Changes in Arctic Winds in the CESM Large Ensemble

John Vavrus

John Miaskiewski

Marika Holland

Muyin Wang

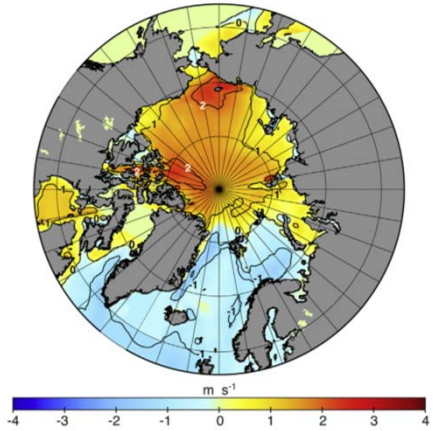
Laura Landrum

Arctic Coastal Erosion: A Growing Problem

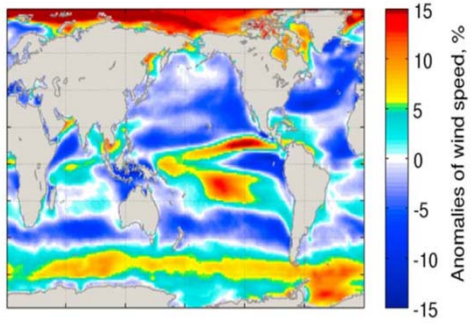
Sea ice loss + Thawing permafrost + Stronger winds? → Coastal Erosion

Prior Research on Changing Arctic Winds

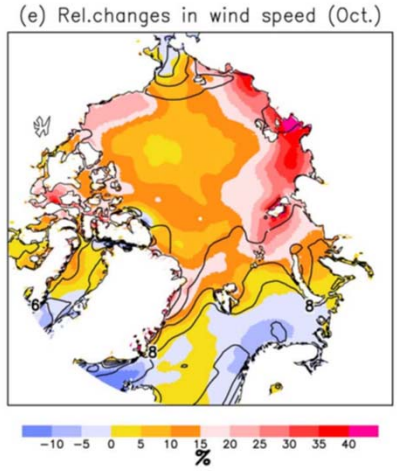
- Stronger wintertime winds in late 21st century (HadGEM2-ES) [Aksenov et al. 2016]



- Stronger winds annually in late 21st century (EC-Earth) [Dobrynin et al. 2012)



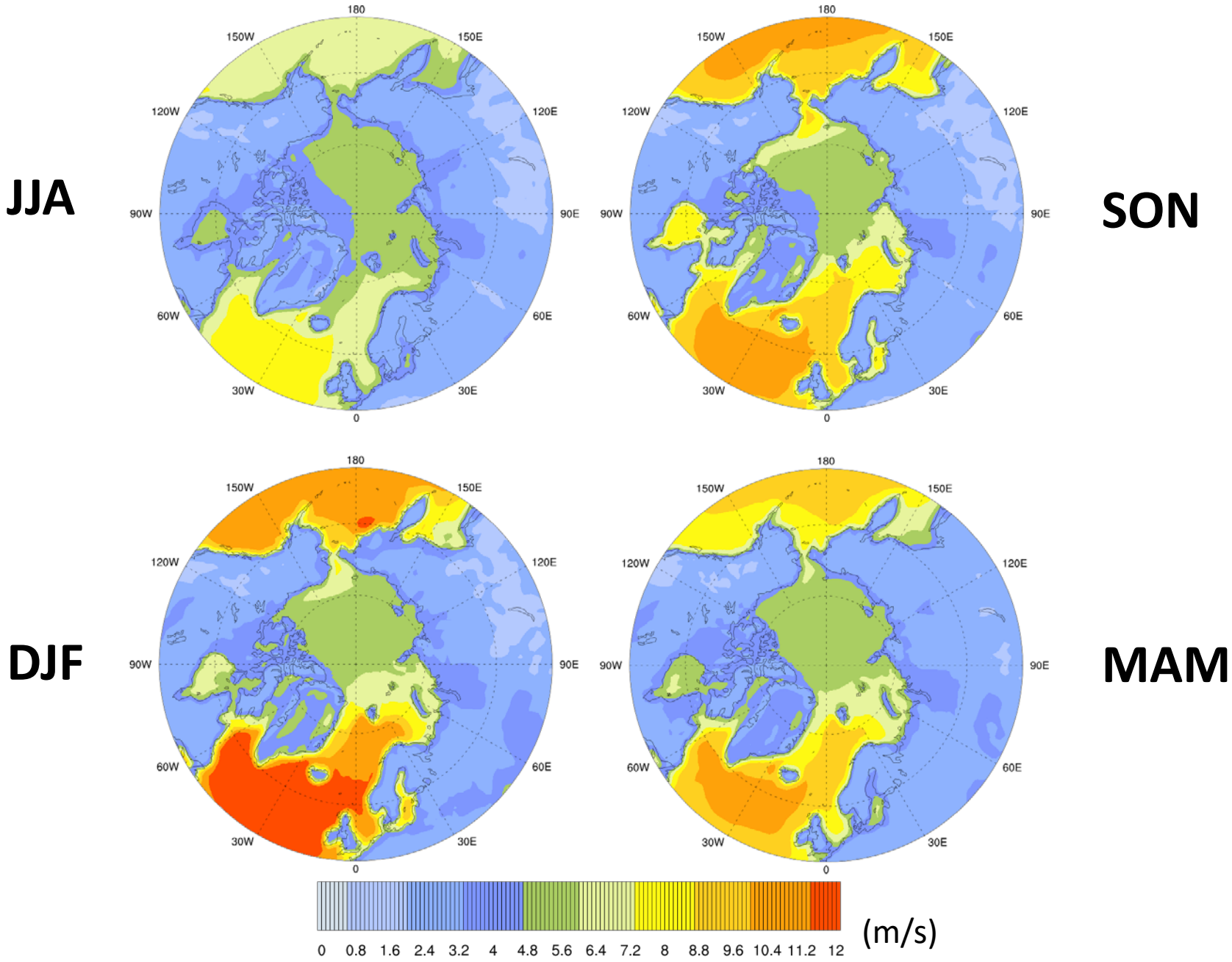
- Stronger autumn winds in mid-21st century (HIRHAM) [Khon et al. 2014]



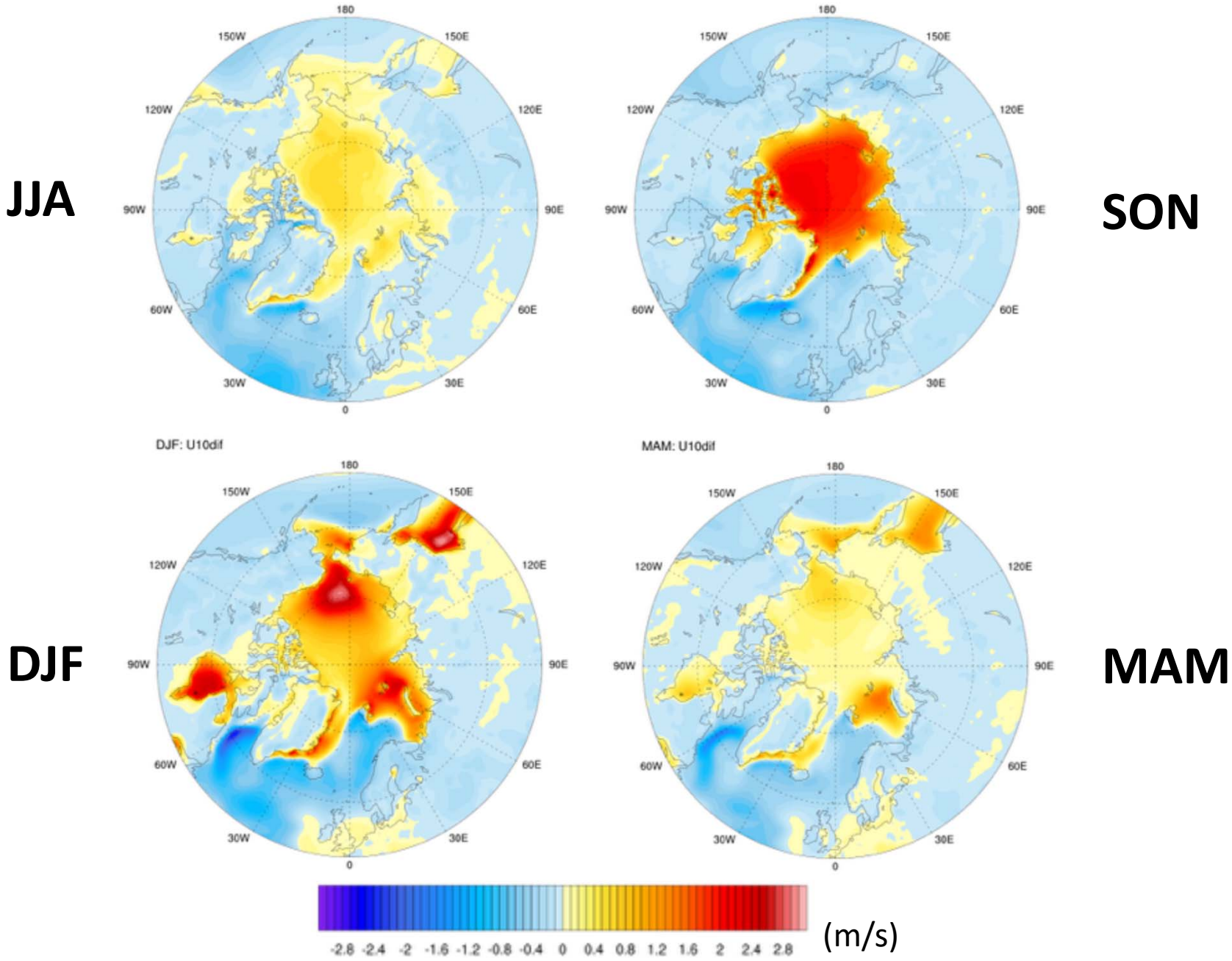
Our Research on Changing Arctic Winds

- CESM Large Ensemble (40 members), late-21st century vs. late-20th century
- "U10": Monthly average wind speed at 10 m height
- Also 850 hPa wind speeds
- All seasons
- Identify patterns and *likely mechanisms*

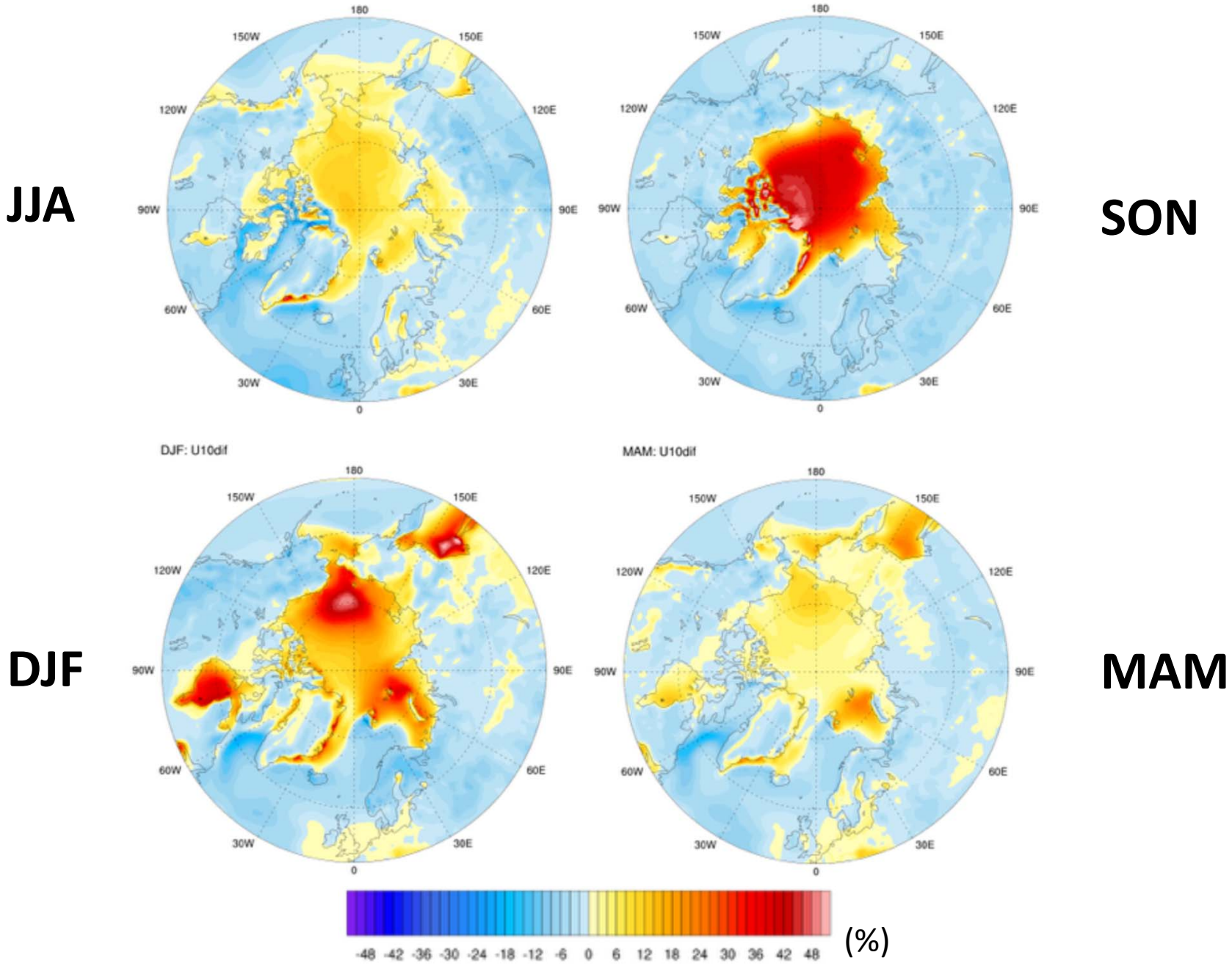
Climatological Mean Near-Surface Wind Speed (1971-2000)



Change in Mean Near-Surface Wind Speed (late 21st c)



Change in Mean Near-Surface Wind Speed (%)



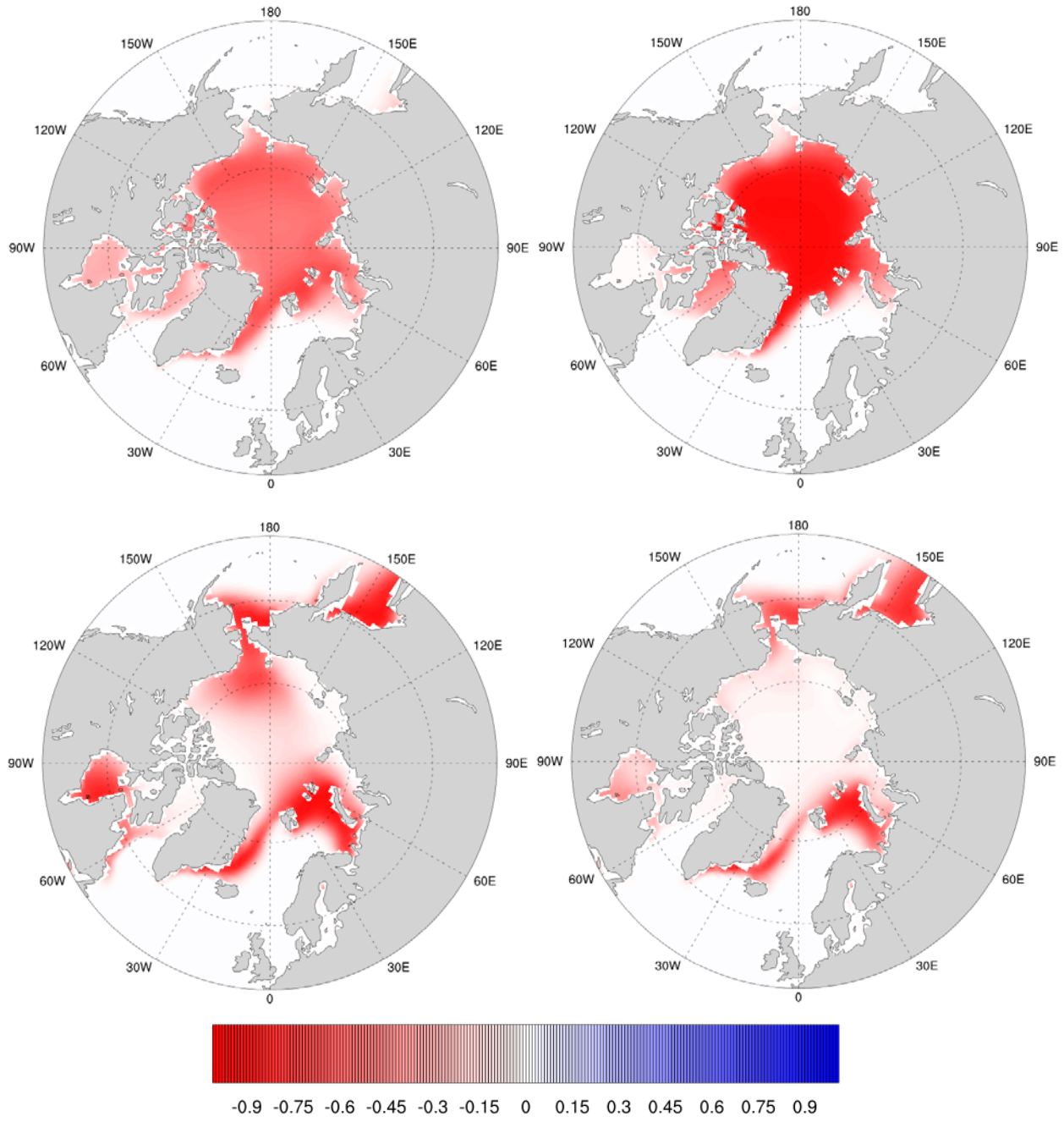
Change in Sea Ice Fraction

JJA

SON

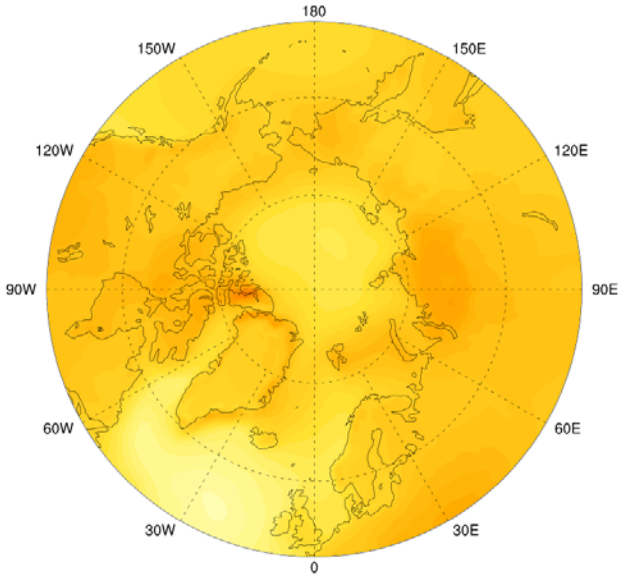
DJF

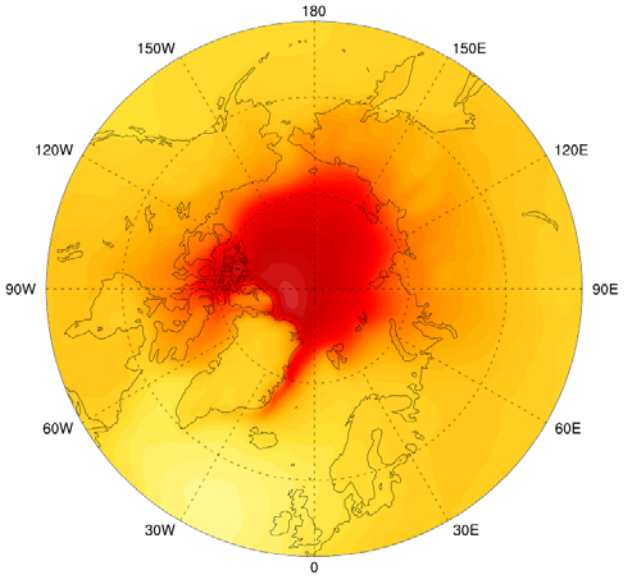
MAM



Change in Mean Near-Surface Temperature

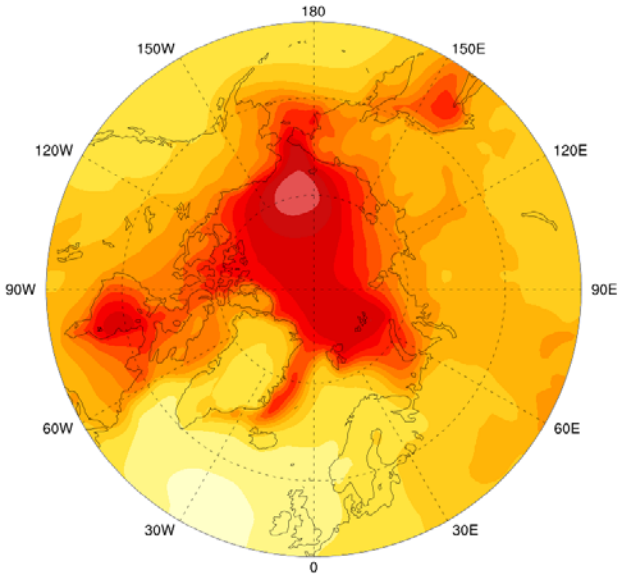
JJA

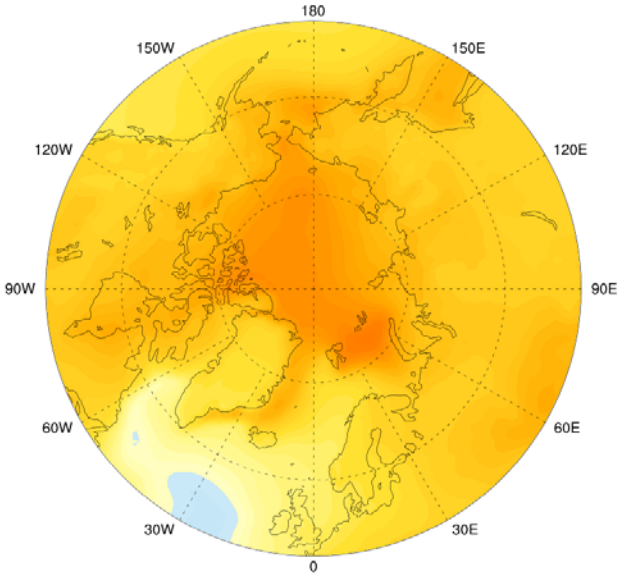




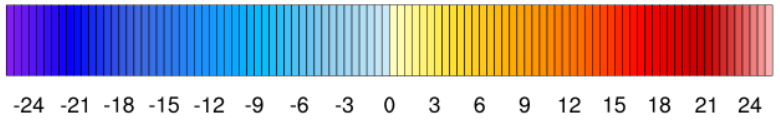
SON

DJF





MAM



Significant Wave Height Dependence on Wind Speed

Significant wave height (H) is highly sensitive to wind speed (U):

Aksenov et al. (2016): $\mathbf{H_{Fut}/H_{Past} = (U_{Fut}/U_{Past})^2}$

H_{Fut} and U_{Fut} = wave height and wind speed in future

H_{Past} and U_{Past} = wave height and wind speed in past

Significant Wave Height Dependence on Wind Speed

Significant wave height (H) is highly sensitive to wind speed (U):

Aksenov et al. (2016): $\mathbf{H_{Fut}/H_{Past} = (U_{Fut}/U_{Past})^2}$

H_{Fut} and U_{Fut} = wave height and wind speed in future

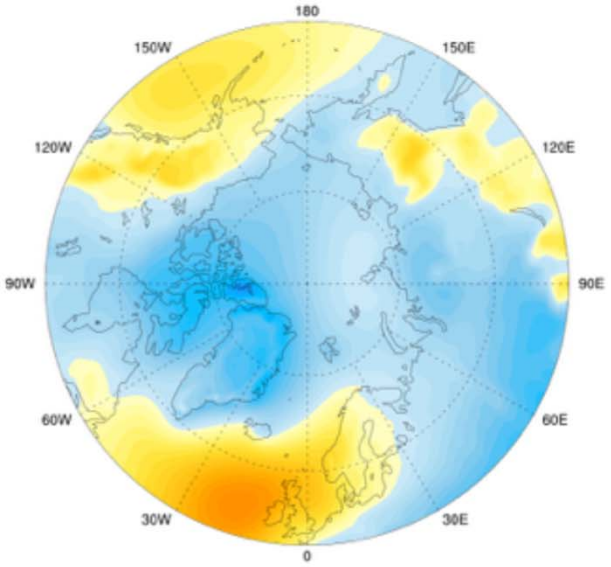
H_{Past} and U_{Past} = wave height and wind speed in past

Maximum increase in mean wind = 50% → more than doubling of wave height

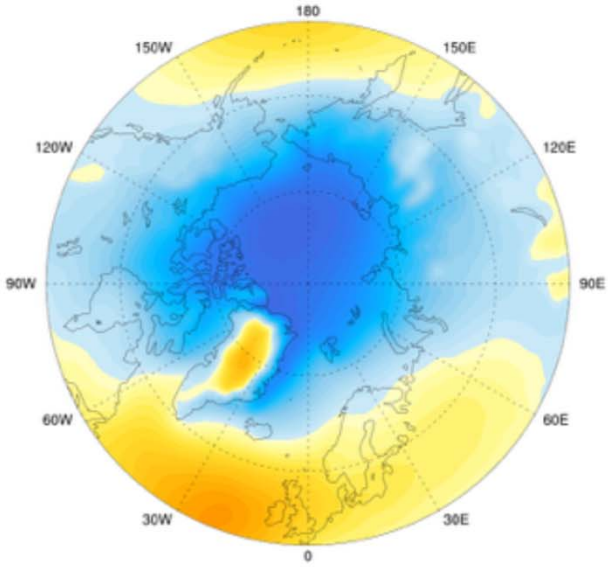
** not even accounting for future transition from ice-covered to open-water **

Change in Mean Sea Level Pressure

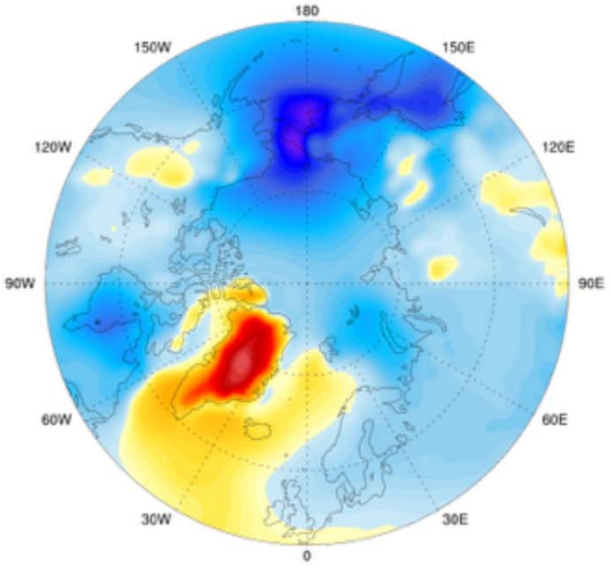
JJA



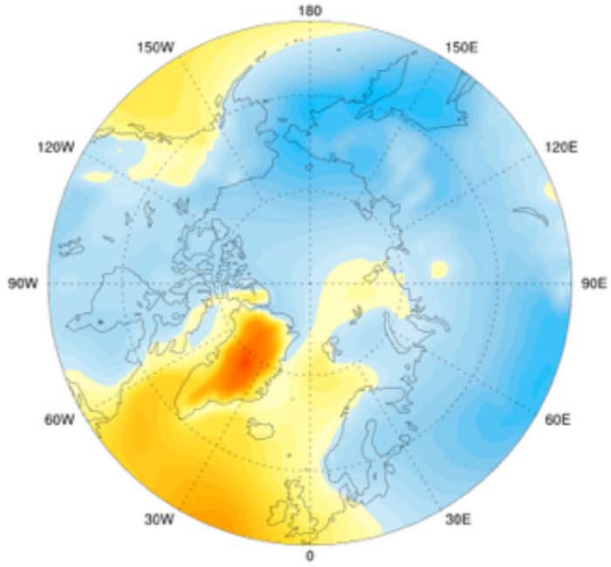
SON

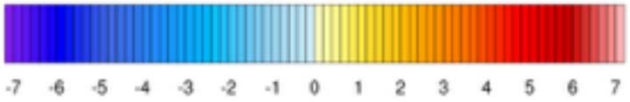


DJF



MAM

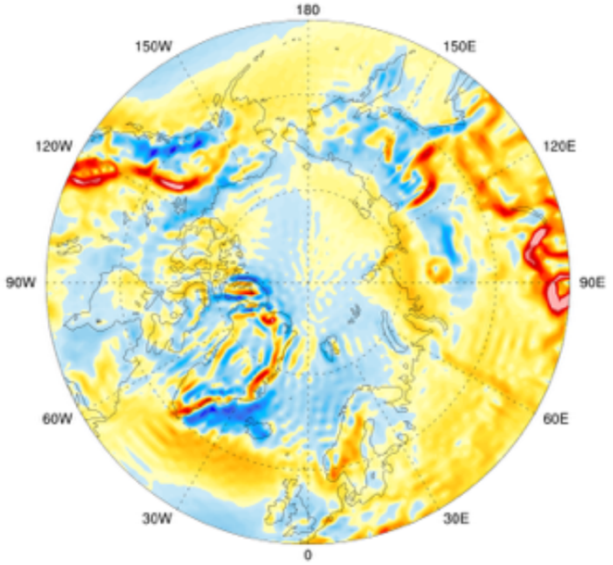




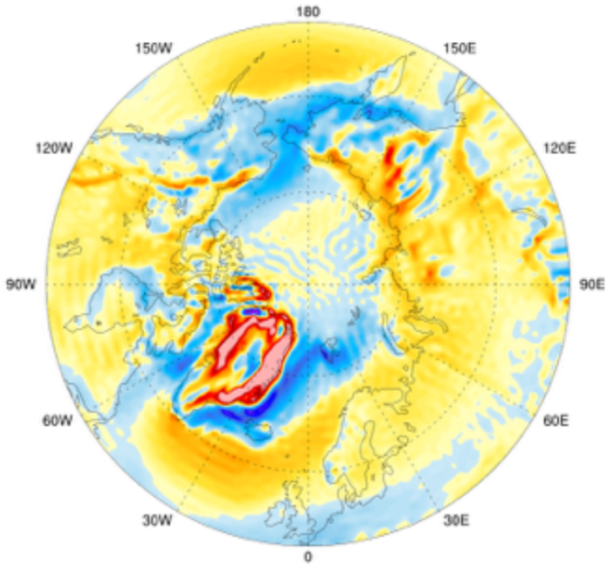
(hPa)

Change in Mean Geostrophic Surface Wind Speed

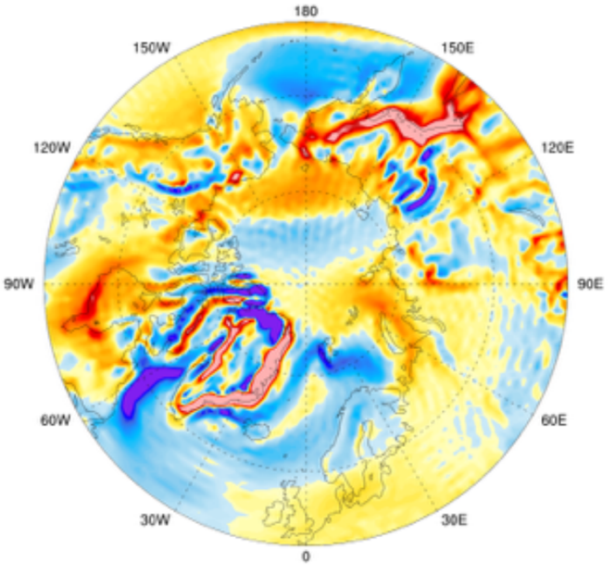
JJA



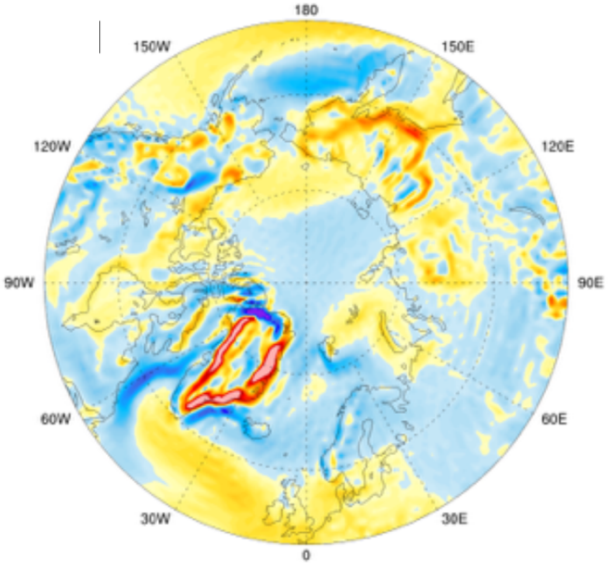
SON

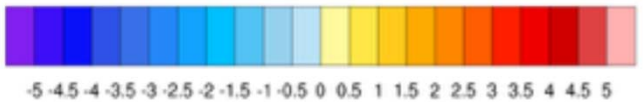


DJF



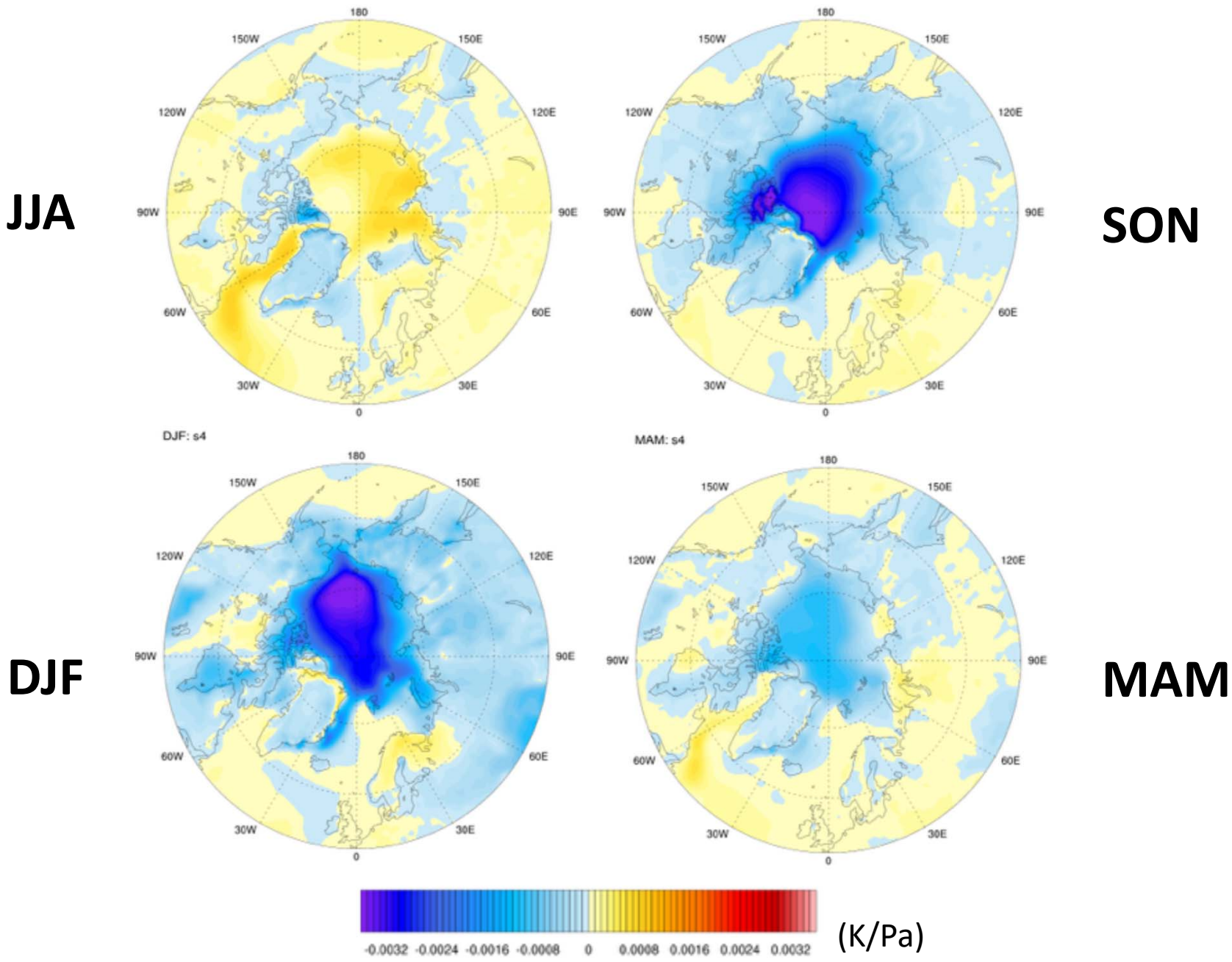
MAM





(m/s)

Change in Low-level Atmospheric Stability



Influence of Atmospheric Stability on Wind Speed

$$U_{10} = U_A \left[1 + \frac{\sqrt{C_{10}^N}}{\kappa} \ln\left(\frac{Z_A}{10} - \psi_m \right) \right]^{-1}$$

Atmospheric
Stability Dependence

Reduced atmospheric stability → stronger near-surface wind

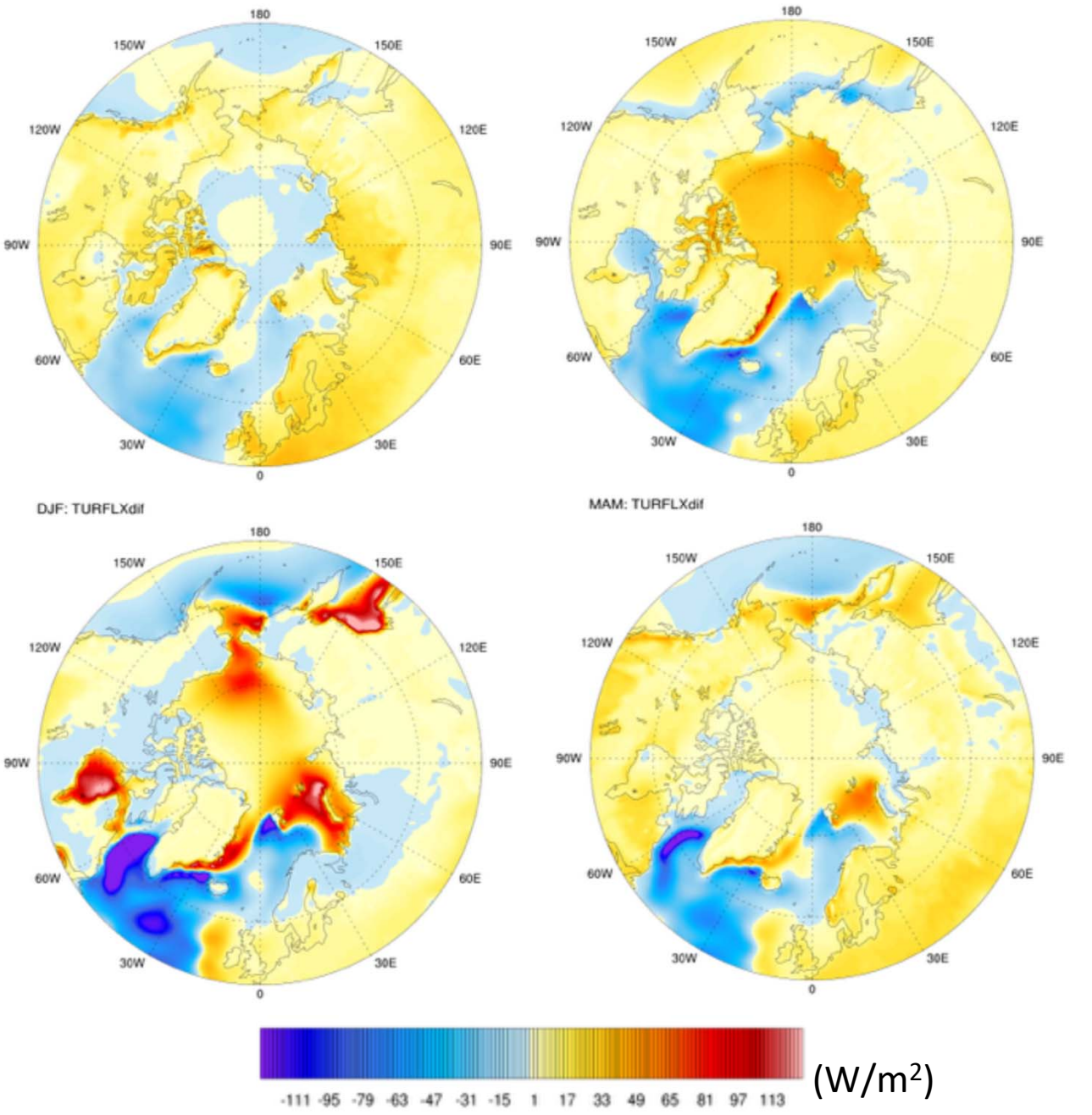
Change in Turbulent Heat Flux

JJA

SON

DJF

MAM



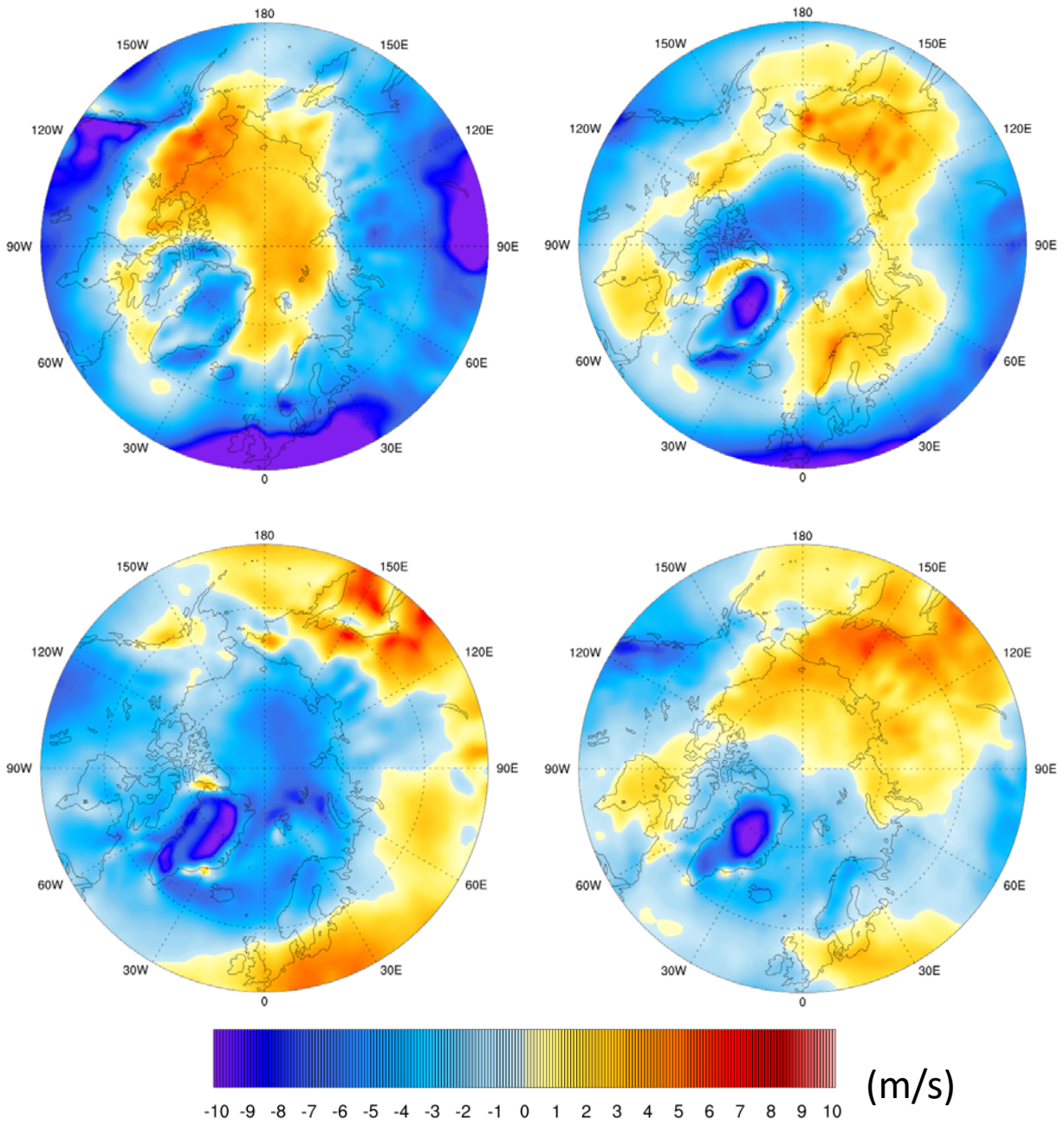
Change in Mean 850 hPa Wind Speed

JJA

SON

DJF

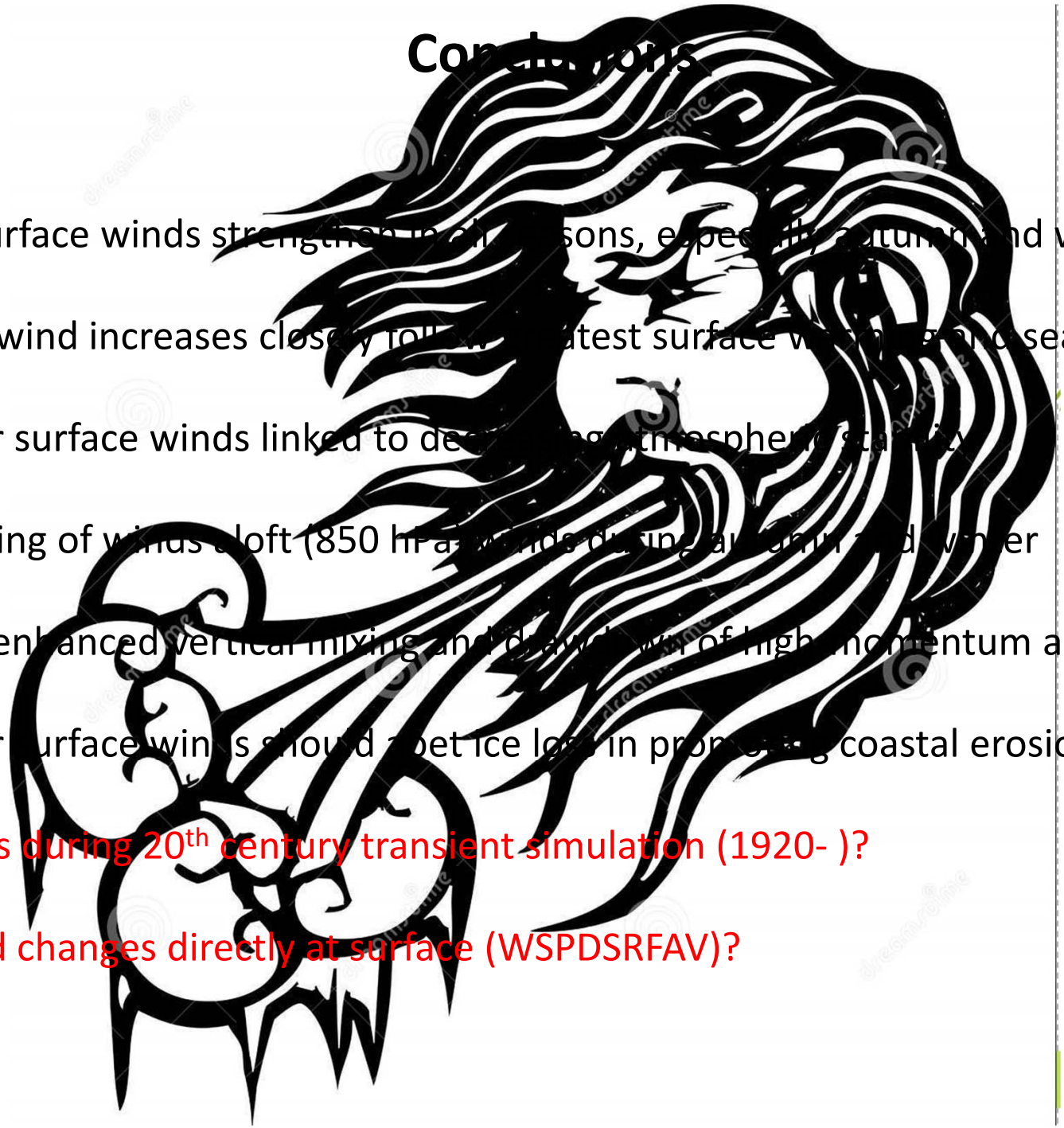
MAM



Troubling Times for Coastal Arctic Communities

Kivalina, Alaska

Conclusions



- Arctic surface winds strengthen in all seasons, especially autumn and winter
- Surface wind increases closely follow greatest surface w[illegible] sea ice loss
- Stronger surface winds linked to de[illegible] atmospheric stability
- Weakening of winds aloft (850 hPa winds during autumn and winter
- Implies enhanced vertical mixing and downward flux of high momentum air
- Stronger surface winds should abet ice loss in promoting coastal erosion

Wind trends during 20th century transient simulation (1920-)?

Future wind changes directly at surface (WSPDSRFAV)?

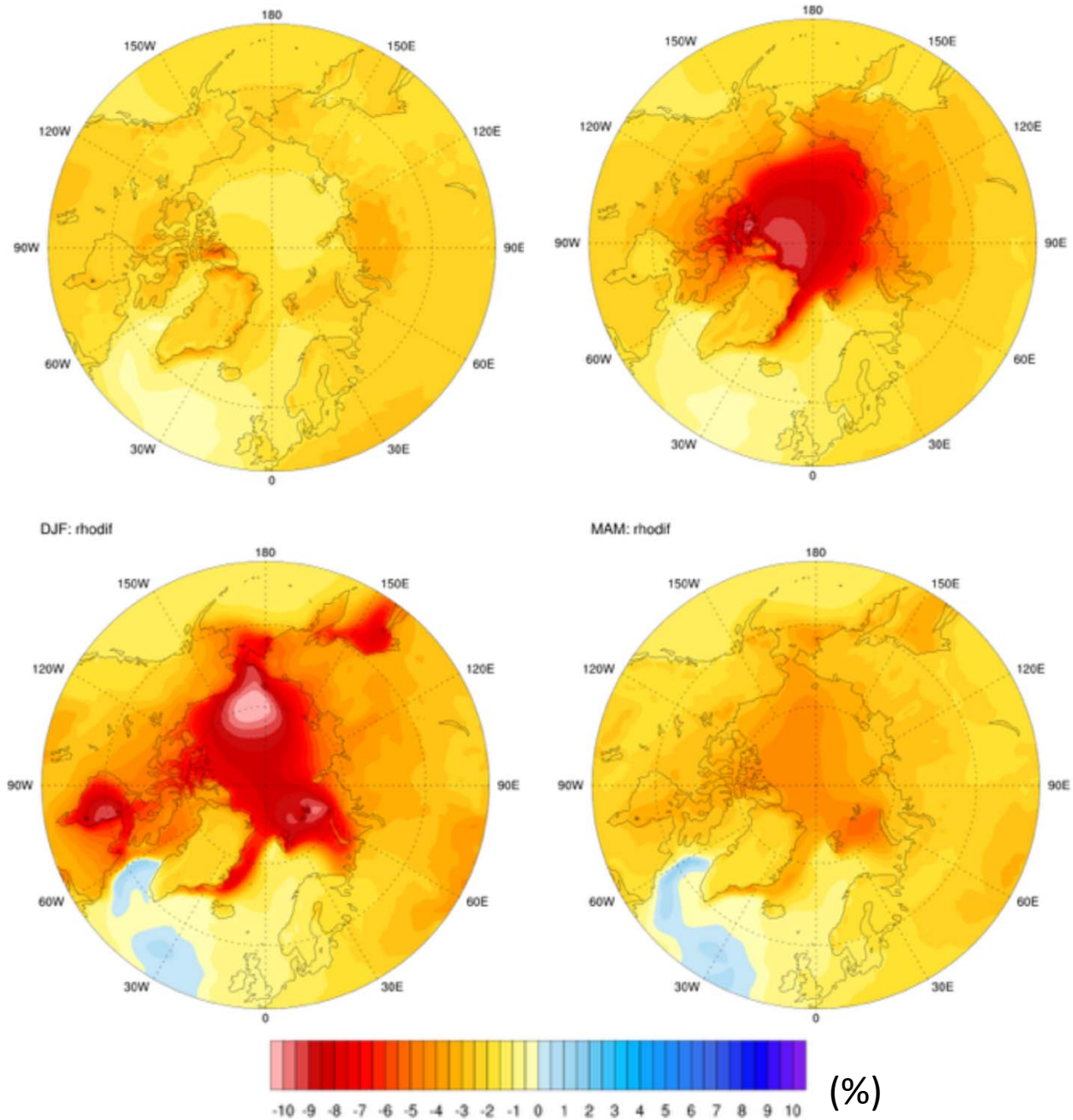
Change in Near-Surface Air Density

JJA

SON

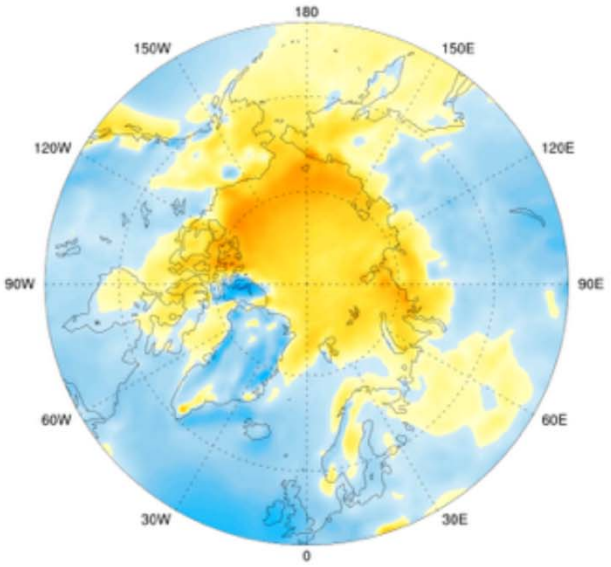
DJF

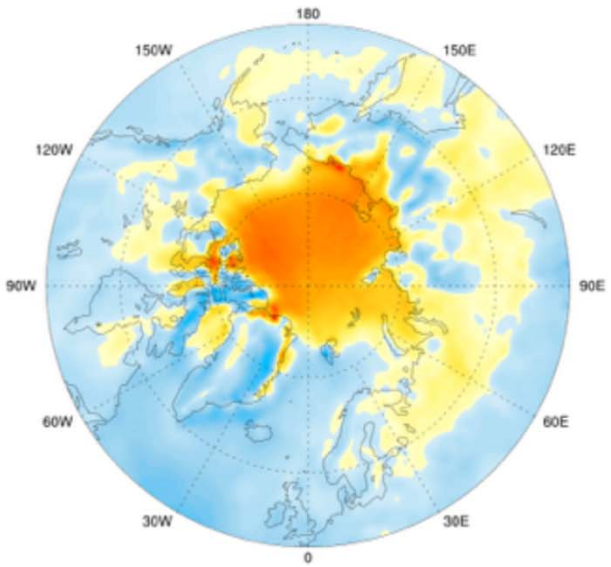
MAM



Change in Strongest Near-Surface Wind Speeds (%)

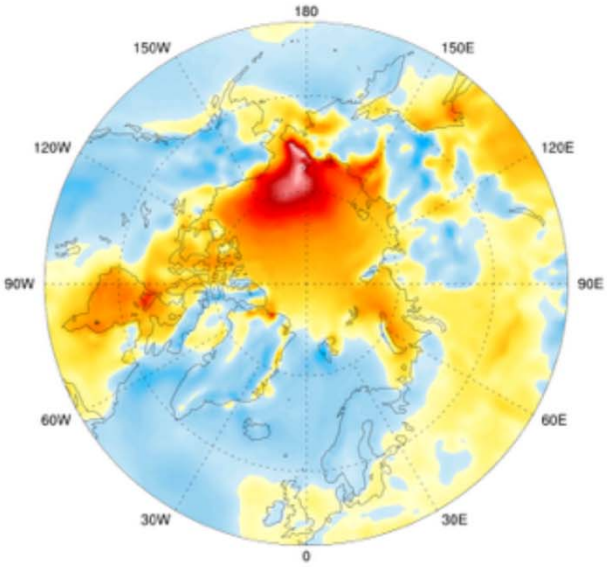
JJA

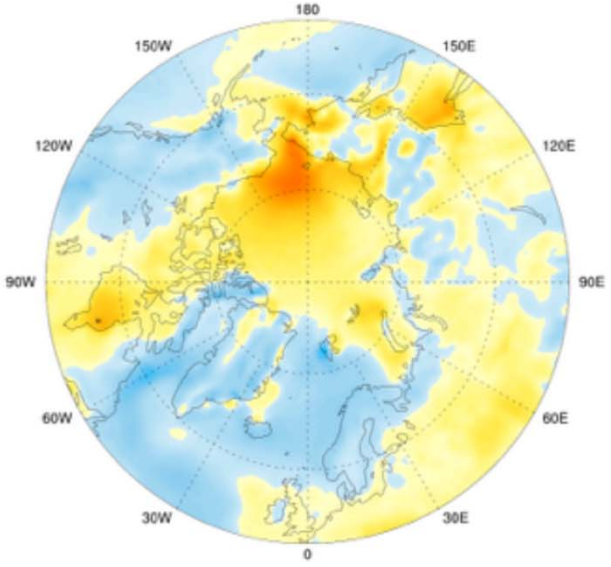




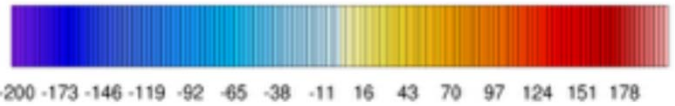
SON

DJF





MAM



(%)