Modelling the ionospheric current system with General Circulation Models

Tim Spain
Atmospheric Physics Laboratory, UCL

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Overview

- What is a GCM?
- GCM
  - Advantages
  - Limitations
- UCL GCMs

A (very) short guide to GCMs for people who aren't modellers

- **G**eneral **C**irculation **M**odel
  - Or: Global Climate Model
- A model of the Earth's atmosphere based around integrating the governing equations with time
- Fluid dynamics of the neutral atmosphere the central feature

GCM neutral atmosphere

- Governing equations always included
  - Navier-Stokes equation
  - Conservation of energy
  - Conservation of matter

- Often included for simplicity
  - Incompressibility
  - Hydrostatic balance

Iono- and plasmasphere

- Plasma transport
- Interaction between ions and the magnetic field
- Ionization of neutral components and recombination of charged components
- Ion-neutral interactions
- Conservation of charge

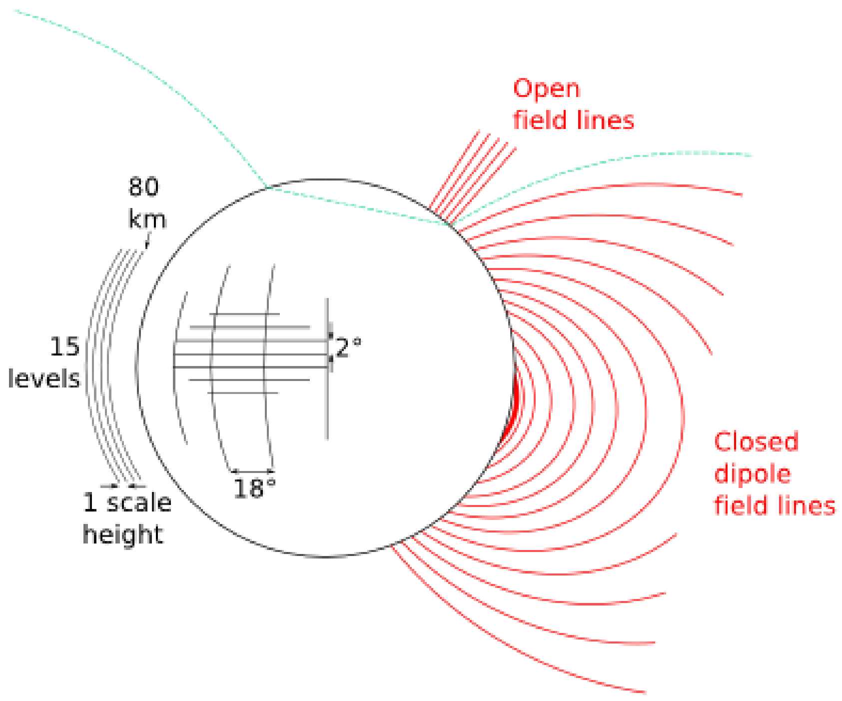
UCL atmospheric models I: CTIP

- **C**oupled **T**hermosphere **I**onosphere **P**lasmasphere
- Developed from the neutral atmosphere model of Fuller-Rowell and Rees (1980; 1983)
- Adds the plasma tube model of Quegan & al. 1982
- Fixed resolution and boundaries
- Dipole magnetic field
  - Aligned, tilted or offset-tilted

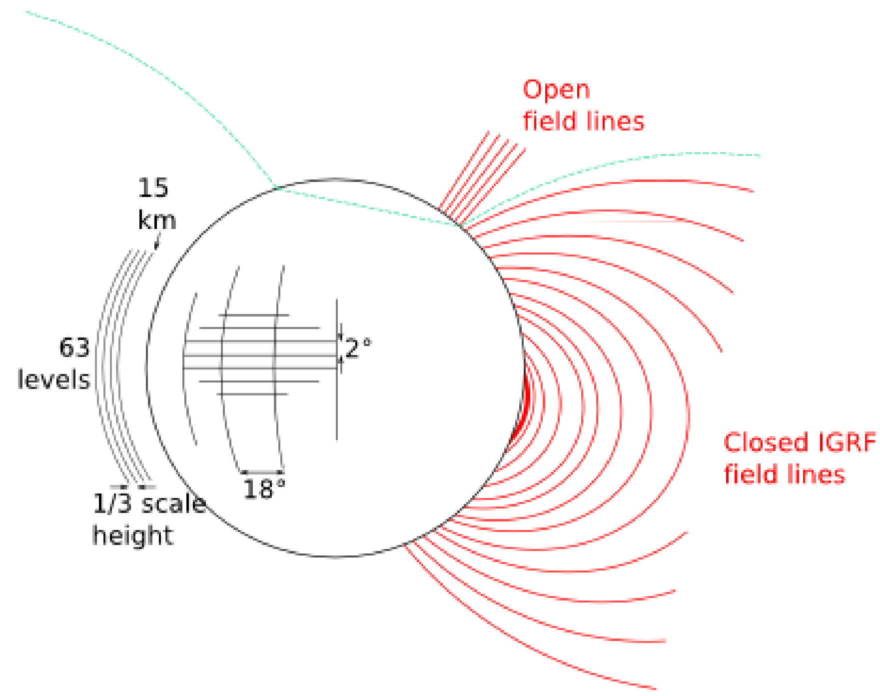
UCL atmospheric models II: CMAT2

- Coupled Mesophere And Thermosphere, version 2
- Initially an extended version of CTIP (version 1, unreleased)
- Flexible resolution and lower boundary
- Ionosphere model separate
  - Global Ionosphere Plasmasphere model of Millward
  - Paramaterized ionosphere
    - Chiu ionosphere
    - PIM ionosphere

Model grids



CTIP



CMAT & GIP

Electrodynamics

- Magnetic field coordinates
  - CTIP: tilted dipole
  - CMAT2: IGRF 2003
- Pedersen and Hall currents
  - Ion-neutral interaction
  - Electric field
  - Electric field due to current divergences
- No parallel currents

GCM advantages

- Global coverage
- Comprehensive model
- Feedback
- High temporal resolution
  - Response to short-lived inputs
- Steady state solution
- Diagnostic fields reveal what physics drives what phenomena

Feedback

- Large currents cause Joule heating
- Increased neutral temperatures drive neutral winds
- Changed ion-neutral interactions change the Pedersen and Hall currents

GCM limitations

- No weather forecasting
- Artificial boundaries (except whole Earth models)
- Complexity
  - Interaction of different parts
- Difficulty of use

Limitations of CTIP

- Fixed resolution
- Low vertical resolution
- Rigid at-rest lower boundary
- No field-parallel currents
- Dipole magnetic field
- Old FORTRAN IV and FORTRAN77 era source code

Limitations of CMAT2

- No electrodynamics
- Long run time (~ten times real time) compared to CTIP and simpler models
- Some components remain unvalidated

Example: Geomagnetic storm

- Shows the high time resolution and rapid response
- A 3 hour storm excites global, propagating waves in the neutral atmosphere, driving currents through ion-neutral drag
- See CTIP video

Conclusions

- GCMs are a valuable tool in the study of ionospheric currents
- Global, comprehensive data coverage
- High temporal resolution and feedback are useful in the study of storm events
- As with all models, there are limitations due to the nature of the model and the assumptions made