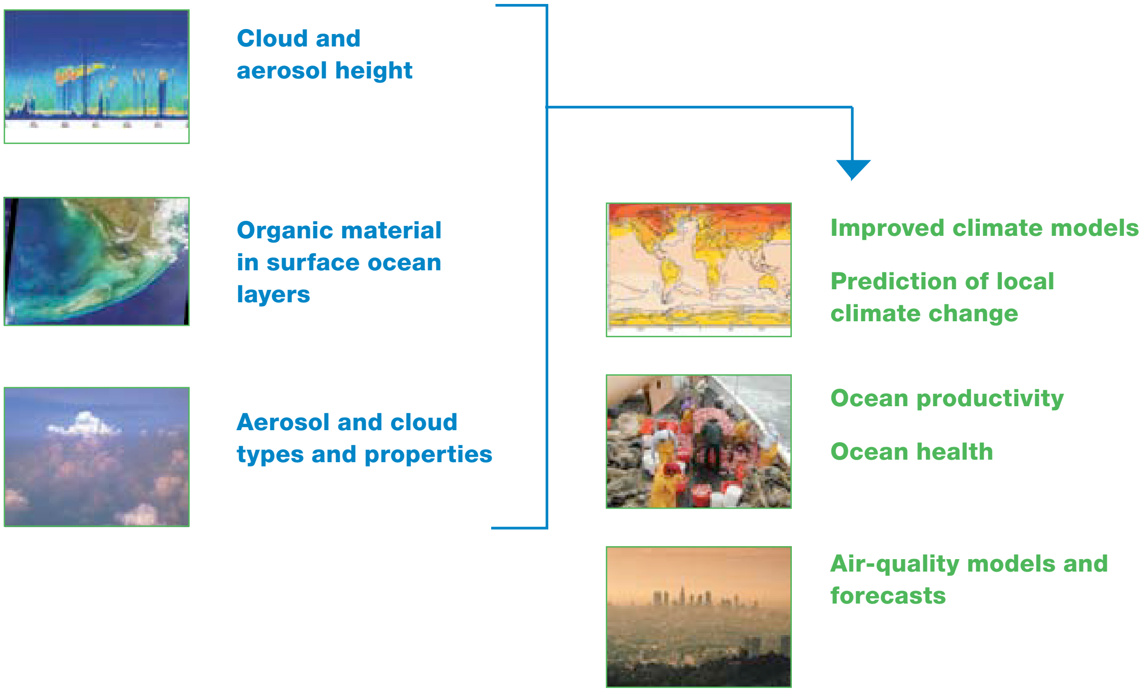
AEROSOL-CLOUD-ECOSYSTEMS (ACE)

Launch: 2013-2016 Mission Size: Large



AEROSOL-CLOUD-ECOSYSTEMS (ACE) MISSION

The primary goal of the Aerosol-Cloud-Ecosystems (ACE) mission is to reduce uncertainty about climate forcing in aerosol-cloud interactions and ocean ecosystem carbon dioxide (CO_2) uptake. Aerosol-cloud interaction is the largest uncertainty in current climate models. Aerosols can make clouds brighter and affect their formation. Aerosols can also affect cloud precipitation and have been linked to decreased rainfall in the Mediterranean. Results from the ACE mission would narrow the uncertainty in climate predictions and improve the capability of models to provide more precise predictions of local climate change, including changes in rainfall. ACE aerosol measurements could also be assimilated into air-quality models to improve air-quality forecasts. Ocean ecosystem measurements would provide information on uptake of CO_2 by phytoplankton and improve estimates of the ocean CO_2 sink. As CO_2 increases, the oceans will acidify, and this will affect the whole food chain, including coral-reef formation. The ACE mission could assess changes in the productivity of pelagic fishing zones and provide for early detection of harmful algal blooms. Benefits of the mission would include enabling the development of strategies for adaptation to climate change, evaluation of the consequences of increases in greenhouse gases, enabling of improved public health through early warning of pollution events, and evaluation of effects of climate change on ocean ecosystems and food production.

Background: The largest uncertainties in global climate change prediction involve the role of aerosols and clouds in Earth's radiation budget and the effect of aerosols on the hydrological cycle. Aerosol climate forcing is similar in magnitude to CO_2 forcing, but the uncertainty is five times larger—an assessment that has not changed from those in earlier Intergovernmental Panel on Climate Change reports. Among the reasons for the uncertainty are that aerosols have a short lifetime in the atmosphere and not all aerosols are alike. Aerosols also have a large effect on cloud formation (the indirect effect) and brightness, and this amplifies their importance in the climate system. Aerosols and the clouds they affect tend to increase reflected solar radiation. Aerosols have probably masked some of the temperature rise associated with global warming. Both the NASA A-Train mission set and the planned ESA EarthCARE mission will provide early information on this problem. ACE is expected to provide many more data and data of much higher quality than those predecessor missions. Higher-quality data are needed to reduce uncertainty about cloud-aerosol interaction among the various types of aerosols and thus improve climate prediction models. ACE aerosol measurements would be NASA's specific contribution to an overall integrated aerosol-measurement plan as envisioned in PARAGON (Diner et al., 2004). The need for an advanced aerosol-cloud mission has also been identified in a series of community workshops conducted by NASA during 2005 and 2006.

ACE would also be able to make next-generation pelagic ocean ecosystem measurements with the same set of instruments. The ocean is a rapid processor of carbon and poses a major uncertainty in global carbon flux. The estimated carbon uptake through the ocean ecosystem is about as large as the total uncertainty in the carbon budget, and recent estimates from O_2:N_2 flux ratios suggest that the current estimates may be much more uncertain than previously believed. Carbon uptake by the ocean is influenced by climate change through changes in wind stress and salinity that produce a concomitant response in zones of upwelling, mixed-layer depth, aeolian fertilization, marine ecosystems, and the export of carbon to marine depths.[2] Still uncertain is the global effect of ocean acidification as dissolved CO_2 content in ocean water continues to increase.

Science Objectives: The scientific goal of the ACE mission is to reduce the uncertainty in climate forcing through the two distinct processes described above. The first objective is to better constrain aerosol-cloud interaction by simultaneous measurement of aerosol and cloud properties with radar, lidar, a polarimeter, and a multiwavelength imager. This multi-instrument payload is needed because aerosols can either enhance or suppress cloud formation, depending on the aerosol type, and aerosol loading can reduce precipitation over continent-wide areas. Because aerosols can be transported over long distances, space-based assessment combined with ground-based measurement is the most scientifically sound and cost-effective approach to quantitatively estimating the effect of aerosols on clouds. The second objective is to estimate carbon uptake by ocean ecosystems through global measurements of organic material in the surface ocean layers. The oceans are an important sink for atmospheric CO_2 and are acidifying as a result of CO_2 uptake. Better estimation of the uptake of carbon and the change in the ocean food chain requires improved measurements of organic carbon with multispectral measurement of "ocean color." The ocean is a dark surface (except at the sun-glint), and aerosols that reflect solar radiation interfere with ocean-color measurement, so it is appropriate to measure aerosols simultaneously with ocean color. The two objectives of aerosol and ocean-color measurements are thus highly synergistic.

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[2] Salinity and temperature both affect the solubility of CO_2 in seawater and hence the carbon uptake.

Mission and Payload: To avoid the sun-glint but take maximal advantage of the reflected solar radiation, ACE would fly in a low-Earth, Sun-synchronous, early-afternoon orbit. The orbit altitude of 500-650 km will allow sufficient orbit lifetime but is close enough to the surface that active-sensor power requirements are not so high as to limit mission lifetime. The notional mission consists of four instruments: a multibeam cross-track dual-wavelength lidar for measurement of cloud and aerosol heights and layer thickness; a cross-track scanning cloud radar with channels at 94 GHz and possibly 34 GHz for measurement of cloud droplet size, glaciation height, and cloud height; a highly accurate multiangle, multiwavelength polarimeter that would measure cloud and aerosol properties, and that, unlike the aerosol polarimetry sensor on Glory, would have a cross-track and along-track swath with a pixel size of about 1 km; and a multiband cross-track visible-UV spectrometer with a pixel size of about 1 km, which would include Aqua MODIS, NPOESS Preparatory Project (NPP) VIIRS, and Aura OMI aerosol-retrieval bands and additional bands for ocean color and dissolved organic matter. Additional use of the lidar for canopy height should be studied.

The core aerosol sensors—the polarimeter and the lidar—provide data on aerosol properties and height. Additional information on aerosols comes from the UV channels of the multiband spectrometer. To determine effects on clouds, the cloud radar would measure droplet size, altitude of glaciation, and estimated total cloud water. The radar, lidar, and polarimeter are the primary cloud sensors; the polarimeter can also determine cloud droplet size. The primary ocean-color sensor is the multiband spectrometer, which has channels sensitive for chlorophyll absorption and dissolved organic matter. The UV bands in the spectrometer can also be used to determine aerosol type and allow for aerosol retrieval over bright surfaces. Aerosol information needed for ocean-color retrieval is derived from the polarimeter and lidar.

Mission Cost: About $800 million.

Schedule: All the instruments have some space heritage. Incremental technology development in lidar, radar, and polarimetry is needed to extend the capabilities for multibeam and cross-track measurements. Technology development is expected to support this mission by 2015-2016 or earlier.

Further Discussion: See in Chapter 9 the sections "Climate Mission 1: Clouds, Aerosols, and Ice Mission (with Proposed Carbon Cycle Augmentation)," "Trace Gases and Aerosols," and "Stratosphere-Troposphere Exchange (STE)"; in Chapter 10 the sections "A Cross-disciplinary Aerosol-Cloud Discovery Mission," "Comprehensive Tropospheric Aerosol Characterization Mission," and Table 10.2; and in Chapter 7 the section "Global Ocean Productivity Mission."

Related Responses to Committee's RFI: 7, 21, 45, 66, 81, 86, 88, 97, 102, and 110.

Reference:

Diner, D.J., T.P. Ackerman, T.L. Anderson, J. Bosenberg, A.J. Braverman, R.J. Charlson, W.D. Collins, R. Davies, B.N. Holben, C.A. Hostetler, R.A. Kahn, J.V. Martonchik, R.T. Menzies, M.A. Miller, J.A. Ogren, J.E. Penner, P.J. Rasch, S.E. Schwartz, J.H. Seinfeld, G.L. Stephens, O. Torres, L.D. Travis, B.A. Wielicki, and B. Yu. 2004. PARAGON: An integrated approach for characterizing aerosol climate impacts and environmental interactions. *Bull. Amer. Meteorol. Soc.* 85:1491-1501, doi:10.1175/BAMS-85-10-1491.