Introduction to I-WRF: A Containerized Framework for Weather Modeling, Verification, and Visualization

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Increasing Flexibility for Weather Research, Building a Pipeline to Recruit New Atmospheric Scientists

- Weather prediction is a vital part of national capacity to support trade and shipping, transportation, agriculture, public safety, energy forecasting, and more
- Global & regional climate modeling is also vital for informing policy, infrastructure planning, insurance, and more
- Modeling and simulation is critical to the development of both daily and long-term weather analysis and prediction
- Atmospheric scientists are in short supply, require a lot of training in both theoretical and technical domains

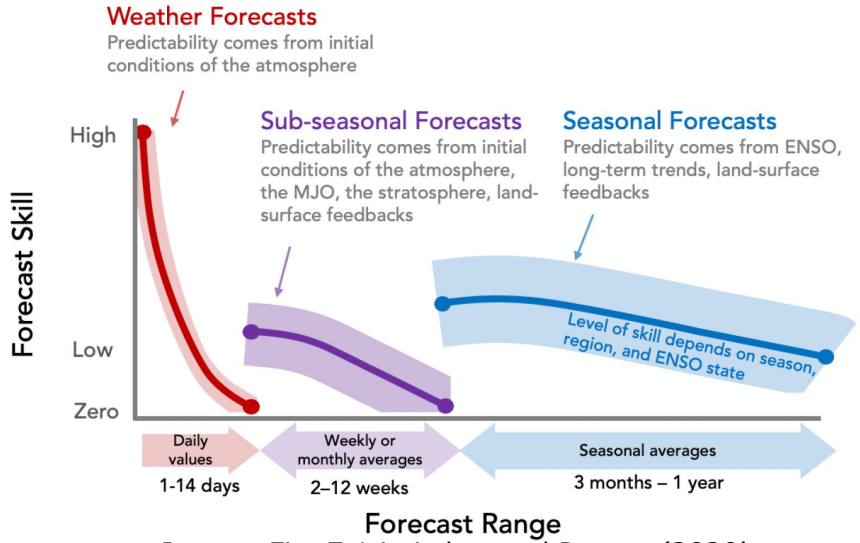
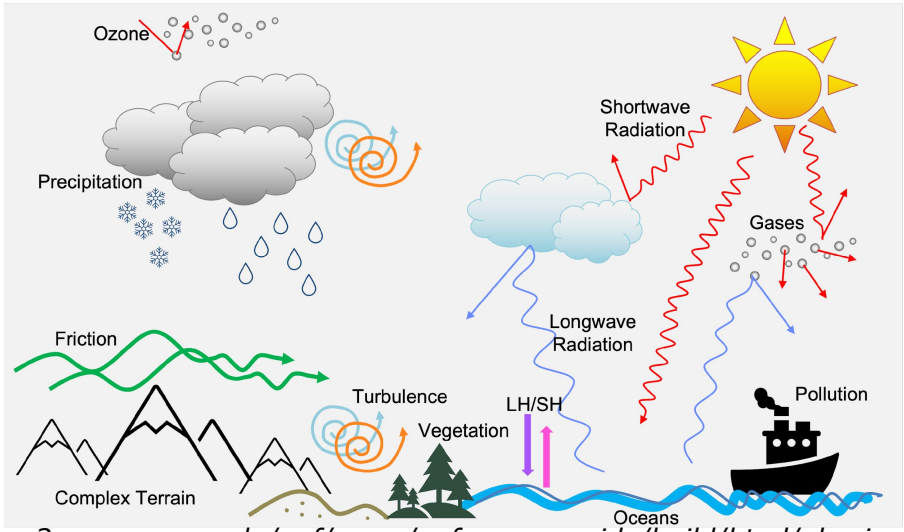
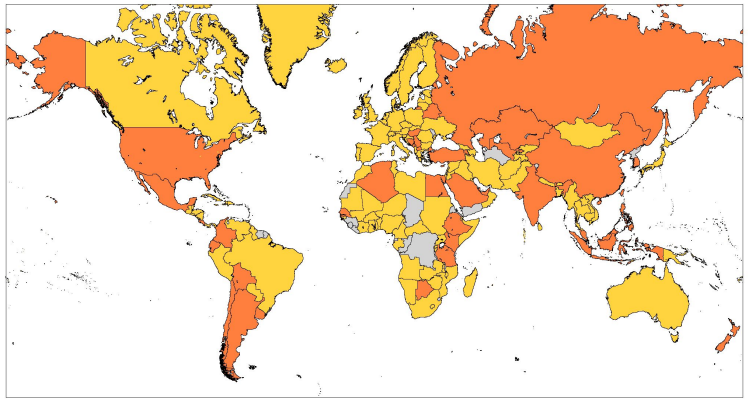


Image: Fig. 7.1 in Lukas and Payton (2020), https://doi.org/10.25810/3hcv-w477



Source: https://www2.mmm.ucar.edu/wrf/users/wrf_users_guide/build/html/physics.html

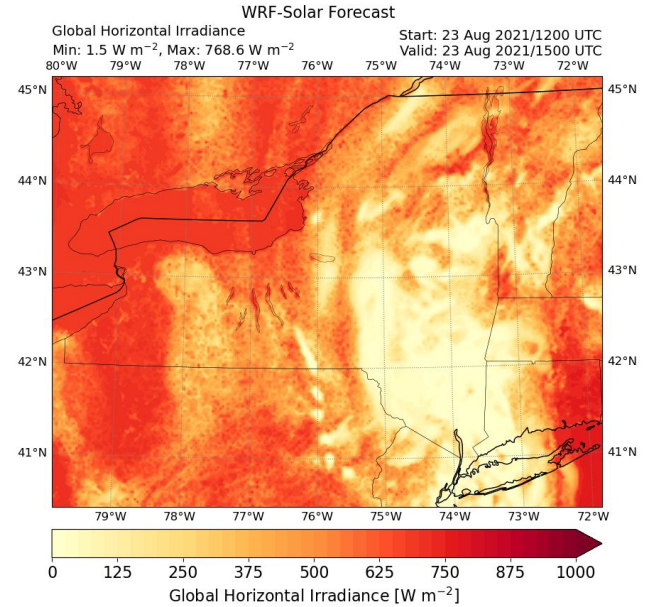
Weather Research and Forecasting (WRF) model



Nations with registered WRF users

Nations where WRF has been run operationally

Source: Fig. 2 in Powers et al. (2017, BAMS)



Source: Fig. 7a in Lee et al. (2024, Solar Energy)

- WRF® is a weather model with a broad range of applications
  - Weather prediction, climate modeling
  - Simulation of events based on characteristics such as land use or cover
  - Chemistry/air quality, wildfire, renewable energy generation, hydrologic forecasting, crop growth modeling, aviation/turbulence, surface transportation, large-eddy simulation, and more
  - Validation and visualization tools for verifying and seeing results
- In development since 2000, with a user base of more than 30,000 worldwide
- Deployment across a wide range of HPC systems, so much as to be included in benchmark suites

WRF Challenges

- Despite this, around *50% of users* attending tutorials at NSF NCAR report difficulty configuring the software for use on whichever computing platform they're using

- Compiling WRF software requires understanding multiple compiler frameworks, a set of required libraries to be built with the same compiler you select for WRF, and a wide range of WRF configuration options

- Need to know where to obtain data for initial conditions & lateral boundary conditions (ICs/LBCs), and observations for verification

- It usually requires some work to get verification and visualization tools configured to ingest WRF output

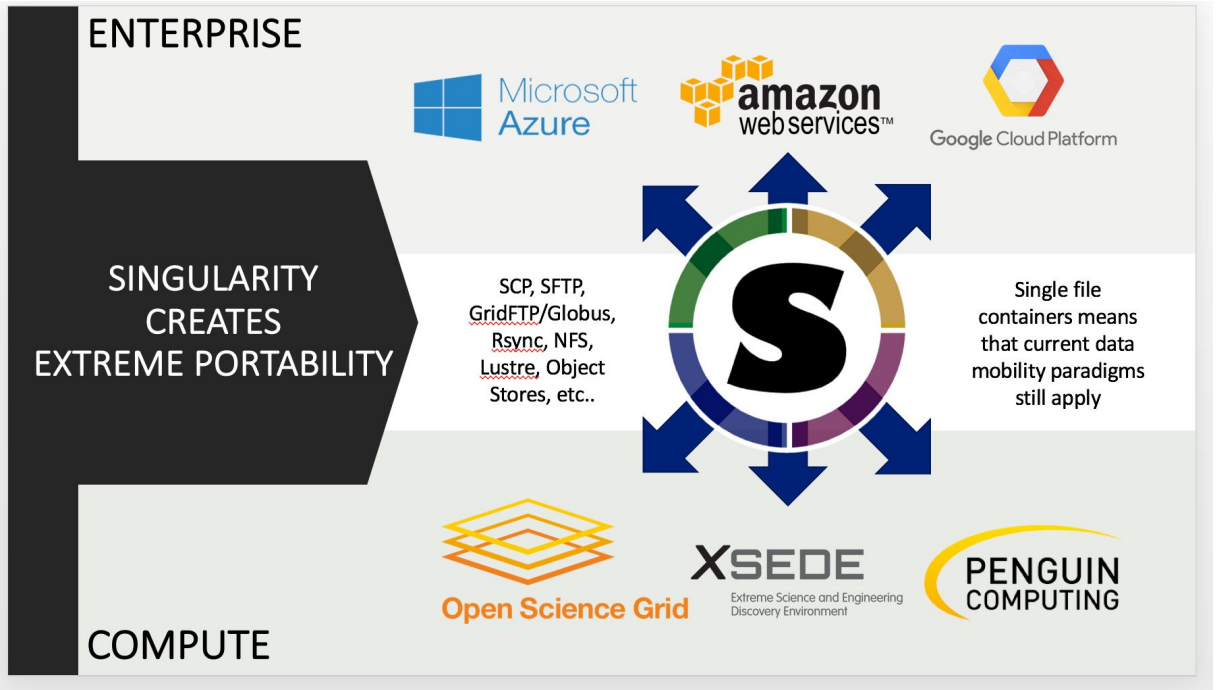
- These technical barriers mean that potential researchers and scholars run into hurdles before they can even get to the weather and climate stuff

Stanczyk, Jan Matejko, 1862. Wikimedia commons

https://www.istockphoto.com/signature/photo/thats-it-im-done-gm936117884-256071691

Application Containerization

- Application is put into a *software container* with all associated libraries and support
- The containerized application is smaller than a virtual machine image, and portable to a number of systems
- I-WRF puts the application, data, and configurations into a portable package



I-WRF Goals

- **Application containers support simplicity, portability, and scalability**
  - Run on a wide range of systems without installation/configuration issues
  - Include data management and interoperability with validation and visualization tools
  - Allow for large-scale problems with multi-node processing

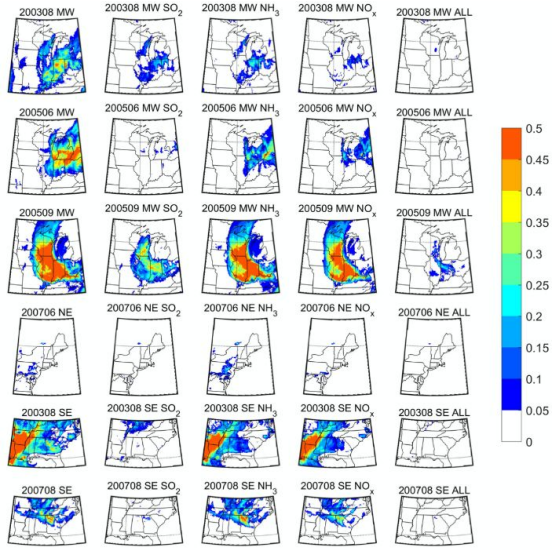
- **Another goal is to bring more researchers into Atmo Science**
  - I-WRF allows a user to try WRF without dealing with installing and compiling software
  - Model weather on your laptop, in the cloud, or on an HPC resource
    - Keep in mind, though, that your laptop doesn't have the computing horsepower of cloud or HPC resources, so the same simulation will take longer on a laptop

I-WRF Science Use Cases — Running at scale to answer research questions

1. Land Use/Land Cover (LULC) Change in the U.S. Northeast and Feedbacks to Extreme Weather Events and Societal Impacts

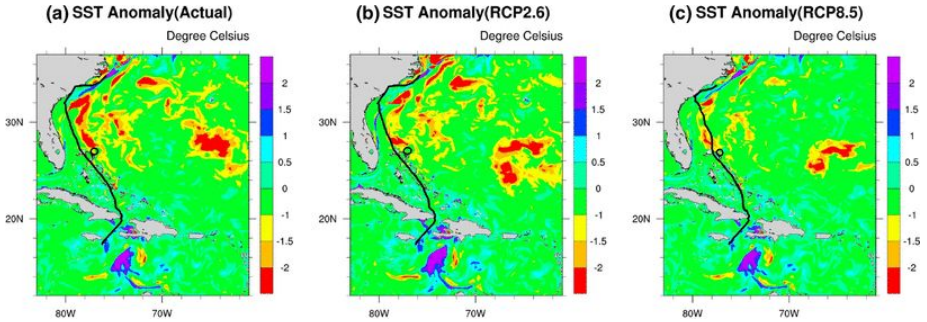
2. Climate Change Impacts on Wind and Solar Energy Resources in the U.S.

3. Air Quality in the Northeast U.S. Urban Corridor in a Changing Climate



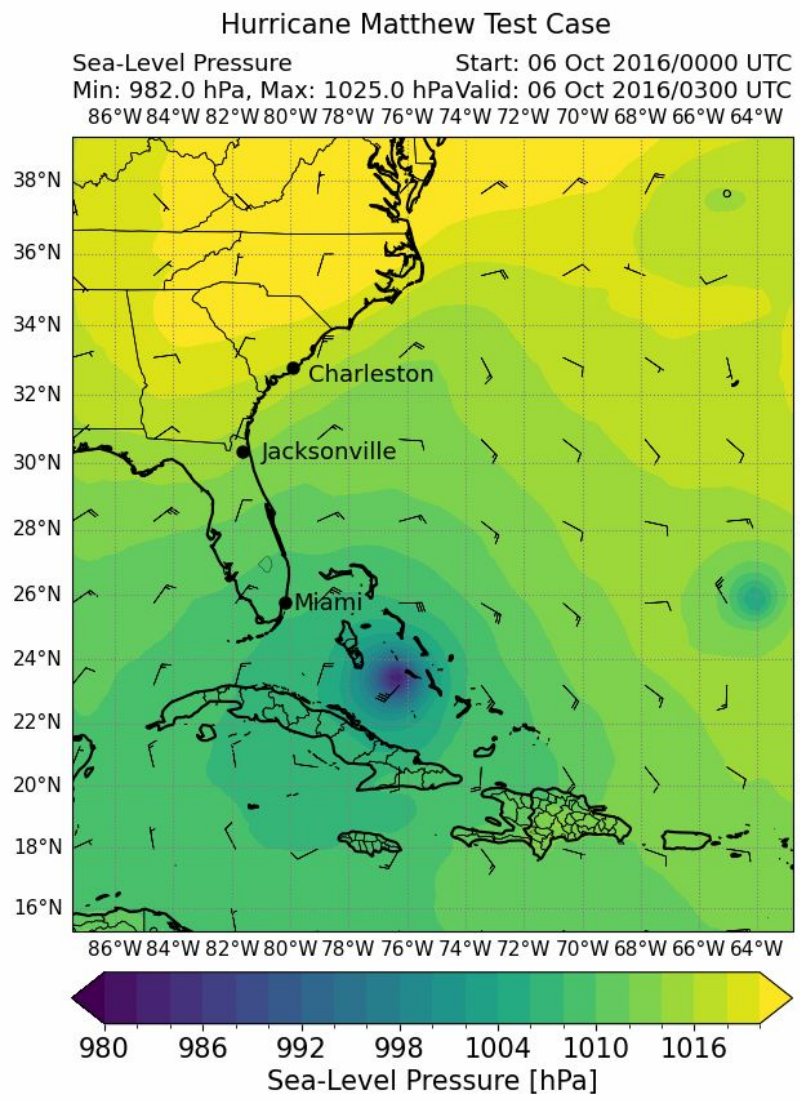
Supporting Broader Engagement in Atmospheric Science

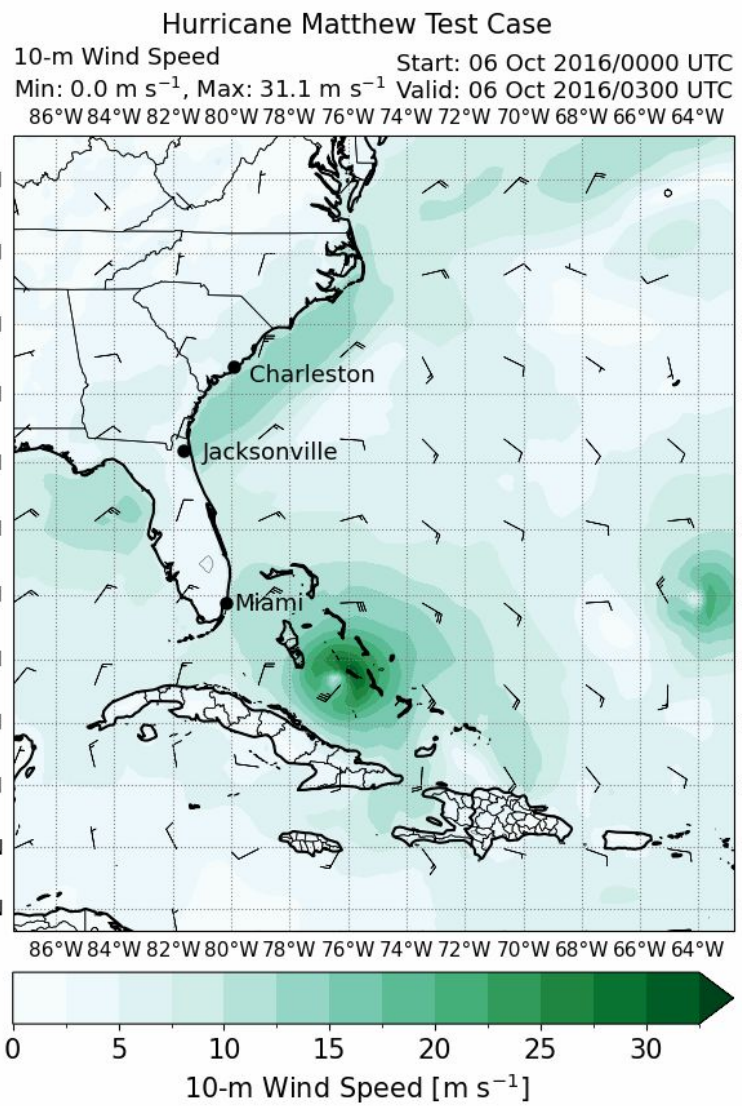
- Users can run sample WRF simulations on a laptop or free cloud resource
- The first I-WRF sample simulation is an event used for the NSF NCAR Online WRF Tutorial: Hurricane Matthew (2016) event

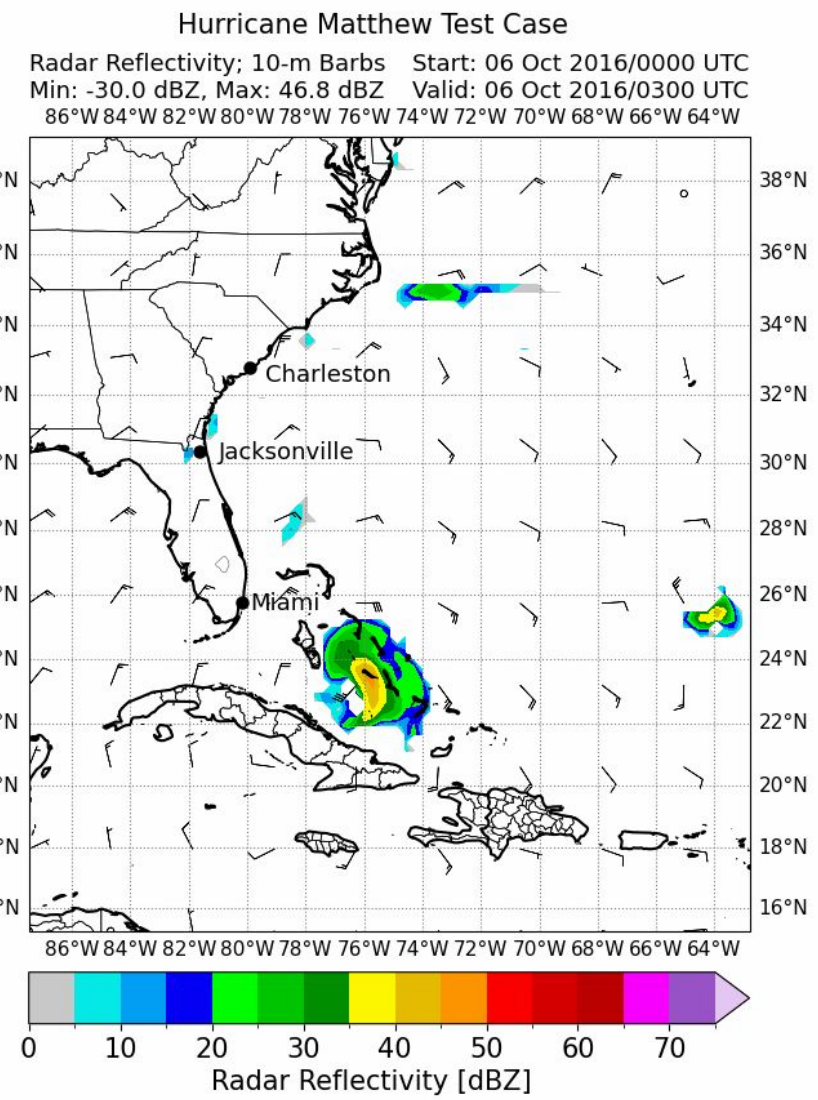


- Making the WRF software both easier to run and relevant to:
  - Increasing recruitment into Atmospheric Sciences
  - Building a **pipeline** of researchers into the discipline
  - Bridging the diversity gap in weather and climate research

I-WRF Hurricane Matthew Test Case Python Visualization







Verifying Model Output with METplus

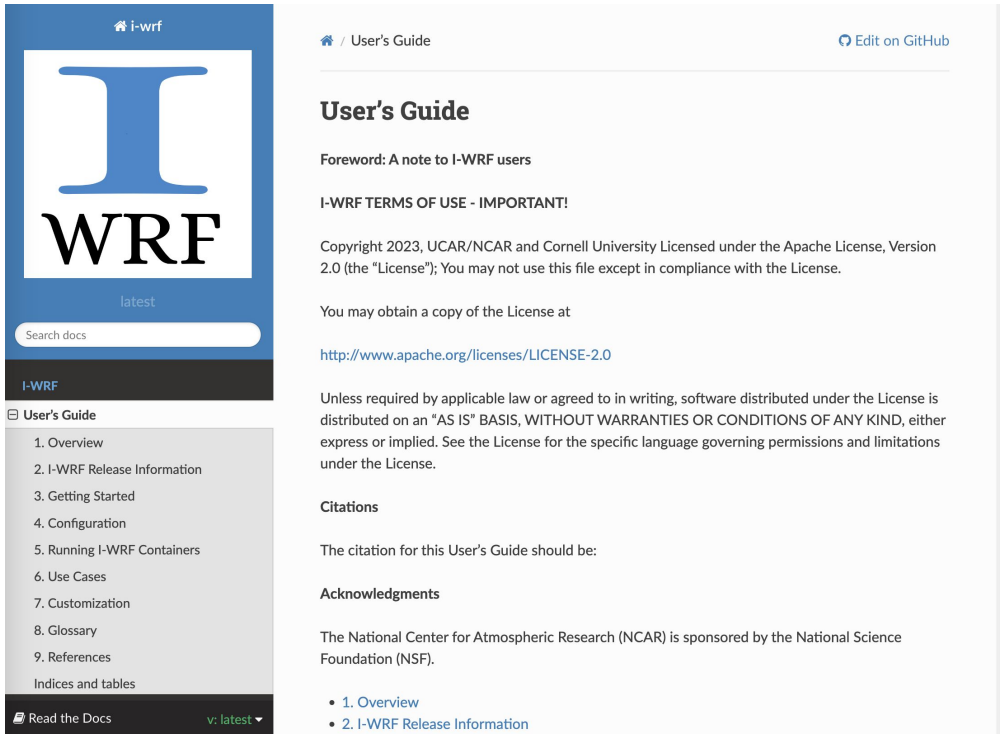
- Model Evaluation Tools (METplus) verification system
  - Developed through support from the 557th Weather Wing of the U.S. Air Force, National Oceanic and Atmospheric Administration (NOAA), and NSF NCAR
  - Verification framework that spans a wide range of temporal (warn-on-forecast to climate) and spatial (storm to global) scales
  - Used operationally by NOAA, UK Met Office, Australian Bureau of Meteorology, and others
  - Large community of users & contributors
- METplus was already containerized
- I-WRF containerizes a METplus configuration for doing some sample verification from the WRF output from the Hurricane Matthew test case, and plotting it (this script not quite ready yet, though, but will be available soon)

METplus

https://dtcenter.org/community-code/metplus

I-WRF Details

- Run it yourself on Jetstream: https://bit.ly/iwrf-matthew
- Overview website: https://i-wrf.org
- User guide: https://i-wrf.readthedocs.io/en/latest/Users_Guide/index.html
- Github site: https://github.com/NCAR/i-wrf
- Help through help@cac.cornell.edu



Building a public I-WRF documentation website using Github and ReadTheDocs