National Aeronautics and Space Administration

EXPLORE EARTH

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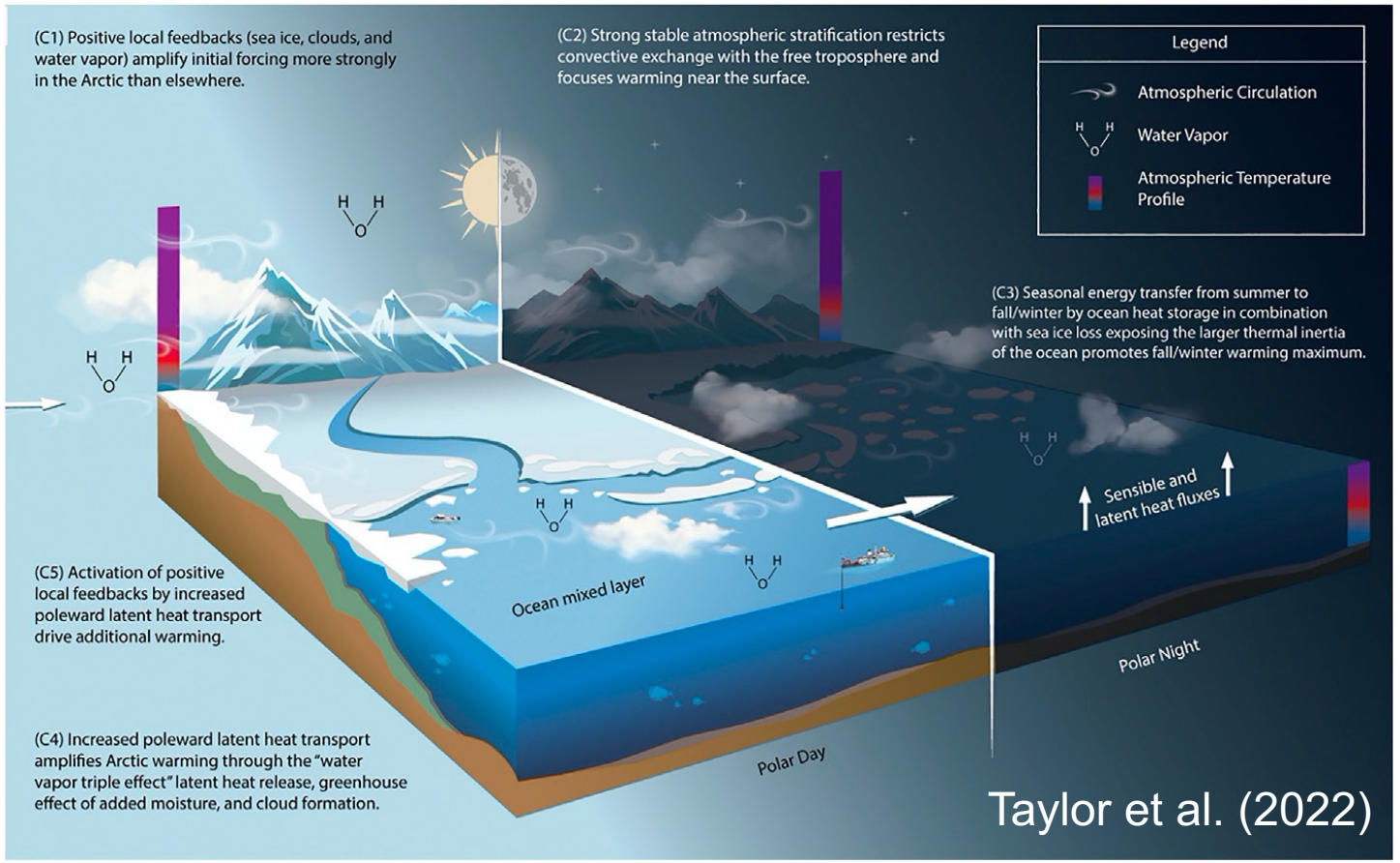
The Science Directorate at NASA's Langley Research Center: External Peer Review

Conceptual Model of Arctic Amplification



The conceptual model highlights the **need to account for local feedback and remote process interactions** within the context of the annual cycle to constrain the high-end of model projections.

- Reducing uncertainty requires the understanding of the factors that influence sea ice survival within the context of the annual cycle.

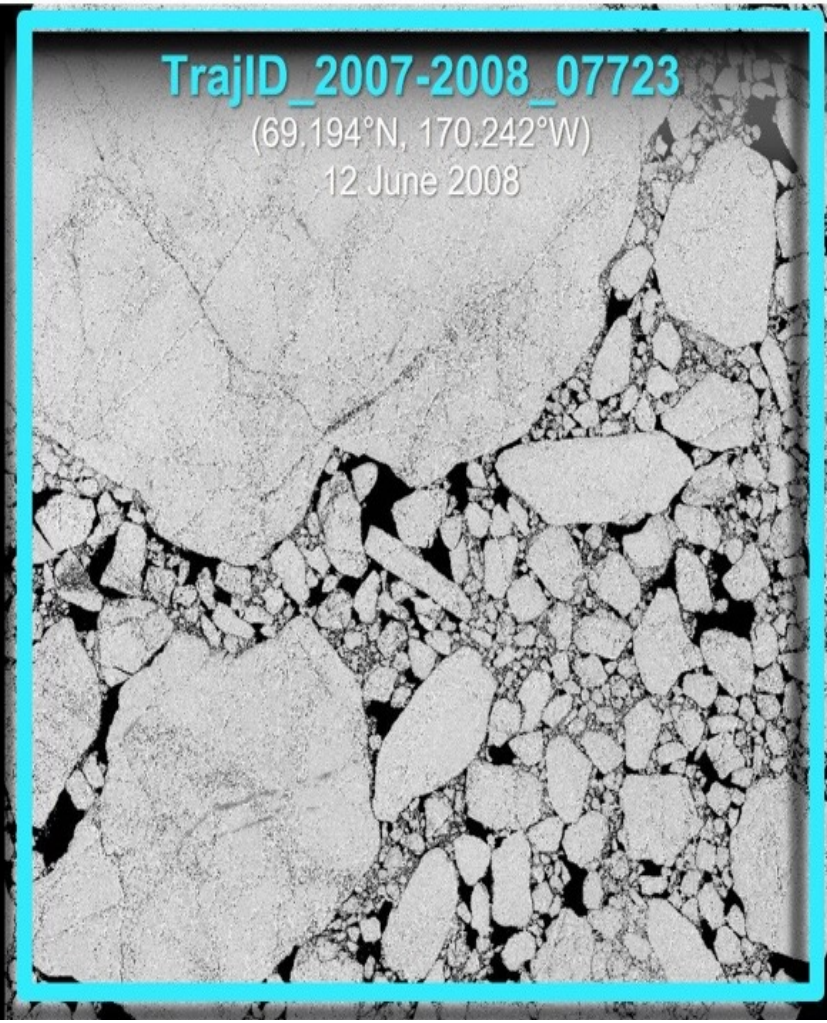
Arctic sea ice parcel database: >1,000,000 parcels

Sea Ice Characteristics:
Ice Type (Buoys/SSM/I): First Year
Concentration (NSIDC/CDR): 90%
Snow Depth (SnowModelLG): 0.06 m
Sea Ice Thickness (PIOMAS): 2.10 m
Surface Albedo (CERES): 0.50
Ice Surface Temperature:

Lifecycle:
Formation: 22 Nov. 2007
Duration: 211 days
End: 20 June 2008
Origin & End Region: Chukchi Sea
Survived: No

Flags:
Cyclone (Melbourne U. Tracker): n/a
Cyclone properties (ERA5): n/a

(Horvath et al. 2023)



Atmospheric State:
Air Press. (ERA5/MERRA2): 1018 hPa
Cloud Cover (CERES): 15%
Precipitable Water (ERA5/MERRA2): 19 kg m^{-2}
Liq. Water Path (CERES): 112 g m^{-2}
Ice Water Path (CERES): 96 g m^{-2}
Air T.(ERA5/MERRA2): 0.95°C
Wind Speed & Direction (ERA5/MERRA2): 8.4 $m\text{-}s^{-1}$ & 39°
Spec. Humidity (ERA5/MERRA2): ~0%
Snowfall (ERA5/MERRA2): n/a
Total Precipitation (ERA5/MERRA2): n/a

Surface Energy Budget:
Upwelling SW (CERES): 134 W m^{-2}
Downwelling SW (CERES): 267 W m^{-2}
Upwelling LW (CERES):312 W m^{-2}
Downwelling LW (CERES): 284 W m^{-2}
Sensible Heat (AIRS): -30 W m^{-2}
Latent Heat (AIRS): ~0 W m^{-2}

- New database enables novel studies on the factors influencing on sea ice parcel survival.

What is sea ice survivability?

The likelihood that a sea ice parcel survives through the summer melts season.

$$\text{Survivability} = \frac{\text{Number of parcels that survived}}{\text{Total number of parcels}}$$

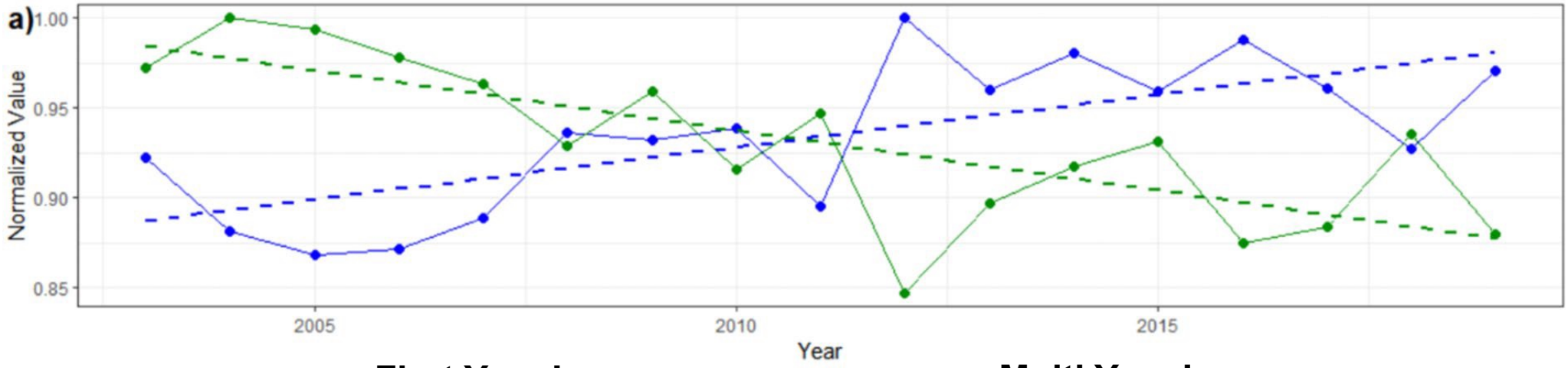
Some factors that influence sea ice survivability

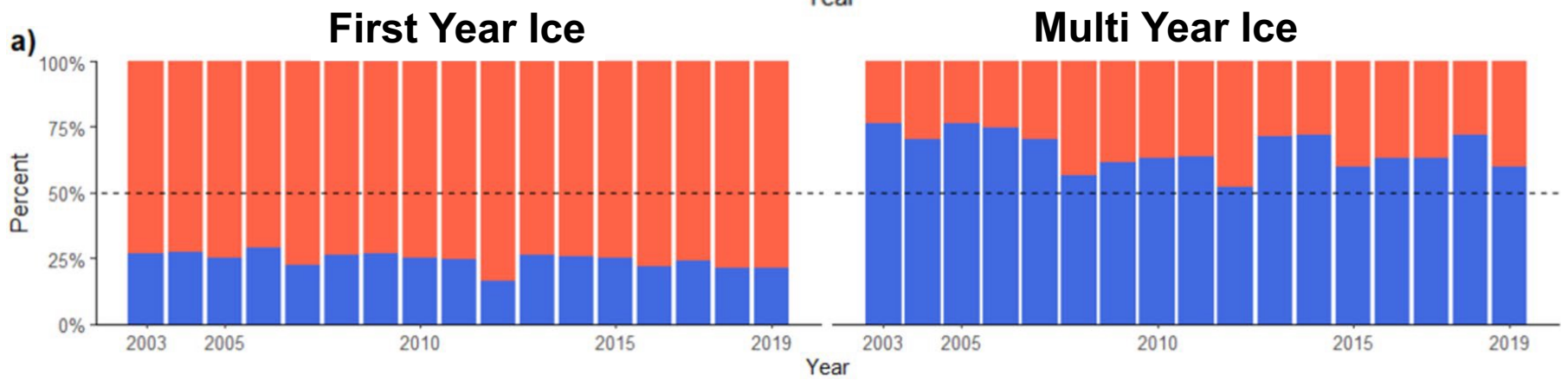
- Sea ice properties (thickness, concentration, topography/roughness, snow depth)
- Sea ice dynamics (convergence and divergence)
- Atmospheric conditions (temperature, humidity, clouds, winds)
- Surface energy budget (surface temperature, turbulent fluxes, albedo, conductance)
- Winds and waves, ocean properties

Inter-annual variability of sea ice parcels

Green: normalized duration
Blue: normalized total parcels

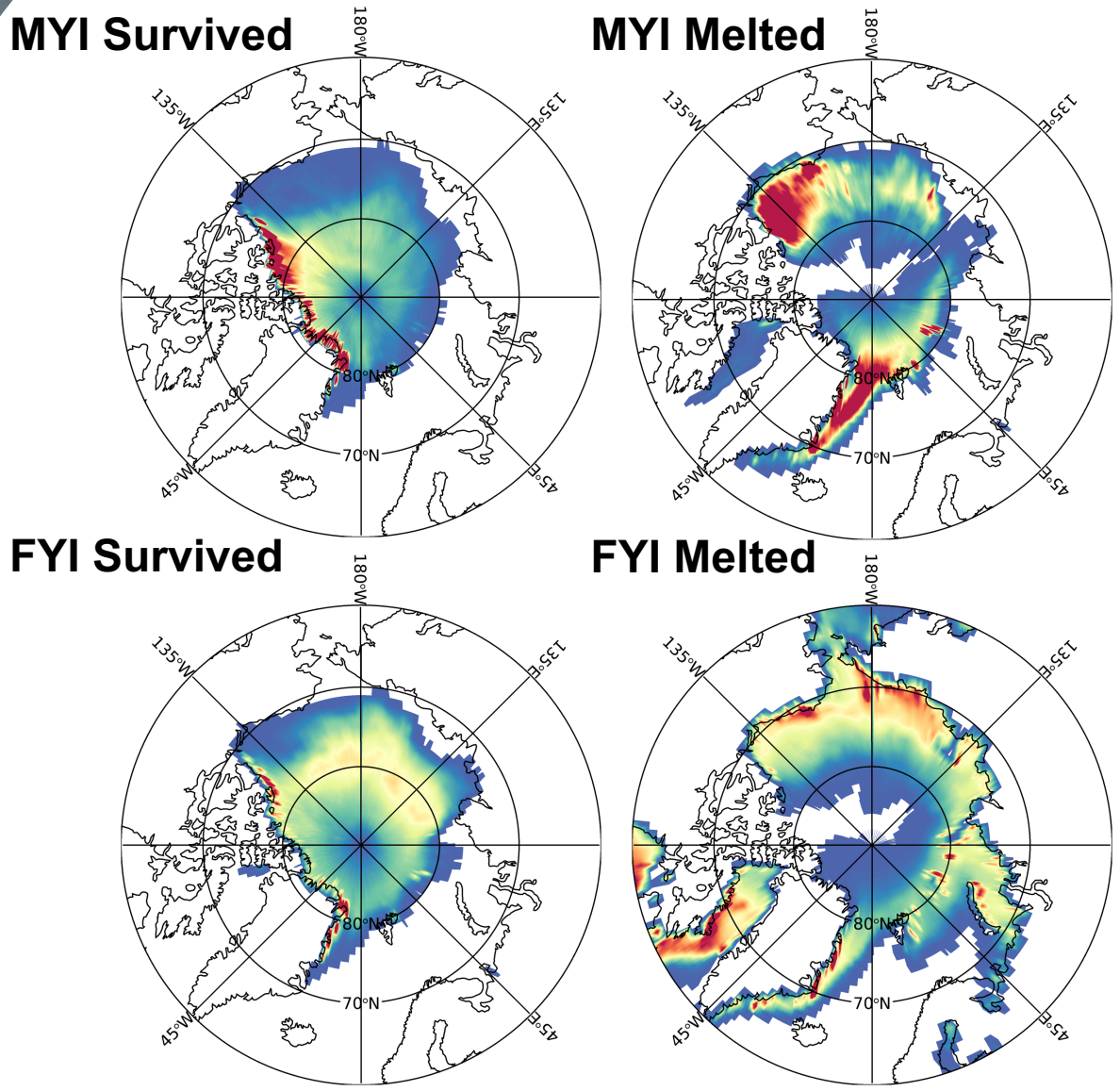
Increasing trend in the number of sea ice parcels and deceasing trend in parcel duration.





Greater inter-annual variability in the survival rate of Multi-year vs. First year sea ice.

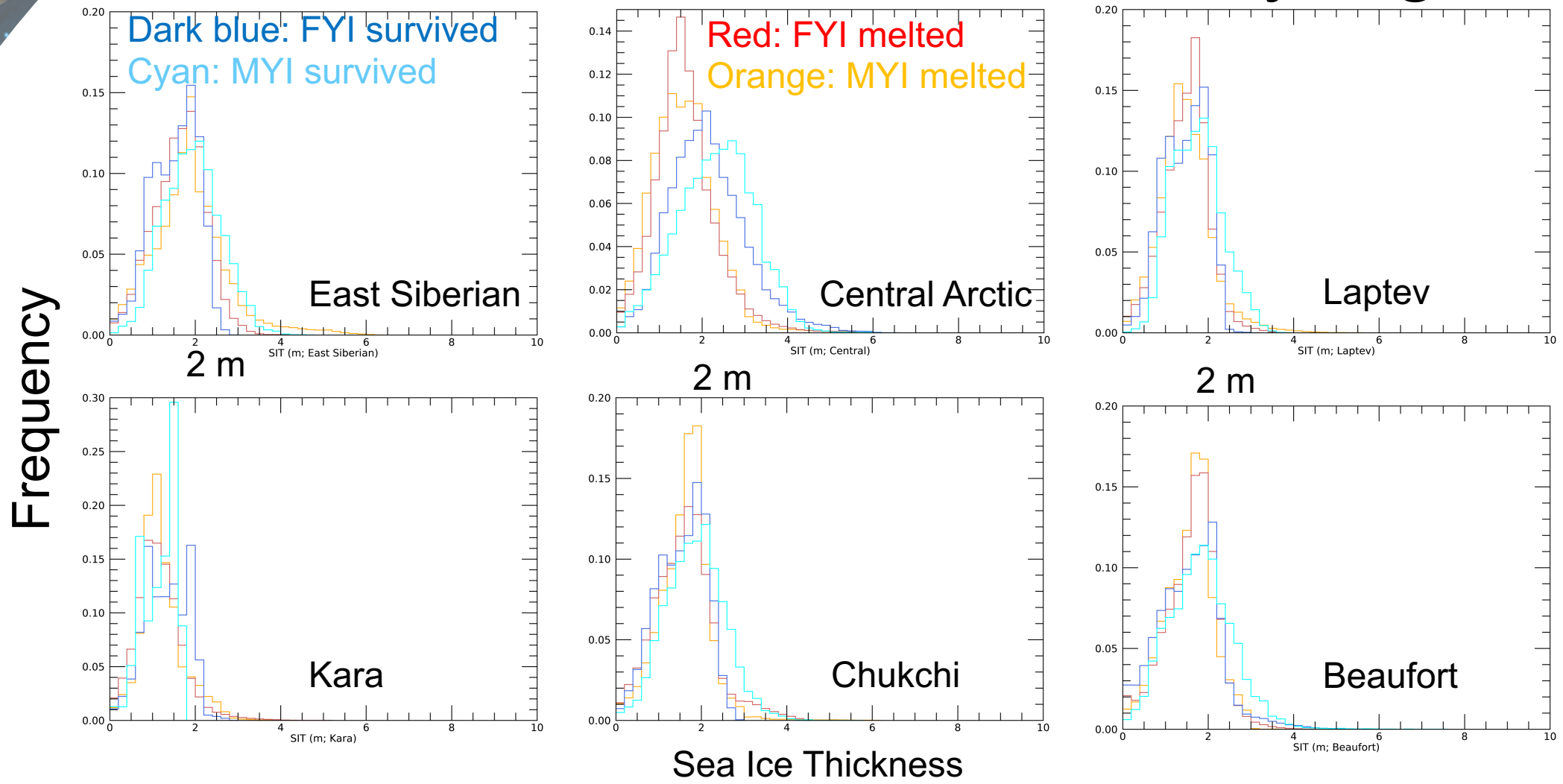
Sea ice havens, graveyards, and nurseries



- **Sea ice Havens:**
  - Central Arctic
  - North of Greenland and the Canadian Archipelago
- **Sea ice Graveyards:**
  - Fram Strait
  - Peripheral Seas
- **MYI Nursery**
  - Central Arctic.

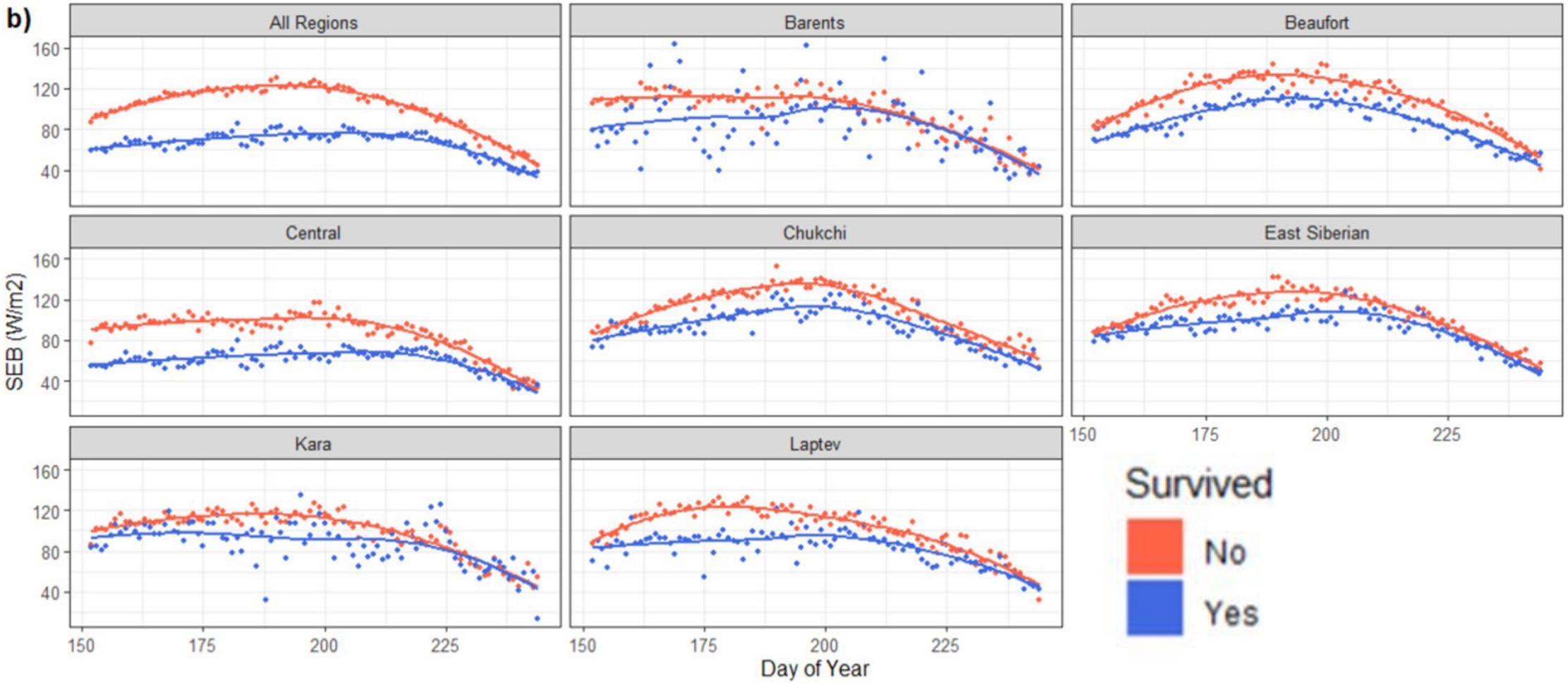
- **FYI survives when it moves towards the central Arctic.**
- **MYI melts out when it is advected into the Fram Strait and Beaufort Sea.**

Sea ice thickness distributions by region



- The Central Arctic is the only region with a strong relationship between sea ice thickness and survivability.
- Thickness is a less important determining factor for determining survivability outside of the central Arctic.

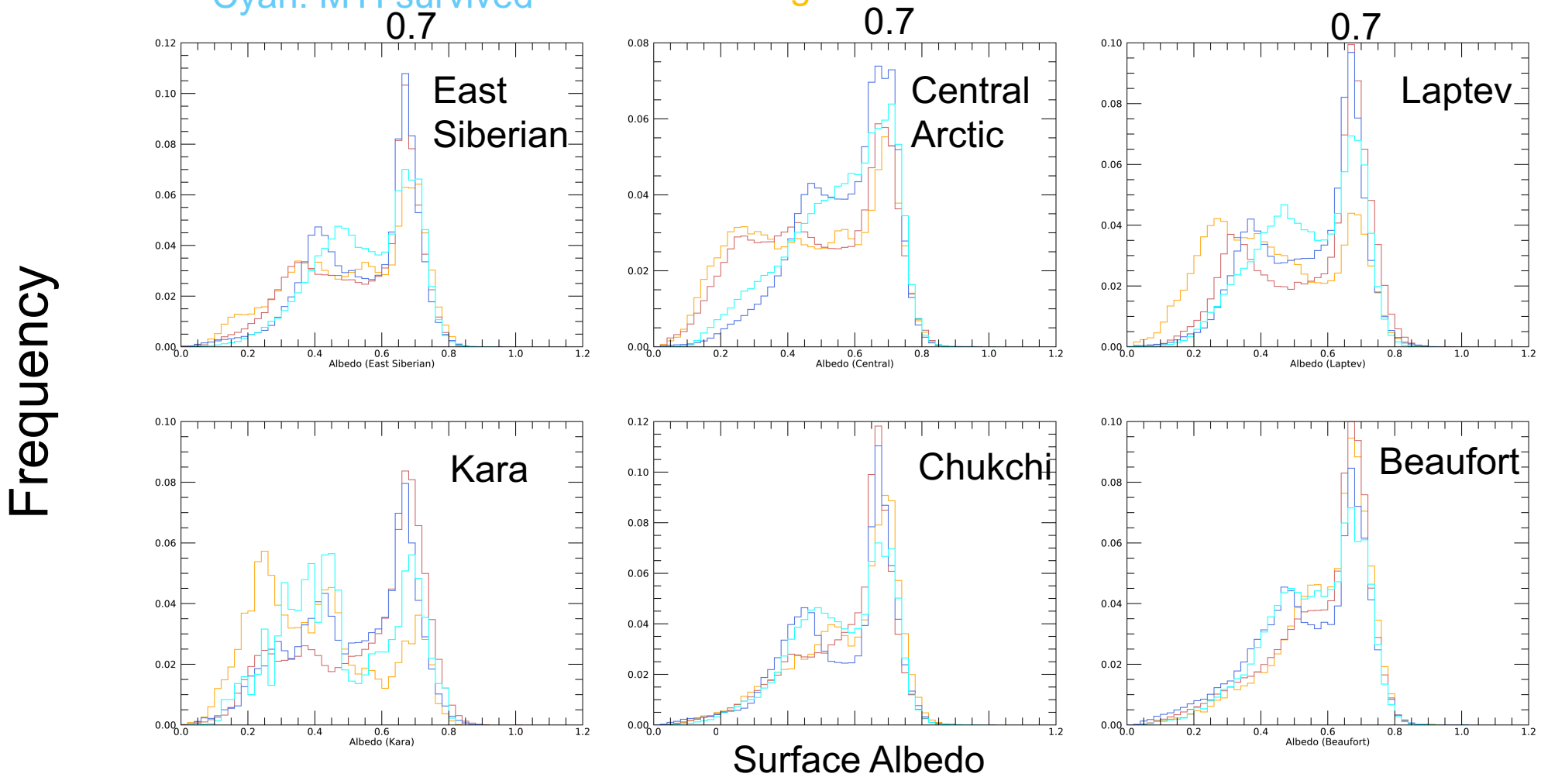
Net surface energy budget and sea ice parcel survivability



Sea ice parcels that melt-out have a more positive net surface energy budget (greater energy input) than survived parcels.

Albedo distribution by region

Dark blue: FYI survived
Cyan: MYI survived
Red: FYI melted
Orange: MYI melted



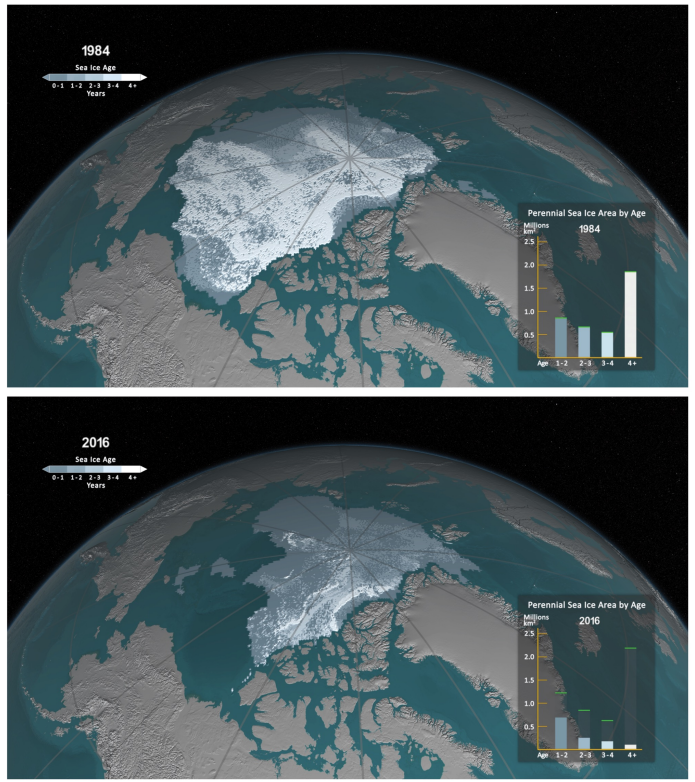
- Parcels the melt-out tend to have a lower surface albedo than parcels survive.
- Thickness is a less important determining factor for determining survivability outside of the central Arctic.

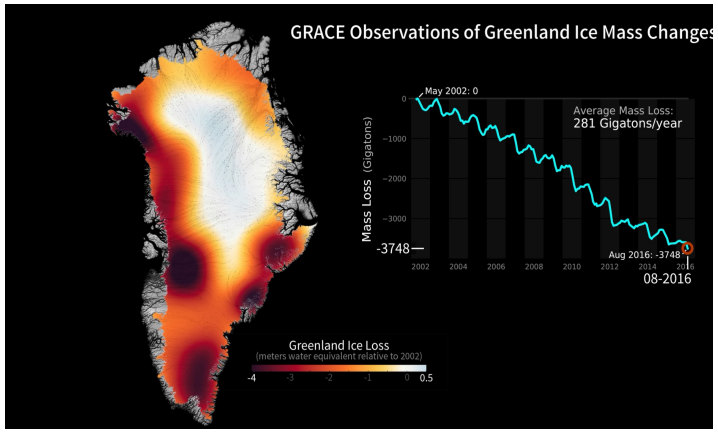
Summary and Takeaways:

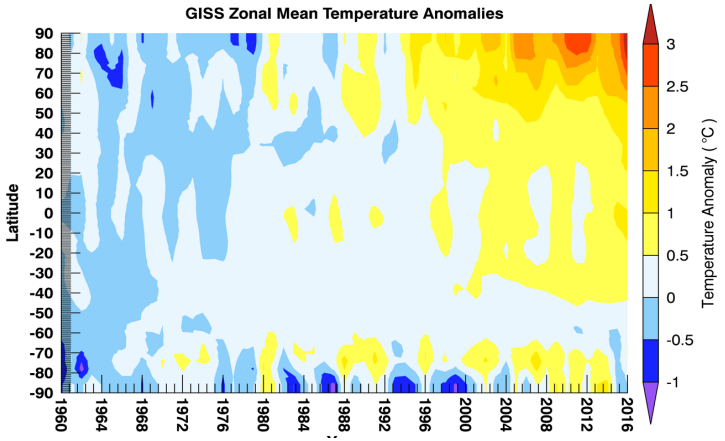
- We have created a Lagrangian database the enable the analysis of the factors that influence the evolution of sea ice parcels as they move around the Arctic (Horvath et al. 2023; https://doi.org/10.5281/zenodo.7554521).
- We find…
  - An increasing trend in the number of sea ice parcels and deceasing trend in parcel duration.
  - Greater inter-annual variability in the survival rate of Multi-year vs. First year sea ice.
  - Sea ice parcels that melt-out have a more positive net surface energy budget (greater energy input) than survived parcels.
  - Thickness is a strong determining factor for parcel survivability in the Central Arctic and less important in other regions.
  - Surface albedo tends to be lower at the start of the melt season for parcels that melt-out.

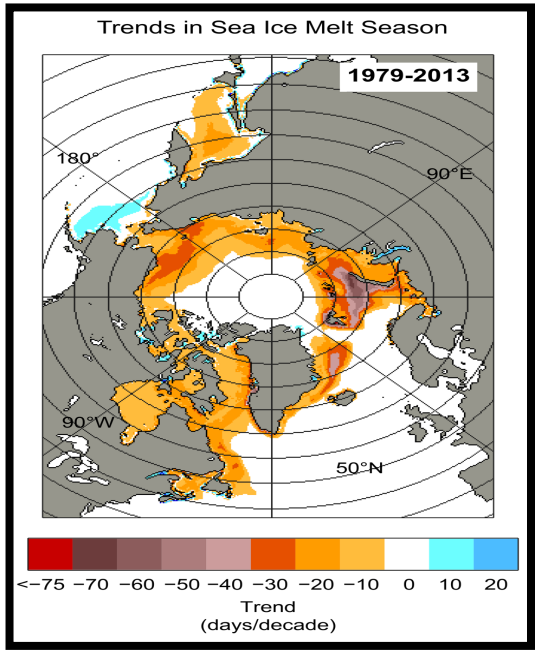
Back-up Slides

Rapid Arctic Change: The physical system



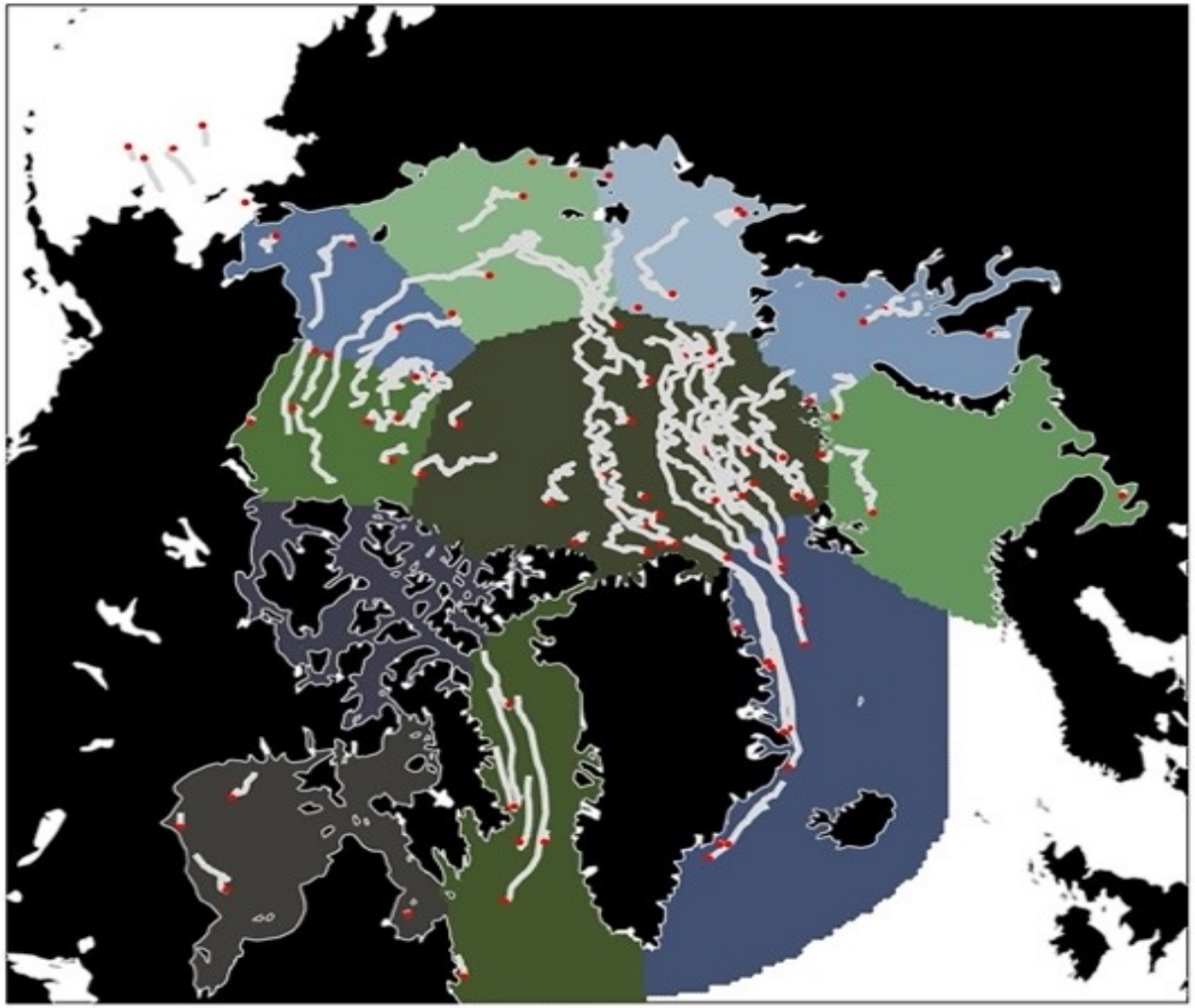






The Arctic climate system is changing fast.

Arctic sea ice parcel database: >1,000,000 parcels

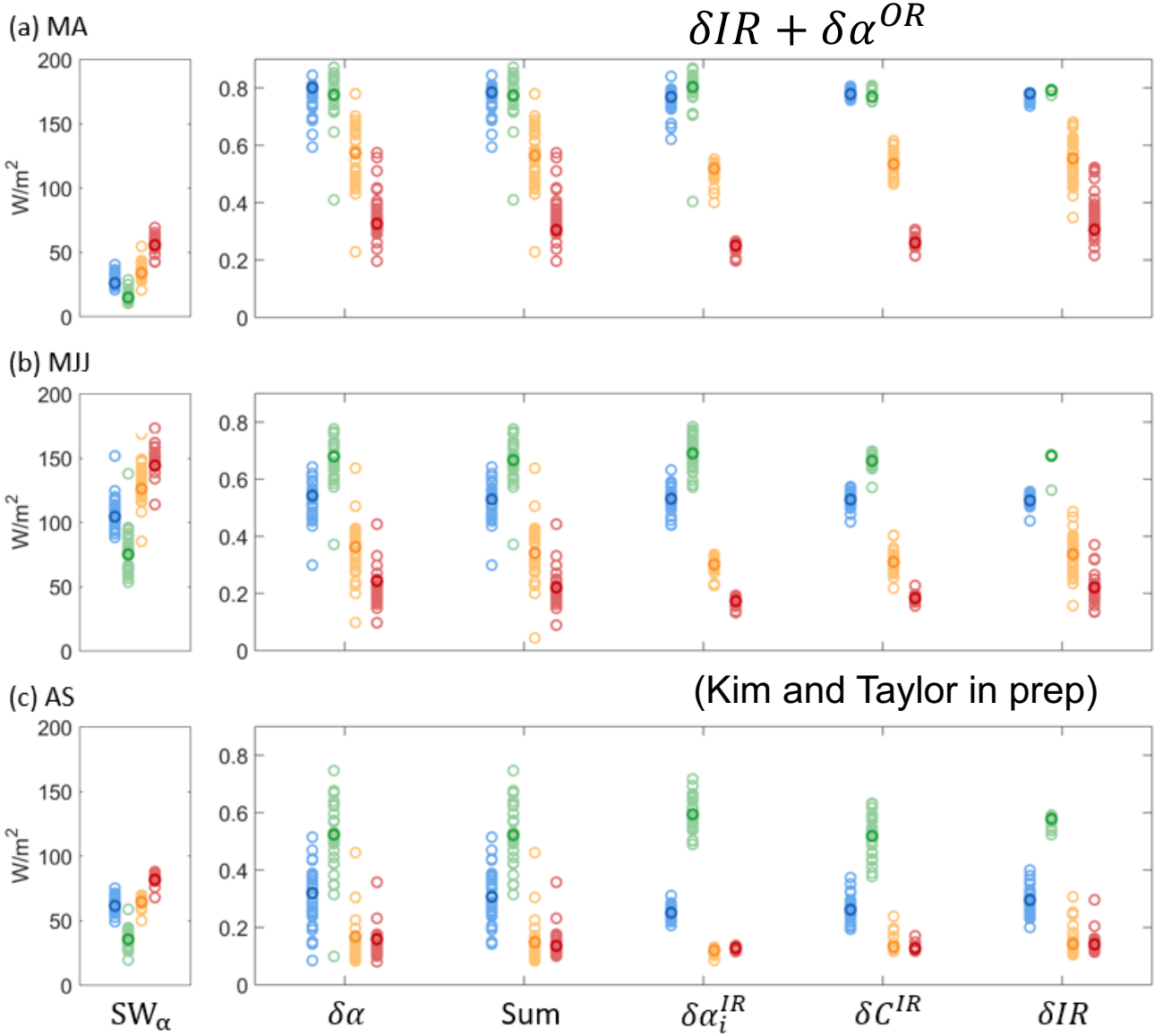


Surface albedo decomposition in models: Seasonality of contributions

$$\delta\alpha = \delta\alpha_i^{IR} + \delta C^{IR} + \delta\alpha_o^{IR} + \delta\overline{\alpha_i' c'} + \delta IR + \delta\alpha^{OR}$$

→The results indicate a strong seasonality of the inter-model spread in the contributions from sea ice albedo, sea ice concentration, and ice region area

→**ARCSIX needs to capture the seasonal evolution of ice albedo for a collection of sea ice parcels**



(Kim and Taylor in prep)

From: Doyeon Kim, NASA Postdoctoral Program