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VHF TOTAL LIGHTNING MAPPING NETWORK IN TUCSON: VERY FIRST DATA ACQUIRED

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1. INTRODUCTION

During the summer of 2007, Vaisala installed a VHF total (cloud plus cloud-to-ground) lightning mapping network in the Tucson, Arizona, USA area. The primary reasons for installing this network were to (1) have a demonstration network for Vaisala customer visits to Tucson, (2) collaborate with Tucson International Airport on improved lightning warnings, (3) collaborate with the Tucson National Weather Service Forecast Office, and (4) learn more about total lightning activity in southwestern USA monsoon thunderstorms.

In this paper, we will describe the Tucson VHF total lightning mapping network layout and expected performance. We will then discuss network performance validation methodology and show the results of this validation analysis.

2. NETWORK LAYOUT AND EXPECTED PERFORMANCE

The Tucson VHF total lightning mapping network consists of four Vaisala LS8000 interferometric sensors located in and around the Tucson area (Figure 1). Sensor baselines are in the 20-60 km range. These baselines are relatively short compared to the typical LS8000 network baselines of 100-150 km. Two reasons for these shorter baselines are (1) good visibility over the Tucson metro area and (2) use of pre-existing Vaisala sites for fast network installation. Sensor locations may be moved to more optimal locations in the future.

Vaisala LS8000 sensors use both VHF and LF frequencies for optimal detection of both cloud and CG lightning, respectively. Since the Tucson VHF total lightning mapping network is located in a region covered well by the National Lightning Detection Network (NLDN), we have not utilized the LF CG lightning detection capabilities of this new network (Biagi et al. 2007). Instead, we have combined the VHF lightning detection capabilities of this network with NLDN CG lightning data for applications and research.

VHF signals detected by the Tucson total lightning mapping network consist of cloud flashes and the in-cloud portion of CG lightning flashes. Figure 2 shows the expected VHF total lightning flash detection efficiency (DE) in the Tucson area as determined by Vaisala's VHF lightning DE model. An altitude of 6,000 m was chosen for the DE calculations because the in-cloud portion of CG lightning flashes should produce some VHF emissions at this altitude for comparisons using NLDN CG strokes as ground truth (see Section 3 for more details). The aqua shading in Figure 2 shows that areas within ~75 km of Tucson are expected to have >90% VHF total lightning flash DE.

VHF total lightning mapping networks typically detect 10s to 100s of VHF source emissions within each cloud or CG lightning flash. Figure 3 shows the expected VHF total lightning source location accuracy (LA) in the Tucson area as determined by Vaisala's VHF lightning LA model. Similar to Figure 2, LA was determined at an altitude of 6,000 m. The aqua shading in Figure 3 shows that the expected VHF source LA is ~1 km in the network interior.

3. PERFORMANCE VALIDATION METHODOLOGY

Lightning data from July-August 2007 were used for DE and LA validation of the Tucson VHF total lightning mapping network. During this time period, the Tucson network detected over 600,000 lightning flashes and over six million VHF sources.

Total lightning flash DE for the Tucson network was determined by using NLDN CG lightning flashes as ground truth. Although the VHF portion of the Tucson total lightning mapping network does not detect CG return strokes, it does detect VHF sources produced by the in-cloud portion of CG return strokes. Therefore, a CG lightning flash was classified as being detected by the Tucson network if it detected a VHF source within 30 km and 300 ms of the first return stroke location and time as reported by the NLDN. A DE was then computed for each 3X3 km grid box in the Tucson area by dividing the number of CG flashes detected by the Tucson network by the total number of CG flashes detected by the NLDN. This method of deriving DE provides a conservative estimate of DE because VHF emissions produced by CG lightning flashes are typically lower in altitude and therefore harder to detect for VHF networks that rely on line-of-sight propagation.

VHF source LA is harder to quantify because VHF sources produced during the in-cloud portion of CG return strokes can be physically separated in space from the CG return stroke ground contact location by up to 10s of kilometers. However, the LS8000 VHF sensor technology uses interferometric techniques to detect and locate VHF sources. Determining a VHF source location using interferometry is based on sensor angle measurements. Therefore, we can use residual angle errors from VHF sources that were detected by greater than two sensors (provides redundant information) to help estimate LA.

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4. VALIDATION RESULTS

Figure 4 shows the results of the DE validation analysis in the Tucson area. The aqua shading represents areas with >90% DE. A comparison with Figure 2 shows that the >90% DE area as determined by the validation analysis matches the expected network performance area of >90% well. As DE drops with increasing range from the network interior, the validation analysis shows slightly poorer DE than was expected by the Vaisala model. This was expected since the Vaisala VHF model determines total lightning flash DE, not CG lightning flash DE. As stated in Section 3, using NLDN CG return strokes as ground truth provides a conservative DE estimate. VHF emissions associated with CG return strokes will be lower in altitude than VHF emissions associated with cloud flashes and therefore harder to see using line-of-sight propagation at long distances.

LA validation analysis showed that for a large number of events residual angle errors calculated from VHF sources detected by more than two Tucson network sensors were between 1.0 and 1.5 degrees. This would imply that the LA in the interior of the Tucson network is ~1 km. A comparison with Figure 3 shows that this is consistent with Vaisala's model expected LA of ~1 km (aqua shade).

In conclusion, Tucson VHF total lightning mapping network DE and LA have been validated and the results are consistent with the expected DE and LA as determined by Vaisala's VHF lightning DE and LA models.

5. REFERENCES

Biagi, C.J., K.L. Cummins, K.E. Kehoe, and E.P. Krider, 2007: National Lightning Detection Network (NLDN) performance in southern Arizona, Texas, and Oklahoma in 2003-2004. *J. Geophys. Res.*, **112**, doi:10.1029/2006JD007341.

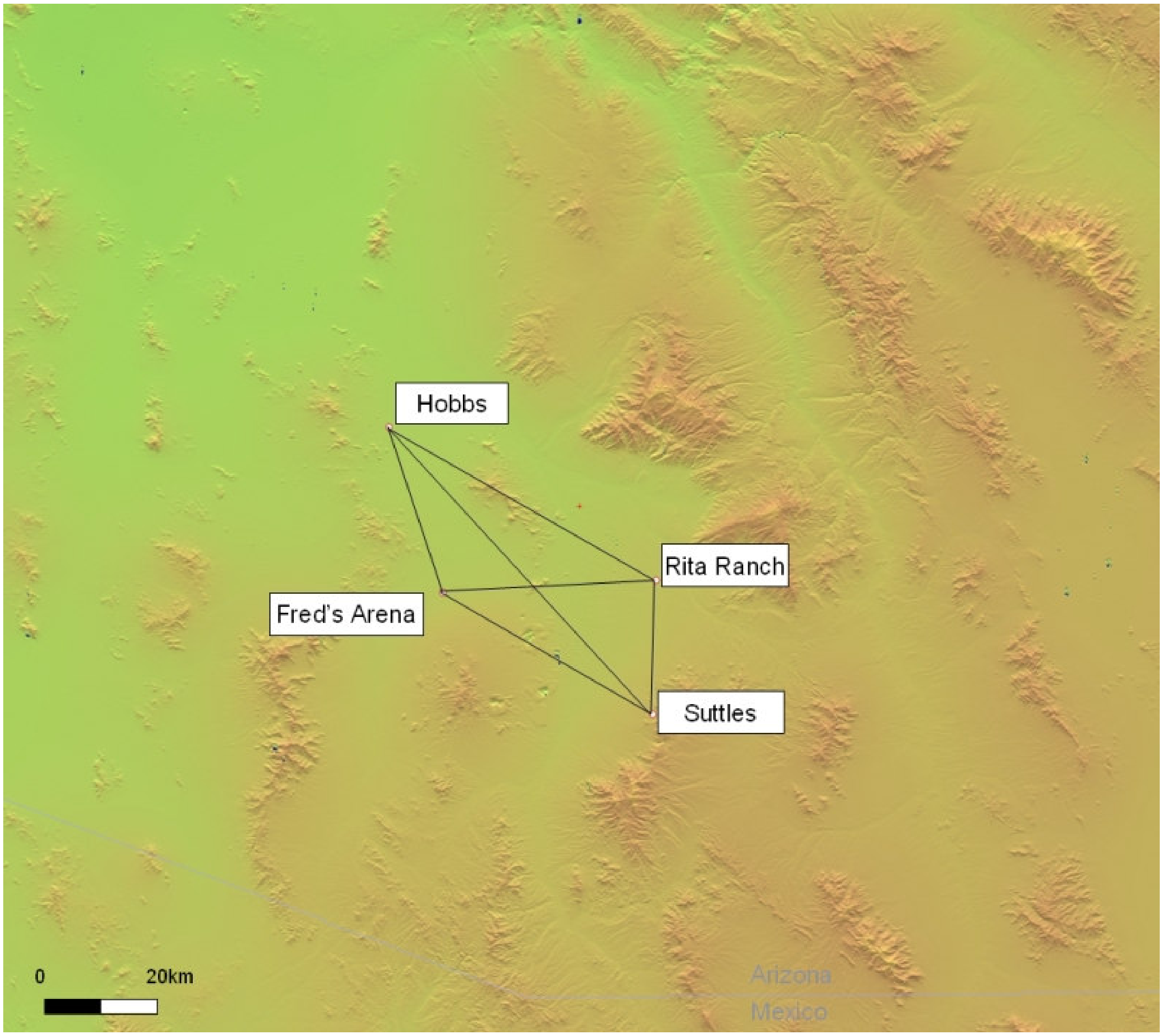

Figure 1. Locations of the four LS8000 sensors that make up the Tucson VHF total lightning mapping network. Sensor locations are labeled and shown by little red circles.

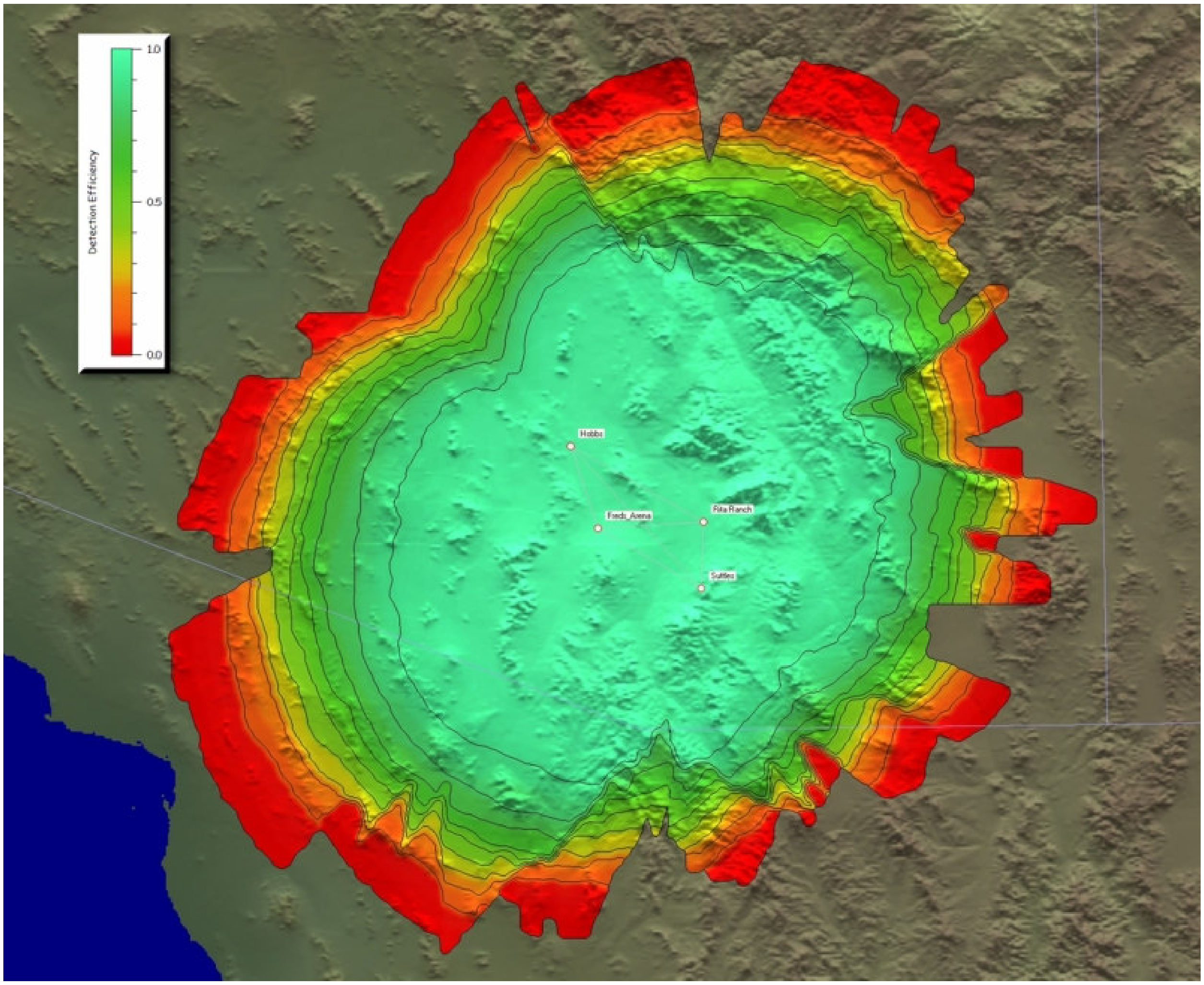

Figure 2. Map showing the expected total lightning flash detection efficiency (DE) for the Tucson VHF total lightning mapping network using Vaisala's VHF lightning model. DE values shown are valid at an altitude of 6,000 m. DE scale shown on the upper left with values ranging between 0 and 1. Multiply these values by 100 for DE. For example, 0.5 means 50% total lightning flash DE. Greater than 90% total lightning flash DE shown by aqua shade.