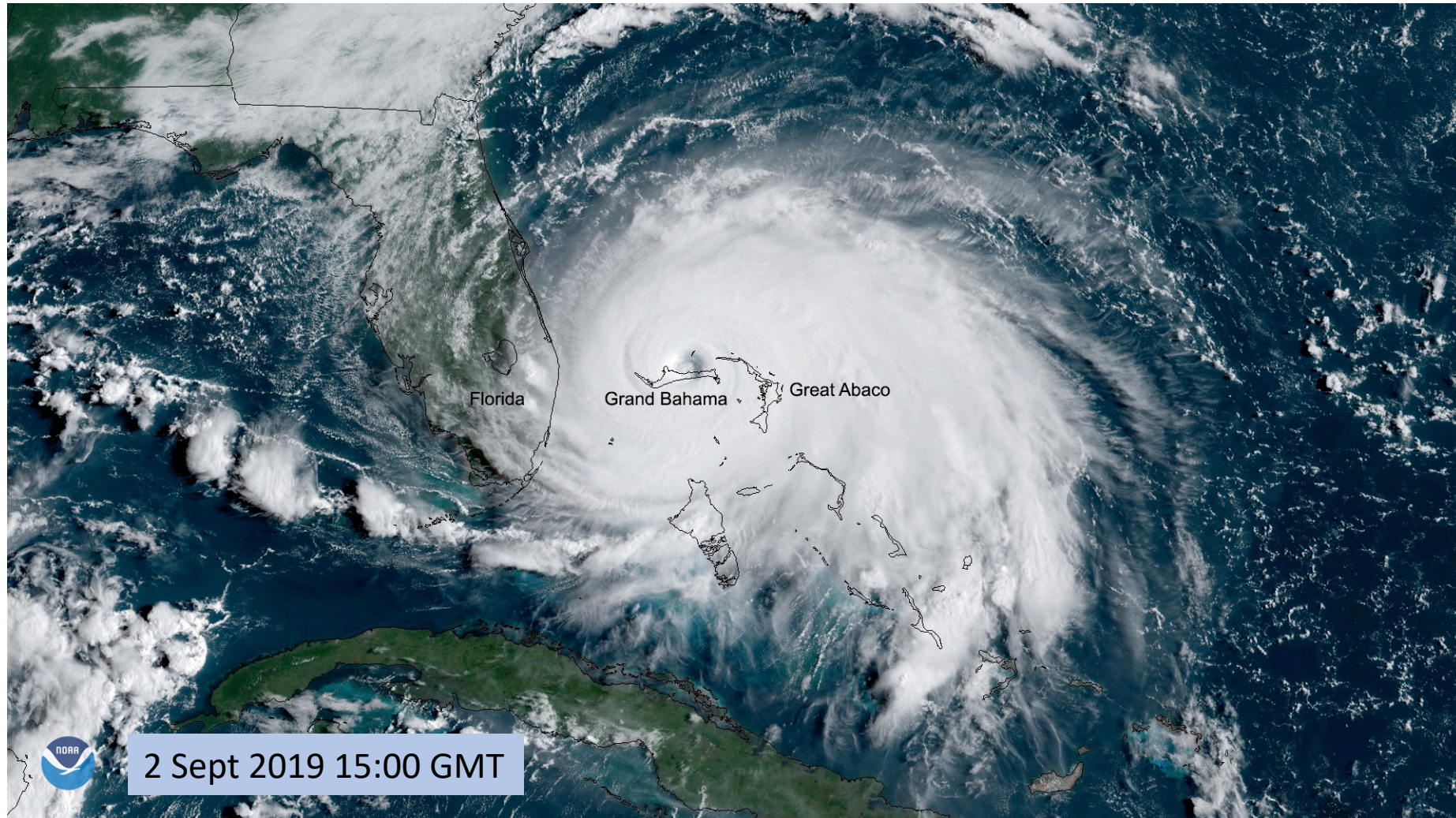


COSMIC-2 Specific Humidity in Hurricane Dorian (2019)



Rick Anthes, Jeremiah Sjoberg, Therese Rieckh, Tae-Kwon Wee and Zhen Zeng
IROWG-8 Virtual Meeting 8 April 2021

Introduction and Highlights

We estimate the bias and random errors of COSMIC-2 (C2) water vapor retrieved from observed bending angles using the new COSMIC 1D-Var retrieval and three reanalyses-ERA5, MERRA-2 and JRA-55 in intense Hurricane Dorian (2019) and its environment. We compute the biases relative to ERA5 and the standard deviation of random errors by the three-cornered hat (3CH) method.

- Above 2 km, C2 biases of specific humidity wrt ERA5 are less than 0.3 g/kg (15%)
- Below 2 km C2 specific humidity has a dry bias up to 2 g/kg.
- STD of C2 errors for $q < 1.0$ g/kg (25%)-comparable to or smaller than ERA, less than MERRA-2 and JRA-55
- C2 precipitable water estimates comparable to ERA5, STD of PW errors smallest of all data sets
- Overall, C2 specific humidity and precipitable water are accurate and precise, with more than 70% of profiles reaching to 1 km or lower

Related presentation on three-cornered hat method and COSMIC-2 errors:

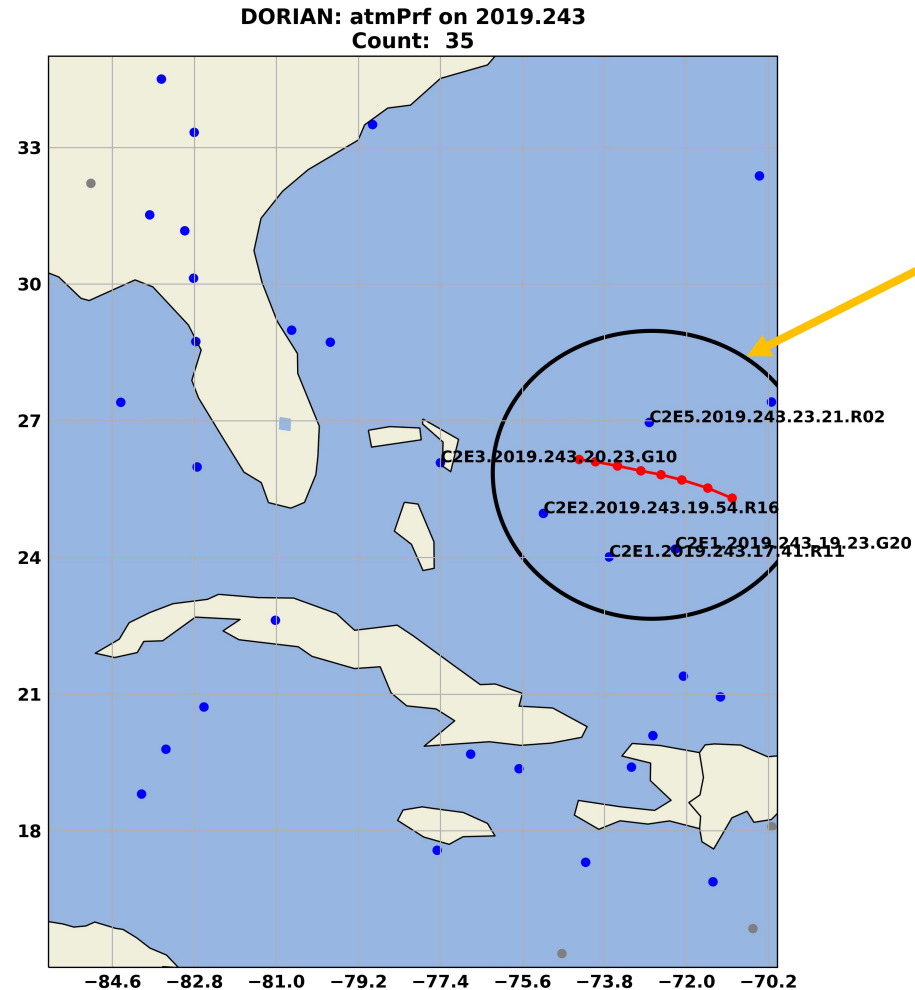
Jeremiah Sjoberg: Estimation of C2 errors using RO only data and the 3CH method (RO-RO-RO). Friday Poster Session 11:05-12:05 AM EDT

C2 temperature and water vapor retrievals in Hurricane Dorian and its environment

- 30 Aug 2019 through 05 Sep 2019
- CDAAC new 1D-Var (wetPf2) temperature and specific humidity q profiles
 - Uses NCEP GFS as first guess
- Comparison of C2, ERA5, JRA-55 and MERRA-2 in three domains
 - Global latitude band 15° - 35° N
 - Dorian window (15° - 35° N, 86° - 70° W)
 - Hurricane (within 350 km radius of Dorian center)
- Two months after COSMIC-2 launch on 25 June 2019. Hardware and processing software not fully optimized—check-out period.

Example of C2 coverage in one day

31 Aug 2019 (2019.243)
3298 global count



Boundary of “hurricane”
Domain-350 km radius

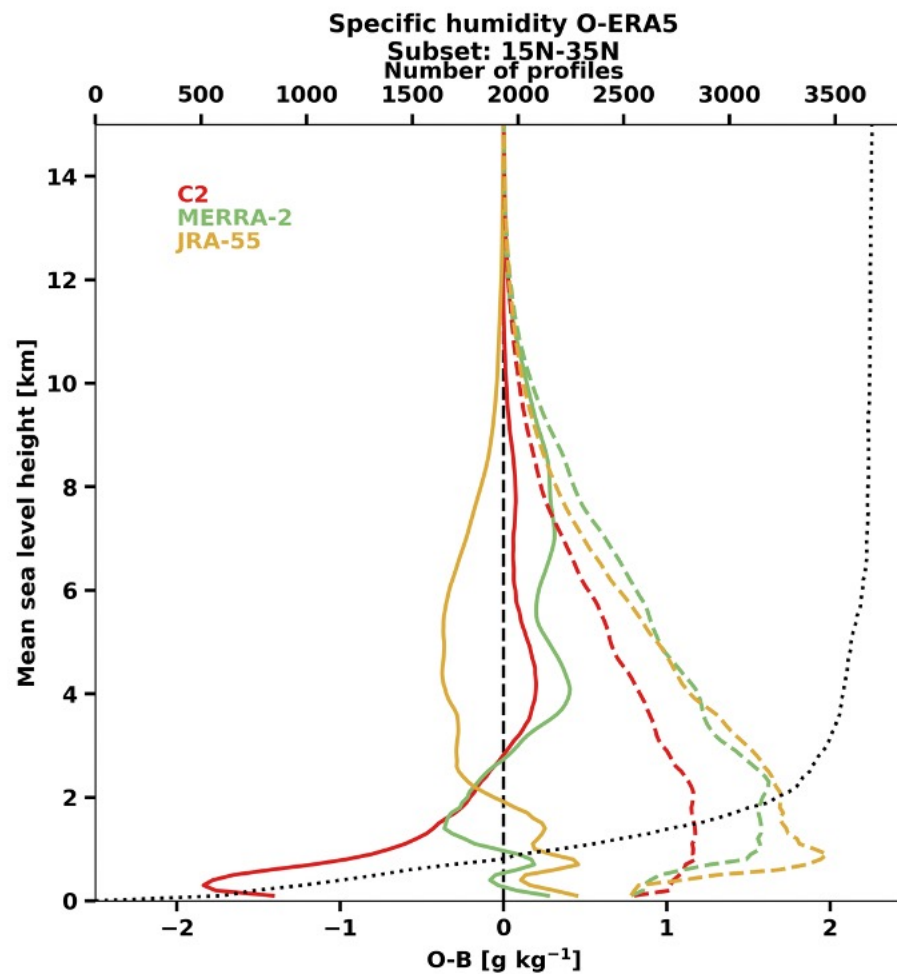
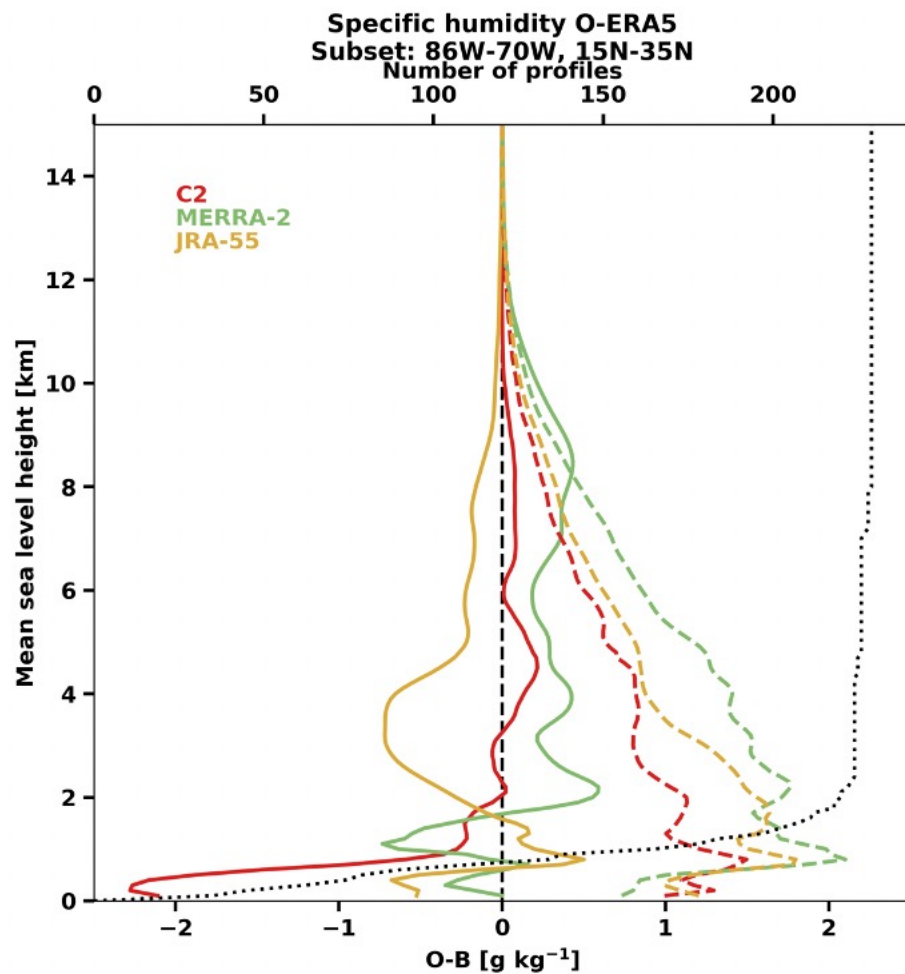
This domain moves continuously
with the storm center

Five profiles in hurricane domain
this day

Specific humidity biases and STD differences wrt ERA5

Dorian window

15°-35°N global

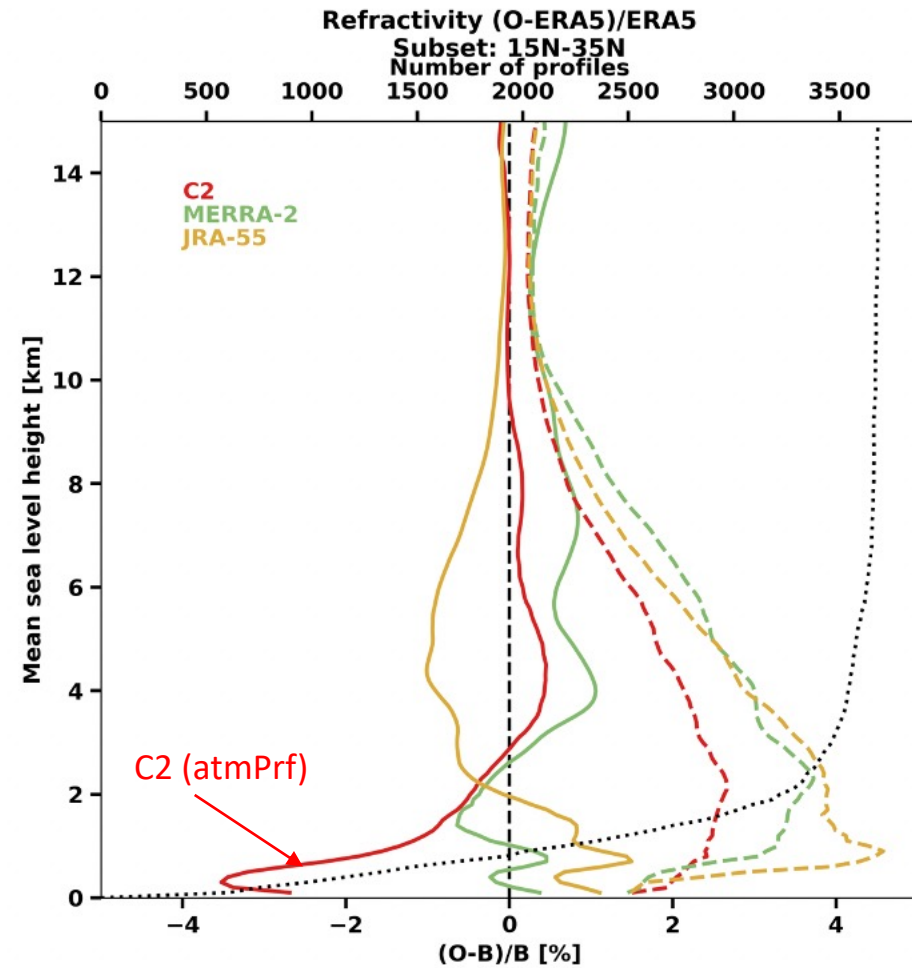
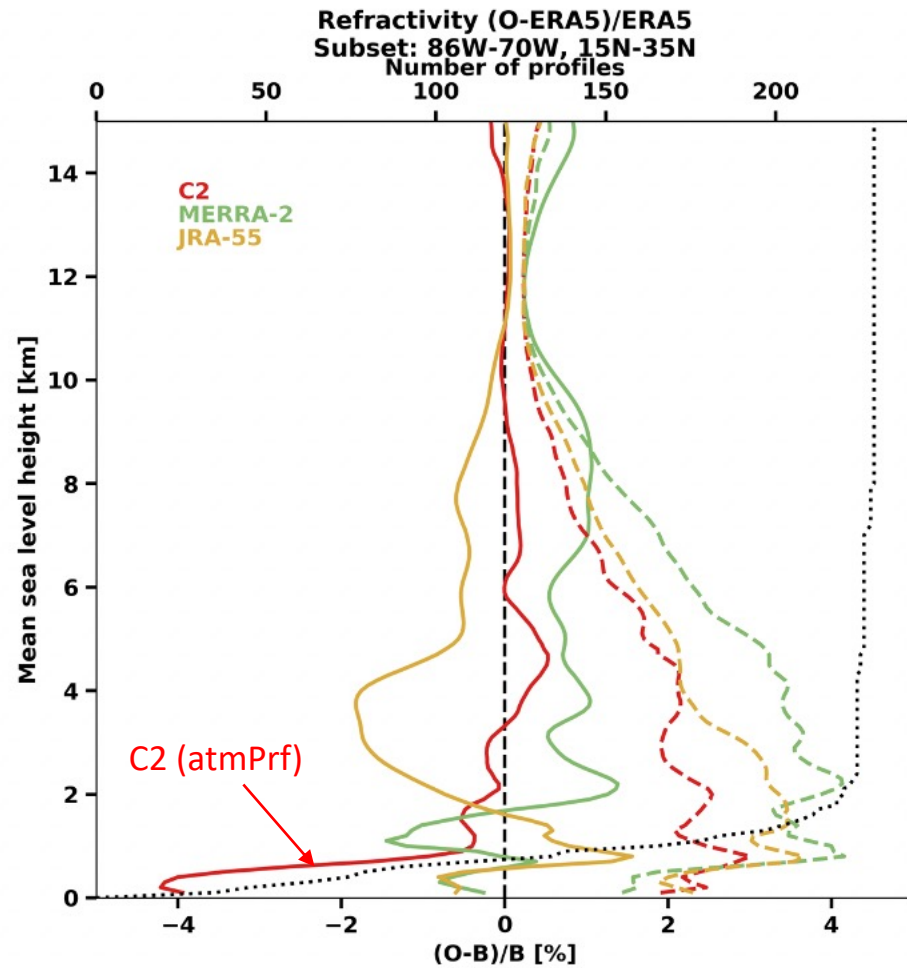


C2 biases < 0.3 g/kg above 2 km; STD < 1 g/kg above 2 km
Dry bias up to 2 g/kg below 2 km

Why is C2 biased dry below 2 km?

- ERA5 is biased wet (no issue with C2)?
 - Doubtful. ERA5 does not show wet bias wrt other data sets.
- GFS (first guess in 1D-Var) is biased dry and this causes C2 bias?
 - GFS is biased dry, but this is not the cause. The C2 observed refractivity (atmPrf), which has nothing to do with GFS, is biased negatively and this bias is associated with the dry bias.
 - Furthermore, the dry bias in the 1D-Var retrieved q is virtually unchanged when the ECMWF analysis, which has a wet bias, is used as the first guess.

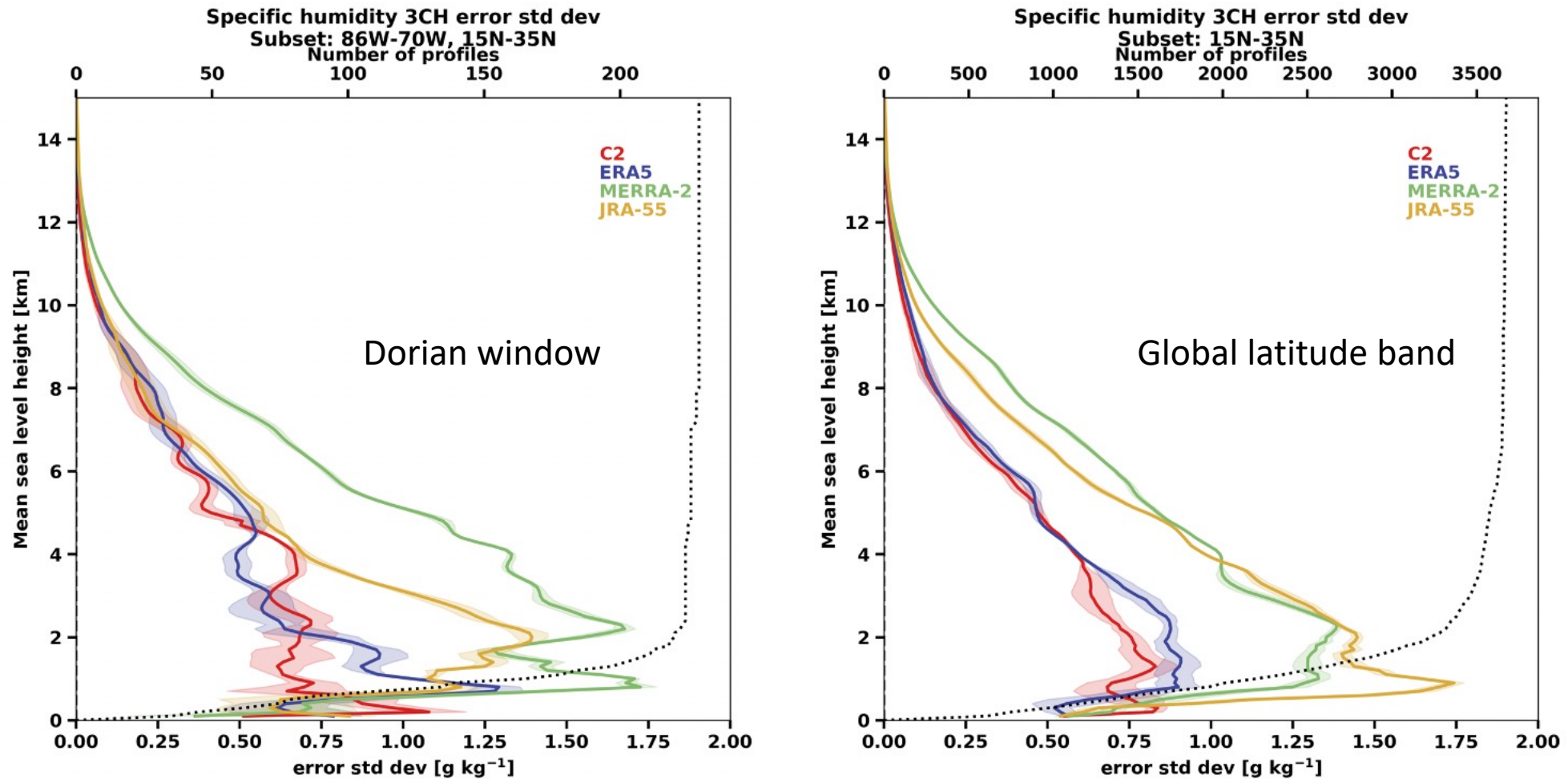
C2 observed refractivity negatively biased below 2 km



Why is C2 refractivity negatively biased below 2 km?

- Super-refraction (SR)?
- Other potential sources of SR?
 - Low SNR in complex moist lower troposphere
 - Horizontal inhomogeneities in the atmosphere
 - Limitations in signal tracking and data processing
- SR is not the cause-no SR in the C2 profiles and we filtered out all data below the highest level of SR found in any of the 4 data sets.

3CH specific humidity random errors



Four data sets give three 3CH error estimates-mean of these estimates shown by solid line; STD of estimates indicated by shading.

Precipitable water (PW)

Data Set	Dorian Window PW (mm)	Dorian Window PW Error (mm)
COSMIC-2	48.29	1.580 (0.193)
ERA5	48.89	2.028 (0.148)
MERRA-2	50.38	2.814 (0.106)
JRA-55	47.11	2.351 (0.127)

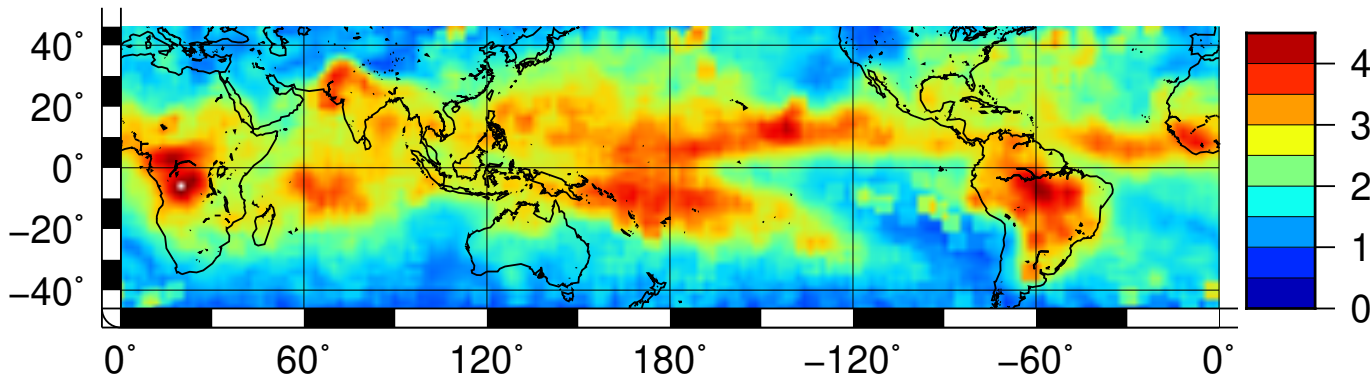
Errors are mean of 3CH error STD estimates and in () the STD of the three estimates

Note-PW values close to TC center often exceed 70 mm or higher (Zhao et al., 2019 <https://doi.org/10.3390/rs11232845>). The values in this table are representative of the large-scale hurricane environment.

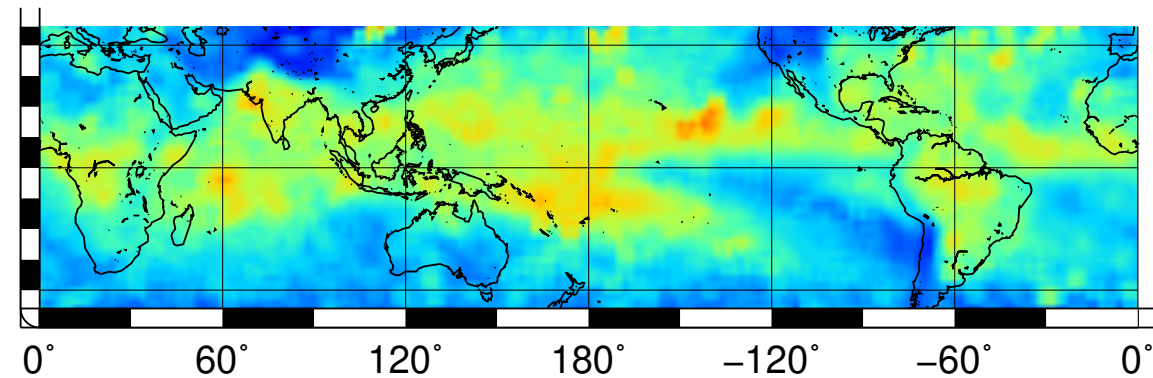
C2 PW improved compared to ECMWF analysis over GFS (1st Guess in 1D-Var)

Precip Water [stdv, mm], 2019.197–2020.032

GFS_{FCST} – ECMWF_{ANAL}



COSMIC2 – ECMWF_{ANAL}



16 July 2019 – 1 February 2020 (200 days)

Summary

- At least 70% of C2 profiles penetrate to 1 km or lower
 - Global latitude band 82% out of 3704
 - Dorian window 70% out of 229
 - Hurricane 89% (16 out of 18) with 72% (13) reaching 200 m
- C2 biases compared to ERA5 (all three domains)
 - 2-15 km $T < 0.3K$; $q < 0.3$ g/kg (15%)
 - 0-2 km q dry bias of up to 2 g/kg; T warm bias 1K
- Dry bias in this study below 2 km is associated with negative observation bias, which is not related to super-refraction or the 1D-Var process.

Summary

- 3CH estimates of C2 STD of errors
 - $T < 0.5K$ $q < 1.0$ g/kg (25%). (Similar to ERA5, smaller than JRA-55 and MERRA-2)
 - Precipitable water similar to ERA5: 48.9 mm with error STD 1.5 mm (3.1%) in Dorian window. C2 PW errors smallest of all data sets.
- C2 precipitable water closer to ECMWF analysis than GFS (1st Guess) from 40°S-40°N over 200 days
- Results similar in three domains-C2 retrievals not significantly different in extreme water vapor content, clouds and precipitation of hurricane.
- Overall, COSMIC-2 temperature, water vapor, and precipitable water are accurate and precise, with most profiles reaching lower than 1 km, even in extreme environment of an intense hurricane.