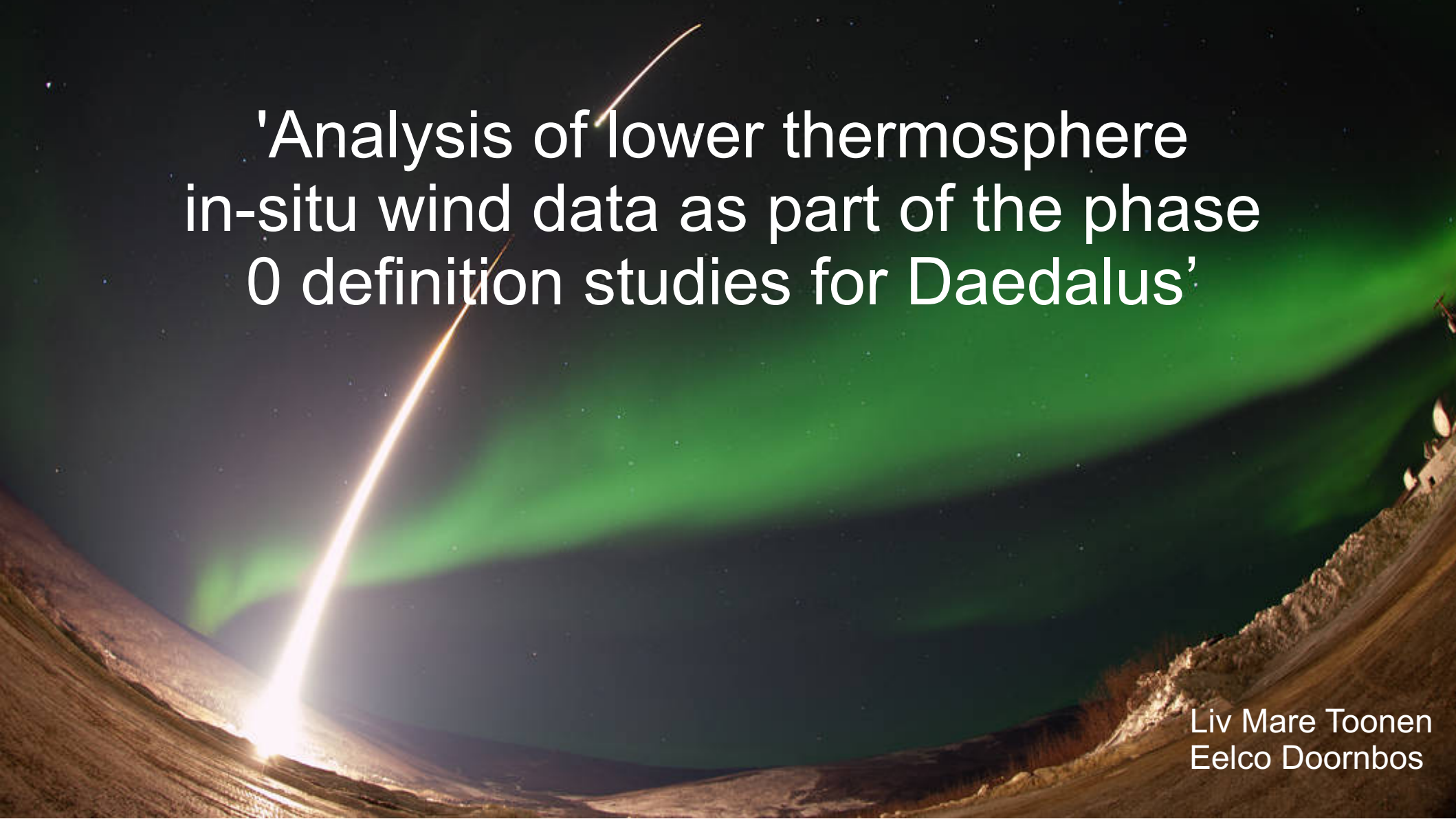
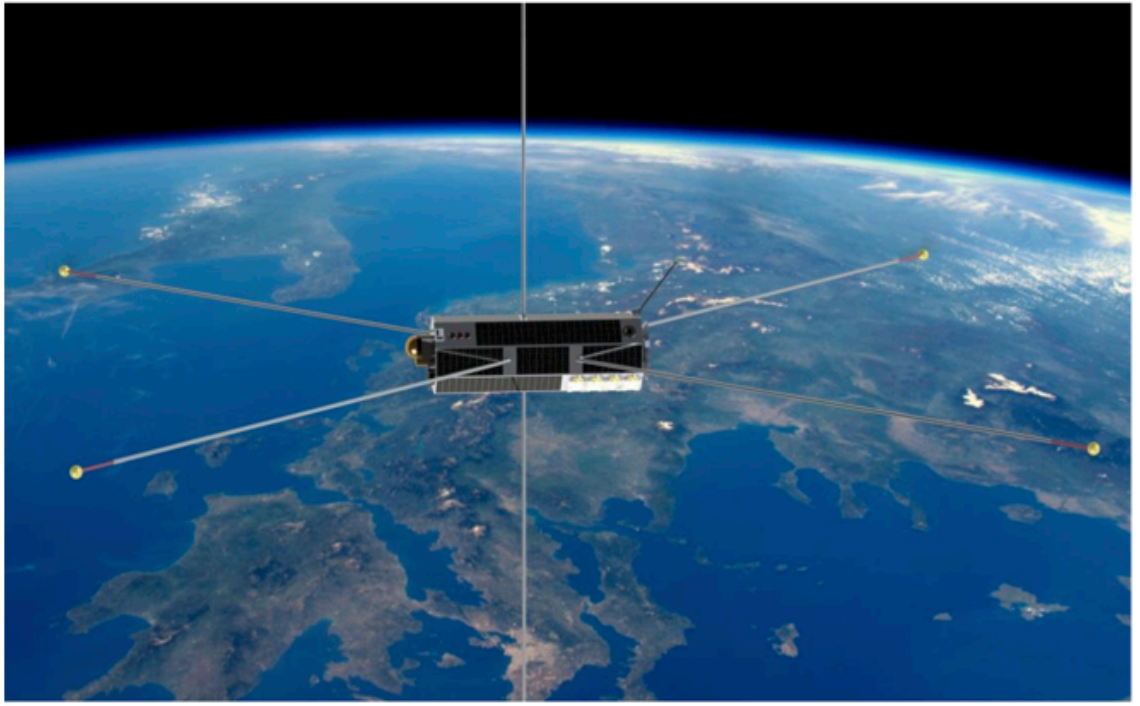
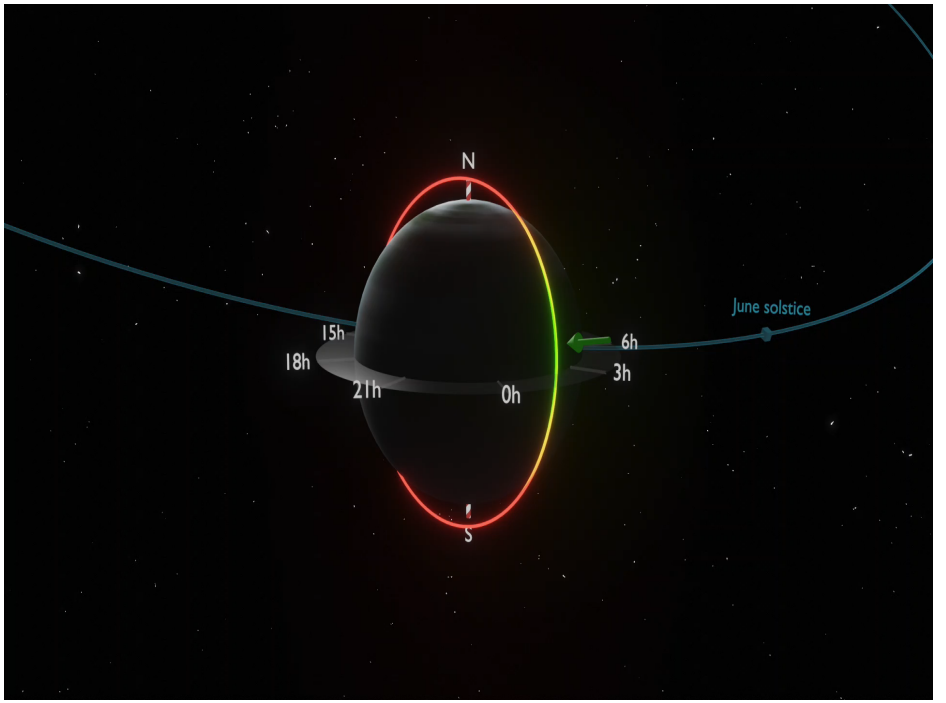


'Analysis of lower thermosphere in-situ wind data as part of the phase 0 definition studies for Daedalus'

Liv Mare Toonen
Eelco Doornbos

Daedalus – a candidate for the 10th ESA Earth Explorer mission





For more information: Sarris et al., 2020
https://doi.org/10.5194/gi-9-153-2020

Table 2. List of Daedalus instruments, measurements, estimated dynamic ranges, accuracies and sensitivities.

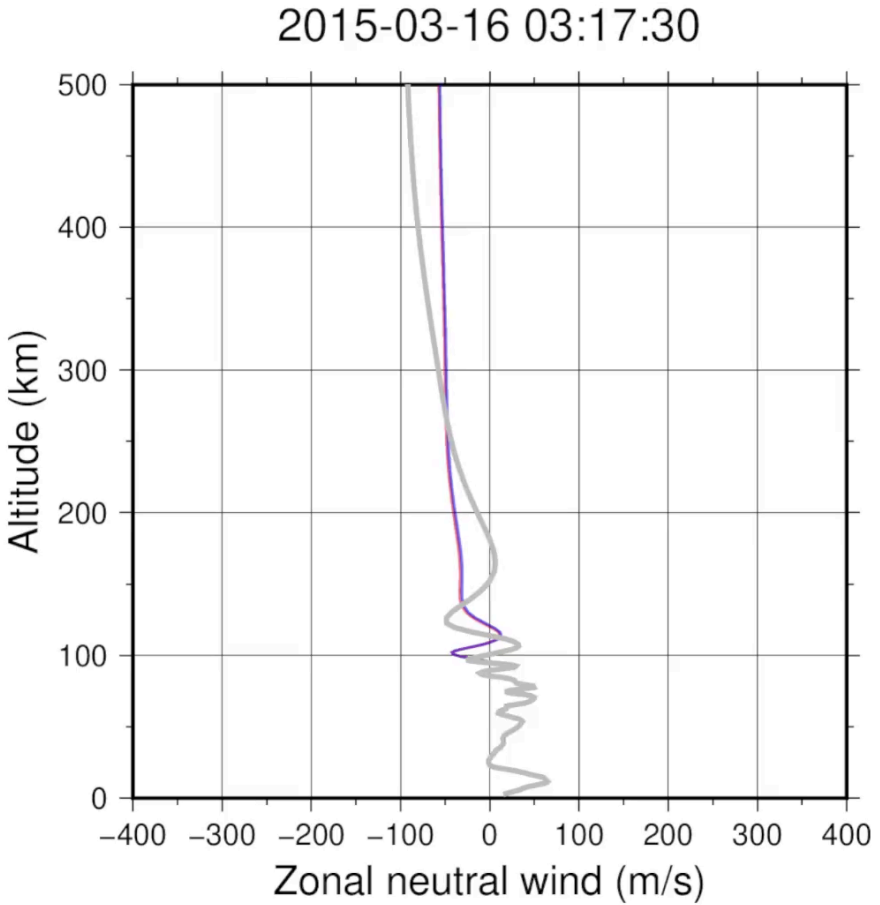
https://doi.org/10.5194/gi-9-153-2020

Instrument	Measurement	Dynamic range	Accuracy, sensitivity
Ion Drift Meter (IDM) and Retarding Potential Analyzer (RPA) or Thermal Ion Imager (TII)	Ion drifts Ion density Ion temperature	$\pm 4\,\mathrm{km\,s^{-1}}$ (along-track and cross-track)	$100\,\mathrm{m\,s^{-1}}$ (along-track and cross-track)
Ram Wind Sensor (RWS) and Cross-track Wind Sensor (CWS)	Ram neutral winds Cross-track neutral winds Differential pressure Neutral temperature	$\pm 1\,\mathrm{km\,s^{-1}}$ (along-track and cross-track)	Accuracy $\pm 10\,\mathrm{m\,s^{-1}}$, sensitivity $\pm 3\,\mathrm{m\,s^{-1}}$ (along-track) Accuracy $\pm 5\,\mathrm{m\,s^{-1}}$, sensitivity $\pm 2\,\mathrm{m\,s^{-1}}$ (cross-track)
Accelerometer (ACC)	Neutral density Wind velocity Thrust of propulsion syst.	$10^{-7}g$ to $10^{-3}g$	Accuracy $\pm 10\,\%$ at 500 km, $\pm 2\,\%$ below 200 km Sensitivity $10^{-7}g$, $\pm 3\,\%$ max systematic error due to uncertainty in drag coefficient
Energetic Particle Detector Suite (EPDS), including the High Energy Instrument (HEI), Low Energy Instrument (LEI) and Energetic Neutral Atom (ENA) instrument	HEI: relativistic electrons, protons, heavy ions LEI: low-energy electrons, ions ENA: energetic neutral atoms	HEI: 10^1–10^6 counts per second LEI: 10^6–5×10^9 eV $(\mathrm{cm^2\,sr\,s\,eV})^{-1}$ ENA: energies 5–200 keV, fluxes 10^2–2×10^6 $(\mathrm{cm^2\,sr\,s})^{-1}$	HEI: accuracy $\leq 20\,\%$ LEI: accuracy $\leq 20\,\%$ for electron energy fluxes above 10^6 eV $(\mathrm{cm^2\,sr\,s\,eV})^{-1}$ ENA: energy resolution of at least 15 keV, flux to better than 20 % for fluxes above 2000 $(\mathrm{cm^2\,sr\,s})^{-1}$
Ion Mass Spectrometer (IMS) and Neutral Mass Spectrometer (NMS)	Ion composition (IMS) Neutral composition (NMS) Relative density	Mass range: 1–50 amu Ions: H^+, He^+, N^+, O^+, NO^+, O_2^+, CO_2^+ Neutrals: H, He, N, O, N_2, NO, CO_2 Density dynamic range: Ions: $\sim 10^2$–$10^7\,\mathrm{cm^{-3}}$ Neutrals: $\sim 10^4$ to $10^{13}\,\mathrm{cm^{-3}}$ Temperature range: 200–2000 K	Mass resolution accuracy M / dM: ~ 30 Mass resolution sensitivity: 1 amu Relative density resolution accuracy: 1 %–10 % (TBD) Relative density resolution: 1 %

Dual-satellite option under investigation

Vertical profiles at satellite latitude and longitude
Thin red/blue lines: TIE-GCM 2.0
Grey line: WACCM-X 2.1

Red/blue dots: TIE-GCM sampled at satellite altitude
Red: Satellite A (perigee 150 km)
Blue: Satellite B (perigee 200 km)

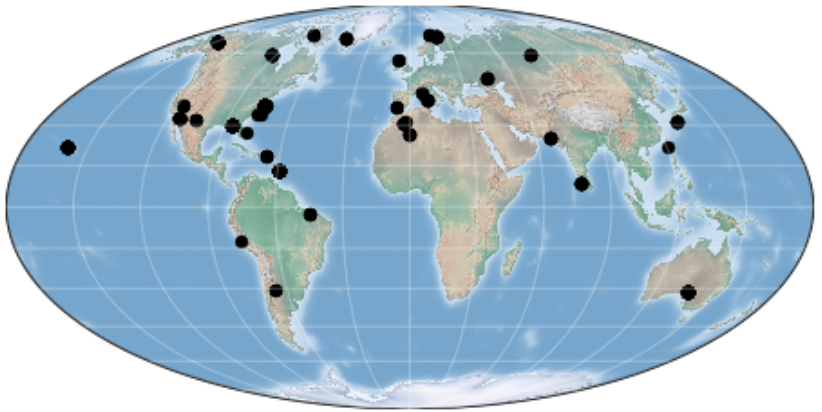


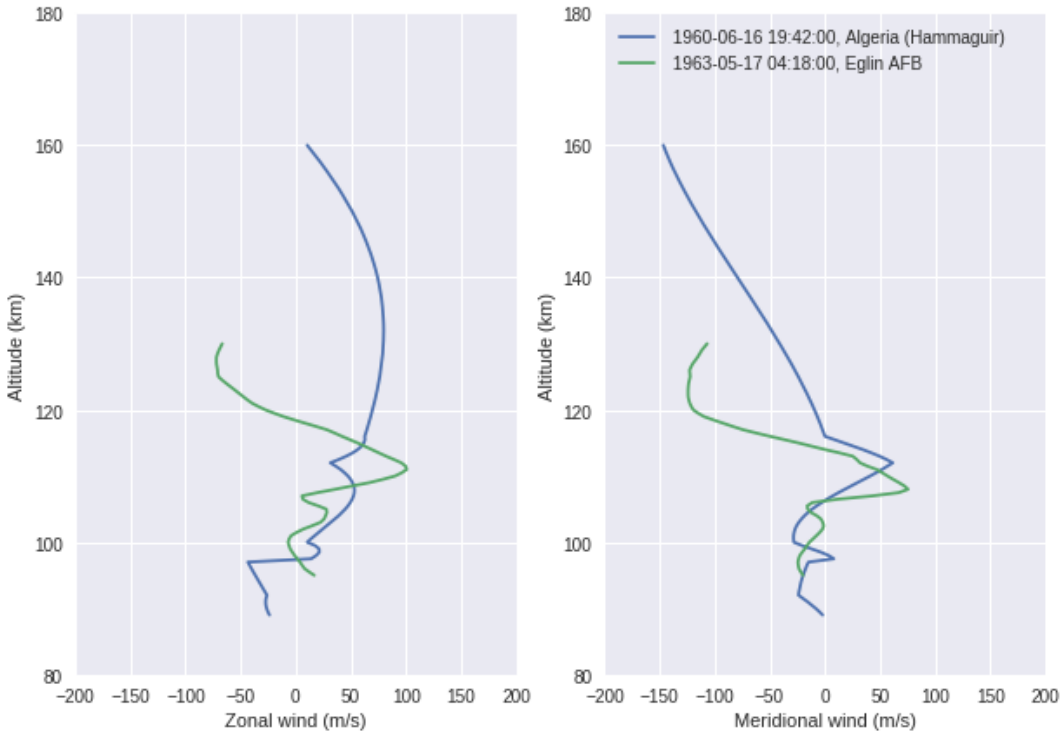
Research questions

1. Identify the overlap and gaps in coverage of in-situ wind data at 100-250 km altitude
2. What are the highest horizontal winds and shears that can be found in this data? When and where can they be expected?
3. What are the advantages and limitations of the use of models (in this case HWM14) in the mission definition.

Sounding rocket chemical tracer (CT) data

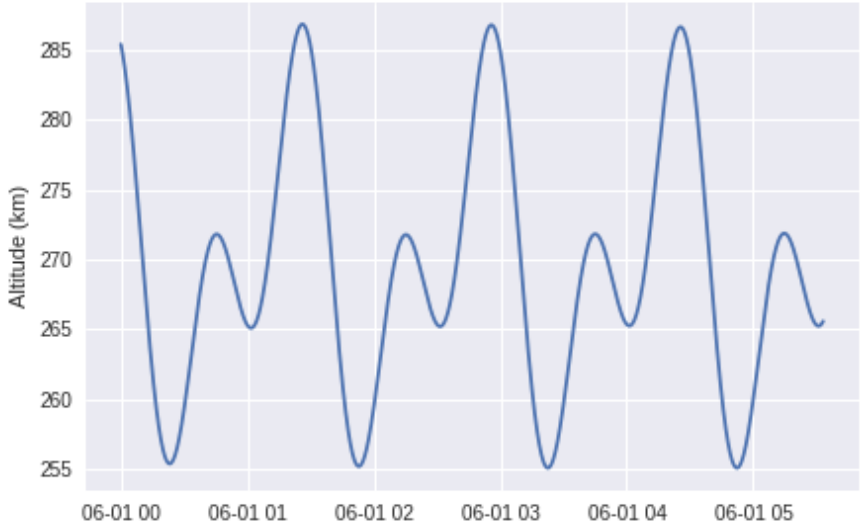
- Data courtesy of Miguel Larsen (Clemson Univ)
- 565 runs (1955-2009)
- 35 locations





GOCE accelerometer data:

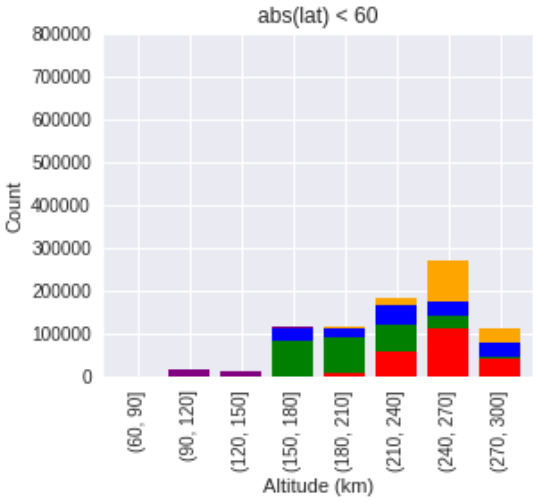
- Cross-track wind derived from accelerations
- Science phase
  - Nov 2009-Oct 2013
  - ~230-270 km
- Deorbit phase
  - 22 Oct 2013-11 Nov 2013
  - ~170-230 km



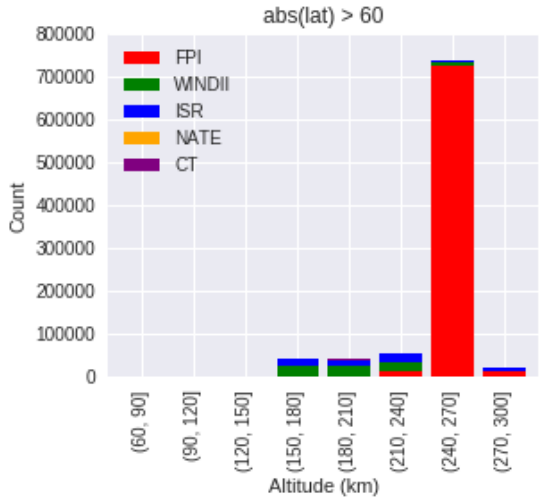
Altitude coverage

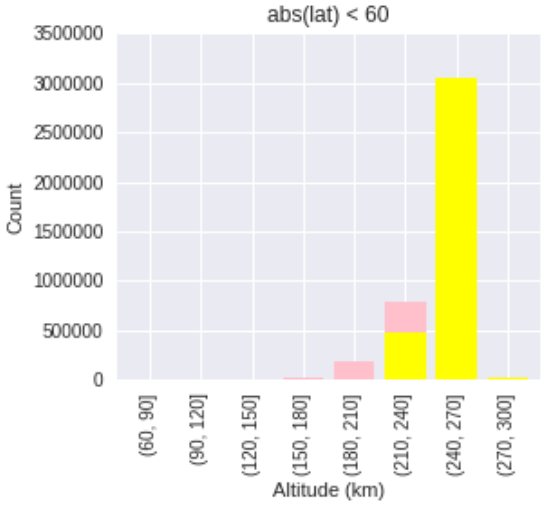
Coverage data of HWM14 database, courtesy of John Emmert and Manbharat Dhadly, NRL

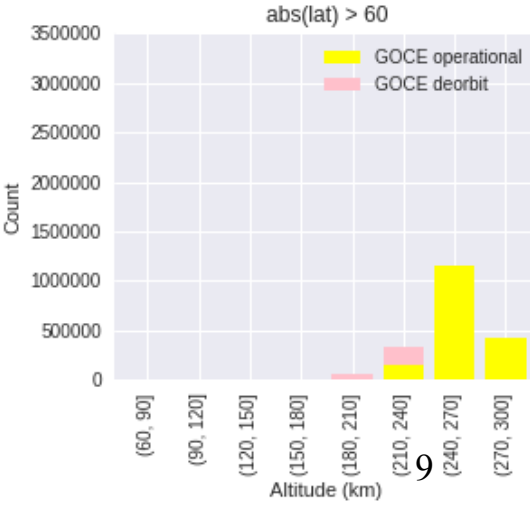
Low- and mid-latitudes



High latitudes







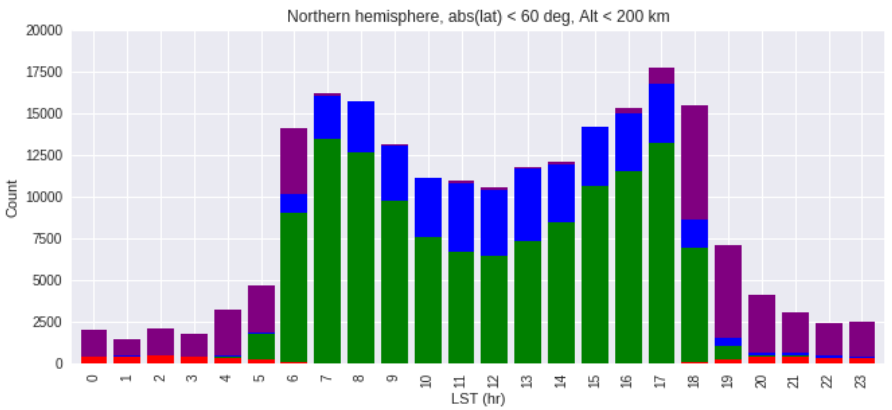
LST coverage: Northern Hemisphere

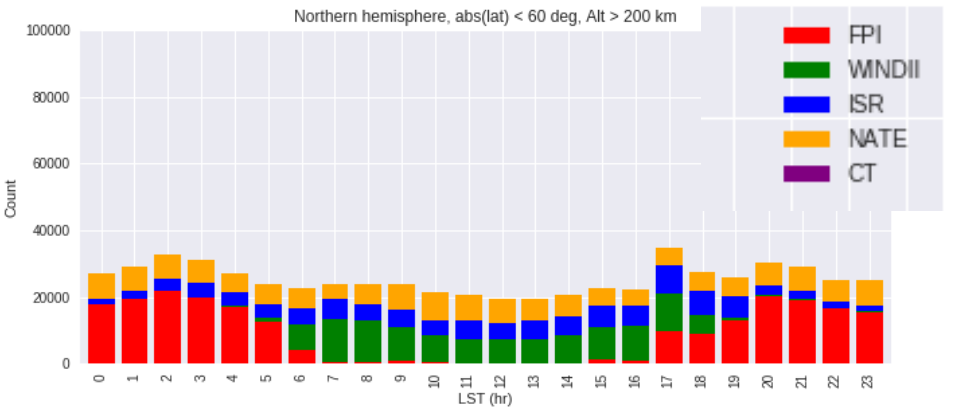
< 200 km

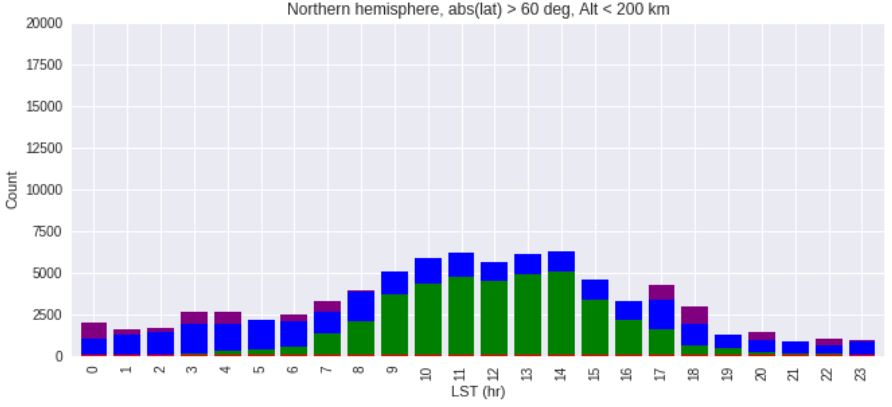
> 200 km

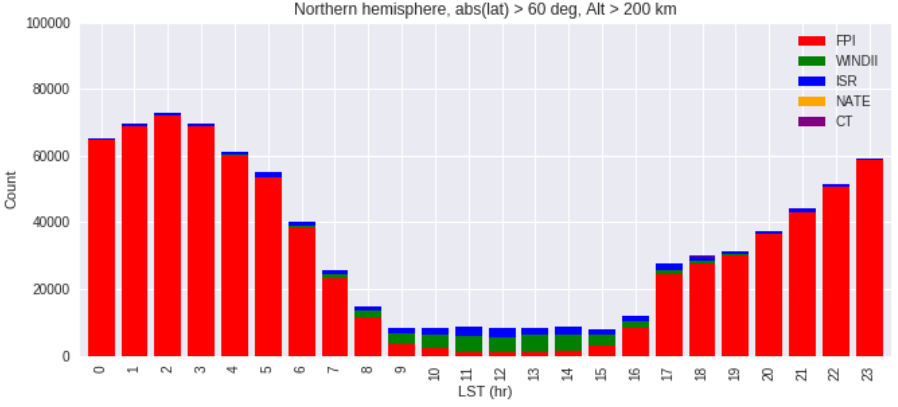
Low- and mid-latitudes

High latitudes

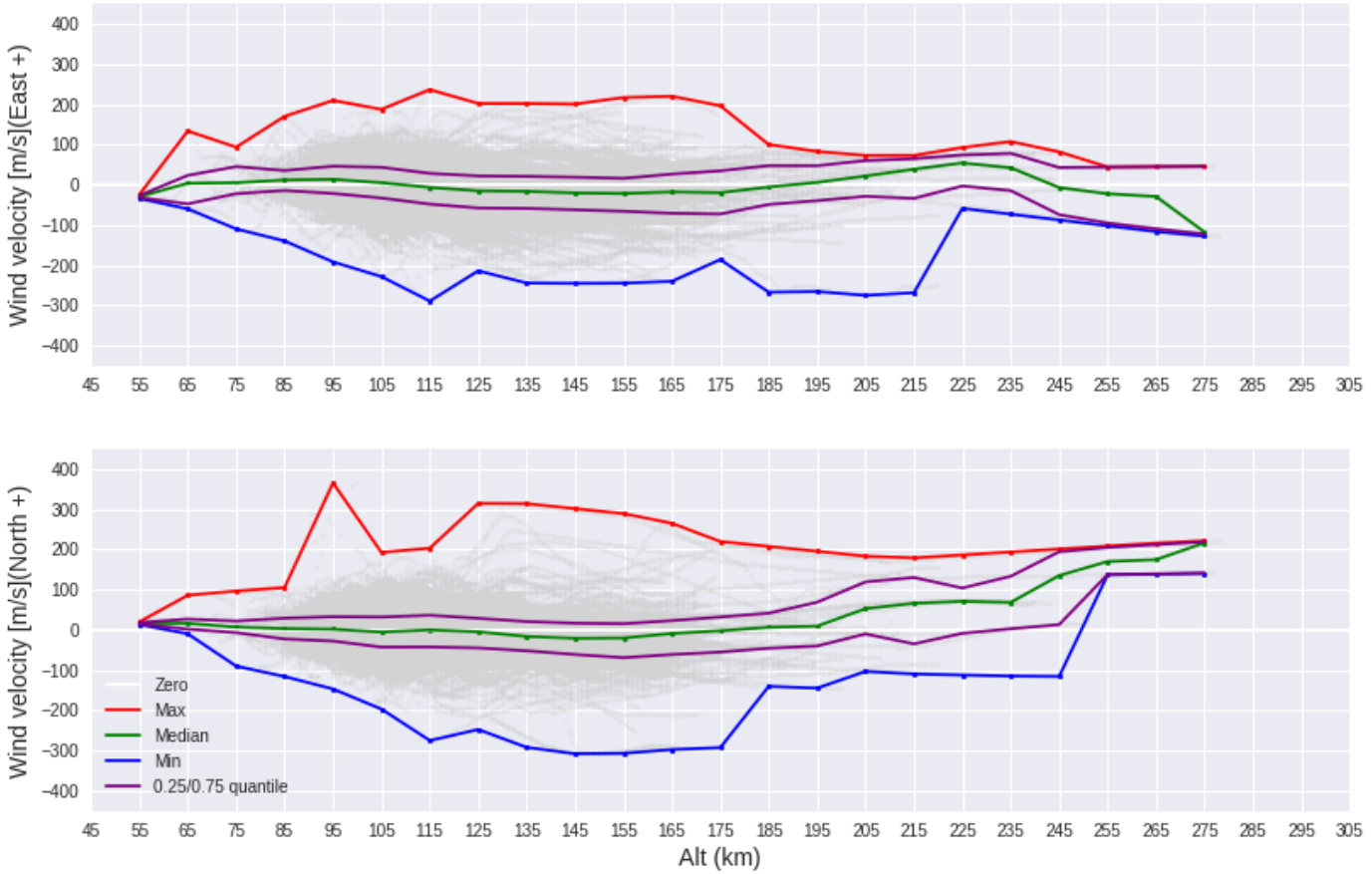




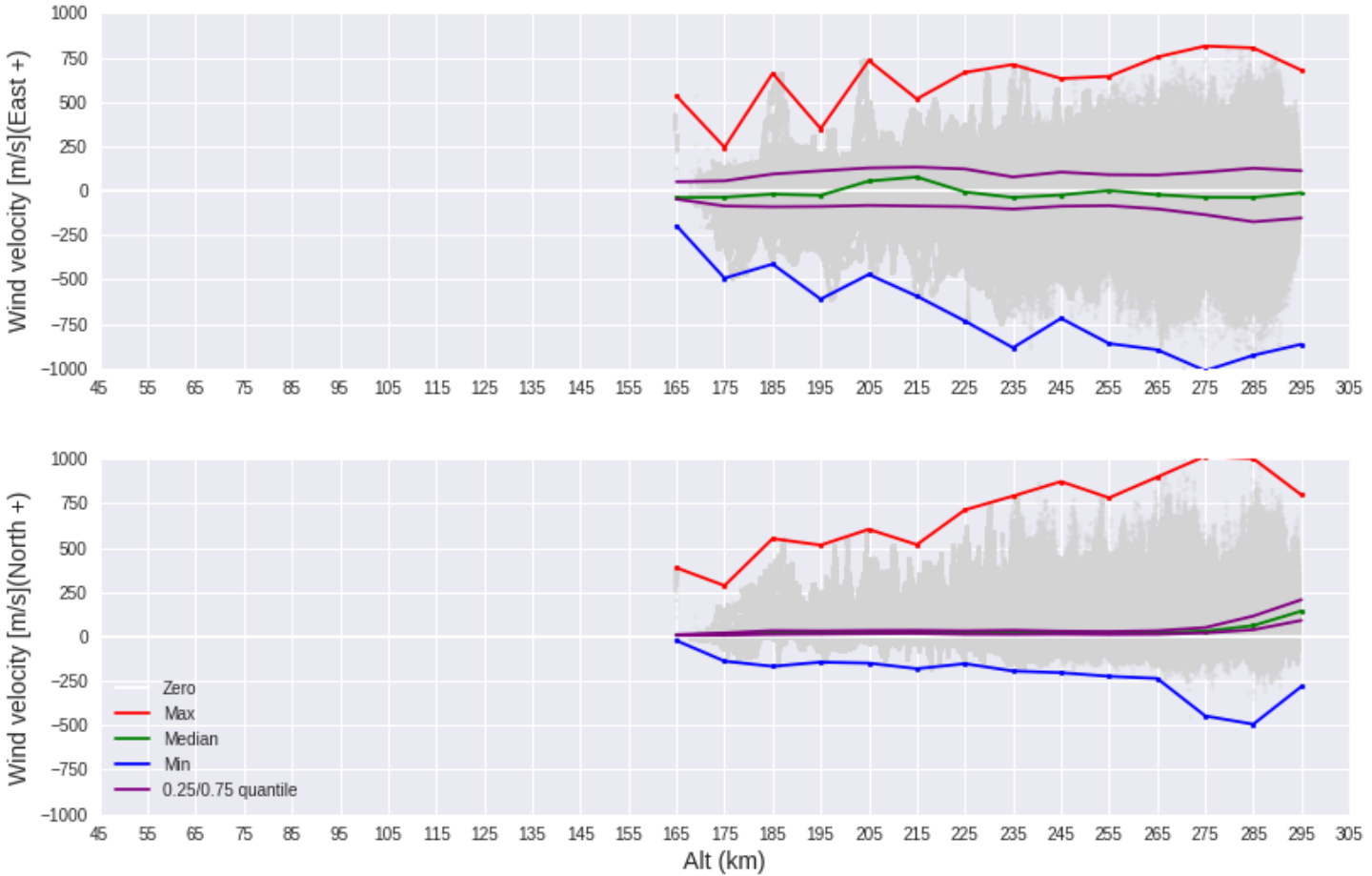




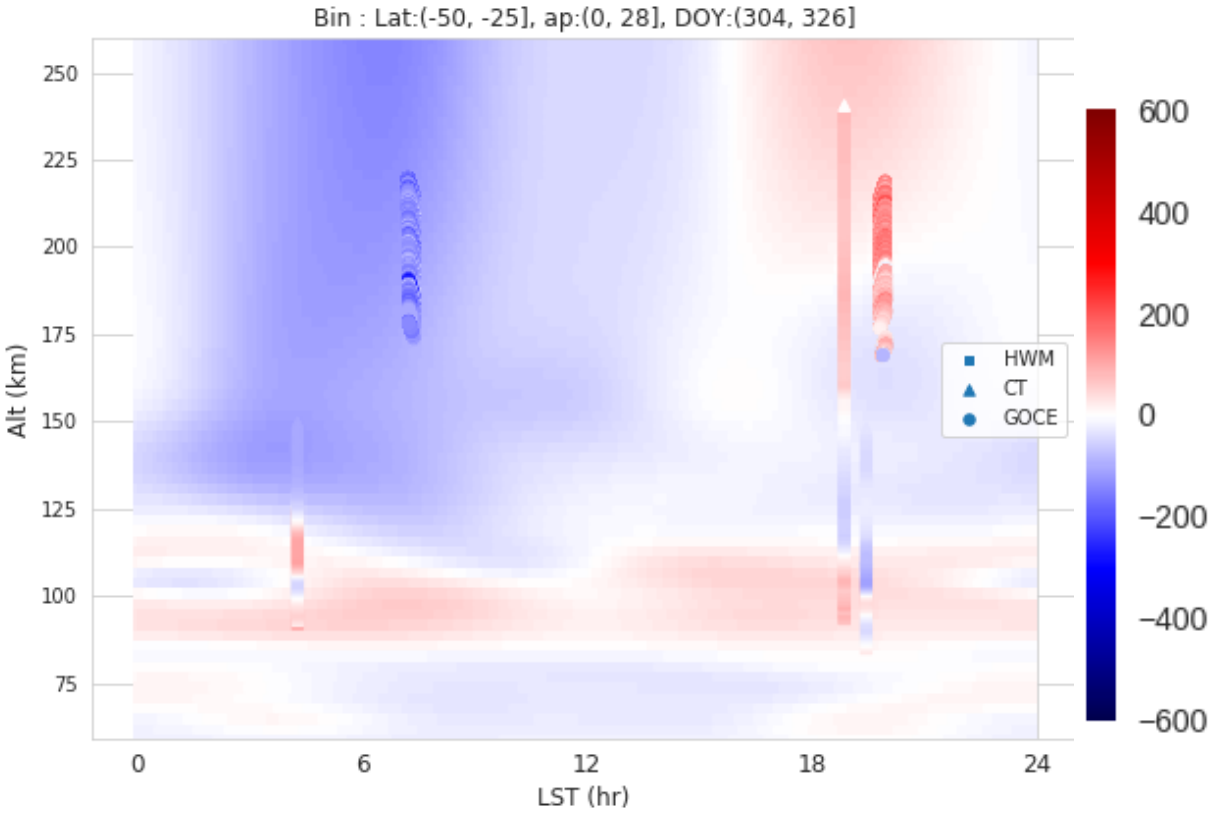
Altitude dependency sounding rocket chemical tracer



Altitude dependency GOCE crosswind



Both data types compared with HWM14



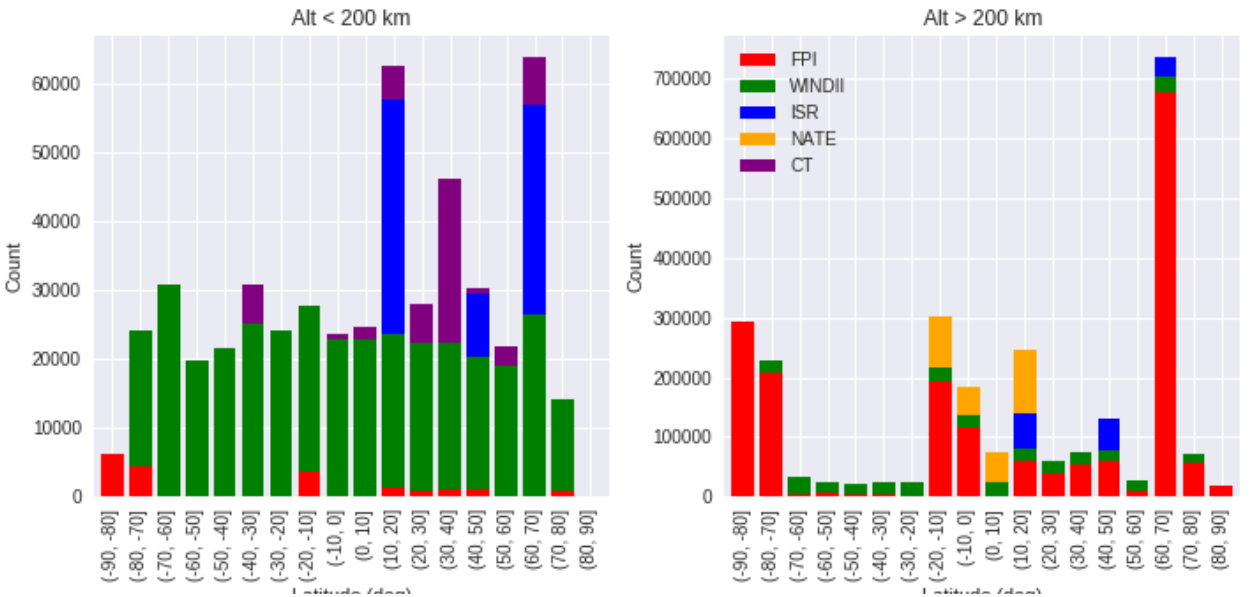
Date	Site	Alt Range	LST
1975-11-07	Woomera	92.0 - 150.0	4.3
1970-11-06	Woomera	93.0 - 150.0	4.3
Oct/Nov 2013	GOCE (Dawn pass)	173.6 - 219.9	7.4
1969-11-01	Woomera	93.5 - 240.5	18.9
1973-11-19	Woomera	96.0 - 148.0	19.5
1973-11-19	Woomera	85.0 - 111.0	19.5
Oct/Nov 2013	GOCE (Dusk pass)	168.9 - 218.9	20.0

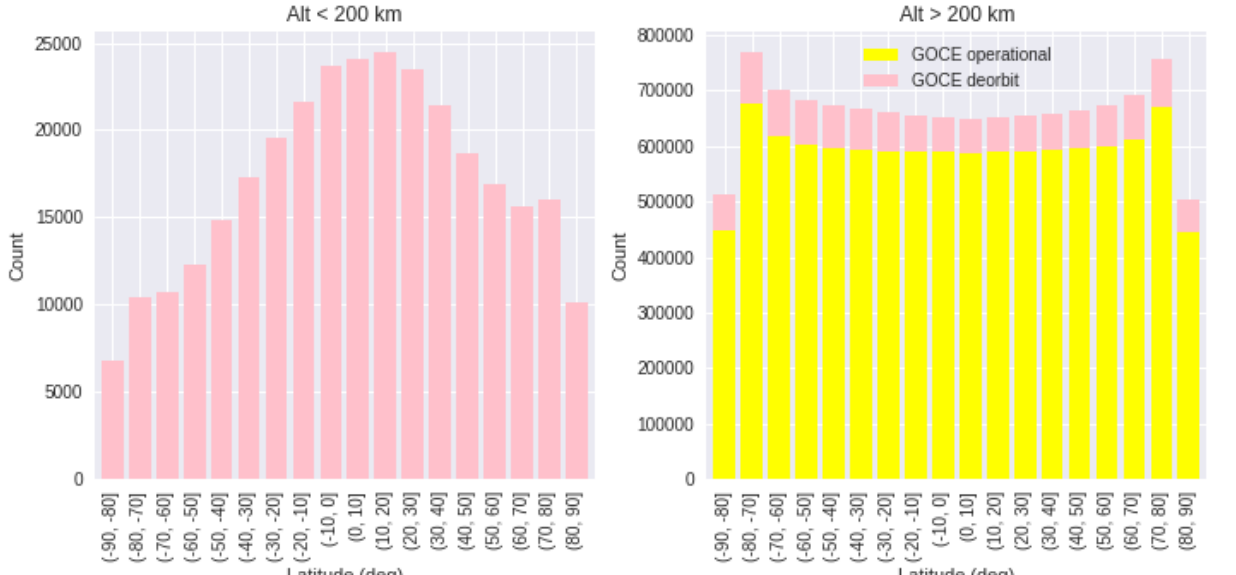
Conclusions

- The sounding rocket chemical tracer data provides unique low-altitude height-resolved measurements in the lower thermosphere, providing information on vertical structure, that is useful for planning the Daedalus mission
- The GOCE deorbit dataset contains much higher winds (up to ~800 m/s) at high latitudes, not found in the sounding rocket data (max ~400 m/s) or HWM14
- The CT dataset contains higher shears at low altitudes which are not found in HWM14
- Similarities in vertical structure found by sounding rockets, GOCE and HWM14
- If selected by ESA, Daedalus could bring unique in-situ wind data in the lower thermoshere, that will be height-resolved, and covers all lat/lon locations and a wide range of season/local solar time conditions

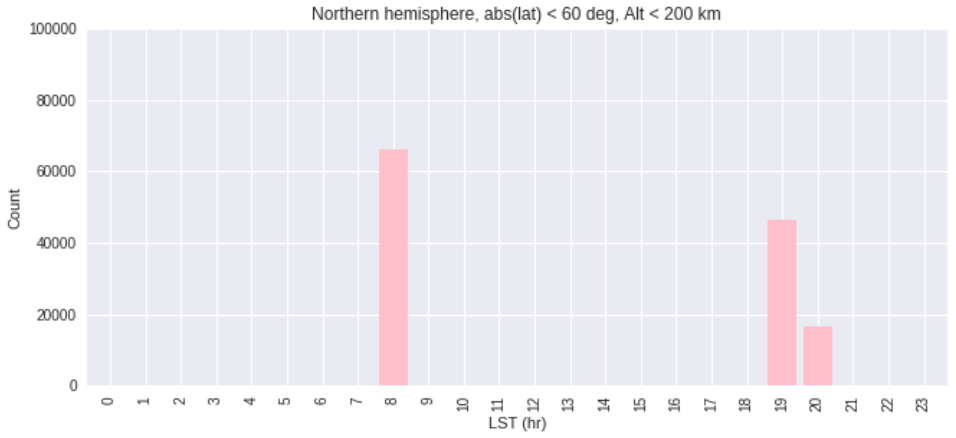
Back-up slides

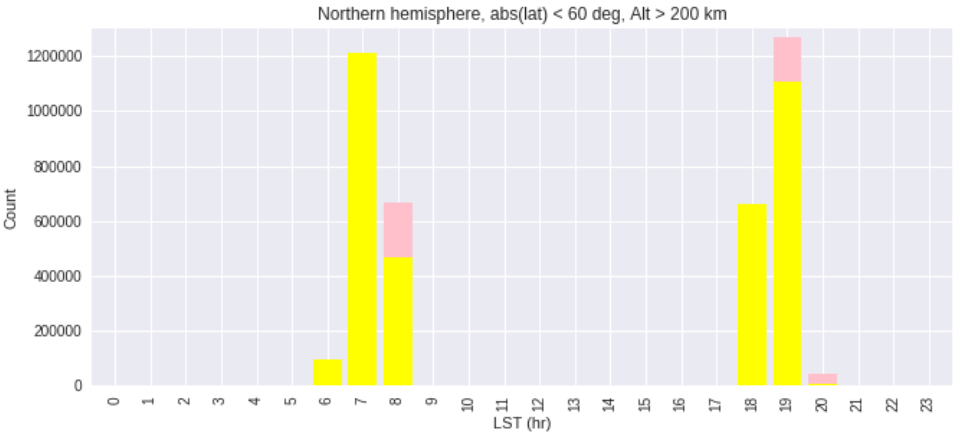
Latitude Coverage

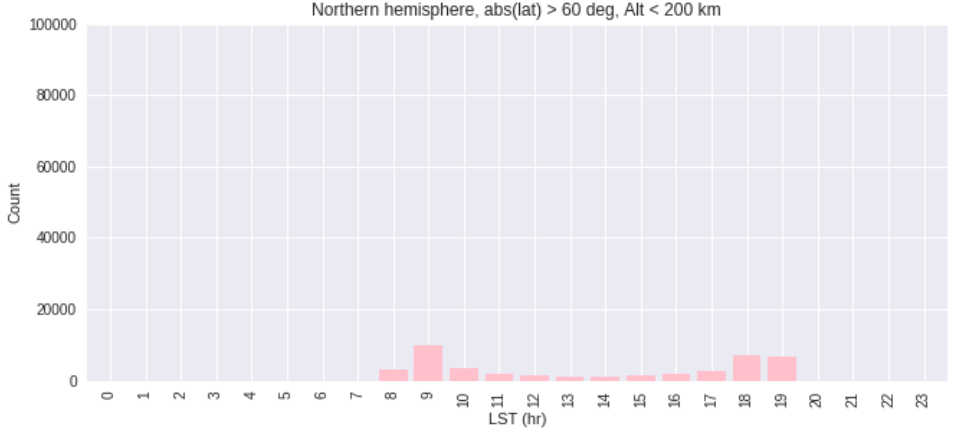


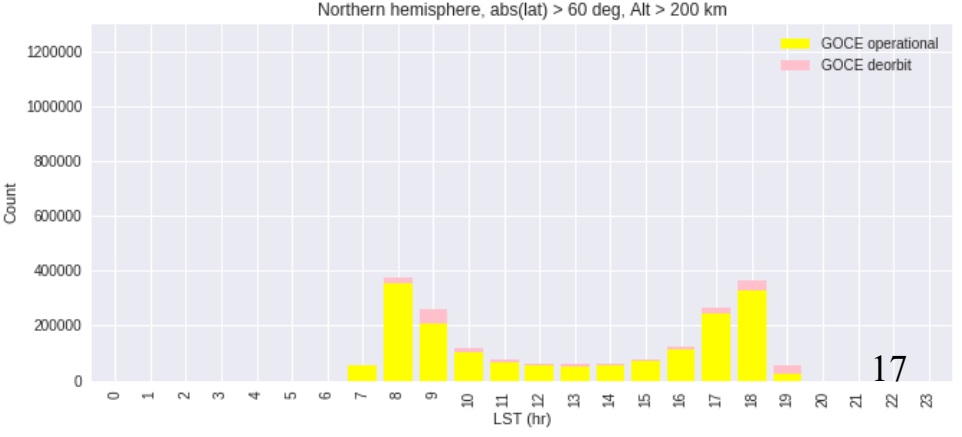


LST coverage: Northern Hemisphere

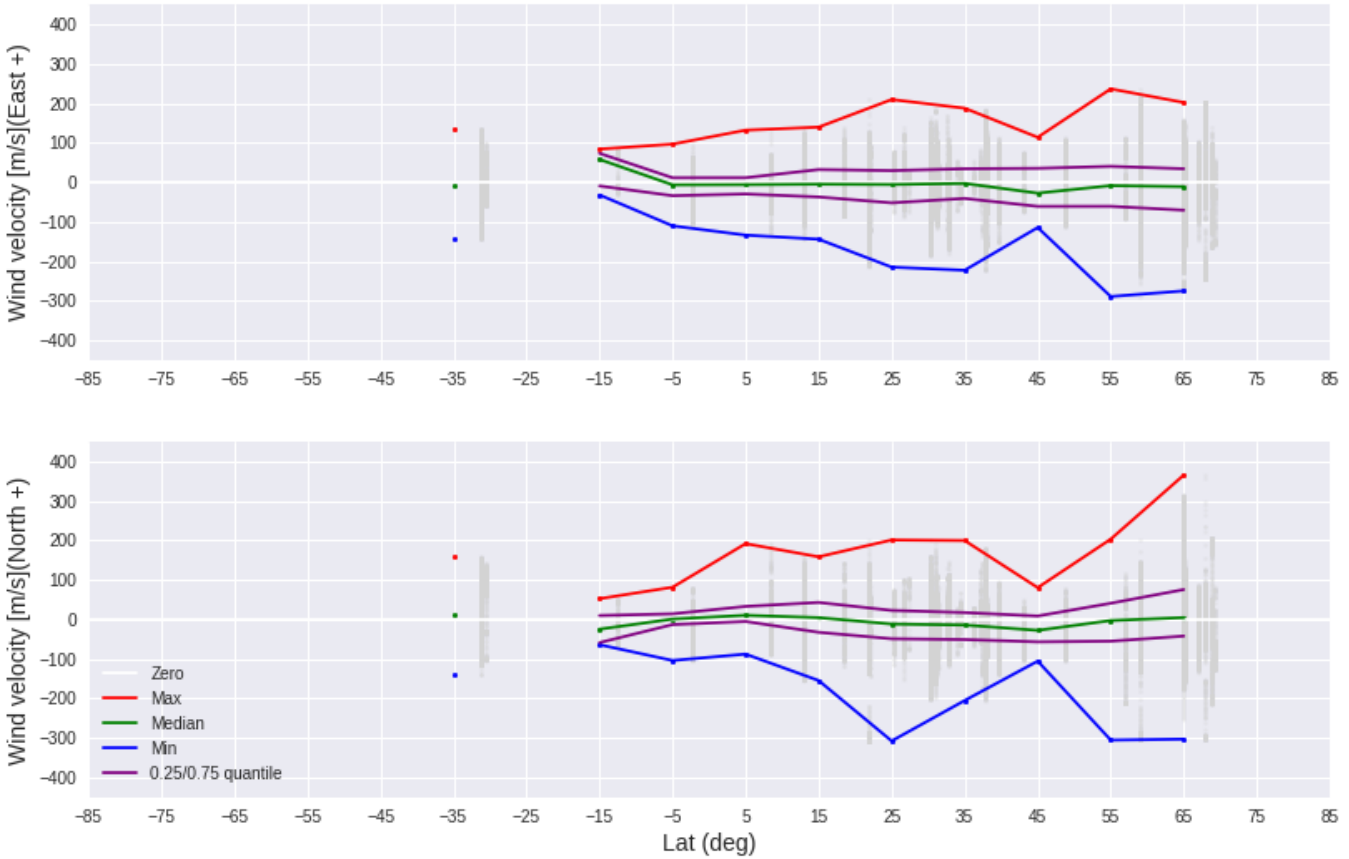




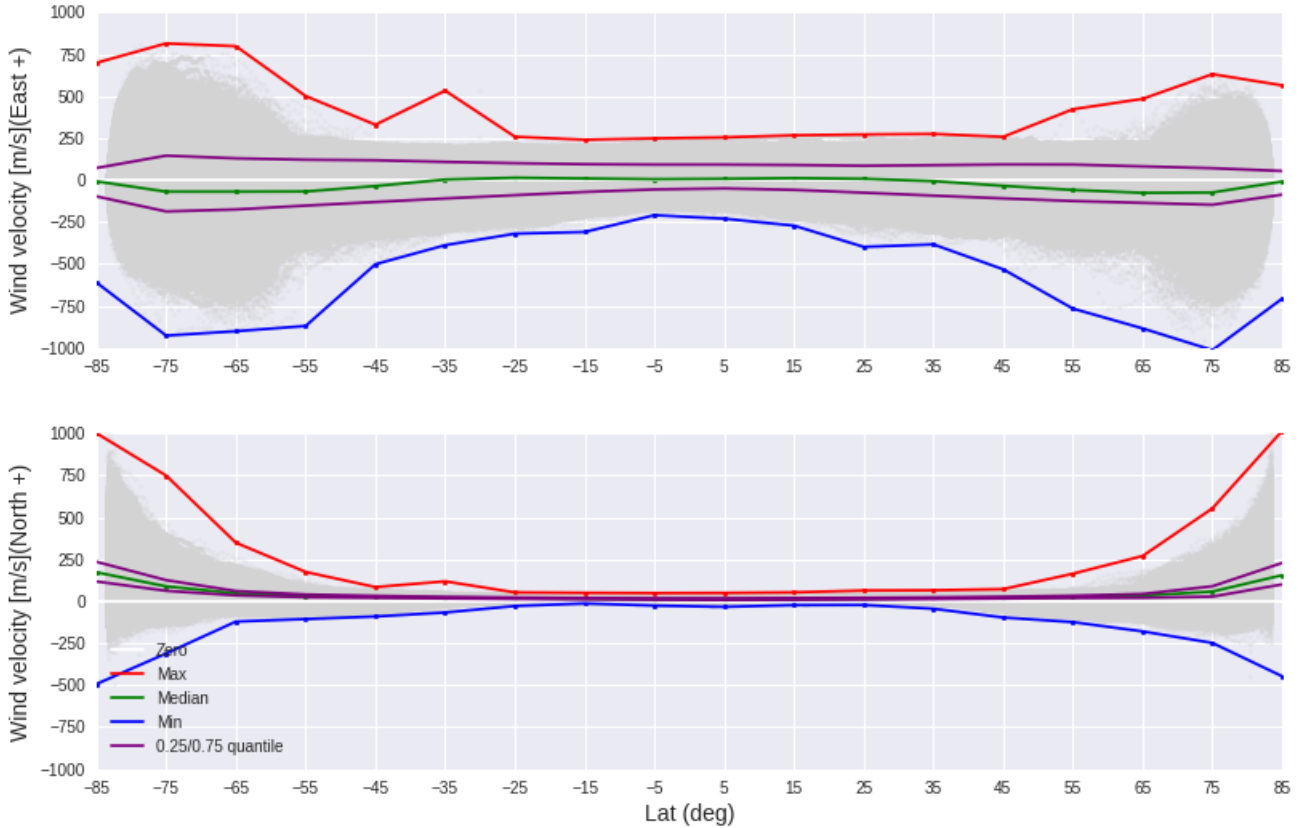




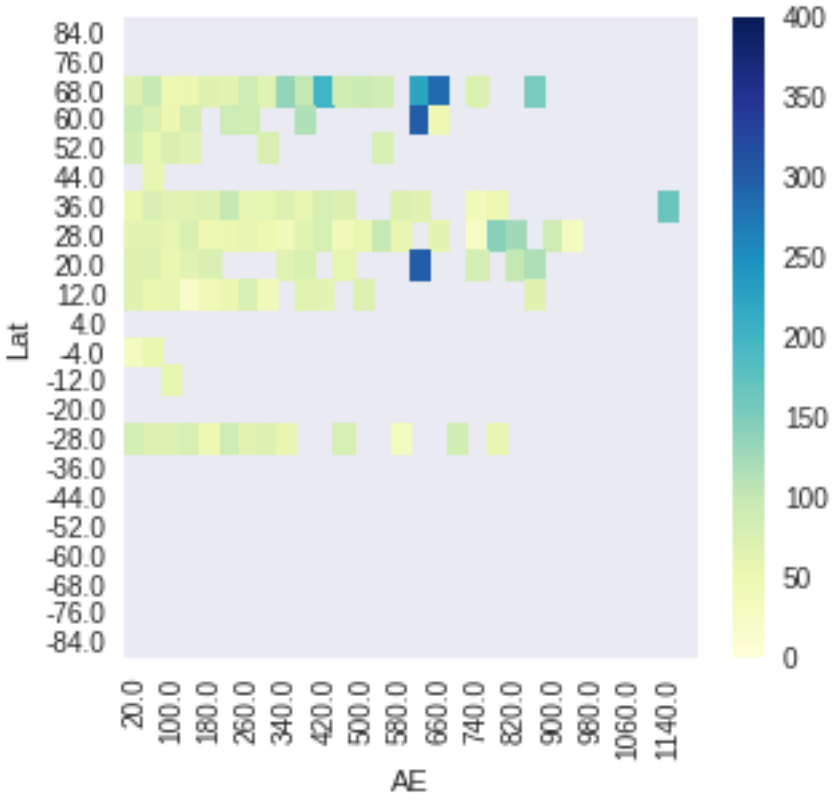
Latitude dependency (CT)

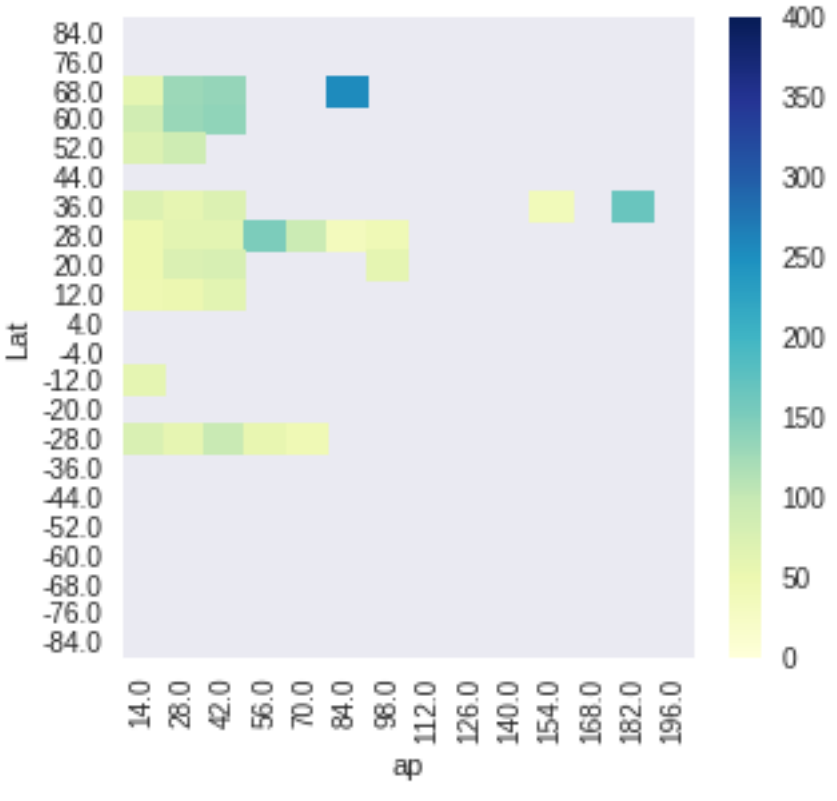


Latitude dependency (GOCE)

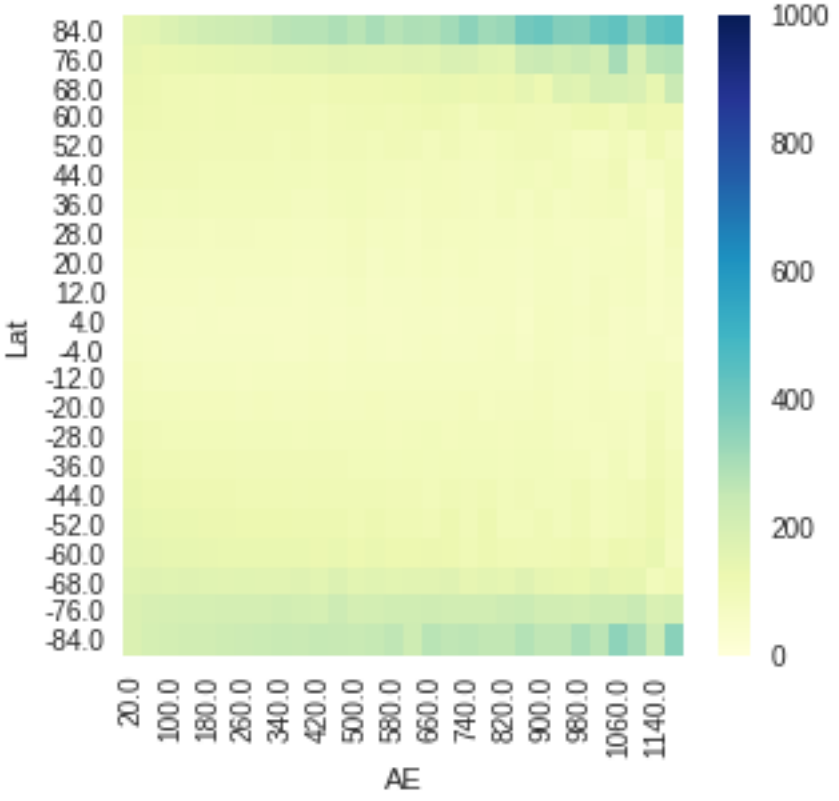


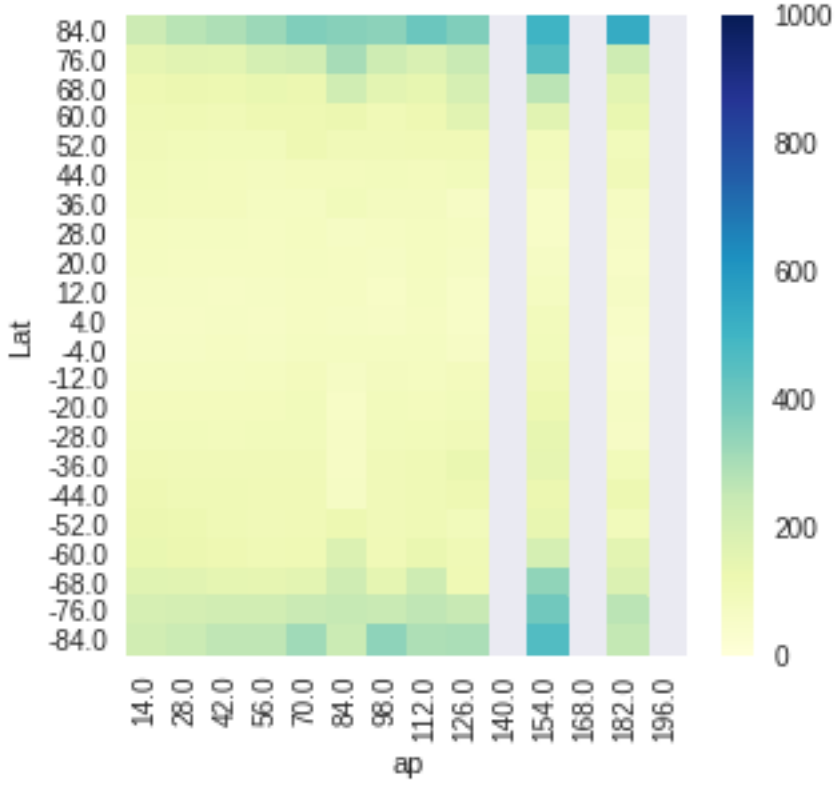
Geomag. activity dependency (CT)



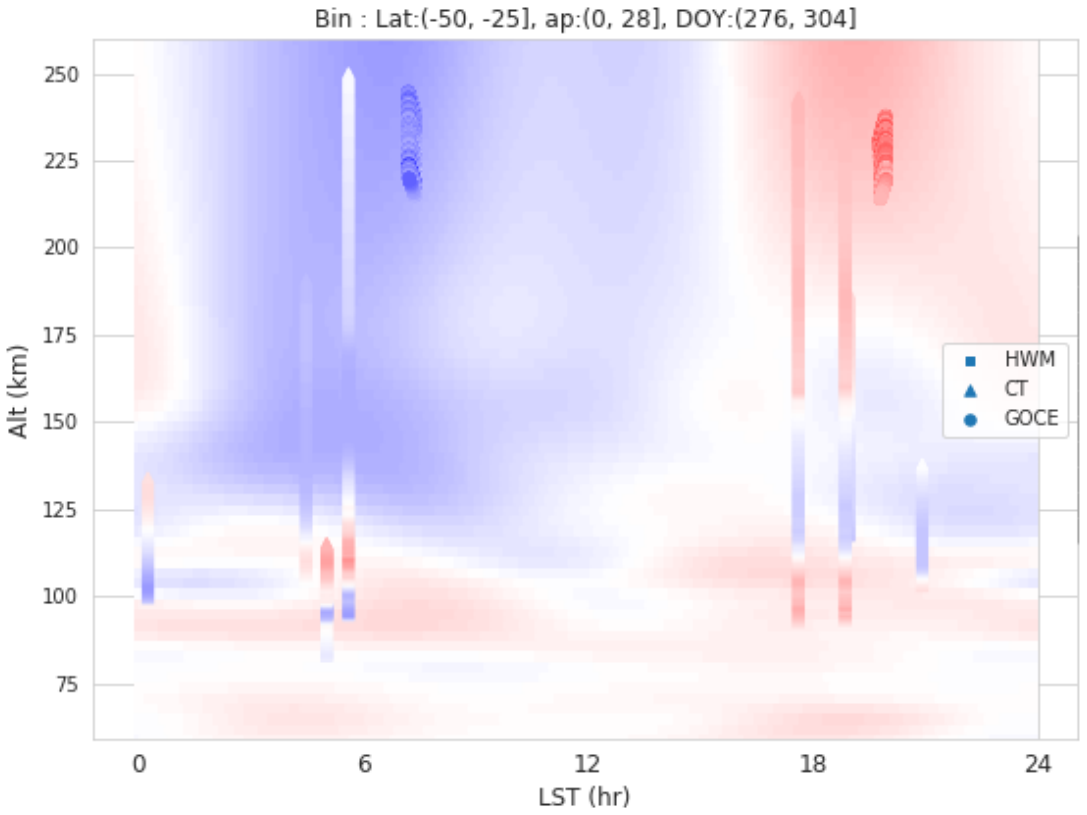


Geomag. activity dependency (GOCE)

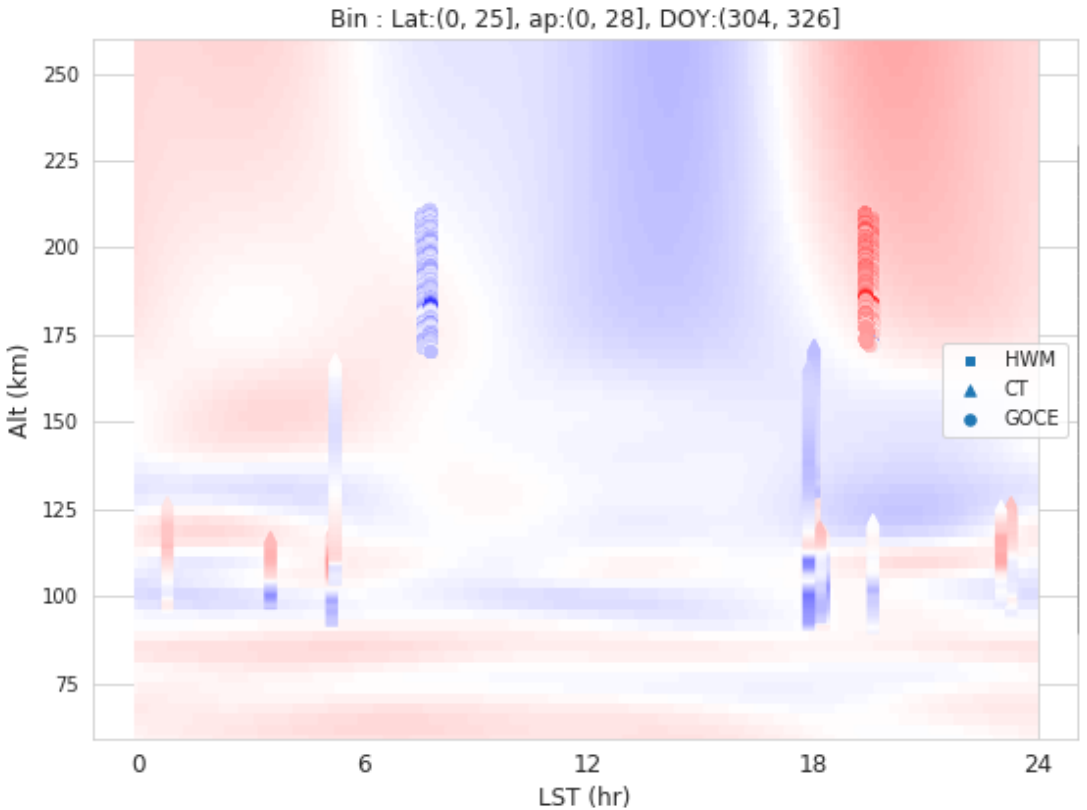




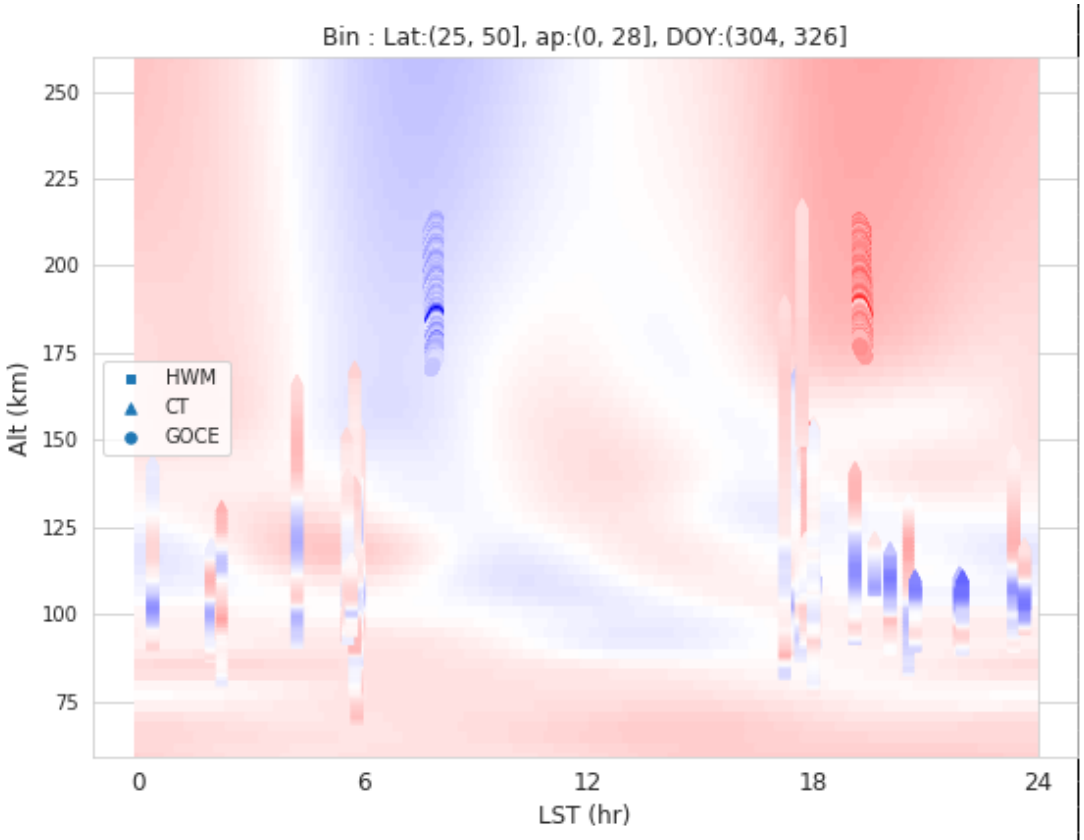
Results



Date	Site	Alt Range	LST
1963-10-16	Woomera	99.5 - 134.0	0.3
1963-10-16	Woomera	104.5 - 191.0	4.5
1972-10-17	Woomera	83.0 - 115.0	5.0
1972-10-17	Woomera	95.0 - 115.0	5.0
1969-10-16	Woomera	94.5 - 250.0	5.6
Oct/Nov 2013	GOCE (Dawn pass)	214.9 - 244.7	7.4
1969-10-16	Woomera	92.0 - 243.0	17.6
1969-10-17	Woomera	93.0 - 239.0	18.9
1963-10-15	Woomera	117.5 - 187.0	19.0
Oct/Nov 2013	GOCE (Dusk pass)	213.9 - 237.9	19.9
1963-10-15	Woomera	103.0 - 138.0	20.9



Date	Site	Alt Range	LST
1965-11-18	Barbados	97.0 - 127.0	0.8
1965-11-18	Barbados	98.0 - 117.0	3.5
1965-11-18	Barbados	93.0 - 119.0	5.2
1964-11-06	Barbados	105.0 - 168.0	5.3
Oct/Nov 2013	GOCE (Dawn pass)	170.0 - 211.0	7.8
1964-11-02	Barbados	92.0 - 166.0	17.9
1963-11-21	Barbados	100.0 - 172.0	18.0
1964-11-09	Barbados	130.0 - 172.0	18.0
1965-11-22	Barbados	94.0 - 120.0	18.2
1965-11-16	Barbados	103.0 - 103.0	18.3
1965-11-17	Barbados	93.0 - 119.0	18.3
1965-11-17	Barbados	92.0 - 113.0	18.3
Oct/Nov 2013	GOCE (Dusk pass)	171.8 - 210.0	19.4
1965-11-18	Barbados	106.0 - 121.0	19.6
1965-11-18	Barbados	91.0 - 122.0	19.6
1965-11-22	Barbados	99.0 - 126.0	23.0
1965-11-17	Barbados	103.0 - 124.0	23.3
1965-11-17	Barbados	93.0 - 127.0	23.3



1965-11-18	Ship 3	81.0 - 131.0	2.2
1962-11-06	Ship 3	94.5 - 103.5	2.2
1966-11-19	Ship 3	92.0 - 167.0	4.2
1964-11-18	Ship 3	93.0 - 140.0	5.6
1962-11-01	Ship 3	97.0 - 120.0	5.6
1965-11-18	Ship 3	94.0 - 152.0	5.6
1962-11-05	Ship 3	95.5 - 116.0	5.7
1965-11-18	Ship 3	78.0 - 138.0	5.8
1965-11-18	Ship 3	89.0 - 171.0	5.8
1964-11-12	Ship 3	93.0 - 153.5	5.9
1962-11-07	Ship 3	70.0 - 140.0	5.9
Oct/Nov 2013	GOCE (Dawn pass)	170.2 - 214.1	8.0
1959-11-18	Ship 3	83.0 - 190.0	17.3
1964-11-05	Ship 3	90.0 - 170.0	17.6
1966-11-18	Ship 3	88.0 - 120.0	17.7
1962-11-14	Ship 3	150.0 - 217.5	17.7
1964-11-02	Ship 3	94.0 - 148.0	17.7
1965-11-03	Ship 3	92.0 - 122.0	17.8
1965-11-18	Ship 3	97.0 - 155.0	17.8
1964-11-10	Ship 3	78.5 - 154.0	18.0
1964-11-11	Ship 3	80.5 - 155.0	18.0
1966-11-16	Ship 3	92.0 - 112.0	18.1
1966-11-19	Ship 3	93.0 - 142.0	19.1
Oct/Nov 2013	GOCE (Dusk pass)	173.5 - 213.3	19.4
1962-11-15	Ship 3	107.0 - 122.0	19.7
1966-11-16	Ship 3	90.0 - 119.0	20.1
1965-11-17	Ship 3	84.0 - 133.0	20.6
1966-11-19	Ship 3	91.0 - 109.0	20.7
1966-11-19	Ship 3	99.0 - 111.0	20.7
1966-11-16	Ship 3	90.0 - 112.0	21.9
1966-11-19	Ship 3	90.0 - 111.0	22.0
1966-11-19	Ship 3	91.0 - 147.0	23.4
1966-11-17	Ship 3	103.0 - 120.0	23.6