Figure 1 | Monitoring the expansion of flowering plants in the maritime Antarctic. Antarctic hair grass — seen in the foreground of the image, which was taken at Anchorage Island, Marguerite Bay, close to Rothera research station in the Antarctic Peninsula — has expanded rapidly over the past 50 years in maritime Antarctica, out-competing the mosses and other lower plants that dominate the vegetation of these ice-free areas. Hill and co-workers[3] show that the grass is able to take up nitrogen in the form of short-chain proteins, which are released during the early stages of decomposition of the protein-rich soils in Antarctica. They propose that this ability gives the species access to a store of nitrogen that is not available to mosses, allowing it to take full advantage of the favourable effect of rising temperatures on photosynthesis in the region.

forms might be the key to explaining the success of Antarctic vascular plants. Using a series of experiments in which they added inorganic forms of nitrogen, amino acids and peptides to soils and plants from Signy (an island off the coast of the Antarctic Peninsula), they explored how Antarctic hair grass acquires nitrogen in the field. Their results provide compelling evidence that the species is able to take up nitrogen as short peptides, and, moreover, that it is able to do so in the presence of microbes, which compete for nitrogen in this form. In fact, the plants acquired nitrogen in this form more than three times faster than they acquired it as amino acid, nitrate or ammonium, and more than 160 times faster than the mosses with which it competes for soil nutrients, indicating that this process operates in the field as well as the laboratory.

Warming of cold Antarctic soils is likely to increase the rate at which the protein-rich organic matter within them decomposes, potentially providing a substantial new source of nitrogen. In this context, the ability of Antarctic hair grass to acquire nitrogen more efficiently than its competitors might provide an important advantage, allowing the species to exploit the beneficial effects that warming has on photosynthetic activity in polar regions. Hill and colleagues propose that this advantage, together with the ability of higher plants to access a larger volume of soil than mosses and other so-called lower plants through their root system, is likely to explain the recent proliferation of Antarctic hair grass in maritime Antarctica.

Antarctic temperatures are still significantly below the 'photosynthetic optima' of both Antarctic hair grass and Antarctic pearlwort[9]. If the conclusions drawn by Hill and colleagues[3] are correct, Antarctic flowering plants are likely to continue to benefit from warming as the supply of nitrogen from decomposition of soil organic matter continues to grow. Vegetation dynamics in the polar regions of both hemispheres should be monitored closely over the coming years to further test this important hypothesis, and to determine whether this pattern of change represents a more widely applicable model of the impacts of climate warming in polar regions. ❐

Nicoletta Cannone is at Insubria University, Department of Chemical and Environmental Sciences Via Lucini, 3, 22100 Como, Italy.
e-mail: nicoletta.cannone@uninsubria.it

References

1. Turner, J. *et al. Antarctic Climate Change and the Environment* (Scientific Committee on Antarctic Research, 2009).
2. Turner, J. *et al. Int. J. Climatol.* **25,** 279–294 (2005).
3. Hill, P. W. *et al. Nature Clim. Change* **1,** 50–53 (2011).
4. Convey, P. & Smith, R. I. L. *Plant Ecol.* **182,** 1–10 (2006).
5. Day, T. A., Ruhland, C. T. & Xiong ,F. S. *Glob. Change Biol.* **14,** 1827–1843 (2008).
6. Vitousek, P. M. & Howarth, R. W. *Biogeochemistry* **13,** 87–115 (1991).
7. Näsholm, T., Kielland, K. & Ganateg, U. *New Phytol.* **182,** 31–48 (2009).
8. Komarova, N. Y. *et al. Plant Physiol.* **148,** 856–869 (2008).
9. Xiong, F. S. *et al. Physiol. Plantarum* **106,** 276–286 (1999).

ATMOSPHERIC SCIENCE

Tug of war on the jet stream

Recovery of the ozone hole and increasing greenhouse-gas concentrations have opposite effects on the jet stream. New model experiments indicate that they will cancel each other out over coming decades, leaving storm tracks at a stand still.

Judith Perlwitz

Over about the past 30 years, depletion of the ozone layer over Antarctica has had a greater effect on climate in the Southern Hemisphere than rising greenhouse-gas concentrations, causing a polewards shift of wind and precipitation patterns. Since about 2000, the so-called ozone hole has stopped enlarging and it is expected to close completely sometime after the middle of the century, in response to a ban on the production and use of ozone-depleting substances under the Montreal Protocol. This raises the question of whether wind and precipitation patterns will revert to their pre-ozone-hole conditions as the ozone layer recovers. Two new studies — one by Polvani and colleagues[1]

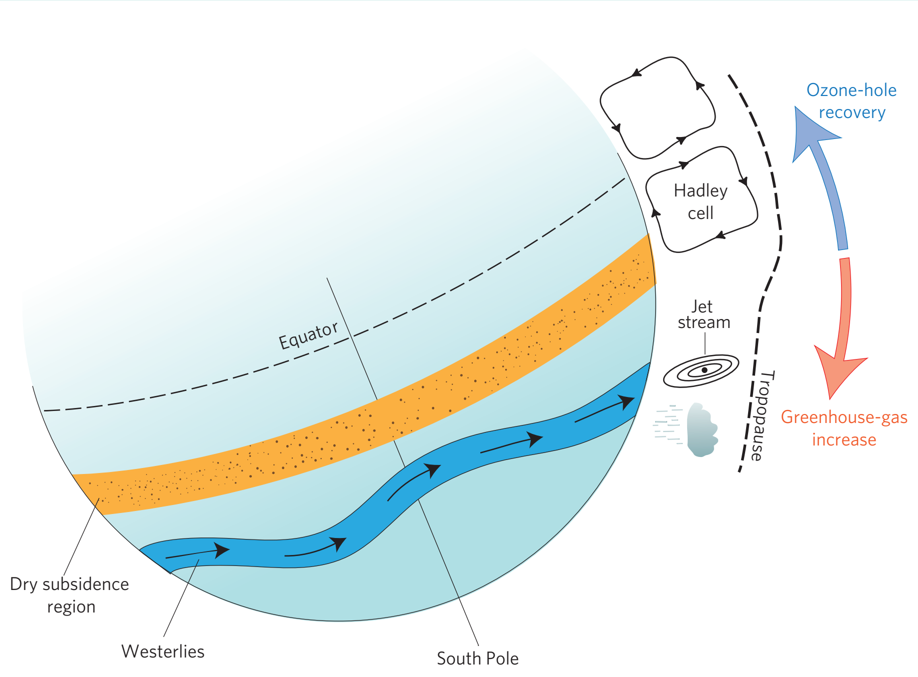

Figure 1 | Impact of greenhouse-gas increase and ozone-hole recovery on climate. The locations of the westerly jet stream and the southern boundary of the Hadley cell, along with the storm tracks and subtropical dry zones associated with them, are affected by increasing greenhouse-gas concentrations and the recovery of the Antarctic ozone hole. Ozone-hole recovery causes them to shift towards the Equator (blue arrow) and increasing greenhouse-gas concentrations drive them towards the South Pole (red arrow). Polvani *et al.*[1] and McLandress *et al.*[2] explored the impact of these two anthropogenic climate forcings on atmospheric circulation and hydrological features over the twenty-first century using climate models. Both studies found that the location of circulation and precipitation patterns will not change during Southern Hemisphere summertime because the two forcings will cancel each other out.

in *Geophysical Research Letters* and the other by McLandress and colleagues[2] in *Journal of Climate* — show that as the ozone hole closes, increasing greenhouse-gas concentrations will counter the effects of ozone recovery, preventing atmospheric circulation from returning to 'normal'.

The ozone layer — located approximately 13 to 40 km above the surface of the Earth — protects life on Earth by absorbing ultraviolet radiation from the Sun. Depletion of the layer not only increases harmful ultraviolet radiation at the Earth's surface, but also affects Southern Hemisphere climate from the South Pole to the subtropics[3,4]. The depletion of Antarctic ozone occurs primarily during late winter/early spring, causing a cooling of the polar stratosphere owing to reduced absorption of ultraviolet radiation. This cooling leads to a delayed summertime response in the lower atmosphere, characterized by a polewards shift of the jet stream that is associated with westerly winds at mid latitudes. This shift has direct consequences for weather at the surface because the jet stream — which is a band of strong winds about 7–12 km above the surface — determines the tracks of storms at mid and high latitudes.

Recent studies show that ozone depletion also causes a polewards expansion of the southern boundary of the so-called Hadley cell — a circulation loop that dominates the tropical atmosphere. In the Hadley cell, which is symmetric about the Equator, air rises near the Equator, flows towards the pole at a height of about 10 to 15 km, descends in the subtropics (at about 30° S and 30° N) and flows back towards the Equator near the surface. The descending branch contributes to the subtropical dry zones, so polewards expansion of the Hadley cell would be accompanied by a polewards expansion of these dry zones, with consequences for water resources and food production in these areas[5,6].

The human-induced increase in greenhouse-gas concentrations is expected to have a similar effect as Antarctic ozone depletion on the location of the Southern Hemisphere jet stream and the Hadley-cell boundary[7]. During the period from 1960 to 2000 these two human-induced climate drivers joined forces, causing a polewards shift of the summertime mid-latitude jet stream in the Southern Hemisphere on the order of about 230 to 300 km, with ozone depletion being the dominant force[2,4]. While greenhouse-gas concentrations are anticipated to continue rising over coming decades, the Antarctic ozone hole is expected to close, so these two factors will begin to exert competing influences on the location of the westerly jet and dry zones. The 'winner' of this competition has not yet been determined.

Climate models of various complexities have been compared to try to determine how climate will respond to these counteracting forces over the coming decades, but these studies have yielded conflicting results[8,9]. This is believed in part to be due to oversimplification of chemical and dynamical interactions in the atmosphere in the models. It is also partly due to the lack of systematic investigation of the impact of the two anthropogenic climate forcings when acting alone and in combination. The new studies by Polvani *et al.*[1] and McLandress *et al.*[2] largely overcome these shortcomings.

McLandress and co-workers[2] used a model that simulates the chemistry and physics of the atmosphere coupled to a model that simulates the ocean and sea ice to address the question, running it several times for the period from 1960 to 2100. Their model not only calculates the evolution of the ozone layer, but also calculates the sea surface temperatures that result from changes in ozone-depleting substances and greenhouse-gas concentrations. Taking a slightly different approach, Polvani and co-authors[1] forced an atmospheric model with pre-defined reduction of the ozone hole and sea surface temperatures taken from simulations made with a coupled ocean–atmosphere model.

Both studies come to the same conclusion. In model experiments in which only the ozone-hole recovery is simulated (greenhouse-gas concentrations do not change and are kept at current levels), the jet stream and southern Hadley-cell border move back to their pre-ozone latitude. In model experiments in which only greenhouse-gas concentrations increase, the jet stream keeps moving polewards. However, when both ozone recovery and greenhouse-gas forcings are included in the simulations, the jet stream and Hadley-cell border stay more or less at their current locations.

Thus, the recovery of the ozone hole is expected to cancel out changes in climate conditions due to increasing greenhouse-gas concentrations over the coming decades. Importantly, however, both studies also indicate that these cancellations are a summertime event. During other seasons, when greenhouse-gas forcing has no competition from ozone forcing, the jet stream and Hadley-cell boundary are expected to shift towards the South Pole.

Is the outcome of this competition fully understood, and are the surmised cancellations certain? Even though the studies agree, several uncertainties remain about the degree to which recovery of the ozone hole will cancel out future circulation changes driven by increasing greenhouse gases. It will depend on how quickly the ozone hole recovers; a faster recovery would displace the jet stream back towards the Equator in the near future. It will also depend on the rate at which greenhouse gases are emitted. A higher rate than the moderate increase assumed in the model simulations will tend to keep the jet stream moving towards the South Pole. So, although the studies by Polvani and colleagues[1] and McLandress and colleagues[2] certainly advance our understanding of likely changes in Southern Hemisphere circulation, it remains to be seen whether the shift will be polewards or Equatorwards; let the tug of war begin. ❐

Judith Perlwitz is at the Cooperative Institute for Research in Environmental Sciences, University of Colorado/National Oceanic and Atmospheric Administration Earth System Research Laboratory, Physical Sciences Division, 325 Broadway, Boulder, Colorado 80305-3337, USA.
e-mail: judith.perlwitz@noaa.gov

References

1. Polvani, L. M., Previdi, M. & Deser, C. *Geophys. Res. Lett.* doi:10.1029/2011GL046712 (2011).
2. McLandress, C. *et al. J. Clim.* doi:10.1175/2010JCLI3958.1 (2011).
3. Thompson, D. W. J. & Solomon, S. *Science* **296,** 895–899 (2002).
4. Polvani, L. M., Waugh, D. W., Correa, G. J. P. & Son, S.-W. *J. Clim.* doi:10.1175/2010JCLI3772.1 (2011).
5. United Nations Environment Programme *UNEP Year Book 2010* Ch. 4, 33–42 (UNEP, 2010); available via http://go.nature.com/7ZERh7.
6. Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. S. J. & Ringler, C. International Food Policy Research Institute Research Brief 15–15 (IFPRI, 2009); available via http://go.nature.com/GlyMxN.
7. Lu, J., Vecchi, G. A. & Reichler, T. *Geophys. Res. Lett.* **34**, L06805 (2007).
8. Son, S.-W. *et al. Science* **320,** 1486–1489 (2008).
9. Son, S.-W. *et al. J. Geophys. Res.* **115**, D00M07 (2010).

POLICY

Changing the rules

The Clean Development Mechanism was designed to allow emissions reductions and sustainable development to proceed hand-in-hand. Analysis now addresses the question of whether — 14 years after its creation — it can be reformed sufficiently to serve current needs.

Niklas Höhne

The Clean Development Mechanism, or CDM, is one of the success stories of the United Nations climate negotiations. At its simplest, it allows developed countries to obtain emission-reduction 'credits' to use against their national emission-reduction targets by funding sustainable-development projects in developing countries (Fig. 1). Current projects are thought to save about 700 million tonnes of carbon dioxide equivalent each year[1] — roughly equal to the annual emissions of the UK. Nevertheless, the mechanism has been heavily criticized, with detractors pointing out that it has made little, if any, contribution to either net global emissions or sustainable-development goals. Writing in *Climate Policy,* Bakker and colleagues[2] argue that tailoring the rules of the mechanism to different countries and types of project — a process known as 'differentiation' — could help address these problems and thereby offer a way of moving towards the CDM's over-arching goal of reducing emissions while contributing to sustainable development.

When the CDM was defined under the Kyoto Protocol in 1997, it represented a compromise between two objectives. Developed countries were seeking a cost-effective way of reaching their national emission-reduction targets by buying 'gains' made in developing countries. On the other hand, developing countries and environmental non-governmental organizations wanted to ensure that any such mechanism would go beyond supporting the cheapest possible ways of achieving emission reductions and actively promote sustainable development.

To accommodate this compromise, the rules for the CDM are tailored to specific groups of countries and technologies: the least-developed countries are exempt from paying administrative charges, small-scale projects can use a simplified set of rules, nuclear power is excluded, and the executive board of the CDM has the authority to prioritize sectors that are under-represented. Furthermore, countries that buy reduction credits have set their own standards for purchasing them. For instance, the European Union does not allow credits from forestry projects to be used owing to uncertainties about the magnitude of their long-term mitigation effect. Some buyers require projects to meet the 'Gold Standard', which defines additional sustainable-development criteria, such as taking the views of local people into account. So, to a certain extent, the CDM is already 'differentiated'.

Bakker and co-workers[2] collated current proposals for differentiating the mechanism further and assessed the impact they would have on the availability of credits from emission-reduction projects. Their analysis indicates that enhancing preferential treatment for countries and technologies that are at present under-represented in the CDM would be the most politically feasible option for improving the mechanism, because this reform would require only small changes to the current set of rules. Recent events support this conclusion: an additional rule on preferential treatment stating that countries with fewer than ten registered projects can apply for a special loan was the only change involving further differentiation agreed at the UN climate conference in Cancun last year. Unfortunately, they also find that this type of reform will do little to address the issue of uneven distribution of projects across regions and sectors that it is designed to address. An alternative way of tackling