Modeling and Data Assimilation for UFS Applications

JPSS/GOES-R Proving Ground Risk Reduction Summit, 24 February 2020

Vijay Tallapragada
NOAA/NWS/NCEP/EMC
Conceptual UFS applications in production covering all NPS applications.

Components of UFS are configured to develop distinct applications while maintaining the dependencies between the applications and products.
### Timelines for transitioning NPS to UFS Applications (planned)

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**WCOSS Moratorium**

- **HAFsv1**
- **HAFsv2**
- **HAFsv3**
- **HAFsv4**
- **HAFsv5**
- **HAFsv6**
- **HAFsv7**
- **HAFsv8**
- **HAFsv9**
- **HAFsv10**

**UFS Application**

- **UFS Medium Range & Sub-Seasonal**
- **UFS Marine & Cryosphere**
- **UFS Seasonal**
- **UFS Hurricane**
- **UFS Short-Range Regional HiRes CAM & Regional Air Quality**
- **UFS Air Quality & Dispersion**
- **UFS Coastal**
- **UFS Lakes**
- **UFS Hydrology**
- **UFS Space Weather**
Recent and Planned Upgrades to the GFS

- **GFSv15.1 (June 2019)**
  - Initial implementation of FV3-based GFS
  - Increase analysis increment & ensemble resolution
  - No DFI

- **GFSv15.2 (November 2019)**
  - Observation changes: GOES-17 AMVs, KOMPSAT-5 GPS, METOP-C AMSU-A and MHS
  - NSST Updates

- **GFSv15.3 (TBD)**
  - Observation changes: COSMIC-2, METOP-C GRAS and IASI

- **GFSv16 (Early 2021)**
  - GSI-based Hybrid 4DEnVar
  - **127 Layers, ~80km model top**
  - Updated physics
  - Modulated-ensemble LETKF (model space localization)
  - 4D-IAU
  - Correlated observation errors
  - VarQC re-design
  - LDAS
GFSv16 Data Assimilation Upgrades

- The GFSv16 will move from 64 layers to 127 layers, raising the model top from 55 km to 80 km.
- 4D Incremental Analysis Update (IAU)
- Replace EnSRF with LETKF (including model space localization and linearized obs operator)
- Intra-channel correlated observation errors for radiances
- Additional channels (AMSU-A ch14 and ATMS ch15, clear-sky radiances from Meteosat 8 (SEVIRI), Himawari 8 (AHI), GOES-16 ABI)
- Variational Quality Control update
- New observations
- “GLDAS”
- Reduced humidity increments in stratosphere
- Improved NSST
## Data Assimilation for Hurricane Models

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UFS: Simplification of Regional Model Production Suite

Long Term

Global  
(10-15 km, 4-24/day)

GFS ➔ GEFS

CONUS/OCONUS  
CAM (3 km, 2-24/day)

Rapid Refresh 
Forecast System

RRFS

Sub-CONUS  
CRM (1 km, on-demand)

Warn on Forecast System

WoFS

GFS/GEFS to subsume 
RAP/NAM/SREF

RRFS to subsume 
HRRR/NAMnest/HREF

What is the 
RRFS and how 
do we get there?

*Material courtesy of C. Alexander
Ongoing Radiance DA Development

- **Hourly** assimilation of radiances
  - Same data as GFS
- Using radiance data through Regional ATOVS Retransmission Service (RARS) to reduce the data latency
- Bias corrections for all satellite instruments are estimated within the regional system

60 hr 3 km forecast

- Coldstart from GFS
- 6 hour forecast at 3 km
- Hourly hybrid 3D-EnVar assimilation
  - Using global EnKF members

*Material courtesy of X. Zhang*
Satellite Data Assimilation at the GMAO

Will McCarty
Global Modeling and Assimilation Office
NASA Goddard Space Flight Center

24 February 2020
JPSS/GOES-R Proving Ground Risk Reduction Summit
Introduction

GMAO’s core mission is to enhance the value of NASA’s observations to understand, analyze and predict changes in the physics, chemistry and biology of the Earth system.

We do this:
- Historically: Reanalysis
- Currently: Forward Processing; S2S
- Future: Targeted research, e.g. OSSEs as a decision support tool

Our goal is to collapse the earth system components to a common modeling and assimilation infrastructure
- Fundamental to this goal is the capability of analyzing the four dimensional atmospheric state
Current State of Radiance Assimilation

Forward processing developments
– ‘New observations’ – and system developments – are considered ‘updates’
– Ultimately constrained by near-real-time availability

Advances in the observing system are apparent through FSOI metric
– Observing System resilience
– Notable differences:
  • Geostationary Atmospheric Motion Vectors (AMVs) & IASI jump w/ advances in observing systems
  • MHS with change in metric
– AMSU-A & RAOB still the most important observing systems by this metric
– This plot predates NOAA-20
Applying Current Methods to Historical Observations

Much of our FP development is aimed at transition to reanalysis

- FP advancements are performed with reanalysis in mind
  - New data not only feeds FP, but also adds to the retrospective observation baseline
  - The FP starting point is implicitly the beginning of baseline
  - Evaluate feasibility of backfilling observation to include entire data record

- Reanalysis systems do not have a NRT constraint
  - Provides additional motivation to consider observations beyond the scope of operational systems

- The hyperspectral IR still accounts for the largest single type of data
  - Only to increase w/ MTG-S IRS; IASI-NG; NOAA-21, etc.
The Future of Radiance Assimilation

The GMAO has a full Global OSSE capability, which can serve as a tool (in a toolbox of tools) to investigate future observing system architectures

– Recent assessment of a constellation of MTG-S IRS-like instruments showed that the GEOS would be consistent w/ other infrared sounding instruments
– Also validated the ‘tracer effect’ via improved temporal resolution as large impacts were seen in wind metrics

OSSEs however are limited
– Today’s approaches
– Today’s observations
– Simulated data too perfect
– Errors difficult to model
Outstanding Questions

Radiance Assimilation is hard
- JEDI hopefully leads towards better cross-agency and extra-agency collaboration

What is the future of all-sky assimilation?
- Many results illustrate the utility of the 183 GHz water vapor measurements that are affected by ice
- What about 118 GHz temperature?
- What role will observations > 200 GHz play? (e.g. Metop-SG ICI)
- All-sky in the IR/Vis?

Spatial/Spectral/Temporal Resolution in the infrared
- How much spectral information is too much spectral information?
- Spatial thinning/hole hunting/etc.?
- Chemistry radiance assimilation in the future?

Other questions
- Station keeping/the early-AM orbits
- The role of small satellites in the future
NESDIS Support to NWP Radiance Assimilation

Kevin Garrett
NOAA/NESDIS Center for Satellite Applications and Research

JPSS/GOES-R Proving Ground/Risk Reduction Summit, February 24-28, 2020, College Park, Maryland
NESDIS Development Supporting NWP

- Radiance product development, TDR/SDR, applied in:
  - Direct assimilation
- Level 2 product development, EDR, applied in:
  - Direct assimilation (e.g. AMV, AOD)
  - Quality control
  - Boundary conditions
- BUFR toolkit development
- Forward operator development
- Data assimilation satellite data integration
  - New sensors, optimization, next generation architecture studies
  - External funding (CIs, JCSDA)

STAR Product Catalog
https://www.star.nesdis.noaa.gov/portfolio/productCatalog.php
### JPSS/GOES-R data exploitation in NOAA NWP

#### Assimilation status in NOAA Data Assimilation/NWP

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#### Optimization level
- **Operational**
- **Non-operational**
- **Input n/a**
CRTM development: all-sky/all-surface DA

Need more advanced forward modeling of satellite radiances:

• Under cloudy/scattering conditions
  • Spectrally consistent optical properties
  • Vectorized RT
  • Evolving model (prior) states, CAM DA

• Under aerosol conditions
  • Global/regional forecast models coupled with chemistry models (e.g. CMAQ)

• Where atmosphere is not opaque
  • More accurate surface handling, land/ocean/cryosphere, L-band to UV
  • Coupled land-atmosphere, sea-ice/ocean-atmosphere assimilation
Satellite radiance assimilation development

- Emphasis on maximizing observation impacts on NWP analysis and forecast
- Gaps highlight the unmet needs for NWP users
- Establish priorities based on potential impact and value
- Need to work closely with partners on all aspects of DA value chain - data delivery, QC, operators, integration

Land Sensitive Radiance Assimilation
- Implementation of emissivity control variable, updated QC, new emissivity background:
  - Plot: 5-10x more (red) ATMS land obs assimilated per GDAS cycle

Hyperspectral Shortwave IR Assimilation
- Summary Assessment Metric Verified vs ECMWF
- New Techniques to Maximize Satellite Impacts
  - Implement new QC, observation errors for SWIR
  - Assess/improve CRTM in SW reg.
  - Run impact experiments and compare to LW
  - Transition to Operations

CRTM-AI vs MonoRTM
- Explore new AI/ML techniques to overcoming current challenges in radiance assimilation
  - Thinning, QC, forward operators (all-sky), post-forecast correction
Satellite radiance assimilation for rapidly updating regional and global models

**Hourly RAP / HRRR radiance assimilation**
- AMSU-A (RARS)
- MHS (RARS)
- IASI (DB, RARS)
- ATMS (DB, RARS)
- CrIS (FSR*) (DB, RARS)
- GOES-16 ABI Radiance data*
- AIRS, SSMIS, GOES-15 sounder → HRRR-AK radiance DA*

* = in RAPv5, HRRRv4

**DB = Direct Broadcast**
**RARS = Regional ATOVs Retransmission Service**

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See [Amanda Back](#) presentation in next panel discussion for summary of RAP/HRRR satellite product assimilation
Challenges and questions

- Will the data be **operationally available** at **low enough latency** for rapidly updating? (direct broadcast critical for hourly updating)
- Can we improve on the **bias correction** for regional models?
- What degree of **channel selection** is needed for regional models compared to global models (because of the lower model top)?
Satellite radiance assimilation for rapidly updating regional and global models

Challenges and questions

- Quantifying regional radiance assimilation impact for data rich and data poor regions? (use of satellite radiance-based verification approaches?)
- Application for storm-scale models (inclusion in 3-km HRRR-AK for 2020, and RRFS - Rapid Refresh Forecast System - in 2023)
- Timing for introduction of enhancements (all-sky radiance, evolution to JEDI)
Satellite radiance assimilation for rapidly updating regional and global models

**Science / Technical Issues**
- All sky radiances
- Transition to JEDI
- Quality control issues
- CRTM enhancements
- Correlated observation errors
- Regional bias correction issues

**Coordination / Communication**
- Further streamlining of data processing and formatting for operational DA
- Coordination of code development for current and new sensors within JEDI

**Global Rapid Refresh Models**
- Work toward global hourly updating
- Data availability / latency issues
- Better integration of radiance and product assimilation

**Evolving / future needs for satellite radiance DA**

**Monitoring / Assessment**
- Further streamlining of sensor/channel monitoring
- Increased FSOI evaluation
- Further application of novel radiance data verification techniques
Use of Radiances in Global Data Assimilation at NOAA/NCEP

Andrew Collard
IMSG@NOAA/NCEP/EMC
Radiance Data Used in the NCEP Global Model

**Microwave:**
AMSU-A: NOAA-15, 18, 19, MetOp-A/B/C, Aqua
ATMS: S-NPP, NOAA-20
MHS: NOAA-18, 19, MetOp-A/B/C
SSMIS: DMSP-F17
Saphir: Megha-Tropiques

**Infrared:**
AIRS: Aqua
IASI: MetOp-A/B
CrIS: S-NPP, NOAA-20
SEVIRI: Meteosat-11 (Meteosat-8, Himawari-9 and GOES-16/17 infrared imagers coming soon!)
AVHRR: MetOp-A, NOAA-18

RED=All Sky Over Sea
Recent and Upcoming Changes to the Global Data Assimilation System.

12th June 2019 Global Model Upgrade
- Forecast model is now based around the Finite-Volume Cubed-Sphere dynamical core.
- All-sky radiance assimilation for ATMS
- Add moisture sensitive channels for IASI and CrIS.
- Implement channels 5 and 6 for SEVIRI on Meteosat-11.
- Assimilate radiances from Saphir on Megha-Tropiques.
- OMPS Nadir Sounder assimilated
- Metop-B ASCAT winds assimilated.
- NOAA-20 CrIS, AMSU-A and MHS radiances as well as GOES-16 AMVs included prior to this upgrade
- Improvements to the use of climatology in Near Sea-Surface temperature analysis.

January 2021 Global Model Package (GFS v16)
- Upgrade is primarily to increase the number of model levels from 64 to 127.
- Introduction of correlated observation errors for IASI and CrIS
- Use of water vapor channels for Meteosat-8, Himawari-9 and GOES-16 infrared imagers.
- Inclusion of sub-gridscale cloud and cloud fraction for microwave all-sky radiances.
- Assimilation of AMSU-A Ch 14 and ATMS Ch. 15
- NOAA-20 VIIRS winds and more aggressive use of ASCAT winds
- Increased use of aircraft data including LATAM and TAMDAR
- 4D-Incremental Analysis Update and replace EnSRF with LETKF

November 2019 Data Upgrade
- Assimilate radiance from MetOp-C AMSU-A and MHS
- Assimilate GOES-17 AMVs
- Assimilate KOMPSAT-5 GPSRO and prepare to monitor COSMIC-2

Future Work
- All-sky infrared assimilation
- Extension of all-sky assimilation to precipitating conditions.
- Microwave all-sky assimilation over land surfaces.
- Getting ready for MTG-IRS.
- JEDI
Important Areas of Development in Next Decade

• Expansion of all-sky assimilation to:
  – All surfaces (coupled DA)
  – Other frequencies (Infrared, maybe visible?)

• Increased use of high-temporal frequency observations
  – Wind increments through tracing effect in DA
Challenges and Opportunities on the Data Side

- Retention of high-value measurements:
  - Threat to microwave frequencies through RFI
  - Retention of the 15μm band for infrared sounders
  - Co-located imagers

- Optimal use of high-volume datasets
  - MTG-IRS

- GPSRO and Doppler Winds
  - Not radiance data – but likely to be increasingly significant.