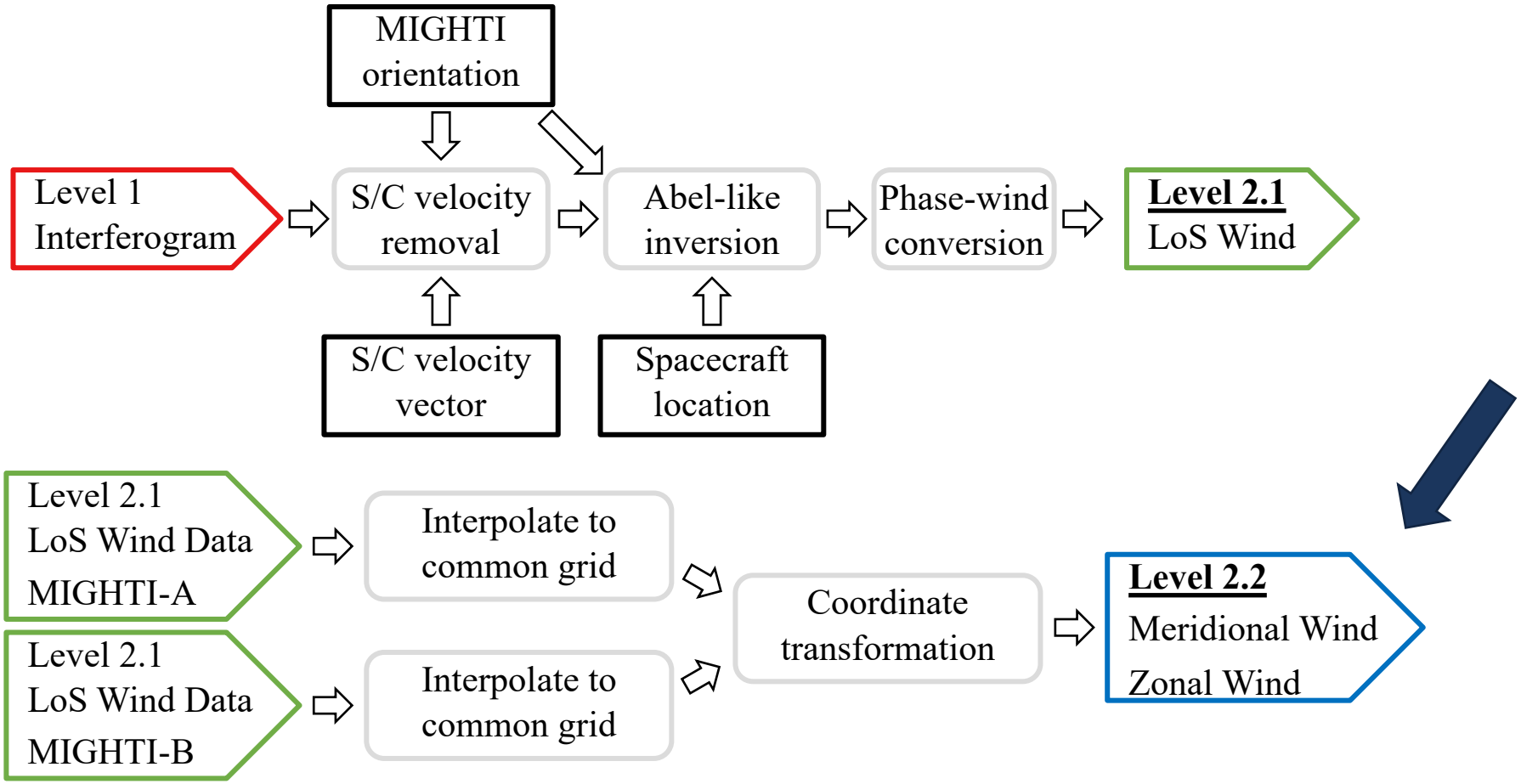
ICON/MIGHTI winds tutorial

Brian Harding
Space Sciences Lab, University of California, Berkeley
bharding@ssl.berkeley.edu

Christoph Englert[2], John Harlander[1], Kenneth Marr[2], Michael Stevens[2], Jonathan Makela[3], and ICON Team

[1]Space Systems Research Corp., [2]Naval Research Laboratory,
[3]University of Illinois – Urbana

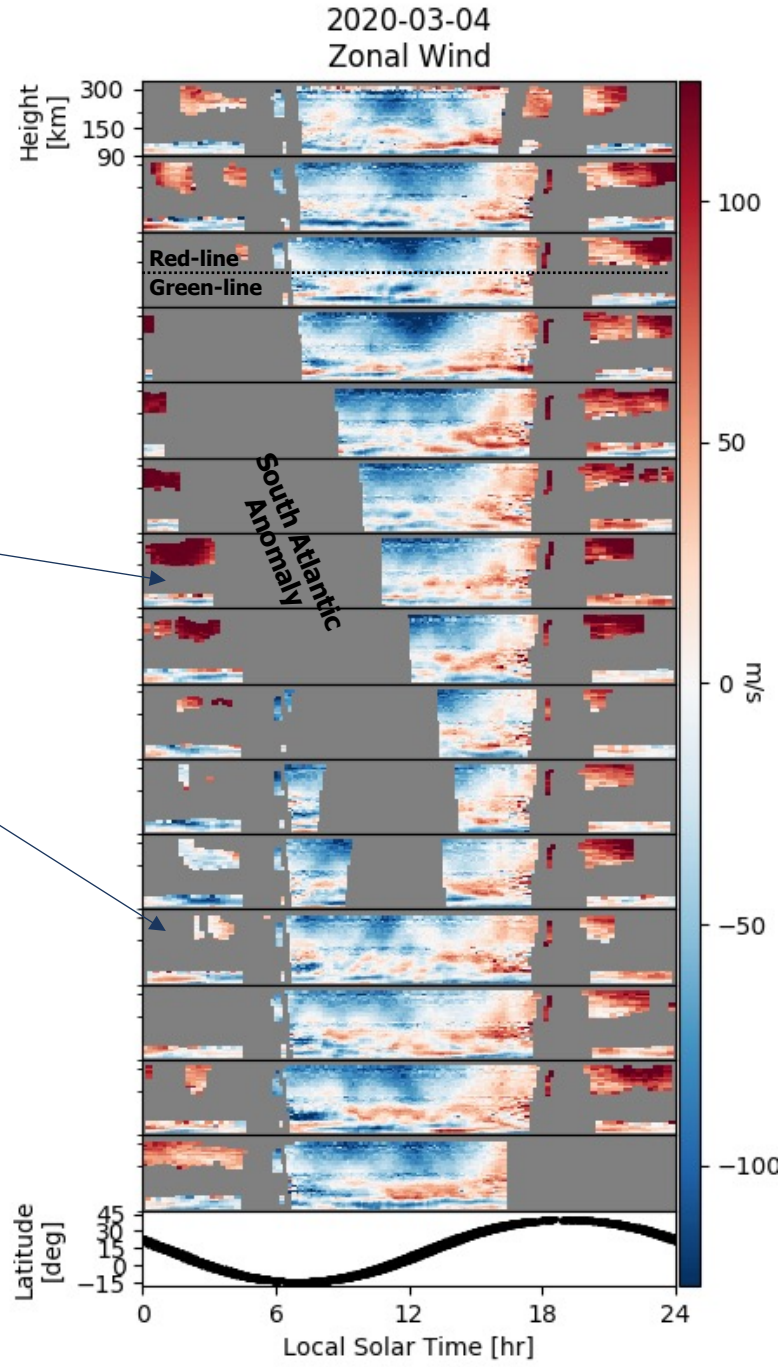
Level 2 wind data



- Primary data variables are **zonal and meridional winds** as function of altitude and time (which is also horizontal distance)
- Other variables include ***error*** (statistical/random error only), ***relative volume emission rate***, ***location***, ***quality flags***, etc.
    - See documentation for more details

Level 2 wind data

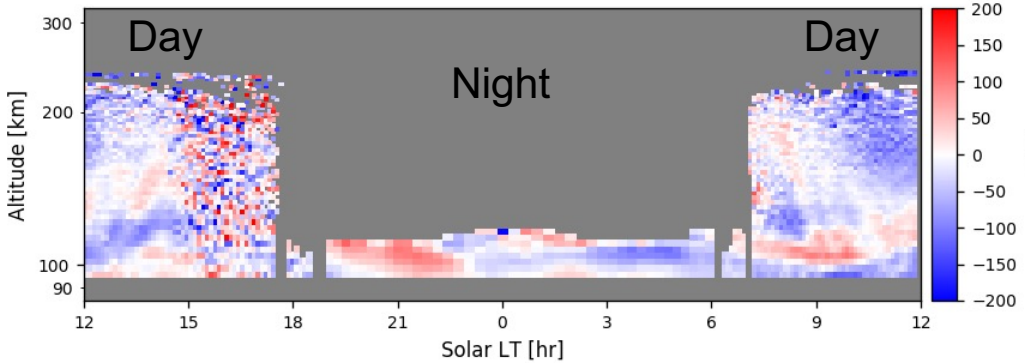
- Wind data are in two separate files:
  - Red line (~150-300 km altitude)
  - Green line (~90-200 km altitude)
- **Daytime**: contiguous coverage ~90-300 km
- **Nighttime**: data gaps
  - ~109 to ~210 km gap: No airglow
  - >210km missing/low-quality when red emission is too dim:
    - Near magnetic equator, especially after pre-reversal enhancement, penetration electric fields, or in ionospheric depletions
    - At midlatitudes when equatorward winds are strong
- Other data gaps:
  - Maneuvers (~20 min gaps)
  - One “safe mode” event (Feb 20-24)
  - South Atlantic Anomaly

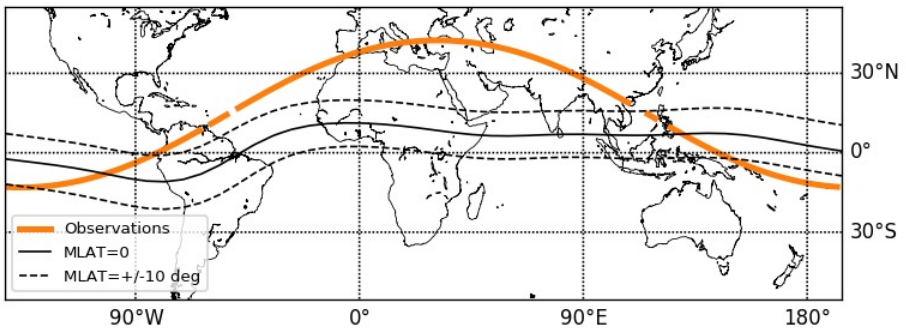


Quality flags

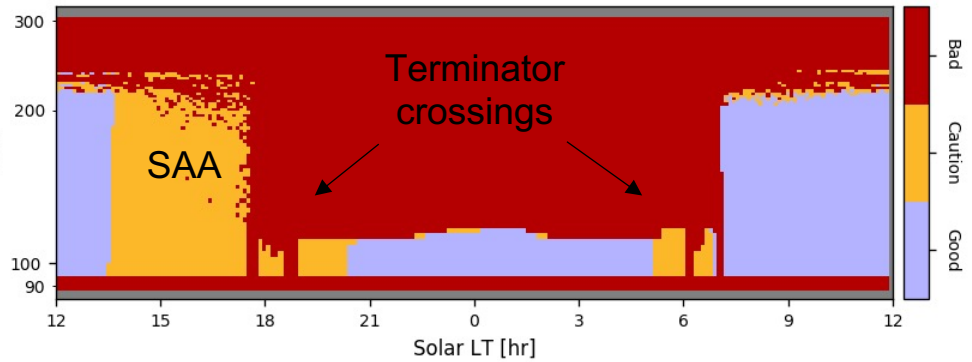
- Numerous quality flags are available, which inform an overall quality variable **ICON_L22_Wind_Quality**:
  - **0 = Bad** (data not available)
  - **0.5 = Caution** (data available)
  - **1 = Good** (data available)
- **Suggestion**: start with “Good” data and add “Caution” data if more coverage is needed
- Quality control algorithms continue to be refined

Green-line zonal wind



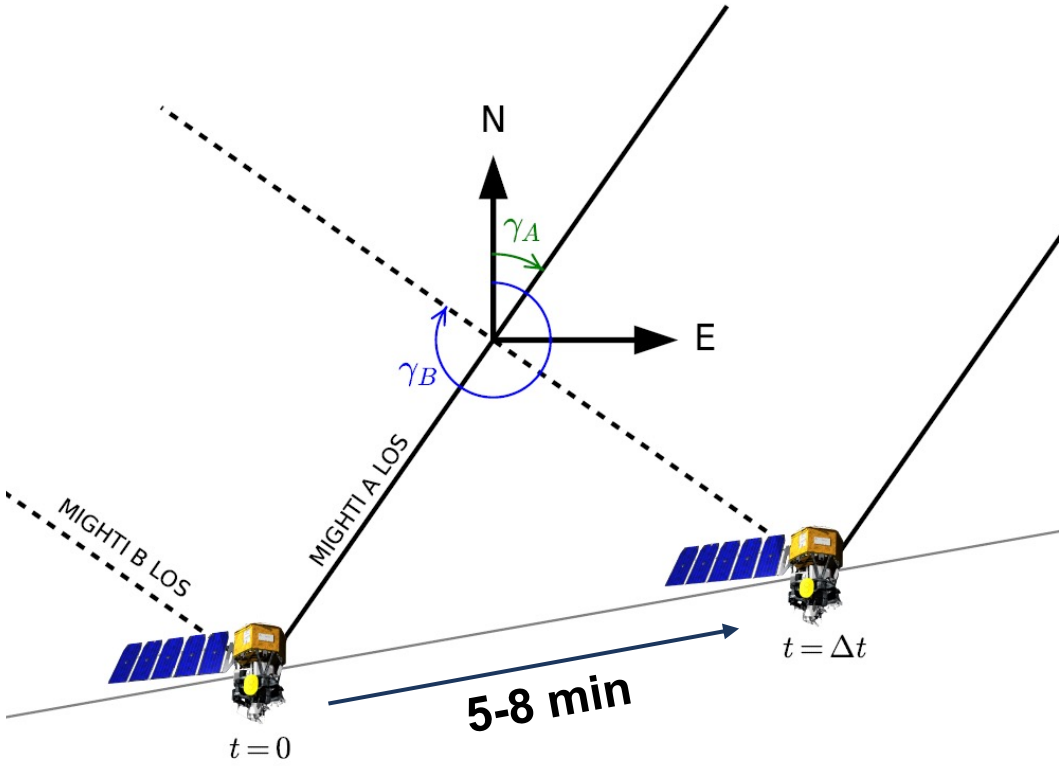


Wind Quality



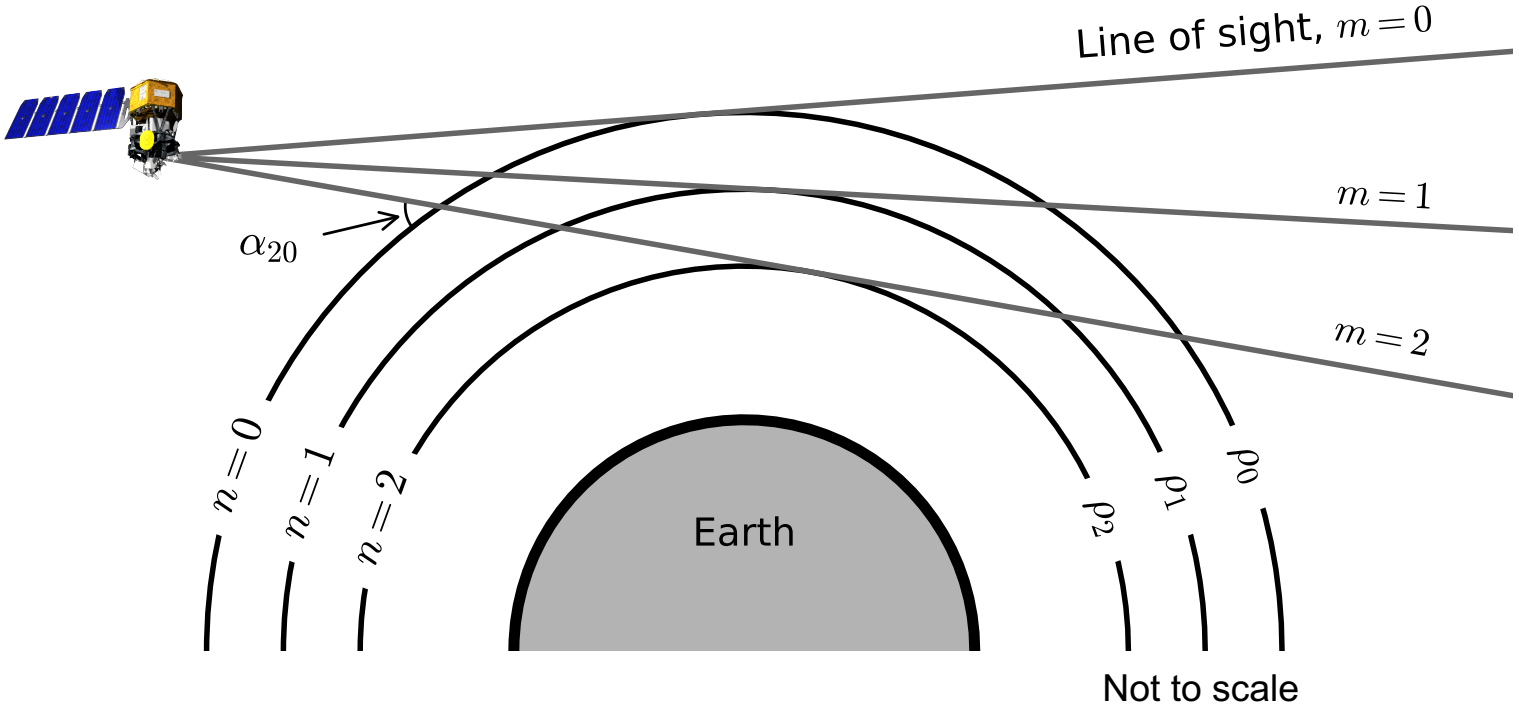
Temporal Resolution

- Daytime: **30 sec** sampling
- Nighttime: **60 sec** sampling
- Assumed stationarity over **5-8 minutes** needed for MIGHTI-A and MIGHTI-B to sample the same location.



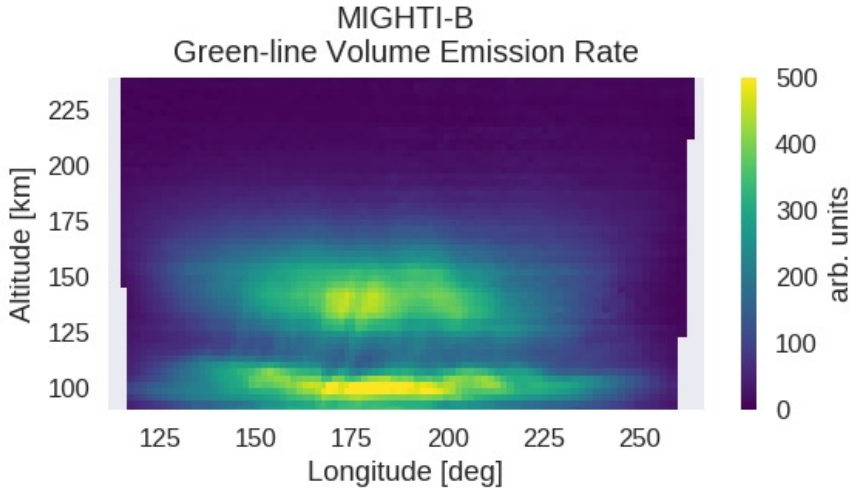
Vertical Sampling

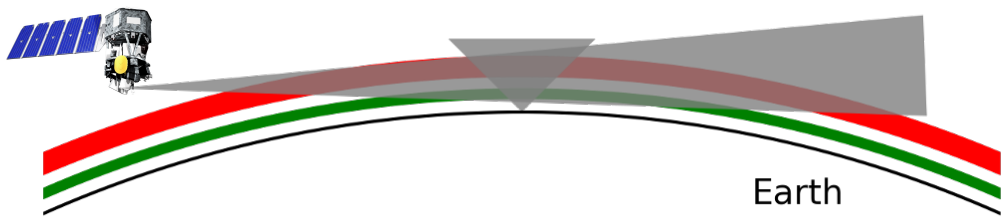
- **~3 km** altitude bins for green line (90 km - ~210 km)
- **~10 km** altitude bins for red line (150 km - 300 km)
- Vertical resolution is further limited by the inversion
- Vertical features will only be resolved if they are coherent horizontally across hundreds of km



Horizontal Sampling

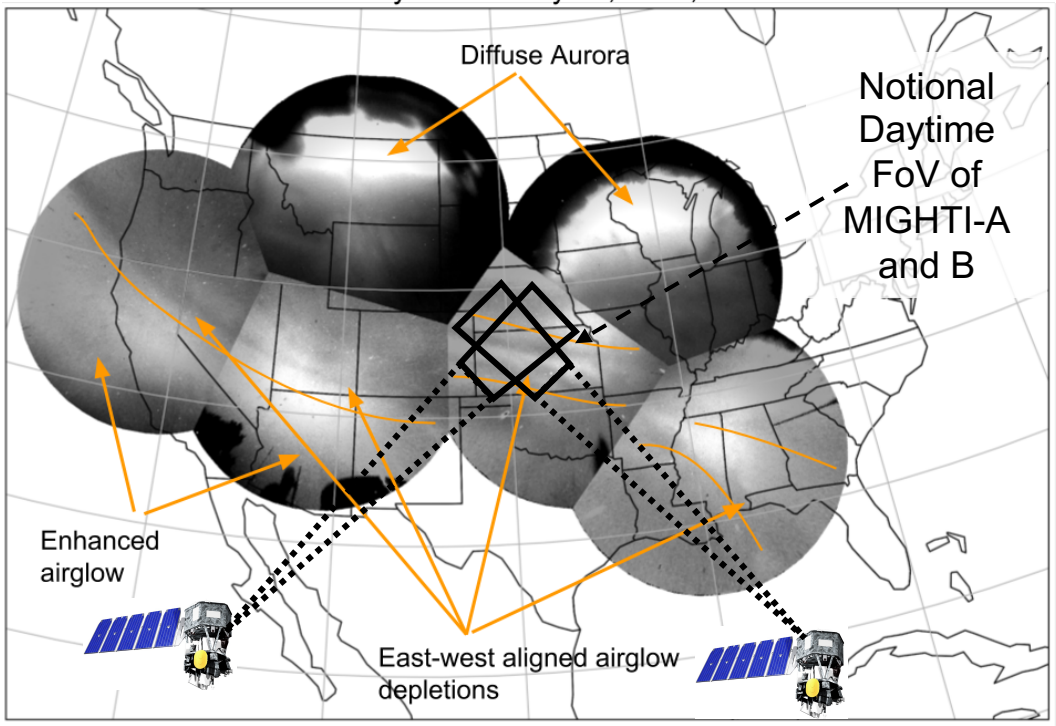
- Ability to resolve horizontal features is limited by:
  - Horizontal field of view: **~140 km**
  - Blur due to spacecraft motion: **~250 km** (day) or **~500 km** (night)
  - Line-of-sight integration: difficult to quantify – **hundreds of km**
- Nevertheless, significant structuring at the small/meso-scale is seen.
  - To quantitatively interpret these, careful consideration of observation geometry is needed





MANGO all-sky red-line cameras

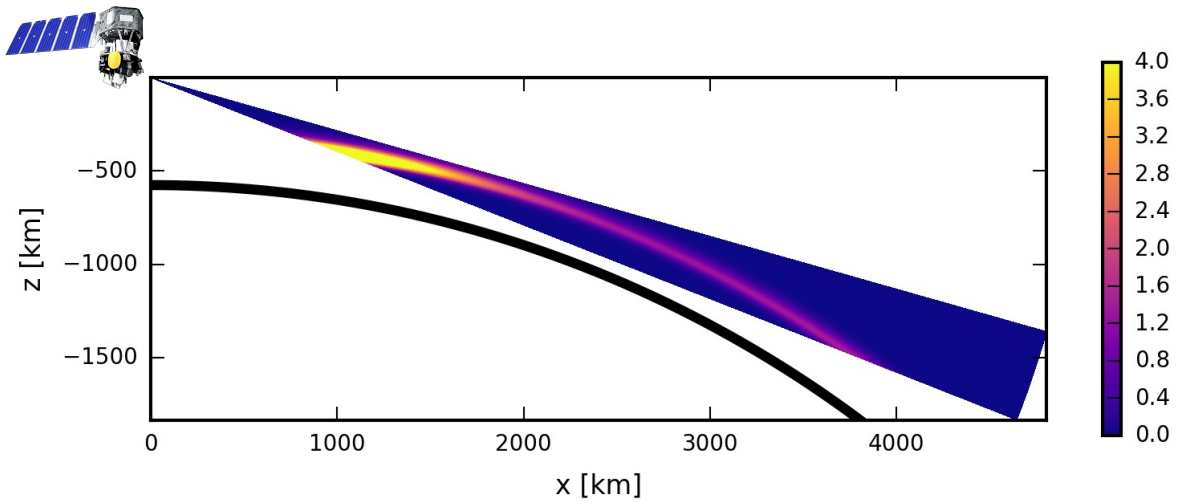
Memorial Day Storm: May 28, 2017, 0625 UT

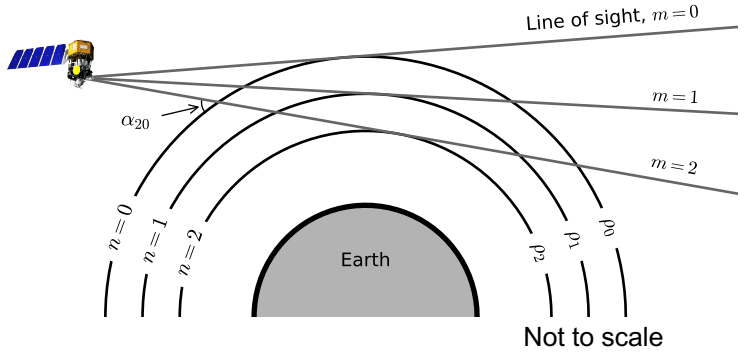


[Courtesy A. Bhatt and E. Kendall, SRI]

Local inhomogeneities

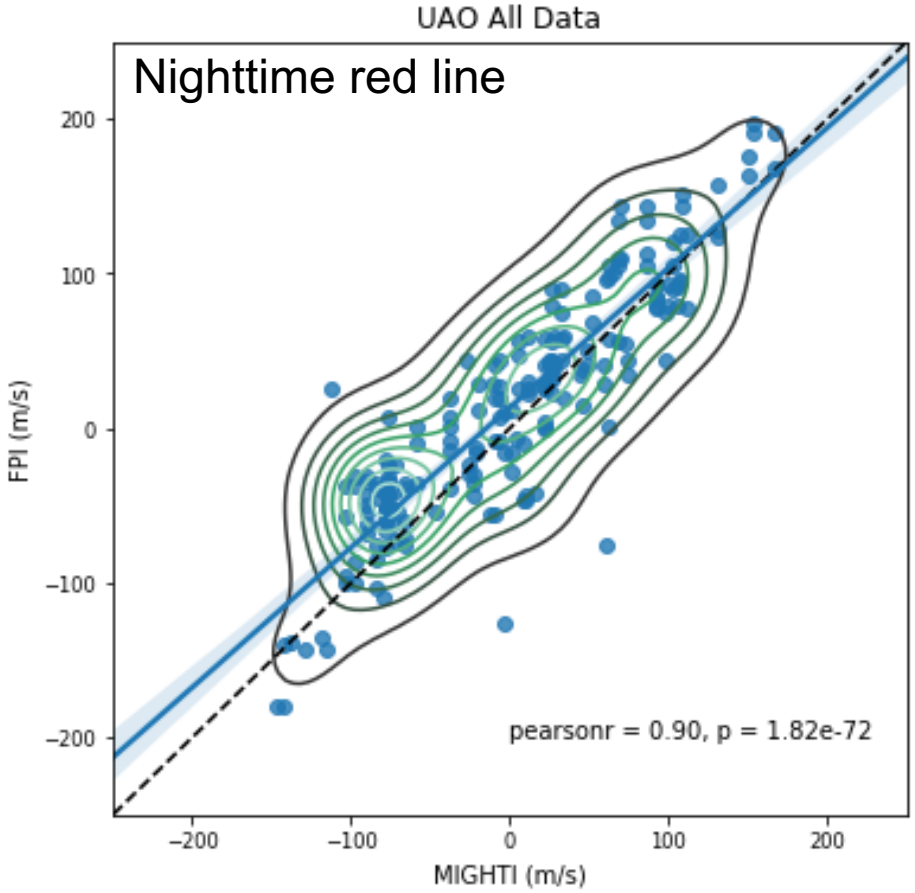
- The Abel-like inversion algorithm assumes that *locally*, winds and emission depend only on altitude, not on latitude/longitude.
  - This assumption fails **near sunset/rise**, and also occasionally in the **red line at night** (e.g., edge of equatorial ionization arc). Errors can be **10s of m/s**
- Where emission is smoothly varying, systematic errors are <2 m/s [*Wu et al.,* 2020, under review]
- We have developed an algorithm to try to detect data that may be affected by inhomogeneities – this will be included in a future release.



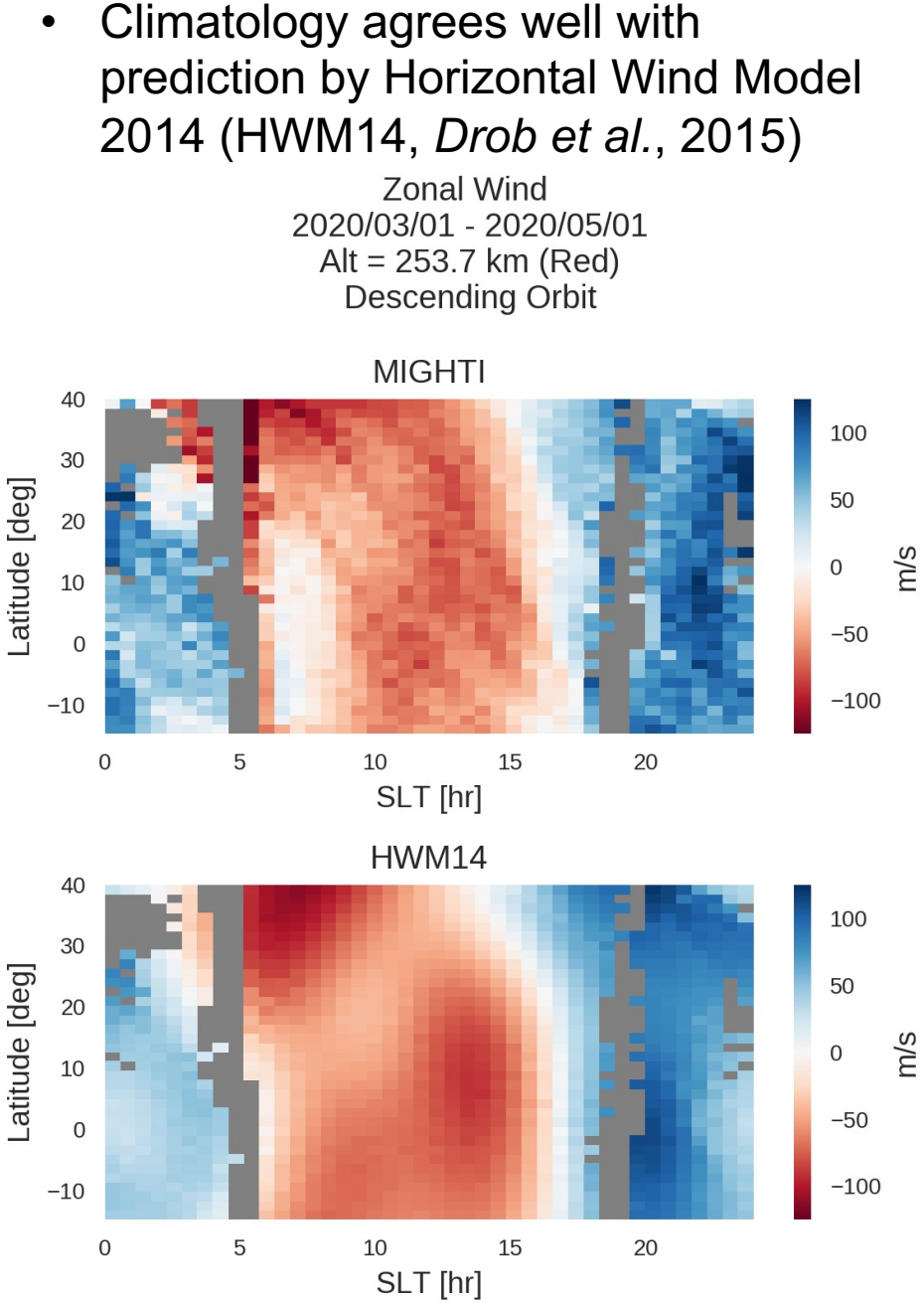


Validation

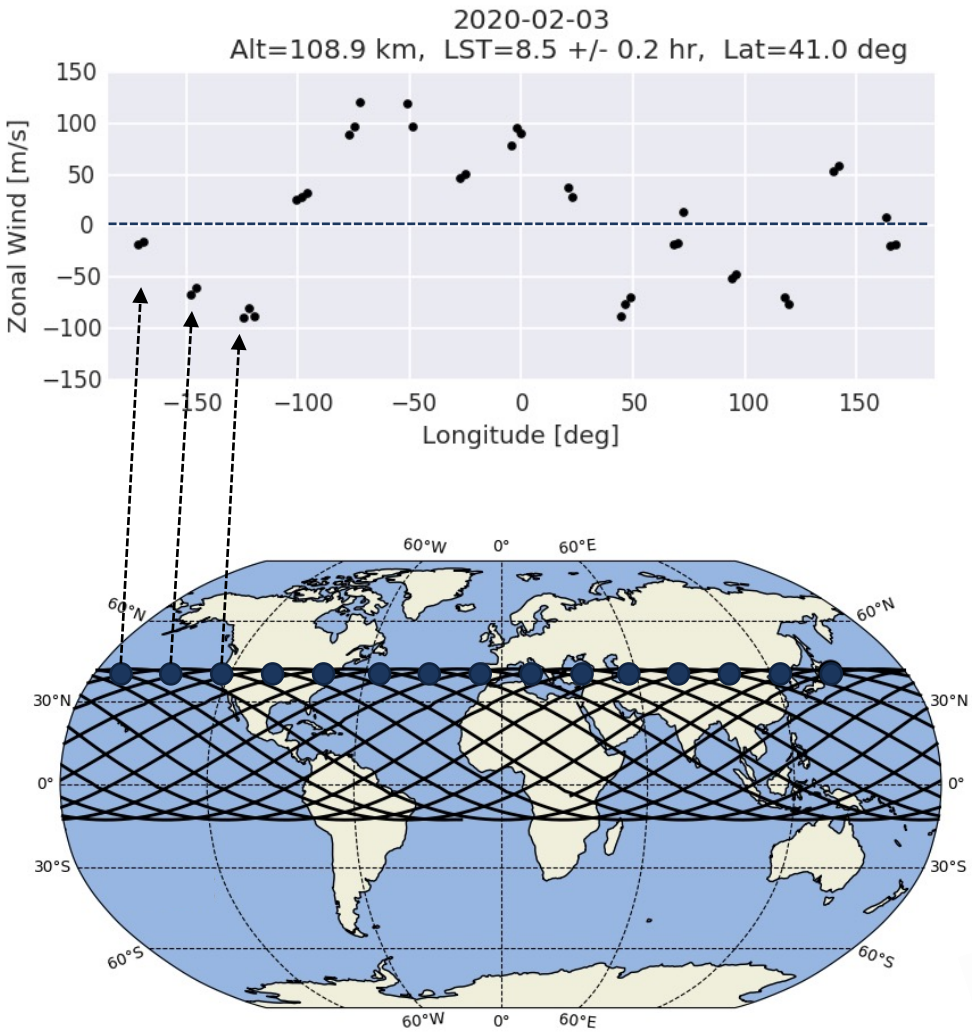
- Comparisons with ground-based Fabry-Perot interferometers (FPIs) show good agreement
  - 74 coincident observations with FPI in Urbana, IL (ρ=0.9)



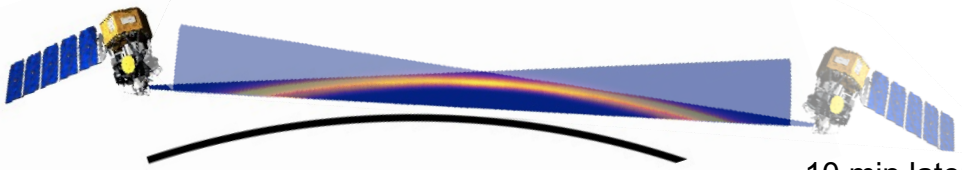
- Climatology agrees well with prediction by Horizontal Wind Model 2014 (HWM14, *Drob et al.*, 2015)



Zero wind and thermal calibration



- In the first released data set (v03) the “zero wind” baseline is set by comparing a 60-day average of data to a 60-day average of HWM14.
- As we learn more about how MIGHTI is performing on-orbit, we expect to adjust the zero baseline.
  - But likely not more than **~20 m/s**
- Errors in daily calibrations may create “jumps” in the zero baseline on day boundaries, estimated <~10 m/s, but outliers occasionally exist.
- **Most relative variations in time, latitude, longitude, and from day to day will not change in future updates**
- Work in progress: use on-orbit “zero wind maneuver” to self-calibrate



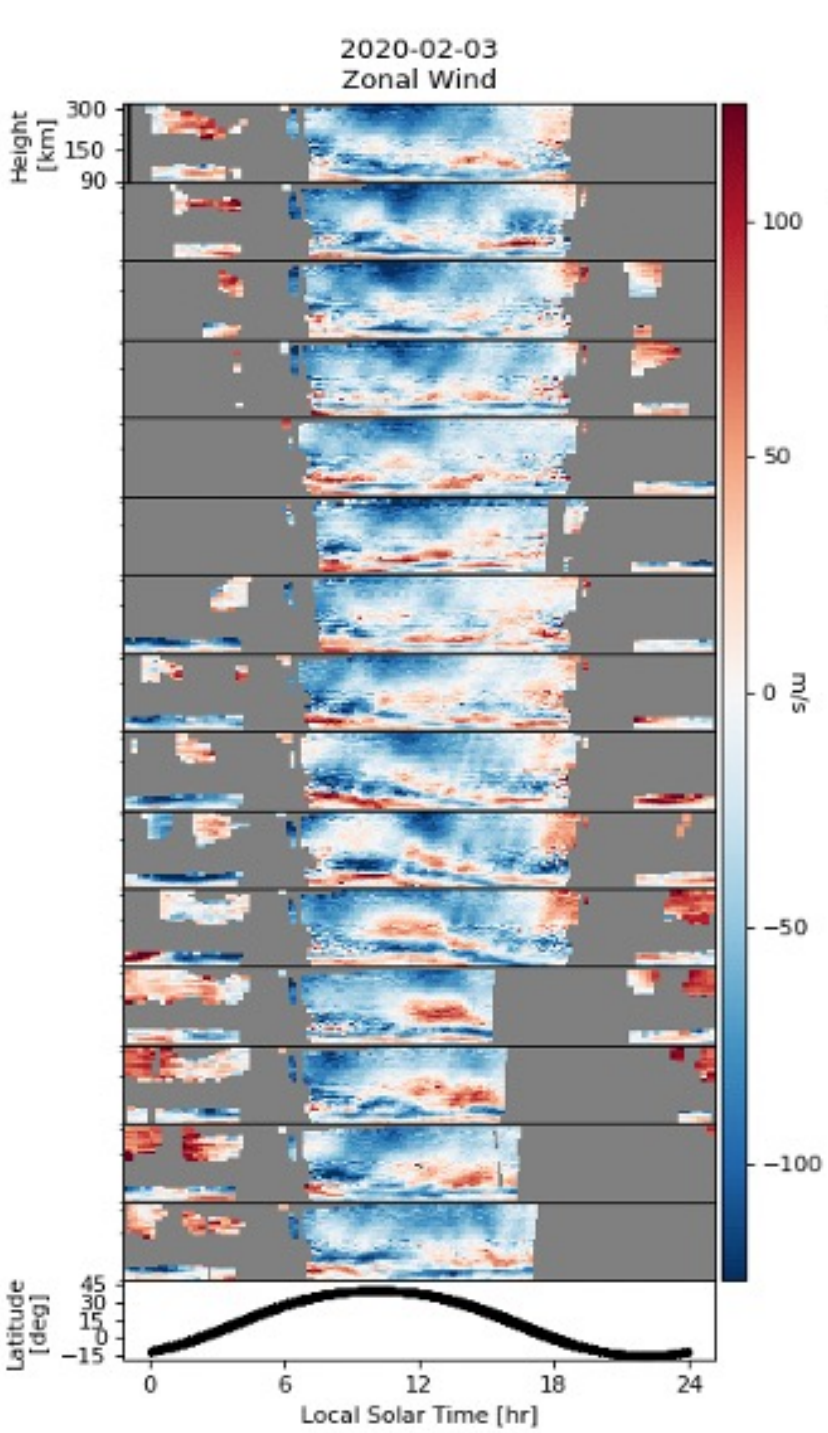
Documentation

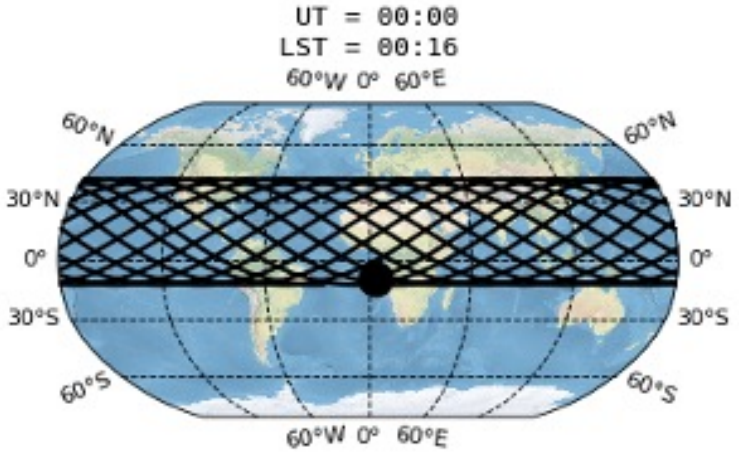
See documentation for more details on known issues:

https://icon.ssl.berkeley.edu/Data

- Known issues with the initial data release (labeled v03) are listed below. These issues are expected to be resolved in future data releases. In future releases, some data points may change by up to 50 m/s, but most changes are expected to be much smaller. Future updates to the "zero wind phase" (discussed in detail in the notes for the wind variable) will change the winds by a bulk offset, but most relative variations in time, latitude, longitude, and from day to day will remain.

- **Known issues with v03**:
  - Some artifacts from preliminary calibrations are present (e.g., thermal instrument drift, detector flat field, and fringe visibility correction). These manifest as artificial offsets that affect a single altitude or a single local solar time, persisting for an entire UT day.
  - The quality flag indicating contamination by the South Atlantic Anomaly is too conservative, so some high-quality data points are given a lower quality factor.
  - The reported wind error includes the effect of dark, read, and shot noise in the observations, but does not include calibration uncertainty. It is likely that a future release will revise the reported error upward by approximately 50%.
  - The bottom two rows of data (corresponding to altitudes of ~88 and ~91 km) are masked out pending updated calibrations. These rows are near the edge of the field of view and not all columns are illuminated, which requires special consideration.
  - Airglow brightness observations are not a required mission product, and no effort was yet made to absolutely- or cross-calibrate the brightness observations for MIGHTI-A and MIGHTI-B, and thus the Relative_VER variable should be treated with caution.
  - A calibration lamp is used for one orbit per day to assess the periodic thermal drift of MIGHTI. This is used to correct all other observations that day. In v03 data, the thermal drift is ascribed entirely to interferometer drift, but some fraction is due to mechanical drift. This will be corrected by using the observed drift of the fiducial notches. The error in the current approach is estimated to be less than 10 m/s.
  - During the one orbit per day when the calibration lamp is on, the wind data are noisier and a slight bias is evident. For this release, these orbits have been labeled with quality=0.5 (i.e., caution). Work is underway to remove this restriction.
  - The top 3-5 rows of the red channel are experiencing a long-term drift relative to other rows. The error is estimated to be zero on 2020-02-01 and approximately 50 m/s on 2020-05-15, for both MIGHTI-A and MIGHTI-B. Users should use caution with data above 273 km. This artifact has been identified as an uncorrected drift in the phase distortion and will be corrected in a future release.





Conclusion

- Use quality flags
- Consider resolution (temporal, vertical, and horizontal averaging)