can measure thousands of atmospheric chemicals at once. My team and our collaborators have shown how a rounded set of environmental measurements can be obtained at one station, called SMEAR II (Station for Measuring Ecosystem-Atmosphere Relationships), in the boreal forests of Finland.

Regional initiatives to combine and broaden space- and ground-based monitoring are established well enough to roll out similar stations globally. These include PEEX (the Pan Eurasian Experiment) and the DBAR (Digital Belt and Road), a research initiative related to China's One Belt and One Road Initiative — a development strategy covering a swathe of 65 countries between China and Europe that reaches as far south as Kenya. The World Meteorological Organization (WMO) is taking steps to establish a global observatory. And the urgency is here: carbon emissions must decline after 2020 (ref. 8).

The scale of the enterprise remains daunting. It requires a wholesale shift in how environmental data are collected and disseminated.

AN INTEGRATED NETWORK

Incomplete coverage from ground stations is the main limit to observations of Earth's conditions. Satellites can continuously monitor some compounds, such as CO_2, ozone and aerosols, almost planet-wide. But they cannot resolve processes or fluxes, or trace the hundreds more compounds of interest. Satellite data must be 'ground-truthed'. Models need data to validate them.

Current networks of ground stations have been set up without considering the big picture. Each discipline or team designs and builds stations to suit its purpose. Greenhouse gases, atmospheric chemicals and ecosystems are monitored at different sites. Funding agencies focus on national interests.

The SMEAR II station takes a more integrated approach. Using state-of-the-art atmospheric mass spectrometers, cloud radars and lidars (light detection and ranging instruments), it observes more than 1,000 variables. These include greenhouse gases, trace gases and aerosols, as well as indicators of photosynthesis, soil temperature, moisture and nutrient gradients.

The challenge is to set up similar stations around the world — and to incorporate local expertise. Good places to start would be the three global regions where coverage is sparse, and in megacities.

HOT SPOTS

The Arctic and boreal regions. Former Soviet Union countries, including Russia and Kazakhstan, are crucial laboratories for global change. They are rich with minerals, oil and natural gas: Siberia contains 85% of Russia's prospected gas reserves, 75% of its coal and 65% of its oil reserves. And climate change is rapidly altering their environments. There is much we don't know. How rapidly will permafrost disappear? Does Arctic greening sequester carbon or produce aerosols? Will methane emissions increase drastically, and so ramp up global warming?

In this region, as elsewhere, researchers need to observe aerosols together with greenhouse gases (such as CO_2 and methane) and other trace gases (volatile organic compounds, nitrogen oxides, ozone, sulfur dioxide, carbon monoxide and ammonia). Two stations are starting to increase the range of observations that they can make: the Tiksi Hydrometeorological Observatory in the River Lena delta in eastern Russia and the Zotino Tall Tower Observatory (ZOTTO) in southwest Siberia, 500 kilometres from Tomsk. Ideally, to cover the region, around 30 comprehensive stations will be needed, spaced 1,000 kilometres apart. A global observatory must appear on the agendas of upcoming meetings of the Russian government and the Arctic Council.

Africa. The continent's population is increasing fast — it has doubled since 1987, and it reached 1.2 billion people in 2015. Meanwhile, once-fertile areas have become dry, challenging water and food supplies and requiring strategies to store rainwater and retain soil moisture[9]. Water and other biogeochemical cycles need to be understood better. But monitoring in Africa is limited mainly to short-term observations of carbon sinks and sources (by the global network FLUXNET) and to some air-quality observations that measure about a dozen variables.

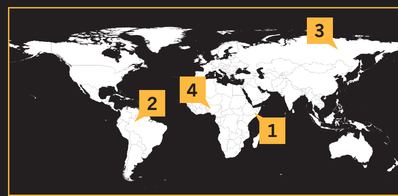
A minimum of 30 stations should be built in Africa. These must comprise at least one in each main ecosystem that is relevant to food and water, including rainforests, savannahs and semi-deserts. Prime sites should be identified with local organizations and scientists. United Nations organizations, development banks and private foundations that work in Africa should add their support.

South America. The Amazon basin is a crucial place to monitor, owing to its vast area and influence on global carbon and hydrological cycles. It forms its own climate system, which is changing[10] as a result of agricultural expansion and deforestation. These disturbances, together with climate shifts, will affect carbon storage and water cycles. Yet there is little information available, and no combined observations. Only the Amazon Tall Tower Observatory (ATTO), located about 150 kilometres northeast of Manaus, Brazil, is taking steps to increase the range and continuity of data obtained.

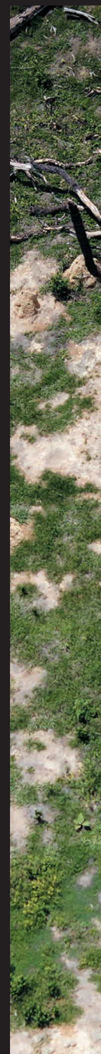
South America needs at least 20 such stations: 7 should be located in the Amazonas region. The exact sites need to be identified with local scientists and organizations.

Four hot spots

Setting up stations to monitor air, soil and ecosystems across Eurasia, Africa, South America and in major cities would fill crucial gaps in a global observatory network.



1 African nations such as Somalia need better monitoring of water cycles to improve strategies that help to retain soil moisture.



Cities. Urban areas are growing: the urban population has tripled since 1970. More than 55% of the global population lives in urban areas. Better data on air quality is a particularly pressing need. Currently, fewer than 15 variables are typically observed at sites in urban areas, and the data quality is often poor.

More than 30 megacities worldwide each contain greater than 10 million people, and hundreds of cities have populations in the millions. Each large metropolis should have at least one comprehensive observatory and a suite of simpler local stations. The Global Mayors' Forum should put the global observatory on its agenda, as should the G20 countries.

COST EFFECTIVE

A global observatory, comprising a network of 1,000 super stations, needs to be established within 10–15 years. Costs would be around €10 million (US$11.8 million) to €20 million per station, or €10 billion