Assessment of New Radio Occultation Measurements at the Global Modeling and Assimilation Office

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Radio Occultation Assimilation at the GMAO

Like most global centers, GNSS radio occultation measurements have been assimilated routinely at the Global Modeling and Assimilation Office for more than a decade

- Near-realtime implementation in the GMAO Forward Processing (FP) system
- Assimilation into reanalysis since MERRA-2 (Gelaro et al. 2017, McCarty et al. 2016)

GMAO systems are built upon the Goddard Earth Observing System (GEOS) atmospheric data assimilation system

- GEOS global earth prediction model in atmospheric configuration
  - Cubed sphere dynamics, 0.01 hPa model top, 72 levels
- Gridpoint Statistical Interpolation (GSI) assimilation procedure, codeveloped with NOAA/NCEP/EMC
  - Bending angle assimilated to 60 km

This talk aims to illustrate three substantial updates

- Implementation of updated observation operator
- Implementation of COSMIC-2
- Assessment of Spire bending angle measurements acquired via the NASA Commercial Smallsat Data Acquisition (CSDA) Program

Update of the Bending Angle Observation Operator

The vertical interpolation scheme in the GSI was updated to handle coarse integrations at the model layer interfaces versus the layer mid-points

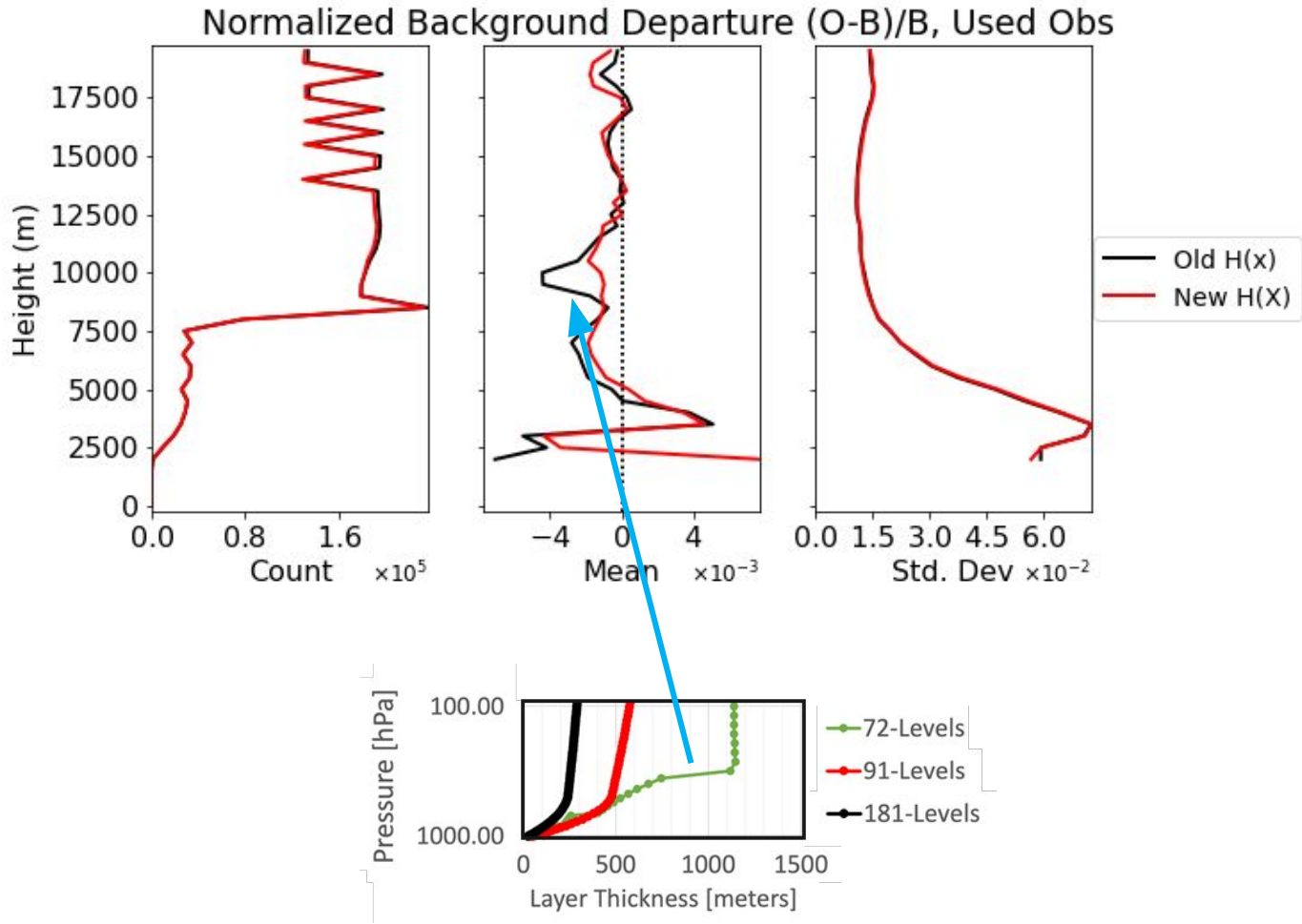
- This issue was determined to be GMAO-centric due to the coarse spacing of the 72 vertical levels in the upper-troposphere
- Resulted in a negative bias in the background departures, particularly between 9 and 10 km

This issue was diagnosed by identifying discrepancies between the GSI and the RO SAF forward operators

- Diagnoses observing system simulated experiments (OSSEs) investigating saturation
- An example of the OSSE transitioning to production/real data systems
- Held up COSMIC-2 implementation, as the bias acted as a “blow torch” in the tropical upper-troposphere

The issue mitigates itself with better vertical resolution

- Fix will be re-assessed with more model levels upgrade anticipated in Q3 2021



COSMIC-2 Testing

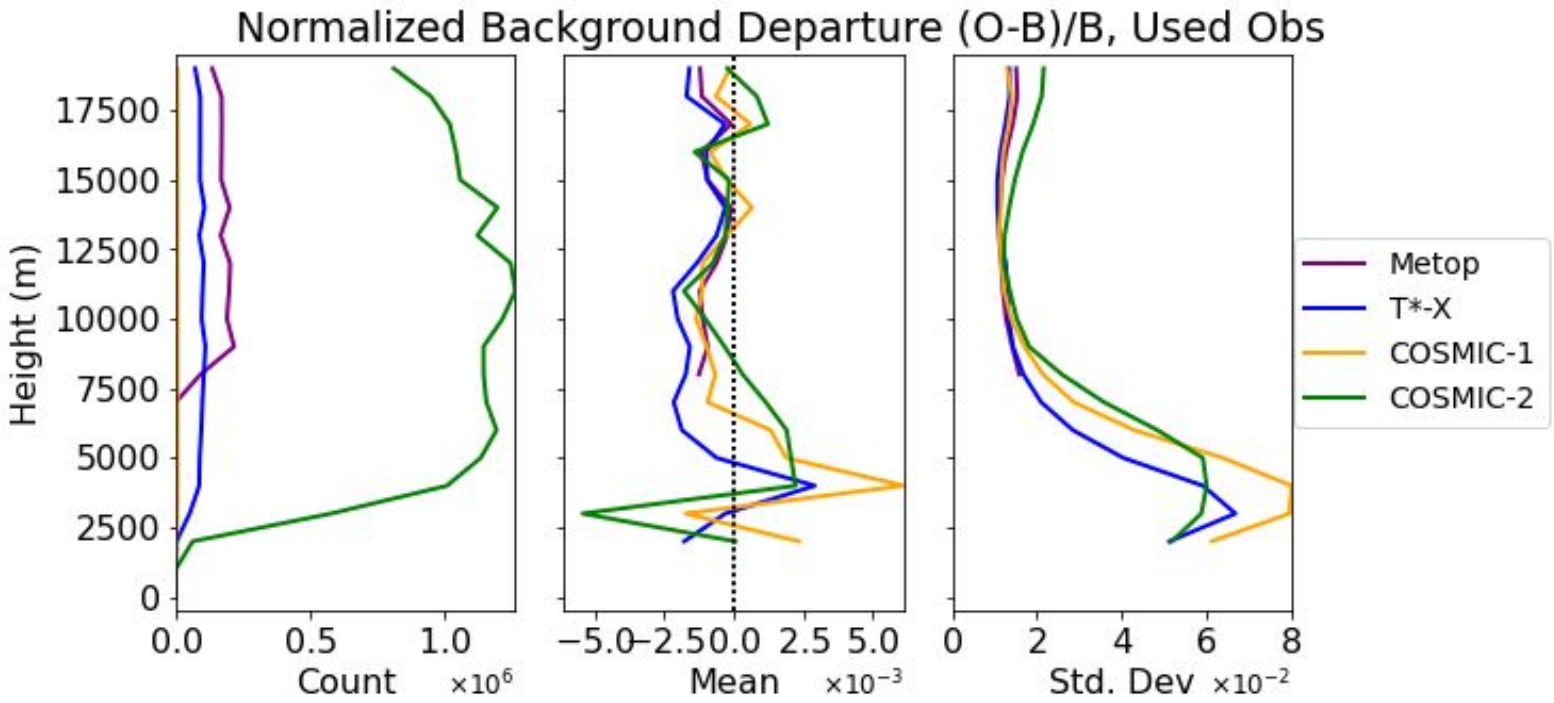
Once the H(x) was improved, GMAO began testing COSMIC-2

- Data was seen to be generally consistent w/ heritage RO data
- QC decisions inherited from NOAA GSI development

Future work may consider different lower tropospheric cut-off

Data volume increase substantial in the tropics (as expected)

- Largest impacts seen in tropics



Implementation of COSMIC-2

CTL: Candidate System

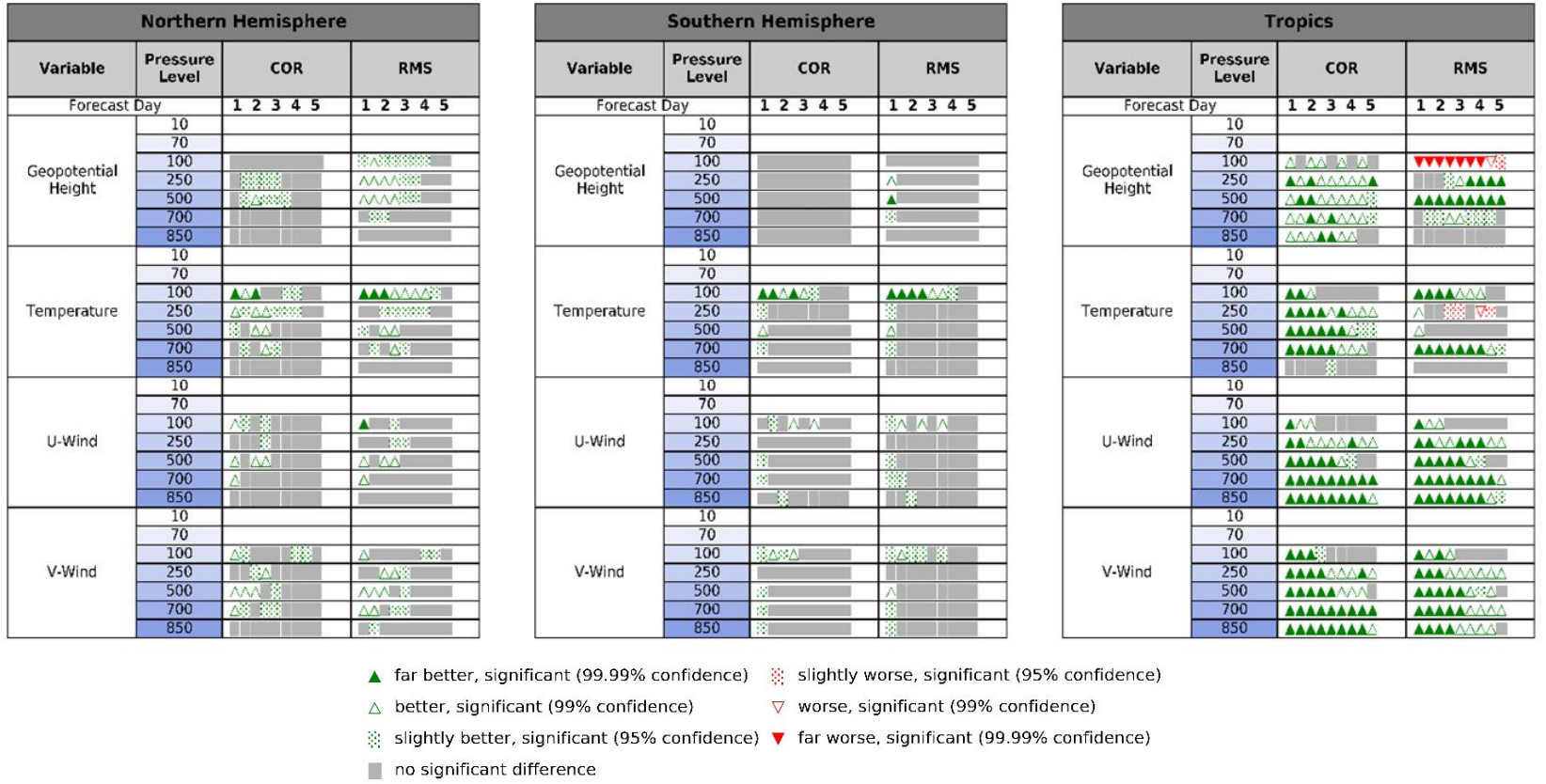
EXP: CTL + COSMIC-2

Largest forecast improvements seen in the Tropics

- Temperature, winds largely improved
- Slight degradation in 100 hPa geopotential height RMS

Testing had a discrepancy in CrIS implementation that may have indirect feedbacks

- Degradation not seen in full FP implementation



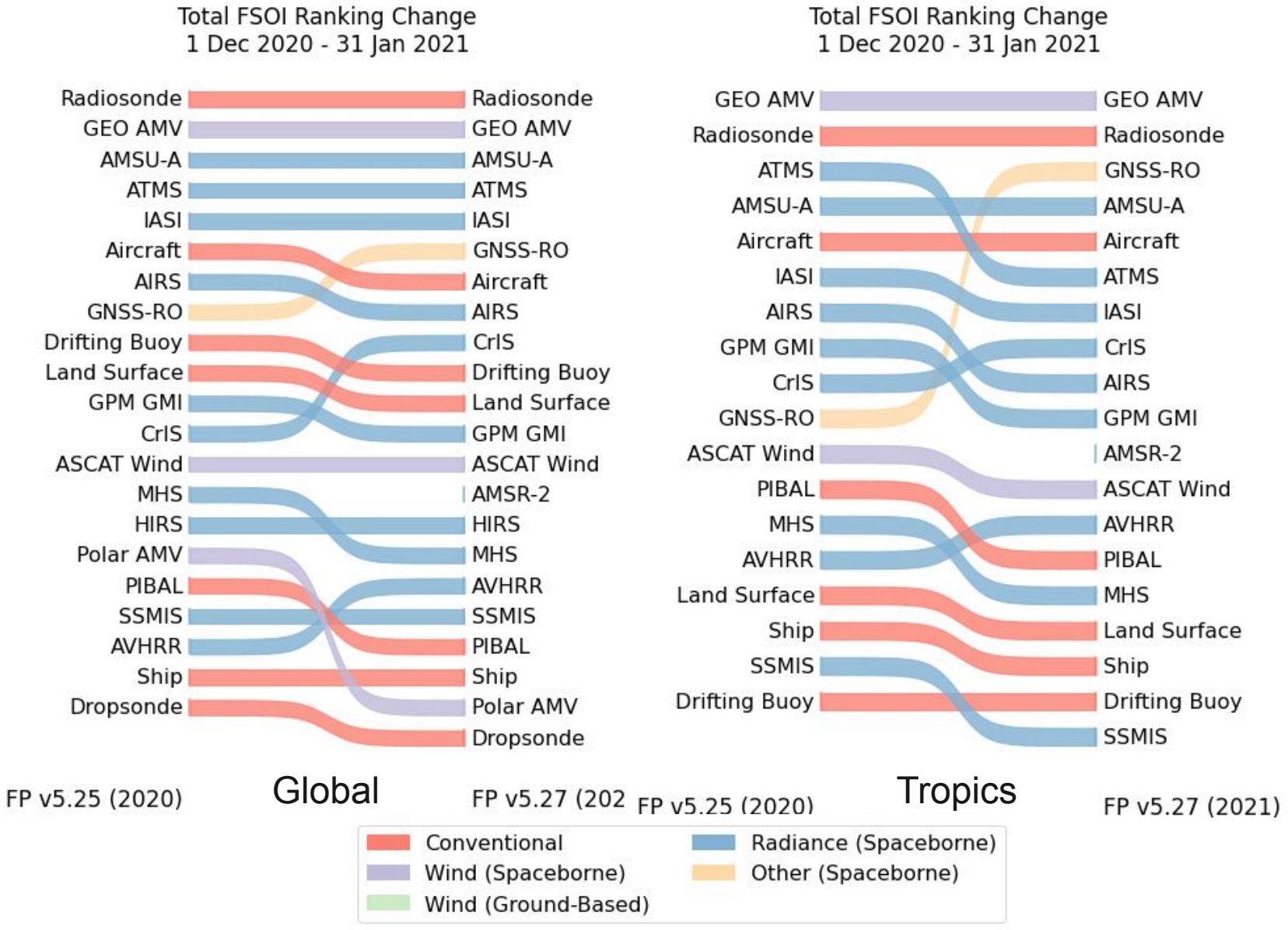
Summary of Implementation – FSOI

The most recent Forward Processing upgrade on 25 February 2021

- COSMIC-2, Ozone Sensitive IR, CrIS Full Spectral Resolution + Correlated Errors, MHS All-Sky, AMSR-2 All-Sky, Metop-C AMSU-A & GRAS

Looking at FSOI…

- RO jumped two positions globally
- RO jumped to 3rd overall, just below AMVs and RAOBs, in the Tropics

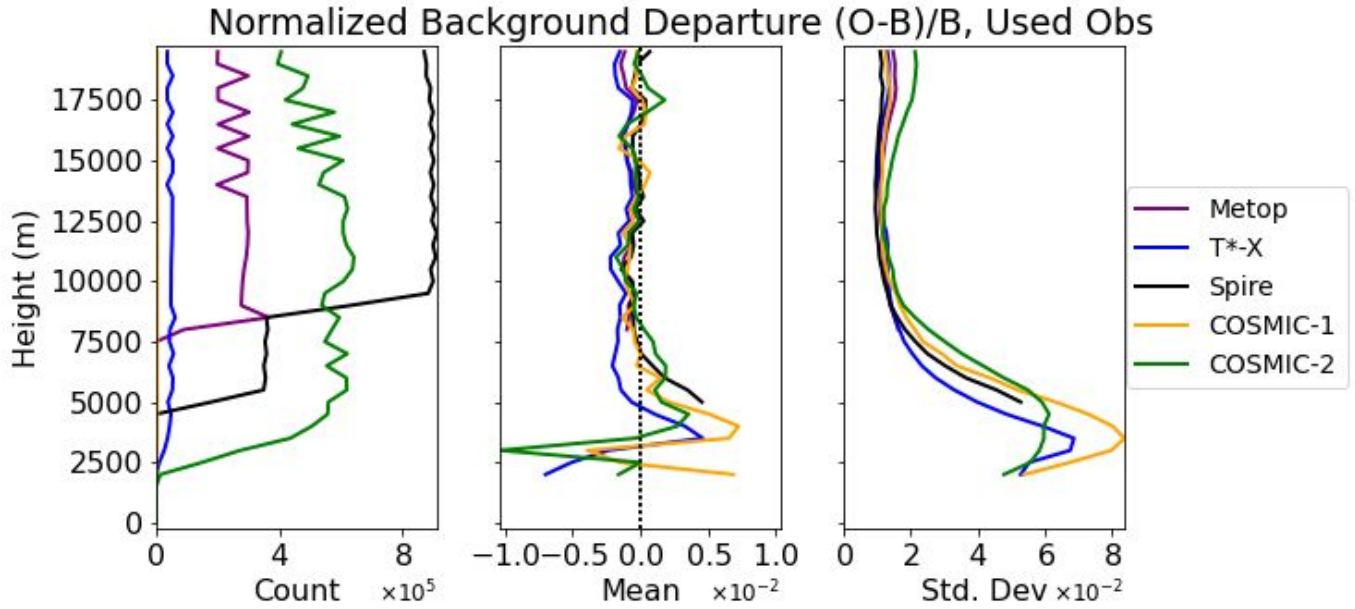


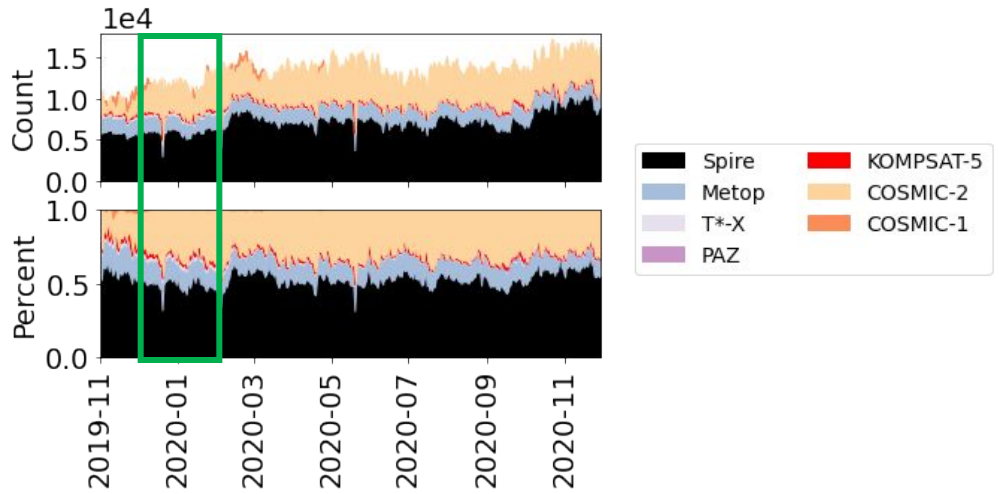
Assessment of Spire Radio Occultation Data

COSMIC-2 testing corresponded to a period that overlapped w/ CSDA Spire holdings
- Dec 2019-Jan 2020
- Spire-produced bending angle bufr profiles

Spire assimilation methodology
- GPS-derived to 5 km; other (GLONASS, GALILEO, QZSS) to 9 km
- Error modeling consistent w/ COSMIC-1

Due to latency, near-realtime implementation of Spire products infeasible
- Considering potential for implementation in future reanalyses





Spire Forecast Scorecard

CTL: Candidate (including COSMIC-2)

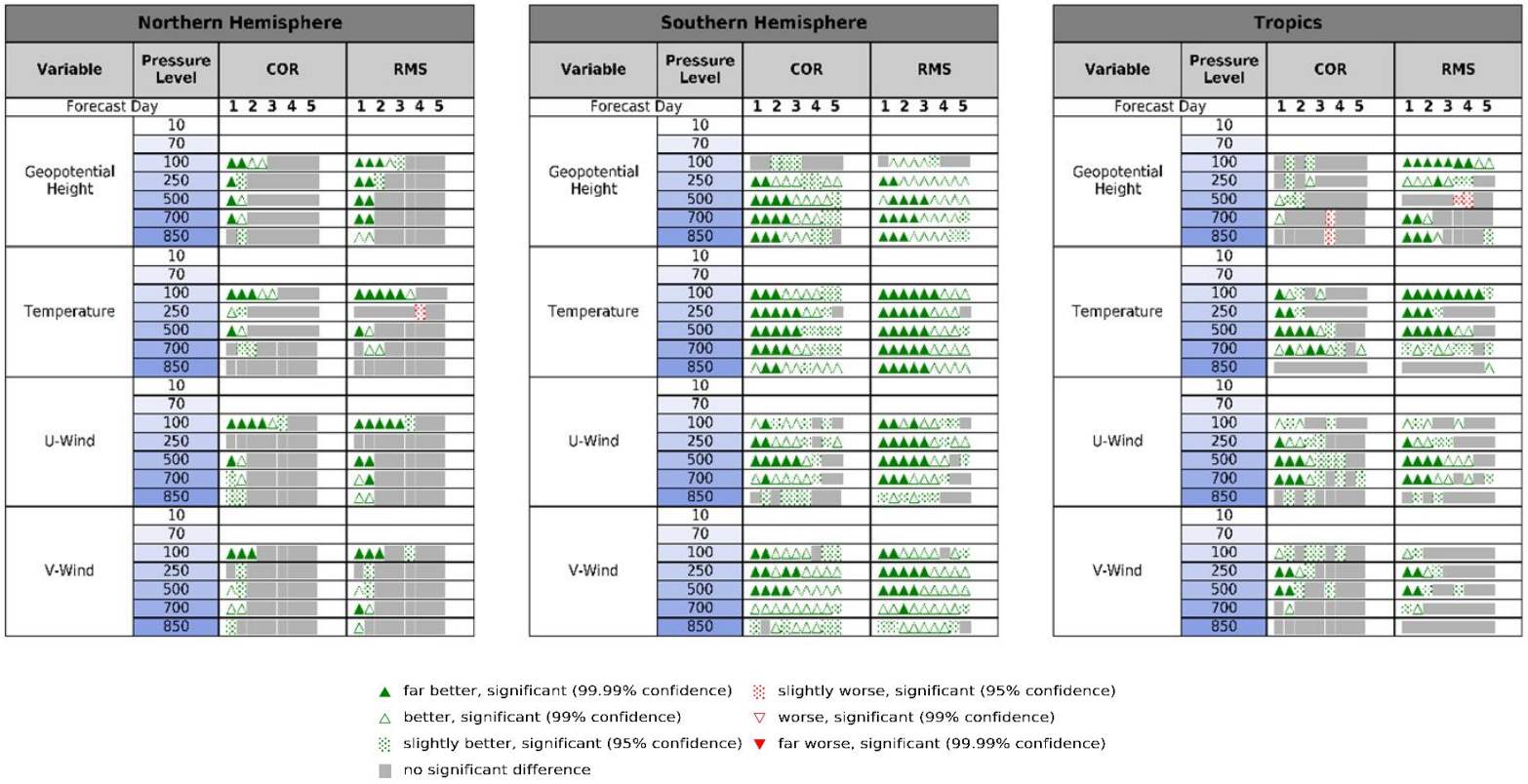
EXP: CTL + Spire

Largest forecast improvements seen in Southern Hemispehre

- Temperature, winds improved across the board

Improvements in N. Hem less apparent

Tropical Improvement seen, even on top of COSMIC-2



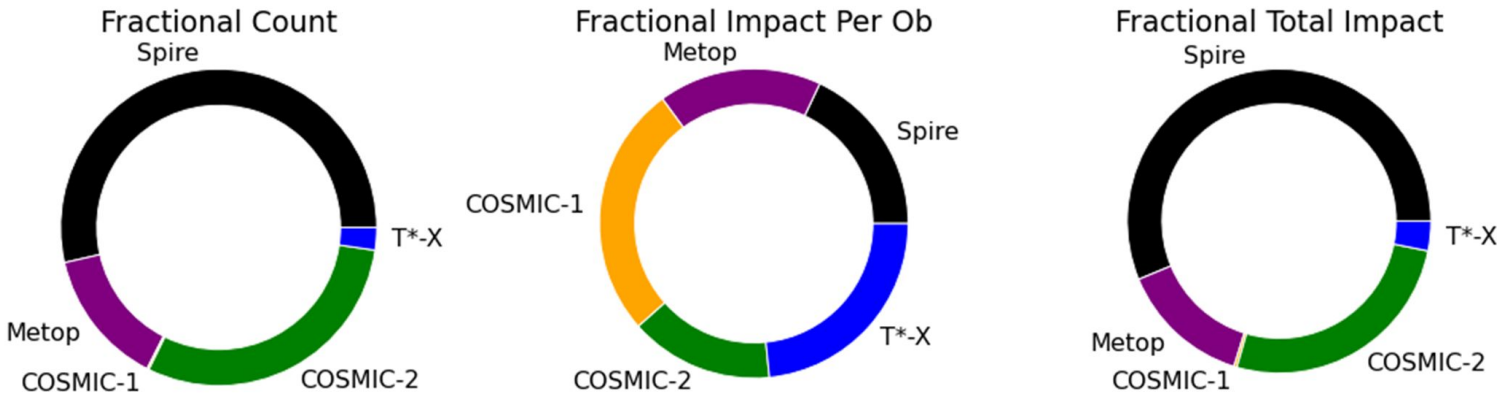
Spire FSOI

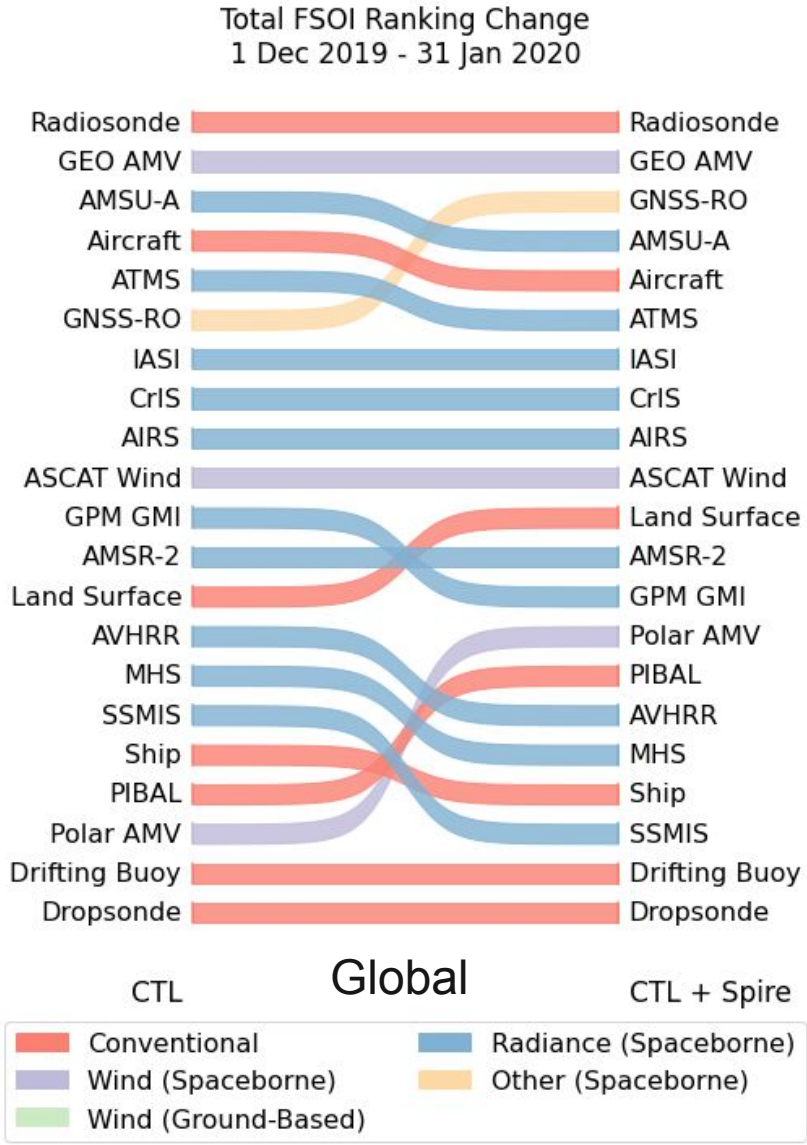
FSOI showns further enhancement of RO as a global observing system by including Spire data

- COSMIC-2 moved GNSS-RO to 3rd overall in the Tropics (earlier slide)
- Spire data fills out global contribution of observing system, moves to 3rd overall globally

Breakdown of FSOI by RO observing system (below)

- Total FSOI scales close to observation count
- Per-observation, the data is similar to other observing systems





Conclusion

The GMAO continues to investigate expansion of their RO observing system

- PAZ, Kompsat-5, GeoOptics (via NOAA CWDP) testing about to start
- Strong desire to fill gap in global observing system between COSMIC and COSMIC-2 for reanalysis
- Reprocessed data
  - Current observation stream taken from operational (Forward Processing) data streams
  - Desirable for next reanalysis (Reanalysis of the 21st Century, R21C)

Contrarily, data assimilation at the GMAO is at a hinge point

- Transition from GSI to JEDI-based assimilation procedure
- How much more to develop?

References

Gelaro, R., W. McCarty, M. J. Suarez, R. Todling, A. M. Molod, and coauthors, 2017. **The Modern-Era Retrospective Analysis for Research and Applications, Version-2 (MERRA-2)**. *J. Climate*, **30**, 5419-5454. DOI 10.1175/JCLI-D-16-0758.1

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