Overarching Scientific Questions:

- What are the physically based metrics that can consistently detect extreme events at different temporal and spatial scales?

What do we know: 1) PDF-based definition/variance-based metrics (Time of Emergence); 2) Impacts/consequence-based metrics; 3) Integrative index.

What do we not know or are we not sure: 1) Definition and distinguishing of "climate extremes" and "weather extremes" (across scale; weather events superimposed on long-term trend)? 2) Tipping point/tipping element/"new Arctic"/regime shift (time scale dependent; ; integrated changes; parameter-dependent – uncertainty; background forcing ~ e.g., winter state); 3) Detrending or not. (step function)

- What are the large-scale atmosphere, ocean, and sea ice settings and underlying processes/mechanisms for conditioning occurrence of extremes?

What do we know: 1) Leading modes of the atmospheric circulation (AO/NAO, El Nino/La Nina, MJO/tropic convection) and teleconnections; 2) Cyclone~~(/polar low)~~ track dynamics (and blocking); 3) The stratospheric polar vortex; 4) Large-scale ocean variability modes (AMO, PDO, AMOC) and sea ice/ocean surface thermal anomalies; 3) Atmospheric heat and moisture transport; ocean heat transport.

What do not know: 1) Dynamic variability of jet streams; 2) Decoupling of AMOC and

- **What are the regional or local scale atmospheric and oceanic drivers for occurrence of extremes?**

What do we know: 1) Cyclones carry atmospheric heat and moisture into the Arctic, increasing downward LW and turbulent heat fluxes; 2) Atmospheric rive (associated with cyclones and blocking), leading to an increase in downward LW.

What do we not know or are we not sure: 1) Dynamic and thermodynamic contributions to sea ice change/temperature events in the context of cyclone activity; 2) Net energy budgets of sea ice; 3) Relative roles of atmospheric and oceanic processes in controlling sea ice mass balance; 4) interactive/feedback processes across the atmosphere/sea ice/ocean (e.g., baroclinic instability); 5) ocean mixing and stratification.

- **What are the feedback processes between large-scale and regional scale systems and across atmosphere, sea ice, and ocean to cause extreme events?**

What do we know: 1) Interactive/feedback processes across the atmosphere/sea ice/ocean (e.g., thermodynamic melt; dynamic opening; albedo feedback).

What do we not know or are we not sure: 1) Ocean heat release (Atlantic/Pacific warm water); 2) ocean mixing and waves; 3) meso-scale and large-scale interactions; 4) feedbacks between atm and sea –ice/open water associated with cyclones/polar low.

- How do the long-term changes (past + future) in the Arctic/global climate system impact the processes mentioned above?

What do we know: 1) Warming trend (both the atmosphere and ocean); 2) Decreasing and thinning of sea ice; 2) AMOC weakening.

What do we not know or are we not sure: 1) Changes in the atmospheric dynamics (cyclone tracks/intensity/frequency/duration, jet streams, blockings, tropical convective activity, the stratospheric polar vortex); 2) AMOC and poleward oceanic heat transport; 3) robustness of signals of changes across different datasets; 3) Greenland icesheet.

- Where are the sources of predictability and impacts of extreme events at different temporal and spatial scales?

What do we know: 1) Impacts (navigation, economic activity, indigenous society, wave surge, coastal erosion, permafrost, ecosystem; pollutant transport)

What do we not know or are we not sure: 1) uncertainty caused by dynamic variability or mean state vs. variability; 2) Direction (positive or negative) of impacts.

Across scale interactions