

Dense Fog over South-Central Arizona on 9 January 2003 and the UPS Radiation Fog Paper

Doug Green
WFO Phoenix, Arizona

INTRODUCTION

An unusually large area of dense radiation fog developed over a portion of south-central Arizona, including the southern half of the Greater Phoenix metropolitan area, during the morning of 9 January 2003 ([Fig. 1](#)). The fog was quite persistent: at Phoenix's Sky Harbor International Airport, visibility lowered to one quarter mile by 1300 UTC (6 am MST), remained at or below one quarter mile until shortly after 1700 UTC (10 am MST), and did not increase to above ½ mile until 1800 UTC (11 am MST). Sky Harbor runway minimums...ceiling/visibility below which all commercial air traffic is sharply curtailed or halted...are 200 feet/one half mile. Consequently, the dense fog had a significant impact on airport operations: a complete ground stop (no departures or arrivals) occurred for over 2 hours, from 1530 UTC to 1730 UTC, and significant delays occurred for 2 ½ hours prior to, and for 1 ½ hours following, the ground stop [Sky Harbor is the fifth busiest airport in the Nation in terms of takeoffs and landings, based on year 2002 statistics]. This TA-Lite describes the synoptic and mesoscale situation immediately preceding the event, highlights the terminal aerodrome forecast (TAF) issued for Sky Harbor by WFO Phoenix at 0600 UTC 9 January, and discusses the applicability of radiation fog forecast guidelines presented in a UPS Airlines paper.

SYNOPTIC/MESOSCALE SITUATION

At 1200 UTC on 8 January 2003, an upper low was centered southwest of San Diego, with a 300 mb jet streak southeast of San Diego ([Fig. 2](#)). During the day, the upper low evolved into an open wave and moved toward south-central Arizona; south-central Arizona was situated under the left entrance region of the jet. Low-level moisture was well above normal over south-central Arizona: surface dew points were 10-13 C, 850 mb dew point values were 7 C at Yuma and 4 C at Tucson., and the 700 mb dew point depression at Tucson was only 3 C. Wind veered from southeast to south in the 850-700 mb layer, and was 15-20 kt. At 500 mb, a west-east thermal gradient existed, with -13 C at Tucson and -20 C at Yuma. Noting the combination of a steepening lapse rate, increased synoptic-scale lift, and abundant low level moisture, the 345 am MST zone forecast for Greater Phoenix called for numerous showers with a chance of thunderstorms during the day and a slight chance for showers during the night. Rain showers affected Phoenix much of the morning, then ended around 1900 UTC (noon MST). At 2130 UTC (230 pm MST), Phoenix Sky Harbor recorded a high temperature of 18 C (65 F) and its lowest dew point, 12 C (53 F). An area of showers and thunderstorms developed over southwest Maricopa County by 2100 UTC, then propagated across the Phoenix area from mid afternoon through early evening ([Figs. 3 and 4](#)). By 0000 UTC (5 pm MST), Sky Harbor airport had received 0.41" from the showers and storms, representative of what fell over the entire Phoenix metropolitan area.

Baker et al (2002), in a paper which documented radiation fog forecast methods employed by UPS airlines forecast personnel, referred to the minimum dew point observed during the warmest daytime hours as the "crossover temperature", and suggest that, if other weather parameters, such as the absence of turbulent mixing, are observed, fog should be forecast "when the shelter temperature is expected to cool to a few degrees below the crossover temperature, rather than a few degrees below the dew point", since this indicates "when saturation will occur aloft". The forecast low at Phoenix Sky Harbor the night of 8-9 January was 11 C (52 F), 1 C (1 F) below the crossover temperature. Based on the UPS paper, fog, with visibility lowering to 1-3 miles, would have been forecast (if the forecast low had been expected to fall 3 or more degrees F below the crossover temperature, ½ mile visibility or less would be forecast). The 2245 UTC (345 pm MST) zone forecast for Phoenix did not mention fog; neither did the Phoenix 0024 TAF for Sky Harbor, primarily because forecasters expected mostly cloudy skies and occasional showers or sprinkles to persist all night. The evening forecaster on duty, noting the persistent small (1-2 C) temperature-dew point spread, occurrence of widespread rain over the Phoenix area during the day, and the likelihood of at least partial clearing prior to dawn, introduced "patchy dense ground fog" wording in nowcasts issued near 0330 UTC, updated the Phoenix zone forecast at 0430 UTC to call for patchy fog later that night through mid-morning on 9 January, and generated the following 0606 Sky Harbor TAF:

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TAF KPHX 090538Z 090606 VRB06KT P6SM SCT060 BKN080 TEMPO 0609 -SHRA BKN050
FM0900 09005KT 6SM BR SCT050 SCT080 TEMPO 0913 VRB03KT 3SM BR SCT030
FM1300 VRB05KT 5SM BR SCT050 SCT080 TEMPO 1316 2SM BR SCT030
FM1600 VRB05KT P6SM SCT080
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By 0800 UTC, the back edge of lower clouds was just south of Sky Harbor ([Fig. 5](#)), and dense fog developed where low cloud coverage was decreasing, especially over and near the community of Casa Grande (CGZ), prompting the issuance of a Dense Fog Warning for northwest Pinal County. However, low clouds and light rain showers were more persistent than forecast at Sky Harbor: a 7 kft overcast sky existed through 1200 UTC, and light rain showers occurred over and near Sky Harbor between 0730 and 1030 UTC. The area of fog over northwest Pinal County gradually expanded north as low clouds cleared out, with visibility at Williams Gateway Airport, situated 22 miles ESE of Sky Harbor, lowering from 5 miles at 0800 UTC to 2 ½ miles at 1100 UTC. However, Sky Harbor visibility improved from 6 statute miles at 1000 UTC to 10 statute miles at 1100 UTC. Consequently, the aviation forecaster made only minimal changes to the Sky Harbor TAF regarding fog potential. At 1200 UTC, Sky Harbor reported a visibility of 5 statute miles due to fog, with a temperature of 54 F (12 C) and dew point of 53 F (12 C). After persisting nearly the entire night, the overcast deck moved north of Sky Harbor shortly after 1200 UTC. Between 1200 and 1300 UTC, dense fog rapidly developed over and near Sky Harbor ([Figs. 6, 7, 8, and 9](#)). A special observation taken at 1243 UTC indicated visibility had lowered to ½ mile; 5 minutes later, visibility had lowered to 1/4 mile. At 1300 UTC, temperature and dew point were 52 F (11 C) [52 F, the minimum temperature, matched the forecast minimum, and was 1 F below the "crossover temperature"]. At Sky Harbor, visibility was at or below 1/4 mile from 1248 UTC until shortly after 1700 UTC, RH = 100% and temp/dew point was 52-53 F (11-12 C).

WES, THE UPS RADIATION FOG PAPER, AND THE FAA

All forecasters at WFO Phoenix reviewed the 9 January 2003 fog event via WES. Real-time mode data display was used for only 1.5 hours, due to time constraints, slow event evolution, and limited real-time monitoring capability. As a precursor to the review/simulation, each forecaster was required to re-read the UPS Airlines fog paper, and discuss its applicability with regard to this event. WES allowed forecasters to re-evaluate all available data prior to the onset of a very unusual weather event, at least in the Greater Phoenix area, increased forecaster understanding regarding the factors that must "come together" for dense radiation fog formation, and note negative factors that precluded dense fog formation over other portions of the CWA, including the northern half of the Greater Phoenix area. In a near-unanimous response, forecasters felt if they strictly adhered to fog forecast guidance provided in the UPS paper, our office would issue more dense fog warnings and forecast lower visibilities due to fog; however, forecasters also felt our FAR regarding both dense fog warnings and ceiling/visibility forecasts less than 200 ft/ ½ mile would increase significantly, while our POD would rise only minimally, at best. Forecasters agreed that forecasting dense fog in an arid environment such as Phoenix is extremely difficult, due to hard-to-detect moisture discontinuities, as well as the rarity of dense fog at Sky Harbor (no dense fog had occurred since January 1998, and the frequency of dense fog has decreased in recent years, partially in response to the observed upward trend in overnight lows attributed, in part, to urbanization).

Dense fog development over and near Phoenix typically is restricted to situations where ALL of the following occur: 1) widespread rain during the day and/or evening preceding fog formation (best way to saturate the low levels); 2) lowest 100 mb layer nearly saturated, 3) persistent small surface dew point depression (high RH); 4) minimum temperature < "crossover temperature", 5) light wind, with little if any shear (little or no turbulent mixing), and 6) broken or less cloud cover (allow for more effective radiational cooling).

FAA air route traffic control center personnel conduct daily air routing coordination calls at or near 1000 UTC. Consequently, accuracy of the 0600 UTC TAF for a major hub such as Phoenix Sky Harbor, where runway minimums come into play, is extremely important, especially when re-routing of air traffic is required.

REFERENCE

Baker, R., J. Cramer and J. Peters, 2002: Radiation Fog: UPS Airlines Conceptual Models and Forecast Methods. Preprint, 2002 Portland Aviation Conference, 6 pp.

Figure 1

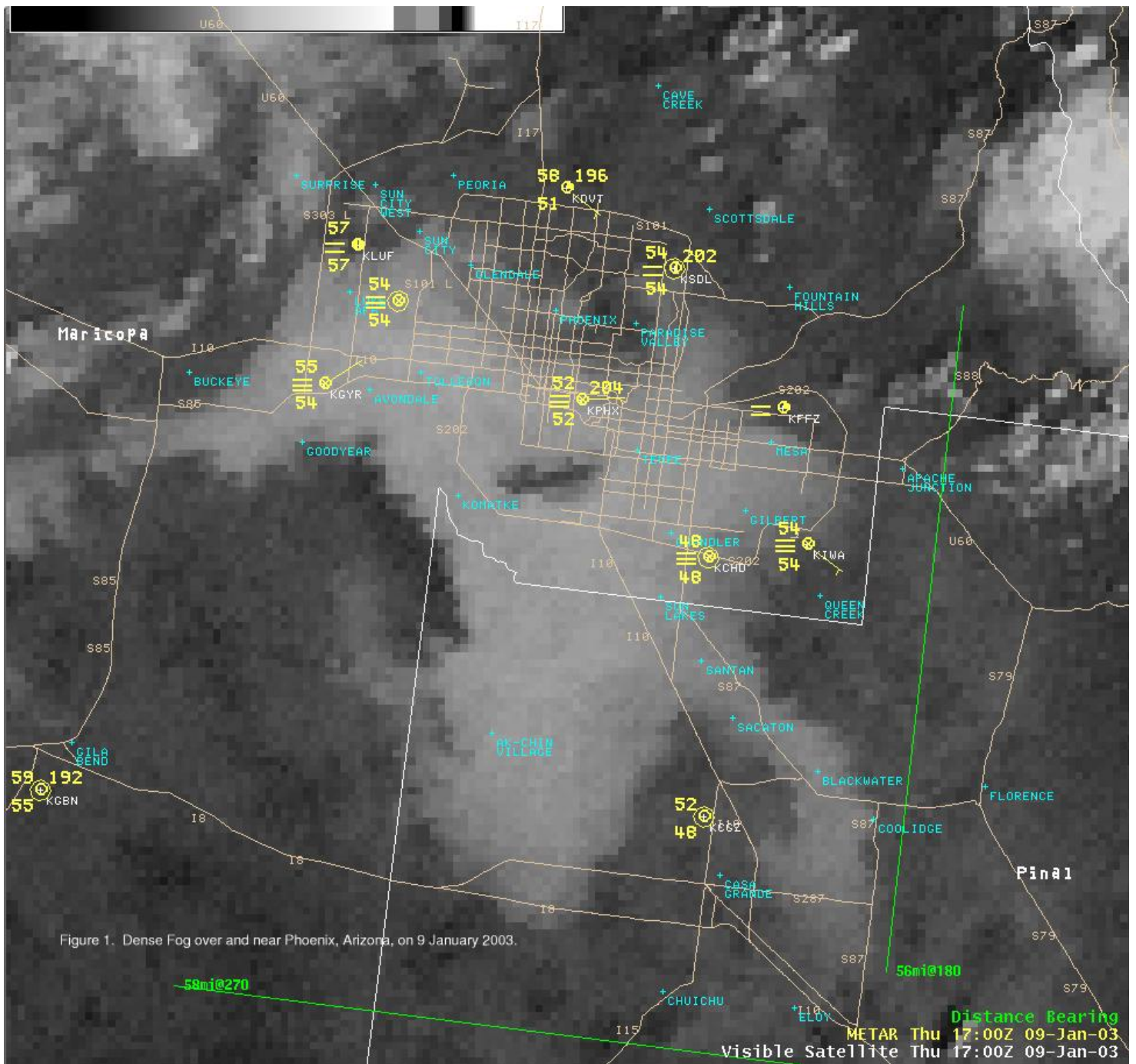


Figure 2

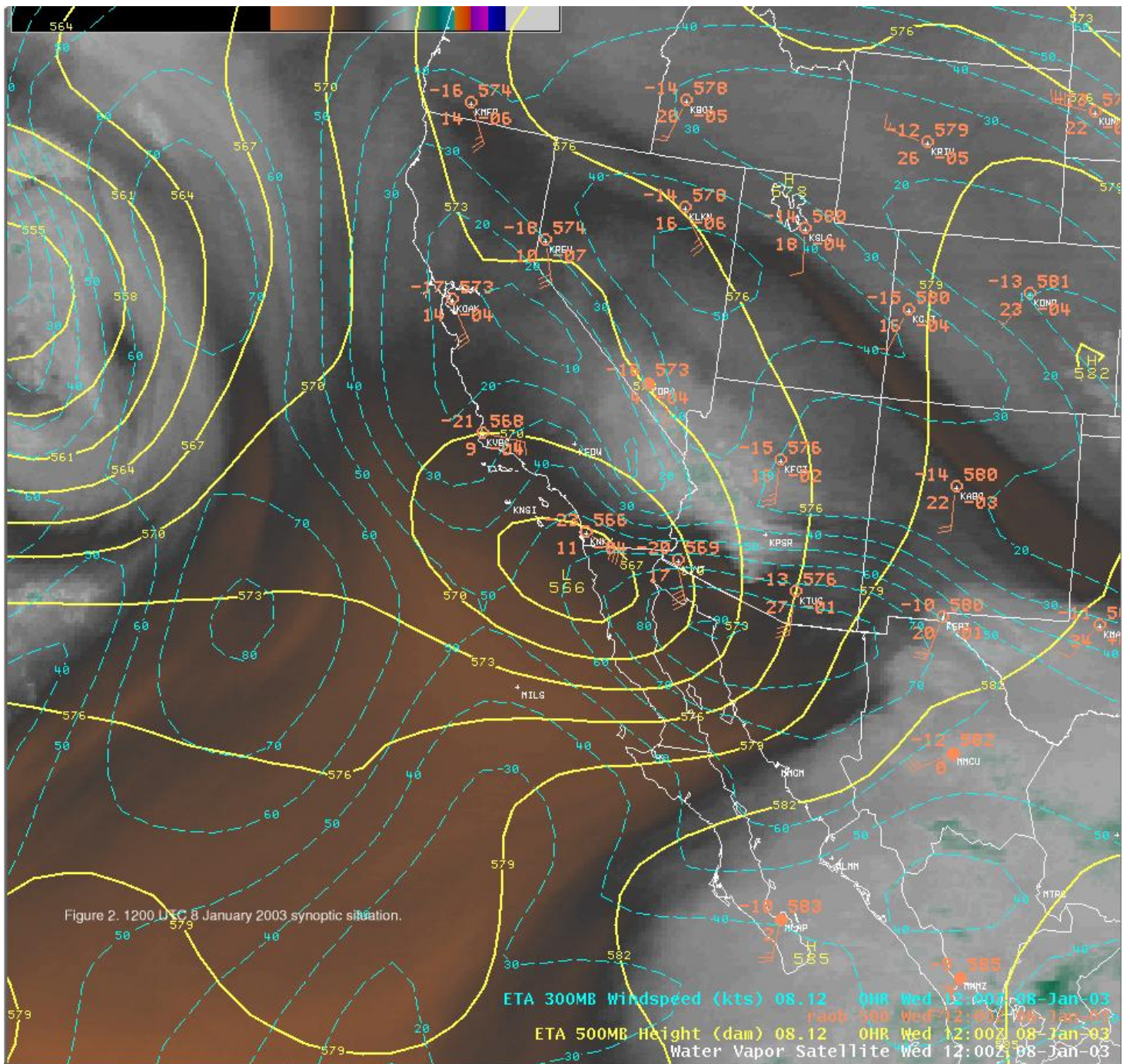


Figure 3

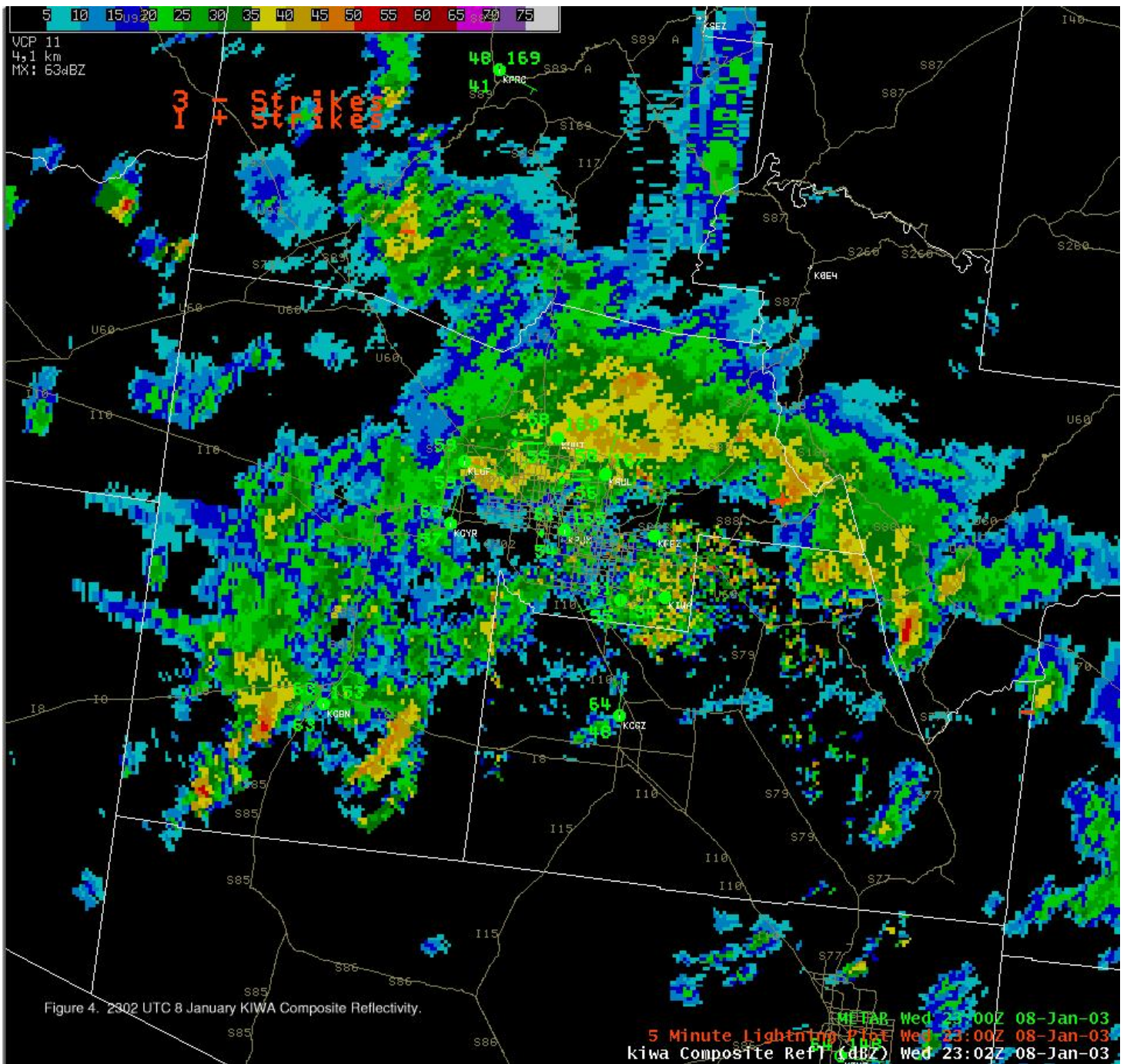


Figure 5

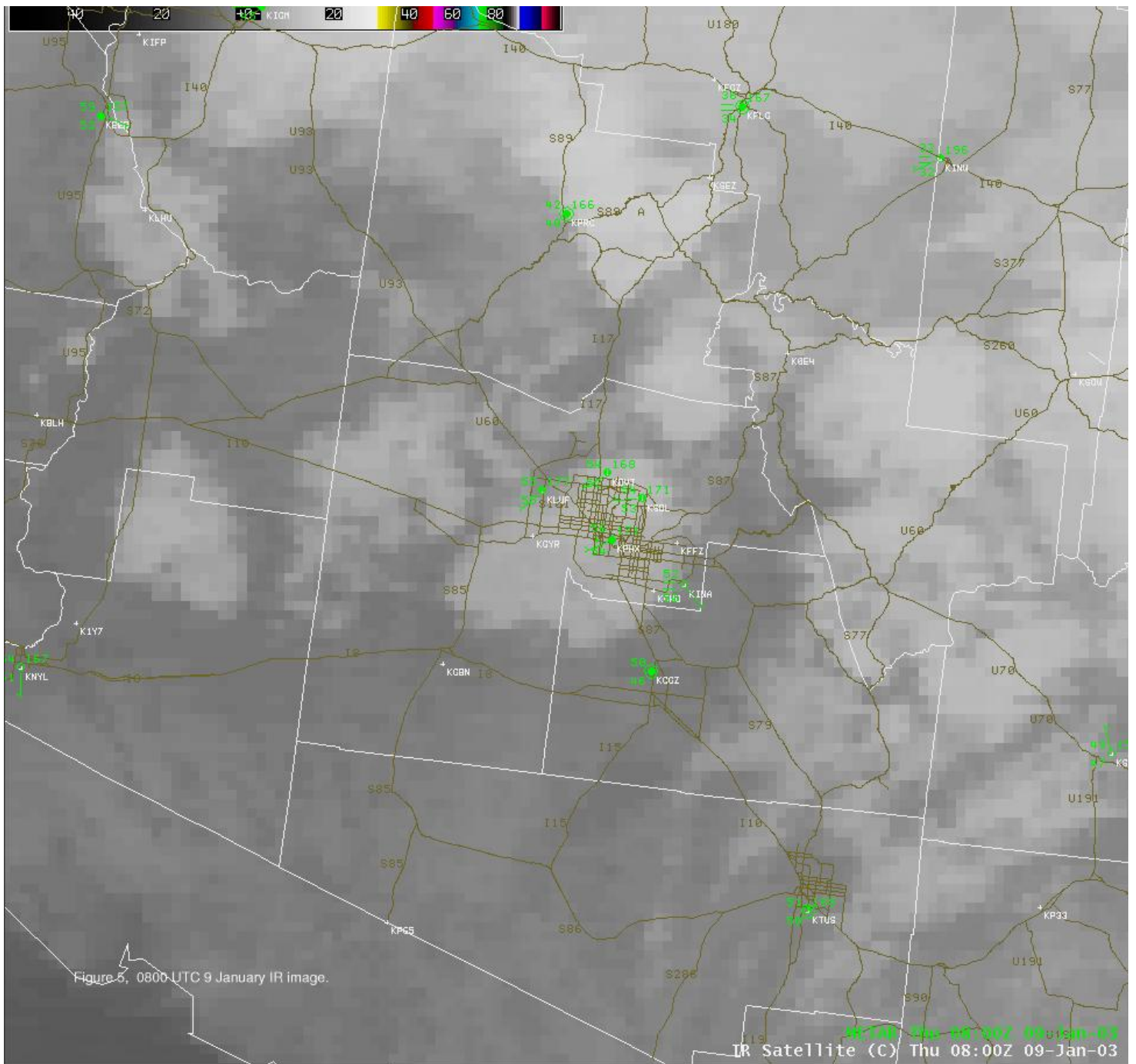


Figure 6

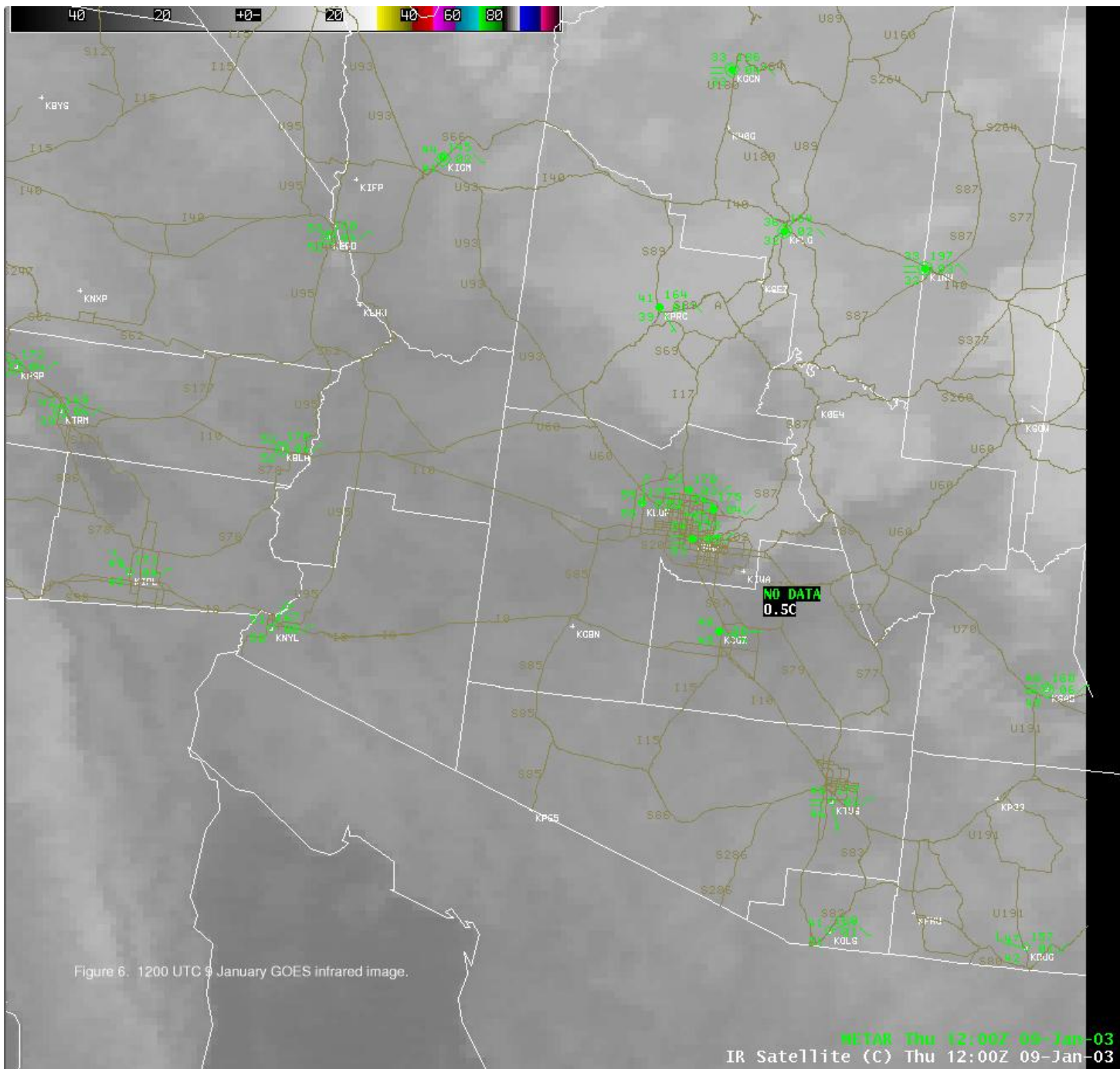


Figure 7

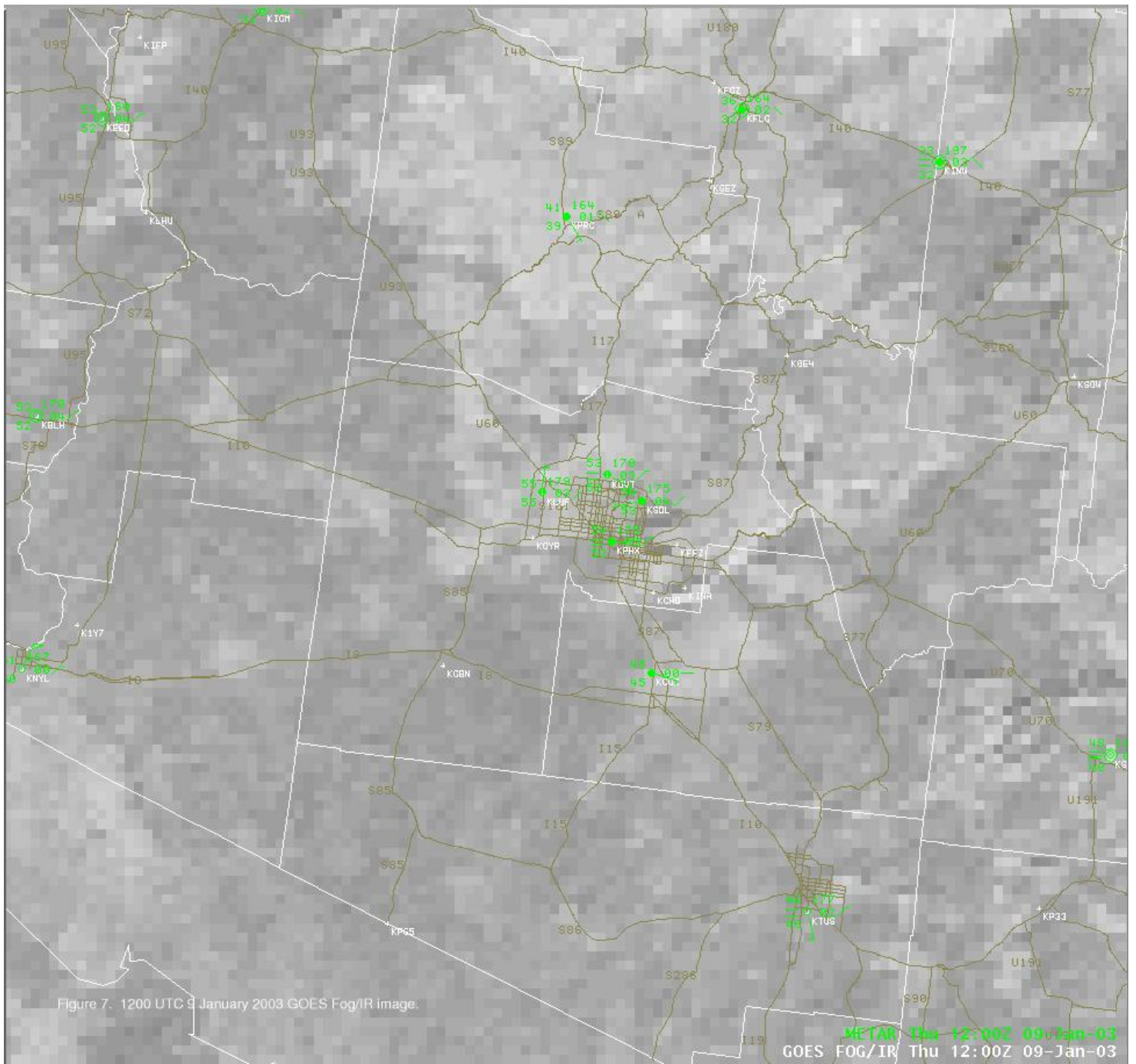


Figure 8

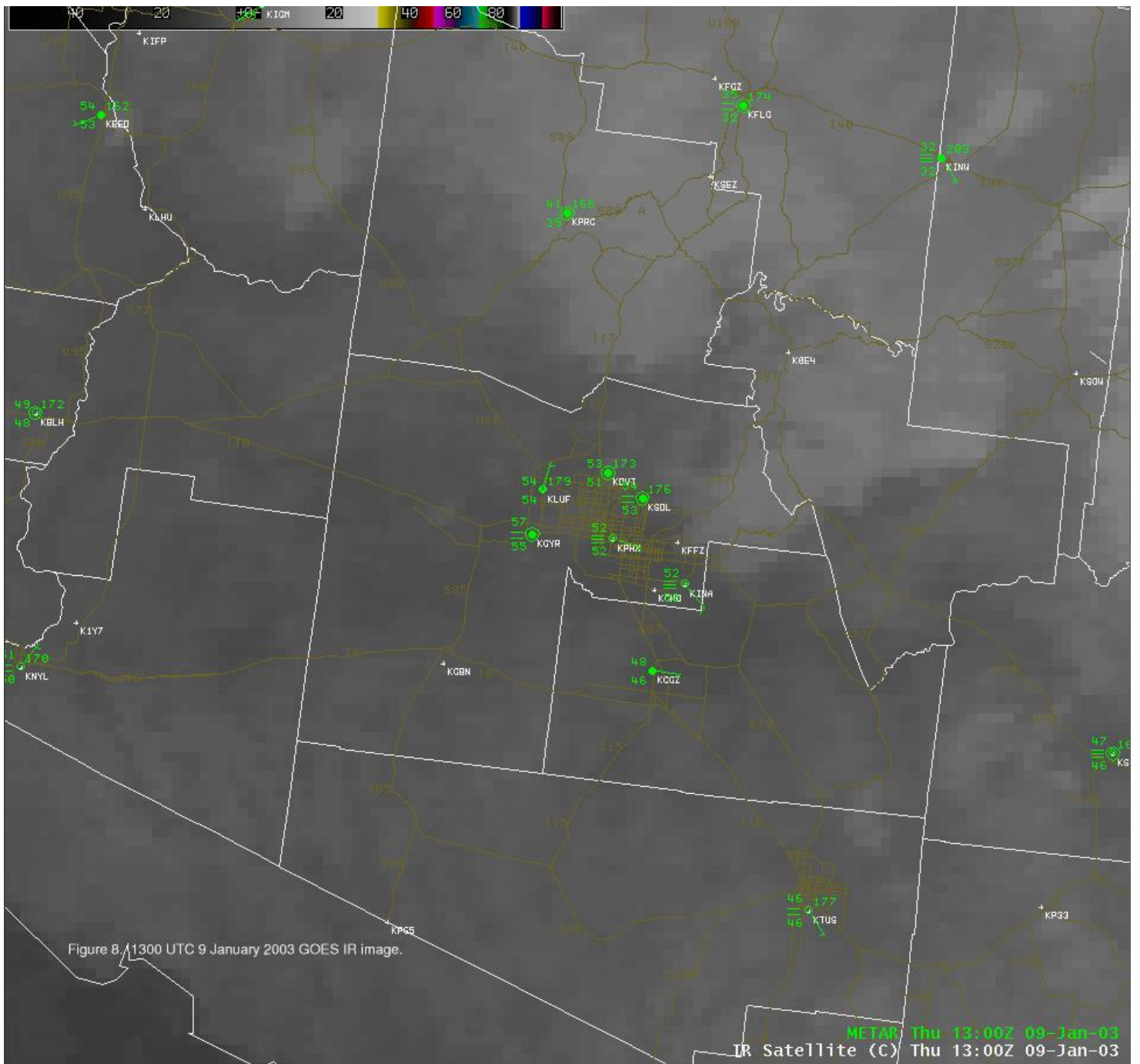


Figure 9

