

## Climatology

## Grey-sky thinking

Without understanding clouds, understanding the climate is hard. And clouds are the least understood part of the atmosphere

“CLOUDY.” As a metaphor, that is not a bad description of the science of climate forecasting. The general trends are clear, but the details are obscure. As it happens, however, the description is not merely metaphorical—for of all the elements that make up the climate, and have to be accounted for in models of it, it is clouds that are the most obscure.

Improving this understanding is the purpose of two new missions by NASA, America's National Aeronautics and Space Administration. One of these missions, a satellite called Aeronomy of Ice in the Mesosphere, or AIM, was launched in April to study so-called noctilucent clouds (depicted above), the highest layer of clouds in the atmosphere. These have been getting brighter and more common in recent years, and also seem to be moving to lower altitudes. The other mission, the Tropical Composition, Cloud and Climate Coupling (TC4) project, will begin on July 16th. It will use radar, balloons and aircraft to look at the role of another sort of high-altitude cloud: cirrus clouds, which get spun off the tops of storms. Meanwhile, a paper published this week in the *Proceedings of the National Academy of Sciences* by Sylvia Knight of Oxford University and her colleagues has emphasised just how sensitive climate modelling is to

assumptions about clouds.

The link Dr Knight is examining, between clouds and what researchers call climate sensitivity (the degree to which a particular input is likely to change the climate), has been apparent for nearly 20 years. But because clouds take different forms at different scales—from microscopic water droplets to weather fronts that span hundreds of kilometres—they are devilishly hard to describe in models that work by manipulating “virtual” chunks of the atmosphere that are 100km (62 miles) across and 100km high.

**Shrouded in uncertainty**

Only recently have such international undertakings as the Cloud Feedback Model Intercomparison Project (CFMIP) and the Cloud System Study of the Global Energy and Water Cycle Experiment begun a systematic comparison of the effects of clouds on dozens of the most important climate models, allowing researchers to start to unravel more precisely the role that clouds play in climate change. In a recent paper in *Climate Dynamics*, Mark Webb of Britain's Hadley Centre for Climate Change and his colleagues reported that clouds account for 66% of the differences between members of one important group of models and for 85% of them in an-

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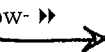
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other group.

These findings have now been complemented by Dr Knight's project, which made use of climateprediction.net, a network of personal computers on which processing time is volunteered by members of the public, to compile 57,000 different runs of a global-climate model developed at the Hadley Centre. She and her colleagues found that 80% of the variation in the climate sensitivity predicted was due to changes in how clouds were described in the model. The cloud characteristics included differences in the ease with which moist air in the tropics travels into the upper atmosphere, the speed with which raindrops fatten and the level of humidity required for clouds to form. Each aspect had a big impact on the degree of warming predicted.

The reason why clouds matter so much to the climate, and their role is so tricky to determine, is because they play two contradictory roles. At low altitudes they help to cool the Earth by reflecting sunlight away from it. At the high altitudes studied by AIM and TC4, however, they trap radiant heat from below, warming things up.

At the moment, many researchers believe it is low-level clouds that matter most. In its first phase, participants in the CFMIP analysed a subset of the 23 models used to compile the most recent report from the Intergovernmental Panel on Climate Change. They concluded that changes in low-level clouds contributed most to differences in the degree of warming those models predicted. And in a paper published two years ago in *Geophysical Research Letters*, Sandrine Bony and Jean-Louis Dufresne reported that an analysis of 15 climate models suggested that low-



▶ level clouds over the oceans contribute most to uncertainty about how tropical clouds affect those models. Low-level clouds are thought to matter more than high-level ones because they are more prevalent and because they are better at reflecting solar heat away from the Earth than they are at trapping it, blanket-like, as high clouds do. However, results from AIM and TC4 may modify this view—which is the main point of deploying them.

Certainly, model-comparison projects alone will not solve the cloud problem. Too much still remains unknown about the physical mechanisms that determine cloud behaviour. That is why new and better observations are needed to improve the fundamental assumptions on which the models are based. The TC4 project will generate new data on the icy cirrus clouds that are formed in the upper atmosphere by heat-driven, or convective, storm systems that coalesce over warm waters in the tropics. By studying these clouds from every angle and at every point in their life cycle, researchers hope to learn more about how these storms, which can drive air more than 13km above the Earth's surface, will contribute to climate change in a warming environment.

In addition to the TC4 campaign and AIM, a string of NASA climate-sensing satellites called the A-train is providing a global survey of the vertical profile of clouds. One of these satellites, *CloudSat*, has given the first glimpses of the middle layer of clouds in the Earth's atmosphere. Meteorologists were once limited to a top-down or bottom-up look at clouds. Since April 2006, *CloudSat*'s radar has, however, been providing a globe-circling slice of the middle layer, a previously unobserved part of the atmosphere.

Another A-train satellite, the Cloud Aerosol-Lidar and Infrared Pathfinder Satellite Observation (CALIPSO)—launched simultaneously with *CloudSat*—will map the location of layers of small particles called aerosols that promote cloud formation. Such particles act as nuclei for the condensation of water vapour into the droplets of which clouds are composed.

Natural aerosols are produced by sea salt, desert dust, volcanic eruptions and smoke from forest fires. Aerosols are also released when cars are driven, chemicals manufactured and fossil fuels burned. Little is currently known about where such particles end up in the atmosphere and what overall effect they have on the climate. CALIPSO will help to correct that. It has already produced pictures of the volcanic plumes created when part of the Soufrière Hill volcano on the island of Montserrat collapsed last year, sending ash clouds high into the atmosphere. Such gritty reality, when combined with the models, should bring some clarity to the problem of clouds. ■