commentary and analysis

- Landsat-7 *Reveals More Than Just Surface Features in Remote Areas of the Globe*
- *Comments on "A Climatology of Derecho-Producing Mesoscale Convective Systems in the Central and Eastern United States, 1986–95. Part I: Temporal and Spatial Distribution"*
- *Reply*

Landsat-7 Reveals More Than Just Surface Features in Remote Areas of the Globe

The *Landsat-7* enhanced thematic mapper plus, ETM+ (Fig. 1), has been gathering information about the earth's surface since early June 1999. On 18 September 1999, while performing a routine quality check of *Landsat-7* ETM+ images being processed at the U.S. Geological Survey's Earth Resources Observation Systems (EROS) Data Center in Sioux Falls, South Dakota, an unusual pattern within some clouds was found and passed to the Science Department at EROS. The science department identified the feature as the classic, but rarely observed, fluid flow pattern known as a Kármán vortex street.

The Landsat image (Fig. 2) was taken off the Chilean coast near the Juan Fernandez Islands (also known as the Robinson Crusoe Islands) on 15 September 1999 (Fig. 3). The rectangular-shaped island in Fig. 3 is Alejandro Selkirk Island (33.75°S, 80.75°W). It is 6.44 km wide, 12.88 km long, at least 0.6 km above sea level throughout the island, and has a maximum peak of 1640 m above sea level. This area lies within the largest of four major regimes of marine stratocumulus clouds, which have a strong diurnal cycle with a nocturnal maximum of thickness and cloud fraction. They dominate the net cloud forcing, especially during summer months, and cause a net cooling of global surface temperature.

The island creates a system of vortices that stabilizes downwind of the object. The unsteadiness of the wind field, cross-island angle of the wind field, fluid characteristics, and topographical features of the island contribute to the alternating appearance of vortices. The vortices off the west (left) side of the island rotate clockwise, whereas those off its east (right) side rotate counterclockwise. Their centers are separated by some distance, l, along a given lane, and by a distance, h, along a perpendicular to each lane (Fig. 4). Von Kármán found that the ratio, h/l, had to be 0.281 in order for the vortex arrangement to be stable within flow past a cylinder (Yuan 1967). The equivalent value for h/l in Fig. 1 falls between 0.4 and 0.5.

We have a stratified atmosphere in which turbulent air (Reynolds number between 80 and 200) flowing past the rectangular Alejandro Selkirk Island creates a system of vortices. The vortices actually form in the separated region of the laminar boundary layer airflow. Locating the point of boundary layer

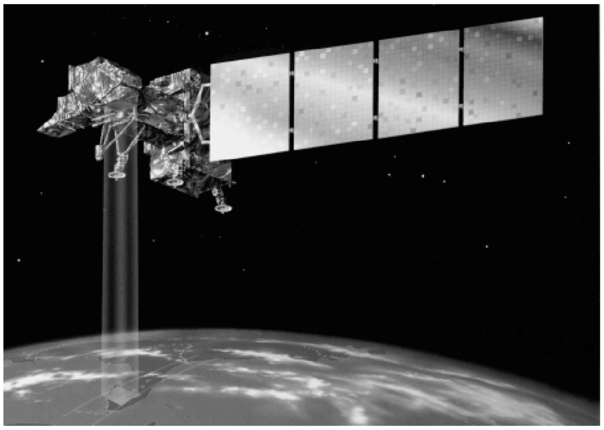

FIG. 1. Conceptualization of *Landsat-7* and its ETM+ instrument in orbit over Florida. *Landsat-7* is about 4.3 m long and 2.8 m in diameter. The ETM+ instrument is an eight-band multispectral scanning radiometer capable of providing high-resolution imaging information of the earth's surface. *Landsat-7* views a 183-km-wide swath when in its sun-synchronous orbit at an altitude of 705 km, a 98° inclination, a descending equatorial crossing time of 1000 LT, and a 16-day repeat cycle. Each scene along its swath is 183 km wide by 170 km long and contains approximately 3.8 GB of data. Nominal ground sample distances, or pixel sizes, are 15 m in the panchromatic band (0.5–0.9 μm); 30 m in the six visible (0.45–0.52, 0.53–0.61, 0.63–0.69 μm), near (0.78–0.90 μm), and shortwave (1.57–1.78, 2.10–2.35 μm) infrared bands; and 60 m in the thermal infrared band (10.5–12.5 μm). The bandwidths provided are half-amplitude bandwidths. (Courtesy of NASA and obtained through EROS Data Center, U. S. Geological Survey.)

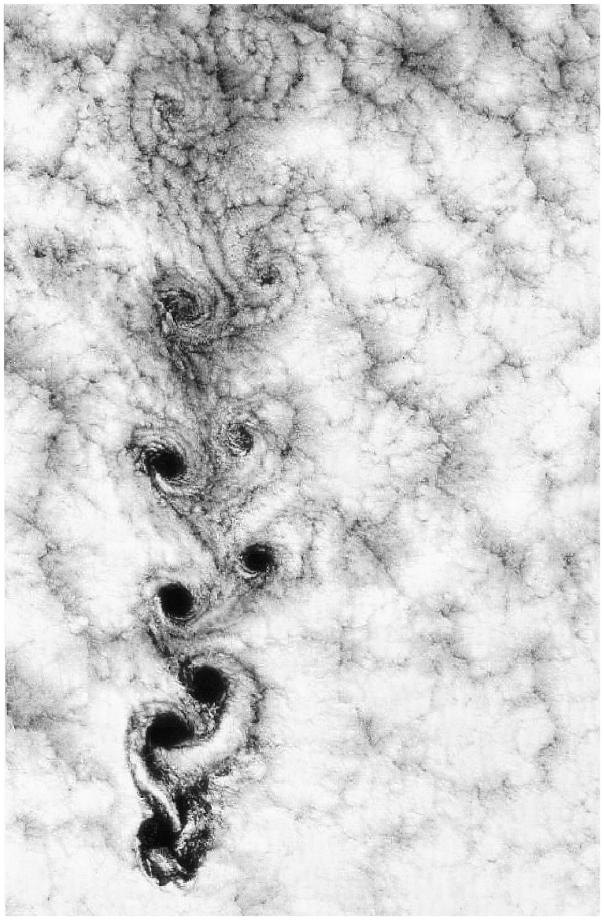

FIG. 2. The origin of the featured fluid flow appears to be Alejandro Selkirk Island of the Juan Fernandez Islands (33.75°S, 80.75°W), known as the Robinson Crusoe Islands. Alejandro Selkirk Island (i.e., the object), whose highest peak is approximately 1640 m above sea level, is approximately 6.44 km wide, 12.88 km long, and at least 0.6 km above sea level throughout the island. (Courtesy of the Satellite Systems Branch, U.S. Geological Survey, EROS Data Center, Sioux Falls, SD.)

FIG. 3. A map of this region.

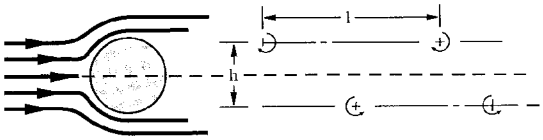

FIG. 4. A schematic showing the system of vortices known as the Kármán vortex street. Adapted from Yuan (1967).

separation requires knowledge of the pressure and free-stream velocity distributions in the vicinity of this island. The areas within the vortex centers are generally clear because the rotating motions induce a vertical wind component whose strength increases with the speed of the rotating air. The direction of the vertical air motions induced by vortices can be determined by using the left-hand rule since we are in the Southern Hemisphere. Thus, a counterclockwise rotation induces a subsiding motion, whereas a clockwise rotation induces a rising motion. The vortices with induced rising air motions appear cloud free because the latent heat released from the cloud droplets that initially form becomes concentrated in the centermost part of these vortices and is enough to evaporate the clouds. As the vortices propagate downstream, their rotational velocities weaken, causing the vorticity centers to fill.

There is a plan to further investigate the physics of the fluid within this image, and these results will be forthcoming. We also wish to note that Kármán vortex streets have been observed on meteorological satellite imagery, for example, around Socorro Island (eastern Pacific off Mexican coast) by R. Fett in the Naval Tactical Application Guide. Space shuttle astronauts have even observed Kármán vortex streets.

Acknowledgments. I would like to provide special thanks to the following for their particular contributions to this piece: Jon Christopherson for finding the image; Ron Hayes for locating the island characteristics; Jay Feuquay and the USGS for allowing us to use the *Landsat-7* image; NASA/USGS press kit (April 1999); Ron Morfitt for reviewing parts of this manuscript; the two anonymous reviewers who provided constructive and inspirational reviews; and Professor John Lewis for encouraging this publication.

References

Yuan, S. W., 1967: *Foundations of Fluid Mechanics.* Prentice Hall, 608 pp.

T. P. DeFelice, D. J. Meyer, and G. Xian
Raytheon, Science Department
Science and Applications Branch, EROS Data Center
Sioux Falls, South Dakota

J. Christopherson
Raytheon, Satellite Systems Engineering and
Development Department
Satellite Systems Branch, EROS Data Center
Sioux Falls, South Dakota

R. Cahalan
NASA/Goddard Space Flight Center
Laboratory for Atmospheres
Greenbelt, Maryland

Comments on "A Climatology of Derecho-Producing Mesoscale Convective Systems in the Central and Eastern United States, 1986–95. Part I: Temporal and Spatial Distribution"

In a 1987 paper, Johns and Hirt (1987, hereafter JH87) defined the derecho phenomenon in contemporary terms and systematically identified cases occurring during the months of May through August in the 4-yr period 1980–83. Although this work suggests a warm-season high-frequency axis exists from the upper Mississippi Valley into the mid-Atlantic states, it could not be considered a climatological distribution for warm-season derechos since only 4 yr of data were included in the study. In the paper discussed here, Bentley and Mote (1998, hereafter BM98) have systematically screened data from all seasons for the 10-yr period 1986–95 to develop a climatology of derecho-producing convective systems. They have found several features that add to our knowledge of derecho frequency distribution. Besides finding the high-frequency axis as had been suggested by JH87, they found an area of higher frequency across the central and southern plains, as well as a winter/spring high-frequency axis from eastern Texas into the Carolinas. They further noted that many of the warm-season cases in the central and southern plains appear to have strong southerly components of propagation resembling "southward bursts" as defined by Porter et al. (1955).

We agree with these general findings. However, we take issue with the distribution of frequency values, particularly those displayed for the warm-season cases (their Figs. 1b and 4). BM98's maximum frequency for derecho-producing mesoscale convective systems (MCSs) (hereafter identified as DMCSs) during the warm season resides in central–northeastern Oklahoma. Further, the BM98 results suggest that during the warm season a point in central–northeastern Oklahoma is 4–5 times more likely to experience a derecho than are most locations in the upper Mississippi Valley region. While higher frequencies might be expected in the central and southern plains region than what JH87's study suggested, the extreme frequency differences displayed in this study appear inconsistent based on operational experience.

BM98 have reasoned that the differences in warm-season frequency patterns between JH87's study and their own findings (Fig. 1) are the result of an anomalous midlevel flow pattern during the short period used for JH87's study. We believe that this effect may explain some of the differences, but not to the extreme displayed in Fig. 1. The month of July has the highest frequency of derecho occurrence nationwide in BM98's study and is close to having the highest frequency in JH87's study. However, the average 500-mb flow pattern for July (both for a 20-yr period in general and for the anomalous year of 1980; their Figs. 2b and 2d, respectively) shows a ridge axis extending generally east–west across the southern plains. This pattern suggests that midlevel flow strong enough to maintain vigorous, rapidly moving, and long-lived bow echoes over Oklahoma would be very infrequent during July. Therefore, BM98's pronounced warm-season frequency maximum over Oklahoma is difficult to explain given typical warm-season flow patterns.

We believe there are several nonmeteorological factors that are likely affecting BM98's results for