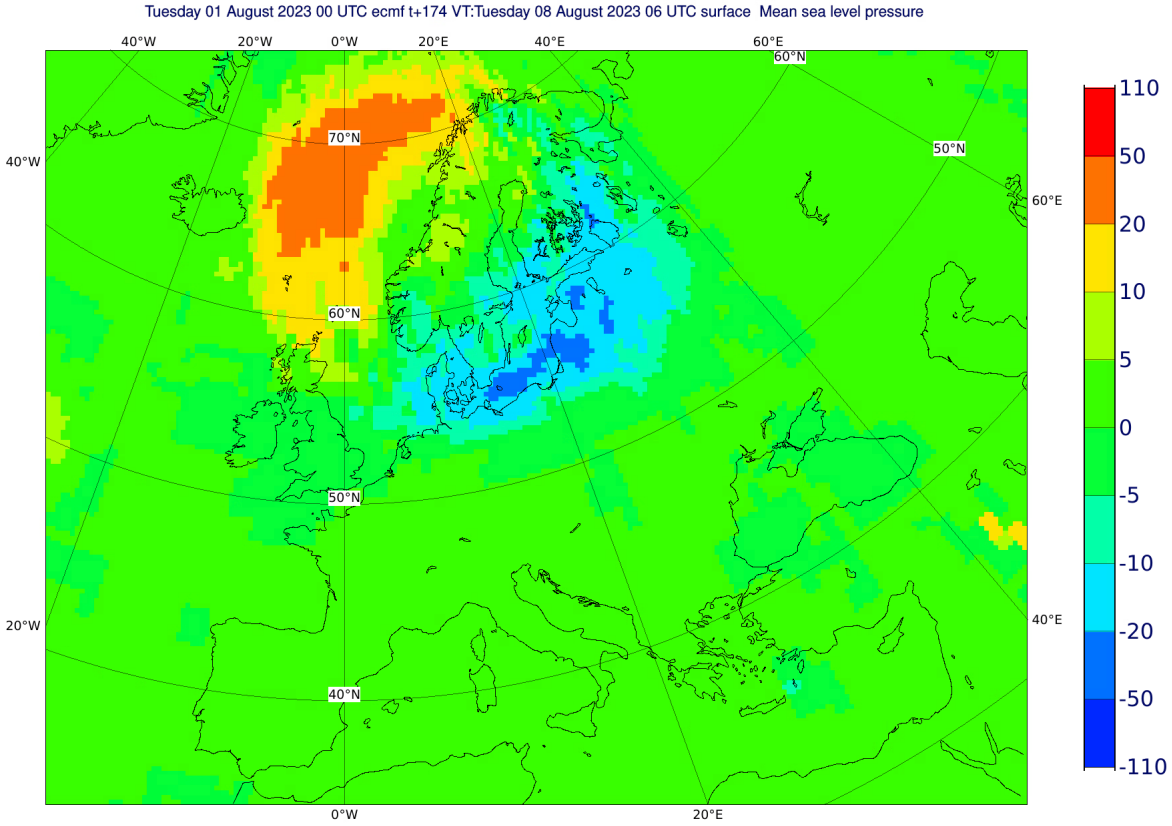
CURV radius 2000 km

Medium 1-50 minus Extended 1-50 Probabilities T+174 from 00 UTC 01 Aug 2023

Differences between probabilities for CURV > +15 (16 pts)



CURV radius 1000 km



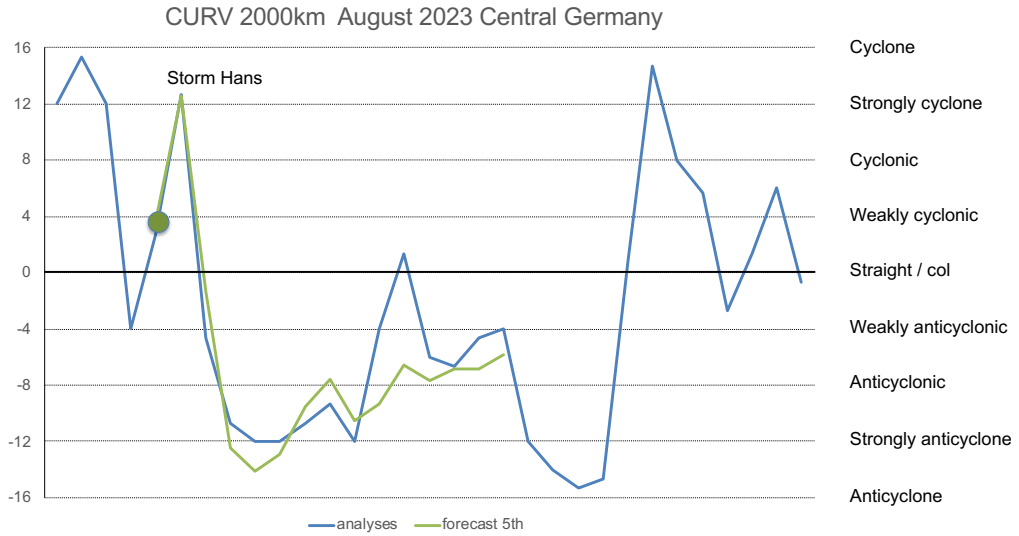
CURV radius 2000 km

Summary

A new diagnostic called CURV has been developed to identify cyclonic and anticyclonic curvature from surface pressure fields or geopotential height

It is being used in the Ensembles Combinations project, and might have several other applications:

Cyclonic / anticyclonic regime forecasts for locations or regions
Verification of synoptic patterns, compare with anomaly correlation
Predictability studies
Regime-based conditional verification or post processing / ML
Blocking identification
Clustering
Climatology …



Ongoing use of CURV for forecasts May 2023 to April 2024:

Identify systematic differences between ensembles
Compare skill of ensembles using a variety of verification measures (globally and regionally)
Examine the benefit of different blending approaches (e.g. different weighting, sub-sampling, time-lagging …)
Examine the behaviour of the CURV diagnostic and optimal use / modifications
Investigate interesting cases or regional aspects of interest