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Exploration of Variable Resolution as a substitute for GCM-driven LES or SPCAM

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In order to explore the possibility of running a variable resolution atmospheric general circulation model (AGCM) with regional refinement over the Atmospheric Radiation Measurement (ARM) sites at the North Slope of Alaska (NSA), possible grid sizes and shapes for areas of refinement were investigated. After researching the climatology of the NSA, grids were created using SquadGen, NCL, and GIMP based upon the location of important climate and weather processes. The optimal shape for the area of refinement varied based on size of the grid, and an AGCM will be run using the three grid shapes we have developed to test the importance of the size and shape of the area of refinement in regard to the output of the AGCM.

Introduction

Motivation

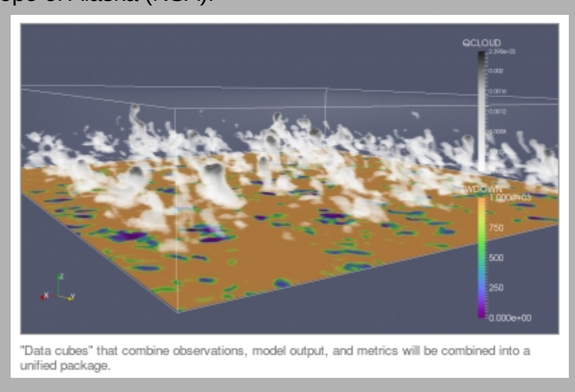
- Exploring the possibility of running a variable resolution atmospheric general circulation model (AGCM) with regional refinement over the Atmospheric Radiation Measurement (ARM) sites at the north slope of Alaska
  - This project investigates the possible grid sizes and shapes for areas of refinement

Background

The ARM Climate Research Facility "is a multi-platform scientific user facility with the objective of providing a detailed and accurate description of the Earth's atmosphere in diverse climate regimes to resolve the uncertainties in climate and earth system models"[1]
The site has "in situ and remote sensing observatories designed to improve the understanding and representation, in climate and earth system models, of clouds and aerosols as well as their interactions and coupling with the Earth's surface"[1]
Potential measurement sites include:

- Barrow
- Oliktok
- Atqasuk (closed ARM site)
- Toolik (NSF site)

The LES ARM Symbiotic Simulation and Observation Workflow (LASSO) is a two year high resolution model development pilot project which combines ARM observations and modeling. It establishes an observational "megasite" at the Southern Great Plains ARM site, and there are plans to create a "megasite" at the North Slope of Alaska. By creating grids for an AGCM that have regional refinement, this project allows for the exploration of the use of variable resolution over the future LASSO megasite which will be located at the North Slope of Alaska (NSA).



"Data cubes" that combine observations, model output, and metrics will be combined into a unified package.

https://www.arm.gov/science/themes/lasso

Climatology of the North Slope
In order to determine the optimal size and shape of the region of refinement, the climatology of the area near and around the North Slope of Alaska was examined. The goal is to have areas which are important to climate processes near the North Slope of Alaska highly refined so that the weather and climate processes can be fully resolved and the North Slope of Alaska can be more realistically and accurately characterized.

[1]http://www.arm.gov/

Areas important for refinement:

- *Topography*
  - Brooks Range
    - Enhances Arctic Frontal Zone (Crawford and Serreze 2014)
  - Coasts
    - Northern coast of Siberia (cyclogenesis) (Serreze et al. 2001)
    - Coasts with treelines (Serreze et al. 2001)
    - Areas of differential heating
      - Between Arctic Ocean and snow-free land, influenced by topography (Crawford and Serreze 2014)
  - Areas influencing wind
    - Differences in wind can be physically tied to representation of terrain off southern coast of Alaska (Hughs and Cassano 2015)
- *Aleutian Islands*
  - Aleutian semipermanent low
  - Moisture transport, Rossby waves breaking (Liu and Barnes 2015)
  - Significant increasing trend in number of cyclones around the Bering Sea-Aleutian Islands (Vavrus 2013)
- *Bering Strait*
  - Loss of sea ice, change in SST (Carton et al. 2015)

Methods

Three main tools were used in creating the grids for the variable resolution model: SQuadGen, NCL, and GIMP.

SQuadGen is an open-source mesh generation utility which uses a PNG file that corresponds to a grid of latitude and longitude to determine a desired area of refinement. Values within the PNG file with a high brightness are refined.
NCL (NCAR Command Language) is an interpreted language created by the National Center for Atmospheric Research (NCAR). This open-source program allows us to create a latitude-longitude plot of a mesh created in SQuadGen which can be exported as a PNG file. NCL also allows us to create other visualizations and is used for data processing.
GIMP (GNU Image Manipulation Program) is an open-source graphics editor which is used in this project to specify areas of refinement by brightening that area of the latitude-longitude plot and exporting it as a PNG file for use by SQuadGen.

The work flow for creating grids for the variable resolution model included using SQuadGen to create a mesh, plotting the mesh to a map of latitude and longitude using NCL and exporting to a PNG file, selecting areas of refinement by editing the PNG file in GIMP, and refining the selected area in SQuadGen using the selection indicated in the PNG file. After the area has been refined, the area must once again be plotted using NCL to ensure that the area has been correctly refined.

SQuadGen ⇨ NCL ⇨ GIMP ⇨ SQuadGen ⇨ NCL

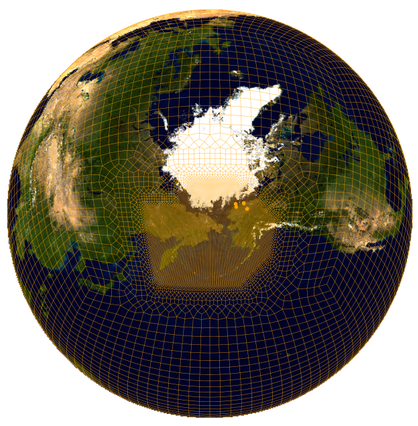
The **resolution** (or grid size) used for the areas of high refinement in this project was ne240. This corresponds to a grid resolution of about 0.125 of a degree of latitude and longitude. Resolution ranges in these grids from about ne30 (about 111km) to ne240 (about 14km).

Work was performed on a PC running Red Hat Enterprise Linux 6.

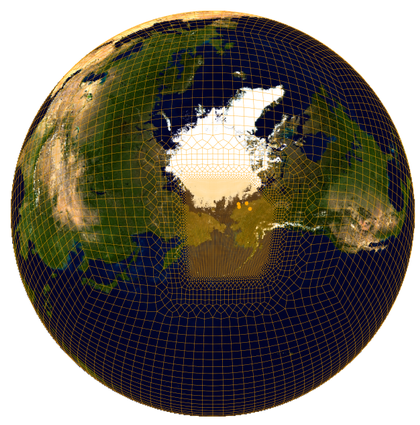
Results

Grid Size	Number of Elements
Small	10,035
Medium	11,437
Large	14,039

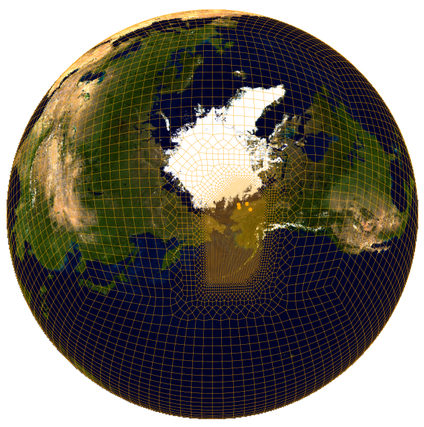
Large



Medium



Small



Discussion

Optimal grid shape varied with the size of the area of refinement as we attempted to capture all of the relevant weather and climate processes as they moved into the North Slope. While originally we envisioned a "price tag" shaped area of refinement or even a trapezoid to be optimal for all sizes, larger size grids needed to be scaled down in irrelevant areas in an attempt to minimize the number of elements.

The benefits of using a variable resolution model mainly include reduced computing time. While running a low resolution model (ne30), an output of 5 simulated years per real-time day is possible. A low resolution grid at ne30 stretches 110km, and includes 30 vertical levels. A very high resolution model (ne240) stretches about 14km, but computation time is very slow and one simulated day is almost equivalent to one real day. The benefit of a high resolution model is that it can provide a more accurate representation of the climate, especially in areas of interest such as clouds. A variable resolution model gives us the benefit of a high resolution model in the region of interest while also avoiding excessive computing time.

We plan to run an atmospheric general circulation model with our variable resolution grids. We will then have the opportunity to investigate whether this alternative to GCM-driven LES or SPCAM may be viable for the LASSO project.

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