



DAVINCI

Deep Atmosphere Venus Investigation
of Noble gases, Chemistry, and Imaging

DAVINCI: Venus Atmospheric Model Comparisons

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DAVINCI Venus : Earth's Twin Sister

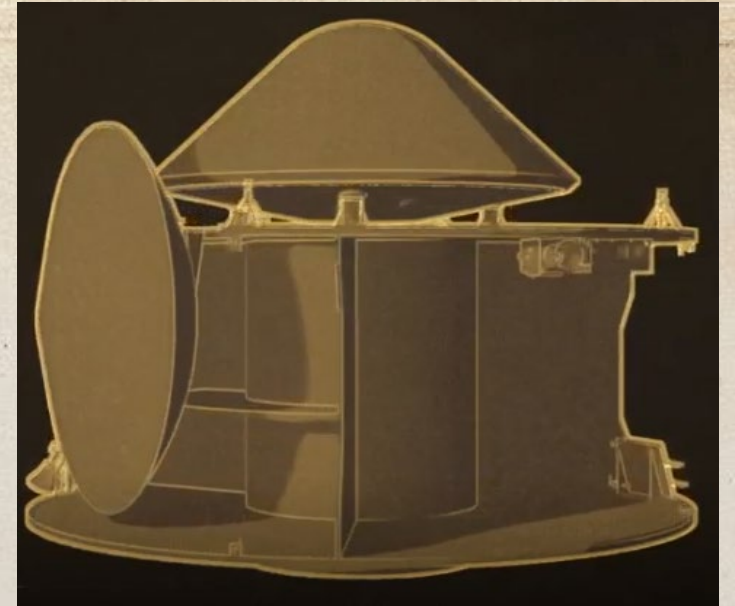
- With similar size and density Earth and Venus evolved into two very different planets
- Understanding the evolution of Venus will provide more insight into the processes that govern global-scale changes of the planet's environment
- Data from past Venus missions in the second half of the 20th century is limited
 - Pioneer Venus, Venera and Vega missions (Orbiter / Probe)
 - Magellan, Venus Express and Akatsuki (Orbiter)
- Future missions are under development after more than three decades
 - DAVINCI, VERITAS, Rocket Lab Venus Probe, EnVision (ESA), Venera-D (Russia), Venus Orbiter Mission (India), VOICE (China)



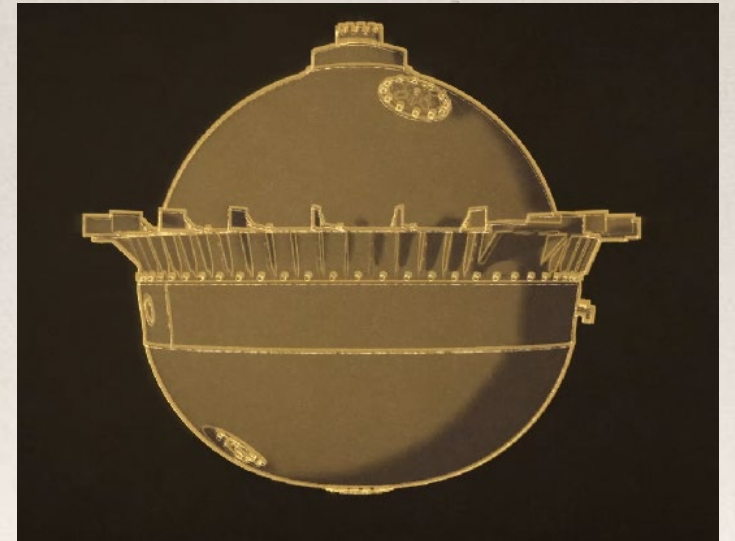
An artist's illustration of NASA's Pioneer Venus 2 approaching Venus. Credit: NASA/ Paul Hudson

DAVINCI DAVINCI Spacecraft

- The DAVINCI spacecraft consists of two parts:
 - Carrier-Relay-Imaging Spacecraft (CRIS)
 - Probe Flight System (PFS)
- PFS is the entry vehicle which houses Zephyr
 - Zephyr is made of titanium and designed to withstand harsh Venus' atmosphere
- CRIS carries two instruments and Zephyr will be carrying five other science instruments
- Zephyr will be the first probe to take high-resolution aerial photographs of Alpha Regio highlands region
 - Studying these rocks can confirm the hypothesis that there were hospitable conditions in Venus' past

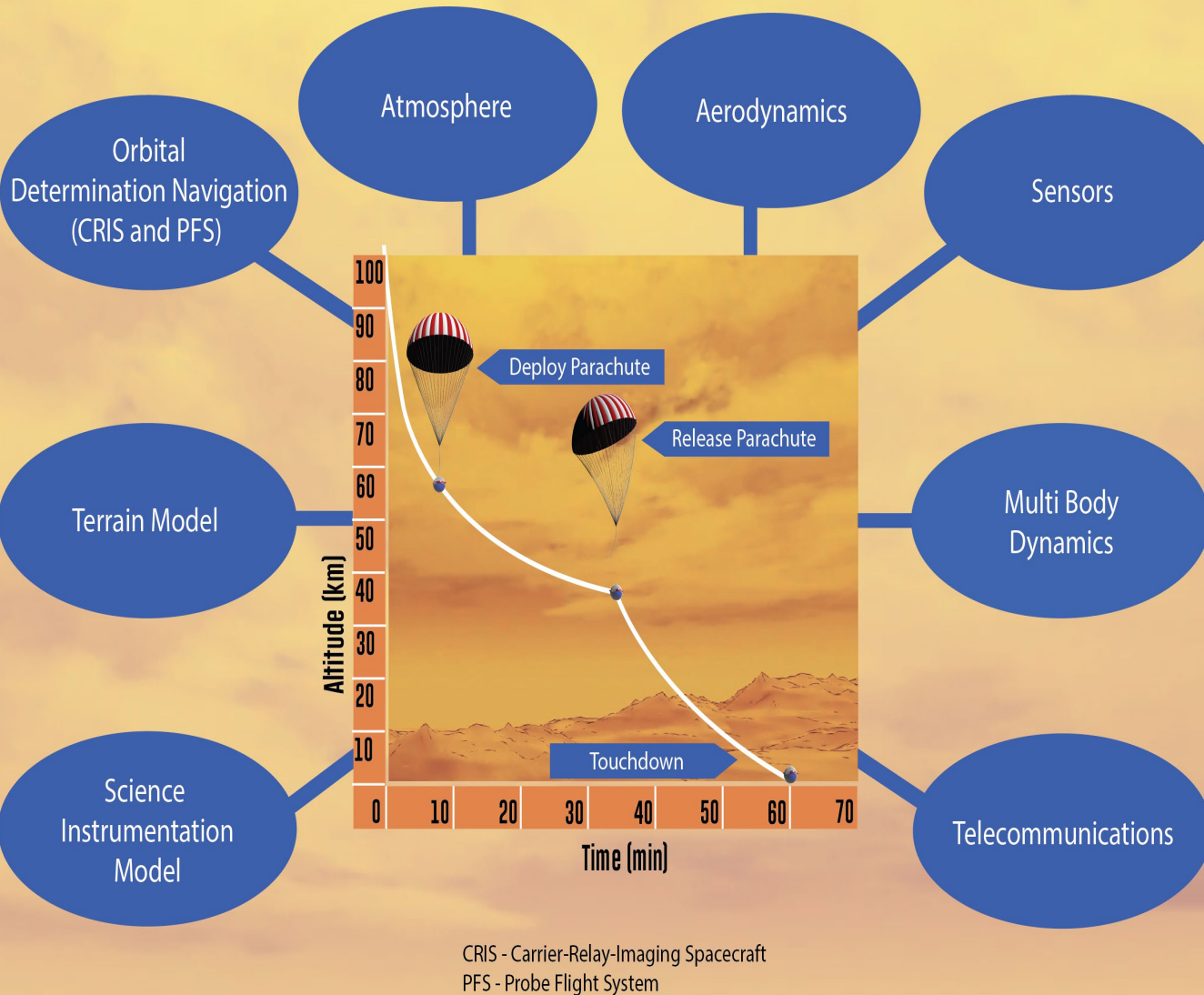


CRIS CREDIT: NASA



Zephyr CREDIT: NASA

Models for Simulation

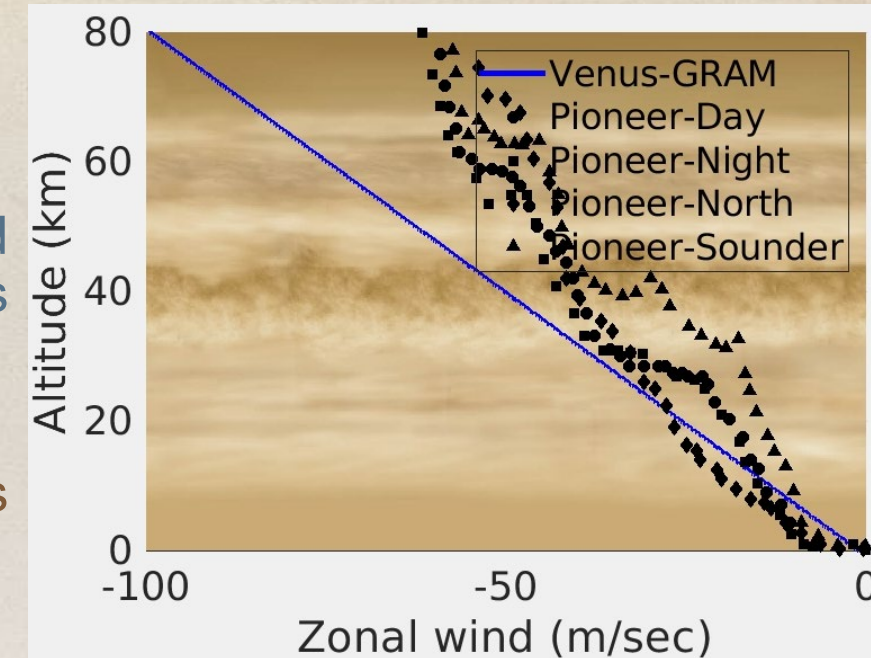


- It is vital that Zephyr lands in the Alpha Regio
 - Zephyr is on the parachute for about 30 min
 - Descent trajectory is highly influenced by the atmospheric and wind models
 - The atmospheric / wind data from past missions is sparse
- It is important to point CRIS towards PFS to relay science data
- Potential Venus atmospheric models:
 1. Venus GRAM (Atmosphere + wind model)
 2. Venus Climate Database (VCD) (Atmosphere + wind model)
 3. Engineering model developed by Lorenz (Wind only model)

Interested in models that provide most conservative values

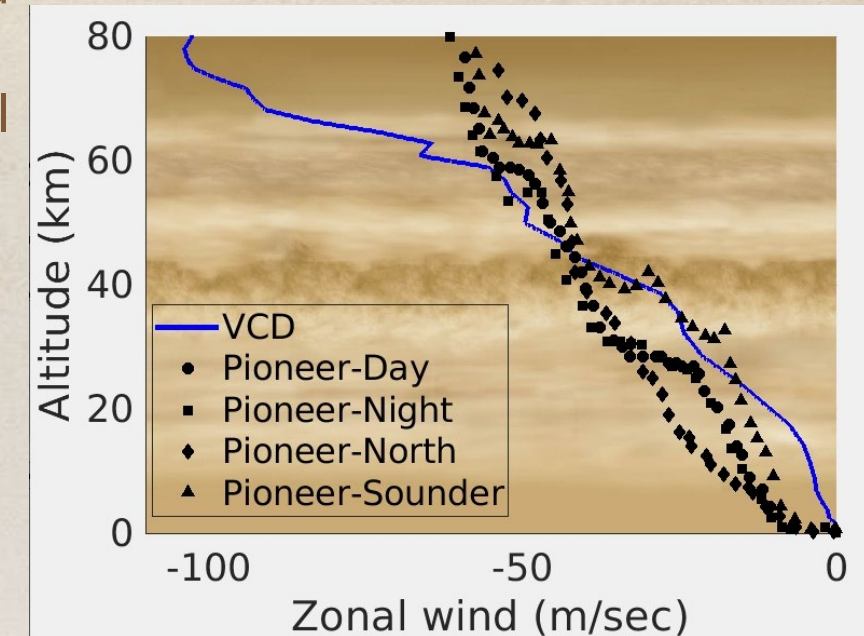
DAVINCI Venus-GRAM

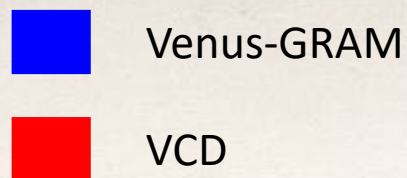
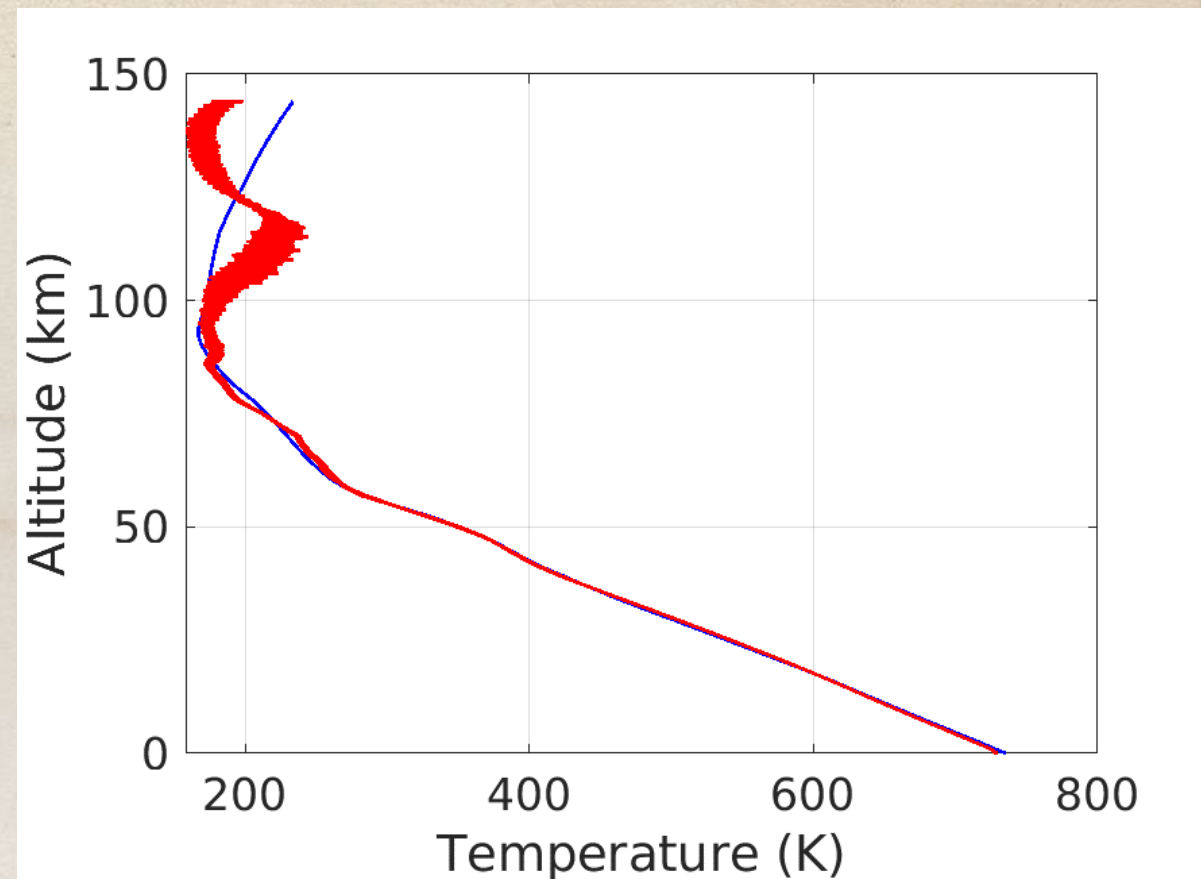
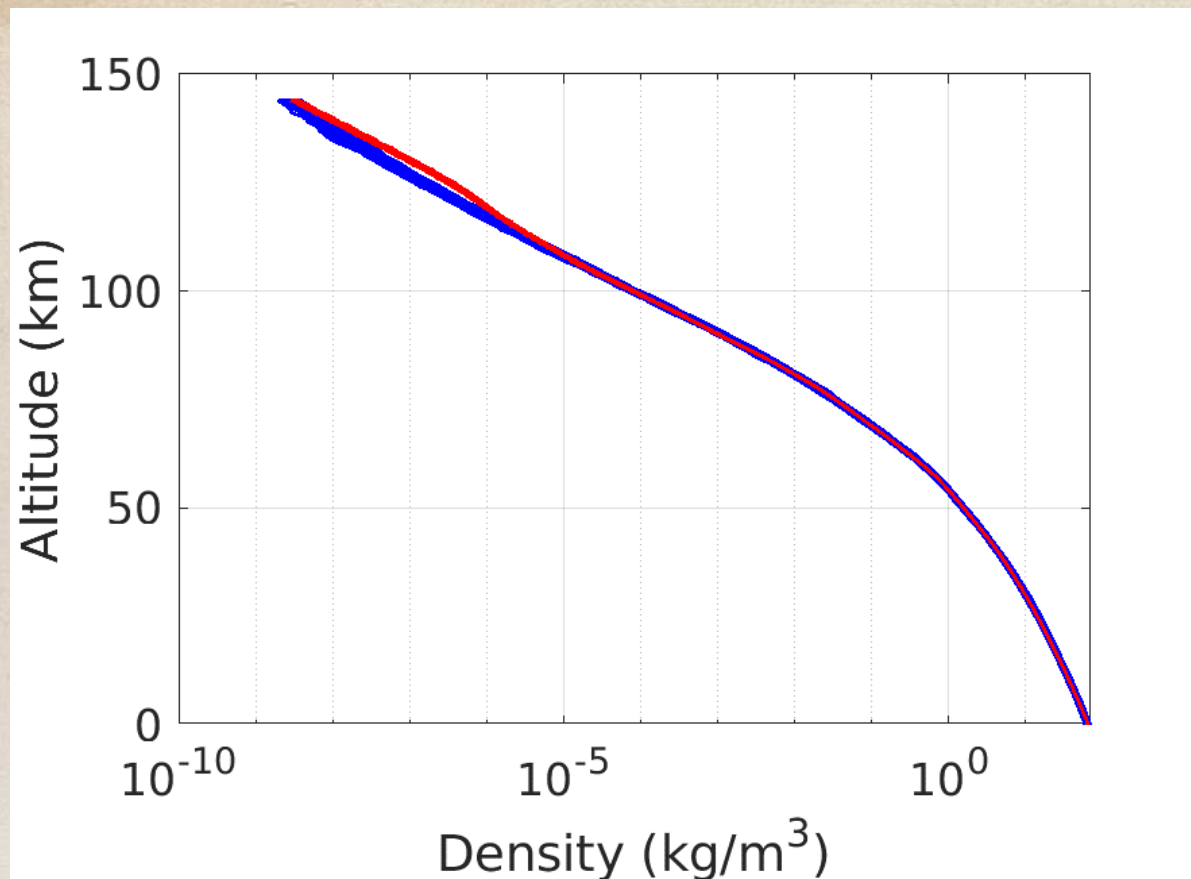
- Venus-GRAM is an engineering-oriented model that provides critical information based on past missions' data
 - Pioneer Venus Orbiter
 - Pioneer Venus large and small probes
 - Venera probe data
- Venus-GRAM atmospheric model can estimate mean values and statistical variations of atmospheric properties as well as winds for Venus
 - Mean values can be queried for any point in the atmosphere
 - Seasonal, geographic, and altitude variations of Venus atmospheric properties and winds are also available
- Venus-GRAM query atmospheric properties such as density, pressure, temperature, and winds using Venus International Reference Atmosphere (VIRA).



DAVINCI Venus Climate Database

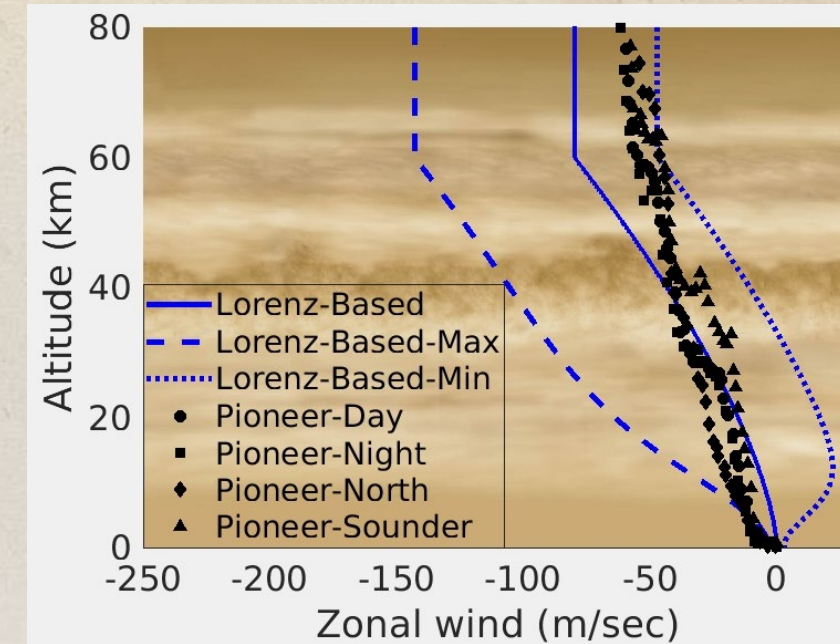
- Developed Laboratoire de Météorologie Dynamique (LMD) with the support of the European Space Agency (ESA) using the data from the Global Climate Model(GCM) simulation
 - Database consists 96 X 97 equally-spaced horizontal grid and 90 vertical levels
 - Database stores one Venus day data to account the diurnal behavior
 - Considers multiple solar and cloud albedo scenarios
- VCD Interpolation
 - Temporal - Linear
 - Horizontal - Bilinear
 - Vertical - Bi-logarithmic (Make it a table)
- VCD variability models
 - Large-scale variability model
 - Small-scale variability model
 - RMS error

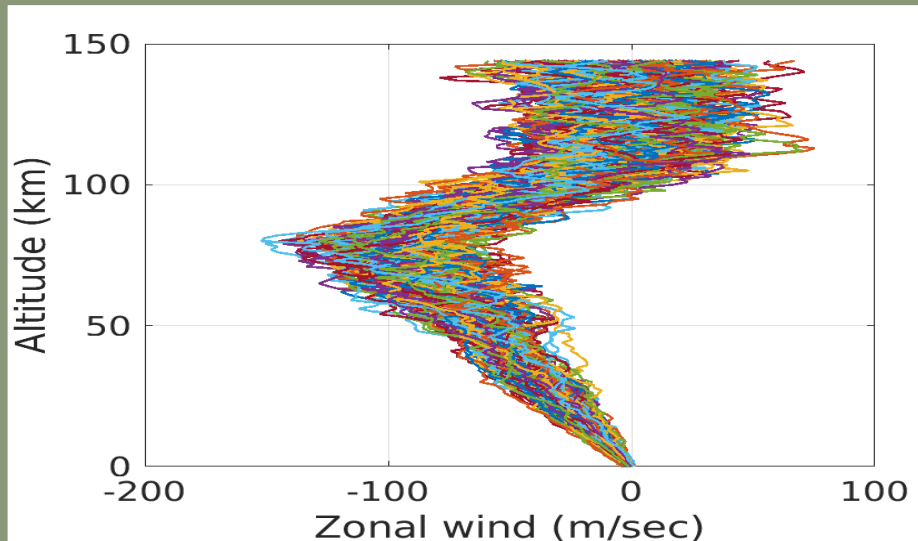




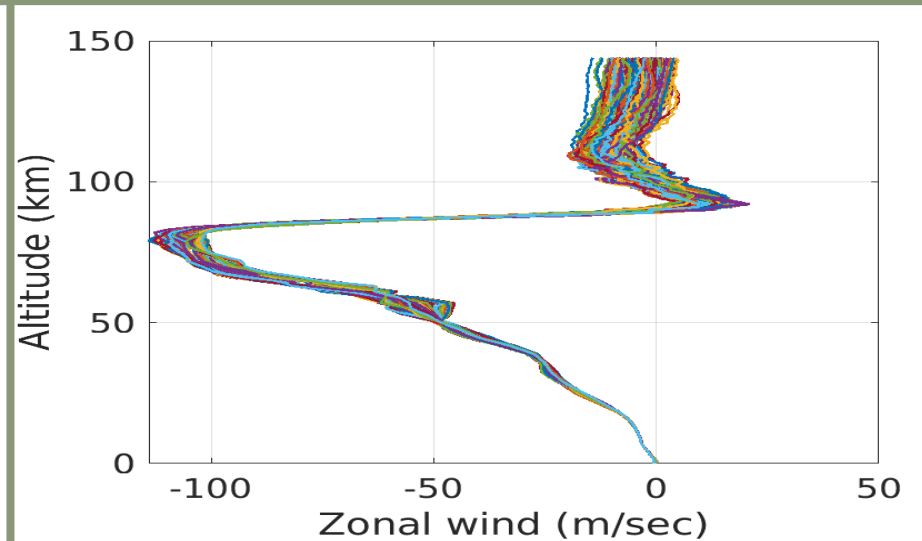
DAVINCI Lorenz-Based Model

- Unlike Venus-GRAM and VCD this model only provides winds and no other atmospheric data
 - We can use Venus-GRAM or VCD along with the Lorenz-based model to compute atmospheric properties such as pressure, density and temperature
- This model is an engineering analytical wind model
- This model gives analytical functions to compute nominal, maximum, and minimum winds as a function of the altitude
- Assumes constant winds above 60 kilometers altitude.
- There is new version of Lorenz-based model under development

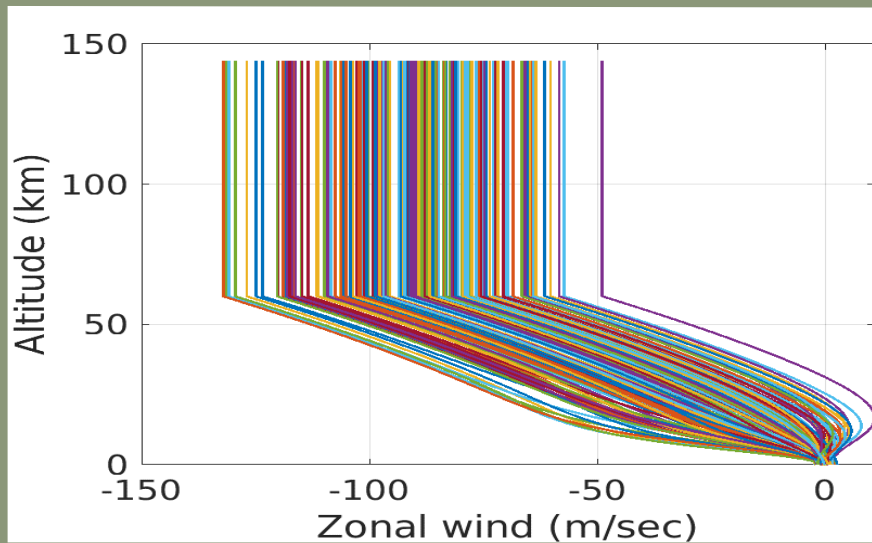




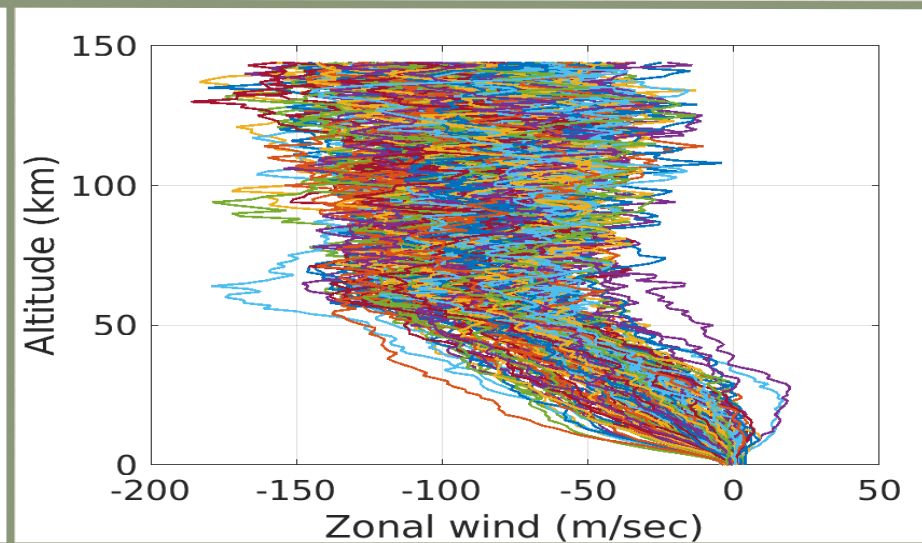
GRAM winds



VCD winds



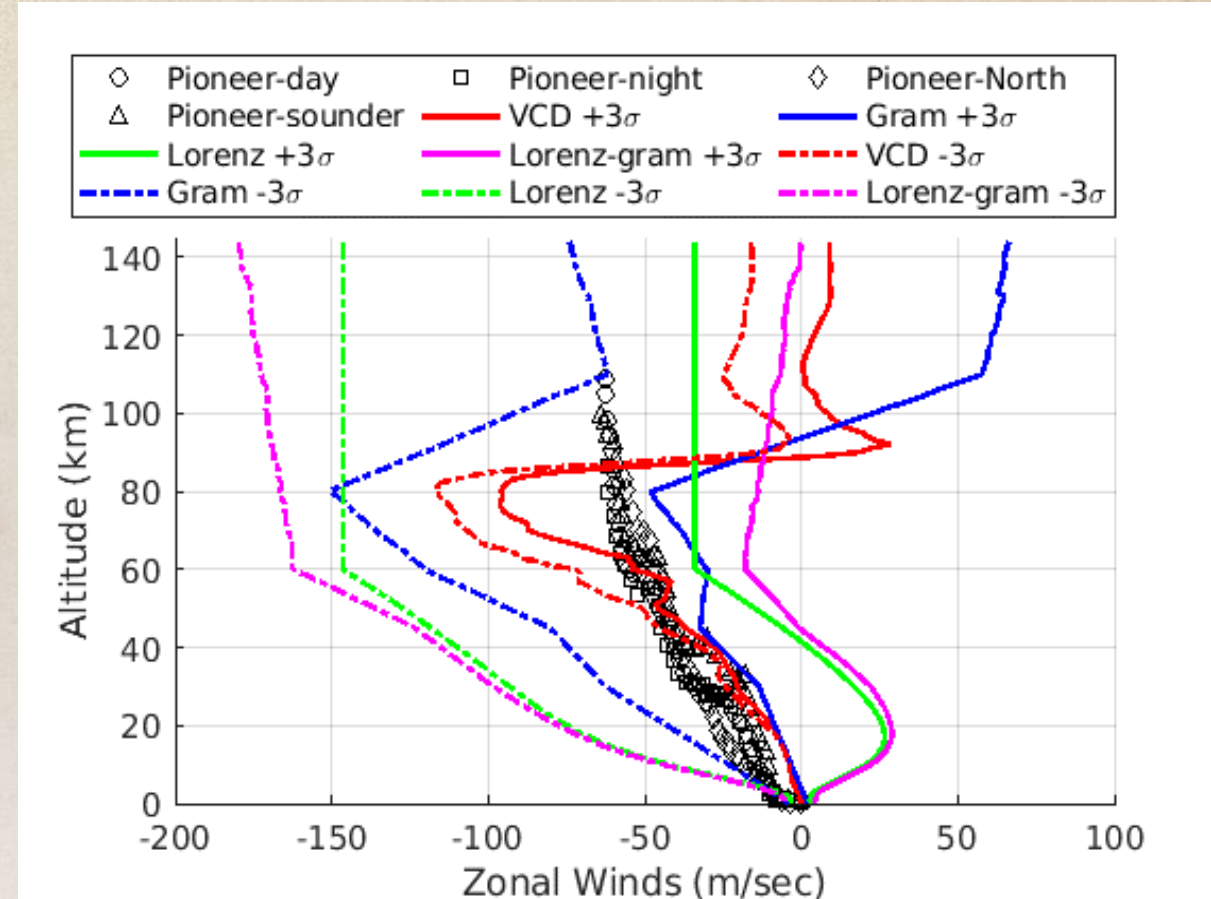
Lorenz winds



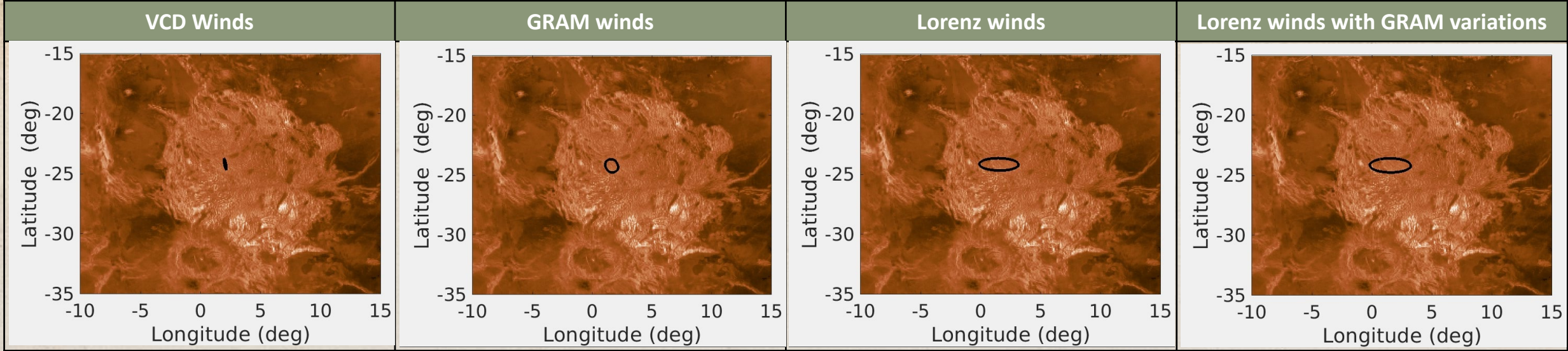
Lorenz winds with GRAM variations

DAVINCI Zonal Wind +/- 3σ profiles

- +/- 3σ profiles of zonal winds from VCD do not enclose the winds observed by the pioneer probes
- The Lorenz-based model provides the largest wind dispersions
- More stressing winds are achieved by adding high frequency noise from the Venus-GRAM to the Lorenz-based wind model dispersions
- This approach is adapted from Mars Entry Descent and Landing (EDL) simulations
- Future version of Lorenz-based model will have high frequency noise



DAVINCI Landing Ellipse Analysis



Wind Model	Semi-major axis (km)	Semi-minor axis (km)	Azimuth of semi-major axis (deg)
No winds	52.55	0.98	-9.91
VCD	50.42	6.38	-9.28
Venus GRAM	60.90	50.13	-25.61
Lorenz	157.5	54.19	-89.09
Lorenz w/ GRAM variations	165.24	61.81	-89.33

DAVINCI Conclusions

- The wind dispersions can significantly affect EDL performance
 - The size of the landing ellipse is directly proportional to the range of wind dispersions
 - The touchdown times are less sensitive to the wind dispersions compared to the peak pointing error
- Lorenz-based wind model provides a conservative assessment of EDL performance (e.g. the large landing ellipse)
 - However, the Lorenz-based wind model has no high frequency noise
 - Future updates of the Lorenz wind model will address this
- This work models stressing winds from Lorenz wind model along with high frequency wind noise from Venus-GRAM
- These wind variations provides the most conservative trajectory analysis



Venus from Mariner 10
(Credit: NASA)

DAVINCI Acknowledgments

- I would like to thank Lorenz, Sebastian (Replace with last names) along with entire VCD team and DAVINCI Council of Atmospheres for their valuable feedback

Thank You

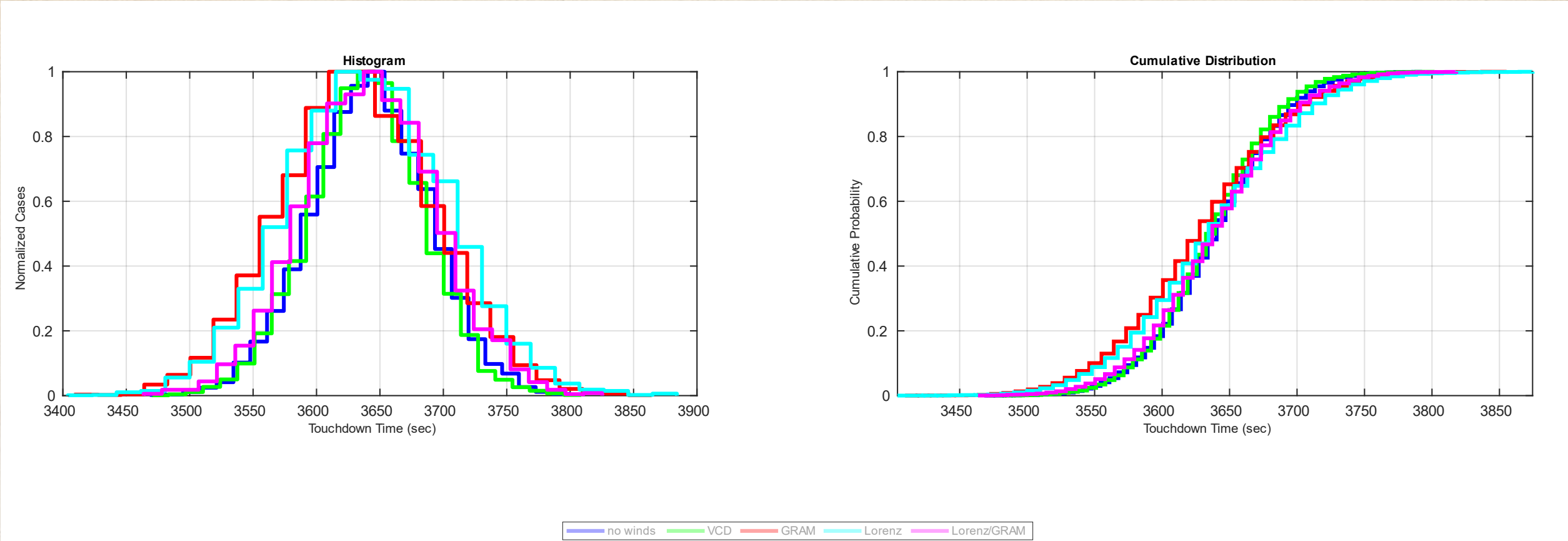
Questions?



Credit: NASA

Backup Slides

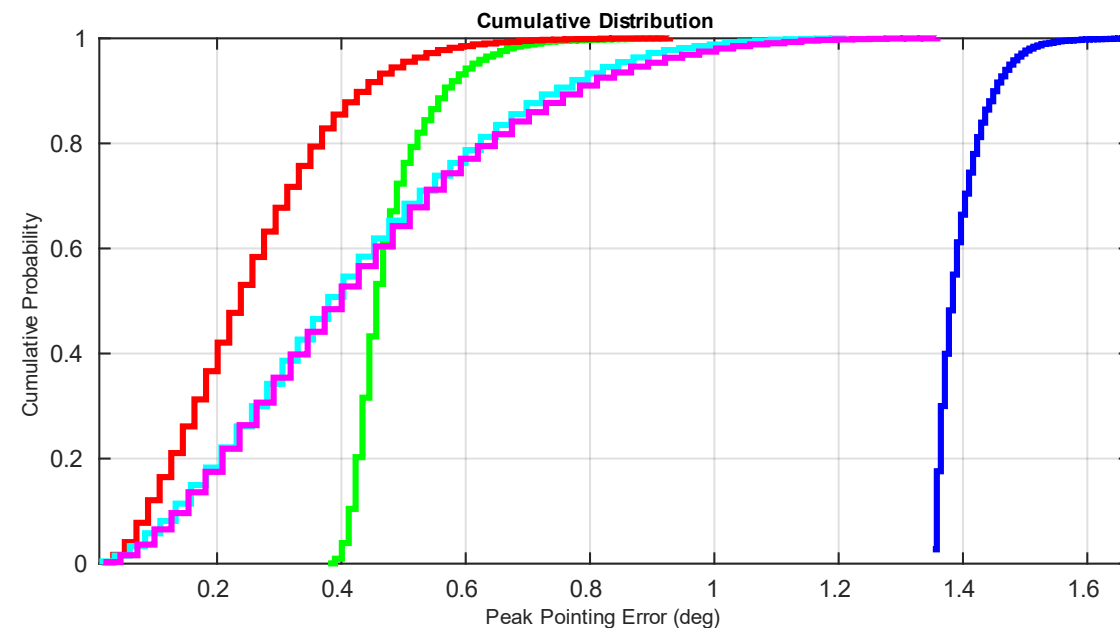
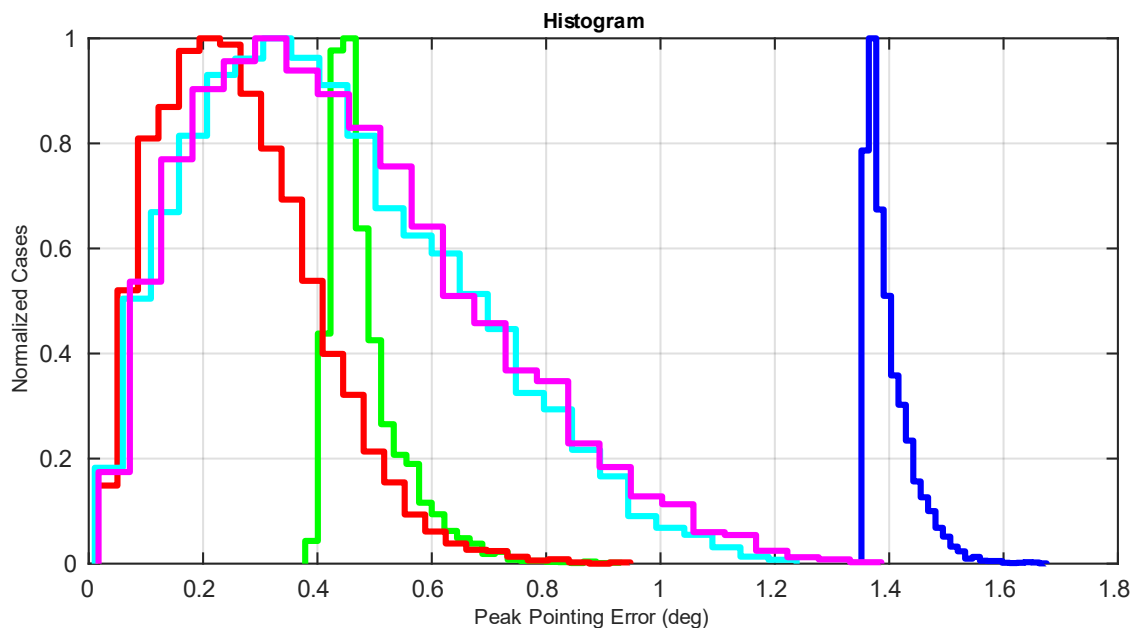
Example of EDL Performance: Touchdown Time



Statistics for:

	no winds	VCD	GRAM	Lorenz	Lorenz/GRAM
Mean =	3642.2165	3639.4287	3632.2256	3640.3644	3641.7781
1-Sigma =	46.1423	44.3678	60.3242	62.0827	51.9309
3-Sigma =	138.4268	133.1034	180.9725	186.2481	155.7926
00.13 %-tile =	3505.2732	3505.8898	3468.7745	3452.8190	3485.7826
50.00 %-tile =	3642.4159	3639.3249	3631.1017	3638.9611	3641.5083
99.87 %-tile =	3778.5707	3777.8237	3817.3088	3843.6487	3802.6712

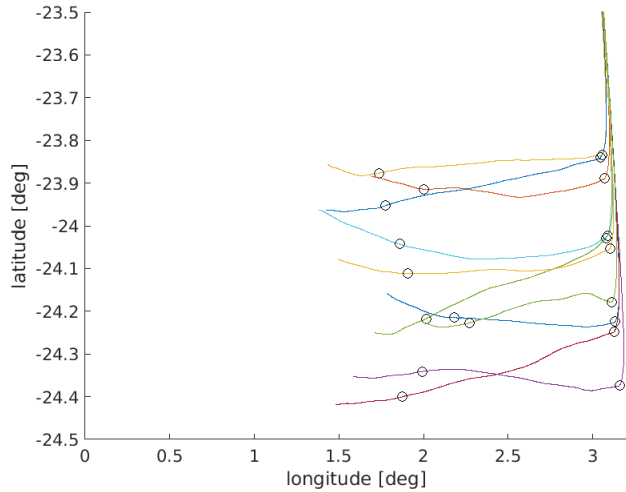
Example of EDL Performance: Peak Pointing Error



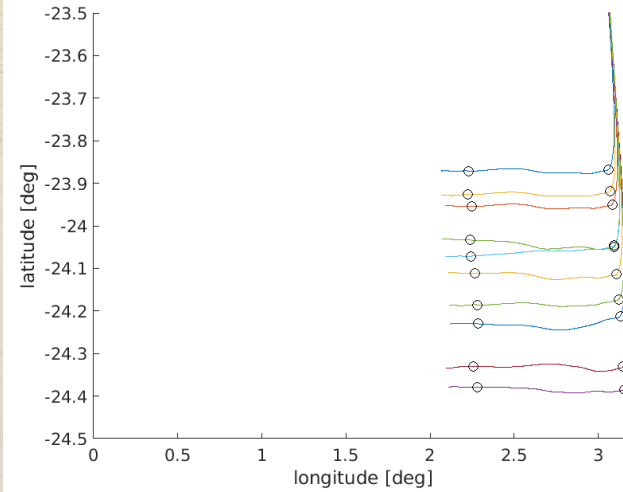
no winds VCD GRAM Lorenz Lorenz/GRAM

Statistics for:

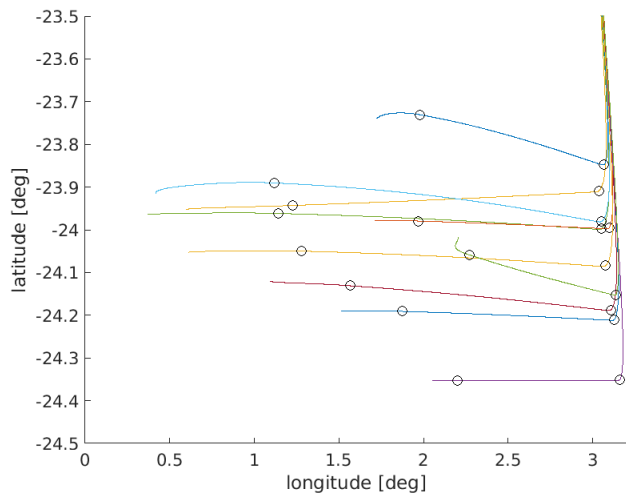
	no winds	VCD	GRAM	Lorenz	Lorenz/GRAM
Mean =	1.3986	0.4835	0.2626	0.4300	0.4465
1-Sigma =	0.0412	0.0674	0.1353	0.2323	0.2442
3-Sigma =	0.1235	0.2023	0.4058	0.6968	0.7327
00.13 %-tile =	1.3535	0.3922	0.0244	0.0214	0.0368
50.00 %-tile =	1.3854	0.4634	0.2459	0.3996	0.4094
99.87 %-tile =	1.6327	0.8710	0.8176	1.1563	1.2637



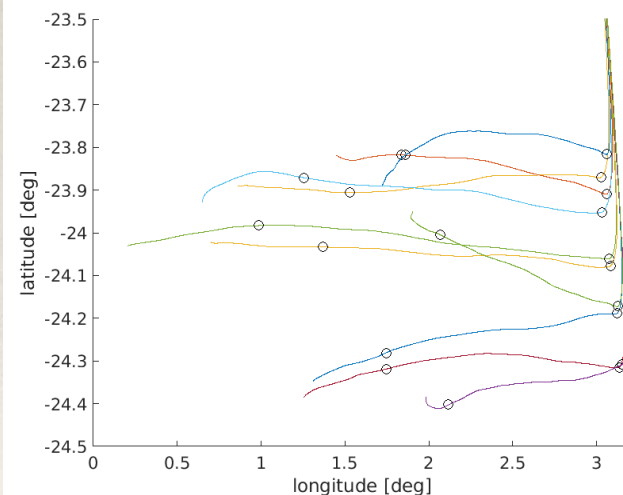
GRAM winds



VCD winds



Lorenz winds



Lorenz winds with GRAM perturbations

Circles represent
parachute deploy and
parachute jettison