A CUBESAT CONSTELLATION FOR THE INVESTIGATION OF THE LOWER THERMOSPHERE CHARACTERISTICS: THE QB50 MISSION

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Introduction

QB50 Objectives

- Achieve a sustained and affordable access to space for small scale research space missions and planetary exploration
- Investigate the lower thermosphere characteristics
- Platform for technology demonstration (formation flight, ablation study, sail structure)
- Educate future engineers/scientists to build more reliable satellites
Introduction

QB50 Main Activities

- Send 50 double CubeSats into LEO in January 2016
- Carry out an unprecedented science campaign to probe the thermosphere with fragmented sensors on ~40 satellites
- Demonstrate new CubeSat technologies
- Support teams with
  - provision of Sensor Units and ADCS
  - guidance on satellite design
- Carry out a test flight since June 2014
Introduction

QB50 Status

**CDR completed for**
- consortium technologies:
  - QuadPack
  - INMS
  - FIPEX
  - mNLP
  - Ground Segment
  - satellites developed by consortium with few left-over issues
- community CubeSats with few left-over issues, no showstoppers:
  - small technical issues
  - some contract signing
  - some frequency
- assembly ADCS
- frequency coordination started
Introduction

QB50 Status

Management: Consortium Consolidation
• central server and mission display centre at VKI
• distribution of Sensor Units
• Launcher
• thermosphere science: measurements predictions carried out
• VKI:
  - 5+4 full time engineers working on small satellites ready to help you
  - clean room, integration room and ground station established
  - up-to-date website to disseminate information
  - forum to facilitate discussion with and among CubeSat teams
• Successful Precursor Campaign
The QB50 Scientific Investigation

- Multi-point (fragmented) measurements focused over poles and equator
- Measure with unprecedented spatial and temporal resolution the anomalies of the thermosphere (auroral particle heating, equatorial density anomaly and equatorial electrojet)
- Compare/cross-correlate with similar/complementary flight data
- Validate and enhance the physical models for the upper atmosphere
- Tune the CONOPS of the Sensor Units to measure transitory anomalies
The Methodology

INMS – Ion and Neutral Mass Spectrometer

FIPEX – Flux Probe Experiment

mNLP – multi Needle Langmuir Probe

QB50 Sensor Unit and Sensitivity

17-Oct-2014 6:00:02 AM - mean profiles

- e⁻ and $T_e$
- O, O₂, NO, N₂ (and ions)

Altitude [km]

Density [cm⁻³]

O₂
N₂
CO₂
He
NO
O(³P)
He⁺
N⁺
N₂⁺
O₂⁺
NO⁺
O⁺(⁴S)
H⁺
-e⁻
Global Ionosphere-Thermosphere Model

GITM solves for:
- 6 Neutral & 5 Ion Species
- Neutral winds
- Ion and Electron Velocities
- Neutral, Ion and Electron Temperatures

GITM Features:
- Solves in Altitude coordinates
- Can have non-hydrostatic solution
  - Coriolis
  - Vertical Ion Drag
  - Non-constant Gravity
  - Massive heating in auroral zone
- Runs in 1D and 3D
- Vertical winds for each major species with friction coefficients
- Non-steady state explicit chemistry
- Flexible grid resolution - fully parallel
- Variety of high-latitude and Solar EUV drivers
- Fly satellites through model

2/2/2010

Courtesy of Dr. Aaron Ridley, Michigan University
The Code Validation

Flight Data for Comparison

**CHAMP** (Challenging Minisatellite Payload)

- \( p = 6823\,\text{km} \)
- Ecc. = \( 7\times10^{-4} \)
- Incl. = 87.18°
- Measures density

**TIMED** (Thermosphere Ionosphere Mesosphere Energetics and Dynamics)

- \( p = 6996\,\text{km} \)
- Ecc. = 0
- Incl. = 74.1°
- Measures atomic oxygen from TIDI and SABER instruments

**EISCAT, Tromsø** (European Incoherent Scatter Radar)

- Latitude = 69.35°N
- Longitude = 19.14°E
- Measures electron density (and temperature) on a vertical profile
Results

Grid sensitivity and comparison with CHAMP data

- MSIS (Mass Spectrometer and Incoherent Scatter data) is an empirical code by the US Naval Research Laboratory, initially developed in NASA
Results

Relative error of GITM compared with CHAMP data

Relative errors span from 100 to 200%

Larger grid spacing shows a general decreasing of the error
Results

Photoelectron Efficiency and CHAMP data

- Photoelectron efficiency cannot be measured directly, large uncertainties
- High PHE shows higher deviation compared with CHAMP than lower PHE
- Investigation is going on to assess the best value of the PHE in all simulations
Results

Investigation of the Thermosphere Characteristics

- Local maxima on 2 and 3 due to particle heating in auroral oval [Baker 2004]
- In 1 and 6 we have a higher concentration of neutrals at the equator
- The double peak at 4/5 and 7/8 is due to the Equatorial Density Anomaly (EDA) [Hedin and Mayr 1973, Liu et al. 2005/2007]
Results

Comparing GITM computations with TIMED atomic oxygen measurements

- Simulated oxygen density is within 25% error range wrt measured data
- Simulations seem catching the general trend (peaks and valleys) but they show a phase shift
Results

Comparing GITM computations with EISCAT electron density measurements

- Relative error of electron density is reduced at 5-10%
Conclusions and Near Future

• An investigation as been carried out to assess to correct boundary conditions and the space discretization for the computations
• Different flight data have been compared to the GITM computations to assess the strength of the code
• Using GITM not only to compare flight data (like the QB50 precursors) but as a tool to predict atmospheric anomalies
• Perform UQ (Uncertainty Quantification) on the code to assess the input parameter sensitivity and establish the uncertainties on the results
• Investigate the sensor unit measurement uncertainties cross-correlating the measurements from the same/different sensor units
Thank you for your attention!