

# Cloud Computing Support for the Weather Research and Forecasting (WRF) Model

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# WRF Cloud Computing Project

## Project Motivation

- Exploit emerging technology
- Position WRF support for increasing cloud modeling demand
- Address bottlenecks impacting WRF support & code testing/contributions

## Primary Goals

- Establish officially-supported WRF in the cloud
- Set up & use globally-accessible cloud-based WRF tutorial materials
- Utilize cloud for automated testing of contributed code
- Full system documentation

# What is cloud computing?

The utilization of remote servers via the internet for computation, and for processing, storing, and managing data

- Instead of running on a local server or supercomputer
- Widely accessible
- Easy to store and share data

# Cloud Service Provider (CSP) Collaborations



- Users manage their own files on AWS servers
- Highly Documented
- Many supported/related applications available

<https://aws.amazon.com>



- Scala manages processes through their local server
  - Provide access to well-known HPC CSPs
- Great application for repeated or regularly-scheduled work
- Limited documentation

<https://scalacomputing.com>

# Cloud Service Provider (CSP) Collaborations

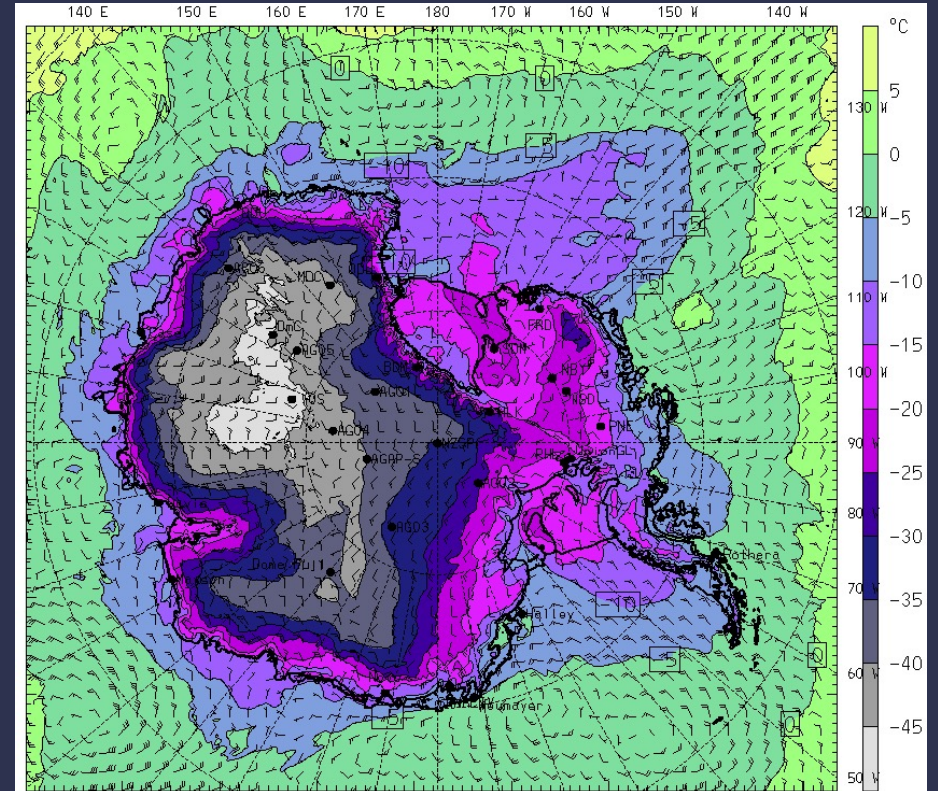


<https://www.penguincomputing.com>



<https://www.rescale.com>

Back-up environment for running real-time forecasts for the AMPS (Antarctic Mesoscale Prediction System) project



Antarctica Surface Temperature (C)  
Valid: 18 UTC 8 Nov 2019

# Cloud Computing for WRF Model Tutorials

Utilized AWS cloud environment to conduct five WRF tutorials

- 2 Local: Boulder, CO
- 2 International – Sydney, Australia & Lincoln, UK
- 1 Virtual

Students use pre-configured WRF environments for hands-on practice sessions

- Each student accesses their own instance (virtual server) for the duration of the tutorial
- Each instance includes
  - Operating System
  - Compilers/libraries/Visualization
  - Pre-compiled WRF/WPS/Post-processing binaries
  - Input data

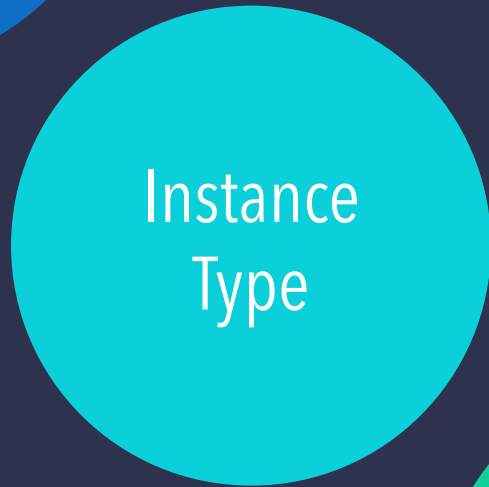


# Cost Example for WRF Model Tutorials



Platform

Amazon Linux AMI (2018.03.0)



Instance  
Type

C4. 4xlarge

- 16 vCPUs (8 actual CPUs)



Tutorial  
Use

- 60 student instances
- ~ 15 hrs/week each

Cost

~\$1250 during  
tutorial week

# Additional Cloud WRF Instructional Sessions

University collaborations: North Carolina A&T and Colorado State University

- Half/full day with graduate students
  - Presented introduction to cloud computing
  - Designed instructional web application for students/professor to follow
  - Provided temporary access to NCAR AWS account

Mini-tutorials given at the WRF & MPAS Annual Workshop

- 2018 and 2019



# WRF Cloud-based Automated Code Testing

Suite of regression tests necessary for all newly contributed code

Developed cloud capability to conduct tests required for submittals of new code to WRF GitHub repository

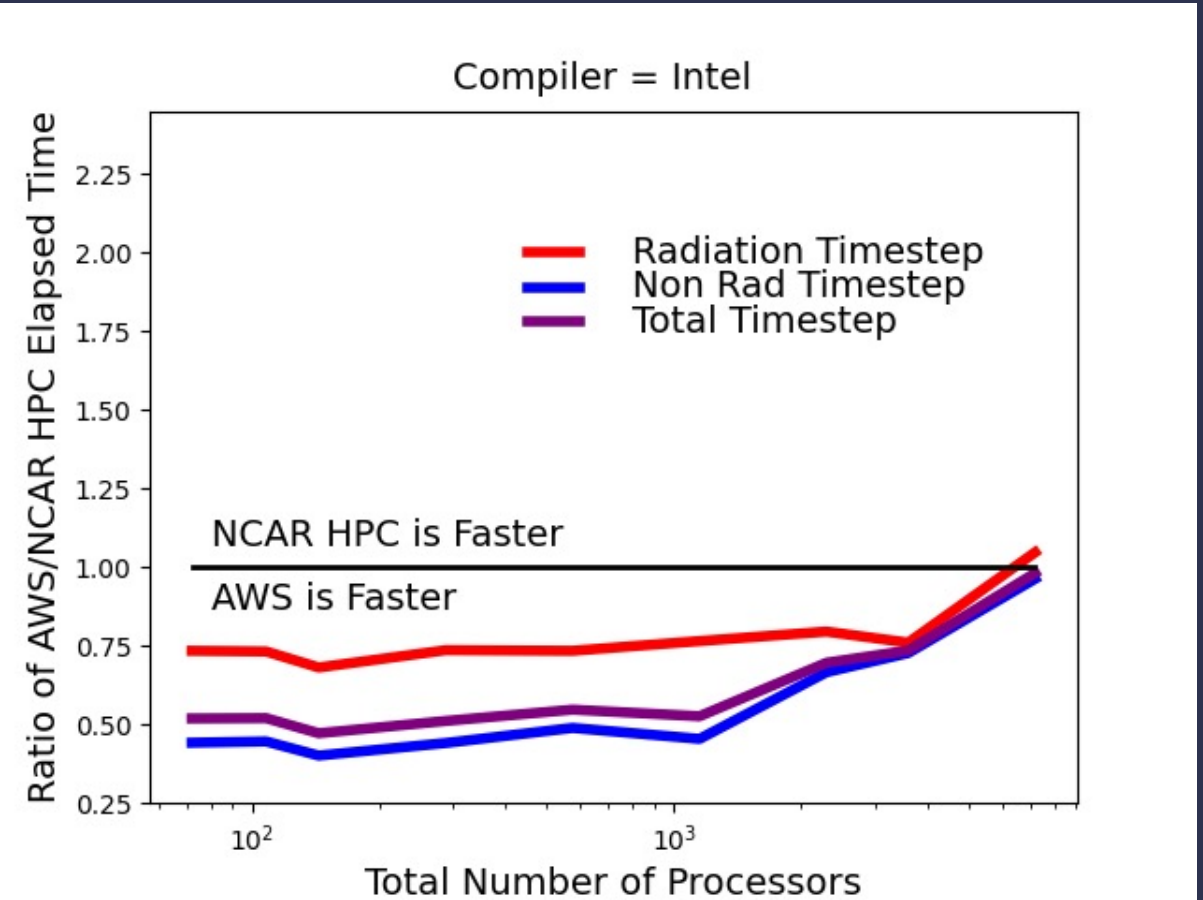
- Developed by Scala Computing, in collaboration with NCAR
- Jenkins software used – supports code development in continuous integration environments
- Automatic test for each new pull request (PR), or change made to PR
- Result of test emailed to developers/contributors

Automated testing is faster and more efficient



# AWS Cloud vs. NCAR HPC Performance

- Single domain
- 1500 x 1500 grid point
- 50 vertical levels
- 20 timesteps



## Cost Savings

- *No capital cost of hardware*
- *No ongoing administrative costs*
- *No idle assets*
- *Only pay for what you use*

Access to the latest compute architectures & tools

Avoid limitations of shared HPC clusters

Elastic storage & functionality

Easy collaboration/sharing

# Advantages of Cloud Computing

# General Cloud Computing Project Challenges

Steep learning curve

Limited or unorganized CSP documentation

Black box systems

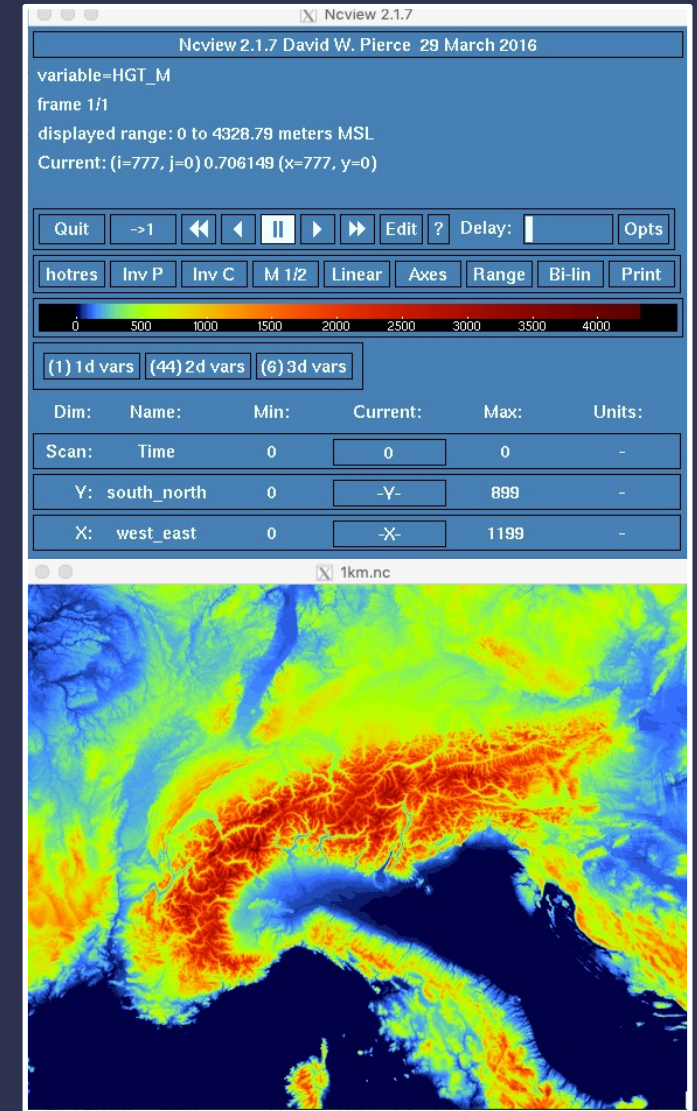
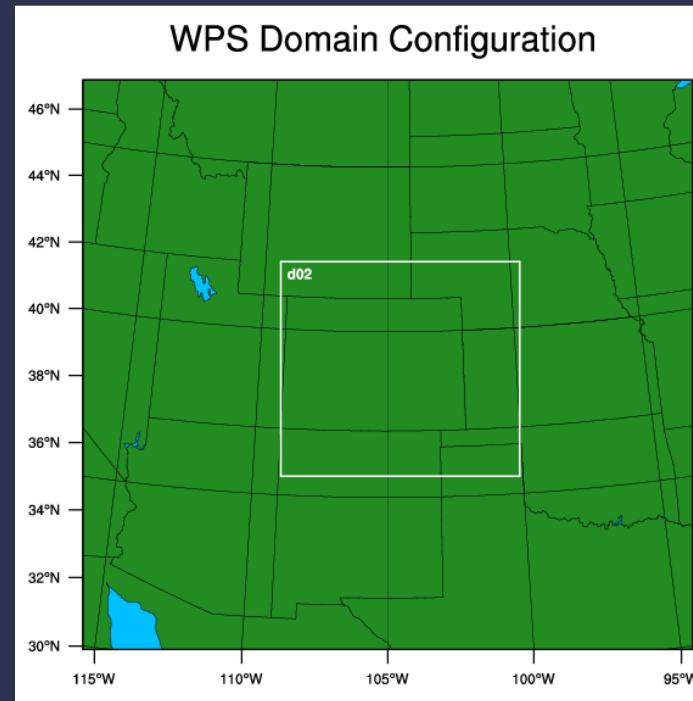
Idle instances and data egress accruing charges

Intel compiler: Difficult to access institutional license, unable to share publicly

# Limited Visualization Issue

Many CSPs require 3<sup>rd</sup> party applications for viewing output

- Unnecessary extra steps
- ***Solution:*** Install X11 & Ncview for quick “pop-up” viewing on screen, while in cloud instance



# Publicly-available Cloud WRF Resources for AWS

## Amazon Machine Images

- Pre-compiled WRF/WPS code (v3.6 – current)
- Includes post-processing & visualization

<https://www2.mmm.ucar.edu/wrf/users/supports/wrfcloud.html>

## Amazon EBS Volumes

- Created with AWS ParallelCluster
- For multi-node simulations

## AWS S3 Bucket Storage

Geographical static data

## Instructional “WRF in the Cloud” Website

- How to use an AWS cloud environment to run WRF

The screenshot shows the 'WRF in the Cloud' website. The header features the title 'WRF in the Cloud Using Amazon Web Services' alongside logos for WRF, NCAR, and Amazon Web Services. Below the header, a welcome message states: 'Welcome to the WRF in the Cloud Online tutorial. This tutorial will introduce the steps for running WRF in the cloud, using the Amazon Web Services (AWS) platform.' A disclaimer follows: 'The instructions given are meant to be used as a guide. Users must have their own account established with AWS, with their own user name and login in order to follow these instructions. If interested in obtaining an AWS account, visit the Amazon Web Services (AWS) website. You may also search to see if your institution an Active AWS Academy Member. If so, you may want to contact the institution's research computing team to see if you may have access through that account.' Below this, a navigation bar prompts the user to 'Click on a tab below for quick navigation.' and contains six buttons: 'Creating an Instance' (orange), 'Remote Access to Your Instance' (grey), 'Your Instance Environment' (yellow), 'Running WPS & WRF on Instance' (teal), 'Creating & Using AMIs' (red), and 'Using Multi-node Clusters' (purple).

# Publicly-available Cloud WRF Resources for Scala Computing

## Scala Compute Platform

- Pre-compiled WRF/WPS code
- Includes post-processing & visualization
- Includes geographic static data
- Includes multi-node cluster use

## Instructional "WRF in the Cloud" Website

- How to use a Scala Computing cloud environment to run WRF

### WRF in the Cloud Using Scala Computing



**Welcome to the WRF in the Cloud Online tutorial.**

**This tutorial will introduce the steps for running WRF in the cloud, using the [Scala Computing](#) platform.**

**The instructions given are meant to be used as a guide. Users must have their own account established with Scala Computing in order to follow these instructions. If interested in establishing a Scala account, please contact the Scala sales team.**



# Project Summary

Ongoing support for WRF in cloud-computing environments

Documentation - providing instructions & resources for using WRF in CSP environments

Using globally-accessible cloud-computing tutorial materials has been successful & beneficial

Cloud-based automated testing for WRF code contribution is an asset to the development team

Benchmarking tests show comparable timing between CSP and HPC environments

We have overcome several cloud-computing challenges, but there are still many things to learn. Tips are welcomed!

*Thank you!*

Powers et al., 2021 (*Early Online Release*):

<https://doi.org/10.1175/BAMS-D-20-0219.1>