Use of Radio Occultation (RO) data in NOAA/NWS for environmental modeling: Current status and future challenges

NATIONAL WEATHER SERVICE

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Outline

- COSMIC-2 Implementation and assessment at JCSDA + NCEP
- NOAA commericial RO delivery order #1: preliminary results for GFS
- Future challenges

COSMIC-2 NWP assessment and implementation at JCSDA/NCEP

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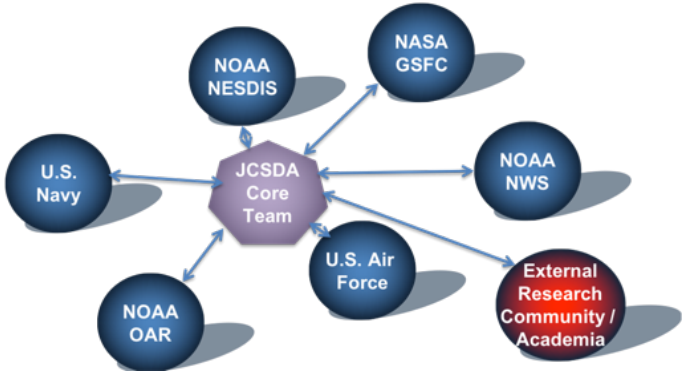
Acknowledgement to UCAR/COSMIC, NESDIS and other COSMIC-2 Cal/Val partners

5th International Conference on GPS Radio Occultation
October 21~23, 2020
Hsinchu, Taiwan (Virtual)

NCEP – JCSDA partnership

The Joint Center for Satellite Data Assimilation (JCSDA)

Accelerate and improve the quantitative use of research and operational satellite data in weather, ocean, climate and environmental analysis and prediction systems.



National Centers for Environmental Prediction (NCEP)

Deliver national and global operational weather, water and climate products and services essential to protecting life, property and economic well-being.

GNSS-RO: Missions and Status at NCEP

Missions	RT availability	Operation Status	Coverage	Counts/day
COSMIC (US/Taiwan)	GTS, real-time dump	Decommissioned	Global	0
METOP-A/B (EUMETSAT)	GTS, real-time dump	In operations (only above 8km)	Global	~1200
TerraSar-X (Germany)	GTS, real-time dump	In operations	Global	~200
TANDEM-X (Germany)	GTS, real-time dump	In operations	Global	~100
KOMPSAT-5 (Korea)	GTS, real-time dump	In operations	Global	~200
COSMIC2 (US/Taiwan)	GTS, real-time dump	In operations	45S-45N (mostly 35S-35N)	~5000
METOP-C (EUMETSAT)	GFS, real-time dump	Retrospective test completed; in parallel assimilation mode	Global	~600
Commercial data	2021?	CWDP data tested. DA capability (with default config.) included in GFS v16 code	Global	TBD
PAZ (SPAIN)	GTS, real-time dump	Retrospective test completed	Global	~150
Megha-Tropiques (INDIA)	GTS (missing since March 2020)	Retrospective test completed	Global	~170->0
Sentinal-6		Scheduled launch in Nov, 2021	Global	

COSMIC-2, launched on June 25, 2019, has become the primary data resource for GPSRO in the tropical and mid-latitude areas

COSMIC-2: Efforts and Milestones

- Early data quality was evaluated throughout the cal/val period

→ Data provisional release on Dec 10, 2019

- Starting in Nov 2019, numerical experiments were performed for updated configurations: (each group includes multiple experiments for finer tuning and tests)
  - Control
  - Control + C2 using default obs. error and QC
  - Control + C2 using default EUMETSAT obs. error and QC (C2 changed its BUFR data vertical distribution to match with other EUMETSAT RO data)
  - Control + C2 with obs error estimated using the method based on Kuo, 2004
  - Control + C2 with turned obs error using the method based on Desroziers, et al., 2005
  - Control + C2 + different gross error threshold (below 5km only, whole profiles)

→ COSMIC-2 public (near real-time) release on March 6, 2020

GTS release on March 16, 2020

- Performed final tuning for COSMIC-2 with inputs from other collaborators (e.g. AOML)

→ NCEP operational implementation (v15.3) on May 26, 2020

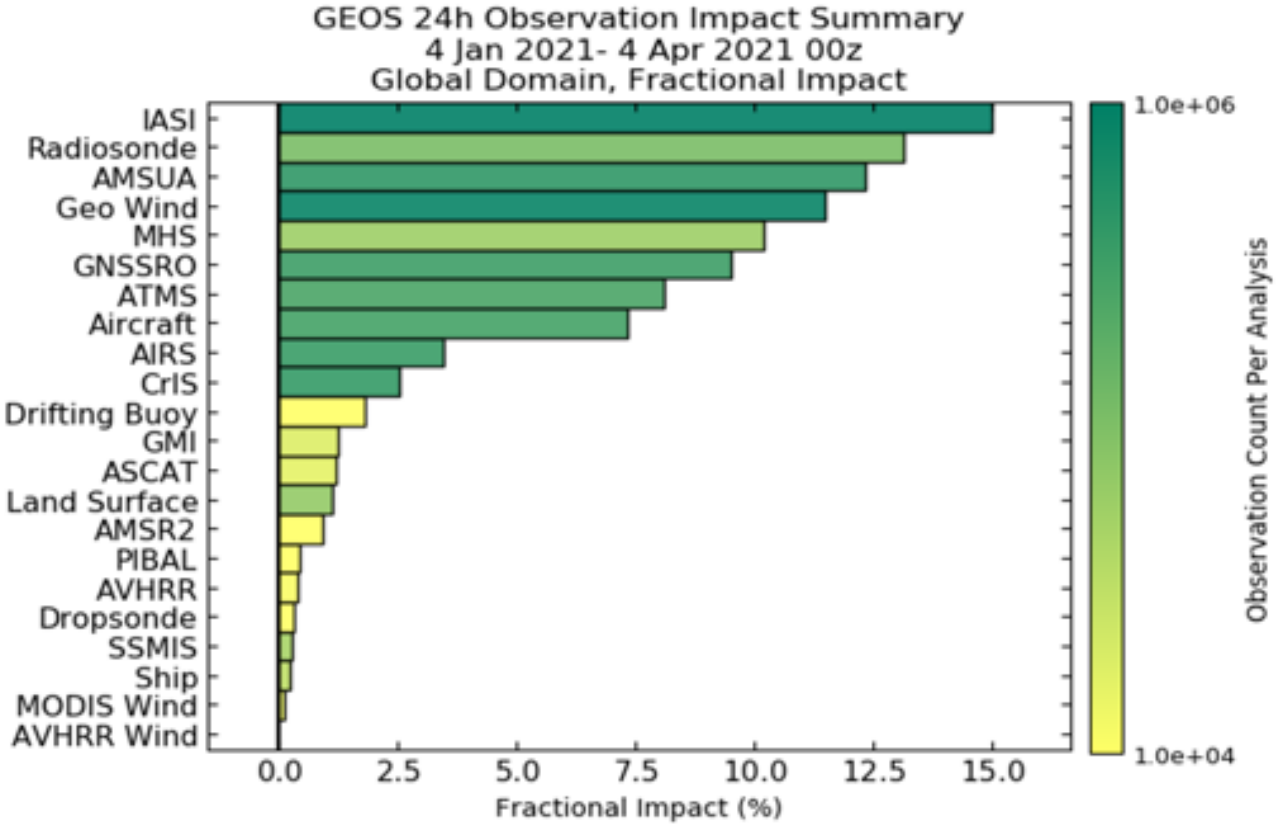
- Continues to work with data processing centers to evaluate processing changes and provide recommendation on their implementation. These changes will/will not affect data quality distributed to the operational/research community

→ Data processing update

- Continue to improve and advance GNSSRO forward operators and prepare for next operational implementation at NCEP

→ Code changes and tests for JEDI and next global system update (GFS v16) at NCEP

Overall GNSS-RO: Forecast Impacts



Results from NASA GEOS-5, which uses same FV3 dynamic core as NOAA GFS

Courtesy of NASA GMAO

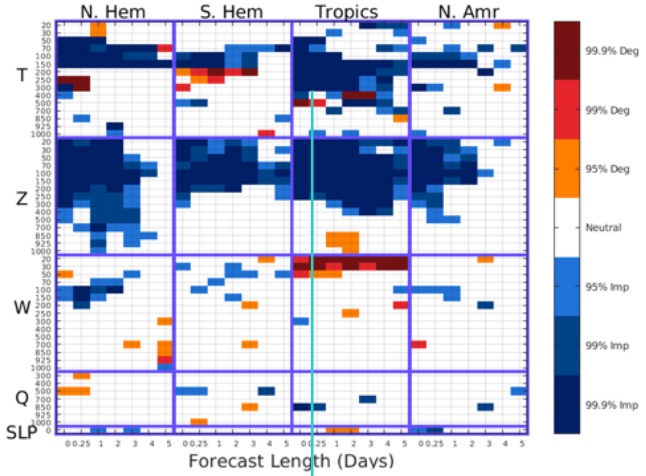
https://gmao.gsfc.nasa.gov/forecasts/systems/fp/obs_impact/

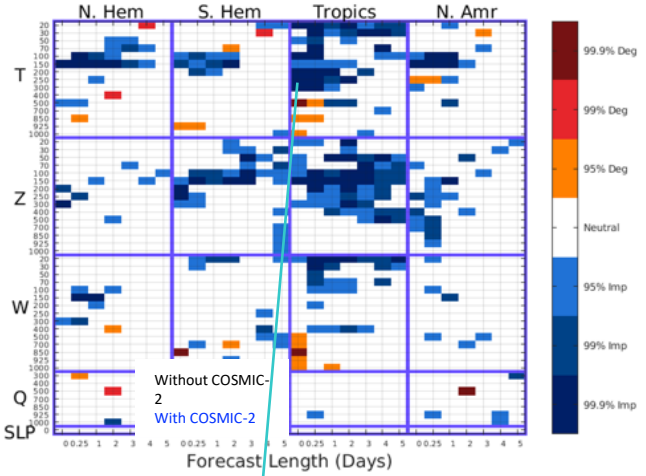
COSMIC-2: Forecast Impacts

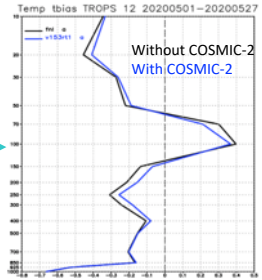
Forecast Impacts

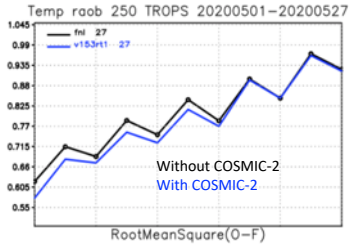
Blue indicates COSMIC-2 reduced forecast errors

Red indicates COSMIC-2 degraded forecast errors



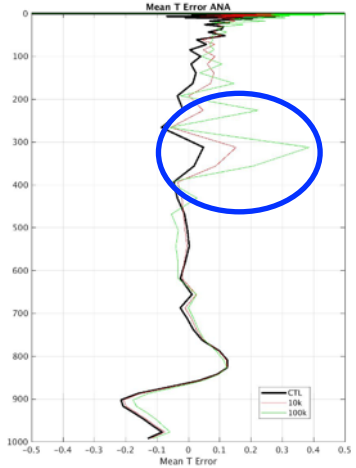


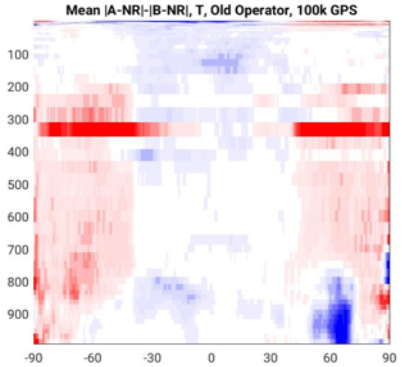


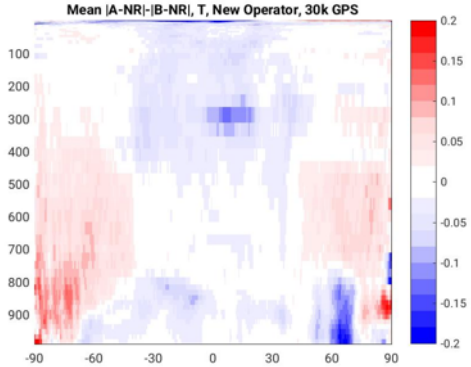


Using results up to May 18, 2020

COSMIC-2: OSSE Results and related DA code changes







Old (default)

New

- A negative spike in bending angle (O-B) caused a positive temperature increment at this level, leading to an anomalously hot layer, during an OSSE study
- The more GPSRO are used, the larger the magnitude of the positive temperature increment and ensuing (bad) hot layer in the analysis
- Code changes were made related to the interpolation from model space to observation space
- 300-400hpa biases are removed due to the code changes
- Biases in lower mid-polar areas may need a separate investigation

(Collaborated with NASA/GMAO)

GNSS-RO Summary and Plans

- COSMIC-2 operational implementation
- GDAS V16 release (implemented March 2021)
- Improving the use of COSMIC-2 and other GNSSRO data in operational system
- Evaluation for NOAA commercial RO data purchase
  - ***See next section for eval of NOAA Delivery Order 1***
- GDAS V16.1 for commercial RO
  - *To be implemented later in 2021*
- *Advanced forward operator study (JEDI)*

Completed
In progress

Major Upgrades to GDAS with GFS v16

- **Local Ensemble Kalman Filter (LETKF)** with model space localization and linearized observation operator to replace the Ensemble Square Root Filter (EnSRF)
- **4-Dimensional Incremental Analysis Update (4D-IAU)**
- **Turn on SKEB** in EnKF forecasts
- **New variational QC**
- Apply Hilbert curve to aircraft data
- **Correlated observation error** for CrIS over sea surfaces and IASI over sea and land
- Update temperature aircraft bias correction with safeguard
- Reduce the distance threshold for inner core dropsonde data to 55km (from 111km or 3*RMW) and add a wind threshold of 32 m/s to **allow more dropsonde data being assimilated**
- **Use CRTM v2.3.0**
- **Assimilate additional GPSRO** (add Metop-C GRAS, more COSMIC-2)
- **Assimilate CSR data from ABI_G16, AHI_Himawari8, and SEVIRI_M08; AVHRR** from NOAA-19 and Metop-B for NSST
- **Assimilate** high-density flight-level wind, temperature, and moisture observations **(HDOBS) in tropical storm environment (first time in operations for GFS)**
- Assimilate AMSU-A channel 14 and ATMS channel 15 w/o bias correction

Preliminary Results from Delivery Order 1 (DO-1) Commercial GNSSRO Purchase in the Global Forecast System (GFS)

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NATIONAL WEATHER SERVICE

March 24, 2021 | OFCM Working Group on Interagency Coordination on Commercial Weather Data

Delivery Order 1 (DO-1)

- NOAA's first contracts to purchase commercial space-based radio occultation data were awarded to GeoOptics and Spire Global in November 2020.
- 500 occultations per day for 30 days
  - ~December 15, 2020 - January 15, 2021
- Goals:
  - Test the data flow and reliability
  - Verify data quality
  - Preliminary impact assessment in the Global Forecast System (GFS)
  - Inform configuration for DO-2 testing (including GFS v16.1 implementation)

Preliminary Testing with the GFS

- Testing was performed in a lower resolution framework
  - 25 km/50 km deterministic/ensemble
  - Operations: 13 km/25 km
- Based on the GFSv16 configuration
  - 127 layers
  - Implemented on March 22, 2021
  - Assimilate GNSSRO up to 55 km
- All tests assimilate Spire and GeoOptics together
  - The commercial RO observations are treated as other operationally assimilated RO observations unless otherwise noted.

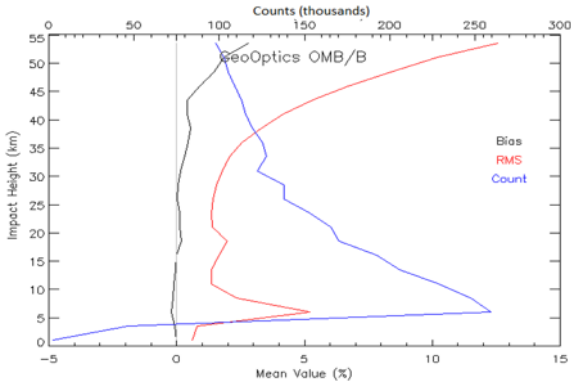
Preliminary Testing with the GFS

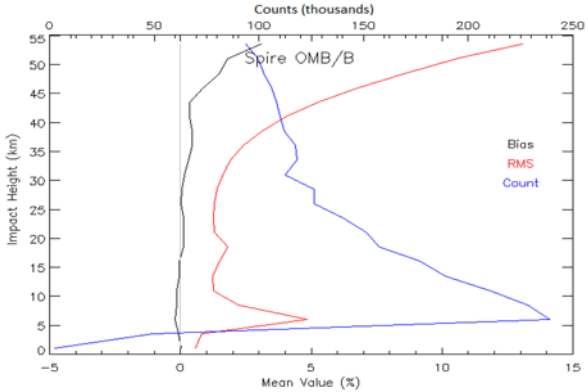
- The first experiment was run assimilating the commercial data the same as other RO data are.
  - Following experiments aim to improve upon that baseline.
- Experiments:
  - **CTL**: Control
  - **EXP**: Control + comm RO
  - **CUTOFF**: EXP + comm RO data removed above 45 km
  - **ERRINF**: EXP + comm RO obs errors inflated by 50% (*ongoing*)

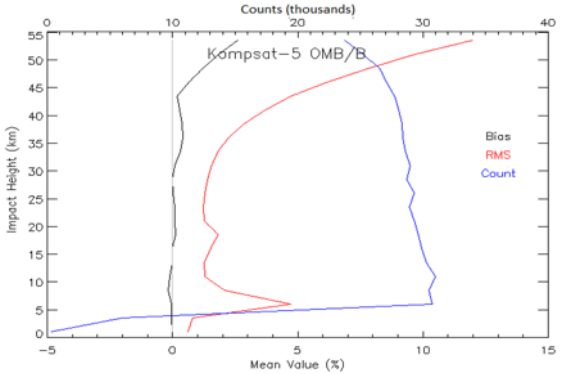
Quality of Commercial RO

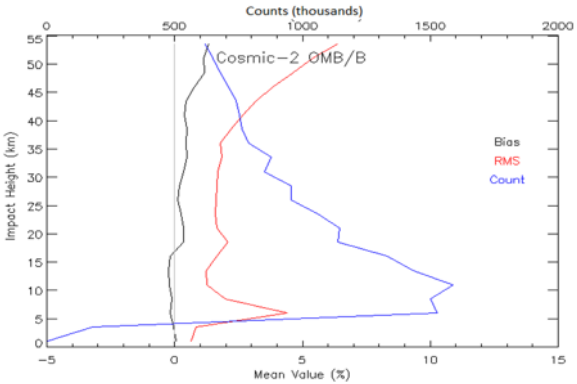
GeoOptics and Spire occultations are found to have similar quality and error characteristics as other operationally assimilated RO data.

Bias
RMS
Count





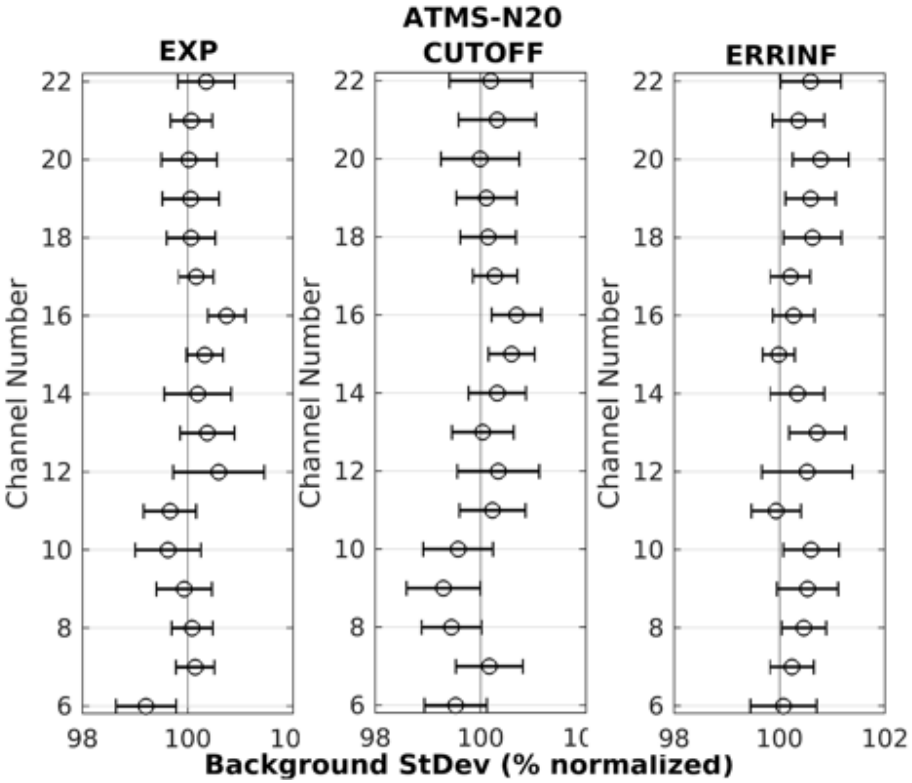




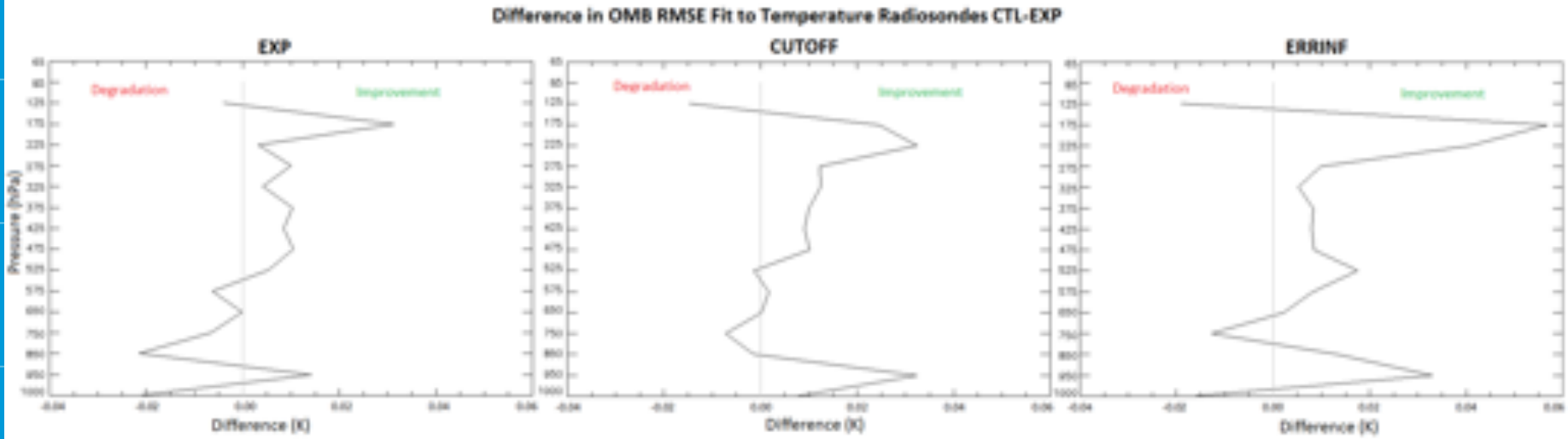
Background Fits to ATMS Channels

Globally averaged OMB fits to ATMS channels for 2020122000-2020122700.

A percent greater than 100 indicates degradation with the assimilation of commercial RO.

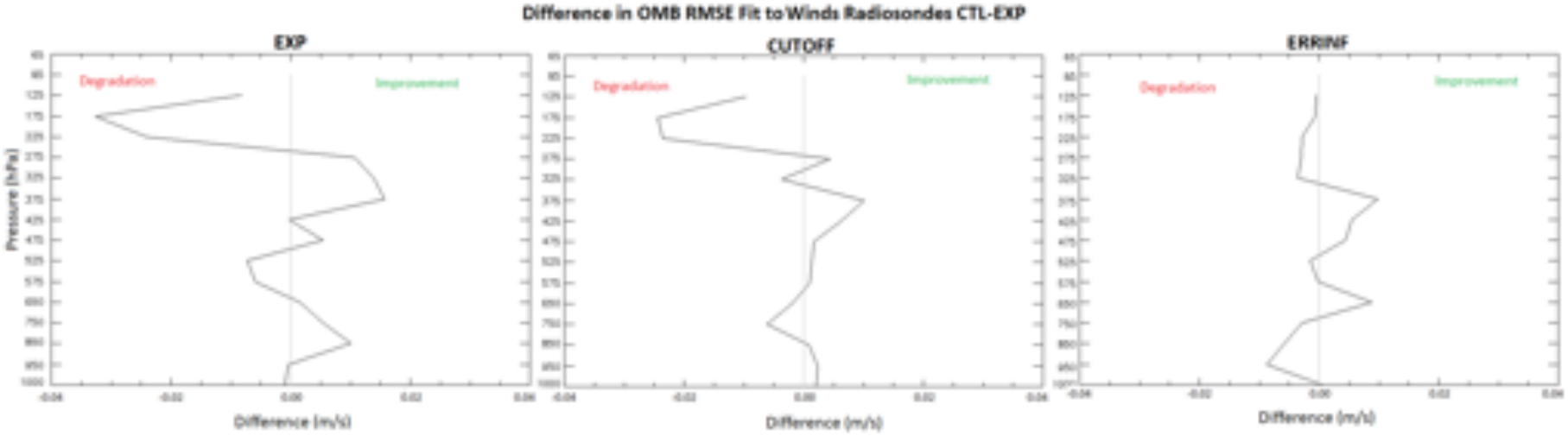


Fit to Temperature RAOBS



The differences in OMB RMS fits to temperature radiosonde measurements in the tropics, from 2020122000-2020122700.

Fit to Winds RAOBS



The globally averaged differences in OMB RMS fits to U winds radiosonde measurements, from 2020122000-2020122700.

Summary of DO-1 Results

- Initial experiment assimilating the commercial RO data had neutral to negative forecast impact in low resolution GFS testing.
- Indications of improvements in fits to temperature, but degradation was seen in the upper layers.
- Two mitigation measures were tested: cut off the commercial RO data above 45 km and inflate the observations errors by 50%.
- Preliminary results show that both methods improve background fits to temperature and wind measurements. Inflating observation errors improves forecast metrics impact at higher levels.

Looking Ahead to DO-2

- Delivery Order 2 has been awarded to GeoOptics for 1300 occultations a day for six months (March through September).
- Data started flowing on March 17 and an operational resolution parallel is running in near real time with the upper layer cutoff included (inflation is pending more testing).
- Implementation of the assimilation of these data in GFS is currently planned for May-June 2021 (GFS v16.1).

Future Challenges and Activities

- Optimize value from assimilation of commercial RO data
  - Added value in tropics/mid-lats given overlap with COSMIC-2?
  - Greater value over high/mid-lats given absence of COSMIC-2?
  - Determine optimal cost vs. benefit for variable data density/distribution, for global as well as limited area/regional high-res models (e.g., HRRR)
  - Determine value in absence of other data vs. just adding to status quo
- How to handle potential exponential growth of new commercial data?
  - New smallsat data may come with short lead time and stay on orbit for only a few years; need capability to rapidly test, eval, and implement
  - NOAA is unlikely to be able to afford all available commercial data >> need ability to determine net forecast benefit per unit cost