Atmospheric Composition Analysis: Evaluating and Utilising Large Language Model's Ability in Recognising Physical Phenomena

香港科技大學 THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Washington University in St. Louis

Ching Ting LEUNG [1] Nick CRISPINO [2] Chenguang WANG [2]

[1]Department of Chemical and Biological Engineering, Hong Kong University of Science and Technology

[2]Department of Computer Science and Engineering, Washington University in St. Louis

Introduction

Atmospheric composition analysis and prediction have long been challenging for chemists and computer scientists due to the vast amount of historical data required and the computational expense of the prediction process. We aim to improve video generation by predicting future frames from earlier ones, thereby significantly reducing the cost and computational demands of traditional methods.

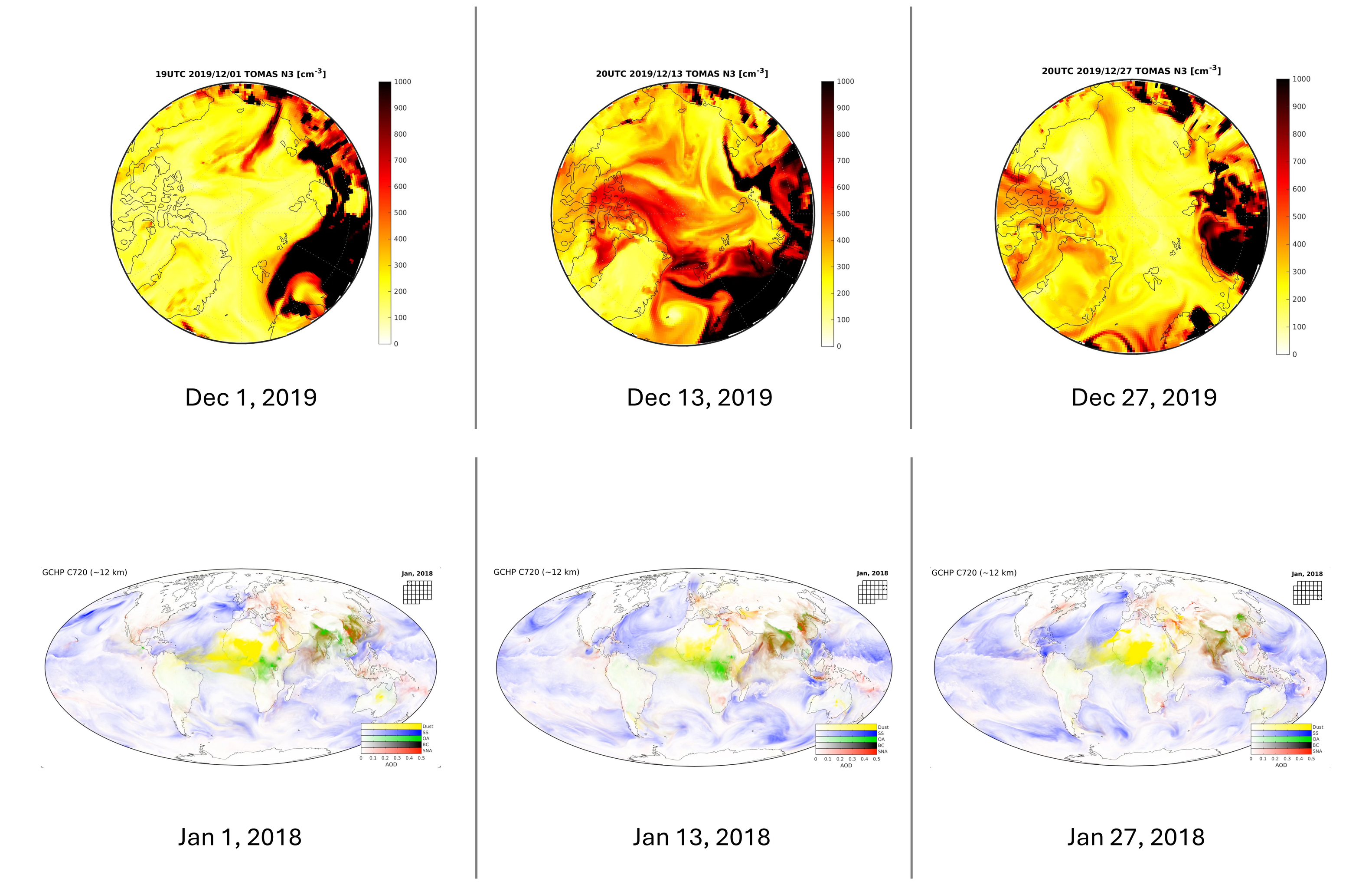


Figure 1. Graphic representation in atmospheric composition analysis. Upper: single-component graphics; Lower: multi-component graphics

Current Methods in Prediction

Mathematical Modelling

Puff model dispersion:

$$<C>(x,y,0,t)=\frac{Q_m^*}{\sqrt{2}\pi^{3/2}\sigma_x\sigma_y\sigma_z}exp[-\frac{1}{2}[(\frac{x-ut}{\sigma_x})^2+\frac{y^2}{\sigma_y^2}]]$$

Plume model dispersion:

$$<C>(x,y,0)=\frac{Q_m}{\pi\sigma_y\sigma_z u}exp[-\frac{1}{2}[\frac{y^2}{\sigma_y^2}+\frac{z^2}{\sigma_z^2}]]$$

Stable Video Diffusion [1] in Machine Learning

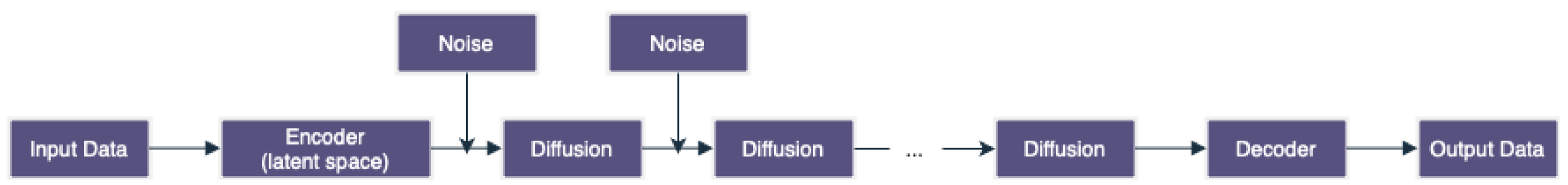
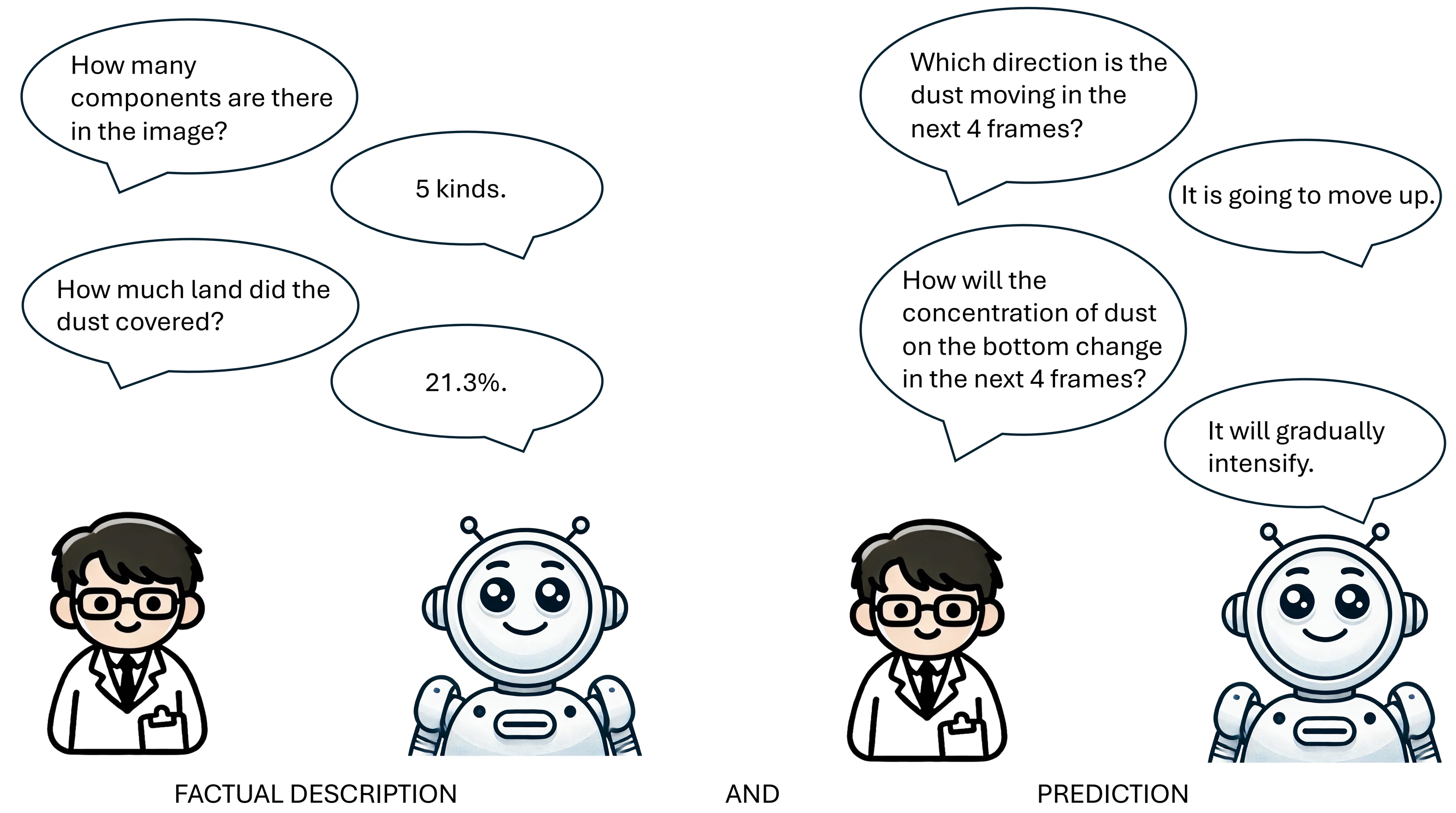


Figure 2. Architecture of a stable video diffusion model.

Basic Understanding of LLMs on Physical Phenomena



Both scenarios necessitate the vision capabilities of large language models; however, prediction demands a more profound comprehension of the model's interpretation of the map. This includes an understanding of the typical movement of particles, variations in concentration, and the interactions between different atmospheric components.

Benchmarking Video Generating AI Performances

Performance is based on the average of below metrics:

1. Detection Score [2]: $\frac{1}{M_1}\sum_{i=1}^{M_1}(\frac{1}{K}\sum_{i=1}^{K}\sigma_{t_k}^i)$
   - Are there unwanted objects appearing?
2. Colour Score [2]: $\frac{1}{M_3}\sum_{i=1}^{M_3}(\frac{1}{K}\sum_{k=1}^{K}s_{t_k}^i)$
   - Are the color generated matching the legends in the original image?
3. Trend Score: $\frac{1}{M_5}\sum_{i=1}^{M_5}(\frac{1}{K}\sum_{k=1}^{K}\delta_{t_k}^i)$
   - Does the trend of color intensity change match the ground truth?
   - How is the extend of matching?
4. Text Score: $\frac{1}{2}\sum_{i=1}^{2}(\frac{1}{K}\sum_{k=1}^{K}\varepsilon_{t_k}^i)$
   - How accurate and detailed is the text generated describing the input image?

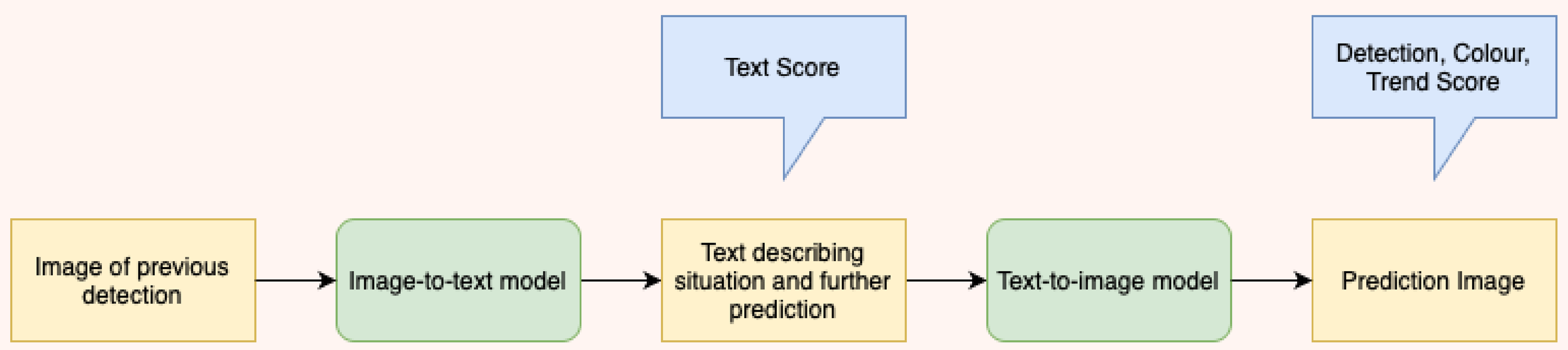
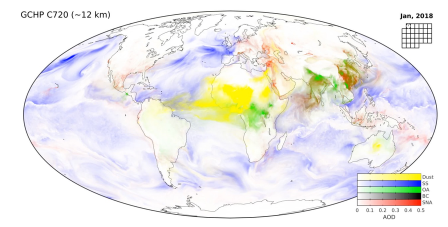


Figure 3. Overall pipeline for image processing and prediction.

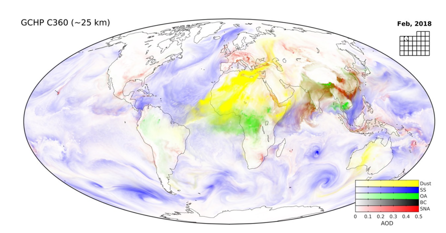
Current Model Performances

Prompt: Identify the yellow cloud on the map and give its center coordinates



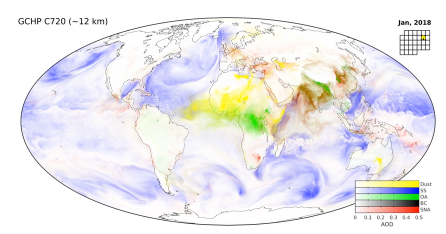
	ChatGPT 4o	Claude-instant-100k	Gemini-1.5-Flash
Coordinates	Latitude: approximately 20°N Longitude: approximately 15°E	Region around the equator at approximately 0.15 AOD	Its center coordinates are approximately 25°N, 35°E
Map recognition	Region of Northern Africa, likely around the central Sahara Desert.	It is predominantly located over central Africa.	Over the Sahara Desert
Graph understanding	The yellow cloud on the map represents dust aerosols	The yellow cloud on the map represent atmospheric dust	The yellow cloud on the map represents dust

Provided frame



Prompt: describe what you think it will happen for the yellow cloud on the image of its position and color intensity after 2 weeks

Ground truth frame for 2 weeks later



	Ground Truth	ChatGPT 4o	Claude-instant-100k	Gemini-1.5-Flash
Position movement	Southward Movements	Eastward movements as dust clouds from the Sahara Desert are often carried by trade winds towards the Atlantic Ocean.	The prevailing trade winds would carry the dust gradually across the Atlantic ocean.	The dust cloud will likely move further west, following the trade winds across the Atlantic Ocean.
Color intensity	Decrease in color intensity	Depends on the activity	Without more specific meteorological data from the intervening time period, dust interaction can depend on sunlight, wind currents and precipitation	The color intensity of the yellow cloud is likely to decrease.

Perspective work

We have explored the capabilities of large language models in understanding physical phenomena. Our next goal is to apply these models to atmospheric composition analysis and prediction, aiming to improve accuracy and efficiency in interpreting atmospheric data and enhancing predictive models for better decision-making in atmospheric sciences.

References

[1] Andreas Blattmann, Tim Dockhorn, Sumith Kulal, Daniel Mendelevitch, Maciej Kilian, Dominik Lorenz, Yam Levi, Zion English, Vikram Voleti, Adam Letts, Varun Jampani, and Robin Rombach. Stable video diffusion: Scaling latent video diffusion models to large datasets, 2023.

[2] Yaofang Liu, Xiaodong Cun, Xuebo Liu, Xintao Wang, Yong Zhang, Haoxin Chen, Yang Liu, Tieyong Zeng, Raymond Chan, and Ying Shan. Evalcrafter: Benchmarking and evaluating large video generation models. 2023.