

Subseasonal Outlook for Extratropical Storminess using NCEP Dynamical Ensembles

Edmund K.M. Chang (Stony Brook University),
Yutong Pan (CPC), Wanqiu Wang (CPC),
and Cheng Zheng (Columbia)

Outline

- Part I: Background Information
 - Storminess indices
 - Lagrangian – track density, intensity
 - Eulerian – Sea level pressure variance
 - Hindcast assessment
- Part II: Preliminary assessment of UFS (P5-P8) – courtesy Cheng Zheng
- Part III: Near real time outlook tool – courtesy Yutong Pan

Part I: Background Information

Extratropical cyclones: significant impacts on society and ecosystem

cnn.com (DC February 4, 2010)



Heavy precipitation/snow



NOAA photo library

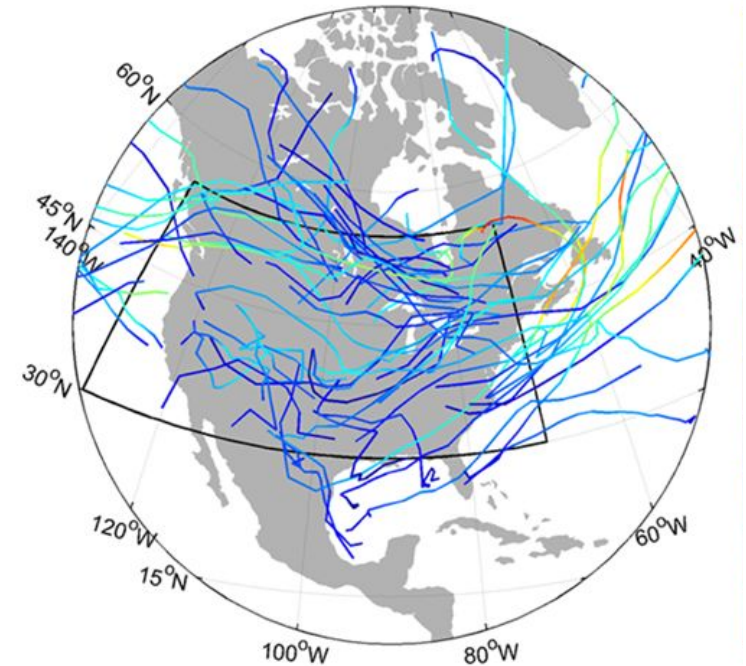


Flooding of train stations during the 1992 nor'easter. Photograph from the Metro New York Hurricane Transport Study, 1995

Storm surge

High winds and waves

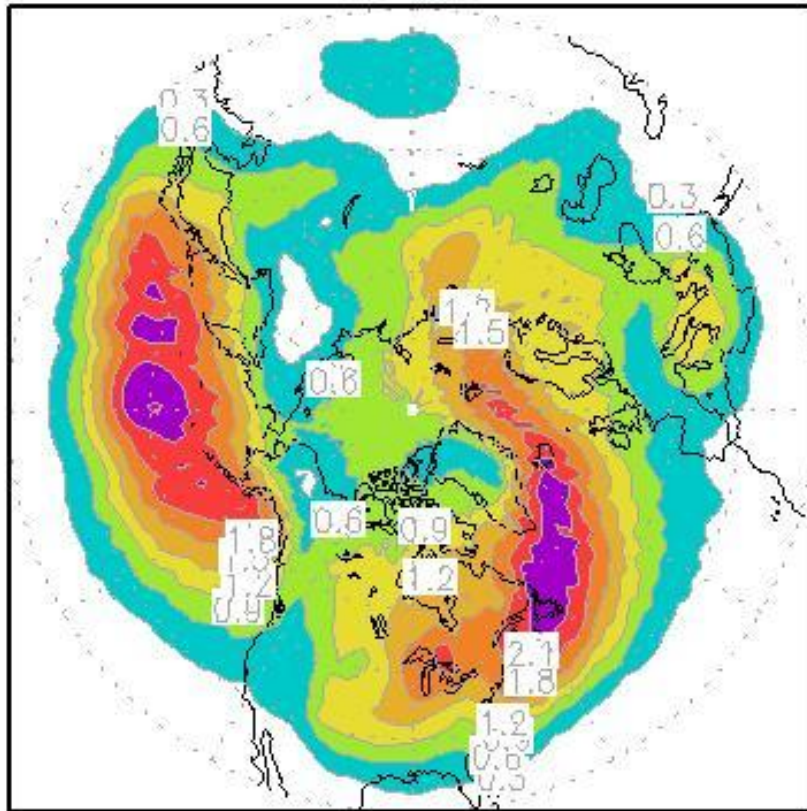
- While individual cyclones (track and intensity) may be predictable out to ~1 week, for week 2 and beyond (including weeks 3-4), storm statistics, or “storminess” is more useful
- Two definitions of **storminess**
 - Lagrangian: Based on statistics of cyclone tracks
 - Track frequency, cyclone amplitude (Yau and Chang, 2020)
 - Eulerian: Based on synoptic timescale variance statistics
 - Sea Level Pressure (SLP) variance
 - Eddy Kinetic Energy (EKE)
 - Both Lagrangian and Eulerian cyclone statistics are highly correlated with significant weather – precipitation and high winds (Yau and Chang, 2020)



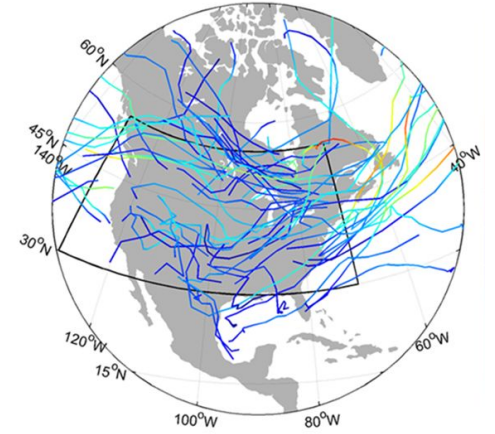
Lagrangian Track Statistics:

GEFSv12 Climatology – Weeks 3-4 DJF 1999-2016

Track Freq



All Cyclones



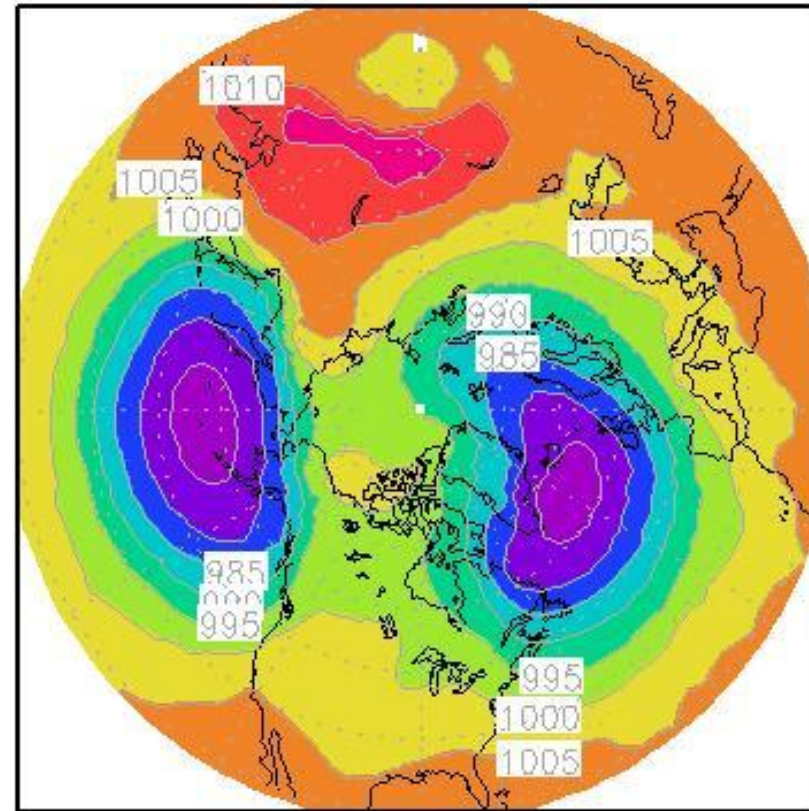
Track frequency (or density):
Number of cyclones that passes within 500 km of each grid point within the period (each cyclone only counted once)

Lagrangian Track Statistics:

GEFSv12 Climatology – Weeks 3-4 DJF 1999-2016

Track Amp

Track Amplitude (or intensity):
Average of the maximum
intensity of all cyclones that pass
within 500 km of each grid point
during the period (each cyclone
only counted once)



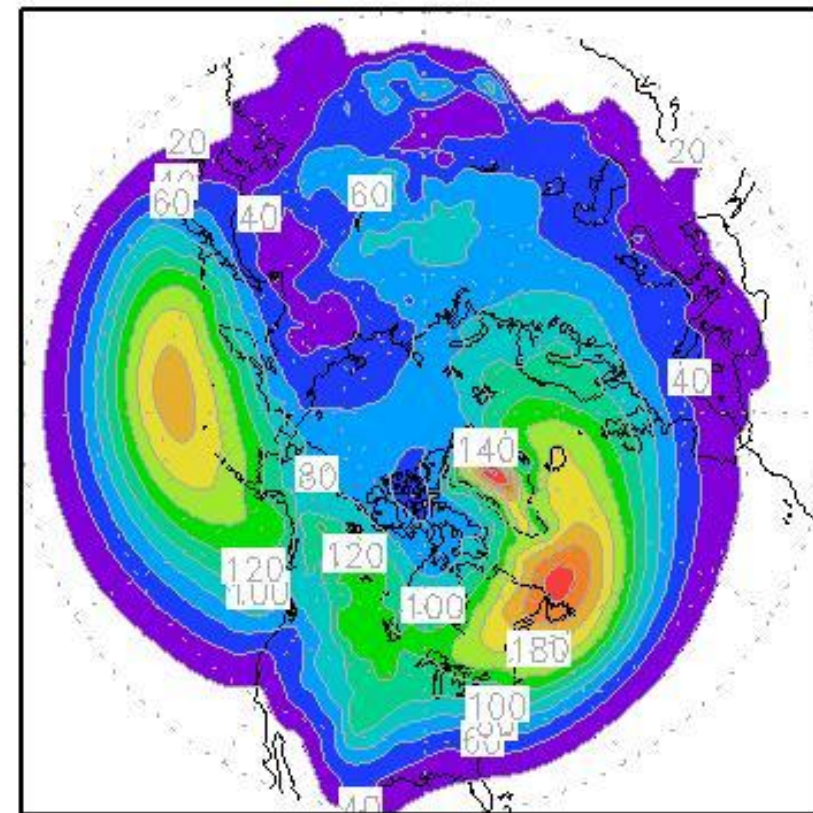
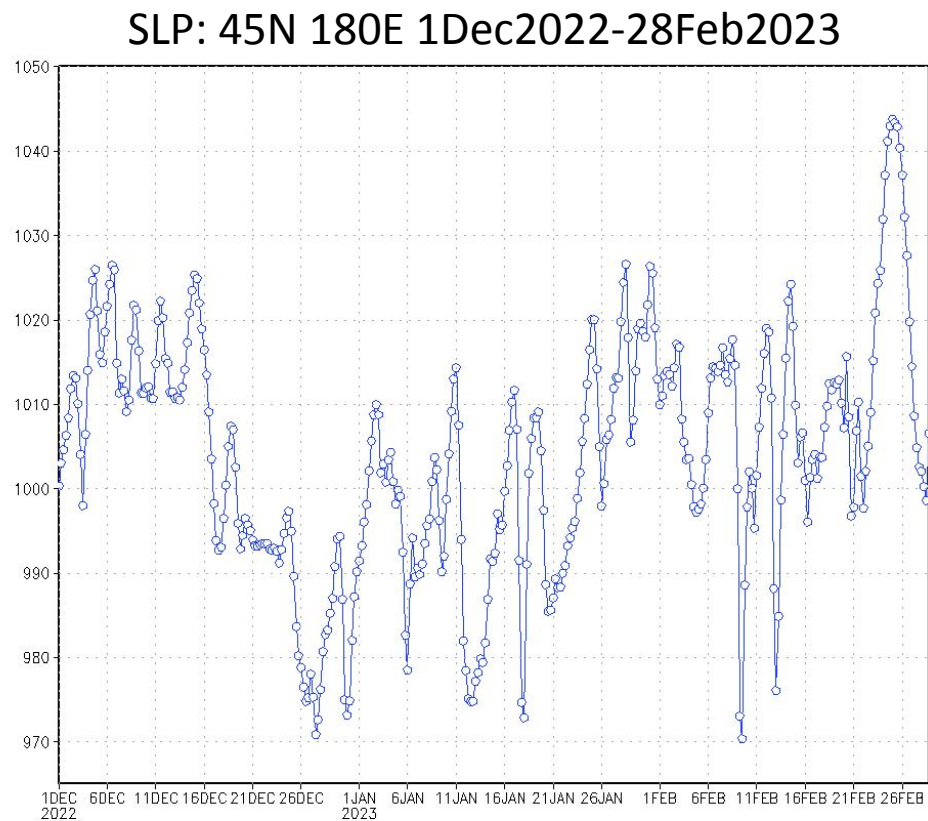
All Cyclones

Eulerian Cyclone Statistics: (Extratropical Cyclone Activity - ECA)

$$EApp = \overline{[(SLP(t + 24hr) - SLP(t))]^2}$$

GEFSv12 Climatology – Weeks 3-4 DJF 1999-2016

EApp

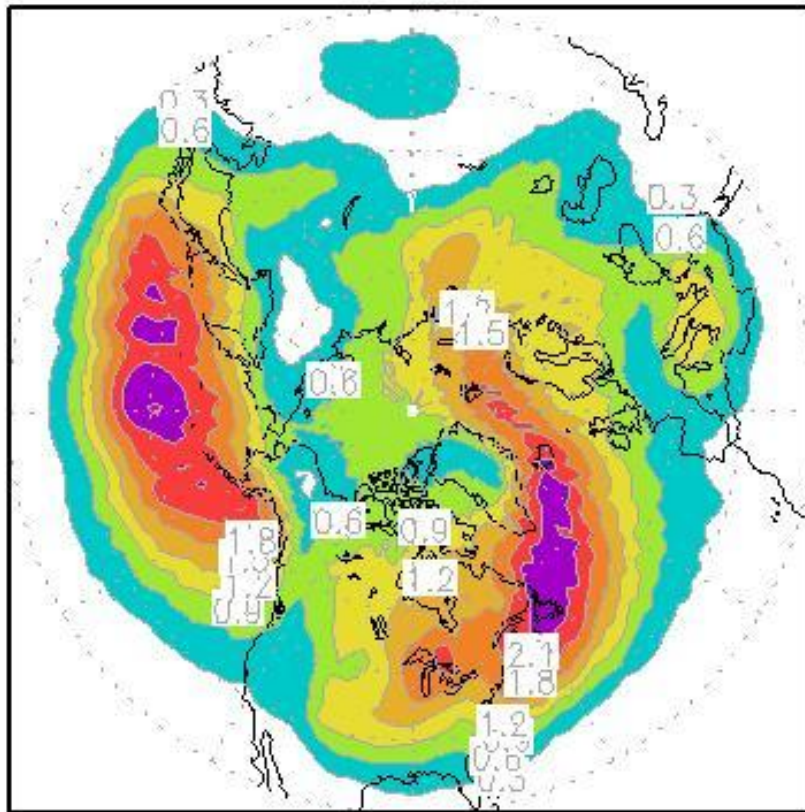


Eulerian Cyclone Statistics:
(Extratropical Cyclone Activity - ECA)

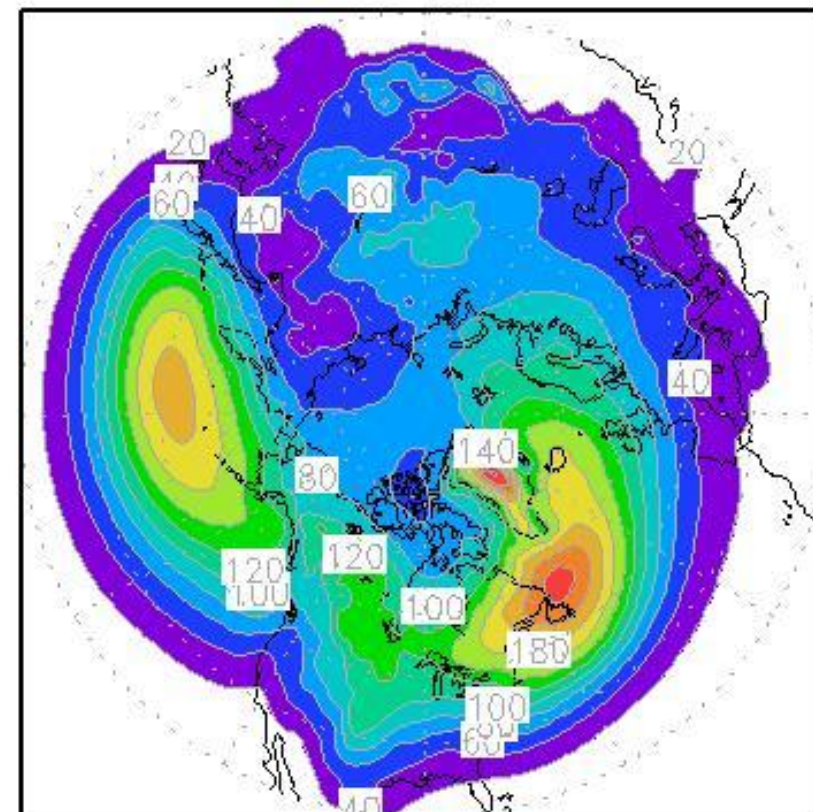
$$EApp = \overline{[(SLP(t + 24hr) - SLP(t))]^2}$$

GEFSv12 Climatology – Weeks 3-4 DJF 1999-2016

Track Freq



EApp



All Cyclones

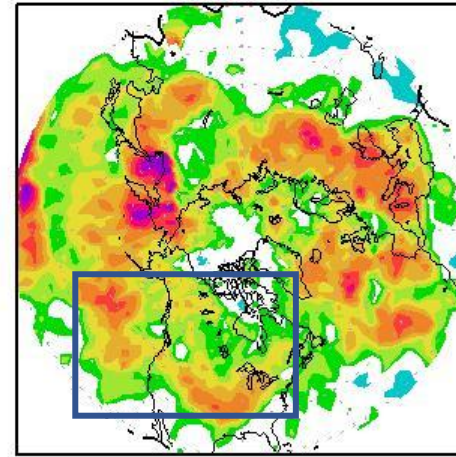
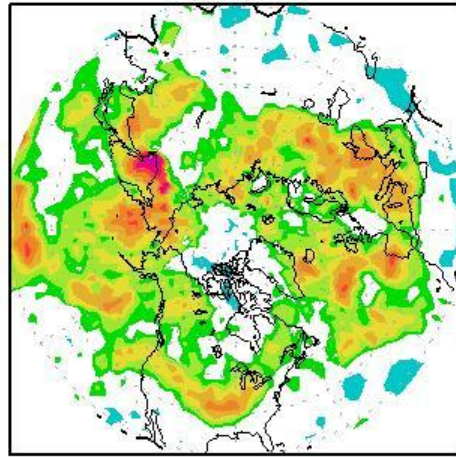
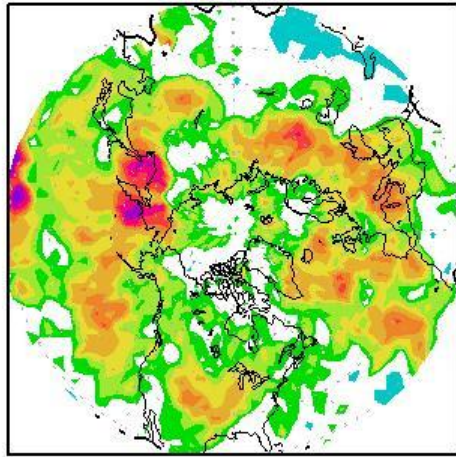
Hindcast Assessment: Data and Method

- GFSv12 reforecasts (1999-2016)
 - Initialized once every week, 11-member ensemble
 - 6 hrly SLP data, $0.5^{\circ} \times 0.5^{\circ}$ smoothed to $1^{\circ} \times 1^{\circ}$
- CFSv2 reforecasts and operational forecasts (1999-2016)
 - Reforecasts initialized once every 6-hr with only one member
 - Lagged ensemble using 12 members (up to nearly 3 days old)
 - 6 hrly SLP data, $1^{\circ} \times 1^{\circ}$
- Cyclone tracking – use tracker of Mark Serreze (1995)
 - Tested using Hodges (Reading U.) tracker – very similar verification results
- Verification – compare with reanalysis (CFSR and ERA5)
 - Anomaly correlation coefficient (ACC) between reforecast and reanalysis

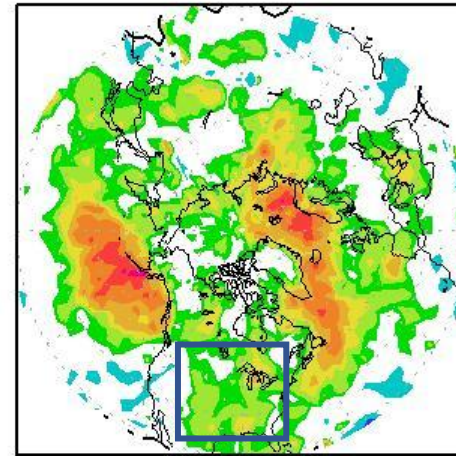
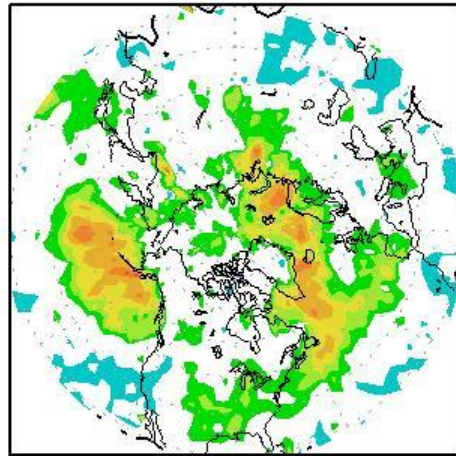
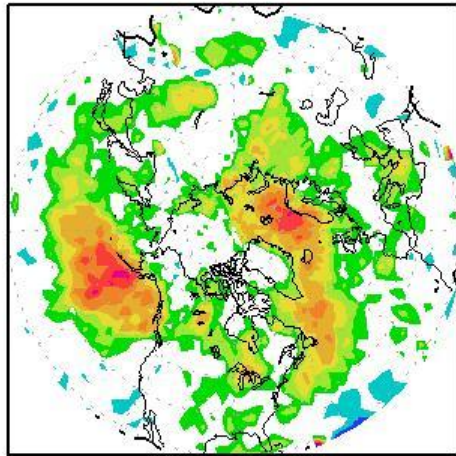
Verification Results – Week 2: All Cyclones (DJF)

GEFSv12 (11-mem) CFSv2 (12-mem) Combined (23-mem)

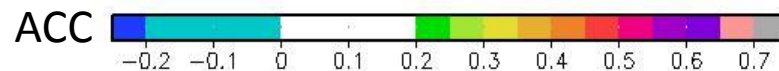
Track Frequency



Track Amplitude



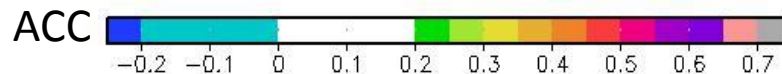
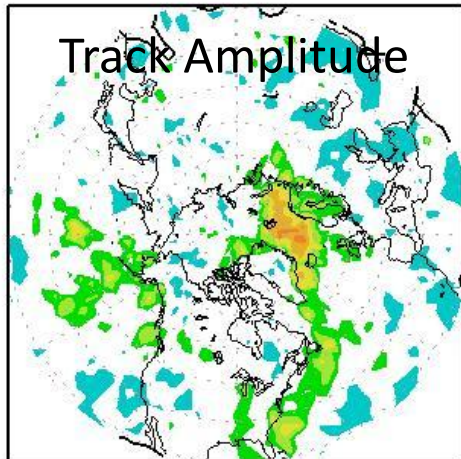
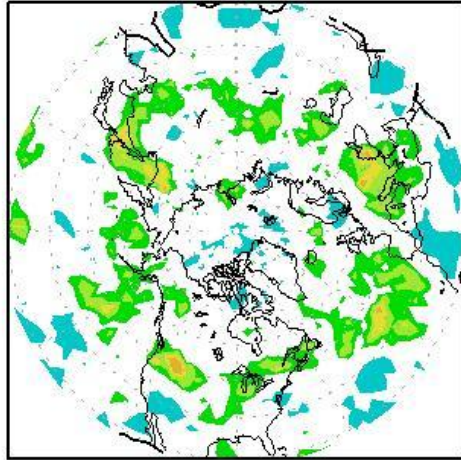
- ACC for GEFSv12 higher than CFSv2
- Combined ensemble better than either
 - True for all cases
- From now on will only show results for combined ensemble



Verification Results – Weeks 3/4: DJF (combined ens)

All Cyclones

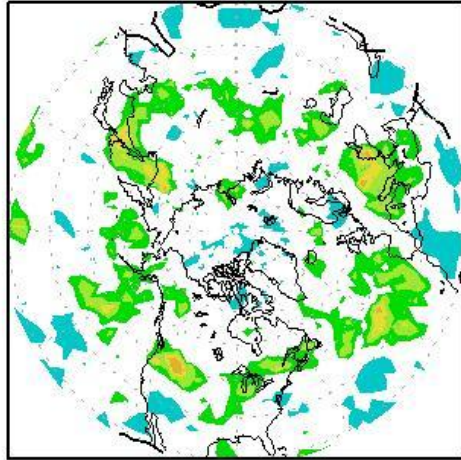
Track
Frequency



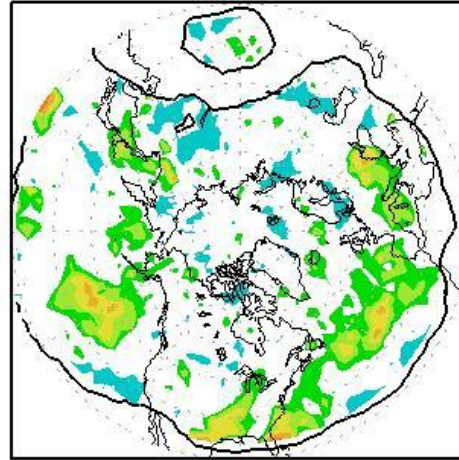
- ACC for weeks 3-4 much lower than those for week 2
- Only rather low ability in predicting either track frequency or track amplitude

Verification Results – Weeks 3/4: DJF (combined ens)

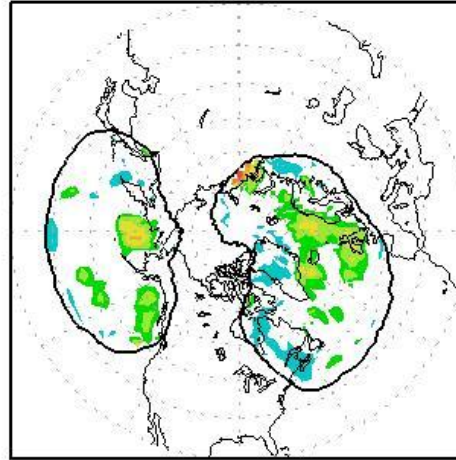
All Cyclones



Mod Cyclones
 $P < 1000$ hPa

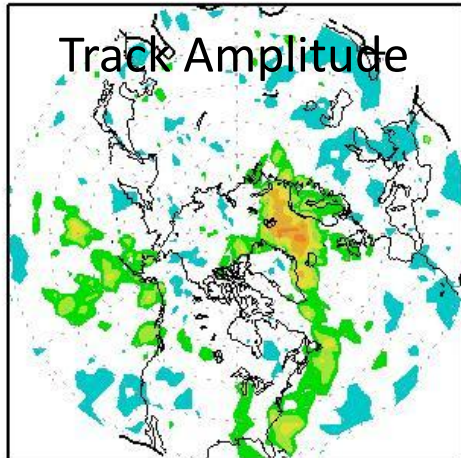


Deep Cyclones
 $P < 970$ hPa



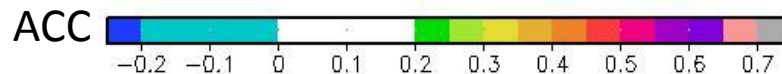
Track
Frequency

Track Amplitude



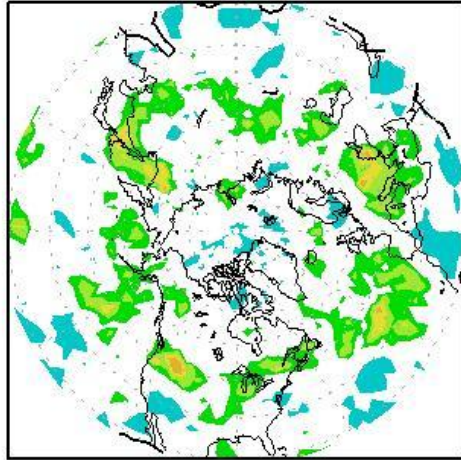
Only over regions
where Track
Frequency > 0.01 per
week (thick black
lines)

- ACC for moderate cyclones slightly better
- Very little ability for predicting frequency of deep cyclones

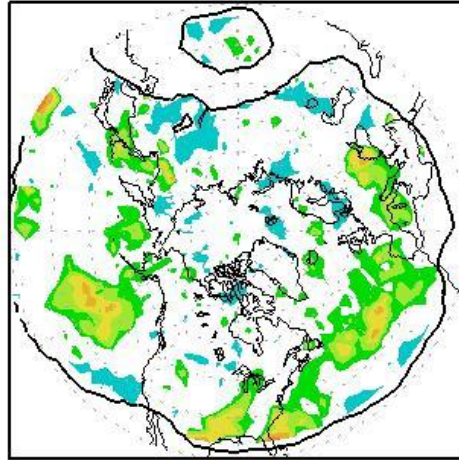


Verification Results – Weeks 3/4: DJF (combined ens)

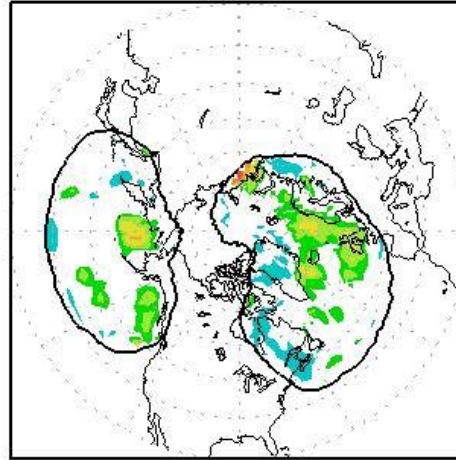
All Cyclones



Mod Cyclones
 $P < 1000$ hPa

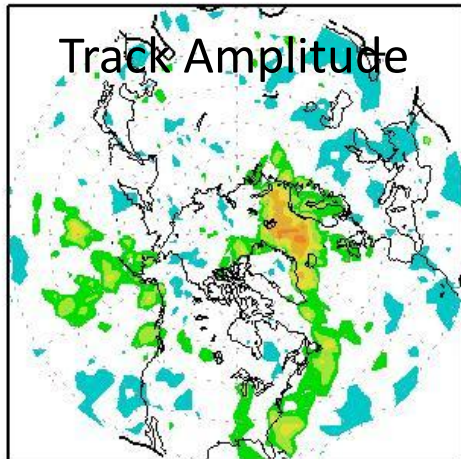


Deep Cyclones
 $P < 970$ hPa



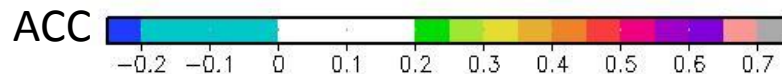
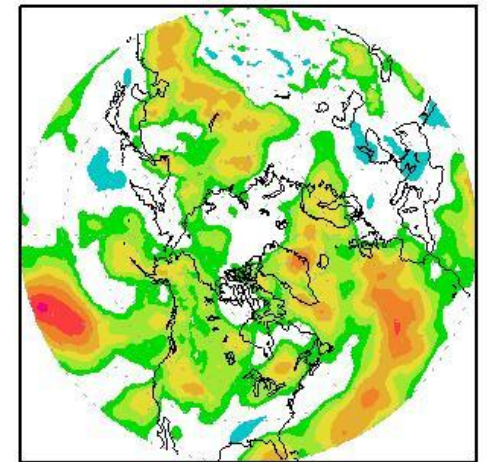
Track
Frequency

Track Amplitude

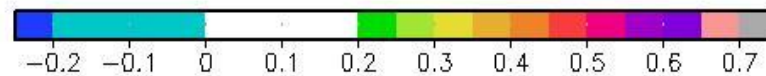
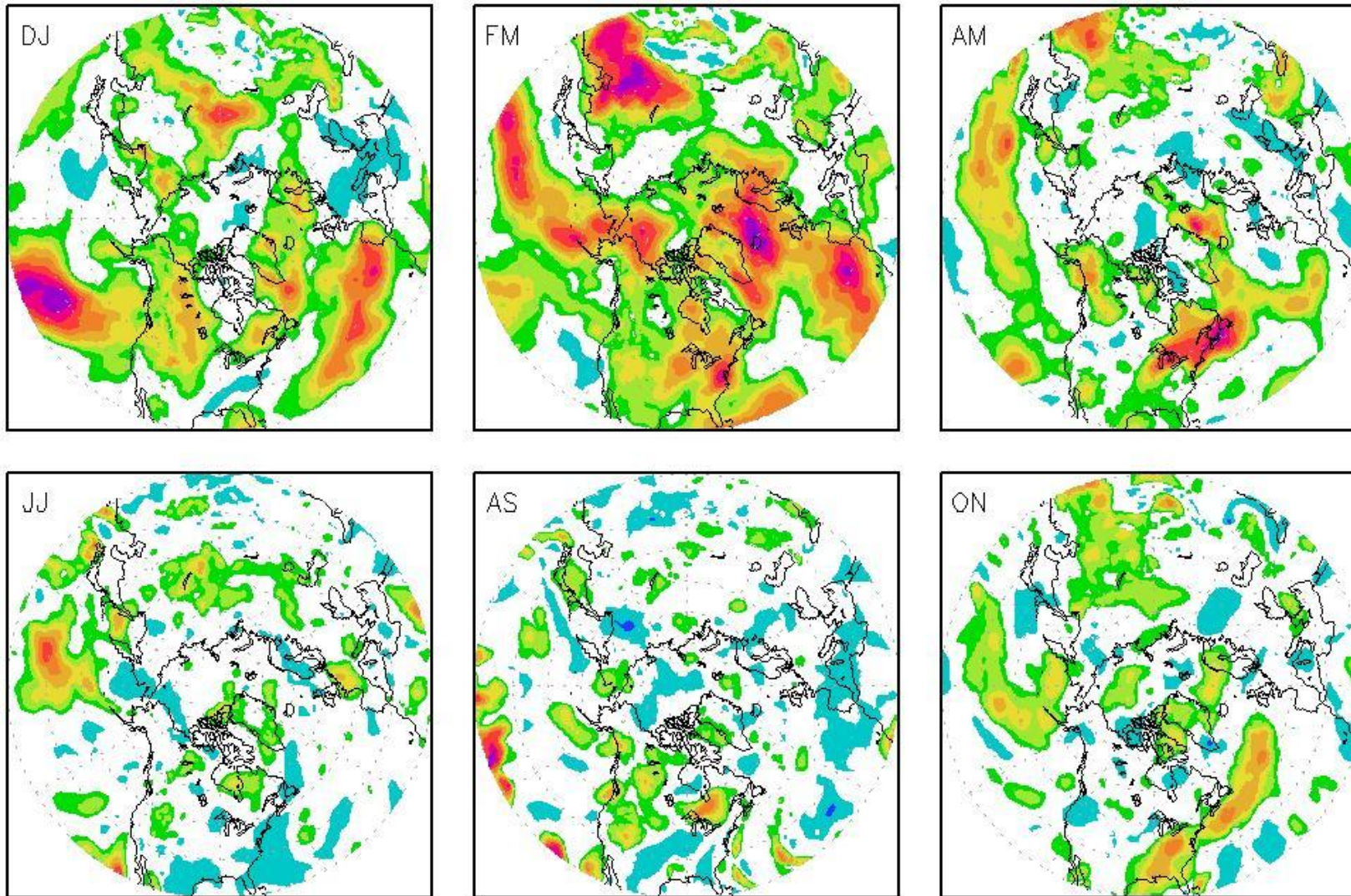


- ACC for SLP variance (EApp) much higher than those for track statistics
- Some ability near Alaska, eastern Pacific, North America, Atlantic, and East Asia

EApp



Seasonal variations in ACC for SLP variance statistics (Weeks 3/4)



23-members

Discussion

- Combined GEFsv12/CFSv2 ensemble consistently does better than either individual ensemble – for all cases
- For Lagrangian track statistics:
 - Week 2 (DJF) ability quite good for both track frequency and amplitude
 - Weeks 3-4 ability for predicting track statistics quite low
- Much higher ACC for ECApp (SLP variance)
- Highest ACC for DJFM, lowest for summer
- Lagrangian statistics (track frequency and intensity) more intuitive to forecasters, but SLP variance much better predicted by models
- Sources of predictability for weeks 3-4 storminess?
 - Modulation by large-scale, low frequency climate variability (Zheng et al., 2018)
 - ENSO and Polar vortex modulations seem to be captured by models
 - MJO and QBO modulations not well captured

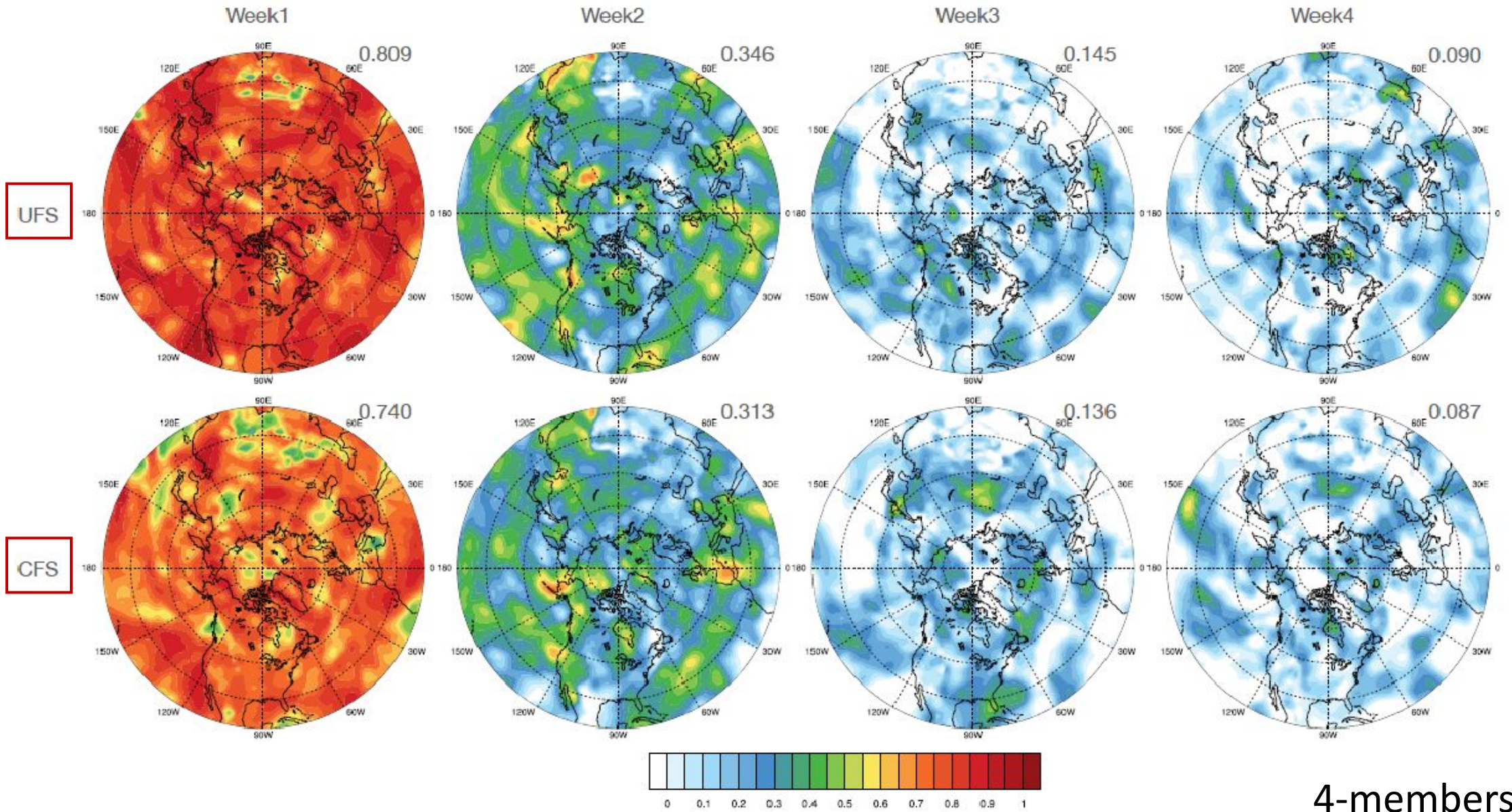
Part II: Preliminary Assessment of UFS products

- UFS prototype versions: P5, P6, P7, and P8
- Hindcasts: Nov-Mar 2011-2018, 00Z 1st and 15th of each month
 - Total of 70 hindcasts
 - 1 ensemble member each
- For comparison: CFSv2 hindcasts and operational forecasts
 - Same initialization days
 - 1 member each at 00z, 06z, 12z, and 18z
- Storminess: Eulerian SLP variance (EApp)
 - Verified against ERA-Interim reanalysis

2011-2018 Nov-Mar
pp ACC (vs ERA-Interim)

4-member ensemble mean

Top right corner of each panel:
ACC averaged over 20N-90N, 180-0

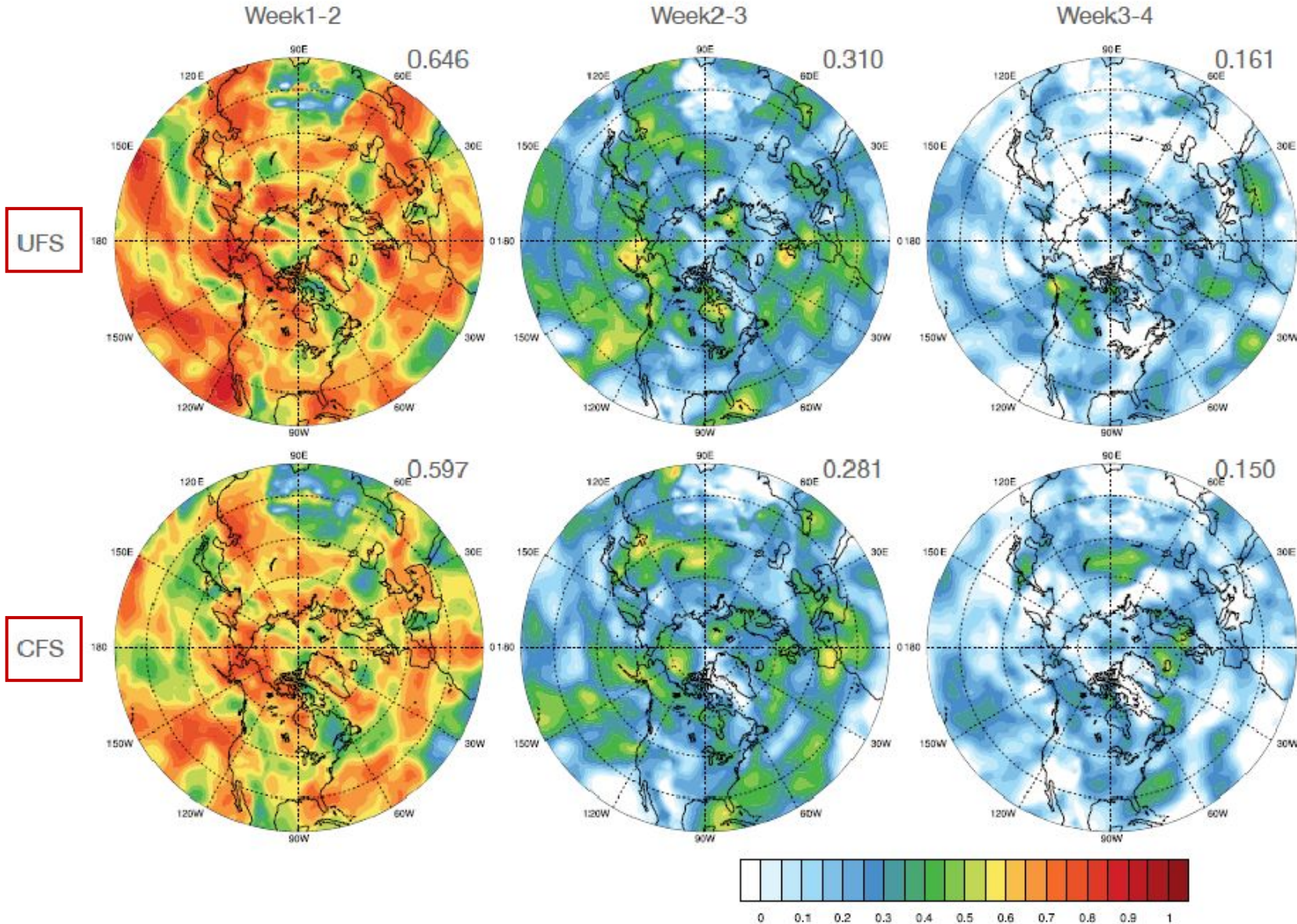


4-members

2011-2018 Nov-Mar
pp ACC (vs ERA-Interim)

4-member ensemble mean

Top right corner of each panel:
ACC averaged over 20N-90N, 180-0



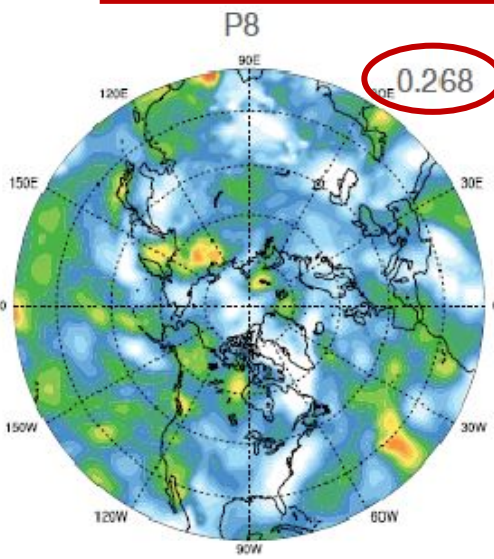
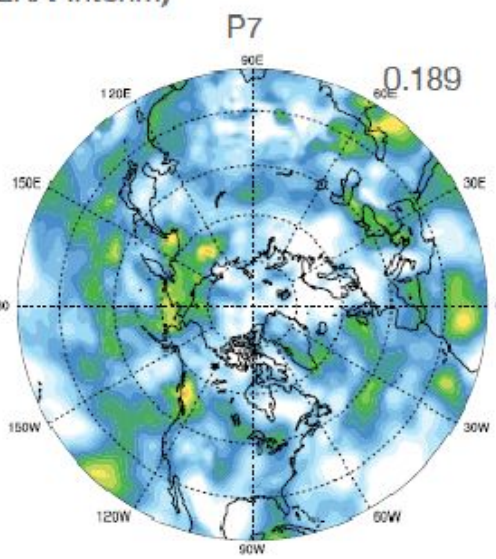
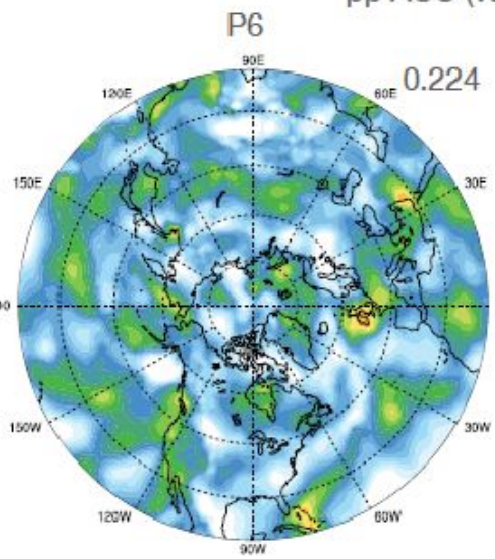
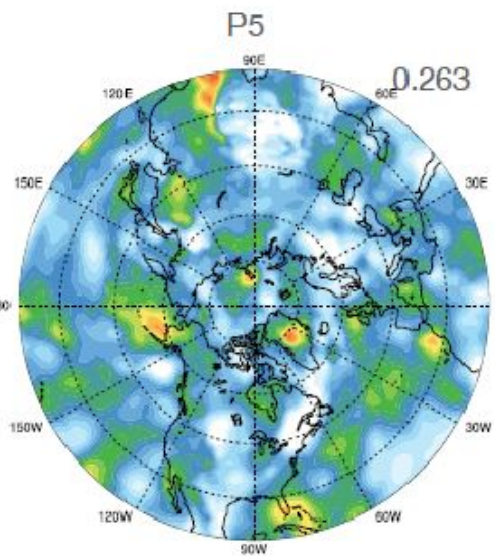
UFS mean slightly better than CFS

4-members

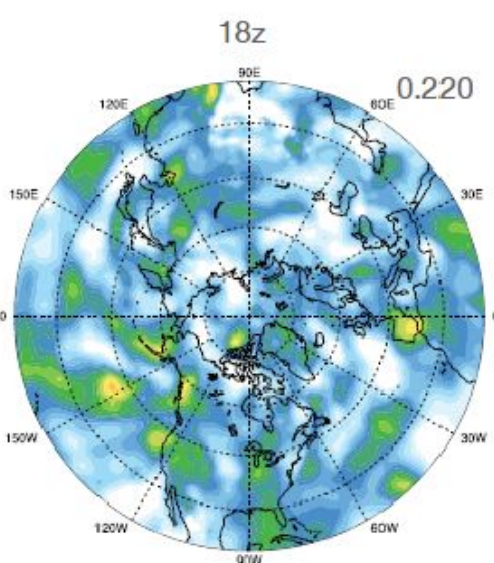
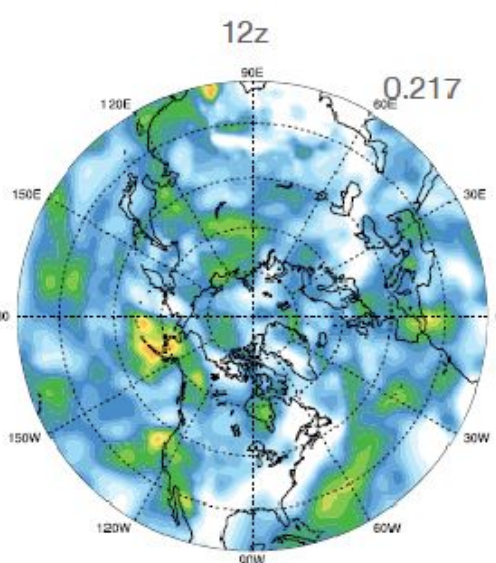
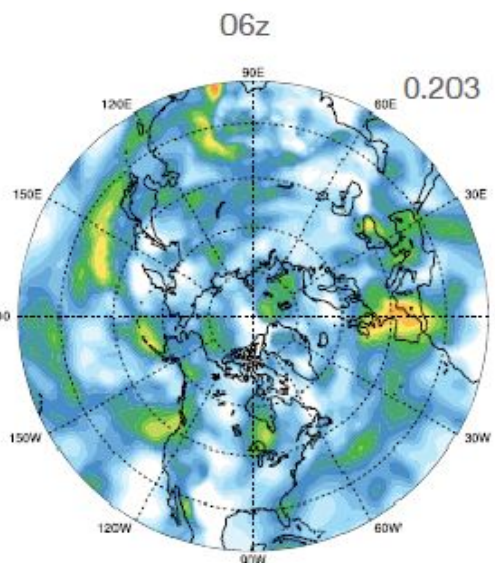
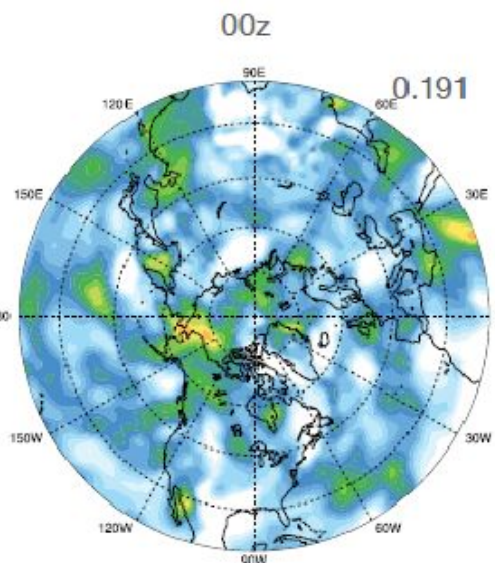
Top right corner of each panel:
ACC averaged over 20N-90N, 180-0

Week2 2011-2018 Nov-Mar pp ACC (vs ERA-Interim) Individual member

UFS



CFS

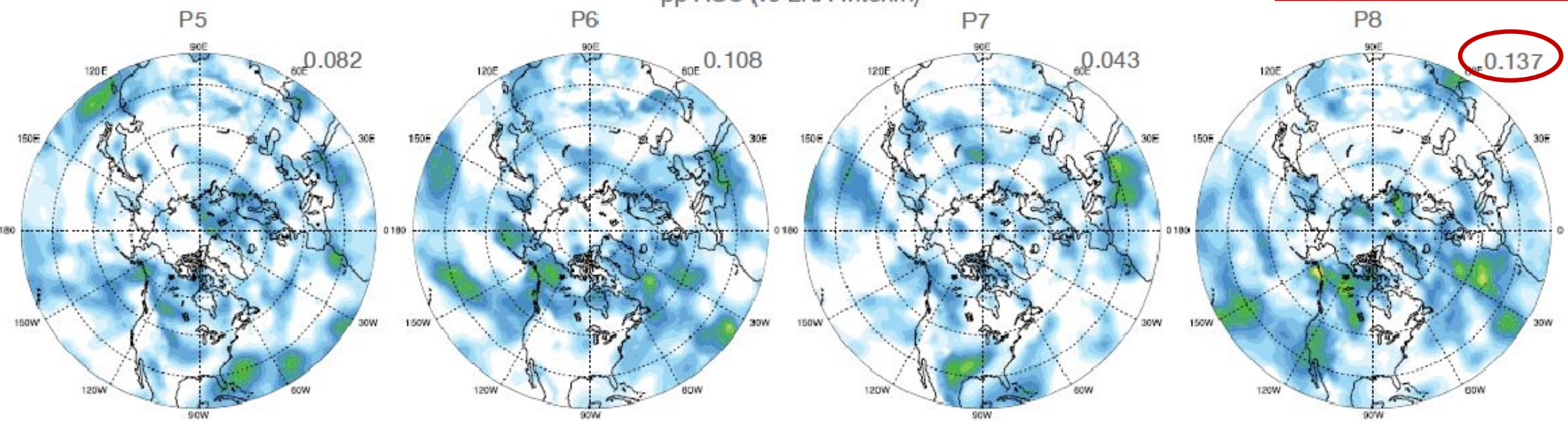


1-member

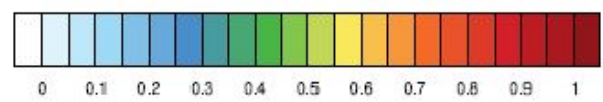
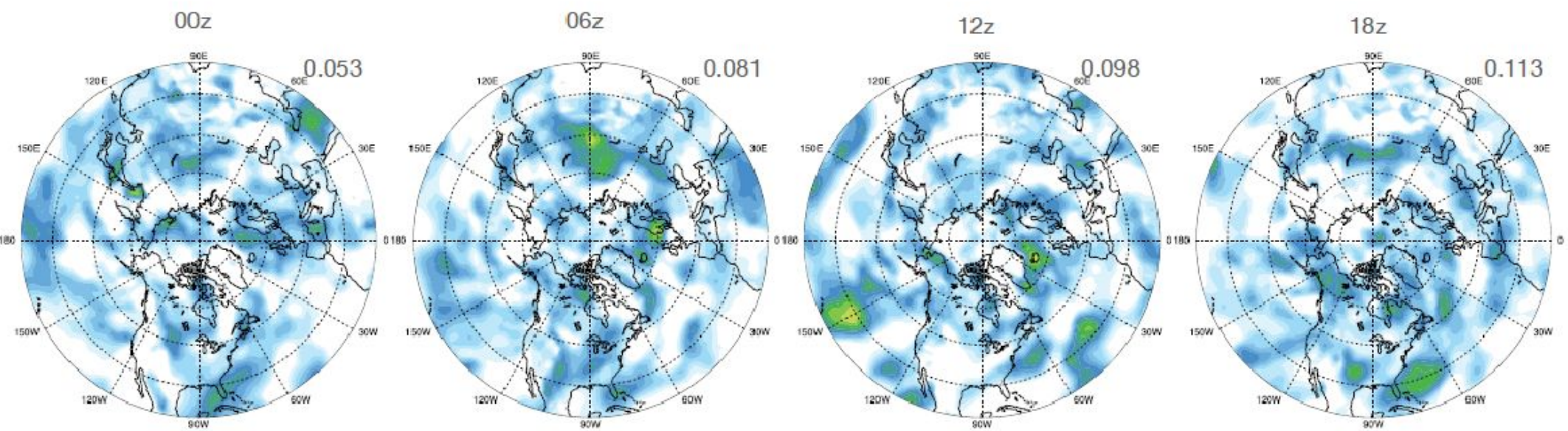
Week3-4 2011-2018 Nov-Mar pp ACC (vs ERA-Interim) Individual member

Top right corner of each panel:
ACC averaged over 20N-90N, 180-0

UFS



CFS



1-member

Discussion

- UFS average ACC better than CFSv2 (even when CFS hindcast starts 18 hours later)
- UFS P8 best, P7 worst
- Caveat: Only 1-member from each version with only 70 hindcasts
 - ACC for ensemble mean should be much higher with large ensembles

Part III: Near Real Time Outlook Tool

Objectives

- To develop a set of subseasonal (week-2 and week 3-4) storm track forecast products to support the NWS Alaska and other regional centers for storm track monitoring and long-lead forecast
- To verify the storminess outlooks

Data

- Model forecasts (6-hourly):
 - GEFSv12 operational 16-day fcst, 124 mbrs (week 2)
 - GEFSv12 operational 35-day fcst, 31 mbrs (weeks 3-4)
 - CFSv2 operational 45-day fcst, 16 mbrs (week 2 and weeks 3-4)

- Observations:
 - Verification: CFSR real time
 - Verification is posted once CFSR data become available

Week-2 and Week 3-4 Outlook Products

- Storm tracks and track density, storm intensity and duration
- Precipitation, 10-m wind
- SLP and day-to-day variance

- Deterministic forecast (ensemble mean)
- Probability forecast (based on distribution of individual member forecasts)
 - Precipitation and 10-m wind speed: exceeding 75th and 90th percentiles
 - Storm intensity: lower than 990, 980, 970, and 960 hPa

Week-2 and Week 3-4 Outlook Web Page

- GEFSv12, CFSv2, GEFSv12+CFSv2 combined storminess outlooks
- Sub-regional maps: Alaska/Arctic, N. Pacific, N. America, and N. Atlantic
- Near real-time storm track outlook and verification are available at:
<https://ftp.cpc.ncep.noaa.gov/hwang/YP/week2/>

NCEP GEFS Week-2 and Week 3-4 Storminess Outlook

For North Pacific, North America, and North Atlantic

Extratropical storm activities have strong societal and economic impacts on mid- and high-latitude regions, including Alaska. To support the NWS Alaska and other regional centers for storm track monitoring and forecasts, a suite of week-2 and week 3-4 storm track outlook products has been developed at CPC based on the dynamical forecast of the NCEP Global Ensemble Forecast System (GEFS).

Extratropical storms are detected and tracked using 6-hourly sea level pressure (SLP) data from the real-time GEFS 16-day and 35-day forecasts and a storm-tracking algorithm (Serreze 1995). The outlooks include storm tracks and track density, storm intensity and duration, precipitation, SLP and 10-m winds, and day-to-day variance of SLP over North Pacific, North America, and North Atlantic, derived from the GEFS week-2 and week 3-4 forecasts for both total and anomaly fields. In addition, GEFS probabilistic forecasts of precipitation and 10-m wind speed exceeding 75th and 90th percentiles, and storm intensity lower than 990, 980, 970, and 960 hPa are also included. Verifications of the real-time forecasts are conducted using the NCEP Climate Forecast System Reanalysis (CFSR). The outlook is updated on a daily basis. More details about this tool are [here](#).

January 2023

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1 ■	2 ■	3 ■	4 ■	5 ■	6 ■	7 ■
8 ■	9 ■	10 ■	11 ■	12 ■	13 ■	14 ■
15 ■	16 ■	17 ■	18 ■	19 ■	20 ■	21 ■
22 ■	23 ■	24 ■	25 ■	26 ■	27 ■	28 ■
29 ■	30 ■	31 ■				

Outlook Products

Regions: Alaska/Arctic, North Pacific, North America, North Atlantic

Variables: Storm tracks, track density, intensity, and duration

7-day precipitation, sea-level pressure, 10-m wind vector and wind speed

Upgrade: Starting from September 24, 2020, forecasts are GEFSv12 based.

GEFSv12: 124-member ensemble forecast

Forecast Archive

2023

| [January](#) | [February](#) | [March](#) | [April](#) | [May](#) | [June](#) | [July](#) |
| [August](#) | [September](#) | [October](#) | [November](#) | [December](#) |

2022

| [January](#) | [February](#) | [March](#) | [April](#) | [May](#) | [June](#) | [July](#) |
| [August](#) | [September](#) | [October](#) | [November](#) | [December](#) |

Initialization: 20230105

NCEP GEFS Subseasonal Storm Track Forecast

Week	Ensemble Members	Northern Hemisphere	Regional Map
Week 2	124	N. Pacific/N. America/N. Atlantic	Alaska/Arctic, N. Pacific, N. America, N. Atlantic
Weeks 3-4	31	N. Pacific/N. America/N. Atlantic	Alaska/Arctic, N. Pacific, N. America, N. Atlantic

Week	Ensemble Members	Regional Storminess Index	Regional Storminess Index
Week 2	124	N. Pacific (177.5°E-140°W, 45°N-57.5°N)	Alaska (177.5°E-140°W, 57.5°N-70°N)
Weeks 3-4	31	N. Pacific (177.5°E-140°W, 45°N-57.5°N)	Alaska (177.5°E-140°W, 57.5°N-70°N)

NCEP CFSv2 Subseasonal Storm Track Forecast

Week	Ensemble Members	Northern Hemisphere	Regional Map
Week 2	16	N. Pacific/N. America/N. Atlantic	Alaska/Arctic, N. Pacific, N. America, N. Atlantic
Weeks 3-4	16	N. Pacific/N. America/N. Atlantic	Alaska/Arctic, N. Pacific, N. America, N. Atlantic

Week	Ensemble Members	Regional Storminess Index	Regional Storminess Index
Week 2	16	N. Pacific (177.5°E-140°W, 45°N-57.5°N)	Alaska (177.5°E-140°W, 57.5°N-70°N)
Weeks 3-4	16	N. Pacific (177.5°E-140°W, 45°N-57.5°N)	Alaska (177.5°E-140°W, 57.5°N-70°N)

GEFS and CFSv2 Ensemble Mean Subseasonal Storm Track Forecast

Week	Ensemble Members	Northern Hemisphere	Regional Map
Week 2	140	N. Pacific/N. America/N. Atlantic	Alaska/Arctic, N. Pacific, N. America, N. Atlantic
Weeks 3-4	47	N. Pacific/N. America/N. Atlantic	Alaska/Arctic, N. Pacific, N. America, N. Atlantic

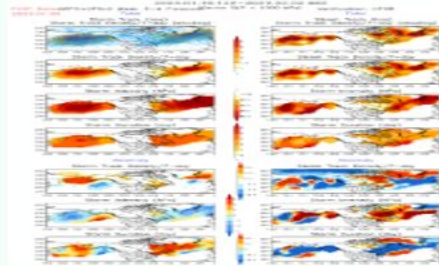
Week	Ensemble Members	Regional Storminess Index	Regional Storminess Index
Week 2	140	N. Pacific (177.5°E-140°W, 45°N-57.5°N)	Alaska (177.5°E-140°W, 57.5°N-70°N)
Weeks 3-4	47	N. Pacific (177.5°E-140°W, 45°N-57.5°N)	Alaska (177.5°E-140°W, 57.5°N-70°N)

GEFS + CFSv2 Week 3-4 Storm Track Forecast

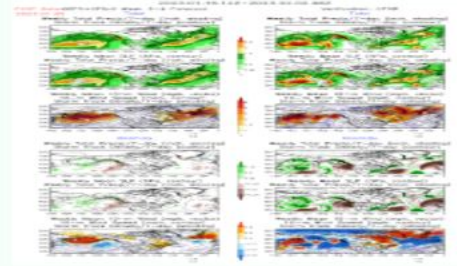
N. Pacific/N. America/N. Atlantic

Issued: 20230105

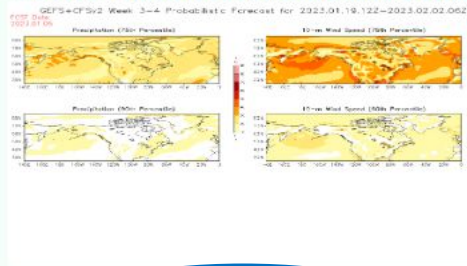
Storm Tracks, Intensity and Duration



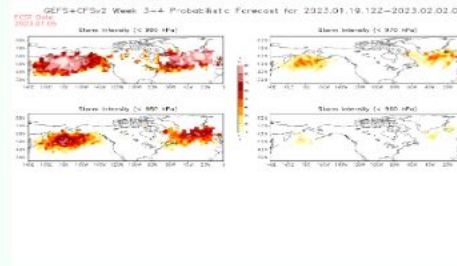
7-day Precipitation, SLP and Wind



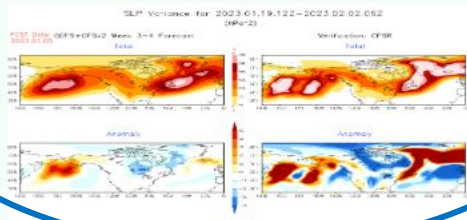
Probability Forecast: Precip. and Wind



Probability Forecast: Storm Intensity



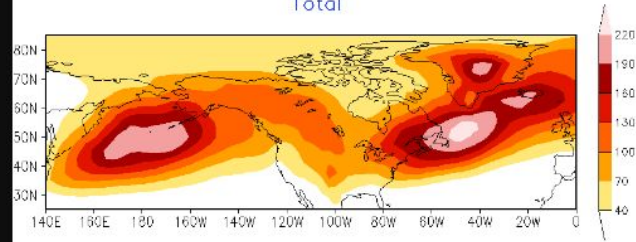
SLP Variance Forecast



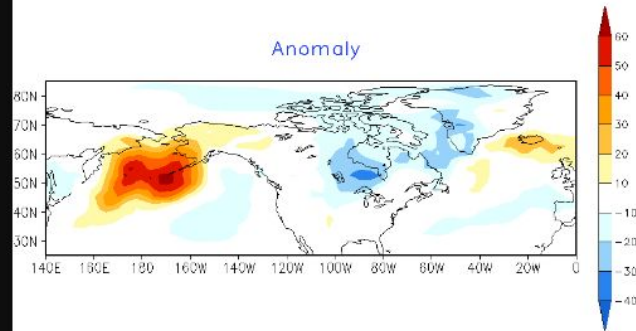
SLP Variance for 2023.01.19.12Z–2023.02.02.06Z (hPa²)

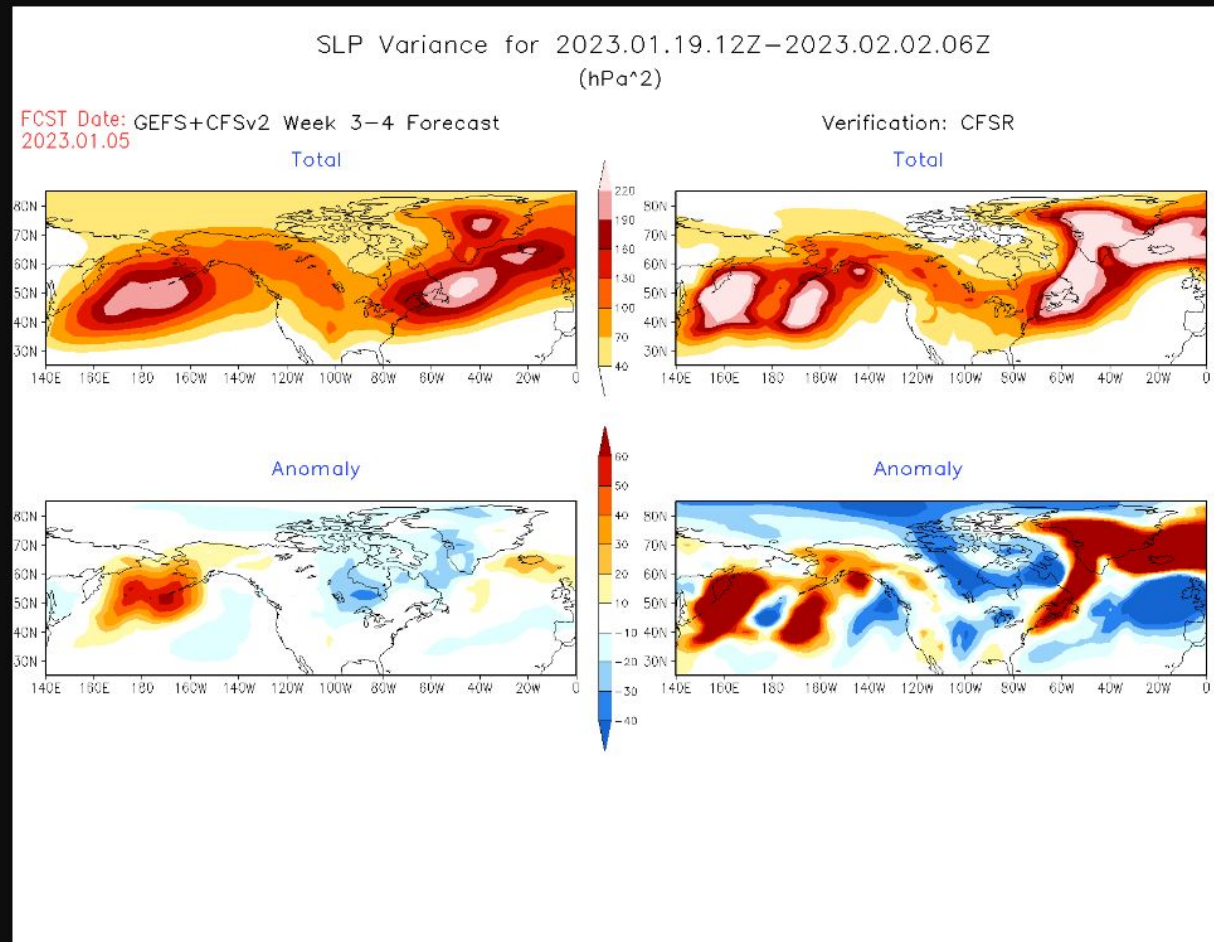
FCST Date: GEFS+CFSv2 Week 3–4 Forecast
2023.01.05

Total



Anomaly





Summary of the Near Real Time Outlook Tool

- Near real-time week-2 and week 3-4 storminess outlooks and verification are available at: <https://ftp.cpc.ncep.noaa.gov/hwang/YP/week2/>
- Skills in operational forecast are expected to be higher than the hindcast skill discussed above due to larger ensemble size in real-time forecast.
- Week 3-4 skill could potentially be higher if we increase ensemble size by using lagged ensemble (e.g. combine forecasts from 3 days to triple the ensemble size).
- We would like to thank NOAA WPO Office of Weather and Air Quality for supporting this project