Space Weather Forecasting using Celery and Django

Making automated, HPC-powered scientific results accessible in near-real time.

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Space Weather Forecasting

Forecasting space weather conditions in the Earth's ionosphere is critical to protecting key infrastructure, such as satellite-based positioning and navigation systems, high frequency radio communications, and the electric power grid.

Variations in space weather are caused by coronal mass ejections from the Sun's surface, travelling up to 5 million kilometres per hour towards the Earth, energising electrons in the ionosphere to **produce disturbances in communications and electrical systems,** as well as spectacular aurorae.

In conjunction with the University of Birmingham's SERENE group, we present a system for operationalising HPC tasks for data assimilation in **space weather forecasting using Celery and Django**. Celery is a distributed task queue that allows us to execute tasks asynchronously in a distributed environment, while Django is a popular web framework that provides a high-level view of user interaction. Our system integrates both these tools to automate the process of running space weather simulations on an HPC cluster for data assimilation and presenting outputs on the website.

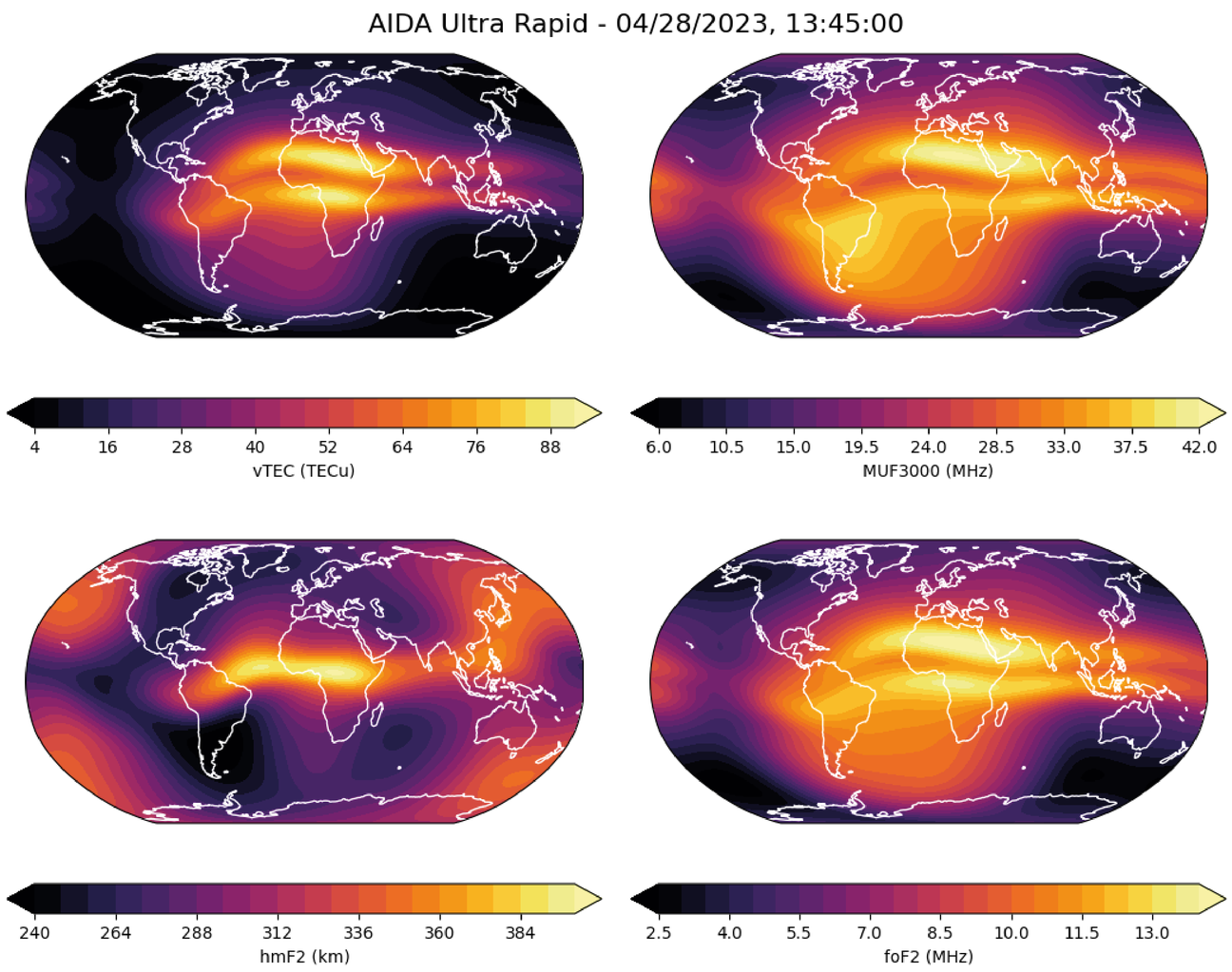

Figure 2D plot showing ultra-rapid (5 minute latency) assimilation output. (Clockwise from top-left): Vertical Total Electron Count, Maximum Usable Frequency, height and value of peak F2 layer frequencies.

Operationalise with **Celery**[1] and **Django**[2]

High-performance computing plays a significant role in simulating and forecasting space weather, as we perform data assimilation on enormous amounts of data that require a large amount of computing power. However, manually running HPC tasks can be time-consuming and error-prone. Automating HPC tasks can greatly enhance efficiency and generate scientific results accessible in near real-time.

The Django website is designed to be modular and flexible and provides an **intuitive web interface for users to submit and monitor their tasks, as well as visualise results.** It allows users to access automated assimilation outputs with 5, 90-minute and daily latencies, as well as forecasts. Users can also define and execute their custom simulations with a run-on request function.

Celery is used to download observational data from hundreds of GNSS and GIRO stations around the world, where the **assimilation ingests up to 250 gigabytes of data per hour**. Then, Celery sends assimilation and forecast jobs to the Slurm scheduler, which enables efficient and resilient resource utilization on a dedicated server. Celery is also used to create visualisations and automate file cleanup.

In conclusion, this project demonstrates that Celery and Django are powerful and flexible tools for operationalising HPC tasks for data assimilation in space weather forecasting. It enables users to efficiently utilize HPC resources while providing an easy-to-use website for interacting with jobs and simulation outputs. Our system applies to a wide range of HPC tasks in research software, and **we believe it will be a useful framework for researchers to operationalise their code.**

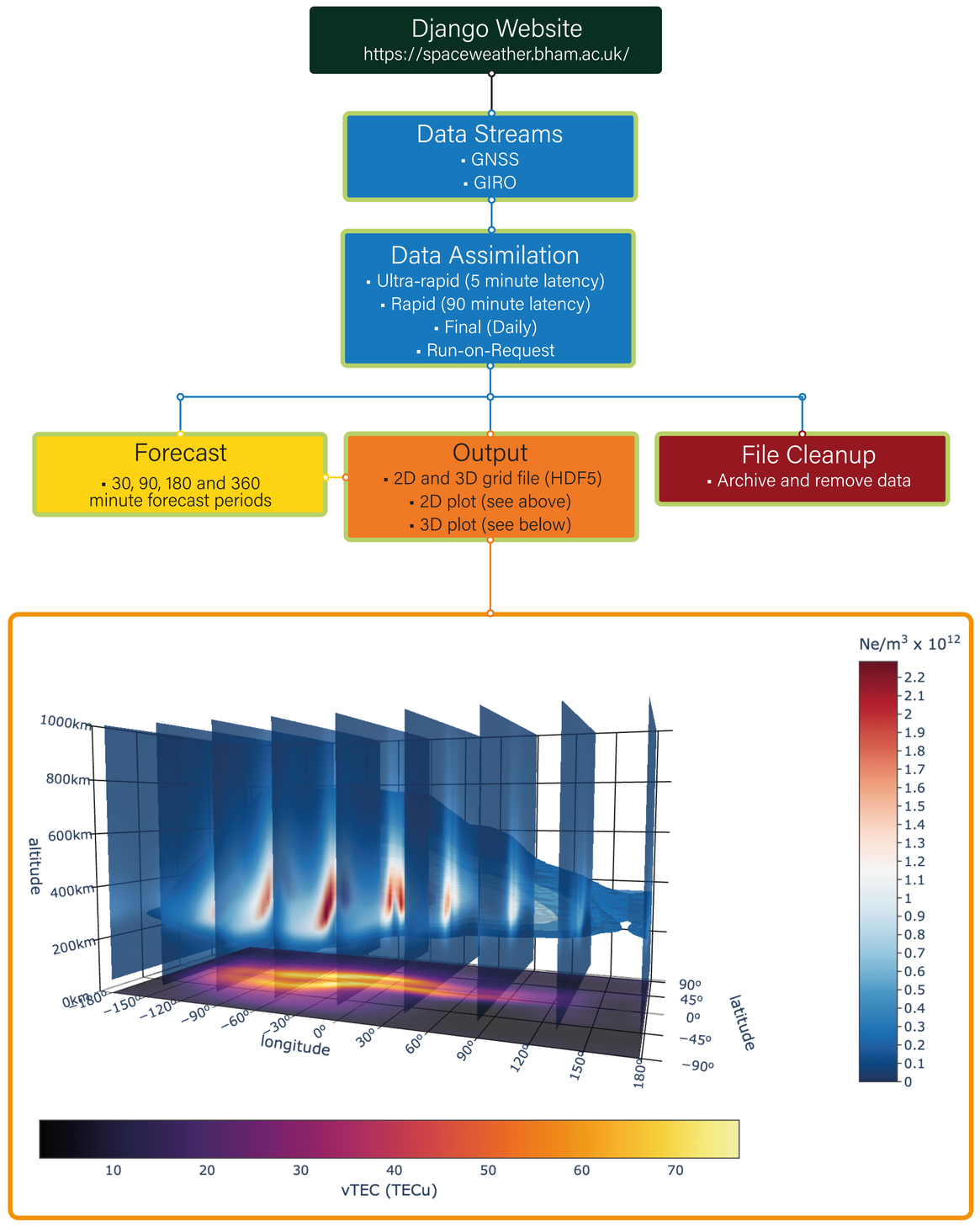

Figure 3D plot showing ultra-rapid (5 minute latency) assimilation output. Total Electron Count isosurface as a function of latitiude, longitude and altitude, with slices in longitude and a vTEC floor.

Acknowledgements

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1. Celery. (2023). Retrieved from https://github.com/celery/

2. Django Software Foundation. (2019). Django. Retrieved from https://djangoproject.com