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Zernike moments as a useful tool for ACE imager temperature retrieval

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The Atmospheric Chemistry Experiment (ACE) was launched in August 2003 aboard the Canadian scientific satellite SCISAT-I, and is at present fully operational. ACE circles the Earth at an altitude of 650 km with an orbital inclination of 74˚. Solar occultation is the primary observation technique used by the onboard instruments, which consist of a high resolution Fourier Transform spectrometer (ACE-FTS), a dual optical spectrophotometer (MAESTRO), and two filtered imagers, subject of this presentation.

While the Sun is setting below or rising from behind the Earth's horizon, at every timestamp, the imagers capture a snapshot of the Sun as seen through the atmosphere. On these pictures, the apparent Sun width is about 25 km at the tangent point and the apparent Sun height varies from almost 0.7 km in the optically thick, lower troposphere were the Sun image is highly flattened by the refraction to its maximum (about 25 km at the tangent point) were refractive effects are negligible.

The refractive index of dry air is very close to unity. Its small variation as a function of temperature and pressure leads to a refractive index gradient in the atmosphere. Although this gradient is very small, atmospheric refraction can be observed due to the large distances traveled by the light in the atmosphere.

For a given temperature profile of an atmosphere, one can calculate the angular displacement between the true and apparent position of an object using ray tracing algorithms (the so-called forward problem). Solving the inverse problem is much more difficult but can lead to determination of aerological data from refraction data. In other words, the inverse problem deals with extracting temperature, pressure and humidity profiles from a series of distorted images of an object of known shape such as the Sun.

Used in image processing, image moments are certain particular weighted averages (moments) of the image pixels' intensities, or functions of those moments, usually chosen to have some attractive property or interpretation. The complex, orthogonal Zernike polynomials were first proposed in 1934 by Zernike. Their moment formulation appears to be one of the most popular, outperforming the alternetives in terms of noise resilience, information redundancy and reconstruction capability.

We will present temperature profiles retrieved from the distorted images of the setting/rising Sun as measured by the ACE imagers, using Zernike moments. These temperature profiles are validated with ACE FTS temperature profiles.