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ARRHENIUS: a Geostationary Carbon Process Explorer for Africa, Europe and the Middle-East

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Tropical and subtropical ecosystems play an important role in the global carbon cycle. The African tropics and subtropics is the most dynamic region of the world with respect to terrestrial carbon flux variability and population growth, which imposes direct carbon emissions and perturbations to the natural ecosystems. The underlying mechanisms such as photosynthesis, respiration, natural and man-made biomass burning, as well as fossil fuel related emissions vary on sub-daily timescales. The forcing by meteorological and climatic factors imposes a fingerprint being variable on the seasonal and inter-annual time-scale. Event-wise emissions such as caused by agricultural burning blend with episodic change in land-use practices and permanent ecosystem degradation. Thus, gaining insights into the functioning of African tropical and subtropical carbon cycling and into its sensitivity to environmental variability and perturbations needs observations from the sub-daily to the seasonal to the year-to-year time-scale. However, the African continent is poorly sampled by current and planned atmospheric observation systems. Establishing a dense and robust ground-based network is logistically challenging. Satellite observations from low-Earth-orbit (LEO) are limited to a single local overpass time per day and, they are frequently cloudy.

The Middle East and Europe are major global players in fossil fuel extraction and usage, respectively. Leakage of carbon gases has been reported throughout the extracting-processing-transportation-consumption chain. Satellite observations from LEO will become progressively available as part of envisioned surveillance concepts. These LEO sensors, however, do not capture characteristic diurnal variations of fluxes, potentially resulting in biased emission estimates and lacking the ability to discriminate between man-made and biospheric flux signals.

The AbsoRption spectRometric patHfindEr for carboN regIonal flUx dynamicS (ARRHENIUS) is a proposed mission concept that will overcome the sampling gaps in the tropics and subtropics and on the sub-daily time scale by adopting a process-focused sampling strategy from geostationary orbit (GEO). For selectable focus regions, ARRHENIUS will deliver quasi-contiguous maps of atmospheric carbon species concentrations (carbon dioxide (CO_2), methane (CH_4), and carbon monoxide (CO)) and a photosynthesis process marker (solar induced plant fluorescence (SIF)) with sub-daily, seasonal, and year-to-year coverage. These observations will be used by top-down inverse atmospheric models and by bottom-up biosphere and land-surface models to inform on regional carbon cycle processes. Being process focused instead of surveillance driven, ARRHENIUS will pioneer a flexible and intelligent sampling approach with short lead times for pointing adjustments. Sampling will be flexible with regard to focus region selection, region extent (typically 3000x2000 km^2), dwell times (typically 2h) and the number of revisits per day (up to 5 times per day), per season and per year. Sampling will be intelligent by actively avoiding regions which are predicted cloudy based on observations of meteorological sounders (such as Meteosat Third Generation) from adjacent orbits. Small footprint sizes (2x2 km^2 at sub-satellite) and flexible day-time observation hours will further support cloud avoidance.