**GEOCAT Fog/Low Stratus (FLS) Algorithm Summary Document**

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## About the Algorithm

The algorithm combines data from multi-spectral satellite imagery and numerical weather prediction (NWP) models along with output from radiative transfer models (RTM) to create the FLS product. As noted earlier, separate algorithms are used during day and night. A key feature of the algorithm is the use of the 3.9 $\mu$m near-IR channel (channel 7 on Himawari-8), which contains both solar and terrestrial components that can be separated. Several different metrics are calculated from the sources and then combined using a Naïve Bayesian statistical model to estimate the probabilities. The Bayesian model is 'trained' using historical data to determine the *a priori* probabilities that are stored in 'look up tables' (LUT) for quick computation.

Three variables are used to drive the FLS algorithm at night, defined when the solar zenith angle is greater than 90°. The first variable is the NWP-based profile of relative humidity (RH) in the lower troposphere. Higher RH represents air closer to saturation and is thus more likely to contain cloud. The second variable is the near-IR 'pseudo-emissivity', which represents the terrestrial component of the radiance at this wavelength. This is defined as the ratio of the observed radiance at 3.9 $\mu$m and the blackbody radiance at this wavelength computed using the IR window channel at 11 $\mu$m (Himawari-8 channel 14) brightness temperature. A low-level water cloud composed of small droplets (e.g. fog or low stratus) emits less radiation in the near IR compared to the window channel. As a result, the pseudo-emissivity will be lower when fog and low cloud are present than without, allowing for a detection to be made. The third variable is the so-called radiometric surface temperature bias (RSTB). This quantity is the difference between the NWP surface temperature and an IR-based (11 $\mu$m) surface temperature, estimated using the RTM to remove the atmospheric portion of the observed radiance. When the RSTB is small, the cloud is more likely to be nearer the surface; larger biases suggest more elevated clouds. Interim probabilities for a given satellite scene are calculated from two LUTs. The first is jointly defined from the pseudo-emissivity and the RTSB. The second LUT is based on the RH. Final probabilities of FLS are identified from the LUTs and historical climatology, and the result is returned.

During the day, defined where the solar zenith angle is less than 85°, four variables are used to drive the FLS algorithm. Two of these variables are the lower troposphere RH profile and the RSTB, as in the night algorithm. The third variable used in the day algorithm is the spatial uniformity of the reflectance at the visible channel (0.65 $\mu$m, channel 3 on Himawari 8), defined by the standard deviation of a 3x3 pixel area centred on the pixel being considered. Lower values of this variable are indicative of FLS, which is horizontally extensive and smooth in appearance on a satellite image. Higher values are more characteristic of cumulus clouds. The fourth variable is the 3.9 $\mu$m reflectance, which considers the solar contribution at this channel. Higher values of reflectance are more indicative of cloud. Two LUTs are used in the day FLS algorithm. The first jointly considers the 0.65 $\mu$m spatial uniformity, the 3.9 $\mu$m reflectance and the RSTB. The second considers only the RH, noting that the RH LUT during day is distinct from that at night.

The FLS Depth is also computed differently between day and night. During the day, liquid water path (LWP) estimates from the DCOMP (Daytime Cloud Optical and Microphysical Properties) algorithm are utilized. These estimate how much liquid water is contained in a cloudy column. Using an assumed value for liquid water content (LWC) of 0.3 g $m^{-3}$, the FLS depth is computed as the LWC divided by the LWP. The FLS depth measurement is not available in the terminator region, when the solar zenith angle is between 70° and 90°. At night, the FLS depth product is a linear regression based of the 3.9 μm pseudo-emissivity. Regression coefficients have been determined based on co-located acoustic sounder, ceilometer and satellite measurements in the San Francisco Bay area. The full regression equation is FLS Depth = -1159.93*$\varepsilon_{3.9}$ + 1295.70, yielding the height in metres.

Calvert, C and M Pavolonis, 2011: GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document for Low Cloud and Fog,, NOAA NESDIS STAR technical report, 74 pp. [Available from: http://www.goes-r.gov/products/opt2-low-cloud-fog.html]