IONOPLANET ONLINE

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IRAP

Objectives

- What for
  - Provide easy access to simple models of planetary ionospheres
  - Allow basic data comparison
  - Provide auxiliary parameters
- How to
  - Available IRAP models
    - Earth, Mars, Venus
    - Jupiter, Saturn
  - Web interface
    - Simulation definition
    - Inputs upload
  - Web service
    - Simulation run
    - Results download

Multi moment approach

- Hypothesis
  - distribution function close to thermodynamical equilibrium

$$f_o(\vec{r},\vec{v}) = n_s \left(\frac{m_s}{2\pi k_b T_s} \right)^{3/2} e^{-\frac{m_s(\vec{v}-\vec{u})\cdot(\vec{v}-\vec{u})}{2k_b T_s}}$$

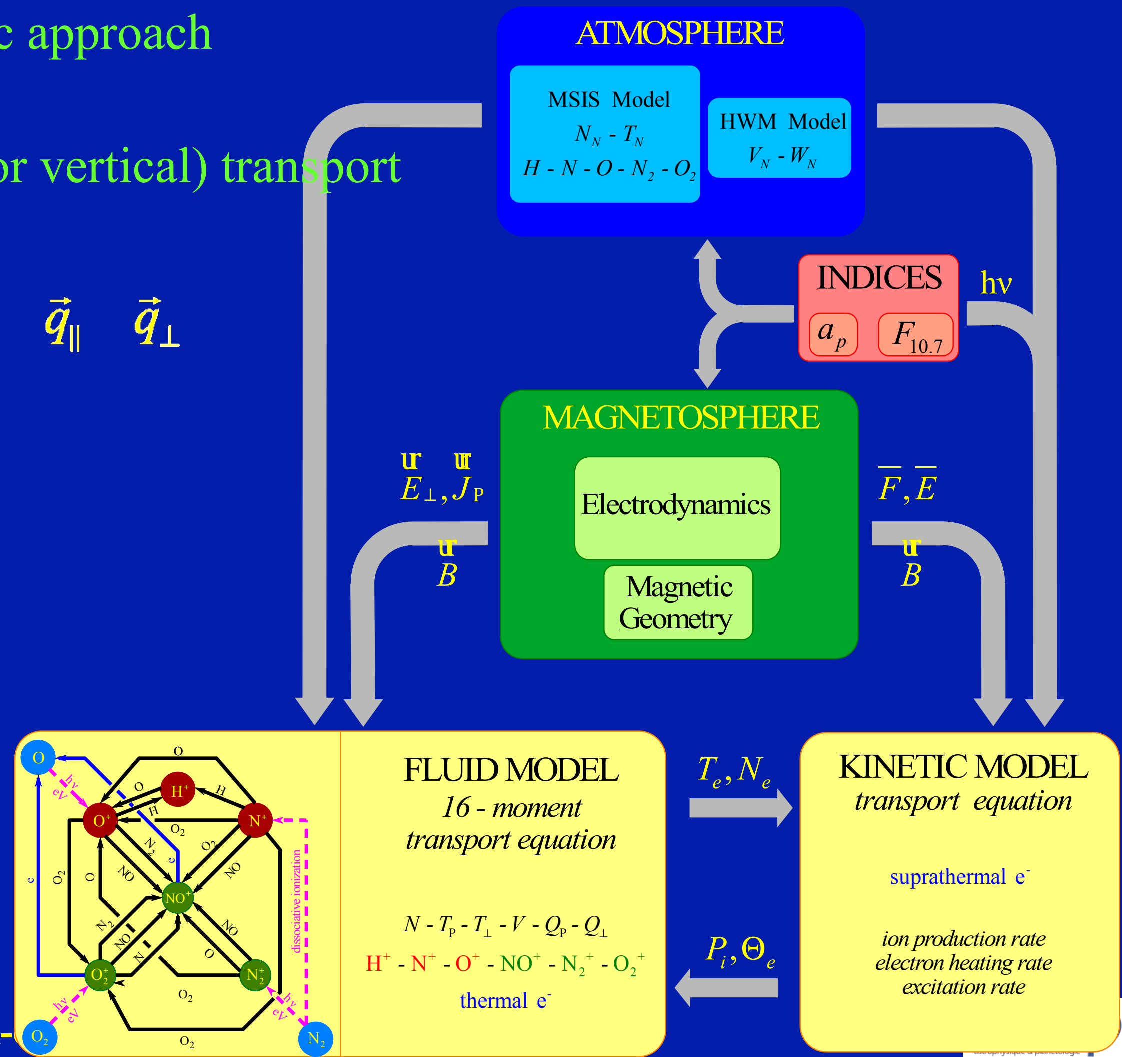
  - expansion as a function of moment of *f*

$$f(\vec{r},\vec{c}_s) = f_o(\vec{r},\vec{c}_s)\left[1-\left(1-\frac{m_s c_s^2}{5k_b T_s}\right)\frac{m_s}{k_b T_s p_s}\vec{q}_s\cdot\vec{c}_s\right]$$

  - mathematical closure
    - higher order moments are function of lower order moments
- Impact
  - no collision / collisionless transition
    - Large dynamical range
  - direct modelling of physical basic mechanisms
    - State equations are a by product

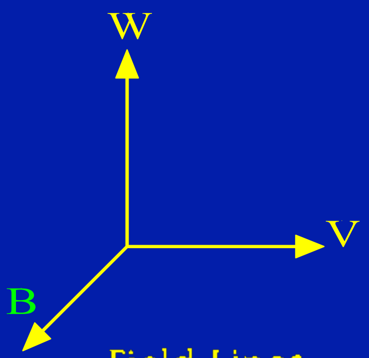
Models characteristics (field aligned or vertical)

- fluid / kinetic model
  - thermal plasma : fluid approach
  - suprathermal electrons : kinetic approach
- fluid module
  - time dependent field aligned (or vertical) transport
  - 8, 13 or 16 moment approach
  - multi species $n \quad \vec{u} \quad T^{\parallel} \quad T^{\perp} \quad \vec{q}_{\parallel} \quad \vec{q}_{\perp}$
- kinetic module
  - steady state electron transport
  - multi stream model
  - variable (E,µ,s)
- full coupling
  - fluid / kinetic
  - MHD / fluid (Mars, Vénus)
- one way coupling
  - electrodynamics / fluid (Earth)
  - electrodynamics / kinetic



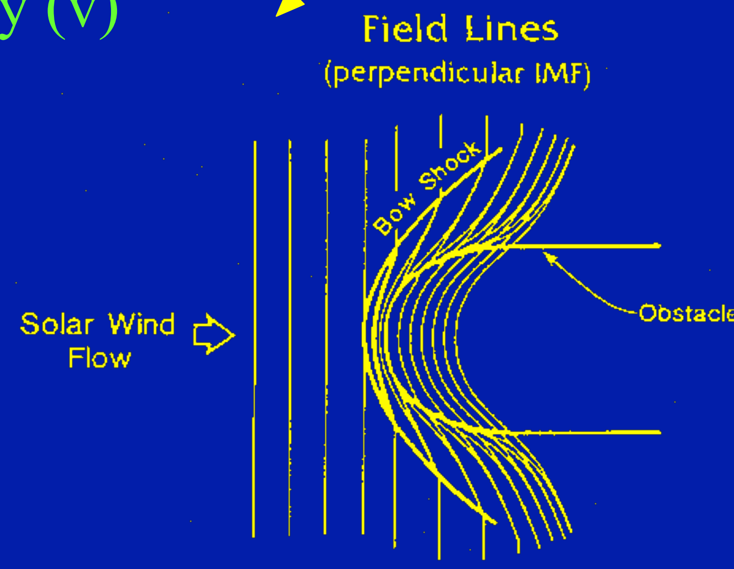
PSWS kick-

Example: Mars model



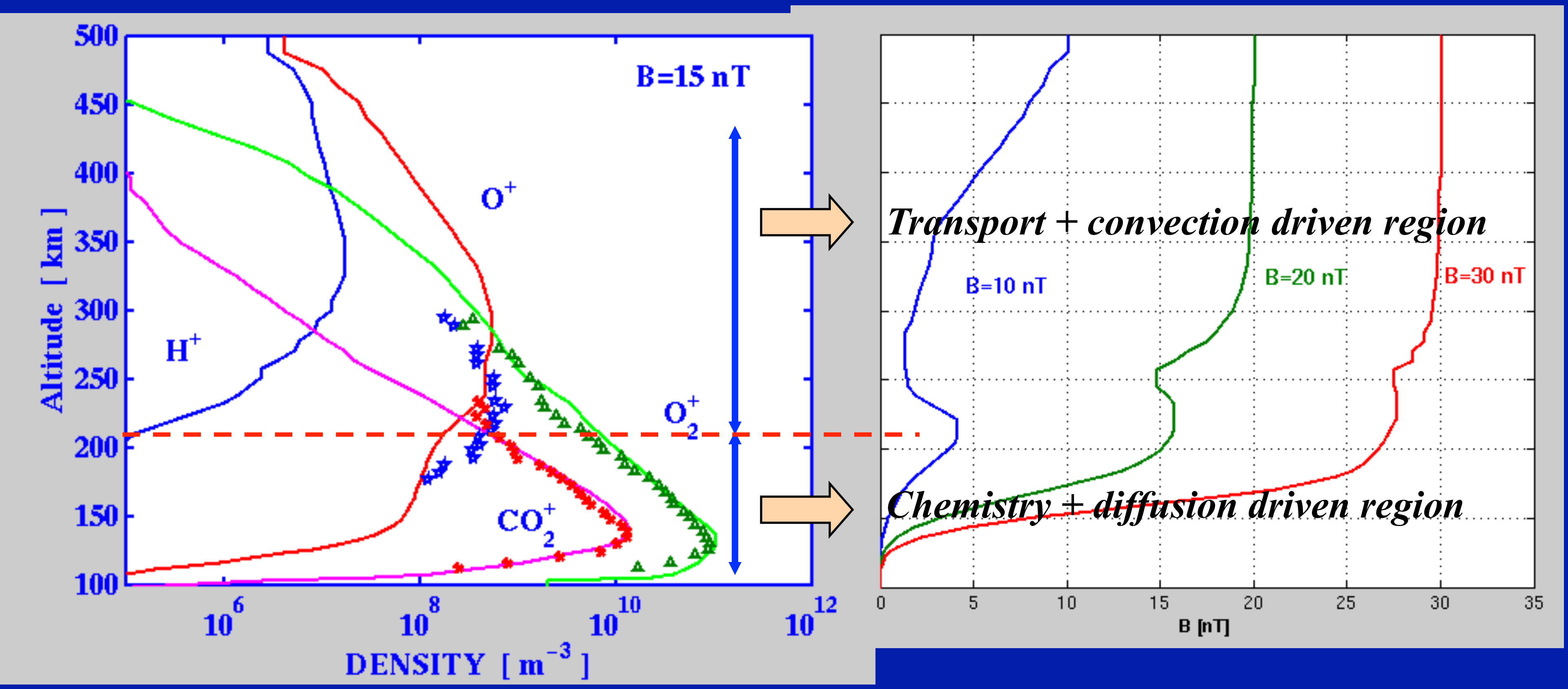
- 1D vertical model
  - 8 moment approach
  - Vertical (w) and horizontal velocity (v)
  - Magnetohydrodynamics coupling
    - Horizontal induced magnetic field
      - frozen field convection
      - diffusive field transport

$$\frac{\partial B}{\partial t} + \underbrace{\frac{\partial}{\partial z}\left(w_e B\right)}_{\text{convection}} + \underbrace{\frac{\partial}{\partial z}\left(D_b \frac{\partial B}{\partial z}\right)}_{\text{diffusion}} = 0$$



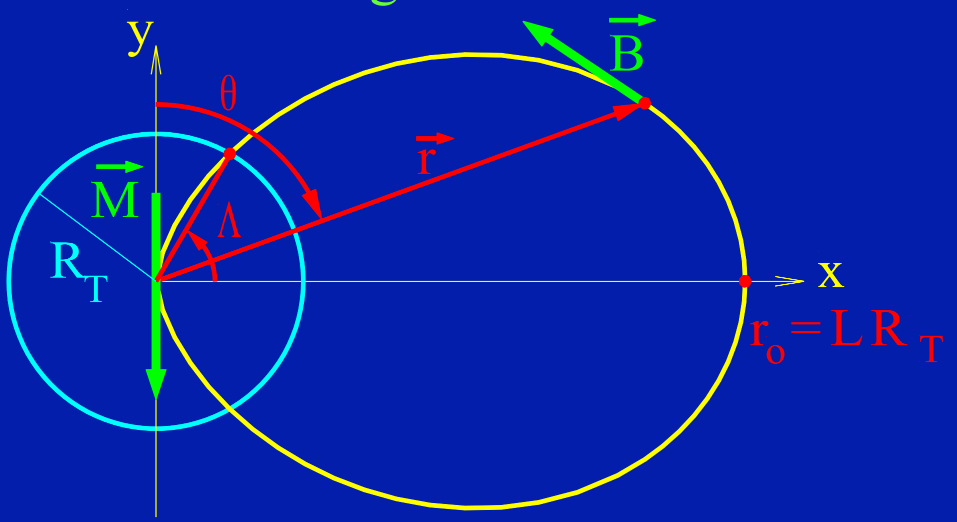
Viking data modelling

- Magnetic field effect



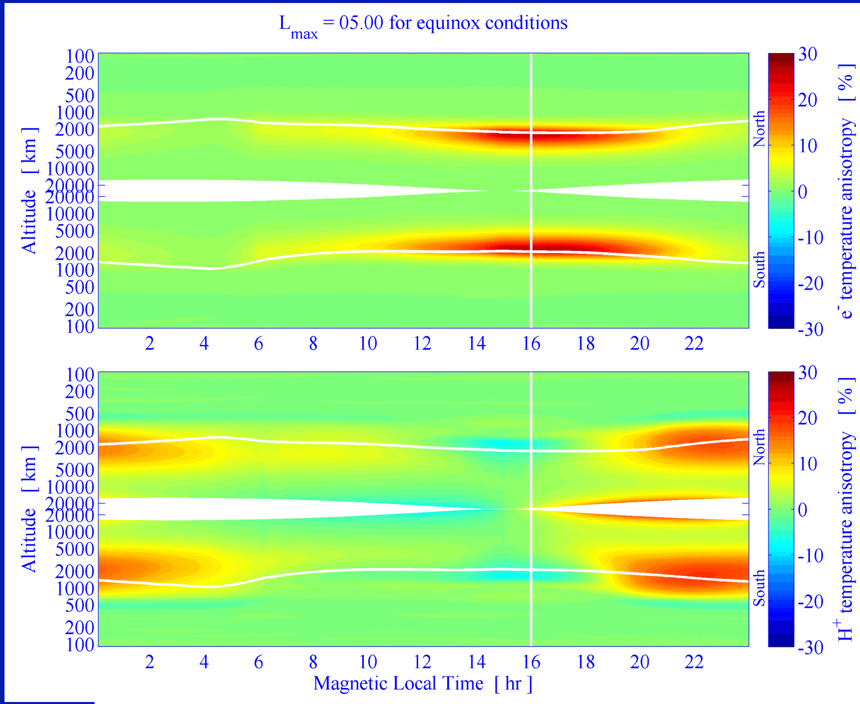
Example: IPIM model

- 1D interhemispheric model
  - Ionospheric and plasmaspheric plasma modelling
  - field-aligned transport
    - eulerian
    - curvilinear coordinates
      - B field dependent
- 2D transport
  - plasma tube convection
    - lagrangian
- 1D+2D = 3D
  - Multi-tube modelling
- Strong variability along a closed magnetic field line
  - forces: gravity and inertial forces (rotation effect)
  - solar illumination
  - particle precipitation
  - interhemispheric effects

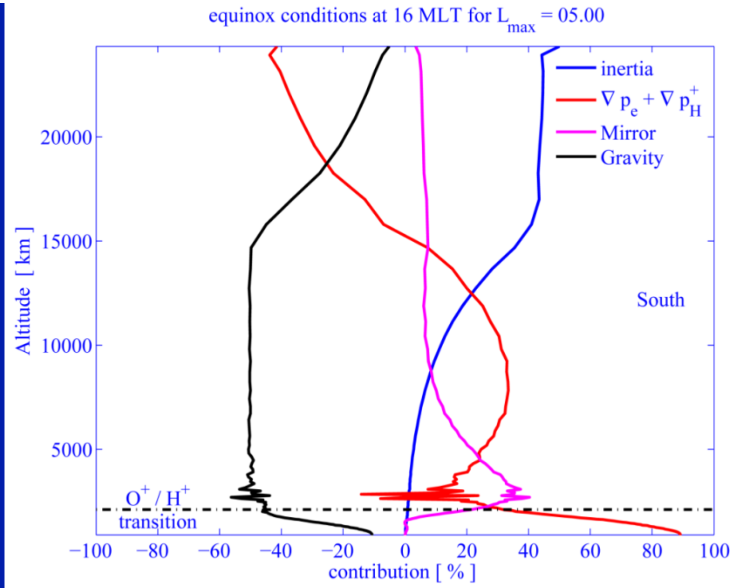


Inertia and magnetic field

- magnetic field geometry effect
  - mirror force
    - temperature anisotropies
      - ions
      - electrons

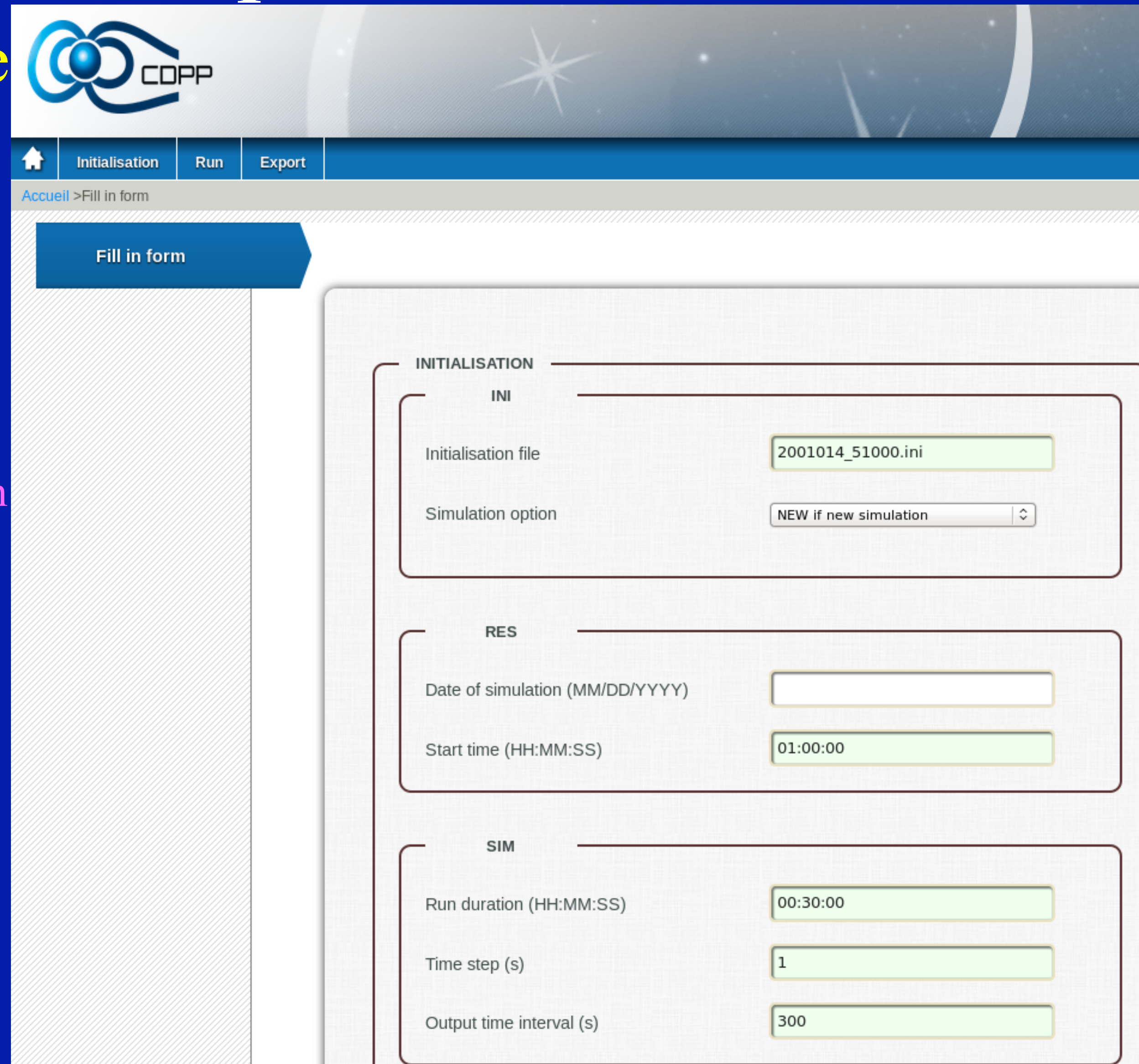


- Planet rotation effect
  - altitude dependent equilibrium
    - at low altitude
      - plasma pressure and gravity
    - transition region
      - Mirroring force and gravity
    - at high altitude
      - plasma pressure and inertia



Inputs

- Web page interface
  - CDPP web site
  - Run definition
    - Date
    - Location
    - Duration
    - Simulation condition
      - Precipitation
      - Convection
      - …
- Input file
  - TBD
    - Need user inputs



Inputs (foreseen)

- Species selection
  - Species input file

Species input file → **Reaction file** → **Chemical scheme**

Species input file

```
 1 N_2^+
 1 O_2^+
 0 NO^+
 0 O^+
 0 H^+
 0 N^+
 0 O^-
 0 O_2^-
 0 O_3^-
 0 O_4^-
 1 NO
 3 NOx NO_3 NO_4
 0 N[2D]
-1 N_2
-1 O_2
-1 O
-1 H
-1 N
-1 e
```

Reaction file

Chemical scheme

N	+ NO		→	N_2	+	O
N	+ O_2		→	NO	+	O
N_2^+	+ e		→	N	+	N[2D]
N_2^+	+ NO		→	NO^+	+	N_2
N_2^+	+ O		→	NO^+	+	N[2D]
N_2^+	+ O		→	O^+	+	N_2
N_2^+	+ O_2		→	O_2^+	+	N_2
NO	+ O	+ M	→	NO2	+	M
O_2^+	+ e		→	O	+	O
O_2^+	+ N		→	NO^+	+	O
O_2^+	+ N_2		→	NO^+	+	NO
O_2^+	+ N_2	+ M	→	O_2^+(N_2)	+	M
O_2^+	+ NO		→	NO^+	+	O_2
O_2^+	+ O_2	+ M	→	O_4^+	+	M

Output

- Output structure
  - Condition of the run
  - Geometry
  - Moments of the different thermal population
  - Moments of suprathermal electrons
  - Production and heating rates
  - Line emissions (when available)
  - *Suprathermal electron distribution function*
- Output format
  - IPIM format
    - Matlab routines available
  - CDF format
    - Upload in AMDA
  - TXT format
    - Reduced set of parameters

User conditions

- Unregistered user
  - Standard runs
    - No action on model parameters
  - Limited choice
    - Specific date
    - Specific conditions ($F_{10.7}$)
  - Standard output
  - No archive
- Registered user
  - Unregistered user
  - Choice
    - Correction of the atmosphere
    - Precipitation input
    - Electrodynamics
    - Species
    - Solar flux spectrum (e.g. flare)
  - Full output
  - Workspace
    - Archiving
    - Restart from previous run

Stage of development

- Project starts on January 1st
- Web interface (ETC 2 months)
  - First prototype written (TRANSCAR online)
    - Needs inputs upload facility
- Web service (ETC 3 months)
  - In discussion with CDPP
- Models availability (ETC 4 months)
  - Available
    - Earth
    - Mars
    - Venus
  - In preparation
    - Planet independent model
      - Jupiter
      - Saturn

Conclusion

- Long term commitment
  - Any improvment on research models will be applied
- Wish to provide a tool with a real add on value
  - Open to discussion to improve the tool
    - User interface
    - Inputs and control parameters for the models
    - Outputs
- However we are not a computer center
  - Limited ressources devoted to the project
    - We need time to implement any change
  - Limited computing facility available
    - You need to be patient to get result from your simulation