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The spatial network of megaregions - Types of connectivity between cities based on settlement patterns derived from EO-data

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ABSTRACT

Megaregions are important phenomena of globalization's new urban scale and form. These regions are considered the drivers of global economy, innovation, technology and the labor market. In combination with the global megatrend of urbanization, new dimensions and patterns are evolving conceptualized e.g. by this term 'megaregion'. Using multi-source and multi-temporal satellite data we classify urban footprints and their spatial evolution since the 1970s of five selected megaregions across the globe, namely the megaregions of Southern California anchord by Los Angeles in USA and the Mexican border area, the mega-region São Paulo–Rio de Janeiro in Brazil, the Nile delta anchord by Cairo in Egypt, the mega-region Amsterdam–Rotterdam, Ruhr–Cologne, Brussels–Antwerp and Lille in Europe, and the megaregion Guangzhou–Shenzhen–Hong Kong in China. Based on this geospatial data set, we develop a spatial metric to measure spatial connectivity between cities based on the continuity of settlement patterns. The network of cities within the particular megaregions is based on demographic information. The result is on the one hand an evaluation of the spatial continuity of settlements between the cities within the networks. On the other hand, comparisons whether the settlement patterns in megaregions across the globe are similar or not are performed. We conclude with the finding that three types of megaregions can be spatially classified and one suggested megaregion is spatially not yet connected.

1. Introduction

When you drive from *megacity Shenzhen* (10.7 million inhabitants) along the Jinggang'ao Expressway via *Dongguan* (8.2 mio) to *megacity Guangzhou* (12.8 mio) and if you then change to the S15 expressway to finally reach *Foshan* (7.2 mio), you have driven 170 km constantly within built environment. There is no obvious visible physical border to peri-urban or rural hinterlands separating these cities, but an endless stretch of settlements. Even if the names of the cities along this route are changing, and accordingly the administrative jurisdiction, this area seems to be geographically *one city*. You could easily extend this trip to 382 km starting further east in Huizhou (3.27 mio) and after reaching Foshan you could go on driving to the south to Jiangmen (4.1 mio) and Zhongshan (1.3 mio). If official counts are reliable, you drive along the living environment of about 50 million people (United Nations, 2014). This reflects a new dimension of urban landscapes, the physical manifestation of the rapidly on-going process of urbanization.

These new dimension of urban landscapes have been conceptualized in geography introducing terms such as *conurbation* (Geddes, 1915), *megalopolis* (Gottmann, 1957), *urban field* (Friedmann & Miller, 1965), *continental city* (Doxiadis, 1968), *urban corridor* (Whebell, 1969), *network cities* (Batten, 1995), *urban network* (van Houtum & Lagendijk, 2001), *city-region* (Scott, 2001), *megalopolitan area* (Lang & Dhavale, 2005), *megacity region* (Hall & Pain, 2006), *functional urban region* (Hall, 2009), *endless city* (Burdett & Sudjic, 2007) or *megaregion* (UN-Habitat, 2008) (for an extensive review of the terminology and their conceptualizations compare Georg, Blaschke, & Taubenböck, accepted for publication).

In general, what these concepts have in common is that they relate to a network of (economically) linked cities, a more or less coalesced spatially polycentric pattern at an interregional scale beyond limits of individual cities. This network of cities is differing to concepts which relate to a singular city dominating an agglomeration spatially and economically such as a *megacity* (United Nations Statistics Division, 2006), a *metropolis* (Hall & Pain, 2006) or a *global city* (Sassen, 1991). Castells proclaims that these changes are making "*the category ("the City")… theoretically and practically obsolete*" (after Pain, 2012; Castells, 2007). However, these concepts trying to capture the new dimension of urbanization are often qualitative; a spatially explicit classification of the global urban landscape is hampered with ambiguity and/or overlap. "*The geographical scale of functionally polycentric megaregions is hard to define because relations conferred on cities by service networks are multi-scalar and fluid; they are determined by markets and organizational operations which are cross-border and dynamic*" (Hall & Pain, 2006; Pain, 2012). Although there is considerable dispute over what the terms might mean, it is not our aim to discuss the differences or overlaps of the various terminologies and definitions of these urban

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concepts; it is rather *our goal* to analyze one aspect of this development, the *resulting new dimensions of spatial settlement patterns* across the globe. Against this background, we relate this study to the concept of *megaregions*.

2. Megaregions: concepts, relevance and spatial units

While cities are pushing beyond their limits they are merging into new massive conurbations, which are linked via certain types of networks, such as highway and high-speed rail, for the purposes of economic competiveness and sustainable development (Ross, 2011). These networks have become natural economic units that result from the growth, convergence and spatial spread of geographically linked metropolitan areas and other agglomerations, now referred to as *megaregions* (e.g. UN-Habitat, 2008; Atlanta Regional Commission (ARC), 2008; Oizumi, 2011). Florida, Gulden, and Mellander (2008) clearly state that megaregions are more than just bigger versions of a city. While the definitions a megacity (>10 million people) or even a megacity (>20 million people) are based on population figures (United Nations Statistics Division, 2006), this parameter alone does not necessarily result into the perhaps most significant territorial units of today's global economy (Florida, 2014; Soja & Kanai, 2007). Florida et al. (2008) calculate the world's 10 largest megaregions house only 6.5% of the world's population, but account for 42.8% of economic activity, 56.6% of patented innovations and 55.6% of the most cited scientists. These numbers support a now familiar geoeconomic logic that in globalization, the largest and densest clusters of socioeconomic activity are those being the most important engines (Harrison & Hoyler, 2015). And as Harvey (2013) remarks, capital surpluses have always been invested predominantly in the process of urbanization. This scale and pace of economic activity is reflected in sprawling and coalescing urbanized landscapes — megaregions.

Ross (2008) pictures the new scale of a *megaregion* by "*the neighborhood is a critical building block for a city, cities are now the building blocks for megaregions*". From a spatial point of view, identifying and delineating megaregions is debate to varying approaches: Marull, Galletto, Domene, and Trullen (2013) use standard subdivisions of countries — European NUTS3 borders — to delimit their analysis on megaregions. The Regional Planning Association in the USA created a scoring system using criteria such as population and employment levels as well as connectivity, and projects these spatially on administrative units of counties (Hagler, 2009). Lang and Taylor (2005) use business flow as a measure for connectivity; however, this reveals that intercontinental connections are outdoing connections to neighboring cities, and thus a spatial regionalization is difficult. Lang and Dhavale (2005) apply census data and argue megaregions include at least two metropolitan areas and more than 10 million residents among other characteristics. Yang, Song, and Lin (2014) also use demographic data to approach the spatial patterns of megaregions. Florida et al. (2008) claim that these areas grow considerably faster in population than the respective nation. Taubenböck et al. (2014) add to this argument and show that megaregions grow spatially significantly faster than individual megacities of the respective country. Ross (2008) provides various criteria to identify megaregions (e.g. transportation network data, freight exchange) and draw the boundaries using the county borders as the basic unit of analysis. Five major categories of relationships that define megaregions are suggested by the Metropolitan Institute at Virginia Tech and the Regional Plan Association (RPA): environmental systems and topography, infrastructure systems, economic linkages, settlement patterns and land use, and shared culture and history (Ross et al., 2009). All of these studies apply existing administrative boundaries for a spatial delimitation (after Ross, 2011).

Earth observation (EO) data allow uncoupling spatial units from administrative boundaries. Trullen, Boix, and Galletto (2013) as well as Florida et al. (2008) e.g. apply EO-data from the Defense Meteorological Satellite Program (*DMSP*), Operational Linescan System (*OLS*) sensor measuring night-time lights at a geometric resolution of 1.1 km to support delimiting spatial extents of megaregions independent from artificial borders. Marull, Font, and Boix (2015) also use DMSP-OLS night-time lights combined with cities as nodes, and the main road and railway infrastructures representing the edges, to measure complexity, polycentricity, efficiency and stability of networks of cities. On higher geometric resolution the E-Geopolis project e.g. derives urban areas based on EO-data and defines continuous built-up areas where at least 10.000 inhabitants live and a maximum distance of 200 m between two constructions can be measured; however, without specific classification of megaregions (E-Geopolis, 2015). Taubenböck et al. (2014) introduce a spatial approach for delineating megaregions without using administrative boundaries. They use settlement patterns derived from multisensoral EO-data (Landsat and TanDEM-X, 30 m). They prove the statement that megaregions are more than just bigger versions of a city also holds true for the evolution of their physical urban landscape. They show how once separated monocentric cities become denser and grow outward, but do not fade out to rural hinterlands, but converge to a spatial contiguity of settlements forming a polycentric landscape stretching over 100 s of kilometers, without a singular dominating spatial center as well as without obvious borders or physical boundaries.

These examples make clear, that there is no generally accepted approach or methodology to spatially define, locate and delimit megaregions. In fact, different criteria may be employed to accomplish different objectives, goals or perspectives. Ross (2011) discusses boundaries of megaregions as malleable based on regional growth and prosperity, but they should also include some capacity for flexibility depending on the purposes. Different purposes, such as environmental, economic development, and transportation planning by mode, require different criteria to delineate and operate within megaregions (Ross, 2011).

Harrison and Hoyler (2015) remark that the *rhetoric use of the term mega-region* has raced too far ahead of the sustained and rigorous empirical work needed to support many of the assertions, assumptions and claims being made in the belief that megaregions do constitute globalization's new urban scale and form. Soja and Kanai (2007) add to this argument, that these economically and geographically global centers are not yet given much attention in the urban research community. Resuming the example used in the first paragraph of this article, Soja and Kanai (2007) also critically remark, that the estimation of 50 million inhabitants for the megaregion seems to be conservative and refers to the dependency on how these regions are defined and bounded. Pain (2012) reminds scholars to be careful about using the same theoretical concepts to describe development patterns being witnessed in different places. Apparently similar urban formations in different continents, and even within the same country, may not be outcomes of the same process or, vice versa, may not result in similar spatial patterns. These new spatial forms and patterns of network relations cannot be mapped using state-centric official statistics — population, employment, commuting, etc. — as employed in traditional European 'functional urban region' analysis (Pain, 2012).

3. Earth observation for megaregion research

With respect to these remarks, this paper seeks to add empirical observations on the current settlement patterns of megaregions, their spatial contiguity between the defining city centers as well as their spatiotemporal evolution.

To do so, we derive the necessary geodata on large area settlement patterns using multisensoral EO-data. While the focus of remote sensing has long been the methodological development on classification approaches turning data into land cover information at multiple scales, recent studies in urban remote sensing are increasingly attempting to turn these land cover classifications into new geographic findings. Examples for EO-based urban studies are the quantification of dynamics of urban expansion over time (e.g. Angel, Parent, Civco, Blei, & Potere, 2011; Bagan & Yamagata, 2012; Griffiths, Hostert, Gruebner, & van der Linden, 2010; Frolking, Milliman, Seto, & Friedl, 2013; Kuang, Chi, Lu,