ATMOSPHERIC SCIENCE

Winds of change

On average, terrestrial near-surface winds have slowed down in recent decades. This change will affect both wind energy and hydrology.

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Watching a windmill or the modern equivalent, a wind turbine, quickly reveals just how fickle wind can be. One day the wind is blowing hard, the next it is still. One might assume that these short-term fluctuations even out, leaving a steady, long-term average wind speed at a given location. However, the available data do not show that. Instead, mid-latitude observations from Australia, China and the United States show declines in surface wind speeds of about 15% over the past 30 years, and the term 'stilling' was evoked to explain this trend[1]. Writing in *Nature Geoscience*, Vautard *et al.*[2] show that an upward trend in land-surface roughness is at least partially responsible for the recent slow-down in near-surface wind speeds.

Anemometers are typically used to measure wind speed. But many scientists are, rightly, sceptical of trends derived from these instruments: instrumental drift, technological change and shifts in measurement sites can all interfere with anemometer records. But evidence for stilling is not solely dependent on these measurements. Widespread reductions in pan evaporation have also been observed over the past 50 years, and have been attributed to a fall in near-surface wind speeds in some regions[1,3]. Interestingly, however, increasing trends in near-surface wind speeds have been observed over the ocean[4]. When first published, this seemed problematic — how could near-surface wind speed increase over the ocean[4] but decrease over land[1–3,5,6]?

The proposal by Vautard *et al.*[2] that widespread increases in vegetation could reduce near-surface wind over land may help to resolve this question, if the predominant wind direction at terrestrial coastal sites is taken into account[7]. Using a quality-controlled database — in which stations with gaps and heterogeneities in the data were removed from the analysis — Vautard and colleagues examined changes in surface wind speeds at 822 terrestrial sites, primarily in the Northern Hemisphere, between 1979 and 2008. Averaging across all sites, they found a reduction in surface wind speed of 0.11 m s^{-1} per decade. Remarkably, this is almost identical to the trends reported in many other regions[1–3,5,6]. The trends in wind speed were essentially the same during the day and night, and varied little with season. Over 50 years, a reduction of this magnitude would affect wind-power generation and many natural physical and biological processes, such as evapotranspiration and air pollution dispersal.

A gradient in wind speed couples surface and atmospheric winds[8]. Hence a change in atmospheric winds and/or a change in the gradient can alter surface winds. On this note, things get really interesting. Vautard *et al.* examined radiosonde observations of upper-atmosphere wind speeds between 1979 and 2008. Over Asia, upper-air winds slowed more than surface winds, implying that the vertical gradient in wind speed became more shallow. This finding is consistent with an increase in atmospheric stability over east Asia owing to aerosol loading[9], where absorption of solar radiation by aerosols warms the upper atmosphere, while simultaneously reducing the solar radiation arriving at the surface. This pattern of surface cooling and atmospheric warming reduces the temperature gradient and increases atmospheric stability. The fall in winds in both the upper atmosphere and at the surface suggests that a reduction in atmospheric circulation contributed to stilling over Asia. In contrast, Vautard *et al.* observed little change in upper-air winds over Europe, despite a clear stilling at the surface. Based on this discrepancy, they suggest that a rise in surface roughness — owing to an increase in vegetative biomass — was responsible for some surface-level stilling in this part of the world. The correlation between satellite-based estimates of greening and stilling is intriguing and lends support to this hypothesis.

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Figure 1 | Wind turbines located on land and at sea. Vautard and colleagues[2] suggest that an increase in land-surface roughness, resulting from an increase in vegetative biomass, has contributed to a reduction in surface wind speeds in the Northern Hemisphere over the past 30 years.

Many climate change impact studies routinely use reanalysis outputs, which employ models to turn meteorological observations into consistent global databases. Reanalysis outputs are convenient: the output is on a grid, has no missing records and can be easily downloaded over the internet. But Vautard *et al.* reinforce that, contrary to observations[1–3,5,6], reanalysis outputs do not capture trends in near-surface wind speeds[5,10]. Clearly these datasets are not yet suitable for examining long-term trends in near-surface winds and related processes such as evapotranspiration.

Vautard *et al.*[2] corroborate that, across the Northern Hemisphere, surface winds have slowed down, and propose that an increase in surface roughness has contributed to the trend. At least two implications are immediately obvious. Stilling seems to be greater at higher elevations[6] that yield much of the fresh water for human consumption. Slower winds in these regions could partially offset any rise in evaporation owing to factors such as rising air temperatures[1,3,11]. Second, wind power depends on the cube of wind speed, and Vautard *et al.* show that stilling results primarily from a reduction in high wind speeds, especially in Asia. Hence, the potential for power generation from wind turbines has fallen in this part of the world over the past few decades. However, the observations were made ten metres above ground. To unequivocally determine the long-term impact of stilling on power generation requires assessments at the typical height of commercial wind turbines. ❐

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HYDROLOGY

Missoula's legacy

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The Channeled Scablands of the northwestern United States stand in sharp contrast to the surrounding wheat fields. Here, tortuous channels cut deep into the dark volcanic bedrock, giant gravel ripples reach nine metres in height, and piles of rock debris dot the landscape. The hunt for the origins of the alien landscape began nearly 90 years ago and finally led to the discovery of the former glacial Lake Missoula. From at least 19,000 to 13,000 years ago, the lake sat along a finger of the Cordilleran ice sheet. But the lake was far from stable: at least 25 times during that period, the ice that dammed the lake disintegrated, and water gushed towards the Pacific Ocean.

The floods may have left behind more than just a scoured surface. Jennifer McIntosh and colleagues at the University of Arizona suggest that flood waters also filled the region's aquifers on their way to the ocean (*Geophys. Res. Lett.* doi:10.1029/2010GL044992; in the press). The aquifer system, known collectively as the Columbia River Basalt Aquifers, stretches across the eastern half of Washington state and northeast Oregon and is an important source of both domestic and agricultural water. Very little water has been added to the system recently, and the bulk of the water is thought to be a remnant from the last glacial period.

Yet, an ice-age source of groundwater is hard to reconcile with data that suggest the climate then was even more arid than today. Instead, based on radiocarbon- and oxygen-isotope measurements of the groundwater, McIntosh and her colleagues suggest that it came from Lake Missoula. The radiocarbon dates from the groundwater match the dates of the floods and coincide with periods when vast amounts of fresh water poured into the Pacific Ocean. Furthermore, the oxygen-isotope composition of the groundwater more closely resembles the proposed composition of the Cordilleran ice sheet than that of rain or snow during the glacial period.

The rushing flood waters must have been able to infiltrate the aquifers rapidly, draining through fractures and faults, and perhaps eroding inlets into the aquifers.

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