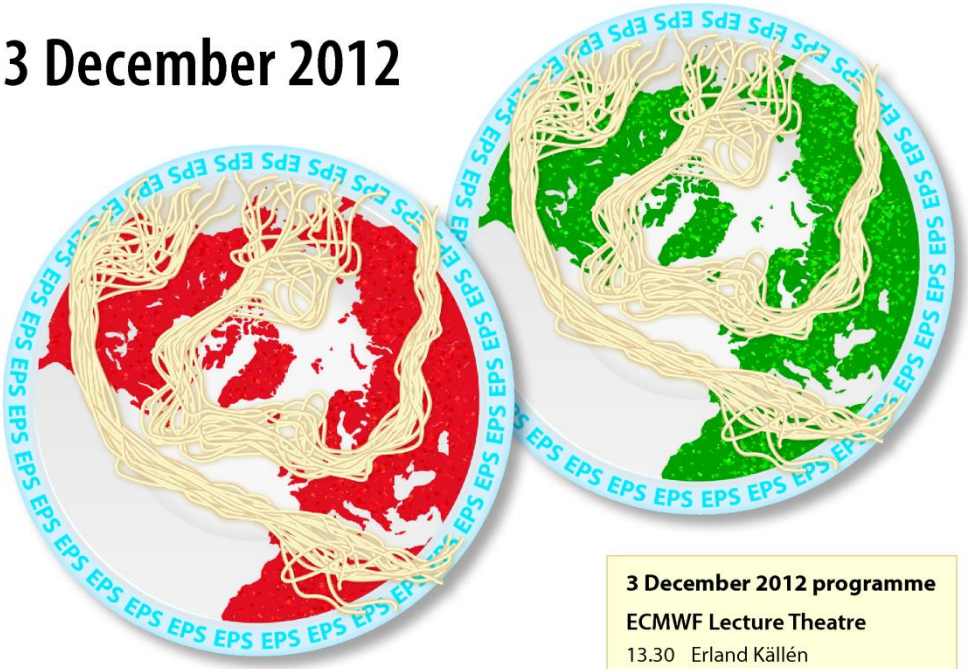
Sannolikhetsprodukter för vädertjänsten

Åke Johansson
SMHI

Twenty years of Ensemble Prediction at ECMWF

3 December 2012



Twenty years ago, on 24 November 1992, the first ensemble forecasts were produced at ECMWF.
At that time, ensemble forecasts were issued three times a week, on Friday, Saturday and Sunday, with 33 members at a T63L19 resolution for up to 10 days. Today, the ensemble system runs twice a day with 51 members at resolution T639L62 to day 10, and T319L62 from day 10 to 15. It uses a coupled ocean-atmosphere model when it is extended to 32 days twice weekly. Worldwide, it is recognised as providing the best global, medium-range and monthly probabilistic forecasts. 'Spaghetti' maps are now firmly on the table of most forecasters!
You are invited to join us to celebrate 20 years of ensemble prediction with an afternoon of talks from people who contributed to its design and implementation in its early days.

3 December 2012 programme

ECMWF Lecture Theatre

13.30 Erland Källén
Welcome

13.45 Stefano Tibaldi
Why ensembles?

14.15 Joe Tribbia
SVs: are they still valuable?

14.45 Tim Palmer
Is the butterfly effect real?

15.15 Coffee break

15.45 Robert Mureau
Do users really want ensemble forecasts?

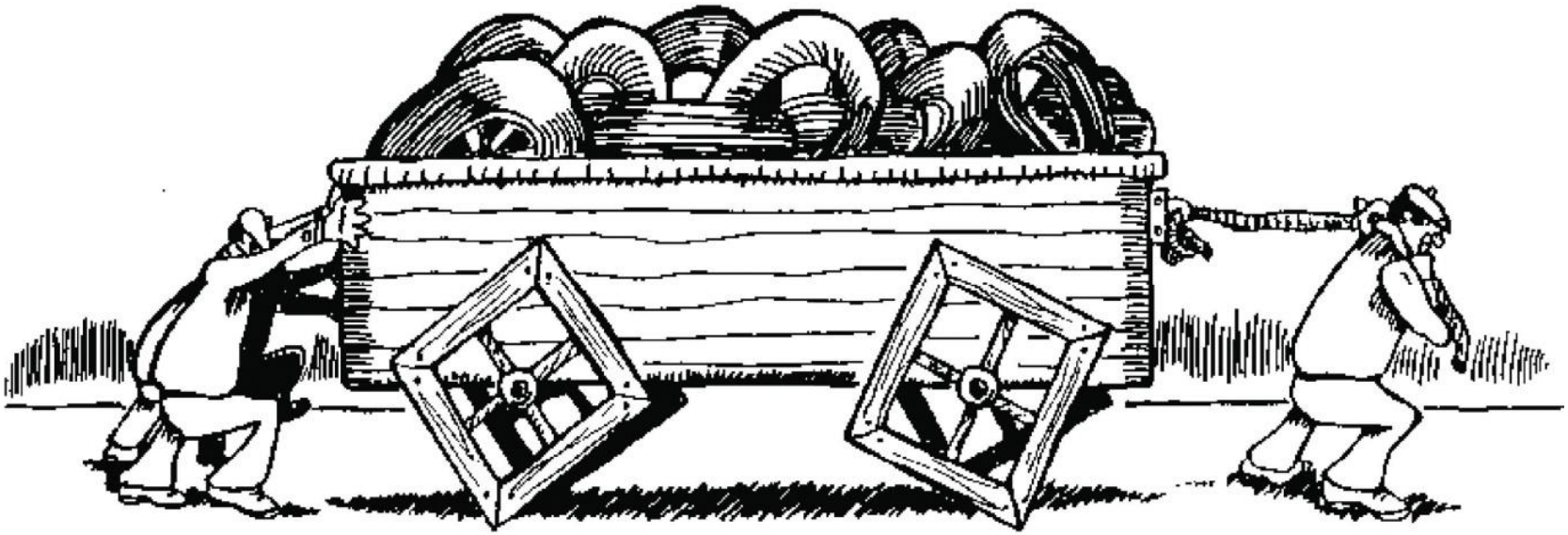
16.15 Jan Barkmeijer
A bright future for linear models?

16.45 Franco Molteni
Ensemble methods and long-range prediction

17.15 Roberto Buizza
What's next?

EPS-produkter i produktionen

Hur skall de se ut?



Är naturen deterministisk eller probabilistisk ?

Den mest fundamentala teorin av hur naturen fungerar är kvantmekaniken vilkas grundläggande lagar är probabilistiska

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NWP är en tillämpning av Navier-Stokes ekvationer
vilkas grundläggande lagar är deterministiska

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Fråga: Hur går det ihop?

Den mest fundamentala teorin av hur naturen fungerar är kvantmekaniken
vilkas grundläggande lagar är probabilistiska

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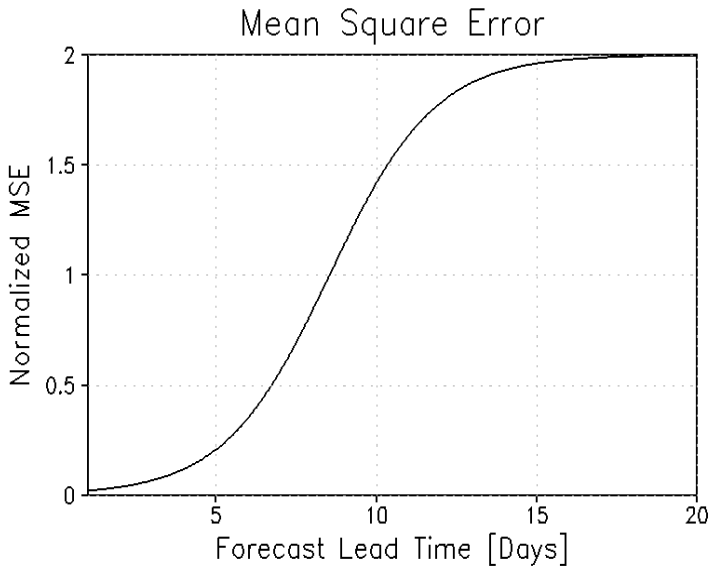
vilkas grundläggande lagar är deterministiska

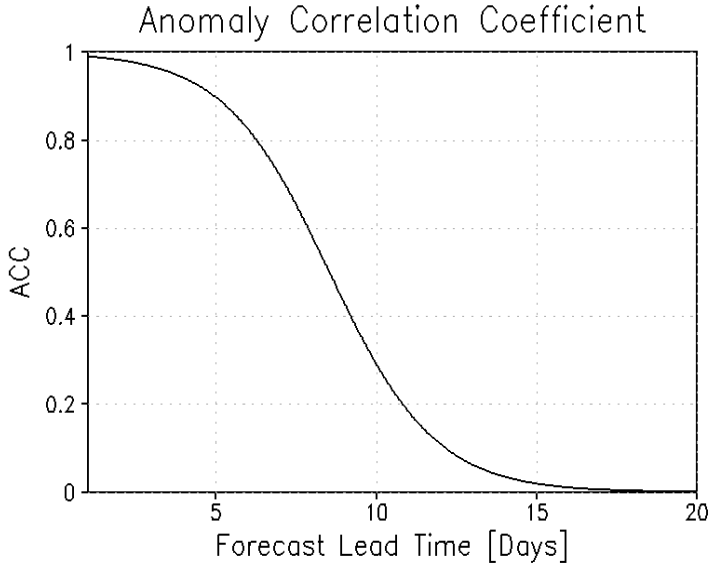
Fråga: Hur går det ihop?

Svar: Naturen är också kaotisk, dvs.

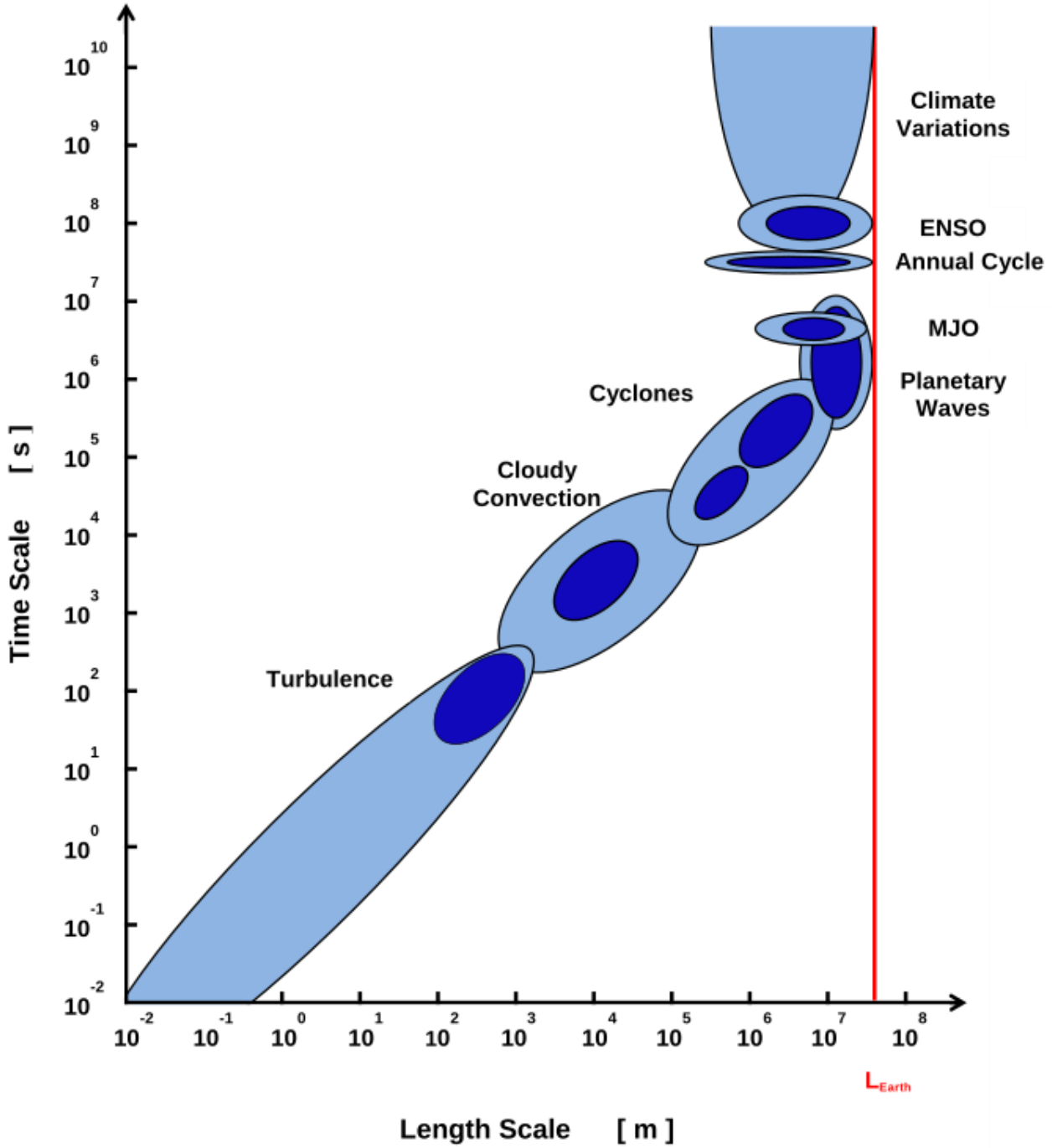
The present determines the future
but
The approximate present does not approximately determine the future

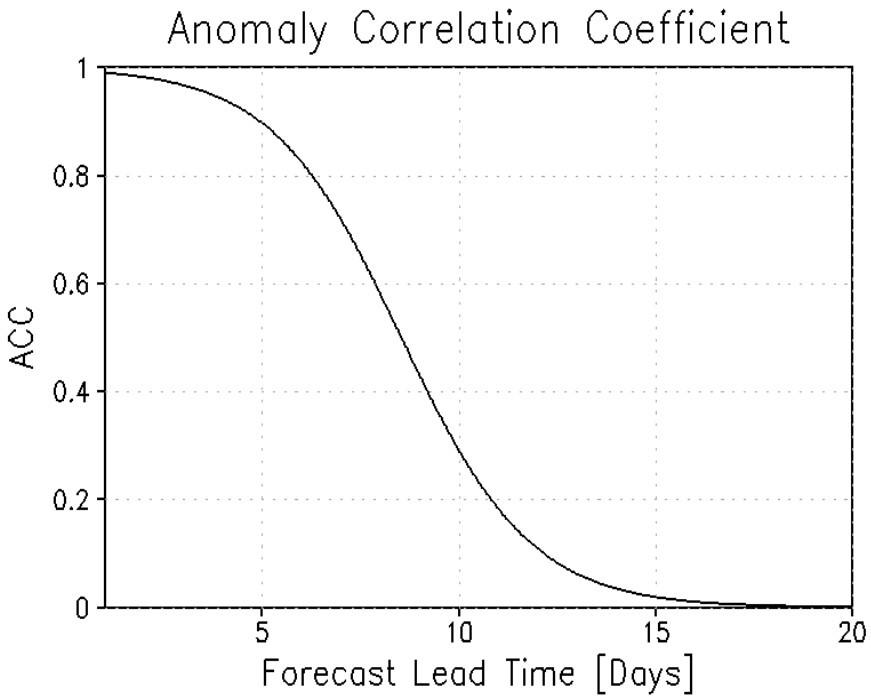
Feltillväxt - Prediktabilitet

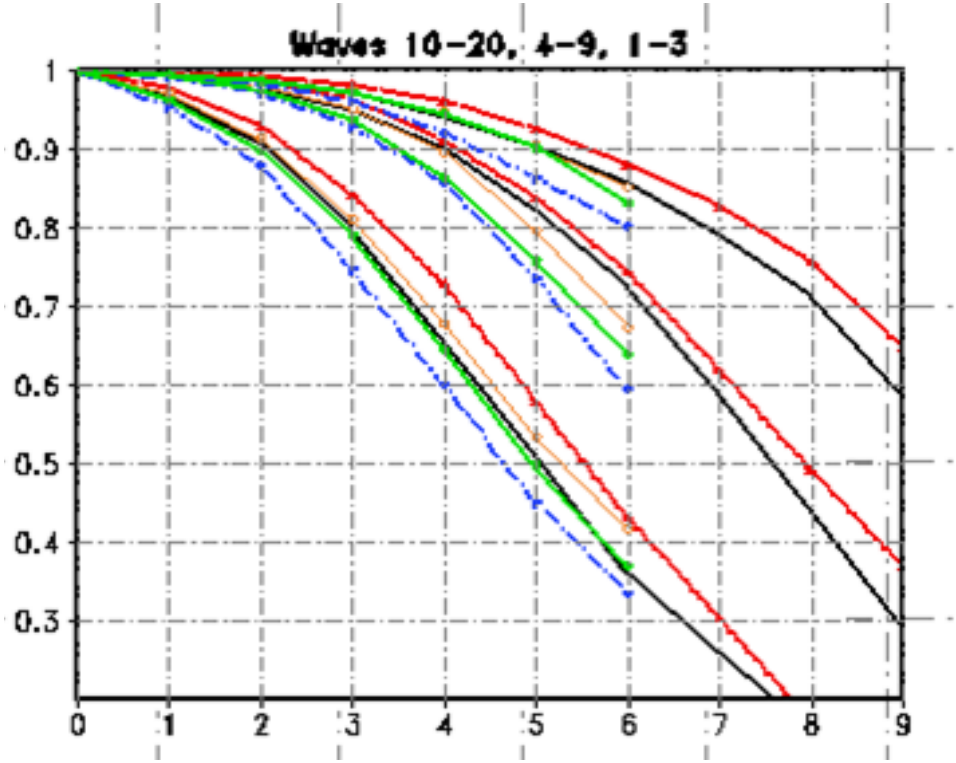


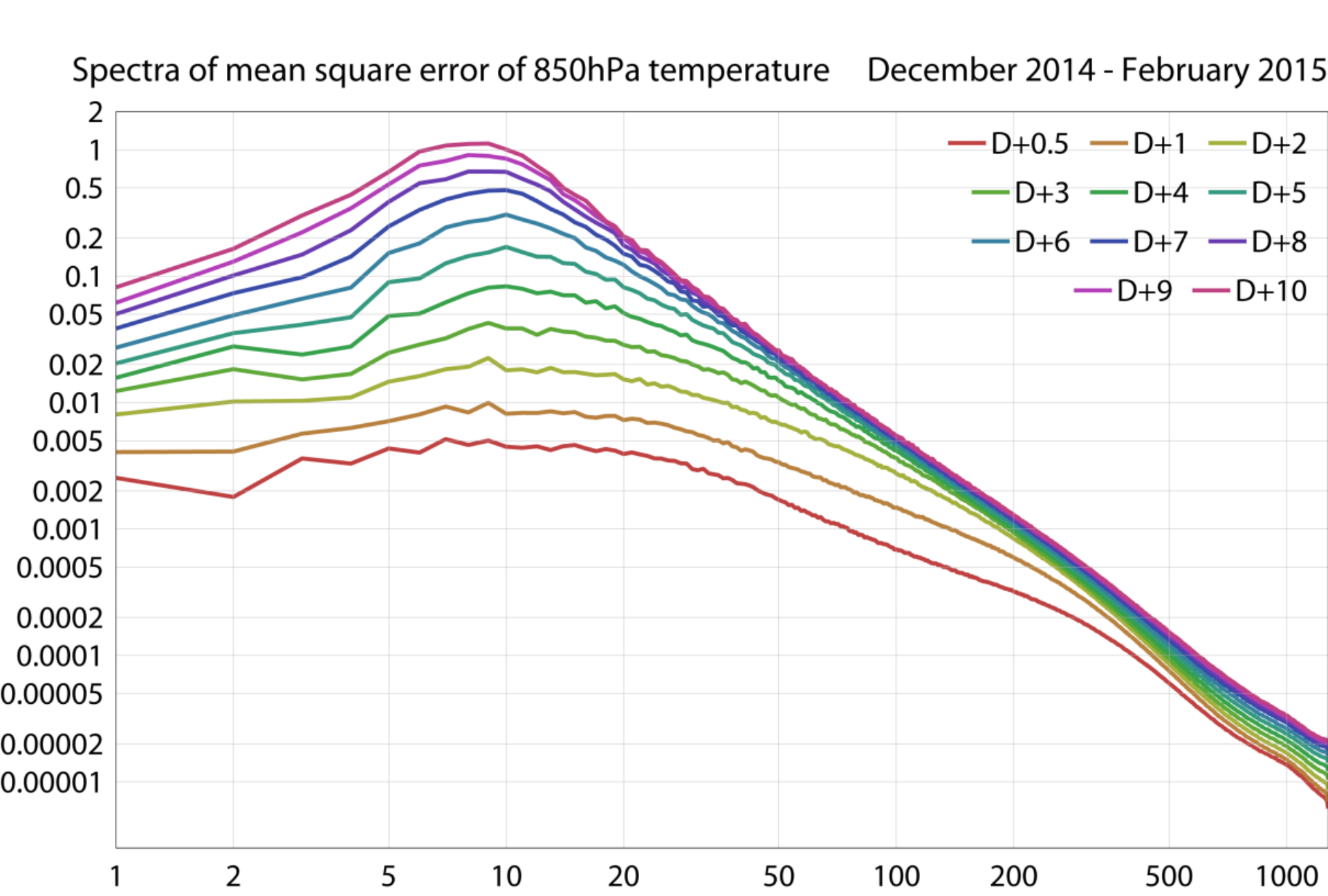


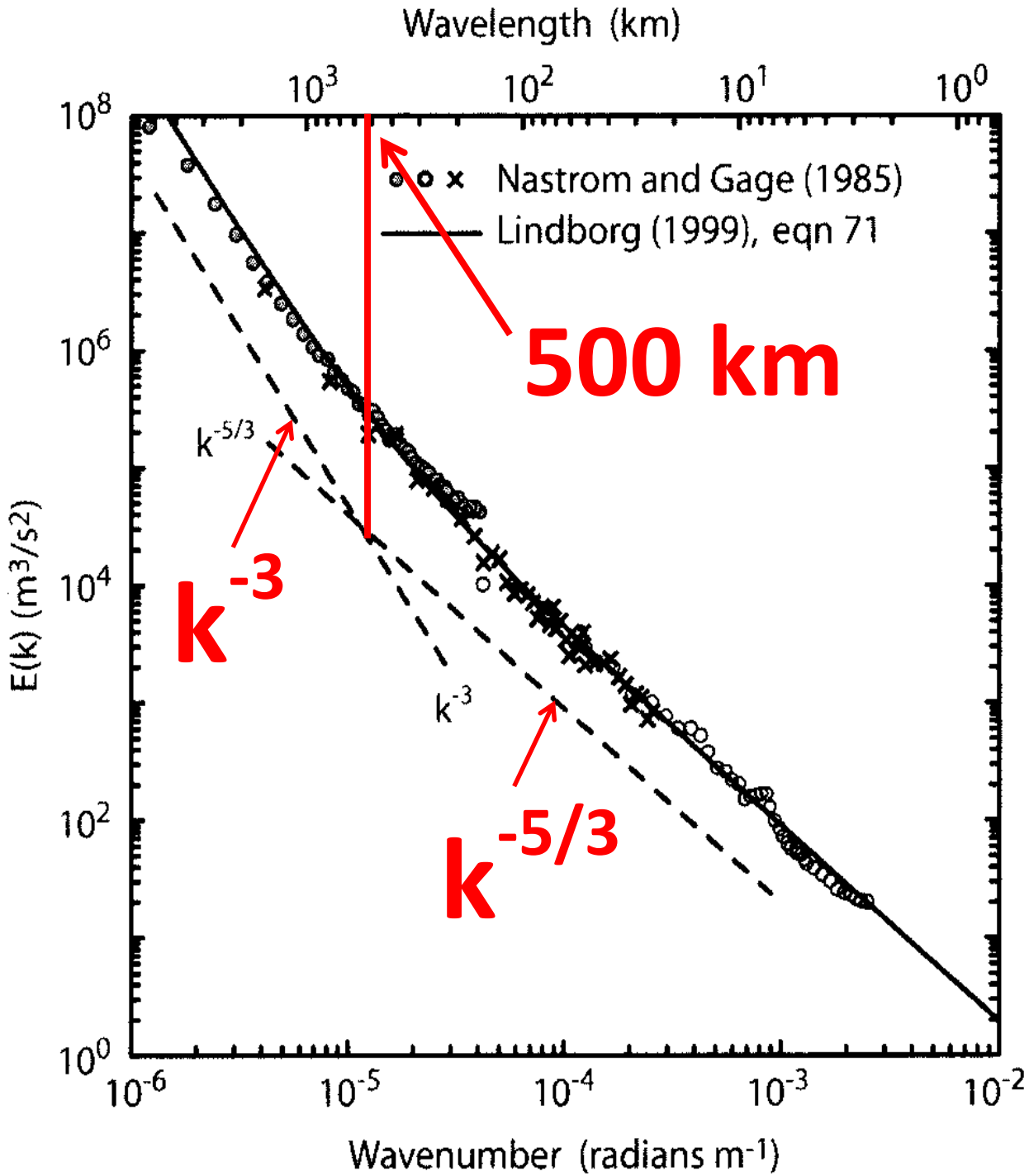
Prediktabiliteten är mycket skalberoende


Time Scale [s]
Length Scale [m]
Climate Variations
ENSO
Annual Cycle
MJO
Planetary Waves
Cyclones
Cloudy Convection
Turbulence
L Earth

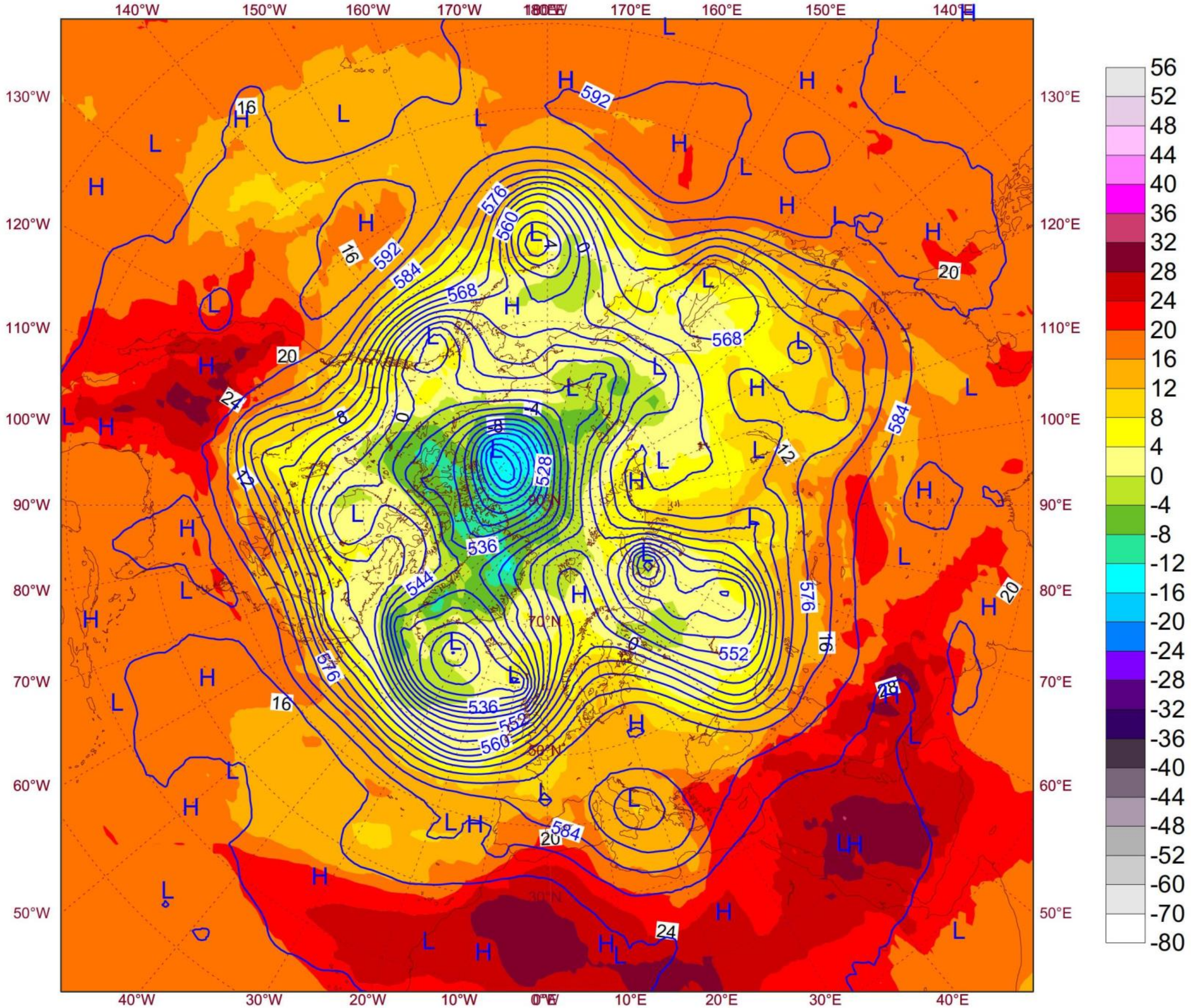

Anomaly Correlation Coefficient
ACC
1
0.8
0.6
0.4
0.2
0
5
10
15
20
Forecast Lead Time [Days]


Waves 10-20, 4-9, 1-3
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
1
2
3
4
5
6
7
8
9

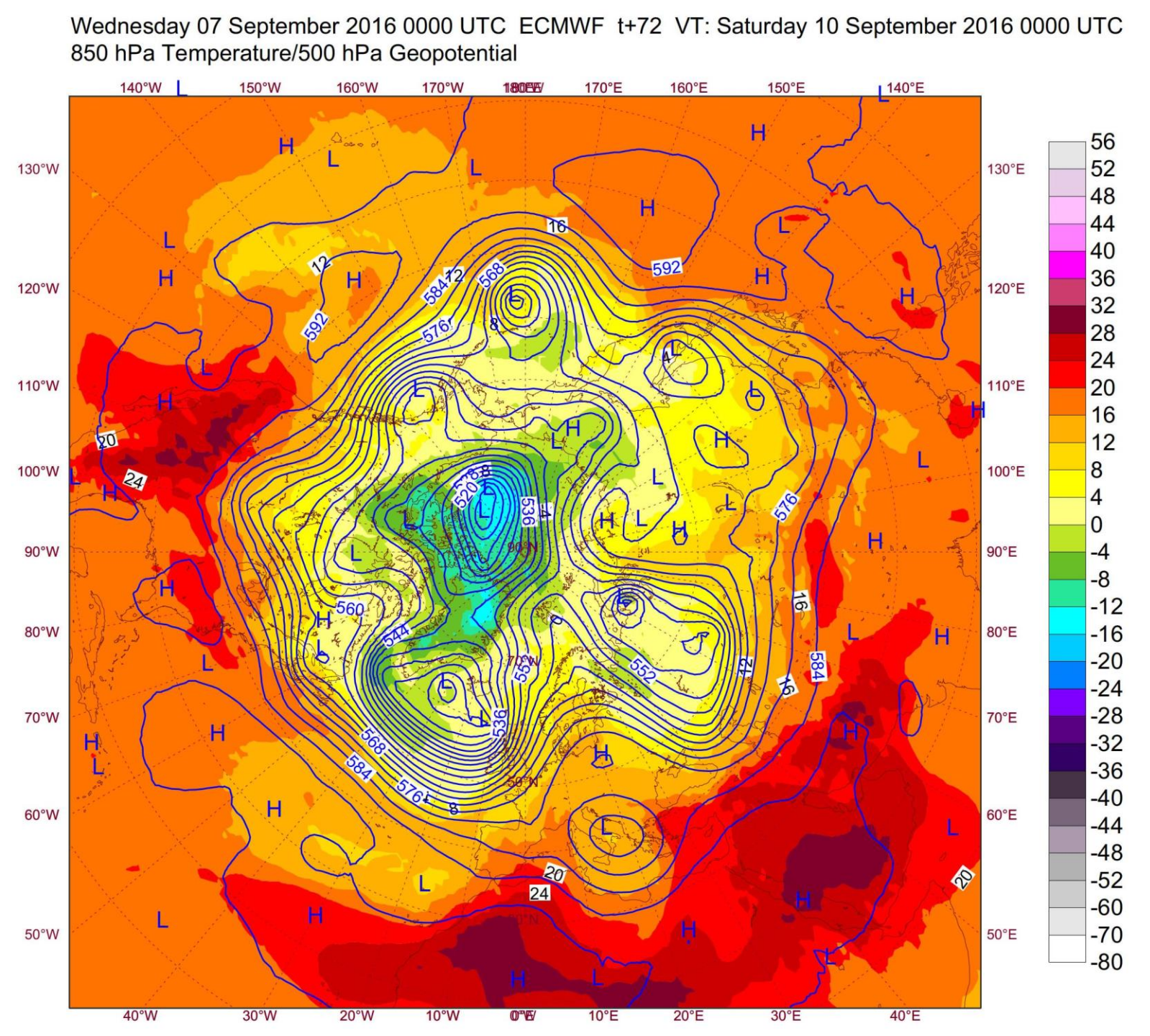

Spectra of mean square error of 850hPa temperature
December 2014 - February 2015
D+0.5
D+1
D+2
D+3
D+4
D+5
D+6
D+7
D+8
D+9
D+10
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0.005
0.002
0.001
0.0005
0.0002
0.0001
0.00005
0.00002
0.00001
1
2
5
10
20
50
100
200
500
1000


Wavelength (km)
10^3
10^2
10^1
10^0
10^8
10^6
10^4
10^2
10^0
E(k) (m^3/s^2)
Nastrom and Gage (1985)
Lindborg (1999), eqn 71
500 km
$k^{-5/3}$
k^{-3}
k^{-3}
$k^{-5/3}$
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
Wavenumber (radians m^{-1})

Saturday 10 September 2016 0000 UTC ECMWF t+0 VT: Saturday 10 September 2016 0000 UTC
850 hPa Temperature/500 hPa Geopotential

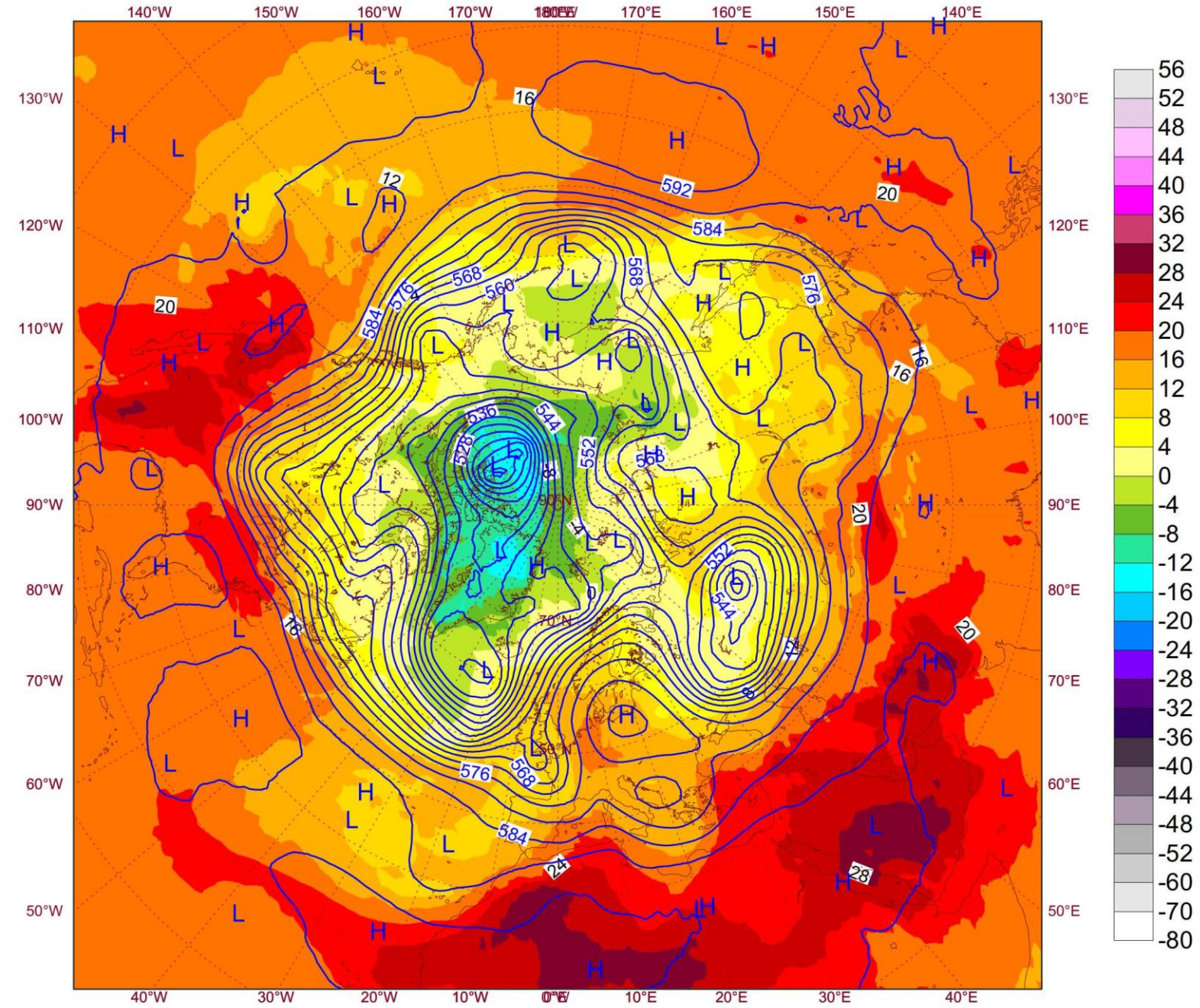


0


Wednesday 07 September 2016 0000 UTC ECMWF t+72 VT: Saturday 10 September 2016 0000 UTC
850 hPa Temperature/500 hPa Geopotential
140°W
150°W
160°W
170°W
180°W
170°E
160°E
150°E
140°E
130°W
120°W
110°W
100°W
90°W
80°W
70°W
60°W
50°W
130°E
120°E
110°E
100°E
90°E
80°E
70°E
60°E
50°E
40°W
30°W
20°W
10°W
0°W
10°E
20°E
30°E
40°E
50°N
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
-4
-8
-12
-16
-20
-24
-28
-32
-36
-40
-44
-48
-52
-60
-70
-80

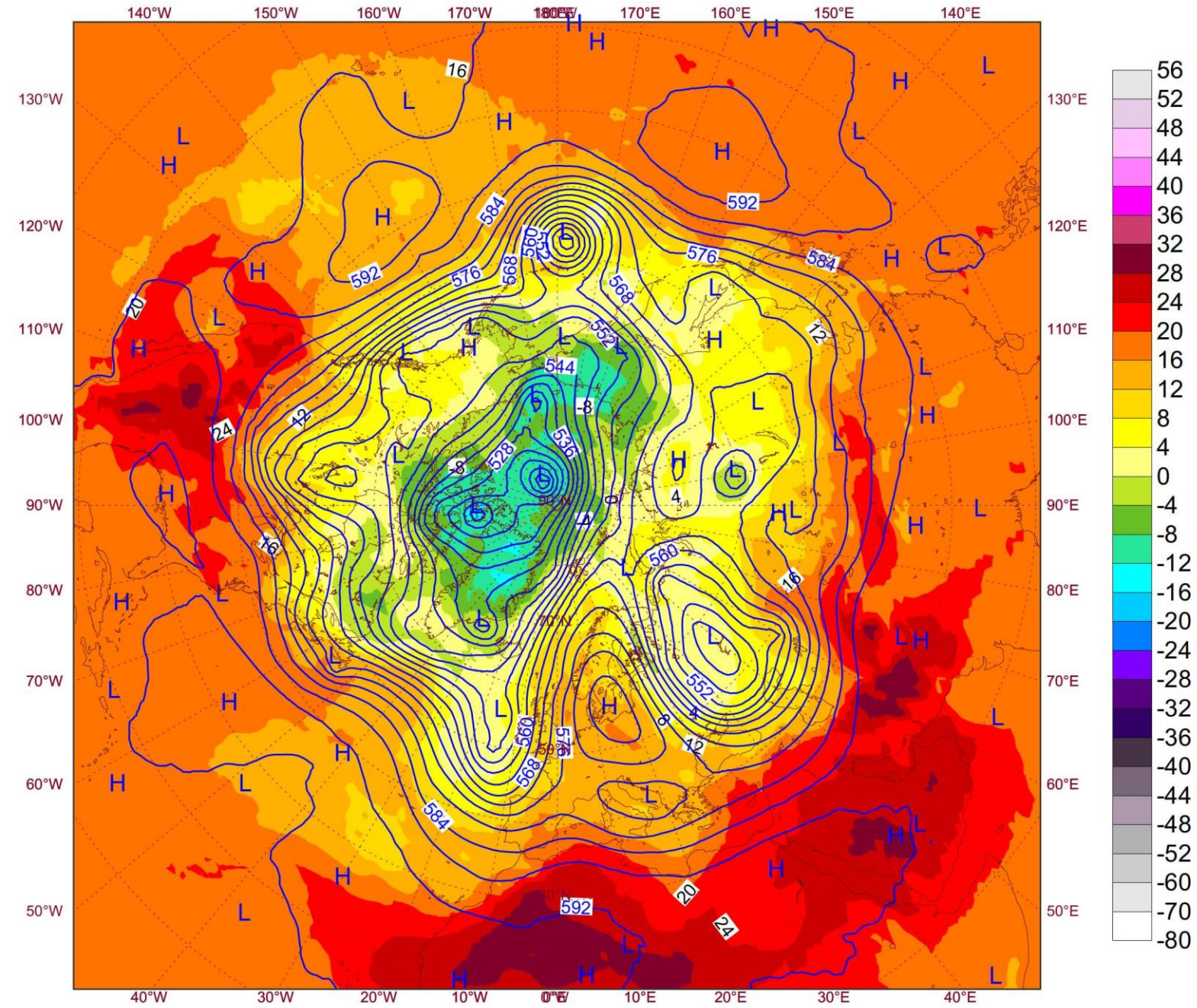
3

Sunday 04 September 2016 0000 UTC ECMWF t+144 VT: Saturday 10 September 2016 0000 UTC
850 hPa Temperature/500 hPa Geopotential



6

Thursday 01 September 2016 0000 UTC ECMWF t+216 VT: Saturday 10 September 2016 0000 UTC
850 hPa Temperature/500 hPa Geopotential



9

EPS-produkter i produktionen

Hur skall de se ut?

SÖK FM - SMHI

Ensemble-prognoser för

- **Finskaliga** **km skala**
- **Kortfristiga** **0-48 timmar**

baserade på limited area modeller

WRF
MEPS

Svårighet med EPS information

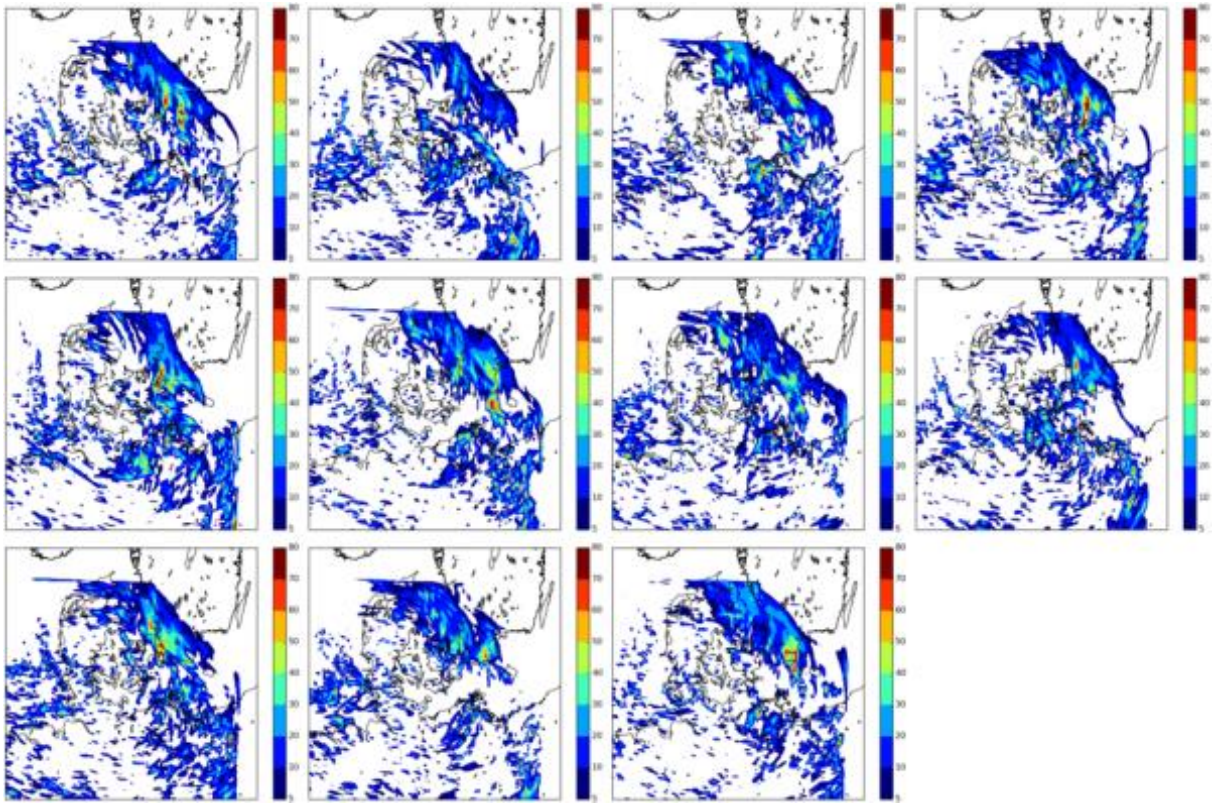
7 dimensioner

Var, x, y, z, t_o, t_F, m

8 principiellt olika sätt att presentera EPS information

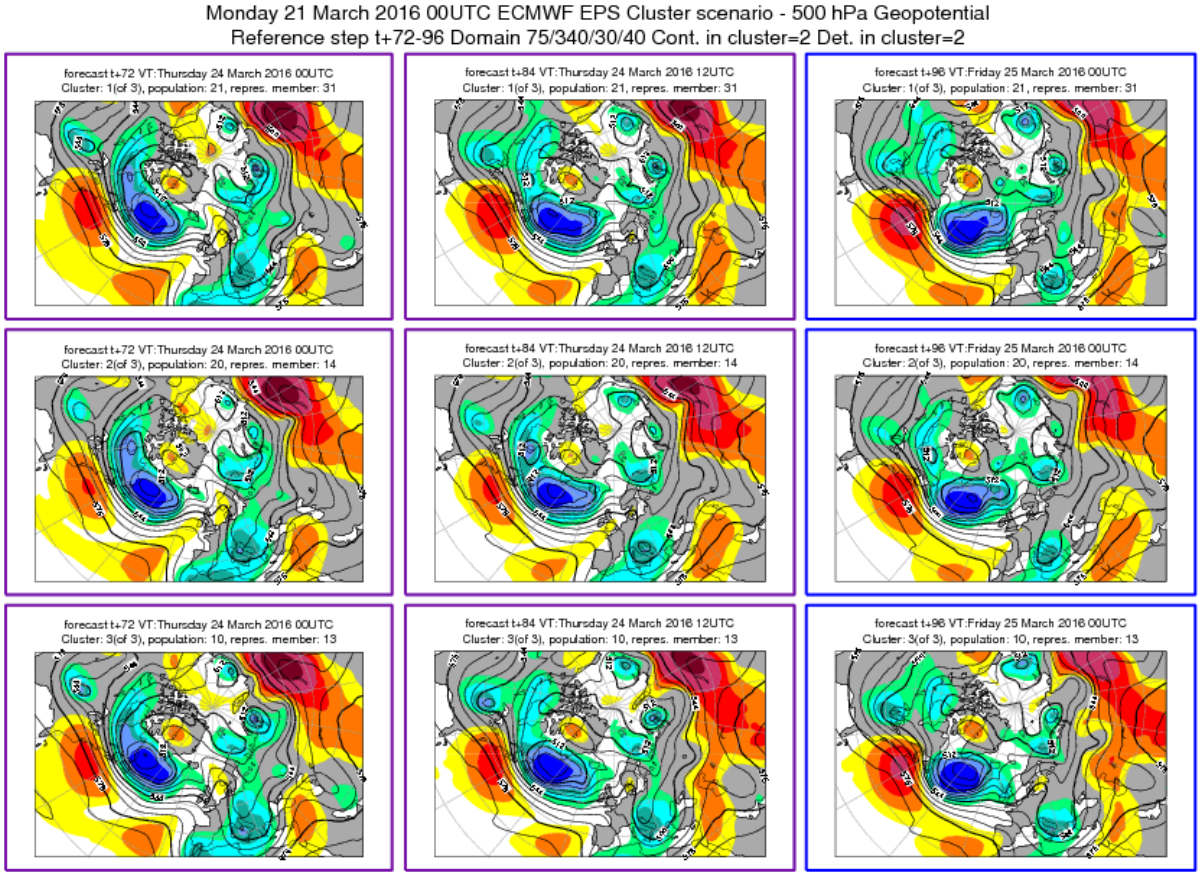
1. Alla individuella ensemble medlemmar presenteras

som horisontella fält / Frimärkskartor



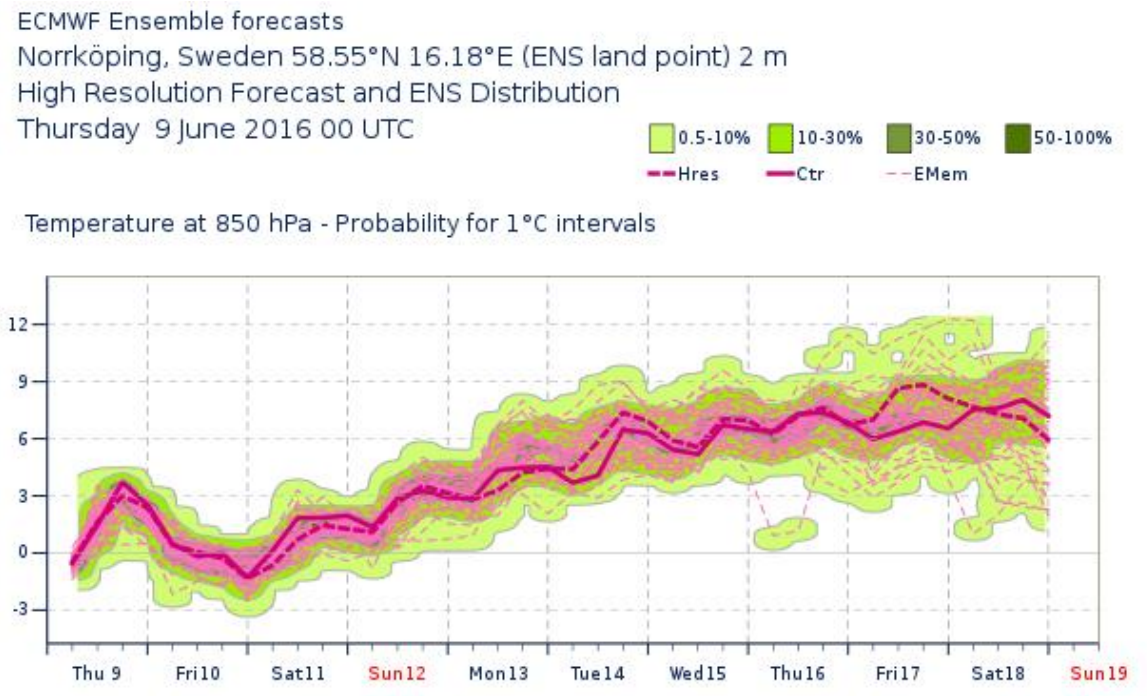
2. Några representativa ensemble medlemmar

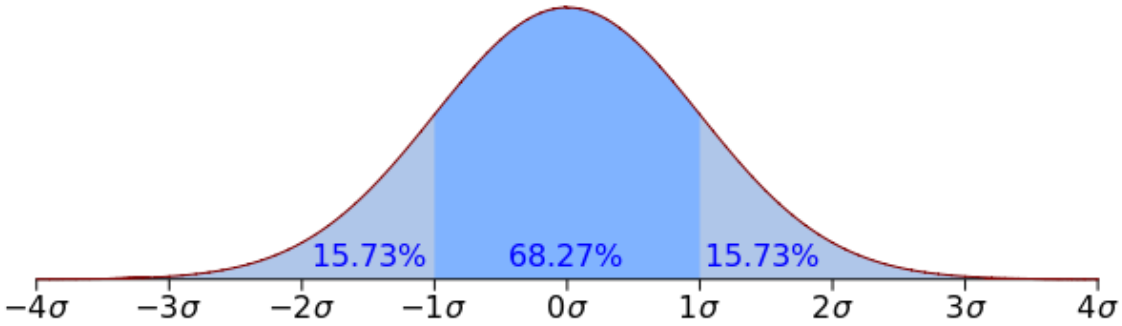
en från var och en av ett antal typiska grupper, eller kluster



3. Sannolikhetsfördelningen presenteras

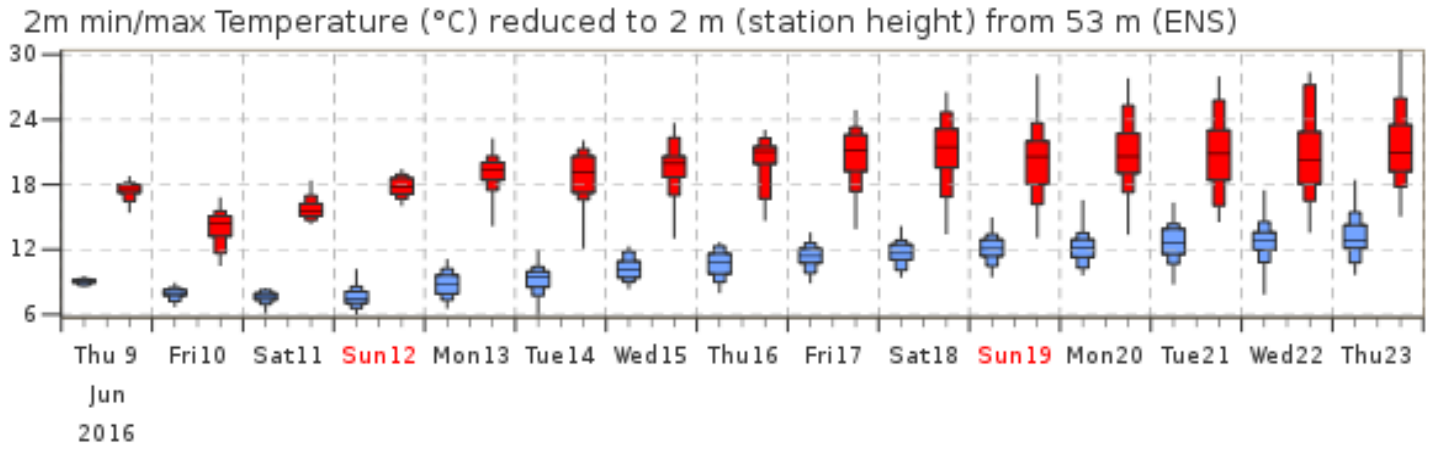
a. som tidsutveckling av PDF
för variabeln V i punkten P / Ensemble Plymer

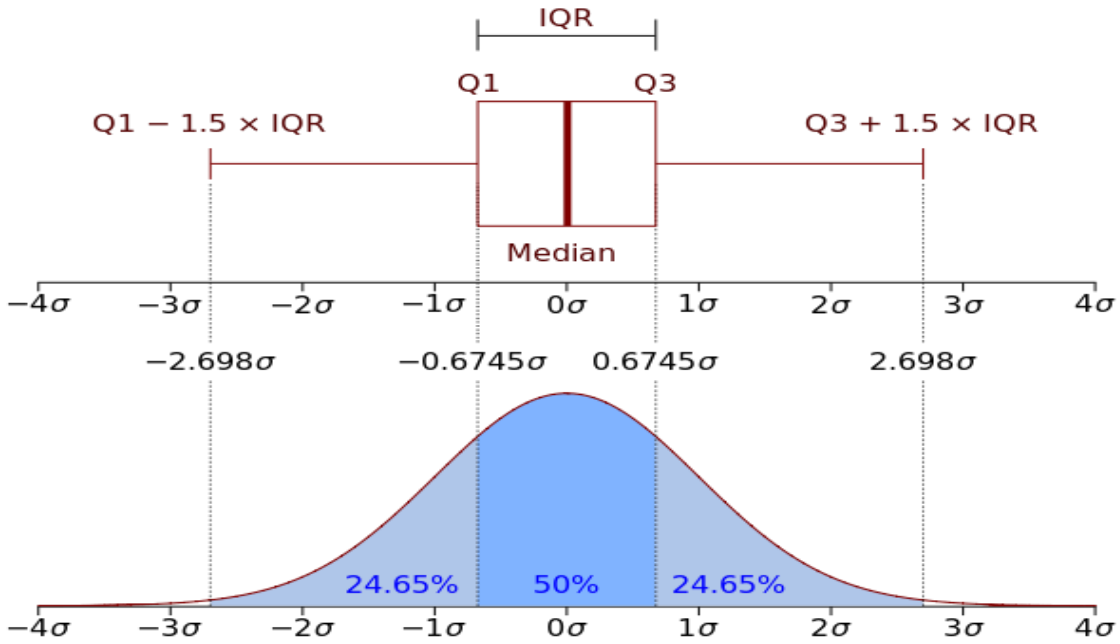




3. Sannolikhetsfördelningen presenteras

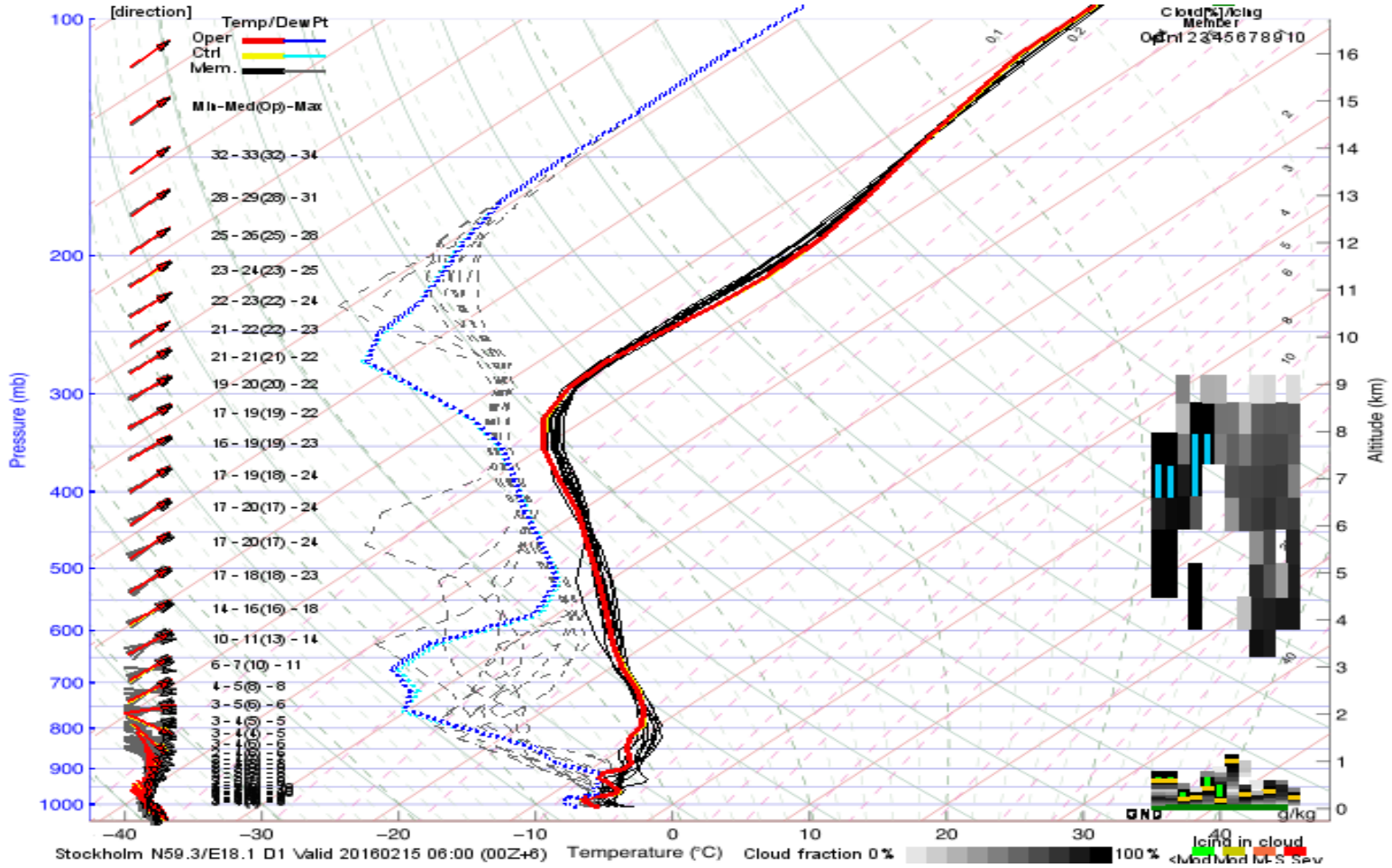
b. som tidsutveckling av lådagram
för variabeln V i punkten P / Förenklade Ensemble Plymer





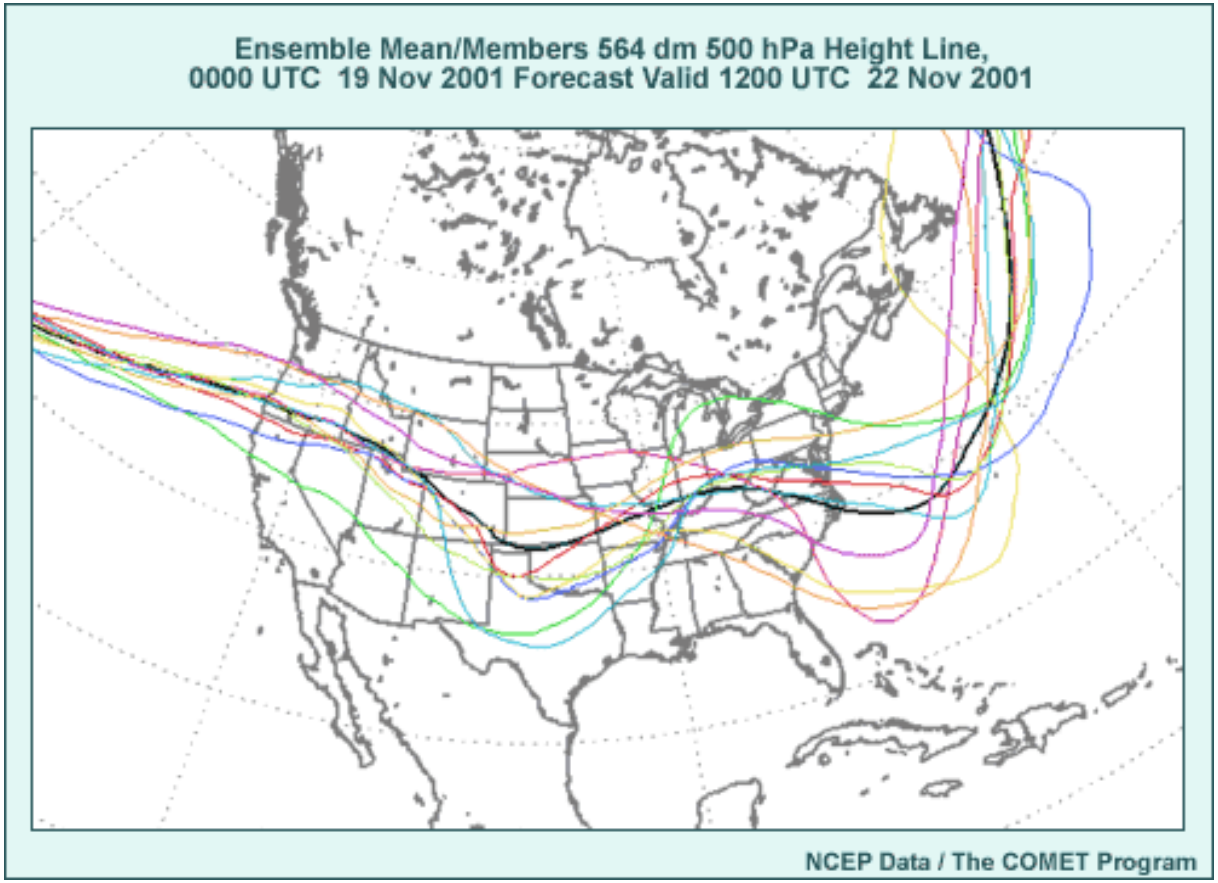
3. Sannolikhetsfördelningen presenteras

c. som vertikalprofiler av PDF för variabeln V i den horisontella punkten P

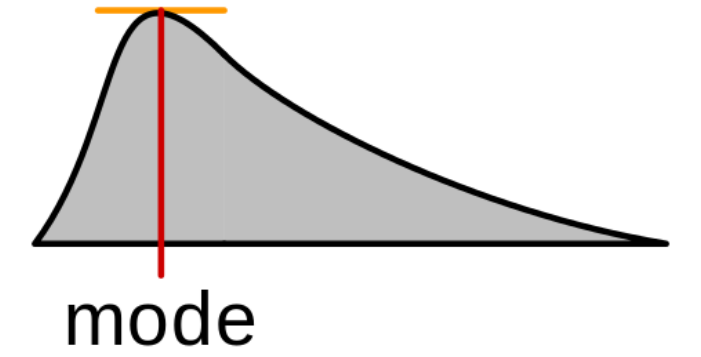


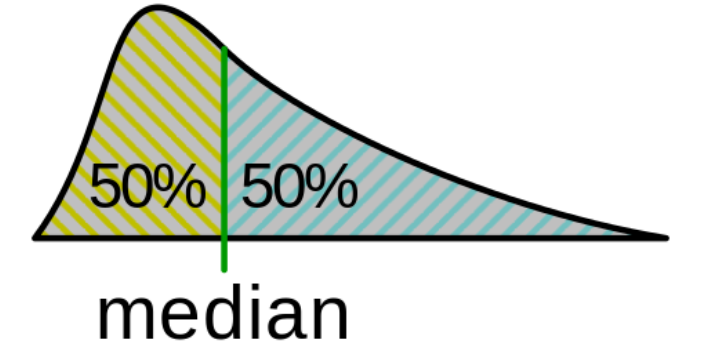
3. Sannolikhetsfördelningen presenteras

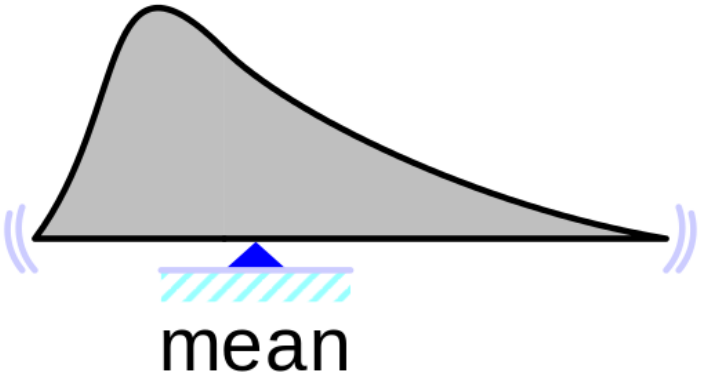
d. för en enskild isolinjes horisontella utbredning så kallade Spagetti-plots / Limited Contour Analysis



4. Centrum av fördelningen

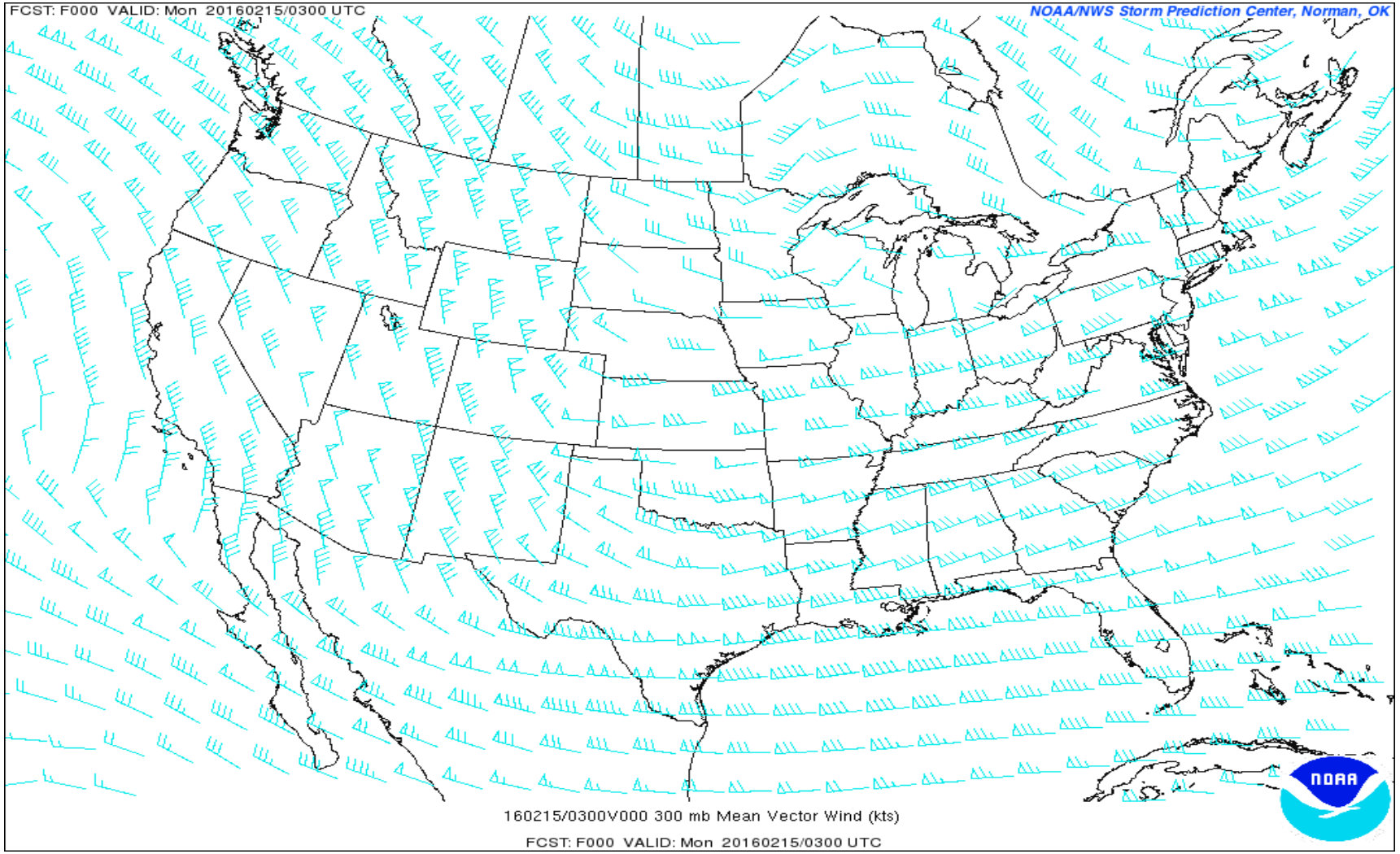






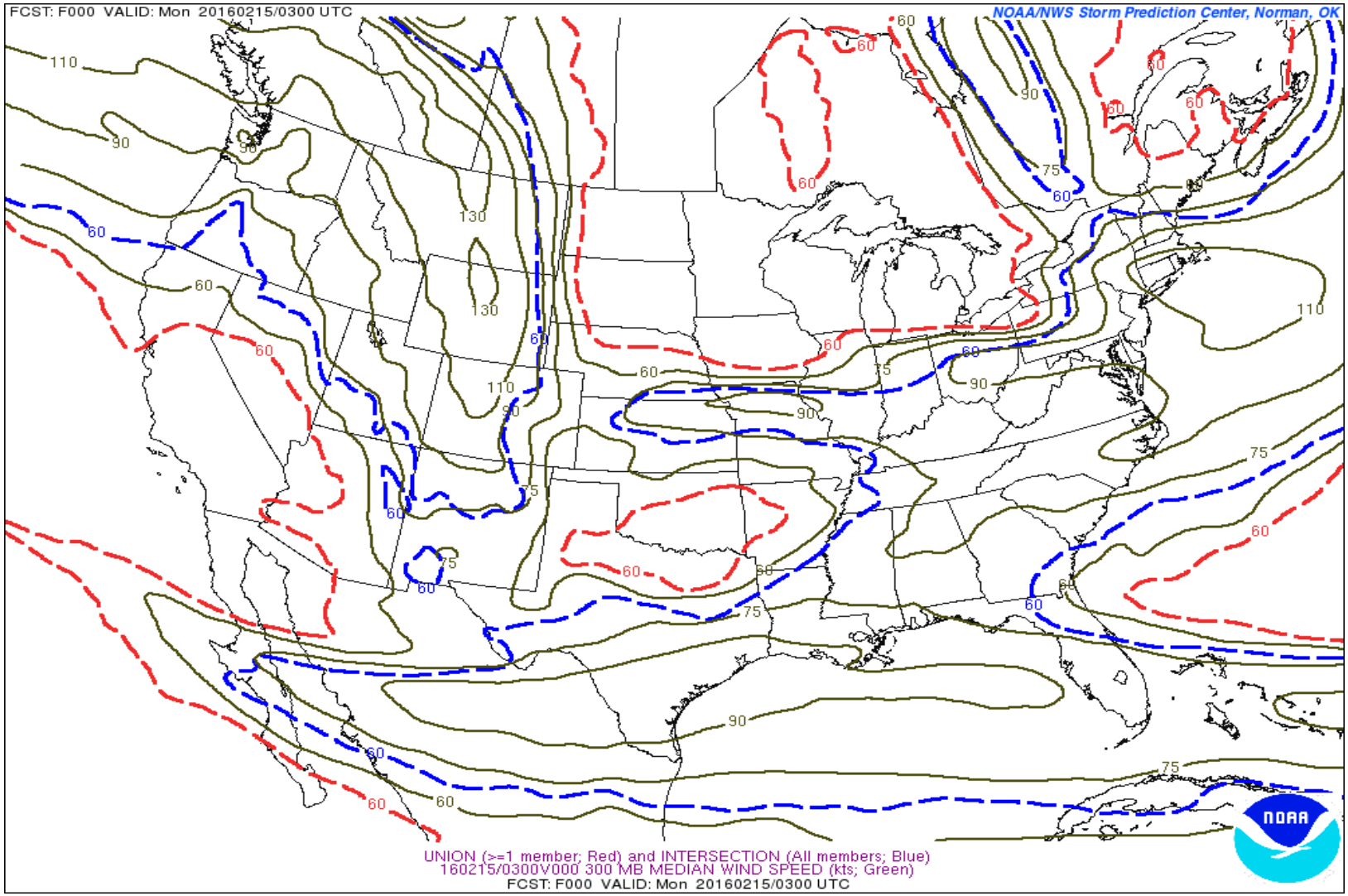
4. Centrum av fördelningen presenteras med hjälp av lägesmåttet

a. Medelvärde (Ensemble Mean)



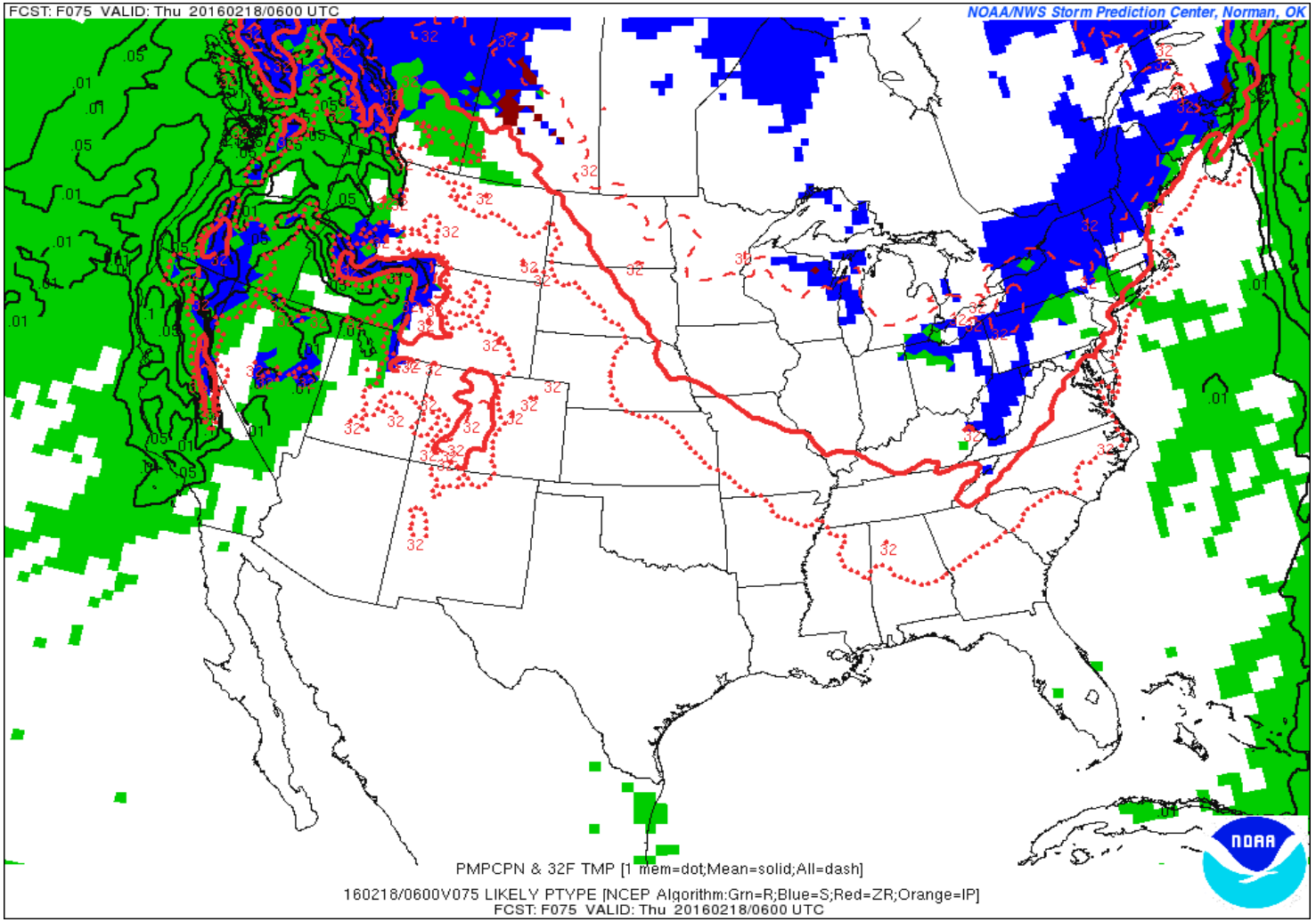
4. Centrum av fördelningen presenteras med hjälp av lägesmåttet

b. Medianvärde

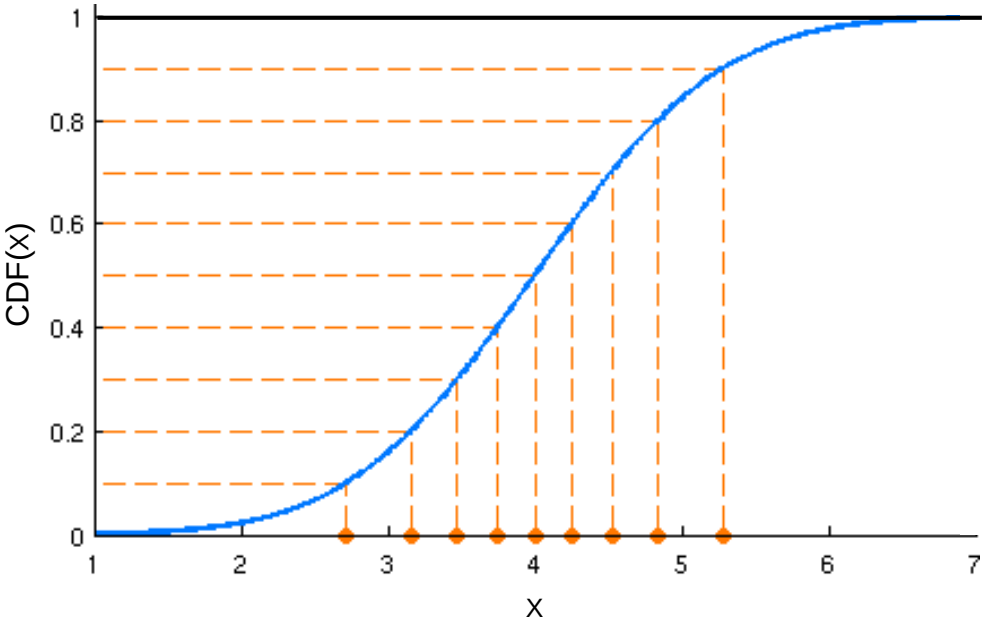


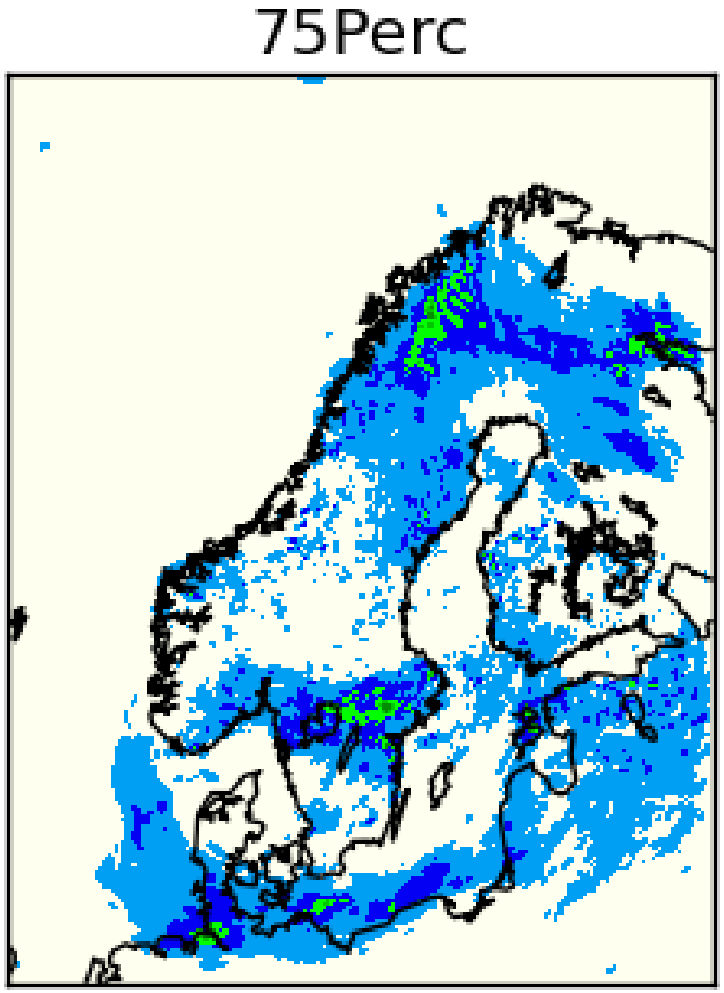
4. Centrum av fördelningen presenteras med hjälp av lägesmåttet

c. Typvärde = Sannolikaste värdet



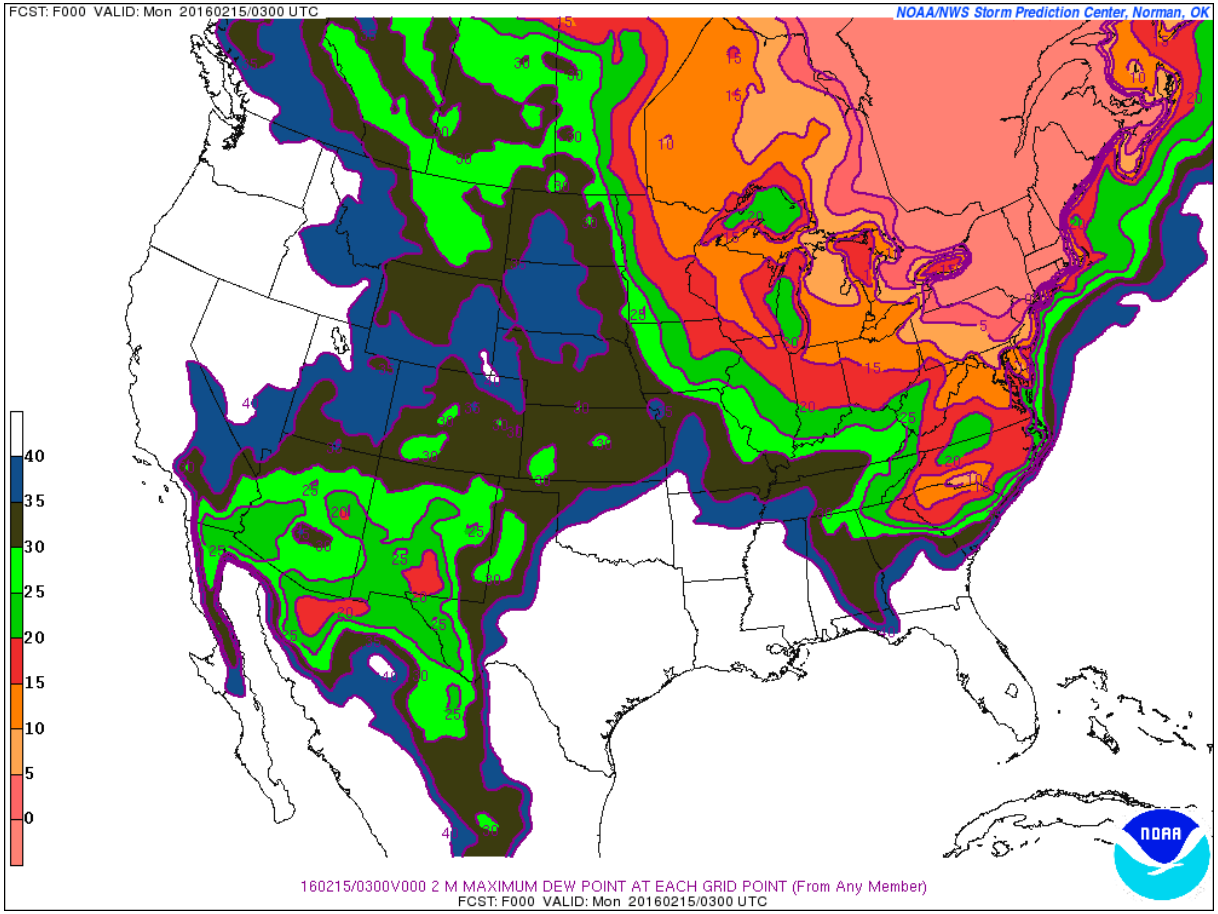
5. En kvantil av fördelningen presenteras som horisontella fält





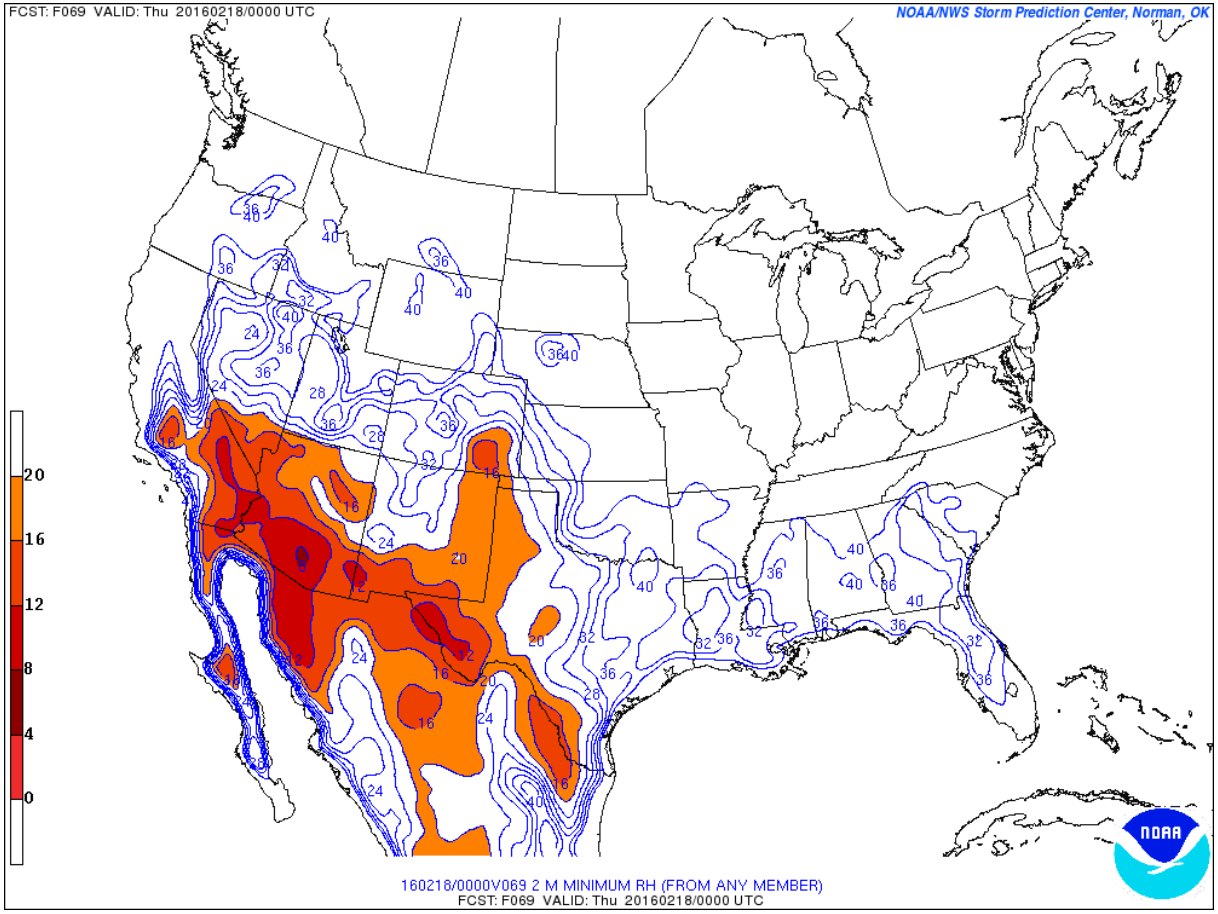
6. Extremvärden hos fördelningen presenteras som fält

a. Maximum-värde



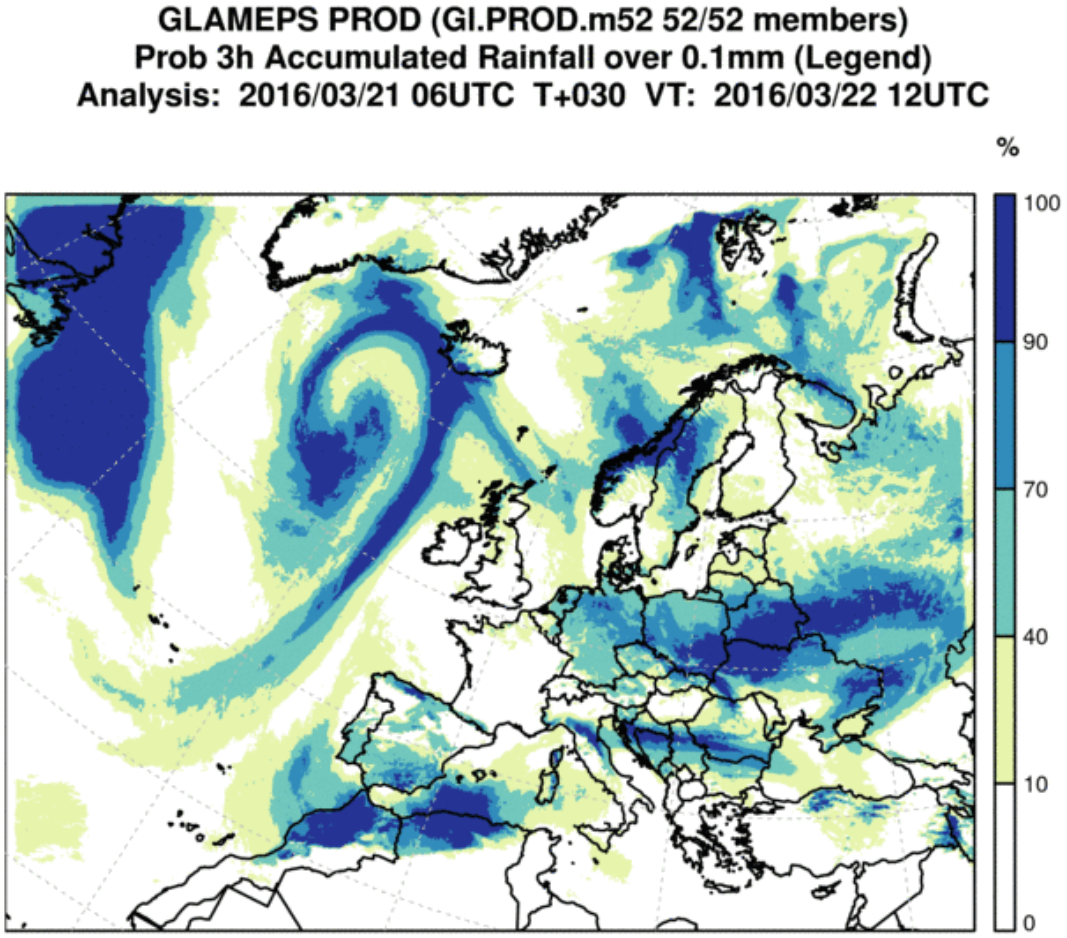
6. Extremvärden hos fördelningen presenteras som fält

b. Minimum-värde



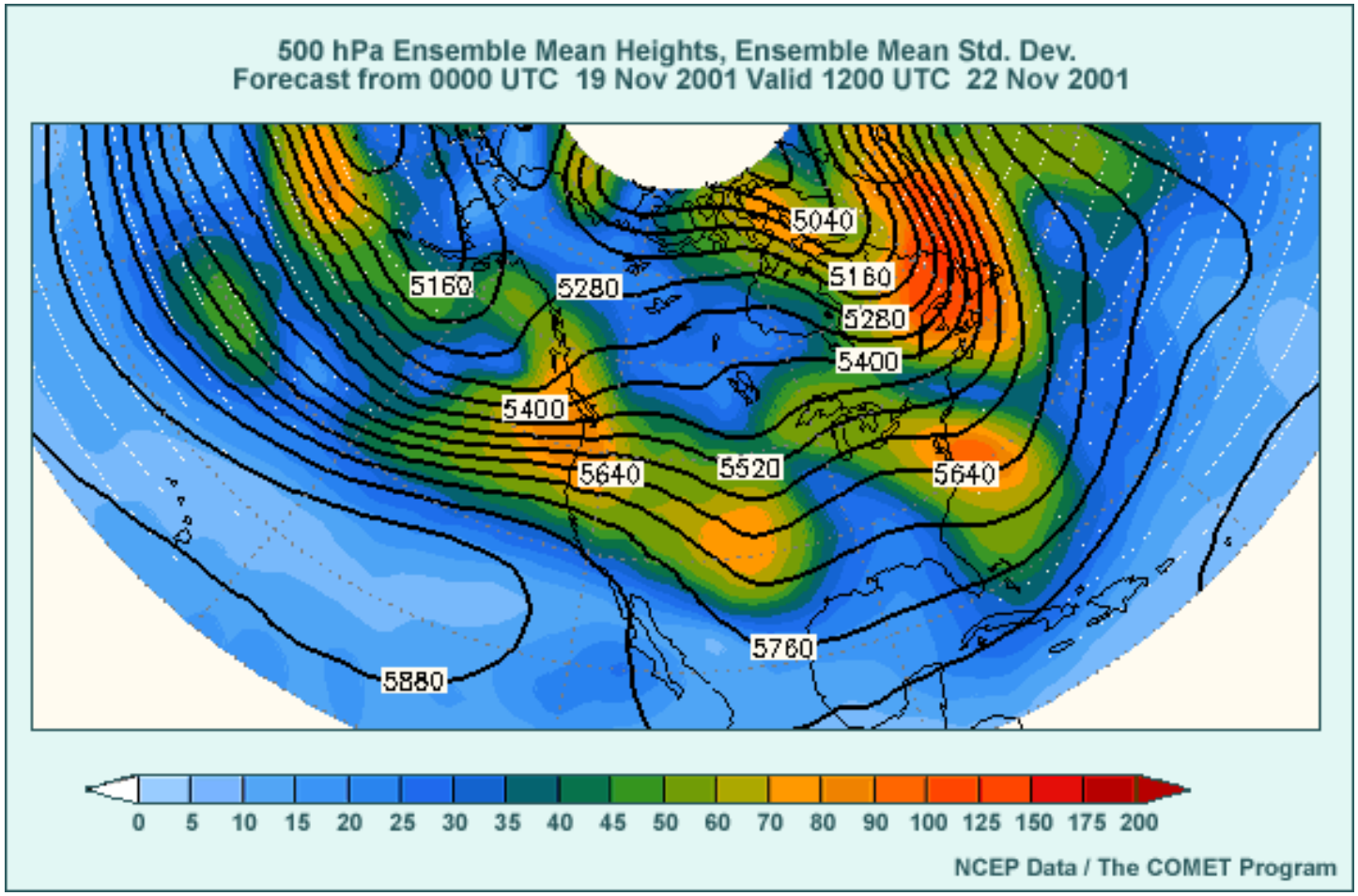
7. Sannolikheten för en händelse presenteras som horisontella fält

Sannolikheten att Variabeln V överstiger ett Tröskelvärde T



8. Osäkerhetsmått presenterade som horisontella fält

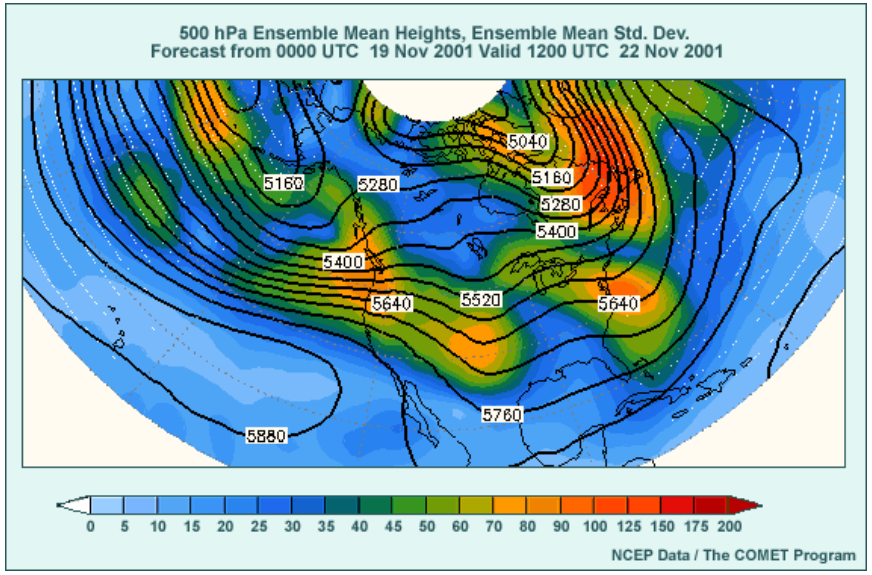
Standardavvikelsen hos ensemblen = Ensemble Spread



EPS-produkter för SMHI - Luftfart

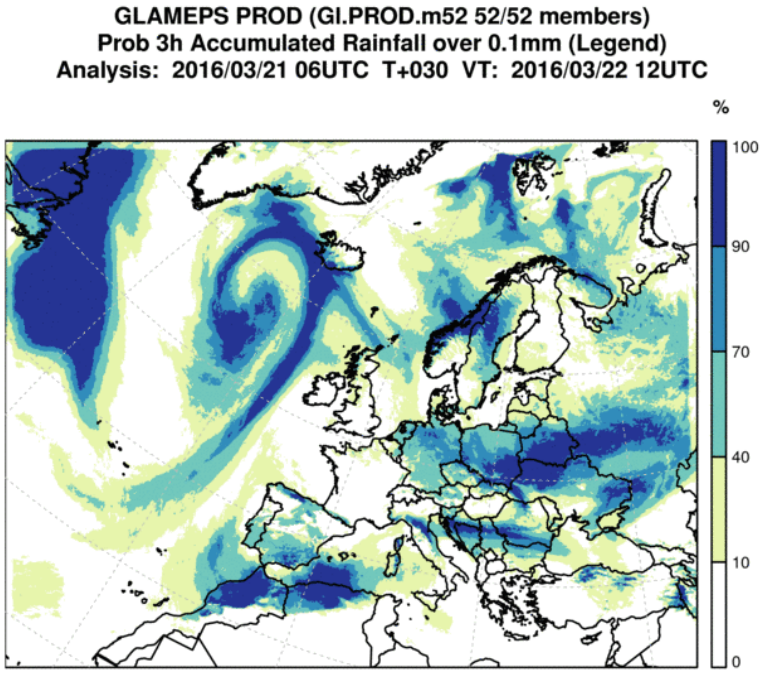
Hur skall de se ut?

Centrum av fördelningen och osäkerhetsmått



Variabel
Höjd till 0ºC isoterm
T850
T2M
Td2M
WS10M
WDIR10M

Sannolikheten för en specifik händelse



Variabel	Händelse
Vindstyrka 2m	> 25 kn
Vindskjuvning 10m – 3000ft	> 30 kn
Temperatur 2 m	< 0 ºC
Molnbas	< 300 m
Sikt	< 5000 m
Underkyld nbd	Existerar

CMEPS data

Operational CMEPS data are produced on three different computers

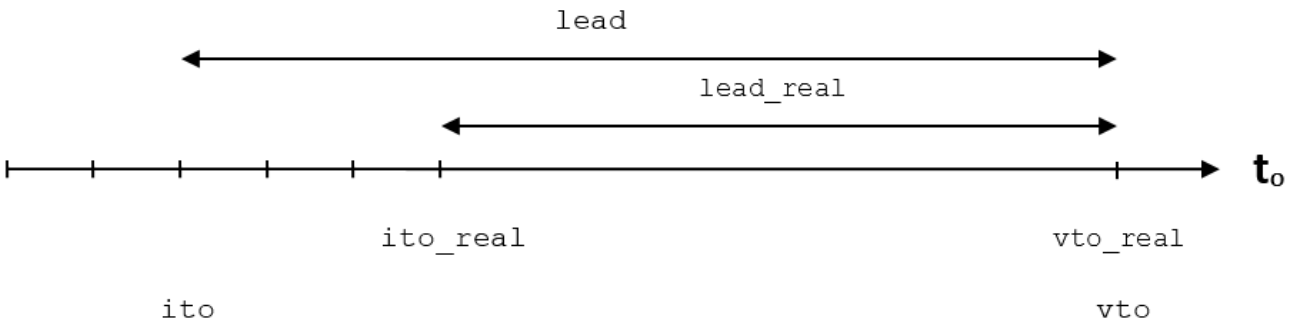
`cirrus/stratus/voima`

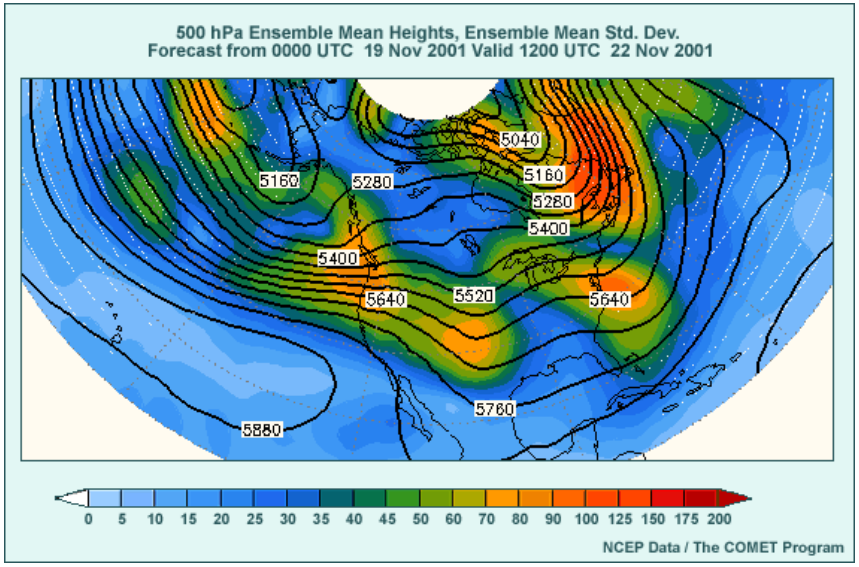
where the different members are produced according to the following schedule

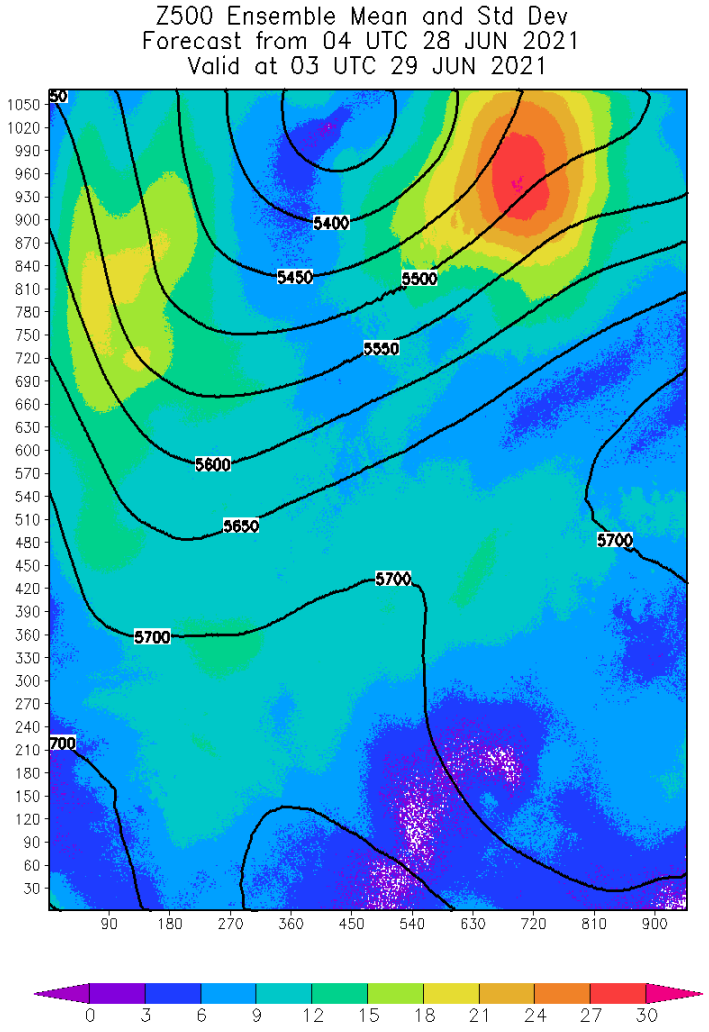
Time (UTC)	CIRRUS	STRATUS	VOIMA
00 03 ... 21	**000**	001 002 012	009
01 04 ... 22	007	003 004 013	010
02 05 ... 23	008 014	005 006	011

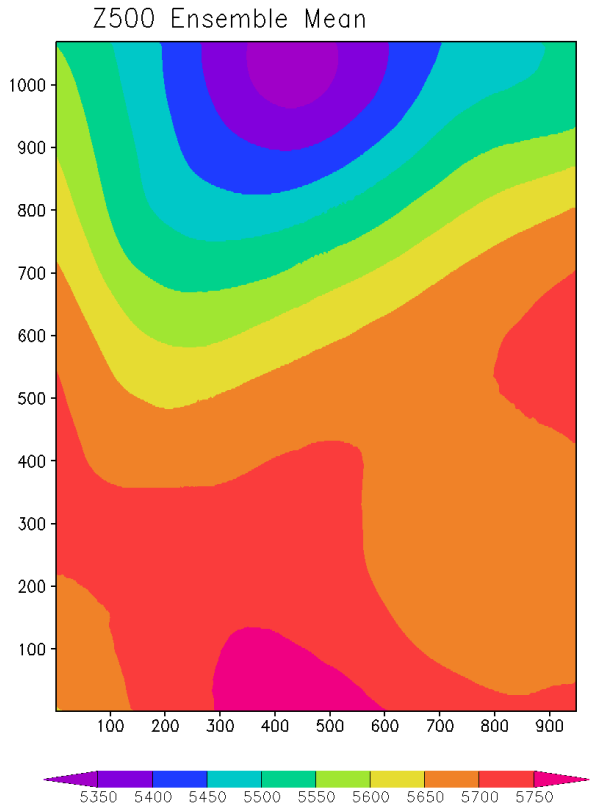
Every hour – ito - there are thus 5 new members produced.

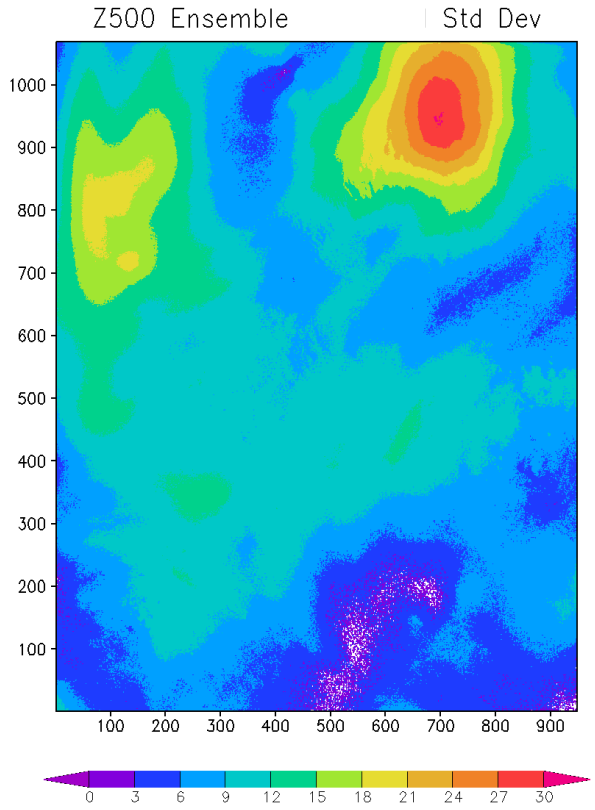
The forecast lead time – lead - is 0, 1, 2, … , 66 hr.

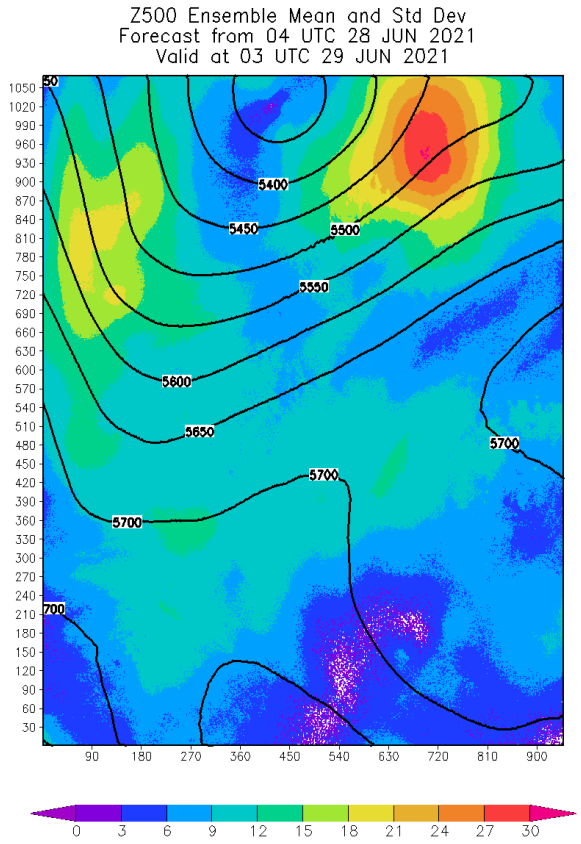


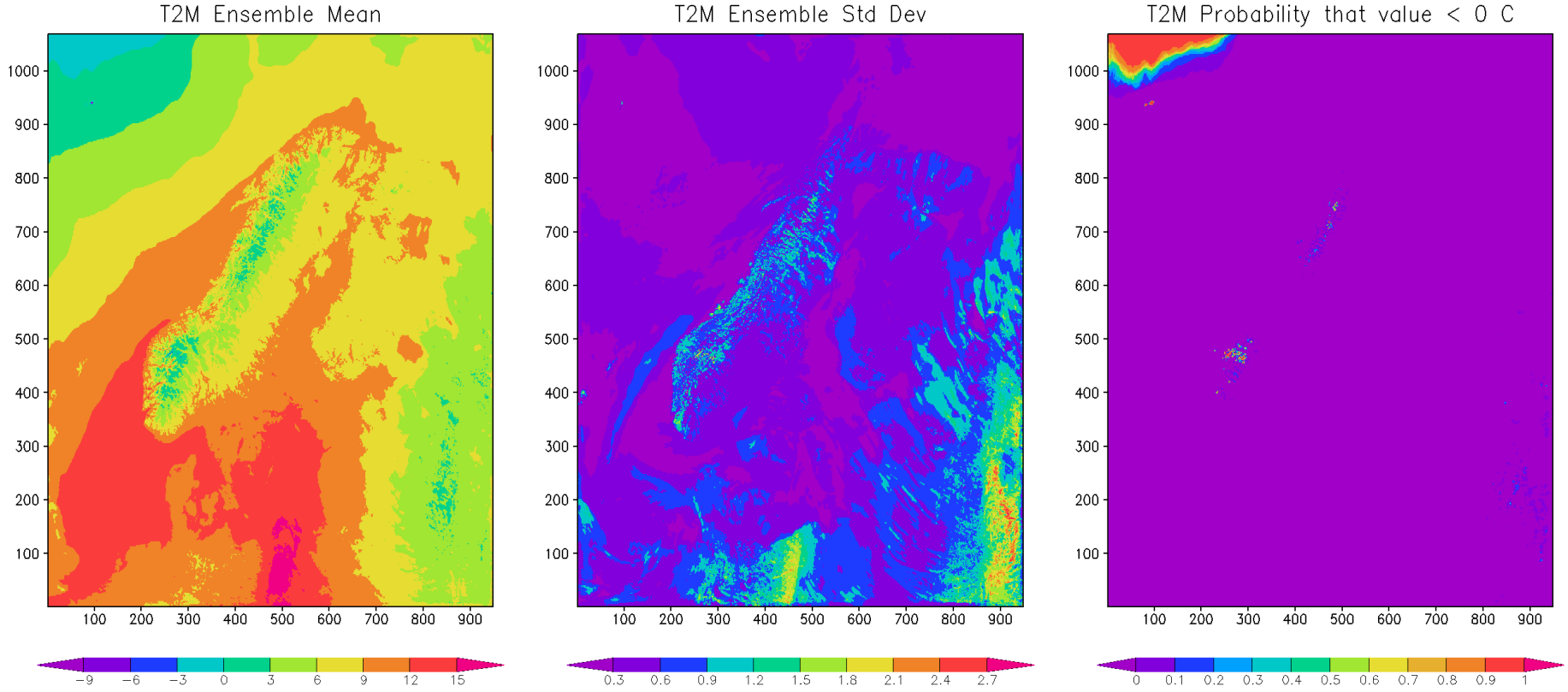

500 hPa Ensemble Mean Heights, Ensemble Mean Std. Dev.
Forecast from 0000 UTC 19 Nov 2001 Valid 1200 UTC 22 Nov 2001
5040
5160
5280
5160
5280
5400
5400
5640
5520
5640
5760
5880
0 5 10 15 20 25 30 35 40 45 50 60 70 80 90 100 125 150 175 200
NCEP Data / The COMET Program

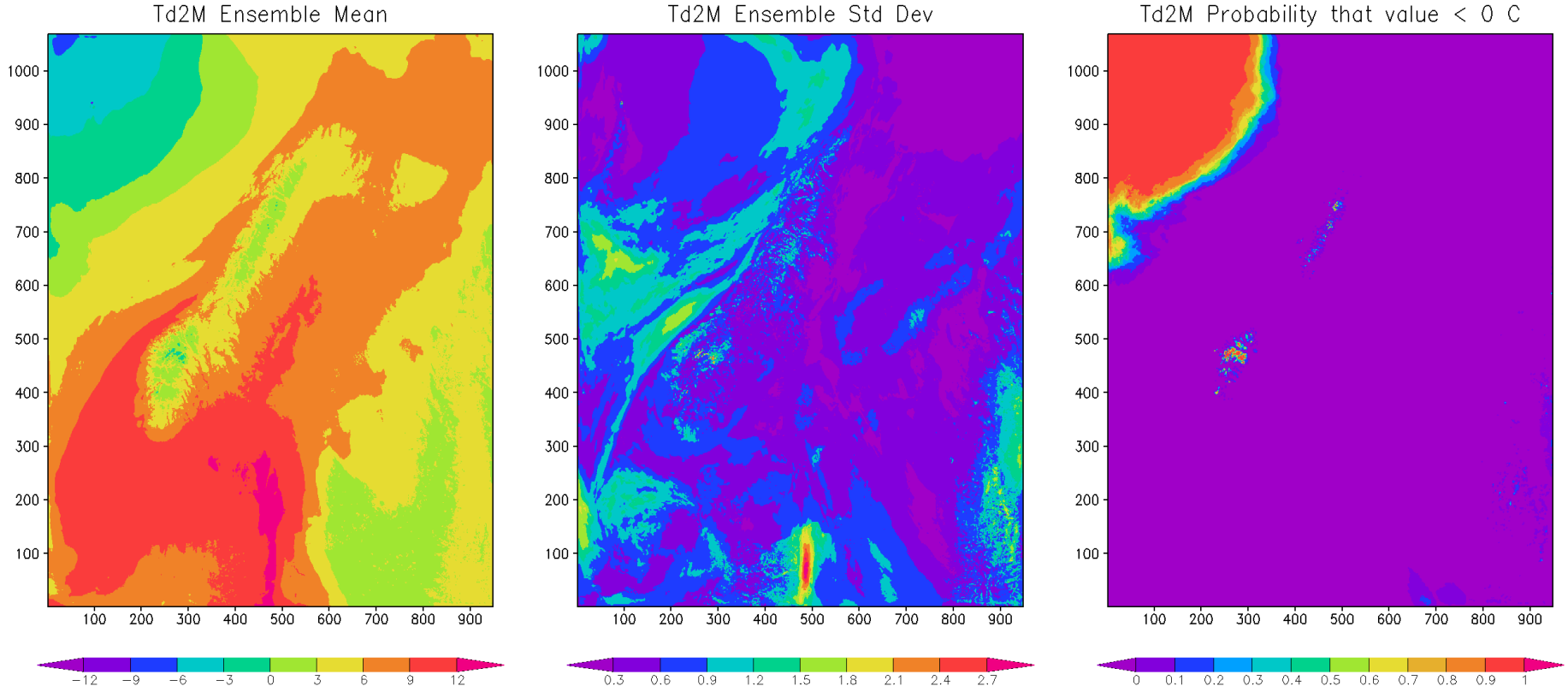

Z500 Ensemble Mean and Std Dev
Forecast from 04 UTC 28 JUN 2021
Valid at 03 UTC 29 JUN 2021
50
5400
5450
5500
5550
5600
5650
5700
5700
5700
700
1050 1020 990 960 930 900 870 840 810 780 750 720 690 660 630 600 570 540 510 480 450 420 390 360 330 300 270 240 210 180 150 120 90 60 30
90 180 270 360 450 540 630 720 810 900
0 3 6 9 12 15 18 21 24 27 30

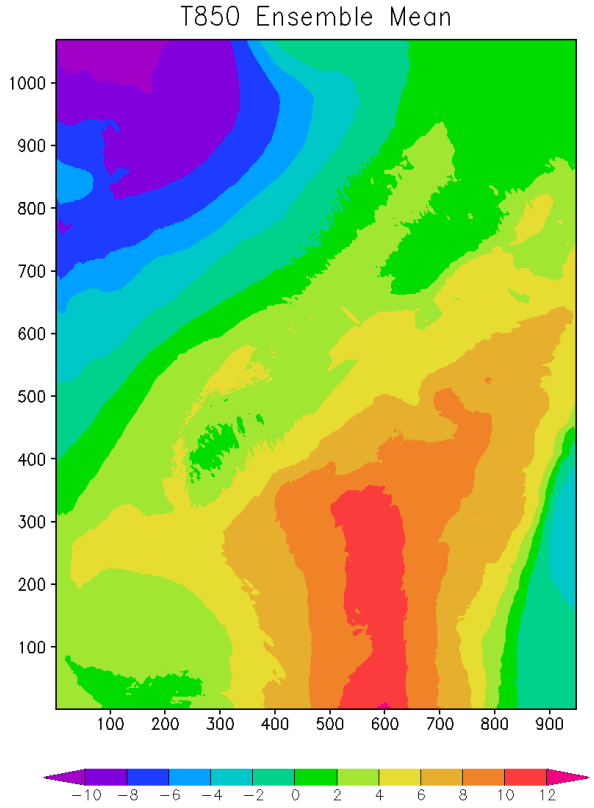

Z500 Ensemble Mean
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
5350 5400 5450 5500 5550 5600 5650 5700 5750

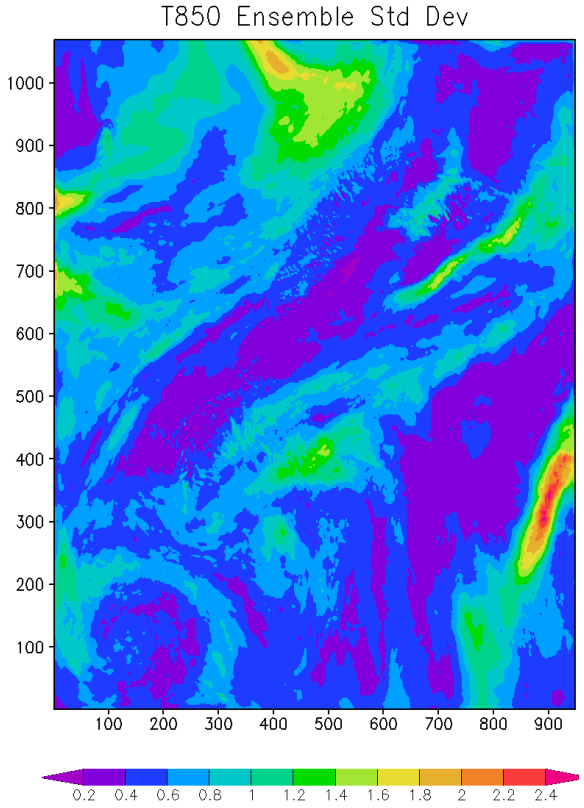

Z500 Ensemble Std Dev
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
0 3 6 9 12 15 18 21 24 27 30

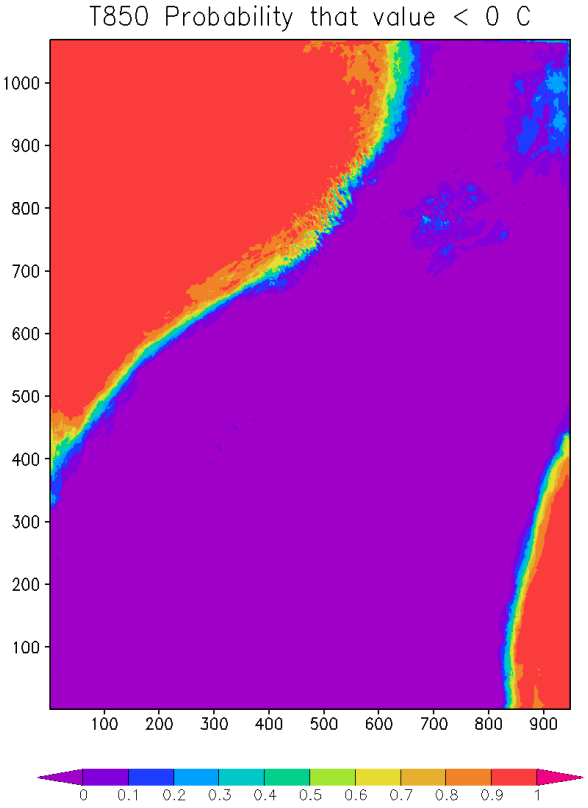

Z500 Ensemble Mean and Std Dev
Forecast from 04 UTC 28 JUN 2021
Valid at 03 UTC 29 JUN 2021
5400
5450
5500
5550
5600
5650
5700
5700
5700
5700
90 180 270 360 450 540 630 720 810 900
0 3 6 9 12 15 18 21 24 27 30

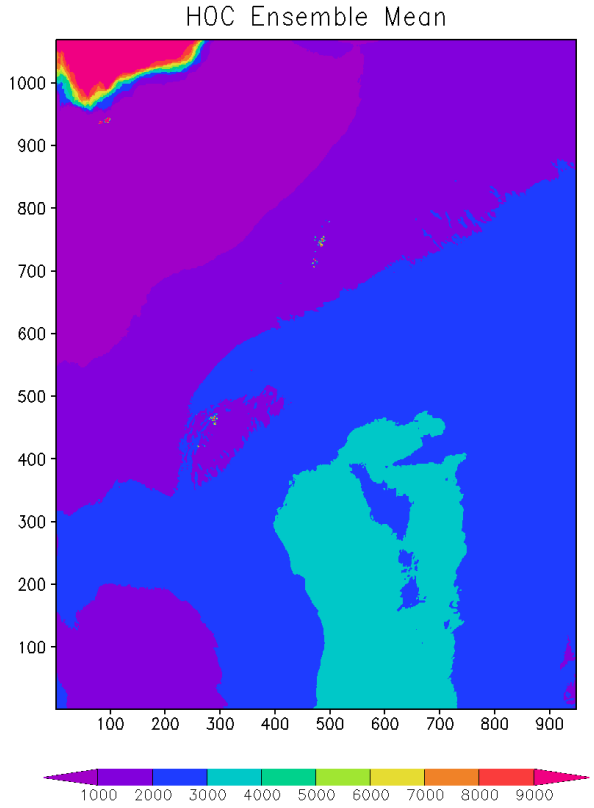

T2M Ensemble Mean
T2M Ensemble Std Dev
T2M Probability that value < 0 C
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
−9 −6 −3 0 3 6 9 12 15
0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4 2.7
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

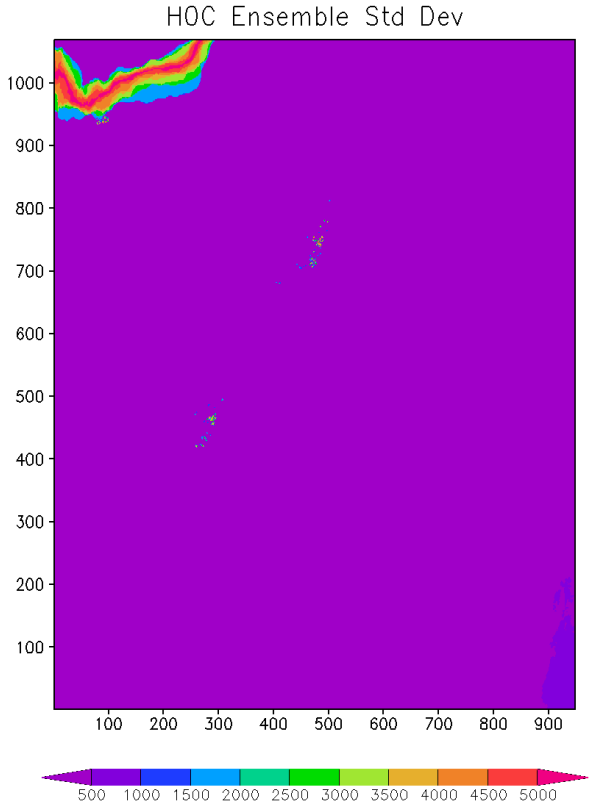

Td2M Ensemble Mean
Td2M Ensemble Std Dev
Td2M Probability that value < 0 C
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
−12 −9 −6 −3 0 3 6 9 12
0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4 2.7
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

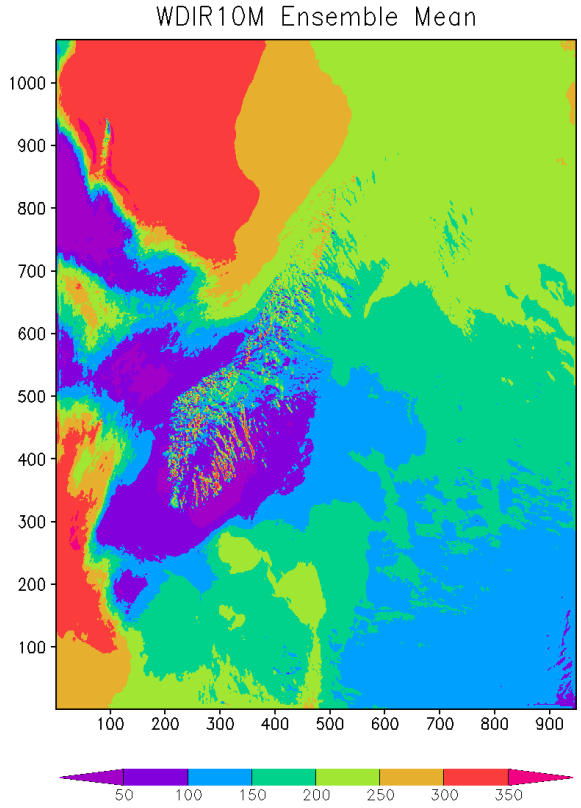

T850 Ensemble Mean
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
−10 −8 −6 −4 −2 0 2 4 6 8 10 12

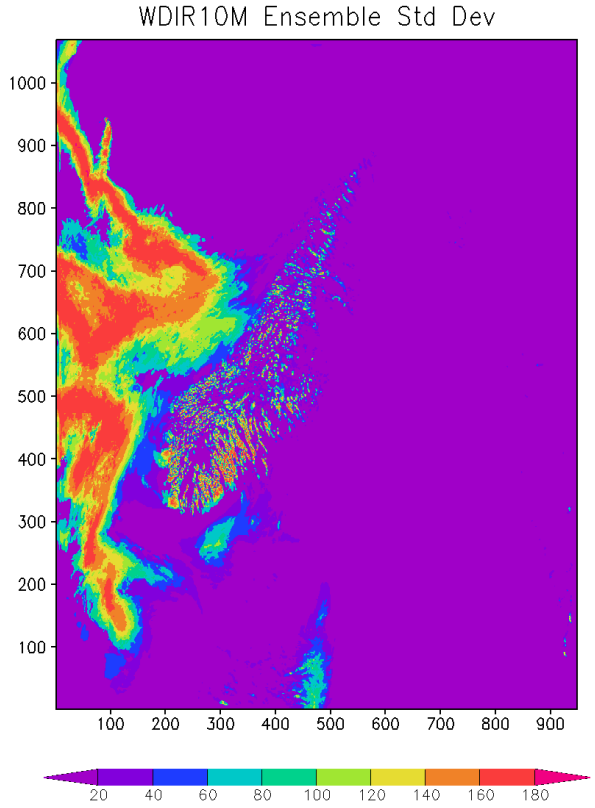

T850 Ensemble Std Dev
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4

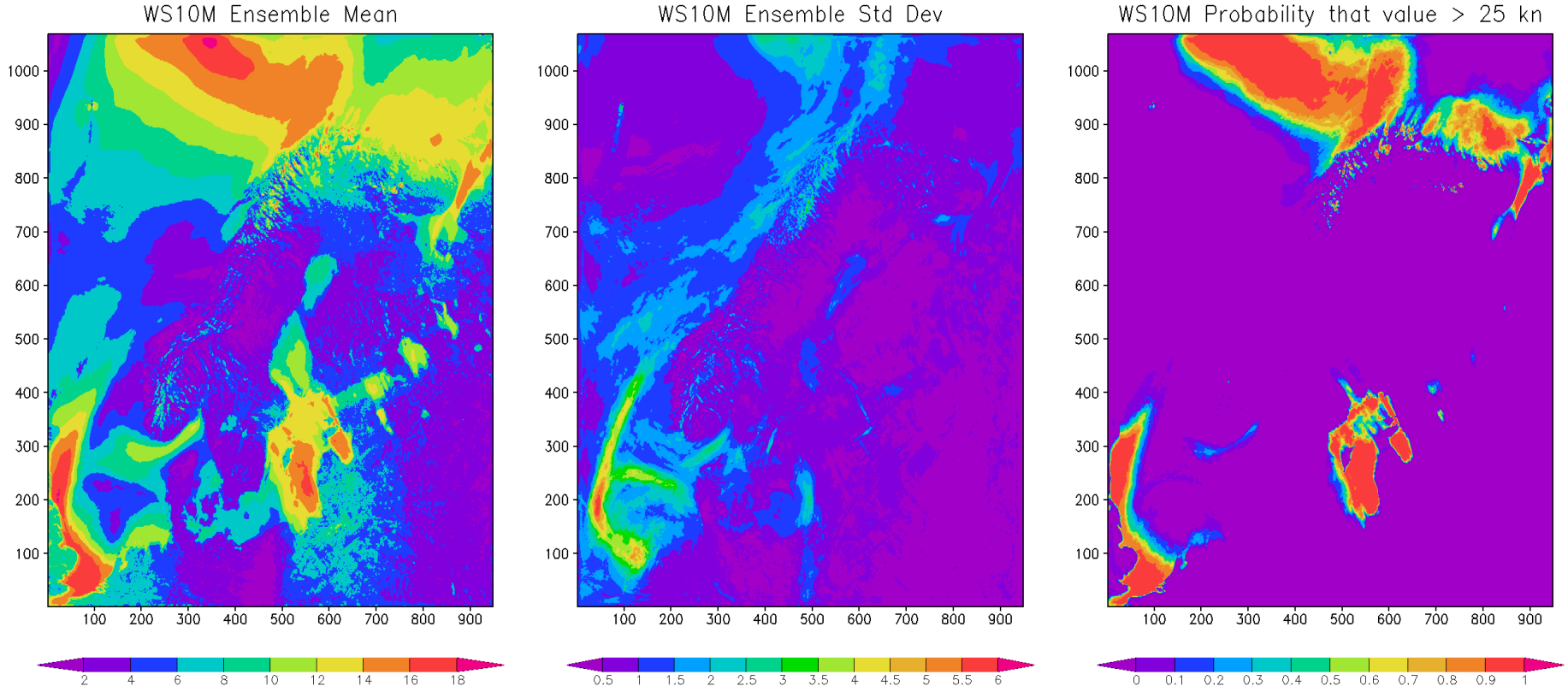

T850 Probability that value < 0 C
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

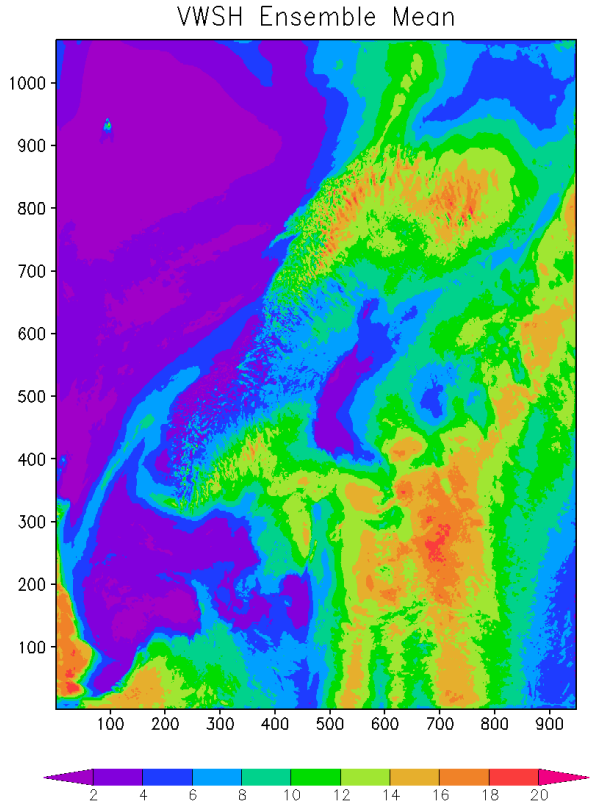

HOC Ensemble Mean
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
1000 2000 3000 4000 5000 6000 7000 8000 9000

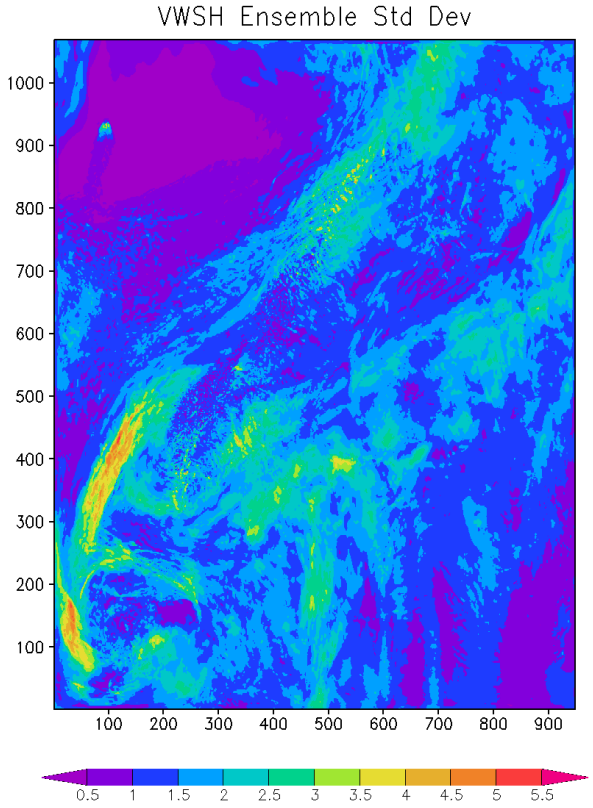

HOC Ensemble Std Dev
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
500 1000 1500 2000 2500 3000 3500 4000 4500 5000

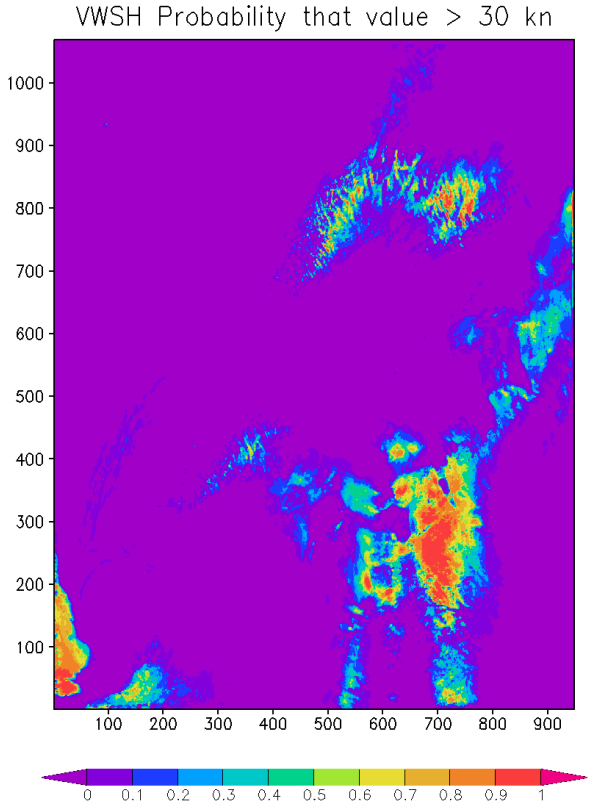

WDIR10M Ensemble Mean
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
50 100 150 200 250 300 350

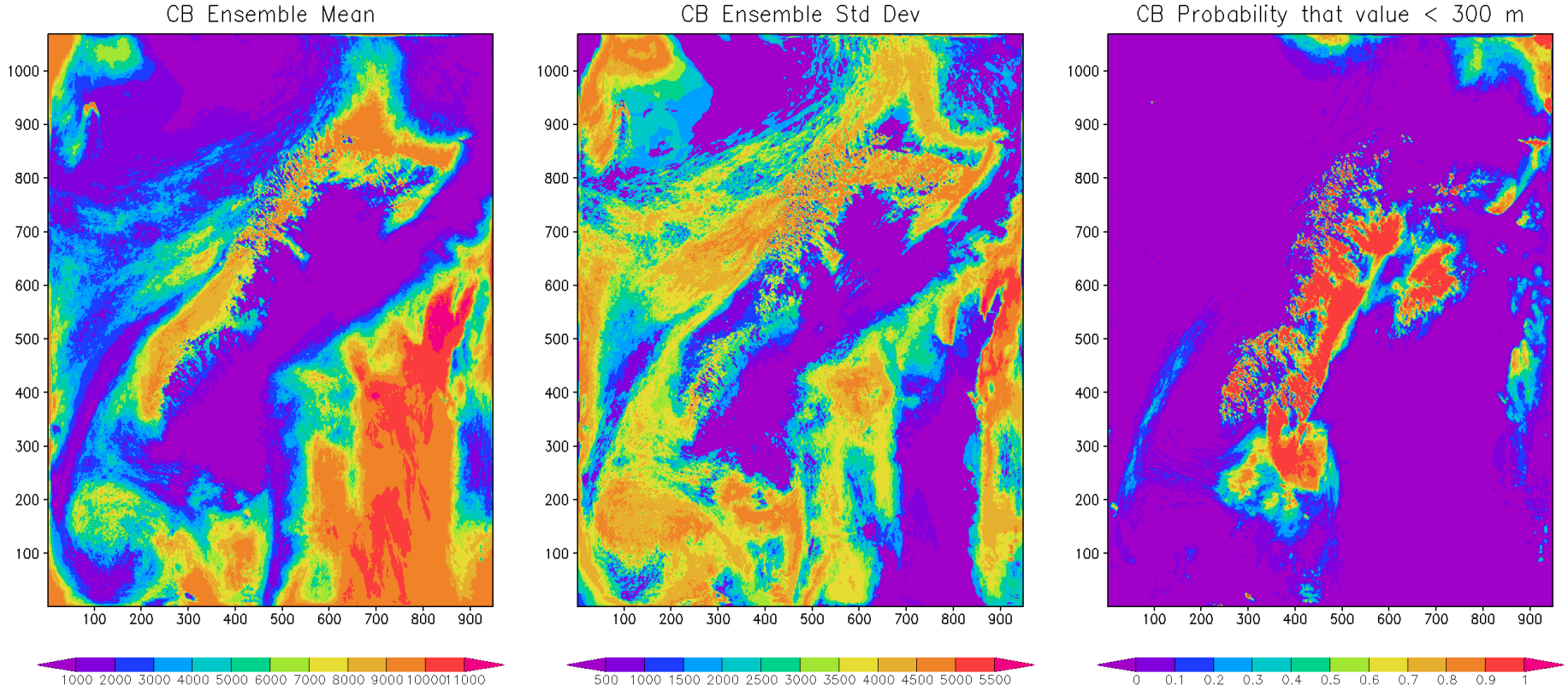

WDIR10M Ensemble Std Dev
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
20 40 60 80 100 120 140 160 180

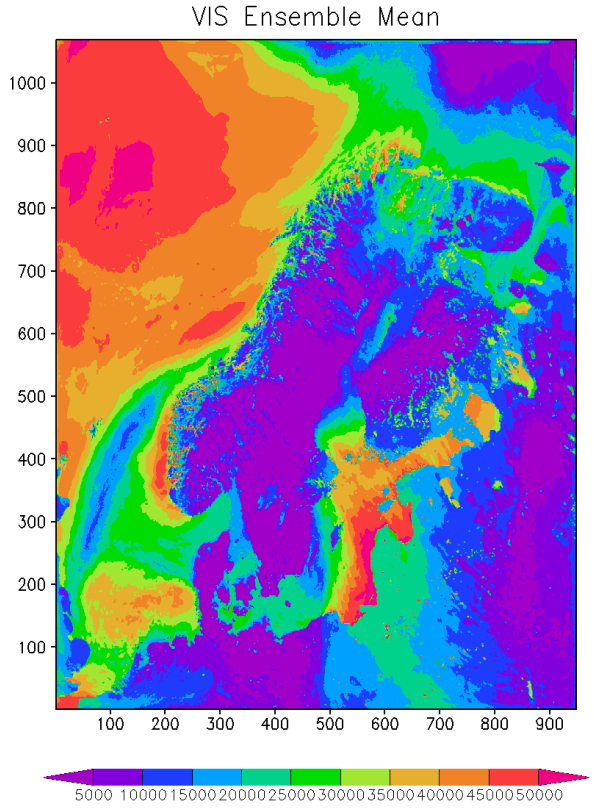

WS10M Ensemble Mean
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
2 4 6 8 10 12 14 16 18
WS10M Ensemble Std Dev
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6
WS10M Probability that value > 25 kn
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

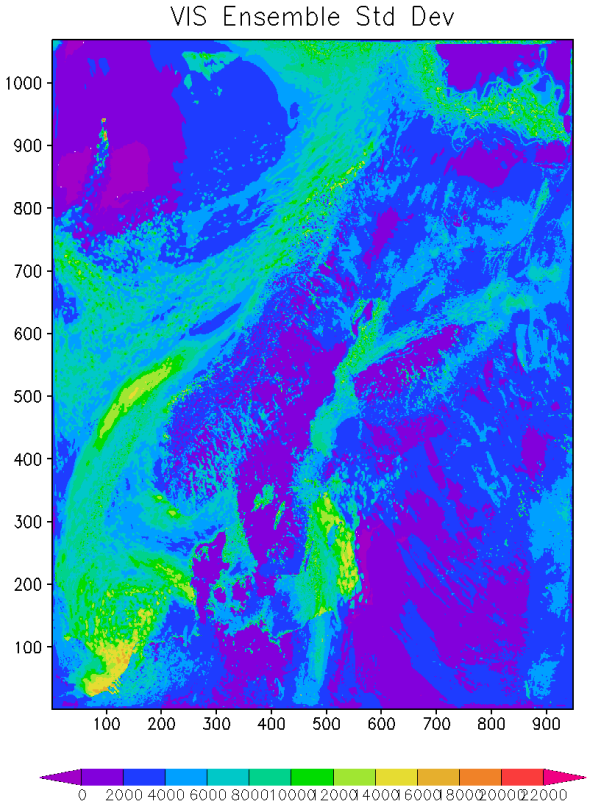

VWSH Ensemble Mean
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
2 4 6 8 10 12 14 16 18 20

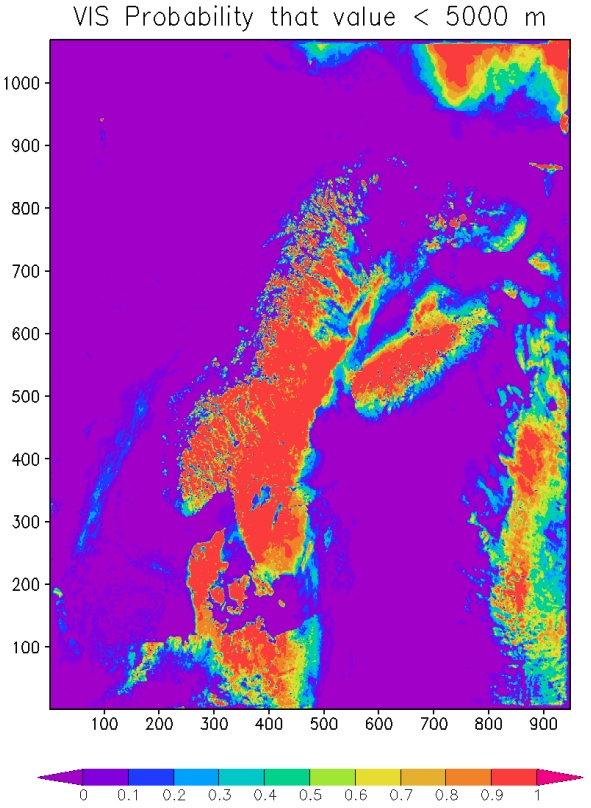

VWSH Ensemble Std Dev
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5


VWSH Probability that value > 30 kn
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1


CB Ensemble Mean
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000
CB Ensemble Std Dev
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500
CB Probability that value < 300 m
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1


VIS Ensemble Mean
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
5000 10000 15000 20000 25000 30000 35000 40000 45000 50000


VIS Ensemble Std Dev
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
0 2000 4000 6000 8000 10000 12000 14000 16000 18000 20000 22000


VIS Probability that value < 5000 m
1000
900
800
700
600
500
400
300
200
100
100 200 300 400 500 600 700 800 900
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

2022