Prime Meridian

(63) December 20, 2016

Arctic sea ice is at its smallest seasonal extent on record.

Above: The extent of sea ice in November 2016 compared with the long-term November mean (mauve line). Image from National Snow and Ice Data Center (NASA Earth Observatory).

Loss of older ice threatens the stability of floating ice cap.

News from the Ecospheres Project:

Snatching a free gift from an alien ocean? Part II (page 12).

In South East England, the leaves have fallen from most of the trees.

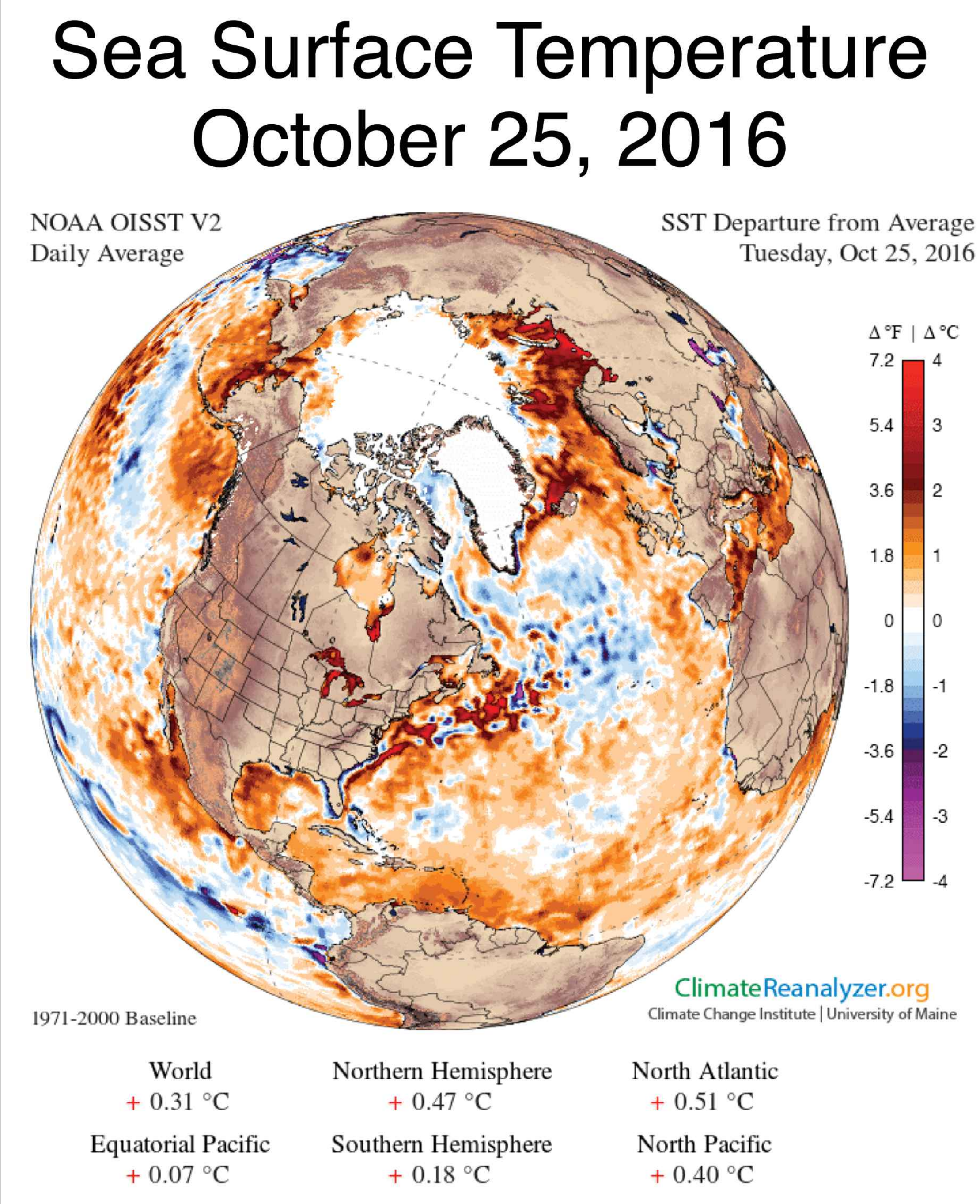
They now lie in fresh carpets on the floors of woodlands and summer's discarded leaves were glittering with frost after a cold spell set in. As they break down over coming months, their nutrients will return to their ecosystems and be re-cycled.

In the Arctic, however, climate scientists have reported an unseasonal warmth.

The Sun set at the north pole at the autumn equinox (September 22) and the months of dark and intense cold have set in across the Arctic. this is the time of year when the northern cap of Arctic sea ice, which was melting and shrinking until September, grows larger again as the sea re-freezes.

However, the loss of ice during summer 2016 was the second greatest on record, and, so far, Arctic sea ice has failed to bounce back with its usual rate of growth. Its areal extent remains, for the time of year, the smallest in a satellite record that began in 1979. Older, thicker ice is also at its lowest ever extent, says the USA's National Snow and Ice Data Center. The Arctic's cap of sea ice seems likely to start next year's melt season in a vulnerable condition.

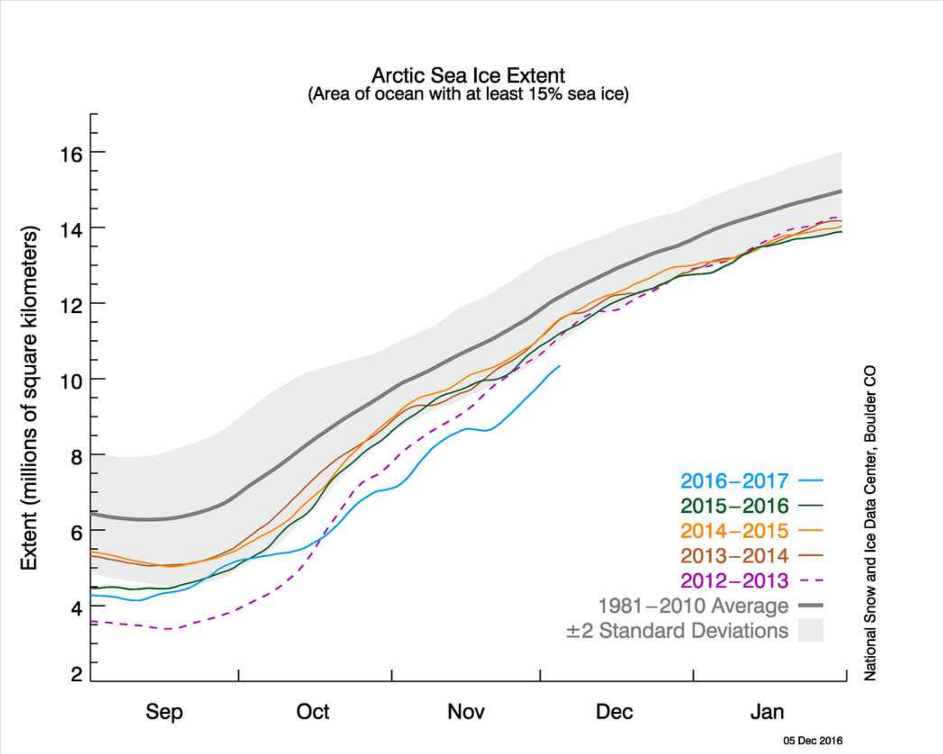
Left: An old coppice near Ash, Kent. November 25, 2016.



Above: A chart of sea surface temperature anomalies for late October 2016, based on NOAA data. In places, the Arctic was around 4ºC warmer than the 1971-2000 norm.

On October 31, 2016, the extent of Arctic sea ice was 7.07 million km^2, which is the lowest value recorded during the decades for which we possess a satellite record. The extent of sea ice is defined as the area over which there is more than 15% coverage by floating ice. The trend continued into November, for which the average ice extent was 9.08 million km^2, some 0.8 million km^2, below the previous record low of November, 2006.Higher than average sea surface temperatures, notable along the Chukchi, Beaufort, Barents and Kara Seas, played a role in reducing the growth of sea ice, although Baffin Bay saw increased ice cover compared with 2006. November saw rare reversals of ice growth.

The warmth has been attributed to an unusual jet stream pattern which brough cyclonic storms and southerly winds from the Atlantic, through the Fram Strait into the Arctic Ocean, rather than, as is usually the case, across Iceland and the Norwegian Sea, into the Barents Sea. The winds were quoted as another factor in low ice extent, having driven ice in the Barents Sea northwards.

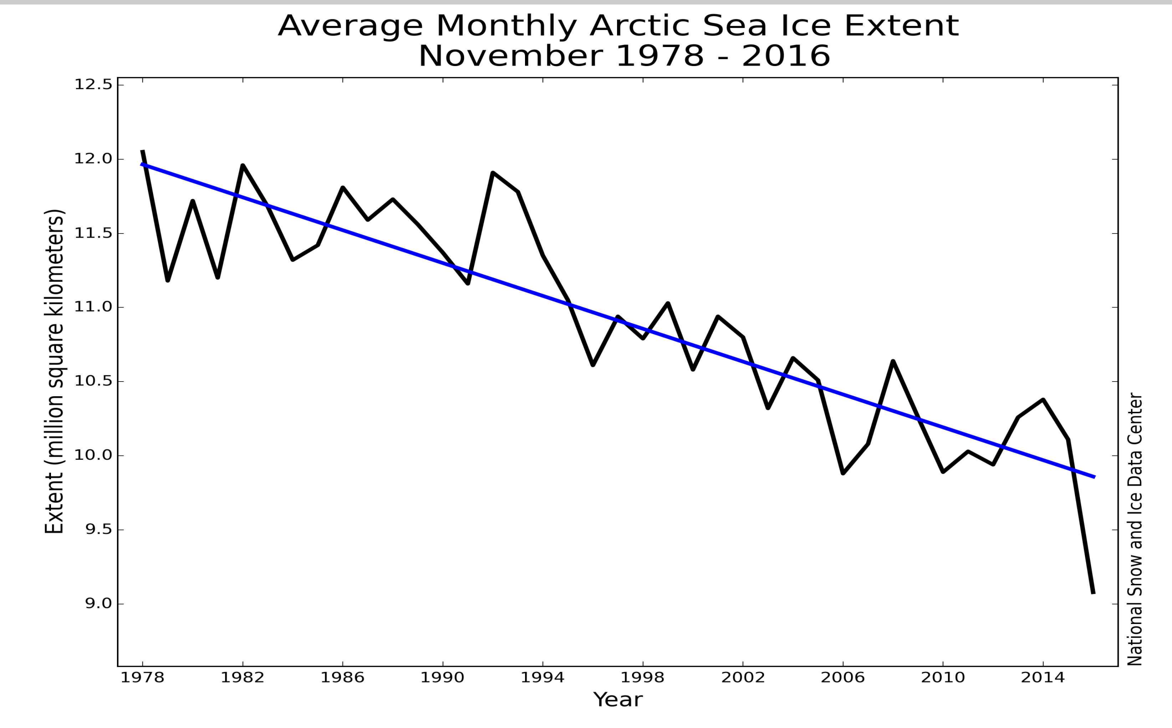


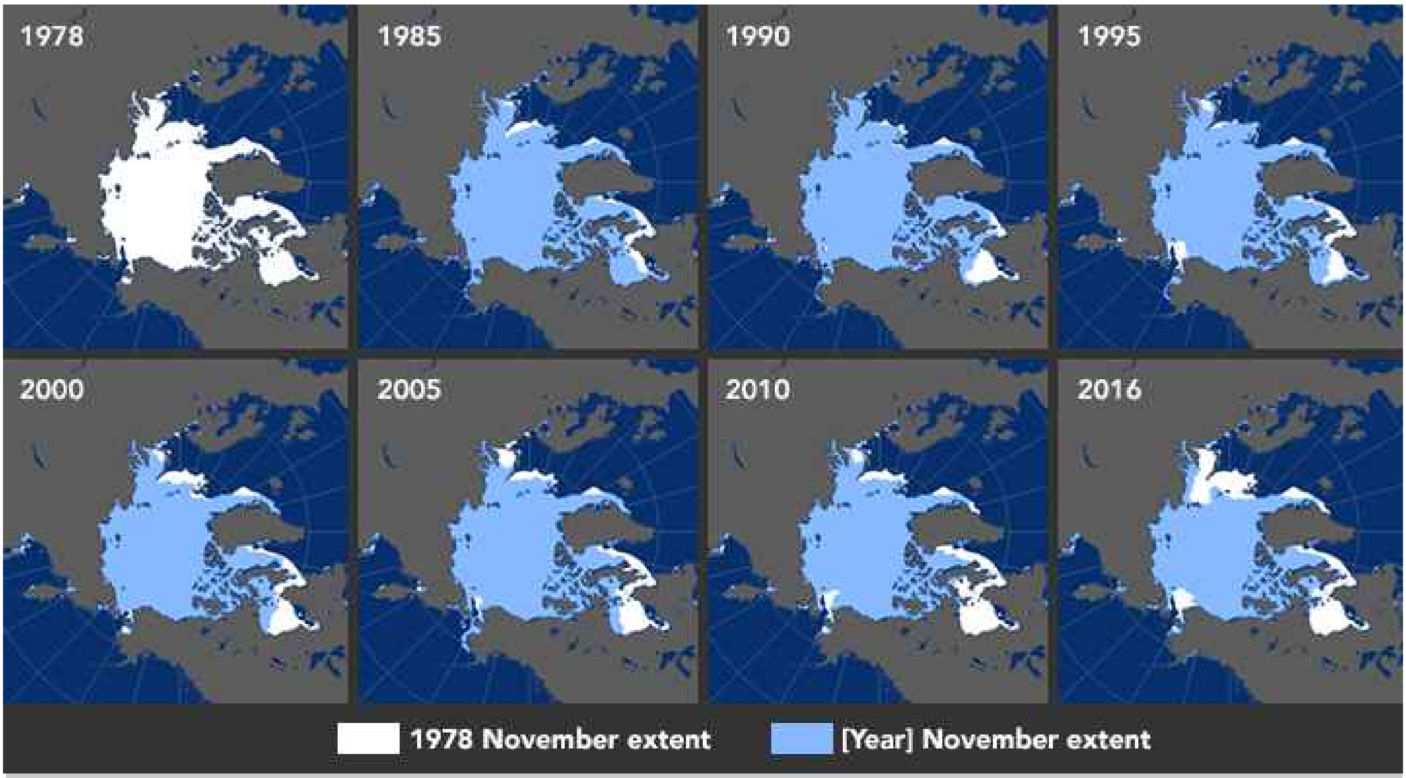
During the early part of 2016, the extent of sea ice was below that of 2012, the year that saw the smallest summer ice cap on record.

Until mid-June this year, the extent of sea ice was even smaller than that in 2012. It then plotted close to the 2012 curve, but slightly above it from the beginning of July. During August and September, the ice cover remained above that of 2012, but by mid-October, the extent of the Arctic sea ice had once again fallen below that for the same dates in in 2012.

"The October freeze-up was very slow and that continued through much of November . . . . times of very slow or even no increase in extent over a few days are not particularly unusual, But to actually have the extent go down over 4 to 5 days in mid-November does seem quite rare." **Walt Meier, Goddard Space Flight Center (quoted by the USA's National Snow and Ice Data Center).**

Summer disappearance of the reflective cap of floating sea ice would enable the Arctic Ocean to absorb more energy from the Sun and this, many argue (Lenton, 2011) could be a "*tipping point*," producing a jump in global climate. Lenon, T. M. (2001). *Nature Climate Change* PUBLISHED ONLINE: 19 JUNE 2011 |DOI: 10.1038/NCLIMATE1143.





Above: Charts published by the USA's National Snow and Ice Data Center illustrating the net decline of November sea ice cover over a period of nearly four decades. Image credit: National Snow and Ice Data Center (NASA Earth Observatory).

Prime Meridian.

This newsletter follows the cycle of the seasons in the woods, fields and hedgerows of S. E. England, alongside global environmental issues. We step back to see our Earth in its astronomical setting and we explore the possibilities for other habitable worlds.

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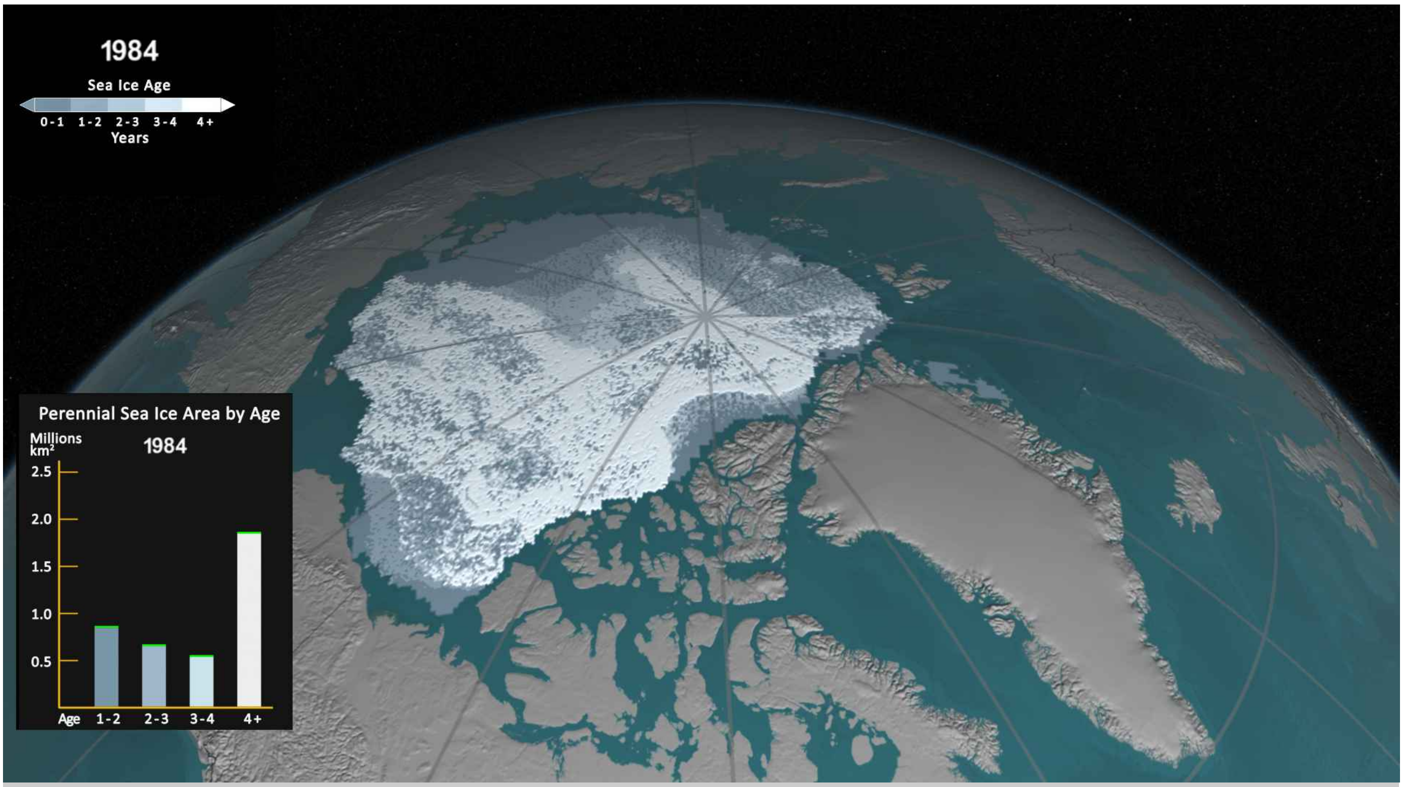
Images in *Prime Meridian* are from M.J. Heath unless otherwise specified).

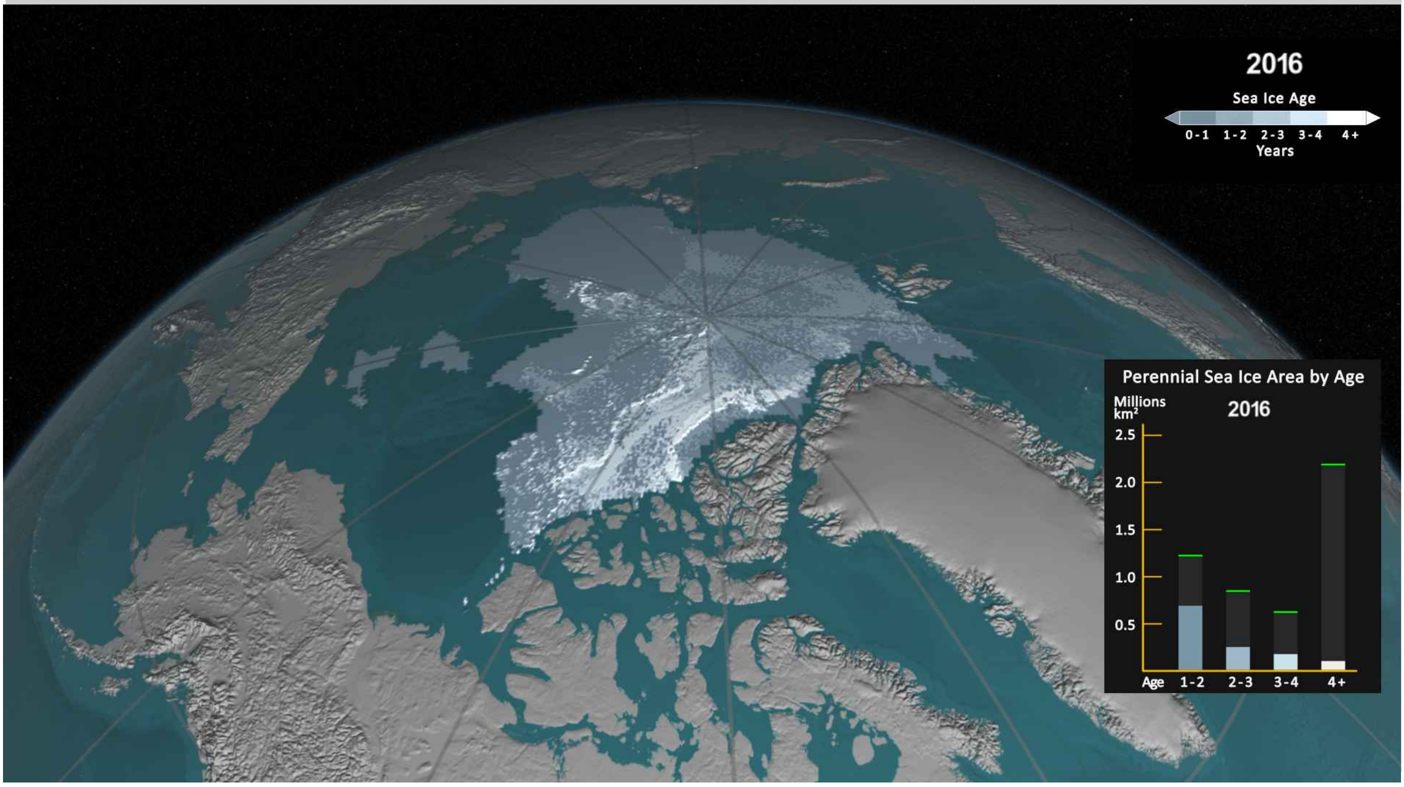
Left: Autumnal beech tree overhangs lane near West Kingsdown, Kent, Oct. 29, 2016.



Long-term loss of multi-year ice threatens the Arctic's floating ice cap.

Multi-year ice survives and thickens over time by growing more during winter than it melts away during summer. The thicker it becomes, the less vulnerable it is to disappearing during the summer melt season. First year ice tends to be only 1 to 2 m thick, older ice 3 to 4 m. A collaboration between the University of Colorado, the National Snow and Ice Data Center in Boulder, Colorado and NASA has concluded that sea ice has been lost from the Arctic in two main bursts. The first has been explained in terms of a change in wind patterns, which saw older ice flushed out of the Arctic Basin. Walt Meier of the NASA Goddard Space Flight Center explained "*two main bursts of thick ice loss: the first one, starting in 1989 and lasting a few years, was due to a switch in the Arctic Oscillation, an atmospheric circulation pattern, which shrunk the Beaufort Gyre and enhanced the Transpolar Drift Stream.*" The second, caused by warmer climate, began in 2000 and has involved the melting of older ice within the Arctic Basin. In the 1980s, old ice used to make up 20% of the sea ice, but now just 3%.

Based on item by Maria-José Viñas (NASA's Earth Science News Team). Graphics by NASA's Scientific Visualization Studio/Cindy Starr.



Seasons in South East England

October, 2016

Above: By October 31, London Planes (*Platanus × acerifolia*), an iconic tree of the UK's capital city, were displaying their autumn colours along the Embankment on the north side of the Thames. The view takes in two churches designed after the 1666 Great Fire of London by Sir Christopher Wren (1632-1723), St Bride's in Fleet Steeet and St Paul's on Ludgate Hill.

A dry October for SE England.

Left: A swathe of cloud looms over the landscape. West Kingsdown, Kent (Oct. 1). Below: Red berries of hawthorn (*Crategus monogyna*) enliven a hedgerow near West Kingsdown (Oct. 9).

The ripening fruits of autumn. Spindle (*Euonymus europaeus*) on Oct. 15 and blackberries (*Rubus fruticosus*) on Oct. 21, in a hedgerow near West Kingsdown. Apples (*Malus*) wet from recent rainfall in South London on Oct. 16.

The provisional UK mean temperature was 9.8ºC (0.3ºC above the 1981-2010 mean) and that for England 10.6ºC (0.2ºC above the mean). SE and central S England were warmer at 11.2ºC (0.1ºC above their October mean).

The Met Office reported "*heavy showers and thunderstorms*," with localised flooding in Cambridgeshire, and between Thanet and Canterbury in Kent on Oct. 1. Heathrow, London received 5 mm of rain. "*Locally heavy*" showers were reported for Oct. 8, but not at Heathrow. A minumum October temperature of about 5ºC was recorded at Heathrow on Oct. 11 and again on Oct. 22. 3 mm of rain fell at Heathrow on Oct. 12 and 2mm on Oct. 13, 16 and 17.

Right: Fields and woodland in the vicinity of West Kingsdown, Kent on Oct. 9 (top) and Oct. 15. Below: An hour and a half after midnight on Oct. 16, the Full Moon gleams on chimney pots and roof tiles in South London.

Above: Fallen oak leaf caught in the web spun by a garden spider (*Araneus diadematus*) between railings in Belair Park, S. London. Oct. 22. Vivid yellow hues of lime trees (*Tilia x vulgaris*), Crystal Palace Park, S. London. Oct. 23.

On Oct. 25, the UK's lowest temperature for October -5.0ºC was, not surprisingly, reported from outside our region, in Scotland (Tulloch Bridge, Inverness-shire). From this date, however, southern England was particularly affected by fog. This had economic implications. The Met Office reported slow traffic, delays to the Isle of Wight ferries and disruption of air travel, which involved arrivals and departures at London's Heathrow and Gatwick airports. However, the temperature reached 20.0ºC at the Needles Old Battery, Isle of Wight.

Lefthand photos: Churchyard of St Peter's and St Paul's, Ash, Kent and nearby hedgerows on Oct. 29. Harbinger of Halloween menace? A black cat stalks in the churchyard (Oct. 21). The impact of pet cats (*Felis catus*) continues to be assessed. One survey (Woods *et al.*, 2003) concluded that: "*a British population of approximately 9 million cats was estimated to have brought home in the order of 92 (85–100) million prey items in the period of this survey, including 57 (52–63) million mammals, 27 (25–29) million birds and 5 (4–6) million reptiles and amphibians.*"

A more recent study (McDonald *et al.*, 2015) of cat predation around the rural villages of Mawnan Smith (Cornwall) and Thornhill (Stirling, Scotland) by the University of Exeter and Queen Mary University of London showed that the number of prey returns per cats per month was 1.89 ± 0.35 at Mawnan Smith and 0.81 ± 0.17 at Thornhill (returns are a fraction of the true predation rate). 58.6% of kills at Mawnam Smith and 72.8% at Thornhill were mammals, with birds accounting for 26.5% and 26.3% respectively. However, the Royal Society for the Protection of Birds remained sceptical about the impact on bird populations. **cDonald, J. *et al.* (2015).** *Ecology and Evolution 5: 2745-2753.* ***Woods , M. et al. (2003).*** *Mamm. Rev. 33: 174-188.*

Sydenham Hill Wood, South London, in its autumnal colours on Oct. 21.

Above: Autumnal trees near West Kingsdown and evening fog at New Ash Green. Oct. 29. Right: Beyond the towers of the Royal Courts of Justice, fog gathers around the the London Eye and Houses of Parliament towards evening on Oct 31. Halloween pumpkins in S. London.

Oct. 28 was particularly sunny in the SE, but fog marked the month's final days. Oct. 31 saw the UK's warmest temperature (22.2ºC) at Trawscoed (Dyfed, Wales) and Heathrow also saw its highest temperature (20ºC), with 20.7ºC at Hampton, Greater London.

The month's rainfall was decidedly low. The UK had 38% of normal (1981-2000) rainfall (6th driest October in a record from 1910); England 43%. SE and S Central England, despite local floods on Oct. 1, enjoyed just 36%.

SE and central S England, Mean max. temp.: 15.1ºC (0.3ºC). Mean min. temp.: 7.2ºC (-0.2ºC). Hours of sunshine: 128.2 (113%). Rain: 33.3 mm (36%). Anomalies re. 1981-2010 norm in brackets. Data in this article have been derived from online publications by the UK Met Office and WeatherOnline (Heathrow).

Below: In the closing hour of October, a family held their own firework display on Telegraph Hill, S. London. Orion was rising in the east. Its main stars lie hundreds of light years (ly) distant.

Global climate: 3rd warmest October in a record commencing in 1880.

According to the USA's National Oceanic and Atmospheric Administration, This was the second month in a row that global mean temperature failed to set a new record for warmth. Figures quoted below are departures from the norm. All anomalies are positive.

"The combined average temperature over global land and ocean surfaces for October 2016 tied with 2003 as the third highest for October in the 137-year period of record, at 0.73°C (1.31°F) above the 20th century average of 14.0°C (57.1°F). This is 0.26°C (0.47°F) cooler than the record warmth of October 2015 when El Niño conditions were strengthening." **Meanwhile, however, there was** *"record warmth across parts of Mexico and the Caribbean, parts of west central Africa, sections of southeastern Asia, western Alaska extending to Far East Russia, where temperatures were more than 5°C (9°F) above their 1981-2010 averages."*

The global mean temperature for land plus ocean was 0.73 ± 0.14 **°C above its October mean, the 2nd highest on record. The oceans, at 0.72 ± 0.15°C above the mean, were 16th warmest on record.. Globally, land areas were their 3rd warmest on record at 0.76 ± 0.14°C above the norm. 2015 was the warmest in each case. In the Northern Hemisphere, the combined mean temperature for land and ocean was 0.81 ± 0.15°C above the mean, the 6th highest on record (2015 was highest). The land was 0.75 ± 0.11°C above the norm. The oceans (0.85 ± 0.14°C) above the mean, were their 3rd warmest, with 2015 as the warmest. In the S. Hemisphere, the mean combined land and ocean temperature (0.65 ± 0.14°C above the mean) was the 3rd highest on record (2015 was the record year). The ocean (0.63 ± 0.15°C above the norm) was the 2nd warmest for October after 2015. The land (0.80 ± 0.18°C above the norm) was the 14th warmest for October (2015 was warmest.**

Source: *NOAA National Climatic Data Center, State of the Climate: Global Analysis for October, 2016.* Published online. Data is provisional.

Above: Our home planet on October 25, 2016 at 12:44:51 GMT (the date chosen for NOAA's chart of sea surface temperatures; see page 2). NASA/NOAA.

A rural lane near Ash, Kent. October 29, 2016.

Snatching a free gift from an alien ocean? Part II.

Martin Heath & Laurance Doyle.

In 1996 we argued, in a presentation to the Europa Ocean Conference, that if plumes of water vapour were shooting out through the icy outer shell of Jupiter's smallest icy moon (as might be expected if water could reach the surface) they might carry microbial-sized organisms or life's chemical traces. These could be sampled by an orbiting space craft. As we recalled in Part I, the idea was met with understandable scepticism. The very existence of plumes was a big "*if*."

Right: A gibbous Europa imaged during NASA's Galileo mission. NASA/JPL/Ted Stryk.

Is the icy shell of Europa simply too thick for any material to find its way upwards from the ocean? Different researchers using different methods and looking at different features, have come to very different conclusions about the thickness of the shell, and the controversy has been dubbed the "*great thickness debate*" (Billings & Kattenhorn, 2005). Although the icy surface of Europa has relatively few craters caused by collisions with smaller Solar System bodies - a sign that the shell must be sufficiently active to erase them, the appearance of the craters we do see implies that the icy layer must be at least 19 km thick (Schenk, 2002) and models for heat flow from (Hussman *et al.*, 2002) implied a 30 to 60 km thick shell above a 100 km deep ocean. In some areas, however, features may have formed over ice just hundreds of meters thick (Williams & Greeley, 1998). Richard Greenberg of the University of Arizona and co-workers have argued that brine regularly escapes onto the surface from fractures (for example, Greenberg 2005;2008, Greenberg *et al.*, 2000).

In addition to an underlying ocean, lenses of water *within* the icy shell could exist underneath so-called "chaos" terrains (about, say 3 km down). A study of a dark feature known as Thera Macula suggested an underlying body of water of similar volume to the Great Lakes (Schmidt *et al.*, 2011).

While waiting for evidence of plumes on Europa, nature provided us with a cosmic consolation prize. Our plume sampling concept was vindicated, unexpectedly, when, in 2005, scientists working on the Cassini probe orbiting Saturn obtained unmistakable pictures of multiple plumes breaking out from Enceldaus, a 500 km wide icy world that circles the giant planet Saturn (Porco *et al.*, 2006). It orbits in 1.37 days, at around the same distance that our Moon orbits around the Earth, so its views of Saturn, its rings (seen edge on) and the other moons, whose tidal effects heat it, would be breathtaking. Despite having a surface at -198°C, it appears to have a subterranean sea being tapped by plumes escaping from its south polar region. The plumes are feeding Saturn's E Ring.

Above: Cassini mission image of Enceladus with unequivocal plume activity (false colour) NASA.

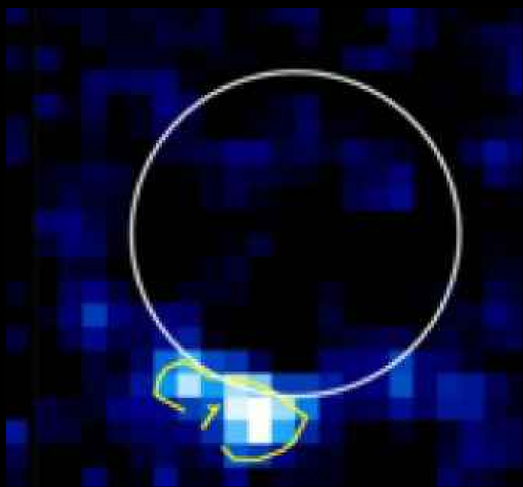
Cassini was later directed through plume ejecta. It was not equipped for a life-hunting mission, but analysis of plume contents favoured the availability of liquid water (Waite *et al.*, 2009), rather than the release of water vapour by geological activity (Kieffer *et al.*, 2006) without the need for a sea. The possibility of life having arisen on Enceladus has received serious discussion (McKay *et al.*, 2008; Parkinson *et al.*, 2008), so Europa now has a rival for the future attention of icy moon astrobiology missions.

Meanwhile, on the Europa front, there was much scientific conjecture and analysis of space probe data, but no real progress towards actually spotting out-gassing of water vapour. Even so, a couple of very interesting theoretical studies by Sarah Fagents and co-workers (Fagents *et al.*, 2000 and Fagents, 2003) set physical constraints on plume activity.

Greenberg's thin ice models have certainly been controversial. From our point of view, the thinner the ice above Europa's ocean, the more opportunities there would be for plumes breaking out. Reviewing Greenberg's 2008 book "*Unmasking Europa*; *The Search for Life on Jupiter's Ocean Moon*,", Kevin Hand of the California Institute of Technology told his readers (Hand, 2009): "*Europa has not yet revealed a smoking gun, as have the icy plumes of Enceladus, to indicate that it is geologically active today. This has left the planetary geology community staring at the limited imagery of Europa, wondering what its surface features reveal about the interior*."

One way or the other, Europa's ocean does appear to be leaky. In a recent study, for example, Michael Brown and Kevin Hand (2013) of Caltech used the Keck telescope to discover an infrared absorpion feature at 2.07 µm, compatible with magnesium sulphates, which they pointed out, could be produced by irradiation of NaCl and KCl-rich brine that had reached the surface.

Abruptly, however, there seemed to have been a major breakthrough. In 2014, Lorenz Roth of the Southwest Research Institute (Texas) and co-workers reported that with the Hubble Space Telescope they had detected 200 km-high plumes breaking out from Europa's south pole for around 7 hours in December 2012. The Hubble's Space Telescope Imaging Spectrograph had detected (near the limits of faintness) UV light from an aurora at Europa's south pole. This might have been created by charged particles whirled up to high energies in Jupiter's powerful magnetic field splitting water molecules from a plume into charged oxygen and hydrogen. The emission of plumes appeared to be intermittent, because, as the team pointed out, no plumes were detected in November observations or previous HST images from 1999.

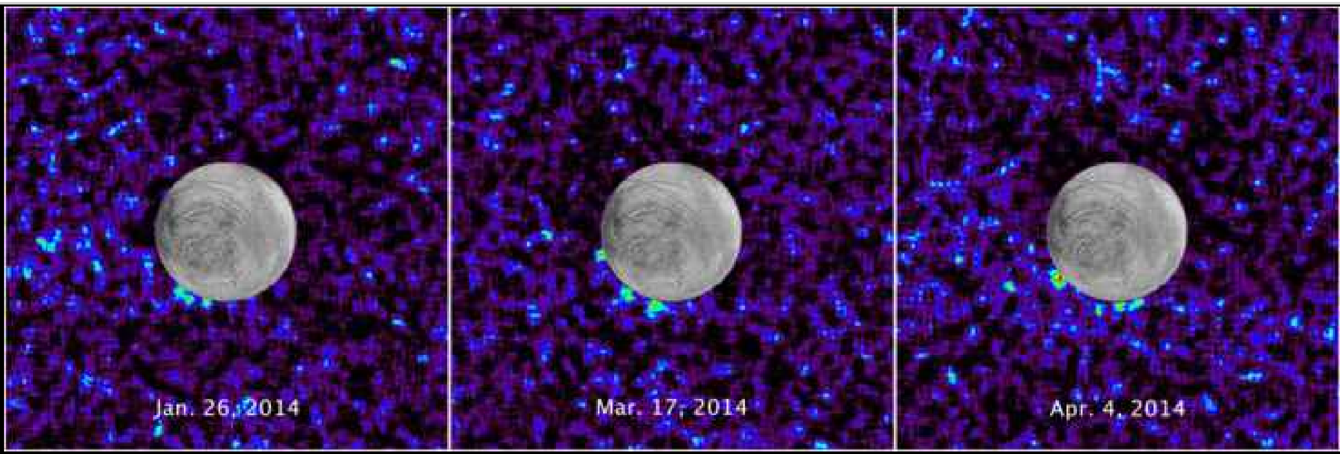


Above right: Observation of Europa with aurora attributed to suspected plume. December, 2012. NASA/ESA/L. Roth.

The team was well aware that even if water vapour were escaping from below ground, it need not be from the ocean itself. It could have been from a pocket of water or even been released from warm ice created by friction along active fault lines.

Then there came a bubble-bursting riposte in December 2014 from Don Shemensky of Space Environment Technologies, Pasadena and colleagues. They had used data from the Cassini probe, which flew through the Jupiter system *en route* to Saturn in 2001, to argue that there were no signs of Europa emitting water vapour. The implied that the small moon was generally inactive. Shemensky concluded that charged particles around Europa, oxygen and sulphur, were being supplied by Jupiter's volcanic moon Io, which belches out regular volcanic plumes of SO_2. In an article for NASA's **online Astrobiology Magazine published on March 24, 2015 under the title** "Europa's elusive water plume paints grim picture for life," Elizabeth Howell quoted him as saying that if there had been a plume of water vapour, it could have been released when a meteorite hit Europa.

Plumes, however, were not yet a lost cause. Late this year, a team led by William B. Sparks of the Space Telescope Science Institute, Baltimore, USA, reported new evidence. This group had studied Europa in the Far Ultra Violet as it had crossed the face of Jupiter as seen from the Earth and in 3 out of 10 cases, material appeared to be present beyond the edge of the disk. Not only was there evidence for plumes near the south pole, but also from an equatorial site. These plumes appeared to reach 200 km into space.



Above: Reconstructions of Europa plume observations by Sparks and co-workers. The observations were actually of Europa in transit against the background of Jupiter, with plumes in silhoutte. NASA, ESA, W. Sparks STScI.

The work by Roth and colleagues had set discussions in motion. Plumes were now firmly on the agenda for discussion. A June 2-3 2014 meeting of NASA's Europa Science Definition Team (SDT) at John Hopkins University had decided that whilst the idea of sampling plumes should not drive mission design, missions should be adaptable enough to take advantage of plumes if they exist. After the latest round of evidence, online *Science Daily* for Sept. 26, 2016 quoted Geoff Yoder, acting associate administrator for NASA's Science Mission Directorate in Washington as saying "Europa's ocean is considered to be one of the most promising places that could potentially harbor life in the solar system . . . These plumes, if they do indeed exist, may provide another way to sample Europa's subsurface."

Right: Artist's impression of a plume erupting from the surface of Europa. Kurt Retherford (Southwest Research Institute).

Our idea had been based on no new observations nor upon any geophysical model . . . . and it could be summarised in one short paragraph. It could be argued that if plumes are real, we hit upon a useful concept through a lucky break. Our guesswork may have paid off, but at this stage, we are not jumping up and down and cheering.

There is still good reason for caution about the idea of sampling plumes for life. The observations reported so far are exciting, but there needs to be better observational support for the reality of plumes and how they behave. If they do exist, they may be too intermittent and unpredictable to enable sampling even by a space craft in very low orbit. Are plumes produced without the need to tap liquid water? If they do tap into an ocean beneath the icy shell, or into a lake within it, that does not mean that Europa is inhabited. Is there really any life down there? If life is present, the density of micro-organisms and bio-products in plume ejecta might be too low for detection.

In Part III, we shall wind up this investigation of the smallest Galilean moon with a look at the kind of habitats that Europa might, in principle, offer for life.

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