Value of Open-Source Data on Clouds to Remote Surveillance Planning

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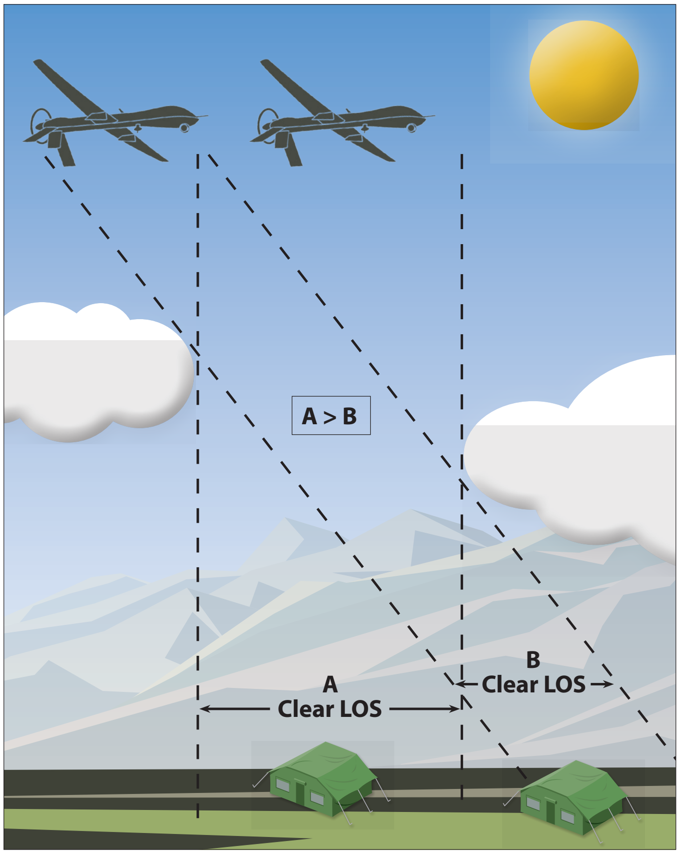
Airborne electro-optical and infrared (EO/IR) sensors are effective in monitoring objects on the ground in the dry climates of the Middle East and portions of Central Asia, but their effectiveness is hindered in cloudier climates found in the Baltic region and the Korean peninsula, for example. Because EO/IR wavelengths cannot penetrate clouds, information on frequency and morphology of cloud cover is useful for intelligence, surveillance, and reconnaissance planning.

A metric of interest in the field of remote sensing is the probability of clear line of sight (PCFLOS), which is a function of location, season, altitude, and viewing angle. For example, a lower PCFLOS would occur in conditions where clouds obscure a satellite-based sensor's ability to acquire its target of surveillance. Thickness and spacing of the clouds would also bear on PCFLOS. A nadir-pointing sensor (nadir being straight down, directly below the sensor) would generally experience a higher PCFLOS than a sensor viewing a target off nadir, since the light path from target to sensor would pass through a greater amount of the cloud layer and thus have a higher probability of hitting a cloud. (See illustration.)



Through three case studies, IDA researchers demonstrated the value of open-source data from satellite-based sensors in predicting cloud frequency in different regions and seasons. The case studies used three primary sources of historical data.

CloudSat, CALIOP, and MODIS are free, easy-to-access, peer-reviewed scientific datasets that provide high-quality measurements of Earth's atmosphere across the globe. (See table on back for details.) Although these datasets are not specifically designed for remote-sensing applications, they provide data about typical cloud coverage in particular locations, seasons, and conditions.

From those data, we can estimate the extent to which clouds block remote sensing over the EO/IR portions of the electromagnetic spectrum. The lower resolutions characteristic of these datasets preclude obtaining detailed images of scattered or broken cloud decks. However, low-resolution datasets also tend to be small and easy to handle, characteristics that proved beneficial for our purposes.

(continued)

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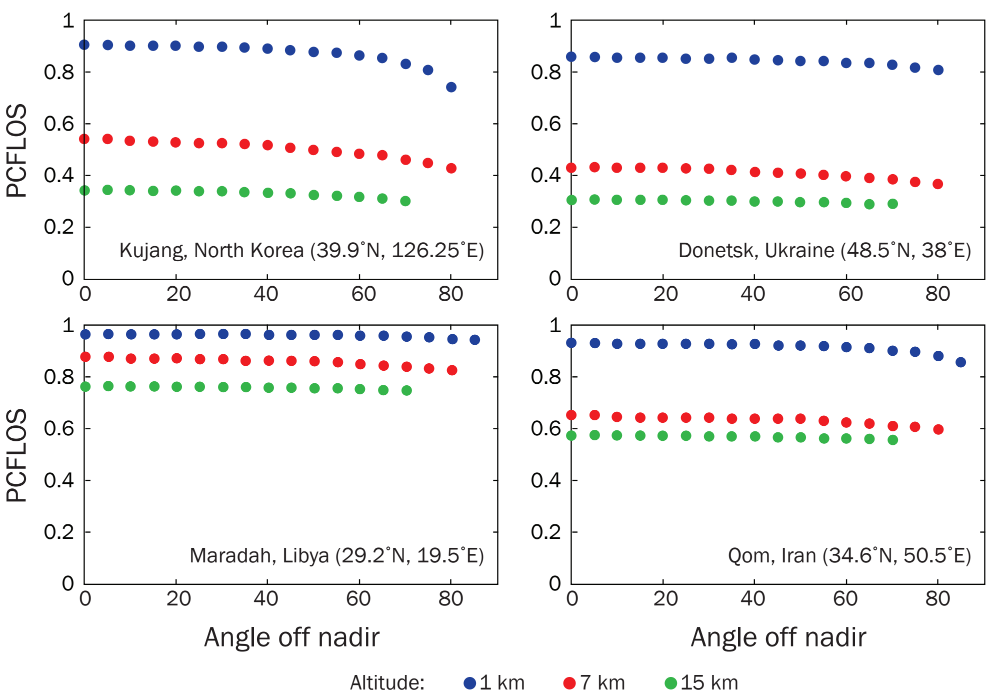
Case Study	Data Source	Characteristics	Application	Relevant Finding
1. Estimating probability of clear line of sight (PCFLOS)	Colorado State University's CloudSat project and Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)	• Description: Vertical cloud profile from active nadir-pointing radar • Resolution: 1 kilometer along track with 250-meter vertical resolution (CloudSat) and 333 meters along track with 30-meter vertical resolution (CALIOP • NASA satellites: CloudSat and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) • Years covered: 2006–11	Combined CloudSat and CALIOP data to estimate PCFLOS as a function of viewing angle	Viewing angle had a marginal effect on visibility through clouds at certain altitudes
2. Cloud Modeling on the IDA Sensing Effectiveness Evaluator (ISEE)	Cloud Mask, a product of NASA's Moderate Resolution Imaging Spectroradiometer (MODIS)	• Planar view of clouds from passive electro-optical/infrared sensors with ±55° field of view • Resolution: 250 meters or 1 kilometer along and across track • NASA satellites: Terra and Aqua • Years covered: 2000–present	Combined two-dimensional MODIS grids, which provide locations of clouds at particular times, with weather patterns over time in a cloud modeling feature of the ISEE	Given times and locations, the ISEE can estimate cloud interference in collection of visual or infrared data
3. Local Spatial Correlation of Clouds in the Baltic Region	MODIS Cloud Mask	• Planar view of clouds from passive electro-optical/infrared sensors with ±55° field of view • NASA satellites: Terra and Aqua • Resolution: 250 meters or 1 kilometer along and across track • Years covered: 2006–11	Applied an autocorrelation function on cloud cover over the Baltic region to MODIS Cloud Mask data to determine if cloud blockage in one location correlates to blockage in another location nearby	Cloud cover is statistically similar at locations up to tens of kilometers apart, suggesting that the likelihood is high that closely located targets would be blocked by clouds at the same time

Results from the IDA case studies indicate that viewing angle is less important than location, season, and altitude when it comes to effectiveness of remote-sensing applications. These four graphs portray the effects of viewing angle and altitude on PCFLOS in four locations, averaged over all seasons. Given the preponderance of large, generally opaque clouds in the Baltic, weather (cloudy or clear) is quite similar on length scales under 10 kilometers. Cloud occurrence doesn't become statistically dissimilar until distances of hundreds of kilometers away. The broken cloud fields that produce strong angular dependence in PCFLOS do not dominate; the most common cloud blockages come from large clouds.



Based on IDA D-8175, *Assessment of Cloud Occurrence and Impact on Remote Sensing Using Global, Open-Source, Scientific Datasets (Redacted)*, A. J. Slawik, E. A. Adelizzi, and G. M. Koretsky, October 2016. Research sponsored by the IDA Independent Research Program.