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SEASONAL VARIATION, THE EARTH'S TILT, AND WSR-88D: A THOUGHT EXPERIMENT

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The WSR-88D radar is a tool designed to evaluate atmospheric phenomena within and below the meso-beta scale (2-200 km). However, the radar provides information for much larger spacial scales - such as *heavenly bodies.* This Technical Attachment (TA) provides a brief example of how the WSR-88D radar can provide planetary (spacial) and seasonal (temporal) information to the user. Although this study is not directly applicable in the daily operational forecast setting, it is offered as a "sidelight".

The WSR-88D radar is designed to both transmit and receive electromagnetic radiation in a very specific wavelength band (≈10 cm). Since the sun emits radiation over almost all wavelengths, which includes 10 cm, solar radiation is intercepted by the radar at certain times of the day. These times, within minutes of sunrise and sunset, occur when the incoming solar radiation is aligned directly into the antenna reflector (dish). Thus, the lowest elevation scans (i.e., 0.5° or 1.5°) are more likely to capture sunrise/sunset due to the low position of the sun above the horizon. Because of the refractive characteristics of the atmosphere (super- and sub-refraction) and the subsequent bending of the radar beam, small time variations occur between the radar-observed and mathematically calculated sunrise/sunset times.

Sunrise/sunset are easily recognized in the reflectivity products generated by the radar (Figs. 1 and 2). A linear reflectivity echo aligned along the radar radial emanating eastward (westward) is indicative of sunrise (sunset). Note that the sky conditions are relatively clear, the time is near 0700 LST, and the elevation scan is 1.5° (Fig. 1). It should also be mentioned that the radial is oriented directly at the sun's position.

The main focus of this TA is to discuss the time variation of the emanating radial for sunrise at two different times of the year. The time difference between Figs. 1 and 2 is approximately 1.5 months, or 47 days (September 30-November 16). During that period, the radial shifts from east to southeast can be observed. Using mathematical calculations, which primarily consist of geometric relationships, the azimuthal variation in the horizon angle between the two days is approximately 20.3° (Appendix A). That is, the angle that the sun rises over the eastern horizon (or "horizon angle", here) is 20.3° farther south on November 16 than September 30.

Planetary geometry, incorporating the earth's tilt and earth-sun relationships, would obviously predict this general movement of the sunrise towards the south between the Autumnal Equinox and Winter Solstice. During this period, the sun's noon declination angle moves from directly overhead at the Equator to directly overhead at 23.5°S. That is, the Northern Hemisphere experiences the seasonal shift from fall to winter. Using a protractor (or simple trigonometry) in concert with the reflectivity products, the azimuthal difference between the two sunrise angles was measured for the two days and is approximately 21° (versus the mathematical solution of 20.3°). The small margin of error is related to author measurement errors while calculating the angle from the reflectivity products.

The WSR-88D radar is a proven tool for evaluating various atmospheric phenomena. This TA illustrates one of many interesting scientific phenomena which can be examined with the radar. In this case, the illustrated example provides numerous scientific ideas for thought. For example, what if a radar were placed on the North Pole? In this scenario, just before (after) the Autumnal (Spring) Equinox, the echoes would revolve around the radar (as the sun would circulate just above the horizon) for 24 hours per day! In fact, the sun would actually trace a "spiral" within the celestial dome as it ascends above the horizon, continuing through the Summer Solstice. This would be displayed as a revolving reflectivity echo along a radial at increasing (decreasing) elevation scans with time as the Summer Solstice (Autumnal Equinox) approaches. Taking this one step further, consider a radar on the Arctic Circle at the Summer Solstice. Here, the radar would display a sunrise at local midnight due north!

Appendix A

$$h_{0^\circ\ \text{above horizon}} \approx \cos^{-1}(-\tan\phi \tan l)$$

$$\gamma = \tan^{-1}\left[\frac{\sin h}{\sin\phi\cos h - \sin l\cos\phi}\right]$$

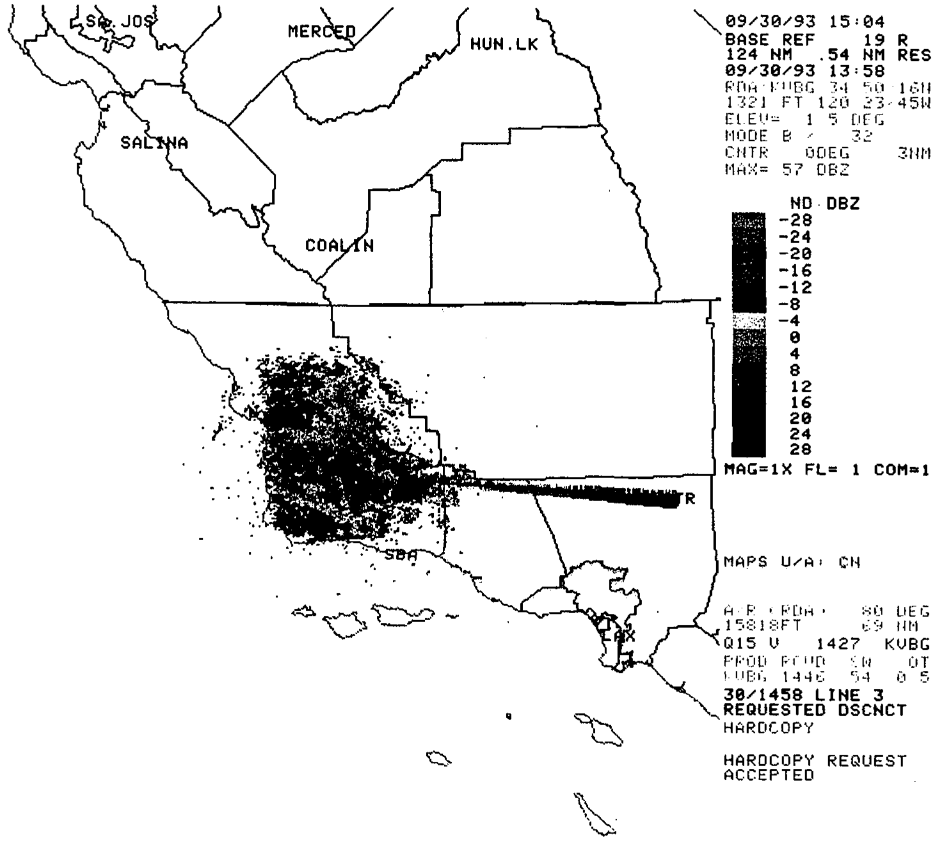
where:

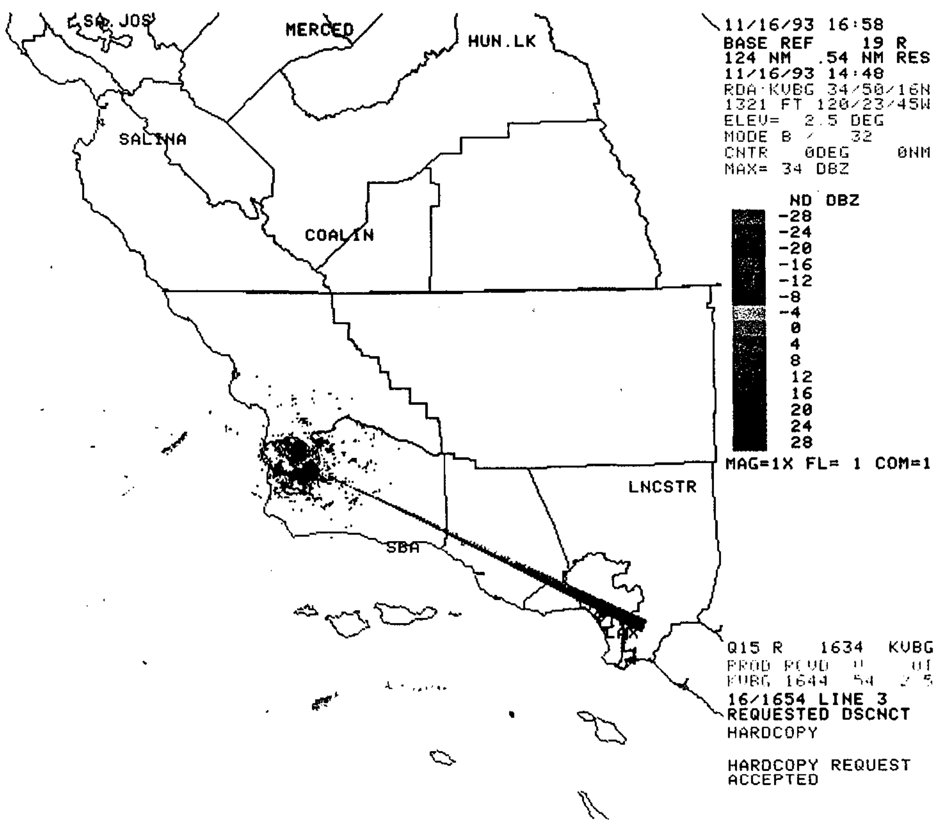
ϕ = *latitude*

l = *sun declination* = $\pm 23.5 \cos\left[\frac{180(D-10)}{366}\right]$

D = *Julian Day*

γ = *degrees originating fm due south of sunrise/sunset position ("+"=east)*





Figures 1 and 2. WSR-88D reflectivity products from Vandenburg AFB, CA for 1358 UTC 30 SEP 1993 and 1448 UTC 16 NOV 1993, respectively. Linear reflectivity band refers to sunrise radiation described in the text.