September 2022

Global Monthly and Seasonal Urban and Land Backscatter Time Series, v1 (1993-2020)

PURPOSE

To provide a 28-year time series of microwave backscatter to support analysis of patterns and trends in growth of global urban building infrastructure.

DESCRIPTION

A detailed description of this data set has been published in the open-access literature:

Frolking, S., T. Milliman, R. Mahtta, A. Paget, D. G. Long, and K. C. Seto. 2022. A Global Urban Microwave Backscatter Time Series Data Set for 1993-2020 Using ERS, QuikSCAT, and ASCAT Data. Scientific Data 9: 88. https://doi.org/10.1038/s41597-022-01193-w.

The authors recommend reading this article to get more information on the data sources and data set development, technical validation, and usage notes. A brief synopsis is provided here.

The Global Monthly and Seasonal Urban and Land Backscatter Time Series, 1993-2020, is a multi-sensor, multi-decadal, data set of global microwave backscatter, for 1993 to 2020. It assembles data from C-band sensors on board the European Remote Sensing Satellites (ERS-1 and ERS-2) covering 1993-2000, Advanced Scatterometer (ASCAT) on board EUMETSAT satellites for 2007-2020, and the Ku-band sensor on board the QuikSCAT satellite for 1999-2009, onto a common spatial grid (0.05 degree latitude/longitude resolution) and time step (both monthly and seasonal). Data sets are provided for all land (except high latitudes and islands), and for urban grid cells, based on a specific masking that removes grid cells with > 50% open water or < 20% built land. The all-land data set allows users to choose and evaluate other urban masks.

Microwave scatterometers are active space-borne sensors that measure the strength of a microwave pulse reflected (backscattered) by the atmosphere and ground back to the sensor. Although primarily designed to measure wind speed and direction on the world's oceans, scatterometers collect data over land (including cities). Scatterometers are generally very stable and well-calibrated instruments, so they can generate useful data time series for detecting change. This urban backscatter data set combines data from three sensors that collectively have data over nearly three decades – ERS (1993-2000), QuikSCAT (1999-2009), and ASCAT (2007-2020) – with some overlap between sensors to explore intercalibration.

As a rough approximation, microwaves scatter from objects larger than their wavelength. The data here are from Ku-band (~2.5 cm) and C-band (~5.5 cm) sensors, so the atmosphere and clouds are mostly transparent, but built structures can be very strong scatterers, with a high degree of backscatter arising from surfaces joining at 90° angles (corner reflectors), such as a wall and the ground.

Backscatter values in the database are reported on a dimensionless decibel scale (dB). Backscatter values in dB are almost always negative, and a more negative value means a weaker backscatter, i.e., more of the microwave pulse is scattered away from rather than back to the satellite sensor. Built structures, with abundant corner reflectors, can generate a strong (less negative) backscatter. For urban grid cells, Ku-band QuikSCAT summer mean backscatter values range from roughly -2.5 dB (e.g., urban core grid cells in Tokyo, Japan) to roughly -16 dB (e.g., lightly built urban grid cells in Khartoum, Sudan).

Figure 1 below shows maps of C-band ASCAT backscatter on an 0.05° lat/lon grid at the beginning (2007) and end (2020) of the ASCAT record in this database for several regions around large cities. Colored grid cells have been classified as urban, and this classification is fixed for the entire record, so the maps show changes (generally increases) in urban backscatter over this 13-year period, but not any lateral urban expansion that may have occurred. C-band backscatter is generally brighter by roughly 1-2 dB than Ku-band, but this offset varies across the world's urban grid cells. Looking at the time series for any one sensor, backscatter from urban grid cells generally increases over the decade of observation, which, since the instruments are stable, represents a change in surface properties, such as an increase in built structures (corner reflectors) and possibly other factors.

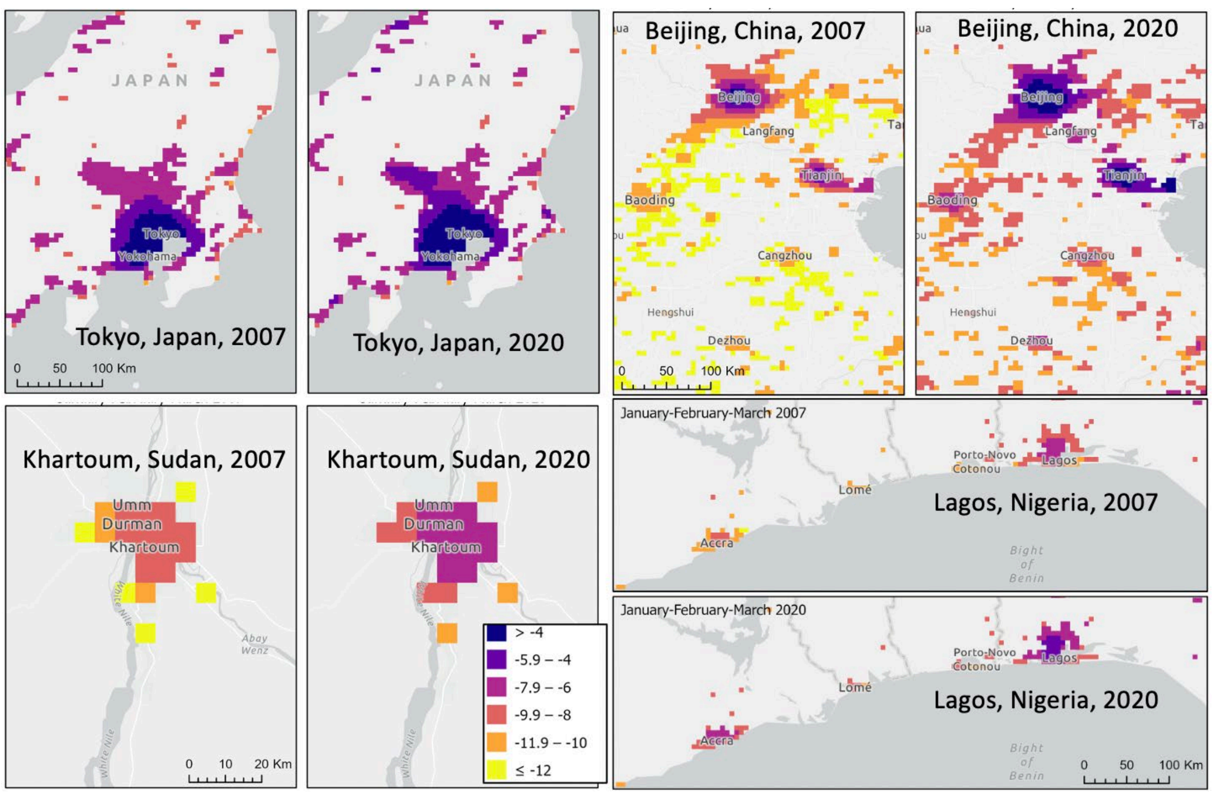

Figure 1. ASCAT Jan-Mar mean backscatter (dB) in both 2007 and 2020 for regions around four large cities. Grid-cell resolution is 0.05° lat/lon. Colored grid cells were classified as urban based on water cover < 50% and built fraction > 20% (see Frolking et al. 2022 for details).

Short-term variation in backscatter can arise from numerous factors, including weather (wet vs. dry surfaces, frozen vs. unfrozen water and ground) and vegetation canopy phenology. The authors recommend developing an annual time series, using a particular time of year (e.g., a particular season or set of months) to average over weather variability and filter out seasonal phenomena.

The data set's spatial resolution is coarse, 0.05° latitude/longitude or roughly 5 km at the equator (e.g., see maps). Towns and small cities will fall within one to a few grid cells, and their urban backscatter signal will have relatively more contribution from the surrounding land. Large cities (e.g., population ~ 1M+) generally cover many more grid cells, and are therefore a better target for urban backscatter analyses.

So what does a particular backscatter value represent, in terms of urban structure? There is a strong linear correlation (overall R-squared value = 0.69) between 2015 ASCAT urban backscatter and a continental-scale gridded product of building volume, across 8,450 urban grid cells (0.05 degree resolution) from large cities in Europe, China, and the United States (see publication Frolking et al., 2022). We found a slightly stronger correlation when anti-log transforming backscatter into a power return ratio, PR = $10^{[\sigma^0/10]}$, where σ^0 is the backscatter in dB from the database. There is scatter around this continental-scale linear relationship, which could be due to a number of factors (e.g., dominant building materials, city-scale road and building orientation, other urban features). This, coupled with the limited regional scope of the correlation between backscatter and building volume (only China, Europe, USA), makes intercomparison of different regions and cities uncertain and qualitative. The strongest application will be evaluation of temporal change for an aggregate set of urban grid cells, such as a city or region (e.g., see figure).

There is an offset between C-band and Ku-band backscatter from both vegetated and urban surfaces that is not spatially constant. Until this offset is better understood and a robust intercalibration for urban backscatter can be developed, the authors advise against analyzing a single 28-year time series across the three sensors. To evaluate urban change, we suggest looking at trends for each sensor (which roughly corresponds to the decades of the 1990s, 2000s, and 2010s) for targets such as a city or region.

ACCESSING THE DATA

The data may be downloaded at https://sedac.ciesin.columbia.edu/data/set/urbanspatial-urban-land-backscatter-time-series-1993-2020/data-download

DATA FORMAT

The Global Monthly and Seasonal Urban and Land Backscatter Time Series data are available in GeoTIFF format (.tif) and netCDF v4 with default internal compression (level 7) format (.nc), packaged in Zip (.zip) files. Data files are available for urban land at a seasonal time step, or all land at seasonal and monthly time steps. Within each Zip file, the data are grouped by sensor: ERS (1993-2000), QuikSCAT (1999-2009), and ASCAT (2007-2020). In order to provide complete years of data in the time series, periods of missing data are represented by individual TIFs or netCDF bands of NoData values. For example, although QuikSCAT coverage begins in July 1999, data layers of NoData values are provided for the months of January through June 1999.

To support lower bandwidth connections, the monthly data are also provided, packaged separately by sensor.

Downloaded Zip files must be uncompressed in a single folder using either WinZip (Windows file compression utility) or similar application. Users should expect an increase in the size of downloaded data after decompression.

Filenames of the GeoTIFFs and netCDFs are as follows:

netCDF: {sensor}_{time period}_{coverage}_sig0_{variable}.nc
GeoTIFF seasonal: {sensor}_{time period}_{coverage}_sig0_{variable}_{year}_{season}.tif
GeoTIFF monthly: {sensor}_{time period}_{coverage}_sig0_{variable}_{year}_{month}.tif

where:

{sensor} is one of: ‘ERS’, ‘QuikSCAT’, or ‘ASCAT’
{time period} is either ‘seasonal’ or ‘monthly’
{coverage} is one of: ‘urban’ or ‘land’
{variable} is one of: ‘mean’ or ‘stddev’
{year} is a year in the range: 1993-2020
{season} is one of: ‘jfm’ (January February March), ‘amj’ (April May June), ‘jas’ (July August September) or ‘ond’ (October November December)
{month} is a month in the range: 01-12 (January-December).

DATA VALUES

Grid cell microwave backscatter σ^0 in dB; both mean (monthly or seasonal) and standard deviation of the mean over that time period. ‘No data’ value = -9999.

SPATIAL EXTENT

64.5°N to 58°S; all land except small and/or remote islands (e.g., Hawai’i) which are not covered in the source imagery.

DISCLAIMER

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RECOMMENDED CITATION(S)

Data Set:

Frolking, S., T. Milliman, R. Mahtta, A. Paget, D. G. Long, and K. C. Seto. 2022. Global Monthly and Seasonal Urban and Land Backscatter Time Series, 1993-2020. Palisades, New York: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/gr2e-dh86. Accessed DAY MONTH YEAR.

Publication:

Frolking, S., T. Milliman, R. Mahtta, A. Paget, D. G. Long, and K. C. Seto. 2022. A Global Urban Microwave Backscatter Time Series Data Set for 1993-2020 Using ERS, QuikSCAT, and ASCAT Data. Scientific Data 9: 88. https://doi.org/10.1038/s41597-022-01193-w.

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