CloudSat Bias on Falling Snow Estimates Over the Daylight Only Operational Period (2012-2019).

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Falling snow is a key component for the global atmospheric, hydrological and energy cycles, and its retrieval from space-based observations represents the best current capability to evaluate it globally. The Global Precipitation Measurement (GPM) Mission Core Observatory, launched in 2014, together with its constellation sensors, can provide quasi-global precipitation estimates every 30 minutes (for level 3 products). Evaluation and validation efforts for such products are crucial, and for global evaluations, one of the most suitable instruments is the Cloud Profiling Radar (CPR) on board CloudSat, which is sensitive to light rain and falling snow. However, due to a battery anomaly in 2011, during its period of overlapping observations with GPM the CPR has operated in a Daylight Only Operations mode (DO-Op) in which it makes measurements primarily during only the daylit portion of its orbit. The goal of this work is to estimate biases inherent in global snowfall amounts derived from CPR measurements due to this shift to DO-Op mode. We use CloudSat's snowfall measurements during its Full Operations (Full-Op) period from 2006 to 2010 to evaluate the impact DO-Op mode would have had during this period. Results indicate that omitting the nocturnal component of the diurnal cycle of snowfall has nonnegligible impact on snowfall amounts in some regions. The lack of nighttime data during DO-Op biases the latitudinally averaged mean snowfall rates as well as some regional values. Hemispheric differences in bias may be due to more pronounced diurnal variability in the northern hemisphere owing to more prevalent land surface versus the southern hemisphere. The results highlight the need to sample consistently with the CloudSat observations or to adjust snowfall estimates derived from CloudSat when using DO-Op data to evaluate other precipitation products.

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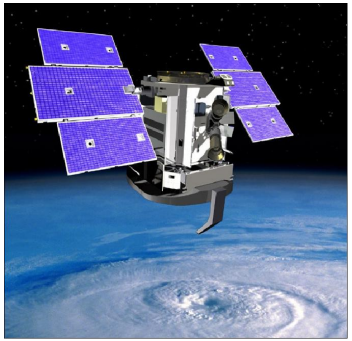
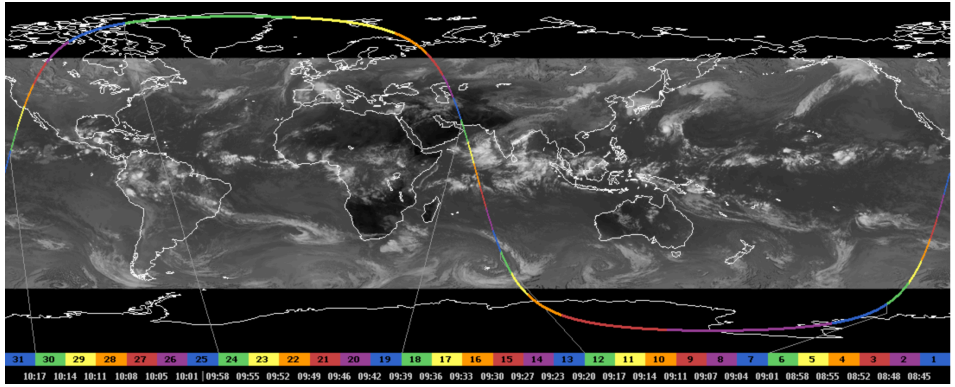
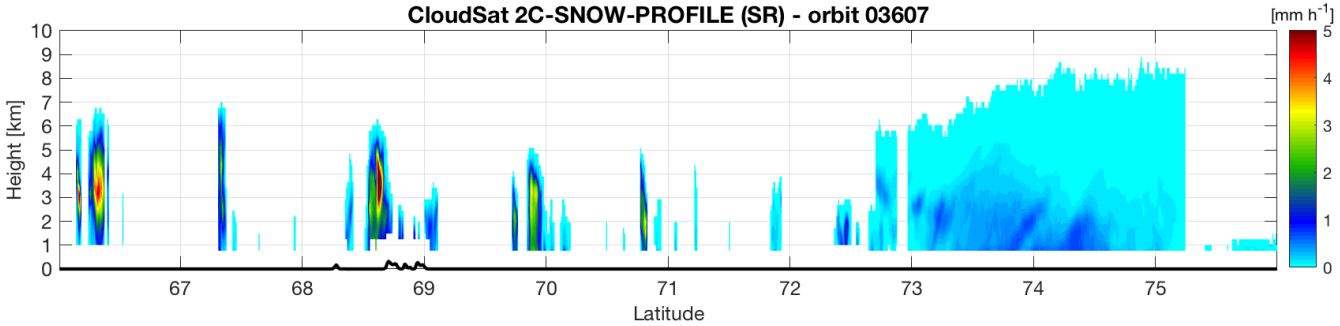
CloudSat





- Nadir pointing radar
- 94 GHz
- ~ 1.7 x 1.4 km spatial resolution
- Polar Orbit
- 82°S – 82°N



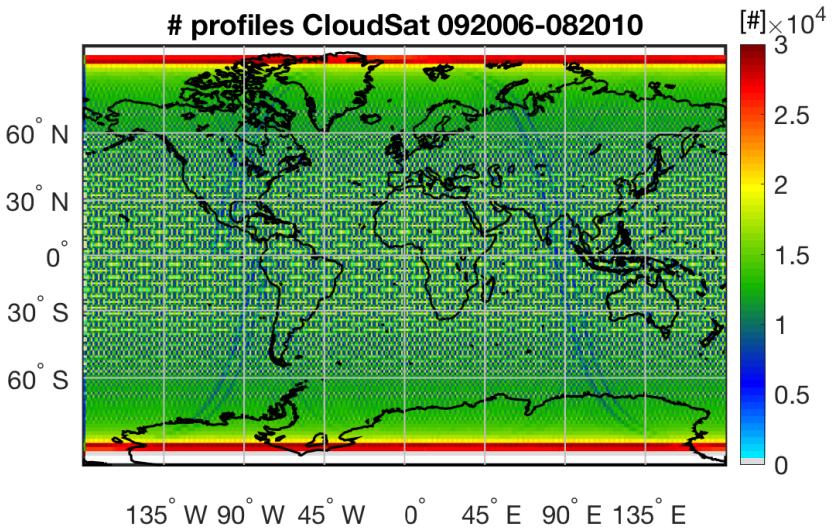
Some operational history…

- Launched in 2006
- 2006 – 2010 Full Operational Mode (Full OP)
- 2011 Battery issues
- 2012 – present Daylight Only Operational Mode (DO OP)

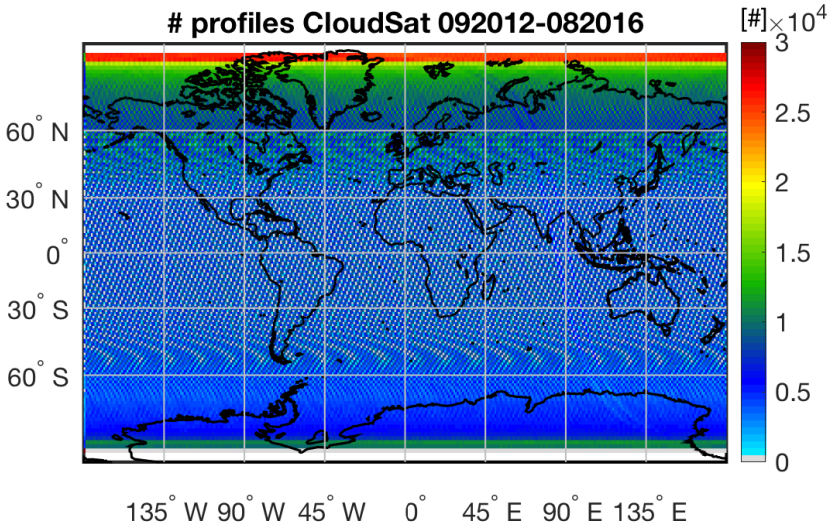
Motivations

- CloudSat is **very sensitive to snow and light rain**…
- Plenty of papers **comparing CloudSat** products to other satellite products, ground based measurements or models.
- Most of them use the **Full OP** (2006-2010)
- With the launch of new precipitation missions (GPM) and with the need to compare recent model outputs, also the **DO OP** (2012 – present) is starting to be widely used

Sampling issues: latitude



Full OP

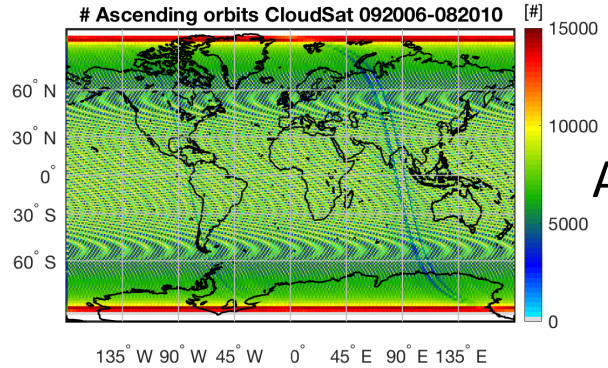


DO OP

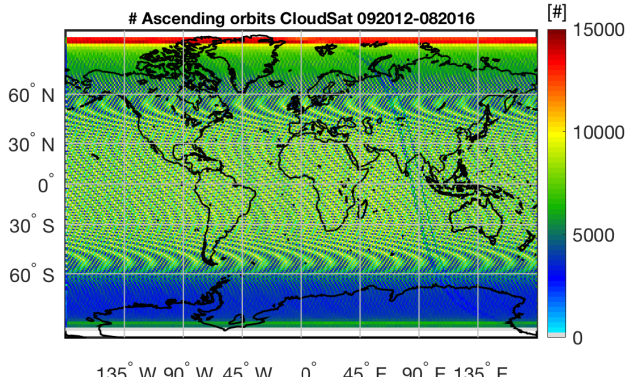
-46% of profiles

Ascending vs. Descending orbits

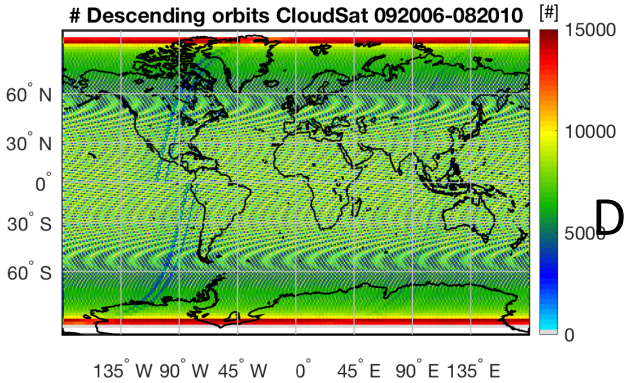
Full OP



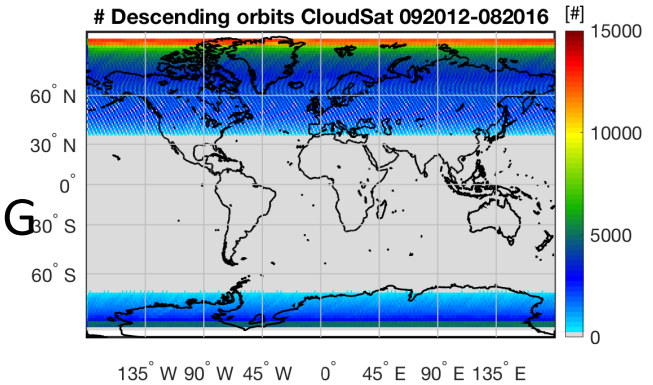
ASCENDING



-10%



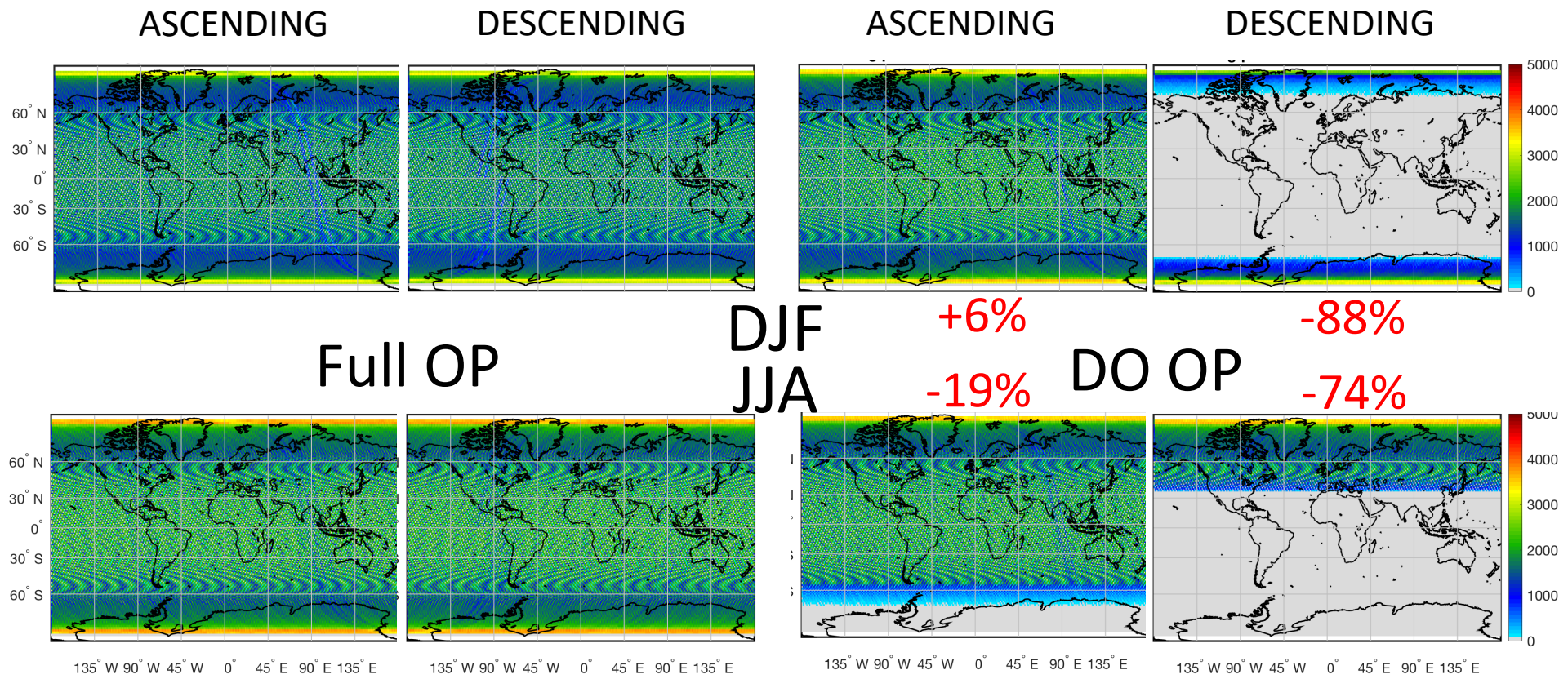
DESCENDING



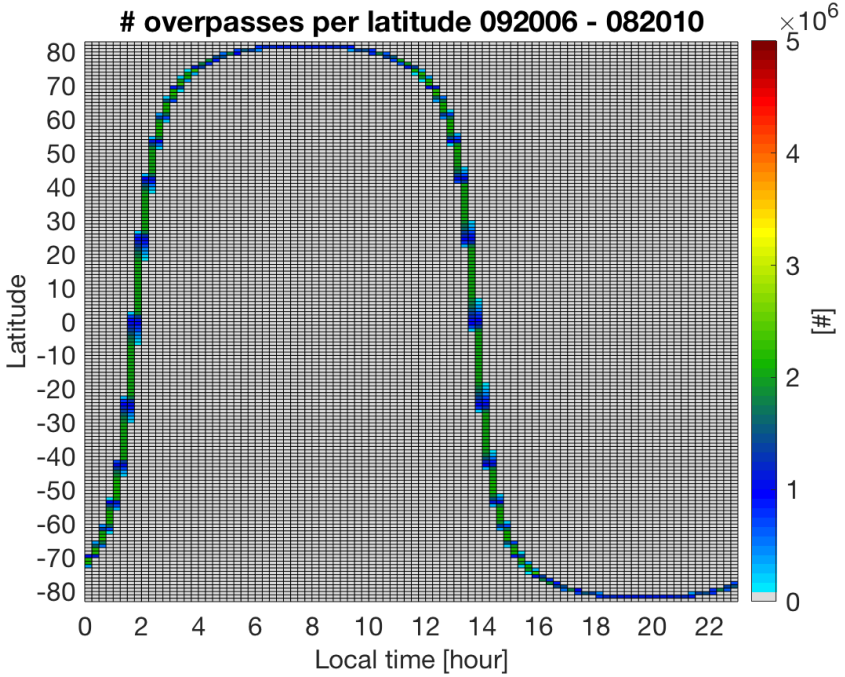
-82%

DO OP

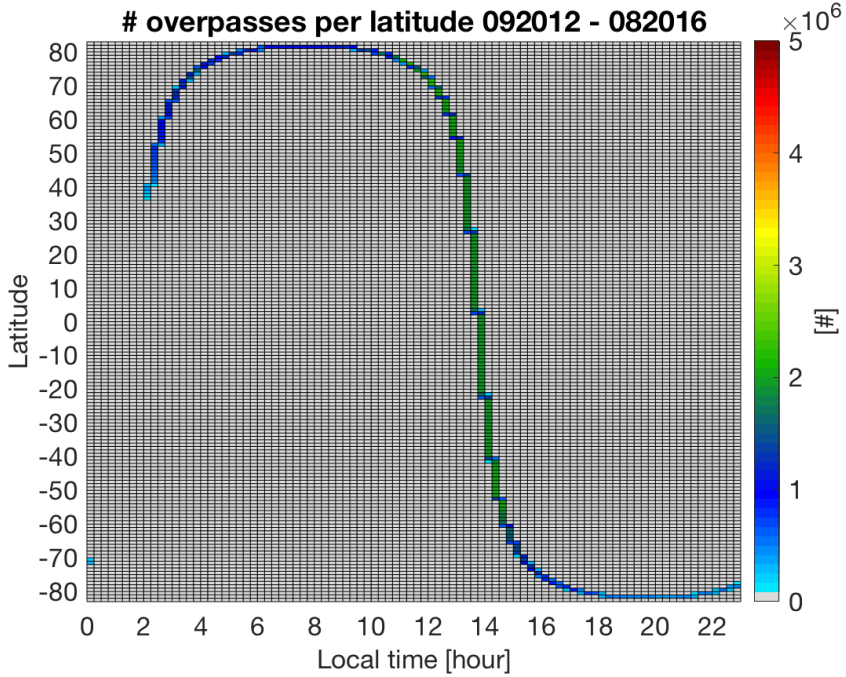
Seasonal orbits



Sampling issues: time

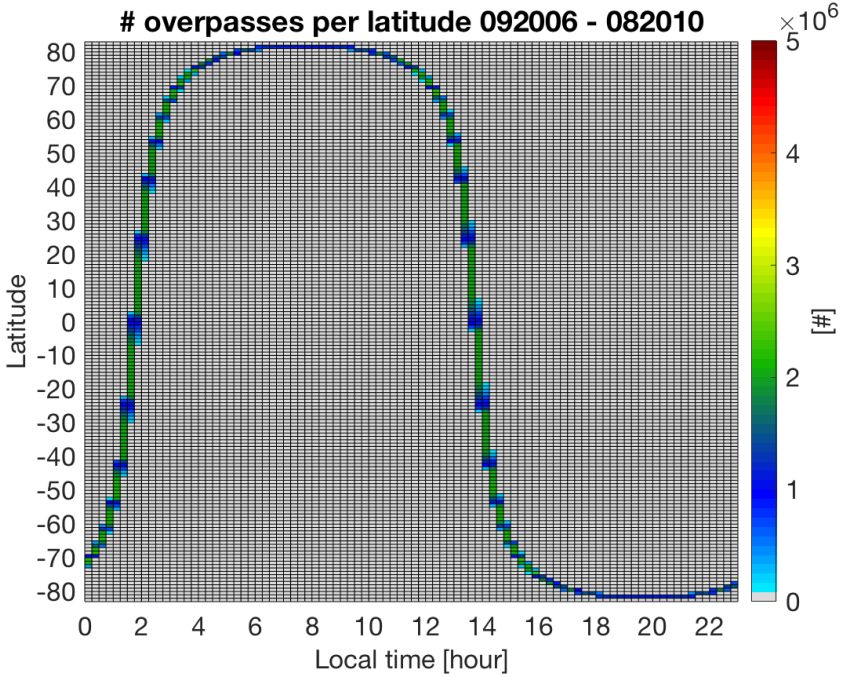


Full OP

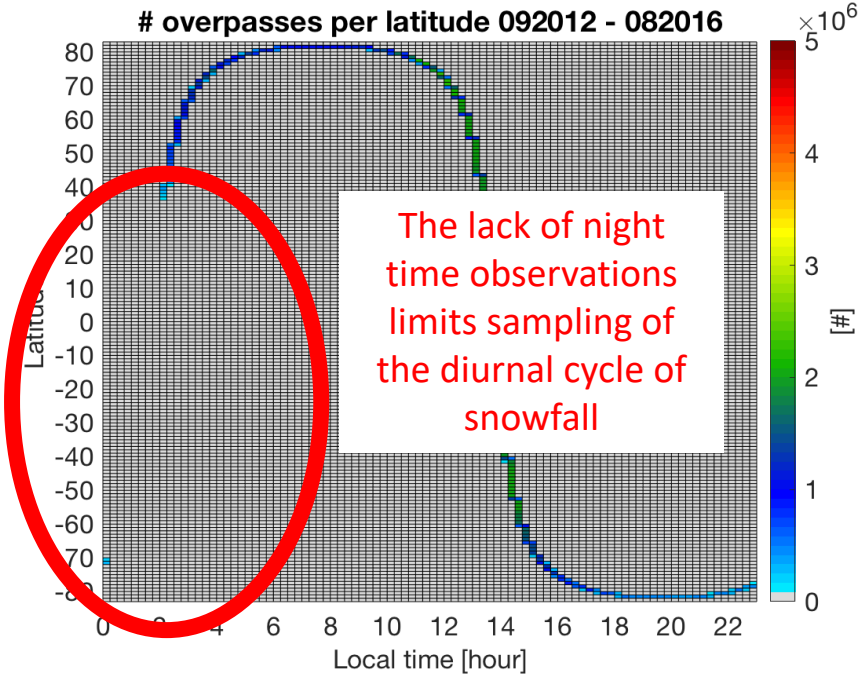


DO OP

Sampling issues: time



Full OP

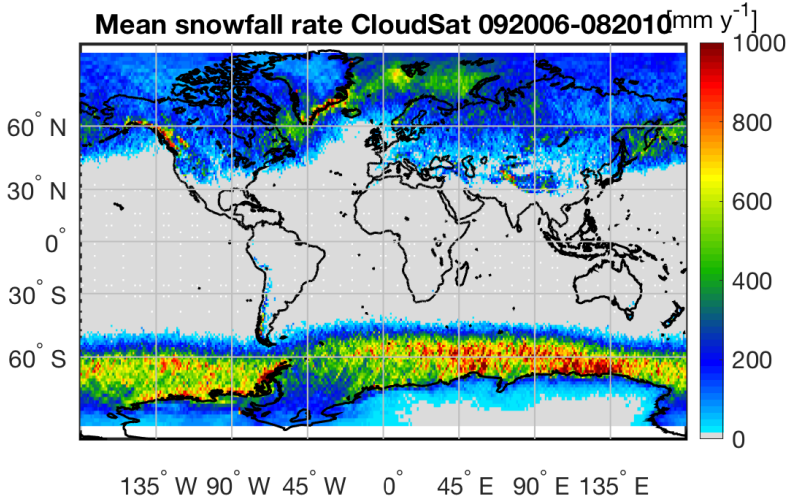


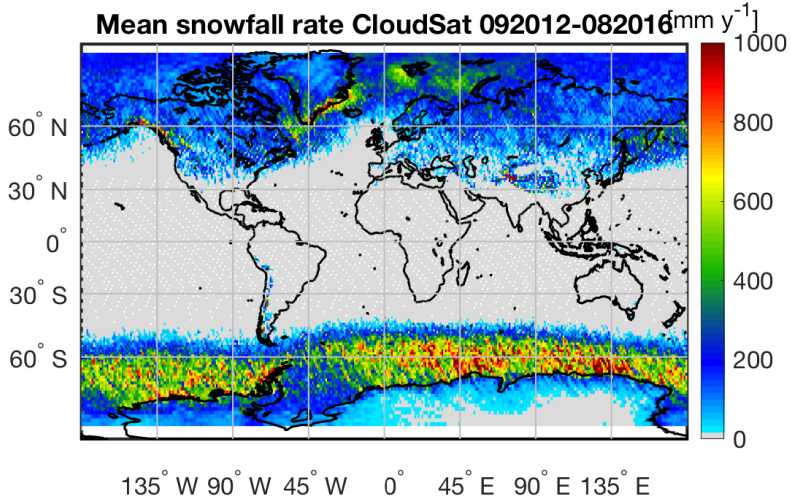
DO OP

Datasets used for this analysis:

- **Full OP:** 2006-2010
- **DO OP:** 2012-present
- **Full OP resampled:** Full OP data sampled as the DO OP dataset
- **Full OP complementary resampled**: Full OP profiles excluded from the resampled dataset

Mean Snowrates





Full OP

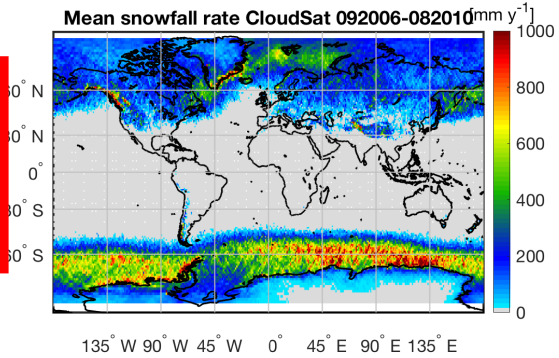
74.65 mmy^{-1}

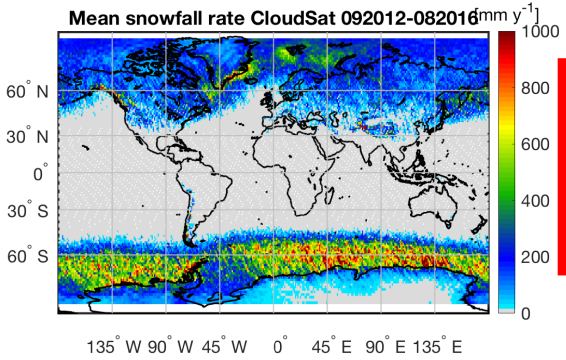
DO OP

68.52 mmy^{-1}

Mean Snowrates

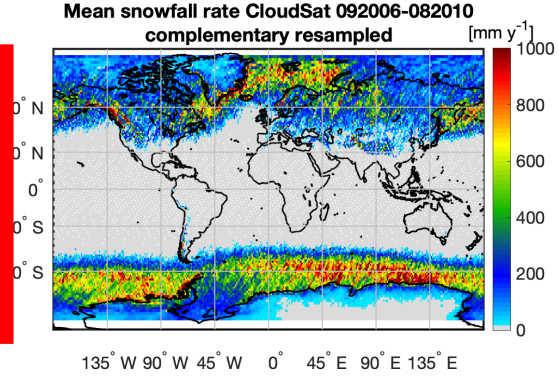
Full OP
74.65 mmy^{-1}

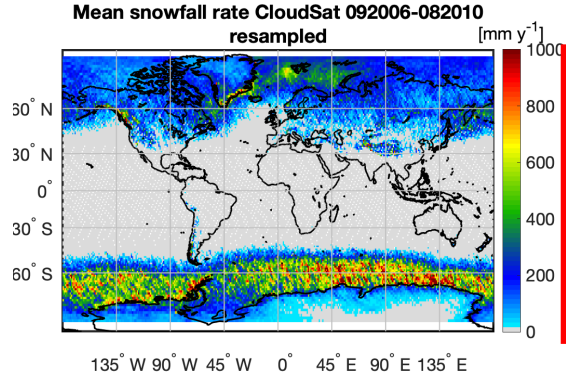




DO OP
68.52 mmy^{-1}

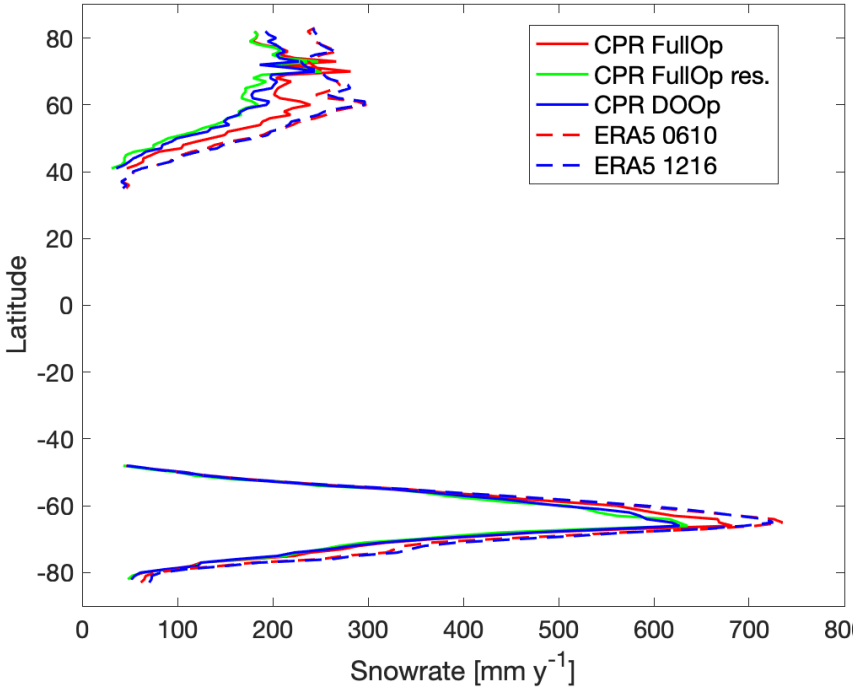
Full OP
Complementary resampled
91.09 mmy^{-1}

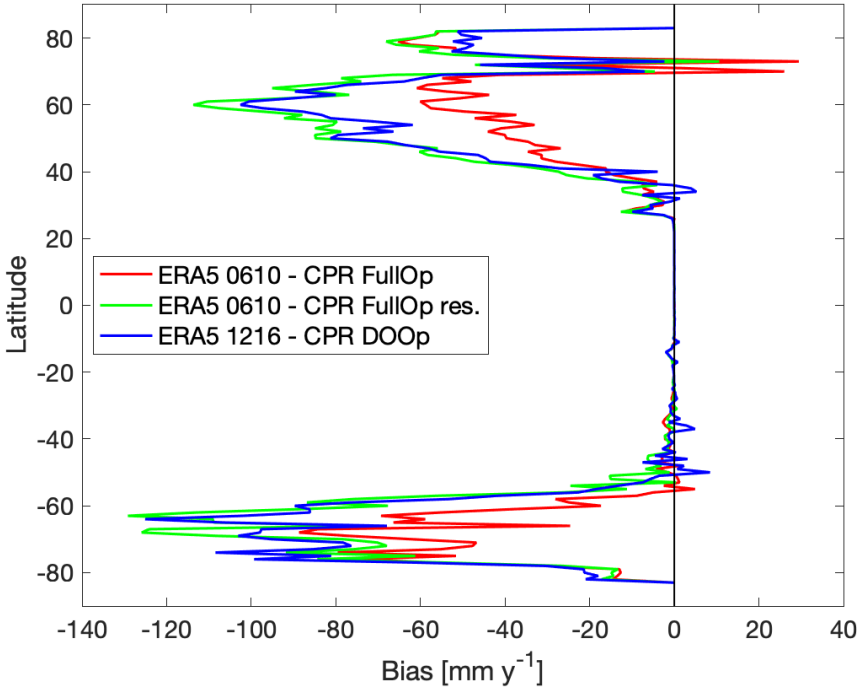




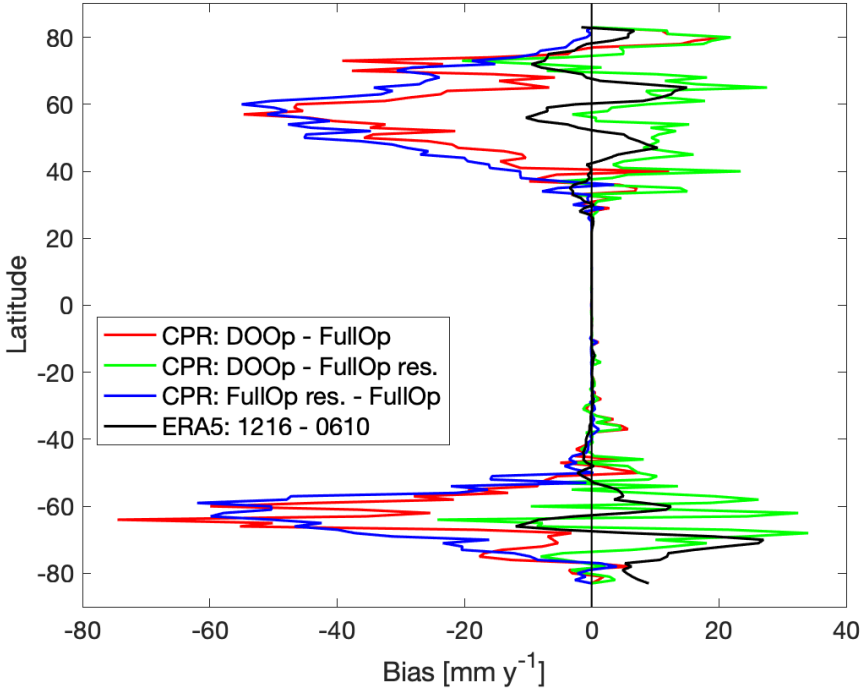
Full OP
resampled
65.52 mmy^{-1}

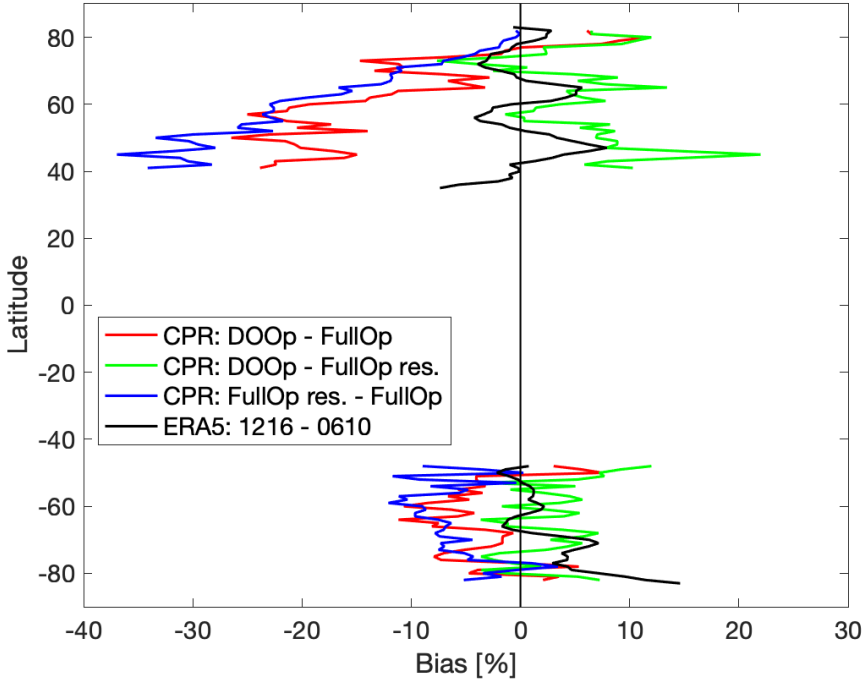
Latitudinal means





Bias

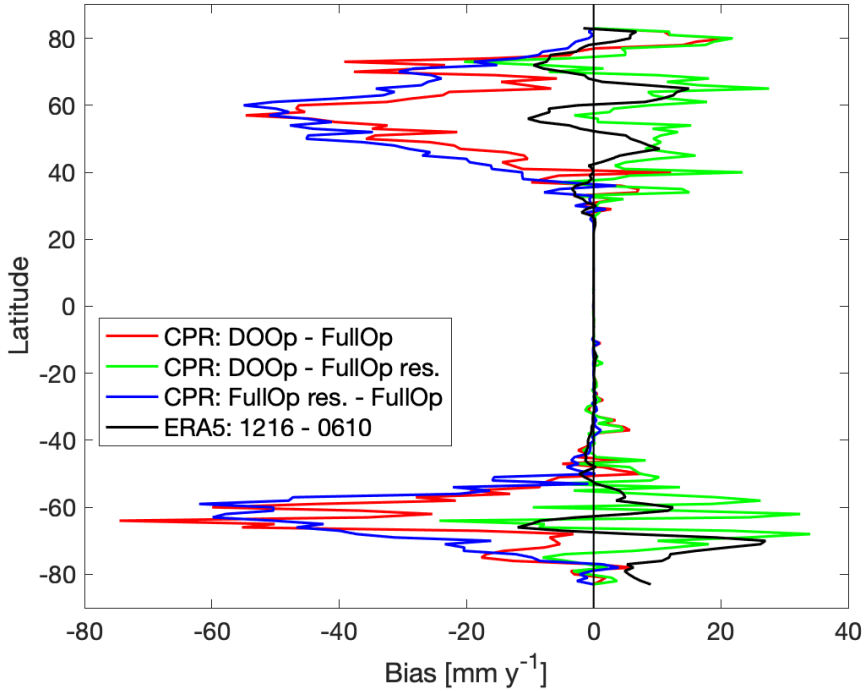

Latitude
Bias [mm y^{-1}]
CPR: DOOp - FullOp
CPR: DOOp - FullOp res.
CPR: FullOp res. - FullOp
ERA5: 1216 - 0610

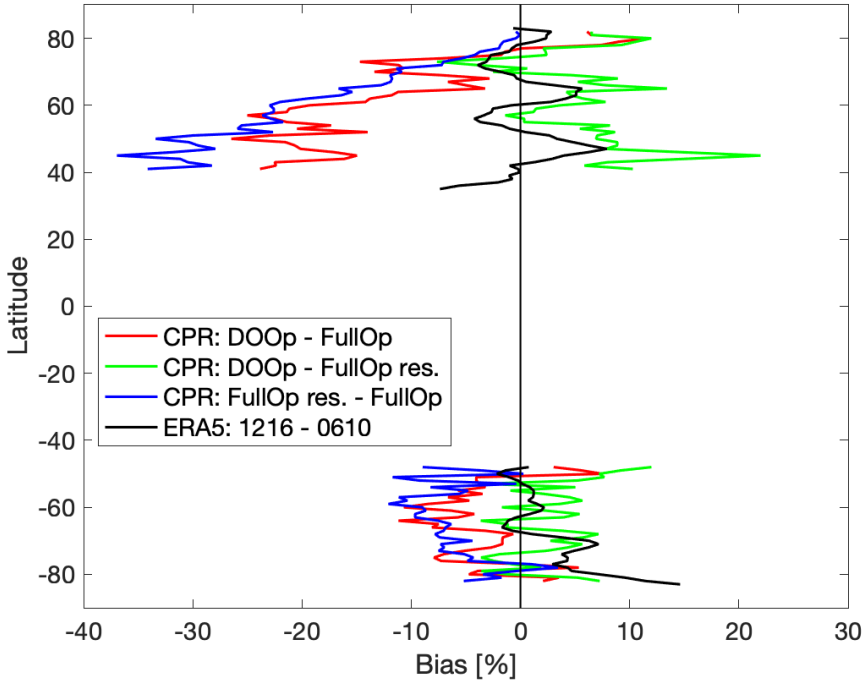

Latitude
Bias [%]
CPR: DOOp - FullOp
CPR: DOOp - FullOp res.
CPR: FullOp res. - FullOp
ERA5: 1216 - 0610

BLUE BIAS: under sampling of DO OP with respect to Full OP (latitudinal and time sampling issues)

RED BIAS: under sampling and precipitation variability between the two periods

GREEN BIAS: precipitation variability between DO OP and Full OP (mostly diurnal snowfall)





Conclusions

- CloudSat has **two operational periods**:
  - Full OP 2006-2010
  - DO OP 2012-present
- DO OP shows **-46% profiles** compared to Full OP
- The differences are **spatial and temporal**
  - **Spatially**: considering ascending vs. descending orbits and seasons, DO OP experiences up to **-88% observations** within a 4 years period
  - **Temporally**: DO OP has **no observations at all between 00 and 02** (local time) and very few between 18 and 00.

Conclusions

- **Global mean snowfall** values are:
  - 8.2% lower in the DO OP compared to Full OP
  - 12.23% in the Full OP resampled when compared to Full OP
- Latitudinal means can reach **biases up to 26%** around 50°N
- **Antarctica is** completely **missing** for austral winter DO OP

- **Be really careful when comparing CloudSat precipitation data** (but also other CloudSat data) **after 2011 because** besides all the well known issues when making comparisons between different sensors or between observations and models (spatial and temporal resolution, sampling, sensitivity of the sensor, algorithm assumptions, etc.) **the Daylight Only Operational Mode has non negligible impacts on results.**

Thank you!

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