# IBM GRAF Update & Roadmap

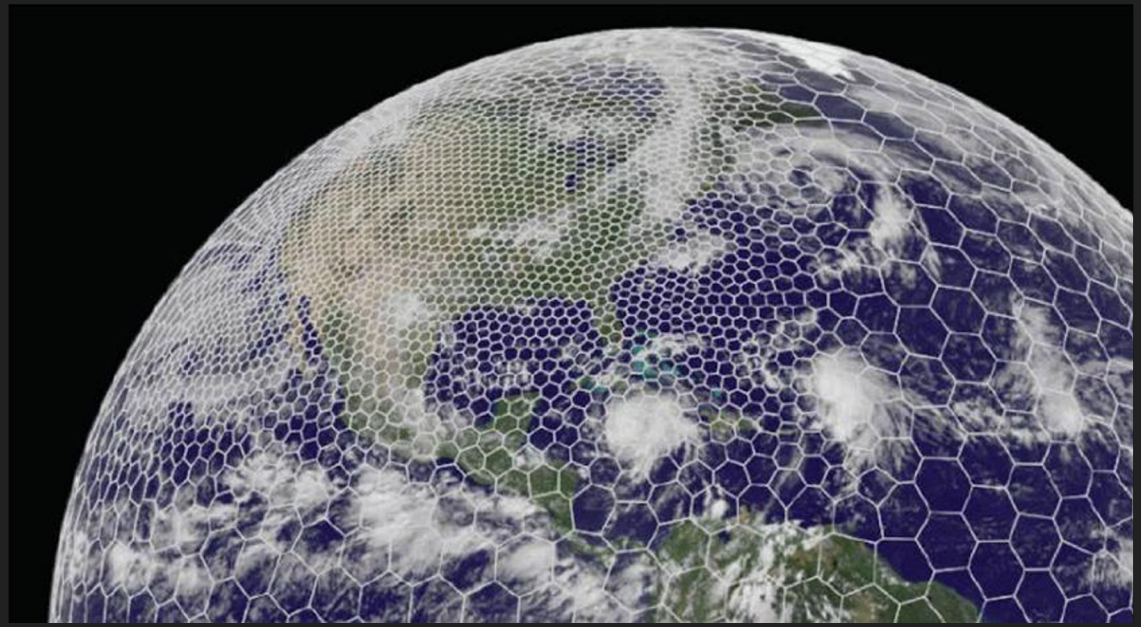
June 8, 2022


## IBM GRAF

**G**lobal High-**R**esolution **A**tmospheric **F**orecasting System


# IBM GRAF Team

**G**lobal High-**R**esolution **A**tmospheric **F**orecasting System



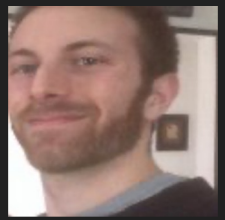
NWP / DA Scientist

?

Brett Wilt

John Wong

James Cipriani

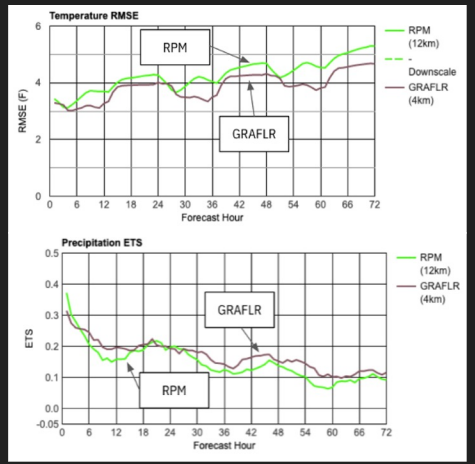


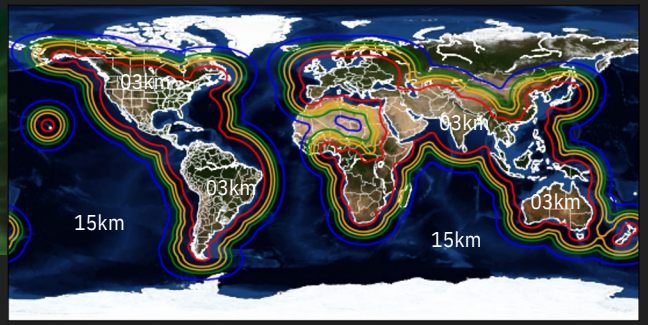
Joe Cahill

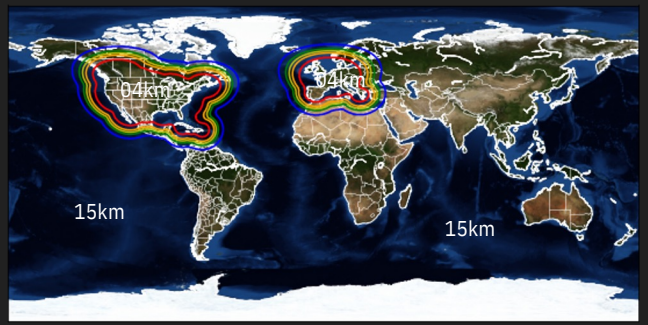
David Heeps

Will Sheridan*


- Completed GRAF-RPM Replacement 09/30/2021
  **"The World's First, Hourly-Updating, Convection Allowing, Global, GPU Weather Model"**
- GRAF-RPM replacement success was defined not only by technology and system implementation, but also superior verification metrics vs RPM





## GRAF (15/3 km)

- Updated 24x Daily
- 01-15h Forecast
- ECMWF Analysis (T-6)
- GSI Data Assimilation (surface only)
- U.S. Nexrad Radar Assimilation (cloud analysis)
- 5, 15, 60 min Forecast Streams
- 24.3 Million Cells
- 51 Atmospheric Levels, 4 Sub-surface Levels
- 30 sec Model Time Step → number_of_sub_steps = 4
- 51 IBM POWER9 AC922 V100 nVidia GPU Nodes (4x)

## GRAFLR (15/4 km)

- Updated 4x Daily
- 01-72h Forecast
- ECMWF Analysis (T-6)
- GSI Data Assimilation (surface only)
- U.S. Nexrad Radar Assimilation (cloud analysis)
- 5, 15, 30, 60 min Forecast Streams
- 4.8 Million Cells
- 51 Atmospheric Levels, 4 Sub-surface Levels
- 37.5 sec Model Time Step → number_of_sub_steps = 4
- 12 IBM POWER9 AC922 V100 nVidia GPU Nodes (4x)

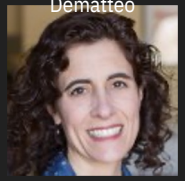
## MPAS (15 km)

- Updated 4x Daily
- 01-72h Forecast (144h internally for R&D)
- GFS Analysis (cold start → no data assimilation)
- 15, 60 min Forecast Streams
- 2.6 Million Cells
- 35 Atmospheric Levels, 4 Sub-surface Levels
- 90 sec Model Time Step
- CRAY ~ 25 CPU Nodes
- Short-Term FOD Backup
- Turbulence, Convective FPG


- How did we get overcome initial widespread GRAF complaints vs RPM ? We Listened !

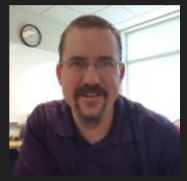
- GRAF Media Task Force → Bi-weekly GRAF feedback discussion with media clients, organized by:

Therese Dematteo



Bill Dow

Pat Feldhausen



- GRAF Feedback Form for media clients to submit feedback, complaints, case examples, etc.

- Result → Significant GRAF forecast skill and product improvements directly attributed to media clients who felt empowered to contribute

## GRAF Task Force Contributors

- Jonathan Belles – Weather Channel Digital
- Brian Alonzo – KAVU, Morgan Murphy, Victoria, TX
- JD Rudd – Charter, Milwaukee, WI
- Kaj O'Mara – KCRG, Gray, Cedar Rapids, IA
- Mark Nelsen – KPTV, Gray, Portland, OR
- Michael Behrens – KYTX, Tegna, Tyler, TX
- Patrick Bigbie – WDAM, Gray, Moselle, MS
- David Biggar - KNBC, Los Angeles, CA

- Many others contributions through GRAF Feedback Form

"We were wrong about GRAF"

"You've got a whole team of very happy weather geeks here in WI because the GRAF has been doing phenomenal!"

"We are loving the GRAF! We are hugging and kissing the GRAF! And so far it's been our great friend here in WI"

"I've had a number of GRAF cases now from previous meetings where it was REALLY good at the stratus layer. Spooky good actually."


## GRAF Improvement Examples

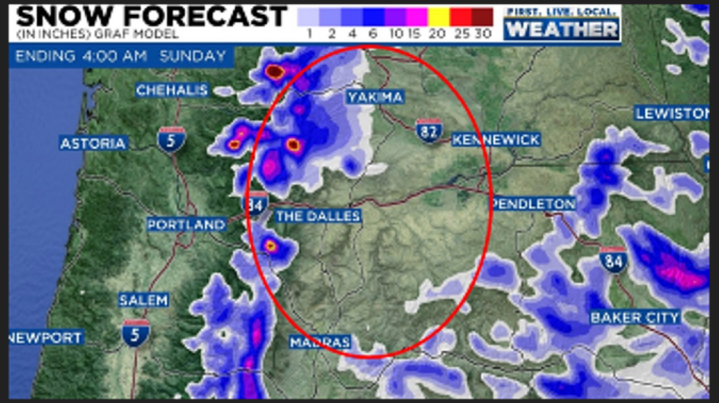
- Worked with Mark Nelsen regarding shallow cold air and snowfall across the Columbia River Basin – KPTV, Gray, Portland, OR (PBL Physics + Orographic Gravity Wave Drag changes)

twitter


FOX 12 OREGON
FOX 12 PLUS
meredith

12z 12/25/2020 GRAF (operational)


12z 12/24/2020 GRAF (operational)

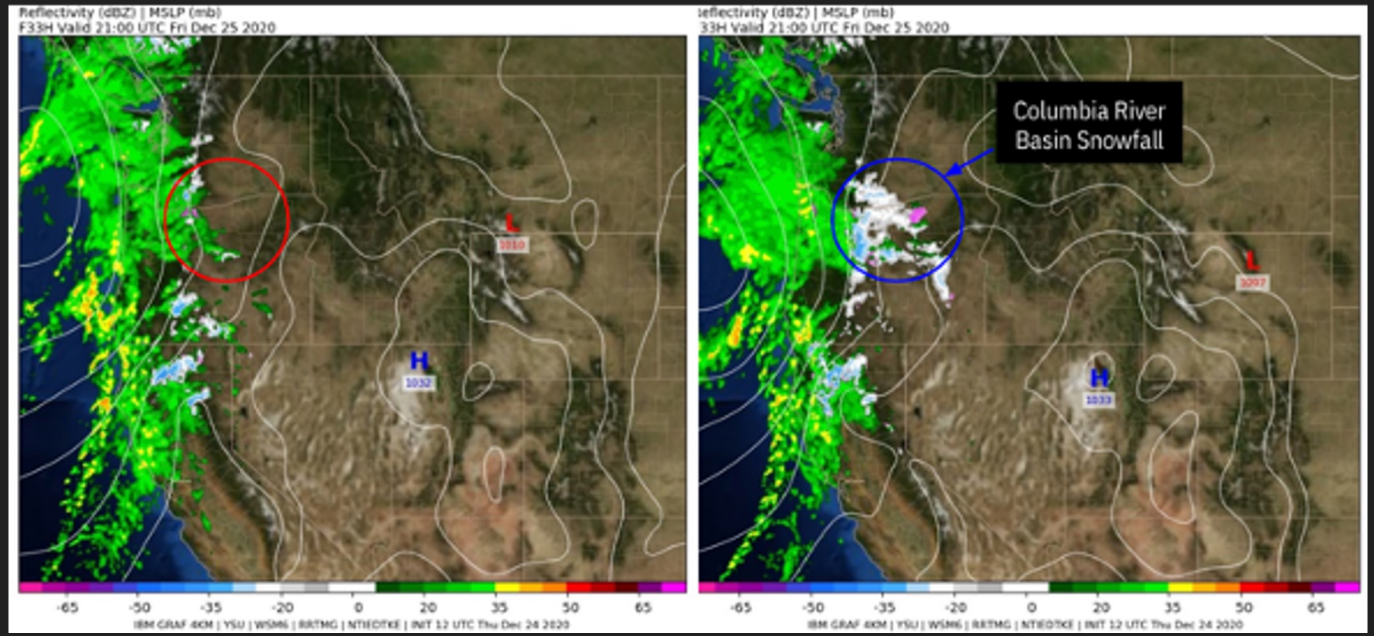



## GRAF Improvement Examples

- Worked with Mark Nelsen regarding shallow cold air and snowfall across the Columbia River Basin – KPTV, Gray, Portland, OR (PBL Physics + Orographic Gravity Wave Drag changes)

12z 12/24/2020 GRAF (operational)

12z 12/24/2020 GRAFX (GWDO + PBL)




## GRAF Improvement Examples

- Worked with David Biggar regarding GRAF wind gust forecasts across southern California – KNBC, Los Angeles, CA

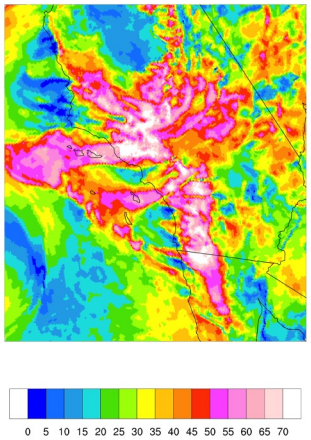
  (New Wind Gust Algorithms)

**Winds - January 19:**

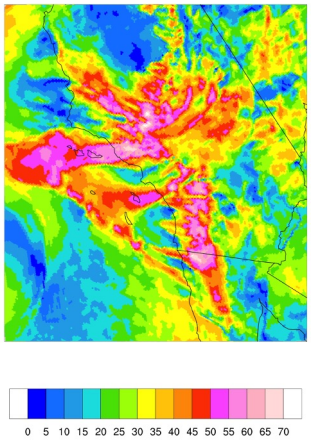
GRAF appears to do "okay" on sustained winds but seems to go overboard on wind gusts. We had a damaging wind event on January 19. NWS in its wind products and Red Flag Warnings were calling for gusts around 60-75mph at the upper end. RPM ended up nailing the gusts, or was slightly underdone in a few cities, but well within the range we were giving on air (50 – max 70). The image below shows the RPM on air.

I do not have a clip of the GRAF, but reviewing text messages about GRAF performance from that day it had gusts 20-30mph higher than observations. GRAF gave one site a 79mph gust, the nearest mesowest obs site had gusts 35-40mph.


GRAF (operational)




GRAF (update)




**5/26/21 - New Orleans**

Fog forecasting has not been good. It was poor during fog season (winter) and radiation events the past two days were way over done as well. I've also shown the contour forecast for rpm tomorrow morning the 27th which paints at least a potentially realistic view of what may happen--mainly inland away from lake and insignificant

RPM:

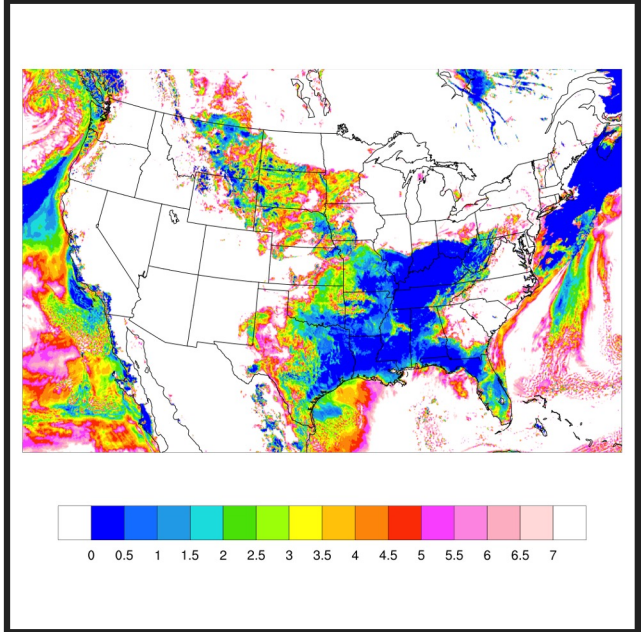

GRAF:


## GRAF Improvement Examples

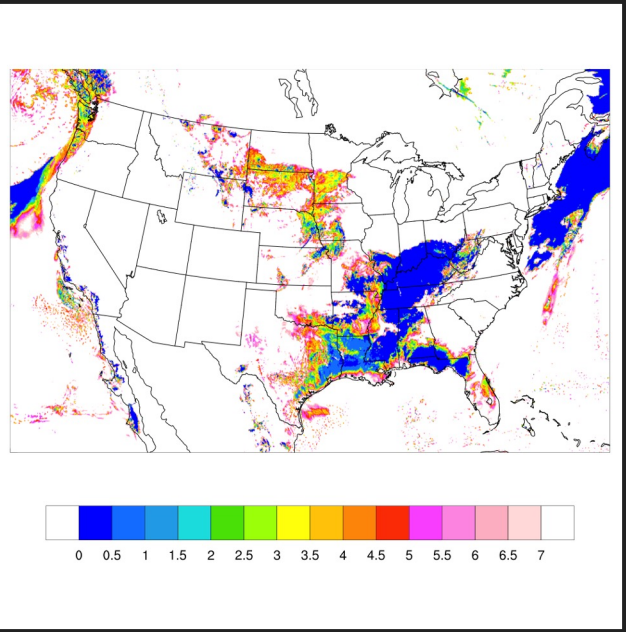
- Worked with David Benard regarding GRAF visibility forecasts across Louisiana – WVUE, New Orleans, LA

  (New Visibility Algorithms - Probability Curves)

GRAF (operational)




GRAF (update)

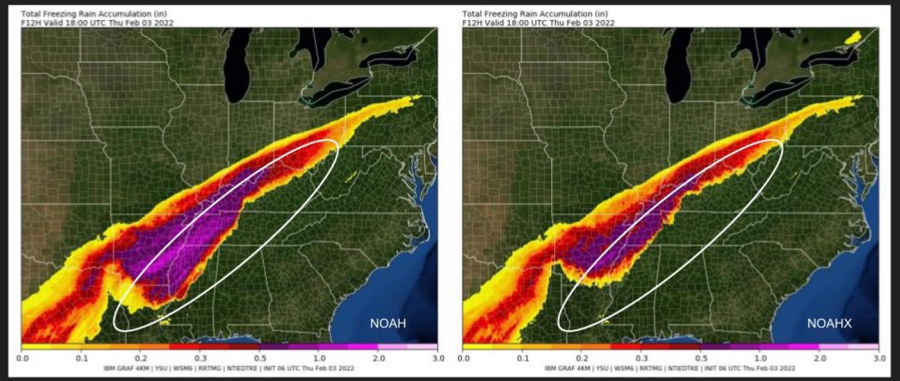



## GRAF Improvement Examples

- Worked with Patrick Bigbie regarding GRAF freezing rain forecasts across Mississippi – WDAM, Moselle, MS

  (Land Surface Model Changes, issue also exists with NCEP GFS)

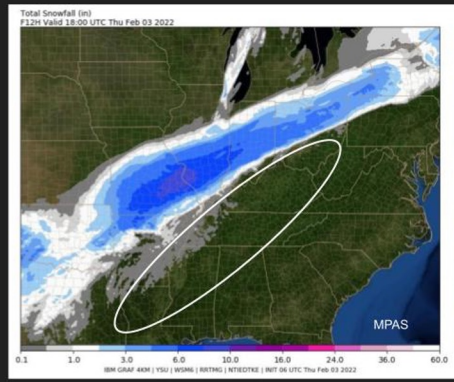
GRAF (operational)



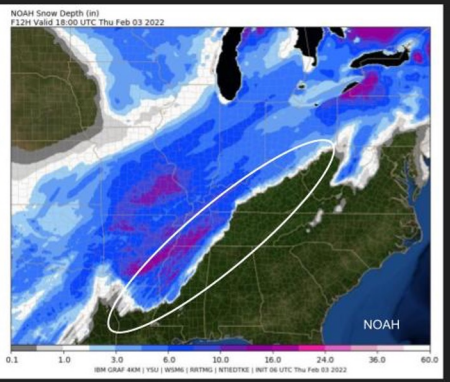

GRAF (update)




GRAF Snowfall




GRAF NOAH Snowfall

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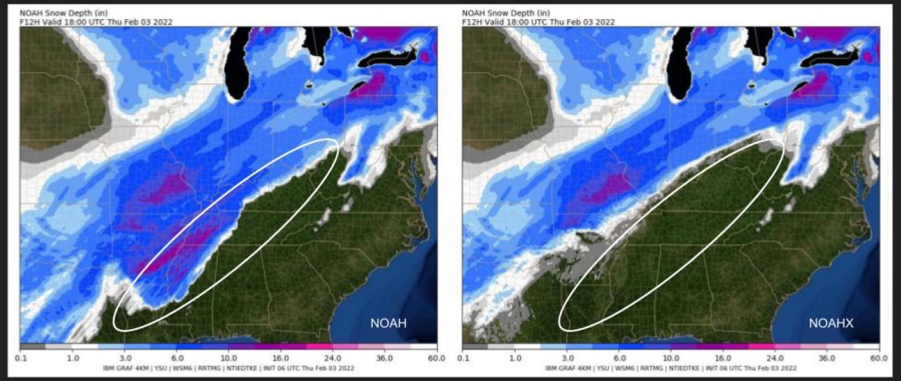
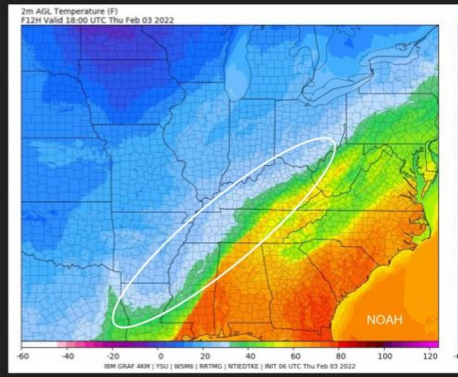


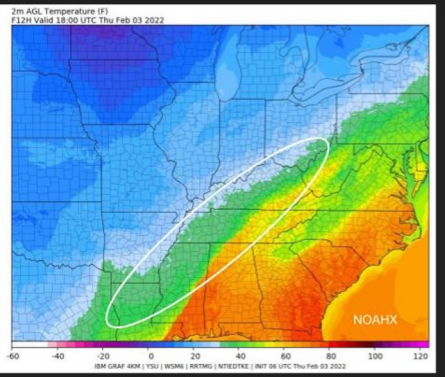

GRAF NOAH (update)




GRAF (operational)




GRAF (update)




## GRAF ProActive Engagement

- Take advantage of social media to engage media clients that may provide direct benefits to GRAF model development
- Provides GRAF educational opportunities for end users

**Dan Skoff** @weatherdan · 7h

Sorry for those developers of the **IBM GRAF** model.

It's trash with arctic air!!!!! It shows near 40s and 50s RIGHT NOW and temps are in the mid 20s in NWA!

That drives a lot of the weather apps' hourly forecasts. That's the reason their so off unless you adjust them.
#arwx


10 9 37

Show this thread

twitter

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**Daniel J. Tomaso** @DopplerDan · Jan 27

Replying to @DopplerDan and @JohnBanghoff

I should also add the model **we** internally **pay for**, the IBM **GRAF**, has been virtually unusable this winter.

> **Tyler Jankoski NBC5** @TylerJankoski · Jan 27
>
> Finally seeing the "TV model" — the IBM GRAF — come into line with our forecast.


# 2021-22 GRAF Updates

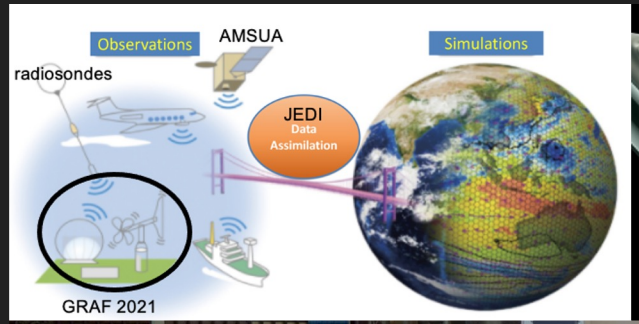

| | |
|---|---|
| → **RRTMG Cloud water effective radius:** | ECMWF: Martin et al.(1994), Wood (2000) + Aerosol assumptions Lowenthal et al. (2004), Boucher and Lohmann (1995)<br>4 - 30 microns |
| → **RRTMG Cloud ice effective radius:** | ECMWF: Sun/Rikus (1999), Sun (2001)<br>12 - 100 microns |
| → **Thompson Cloud Fraction:** | Significant MPAS bug fix regarding scale aware Dx units<br>psuedo cloud contribution to qc, qi updates requires model diagnosed layer (2 points)<br>limit qc, qi update |
| → **WSM6 Microphysics:** | Tuned autoconversion threshold to reduce false alarm precipitation<br>Reduced evaporation rate for sub-saturated layers<br>Improves convective cold pool, gust fronts, and overall convection placement<br>Increases light/moderate precipitation coverage near convection |
| → **YSU PBL:** | Modifications to asymptotic length scale above PBL |
| → **nTiedtke Scale-Aware Convection:** | Reduced shallow cumulus scale aware entrainment rate<br>Reduced cloud to precipitation scale aware conversion rate<br>Restricted shallow cumulus cloud to precipitation conversion<br>Reduces convective feedback issues |
| → **NOAH Land Surface:** | Freezing rain vs snow accumulation changes<br>2m Temperature improvements over deep snow cover<br>Fractional snow melt |
| → **Diagnostics:** | Numerous product updates (wind gust, visibility, freezing rain, etc) |

# GRAF-JEDI Data Assimilation


Prioritize Business Impacts

Improve GRAF
Precipitation Skill

Standard Data Assimilation Sources



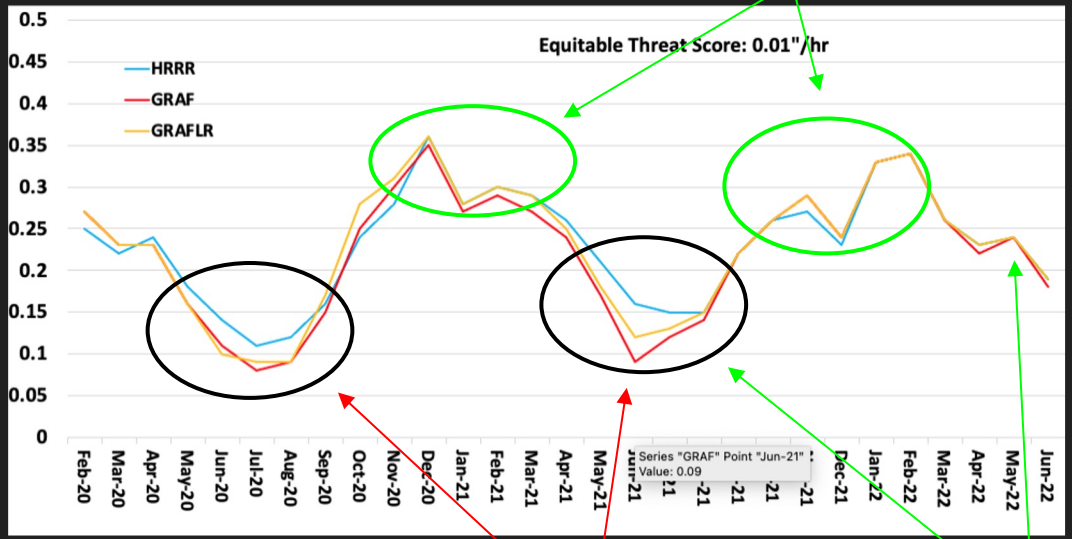

Unique & Proprietary Data Sources



# Why GRAF-JEDI Data Assimilation ?

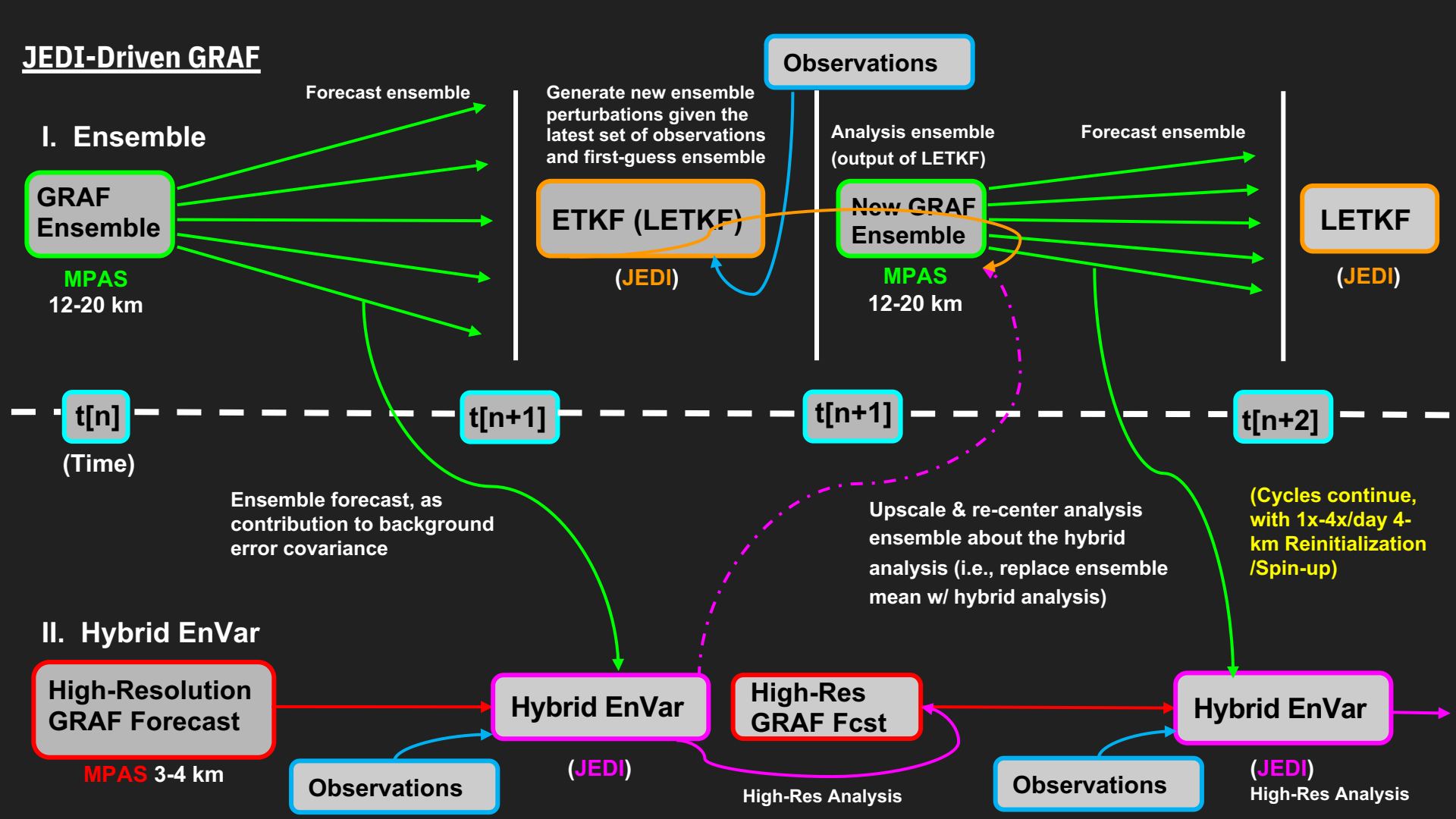
- Convective season decreases time scale of atmospheric changes, increases precipitation forecast uncertainty
- GRAF currently at a 6-hour disadvantage to a fully-updated atmospheric column from data assimilation (surface observations only)

GRAF similar to NCEP HRRR during non-convective season (stratiform precipitation)

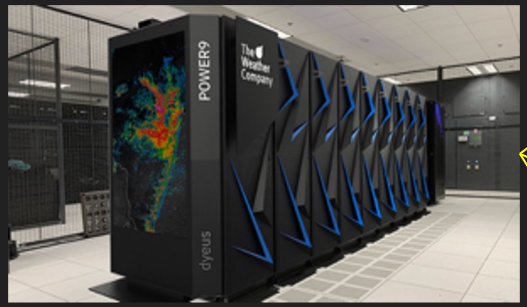



GRAF precipitation skill drops significantly vs NCEP HRRR during the convective season, primarily due to lack of a robust data assimilation system

Year over year nTiedtke, WSM6, YSU positive impacts so far


JEDI-Driven GRAF
I. Ensemble
Forecast ensemble
GRAF Ensemble
MPAS 12-20 km
Observations
Generate new ensemble perturbations given the latest set of observations and first-guess ensemble
ETKF (LETKF)
(JEDI)
Analysis ensemble (output of LETKF)
New GRAF Ensemble
MPAS 12-20 km
Forecast ensemble
LETKF
(JEDI)
t[n]
(Time)
t[n+1]
t[n+1]
t[n+2]
Ensemble forecast, as contribution to background error covariance
Upscale & re-center analysis ensemble about the hybrid analysis (i.e., replace ensemble mean w/ hybrid analysis)
(Cycles continue, with 1x-4x/day 4-km Reinitialization /Spin-up)
II. Hybrid EnVar
High-Resolution GRAF Forecast
MPAS 3-4 km
Observations
Hybrid EnVar
(JEDI)
High-Res GRAF Fcst
High-Res Analysis
Observations
Hybrid EnVar
(JEDI)
High-Res Analysis


# Preliminary GRAF Expansion Plans (Q4 2022 - Q1 2023)

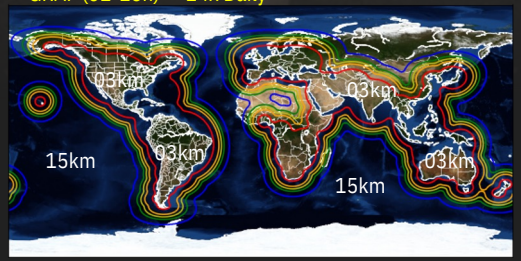




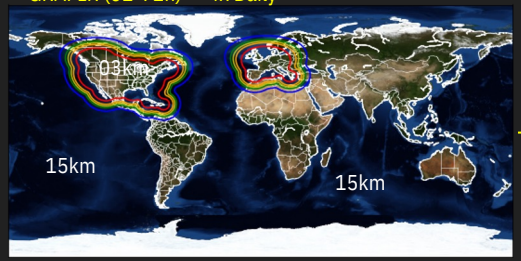
Triple GRAF compute capacity !

| | |
|---|---|
| Total Nodes Available: | 81 GPU Nodes |
| GRAF: | 51 GPU Nodes |
| GRAF DA: | 12 GPU Nodes |
| GRAFLR: | 12 GPU Nodes |
| Research: | 15 GPU Nodes |

GRAF (01-15h) → 24x Daily

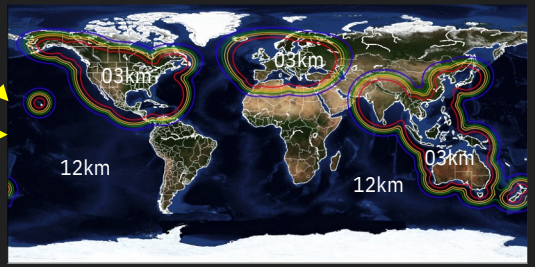



GRAFLR (01-72h) → 4x Daily




## Unified GRAF (12/3 km)

- **Updated 24x Daily, 01-72h Forecast**
- **JEDI Data Assimilation (Hybrid EnVar)**




| | |
|---|---|
| Total Nodes Available: | 236 GPU Nodes |
| GRAF: | 180 GPU Nodes |
| GRAF DA: | 30 GPU Nodes |
| Research: | 26 GPU Nodes |

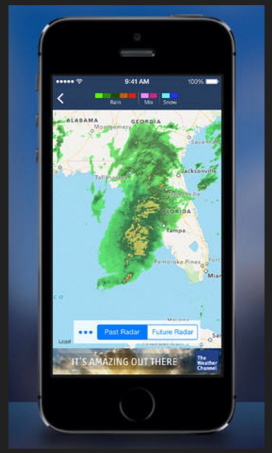
# Goals


GRAF Max Clients

- New Cloud Product
- SevereWx Products
- Snow Depth Animations
- GRAF Point Data Queries ?

# Expand GRAF Business Opportunities

## B2C





## B2B