SPACE SHUTTLE DISCOVERY LAUNCH PLUME AS SEEN FROM GOES-8 IR

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Abstract

The night launch of the Space Shuttle Discovery on 3 February 1995 was the first time that high resolution IR imagery from the Geosynchronous Orbiting Environmental Satellite 8 (GOES-8) was used in Shuttle weather forecasting by the National Weather Service Spaceflight Meteorology Group. The improved resolution over GOES-7 imagery was evident by viewing of the launch exhaust plume in the GOES-8 longwave IR (10.7 μm) channel, noticeable before only in the 1 km visible imagery. The Shuttle was launched into a high inclination orbit (51.6° inclination from the equator), hence the ground footprint of the launch trajectory was northeastward from the Kennedy Space Center, Florida. One IR image captured the launch plume before dissipation by strong winds aloft.

1. Observations

Visible satellite imagery routinely reveal the plumes associated with Space Shuttle launches during daylight hours. Detecting plumes during night launches is more difficult, due to the lower resolution of the IR channels as compared to 1km visible imagery. There is now a higher likelihood of detecting a Shuttle launch plume at night since the GOES-8 (the first of the next generation GOES I-M satellites) longwave IR imagery has about 2.3 times improvement in resolution at the satellite subpoint over GOES-7 longwave IR (Purdom 1994).

Space Shuttle *Discovery* was launched as STS-63 at 0522 UTC 3 February 1995 from the Kennedy Space Center, Florida. Images from GOES-8 were available to the Spaceflight Meteorology Group (SMG) for launch support in a quasi-operational mode for the first time on this night. Figure 1 shows *Discovery's* launch exhaust plume as viewed by the GOES-8 longwave IR channel, shortly after launch. The satellite began scanning at 0532 UTC so the actual scan in the Florida area would have been at approximately 0537 UTC (about 15 minutes after launch). Movie loops of satellite imagery showed that no clouds were present in the suspected plume area prior to the time of Fig. 1. Special rapid-scan operating modes for both GOES-7 and GOES-8 have been developed and implemented for Space Shuttle launch and landing support, but were not yet available for GOES-8 this night. Experience has shown that the launch plume typically lasts twenty minutes or less, but in rare instances remnants of the plume have been observed in visible satellite imagery for up to ninety minutes after launch.

Figure 2 is a zoom of Fig. 1 with geographical boundaries and a legend for the temperature gray scale located near the bottom of the image. The ground footprint of the nominal ascent trajectory from the surface to 160,000 ft Above Ground Level (AGL) for this launch of *Discovery* is overlaid upon Fig. 2. The midpoint of the trajectory is approximately 30,000 ft AGL. The TA enhancement curve (Clark 1983) for IR imagery developed by NOAA's National Environmental Satellite, Data and Information Service (NESDIS) has been applied to both figures (brightness/temperature values for the plume have been converted to white on Fig. 2 for photographic clarity). The warmer portion of the TA curve was developed to improve land/water/low cloud top contrast. Experimentation at SMG showed that this was the best of the NESDIS standard enhancements to display the launch plume and to inspect for low clouds. Radiance temperatures along the length of the plume ranged from 285.7° K to 286.8° K (12.5° C to 13.6° C) from west to east. This falls in the large linear stretch region of the TA curve between 302.5° K to 273.5° K.

Exhaust gases from the Shuttle main engines and the solid rocket motors are quite hot. Satellite measured radiance temperatures were, therefore, much lower than one would expect. Two possible explanations for this are: 1) averaging over the sampling volume and 2) rapid mixing with the surrounding cool air. The vertical dimension of the plume is long, but the horizontal dimension is estimated to be less than the satellite imagery resolution. As mentioned above, the launch plumes usually dissipate after only a few minutes. Inspection of the data from the rawinsonde (Fig. 3) released at 0451 UTC shows that the atmosphere was relatively dry through a considerable depth of the troposphere. Winds off the surface increased to near 130 knots at 262 mb. Strong dry winds through much of the troposphere should aid mixing by stretching and deforming the plume quite rapidly.

2. Discussion

Improved resolution IR satellite imagery from the new generation of geosynchronous meteorological satellites has brought many new opportunities to measure and observe the atmosphere. One example has been the viewing of a Space Shuttle launch plume for the first time at night. Space Shuttle weather support often depends on precise observation and forecasting of cloud formation, motion, and dissipation. Nighttime detection of clouds, especially low clouds, has proven difficult at times because of the lower resolution of IR imagery compared to visible imagery and the sometime small differences between low cloud top radiance temperature versus the ground temperature. In the GOES-7 era, SMG forecasters could improve cloud and fog detection at night by using the polar orbiting satellites to observe low clouds. However, this depended upon the coincidence of polar-orbiting satellite data being available in real time over the central Florida area near Shuttle launch and landing times. The GOES-8 and GOES-9 satellites will provide continuous coverage of central Florida with high resolution IR imagery. Use of the short wave IR channel (3.7 μm) and multispectral differencing of images will lead to more improvement in forecasting low clouds and fog.

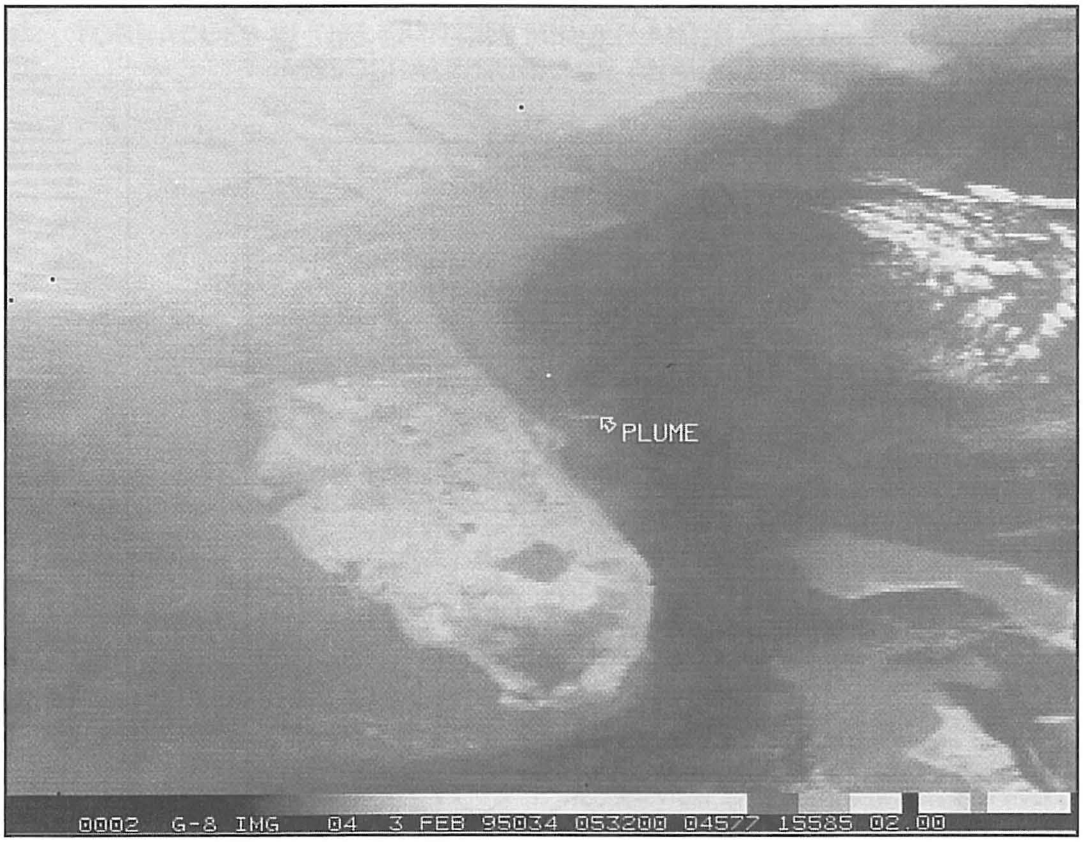

Fig. 1. GOES-8 IR image of Florida beginning 0532 UTC 3 February 1995.

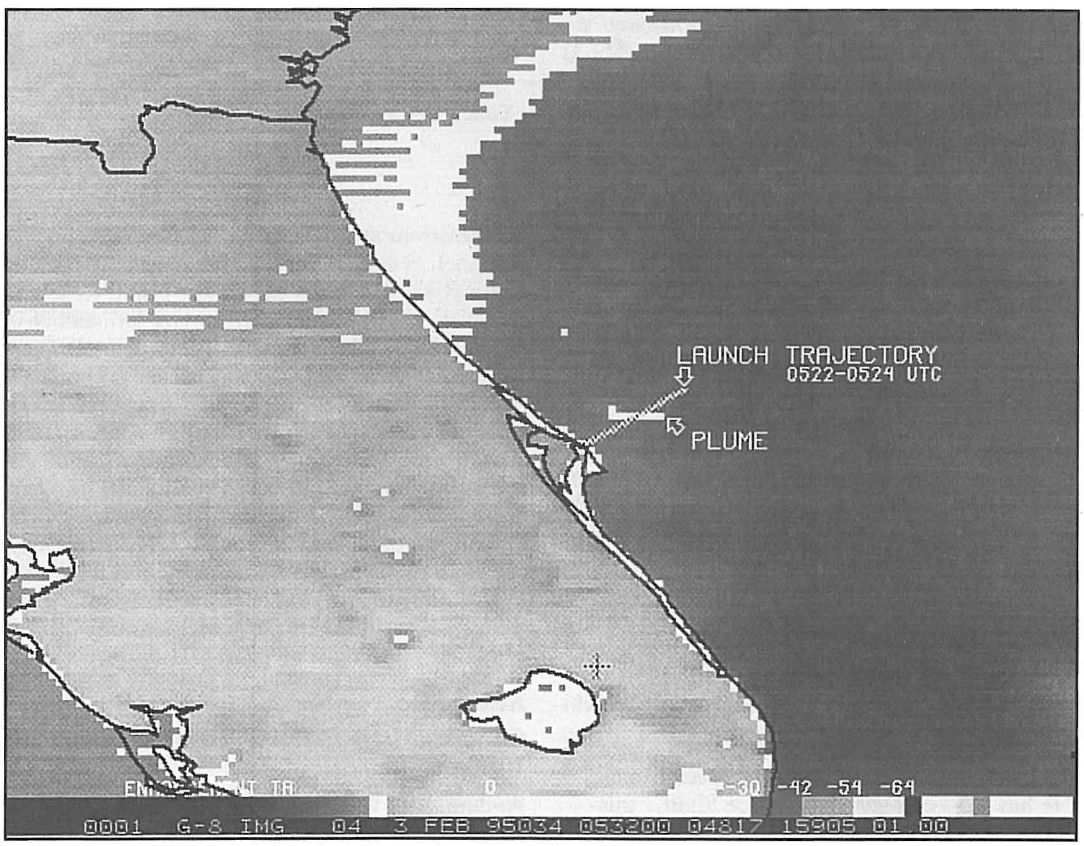

Fig. 2. Kennedy Space Center area (2x zoom of Fig. 1).

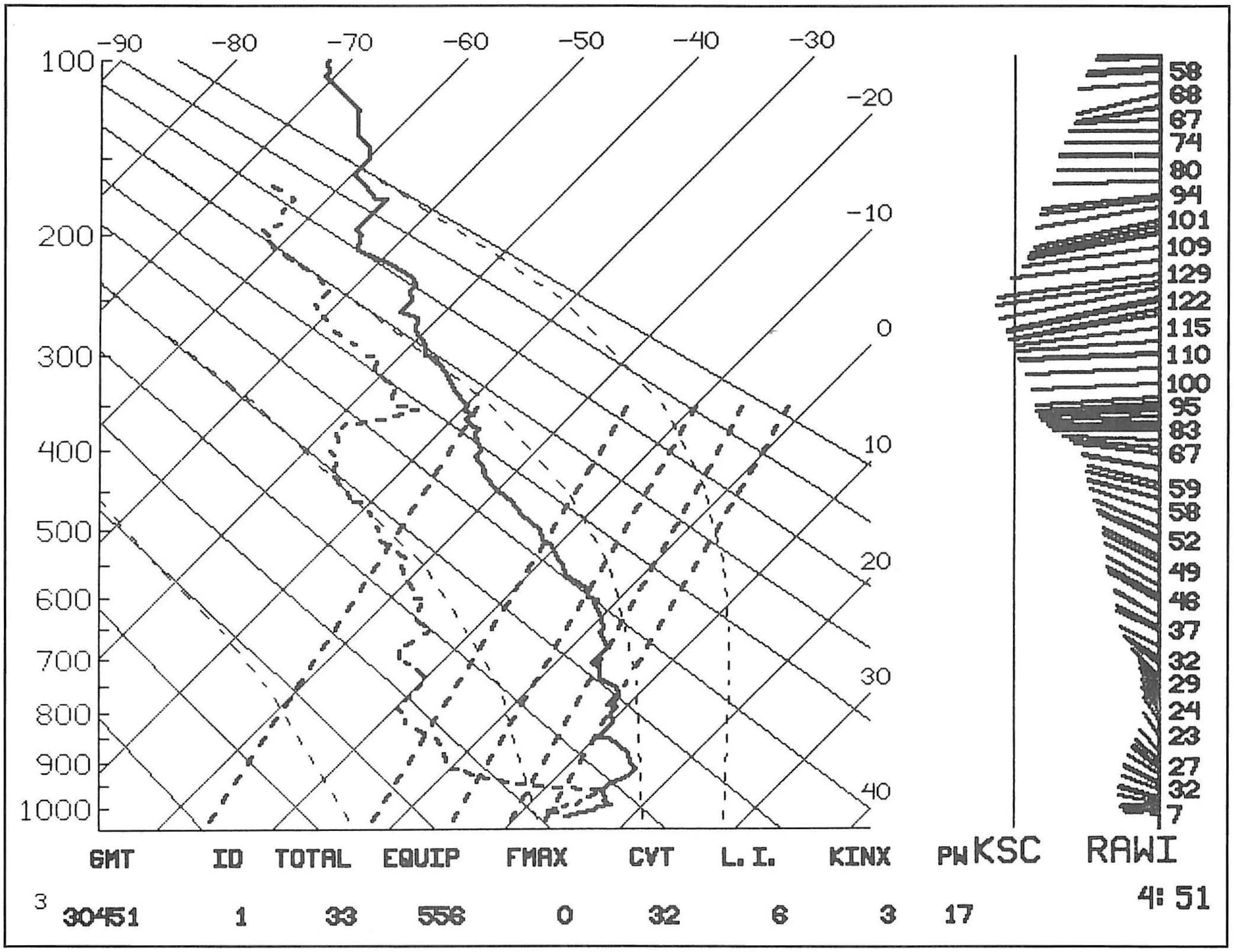

Fig. 3. Skew T-log p diagram of 0451 UTC 3 February 1995 Kennedy Space Center rawinsonde.

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Frank C. Brody has been the Chief of the Spaceflight Meteorology Group since 1991. Under Frank's leadership, SMG has received a NOAA Unit Citation, a NASA Manned Space Flight Awareness Award, and a NWS Modernization Award. Previous to SMG he worked at NWS National Headquarters, National Meteorological Center, and at NWS Forecast Offices in Raleigh, Charleston, and Washington DC. He is a charter member of the National Weather Association and a NWA Councilor. He is also a member of the NWA Atmospheric Technology Committee. He received his BS in Meteorology from The Pennsylvania State University in 1977.

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