Arctic Research in the Year(s) of Polar Prediction

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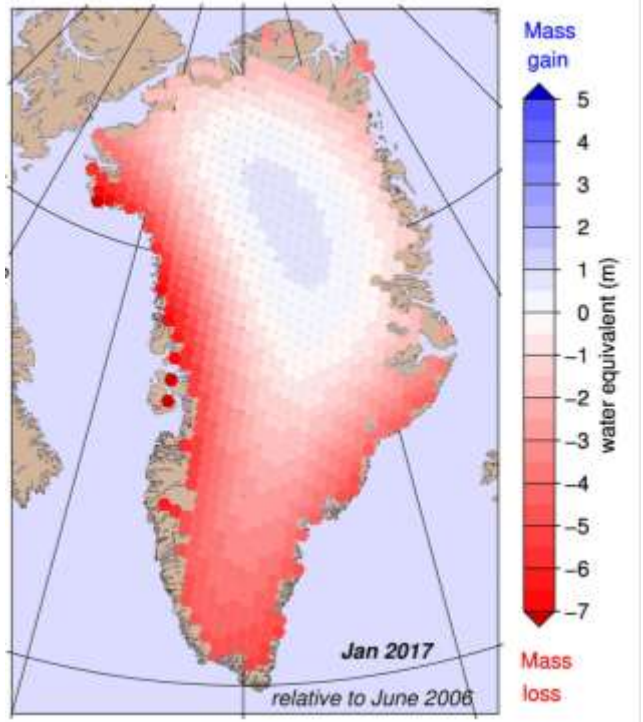
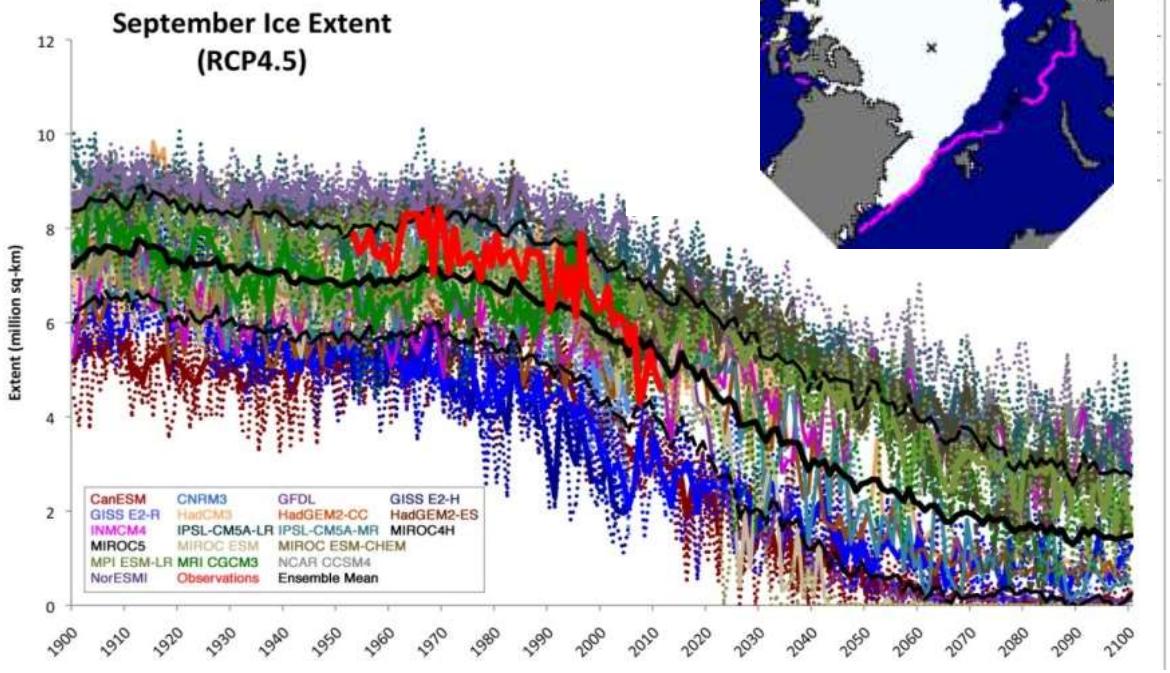
With contributions from Gijs de Boer and Bart Geerts

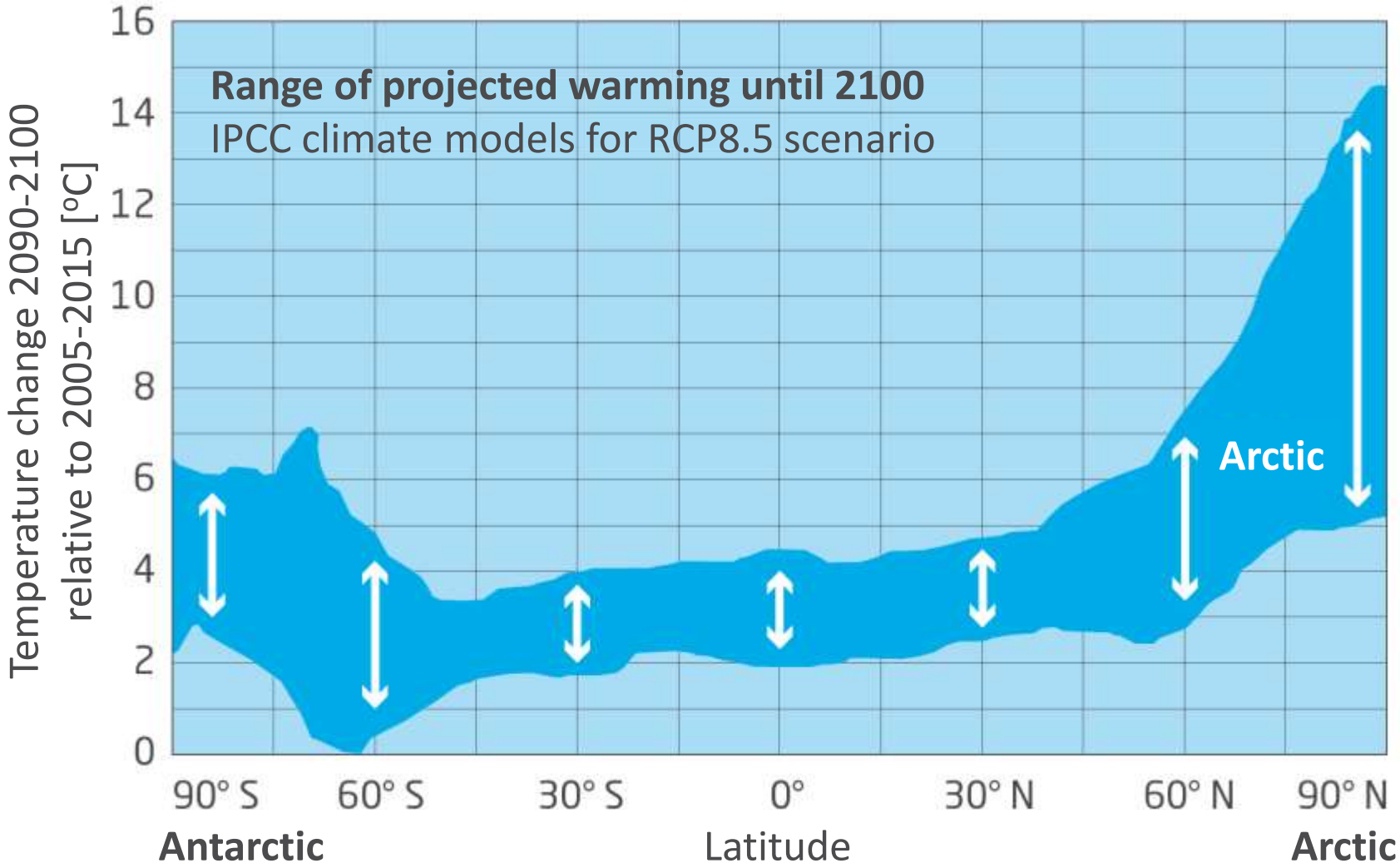
Arctic System Change

- Cryospheric melt: albedo feedbacks, energy transport, GHG, sea-level
- Large-scale fluxes and Ocean circulation shifts
- Ecosystem, habitat, ocean productivity, ocean acidification





Alarming Uncertainties



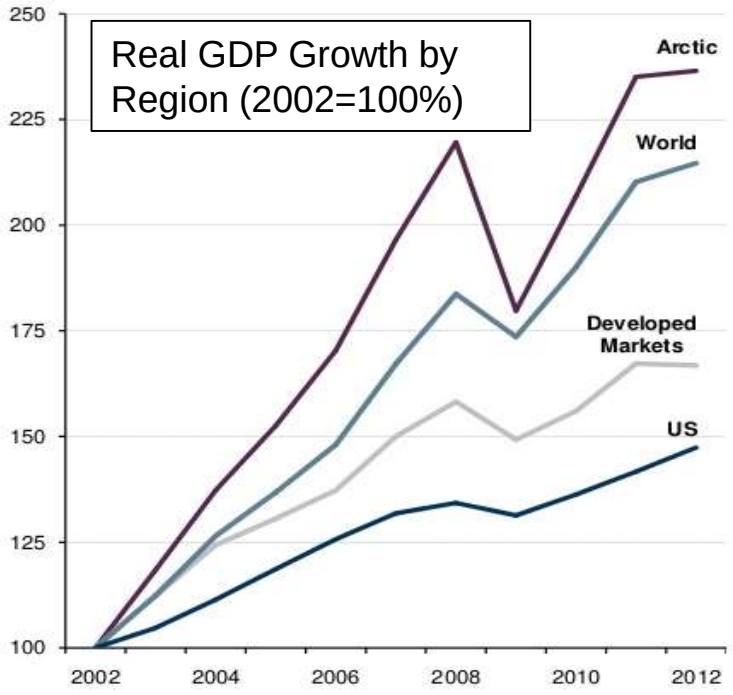
Two things to ponder

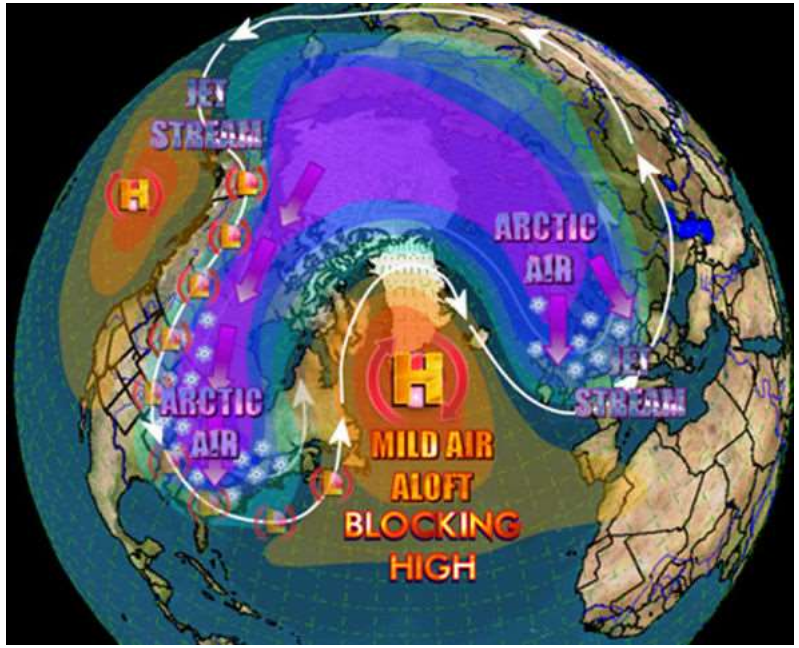
1) What is the (combination of) mechanisms leading to Arctic Amplification?

2) Large intermodal spread suggests fundamental lack of understanding and potentially large sensitivities.

Why do we Care?

The Arctic is Opening





1. Circulation >> Weather Forecasting
2. Climate Change and Prediction
3. Economics: Resource development, transportation, tourism, etc.
4. Ecosystem: productivity, fisheries
5. National Security: Navigating & operating

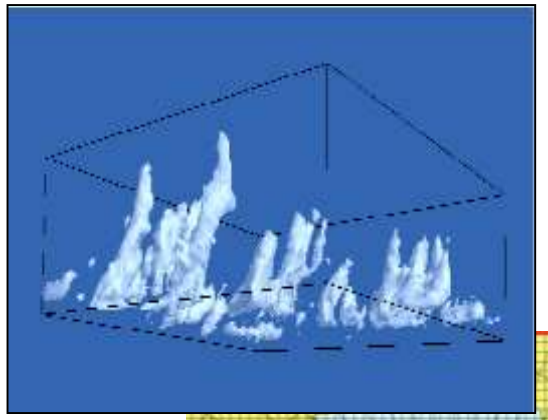
Where else on Earth is change so impactful?

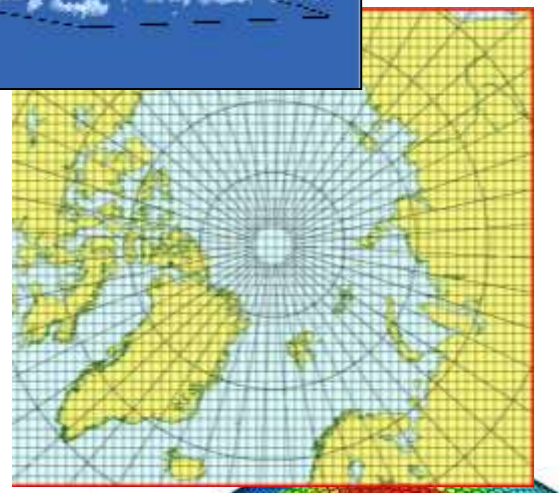
High Latitudes is a DOE CESD Strategic Grand Challenge Area

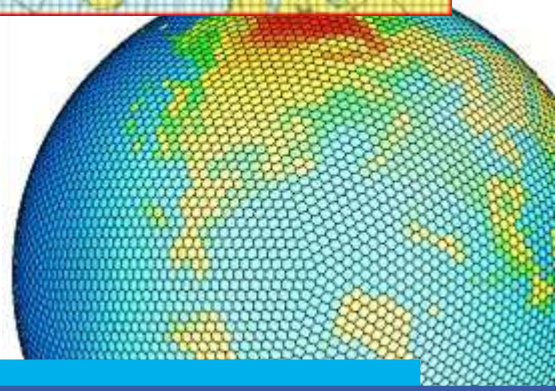
Strong Need to Improve Models

1) Weather / Sea-ice; 2) Climate; 3) Process

All require process representation of a changing Arctic







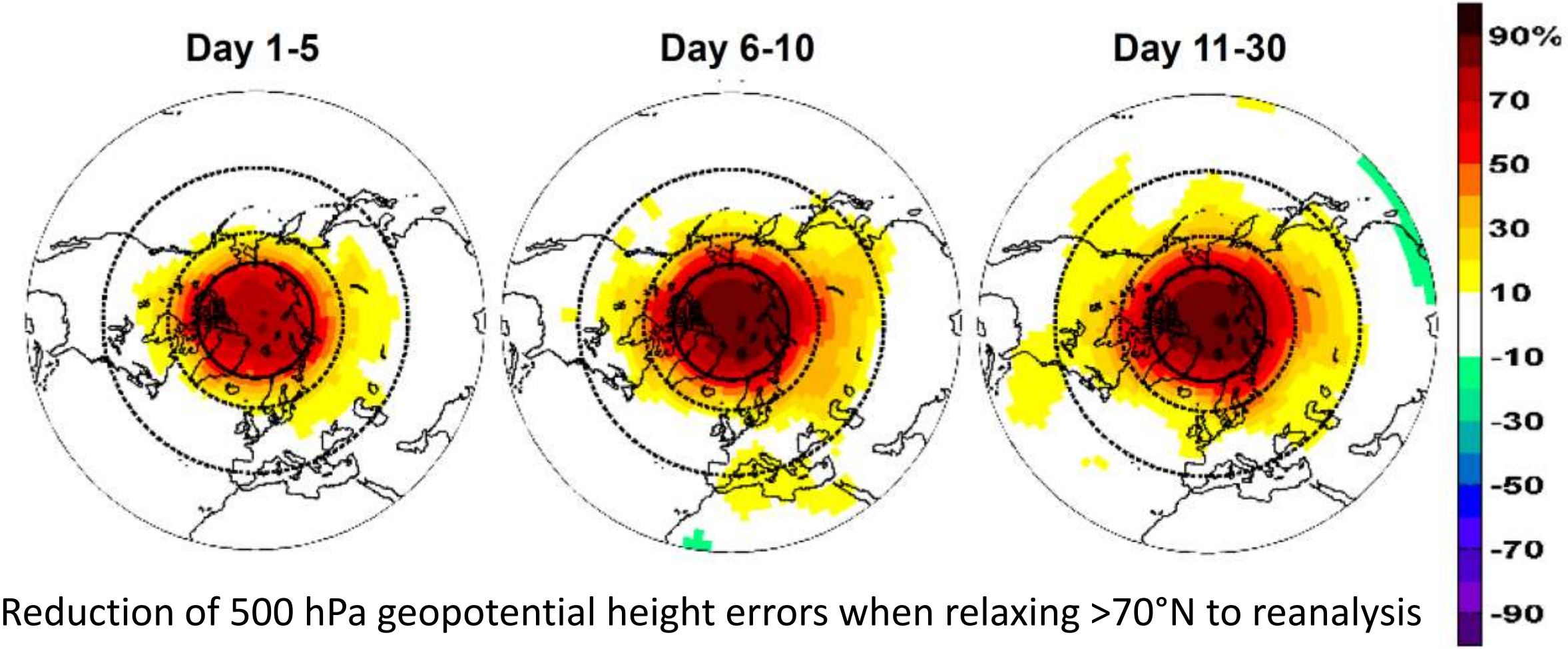
Conclusions from IPCC

- **Limited progress in modeling Arctic system**
- **Major Arctic deficiencies: clouds, boundary layer, winds, surface fluxes, ocean mixing**
- **Severe lack of observational data**

Coupled regional and global models are the frontier

Need to focus on processes

Motivating the Polar Prediction Project



Reduction of 500 hPa geopotential height errors when relaxing >70°N to reanalysis

Jung et al. 2014

Year of Polar Prediction

Enable significant improvement in environmental prediction capabilities for the polar regions and beyond, by coordinating a period of intensive observing, modelling, prediction, verification, user engagement and education activities.

- Part of WMO's 10-year Polar Prediction Project
- 21 nations, 82 endorsed projects, joint effort of weather and climate communities
- Enhanced modeling and observing activities
- Support model development, assessment, and verification
- Special interest in coupled models

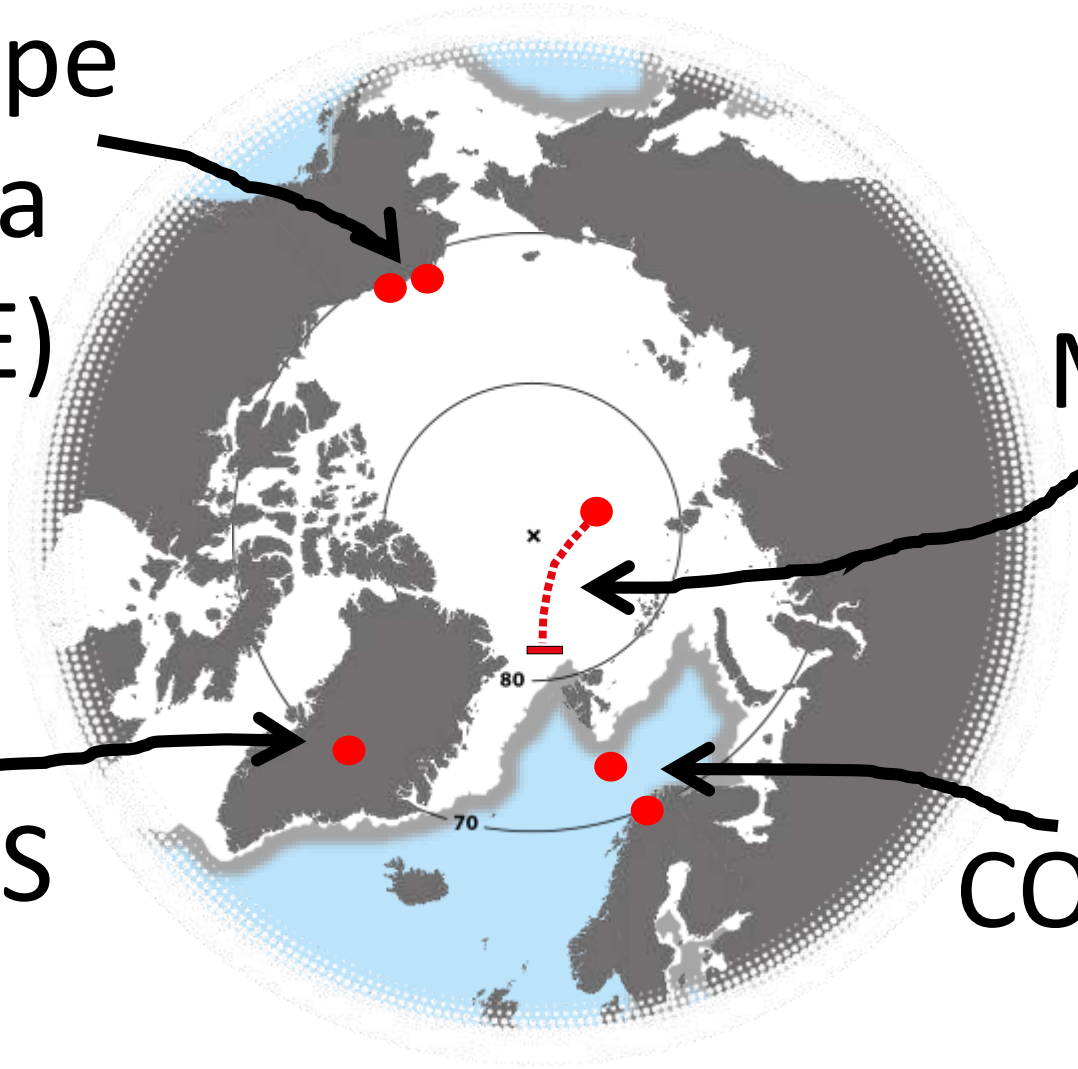
Year of Polar Prediction

Preparation Phase 2013 to mid-2017	Core Phase mid-2017 to mid-2019	Consolidation Phase mid-2019 to 2022
Community Engagement	Intensive Observing Periods & Satellite Snapshot	Consolidating YOPP Research
Alignment with other Planned Activities	Dedicated Model Experiments	From Research to Operations and Services
Development of Implementation Plan	Coupled Data Assimilation	YOPP Legacy
Preparatory Research	Research into Use & Value of Forecasts	Determining Success of YOPP
Summer School Workshops	Intensive Verification Effort	Outreach & Communication
Fundraising & Resource Mobilisation	Summer School & Workshops	Coordination

- Special Observing Periods (2018 – 2020)
- YOPPsiteMIP: Comparisons at observing stations with MODFs

DOE's major observing contributions

North Slope of Alaska (POPEYE)



MOSAiC

ICECAPS

COMBLE

POPEYE

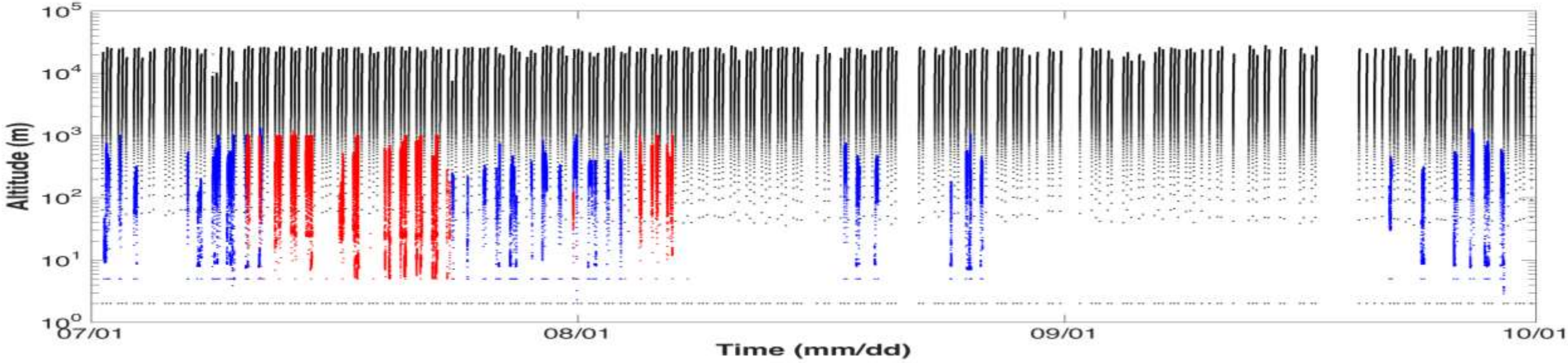
Profiling at Oliktok Point to Enhance YOPP Experiments (*PI: Gijs de Boer*)

Goal: Use remotely piloted instruments to profile the ABL towards enhanced evaluation of ABL processes in operational models

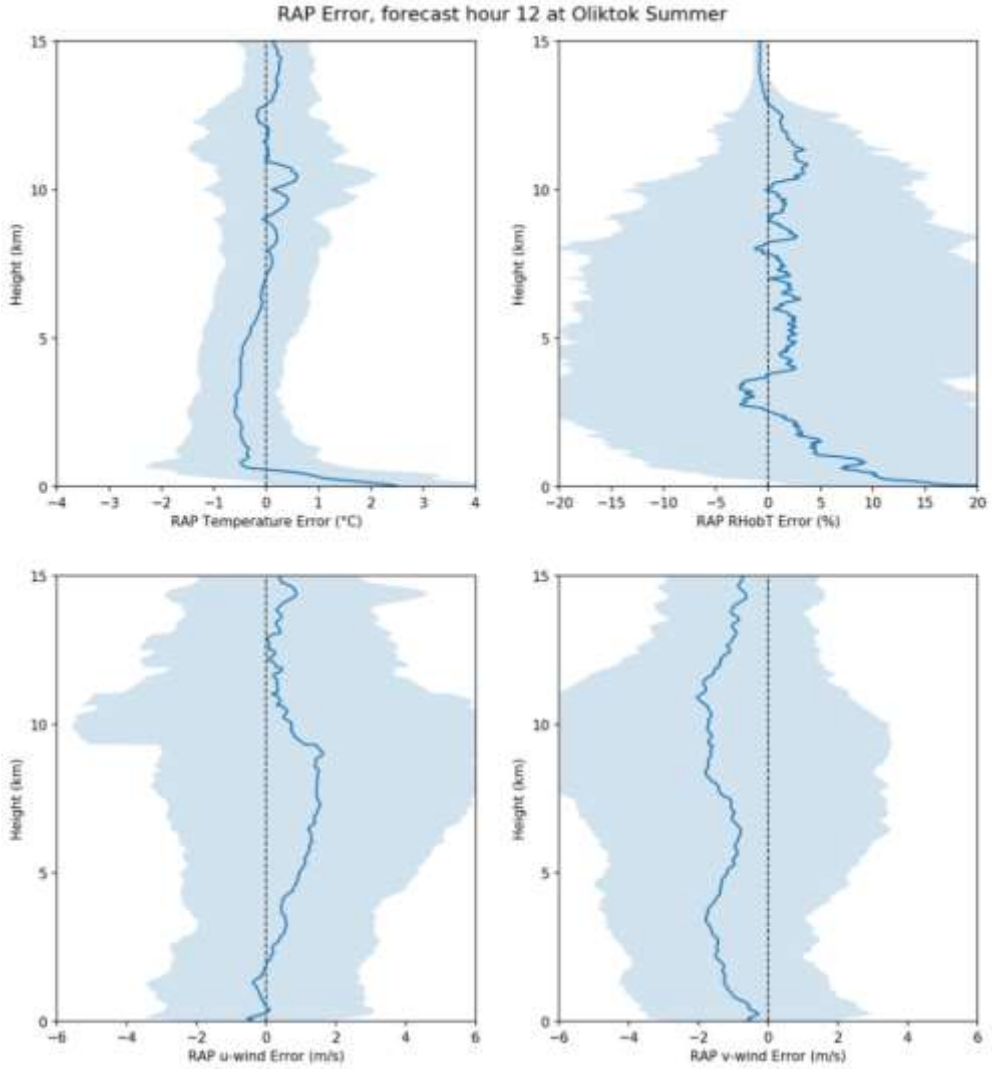
- Detailed process understanding: Vertical stratification, aerosols, stable ABLs, etc.
- Use SCM to evaluate relevant physical parameterizations in a variety of conditions
- Assessment of operational products (Reanalyses, RAP, HRRR-AK, etc.)

POPEYE

- 1 July – 30 Sept 2018 (YOPP Special Observing Period #2)
- Oliktok Point, AK near the AMF3
- Enhanced profiling using ARM's unique capabilities, in coordination with enhanced profiling across the Arctic for YOPP
- 238 sondes, 121 hours of tethered balloon, 64 hours of Data Hawk

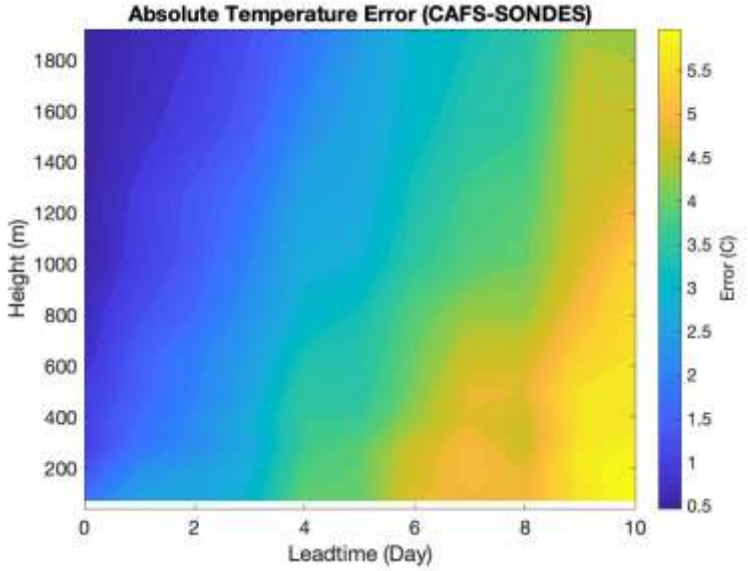


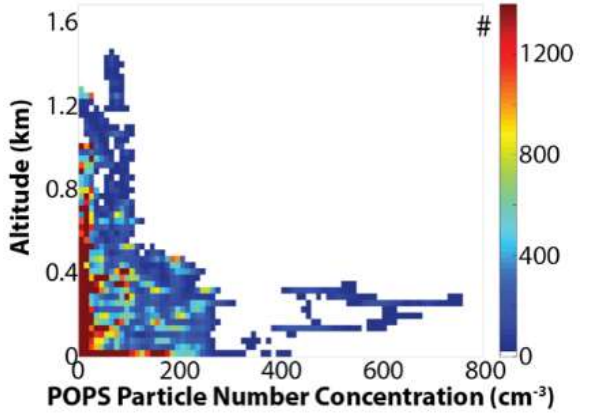
POPEYE – sneak peak at science

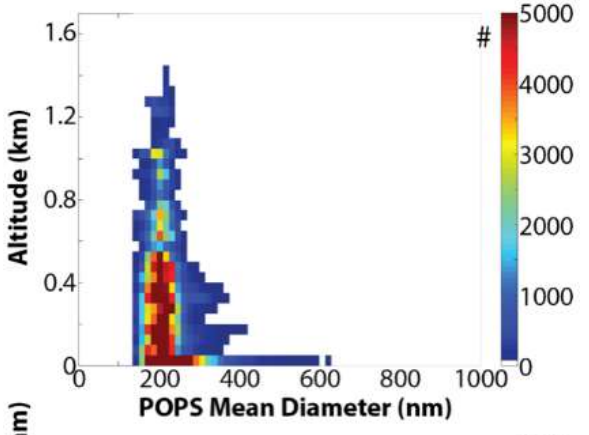


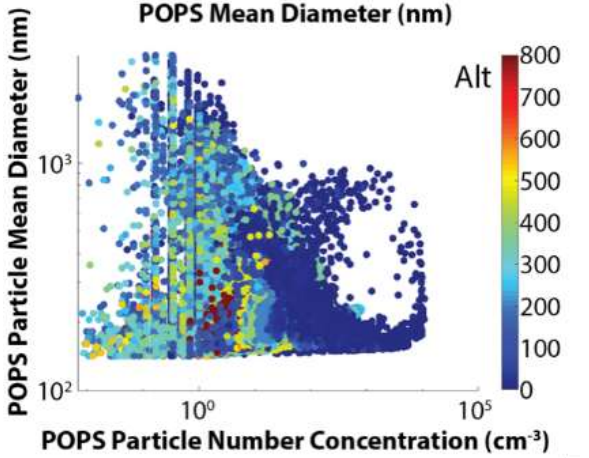
Early Information

- Assessment of forecast model errors in vertical and over forecast time
- Profile information on aerosols and other properties







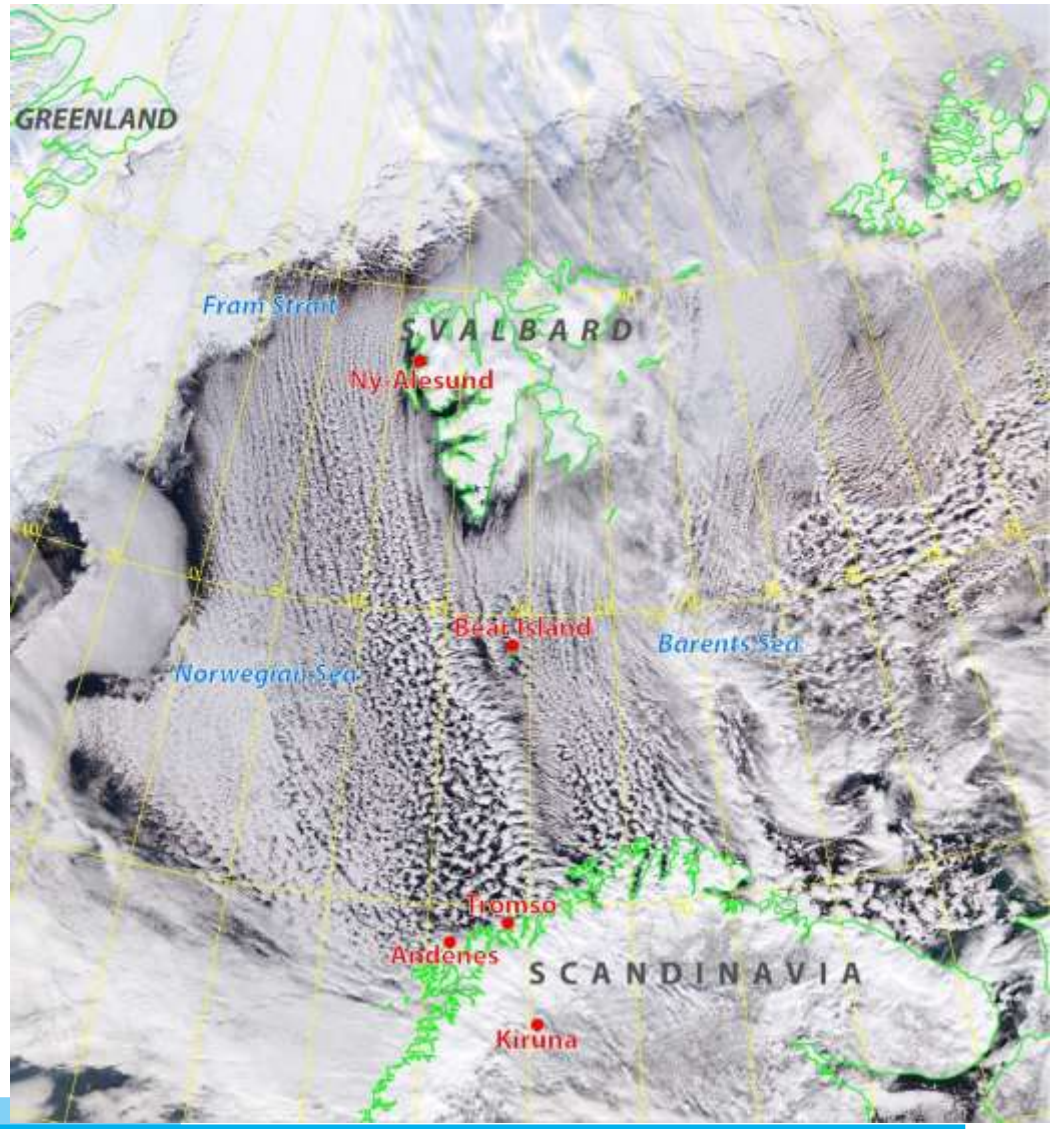


COMBLE

Cold Air Outbreaks in the Marine Boundary Layer Experiment (*PI: Bart Geerts*)

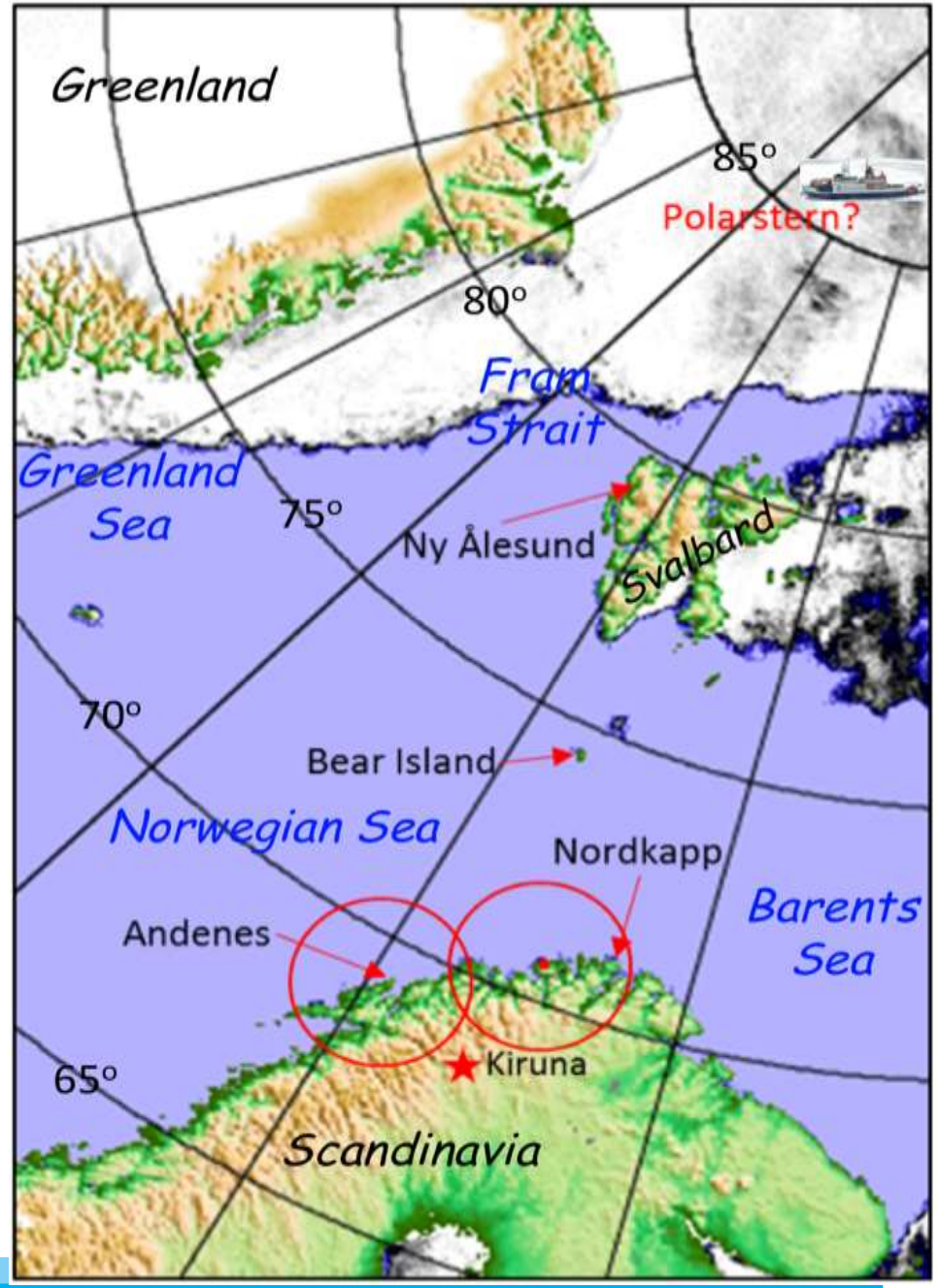
What is the role of marine boundary layer clouds during cold air outbreaks over open water in the Arctic climate system?

- Air Sea Exchange + ABL development
- Mesoscale Organization
- Cloud and Precipitation
- Aerosol
- Polar Lows

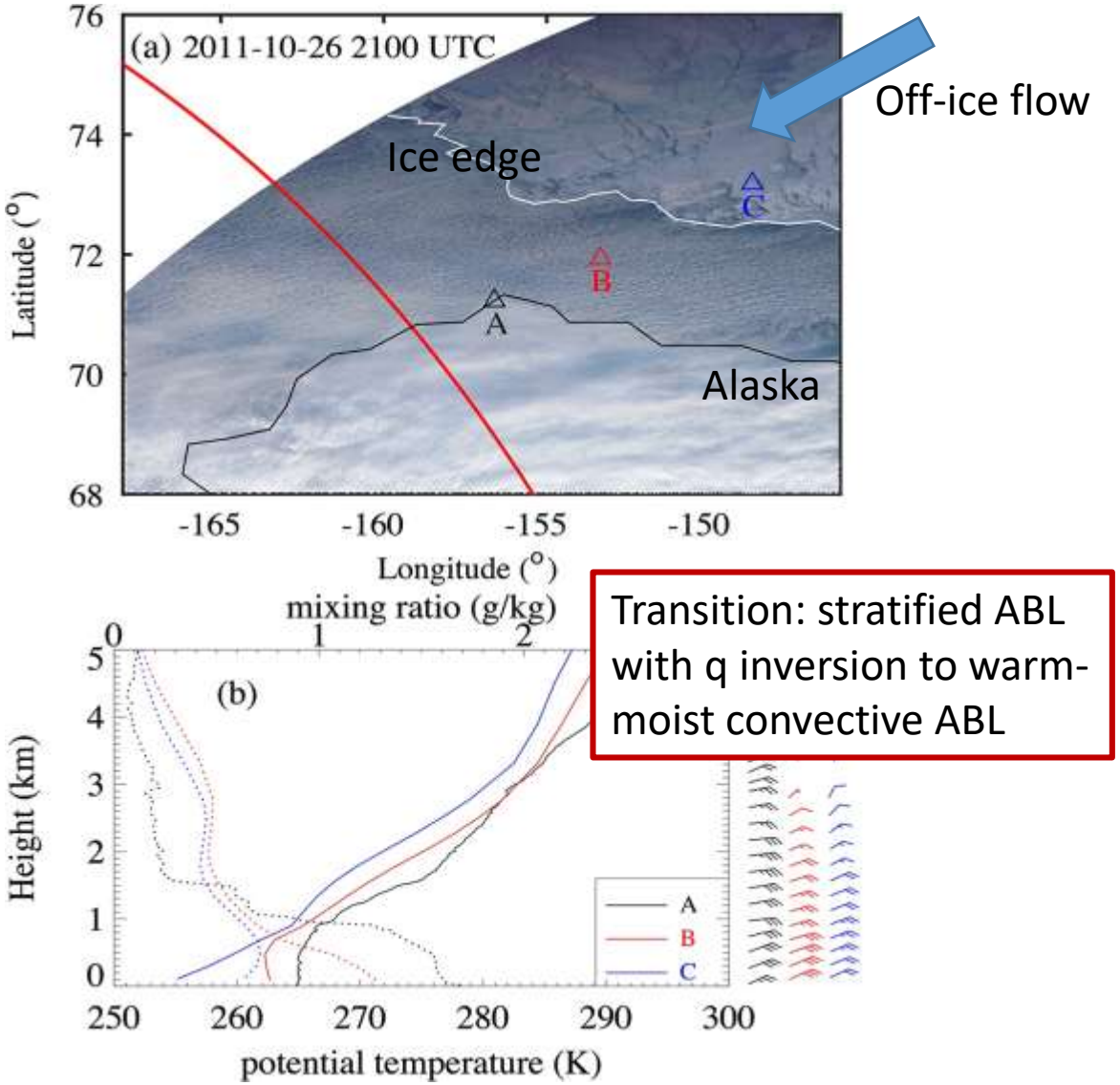


COMBLE

- 1 Jan – 31 May 2020
- **Andenes**: AMF1+AOS+Radiosondes
- **Bear Island**: Basic clouds, winds, surface energy budget, soundings
- 3-hourly soundings during CAOs
- Natural synergy with MOSAiC and NyAlesund

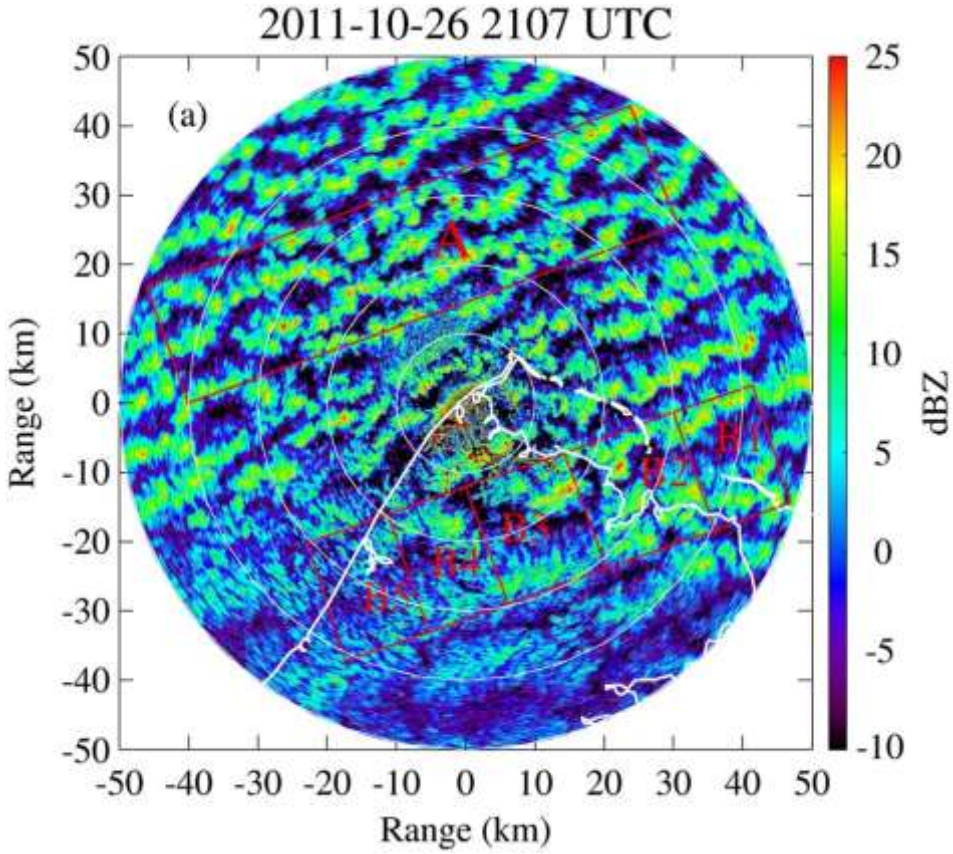


COMBLE – sneak peak at science



Transition: stratified ABL with q inversion to warm-moist convective ABL

Convective cells aligned with winds. Diminished convection over land with limited surface turbulent heat fluxes.



Wang, Geerts, Chen 2015

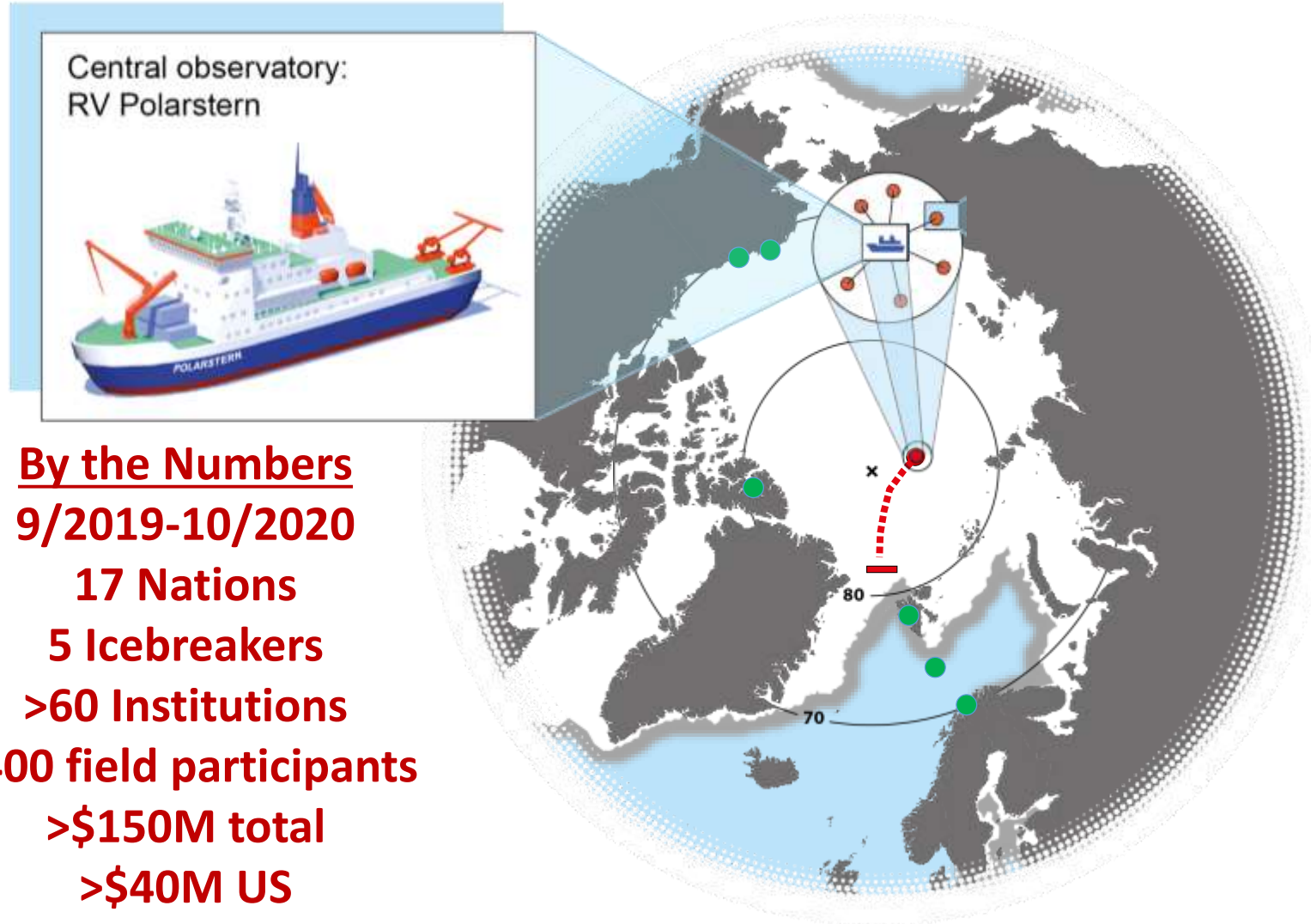
MOSAiC

Multidisciplinary drifting Observatory for the Study of Arctic Climate (*PI: Matthew Shupe*)

What are the causes and consequences of an evolving and diminished Arctic sea-ice cover?

- **Energy budget of atmos-ice-ocean**
- **Sea-ice dynamics and thickness**
- **Cloud/ABL/Precip/Aerosol**
- **BGC Processes**
- **Ecosystem responses**
- **Large-scale fluxes and feedbacks**

MOSAiC



By the Numbers

9/2019-10/2020

17 Nations

5 Icebreakers

>60 Institutions

>400 field participants

>$150M total

>$40M US

Focus on Coupled System Processes:
Atmos-Ice-Ocean-BGC-Eco

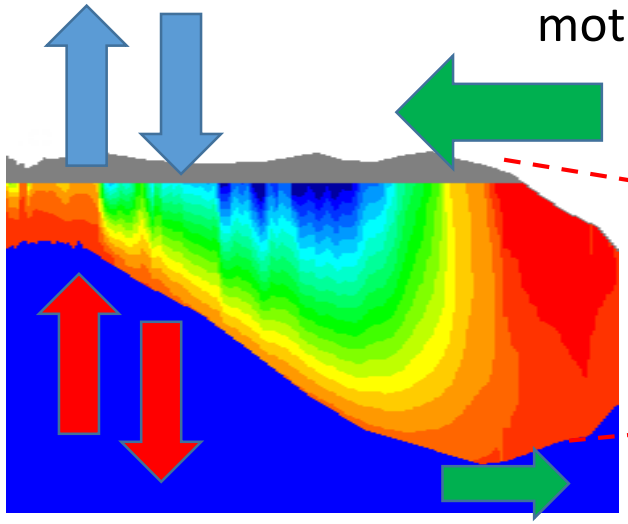
1. **Central Observatory**
   - Intensive, comprehensive
   - ARM Mobile Facility II
   - Many other projects
2. **Distributed Network:**
   - Spatial Characterization
   - Drifting model grid box
   - 50km
3. **Aircraft and Ground Stations:**
   - Flights along advective pathways
   - Network of key stations

www.mosaic-expedition.org

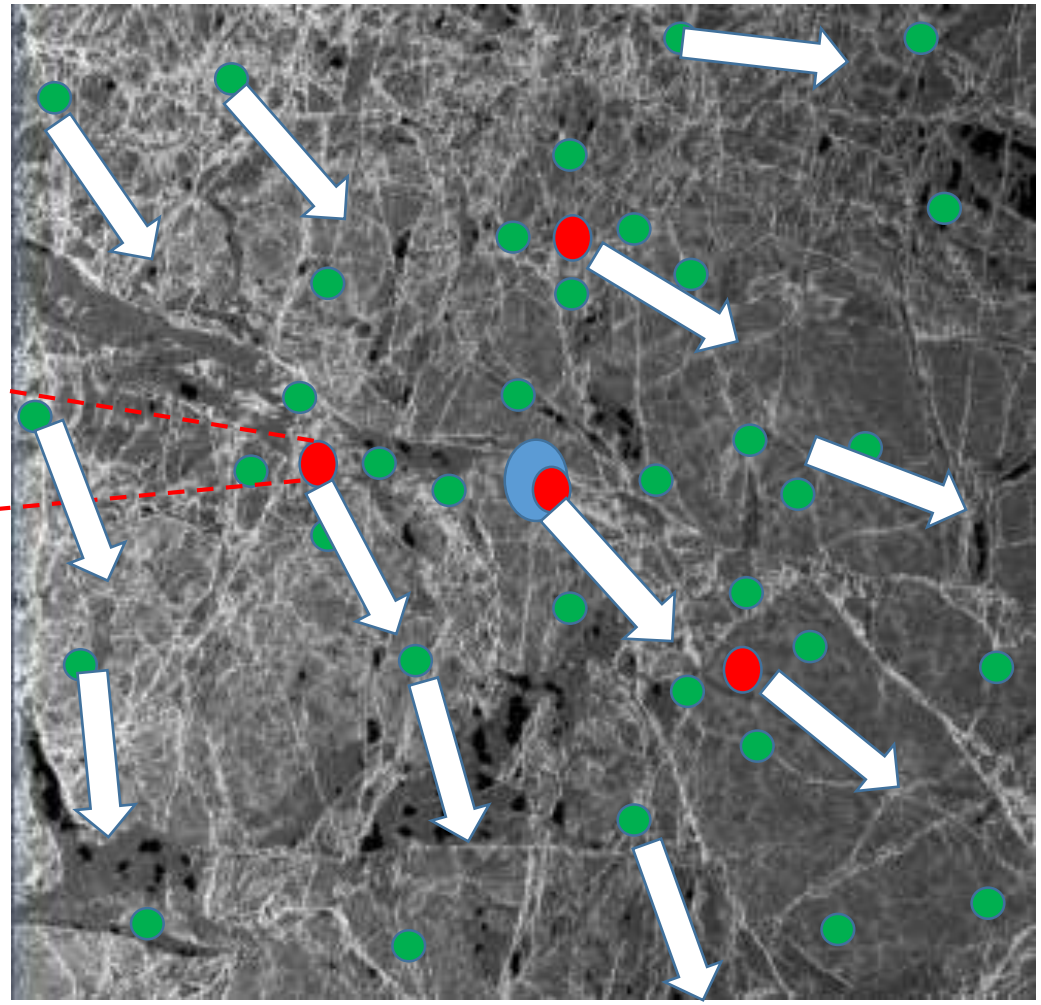
MOSAiC – sneak peak at science

Thermodynamic budget:
Energy and mass

Dynamic budget:
Momentum transfer &
motion/deformation



MOSAiC Distributed Network

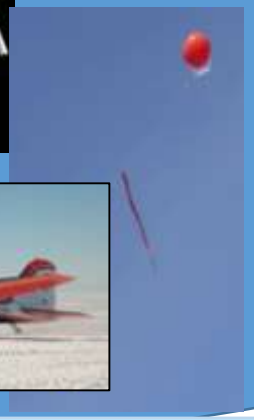


Can we achieve:

- Thermodynamic closure at representative points?
- Representation of domain-wide dynamic impacts?
- Joint understanding of ice thickness distribution?

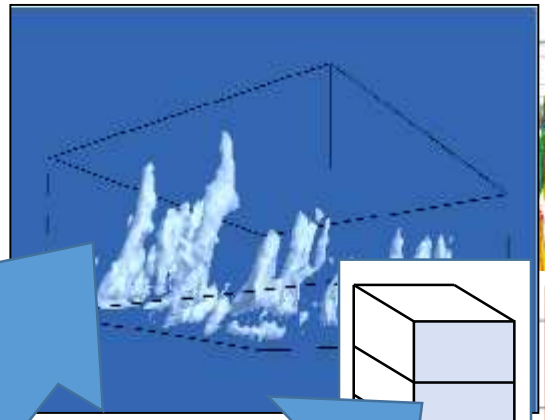
Advancing Models

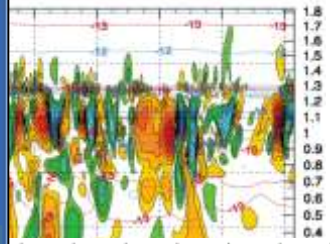
Entering a prime time for
Arctic model advancement!



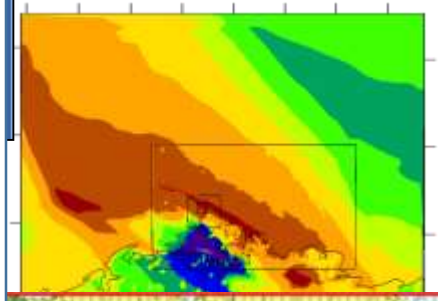
Unprecedented Observations
MOSAiC, COMBLE, NSA, OLI,
$(AC)^3$, aircraft, & more

High-Res / LES Models
LASSO Arctic, $(AC)^3$

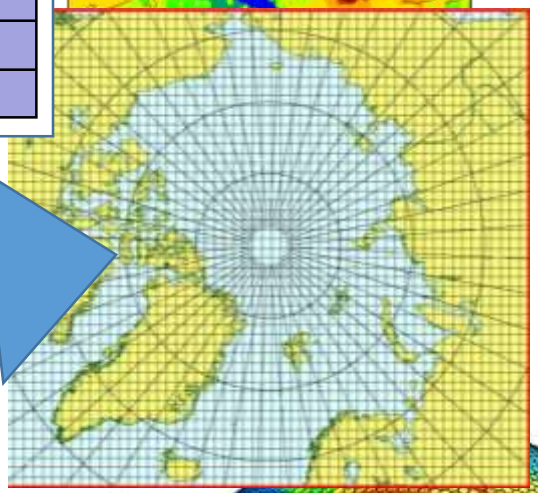




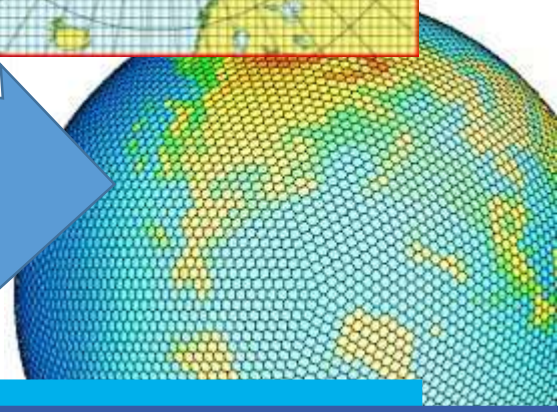
SCM / Coupled SCM
YOPP



Regional Modeling
HiLAT-RASM, Polar-CORDEX, CAFS



Global Modeling
E3SM, CESM, YOPP, CMIP6



Huge Opportunity to Advance Arctic Science…. Get Involved!

- Science proposals to future ASR FOAs ("free proposal ideas" on my poster)
- Propose to use ARM's unique resources (i.e., Oliktok TBS)
- Observational Analysis Opportunities
  - Comparative analyses across facilities
  - Flow into / out of the Central Arctic
  - Many "first-of-their-kind" data sets (radars, aerosols, etc.)
- Modeling Opportunities
  - Observation- and process-based model assessment
  - Possible LASSO focus
  - Opportunity for operational model assessment through YOPP
  - Many options for CMIP6 model evaluations


Thanks!