PODEX experiment to reshape future of atmospheric science

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On Aug. 22, 2012, the ER-2 took off from Dryden Aircraft Operations Facility in Palmdale, Calif. One of the instruments on board would later fly with the PODEX experiment. Credit: NASA/Matteo Ottaviani

NASA scientists and engineers are working now to lay the groundwork for the Aerosol-Cloud-Ecosystem (ACE) mission, a satellite that will dramatically change what we can do from space to learn about clouds and aerosols.

Satellite Earth science missions don't start at the launch pad or even in orbit. They start years before when scientists test their new ideas for instruments that promise to expand our view and understanding of the planet. NASA scientists and engineers are working now to lay the groundwork for the Aerosol-Cloud-Ecosystem (ACE) mission, a satellite that "will dramatically change what we can do from space to learn about clouds and aerosols," said ACE science lead David Starr of NASA's Goddard Space Flight Center in Greenbelt, Md.

How should the satellite's instruments be designed, and how can the data be turned into useful information for research? To find out, three teams have each developed prototype instruments that will be put to the test this month during the Polarimeter Definition Experiment (PODEX) in Southern California.

For three weeks starting Jan. 16, instrument teams will collect data during seven flights on the ER-2 – a high-altitude aircraft based at NASA's Dryden Aircraft Operations Facility in Palmdale, Calif. By virtue of its ability to operate at altitudes up to 70,000 feet above the ground, the aircraft simulates the view from space.

The instruments flying on the ER-2 are a new class of polarimeters, an instrument that can give increasingly detailed information about aerosols and clouds. Aerosols are tiny airborne particles from a variety of sources – such as from the tail pipe of a car to dust and sea spray lifted up by the wind. They can stay in the atmosphere for up to a week where they affect human health, cloud formation, precipitation and Earth's radiation budget. But the complex nature of aerosols and clouds poses challenges in deciphering their influence on climate.

As the instrument teams have demonstrated, however, there's more than one way to build a polarimeter. Testing the technology this month are three instrument teams led by: Brian Cairns, of NASA's Goddard Institute for Space Studies in New York, principal investigator for the Research Scanning Polarimeter (RSP); David Diner, of NASA's Jet Propulsion Laboratory in Pasadena, Calif., principal investigator of the Airborne Multiangle SpectroPolarimetric Imager (AirMSPI); and J.

Vanderlei Martins, of University of Maryland Baltimore County, principal investigator of the Passive Aerosol and Cloud Suite (PACS) polarimeter.

Starr, who has worked in the field leading airborne science campaigns since 1986, will oversee the polarimeter instrument teams as PODEX project scientist. He spoke with NASA's Earth Science News Team's Kathryn Hansen about the experiment and how it could reshape the next generation of atmospheric science.

Question (Q): What is a polarimeter?

Answer (A):Traditional radiometers measure radiation intensity over a particular range of wavelengths, which are converted into products such as images of Earth's surface, clouds and aerosols. Launch of radiometers aboard NASA's Terra satellite in 1999 is, in part, what got people jazzed up about aerosols – we realized how they're blowing around the planet, then we realized the potential significance of their impact on health, clouds, Earth's radiation budget and precipitation.

Polarimeters – sensors that detect the polarization of light – work in a similar way, but have the potential to provide more information about particles, such as shape and size.

Q: Why does this approach work?

A: It works because the polarization of reflected sunlight is sensitive to what it hits.

Incoming sunlight is unpolarized, which means that the planes of vibration of the light waves are randomly oriented. When the sunlight interacts with Earth's atmosphere or surface, the light waves can vibrate in preferred orientations. For example, interaction with highly structured particles or objects – things like industrial soot particles, dust, vegetation, or ice crystals in a cloud – can dramatically change the polarization of reflected sunlight.

Q: What can polarimetry tell us about aerosols?

A: Aerosols are a tough problem. Unlike clouds, when looking at Earth from space you really have to look hard to see them. You're often looking at a subtle signal and that makes it hard to be quantitative and accurate. Data from MODIS (radiometers aboard NASA's Terra and Aqua satellites) are of great value, but interpretation of that data depends on educated guesses regarding the types of aerosols in a particular scene, which significantly affects the conclusions.

In the case of aerosols, polarimetry provides a way to estimate their composition from space, which has not previously been possible. With measurements that discriminate the types of aerosols that are present, we eliminate a significant source of uncertainty.

Q: What can polarimetry tell us about clouds?

A: Clouds composed of liquid droplets or ice crystals both modulate the planet's radiation budget and directly affect climate.

For clouds composed of liquid droplets, the size and quantity of the drops determine how much solar radiation they will reflect. For example, low-level stratocumulus clouds cover vast areas of the ocean and strongly regulate the heating of the ocean by blocking solar radiation before it gets to the ocean surface. Polarimetry measurements from various angles offer the promise of more robust measurements of droplet size, which can range in diameter from about 10-30 micrometers or more. Even relatively small differences can be significant for climate.

For clouds composed of ice crystals, the radiative properties of the clouds are quite sensitive to crystal size, quantity and also shape. We learned from previous fieldwork that the size of particles in ice clouds is quite variable, spanning a large range compared to liquid clouds. Cirrus clouds, for example, can be composed of ice crystals ranging from a few microns to 1 millimeter, or greater. Consequently, different cirrus clouds may look very different to the eye. Crystal shape is also quite variable and can be complex. Because of the structure ice crystals, it has long been known that polarimetry has a lot of promise for remote sensing of cirrus clouds and their properties.

Q: Is this new technology?

A: : In the 1970s there was some discussion about polarimetry, but aerosols were not a popular remote sensing topic at the time. Kuo-Nan Liou, one of the fathers of atmospheric radiative transfer, previously suggested flying polarimeters to sense ice clouds because we were having a difficult time with regular radiometers. The French space agency CNES flew a coarse-resolution polarimeter on the POLDER satellite, and NASA flew one on the Glory satellite that failed to reach orbit. So, we're just opening this door but it has a lot of potential.

The PODEX experiment is about developing an area of technology and remote sensing and getting it ready for space. If you look back two to six years before Terra, NASA flew simulators for the purpose of preparing for the MODIS instrument and to work on algorithm development for MODIS data. We're now trying to do that for the next generation of technology that we plan to fly in the early 2020s. We're not simply re-flying Terra or Aqua. This is a major step toward new technology to reduce errors and uncertainties in aerosol and cloud observations from space.

Q: Why fly three polarimeters?

A: PODEX is an experiment to provide a basis to push each of the existing polarimeter designs to greater maturity. The data we collect will greatly facilitate algorithm development – data processing that allows us to derive geophysically relevant aerosol and cloud properties. This is where the real value of the measurements resides. For a satellite mission, we also need to be able to quickly process large volumes of data without human intervention – also a significant challenge.

Progress toward this goal will result in data we can use to address a number of key design questions for a spaceborne polarimeter. For example, how accurate do the radiance and polarization measurements need to be to achieve specified goals in accuracy for the derived geophysical parameters? How can we best achieve that accuracy? Similarly, what spatial resolution can we achieve? How many angles should be observed? How many spectral channels should be polarization capable? Which ones are optimal?

While there are strong opinions as to the likely answers to such questions, we do not have sufficient observational basis to adequately confirm or deny the theoretical arguments. PODEX seeks to push this enterprise forward and ultimately enable the optimal cost-effective design of such an instrument for the ACE mission.

At some point we turn a corner and start building something to fly in space. What's the design? What's the impact of that design on algorithm development and data products? Right now that's all on paper.

Provided by NASA's Goddard Space Flight Center

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