Introduction to Thermospheric Mass Density Data

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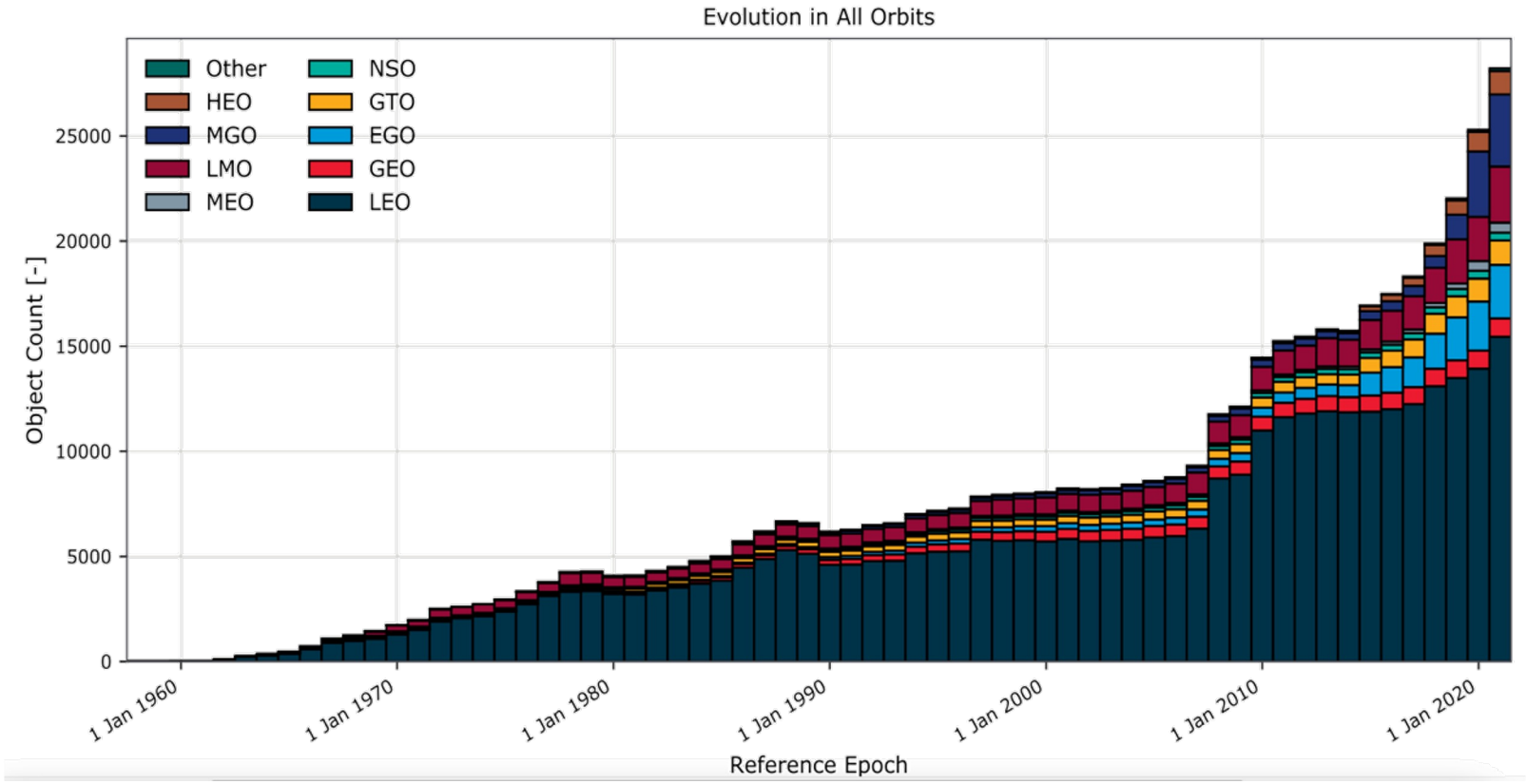
Overview

1. Motivation and Introduction
2. Thermospheric Density Models
3. Sources for Density Field Data

Question to everyone

Why do you think space weather models are important?

Motivation: Importance of Thermospheric Density Model

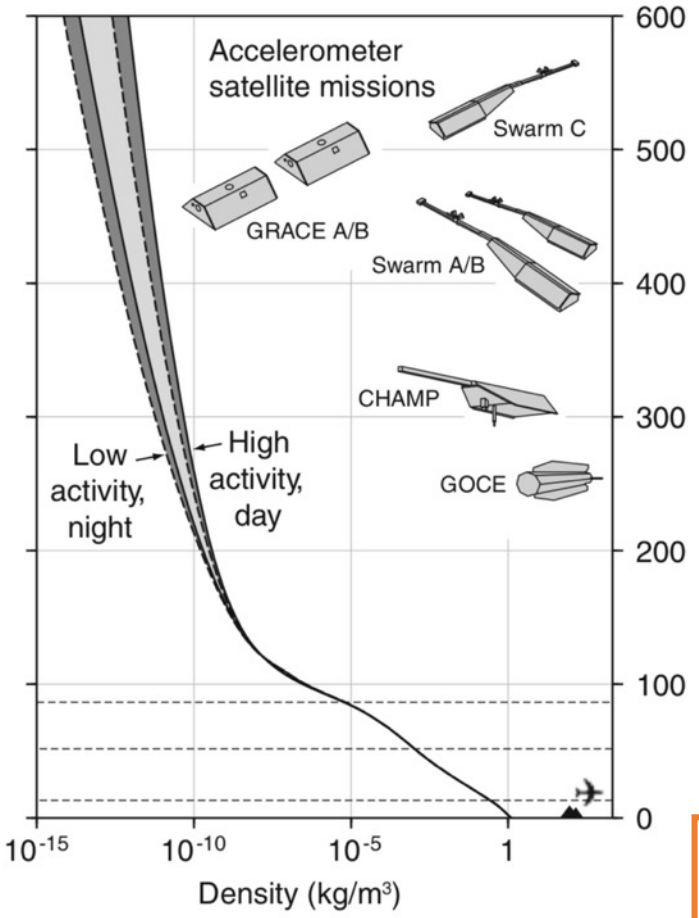


The number of tracked Low Earth Orbit (LEO) space objects are expected to further increased due to:

- Improvement in sensing capabilities
- Increased space activities (mega constellations planed in LEO)

Perturbed by Earth's Upper Atmosphere

Motivation: Thermospheric Density



Doornbos 2012 - Thermospheric Density and Wind Determination from Satellite Dynamics

- Thermospheric density versus altitude:
  - 0 km: 1.225 kg/m^3
  - 10 km: 0.4127 kg/m^3
  - 400 km: 10^{-11} - 10^{-13} kg/m^3
  - 600 km: 10^{-12} - 10^{-14} kg/m^3

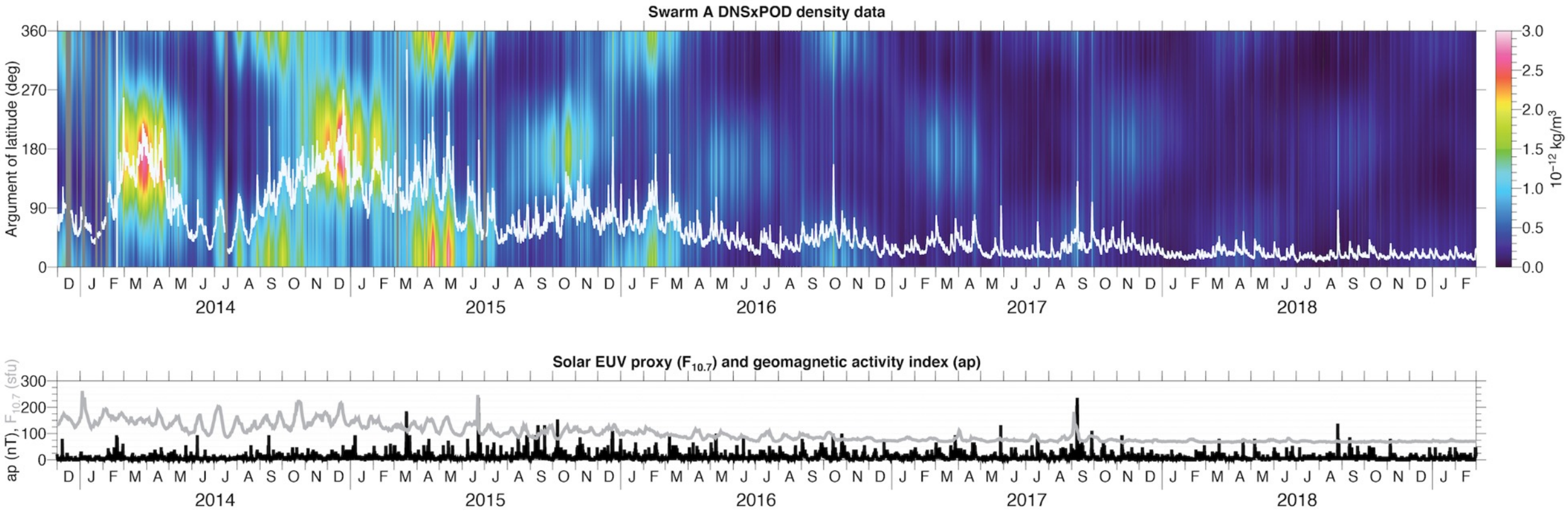
Can change by **orders of magnitude** due to solar and geomagnetic activity

- Due to the large variation and the inaccurate estimates of the thermospheric density, ρ
  - atmospheric drag is the **largest source of error** in orbit prediction for LEO space objects

To better predict and track these space objects, improvement in the thermospheric density model is essential.

Motivation: Effect of Space Weather on Thermospheric Density

Swarm neutral density



March et al. 2019 - Newly derived thermospheric products for CHAMP, GRACE, GOCE and Swarm

Thermospheric Density Models

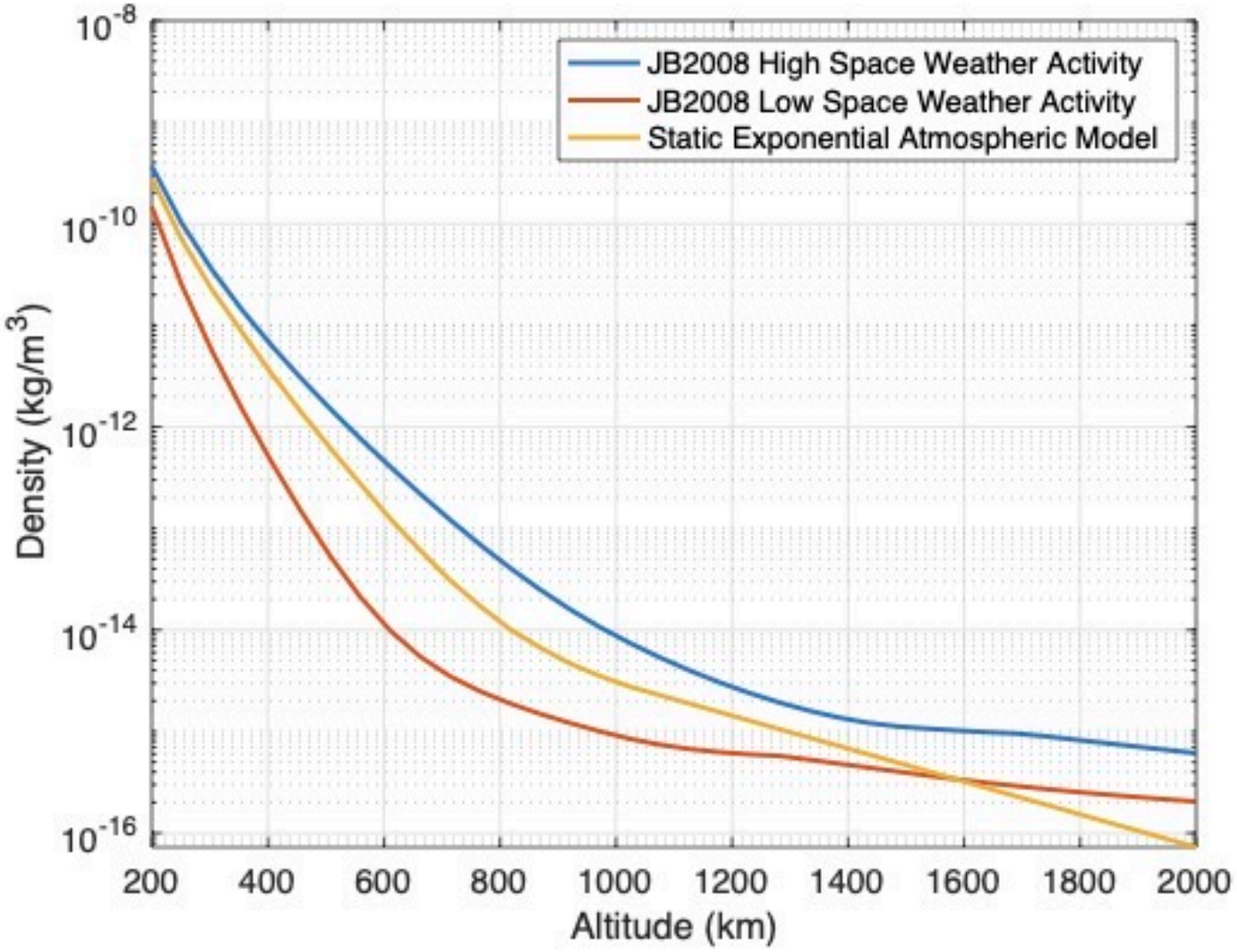
State of practice:

- Empirical models:
  - Based on historical data
  - + Fast
  - ○ Limited accuracy
- Examples:
  - Jacchia Bowman 2008 (JB2008)
  - Naval Research Lab Mass spectrometer Incoherent Scatter Radar (NRL-MSISE00)
- Static models:
  - Ignore space weather effects

State of art:

- Physics-based models
  - First-principle, 3-D, nonlinear: solves the three-dimensional momentum, energy and continuity equations
  - Forecast ability
  - Require parallel resources for real-time evaluation
- Examples:
  - Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM)
  - Global Ionosphere-Thermosphere Model (GITM)

Comparisons between static density model and JB2008



Where to generate these density data?

JB2008:

- NASA's community coordinated modeling center (https://ccmc.gsfc.nasa.gov/models/)
  - Online web service to generate density field
- Multiple user developed toolboxes and functions to evaluate and run them on your own machine
  - Examples: Mathworks file exchange (Matlab) and Github – pyatmos (Python)

TIE-GCM:

- NASA's community coordinated modeling center (https://ccmc.gsfc.nasa.gov/models/)
  - Online web service to generate density field
- Download source code from TIE-GCM website and compile a version to run on your own system