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# What can we learn from Earth's 'skin' temperature?

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Air temperature at different altitudes in the atmosphere is well monitored from satellites on a daily basis. A less known variable is the land surface temperature, also called radiometric temperature, or as used here, skin temperature,  $T_{skin}$ : a measure of Earth's upper crust temperature. It is called 'skin' temperature since it corresponds to the radiation emitted from depths as small as 10–20 micrometres (McKeown *et al.*, 1995). The relationship between  $T_{skin}$  and the commonly used near-surface air temperature is complex: differences can reach several to ten or more degrees under cloud-free, low wind speed conditions since land heats much faster than air. On the other hand, the difference between air and skin temperature is smaller under cloudy conditions or when solar insolation is low (Good, 2016).

$T_{skin}$ , therefore, depends on the energy fluxes between the surface and the atmosphere. It is an important factor for

studying Earth's energy balance, convection at the surface, and monitoring droughts and land use, among many other applications (Rhee *et al.*, 2010; Zhou *et al.*, 2003).

## Tracking skin temperature from space

In the framework of the IASI-FT ERC advanced project, I am analysing the skin temperature (Safieddine *et al.*, 2020) provided by the family of IASI instruments (Clerbaux *et al.*, 2009) on board the Eumetsat Metop series of polar-orbiting satellites. IASI is developed by the French Space Agency CNES, and is a sophisticated and versatile mission that was designed to fulfil the needs of three communities: numerical weather prediction, climate research and atmospheric composition monitoring. IASI is a unique sounder in the satellite era, measuring 'calibrated' radiances in the thermal infrared spectral range, at a global

scale and revisiting all points on the Earth's surface twice a day. The recorded radiance spectra exhibit signatures associated with spectroscopic absorption/emission lines of molecules present along the optical path between Earth's surface and the satellite detectors. In spectral bands where nothing absorbs, we get information on the surface properties and skin temperature can be calculated.

The instrument has a very good horizontal coverage, providing more than 1.2 million (15 GB) radiance spectra per day with a footprint on the ground of 12km diameter pixel (at nadir). IASI is a groundbreaking remote sensor, allowing near-real-time mapping of chemical species and meteorological variables, contributing to our understanding of atmospheric and climate processes. More than 13 years of data are now readily available, with three instruments currently orbiting around the Earth.

## Applications

Skin temperature is affected by surface properties directly, and since Earth's surface is continuously changing,  $T_{skin}$  is too. Its monitoring can have many applications.

## Urban heat/cool islands

In popular culture, we hear that cities are warmer than rural areas, and this is translated in the skin temperature as we show it here for Paris with the satellite observations. This is known as the urban heat island effect. The temperatures during the day and the night in central Paris can be up to 1.5° higher than the suburbs in June, July, August (JJA) during the day, and up to 3° higher during the night. Skin temperature depends on surface properties which are directly affected by human activity: during the day, the hot island effect is more centred on Paris itself due to the high anthropogenic activity (traffic, industry, etc.). At night, this effect also shifts to the suburbs, where a good part of the population lives. This shows that within 100km, cities and their suburbs consist of a patchwork of different environments and surface characteristics with contrasting radiative, thermal and moisture properties. Urbanisation and future urban expansion will therefore have a direct effect on the energy exchanges between the surface and the atmosphere.

In Riyadh (Saudi Arabia), a city located in the middle of the desert, on the contrary, the city acts as an urban 'cool' island: it is colder than its surroundings, but only

Land surface temperature or 'skin' temperature tells us how land-use change affects Earth's temperature.

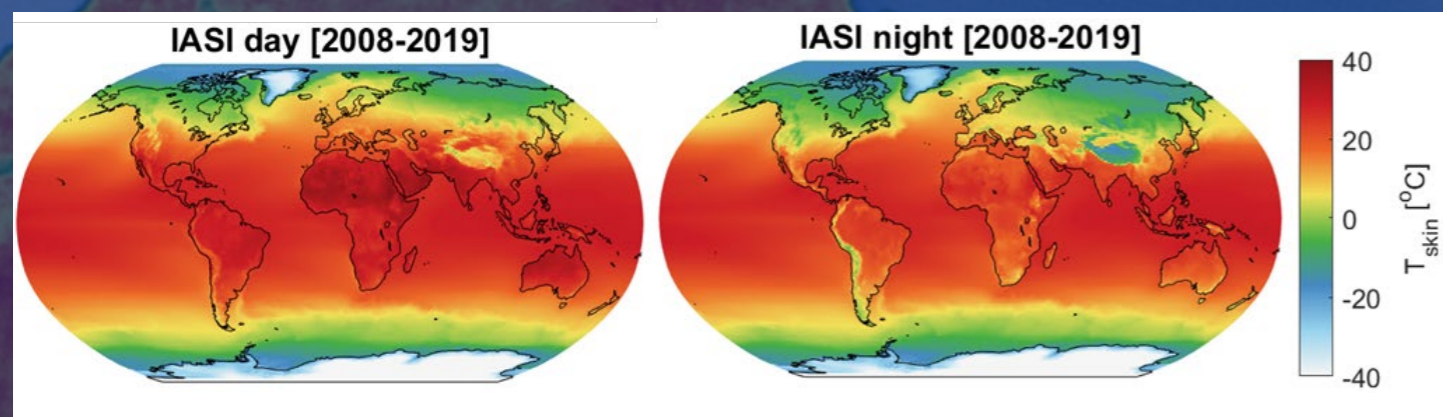


Figure 1: Global skin temperature average over 12 years from IASI day (left) and night (right) observations. We can see latitudinal skin temperature variability. Temperature is also lower at night, much like air temperature.

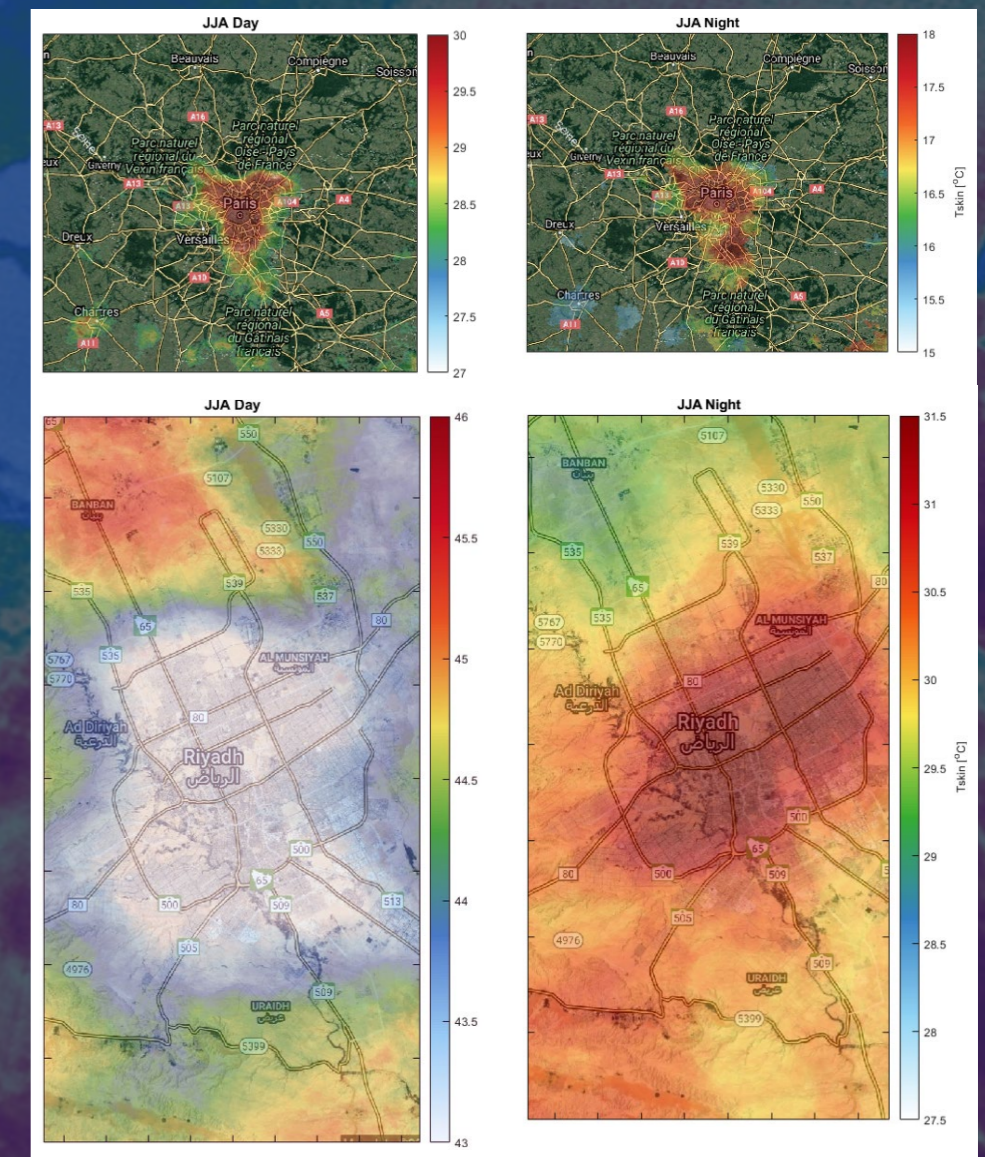


Figure 2: IASI day and night observations of skin temperature during summer (June, July and August) for Paris and Riyadh. Paris during the day and the night is warmer than the suburbs. In Riyadh, the capital located in the desert of the Arabian Peninsula, the city exhibits the opposite effect during the day and acts as an urban 'cool' island. Both examples show how humans intervene through urbanisation to the thermal energy balance.

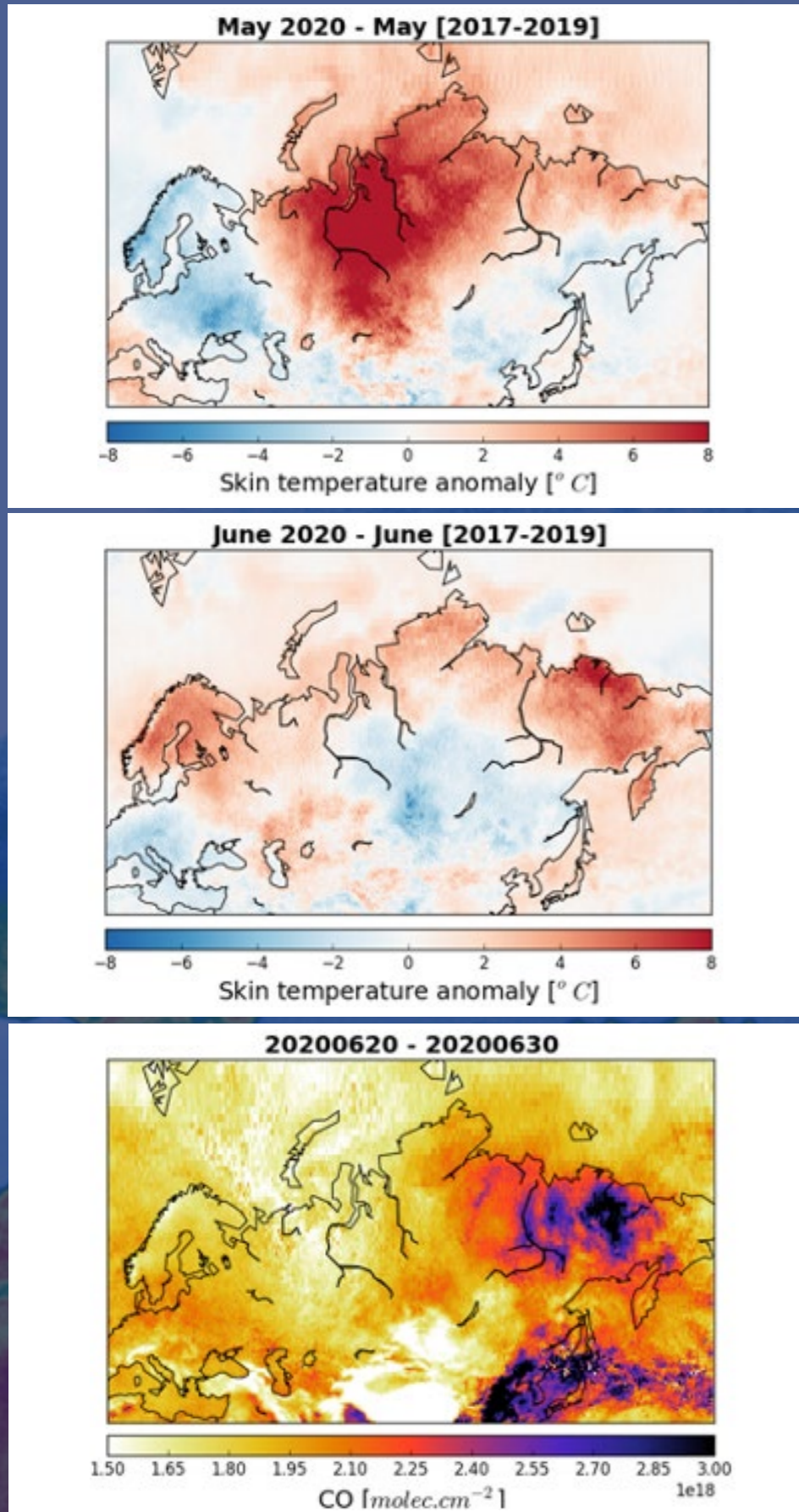


Figure 3: May and June 2020 were unusually hot with skin temperature anomalies reaching more than 8° in Russia. This translated in a heat-wave and a drought and consequently in large fires in Siberia. The lower panel of this figure shows carbon monoxide concentrations from IASI, used as a tracer for fire activity.

during the day. While this is uncommon for cities, desert cities commonly exhibit this effect. With high solar radiation (as it is the case in summer), the desert sand becomes very hot, with skin temperatures reaching 60–70°C. Imagine being on the beach on a very sunny hot day. Without proper sandals, your feet will burn. If the air temperature is 30°C, the sand temperature can be tens of degrees hotter. In short, and under sunlight, sand is probably one of the hottest surfaces on the planet, and therefore cities in the desert with buildings, roads, and parks are cooler than the desert, hence the urban cool island effect. At night, the desert sand cools faster than the urban city, and Riyadh becomes a typical urban heat island.

### Heat-waves and fires

The unusually high temperature in Russia during May 2020 triggered droughts that in turn led to huge fires, mainly in eastern Siberia. The Russian Forest Management Agency reported that by early July, 14 million hectares (more than the area of Greece) had burned. In these uninhabited areas, the uncontrolled fires generated smoke visible on many satellite images. The fires generated carbon monoxide, a typical fire tracer, which is easily monitored with the IASI instrument (Figure 3).

With climate change, more frequent heat-waves, droughts, and fires are expected. As Figure 4 shows, 2020 was particularly hotter than the average for many countries in Europe. In fact, North European countries exhibited in 2020 positive anomalies of +2 degrees, and even France and Belgium recorded all year long similar positive anomalies.

With an unyielding urban expansion, frequent extreme events and climate change will be exacerbated. Current and future satellite missions will be able to monitor these effects from space, and skin temperature is a valuable tracer to follow the impact of land-use change on Earth's thermal balance.

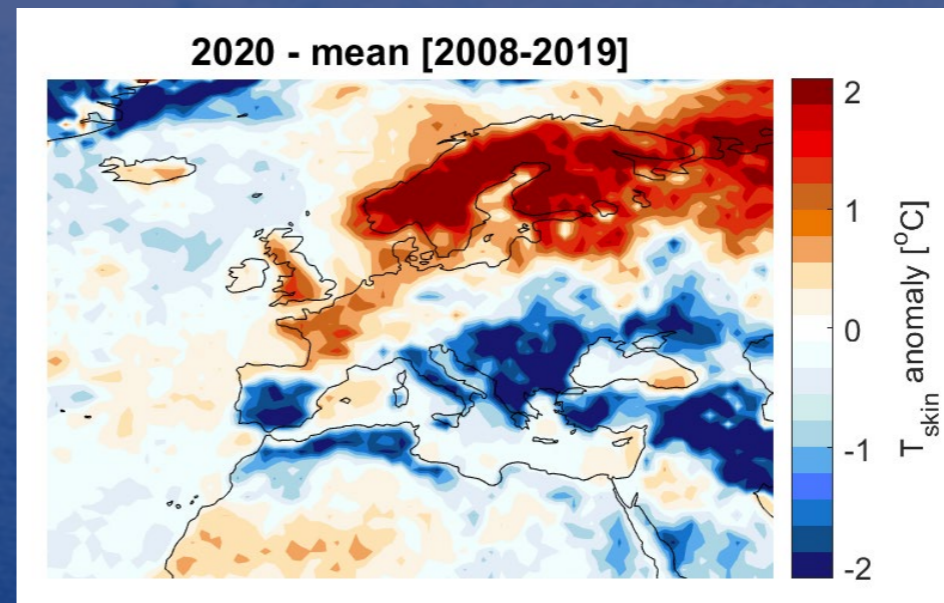


Figure 4: Skin temperature anomaly in 2020, calculated as the  $T_{skin}$  annual average – the mean of all other years of IASI observations.

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### PROJECT NAME

IASI-FT

### PROJECT SUMMARY

The ERC advanced "IASI-FT" project exploits the space-based instantaneous spectrally resolved observations provided by the family of IASI thermal infrared instruments to (1) monitor atmospheric composition changes and (2) establish climate records.

More than 3.5 million of data are available each day, from which near-real-time and information on the atmospheric state can be inferred.

### PROJECT LEAD PROFILE

Sarah Safieddine is currently a CNRS research scientist and works at LATMOS/IPSL (Sorbonne Université, Paris). She has a PhD from Sorbonne University (2015). She spend two years as a postdoctoral associate at the department of civil and environmental engineering at the Massachusetts Institute of Technology (MIT), followed by two years of postdoc at LATMOS before getting her CNRS position. Sarah is an expert in satellite remote sensing for the study of atmospheric composition and more recently interested in temperature and the biosphere-atmosphere interactions.

### PROJECT PARTNERS

The IASI-FT team resides in two locations. The LATMOS group is part of the Sorbonne University, downtown Paris. The SQUARES group is established at Université Libre de Bruxelles. This configuration has already led to numerous papers on atmospheric chemistry over the past 18 years, strong international collaborations, outreach actions/media interest, and sustainable distribution of data for societal purposes.

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