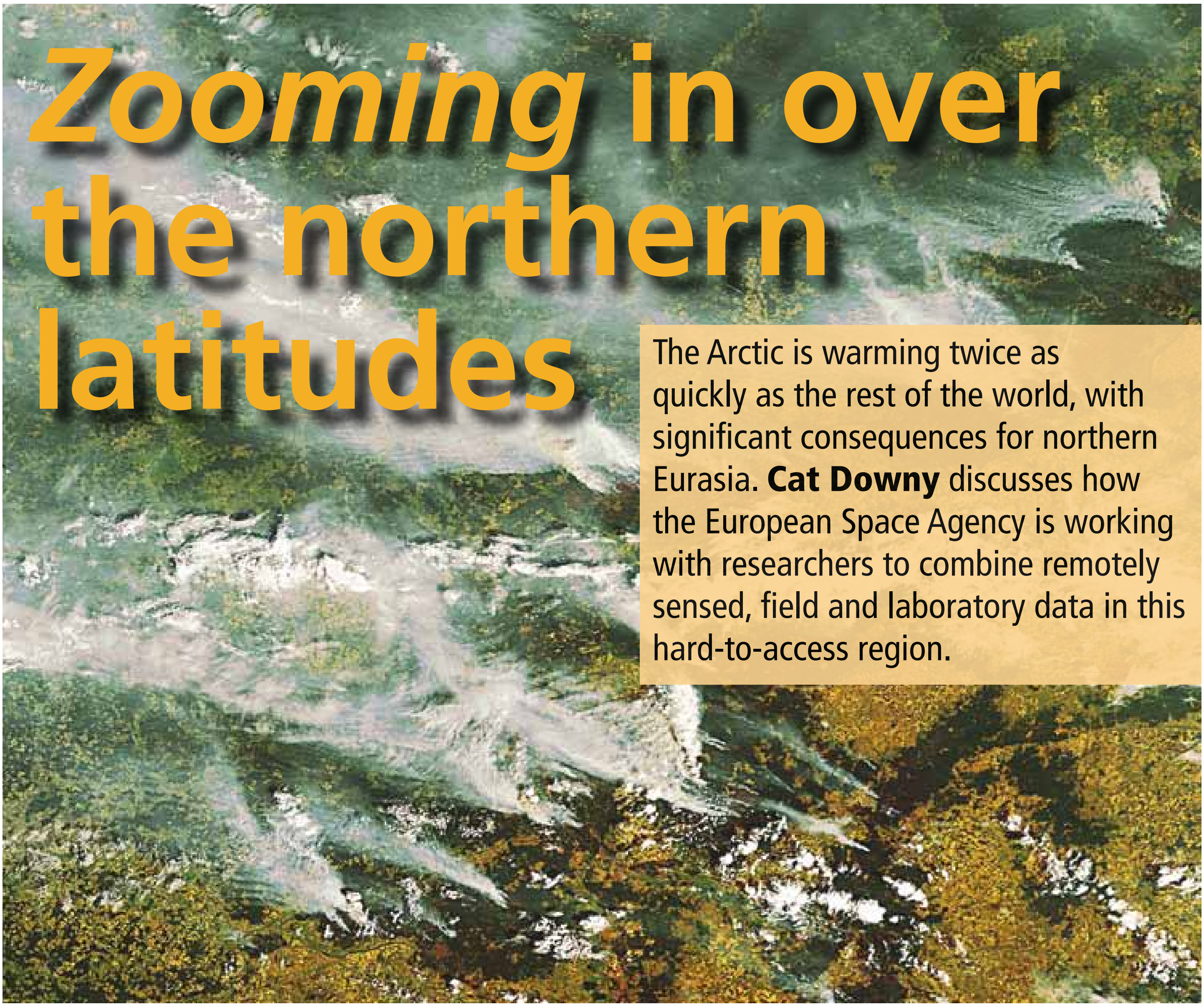
Zooming in over the northern latitudes

The Arctic is warming twice as quickly as the rest of the world, with significant consequences for northern Eurasia. **Cat Downy** discusses how the European Space Agency is working with researchers to combine remotely sensed, field and laboratory data in this hard-to-access region.



European Space Agency/Envisat. Smoke over Moscow.

Warming-induced changes are progressing faster than predicted in some boreal regions, suggesting a potential non-linear response to climate change. Despite this, we know comparatively little about the response of the Eurasian boreal zone. Although a limited number of sites are well studied, the size and inaccessibility of the land area pose a challenge for monitoring, measuring and assessing how changes feed back into regional and global climate. This is not ideal given this vast region represents the largest terrestrial ecosystem on Earth and is estimated to store more carbon than the temperate and tropical forests combined.

Thawing permafrost could release huge amounts of carbon.

Satellites provide a wealth of observations on the land-atmosphere interface in northern Eurasia. We need to transform these into information that will help us understand the climate system. With this in mind, the European Space Agency (ESA) has set up several projects with scientists working in the tundra and boreal regions. These projects combine satellite observations with field and laboratory data in innovative ways to provide better services for monitoring and tracking environmental changes. Here I consider three examples of how this collaboration might increase our understanding.

Monitoring permafrost

In a warming world, thawing permafrost could release huge amounts of carbon and methane to the atmosphere (see page 12 of this issue); monitoring changes to the permafrost is thus critical. The ESA Permafrost project brought together groups of scientists specialising in permafrost, in conjunction with the International Permafrost Association (IPA), to develop observations and tools to monitor permafrost. Existing satellite products of key indicators of permafrost change were harmonised, adapted and validated over three scales – local, regional and pan-Arctic – in response to a range of user requirements. The pan-Arctic products cover all permafrost-affected areas north of 55°N, while five regional service cases have been identified for higher resolution products.

A 'Permafrost Processing System' integrates the new satellite products with existing information on the state of permafrost. Where there is enough information, the system automatically processes new data to update features such as land-surface temperature, soil moisture, surface state (frozen/unfrozen), and lake distribution. This allows updates on some features to be sent out to the permafrost community on a weekly basis. The new datasets are available online along with tools to visualise the data, and also via the PANGAEA Open Access library (DUE Permafrost Project Consortium 2012). These products have also proven useful beyond the monitoring of permafrost; some have already been used to test regional models, such as land-surface models as well as global climate models. Others have applied the products to test tree ring series of ^{13}C and for coastal erosion and weathering studies.

Methane emissions

Although the total quantity of methane emitted each year is fairly well understood on a global scale, the sources of methane and their spatial and temporal distribution are not well constrained. Boreal Eurasian lakes and wetlands are a significant source of natural methane emissions but remain poorly quantified. ESA's ALANIS (Atmosphere-LANd Interaction Study) Methane project uses satellite data to test the UK Met Office's land-surface model JULES. During the project, datasets of regional and local wetland-extent dynamics, snowmelt onset/duration/end, freeze onset and atmospheric methane concentrations were developed, extended and improved (Bartsch *et al.* 2012). These were then used in the first large-scale evaluation of the JULES wetland emission scheme, with the aim of improving its estimates of methane emissions. The datasets were able to successfully highlight areas for improvement – for example, the treatment of wetland hydrology and atmospheric chemistry – with a view to increasing our confidence in climate models. The importance of consistency when evaluating models was also made clear, both in terms of defining parameters and coverage in time and space, the latter being more important than having high-resolution data.

Smoke-plume heights

Biomass burning events in boreal regions have consequences for carbon storage and can have a significant impact on the atmospheric chemistry from regional to global scales. Most fires deposit their emissions in the atmospheric boundary layer (below about two kilometres). However, in certain conditions and particularly at high latitudes, fire emissions can be injected into the upper troposphere or even higher, in the lower stratosphere (around 10km). Here the trace gases and aerosols have a much longer lifetime and therefore have a much longer lasting impact on the atmosphere, over a greater region.

The ALANIS Smoke Plume project is helping put together more reliable knowledge of plume injection heights, as well as a proper tracing of related fire emissions into the atmosphere. We can model these processes much better as a result of the new satellite products for fire-burned area, carbon monoxide (CO) emissions and plume injection height developed by the project (Muller *et al.* 2011). The integration of atmospheric CO into a land-atmosphere model, specifically designed to characterise fire-plume dispersal, confirmed that smoke plumes can be tracked reasonably well with satellite data. But it also highlighted a number of interesting discrepancies between estimates of fire emissions. For a few fire events the emission estimates were much higher than originally modelled; in these cases it was found that the extra emissions came from peat burning below ground. Peat burning is hard to account for using standard approaches to emission estimates but has important consequences for long-term carbon storage and therefore its representation in land-surface models needs improving if we are to understand future climate feedbacks.

Peat burning is hard to account for using standard approaches.

Our understanding of climate change in the northern latitudes hinges on steady and continuous monitoring. ESA will continue to work with IGBP and other communities to ensure that this need is met. ■

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