#A05 Future Directions Poster: High Resolution Atmospheric Measurements and Modeling in the Arctic

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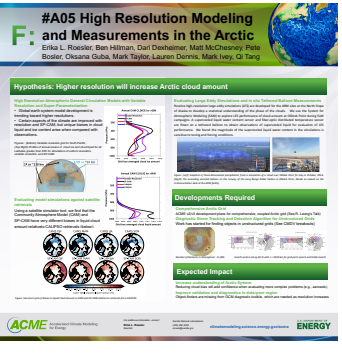
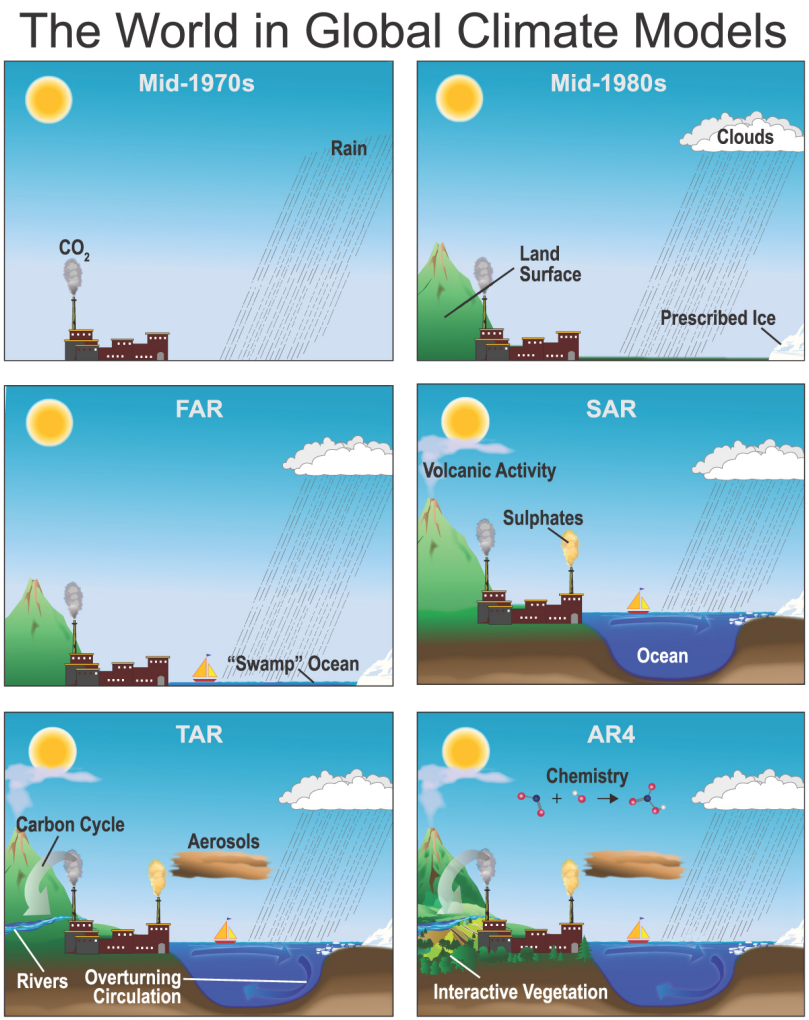
Thanks to Gijs deBoer and Oliktok Site and Science Teams



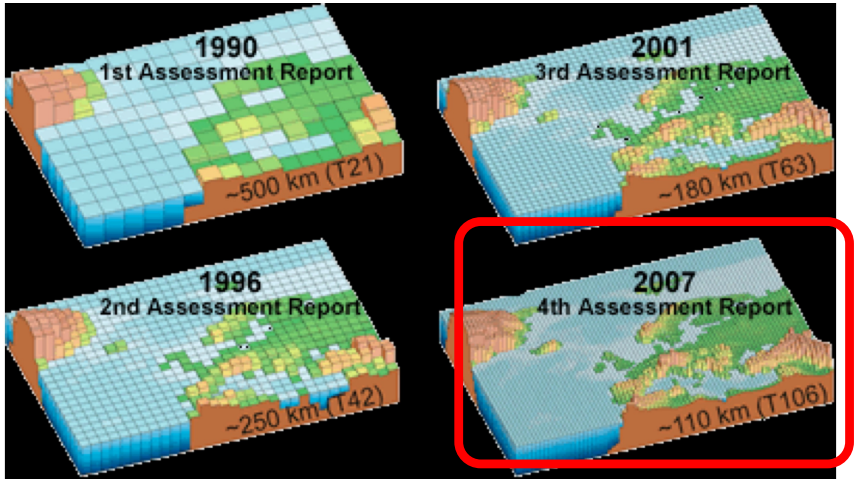
June 5, 2017

Earth System Model development is trending towards higher resolutions.



We get from Earth System Models:

- Process understanding of climate system
- View into chaotic system
- Estimates of future climate



Figures from IPCC AR4 WG1 Ch1 (2007)
Today: 110km is "low" resolution

Warming Arctic is changing the Earth System – what might it look like 30 years from now?

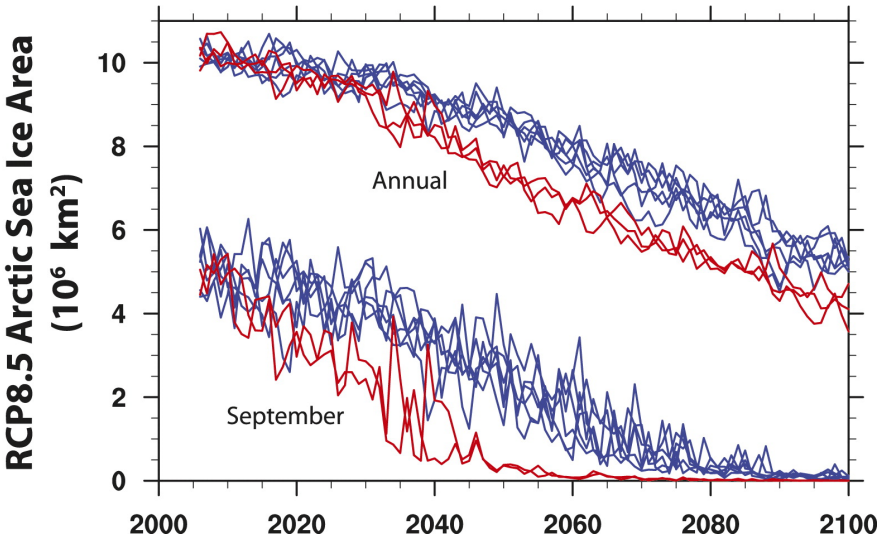
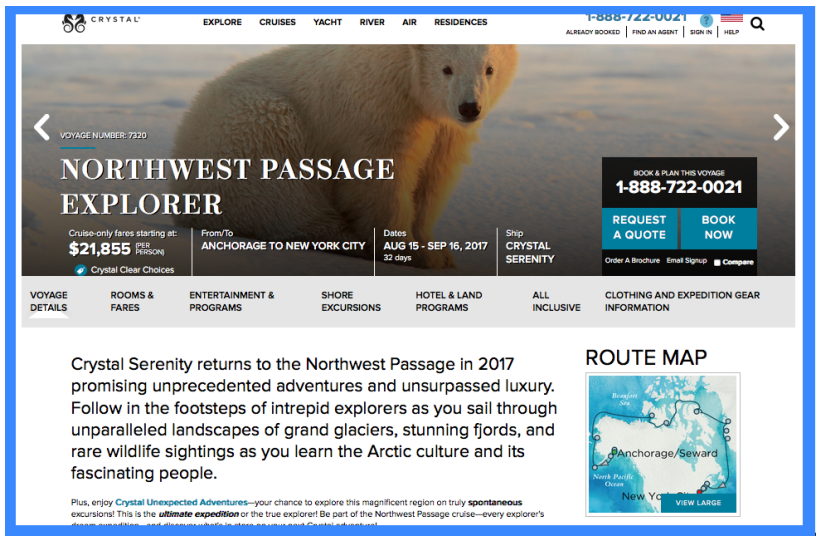


Figure from Meehl et al (2013)

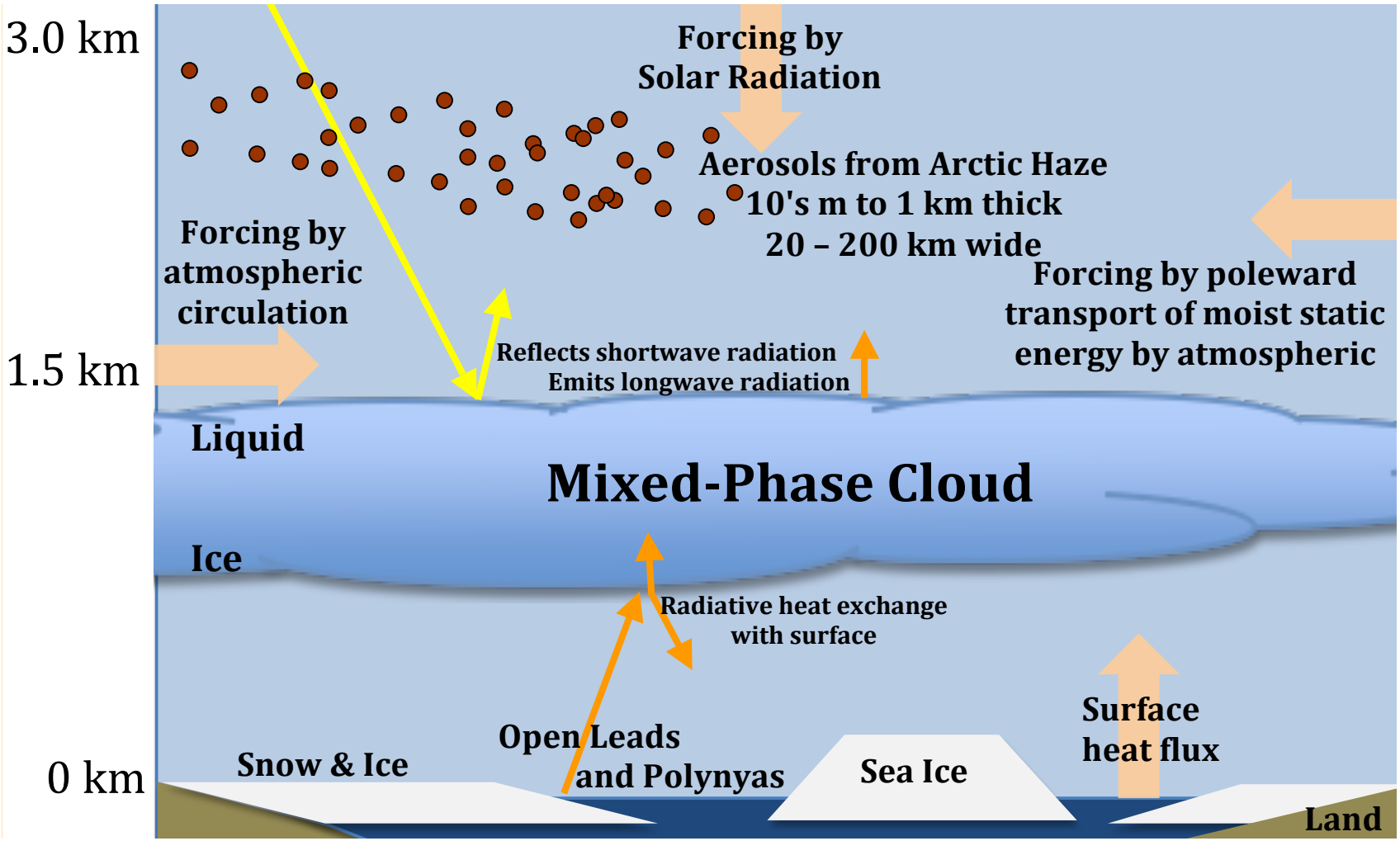


- Ice-free summer predicted in 2040-2060, not 2100
  (Sept. 2016 min: 4.14 x 10^6 km^2)
  CCSM4 (older) vs CESM1 (newer)

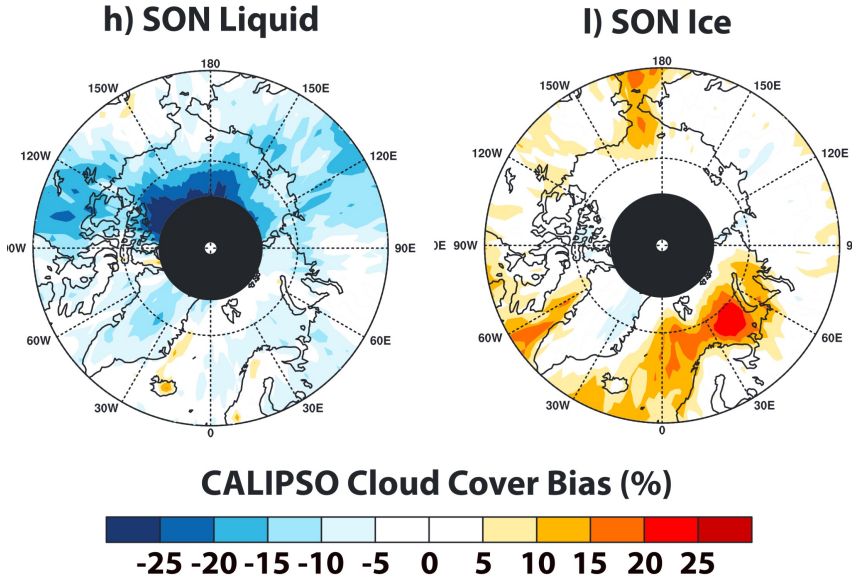
- Future Arctic climate is predicted to have more coastal erosion, increased precipitation, and more freshwater runoff (Koenigk et al 2013)
  $\rightarrow$ **Which will impact security, operations, infrastructure, and future opportunities**

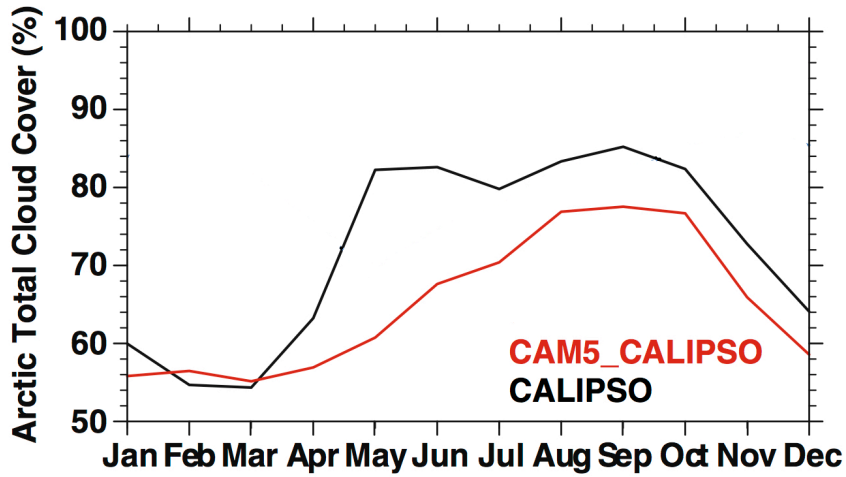
Why Clouds? Clouds are component of Arctic climate system that lock-in heat most of the year.

How will clouds change, and how to quantify that change?



Model's phase and cloud amount do not agree with observations

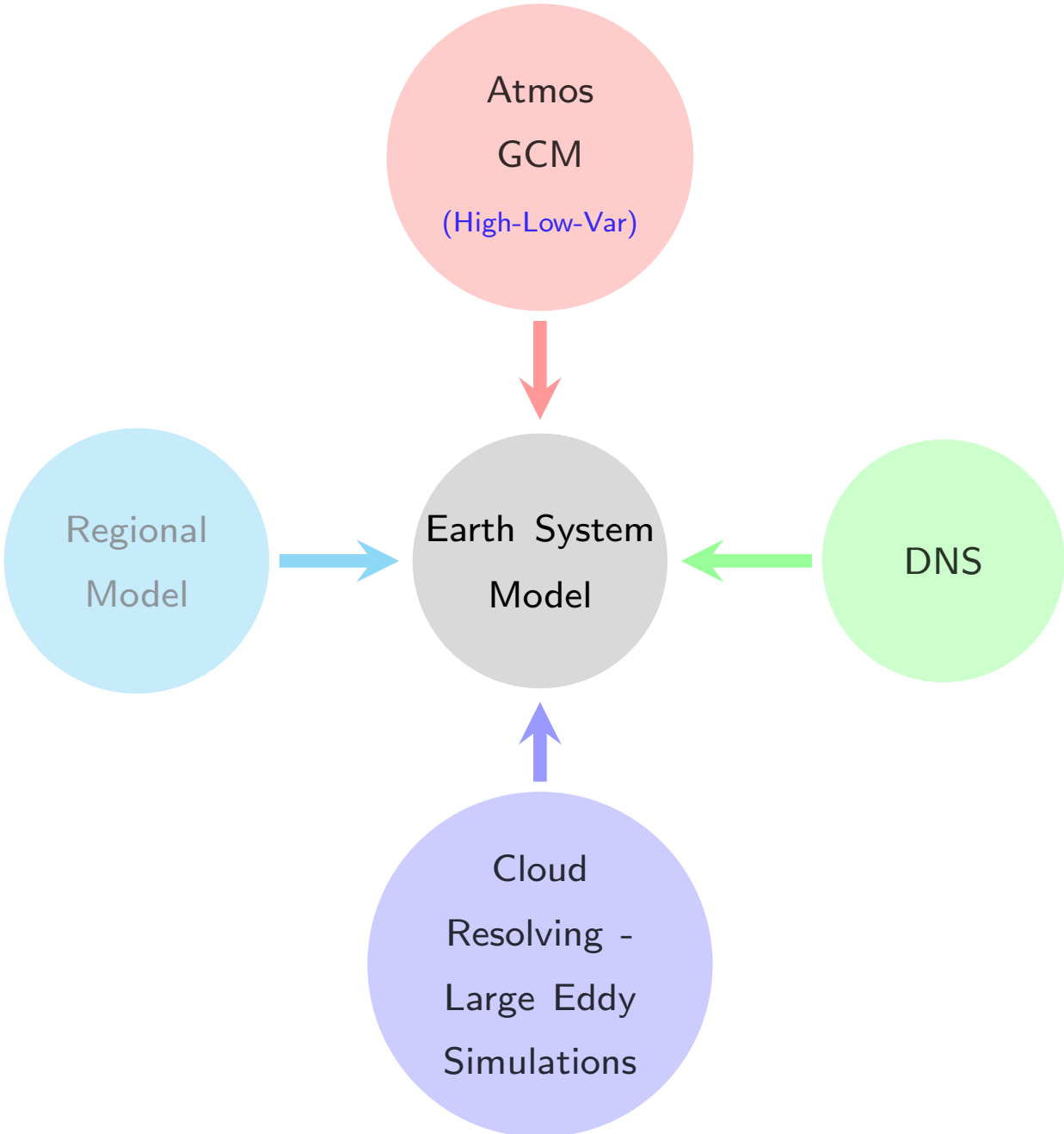




Figures adapted from Kay et al 2016 a,b comparing Community Atmosphere Model (CAM) with CALIPSO satellite observations

- How to make more clouds in model and fix the phase partitioning bias?
  - Improve microphysics *??*
  - Something in large-scale dynamics *??*
  - Compute measurement uncertainty *??*
  - **Increase resolution** $\rightarrow$ Nonhydrostatic Atmospheric General Circulation Models (AGCMs) are under development.
    $\rightarrow$ Uncertain **how** or **if** resolution will change Arctic clouds

Model resolution heirarchies used to solve cloud problem



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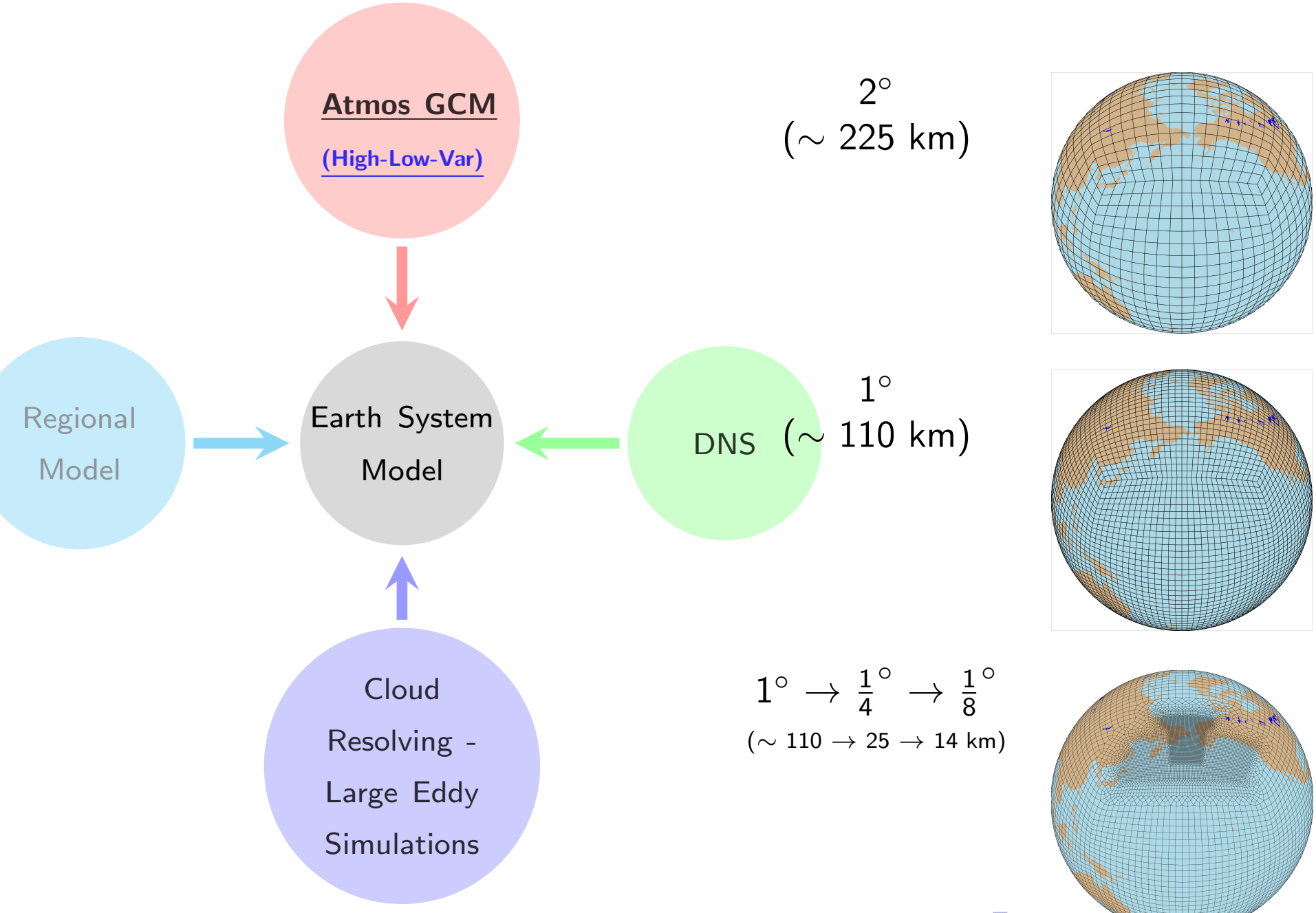
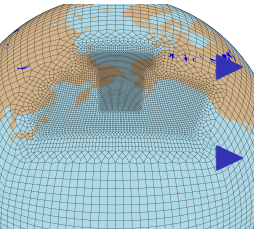
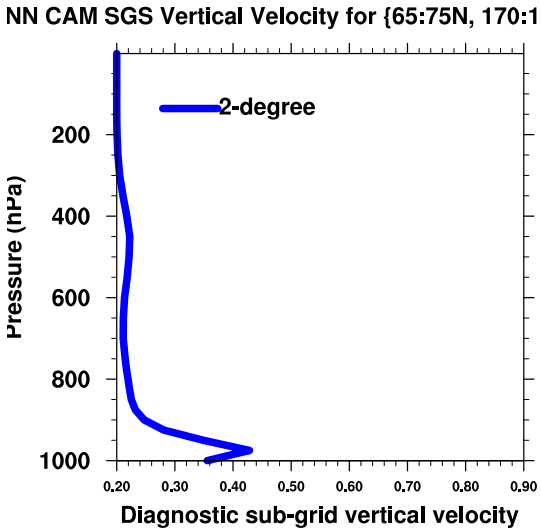
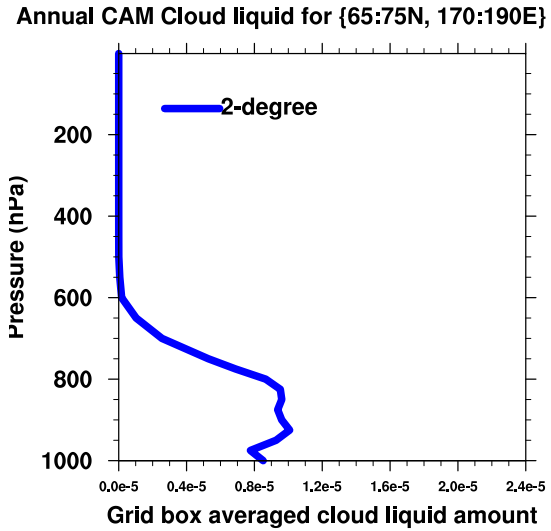


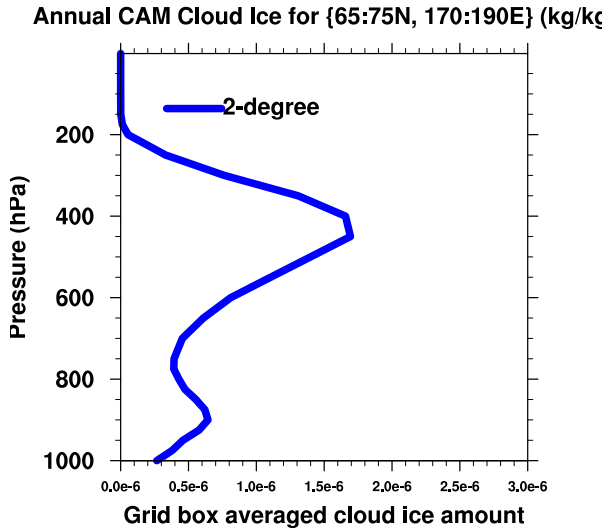
Subgrid-scale vertical velocity increases with resolution, and Arctic cloud's phase shows resolution sensitivity



- Model: ACME v0.1
- Compset: F1850 (Atmosphere-only, pre-industrial conditions)
- Length and area: Average of 5 years, over Bering Strait ($\frac{1}{8}^{\circ}$)







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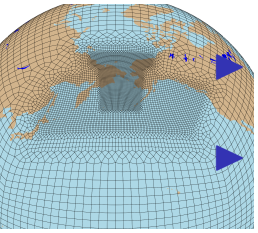

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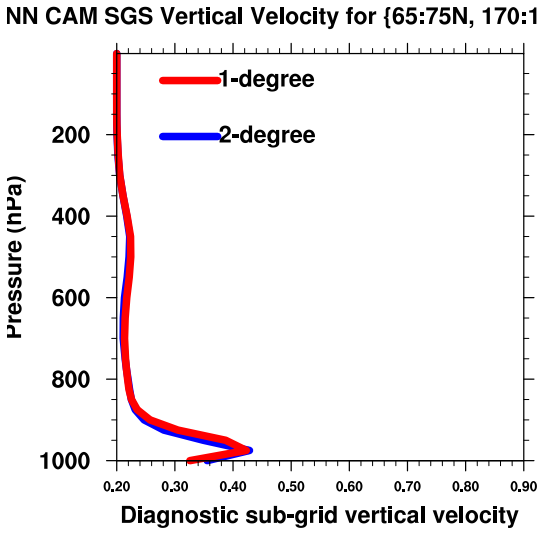

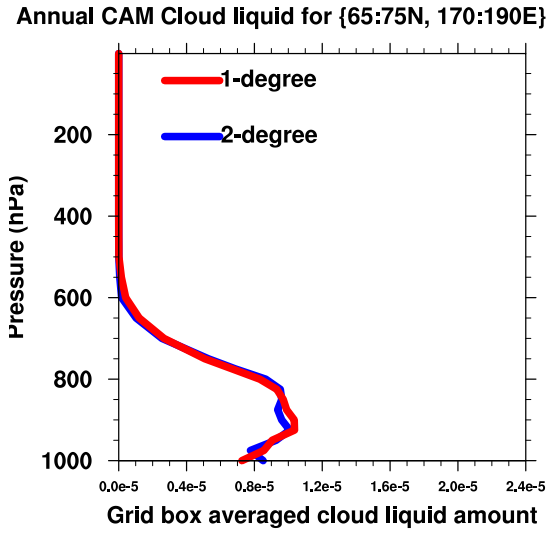

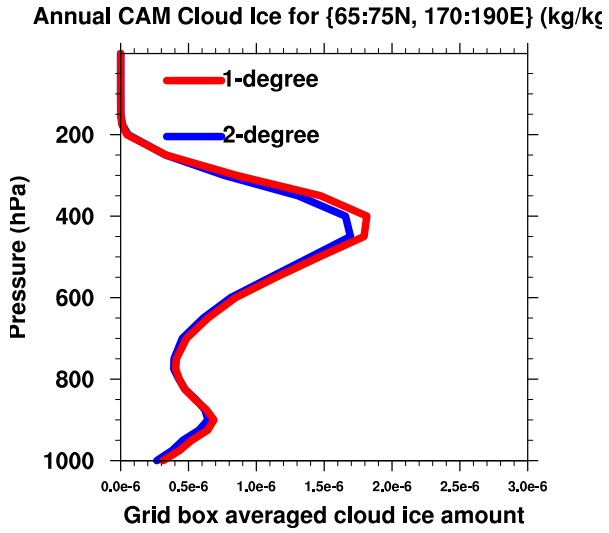

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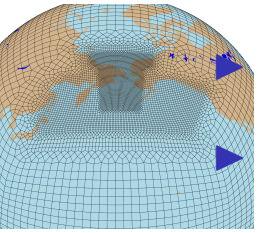

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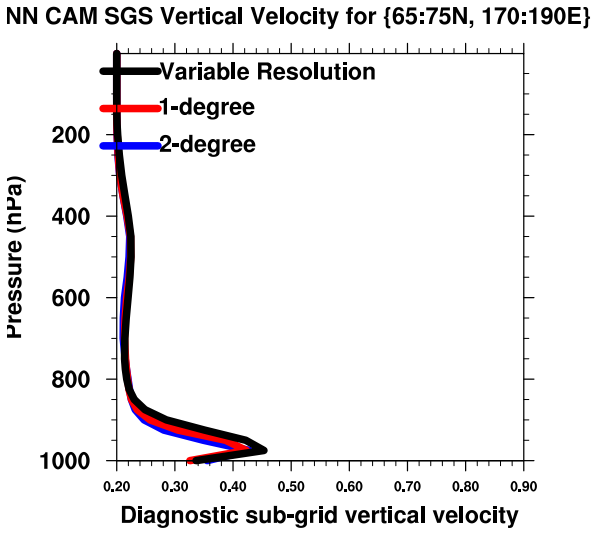
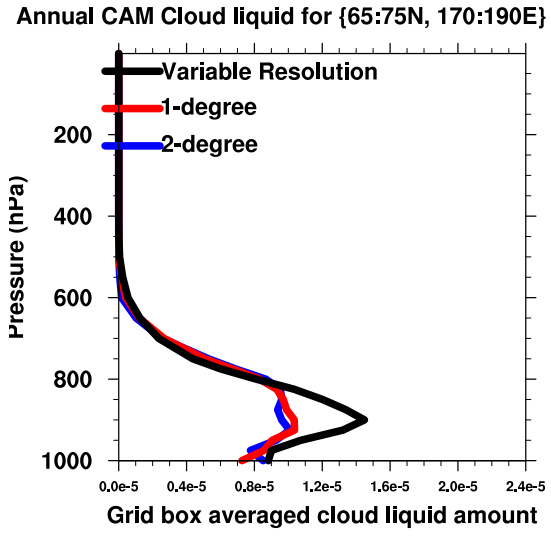
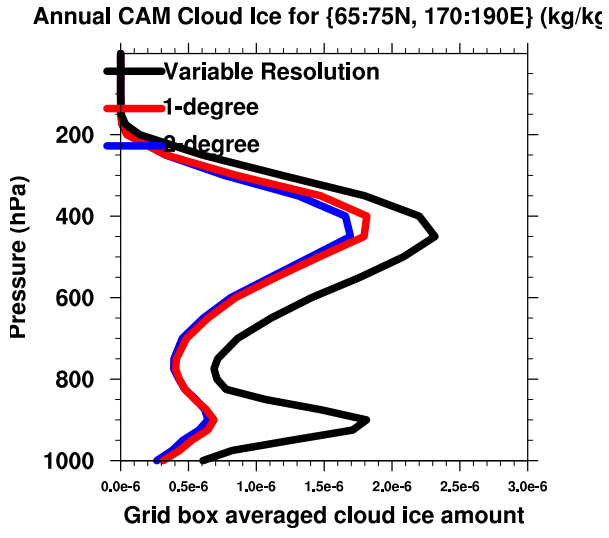
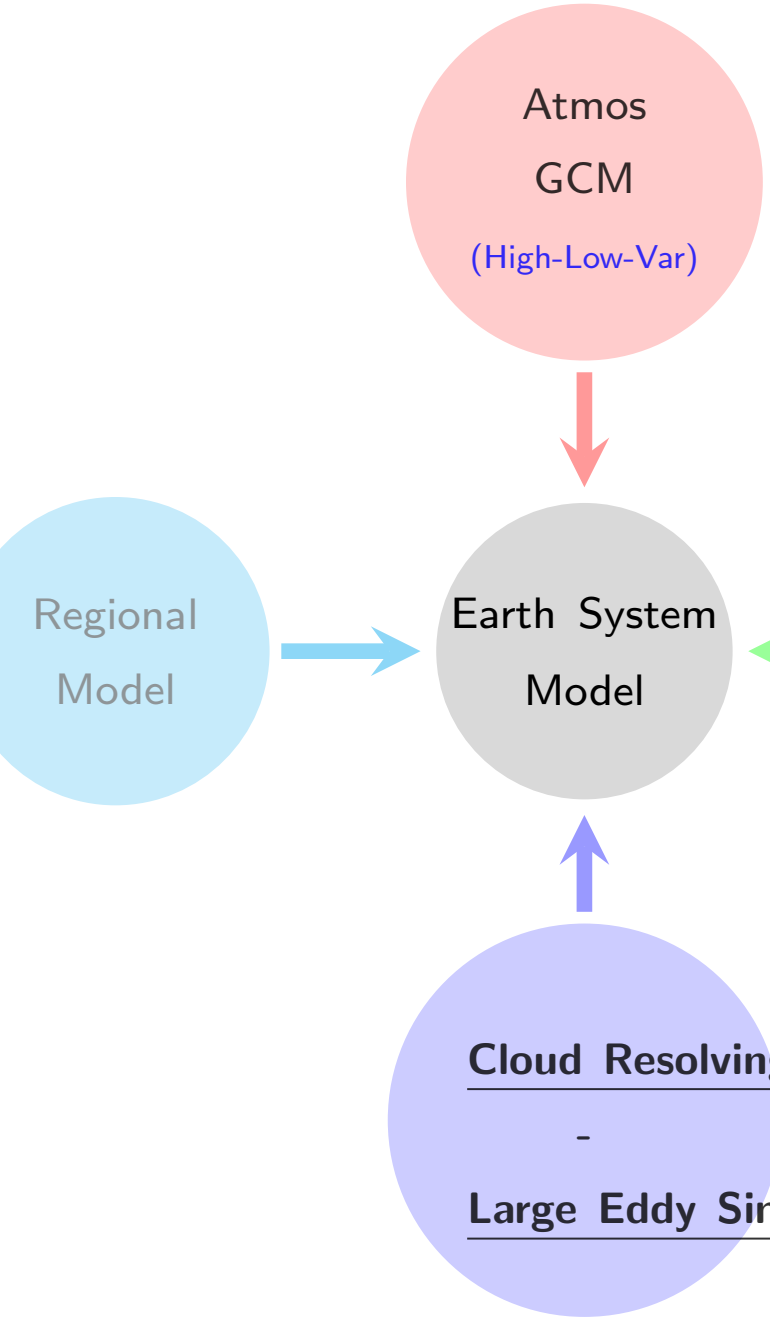


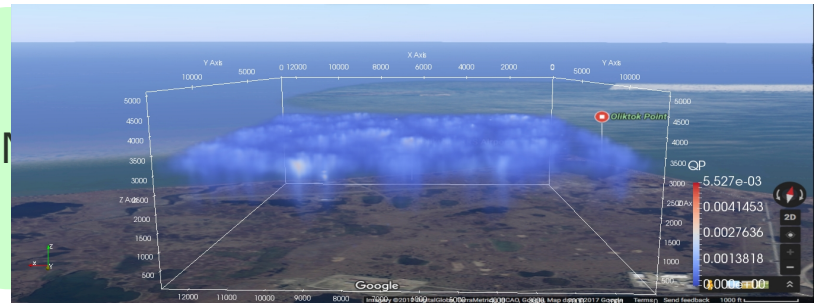




Next: Use ACME v1 $\frac{1}{4}^\circ$ data, check tuning for energy balance

Model resolution heirarchies used to solve cloud problem





Example of precipitating liquid and ice from a simulated cloud with SAM over Oliktok Point.

Cloud-Resolving Model (CRM) - Large Eddy Simulation (LES)

- Traditionally used to simulate several hours to several days of intensely observed cloudy event
  But what would year-long LES simulations yield?
  → CESAR (Cabuaw, Netherlands) (Schalkwijk et al. 2015)

→ LASSO (ARM's Southern Great Plains site)

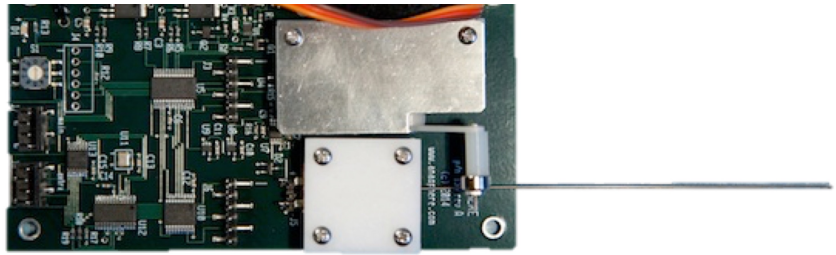
Cloud-Resolving Model (CRM) - Large Eddy Simulation (LES)

- Configuration, Initialization, and Boundary Conditions
  - System for Atmospheric Modeling (SAM), v 6.10.10 (courtesy of Marat Khairoutdinov)
  - ARM's Single Column Model (SCM) ECMWF Reanalysis *to be changed*
  - Resolution: Δ x = Δ y = 100 m; Δ z = 40 m
  - Domain size: 12.8 km x 12.8 km (horizontal); 5.1 km (vertical) *Fits inside one high-resolution GCM grid box!*
  - One month of October, 2016 at Oliktok Point, Alaska
  - One year of Jan-Dec 2000 at Barrow, Alaska

In Situ Cloud Measurements at Oliktok in October, 2016 used to constrain simulations

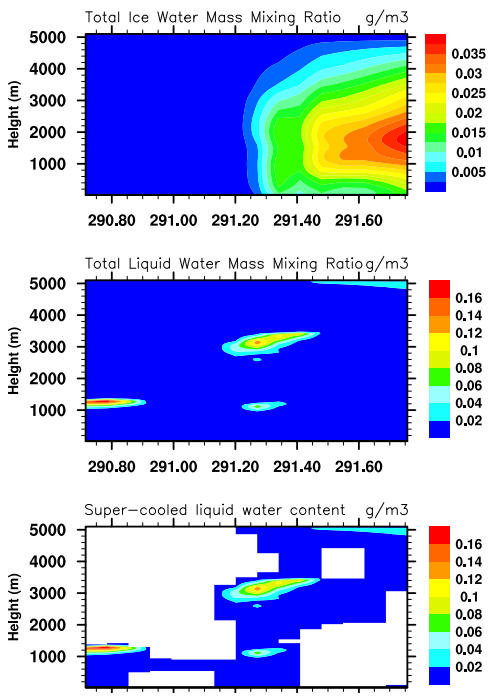
The AMF-3 and ARM tethered balloon, as seen by a DataHawk in October 2016

Photo Credit: http://ciresblogs.colorado.edu/alaska-unmanned-3/2016/10/19/more-good-weather/
http://ciresblogs.colorado.edu/alaska-unmanned-3/2016/10/20/beginning-to-feel-like-the-arctic/



Supercooled Liquid Water Sensor from Anasphere

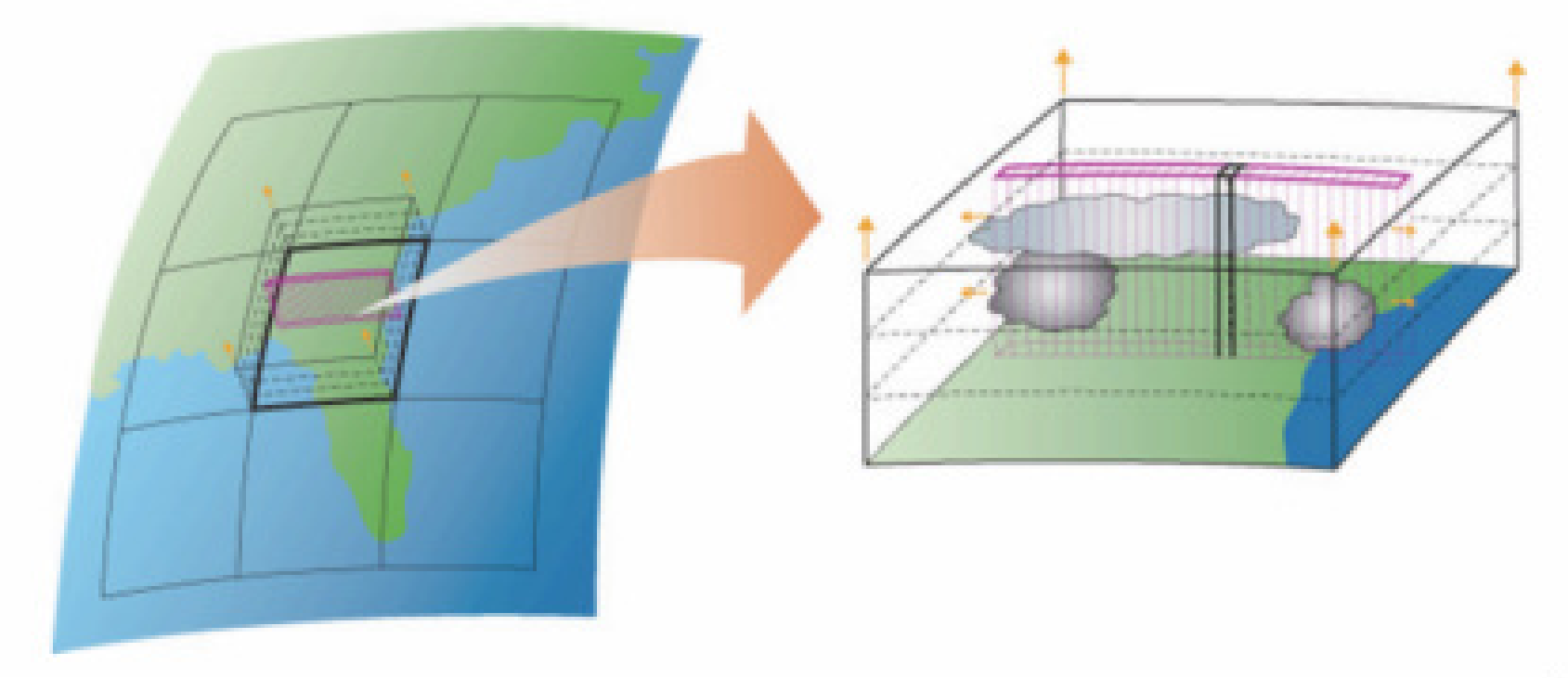
SAM-LES simulated clouds at Oliktok in October, 2016 compared to Tethered Balloon Sensors



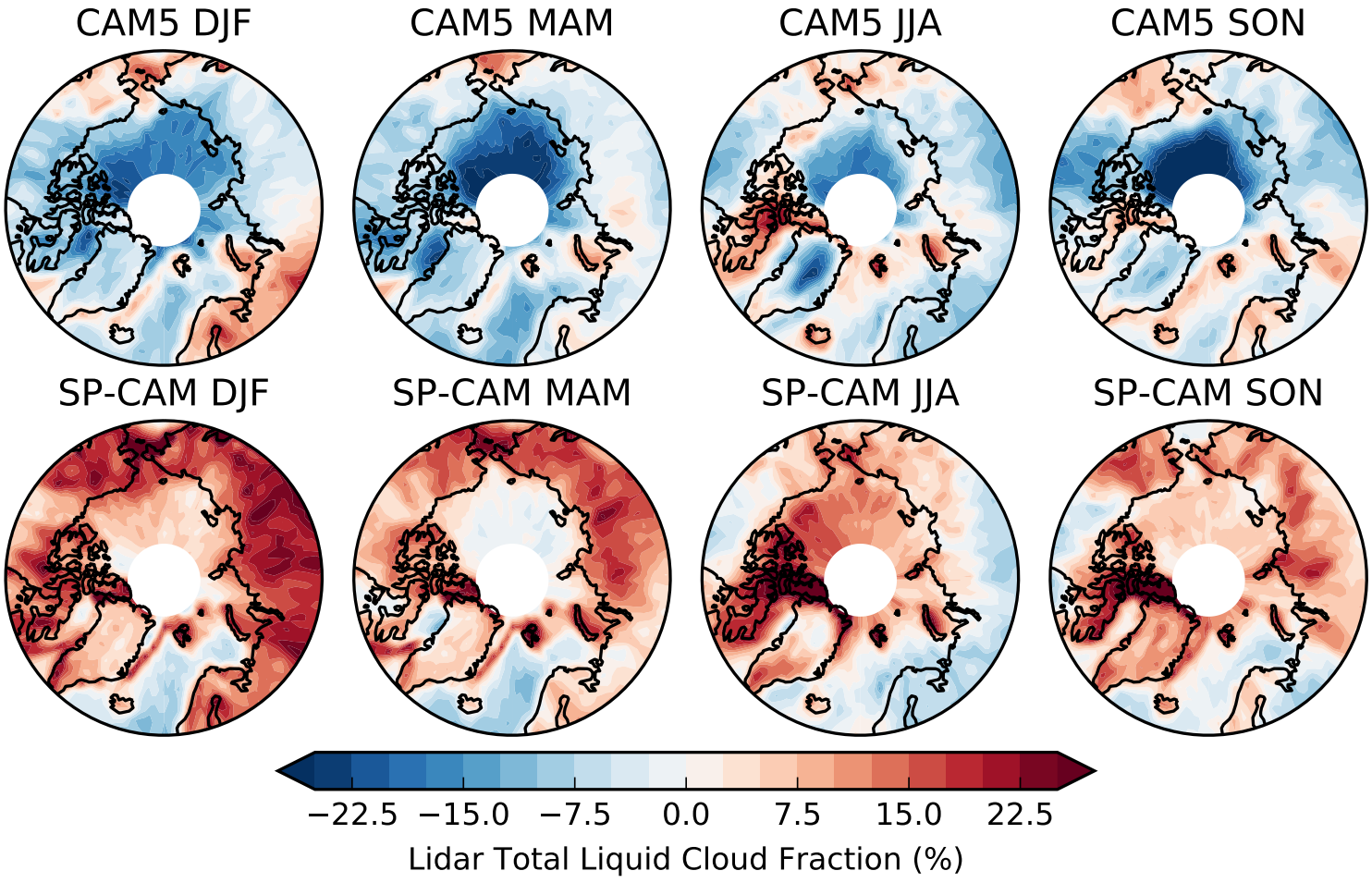
- Preliminary comparison of cloudy event on Day 290 shows SAM-LES underpredicts supercooled liquid water content compared to observations from balloon sensor by order of magnitude.
- Sensitivity tests are ongoing to test amount of water in forcing and initialization and ice assumptions in microphysics.

Atmospheric model configurations tested:

1. Variable Resolution Atmospheric General Circulation Model
2. Cloud-Resolving Model (CRM) - Large Eddy Simulation (LES)
3. **Embedded CRM** Atmospheric General Circulation Model



Embedded CRM Atmospheric General Circulation Model **OVER**-predicts cloud compared to **space-based** CALIPSO observations.



Summary

- Goal is to reduce Arctic low cloud bias
- Preliminary results of three atmospheric model configurations
  1. **Variable Resolution Atmospheric General Circulation Model**
     $\rightarrow$ Increasing vertical velocity appears correlated with higher liquid water content.
  2. **Cloud-Resolving Model (CRM) - Large Eddy Simulation (LES)**
     $\rightarrow$ Simulations underpredict supercooled liquid water content when compared to sensors on tethered balloon at Oliktok Point, October 2016. There is ongoing work to understand the bias.
  3. **Embedded CRM Atmospheric General Circulation Model**
     $\rightarrow$ Most complicated and expensive configuration.
     $\rightarrow$ More work need to understand positive cloud liquid and ice biases.