Developing and Verifying a Subseasonal Outlook Tool for Extratropical Storminess

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Outline

- Part I: Background Information – Edmund Chang
  - Storminess indices
    - Lagrangian – track density, intensity
    - Eulerian – Sea level pressure variance
  - Hindcast assessment

- Part II: Near real time outlook tool – Yutong Pan

Part I: Background Information

Extratropical cyclones: significant impacts on society and ecosystem

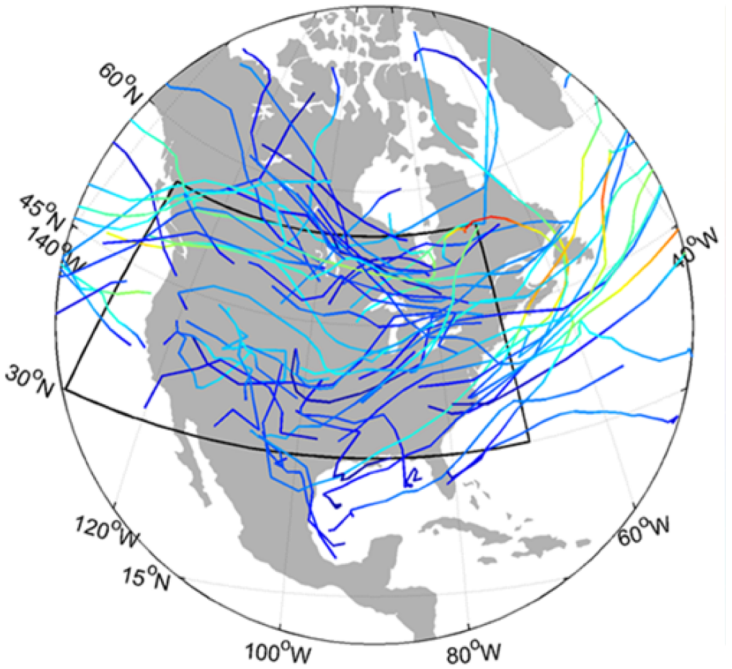
Heavy precipitation/snow

High winds and waves

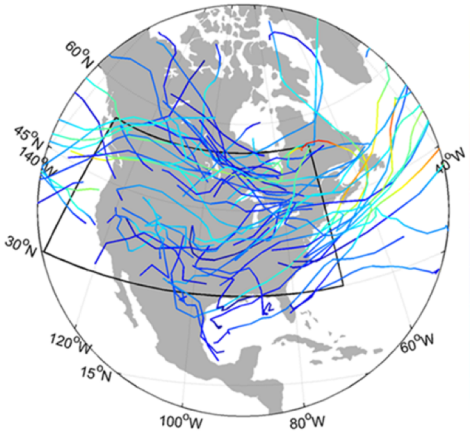
Storm surge

- 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

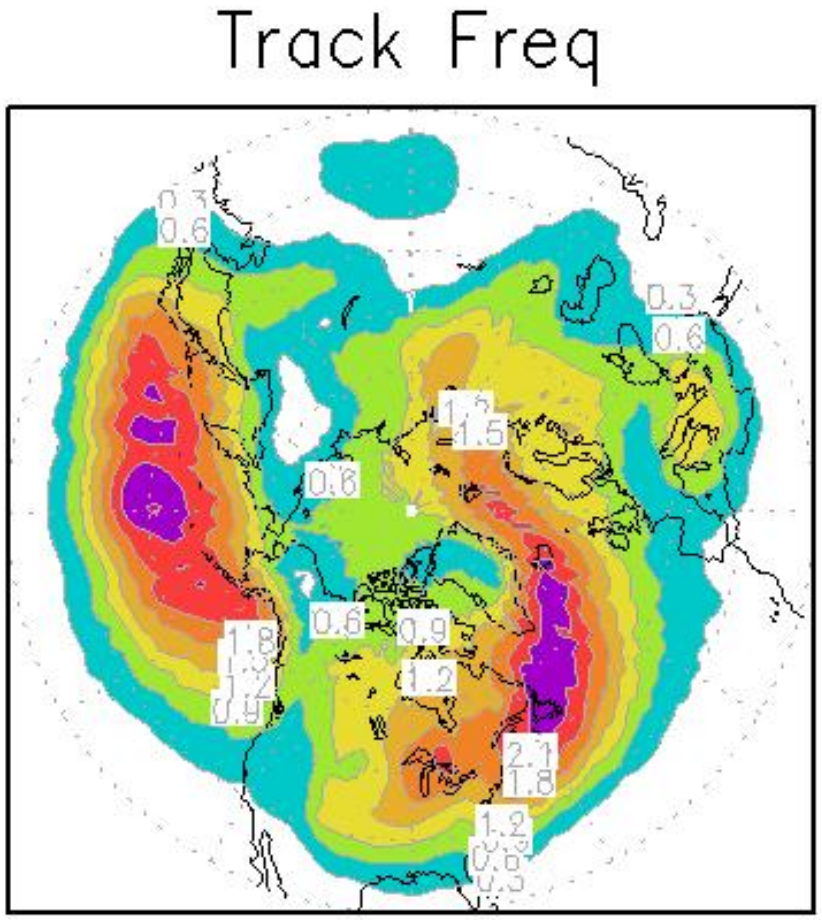
- Two definitions of storminess
  - Lagrangian: Based on statistics of cyclone tracks
    - Track frequency, cyclone amplitude, accumulated track activity (Yau and Chang, 2020)
  - Eulerian: Based on synoptic timescale variance statistics
    - Sea Level Pressure (SLP) variance
    - Eddy Kinetic Energy (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



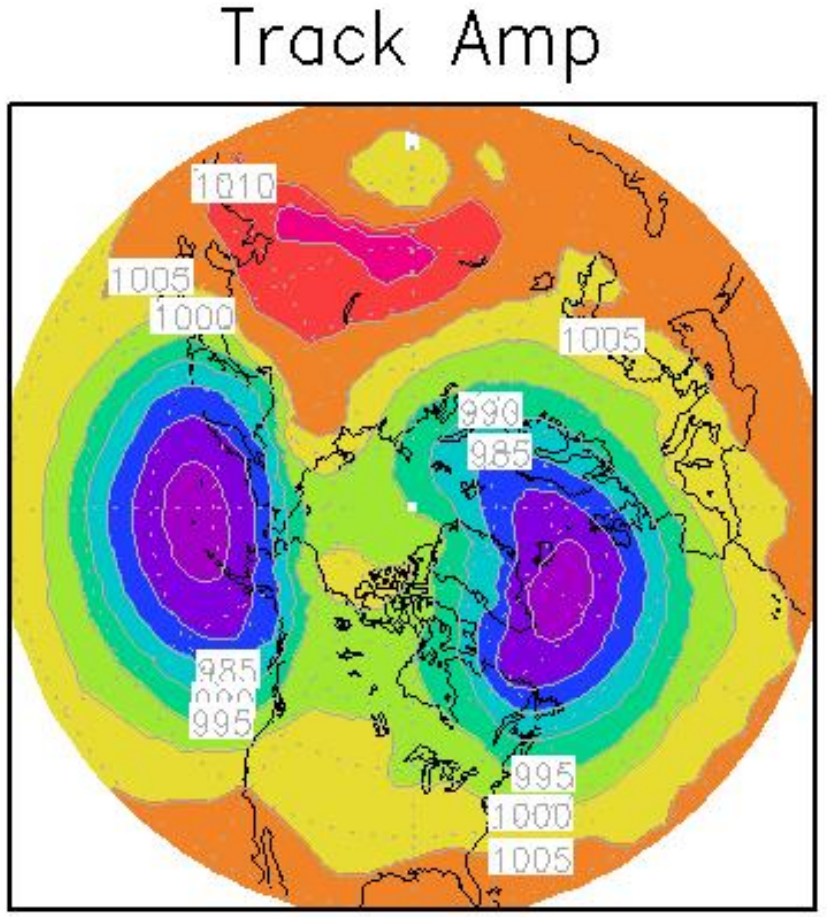
Track frequency (or density): Number of cyclones that passes within 500 km of each grid point within the period (each cyclone only counted once)

All Cyclones

Lagrangian Track Statistics:

GEFSv12 Climatology – Weeks 3-4 DJF 1999-2016

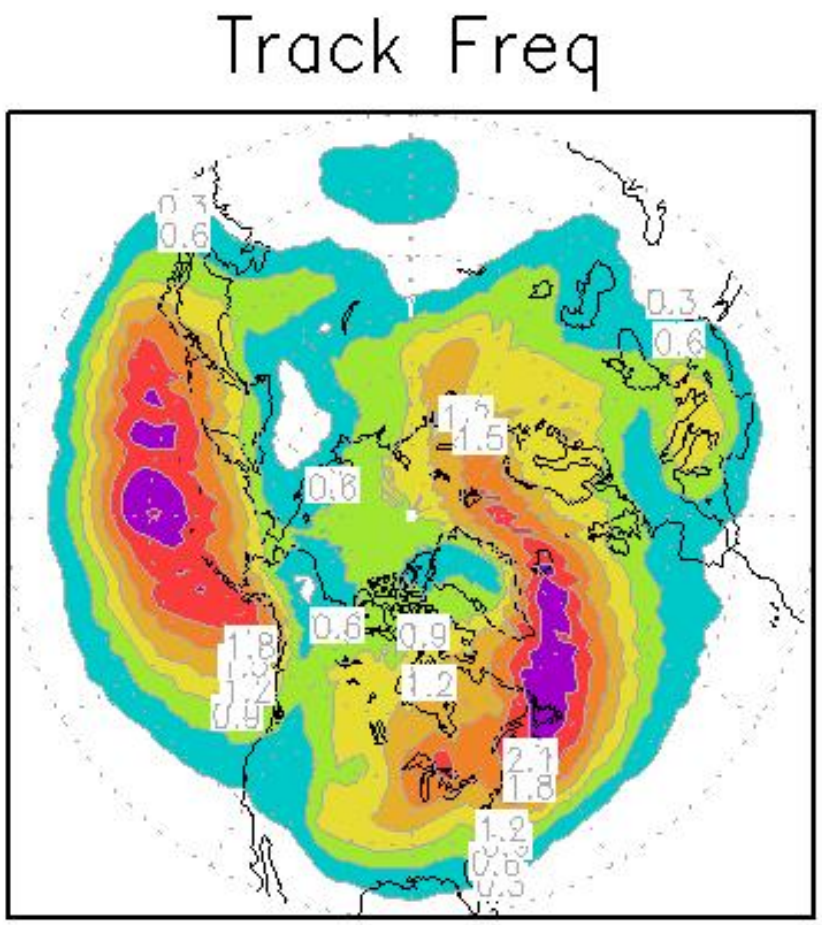
Track Amplitude (or intensity): Average of the maximum intensity of all cyclones that pass within 500 km of each grid point during the period (each cyclone only counted once)



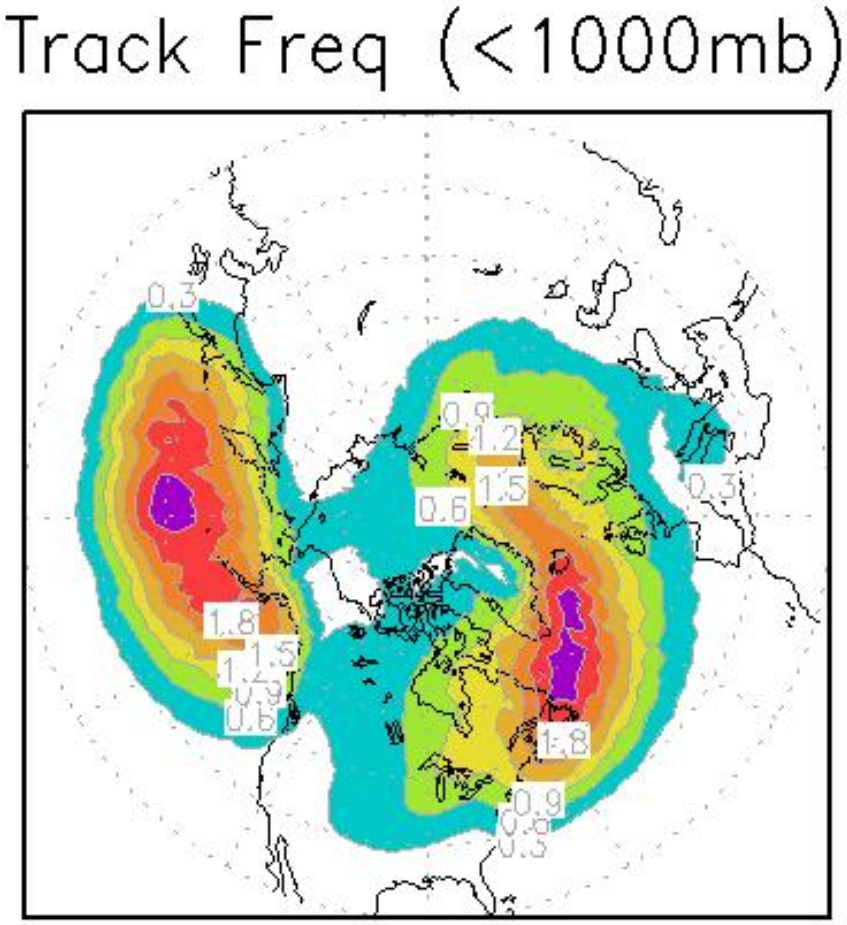
All Cyclones

Lagrangian Track Statistics:

GEFSv12 Climatology – Weeks 3-4 DJF 1999-2016



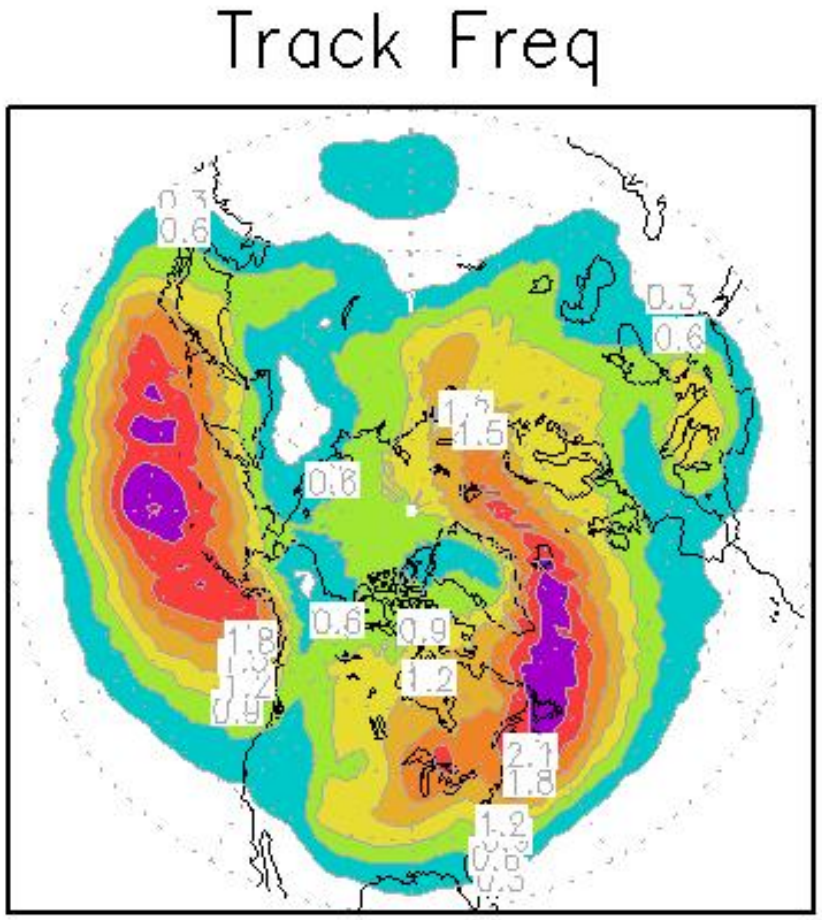
All Cyclones



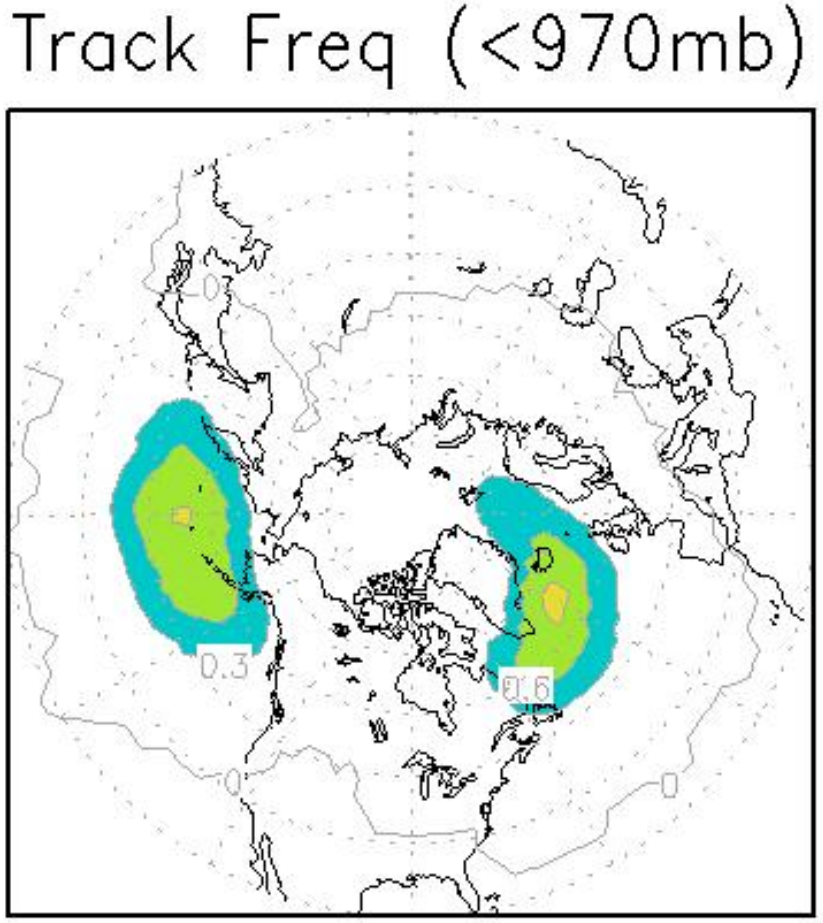
Moderate Cyclones

Lagrangian Track Statistics:

GEFSv12 Climatology – Weeks 3-4 DJF 1999-2016



All Cyclones

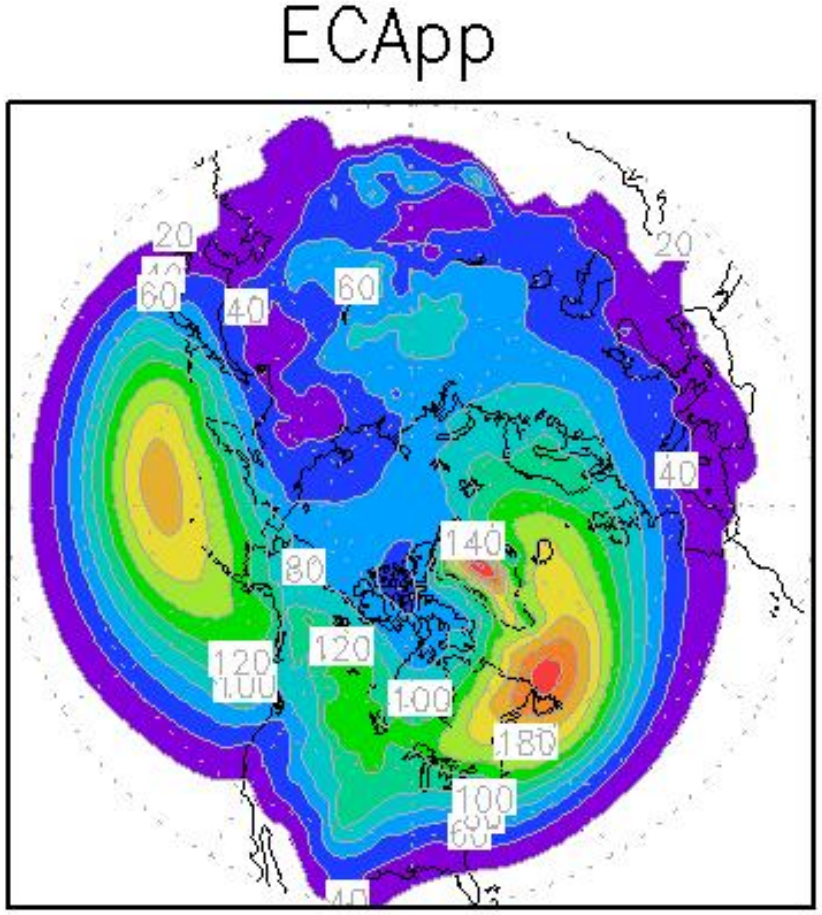


Deep Cyclones

Eulerian Cyclone Statistics:
(Extratropical Cyclone Activity - ECA)

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

GEFSv12 Climatology – Weeks 3-4 DJF 1999-2016



Eulerian Cyclone Statistics:
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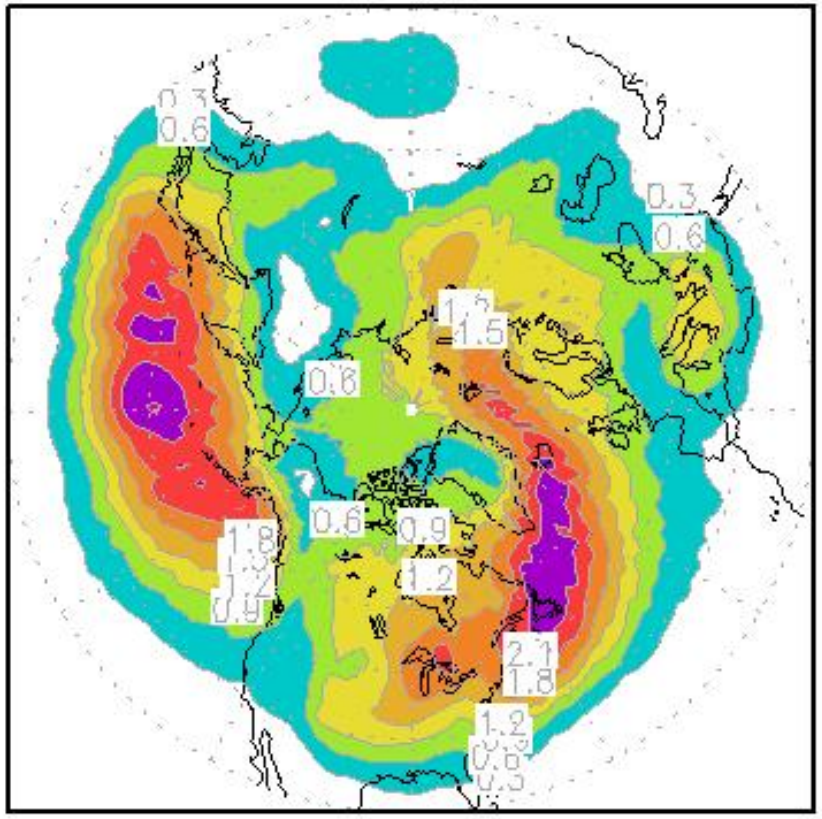
$$ECApp = \overline{[(SLP(t + 24hr) - SLP(t)]^2}$$

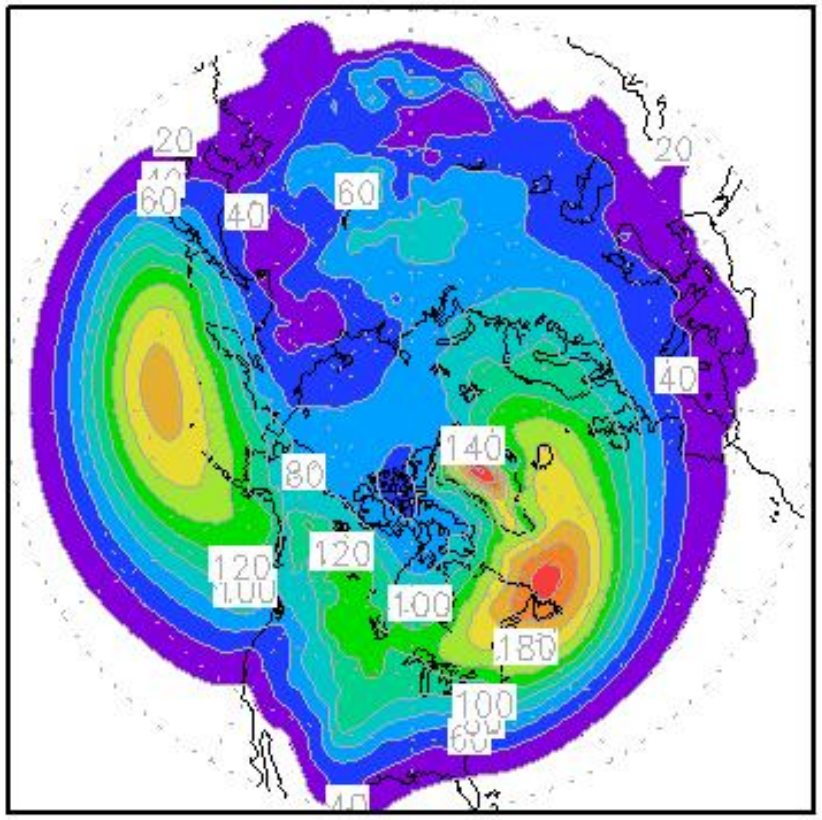
GEFSv12 Climatology – Weeks 3-4 DJF 1999-2016

Track Freq



All Cyclones

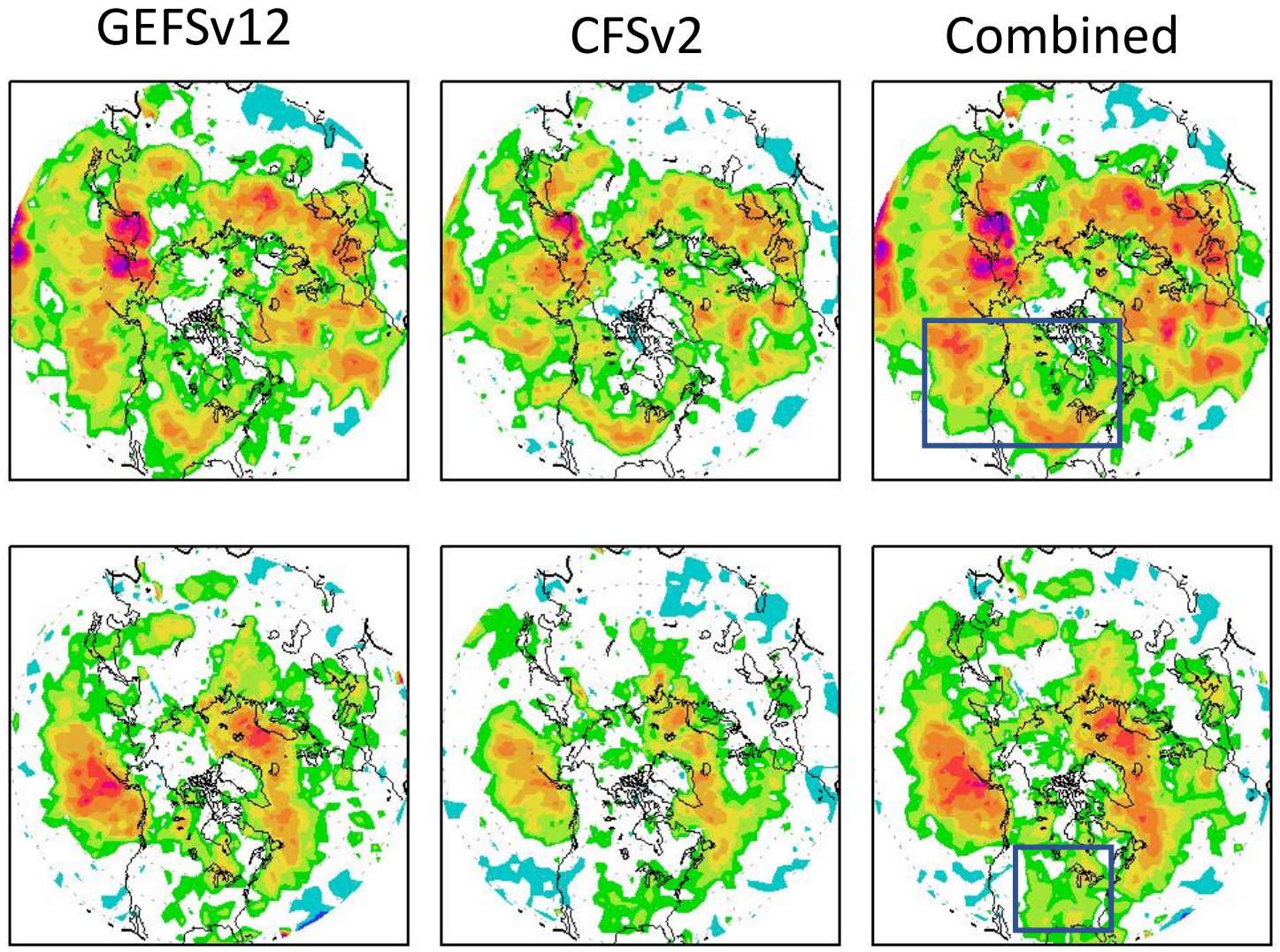
ECApp



Hindcast Assessment: Data and Method

- GEFSv12 reforecasts (1999-2016)
  - Initialized once every week, 11-member ensemble
  - 6 hrly SLP data, 0.5°×0.5° smoothed to 1°×1°
- 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°×1°
- 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)

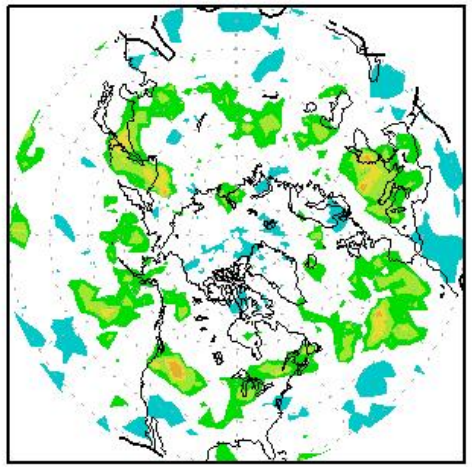


- ACC for GEFSv12 higher than CFSv2
- Combined ensemble better than either
  - True for all cases
- From now on will only show results for combined ensemble

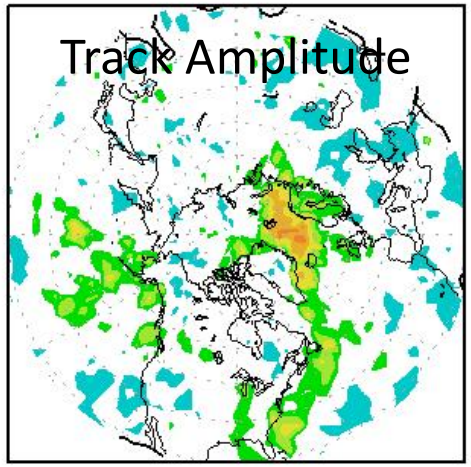
Verification Results – Weeks 3/4: DJF (combined ens)

All Cyclones

Track Frequency



Track Amplitude



ACC

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

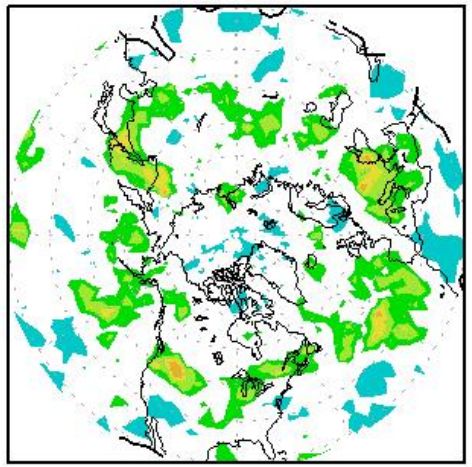
Verification Results – Weeks 3/4: DJF (combined ens)

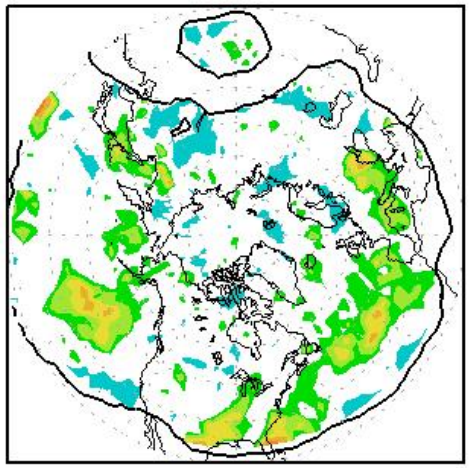
All Cyclones

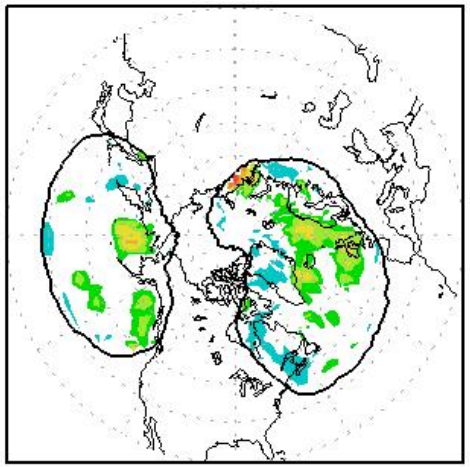
Mod Cyclones
P < 1000 hPa

Deep Cyclones
P < 970 hPa

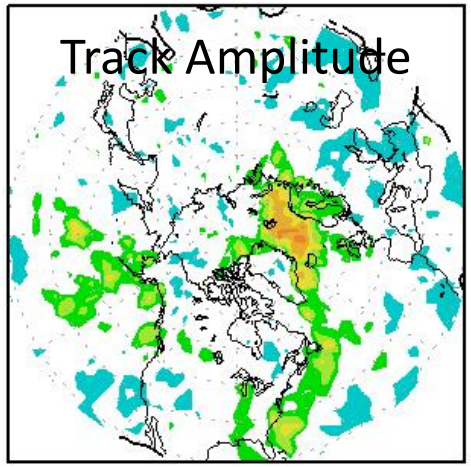
Track Frequency







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

ACC

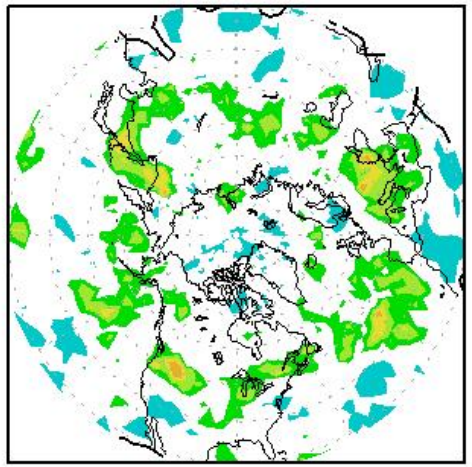
Verification Results – Weeks 3/4: DJF (combined ens)

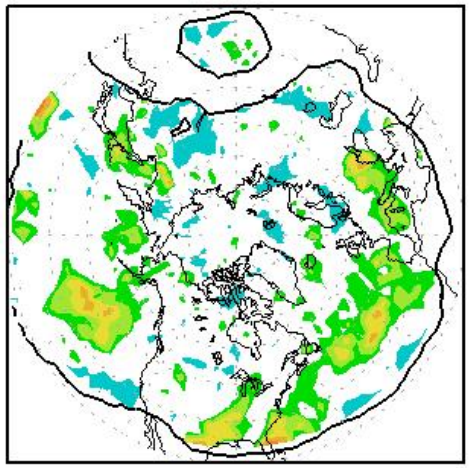
All Cyclones

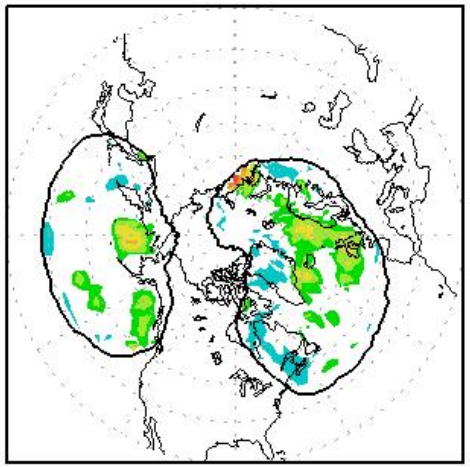
Mod Cyclones
P < 1000 hPa

Deep Cyclones
P < 970 hPa

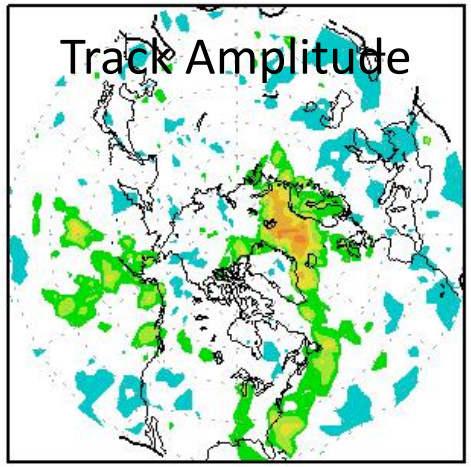
Track Frequency



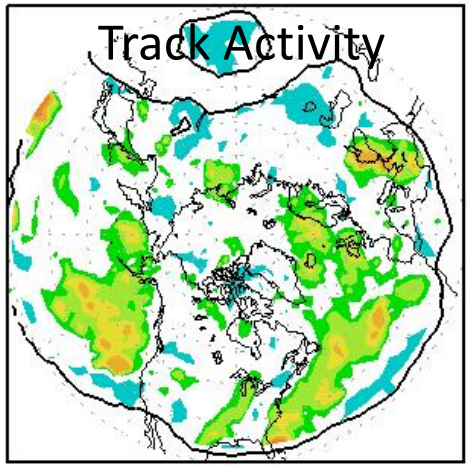




Track Amplitude



Accumulated
Track Activity



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

- ACC for Accumulated Track Activity (ATA) – a measure that combines information from track frequency and amplitude – is better than those for either track frequency or amplitude
- Some ability in the vicinity of Alaska and off the east coast of North America

ACC

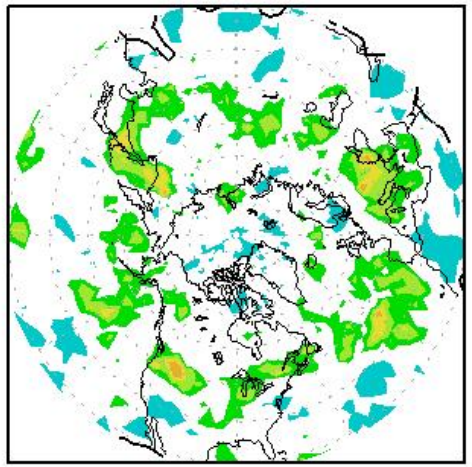
Verification Results – Weeks 3/4: DJF (combined ens)

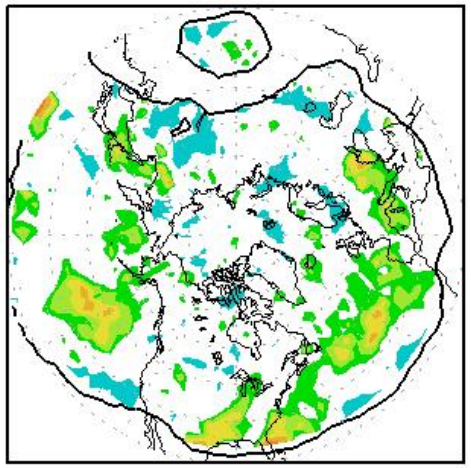
All Cyclones

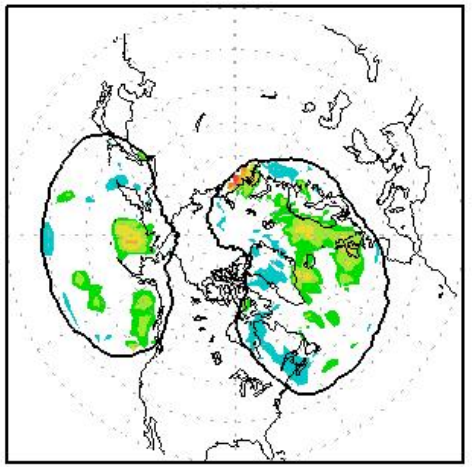
Mod Cyclones
P < 1000 hPa

Deep Cyclones
P < 970 hPa

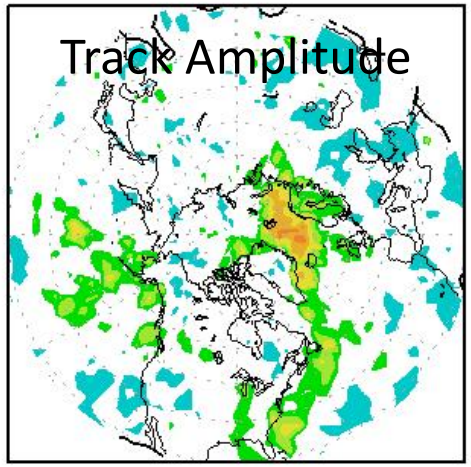
Track Frequency



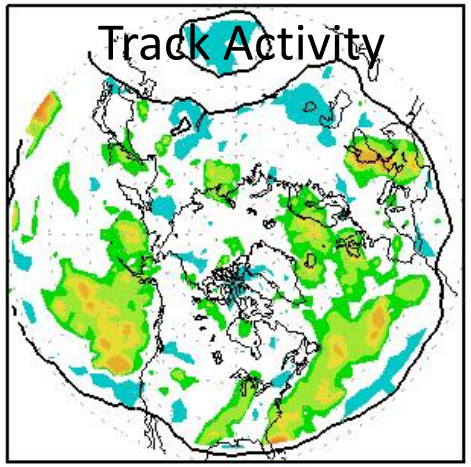




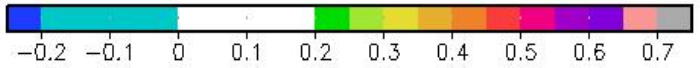
Track Amplitude



Accumulated
Track Activity

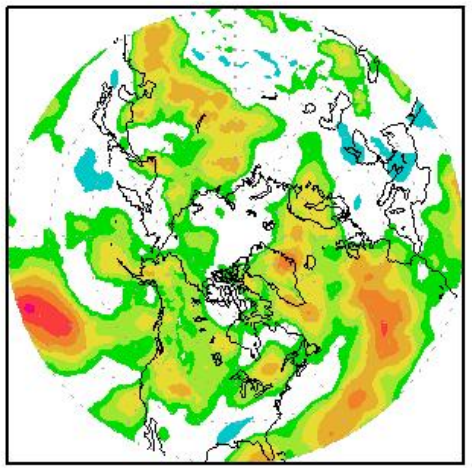


ACC

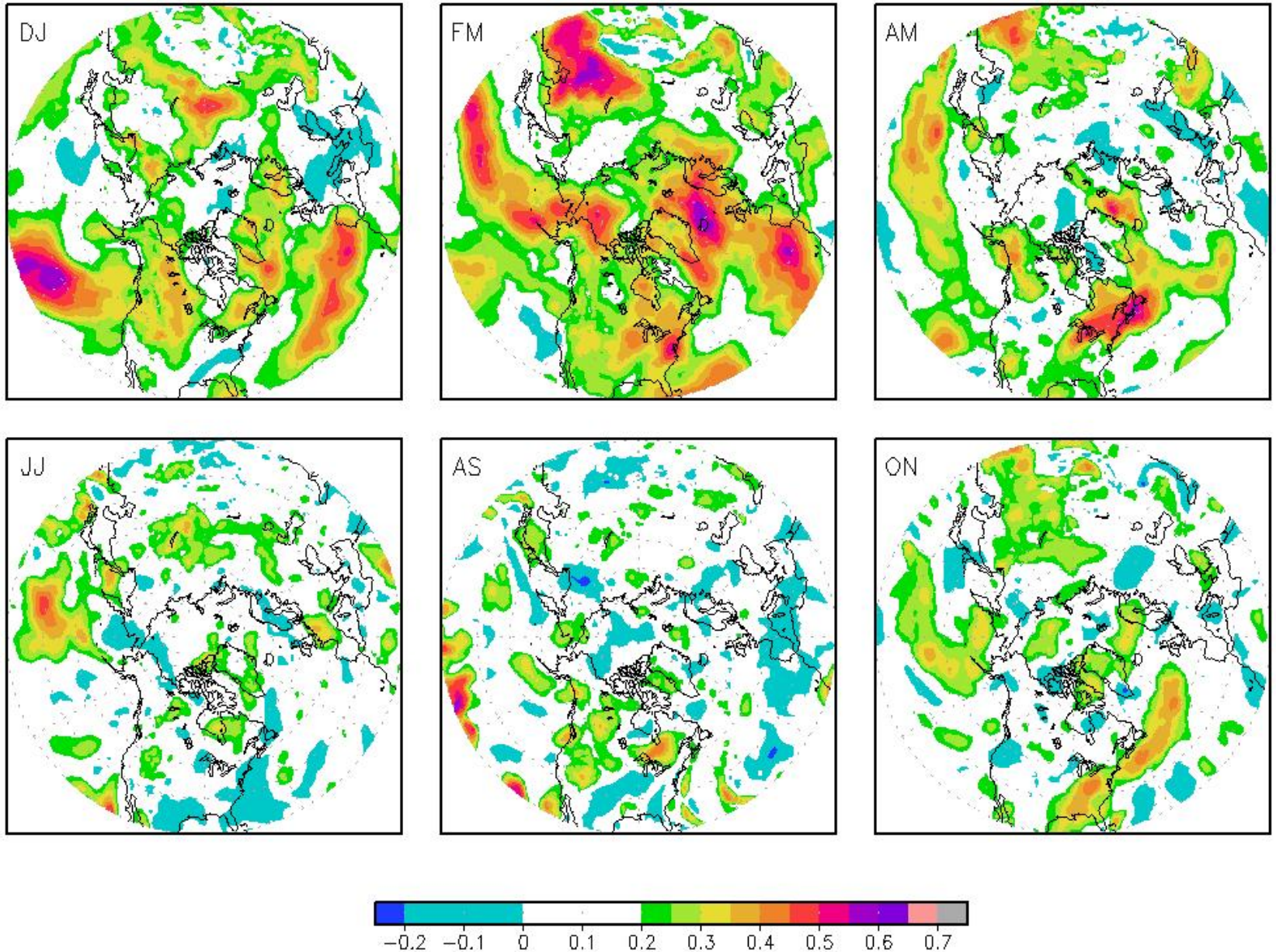


- ACC for SLP variance (ECApp) much higher than those for track statistics
- Some ability near Alaska, eastern Pacific, North America, Atlantic, and East Asia

ECApp



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



Discussion

- Combined GEFSv12/CFSv2 ensemble consistently does better than either individual ensemble – for all cases
- Week 2 (DJF) ability quite good for both track frequency and amplitude
- Weeks 3-4 ability for predicting track statistics not as high
- Some ability for ATA (accumulated track activity) over East Pacific near Alaska and just off the U.S. east coast
  - Higher ACC for ECApp (SLP variance)
- 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
- Highest ACC for DJFM, lowest for summer
- Lagrangian statistics (track frequency and intensity) more intuitive to forecasters, but SLP variance better predicted by models

Part II: 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, and
- To assess the forecast skill

Data

- Model forecasts (6-hourly):
  - GEFSv12 operational 16-day fcst, 124 mbrs
  - GEFSv12 16-day hindcast, 5 mbrs
  - GEFSv12 operational 35-day fcst, 31 mbrs
  - GEFSv12 35-day hindcast, 11 mbrs
  - CFSv2 operational 45-day fcst, 16 mbrs
  - CFSv2 45-day hindcast, 4 mbrs
  - Hindcast period: GEFSv12, 1999-2019 (21 years); CFSv2, 1999-2010 (12 years)
- Observations:
  - Verification: CFSR real time
  - Skill assessment: CFSR archive (1999-2019)

Methods

- Storm detecting and tracking are based on the algorithm developed by Serreze (1995):
  - Using 6-h SLP data on 2.5°x2.5° grid
  - Center SLP ≤ 1000 hPa
  - Center SLP at least 1 hPa lower than surrounding grid points
  - Maximum distance a storm can move is 800 km/6 hr
- Storm track density: total number of storm centers within a 250-km radius for each grid point divided by ensemble members
- Storm intensity: mean storm center SLP within a 250-km radius for each grid point
- Storm duration: mean lifetime of storms passing through a domain of 250-km radius for each grid point

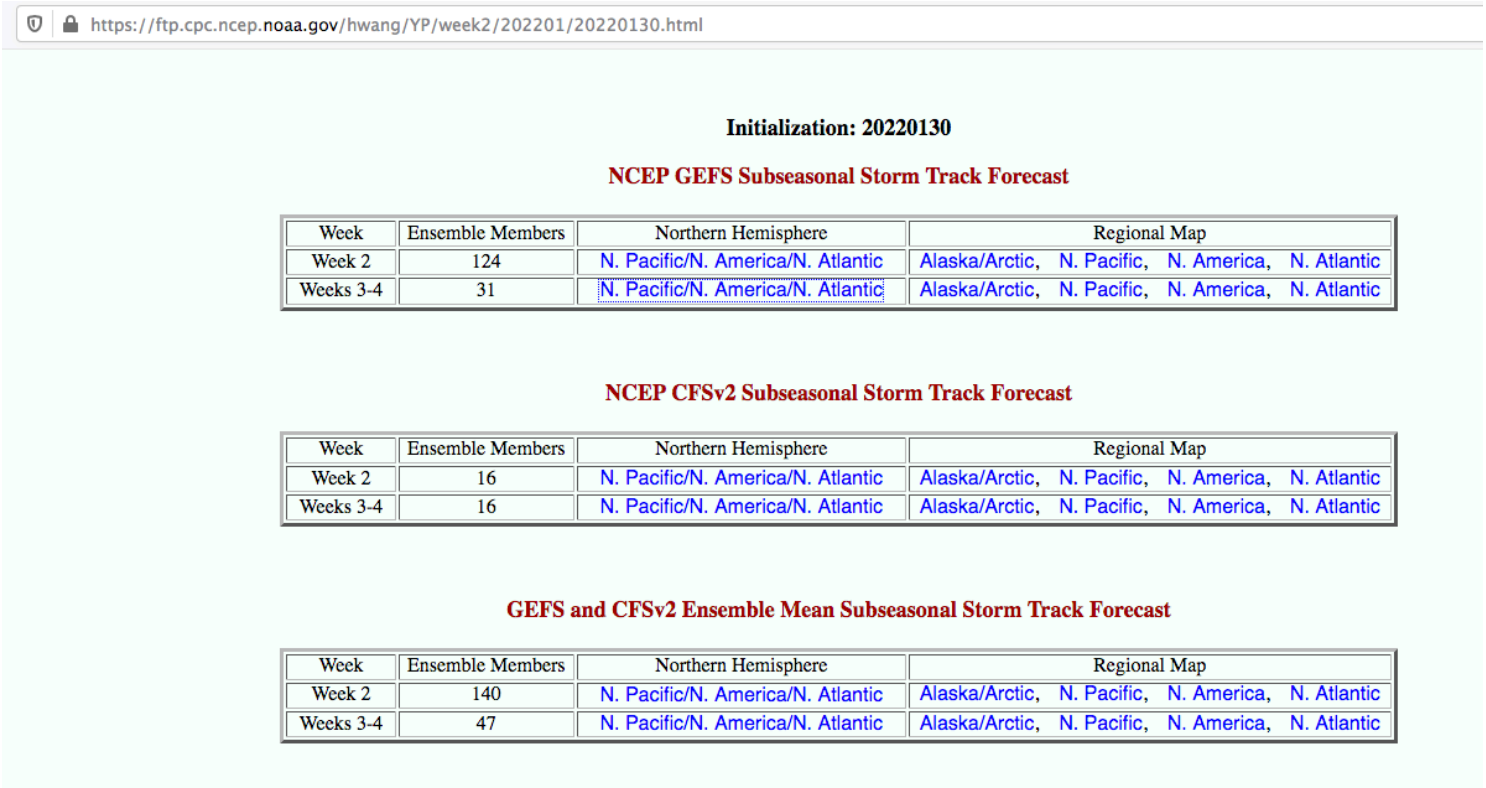
Week-2 and Week 3-4 Outlook Products

- 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

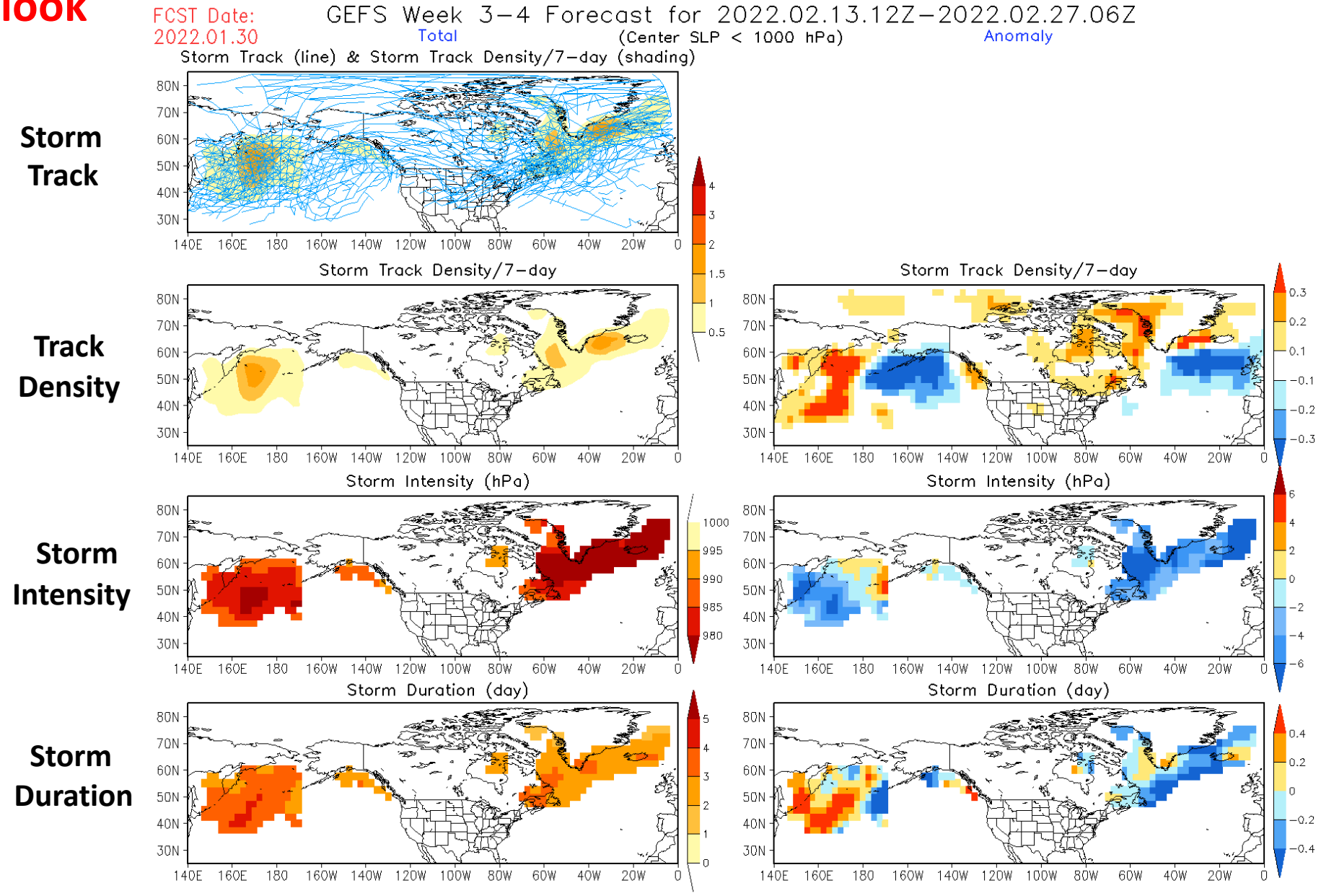
Week-2 and Week 3-4 Outlook Web Page

- 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/



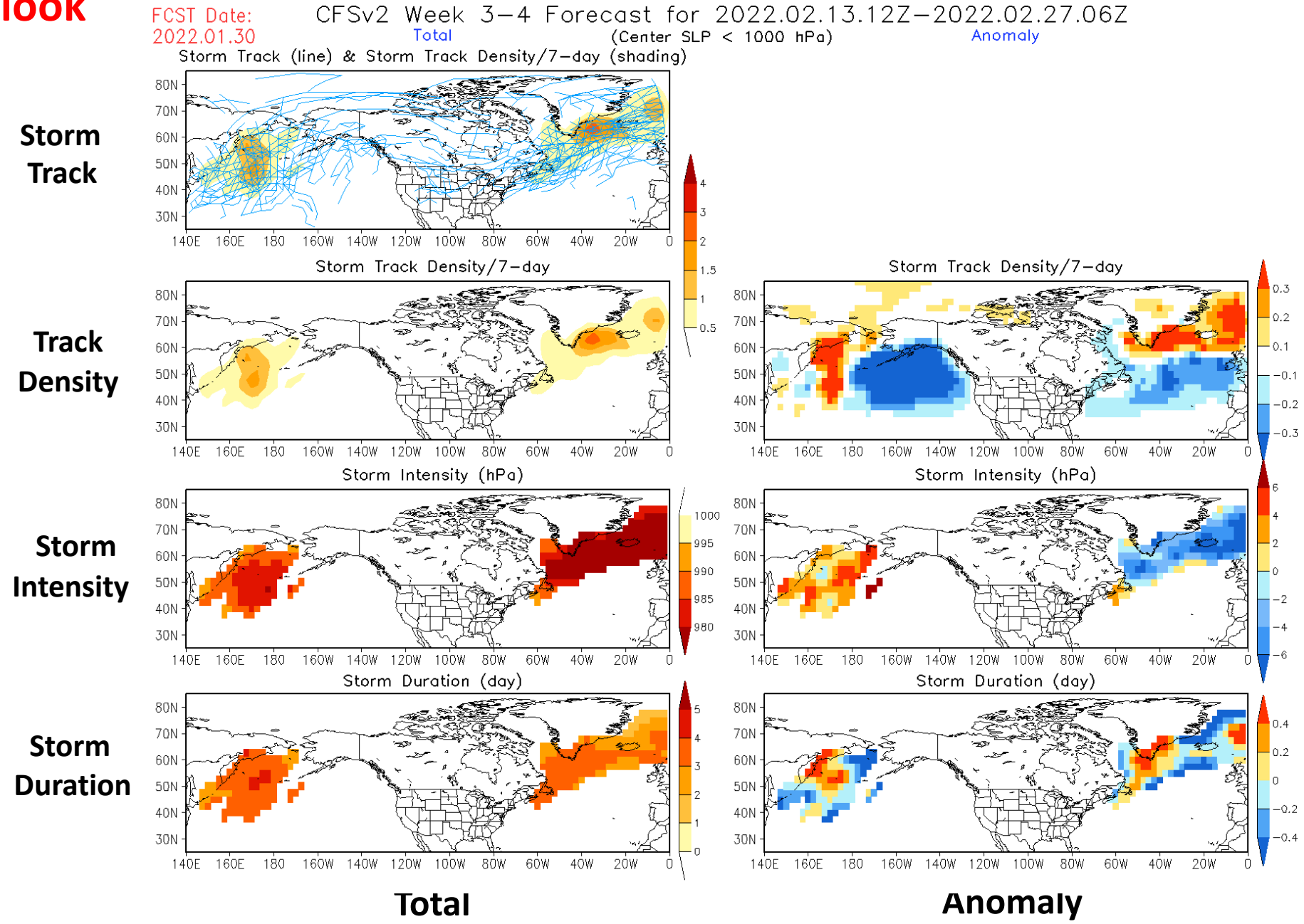
GEFSv12
Week 3-4 Outlook

Storm Track, Track Density, Storm Intensity and Duration



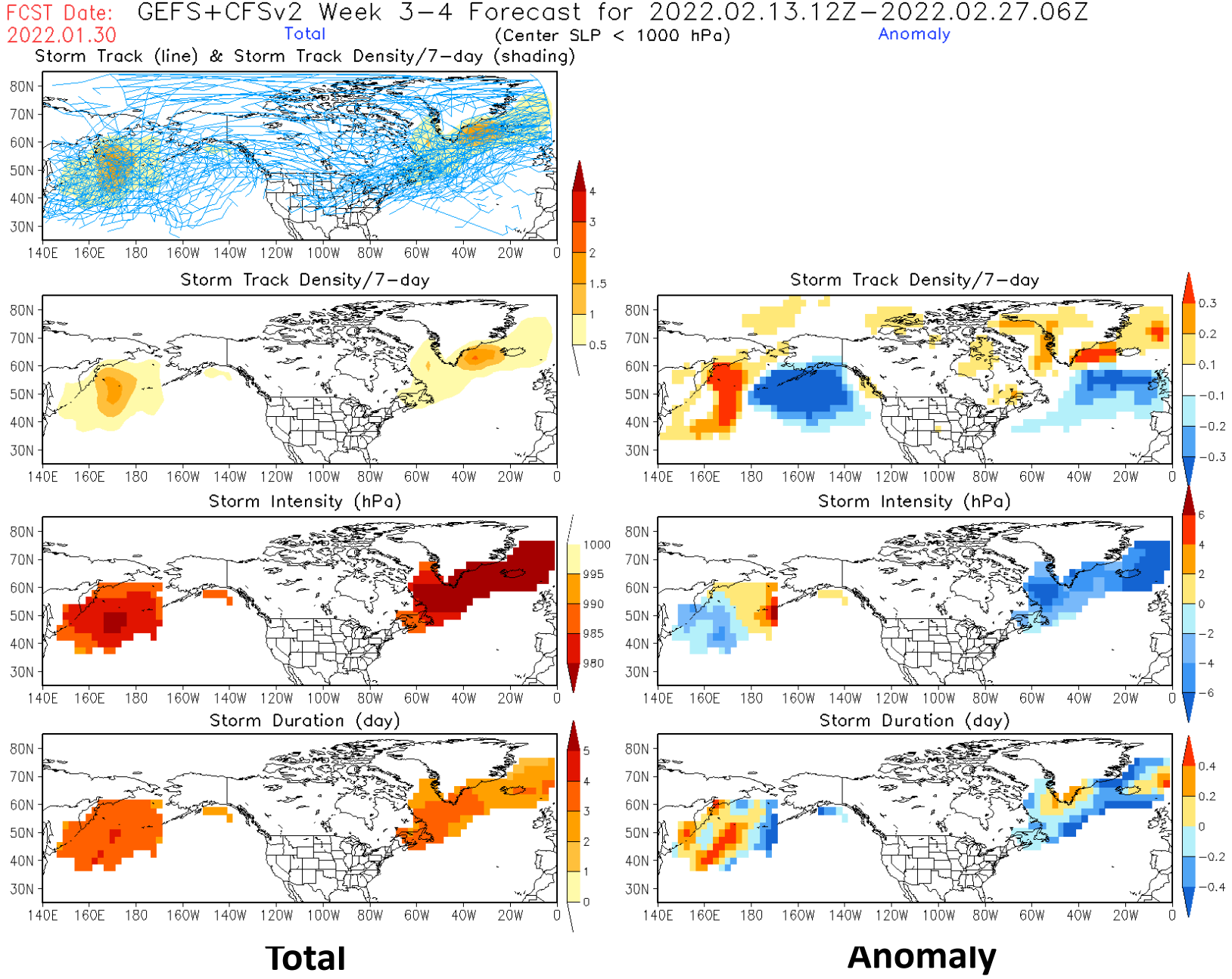
CFSv2
Week 3-4 Outlook

Storm Track, Track Density, Storm Intensity and Duration



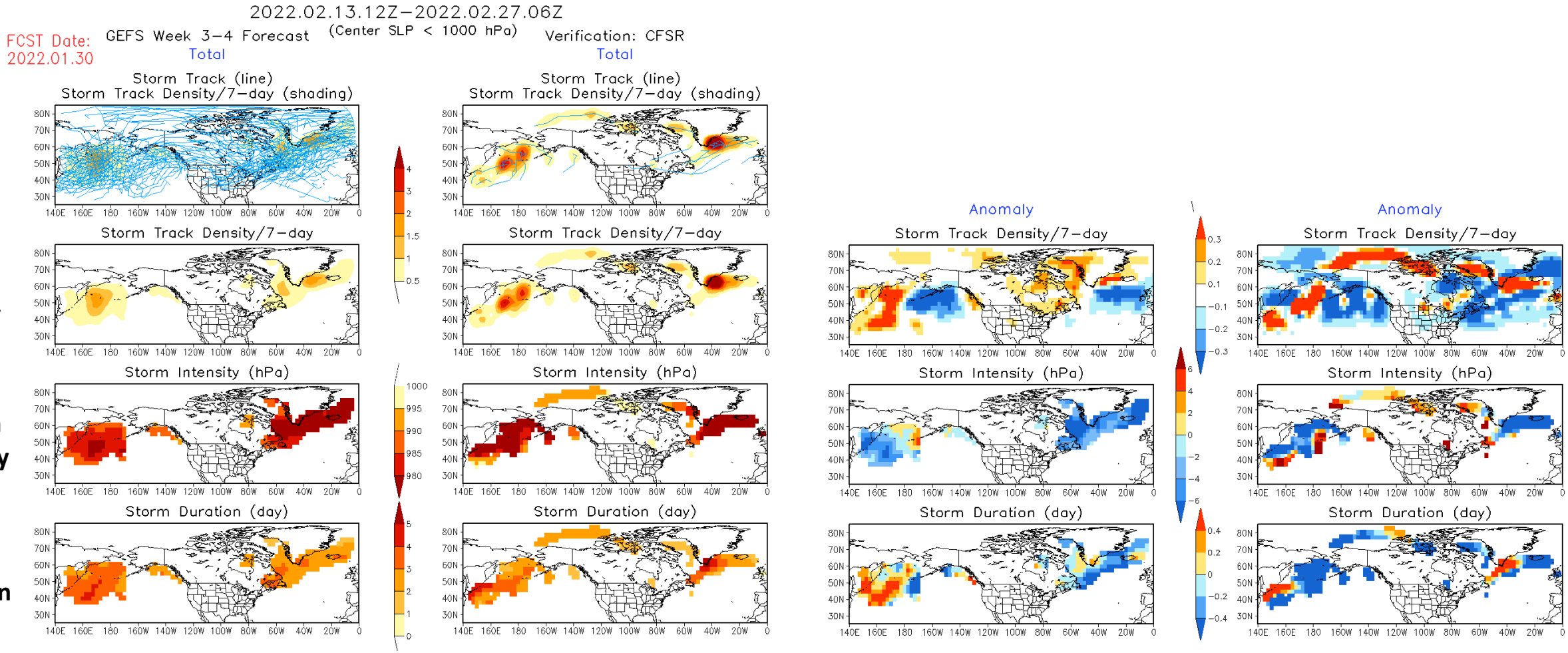
Combined Week 3-4 Outlook

Storm Track, Track Density, Storm Intensity and Duration



Verification of GEFSv12 Week 3-4

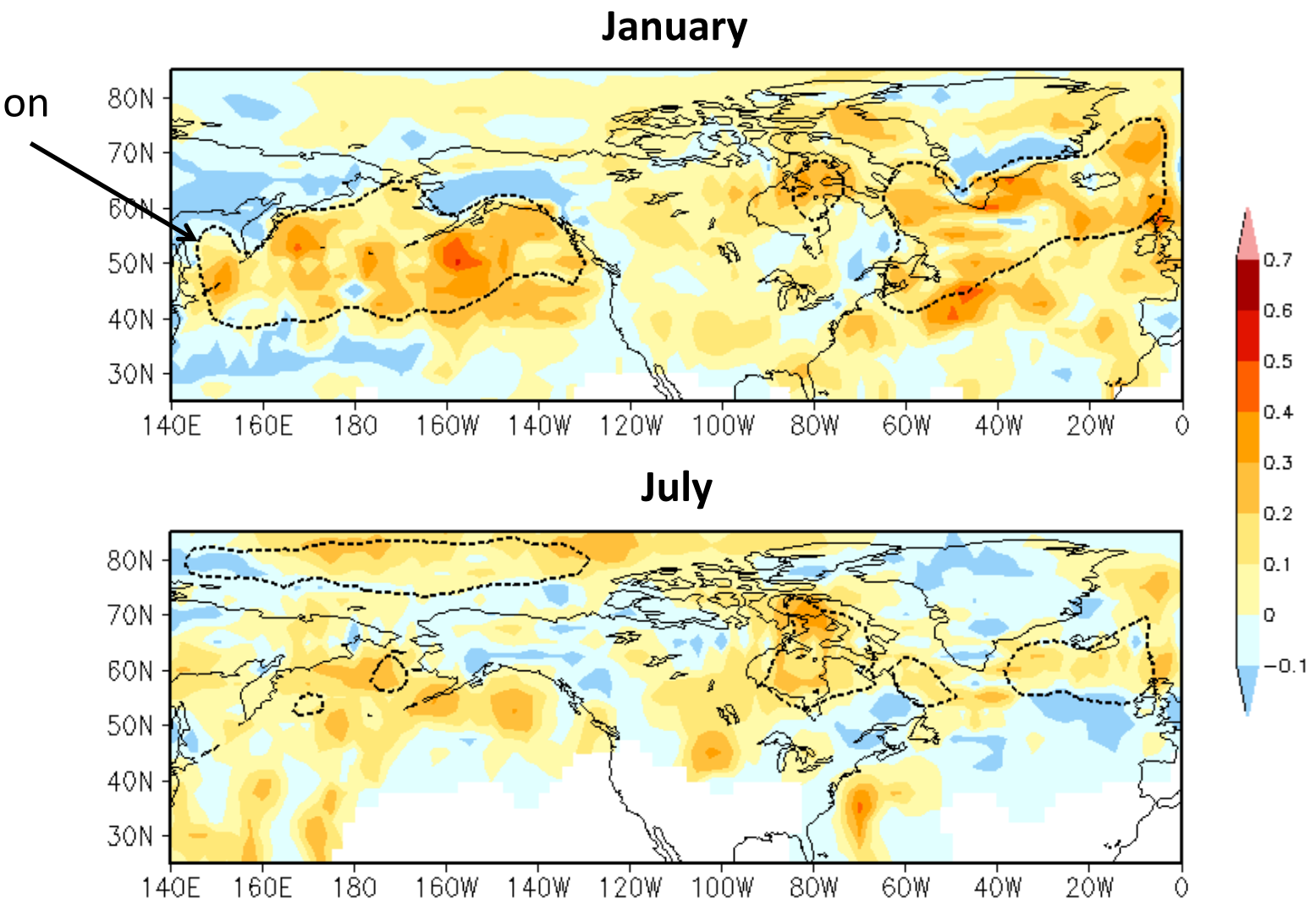
Storm Track, Track Density, Storm Intensity and Duration



Forecast Skill

Anomaly Correlation (AC) of Week 3-4 Storm Track Density between GEFSv12 21-year hindcast and CFSR

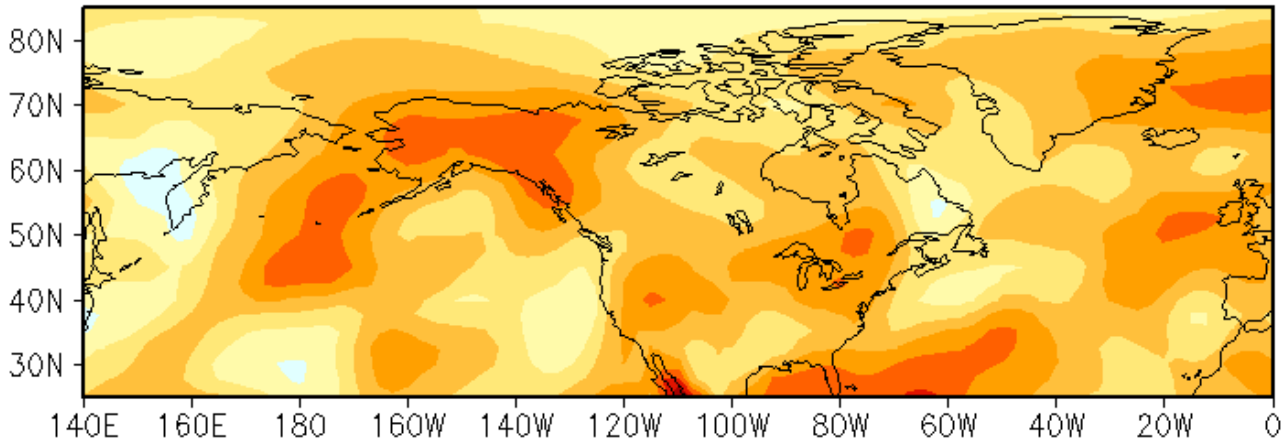
Climatologically storm-active region



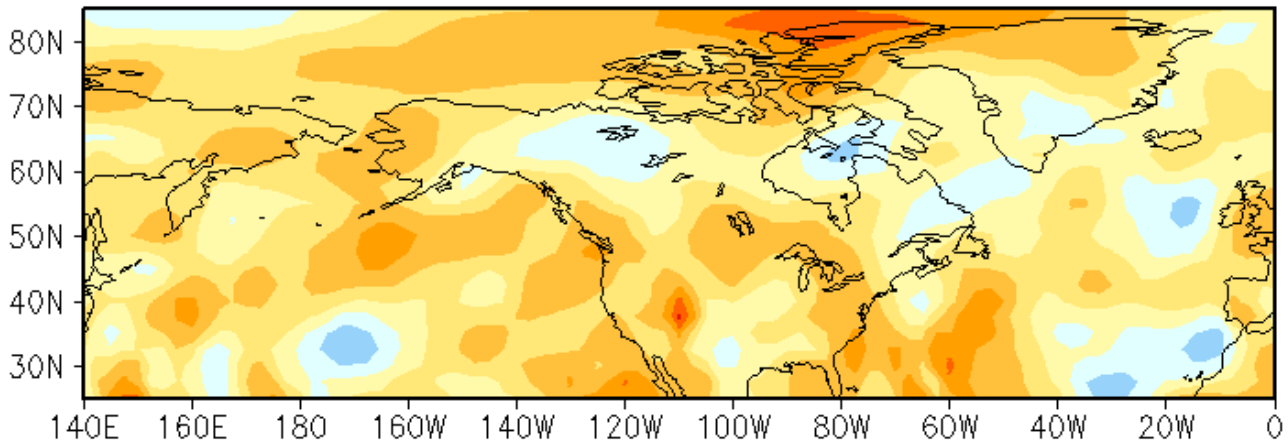
Forecast Skill

Anomaly Correlation (AC) of Week 3-4 Day-to-Day SLP Variance between GEFSv12 21-year hindcast and CFSR

January



July



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/

- Anomaly correlations of week-2 and week 3-4 forecasts indicate a certain level of skill for storm track density over the mid- and high-latitudes, and better skills for precipitation, SLP, and day-to-day SLP variance. Forecast skill of week-2 is relatively higher than the week 3-4.

- Skills in operational forecast are expected to be higher than the hindcast skill due to a larger ensemble in real-time forecast.

- To improve the forecast skill, especially for the week 3-4, we will test increasing ensemble member by using up to 3-day lag.