Weather Radar for use In Space Launch Operations

Background

Weather radar data can be a valuable resource to detect, analyze, and record atmospheric phenomena in support of Space Launch Operations. Weather radar is the primary tool for nowcasting the atmospheric conditions required to ensure the safety of the ground personnel, the local populace, and high-value equipment both during launch and ground movement phases of operation. Weather radar data is also highly useful to analyze flight performance following launch operations.

SIGMET's Interactive Radar Information System (IRIS) software package provides several products to analyze local lightning potential; detect, locate and track precipitation and verify the low-level windfield – the primary environmental concerns to launch operations. SIGMET has experience with several sites using RVP8/RCP8 hardware and IRIS to support Space Launch Operations. These include locations in Florida, Virginia, Wake Island, The Republic of the Marshall Islands, and a mobile sea-borne launch platform. The following sections will describe IRIS products used to evaluate these environmental concerns.

Lightning Potential

Radar data can be used alone or with field mill and lightning detection networks to evaluate local lightning potential and track the movement and strength of lightning producing storms. For natural lightning a separation of charge must occur to the point where the electric potential field is strong enough to discharge without much outside influence. However, triggered lightning can be caused by an object moving at high rates of speed through the atmosphere when the electric potential is too low for natural lightning to occur. Charge separation is thought to be achieved by strong updrafts within convective storms by lifting graupel, which becomes positively charged above the freezing level, to high altitudes while smaller negatively charged particles collect near the base of a cloud. Radar can be used to evaluate if the conditions have been met to produce an electric potential field.

One method of evaluating the electric potential with radar is to identify high reflectivity (dBZ) values above a certain altitude. This criterion could indicate graupel has exceeded the altitude needed to produce a electrical potential field. Several research studies have been conducted to identify values for such a criterion. The results from these studies are usually also dependant on time of year, latitude, oceanic vs. continental, etc. An example of one such criterion from a study conducted near the equator concludes that when 30 dBZ exceeds 30,000 ft for a period of 10 minutes, enough separation of charge has occurred to produce natural lightning. This criterion gives warning of a potentially electrified storm before the first lightning strike.

Evaluating the triggered lightning threat can use some form of this criterion. Field mills that measure the electric potential through a column of air used in conjunction with radar provides a much better solution. The Kennedy Space Center uses more than 30 criteria to determine the triggered lightning threat using radar and other data sources.

The IRIS TOPS product provides an ideal solution to detect the occurrence of a specific reflectivity value above a certain altitude. The TOPS product can be configured to show the highest altitude of any reflectivity value, 30dBZ, 27dBZ, 6dBZ, etc. So using the 30/30 criteria a TOP product has been designed to show the altitudes of the highest 30dBZ contour in the example images (Figure 1).

An IRIS WARN product can be used to give an operator an audible and pop-up window warning message when a condition occurs that breaks the lightning criterion. For instance, launch criteria specify that no lightning or potential lightning must exist within 20 km from the launch site. A WARN product could then configured to give notice to the operator when 30dBZ echos are identified above 30,000 feet within 20 km of the protected launch site indicating storm that has potentially become electrified. All other storms that exceed the 30/30 criteria outside the 20km will not produce an audible or pop-up window warning but will still appear in the IRIS display (Figure 2).

A TRACK product could also be configure to calculate the speed and direction of storms that exceed 30/30 criteria. A warning to the operator can also be given when a storms current trajectory will move it through the protected area within a given amount of time (Figure 3).

The 30/30 criterion used in the example above implies the existence of graupel above a certain altitude. If a weather radar has dual-polarization capabilities, algorithms exist to explicitly identify particles within a sample volume. Explicit graupel detection would lower the false alarm rate while maintaining the same amount of protection to personnel and assets. IRIS WARN and TRACK products can also be configured to give pop-up and audible alerts using the same method above.

The newest feature within the IRIS software package is an integrated lightning/radar display (Figure 4). The lightning data is ingested and displayed in real-time. A typical radar product updates about every 5-10 minutes due to the length of time needed to complete a volume scan. The integrated real-time display feature of the lightning data gives an operator better situational awareness to current conditions.

An existing lightning detection network is all that is needed to work within IRIS. Different characteristics of the lightning data may be displayed within IRIS, including polarity, estimated peak current, and cloud-cloud vs. cloud-ground information.

Precipitation

Precipitation location and intensity can be an important factor during launch operations. Ground-based communications and tracking stations may lose contact with the launch vehicle during periods of heavy rain either on top of the site or in the sector between the ground site and launch vehicle. Some launch vehicles may also have criteria to prevent a flight through precipitation. The IRIS TRACK and forecasting tools will enable an operator to predict when the launch site and support facilities will be clear of precipitation.

In addition to the IRIS TRACK and WARN products, the locations of ground-based assets and precipitation-free sectors can be added to the map overlay. This makes it easy for operators to monitor these areas and determine if precipitation is violating a launch criterion.

Low-Level Winds

Many launch vehicles have a maximum horizontal wind criterion to prevent launches during unsafe wind conditions. High winds can also be a factor in ground operations such as moving a launch vehicle or emplacing it into a silo. Launch sites usually have an array of anemometers to measure the local wind conditions. A Doppler weather radar's radial velocity data can cover a larger area and give earlier warning for impending winds gusts. The radial velocity data can be also used along with radiosonde data for post-flight analysis of the launch trajectory.

Summary

A weather radar plays a vital role in supporting Space Launch Operations and as well as ground movements of launch vehicles. Radar is the primary tool to assess if atmospheric conditions will allow the safe handling of potentially explosive material ensuring the safety of personnel and high-value assets.

SIGMET has installed signal and radar control processors and IRIS on weather radars located with five space launch facilities and has good relations with the meteorologists and operators at these sites. SIGMET has a meteorologist on staff whose background includes using the RVP8 and IRIS as tools in support of Space Launch Operations. This experience should give the Brazilian Space Center the confidence to work closely with ATMOS and SIGMET to install and configure a weather radar in support of the Brazilian Space Center operations.

References:

Walter A. Petersen, Steven A. Rutledge and Richard E. Orville. 1996: **Cloud-to-Ground Lightning Observations from TOGA COARE: Selected Results and Lightning Location Algorithms.** *Monthly*

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Charlotte A. DeMott and Steven A. Rutledge. 1998: **The Vertical Structure of TOGA COARE Convection. Part I: Radar Echo Distributions.** *Journal of the Atmospheric Sciences*: Vol. 55, No. 17, pp. 2730–2747

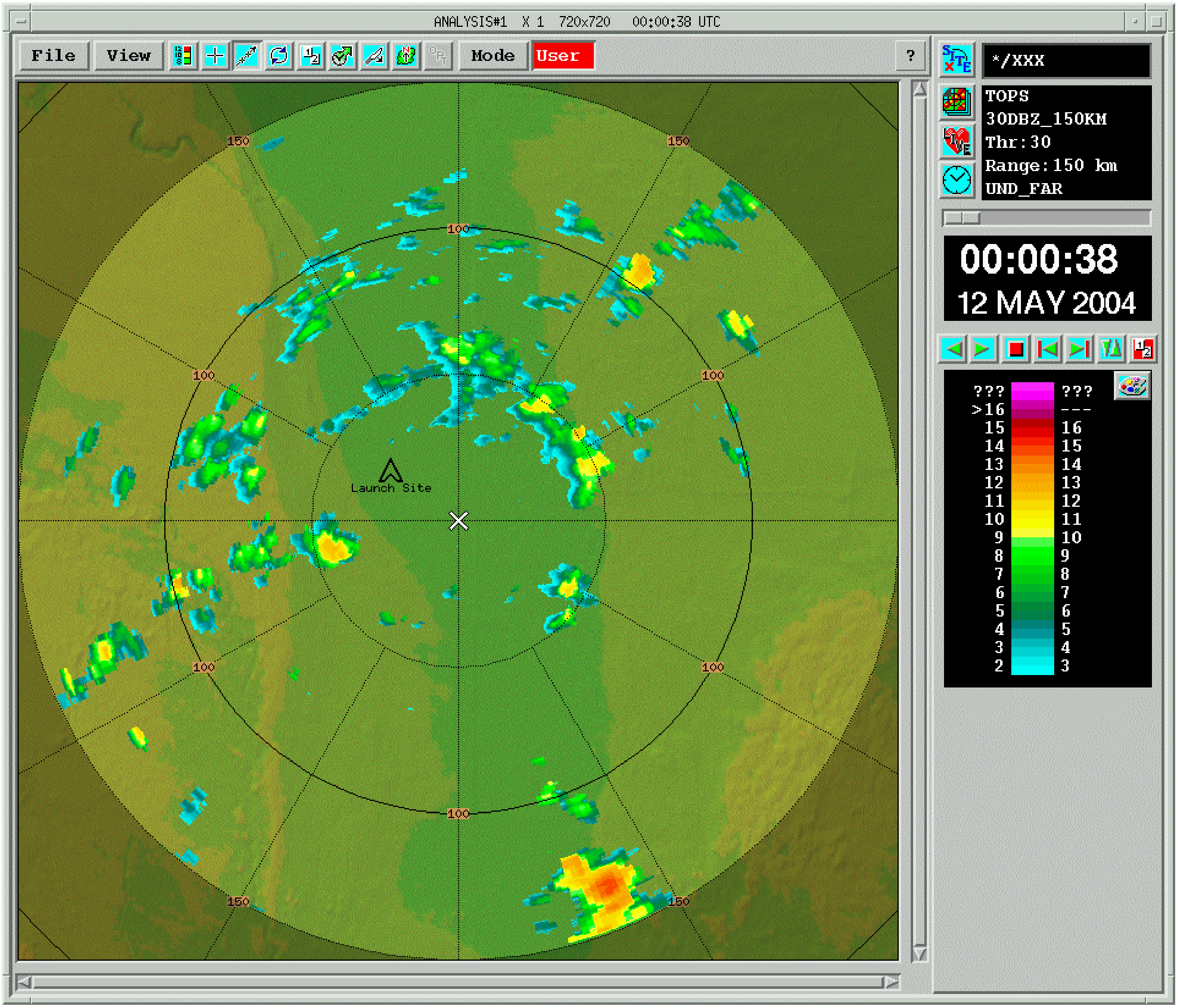

Figure 1: Iris TOPS product showing maximum height of 30 dBZ contour in the column at each pixel. The 30dBZ contour may be used to imply graupel exists above a certain altitude indicating the electric potential field is building.

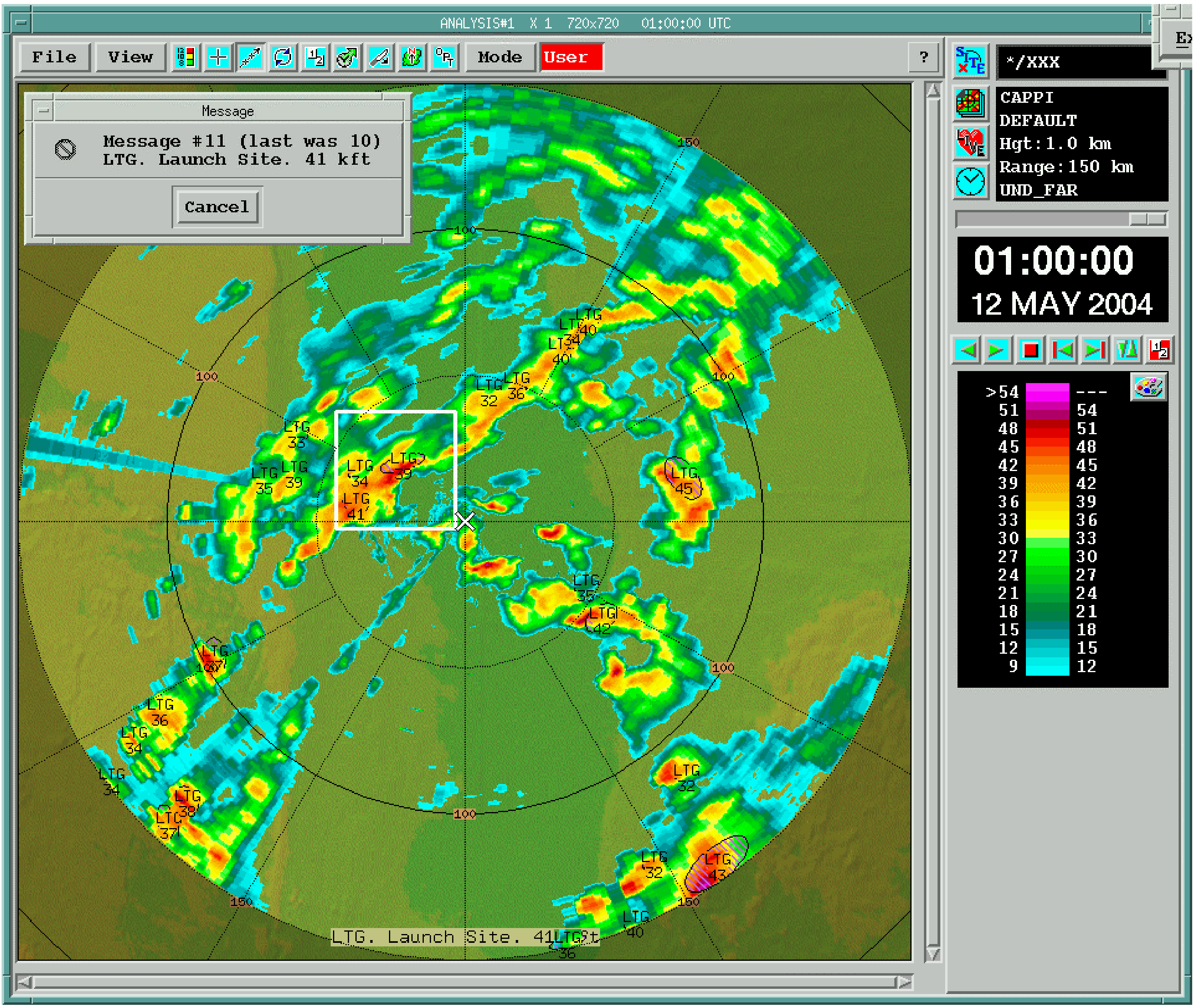

Figure 2: Iris CAPPI product showing dBZ at 1km altitude. An Iris WARN product configured to show the location of 30dBZ contours exceeding 30,000 feet is overlaid on the CAPPI product. A pop-up message box is displayed indicating the 30dBZ criterion has been exceeded within 20km of our launch site. The protected launch site is highlighted by the white box. When the 30dBZ contour is below the threshold the box around the protected area appears black (not shown).

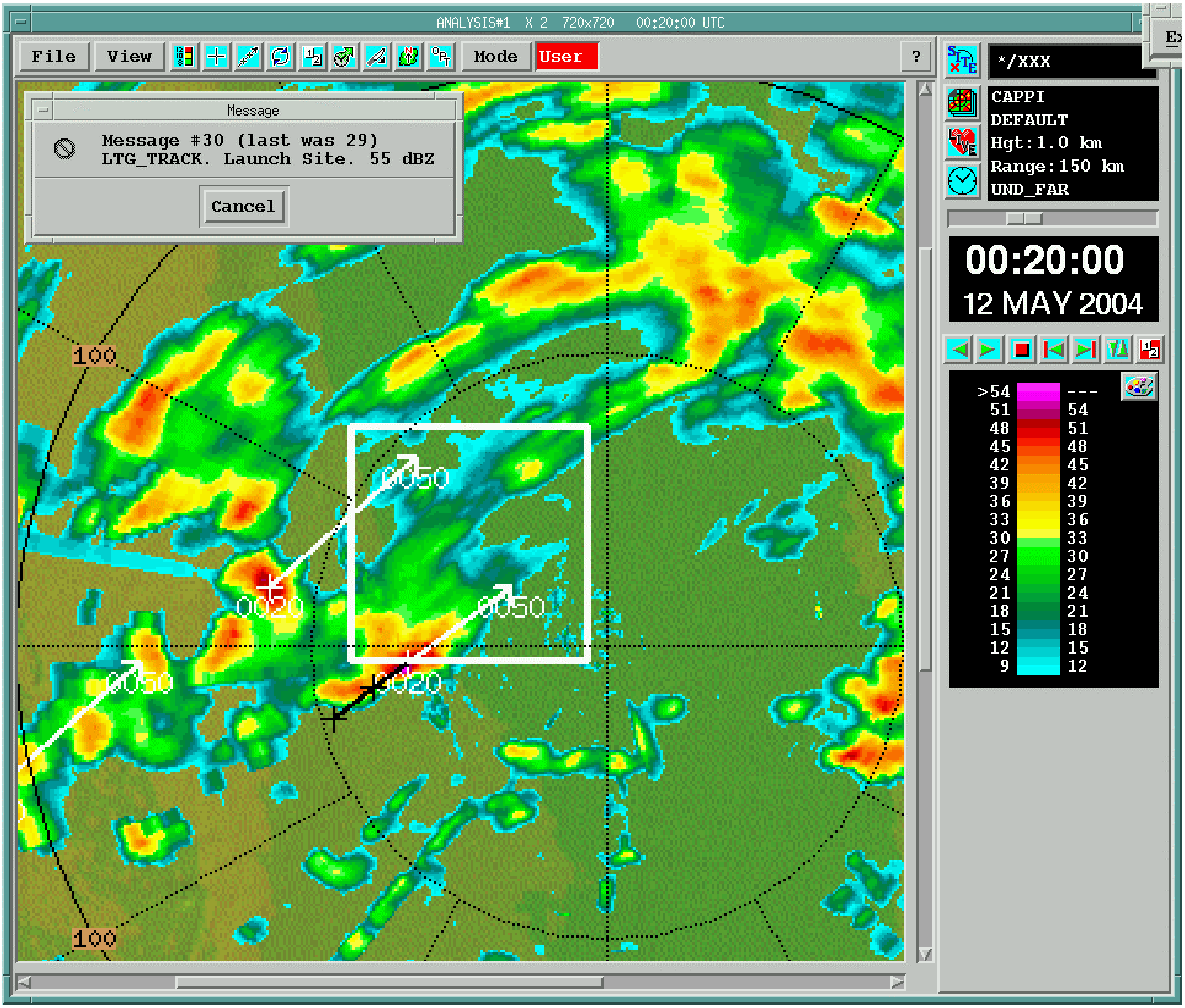

Figure 3: Iris CAPPI product showing dBZ at 1km altitude overlaid with a TRACK product configured to follow 30dBZ contours above 30,000 feet. This display indicates two cells trajectories violating our 30/30 criterion will soon enter the protected area around the launch site. The white arrows are the expected position 30 minutes from now if the storm continues on the same trajectory. The black line is the storms recent path. The time used to forecast the storms position is configurable by the user.

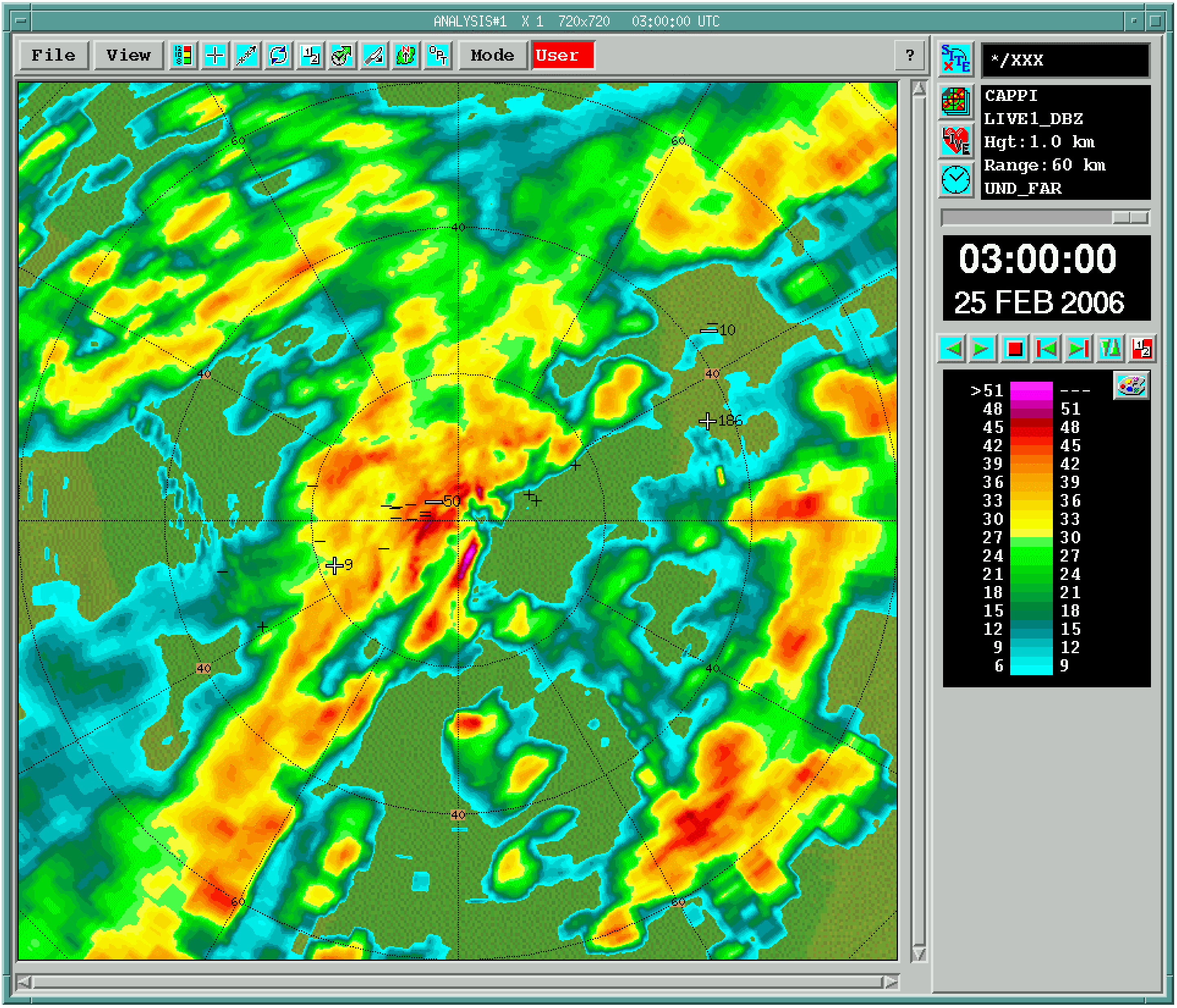

Figure 4: Integrated lightning and radar display showing CAPPI radar data and real-time lightning polarity data. The highlighted + and – are live strikes while the smaller icons are the strikes within the last 30 seconds. The value displayed next to the current strike is the estimated peak current in kilowatts. The amount of lightning data to be retained in the display is configurable by the user from a few 10's of seconds to several hours.