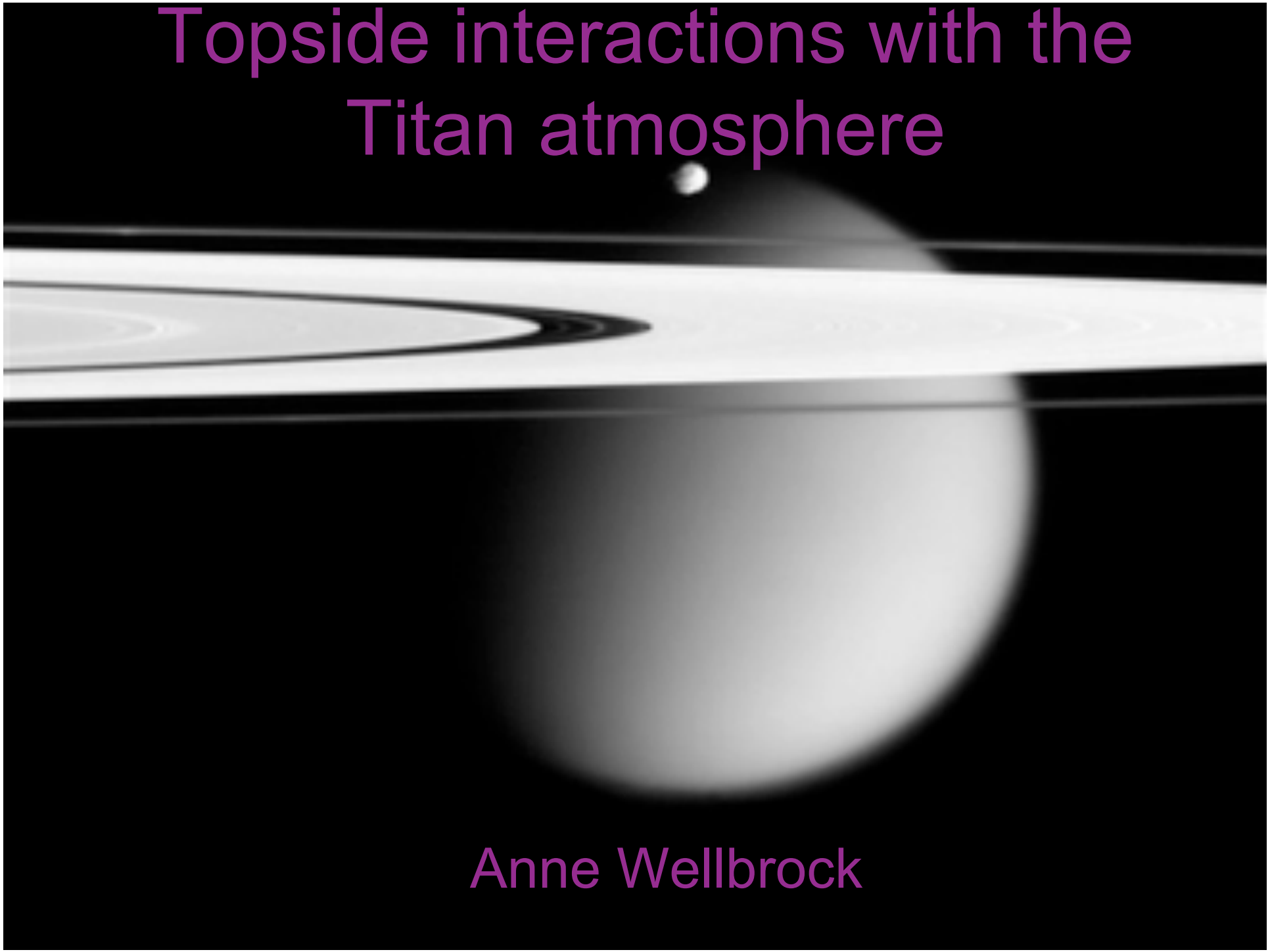
Topside interactions with the Titan atmosphere



Anne Wellbrock

Outline

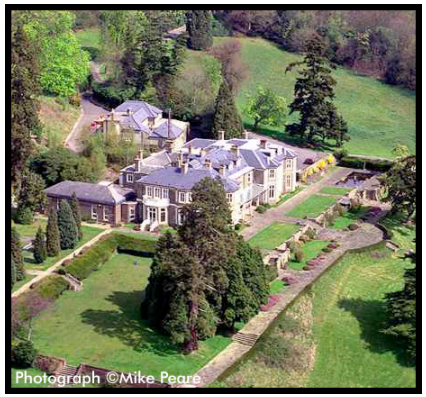
1. About me
2. Introduction
3. Introducing Titan and its atmosphere
4. The UCL Titan thermosphere code
5. The interaction with Saturn´s magnetosphere
6. Summary

1. About me

- Trainee at ESAC in 2005
- BSc in Physics at THE UNIVERSITY OF WARWICK
- Currently on MSc in Astrophysics course at UCL
- From September 2007: 4-year STFC funded PhD at UCL

  (UCL MSSL Space and Climate Physics and UCL Physics & Astronomy)

Science & Technology Facilities Council

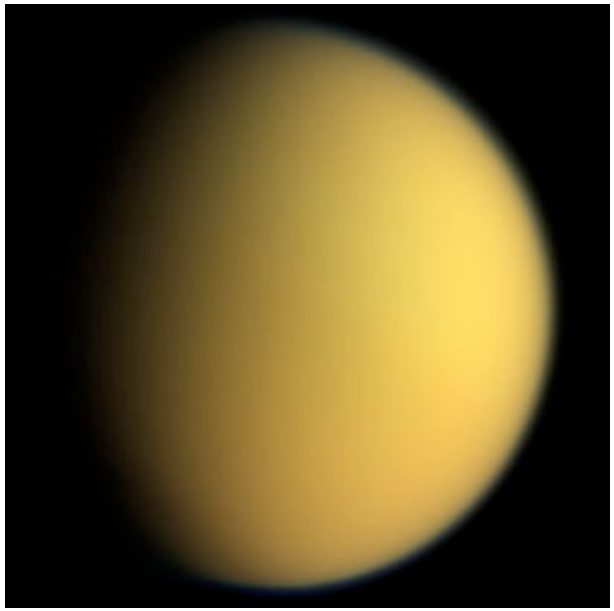


Supervisors: Andrew Coates and Alan Aylward

2. Introduction

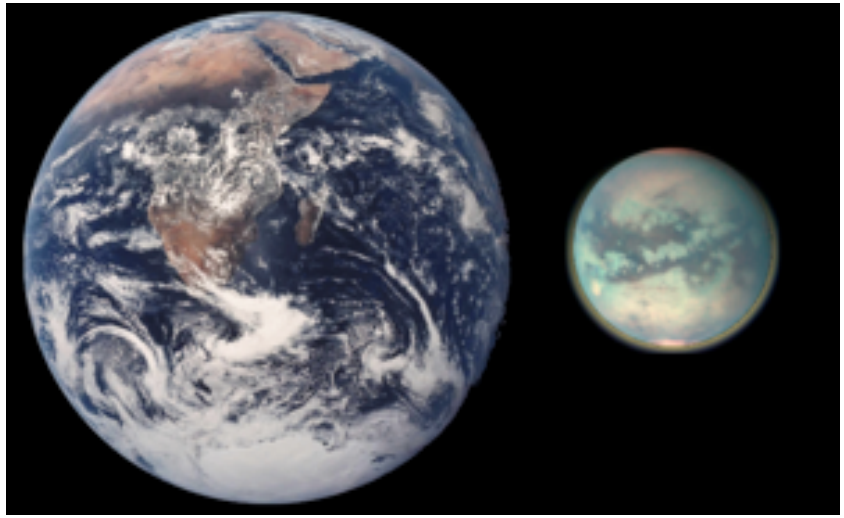
- Titan: Saturn´s largest moon
- I study the upper atmosphere (thermosphere and ionosphere) using a General Circulation Model (GCM) of the thermosphere and data from the Cassini-Huygens mission

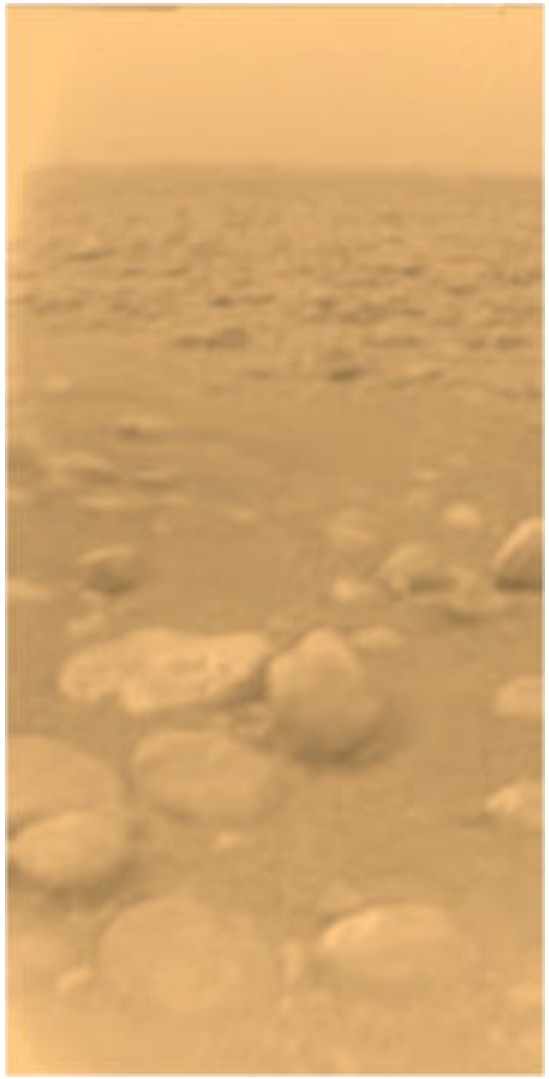
3. Introducing Saturn´s moon Titan



Source: NASA/ESA

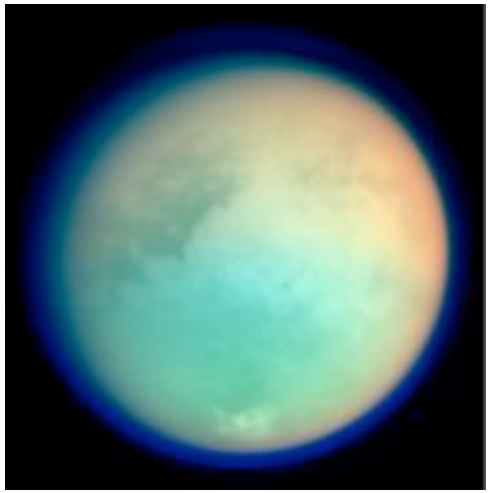
- 2nd largest moon in Solar System
- Radius: 2575 km
- Orbits Saturn at ~20 Saturn radii
- Orbital & rotation period: 16 days (synchronous rotation)
- Dense, extended nitrogen atmosphere with 1.6% methane + traces of other organic molecules, Ar and CO_2
- Surface pressure: 1.45 bar
- Surface temperature: 94 K

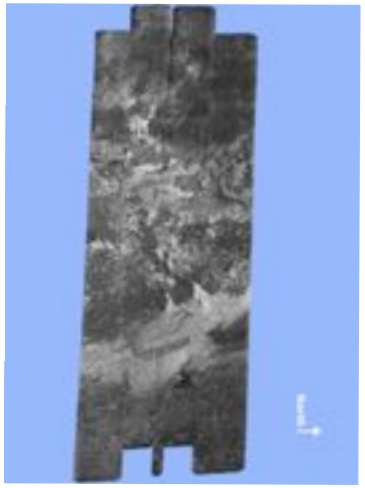


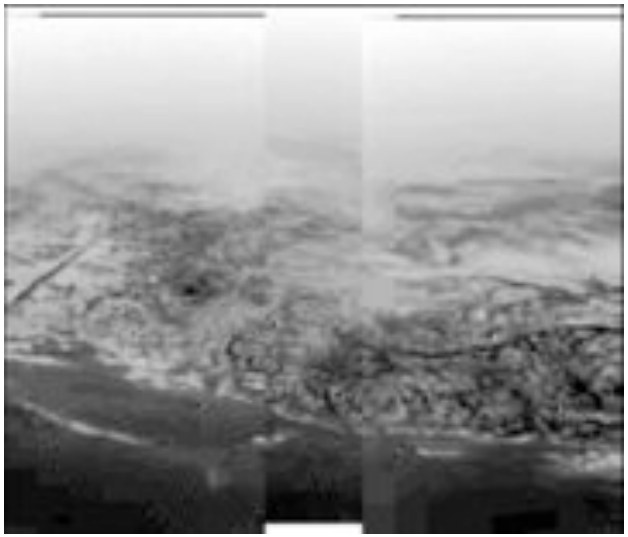


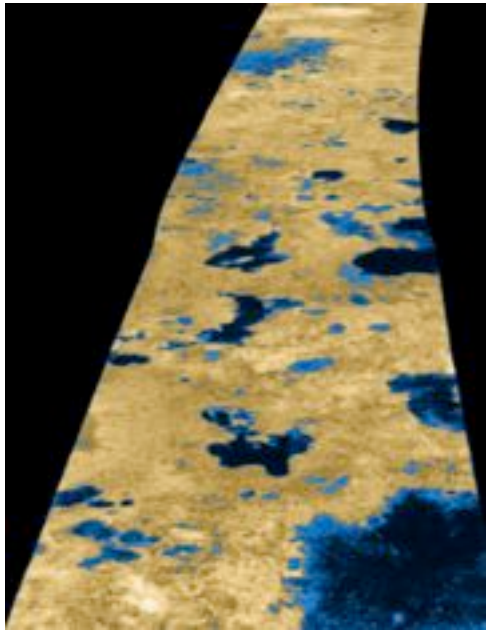
Sources: NASA/ESA

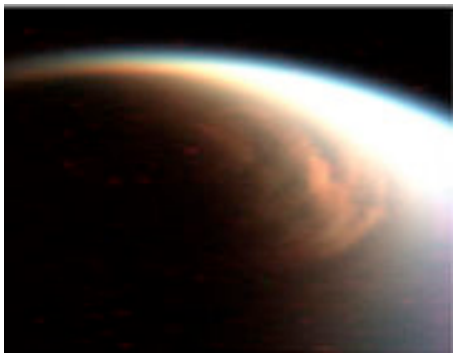
Active methalogical cycle: Evidence for lakes and clouds!

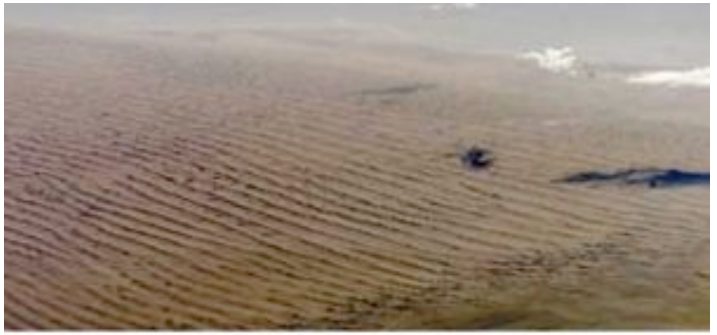


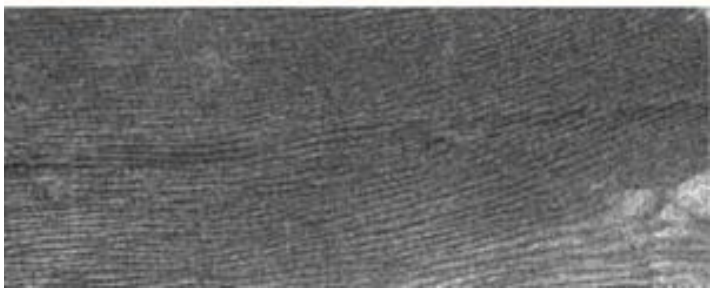






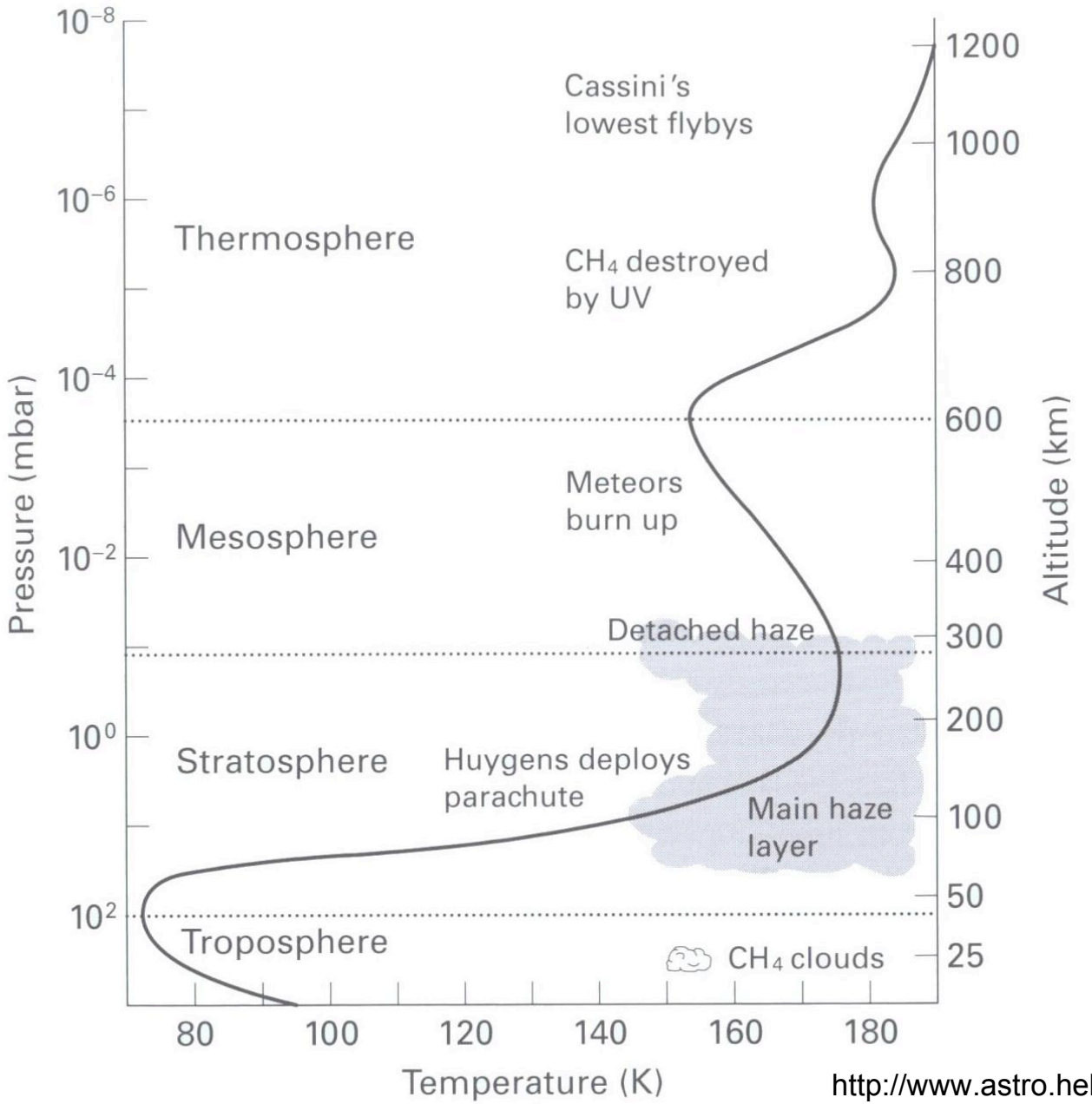






Sources: NASA/ESA

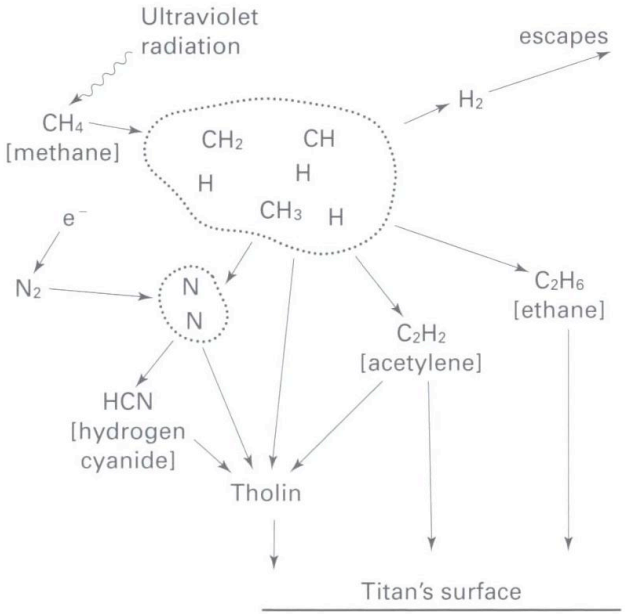
Titan´s temperature profile



http://www.astro.helsinki.fi/~naranen/titan/titan.html

Titan´s thermosphere

- Steep vertical T gradient in bottom part
- Then T becomes ~height independent => exospheric T ~185K
- Main cooling mechanism in thermosphere: IR cooling due to pure rotational lines in hydrogen cyanide (byproduct of ionospheric chemistry)
- T and altitude range: 140K @ 600km to 190K @ 1400km



http://www.astro.helsinki.fi/~naranen/titan/titan.html

Titan´s ionosphere

Significant amount of particles become ionised > 800km due to

1. Solar UV radiation
2. Energetic plasma from Saturn´s magnetosphere (mainly impact ionisation by fast electrons)

4. The UCL Titan thermosphere code - a general circulation model

- Calculates the dynamics of the thermosphere
- Solves momentum, energy and continuity equations
- On a spherical grid of longitude, latitude and pressure level
- Pressure levels correspond to altitudes of 600km to 1400km

- Momentum equation:

$$\frac{d\vec{U}}{dt} = \vec{g} - \frac{1}{\rho}\vec{\nabla}p - 2\vec{\Omega} \times \vec{U} + \frac{1}{\rho}\vec{\nabla}(\mu\vec{\nabla}\vec{U})$$

Gravity term

P gradient term

Coriolis term

Viscosity term

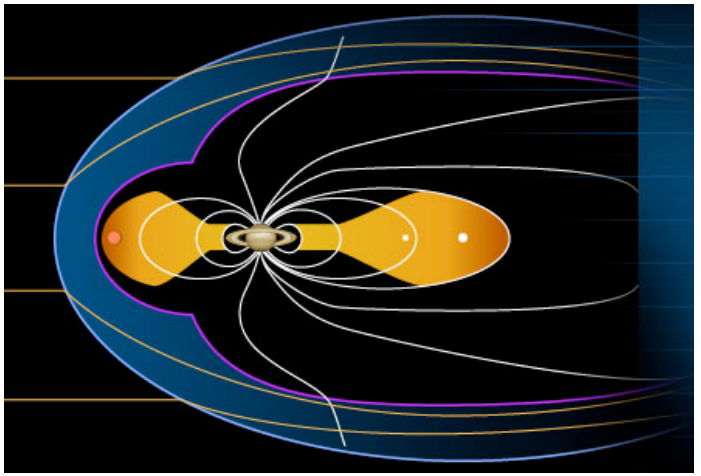
- Continuity equation: Calculates vertical winds
- Energy balance: Expressed as sum of internal and external energy sources and sinks (such as adiabatic heating and cooling, radiative cooling in rotational lines, heat conduction, …)

External energy sources

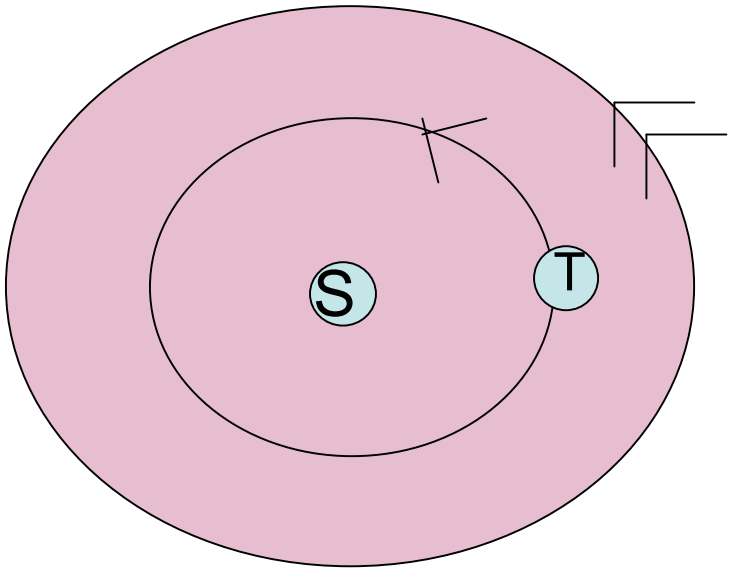
- Only external energy source considered in this model so far: Solar (E)UV radiation

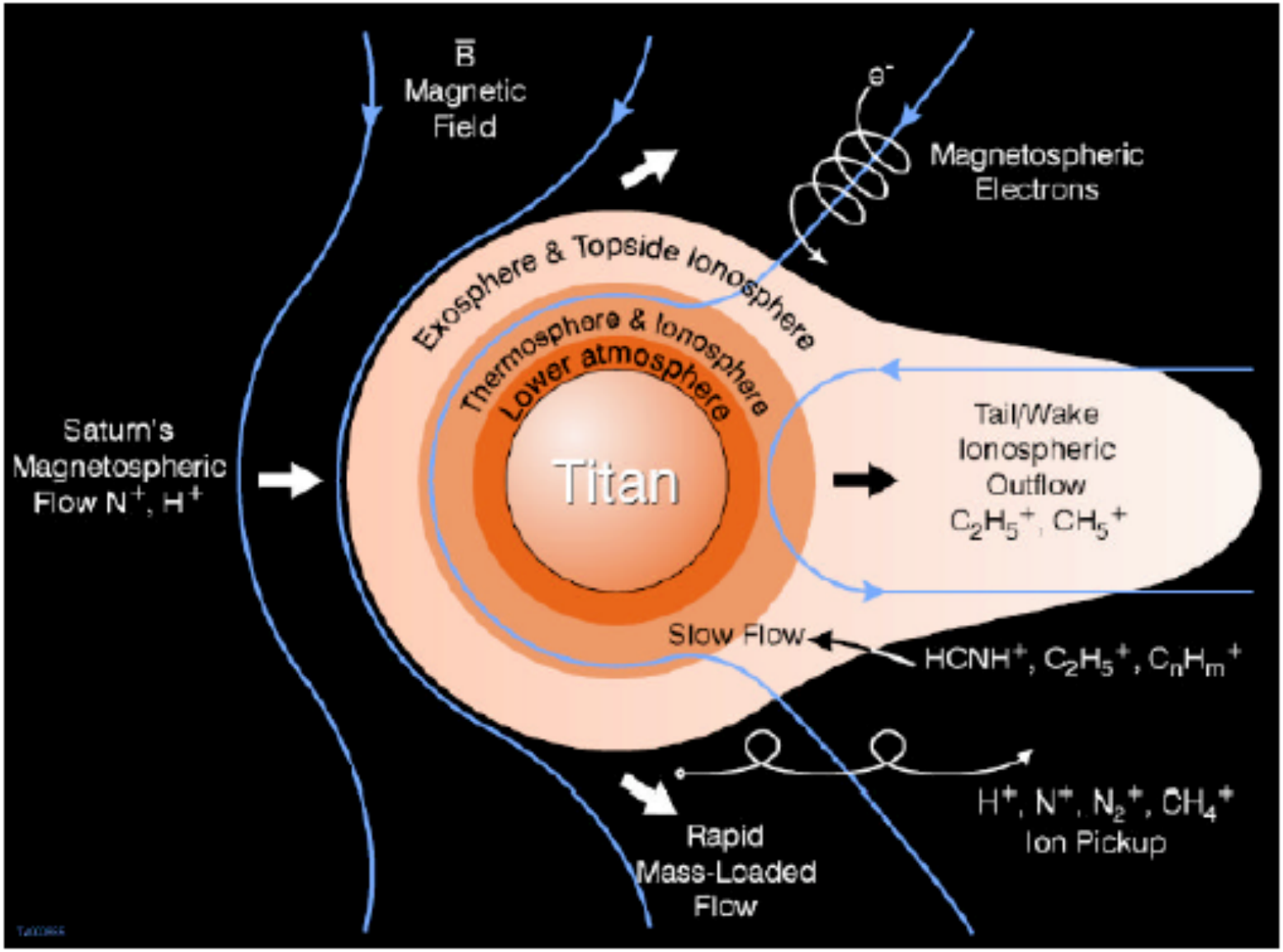
- Next step:
  Implementation of energetic plasma from Saturn´s magnetosphere as an additional energy source

5. Titan´s interaction with Saturn´s magnetosphere



- Saturn´s magnetosphere corotates with the planet
- Saturn´s rotation period: ~10 hours i.e. << Titan´s orbital period (16 days)
- Therefore, the corotating plasma is incident on Titan´s trailing edge with a speed of ~120 km/h (subsonic)




B
Magnetic
Field
e⁻
Magnetospheric
Electrons
Exosphere & Topside Ionosphere
Thermosphere & Ionosphere
Lower atmosphere
Titan
Saturn's
Magnetospheric
Flow N⁺, H⁺
Tail/Wake
Ionospheric
Outflow
C2H5⁺, CH5⁺
Slow Flow
HCNH⁺, C2H5⁺, CnHm⁺
H⁺, N⁺, N2⁺, CH4⁺
Ion Pickup
Rapid
Mass-Loaded
Flow

6. Summary

- To accurately model the dynamics of Titans´s thermosphere, it is necessary to include not only solar radiation as an external energy source, but also the energetic plasma from Saturn´s magnetosphere
- This is difficult to implement since there is a strong spatial and time dependence
- Therefore fast electron fluxes (and hence ionisation rates) vary considerably with time and location
- Different special cases need to be investigated in more detail separately

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