Forecast applications driven by High-Performance Computing at The Weather Company

Todd Hutchinson 28 October 2016

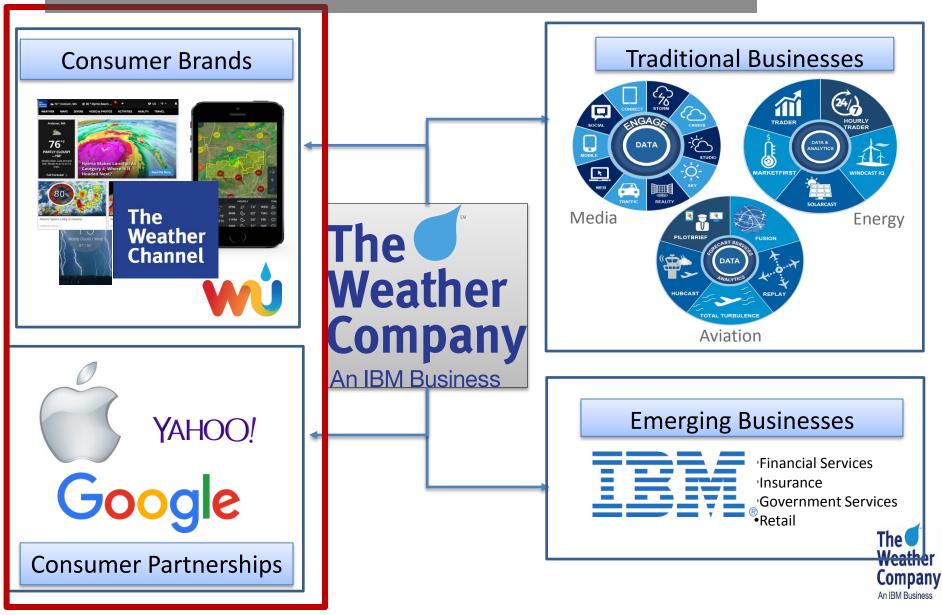


Overview

- Consumer Products and Forecast Production
- Business applications and examples
- Use of Amazon Web Services
 - Forecast Generation
 - -NWP
- Practical use of AWS for development and testing



The Weather Company Businesses



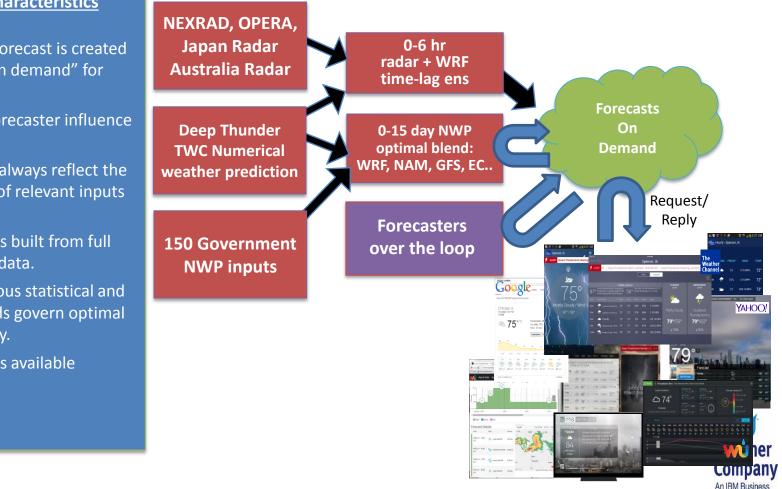
TWC Consumer Forecasting Portfolio

Туре	Period	Description	Update Freq.	Resolution	Coverage
Current Conditions	Now	Current weather on the ground	On demand	~ 250 m	Global
Short-term	Next 6 hrs	Rapid update full weather forecast	On demand	~250 m / 15 minutes	Global
Medium Term	Days 1-15	Full weather forecast	On demand	~250 m / hourly	Global
Sub-Seasonal	Weeks 3-5	Weekly temp averages	Twice Weekly	10 km / biweekly	NA, Europe, East Asia
Seasonal	Months 1-4	Monthly temp and precipitation anomalies	Twice Monthly	10 km/month	NA, Europe, East Asia



Forecast Engine Components

Core Infrastructure that drives billions of forecasts per day



Some Key Characteristics

Personal: Every forecast is created and delivered "on demand" for each user.

Human Input: Forecaster influence retained.

Fresh: Forecasts always reflect the latest collection of relevant inputs from all sources.

Precise: Forecasts built from full resolution input data.

Optimized: Various statistical and scientific methods govern optimal forecast assembly.

Global: Forecasts available worldwide

Forecast-On-Demand Statistics

- Forecasts customized upon request based upon users location and elevation
- On average 11 Billion forecasts/day with peak of 26 Billion
- Mean forecast creation time ~ 11 ms.
- Mean total request-to-delivery time < 300 ms.
- Used by all TWC consumer forecast systems (The Weather Channel, weather.com, WeatherUnderground, Intellicast)
- Drives our partner's weather including Apple, Google, Yahoo!, IBM and most domestic TV stations
- Deployed in multiple AWS global regions to support redundancy and loadbalancing
- On-Premise high-performance computing support NWP



Forecast Engine Cloud Components

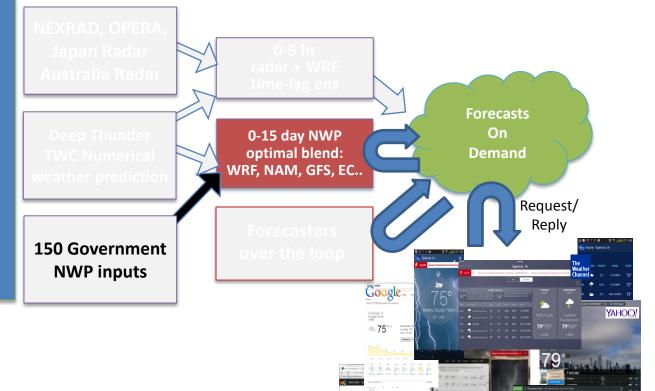
Cloud Application Characteristics

High-Availability: Redundancy across data centers (i.e., US East, US West, Singapore, and Ireland).

Fresh Data: Input data is always in memory and continually updated.

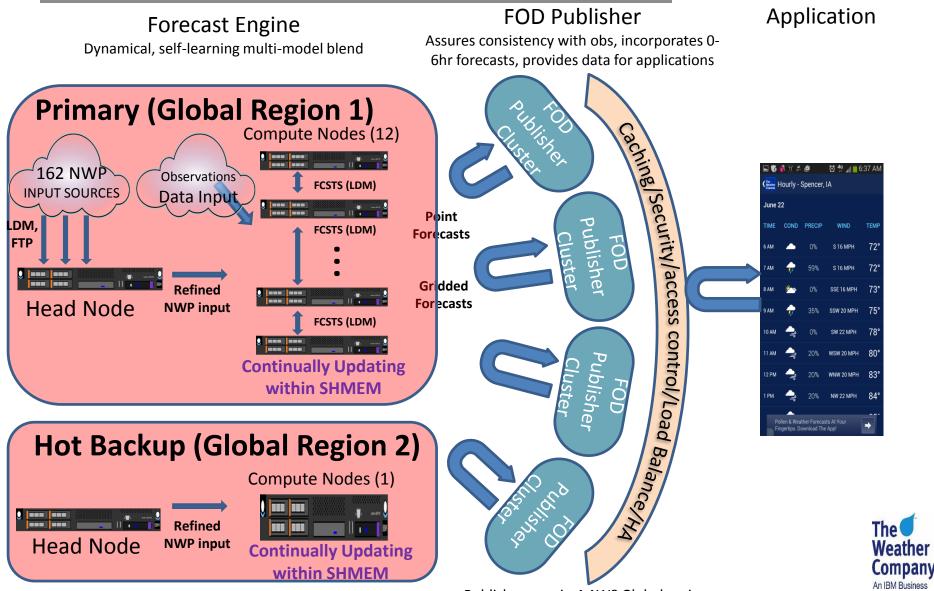
On-Demand: Calculations are triggered by user request.

Rapidly scalable: If user requests increase, servers can be quickly provisioned to meet demand



An IBM Business

0-15 day Forecast Engine in AWS Cloud



Publisher runs in 4 AWS Global regions

TWC Computing: On-Premise

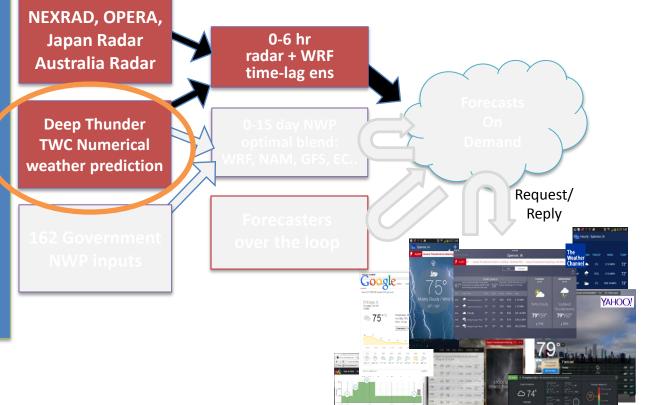
On-Premise Characteristics

HPC: Processing requires lowlatency/high-bandwidth interconnects.

Scheduled Processing: Jobs take significant time to run (minutes to hours) and run as batch (triggered by clock or data arrival).

Local Redundancy: HPC systems built with redundancy internal to cluster.

Push: Data pushed from core systems to on-demand systems.



An IBM Business

TWC and IBM Research NWP Programs joined

Deep Thunder

Deep Thunder excels with **Local**scale Forecast applications

Deep Thunder couples **Renewables** & Air Quality capabilities

Deep Thunder brings **Additional Investments** In Research



Jan 29, 2016

RPM

RPM delivers operational **Global** weather forecasts

RPM drives **Graphical Television** forecasts

RPM provides **Turbulence** and **Icing** forecasts for airlines

Global Thunderstorm forecasts







Compute Details: On-Premise NWP

Numerical Weather Prediction System

- Forecasts out to 3 days
- Provides global 13km coverage, regional 4km
- Forecasts updated every 1 6 hours
- WRF 3.7.1, NCEP GFS/RAP + radar Init

• On-Premise Compute Facilities

- 2600 CPU cores in Andover, MA, USA
- QDR/FDR Infiniband
- Data Center with redundant power, cooling, 7x24 support

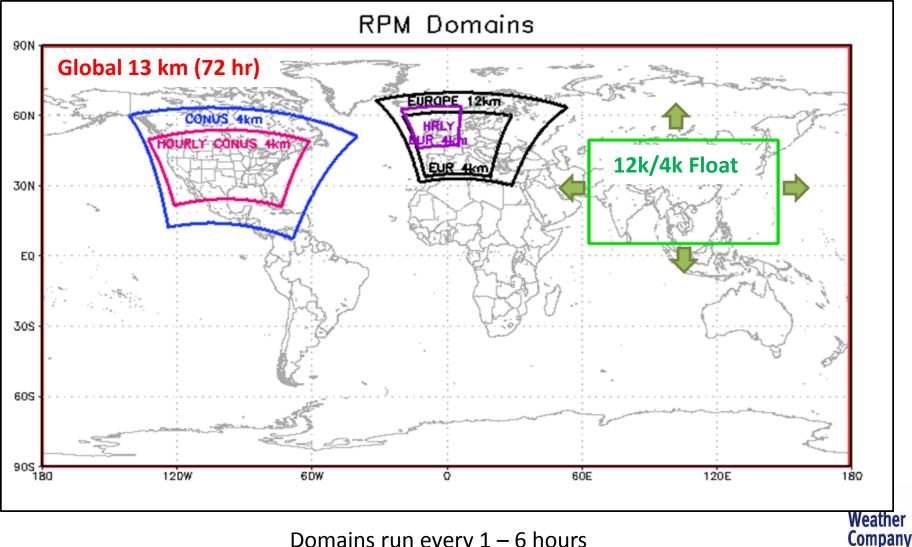








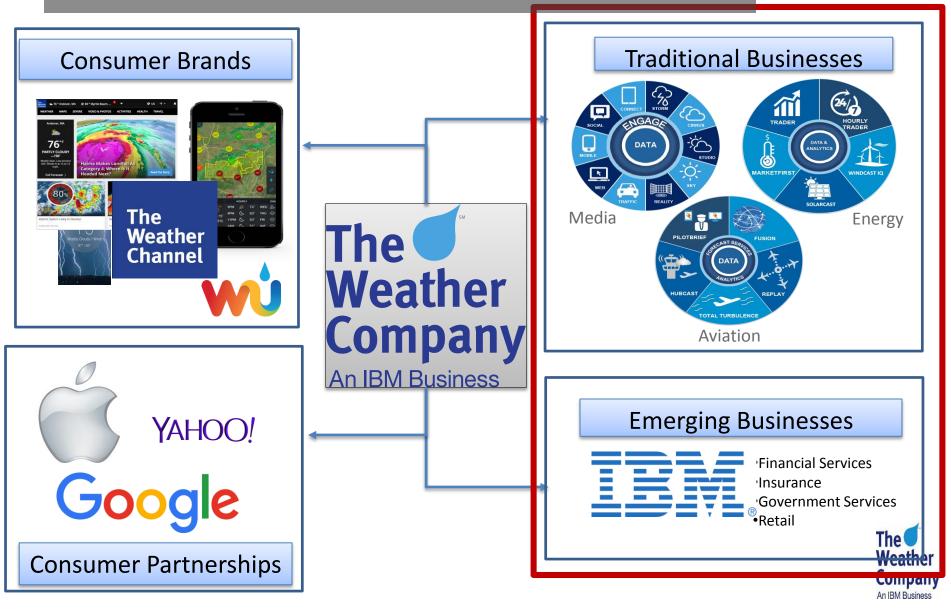
NWP Domains



Domains run every 1 – 6 hours

An IBM Business

The Weather Company Businesses

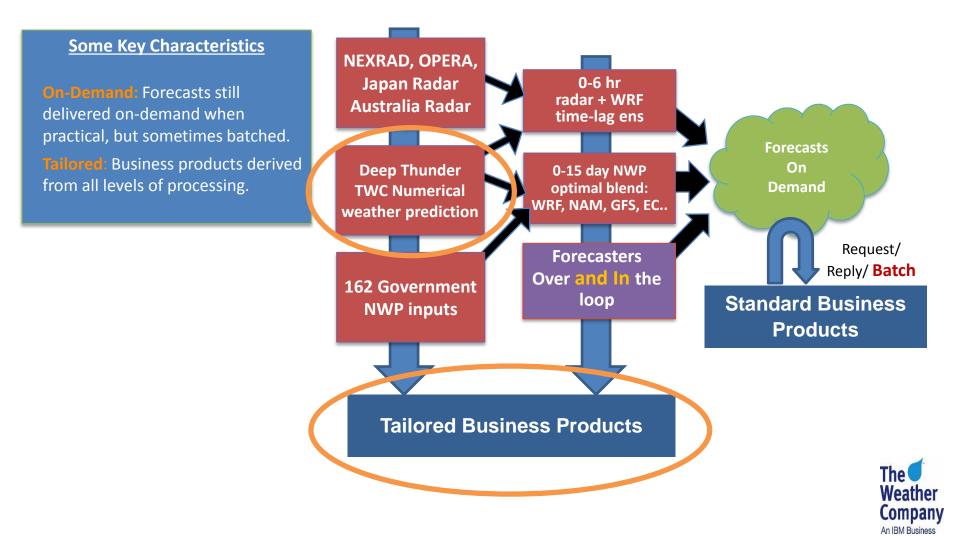


Traditional B2B Businesses

Media Services	 85% of the US TV stations Most national broadcasters Weather and Traffic solutions White label digital products 	•	
Aviation Services	 85% of major US airlines 20% of top 100 global airlines 		Image: Source of the second secon
Energy	 Over 300 power trading clients worldwide Proprietary renewable energy forecasting system 		Image: Societte generale Image: Societte generale Bankof America Image: Societte generale Bankof America Image: Societte generale Image: Societte generale Image: Societte generale Image: Societee generale Image: Societee



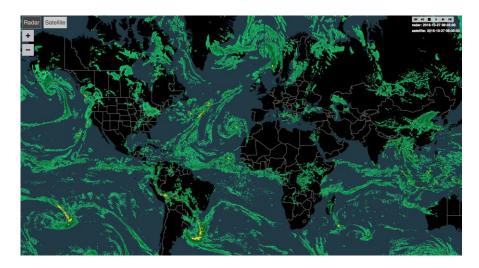
Business: TWC Business Products

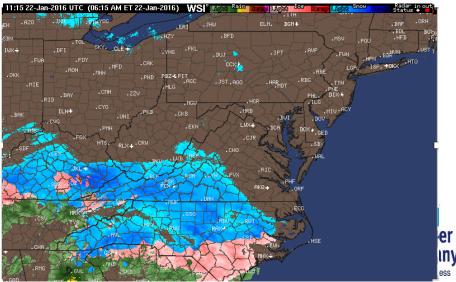


Media: Global Precipitation Analyses

• Global Precipitation Estimate:

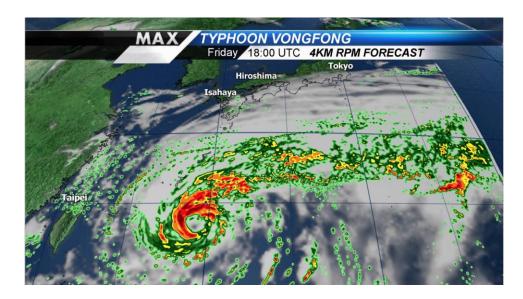
- Radar Analysis + Global/Regional NWP forecasts
- 1km Precip Type analysis
 - derived from 13/4km WRF vertical temp/moisture
 - adjusted with surface observations, elevation
- Produced every 5 minutes Globally





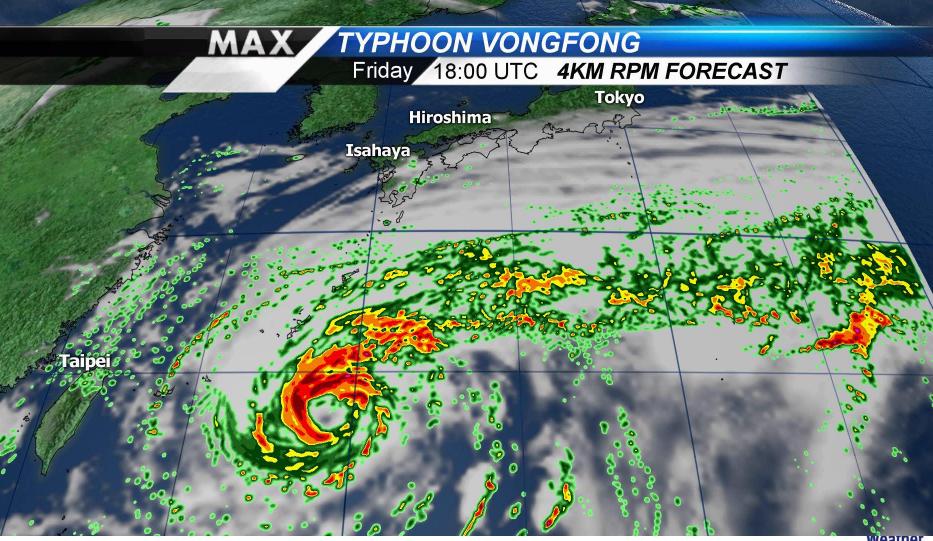
Media: Forecast Precipitation

- Forecast Precipitation
- Widely used in television media
- Often labeled "Futurecast" or "RPM"
- Globally available at 4-13 km resolution





Media: Forecast Precipitation





Media: Max Sky: A visualization of tomorrow's weather

- WRF provides forecasts to define cloud type, flow, height, precipitation intensity
- Artists generate cloud textures
- Computer Graphics engineers use Sun location to properly light clouds
- nVidia GPU's are used heavily in the graphics generation.



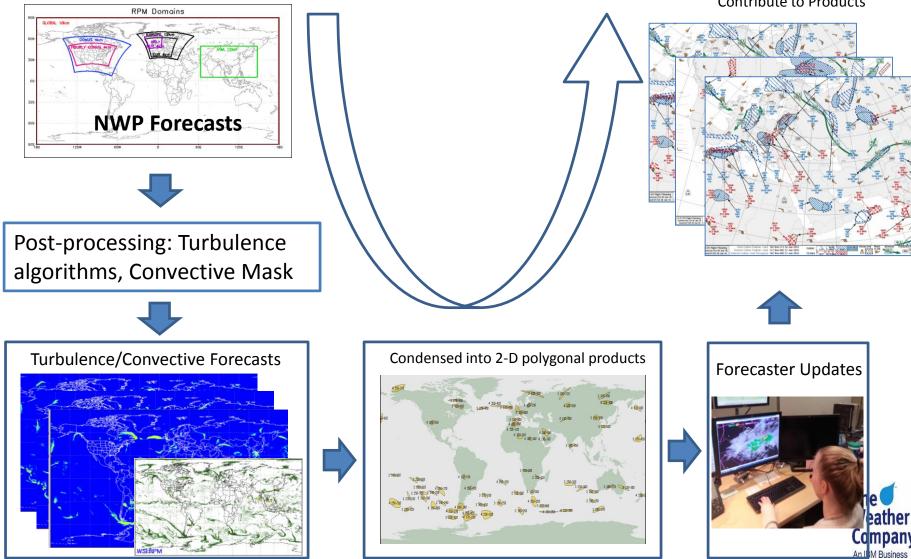


Media: Max Sky: A visualization of tomorrow's weather



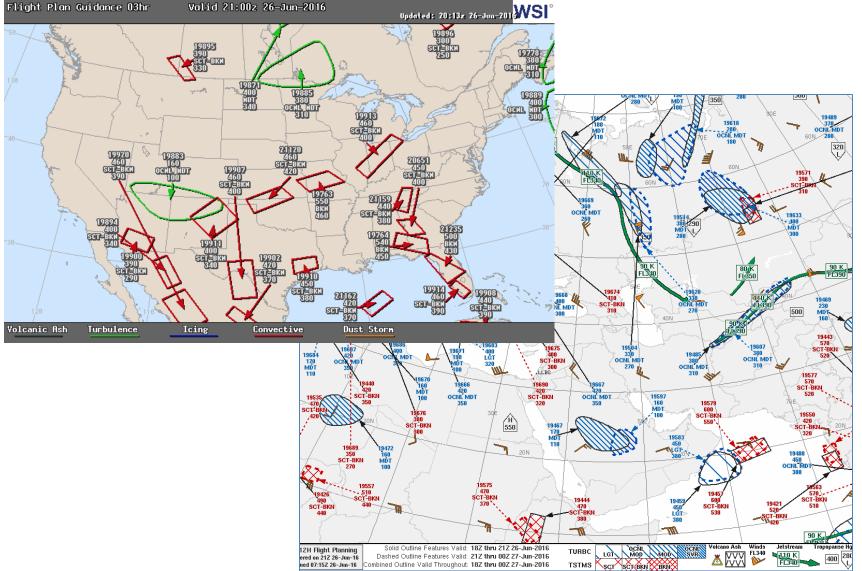


Aviation: Enroute turbulence



Contribute to Products

Aviation: Enroute products

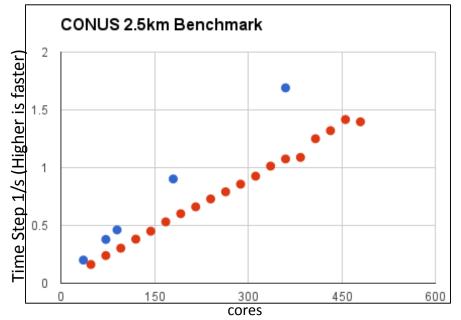




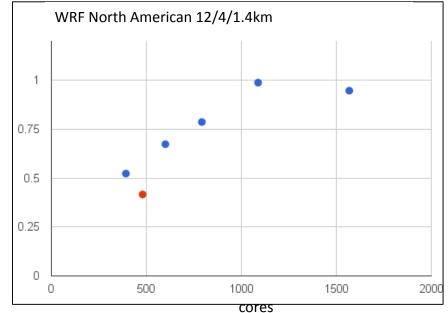
AWS EXPLORATION AND DEVELOPMENT PROCEDURES

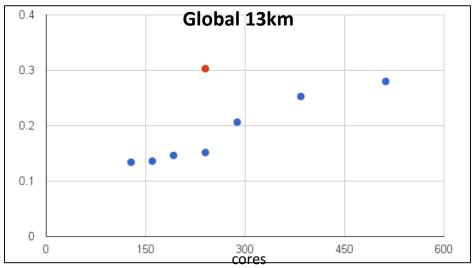


NWP (WRF) scaling on AWS



On-Premise (Ivy Bridge/IB)
 AWS Cloud (Haswell/ethernet)



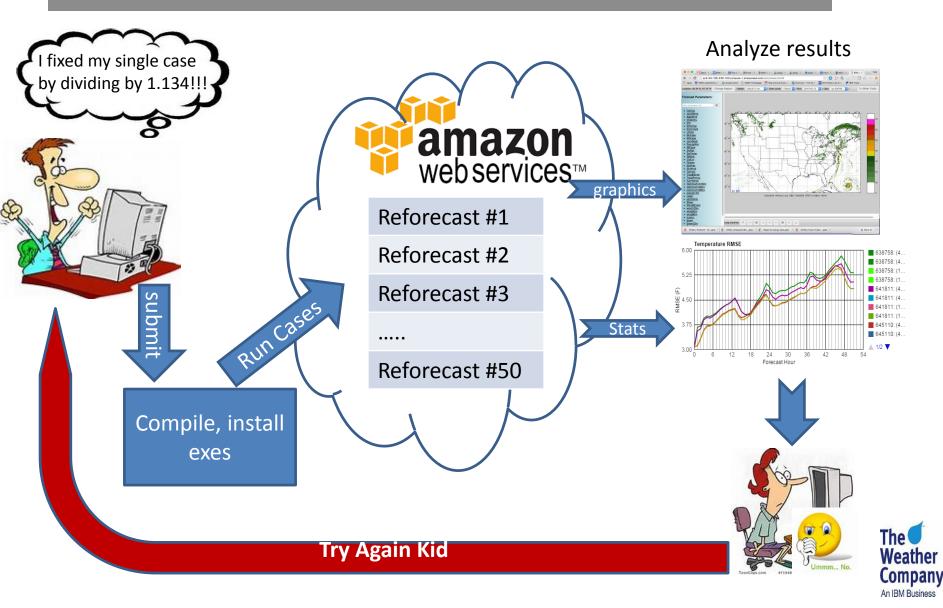


NWP on AWS Scaling

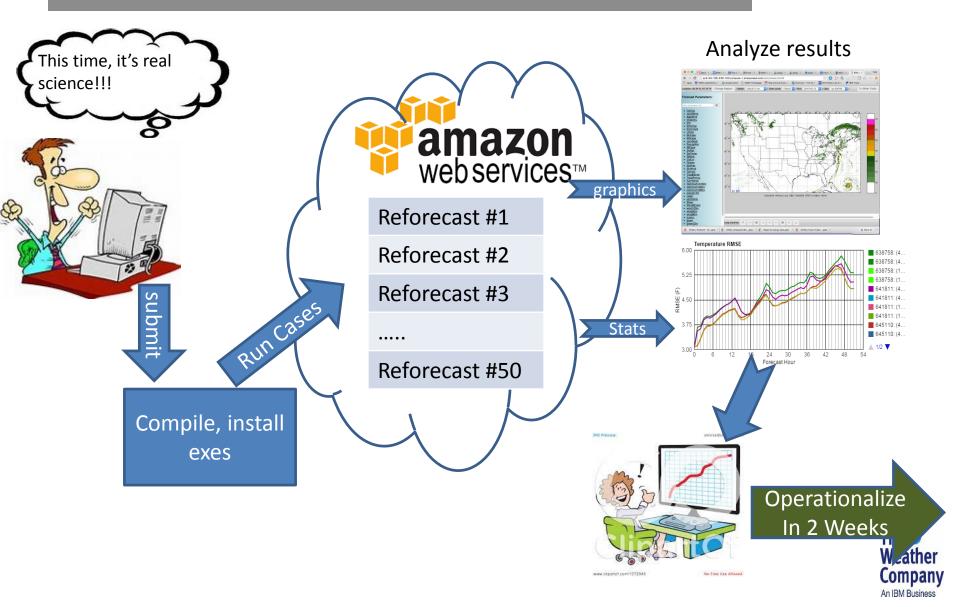
- Some WRF workloads scale to O1000 cores
 - nodes must be in same "placement group"
 - must use SR-IOV (enabled in default AWS Linux)
- AWS great for large-scale, rapid, testing



Development and Testing on AWS

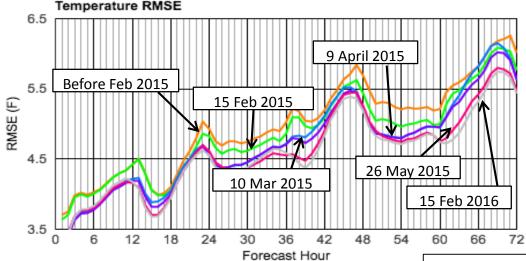


Development and Testing on AWS



Improvements past 2 years

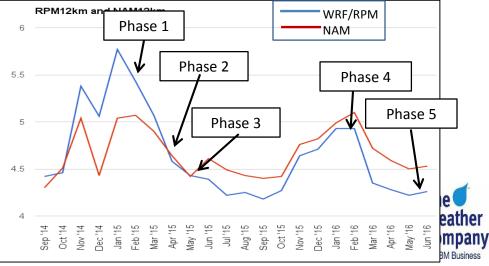
Continuous 2m Temperature Improvement



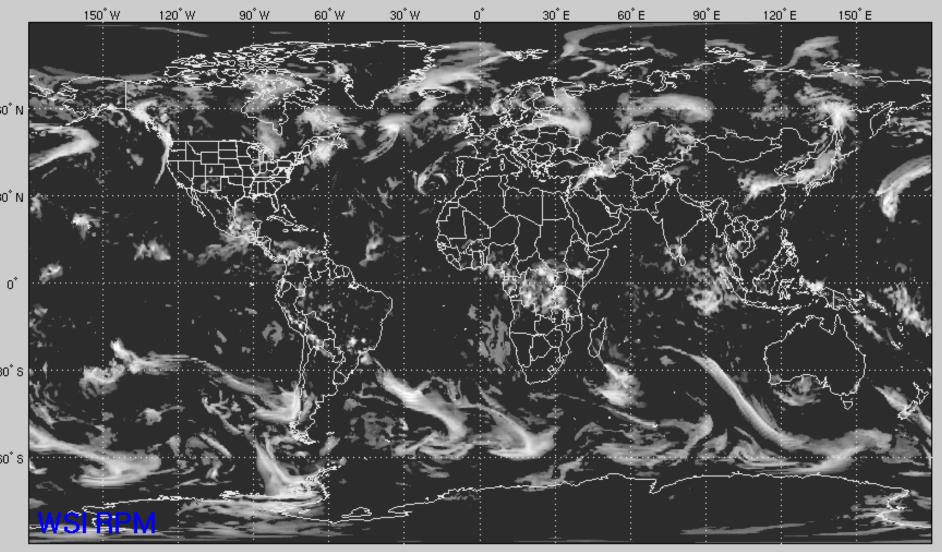
50-case verifications for updates that were promoted to operations

Ph. Upgrade

- Urban soil init. to eliminate moisture sinks
- 1 NAM snowcvr + updated snow thermal eqns
- 2+3 Updated surface layer equations
- 4 Updated to RRTMG Radiation
- 5 Initialize with 2 km sea-surface temperature
- 6 Initialize with 1km snow depth



Global Clouds



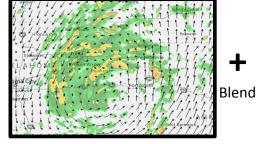
Visible Satellite 20141020 0100Z fcstHr 01:00

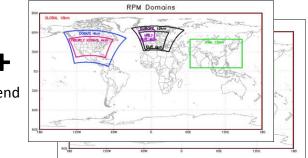
Consumer: WRF contributions to FoD

Spatial analysis of Radar Extrapolation: POP + precip rate Weighted average of subsequent runs spatially analyzed precipitation fields provides POP; latest run provides precip rate

Every 5 min

0-6 hr radar + time-lag WRF ens







Updated when new data arrives

0-15 day NWP optimal blend: WRF, NAM, GFS, EC.. Optimally weighted, dynamic blend of 162 Model members WRF contributes to blend, and is often the most highly weighted (0-72 hrs) for precipitation



