Cloud – WRF in a CMU Classroom

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2021 DTC Cloud Container Workshop

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A Little About Me

- Teaching Atmospheric Modeling at CMU for the past 5 years.
- Not an everyday mesoscale modeler.
- Never really used a cloud instance prior to this course.
- Class materials generally home brewed with limited computation. Taught a 3-class load for Spring 2021.
- Run a small Jupyterhub teaching server that was funded by a Unidata Equipment grant.

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Student Background/Preparation

- Students taking the class were senior undergraduates, final semester of degrees. 12 students total. Class had an unusually **large** number of broadcasters.
- CMU program covers the following:

Freshman	Sophomore	Junior	Senior
MET 260 Intro to Met	MET 310 Thermo	MET 330 Synoptic 1	MET 310 Synoptic 2
MET 312 Instruments	MET 320 Phys. Met.	MET 335 Dynamics I	MET 320 Dynamics 2
			MET 450 Mesoscale
			MET 460WI Clim. Dyn.
			MET 480WI Modeling

Pre-requisite Classes:

- MTH Calc I, II & III
- MTH 234 Lin Alg/Diff Eqn.
- CPS 180 Intro Java
- MET 450 Mesoscale

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MET480WI Learning Objectives

- *Describe* the components of atmospheric models.
- *Derive* simple numerical approximations using Taylor series expansions.
- *Convert* partial differential equations describing the atmosphere to difference equations.
- *Evaluate* the stability of common numerical approximation methods.
- *Calculate* parameters using the Courant-Friedrichs-Lewy criterion.
- *Describe* the advantages and disadvantages of different vertical coordinates used in atmospheric models.
- *Compose* and *modify* simple computer code that completes numerical analysis related to finite differencing.
- *Demonstrate* proficiency in Linux by using the command line to complete simple tasks, and learn the basics of data analysis and display in Python.
- *List* the advantages and disadvantages of the different parameterizations used in numerical models.
- *Identify* the different kinds of errors inherent to numerical modeling.
- *Configure* and *run* a real case with atmospheric models, *evaluating* output.

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MET480WI Class Preparation

- Student Preparation in Class:
  - Students had classes in numerical differencing, errors, stability and the 1D wave equation, model properties (resolution, terrain, coordinates), concepts and limitations were discussed, including parameterizations (radiation, microphysics, convective, boundary layer, land surface).
  - Scaffolding coding through linux and python labs, simple models through a Jupyterhub setup – 1D Wave solutions, simple radiation and boundary layer, 2 moment microphysics.
  - Students were introduced to WRF basics using idealized quarter_ss and 2D squall cases and physics ensemble.
  - Main course project is an analysis and visualization of a case study where the models failed to predict an event using externally sourced model data.

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Cloud/Containerized WRF Approach

- Approach:
  - Pre-survey was run prior to the course to ascertain knowledge level.
  - Prior to the DTC team guest classes, students had pre-prepared accounts and had two 1 hour lab sessions running through how to access and setup an AWS instance.
  - 2x 1hr 50 minutes sessions with DTC staff in classroom.
  - Post-survey was run after the course during semester, but had poor response rate. However, students provided feedback unsolicited, including through SOS comments.
  - No grade associated with running through these tasks.
  - Majority of students running windows machines or on Met Lab computers (PC).
  - Hybrid class format (some in classroom, others remote).

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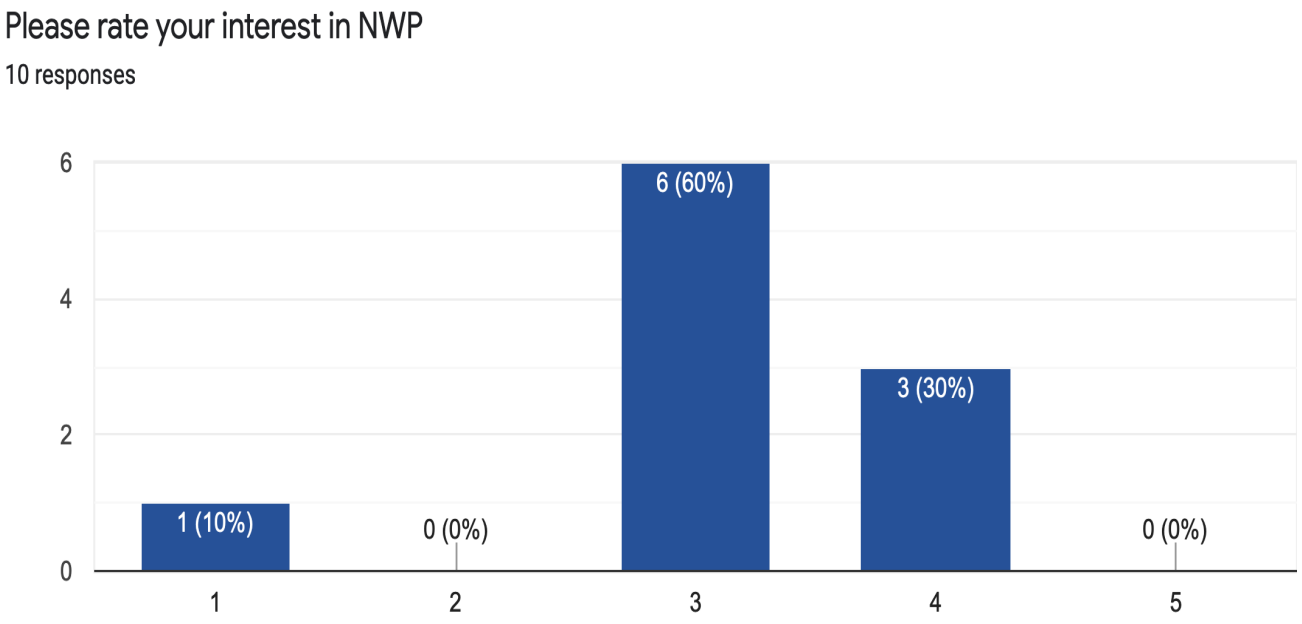
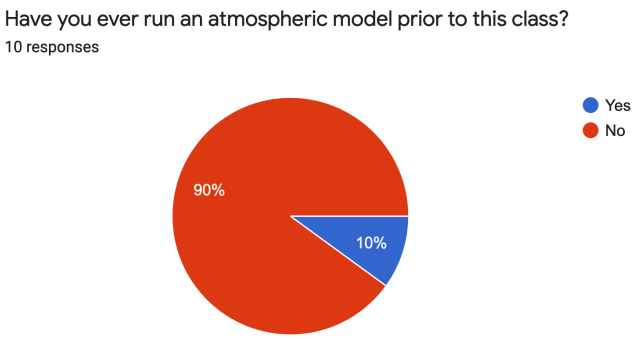
Pre-Survey





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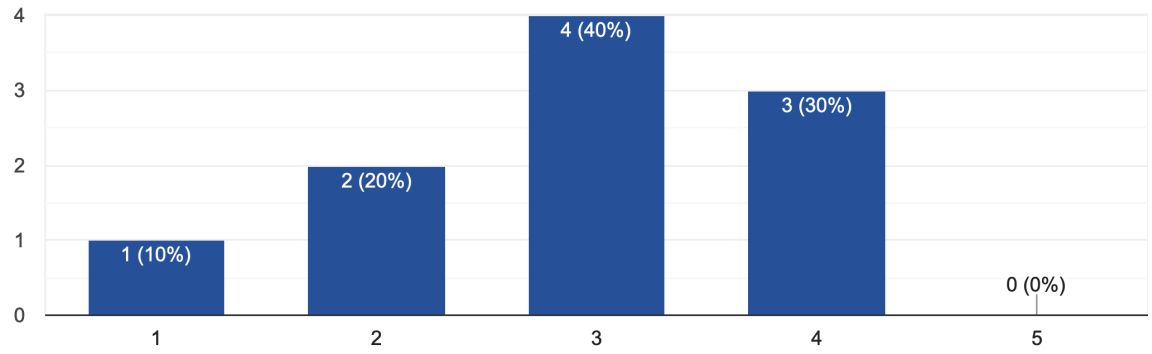
Pre-Survey

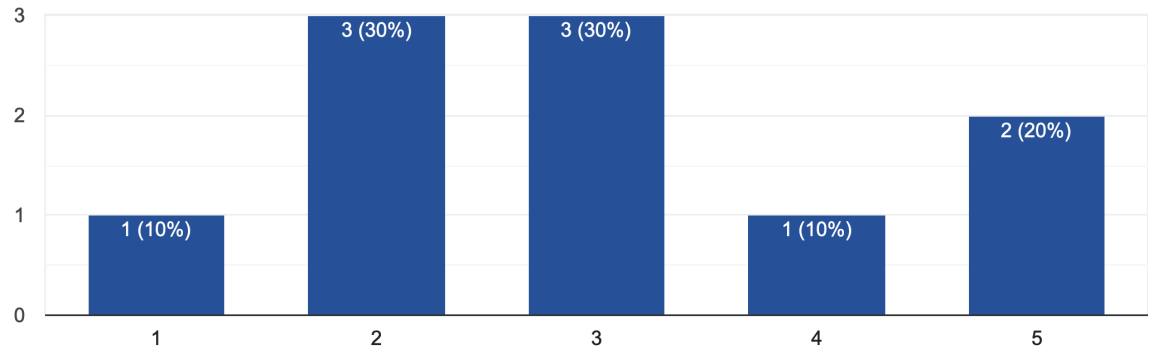
How confident are you explaining what NWP is/does?

10 responses



I can describe the basic components of NWP

10 responses



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Response & Comments Following

- Student Feedback (SOS):
  - ‘Make the WRF guest speaker section of the course optional or elective for those going into that sector.’
  - ‘For broadcasters, no news station cares if they know modeling or how to run a model or not.’
  - ‘with the amazon cloud I wished we learned that earlier so that I could become comfortable with it and attempt to use it in my capstone project.’

- General Responses:
  - Students generally felt they understood NWP, basic commands in linux, why we should use containers, but didn’t feel like they could explain them.
  - Students become moderately comfortable with running WRF on the cloud and found the tutorials helpful, despite never having run a model prior to the class.

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Response & Comments Following

- Were there any aspects of the tutorials you felt were unclear?
  - How to run the tutorials/components on windows/PC.
- Was the order of instructional material appropriate to aid in the learning process? Please suggest changes, if applicable.
  - Yes, the follow-along tutorial page was VERY helpful. Just need to slow it down and do it in increments.
- What improvements would you suggest for the hands-on learning tutorial?
  - Run the tutorial in increments, NOT over a 2 day period. Perhaps touch on it through the semester just to get familiar with the concepts. Slow down the process.
  - Introductory material needs to come more slowly.

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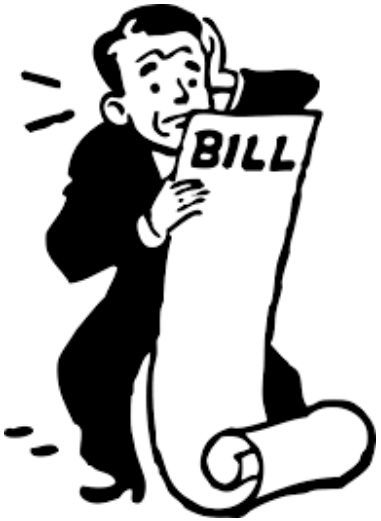
Thoughts, Insights & Observations

- Costs: Total costs to run the course were ~$300 for basic runs only, accounts for instructors and 12 students. Limited to no data egress. (Make sure you remove volumes as will put you over quota).
- When setting up EC2 instance you need to create student accounts, request increases to virtual core limits, and instance limits even to run using the C4.4x setup from the tutorial.
- Students weren't brought up in the limited data generation – may not necessarily understand pay per usage (with education went ok).



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Thoughts, Insights & Observations

- Scaffolding of relevant skills eases the transition.
- Windows based tutorial is essential if this is going to see wide deployment in the community.
- Would be extremely difficult to run a class like this as a single instructor – having assistants will make troubleshooting far easier and the class productive.
- Students found pace a little too quick – need to spread out over more classes.
- Undergraduates benefit from the ease of implementing the docker containerized version at least at the outset.

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Thoughts, Insights & Observations

- Offers an excellent path to allow for a more interactive and accessible approach to teaching atmospheric modeling, particularly at resource limited and undergraduate institutions.
- Once you get students up to speed – they really like it (*unless they are broadcasters*).
- For graduate students – should have more focus on how modify the environment and developing there own containers.
- Finding budget may limit scalability to graduate classes or more intense computation.

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CMU Modeling Classes Moving Forward

- Program now has Meteorology specific Unix/Python programming courses and electives → Students better prepared coming in.
- Plan on integrating AWS cloud containerized WRF standard in course for canned cases – may move idealized cases to this platform as well.
- Provided available resources, students will be running their own cases using at least one WRF simulation appropriate to the case.
- Contemplating class ensemble approaches to provide comparisons across microphysics/assimilation strategies.

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