World Settlement Footprint (WSF)

Hendrik Zwenzner[1], Thomas Esch[1], Julian Zeidler[1] Gotthard Meinel[2], and Jonas Eberle[1]

[1]German Aerospace Center (DLR), Muenchener Str. 20, 82234 Wessling
[2]Leibniz Institute of Ecological Urban and Regional Development (IOER), Weberplatz 1, 01217 Dresden

Abstract

Urbanization is the cause and consequence of most environmental and societal changes on Earth. In order to understand and manage its negative impacts, it is of utmost importance to gain detailed knowledge of the distribution and evolution of human settlements. With this pilot a novel and unique dataset - the global World Settlement Footprint (WSF) Suite - is proposed to the NFDI4Earth community together with the IOER Monitor, a German national land cover database. The objective of this pilot is to integrate these datasets into the NFDI4Earth infrastructure and make them accessible to a broad user community according to the FAIR principles and common standards. Stakeholders are data and infrastructure providers, data and system integrators as well as users from different scientific domains, public authorities, and decision-makers. We expect that the NFDI4Earth will advance and highly benefit from this pilot since the offered datasets are a valuable data source for many research applications. Besides, it can be seen as a precursor for numerous other satellite data applications, services and interoperability approaches to be integrated into NFDI4Earth.

I. Introduction

Today, more than half of the world's population is living in urban areas and the trend of rapid urbanization is ongoing. Since settlements - and urban areas in particular - represent the centers of human activity; the environmental, economic, political, societal and cultural impacts of urbanization are far-reaching. They include negative aspects like the loss of natural habitats, biodiversity and fertile soils, climate impacts, waste, pollution, natural and man-made disasters, crime, social conflicts or transportation and traffic problems, making urbanization to one of the most pressing global challenges. Accordingly, a profound understanding of the global spatial distribution and evolution of human settlements constitutes a key element in envisaging strategies to assure sustainable development of urban and rural settlements.

We provide here a new 10m resolution (0.32 arc sec) global map of human settlements on Earth for the year 2015, namely the World Settlement Footprint 2015 (WSF2015). Additionally, the upcoming Sentinel-2 based WSF2019 and the WSF Evolution will be part of this pilot, the latter being an annual time series of the World Settlement Footprint at 30m resolution from the years 1985 to 2015. These datasets have been generated by means of an advanced classification system which, for the first time, jointly exploits multi decadal open and free optical

and radar satellite imagery. The WSF2015 has been validated against 900,000 samples labelled by crowdsourcing photointerpretation of very high resolution Google Earth imagery and outperforms all other similar existing layers. In particular, it considerably improves the detection of very small settlements in rural regions and better outlines scattered suburban areas. The dataset can be used at any scale of observation in support to all applications requiring detailed and accurate information on human presence (e.g., socioeconomic development, population distribution, risk assessment, etc.).

Complementary to the global World Settlement Footprint dataset, this pilot includes the IOER Monitor data sets, a national high-resolution database of geospatial indicators for settlement and urban open-space structures in Germany. This database can provide high resolution (2.5m) reference data of land cover, e.g. for the validation of satellite-based classification of human settlements such as the WSF. Since the IOER Monitor is based on data from official survey and mapping that are subject to legal obligation for being updated, the continuation of the IOER long-term series on land use is assured.

II. Pilot description

The technological backbone on which the WSF2015 layer has been created is manifold. Concerning radar data, pre-processing and feature extraction for ~107,000 Sentinel-1 scenes acquired in 2014-2015 have been performed on Google's Earth Engine cloud computing platform. As regards optical imagery, pre-processing and feature extraction have been performed for ~217,000 Landsat-8 scenes acquired in 2014-2015 with less than 60% cloud cover and downloaded from US Geological Survey (USGS), European Space Agency (ESA) and the Google Cloud Storage. The resulting dataset, for which more than 1.5 Petabytes of intermediate products were generated, is referred to as Landsat TimeScan 2015. Specifically, the whole processing has been carried out at the IT4Innovations Czech supercomputing center (Ostrava) in the framework of ESA's Urban Thematic Exploitation Platform (U-TEP) project. The classification of the data has been also carried out in the same infrastructure, whereas post-classification activities have been performed in the Calvalus system available at DLR's Earth Observation Center. The final WSF2015 is obtained as a mosaic of ~14K tiles (where at least a single settlement has been detected).
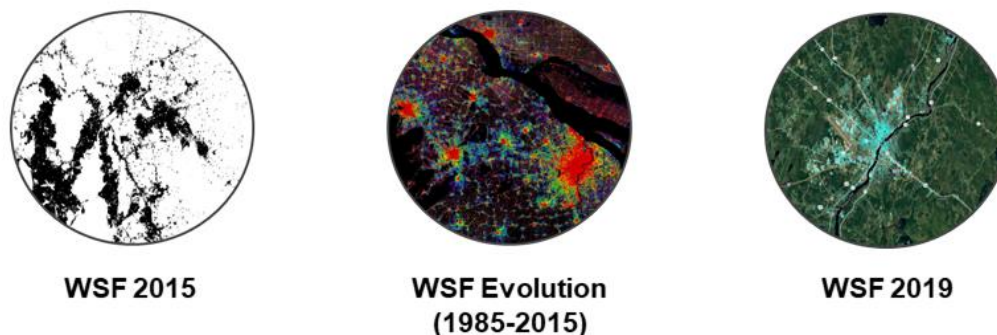

WSF 2015   WSF Evolution   WSF 2019
                  (1985-2015)

Figure 1: Datasets of the World Settlement Footprint Suite to be implemented for the NFDI4Earth pilot

The World Settlement Footprint Suite will be made accessible via the EOC Geoservice of the Earth Observation Center (EOC) of the German Aerospace Center (DLR), which provides discovery, visualization, and direct download services for a selection of the geospatial data hosted by the German Satellite Data Archive (D-SDA). The EOC Geoservice provides a map client as well as standardized OGC interfaces. Each geospatial data set is accompanied by metadata compliant with INSPIRE and GDI-DE. Those metadata is harvested by national (Geoportal-DE), European (INSPIRE Portal) or global (GEOSS Portal) data portals and make datasets findable and accessible on these portals.

The proposed solution for this pilot is to make the WSF Suite accessible via the EOC Geoservice, including the provision of OGC Services (WMS, WCS, and CSW) as well as to facilitate direct download (HTTP) of single tiles. DOIs will be assigned to the individual datasets and all data sets will be accompanied by ISO/INSPIRE compliant metadata. It is our aim to provide this unique and innovative dataset to the NFDI4Earth community and integrate it into the NFDI4Earth infrastructure, thus making it visible and accessible to a much broader user base. The innovation compared to predecessor data sets, such as the Global Urban Footprint (GUF), is revealed by the fact that for the WSF open and free multi-temporal optical and radar satellite imagery has been used. This allows for higher accuracy and systematic updates. Whereas the GUF, which is based on commercial TerraSAR-X/TanDEM-X single-date radar imagery from the year 2012, can sometimes suffer from misclassification errors caused by specific acquisition conditions. Furthermore, commercial imagery in this case prevented for systematic updates due to high costs and direct download is limited due to license restrictions.

Since 2010, the Leibniz Institute for Ecological Urban and Regional Development (IÖR) has been providing research data infrastructure services (i.e. IÖR-Monitor) for empirical spatial, environmental and social science domains to describe land use for Germany. The spatial data service with a high level of accuracy covers a wide range of thematic areas such as: land cover, buildings, ecosystem functions, infrastructure, and settlement structures, including their changes over time. In total 85 indicators describe the status and development trends in high spatial resolution up to the lowest administrative district level as well as in INSPIRE-compliant geographical grids up to a 100m raster. It provides also an annual data product on land use in 2.5m resolution. The input data sources are the official surveying data (e.g. ATKIS Basis-DLM, HU-DE), special geodata sets from federal authorities (e.g. LBM-DE), and official statistics as well as information from European remote sensing data or services (e.g. Sentinel-2, Copernicus HRL Imperviousness). The time series starts in 2000 and is supplemented annually since 2008. Using image-analytical methods, the time series will be successively supplemented for the whole country from digitized historical topographic map series back to the year 1850. The resulted information is made available online via a dedicated web portal in the form of interactive maps, diagrams and tables as well as via OGC services (WMS, WCS, WFS). Recently, the IÖR-Monitor was also accredited as a research data center by the German Data Forum (RatSWD).

III. Relevance for the NFDI4Earth

The WSF-Suite will be a valuable product in support to all applications and users requiring detailed and accurate information on human presence. In particular, combined either with other EO or non-EO-based datasets (e.g., related to climate, health, economy, demography, etc.), it will enable deriving indices and metrics of help not only for scientific research but even decision making. The GUF has been used by approximately 600 scientific institutions, including the universities of Yale and Oxford, CIESIN, WWF, JRC, ESA, World Bank and the UN.

Apart from the various potential users this pilot comprises several stakeholders: (1) EOC scientists, who created, collected, processed and analyzed this dataset: they benefit from the higher visibility and the wider user spectrum within the NFDI community and their feedback. (2) Data curators, infrastructure providers and system/data integrators related to the EOC Geoservice being responsible for the data accessibility of the WSF Suite: they can bring in their expertise and can benefit from tools and standards which are established in NFDI4Earth.

All elements of FAIR will be addressed by this pilot. Special emphasis will be put on the quality and comprehensiveness of the metadata. Innovative interoperability approaches will be applied. With regard to the research data life cycle this pilot focusses on the parts 'data published' and 'data reused'. The long-term archiving of the WSF Suite will be performed by the German Satellite Data Archive (D-SDA). This archive facility shall in the medium-term also become a part of the NFDI4Earth infrastructure. Currently, DLR is establishing together with the Leibniz Computing Center (LRZ) a High Performance Data Analytics (HPDA) platform with about 40 Petabytes online storage and advanced processing capabilities. At this stage, the WSF algorithms are implemented and the periodic updates beyond the WSF2019 will be generated on the HPDA platform. This offers various processing possibilities for DLR and LRZ users such as on-demand processing, the generation of higher level products by combining the WSF with other data, working with data cubes or performing some specific visualization approaches. Since both DLR and LRZ are part of the NFDI4Earth consortium, this pilot may even pave the road to open this up to the NFDI4Earth community in the future.

Within the framework of the NFDI4Earth pilot, it is planned to establish the IOER-Monitor as a component of the NFDI4Earth and to link its data offers in order to serve as reference information. The prime goal is to enhance the visibility and adaptability of the IOER-Monitor as a fundamental data source for spatial development issues in Germany and to achieve a quality profile as a research data infrastructure. In addition, the pilot will create an interface to the NFDI KonsortSWD by implementing a Social Spatial Science Research Infrastructure (SoRa) and work on the FAIR-compatible expansion of the IOER-Monitor.

IV. Deliverables

1. Technical Operability Document (WSF Suite and Reference Data Set)
   a) List of developed interfaces
   b) Metadata specifications
   c) Data Guide
2. WSF Suite - NFDI4Earth Implementation Roadmap Document

V. Work Plan & Requested funding

Task / Milestone	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Data Integration / Data Access												
WSF 2015 (WMS, WCS, HTTP Download, metadata, DOI)	██	██	██	██								
WSF Evolution (WMS, WCS, HTTP Download, metadata, DOI)				██	██	██						
WSF 2019 (WMS, WCS, HTTP Download, metadata, DOI)							██	██	██			
2,5m Land Cover Reference Data (WMS, WCS, HTTP Download, metadata, DOI)										██		
Final Integration of WSF Suite in NFDI4Earth											██	██
Final Integration of IOER-Monitor in NFDI4Earth											██	██
Deliverables												
Technical Operability Document (WSF Suite and Reference Data Set)							░					██
WSF Suite - NFDI4Earth Implementation Roadmap Document							░					██

Figure 2: Gantt chart showing the schedule of the planned implementation and milestones of the pilot during the one-year implementation phase

We kindly request a funding of a one year full time equivalent in order to implement the proposed NFDI4Earth pilot.