

Daedalus

a Candidate ESA Earth Explorer Mission for the Exploration of the Lower Thermosphere-Ionosphere

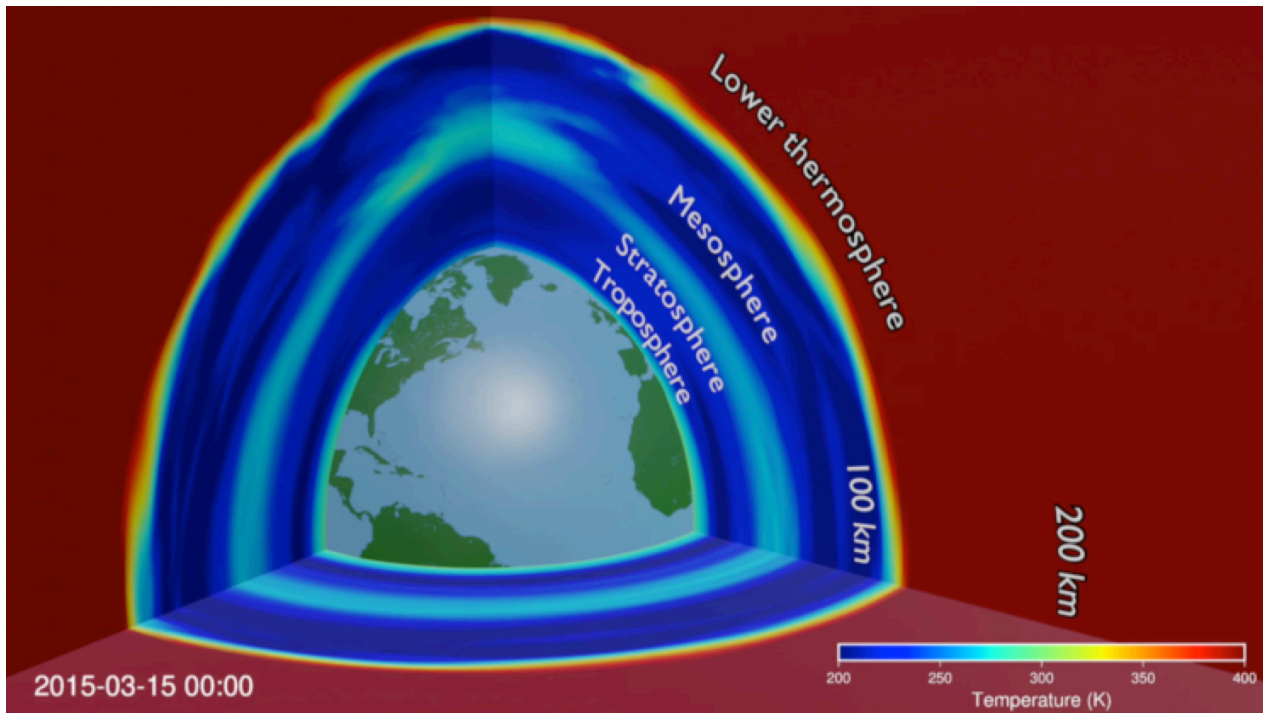
Theodoros Sarris and the Daedalus Science Study Team

EGU-2020, Thu, 07 May, 08:30–12:30



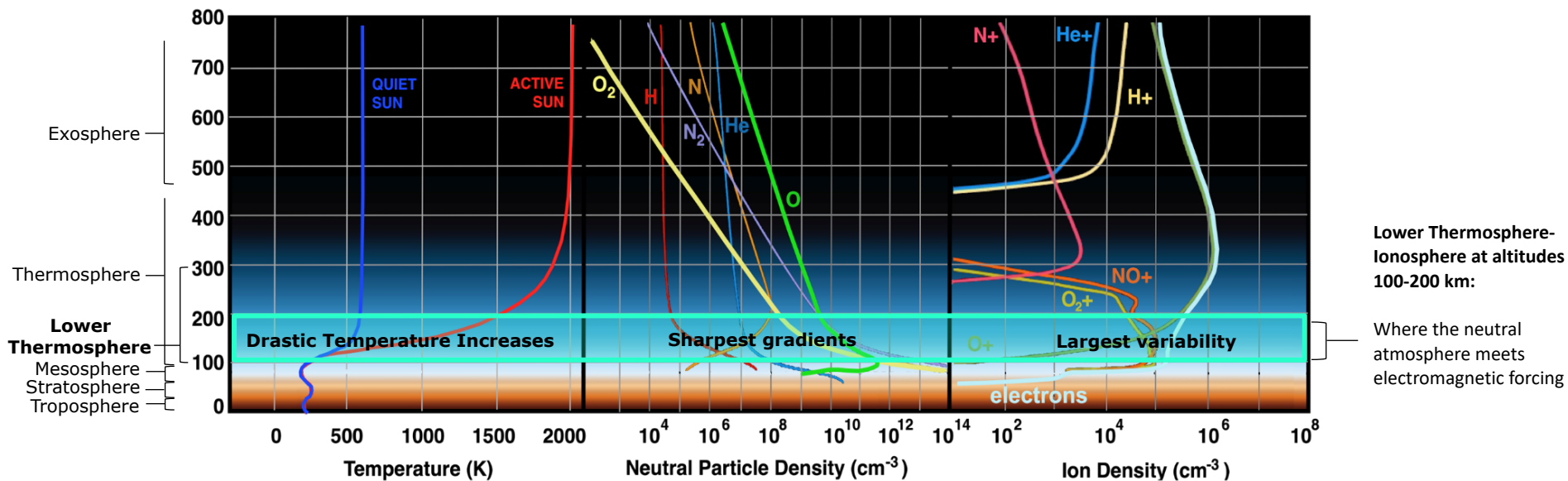
Background and Justification

Lower Thermosphere-Ionosphere: A key transition region in the atmosphere



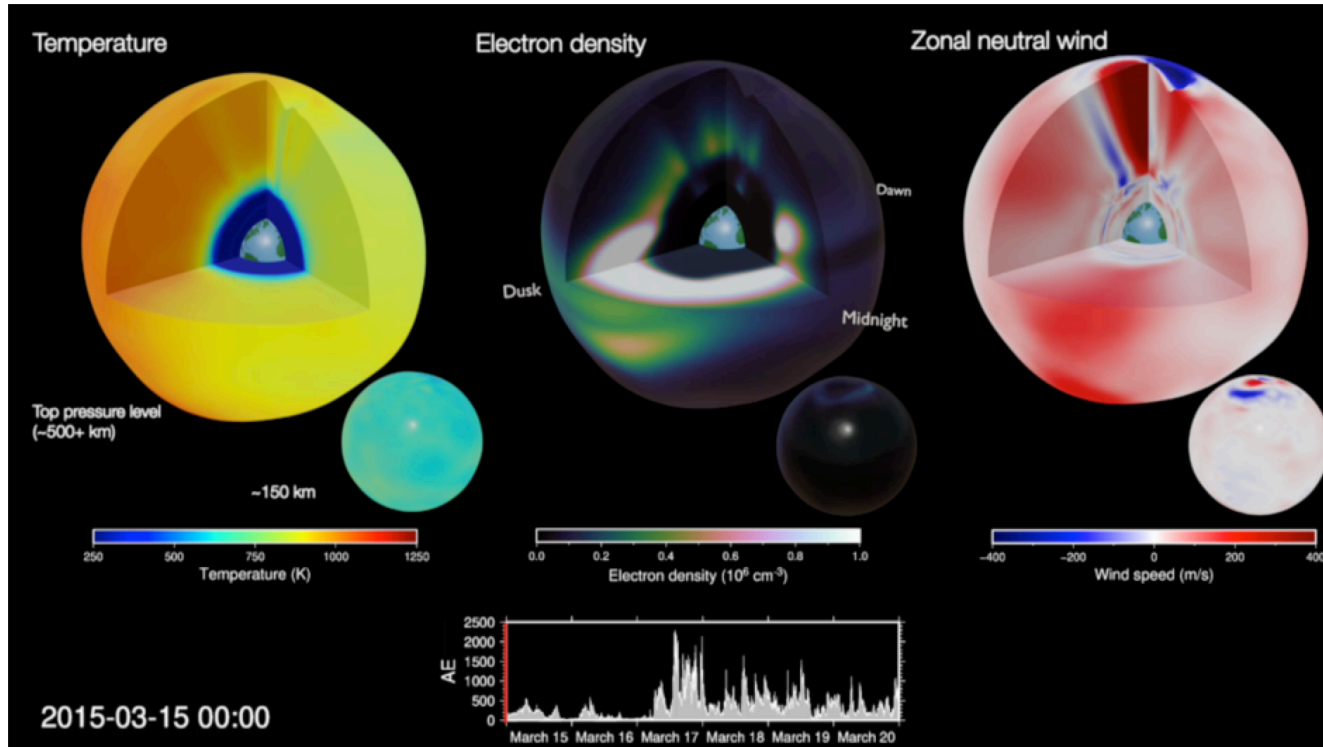
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Lower Thermosphere-Ionosphere: A key transition region in the atmosphere



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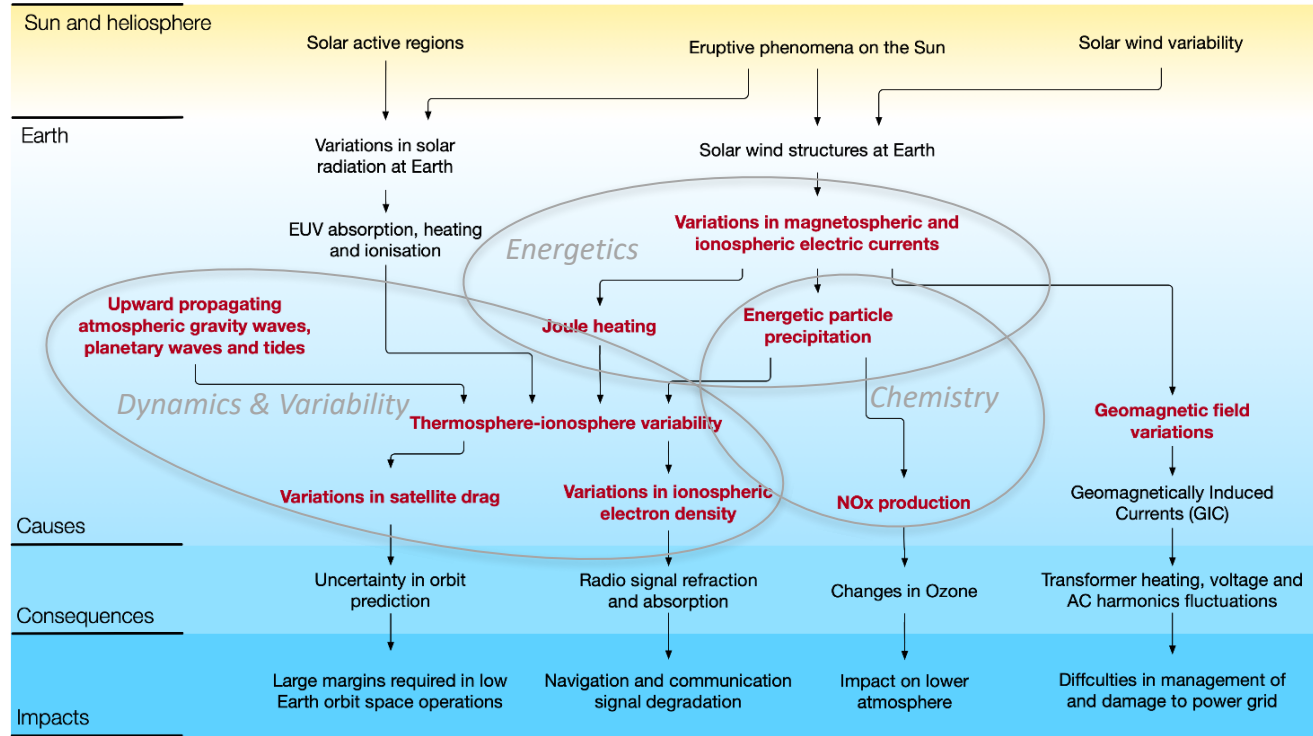
The Lower Thermosphere-Ionosphere during the 2015 St. Patrick's Day geomagnetic storm on March 17



WACCM-X simulation by Federico Gasperini (NCAR/HAO), AMIE assimilation of ionospheric electrodynamics by Gang Lu (NCAR/HAO), AE index data from WDC for Geomagnetism Kyoto, animation by Eelco Doornbos (KNMI)

Background and Justification

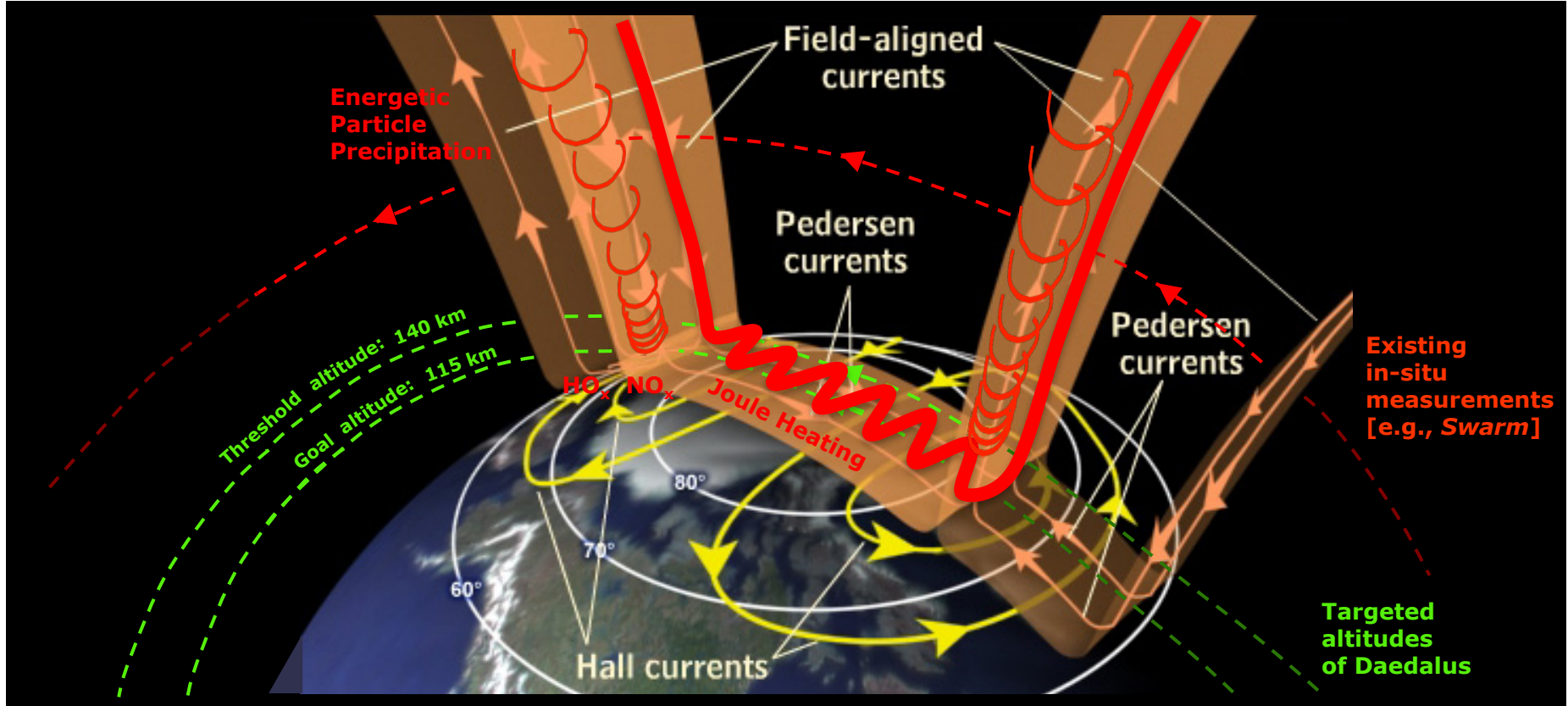
Overview of main processes in the Lower Thermosphere-Ionosphere



Processes that Daedalus will directly observe in-situ are **marked in red**

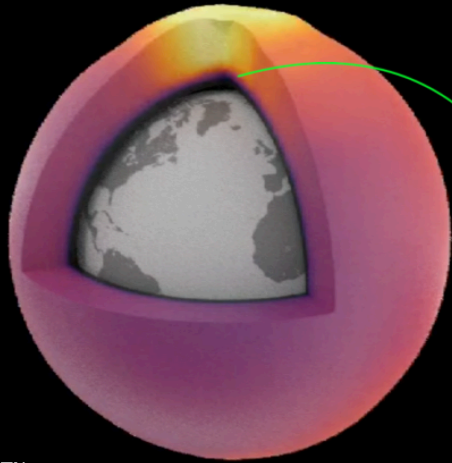
Mission Objectives

Joule heating & particle precipitation in the Lower Thermosphere-Ionosphere and targeted altitudes of Daedalus



Mission Objectives

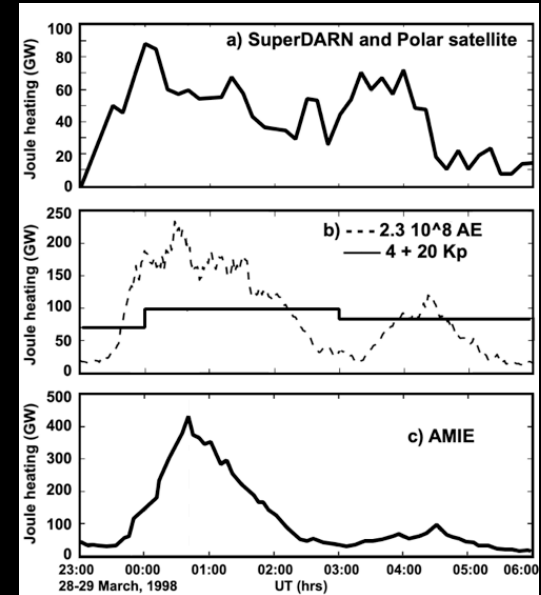
Daedalus in-situ sampling of Joule heating at the regions where it maximizes



- TIE-GCM TN
- 600-1200 K
- Height 5x

Scene Generation simulations for
Daedalus Performance Demonstration

Discrepancies in existing Joule heating estimations

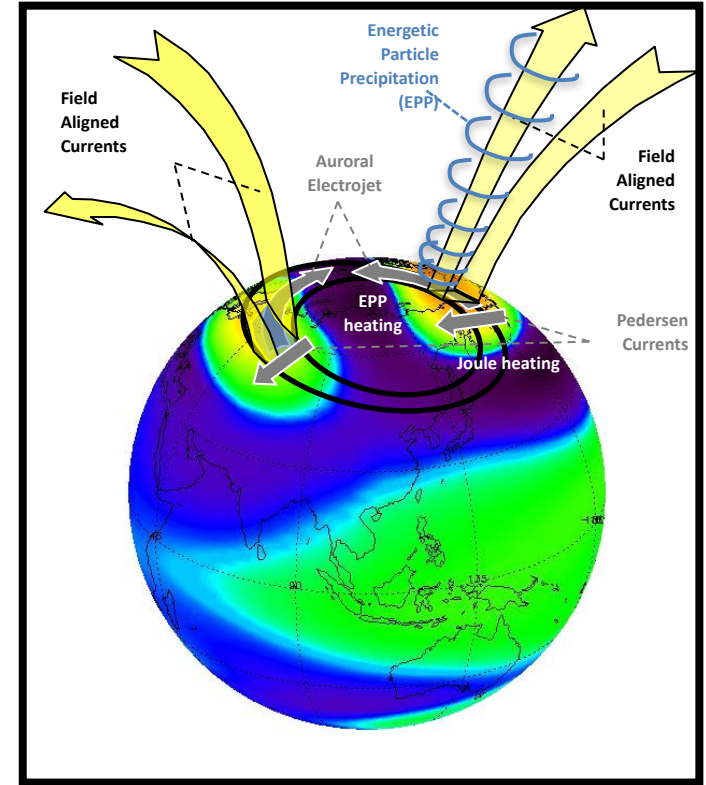


Palmroth et al., Ann. Geophys., 2004

Mission Objectives

A. Science Questions related to **Energetics**:

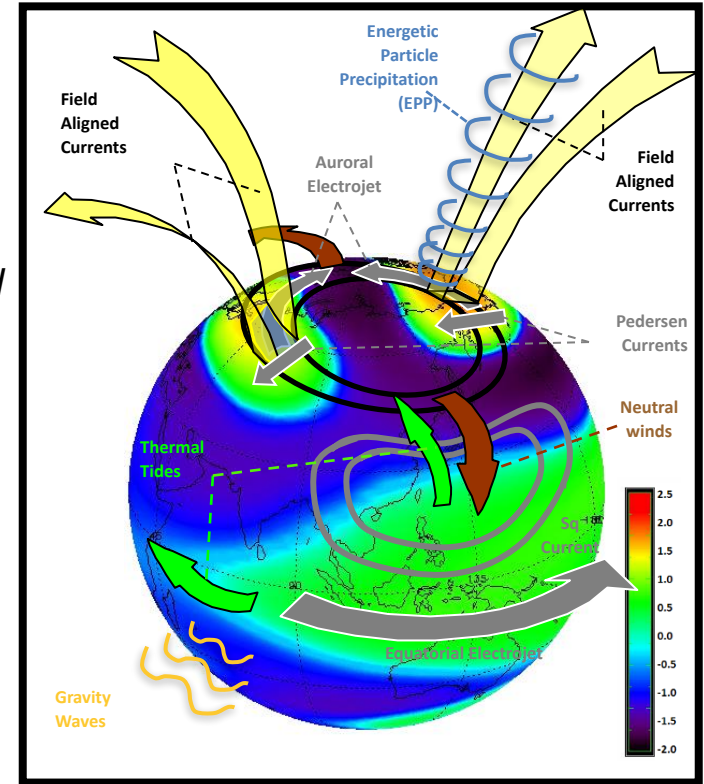
- *What is the energy deposited per unit volume at Lower Thermosphere-Ionosphere altitudes via Joule heating & Energetic Particle Precipitation?*
- *How does this energy deposition affect the local transport, thermal structure, & composition within Lower Thermosphere-Ionosphere altitudes?*



Mission Objectives

B. Science Questions related to **Dynamics** :

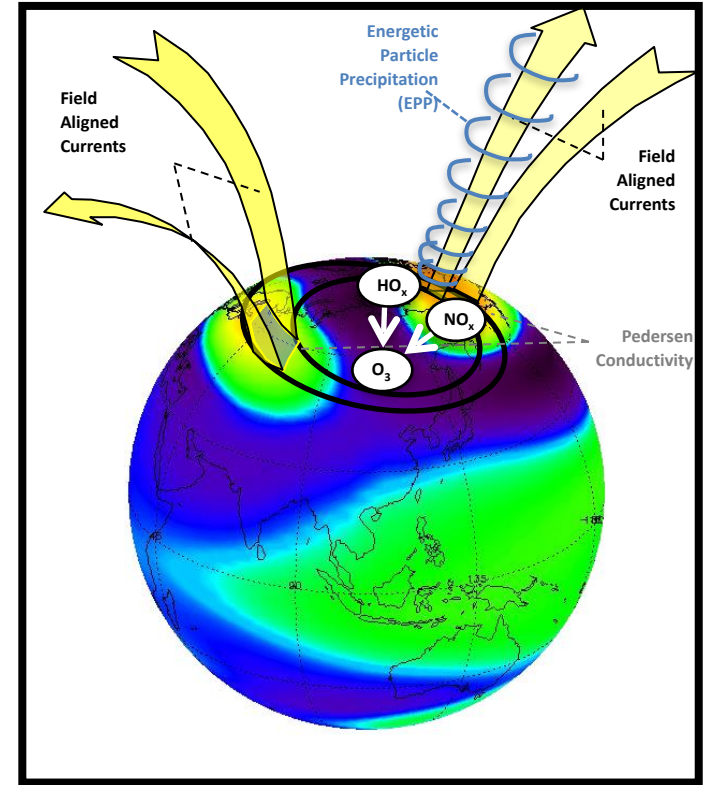
- *What are the relative contributions of solar, magnetospheric, and atmospheric forcing influencing Lower Thermosphere-Ionosphere fluid dynamics and electrodynamics at high, mid and low latitudes?*
- *What are the amplitudes and spectra of small-scale Gravity Waves in the Lower Thermosphere-Ionosphere ?*
- *How do large shears, sharp gradients, and small-scale plasma instabilities develop in the Lower Thermosphere-Ionosphere ?*



Mission Objectives

C. Science Questions related to **Chemistry:**

- *What are the effects of Energetic Particle Precipitation on the ionisation and composition of the Lower Thermosphere-Ionosphere?*
- *What are the dominant processes in HO_x and NO_x production in the Lower Thermosphere-Ionosphere?*
- *How much Energetic Particle Precipitation strikes onto the mesosphere/stratosphere?*



Mission Requirements

Daedalus Derived Products:

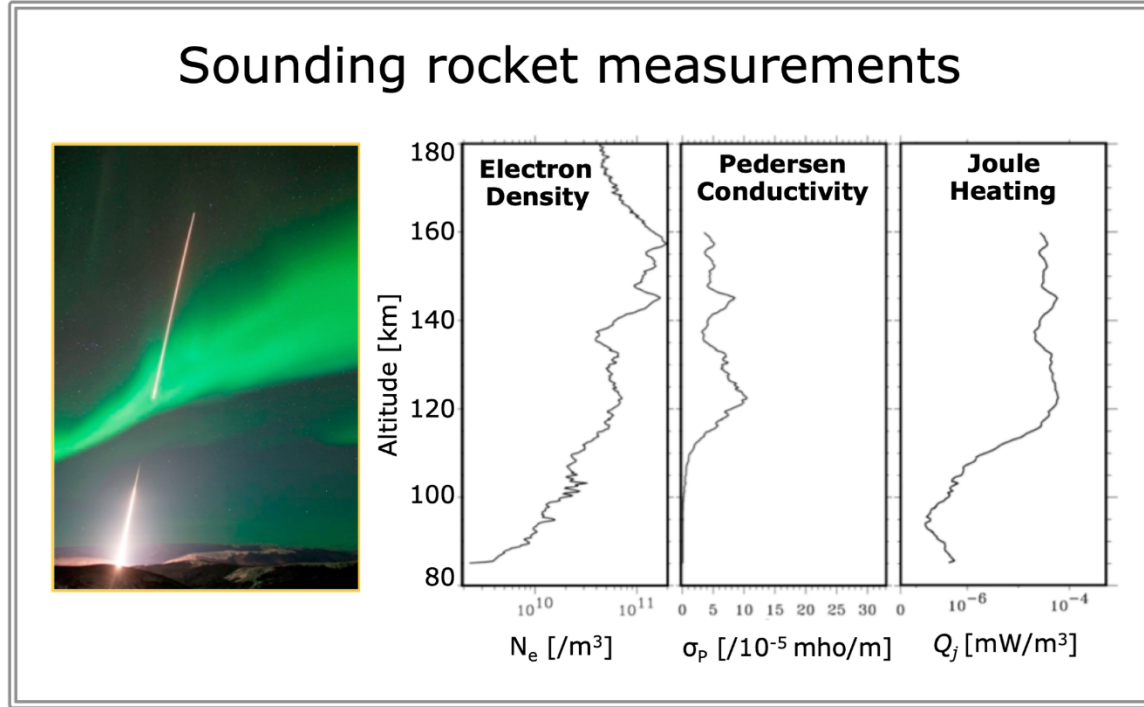
	Derived Product	Derived Product Symbolism
Heating Sources	Joule Heating (q_j)	$q_j = j \cdot (E + \mathbf{u}_n \times \mathbf{B})$
	Ohmic Heating (q_Ω)	$q_\Omega = \sigma_p \mathbf{E} + \mathbf{u}_n \times \mathbf{B} ^2$
	Frictional Heating (q_f)	$q_f = m_{in} v_{in} N_e \mathbf{v}_i - \mathbf{u}_n ^2$
	Poynting Vector (S) in the neutral gas frame	$S = (\mathbf{E} + \mathbf{u}_n \times \mathbf{B}) \times \Delta \mathbf{B} / \mu_0$
	Energetic Particle Precipitation heating (q_{EPP})	q_{EPP} (upper limit)
Currents	In-situ current density (j): Hall (j_H) and Pedersen (j_p) currents	$\mathbf{j} = q N_e (\mathbf{v}_i - \mathbf{v}_e)$ or: $\mathbf{j} = j_p + j_H$ $j_p = \sigma_p E^*$, $j_H = \sigma_H \mathbf{b} \times E^*$
	Magnetic Forcing (MF)	$\mathbf{j} \times \mathbf{B}$
	Field Aligned Currents (FAC)	$\Delta B / (\mu_0 \Delta x)$
	Magnetic Field Residuals (ΔB)	$\Delta B = B_{obs} - B_{mod}$
Conductivity & Cross-Sections	Conductivities	$\sigma_p, \sigma_H, \sigma_\parallel$
	Ion-Neutral Cross Sections	σ_{in}
	Ion-Neutral Collision Frequencies	ν_{in}

Daedalus Geophysical Observables:

	Abbreviation	Geophysical Observable	Commonly used instruments	Instrument Abbreviations
Ionosphere	\mathbf{v}_i	Ion Drift velocity	Thermal Ion Imager or Ion Drift Meter and Retarding Potential Analyzer	TII or IDM/RPA
	T_i	Ion Temperature		
	T_e	Electron Temperature	Langmuir Probe and Mutual Impedance Probe	LPB and MPI
	N_i	Ion Number Density		
	N_e	Electron Num. Density		
	TEC	Total Electron Content	GNSS Receiver	GNSS
	n_{ix}	Ion Composition	Ion Mass Spectrometer	IMS
thermosphere	\mathbf{u}_n	Neutral Wind Velocity	Ram Wind Sensor and Cross-Track Wind Sensor	RWS/CWS
	N_n	Neutral Density	Accelerometer	ACC
	T_n	Neutral Temperature	Neutral Mass Spectrometer	NMS
	n_{nx}	Neutral Composition		
fields & energetic particles	$j_{high}, j_{med}, j_{low}$	Energetic Particles	Energetic Particle Detector	EPD
	\mathbf{B}	Magnetic Field	Magnetic Field Instrument	MFI
	\mathbf{E}	Electric Field	Electric Field Instrument	EFI

Mission Requirements

In-situ sampling
by rockets:

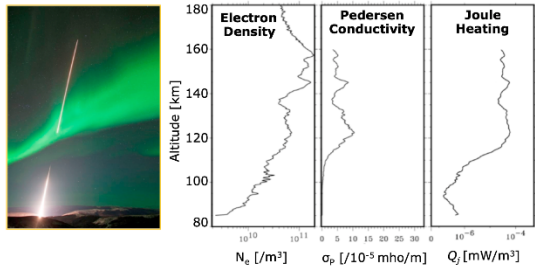


Mission Requirements

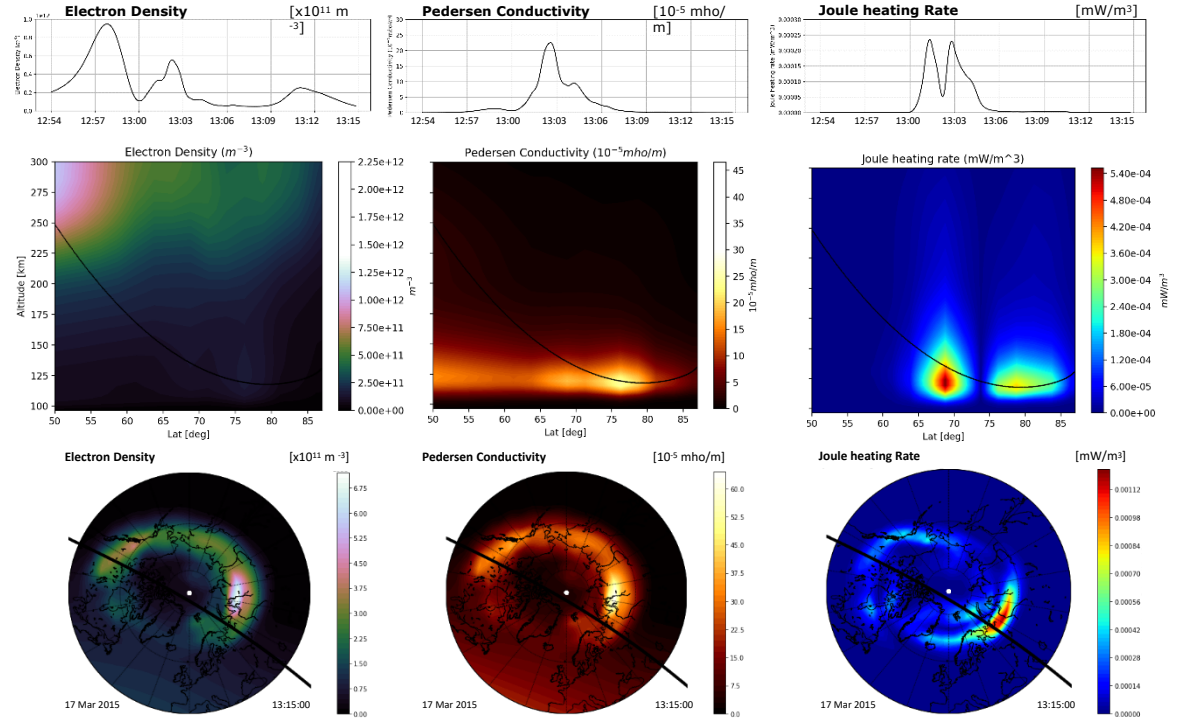


Sarris et al., Geosci. Instr. Dev., 2020

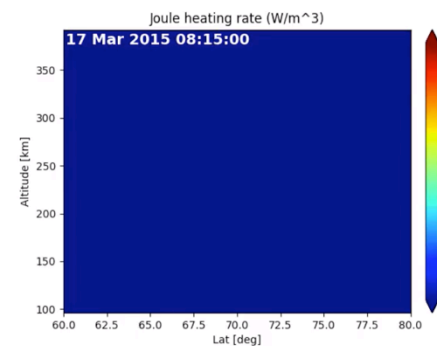
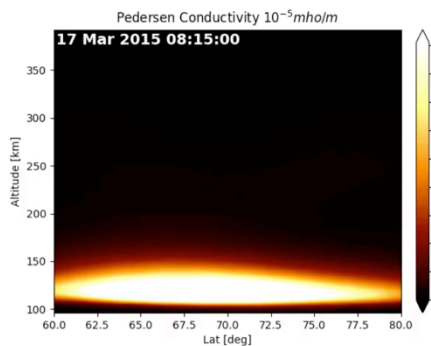
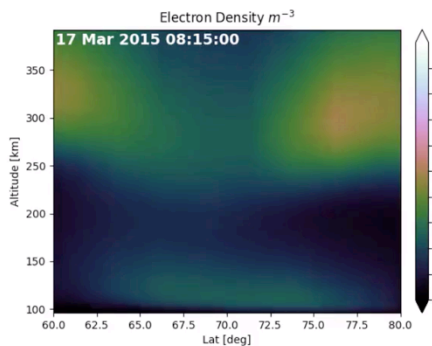
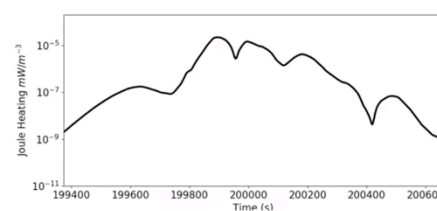
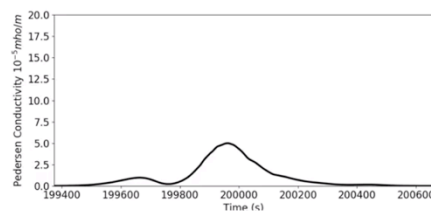
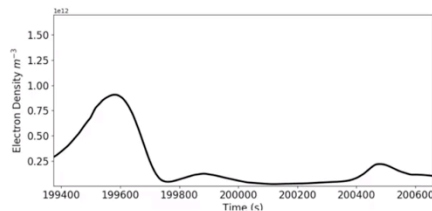
Sounding rocket measurements



Daedalus in-situ measurements

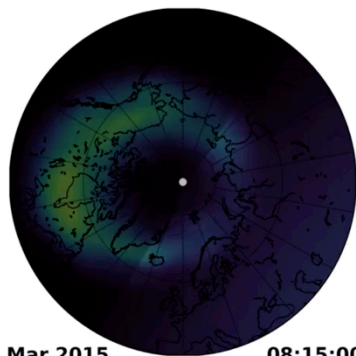


Electron Density [$\times 10^{11} \text{ m}^{-3}$] Pedersen Conductivity [10^{-5} mho/m] Joule heating Rate [mW/m^3]



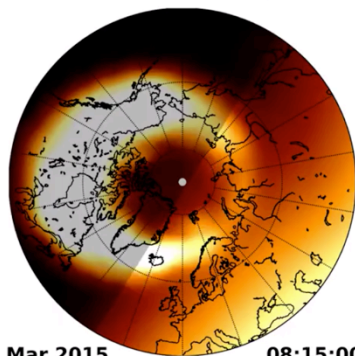
Electron Density

[m^{-3}]



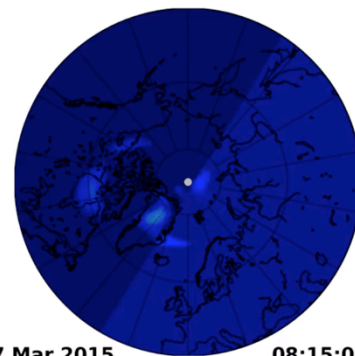
Pedersen Conductivity

[mho/m]



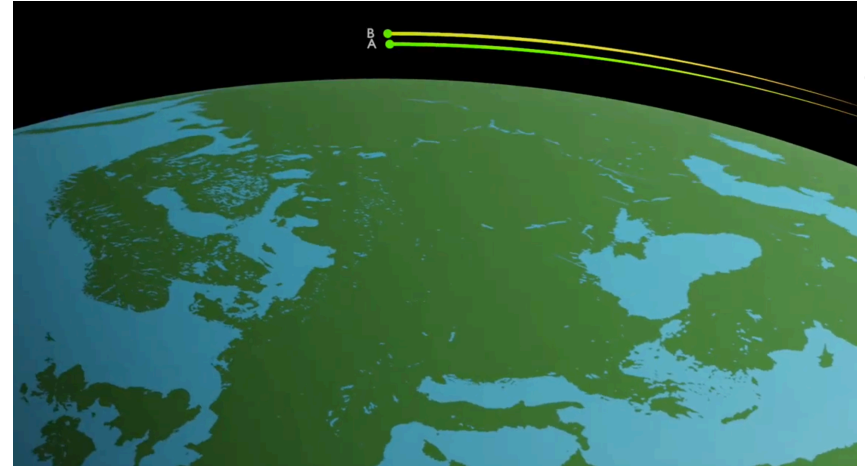
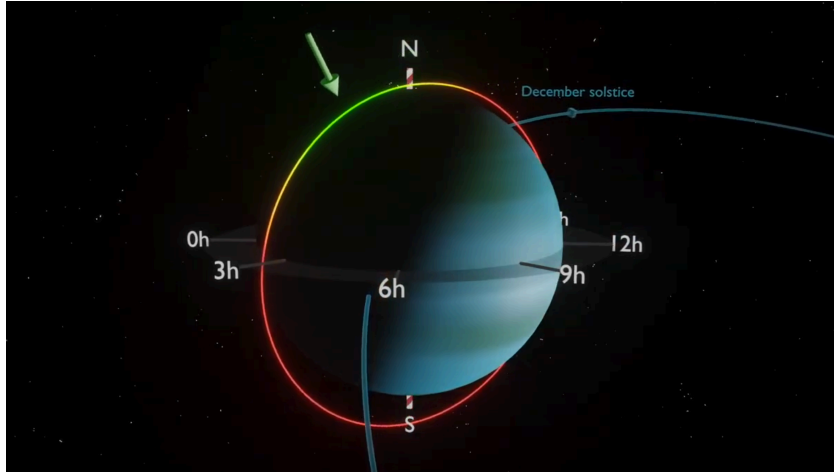
Joule Heating Rate

[mW/m^3]



Mission Concept

Perigee and Local Time precession and Coverage (movie) Preliminary concept with twin s/c configuration (movie)



Summary and Conclusions

- The QUEST for Daedalus is to explore the atmosphere-space transition region
- The AIM is to better understand the atmosphere-space connection that plays out there
- The PATH to science closure is to establish sufficient coverage of the relevant regions at the necessary scales with sufficient instrument performance

Daedalus will improve our understanding of the **energetics**, **dynamics** and **chemistry** of the atmosphere-space transition region in the lower thermosphere-ionosphere, and of the neutral-plasma interactions that affect them.

Consortia institutes and partners



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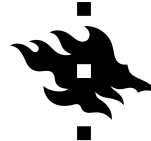
Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**



Royal Netherlands
Meteorological Institute
Ministry of Infrastructure
and Water Management



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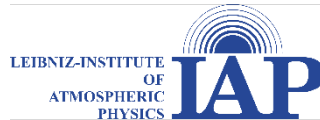


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More information on Daedalus

For more detailed information on the mission definition and science visit:

- The **Daedalus website** at <https://daedalus.earth/>
- Our **virtual conference** (originally planned as a splinter during EGU2020) with several presentations and discussions by scientists ([agenda here](#)). Registration is possible via: <https://tinyurl.com/vkvumuq> .
- The **Daedalus paper** with preliminary mission description: *Sarris et al., Geosci. Instrum. Method. Data Syst., 2020*, <https://doi.org/10.5194/gi-9-153-2020>