Results on Titan's Atmosphere Structure by the Huygens Atmospheric Structure Instrument (HASI)

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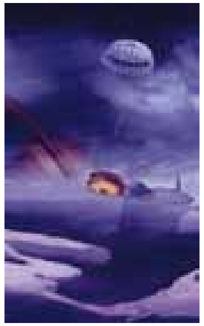
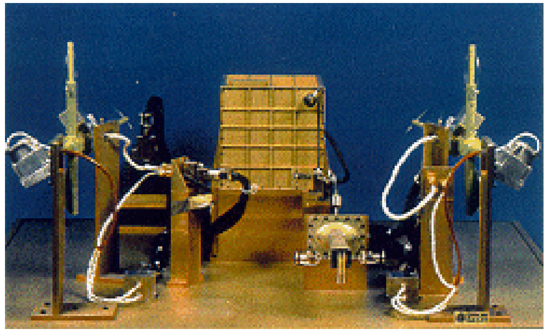
Huygens Atmospheric Structure Instrument (HASI)



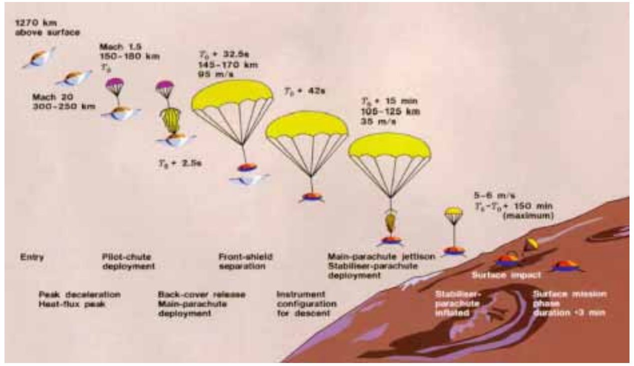
H.A.S.I.
Huygens Atmospheric Structure Instrument
on the Cassini-Huygens mission

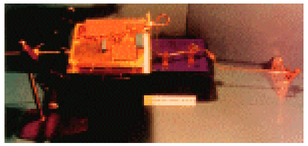


Principal Investigator: M. Fulchignoni

- **Study of Titan's atmosphere and surface**

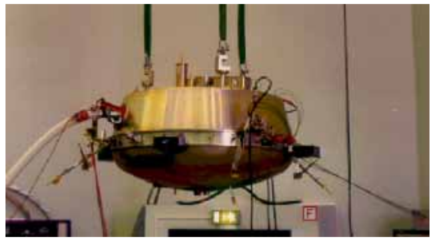
by measuring





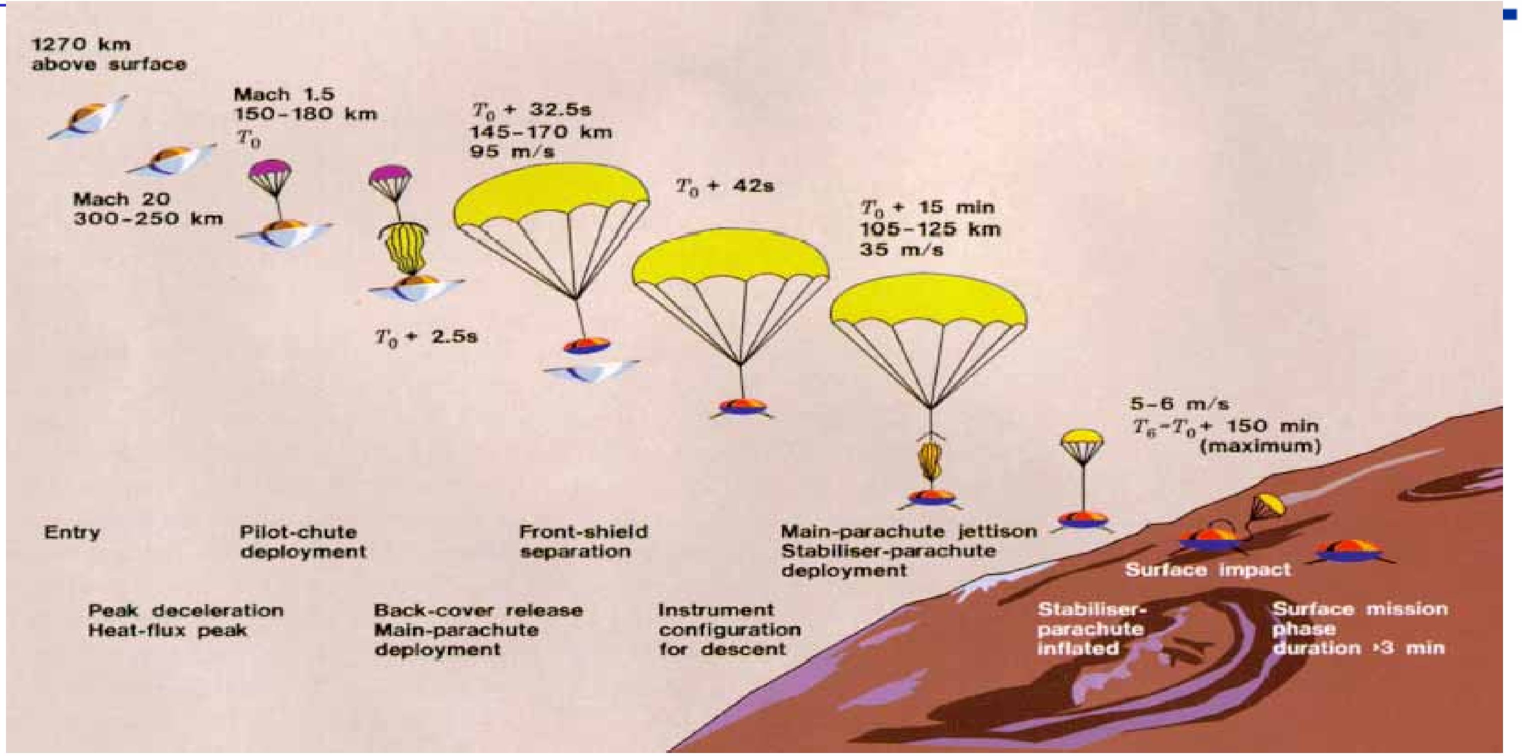
- **acceleration** (ACC)

- **pressure** (PPI)
- **temperature** (TEM)



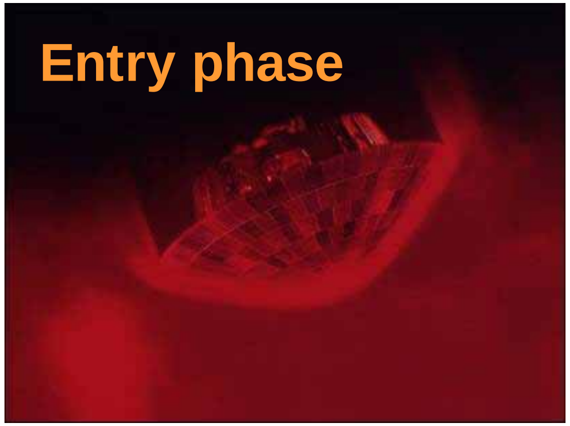
- **electrical properties** (PWA, RAU)
- ***Heritage: Pioneer Venus, Venera, Galileo, and Viking probes***

HASI operations



- HASI was the first instrument to be operating
- ACC measurements started at ~2800 km
- After parachute deployment, direct p & T, and electrical measurements
- HASI data represent the unique contribute to the Huygens probe trajectory and attitude reconstruction

HASI measurements at Titan



- *From ~ 1500 to 160 km*

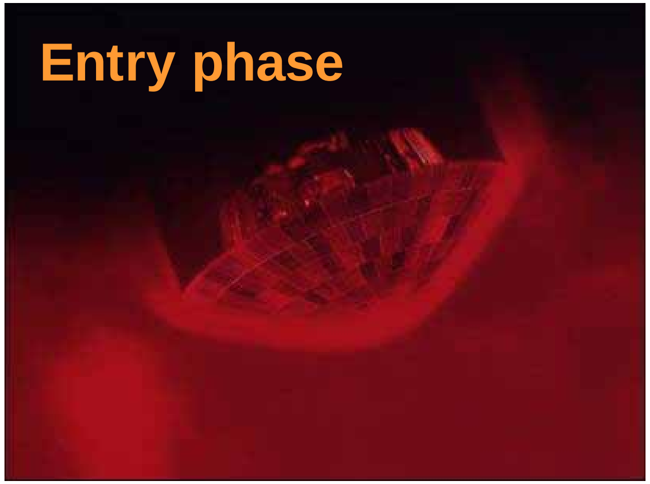
  atmospheric physical properties from **accelerometer data**

- *From ~ 160km down to surface descent under parachute*

  T & **p** directly measured by sensors having access to the unperturbed field outside the probe boundary layer.

  PWA booms deployed: direct measurements of **electrical properties** and **acoustic recording**

Upper atmosphere



Hydrostatic equilibrium

$$dp=-g\rho dz \qquad (1)$$

Equation of state of perfect gas

$$\rho= \mu p/RT \qquad (2)$$

$$\rho(z)=-2(m/C_DA)(a/V_r^2)$$

V_r and z from measured acceleration & initial conditions

<u>Indirect T & p measurements</u>

Hydrostatic equilibrium + perfect gas

$$dp=-g\rho dz=-(pg\mu/RT)dz$$

gravity

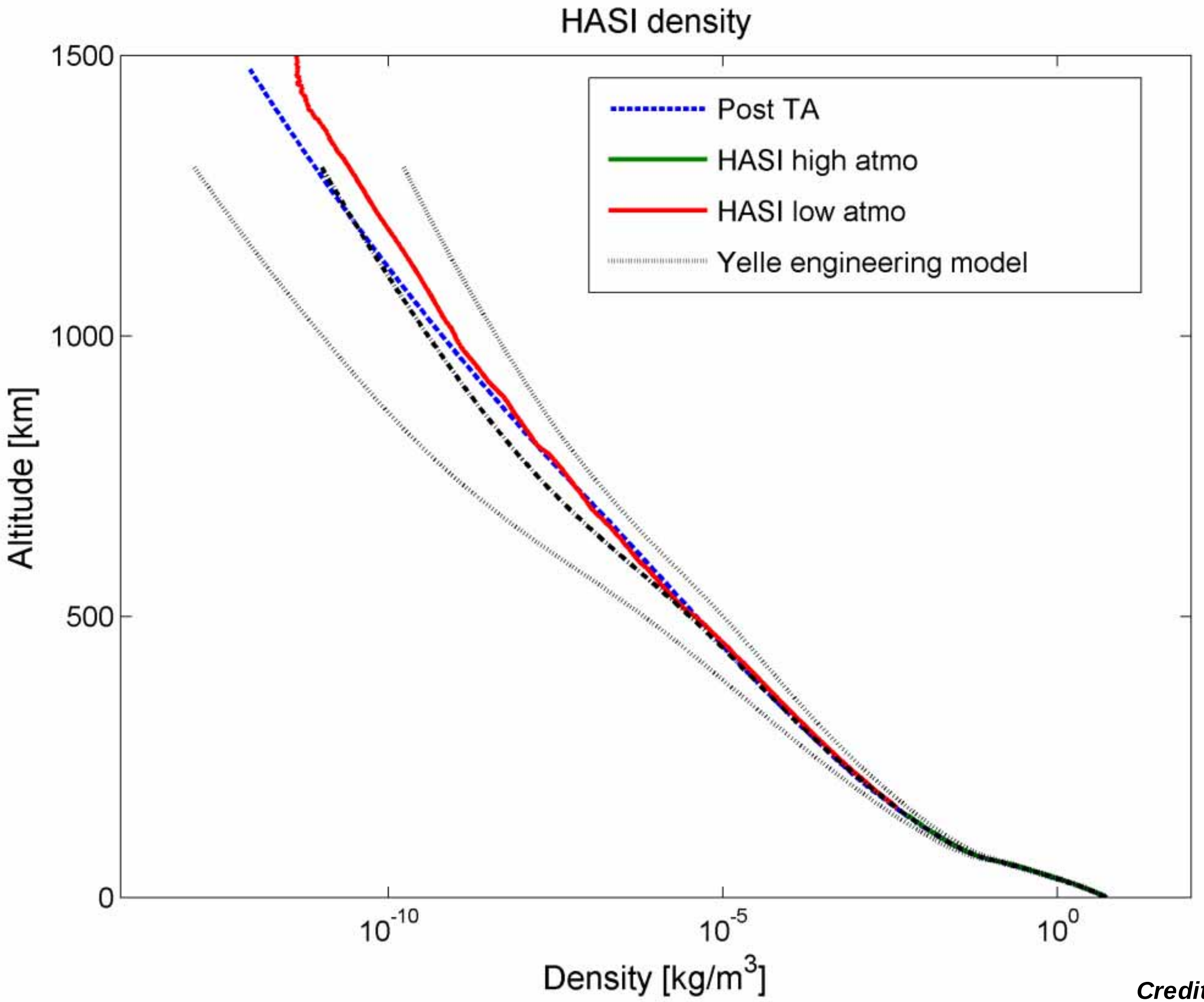
$$g(z)=g_0(R_{Titan}/z)^2$$

p(z) integrating (1) with measured $\rho(z)$ (initial condition to be assumed)

T(z) from (2) $\quad T= \mu p/\rho R$

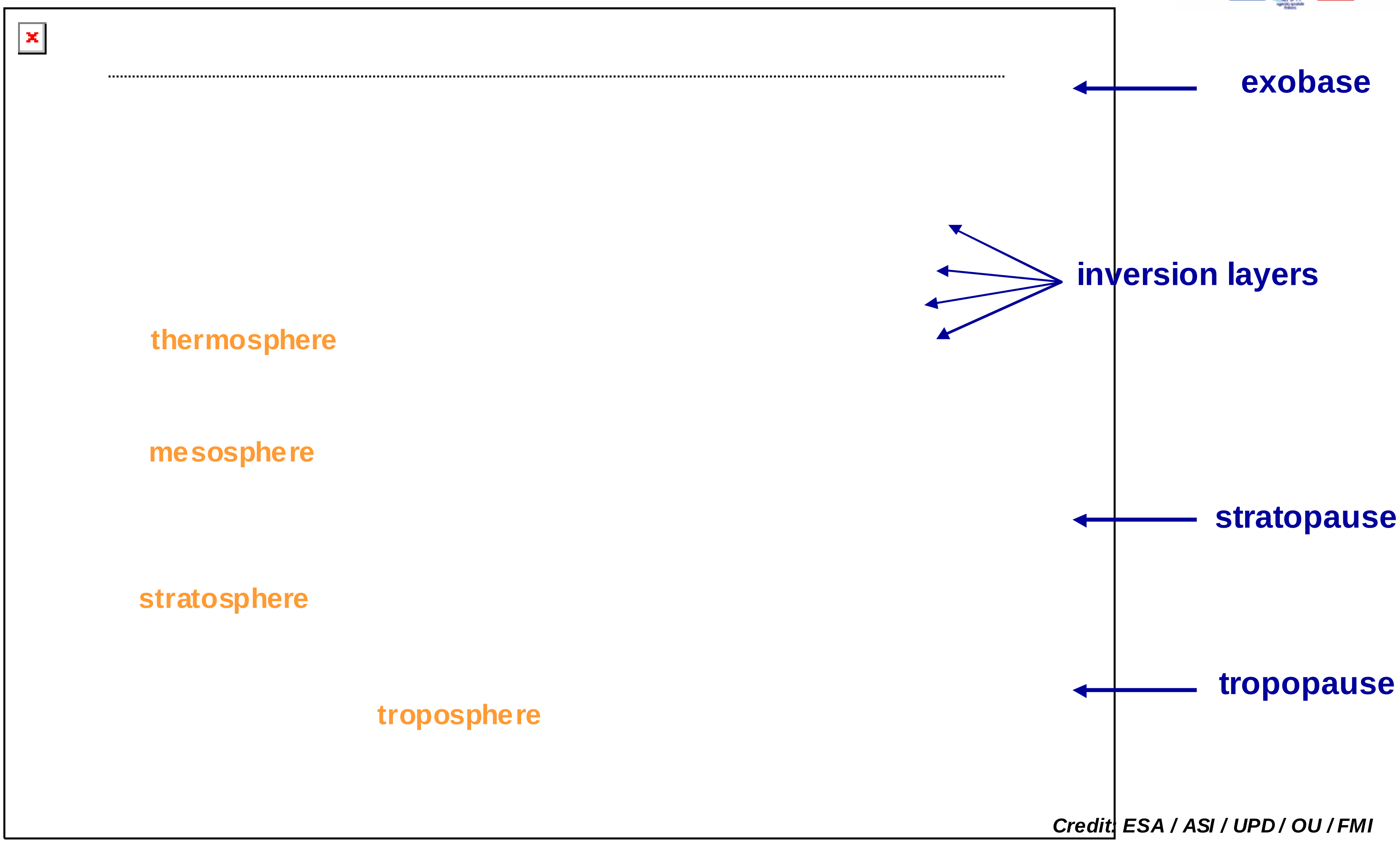
<u>Density, pressure and temperature profiles</u>

HASI density profile

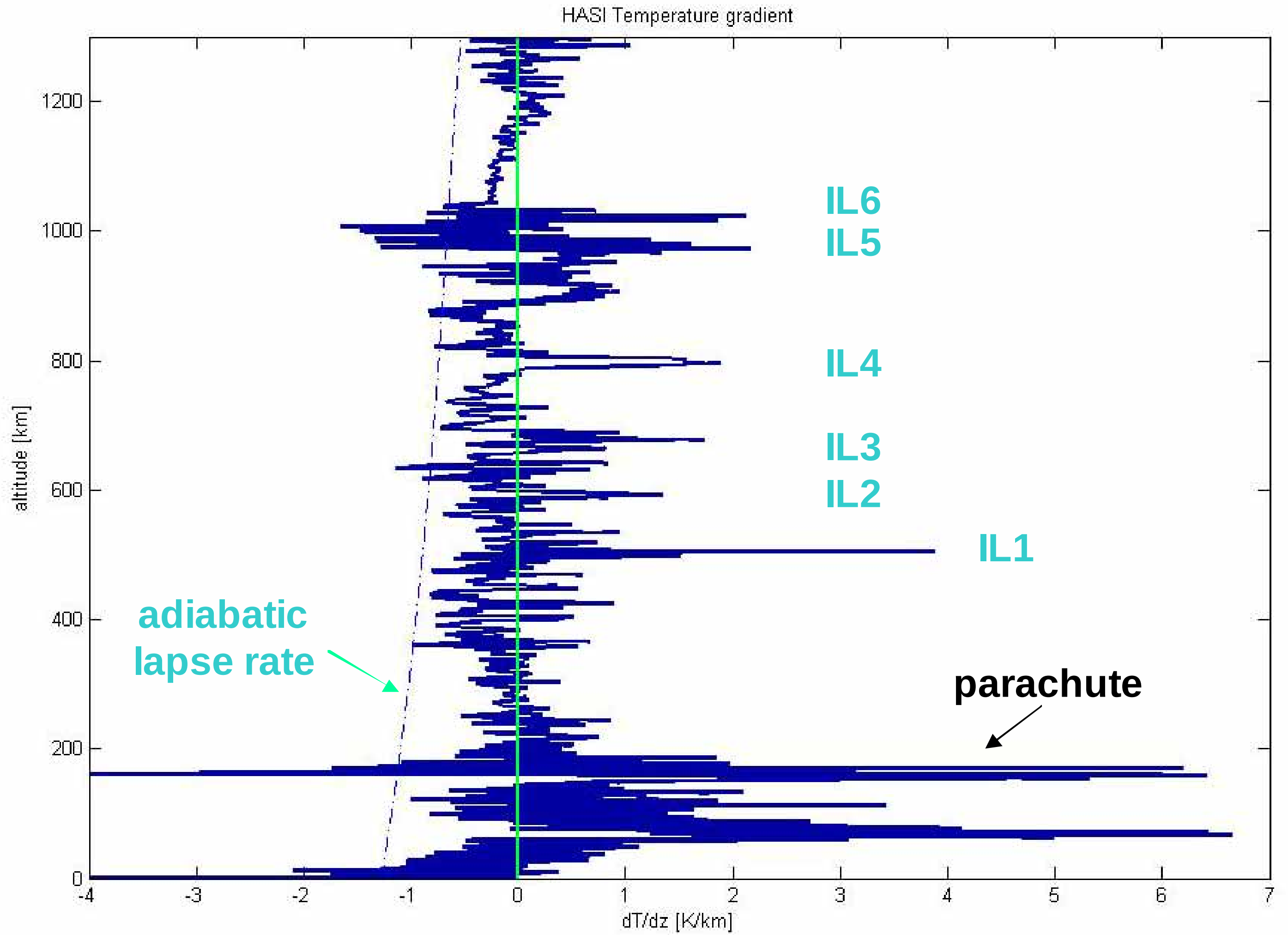


Credit: ESA / ASI / UPD / OU /

HASI temperature profile



HASI temperature gradients



1020 km
980 km

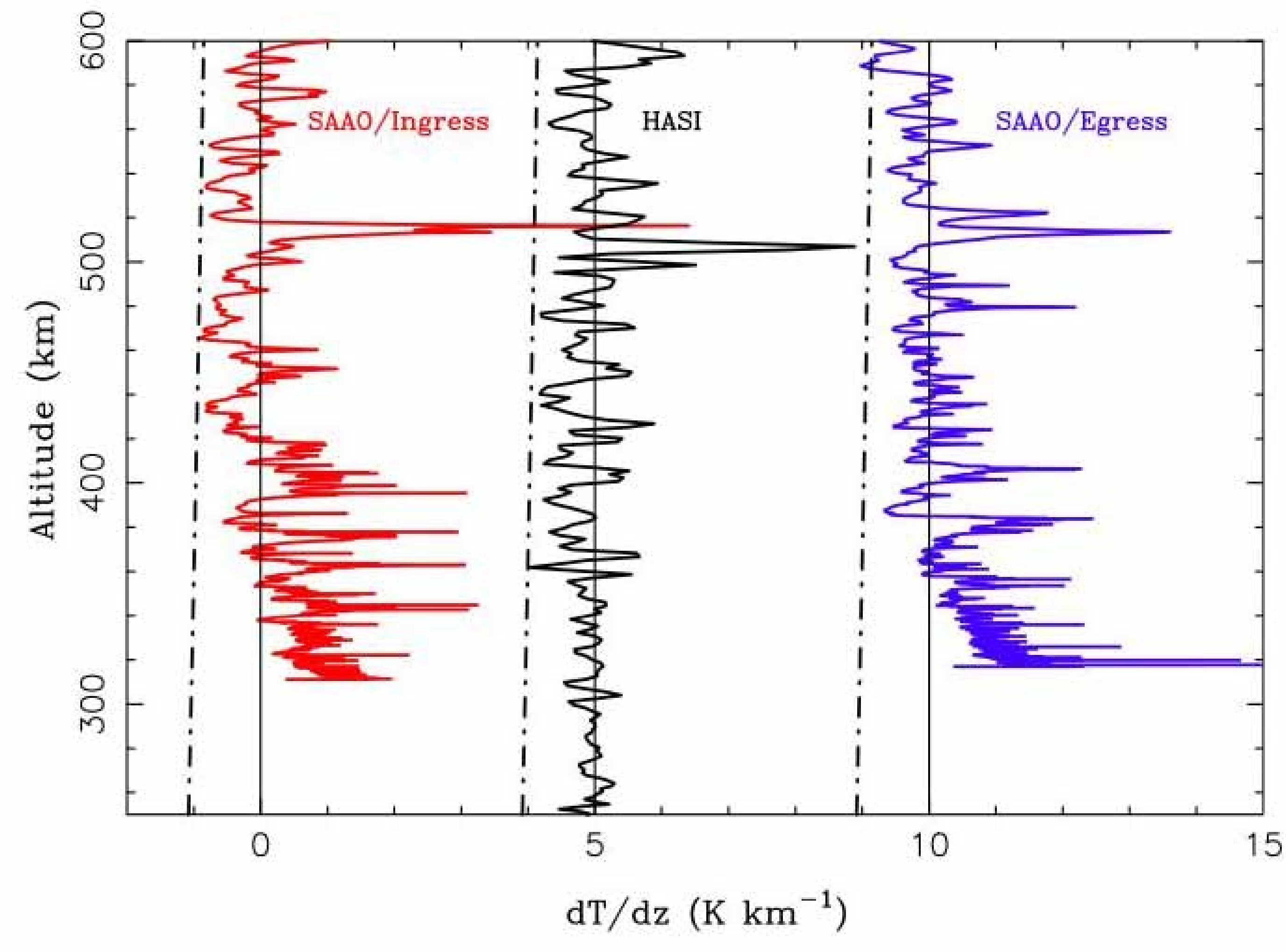
800 km

680 km
600 km

510 km

Credit: ESA / ASI / UPD / OU / FMI

HASI vs Nov2003 stellar occultations



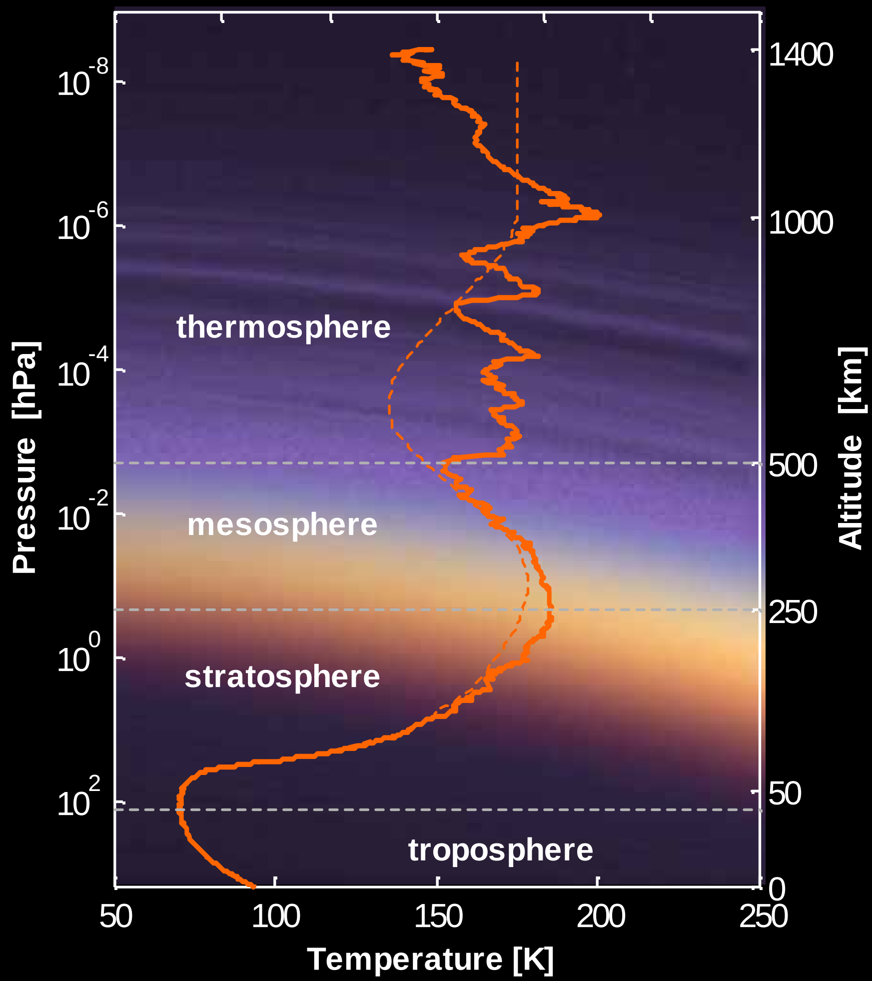
Credit: ESA / ASI / UPD / OU / FMI / B. Sicardy et Titan's occultation team

Titan's atmospheric structure

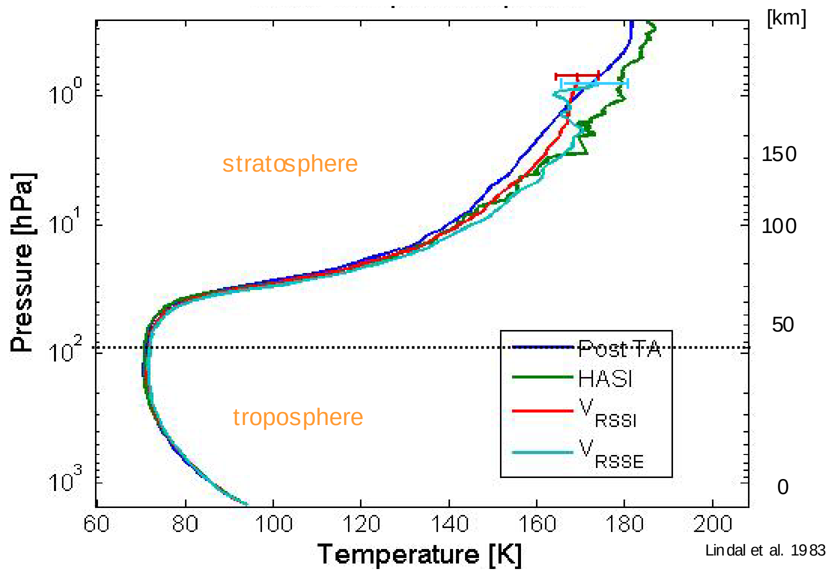
- In the **upper atmosphere** density & temperature higher than expected. Wave-like nature of thermal profile => atmosphere is highly stratified and variable in time.
  Stratopause ~187 K at 250 km

- **Lower stratosphere** & **tropopause:** very good agreement with Voyager 1 temperature.
  Tropopause ~ (70.43±0.25)K at 44 km
  (113±1 mbar)

- At **surface**:
  Temperature (93.65±0.25) K
  Pressure (1467±1) mbar

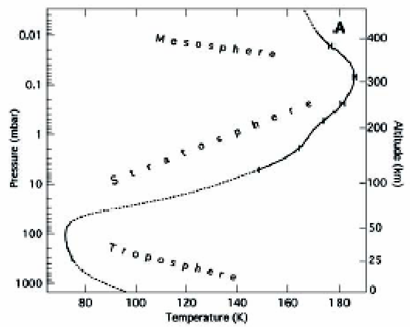


Comparison with Voyager and Cassini results



- **Very good agreement(within error bars with Voyager RSS profiles (pure N_2)**
- **At tropopause HASI T ~ 1K colder, but assuming 98.5% N_2+1.5% CH_4 -> 70.5 K** [Lellouch *el al.* 1989]
- **Temperature variations in lower stratosphere coherent with linear, free propagating gravity waves as derived from Voyager RSS** [Friedson, 1994]

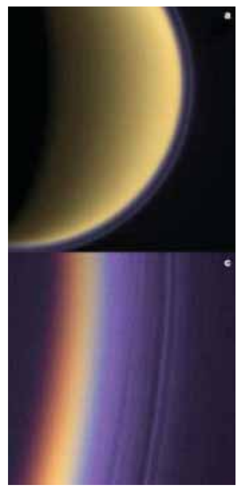
- **Stratopause ~187K at 250 km (0.3 mbar)**
- **CIRS stratopause at higher levels (~ 350 km) for similar T (186 K) at 15°S**



[Flasar et al 2005 *Science*]

- **Presence of layers also confirmed by observations of stellar occultations and Cassini ISS.**

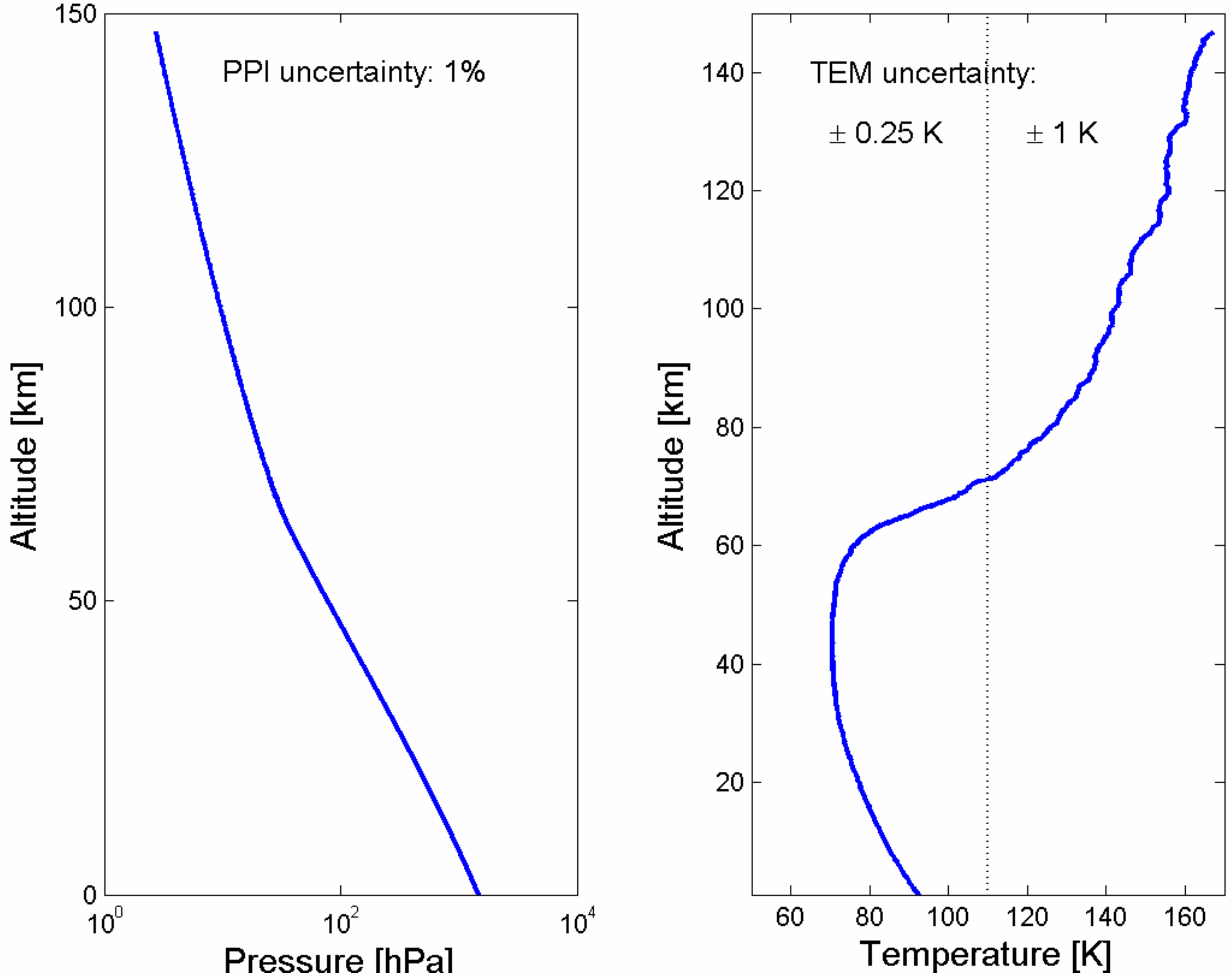
[Porco et al 2005 *Science*]



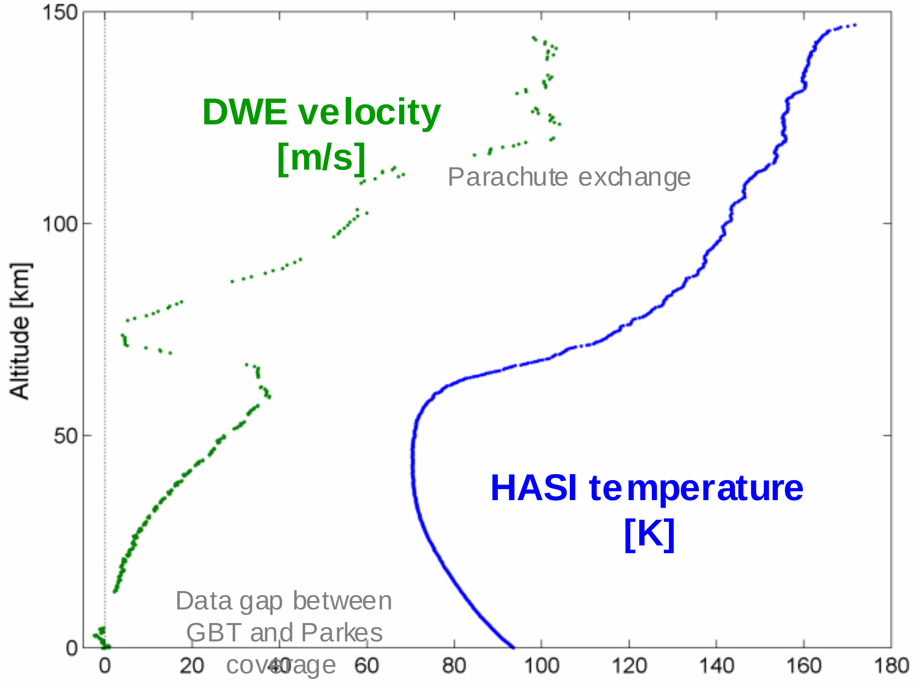
- **Variability and waves observed also by INMS**
- **Exopause at ~1380 km similar values estimated by INMS**

[Waite *el al.* 2005 *Science*]

HASI descent phase

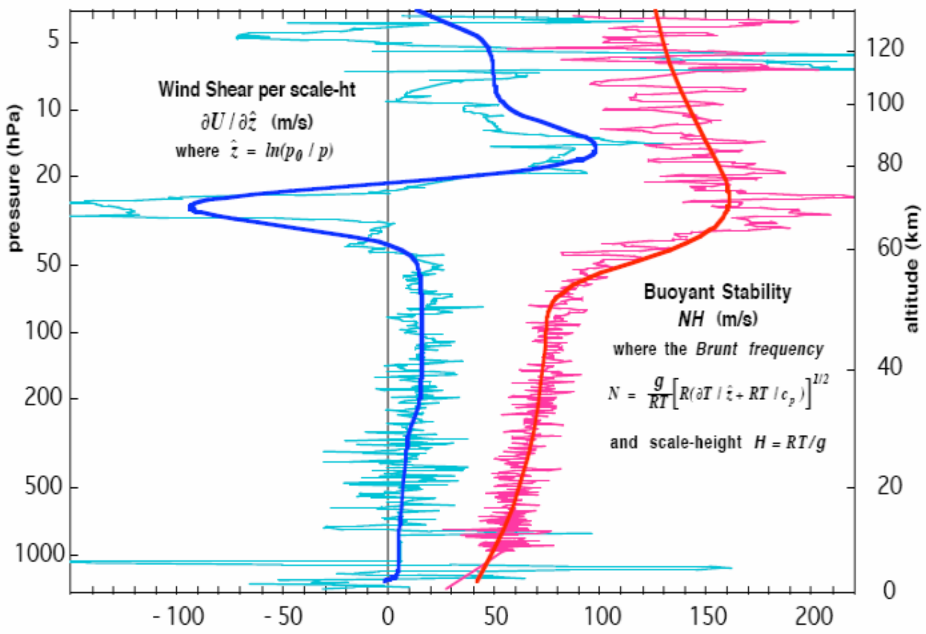


Preliminary meteorological interpretation: correlation of HASI and DWE data



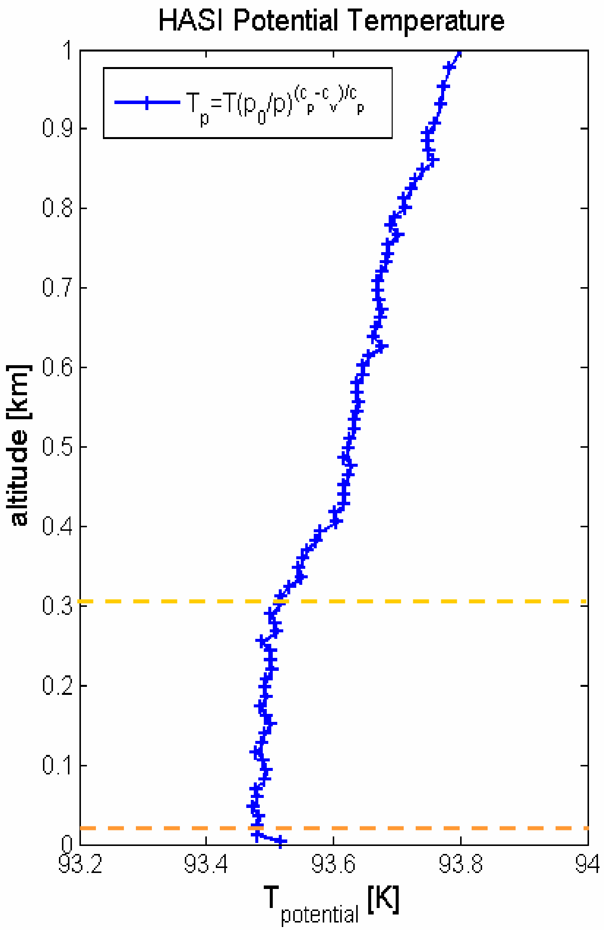
Vertical profile of T and wind analysed as wind shear and buoyant static stability

Correlation of the unexpected strong vertical wind shear with Titan's more buoyant stratified region.

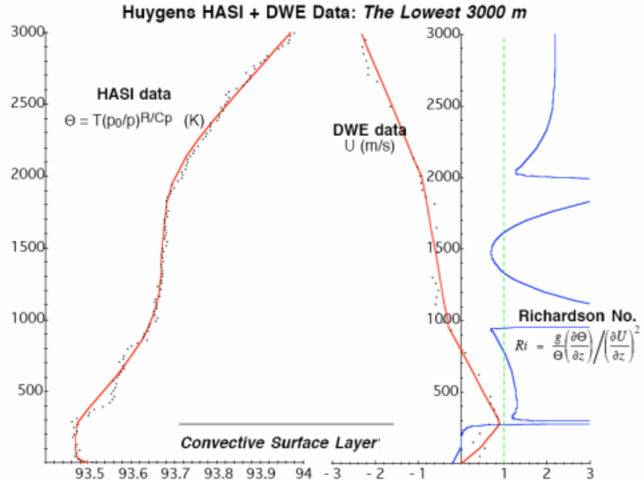


Planetary Boundary Layer

Planetary Boundary layer up to **300 m**



[Tokano *el al.* 2006 *in press*]



well mixed potential temperature, strong vertical shears and a thin region of Richardson number Ri~1.

Mixed layer
up to ~300 m

Surface layer
0 - 5 m

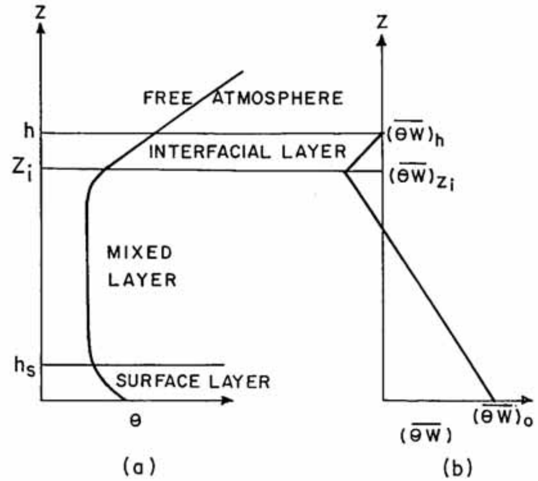


Figure 1. Three-layer structure of the convective boundary layer (Deardorff, 1979).

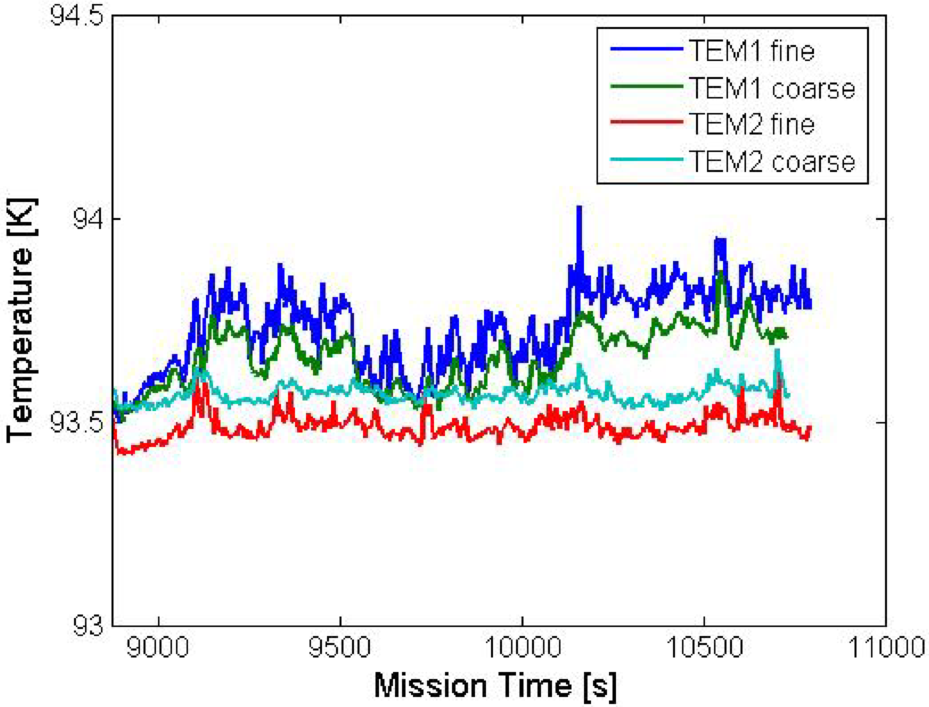
Titan's meteo

- **Planetary Boundary layer** up to **300 m** by potential temperature.
- Correlated analysis of DWE and HASI data reveals: a significant correspondence of wind shear and buoyant stability structures both in Titan's stratosphere and lower tropopause
  - **Lower stratosphere**: the unanticipated strong vertical wind shear region between 60 and 90 km is correlated with Titan's most buoyantly stratified region – a layer of roughly one-scale-height where the smoothed Richardson number is small (Ri ~2–5).
  - **Near surface atmosphere**: correlation of HASI and DWE confirm the presence of the PBL characterized by a well mixed potential temperature, strong vertical shears and a thin region of Richardson number Ri~1 in the lowest 3 km.
- Meteorologic conditions monitored at the surface for half an hour:
  Temperature 93.65±0.25 K
  Pressure 1467±1 hPa

Surface phase

Meteo at surface:

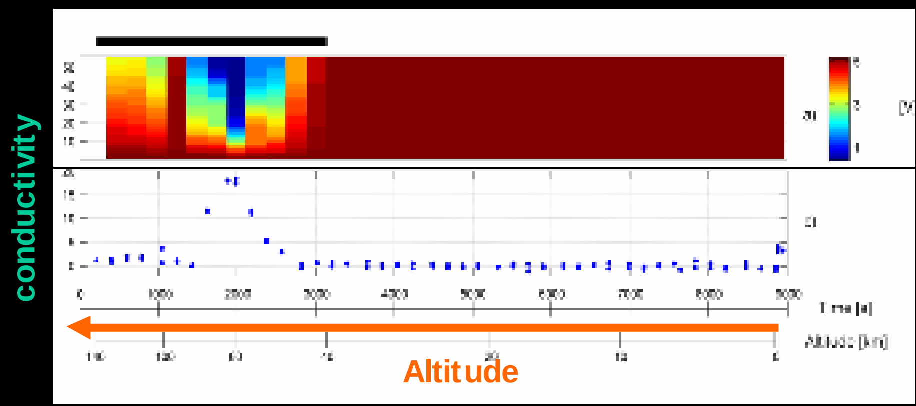
- **Temperature 93.65±0.25 K**
- **Pressure 1467±1 hPa**



Titan's atmospheric electricity

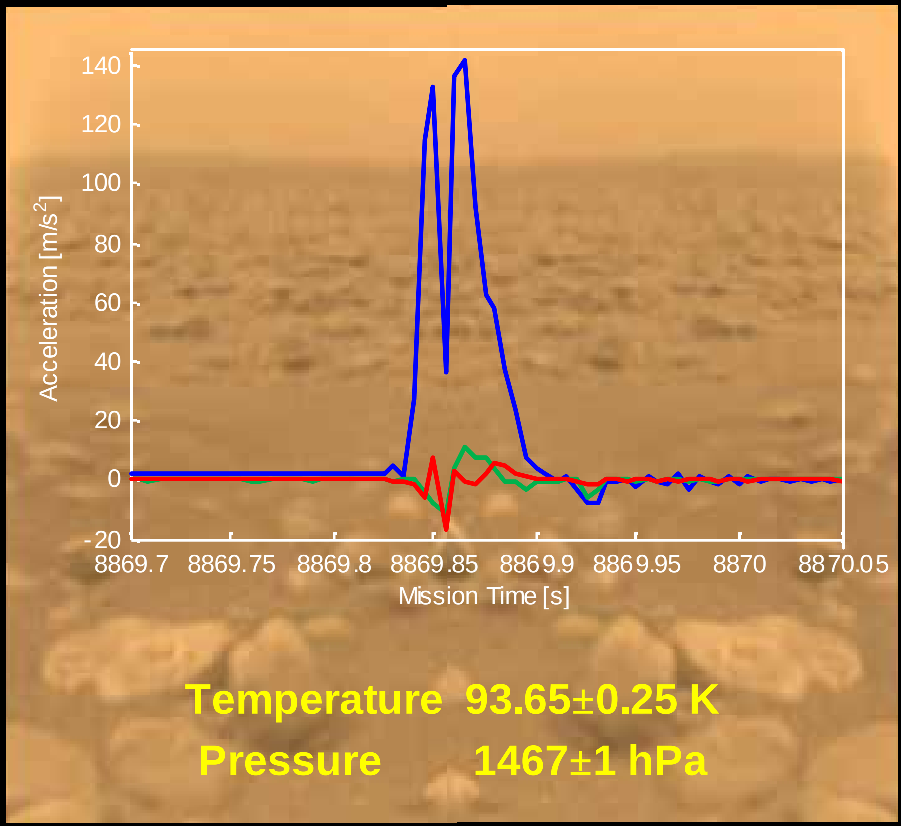
- Presence of charged particle species (electrons and, positive and negative ions).
- Lower ionospheric layer between 140 and 40 km induced by cosmic rays with electrical conductivity peaking near 60 km.
- Detection of some events of electrical discharges (potential signature of lightning).

Permittivity Wave Altimetry (PWA) signature of the ionosphere



Titan's surface

- Impact signature: instant & trace. **Solid unconsolidated** surface (e.g. gravel, wet sand).
- No evidence of liquid reflectance. The measured relative permittivity (of the order of 2) constrains the soil composition.
- Meteorological conditions monitored for half an hour after impact



Summary

- Exobase at 1380 km (n~2E07 cm-3).
- Upper atmosphere warmer than expected (Yelle et al.)>
  Stratopause at ~ 250 km (~ 187 K)
  (same value retrieved by CIRS, but at different altitude-pressure level)
- Several temperature variations observed in the thermosphere possibly related to inversion layers and other dynamic effects
- Mesopause detected at ~490 km (~152 K)
- Inversion layer at 510 km (mesopause) as observed during Titan's stellar occultation
- Temperature structure of the lower atmosphere in very good agreement with the Voyager 1 RSS and IRIS measurements (Lindal *et al.* 1983, Lellouch *et al.* 1989)
- Tropopause (70.43±0.25)K at ~ 44 km (115±1)hPa.
- Preliminary meteorological interpretation.
- PBL convective layer of 300 m confirmed also by correlation with DWE data,
- At surface: ~94 K and 1467 hPa

Conclusions

- The temperature and density profiles inferred by HASI are of great value since they provide
  a) an accurate determination of the whole atmosphere (from ground up to exobase)
  b) the only new and independent definition of the tropospheric thermal structure
  c) atmospheric parameters based on very precise characterization of the chemical structure

- Comparisons with Cassini and groundbased observations evidence some differences that should be investigated and that could imply variability of Titan's atmospheric structure.

- Information gathered from HASI pertain to one site along the Huygens probe descent trajectory, but combined with measurements from Cassini could contribute to improve the knowledge of Titan's atmospheric structure at all latitude and longitudes covered by Cassini.