Atmospheric Radiation Measurement
Climate Research Facility
U.S. Department of Energy

Climate Education Update

NEWS AND INFORMATION ABOUT CLIMATE CHANGE STUDIES FOR TEACHERS AND STUDENTS

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The Department of Energy's Atmospheric Radiation Measurement (ARM) Climate Research Facility supports education and outreach efforts for communities and schools located near its sites. The mission of the Education and Outreach Program is to promote basic science education and community awareness of climate change research by focusing on three goals: student enrichment, teacher support, and community outreach.

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TWP-ICE: What's it all about?

by Dr. Jim Mather, ARM scientist

In January and February 2006, the Atmospheric Radiation Measurement (ARM) Program is sponsoring a major field experiment at the Darwin ARM site, in collaboration with the Australia Bureau of Meteorology (BOM) and investigators from the United States, Australia, the United Kingdom, Japan, and Canada. The primary aim of the Tropical Warm Pool – International Cloud Experiment (TWP-ICE) is to obtain detailed observations of cirrus clouds using high altitude aircraft in conjunction with remote sensing observations and meteorological observations designed to characterize the atmospheric environment.

In the tropics, cirrus generated by powerful convective storms cover very large areas. These clouds have a large impact on climate by reflecting incoming solar energy and by absorbing infrared energy emitted by the earth's surface and by the atmosphere. While the importance of cirrus is well known, the detailed composition of these high altitude clouds is not. Therefore, the study of tropical cirrus remains an area of very active research and is one of the main themes of research associated with the tropical western Pacific ARM sites located in Manus, Papua New Guinea; Nauru; and Darwin, Australia. Understanding of tropical clouds, gained from ARM's tropical measurements and data, will ultimately be important for improving the representation of these clouds in climate and weather models.

ARM's research site in Darwin, Australia

The Darwin ARM site includes instruments designed to observe cloud properties. Two key instruments for retrieving cloud properties are the millimeter cloud radar and the micropulse lidar. These instruments emit pulses of electromagnetic energy – pulses of microwave energy in the case of the radar and visible light in the case of the lidar. The pulses are reflected back to the instrument by particles in the atmosphere. By studying the details of the reflected signals from the radar and the lidar, in conjunction with other ARM instruments, it is possible to obtain some information about the composition of a cloud over the site. However, the process of deriving cloud information from the measurements generally requires making some assumptions about the cloud composition. To improve the quality of the products derived from the radar and lidar it is extremely useful to have additional information about the content of the cloud which can then be used to improve the assumptions that are built into the radar and lidar cloud retrievals.

Research in the sky

During TWP-ICE, five aircraft will be flying missions over the ARM site. Two of these aircraft, the Proteus and the Egrett, will carry instruments that measure the size and shape of cirrus ice particles. The Proteus is operated by the U.S. Department of Energy while the Egrett and the Dornier are operated by the United Kingdom ACTIVE (Aerosol and Chemical Transport in Tropical Convection) Program. The remaining two aircraft are jointly operated by various institutions and programs. The measurements from the Proteus and Egrett will provide detailed information about the composition of these high altitude clouds. Missions will be flown to characterize ice particle size, shape, and concentration, as well as how they depend on various environmental parameters such as altitude and distance from the storm core. A third aircraft, a Twin Otter, will fly far below the Proteus and Egrett and will carry two upward-looking remote sensors, a cloud radar and a cloud lidar. By flying these remote sensors below the high altitude, in-cloud aircraft, the amount of coincident in-cloud and remotely sensed cloud data will be greatly increased versus relying solely on overpasses of the ARM site.

To further increase the amount of coincident remote sensing and in-cloud validation data, a second ground site will be instrumented with a cloud radar and a cloud lidar along with many of the radiation and meteorological sensors found at the ARM site. This second site will be located on the CSIRO (Commonwealth Scientific and Industrial Research Organization) oceanographic research vessel, the Southern Surveyor. The Southern Surveyor will be based 100 km west of Darwin in the Timor Sea. The ship will be constantly moving within a 25 km square in order to make measurements of atmospheric and ocean heat fluxes.

There will be two low-altitude aircraft to round out the TWP-ICE, the Dimona and the Dornier. The Dimona will fly at very low altitudes, below 1 km, and will focus on radiation and heat flux measurements and on characterizing the distribution of temperature and humidity in the vicinity of convective storms. The Dornier will fly in a broader vertical region, up to about 5 km, and measure meteorological parameters such as temperature and humidity as well as aerosol distributions. Aerosols are small particles with various chemical compositions (e.g. sea salt, mineral dust, or sulfuric acid). Cloud particles preferentially form on aerosols and the ease with which cloud particles form depends on the chemical and physical characteristics of the aerosol, so measuring the aerosol properties is important for understanding the life cycle of cloud particles.

The Dornier will measure temperature and humidity.

Measurements from the Darwin region will provide very useful constraints for running meteorological models to simulate cloud systems for the experiment period. In order for model simulations to properly represent conditions experienced during the experiment, another necessary constraint involves the horizontal boundary conditions around the experiment domain. In particular, it is important to measure the distribution of temperature and humidity around the boundaries of the experiment area. To fulfill this requirement, there will be five radiosonde sites, each approximately 150 km from Darwin, forming a rough circle 300 km in diameter. Four of these weather balloon launch sites will be located at rural land-based sites and the fifth will be on the Southern Surveyor. College students are the majority of weather balloon launching staff. A large number of students will be working because balloons will be launched around the clock (every three hours) for the entire 24-day duration of the experiment. The data set from these balloons will be an unprecedented source of data for constraining meteorological models in the tropics.

TWP-ICE will simultaneously measure the detailed properties of cirrus clouds in the Darwin region. At the same time, balloon, air and surface based measurements will provide detailed measurements of the meteorological environment in which the cirrus-generating convective storms form. It is anticipated that this combination of measurements will provide important insights into the life cycle of tropical cirrus clouds that can be used for the improvement of meteorological models for both weather prediction and climate change studies. ■ *by Dr. Jim Mather*

Teacher's Notes

Cloud Cover and Temperature

The earth's climate varies from place to place. Locations near the equator tend to be constantly hot and wet, such as the Pacific islands and the Amazon Basins. Some places near the North and South Poles, such as Antarctica and Greenland, are extremely cold and dry.

The main cause of this variation of temperature is the amount of solar energy that is received. In general, in higher latitudes further away from the equator, less solar radiation is received, and lower temperatures are experienced. On a global scale, the amount of energy received from the sun is much greater in the Southern Hemisphere during December and January each year, and much less during June and July. In the Northern Hemisphere, radiation is greater during June and July and less during December and January.

Cloud cover affects temperature. Thick cloud reflects incoming solar radiation by day and also prevents much of the long-wave ground radiation (by night) from leaving the lower layers of the troposphere. So cloudy conditions cause lower temperatures by day and higher temperatures by night. Cloud cover is usually given in a unit known as *okta*. One okta means on eighth of the sky. If they sky is completely covered in cloud, the cloud cover is given as 8 oktas, or 8/8. If the sky is half covered, the cloud cover is given as 4 oktas, or 4/8. Clouds can be low [0-3 km high], medium [3-6 km high] or high [over 6 km high]. Very high clouds, which are made of ice crystals, are known as cirrus clouds. Flat clouds are know as stratus. Clouds that have a rounded, fluffy shape (very common in the Pacific) are called cumulus. Low black or grey clouds that bring rain are known as nimbus.

Microclimates

Have you ever noticed how much cooler it is in the shade than in direct sunlight? Of course! Or how much hotter it feels to stand on pavement as opposed to a grassy patch of land? Temperature differences within a small area are indications of microclimates: very small-scale climate conditions. The following are a few examples of microclimatic variation:

- Dense, cold air sinking into the bottom of a valley can make the valley floor 20 degrees Celsius colder than a slope only 100 meters higher
- Winter sunshine can heat the south facing side of a tree (and the habitable cracks and crevices within it) to as high as 30 degrees Celsius, while the temperature only a few centimetres away from the tree is below freezing in a high latitude case, i.e., not in the Pacific
- The air temperature in a corn or wheat field can vary by 10 degrees Celsius from the soil to the top of the canopy.

Frogs, beetles, and other small animals experience temperature changes on even small scales (e.g., pockets of coolness formed by crevices in tree bark, the shade of a leaf, or moist soil beneath a rock). Such small-scale temperature variations might seem unimportant, but they help set the distribution and abundance.

Air temperature varies from one location to another (spatially) and from one time to another (temporally). For example, there are large variations in temperature with latitude (it is warmer at the equator and cooler at the poles) and over the seasons (it is warmer in summer and cooler in winter). Given these variations, how do meteorologists know the temperature of the entire planet? Average global temperature can be determined by dividing the globe into a grid and averaging temperatures collected from weather stations in each cell of the grid. Local temperatures reported on the evening news and in daily newspapers are determined much the same way, but on a regional scale. The same principle of averaging temperatures to calculate a single temperature for an area can be applied to the classroom and the school yard.

Hands-on Learning

Lesson 1: Observing Cloud Cover

The objective of this activity is to learn observation skills and practice recording data. Students will learn how to determine cloud types, cloud heights, and cloud cover.   Each student or group of students will need the following:

- Cloud chart from local meteorological service
- Student recording sheet (example provided below)
- Knowledge of the Beaufort Wind Scale, which can be found on the National Oceanic and Atmosphere Administration's web site at http://spc.noaa.gov/faq/tornado/beaufort.html

Procedure

- After a brief introduction to cloud types, cloud cover and the Beaufort Wind Scale, students should leave the classroom and go outside.
- Where possible, observations should be made at a site where the view is relatively interrupted so that students can see as much sky as possible.
- For recording wind speed, the students should be encouraged to look at objects that are high up, as opposed to those that are at ground level.
- Each student should record his/her observations in the appropriate space on the student recording sheet.
- Observations can be made daily for a week and then compared with those of fellow classmates.

Date	**Time**	**Wind Speed** (Beaufort)	**Cloud Cover** (okta)	**Cloud Height** (low, med, high)	**Cloud Shape** (cirrus, stratus,, etc)

Lesson 2: Understanding Microclimates

The objective of this activity is to identify, measure, and average microclimatic, temperatures in a particular region. Each student or group of students will need the following:

- Large white piece of paper or chalkboard
- Pencils and erasers or chalk
- Thermometer

Procedure

- Discuss the difference between the following pairs of terms: climate versus microclimate, and climate versus weather. Give examples of each.
- Temperature is a good example of an important environmental condition that might vary on a microclimatic scale. List other environmental factors which might vary on a relatively small, or microclimatic, scale.

1. Working individually or in small groups, students should identify and draw a small-scale map of an area to be sampled (e.g., the classroom, playground, park, backyard).
2. Help students divide the map into a grid and identify potential locations for microclimatic differences (e.g., under shaded rocks, on the sunny side of a building, on concrete versus a grass field).
3. Students should take thermometers to different locations identified on the map. Students will record the air temperature in these locations, making sure enough time is allowed for thermometers to acclimatise to their surroundings (approximately 5-10 minutes).
4. Students should record the data on the appropriate grid of their map, compare information with fellow classmates and calculate averages.

A Closer Look at Cirrus Clouds

by Lis Cohen, University of Utah

During the Tropical Warm Pool International Cloud Experiment (TWP-ICE) scientists will investigate the properties of tropical cirrus clouds. Cirrus clouds are composed of small particles, mostly ice crystals, and are often in the form of delicate white filaments, patches or narrow bands. Cirrus clouds play a substantial role in the earth's climate system because they can either warm or cool the earth system depending on the properties of the clouds. The cirrus cloud layers cool the earth by reflecting sunlight back into space, which reduces the amount of sunlight (visible radiation) that reaches the earth's surface. Cirrus can warm the earth's atmosphere by absorbing some of the earth's infrared radiation that would normally escape to space – effectively trapping this energy within the climate system.

An instrument shelter houses the MMCR; the large object on top of the shelter is the MMCR antenna.

The amount of cooling and warming from these effects depends on several factors including: properties of the underlying surface and atmosphere, the cloud coverage, cloud height, cloud thickness, the mass of condensed water within the cloud, and the details of the ice crystal sizes.

During TWP-ICE, scientists will determine how the cirrus clouds form, how they are maintained, and what determines the evolving properties of these clouds. Scientists think that the properties of the cirrus clouds often rely on the characteristics of the source of the cloud layer, either the anvil of a cumulonimbus thunderstorm cloud or from other atmospheric dynamics such as turbulence. Using data from the geosynchronous satellite located over Darwin, scientists can identify and track the cirrus clouds from space. The Millimeter Cloud Radar (MMCR) and lidars at the ARM site show the cirrus properties, such as thickness and temperature, from the ground. Scientists will also employ several aircraft that will fly within and underneath the cirrus during the experiment to gather information on ice crystal sizes and condensed water mass.

Inside the instrument shelter, an ARM scientist reviews data collected by the MMCR.

The properties of tropical cirrus clouds will be better understood as a result of the data collected during TWP-ICE, and scientists will use this new knowledge to correctly quantify how cirrus heat and cool the atmosphere, which will enable a better understanding of their role in the climate system.

Lis Cohen is a graduate student from the University of Utah studying clouds and their effects on climate. She is one of several university students who will work at the ARM site in Darwin during TWP-ICE.

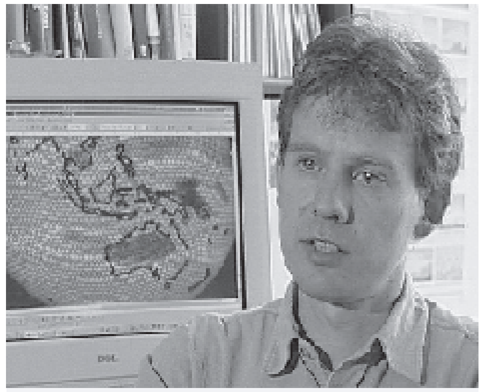
As an undergraduate at Cornell University in New York, USA, Lis doubled majored in Atmospheric Science and the Science of Earth Systems with a concentration in Climate Dynamics. Lis has worked as a television meteorologist, and like many young atmospheric scientists, is interested in teaching others about clouds, climate and weather. She currently teaches in public schools around Salt Lake City, UT, USA.

New Kiosk for Darwin Museum

The Museum and Art Gallery of the Northern Territory in Darwin, Australia will soon be home to the newest ARM kiosk in the *Climate Change: Science and Traditional Knowledge* series. The kiosk focuses on ARM's research in the Tropical Western Pacific and the effects of climate change in Darwin.

Interviews with scientists from the ARM Program and Australian Bureau of Meteorology provide kiosk users with a thorough introduction to the basics of climate research. Important questions such as "What is atmospheric radiation?" and "What is the role of clouds in climate?" are addressed in short interviews captured on video. Users only need to press a button to get factual information on how scientists study clouds, climate, and weather at the ARM site in Darwin.

"A climate model, unlike the model of a little car, is not something you can hold in your hand," explains Dr. Christian Jakob, research scientist from the Australian Bureau of Meteorology. "It is a computer program based on the laws of physics and contains instructions for the computer to calculate how the atmosphere, the ocean and land will change given the state they are in right now.



Dr. Christian Jakob, Research Scientist

In addition to scientific information, the kiosk offers a diverse local perspective on climate change from people living in the Darwin community. Mackerel, barramundi and prawn fishermen discuss how climate change impacts the seafood industry, while traditional landowners explain how long-term changes in climate could affect traditional bush burning. Seasonal changes are a common thread in many of the interviews.

The kiosk project is a collaborative effort between ARM and the Museum and Art Gallery of the Northern Territory to promote awareness of climate research in the Darwin community and to encourage interest in atmospheric sciences among students. While the full kiosk display will be located at the museum for visitors, teachers, and students to use, the kiosk software is available on DVD for classroom use.

Beginning February 16, 2006, the kiosk will be available for viewing at the museum. Teachers interested in obtaining a copy of the kiosk for classroom use can contact ACRF Education and Outreach for more information.

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