A newsletter following global environmental issues alongside the cycle of the seasons in Southern England

Prime Meridian

(49) January 31, 2015

Putting our Earth into perspective.

Image credit: Prokaryotes CC BY-SA 4.0

The opening of a new year is an appropriate time to step back in our minds and to look at our own world from a distant vantage point.

The possibility of an undiscovered massive planet in the distant Solar System – announced a couple of weeks ago - underlines the fact that there is much that we do not yet know about how our planet and its sibling worlds came into being some 4.55 billion years ago or how common truly Earth-like worlds really are in the cosmos at large. It also reminds us of how beautiful, fragile and lonely is the world on which we live.

The existence of what has been called "*Planet Nine*" (artist's guesswork above) has been inferred from the way in which a number of known small bodies orbiting far from the Sun, have highly elongated orbits whose perihelia (closest points to the Sun) are clustered together in space. Computer simulations by two leading researchers, Konstantin Batygin and Mike Brown from the California Institute of Technology at Pasadena have shown that this can be explained by a planet with a mass of at least ten times that of the Earth, in a highly eccentric orbit that brings it no closer to the Sun than 200 times the average distance between the Earth and the Sun (200 Astronomical Units) and as far out as 1,200 AU. The amount of energy that it would get from the Sun would vary between 1/40,000 to 1/1,440,000 that enjoyed by the Earth. It would take around 20,000 years to circle our Sun.

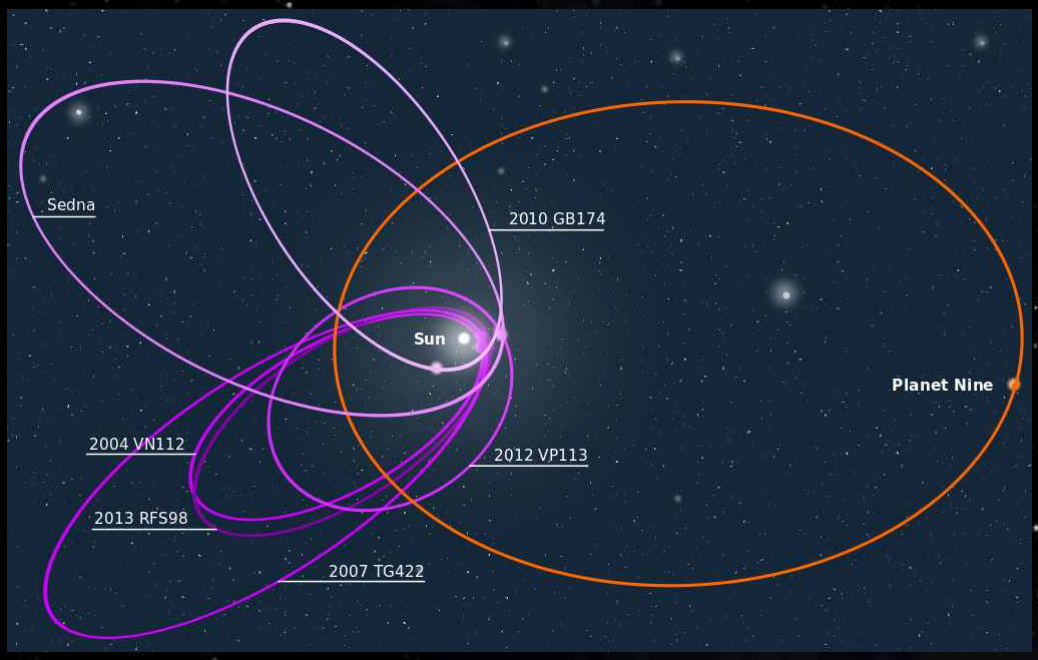


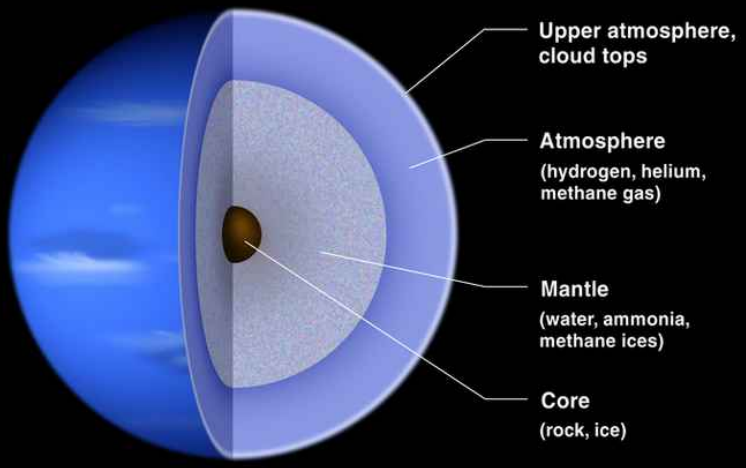
Image credit: Caltech.

2015: World's warmest December and warmest year on record (pages 9 &10).

Dark worlds far from our Sun: could Planet Nine or other undiscovered worlds provide homes for life? Life on Earth offers us clues.

Martin J. Heath and Laurance R. Doyle (Ecospheres Project; LRD is also with the SETI Institute).

If it exists - and we cannot say that it does until it has actually been seen - what kind of place is Planet Nine? With a minimum mass ten times that of the Earth, it could well be an ice giant, like Uranus or Neptune, which have cores of denser material overlain by deep layers of ices which are stable at high temperatures and which exist only under enormous pressures. Uranus is about 14.53 and Neptune 17.15 times the mass of our world. On the other hand, it just *might* be a gigantic version of a terrestrial planet (a planet which, like Earth, has a metallic core surrounded by silicate rocks).



NEPTUNE

Studies of other planetary systems have raised a range of possibilities, such as terrestrial planets smothered by water masses that make up a large fraction of the planet's mass (oceans would turn to high pressure ices at depth) or embedded in extensive hydrogen and helium envelopes. In any event, a major planet at that distance from the Sun need not have formed there, but could have been thrown out of the zone closer to the Sun during the earliest days of the Solar System, when the orbits of the planets may have been much more unstable than today. Outermost of the presently known giant planets is Neptune (NASA diagram, above), which lies at a distance of roughly 30 AU from the Sun and receives 1/900 times less energy from the Sun than we do. Planet Nine would take us into much deeper space.

As scientists who investigate what makes planets potentially habitable, we have been wondering whether the putative Planet Nine or its possible moons, unpromising as they may seem, might, even so, be homes for life. It's not entirely implausible. Recent discoveries about the astonishing diversity of life down here on Earth have raised hopes for the possibility of life in unEarth-like environments.

The cold, dark depths of space need not be as hostile to life as one might think. Some brave writers, such as Arthur C, Clarke in his 1971 story *A Meeting with Medusa* have argued that floating organisms could thrive in the atmospheres of gas giant planets, such as Jupiter or Saturn (318 and 95 times the mass of the Earth respectively), which have no solid surfaces as such. These planets have extremely hot interiors and although this means that they could have comfortably warm upper atmospheres with clouds of water droplets even in the absence of a star, it also means that airborne life would be in danger of being destroyed as they were carried down by convection currents into hellish depths. Icy moons, on the other hand, particularly if they are heated by tidal effects from other moons, could harbour oceans far beneath their surfaces or support bacterial-grade organisms in warm, wet crusts.

Suppose, however, that the new world were a rocky body, but swathed in a massive atmosphere of hydrogen. Back in 1999, D. J. Stevenson of Caltech pointed out that if an Earth-sized rocky body were to be ejected from an unstable planetary system, away from its parent sun and into interstellar space, it might still be able to support seas of liquid water on its surface, if it had managed to pick up a hydrogen envelope about a thousand times more massive than our atmosphere from the cloud from which its sun formed. It could easily hang on to this hydrogen envelope in the cold of deep space. The pressure would make the atmosphere sufficiently opaque in the far infra-red to trap geothermal energy coming up through the ground. It was even argued: "*it is conceivable that these are the most common sites of life in the Universe*." As our knowledge of other planetary systems grows, it has become clear that there is nothing implausible in this idea. We actually know of a number of free-floating planets, although they are all giant worlds. Other researchers pointed out that planets with massive hydrogen atmospheres and cosily warm surfaces might exist in the outer parts of planetary systems.

If such a world had failed to pick up a thick hydrogen atmosphere before it was hurled out into deep space, it might be able to keep an ocean of liquid water deep under ice, even if the surface which it presented to space were cold enough for Earth's atmospheric gases to freeze out. According to Eiichi Tajika of the University of Tokyo, a rocky planet with more than four times the Earth's mass, would produce sufficient heat from its interior to make this possible.

We do not need to think in terms of such controversial ideas as ecosystems in the atmospheres of gas or ice giant planets to bring life on dark worlds into the realms of the believable.

Many bacteria thrive deep within the Earth's crust and there is debate about whether their biomass is a minor percentage of or even exceeds that of life on the Earth's surface. For example, boreholes at Gravenborg, Sweden have revealed heat-loving bacteria living at a depth of nearly 5.3 km and temperatures of 65 to 75ºC (Szewzyk *et al.*, 1994).

Many of the organisms that live around hot water vents on the ocean floor make use of oxygen dissolved in sea water and this has been produced by plants carrying out photosynthesis in the sunlit realms above. This, however, is not the whole story.

About a decade ago, J. Thomas Beatty of the University of British Columbia, Vancouver, Canada and co-workers were **using a submersible to explore the environment of hot water vents on the floor of Earth's oceans 2.4 km down, when they discovered a strange green sulfur bacterium *"GSB1"* along the East Pacific Rise. These bacteria carry out photosynthesis, but not of the kind carried out by green plants and can exploit very low light levels. GSB1 can actually carry out photosynthesis using the energy radiated from water at 300ºC (water doesn't boil at 100ºC at ocean floor pressures). They pointed out (Beatty *et al.*, 2005, p. 9,306): *"If photosynthesis could take place in geothermally illuminated environments, it would increase the diversity of photosynthetic habitats both on Earth and on other worlds that have been proposed to possibly harbor life."* This kind of photosynthesis does not split water to liberate oxygen, which is needed to power the metabolism of multicellular plant and animal life. Does that rule out anything beyond bacterial grade organisms on dark worlds?**

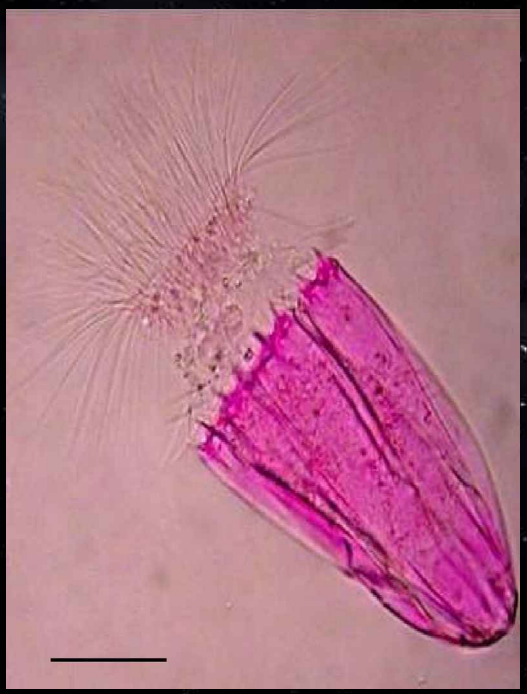


Image credit: R. Danovero *et al*. CC BY 2.0.

An amazing discovery in oxygen-starved sediments in the 3.5 km deep L'Atalante "dead zone," of the Black Sea has challenged long-held ideas and raised interesting questions about options for multi-cellular life beyond the Earth.

Robert Danovaro of the Polytechnic University of Marche and his team reported 1 mm long multi-cellular animals, members of the phylum the Loricifera, that can live and reproduce in the absence of oxygen and light (Danovaro *et al.*, 2010). They wrote:"*The discovery of these life forms opens new perspectives for the study of metazoan life in habitats lacking molecular oxygen.*"

These kinds of discoveries do not *prove* that life with suitable adaptations could evolve on planets and moons way out in the depths of space, but they do make cautious optimism respectable.

For the foreseeable future, however, the outer Solar System will be keeping its secrets.

ZOOLOGICAL NOTE: The alien-looking creature shown in the photo above (from R. Danovaro *et al.*, 2010) is a member of the phylum Loricifera. It is the previously undescribed *Spinoloricus* sp.. The picture was obtained by using light microscopy and the specimen was stained with Rose Bengal. The size of the scale bar is 50 µm, which makes the organism about a third of a mm long. Its habitat was in a hypersaline layer on the floor of the Black Sea, whose density of about 1.23 g per cm^3 means that it does not rise and mix with overlying water layers containing oxygen. Instead of mitochondria (the organelles inside our cells which enable food-stuffs to react with oxygen during respiration) these animals, which are obliged to live in anaerobic conditions, posses another organelle, the hydrogen-producing hydrogenosome, which, it is widely believed, evolved from the mitochondrion.

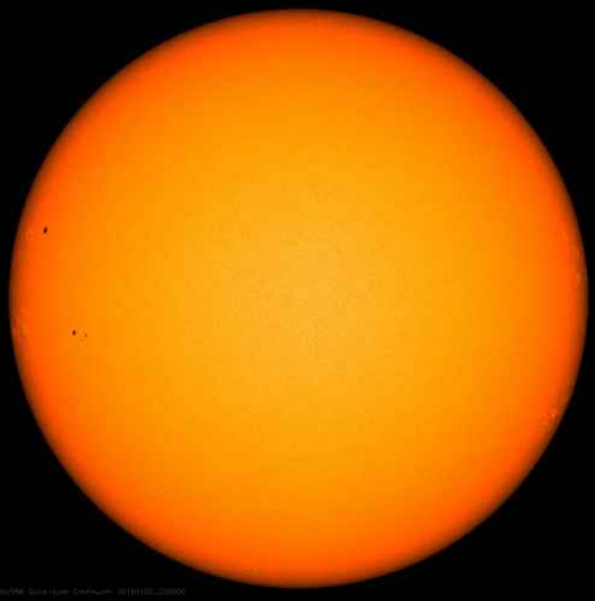
Batygin, K. & Brown, M. E. (2016). *Astronomical Journal* doi:10.3847/0004-6256/151/2/22. **Beatty, J. T. *et al.* (2005).** *Proc. Natl. Acad. Sci. U.S.A.* 102: 9306–9310. **Danovaro, R. *et al.* (2010).** *BMC Biology* doi:10.1186/1741-7007-8-30. Stevenson, D. J. (1999). Life-sustaining planets in interstellar space? *Nature* **400**: 32. **Szewzyk, U. *et al.* (1994).** *Proc. Natl. Acad. Sci. U.S.A.* 91: 1810–1813. **Tajika, E. (2008).** *Astrophysical Journal Letters* 680: L53–L56.

January 2, 2016: Earth at perihelion.

Our planet passed through the closest part of its orbit to the Sun (perihelion) at 22:49 GMT on January 2.

At this time, it was 0.9833039 of its average distance from our star according to former NASA eclipse expert Fred Espenak.

The average distance of the Earth from the Sun is known as the Astronomical Unit. In August, 2012, a meeting of the International Astronomical Union in Beijing voted to adopt a fixed value of 149,597,870.7 km.



Above: The Earth as seen by the NASA/NOAA DSCOVR satellite on January 2 at 05:55:53.

Left: The Sun from NASA's Solar Dynamics Observatory on January 2 at 23:00:00.

This average temperature of the Sun's disc is roughly 5,800 K (Kelvin scale starts at absolute zero and 273.16 K = 0ºC). Because the line of sight penetrates to a greater depth (and so to hotter layers) in the centre of the disc and to shallower depths (cooler layers) around the edge (astronomers call this the "*limb*," the centre appears brightest and the limb dullest. This is known as "*limb darkening*."

Safety tip: Do not look at the Sun through telescopes, binoculars, cameras or unaided eye.

January 30, 2016. The day ends. Looking over the landscape around West Kingsdown, Kent, England.

In this issue of Prime Meridian, we have opened the year by looking forwards to exciting discoveries that beckon for future generations. We now take a concerned look in the rear view mirror as we bid farewell to 2015. The year just gone has been cited by climatologists as globally the warmest year in a record which began in 1880.

The pace of technological innovation and of our civilisation's impact on our home planet is accelerating. What we do now and in the next few decades will decide whether the great adventure of civilisation ends in triumph or tragedy. We are only now beginning to understand just how profound our impact is. In coming issues of Prime Meridian, we will be discussing research published in major peer-reviewed science journals which asks whether global warming caused by *Homo sapiens*' release of greenhouse gases will be so massive as to modify the natural cycle of the ice ages.

Seasons in South East England

December, 2015

Above: The Sun sets behind a belt of trees on Dec. 23, the day after the winter solstice. New Ash Green Kent (P. Stanford).

"an exceptional and record-breaking month." UK Met Office.

Thanks to a warm and moist tropical air mass assailing the UK for most of December, the UK enjoyed a mean temperature of 7.9ºC, an impressive 4.1ºC above the 1981-2010 norm - the warmest December since the record began in 1910. It was the warmest December in Central England since 1659. In S. England, it was even warmer, with temperatures 5 to 6ºC above the norm. No frosts were recorded in Wales or central southern England. The UK received a record 191% of its normal December rainfall. The W and N were hit by 2 to 4 times the usual amount and according to the UK Met Office "*severe flooding was exacerbated by saturated ground conditions following very wet weather in November in these areas.*" While TV screens brought a succession of flood stories from the north of Britain, the SE was let off lightly and rainfall was near-normal.

Left: Dec. 2: Evening in central London. Dec. 3: Christmas tree in Trafalgar Square. Dec. 5. Storm Desmond arrives (NASA). Below: Dec. 8. Yellowed leaves linger on silver birch (*Betula pendula*) and rainfall spatters the windows of a London bus.



Above: London, England. Christmas service (Dec. 8) in the chapel at King's College, London. Lights from windows glisten on wet flagstones in Church Court, and a Christmas tree sits outside the historic Middle Temple Hall, which saw the first performance of Shakespeare's *Twelfth Night*, in 1602 (Dec. 10, 2015).

The lowest temperature at Heathrow (Greater London) was 4ºC on Dec. 9. Dec. 13 saw the UK's lowest temp. (-8.7ºC) Dalwhinnie (Inverness-shire). The UK's maximum temp. of 17.2ºC was likewise recorded (Dec. 16) at outside our region at Teignmouth (Devon) and at Achnagart and Plockton (Highland). The month's highest temp. at Heathrow was over 16ºC on Dec. 19. That same day, Gravesend (Kent) enjoyed 17.1ºC, just a whisker short of the UK's maximum temperature. The most notable days for rainfall at Heathrow were Dec. 8 (3 mm), Dec.10 (4 mm), Dec. 5 (5 mm), Dec. 22 (5 mm) and Dec. 30 (7 mm) – all rather modest compared with the drenching received up north (from 18:00 on Dec. 4 to 18:00 GMT on Dec. 5, a record 341.4 mm of rain fell at the Honister Pass in Cumbria), which was battered by a succession of strong depressions. The Met Office regions SE England and Central S and East Anglia recorded just 0.2 day of air frost (9.8 days less than usual for the former and 9.9 days for the latter).



Left: Dec. 12, 2015. Country lane runs between a bare hedgerow (left) and small wood (near West Kingsdown). Dogwood (*Cornus sanguinea*) on woodland margin. Bare trees rise from Sydenham Hill Wood, South London.

The mild conditions mimicked spring.

Below (South London): Lesser celandine (*Ranunculus ficaria*) in full flower in West Dulwich, on Dec. 16. Daffodils (*Narcissus*) and *Primula* species bloom in Norwood Park on December 22 (winter solstice).



Above: December 15, 2015: Soyuz TMA-19M rocket lifts off from the Baikonur Cosmodrome in Kazakhstan. Amongst the crew of Expedition 46 was major Tim Peake (European Space Agency), the first representative of the UK on the International Space Station. The ISS (bright point at left) passing over Britain on Dec. 19 at 16:59. It orbits at an altitude of around 400 km. The Half Moon at right is surrounded by a "corona," with a distinctive outer rusty-coloured ring. It is caused by light passing through water droplet clouds. Storm Eva (NASA) arrived at the UK on Dec. 23, bringing widespread flooding and strong winds to the northern areas of Britain.

On the wildlife area in Belair Park (London Borough of Southwark) the bare branches of the water-side trees black poplar (*Populus nigra*) and alder (*Alnus glutinosa*) form the tree canopy. The evergreen species holly (*Ilex aquifolium*) forms a hedgerow along the NE margin of the Park. Its red berries are a seasonal feature celebrated in numerous Christmas cards.

Below: Houses located near the edge of the fields and woods at New Ash Green were lit up in celebration (Dec. 22, 2015). Worshippers gathered on December 24/25 for the Midnight Mass at All Saints Church, West Dulwich. On a chilly Christmas morning after the service (around 01:20 GMT) a Full Moon shone down from a clear sky.

SE and central S England, mean max. temp.: 12.8ºC (5.0ºC); mean min. temp.: 8.2ºC (6.2ºC). Hours of sunshine: 33.5 (66%). Rain: 83.9 mm (100%). Anomalies re. 1981-2010 norm in brackets. Source UK Met Office.

2015 drew to its close . . . .

The Paris climate summit was held in December and the year ended with renewed warnings about the need to tackle human-made climate change and hopes that new intenational agreement would bring that about.

According to a statement issued on November 25, 2015 from the World Meteorological Organization (Geneva), "*The global average surface temperature in 2015 is likely to be the warmest on record and to reach the symbolic and significant milestone of 1°Celsius above the pre-industrial era. This is due to a combination of a strong El Niño and human-induced global warming* ". The period 2011 to 2015 was the warmest half decade on record.

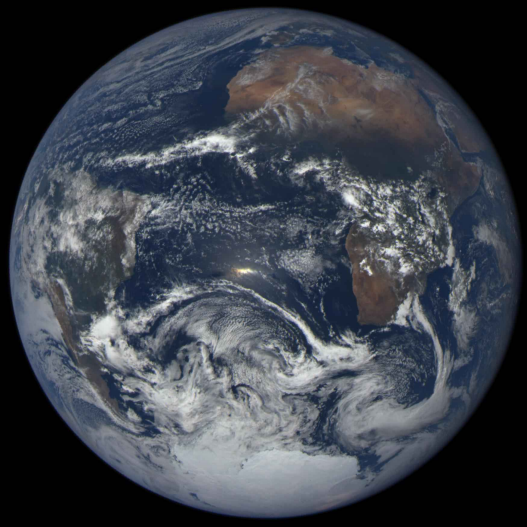
December 31, 2015. The floor of a small wood near West Kingsdown, Kent. Ivy (*Hedera helix*) and dog's mercury (Mecurialis perennis) rise through the carpet of fallen leaves and twigs. The leaves of wild arum (*Arum maculatum*) are typically seen in April to May, but had clearly been emerging here for some weeks.

At around 08:17 GMT, a few minutes after the final day of the year had dawned, the waning Half Moon hung in an ashen blue sky. Common wood pigeons (*Columba palumbus*) perch in a bare tree (New Ash Green; P. Stanford). By around 14:55 GMT, the descending Sun was being swallowed by banks of cloud hugging the horizon in South London.

Global climate: December 2015 - the year concluded with not only record warmth, but extraordinary warmth.

"This is the first time the global monthly departure from average has surpassed 1°C and is the largest margin by which an all-time monthly temperature record has been broken. Incredibly, the December 2015 temperature also surpasses the December record temperature set last year by 0.29°C"

After analysis of measurements, that was the pronouncement of NOAA, the USA's National Oceanic and Atmospheric Administration. The record dates back to 1880.



The Northern Hemisphere's winter solstice. Above right: Our hemisphere is in the depths of winter, whilst the Southern Hemisphere, tilted toward the Sun, is enjoying mid-summer. The ice-bound continent of Antarctica and the forested areas of Africa and South America are prominent. The Sun is glinting off the ocean in the centre of the disk at the Tropic of Capricorn. The DSCOVR image of the Earth was taken on December 22, 2015 at 12:58:44 GMT. NASA/NOAA.

The 20th Century average global temperature for December was 12.2°C. The combined mean for land and ocean taken together was 1.11 ± 0.07°C higher than this. Land areas were 1.89 ± 0.11°C warmer and oceans were 0.83 ± 0.03°C warmer than their means - both the warmest on record.

In the N. Hemisphere, the combined mean temperature for land and ocean was 1.417 ± 0.07°C, the land areas a notable 2.37 ± 0.12°C and the oceans 0.98 ± 0.03°C above their norms - all the warmest ever recorded. The same was seen in the S. Hemisphere, where the mean combined land and ocean temperature was 0.80 ± 0.06°C, the land 1.27 ± 0.11°C, and the ocean 0.72 ± 0.03°C above their norms, in every case the warmest recorded.

NOAA reported that *"The highest temperature anomalies (more than 5°C / 9°F above the 1981-2010 average) were observed across much of northern Eurasia and eastern North America, driving much* [sic] *the global record warmth. It was cooler than average in eastern Russia, regions of central and northern Africa, and part of central South America, according to the December Land & Ocean Temperatures Departure from Average and Percentiles maps above. No land areas were record cold in December."*

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A major factor in raising the global mean temperature was the very strong and almost record El Niño (warm) conditions in the central and equatorial Pacific. NOAA's annual report stated *"This is the first time in the NOAA record that a monthly temperature departure from average exceeded 1°C or reached 2°F and the second widest margin by which an all-time monthly global temperature record has been broken. (February 1998 broke the previous record of March 1990 by 0.13°C / 0.23°F.)"*

Source: *NOAA National Climatic Data Center, State of the Climate: Global Analysis for December, 2015.* Published online. Data provisional.

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Email: prime-meridian01@hotmail.com Website: www.ecospheresproject.org

2015 – the warmest year on record.

NOAA's annual analysis confirmed some remarkable statistics. Apart from January (2nd warmest since 1880) and April (3rd warmest since 1880), every month of 2015 set a new record for warmth. According to NOAA, "*This is not only the highest calendar year temperature, but also the highest temperature for any 12-month period on record. . . . The 2015 temperature also marks the largest margin by which an annual temperature record has been broken. Prior to this year, the largest margin occurred in 1998, when the annual temperature surpassed the record set in 1997 by 0.12°C (0.22°F).*"

This was the fourth year to set a record high in the 21st C, 2005, 2010 and 12014 having also done so. It was the 39th consecutive year since 1977 that the annual temperature has exceeded the 20th C mean. 15 of the 16 warmest years have occurred during this century (2009 tied with 1998 in 6th place).

For the year as a whole, the global average for both land and ocean was 0.9 ± 0.08°C above the 20th C mean of 13.9°C. This topped 2014, the previous record holder by 0.16°C. Land areas were 1.33 ± 0.18°C warmer and oceans were 0.74 ± 0.00°C warmer than their means. In the N. Hemisphere, the combined mean temperature for land and ocean was 1.09 ± 0.11°C, the land areas 1.44 ± 0.21°C and the oceans 0.87 ± 0.00°C above their norms. In the S. Hemisphere, the mean combined land and ocean temperature was 0.70 ± 0.06°C, the land 1.04 ± 0.11°C, and the ocean 0.64 ± 0.02°C above their norms. Every one of these values set a new record.

NOAA estimated that, "*Overall, the global annual temperature has increased at an average rate of 0.07°C (0.13°F) per decade since 1880 and at an average rate oftemperature has increased at an average rate of 0.17°C (0.31°F) per decade since 1970.*"

Images of 2015 (clockwise from top): Near West Kingsdown, Kent. Jan. 4, a foggy start to the month. Afternoon sunshine casts long shadows on Mar. 6. Bluebell wood on Ide Hill, Kent on April 21. Wheat ripens on hill side near Ash, Kent on July 11. Autumn colours over Sydenham Hill Wood, South London on Nov. 9. A bare hedgerow with clematis gone to seed (near West Kingsdown), on the drab final day of 2015.