Cloud-Based Numerical Weather Prediction for Near Real-Time Forecasting and Disaster Response

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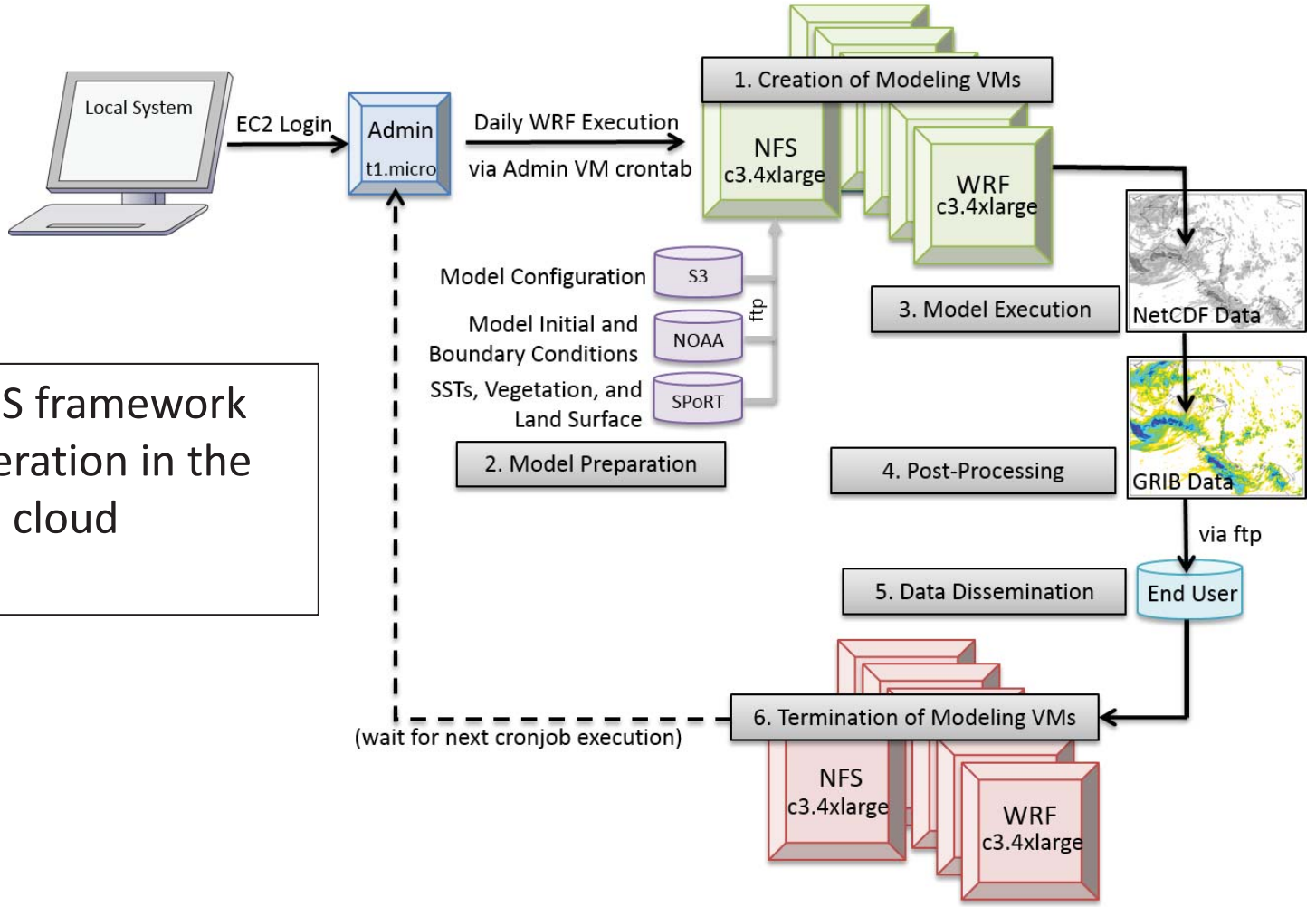
Background

- Cloud computing capabilities have rapidly expanded within the private sector, offering new opportunities for meteorological applications
- Collaborations between NASA Marshall, NASA Ames, and contractor partners led to evaluations of private (NASA) and public (Amazon) resources for executing short-term NWP systems
- Activities helped the Marshall team further understand cloud capabilities, and benchmark use of cloud resources for NWP and other applications

Timeline

- 2011-2012
  - Collaborations with Ames to run the NOAA/NWS Science and Training Resource Center (STRC) Environmental Modeling System (EMS) on Nebula, a private cloud environment that was available within NASA
  - Early benchmarks were promising and further concepts were explored
- 2012-2013
  - Technical work to improve run-time performance, transition of the system to the Code I Private Cloud at Ames. Daily forecast runs were set up to perform validation metrics.
- 2013-2014
  - Capabilities established at Ames were transitioned to the Amazon Elastic Compute Cloud (EC2) and to control at Marshall.
  - Exploring applications with the SERVIR team to allow international partners to build their own NWP applications.

“Clouds in the Cloud”

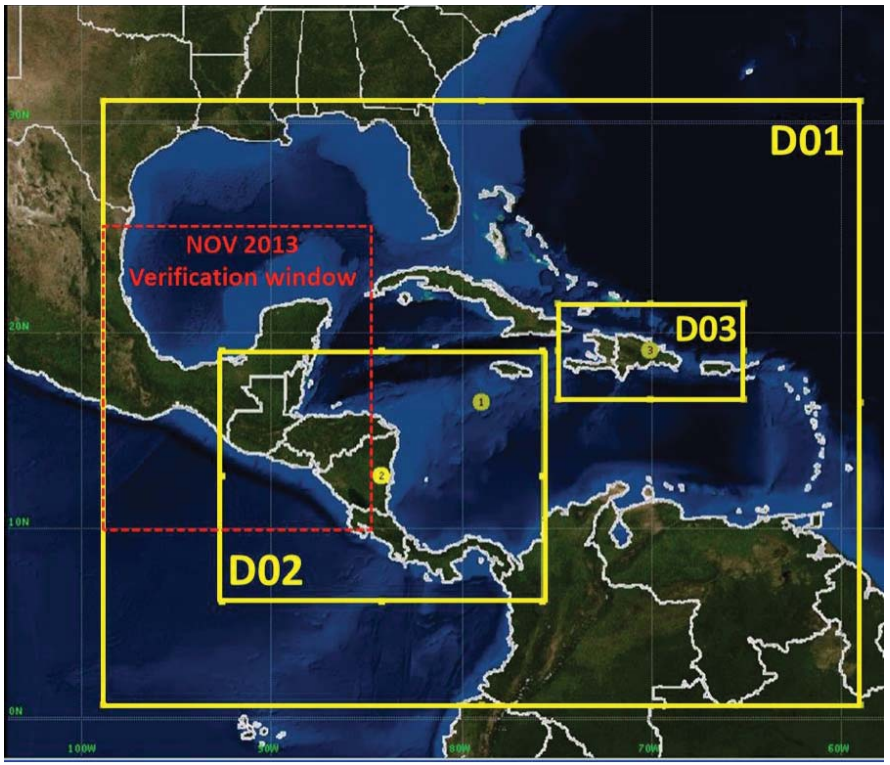


Resulting STRC EMS framework established for operation in the Ames and Amazon cloud environments.

For more details, see “Clouds in the Cloud: Weather Forecasts and Applications within Cloud Computing Environments”, by Molthan et al. as an *Early Online Release* for publication in BAMS

Example Application

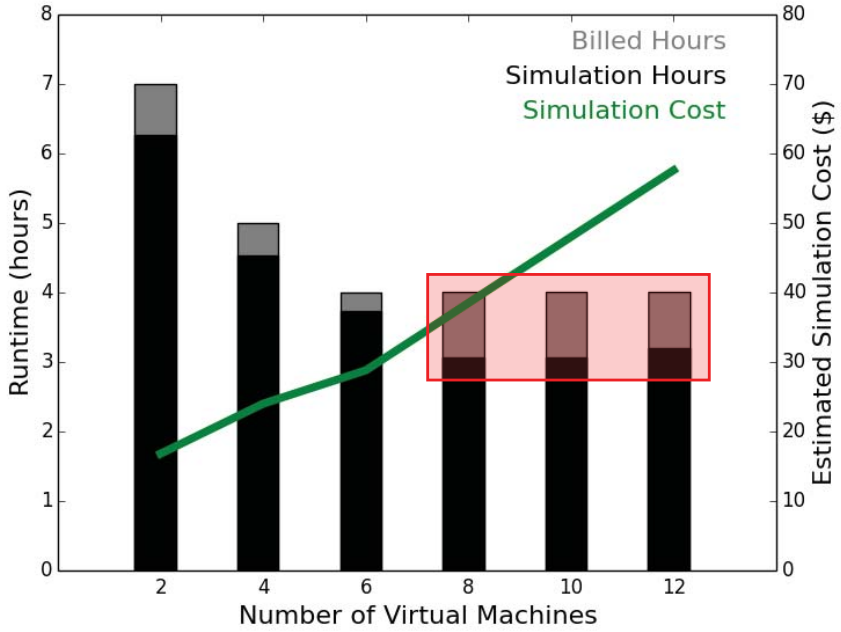
- The SERVIR Project at NASA's Marshall Space Flight Center partners with USAID to provide "capacity building" support to developing countries
- Goal: Explore cloud computing as a new "capacity" built for regional NWP and spinoff applications



Cloud-based NWP domains established to support SERVIR partners in Mesoamerica.

Simulation Costs

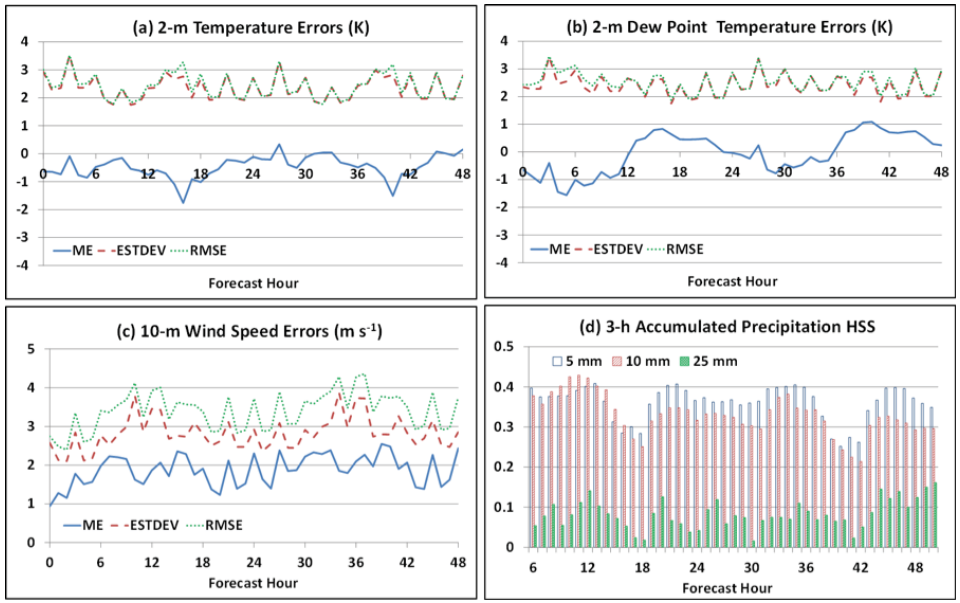
- To be an effective solution, simulation costs must be relatively cheap and offer benefits over simply purchasing physical hardware
- The team performed benchmarks to assess runtime and estimated cost, identifying needs to further improve and optimize WRF runtime performance



Runtime performance and estimated cost for various configurations of EC2 virtual machines. Diminishing marginal utility is highlighted at VM counts of 8 and greater.

Verification

- In addition to regional NWP, the team established verification capabilities for end users
- Simulations were evaluated in November 2013, compared to available satellite and surface weather data



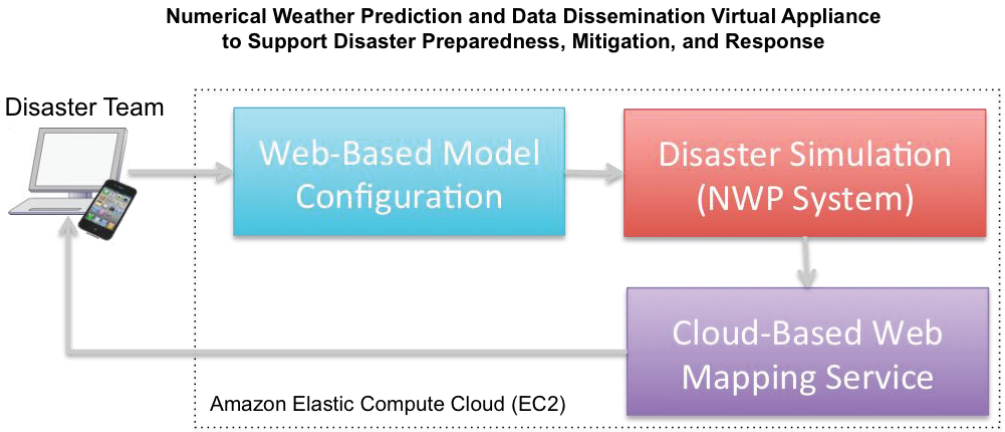
An example of verification statistics for simulations in 2013, identifying some opportunities for improvement that would further reduce temperature and precipitation biases.

Potential Applications

- Developing countries have a need for higher resolution, regional NWP at finer scale than provided by current global simulation systems
- Ideally, a full ensemble could be provided, but in many cases a single forecast can provide additional detail for significant weather scenarios.
- Cloud resources could serve as a “gap filling measure” where NWP can be provided quickly without disrupting other operational systems
- Examples:
  - Local simulation of heavy precipitation for landfall prediction requires simulation of orographic influence
  - Air quality simulations require special configurations of NWP to meet their needs
  - Localized extremes in temperature, wind, and other parameters that are not resolved on the local scale by global models
  - Other physical models beyond NWP (e.g. hydrology and streamflow)
  - Short-term needs for NWP to support expected or active disaster scenarios, such as torrential rains and flooding, severe weather, humanitarian response, etc.

Disaster Emphasis

- Disaster events often benefit from NWP
  - Pre-event predictions of hazards, such as heavy rain, wind, or severe weather
  - Post-event predictions of sensible weather for responder safety, mission planning, etc.
- Establish a cloud-based appliance to support NWP in response to likely disaster scenarios
  - Pre-select ideal configuration and decision aids useful to responders

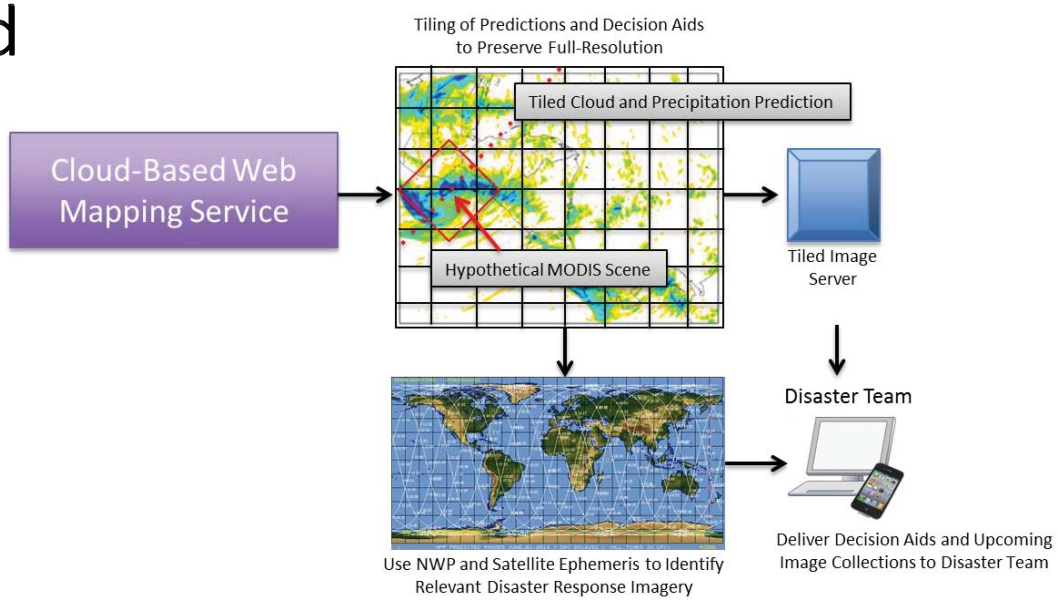


Workflow concept to allow users to web-configure a simulation for their disaster response needs.

Web-based concept where users define a region of interest and select model pre-configuration tailored to a specific disaster scenario.

Disaster Emphasis

- In addition to NWP, cloud resources can be leveraged to provide other types of support.
- Often, responders are provided a variety of remote sensing products and imagery for assessment.
- Cloud resources can be used to establish disaster-specific imagery and dissemination to handheld devices.



Conceptual model using cloud-generated NWP as a decision aid for selecting, staging, and delivering other remotely sensed products for disaster support.

Future Work

- Cloud computing resources offer several opportunities for meteorological and satellite applications
  - The team will continue to explore further efficiencies in the NWP component, through higher-powered VM instances, faster internal networking, and other options
  - New capabilities for acquiring and disseminating imagery through cloud platforms will be explored
- Questions?
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