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## **New Directions: Infrared remote sensing of the troposphere from satellite: Less, but better**

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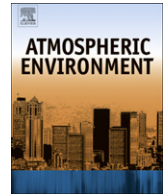
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### New Directions: Infrared remote sensing of the troposphere from satellite: Less, but better<sup>☆</sup>



Satellite observations have provided a continuous survey on the state of the atmosphere for the past three decades. Current spaceborne instruments feed the weather forecasting models, contribute to climate assessment, and monitor rapid changes in tropospheric composition. Tracking episodic events such as fires, volcano plumes or pollution peaks is now possible from space.

In terms of Earth observing capability, the horizon is shrinking as only a few new satellite missions have been approved and will be financed in the coming years. Since there is a substantial delay between the planning and conception of a mission and its actual launch, there is rising concern that in the 2020–2030 timeframe, our ability to monitor the atmosphere will strongly decline [e.g. [National Academy of Science Report, 2012](#)]. This is particularly true for polar-orbiting infrared sounders<sup>2</sup> that have been flying since the beginning of the observation era.

Infrared nadir viewing instruments use the thermal radiation emitted by the Earth's surface and the atmosphere to measure atmospheric spectra. The recorded radiance spectra exhibits signatures associated with spectroscopic absorption/emission lines of molecules present along the optical path between the Earth's surface and the satellite detectors, from which geophysical data such as temperature profiles and atmospheric concentrations can be derived. Several missions based on this principle are currently in polar orbit, with various characteristics: Mopitt/TERRA (since 2000), AIRS/AQUA (since 2002), and TES/AURA (since 2004) forming the US EOS "afternoon" constellation of satellites; the TANSO sensor flying on the Japanese GOSAT platform (since 2009); the CrIS spectrometer on the US NPP satellite (2011); and finally the two IASI instruments embarked on the EU MetOp suite of "mid-morning" satellites (MetOp-A since 2006 and MetOp-B launched in 2012).

The selection of a satellite mission is a long-term process involving research and operational communities, industry and space agencies. Scientists first define the goals of the mission, establish the scientific requirements to fulfill these goals (what to measure, with which accuracy, and at what spatial/temporal sampling) and then translate these needs in terms of instrumental specifications (what spectral range, which radiometric performance/spectral resolution, what footprint/horizontal coverage). Industry – usually

under the umbrella of a space agency – then designs a concept of instrument and iterations with scientists allow to prioritize the requirements and to relax some specifications if needed.

Cost versus "societal benefit" is the driving factor for a mission's selection. The cost of an instrument depends on technical feasibility, on the weight/size of the instrument, and on the availability of existing expertise/previous instruments using the same technology. The societal benefit encompasses a range of different factors covering enhancement of the scientific knowledge, direct/indirect benefit to industry, saving money, improving societal welfare or life/health preservation. And this cost–benefit ratio has to be modulated by the launch opportunity, which depends on space agencies' priorities, international cooperation, commercial opportunities, and is linked to the political/economic context.

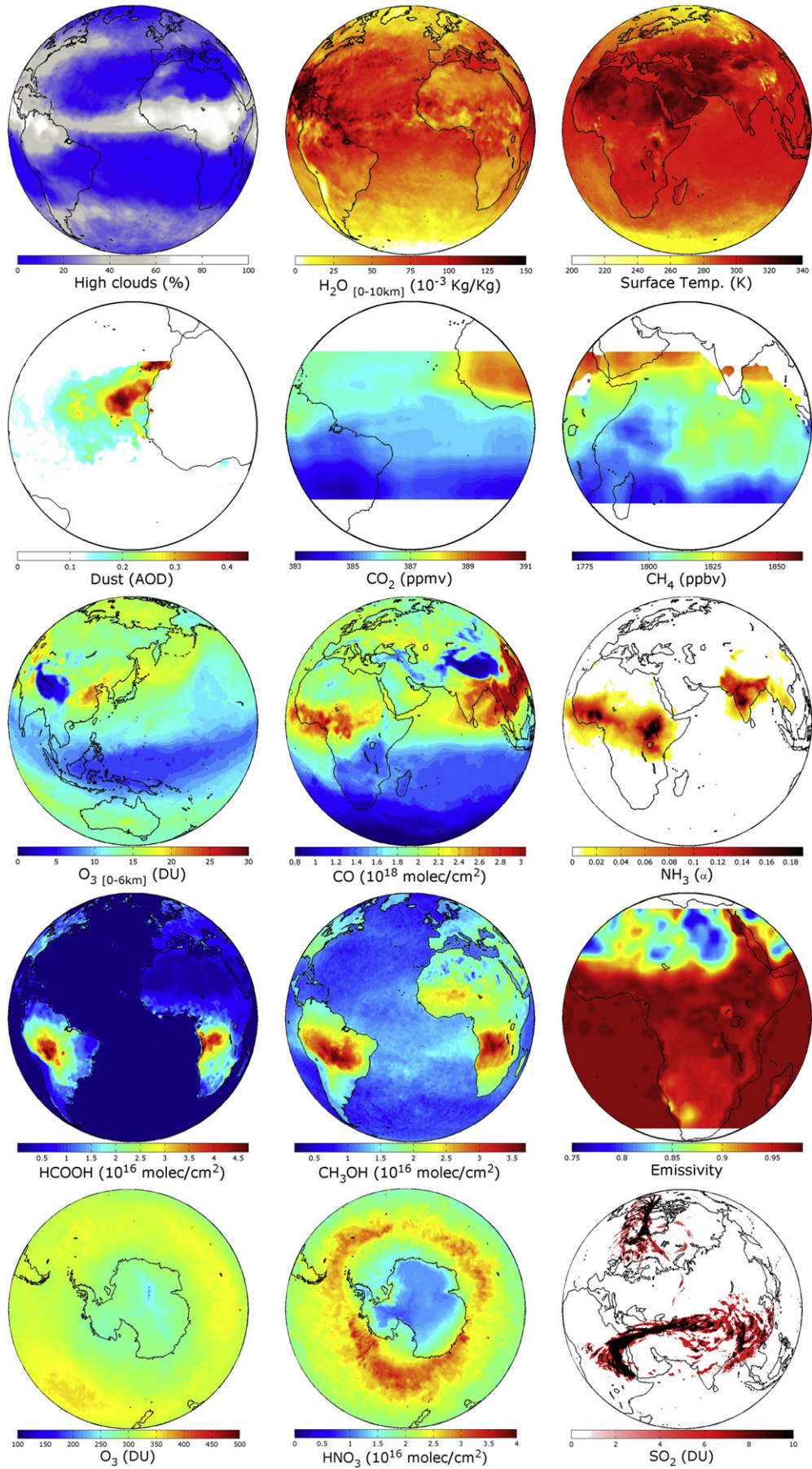
The IASI/MetOp mission is an expensive but versatile mission that fulfills the needs of three different communities: numerical weather forecast, climate research and atmospheric composition monitoring. In order to converge on the design of such an instrument all three communities had to make "reasonable accommodations". The IASI sounder provides observations of meteorological/climate variables, as well as more than 25 atmospheric species (see [Fig. 1](#)),<sup>3</sup> including some reactive gases that were never thought to be measurable from space (e.g. ammonia, formic acid, acetylene, hydrogen cyanide). It combines the advantages of several of the previously launched sensors, and continuity in the monitoring will be insured by the launch of IASI on three successive MetOp with radiometric and spectral stability, making it suitable to record long-term series of climate variables. Six years after the launch of the first IASI, it is now recognized that it has the largest single impact of any instrument on any satellite for weather forecast, and it is also an exceptional sensor for atmospheric composition changes monitoring.

In the future instruments will need to evolve to deliver observations at the scale and level of detail desired by users and decision makers: there is a need for continuity in the observation, with more frequent overpasses, more information closer to the surface, along with smaller footprints to avoid clouds. Plans continue to develop future Earth observing missions, but in light of the changing financial situation in the US and Europe, there is some urgency to rationalize our needs in terms of Earth observing missions for the future. Europe now conveys much of the satellite effort for future Earth atmospheric observation from space, with foreseen meteorological payloads with

<sup>☆</sup> Something to say? Comments on this article, or suggestions for other topics, are welcome. Please contact: [new.directions@uea.ac.uk](mailto:new.directions@uea.ac.uk), or go to [atmos.env@uea.ac.uk](http://atmos.env@uea.ac.uk), <http://www.elsevier.com/wps/find/journaldescription.cwshome/246/authorinstructions> for further details.

<sup>2</sup> Here we focus on passive remote sensors that exploit the thermal infrared spectral range to probe the troposphere, but the same reasoning may apply for active sensors, instruments using other spectral ranges, and stratospheric sounders.

<sup>3</sup> See: [http://smc.cnes.fr/IASI/Fr/A\\_publications.htm](http://smc.cnes.fr/IASI/Fr/A_publications.htm) for more information on the IASI products.



**Fig. 1.** Global maps for some of the products measured by the IASI mission. Reddish colors indicate high values. Some species, e.g.  $\text{SO}_2$ , are only observable under specific conditions such as when a volcano erupts.

atmospheric chemistry sensors onboard: in 2020 there should be an unprecedented combination of more frequent observations with smaller footprints provided from the geostationary orbit (Meteosat Third Generation (MTG)/Sentinel 4 program), along with more precise measurements from the polar orbit (MetOp-Second Generation satellites as part of the EPS-Second Generation/Sentinel 5 program). Together with several other instruments, the latter should embark the IASI-New Generation (IASI-NG) mission, currently designed by CNES,<sup>4</sup> that builds on the heritage of IASI, with both the spectral resolution and the signal/noise ratio improved by at least a factor of two. This will enable the detection of even more species, and make it possible to probe deeper in the troposphere with more accuracy. With the launch of three successive IASI-NG starting from ~2020, more than 20 years of observations will be added to the 15 years from IASI. As for IASI, all the data will be freely available to all, almost in real time.

The claim that we are reaching the end of a golden age for atmospheric sounding from space is misleading. There is indeed a decrease of foreseen atmospheric remote sensing instruments in terms of number, in particular for the afternoon orbit covered by the US. But envisioned tropospheric sensors will surpass

the performances of current instruments and should continue to feed the current scientific/societal needs and also open new possibilities, provided a good temporal sampling is insured.

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