VIIRS CAPTURES AURORA MOTIONS

BY CURTIS J. SEAMAN AND STEVEN D. MILLER

Auroras are the visible manifestation of interactions between the atmospheres of the Sun and the Earth. Massive amounts of high-energy hydrogen and helium atoms, spewed from the solar atmosphere during coronal mass ejections and solar flares, reach Earth several days later. When these particles reach Earth's magnetosphere, they accelerate and channel down along magnetic field lines toward the poles. When they reach the upper atmosphere (100–400-km altitude), they collide with oxygen and nitrogen molecules. The excited-state molecules release a spectrum of visible light that appears as rapidly fluctuating sheets and curtains of light that is visible at night from the surface. The correlation between strong auroral activity and geomagnetic storms makes them harbingers for possible problems with electrical power grids, surface-based radio communications, low-orbiting satellites, and increased radiation exposure at commercial aircraft altitudes (e.g., www.swpc.noaa.gov/info/RadHaz.html).

The Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the *Suomi National Polar-Orbiting Partnership* (*NPP*) satellite contains the day/night band, an imaging radiometer that is capable of detecting extremely low amounts of visible wavelength light at night. The day/night band's 500–900-nm response allows it to observe the details of auroras at both poles. This bandwidth captures the primary emission lines of atomic oxygen (557.7 and 630 nm) as well as molecular nitrogen emission lines in the 600–700-nm range that are observed in auroras.

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DOI:10.1175/BAMS-D-12-00221.1

The day/night band has captured images of auroras during a new moon (Fig. 1) and near-full moon (Fig. 2). Both of these auroras occurred near the coast of Antarctica, as shown in Figs. 1a and 2a. The images of Fig. 1 were acquired at approximately 1856 UTC on 15 September 2012. This aurora was associated with "low" geomagnetic activity as given by the planetary "Kennziffer" geomagnetic index (K*p*) scale, with a K*p* value of 2 (see, e.g., www.gi.alaska.edu/AuroraForecast). The images of Fig. 2 were captured at approximately 0022 UTC on 1 October 2012. This aurora was associated with higher geomagnetic activity (K*p* = 4) caused by a coronal mass ejection observed on 27 September 2012 (see www.swpc.noaa.gov/WhatsNew.html). Upon close inspection, it appears that these images contain information about the motion of the aurora.

The day/night band senses the Earth via a constantly rotating mirror which directs reflected/emitted light onto a charge-coupled device (CCD) array of detectors. These detectors are aggregated into a set of 16 pixels, oriented in the along-track direction. The sensor scans in a direction perpendicular to the flight path (cross-track), and each scan produces a strip of imagery that is approximately 3,040 km in the cross-track and 12 km in the along-track dimensions. One rotation of the mirror comprises a full scan. A series of 64 scan-angle-dependent "aggregation modes" preserves 742 m × 742 m pixel resolution across the entire scan. Each Earth scan is about 0.56 s long, and it takes about 1.79 s for the mirror to complete a rotation from one scan to the next. For most natural phenomena sensed by the day/night band, motion during this time interval is negligible, and the edges of features spanning multiple scan lines appear continuous, as if viewed instantaneously. Such is not always the case for rapidly fluctuating auroral boundaries.

The "saw tooth pattern" discontinuities that are most apparent in Figs. 1b and 2c are caused by the cross-track relative motion of the aurora, resulting in a shift in its position between adjacent scans. These same shifts were not observed in the surface or meteorological cloud fields (Fig. 2b). The auroras in both

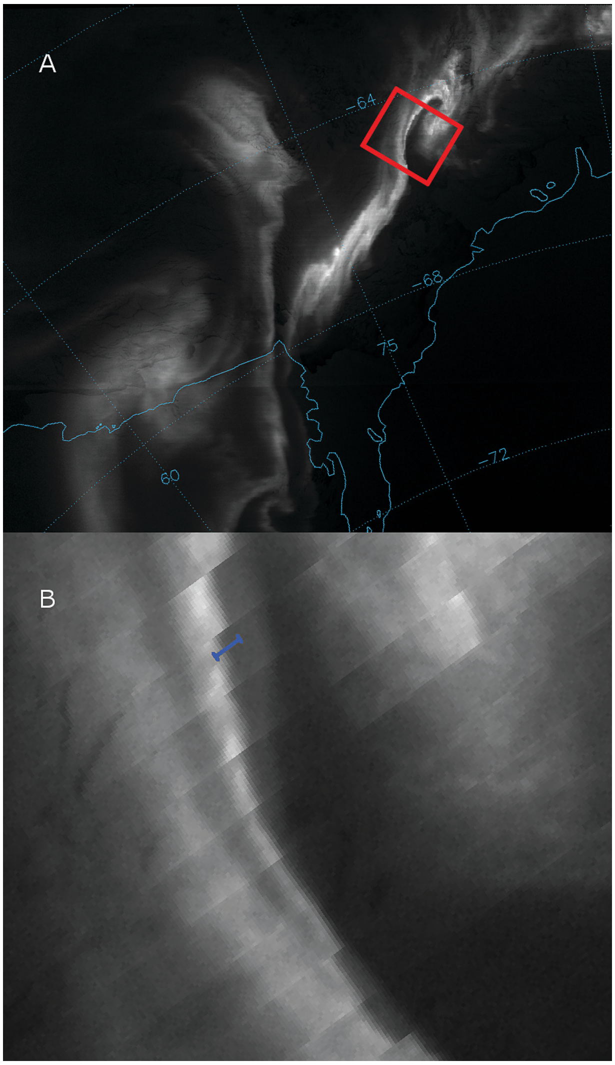

Fig. 1. VIIRS day/night band images of the aurora australis off the coast of Antarctica, taken 1856 UTC 15 Sep 2012. (a) Broad view with latitude and longitude lines plotted and (b) zoomed in on the box highlighted in (a). The area of the inset (b) as indicated by the red box in (a) is 114 km x 134 km. The blue bar in (b) represents a length of 6 km.

examples occurred near the center of the scan swath (near satellite nadir) where "bow-tie" effects are negligible. The shift in auroral boundary position from one scan to the next in these images is up to 10 pixels, corresponding to a cross-track relative speed of up to 4.2 km s^{-1}. The observed shifts in the position of the aurora in Fig. 1b are typically 3–5 pixels (1.3–2.1 km s^{-1}), while the aurora in Fig. 2c moved 5–8 pixels between scans (2.1–3.3 km s^{-1}). These speeds are consistent with previous surface-based observations of aurora motions, which usually fall in the range from 0–3 km s^{-1}. Auroral curls have been observed to move at speeds of up to 90 km s^{-1}.

These auroral motions are related to fluctuations in the Earth's magnetic field resulting from geomagnetic storms, and are evidence of the morphology of so-called "auroral substorms." These magnetic fluctuations may cause surges in the electric power grid, which may lead to power outages. Induced electrical currents caused by these fluctuations may lead to corrosion in metallic oil and gas pipelines (see, e.g., http://aurora.fmi.fi/gic_service/english). The significance of sudden changes in aurora boundary may provide useful instantaneous information about the magnetospheric state.

The day/night band provides information on these fluctuations for the first time from nighttime visible-wavelength satellite imagery. Prior to the launch of VIIRS aboard the *Suomi NPP* satellite, visible imagery of aurora was possible from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS), which typically only characterizes the motion of the aurora between orbits (a period of 101 min). This is due primarily to differences between how the day/night band and OLS image the scene. The day/night band's multiline CCD scan (16 lines at a time), and associated 1.79-s delay between adjacent scans, provides sufficient time for fast-moving auroral features to exhibit significant spatial shifts, whereas the OLS single-line scans and relatively short ~0.42-s delay between adjacent scans reduce this time window. In addition, the large, overlapping instantaneous fields of view (IFOV) of the OLS results in coarse spatial resolution of 2.2–5.4 km, which results in a blurring of auroral features and precludes easy inference of motion.

The constant horizontal resolution along the scan in the day/night band, which is significantly greater than the OLS, provides a unique opportunity to observe relatively small-scale, rapid motions of the aurora that have never before been captured by a meteorological satellite.

FOR FURTHER READING

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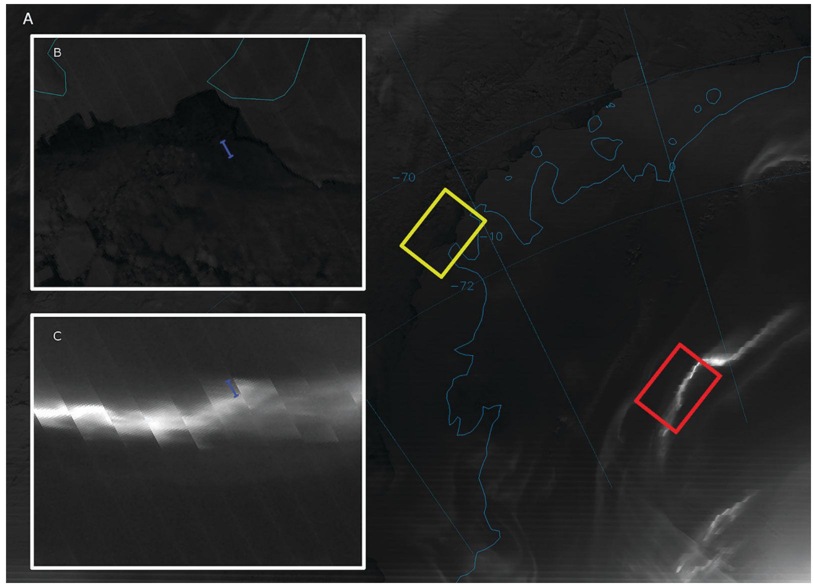

Fig. 2. VIIRS day/night band images of the aurora australis over Antarctica, taken 0022 UTC 1 Oct 2012. (a) Broad view with latitude and longitude lines plotted. (b) Zoomed in on the yellow box highlighted in (a), focused on icebergs visible in the moonlight. (c) Zoomed in on the red box highlighted in (a), focused on an element of the aurora. The area of both insets (b and c) is 93 km x 122 km. The blue bars in (b) and (c) represent a length of 6 km.