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ACTINOFORM CLOUDS OF THE SOUTH PACIFIC: SELF-ORGANIZATION IN THE MARINE BOUNDARY LAYER

Roger Davies
Jet Propulsion Laboratory, Pasadena, California
Michael J. Garay
Department of Atmospheric Sciences, University of California Los Angeles, California

1. INTRODUCTION*

Actinoform clouds are marine convective clouds having a radial pattern or structure (Agee, 1984). They are apparently associated with a larger class of shallow convective clouds known generally as mesoscale cellular (or shallow) convection (for a review see Atkinson and Zhang, 1996). More typical types are the "open" and "closed" hexagonal cells, with the former being clear in the center and cloudy at the cell edges, and the latter being cloudy in the center and clear at the edges. Such cells bear a striking resemblance to Rayleigh-Bénard convection produced in the laboratory.

The study of these types of clouds dates back to the beginning of the era of satellite meteorology. The first weather satellite, TIROS 1, was launched in 1960. Some of the earliest pictures sent back were of clouds showing cellular structure on a scale between 50 and 100 kilometers (Kreuger and Fritz, 1961). Such cloud patterns are too large to be perceived by observers on the ground, but too small to appear on synoptic weather maps. Actinoform clouds, which tend to resemble "leaves" or "spiders" (see figure) and larger systems of such clouds which resemble "millipedes," are much less common than either open or closed cells. These clouds were first reported by Hubert (1966) in imagery from the Nimbus-1 satellite.

Mesoscale cellular convection, in general, appears to be a phenomenon of the marine boundary layer. Agee *et al.* (1973) provide a climatology of the regions worldwide where open and closed cells tend to occur. Closed cells, in particular, appear preferentially in tropical or subtropical waters off the western coasts of continents. This also tends to be the regime of cold ocean currents. A typical example is off the coast of Peru in the South Pacific where the cold Peru or Humboldt Current flows away from the mainland.

* *Corresponding author address*: R. Davies, Jet Propulsion Laboratory, 4800 Oak Grove Drive, M/S 169-237, Pasadena, CA 91109-8099; email: roger@jord.jpl.nasa.gov.

Actinoform clouds have intriguing structures that are visually interesting examples of the self-organization possible in a convective fluid. These structures also act as indicators of air-sea interaction within the marine boundary layer. Detailed study of these clouds may help in the development of improved parameterizations of the albedo of marine boundary layer clouds for climate studies.

2. DATA

Using imagery from the Multiangle Spectroradiometer (MISR) onboard the Terra satellite, we have found examples of actinoform clouds in a number of regions around the world, including off the southeastern coast of Australia and off the western coast of equatorial Africa. However, these clouds appear most frequently over the westward extension of the Peruvian current in the tropical South Pacific. This location is particularly advantageous because, in addition to the data from MISR, we are able to observe the clouds using imagery from the GOES-West satellite located at 135^{o} W longitude. The MISR imagery provides high spatial (275 m) and calibrated radiometric resolution (Diner *et al*. 1998). The GOES imagery, although at a lower resolution (1 km visible, 4 km IR), provides temporal continuity and a broad perspective on the meteorological situation. Other useful information related to these clouds has been obtained from the SeaWinds instrument on the QuikSCAT satellite, the microwave imager on the Tropical Rainfall Measuring Mission (TRMM), and reanalysis data from the National Center for Environmental Prediction (NCEP).

Observed from space, the self-organization of some actinoform cloud systems is seen to extend over linear distances greater than 2000 km and cover an area greater than 1 million square kilometers. Individual, identifiable clouds within this larger system have scales on the order of 90,000 square kilometers and can easily be tracked for over 2 days on GOES IR imagery. The size and persistence of these features makes it remarkable that they have been so little studied.

3. RESULTS AND DISCUSSION

The earliest theory of actinoform clouds was due to Hubert (1966) who postulated that such clouds were a transitional form of cellular convection occurring between regions of closed and open cells. However, we find little evidence that actinoform clouds represent a transition zone between closed and open cell structures. In fact, they often occur entirely within a region of closed or open cellular convection.

Examination of the low level wind environment using scatterometer data from SeaWinds and cloud track winds from MISR shows that the self-organization which defines these clouds appears to be most prevalent in conditions of light wind. Cloud height information can be obtained from GOES 10 µm brightness temperatures and from MISR stereo retrievals. These data indicate that the clouds tend to occur one to two kilometers above the sea surface. However, high-resolution analysis of these clouds indicates that their microphysical structure can change systematically and significantly over distances of only a few kilometers.

We also use the satellite measurements to determine the albedo and cloud radiative forcing typical of actinoform clouds, and address the issue of parameterizing these findings in the context of climate modeling.

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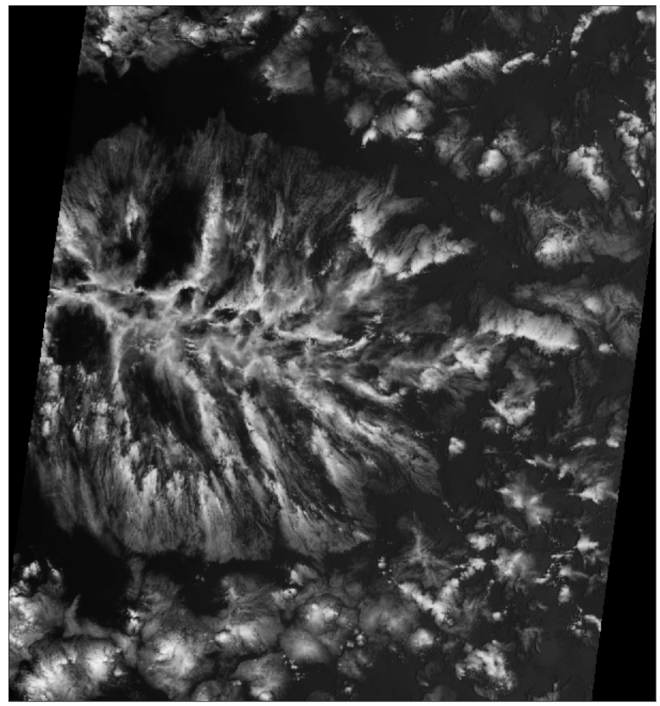

Fig. 1 Actinoform cloud over the South Pacific. MISR orbit 10184 on 16 November, 2001 at approximately 13°S 100°W. The swath width is approximately 350 km.