AMSIMP: An Open Source Implementation to Simulating Tropospheric and Stratospheric Dynamics on a Synpotic Scale

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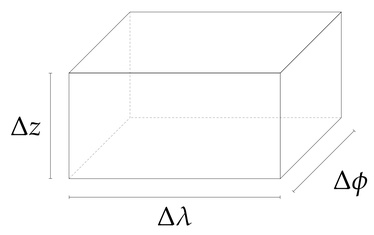
Introduction

This **project hypothesises** that it is **possible to create** an **open-source implementation** to **simulating tropospheric** and **stratospheric dynamics** on a **synoptic scale**, that **such software** is **consistent and reliable**, and that the software **consists of high-quality source code**.

Parameterisation of Simulation

Within the software, the **globe** is **divided into cells**. You can imagine this as **cutting** the **atmosphere** up into **cuboids** of air of **equal volume**. It then **solves** the relevant **equation** at the **middle** of the **cell**. After which point, this value is **used as** an **approximation** for the **entire cell**.



The **key equations** utilised within the software are represented **in discretized form** below:

$$u_g = -\frac{1}{\rho f}\frac{\Delta p_y}{2\Delta y} \tag{1}$$

$$v_g = \frac{1}{\rho f}\frac{\Delta p_x}{2\Delta x} \tag{2}$$

$$T^{n+1}_{x,y,z} = T^{n-1}_{x,y,z} + u\frac{\Delta t}{\Delta x}(\Delta T_x) + v\frac{\Delta t}{\Delta y}(\Delta T_y) \tag{3}$$

$$W^{n+1}_{x,y,z} = W^{n-1}_{x,y,z} + u\frac{\Delta t}{\Delta x}(\Delta W_x) + v\frac{\Delta t}{\Delta y}(\Delta W_y) \tag{4}$$

$$\rho^{n+1}_{x,y,z} = \rho^{n-1}_{x,y,z} - u\frac{\Delta t}{\Delta x}(\Delta \rho_x) - v\frac{\Delta t}{\Delta y}(\Delta \rho_y) \tag{5}$$

$$p = \rho RT \tag{6}$$

Contour Plot

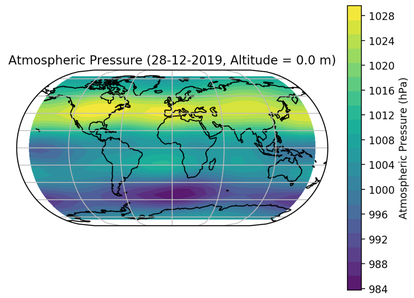


Figure 1: An Example Atmospheric Pressure Contour Plot

Open Source Software

Open Source Software is software with **source code** that **anyone** can inspect, **modify**, and enhance. **Programmers with access** to the source code can **improve** that **program** by **adding features** to it, or by **fixing bugs**. If an **atmospheric dynamics simulator** became **available** to the **open source community**, it could **lead to** a **low cost**, and **high quality simulator** ultimately being produced. If such an event occurs, it could, **theoretically**, vastly **enhance** existing **numerical weather prediction software**.

Benchmarking Method

To prove the hypothesis, it was determined that a series of appropriate benchmarks would be carried out in the areas of performance, accuracy, and code quality.

- The **performance benchmark** would **demonstrate whether** or not the **software** has **consistent and reliable performance**.
- The **accuracy benchmark** would **highlight whether** or not the **forecasts produced** by the software has a **reasonable level of accuracy**.
- The **code quality benchmark** would **indicate whether** or not the **source code** of the software was **of high quality**.

Results

Forecast Day	$\bar{x}$	σ	$\frac{\sigma}{\bar{x}}$
1	48.71941	1.6192	0.03324
2	82.05565	3.14003	0.03827
3	122.0275	6.96494	0.05708
4	164.84392	6.02163	0.03653
5	209.37133	7.62972	0.03644

In regards to the performance benchmark, the time it took to generate a five-day forecast was measured. The **statistical analysis** of the results **found** that the **mean coefficient of variation** ($\frac{\sigma}{\bar{x}}$) was approximately, **0.04**.

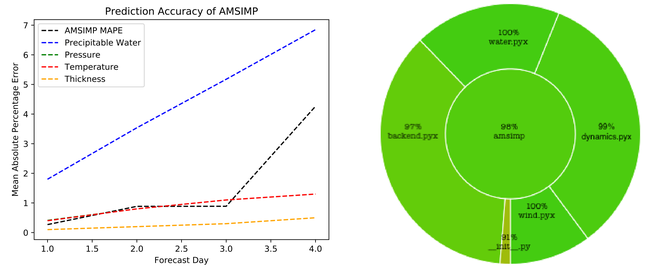


Figure 2: Results of Accuracy (L) and Code Quality (R) Benchmarks

In regards to the accuracy benchmark, it showed that a **four-day forecast** produced software had a **mean absolute percentage error** of approximately **1.56%**.

In regards to the code quality benchmark, it indicated that the software had a **code coverage** of approximately **98%**.

Conclusions

The results of the **performance benchmark demonstrated** that there was a **low variation** in **execution time**, proving that the **performance of the software** was **consistent and reliable**. The results of the **accuracy benchmark indicated** that the **forecast produced** by the software is **accurate**, which further proves its consistency and reliability. This **code quality benchmark signified** that the **software has** a **lower chance** of **containing undetected bugs**, ultimately **demonstrating** that the **quality of** the **source code is high**.

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