Four Projects/Theses in Atmospheric and Environmental Physics

One of the major difficulties in producing reliable climate predictions using models is the lack of data on the way in which the atmosphere couples energy, dynamics and composition within the Earth's climate system. The upper atmosphere is where the major solar influences are felt, and there is a growing body of evidence that these effects propagate downward into the climate system in the troposphere. The following projects examine key parameters in the Earth system that will provide the observational constraints that will ultimately yield more accurate climate predictions.

1. Meteor radar observations of the upper atmosphere

The SuperDARN radars (http://superdarn.jhuapl.edu/) are a collection of 24 HF radars spanning the mid-to-high latitudes in both the north and south hemisphere. In their nearest range gates they record echoes from the ionisation trails left by meteors as they burn up in the upper atmosphere (80-100km altitude). Tracing the evolution of these meteor trails provides an estimate of the horizontal winds in the upper atmosphere. Taken together the SuperDARN radars provide an unprecedented long-term view of the dynamics of the upper neutral atmosphere. Many potential projects using data from the SuperDARN radars are available, among them:

Solar forcing of planetary waves.

Planetary waves are planetary-scale oscillations in the Earth's atmosphere driven by the interaction between the sun and the Earth's surface. They are either stationary with respect to the Earth's surface or propagate eastwards or westwards with periods ranging between two and several tens of days. They transfer energy and momentum between vertical layers in the atmosphere, drive meridional circulation in the stratosphere and in the middle atmosphere they can be the largest periodic oscillations observed. This project will use long-term data recorded by SuperDARN radars to try to answer what causes these wave amplitudes to vary from one year to the next. The relative contributions of solar geomagnetic, solar radiative and internal atmospheric-processes will be investigated. Additional work deducing the long-term trends in planetary-wave amplitudes would be part of a full thesis work.

Atmospheric tides in the mid latitudes.

The upper atmosphere oscillates at tidal periodicities (24, 12, 8 hours) driven primarily by periodic solar heating of stratospheric ozone. At high latitudes the zonal structure of these tides is a complicated mix of migrating (so-called sun-synchronous) and non-migrating components, and separating out the relative influence of these components is important in understanding the drivers of the variability of the Earth's atmosphere. This project work will use SuperDARN radar data to separate out the different modes of tidal oscillations and quantify how they are influenced by solar activity and energetic particle precipitation. Additional thesis work would involve modelling these tidal modes and their perturbations.

2. Dynamical-chemical coupling in the polar middle atmosphere.

Effect of particle precipitation on upper atmospheric ozone.

The aim of this project is to quantify the extent to which energetic particle precipitation (EPP) into the polar upper atmosphere changes ozone concentrations between 30 and 80 km. A two-year database of hourly ozone profiles from Troll Station, Antarctica will be compared with EPP indices using time-series and correlation analysis. The outcome would be to state how much EPP affects the ozone and how those induced changes compare with the background, non-EPP induced variability. For a master's thesis, this would be extended to include modelling of how the changes in ozone might affect the winds in the Antarctic.

Effect of particle precipitation on middle atmospheric winds.

The aim of this project is to quantify the extent to which energetic particle precipitation (EPP) into the polar upper atmosphere changes the upper atmospheric winds between 72 and 95 km altitude. An extensive database of middle atmospheric winds from Rothera Station, Antarctica, will be examined. The data will first be used to form the wind climatology in this region. Next, the data will be used to form a super-posed epoch analysis using the DE index of high-energy particle precipitation into the atmosphere, and an extensive uncertainty analysis will be performed to indicate the significance of these results. This will be done using the data with and without the climatology removed in order to separate seasonal effects in the sampling. Results of this would be extended into a full master's thesis by comparing the changes in the wind with variations of middle atmospheric ozone above Antarctica.

3. Airglow dynamics

The chemical reactions that take place in the middle atmosphere result in luminescence that we call airglow. This light, confined to a thin shell near 90 km, is observable by spectroscopic instruments on the ground, and may be used to remotely sense the composition and temperature of the atmosphere where it is produced. Atmospheric waves passing through this shell modulate the temperature, and these changes may be used to quantify the wave energy in the middle atmosphere.

Global small-scale wave variance.

By using a global network of ground-based airglow observations associated with the Network for the Detection of Mesospheric Change (NDMC), a global picture of small-scale wave energy, which drives global circulation and is a critical component of atmospheric climate and weather models, may be obtained. The climatology of wave variance and its geographical and geomagnetic variation will be determined. Further thesis work will involve comparing the resulting climatology of wave variance with solar-radiative and solar-particle indices to quantify external driving factors.

Ultra-fine-scale wave structure using the Nordic Optical Telescope.

The Nordic Optical Telescope (NOT) at La Palma records background emission lines from the terrestrial atmosphere's airglow. These emissions contain a wealth of information on the chemical and dynamical state of the Earth's atmosphere. We have service observation data that can exploit the high spatial (10 m) and temporal (10 s) resolution of the telescope to extend the range of dynamics normally observed with airglow into the realm of dynamic instability structures and infrasonic waves. Initial data analysis will extract the smallest scales observable using the telescope data, and additional thesis work will compare these fluctuations with infrasonic signals recorded simultaneously.

4. Preparatory studies for the MATS satellite

To improve our understanding of gravity waves in the mesosphere, the MATS satellite will be launched in 2019 (http://www.snsb.se/en/Home/Space-Activities-in-

Sweden/Satellites/Mats/). This satellite is currently undergoing prototype testing and verification, and will provide the first 3 dimensional reconstruction of gravity waves in the upper mesosphere. This will be achieved by observing variations in airglow (light emission caused by exited oxygen molecules) and noctilucent clouds (clouds existing at 80 km).

Prior to launch methods for analyzing and interpreting the data generated by the measurements must be developed, and for a student interested to work with this upcoming project some suggestion of thesis topics are suggested below. These will be carried out in collaboration with our Swedish collogues at Stockholm University and Chalmers Technical University.

Realistic Gravity wave scene generation from a high resolution weather forecast model.

In order to simulate the observations realistic simulations of the expected wave activity is required. Large scale weather forecast models have problems accurately simulating these waves, and the thesis project involved setting up a high resolution model and identify under which conditions GW can be observed by MATS and what characteristica the instrument reliably can extract from these waves.

Automatic identification of coherent wave structures in MATS fields

The goal of MATS is to provide a global climatology of wave structures in the mesopause region. As such, methods for automatically extracting wave properties from MATS images (or tomographically reconstructed intensity or temperature fields) is needed. Methods based on the fast-Fourier transform have been developed for the use in one of MATS channels, and the thesis objective is to extend these methods to better utilize the information avalible on the tomographic 3D data which will be generated by MATS.

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