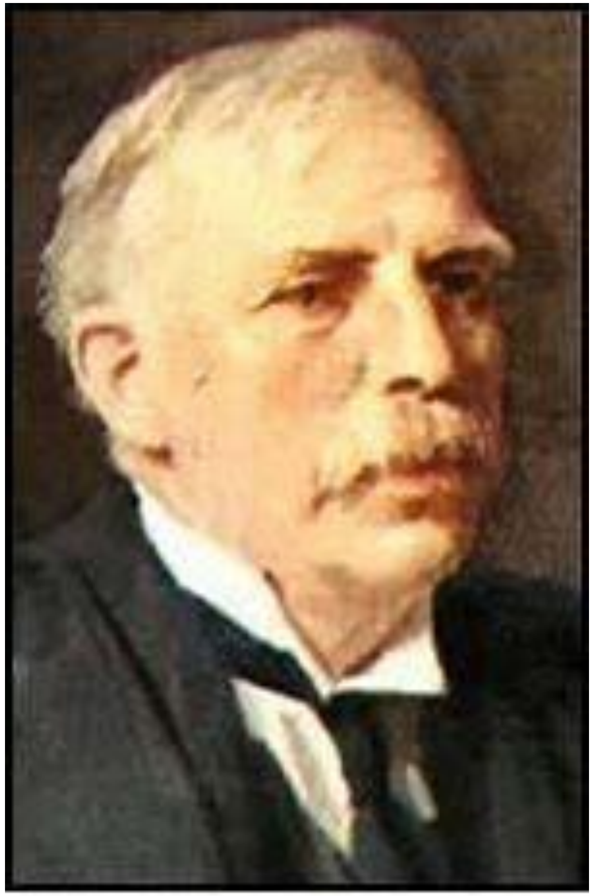
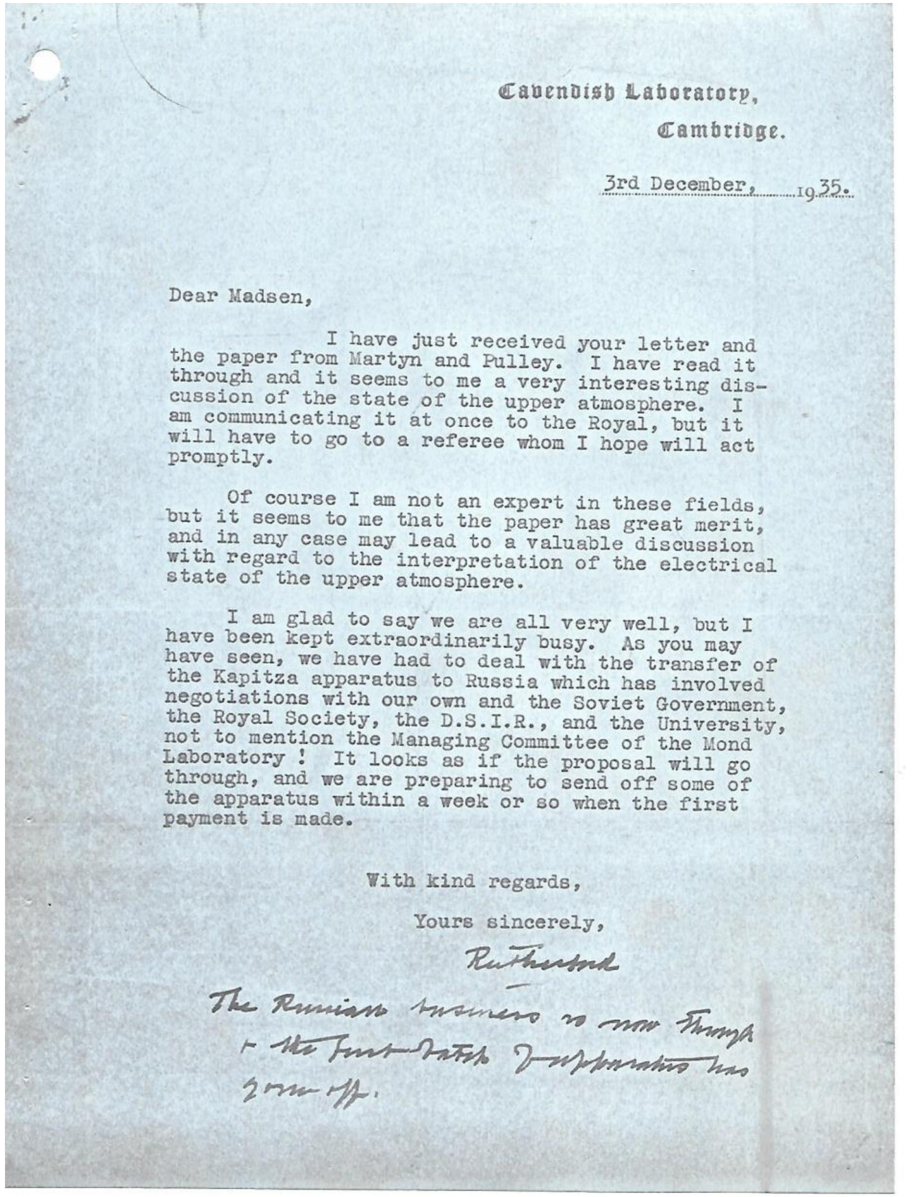
1.Temperature & Constituents of Upper Atmosphere 1935-2020.

RADIO RESEARCH AT SYDNEY UNIVERSITY ELECTRICAL ENGINEERING DEPT WITHIN THE RADIO RESEARCH BOARD OF CSIRO BY D F MARTYN & O O PULLEY UNDER THE SUPERVISION OF J P V MADSEN.

2.1935 Royal Society Paper Sponsored by Lord Rutherford.





Cavendish Laboratory,
Cambridge.

3rd December, 1935.

Dear Madsen,

I have just received your letter and the paper from Martyn and Pulley. I have read it through and it seems to me a very interesting discussion of the state of the upper atmosphere. I am communicating it at once to the Royal, but it will have to go to a referee whom I hope will act promptly.

Of course I am not an expert in these fields, but it seems to me that the paper has great merit, and in any case may lead to a valuable discussion with regard to the interpretation of the electrical state of the upper atmosphere.

I am glad to say we are all very well, but I have been kept extraordinarily busy. As you may have seen, we have had to deal with the transfer of the Kapitza apparatus to Russia which has involved negotiations with our own and the Soviet Government, the Royal Society, the D.S.I.R., and the University, not to mention the Managing Committee of the Mond Laboratory ! It looks as if the proposal will go through, and we are preparing to send off some of the apparatus within a week or so when the first payment is made.

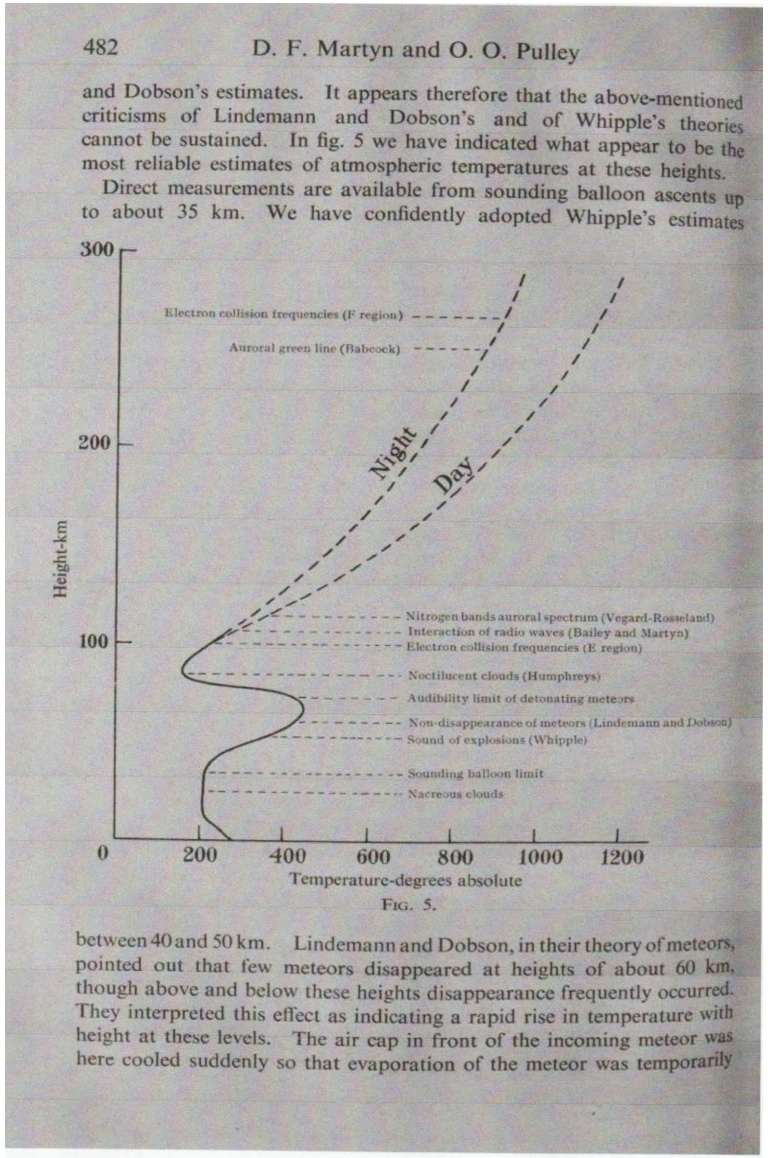
With kind regards,

Yours sincerely,

Rutherford

The Russian business is now through & the first batch of apparatus has gone off.

3.D F Martyn & Temperature Graph. Noctilucence.



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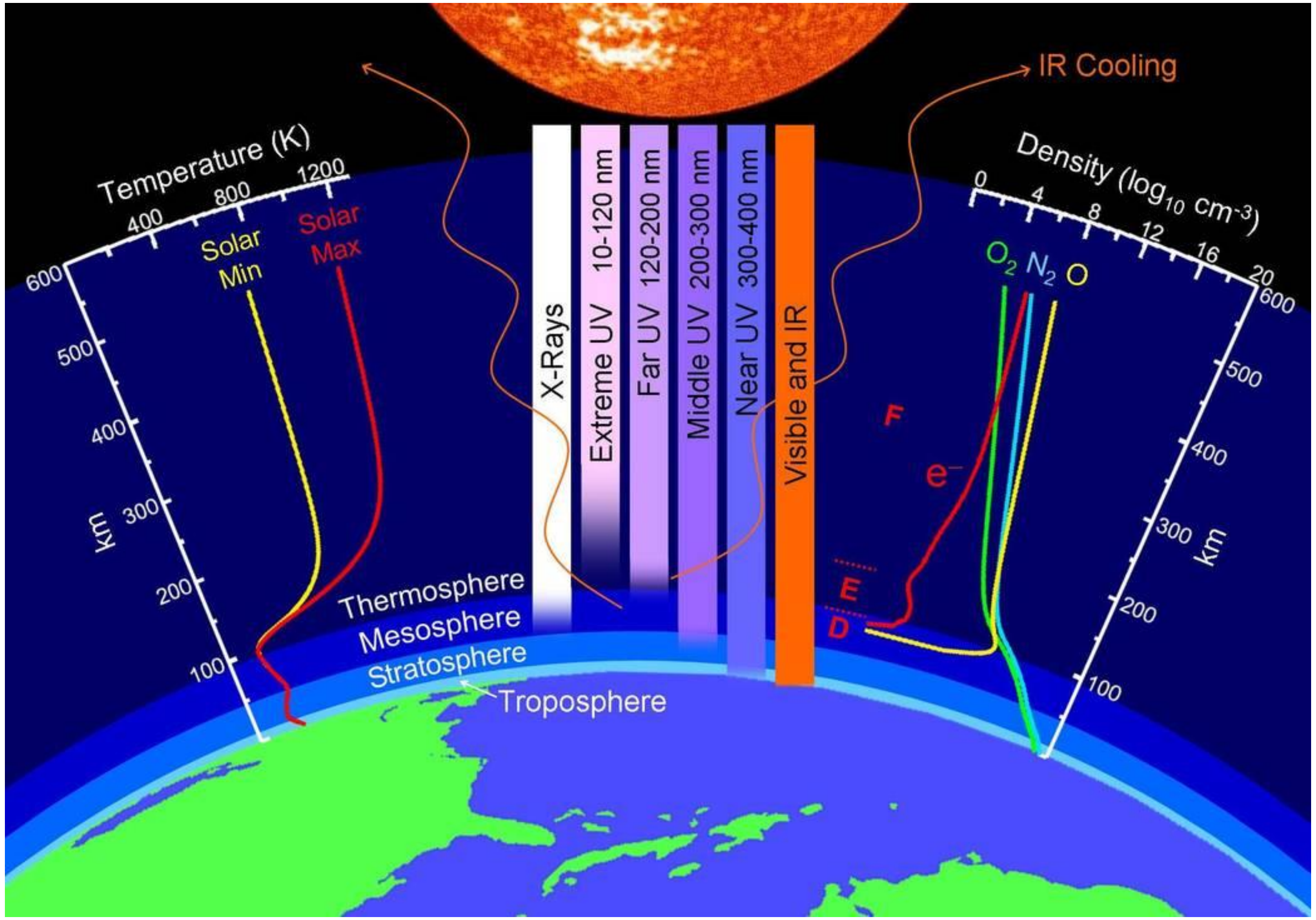
and Dobson's estimates. It appears therefore that the above-mentioned criticisms of Lindemann and Dobson's and of Whipple's theories cannot be sustained. In fig. 5 we have indicated what appear to be the most reliable estimates of atmospheric temperatures at these heights.

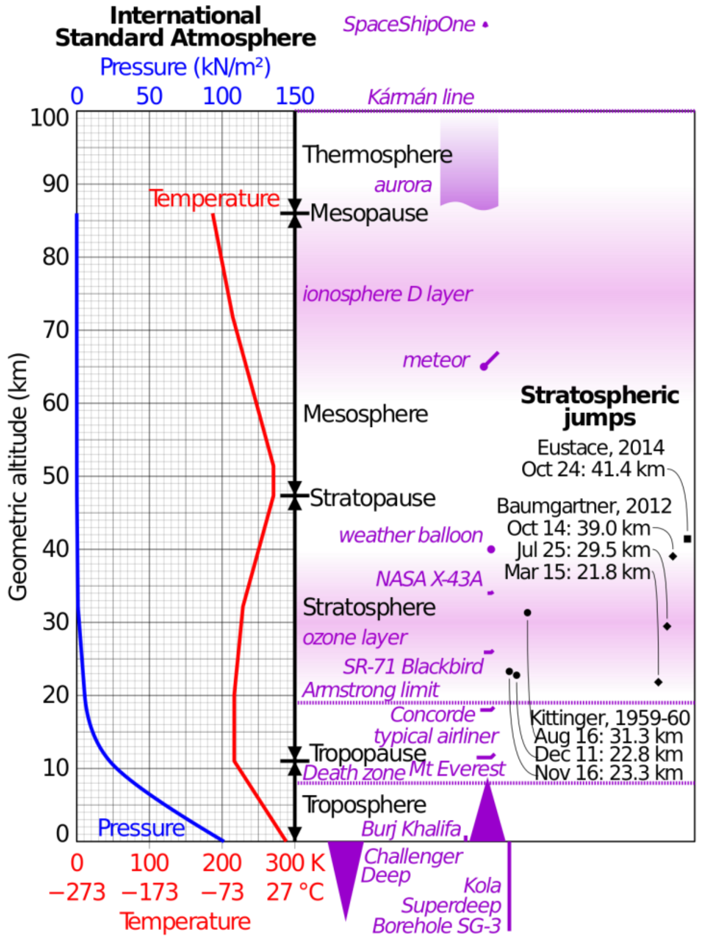
Direct measurements are available from sounding balloon ascents up to about 35 km. We have confidently adopted Whipple's estimates

Fig. 5.

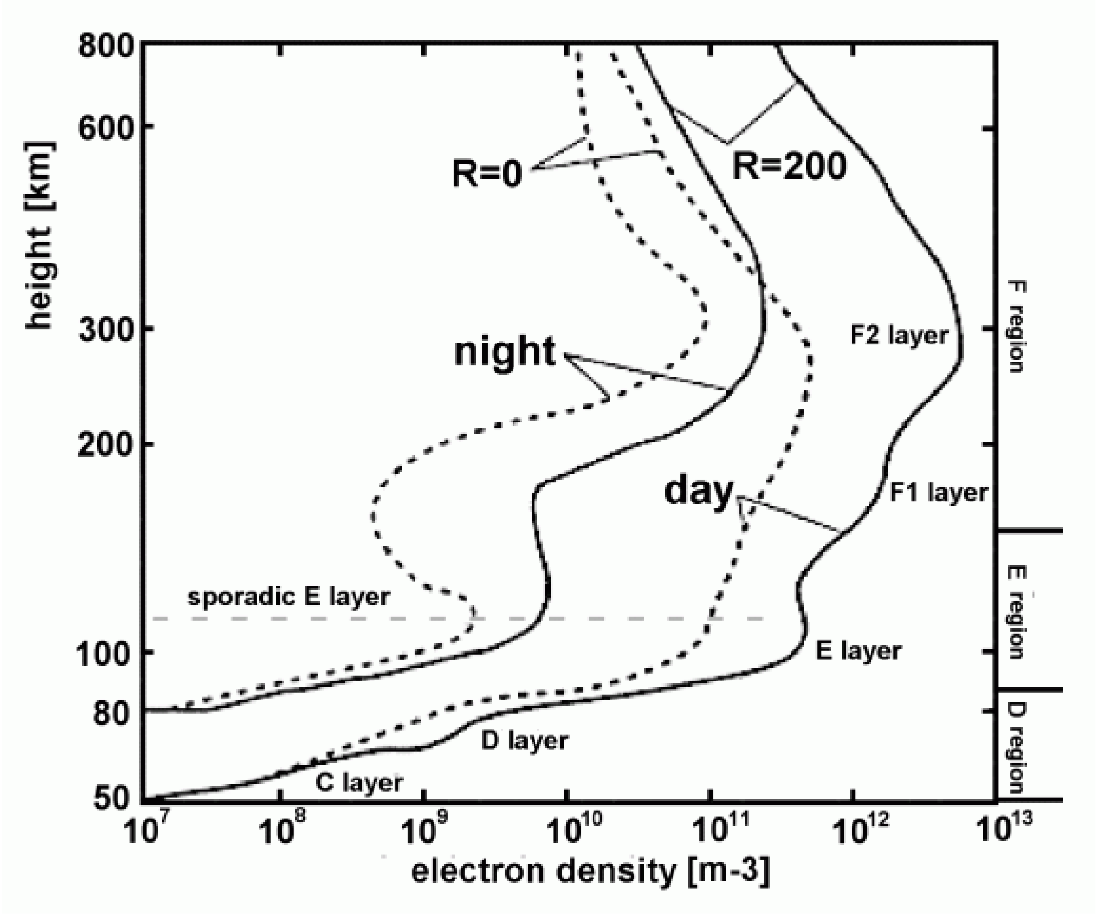
between 40 and 50 km. Lindemann and Dobson, in their theory of meteors, pointed out that few meteors disappeared at heights of about 60 km, though above and below these heights disappearance frequently occurred. They interpreted this effect as indicating a rapid rise in temperature with height at these levels. The air cap in front of the incoming meteor was here cooled suddenly so that evaporation of the meteor was temporarily

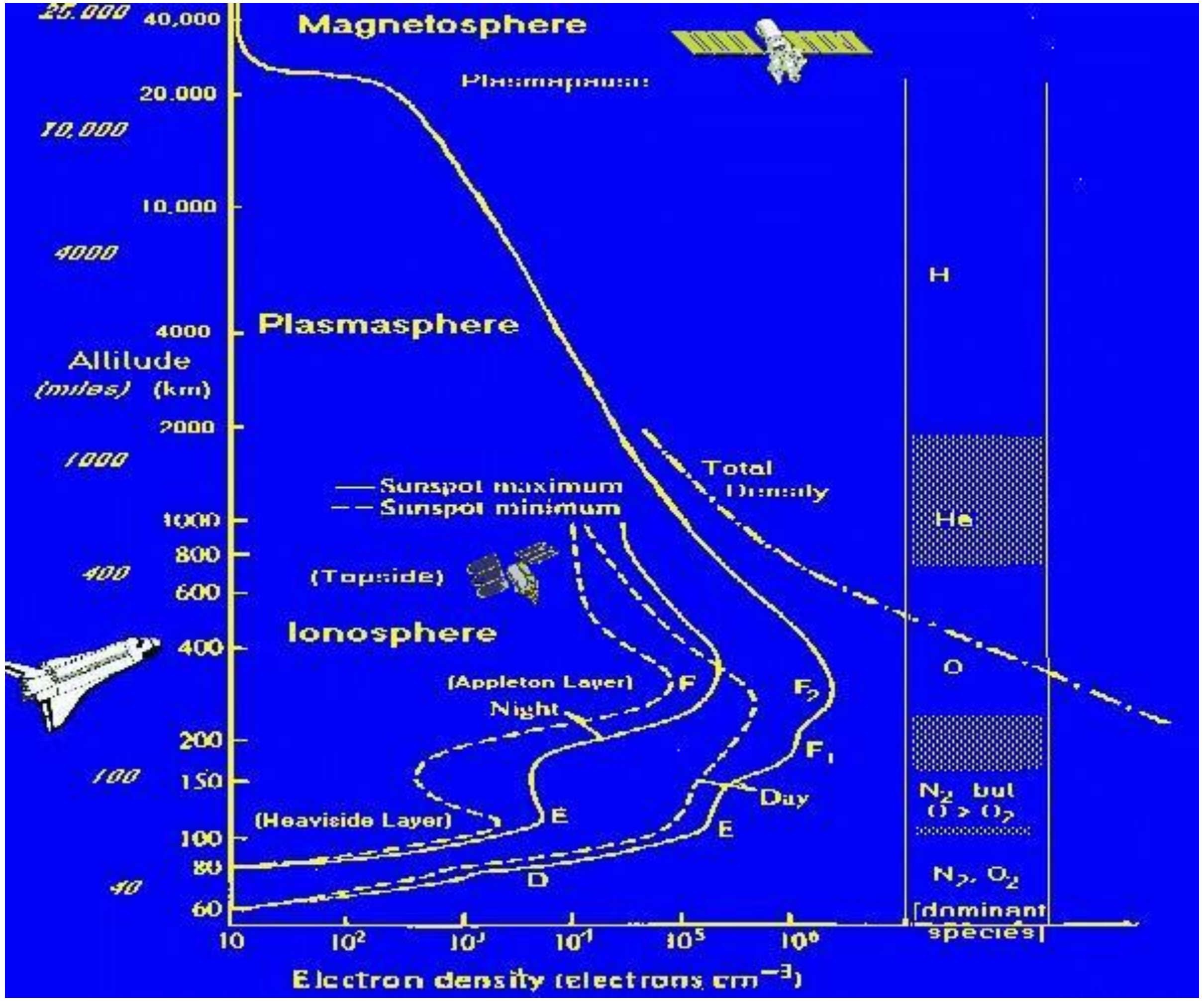
4.International Standard Atmosphere.



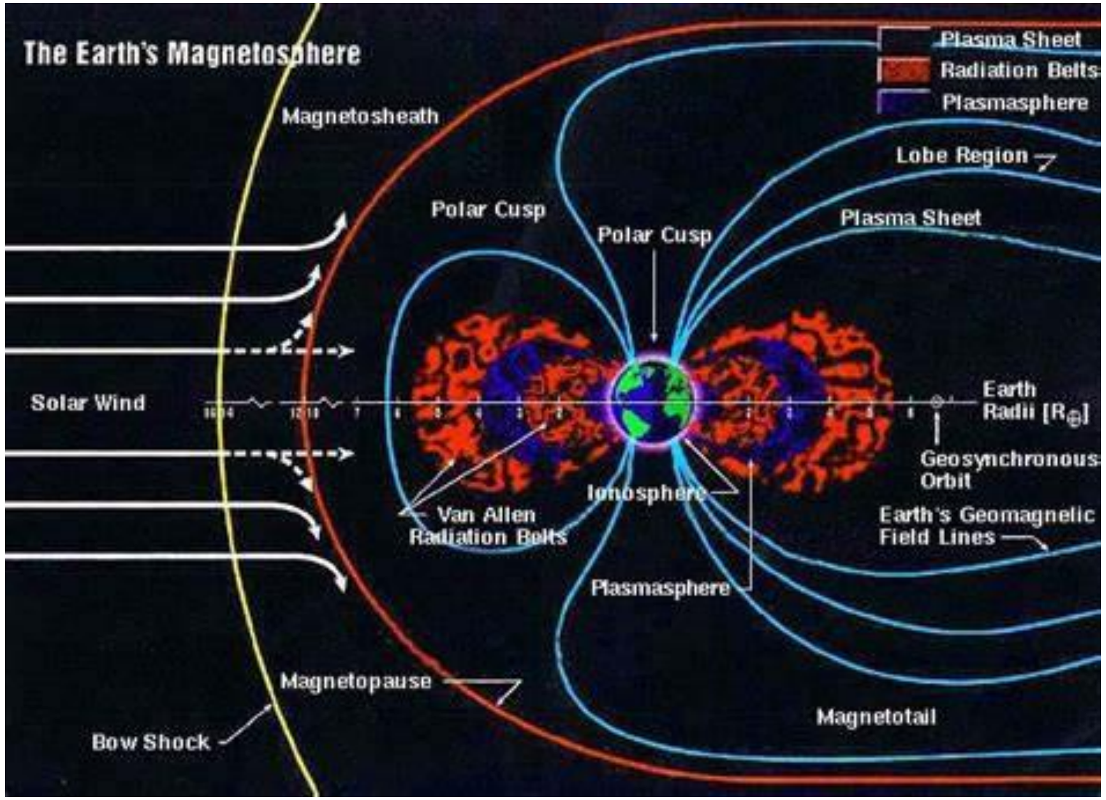


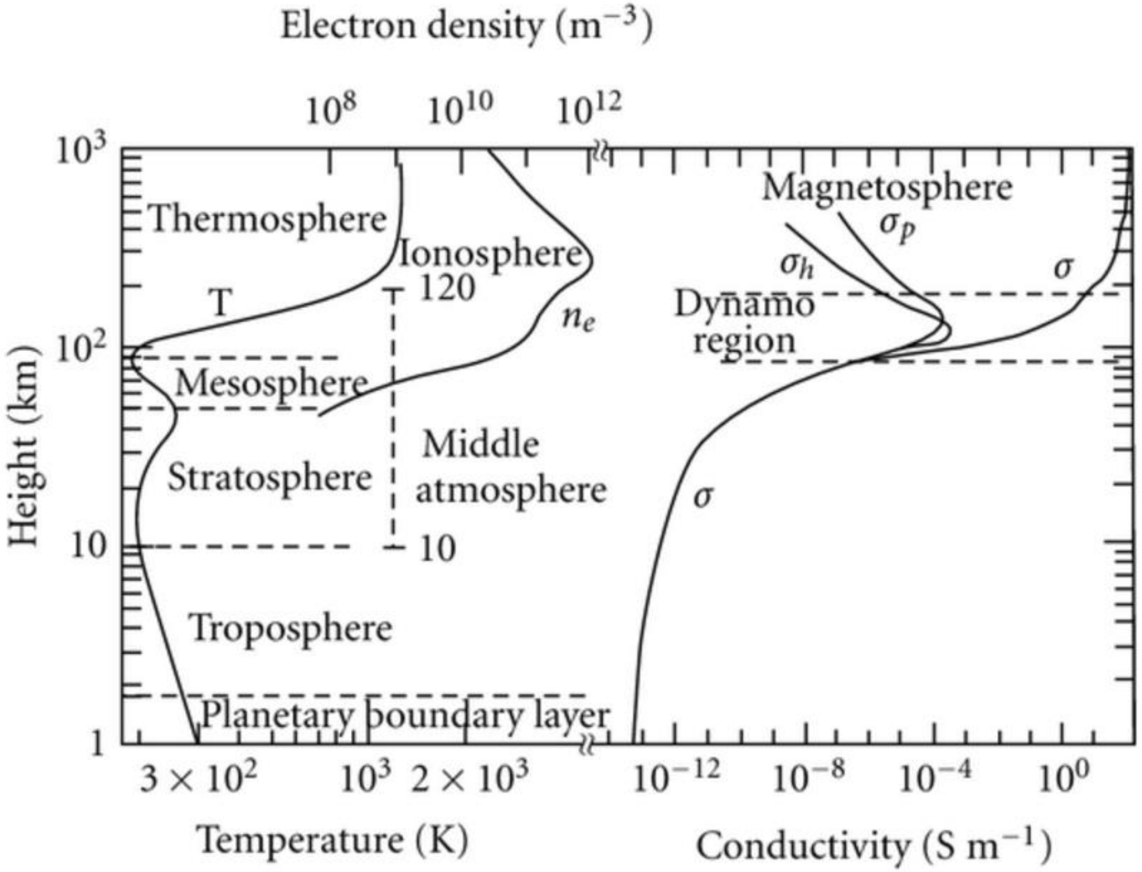
5.Electron Density Layers & Map.



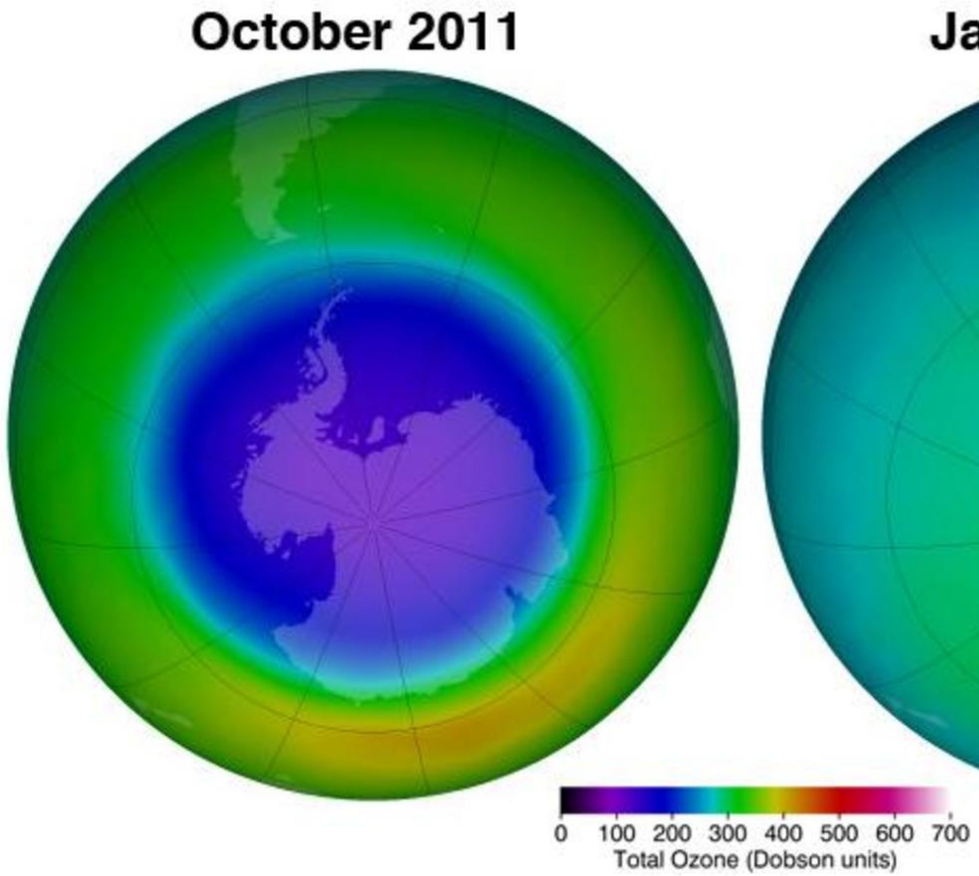


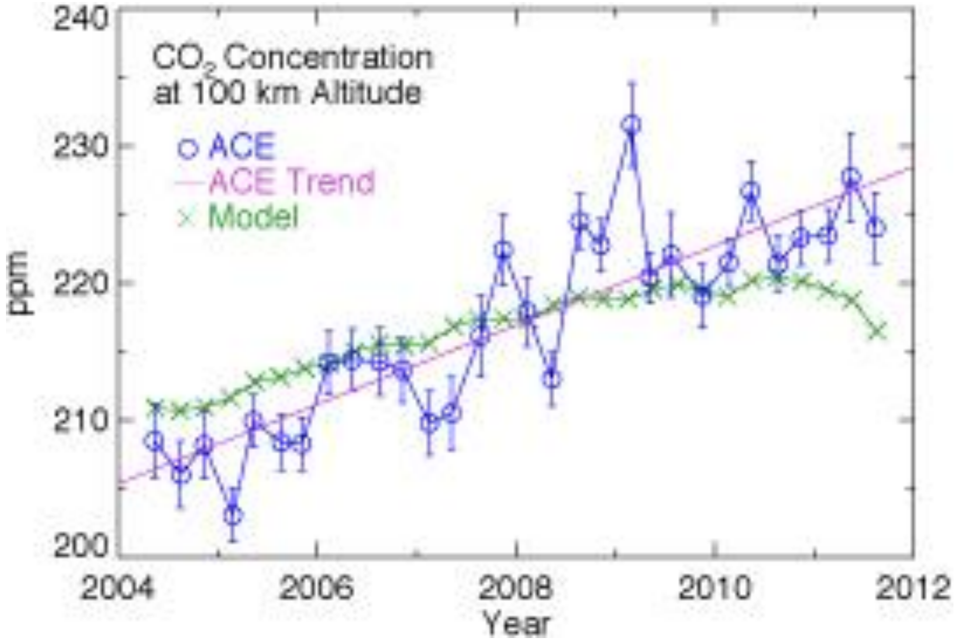
6.Magnetosphere & Properties.





7.Ozone Holes & CO2 at 100 km Altitude.





8.Satellite atmosphere Temperature Trend 1979-2005. Antarctic 1,000 year CO2 & CH4.

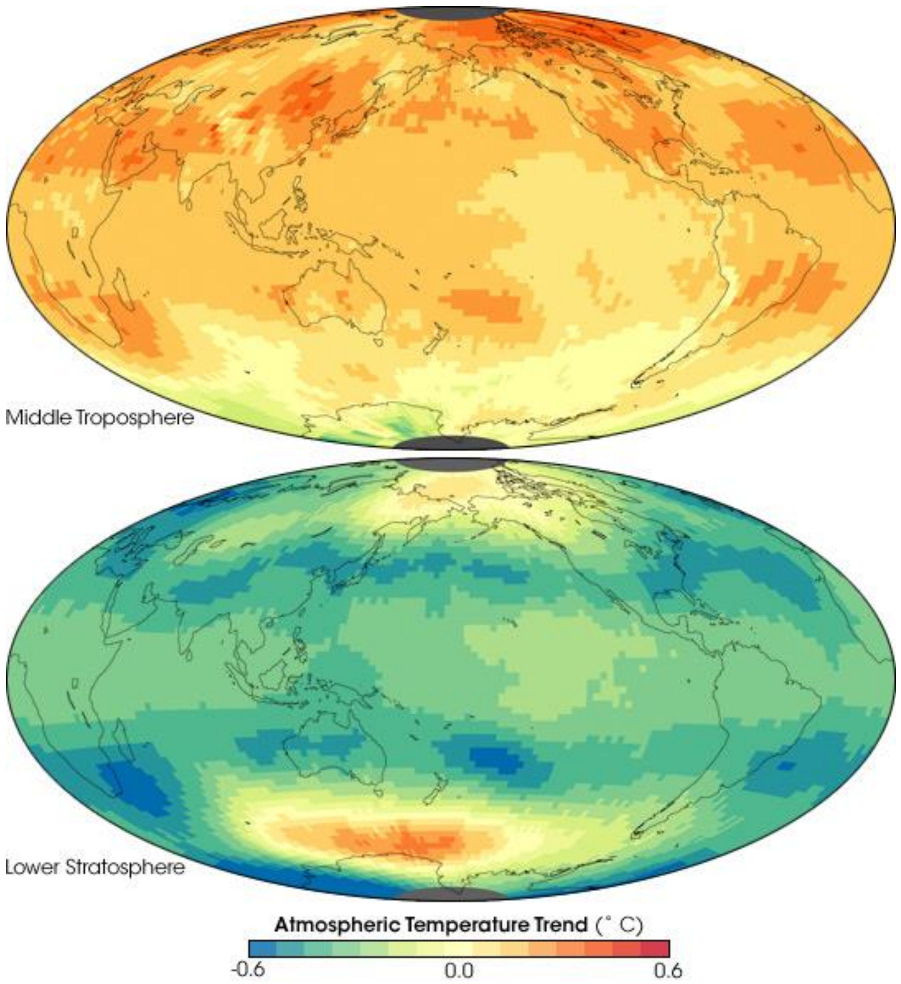
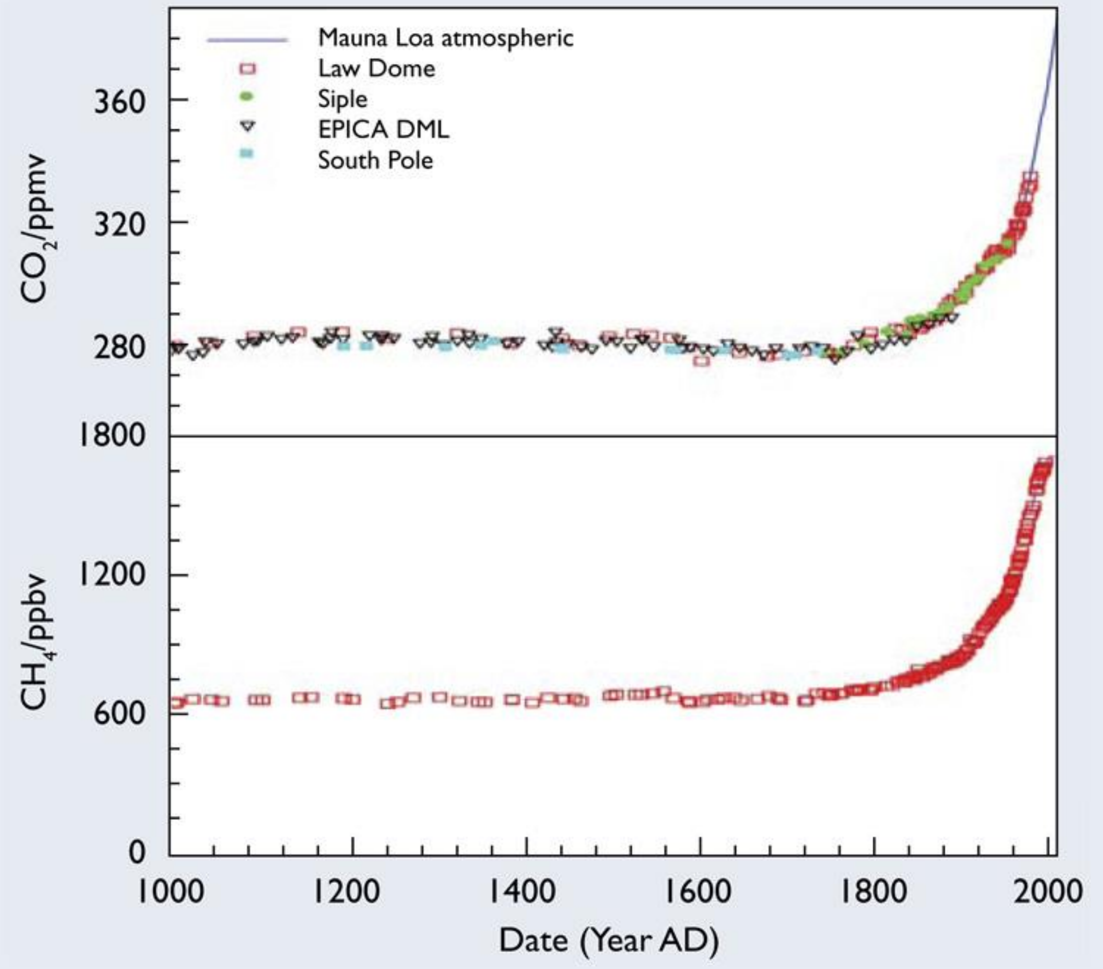
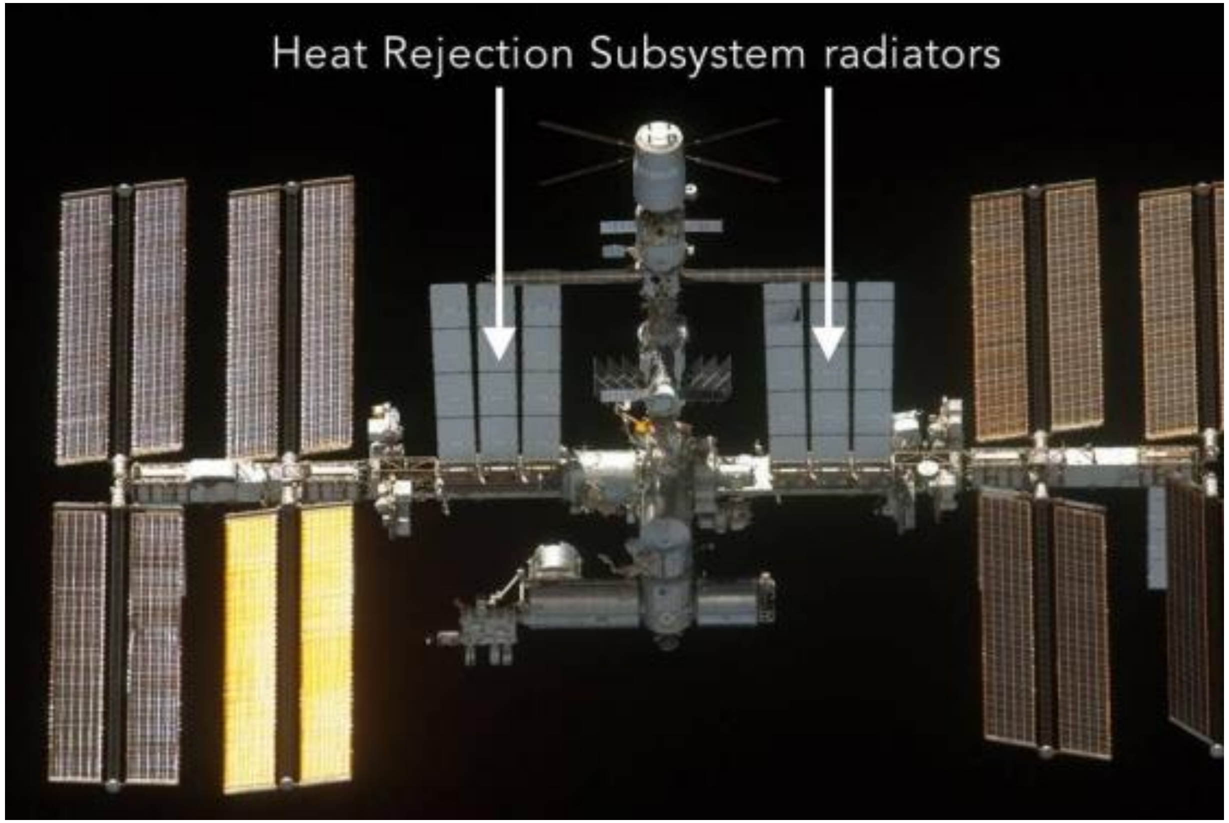


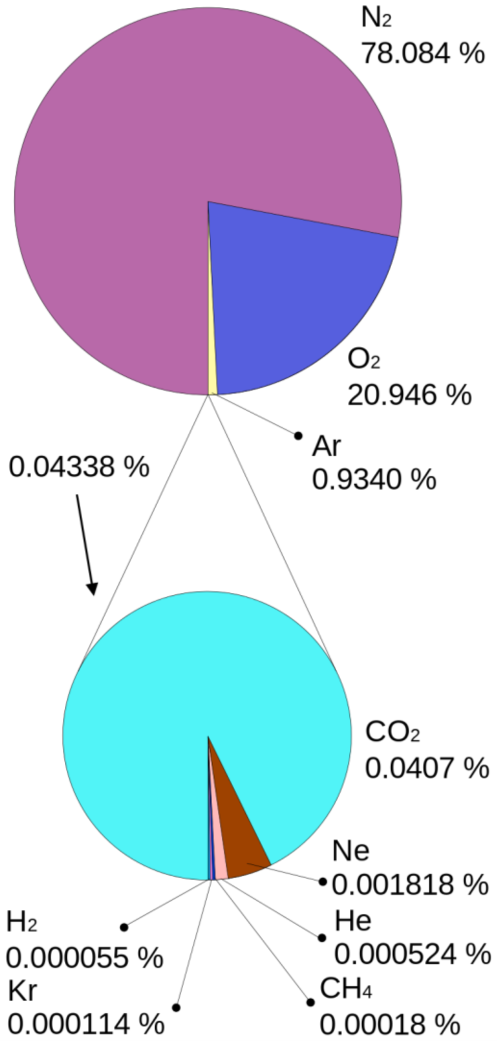
Fig. 2: CO_2 and CH_4 over the last 1,000 years[1-4]

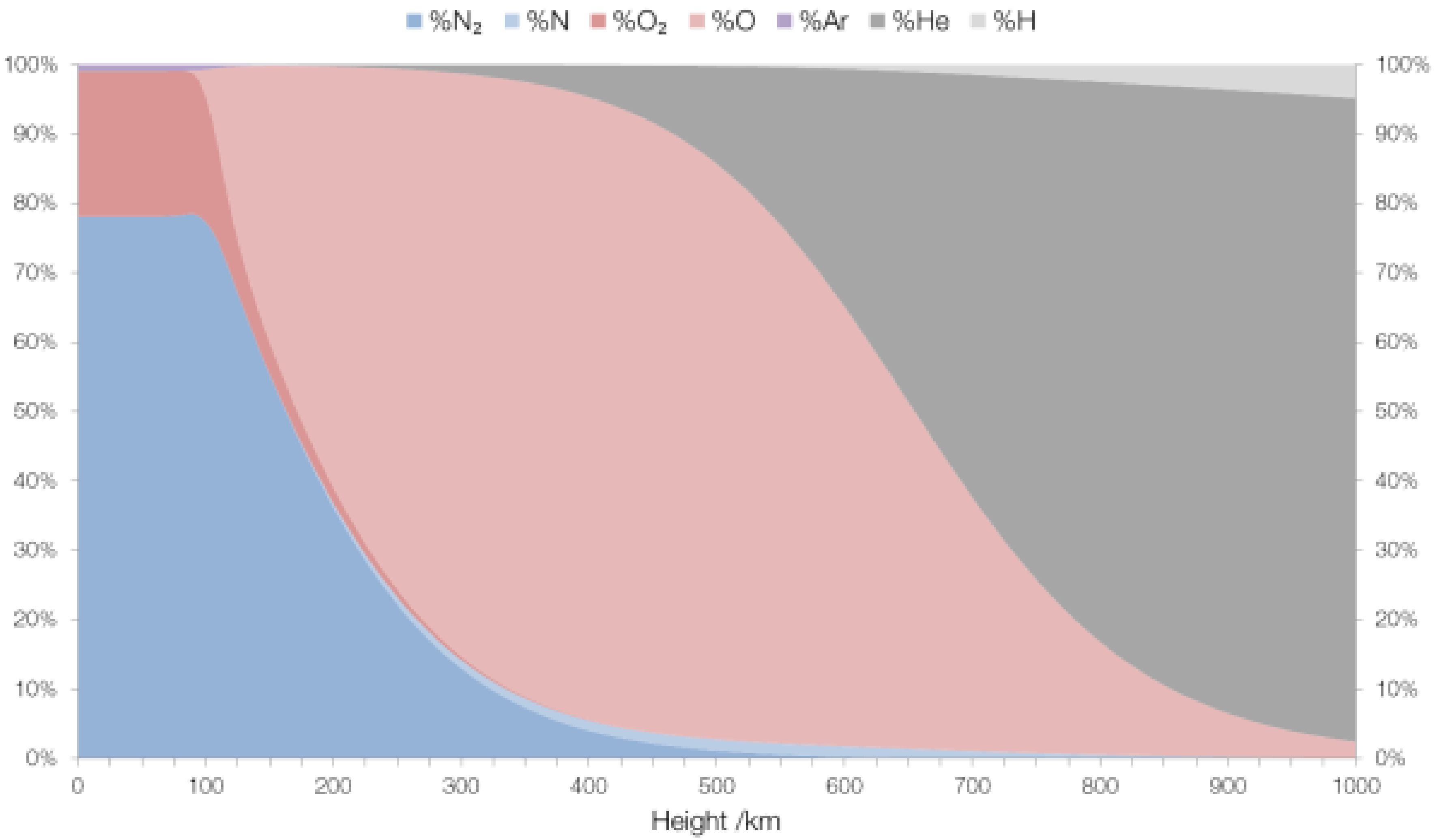


9.International Space Station: Heat Rejection System. Nile at night.

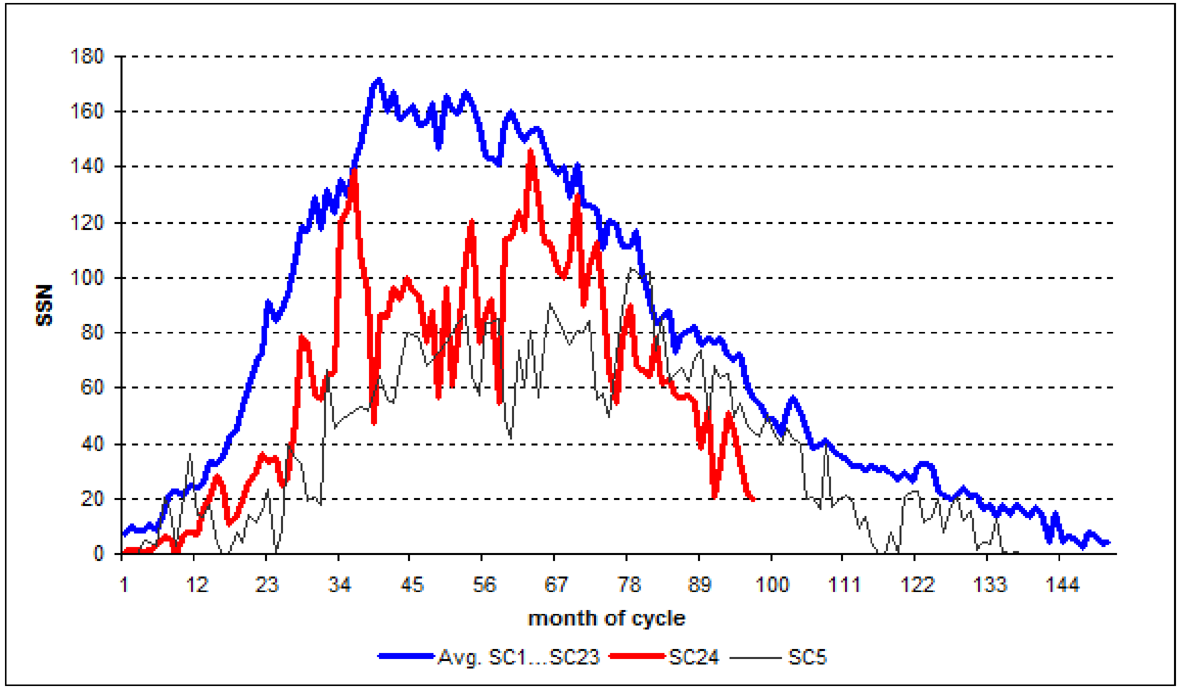


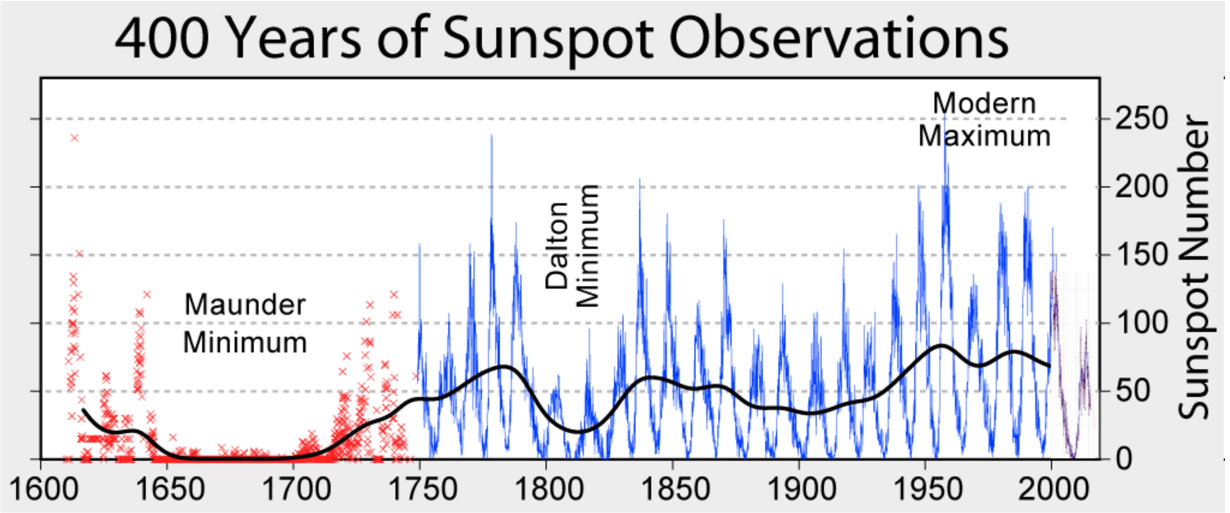
10.Composition of the Atmosphere.





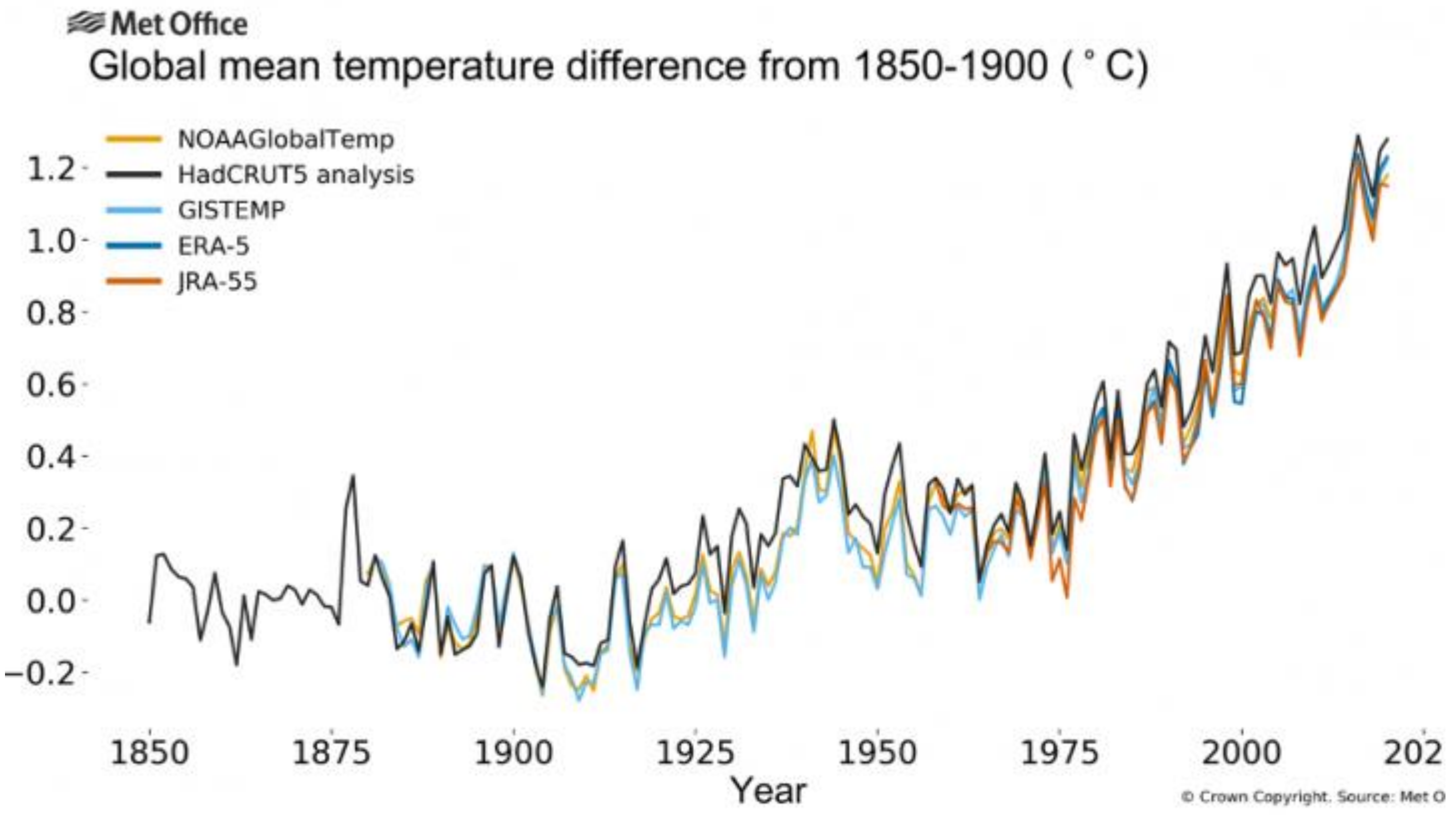
11.Sunspot cycle & Activity.



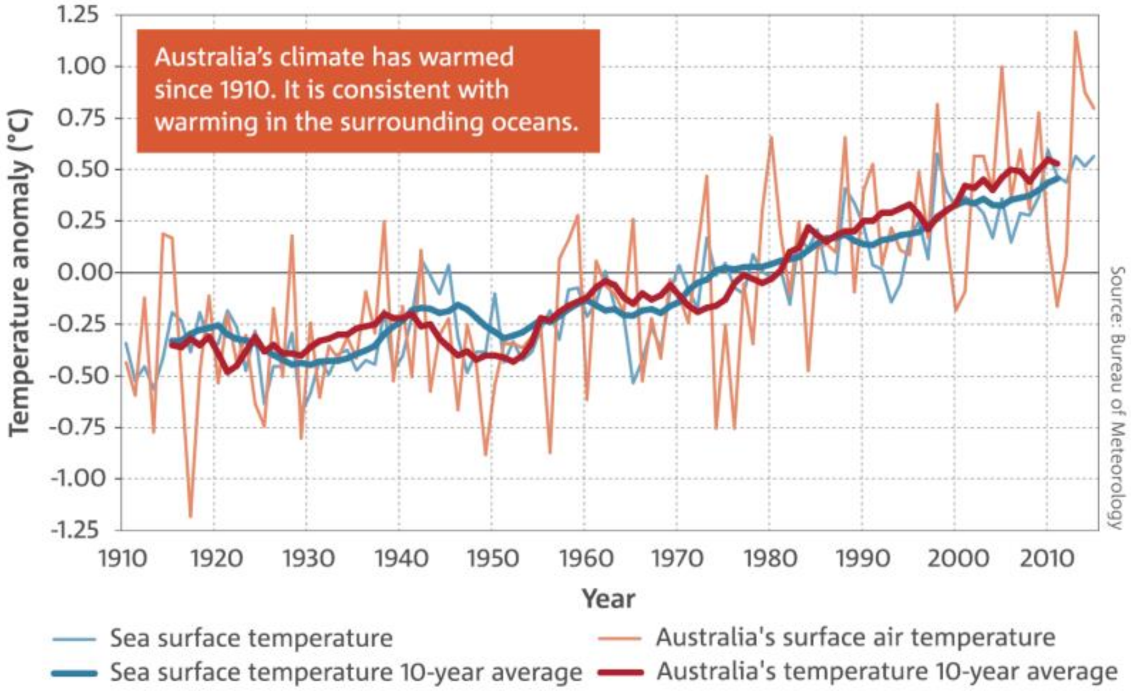


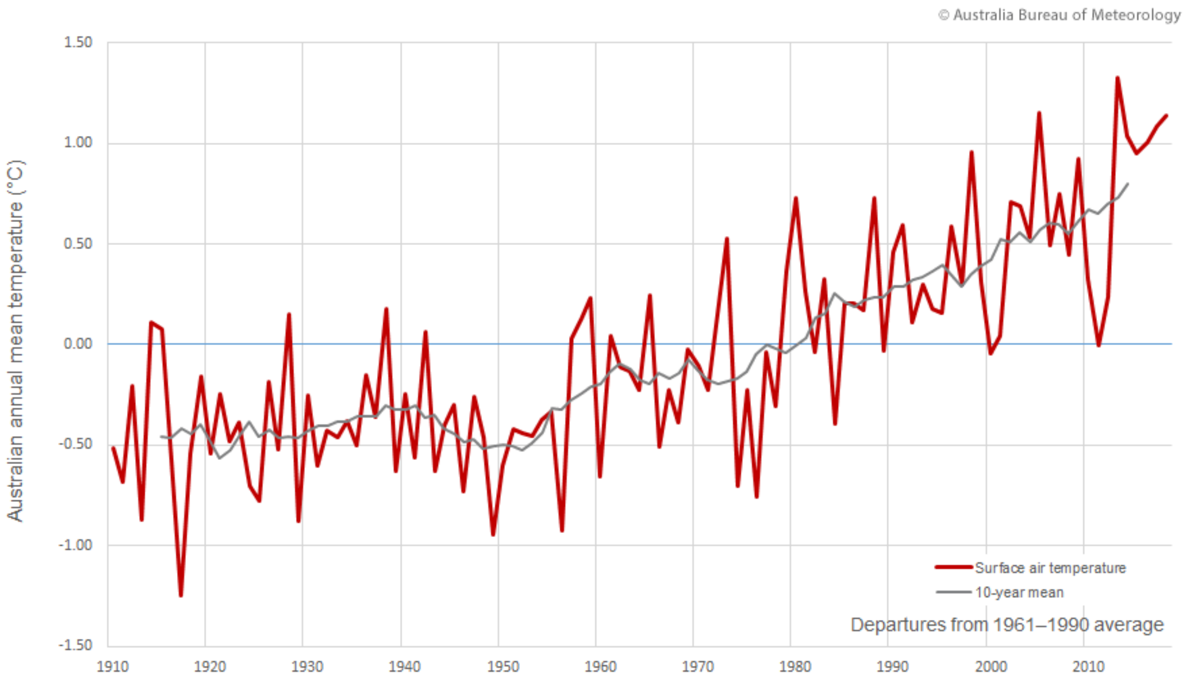
12.Global Mean Temperature.

- Since 1980, 0.7 dg C increase.

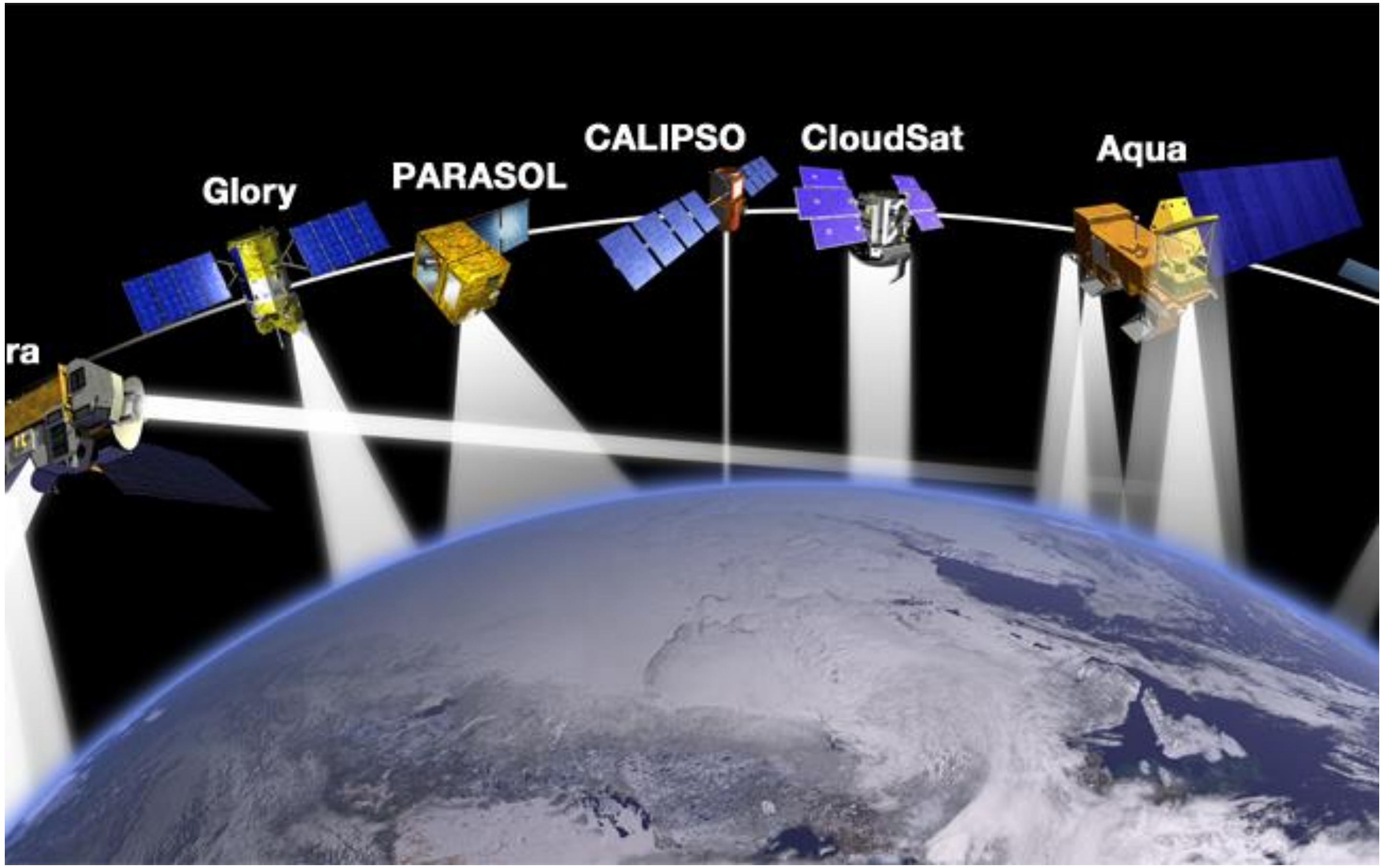


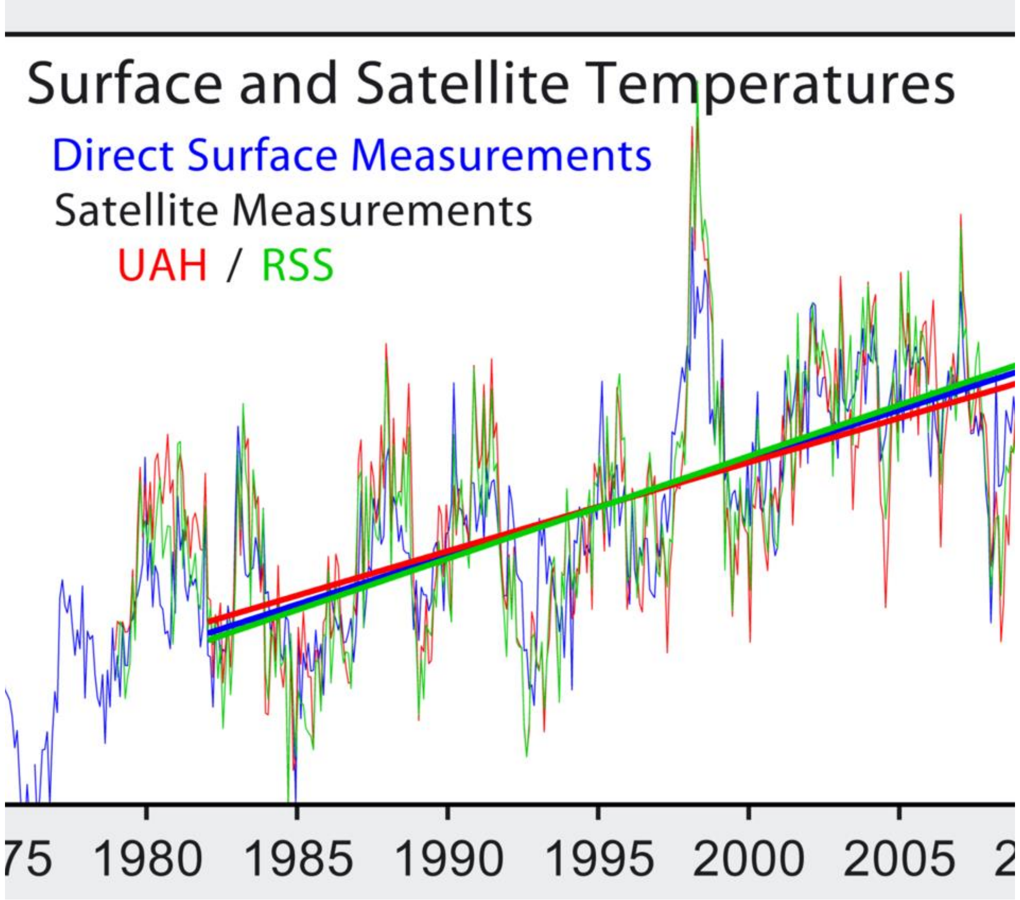
13.Australian Sea & Air Surface temperature since 1910.



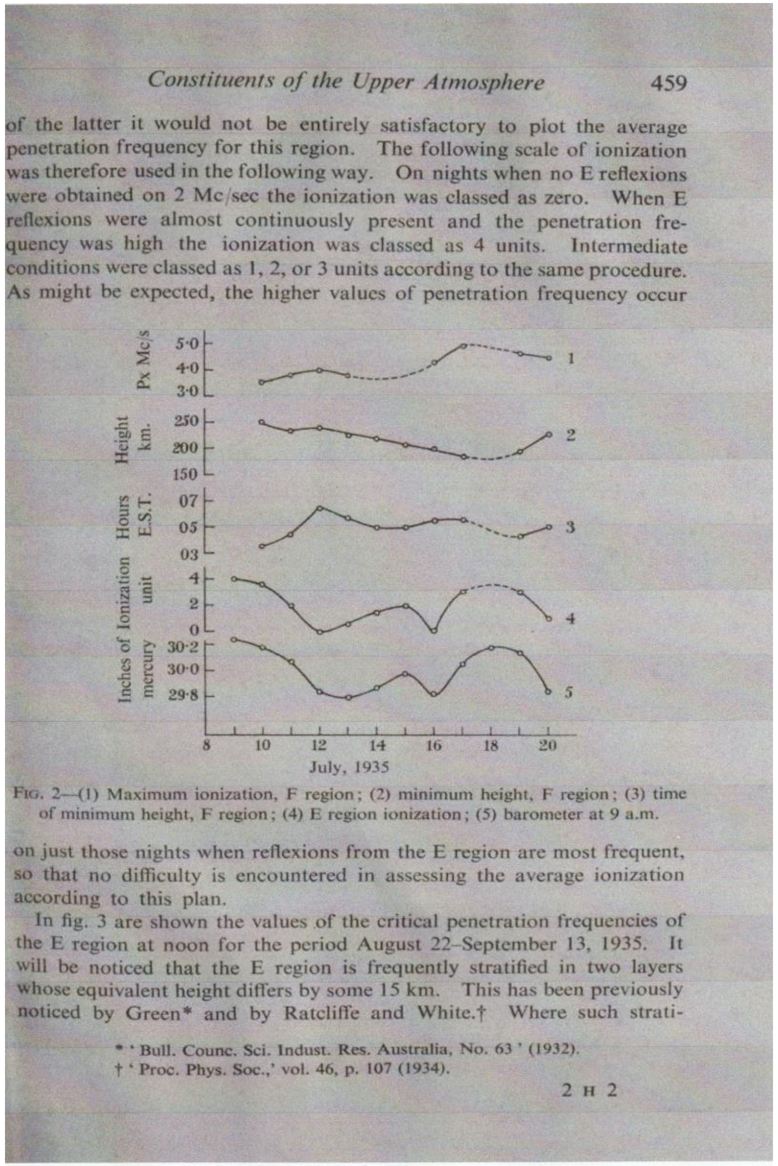


14.Surface & Satellite Temperatures since 1975.





15.Martyn Surface Pressure & E Layer Ionosphere correlation.



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of the latter it would not be entirely satisfactory to plot the average penetration frequency for this region. The following scale of ionization was therefore used in the following way. On nights when no E reflexions were obtained on 2 Mc/sec the ionization was classed as zero. When E reflexions were almost continuously present and the penetration frequency was high the ionization was classed as 4 units. Intermediate conditions were classed as 1, 2, or 3 units according to the same procedure. As might be expected, the higher values of penetration frequency occur

FIG. 2—(1) Maximum ionization, F region; (2) minimum height, F region; (3) time of minimum height, F region; (4) E region ionization; (5) barometer at 9 a.m.

on just those nights when reflexions from the E region are most frequent, so that no difficulty is encountered in assessing the average ionization according to this plan.

In fig. 3 are shown the values of the critical penetration frequencies of the E region at noon for the period August 22–September 13, 1935. It will be noticed that the E region is frequently stratified in two layers whose equivalent height differs by some 15 km. This has been previously noticed by Green* and by Ratcliffe and White.† Where such strati-

* 'Bull. Counc. Sci. Indust. Res. Australia, No. 63' (1932).
† 'Proc. Phys. Soc.,' vol. 46, p. 107 (1934).

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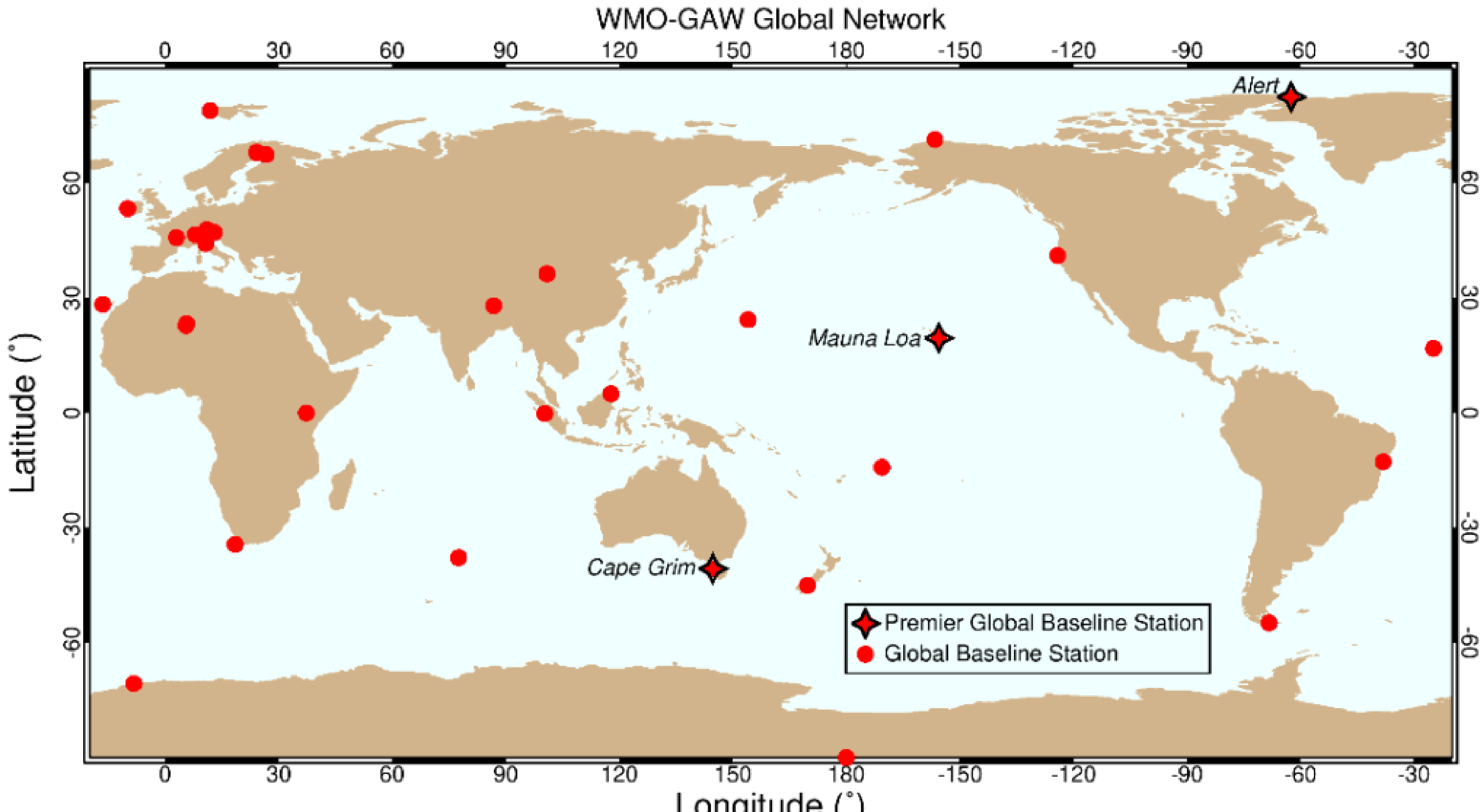
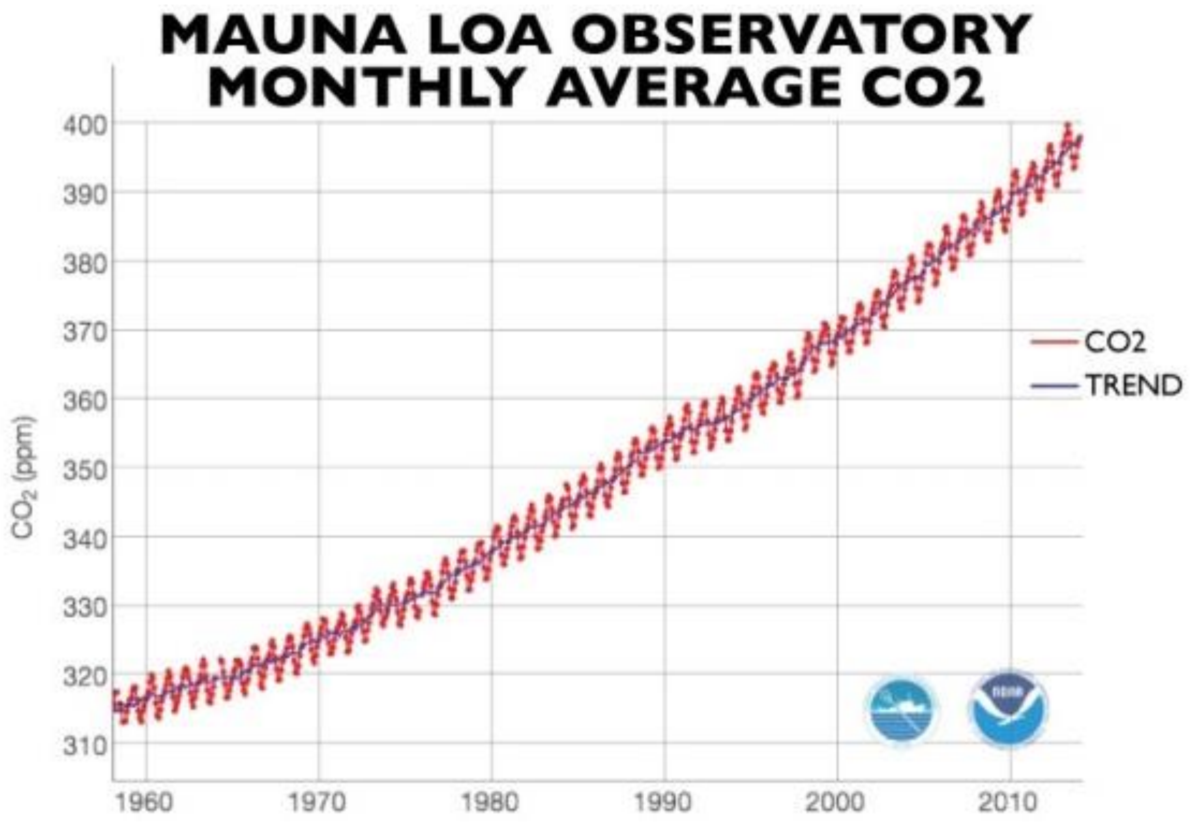
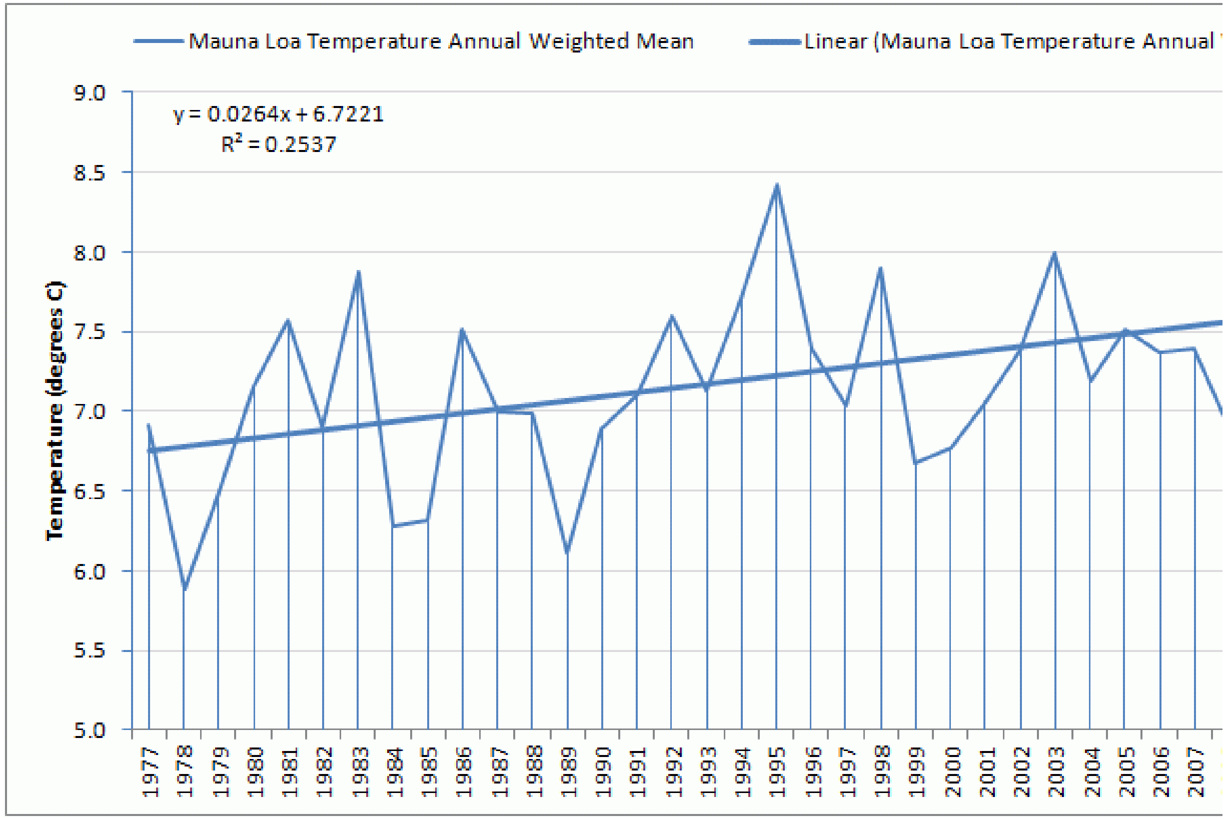
16.Global Baseline Weather Stations.



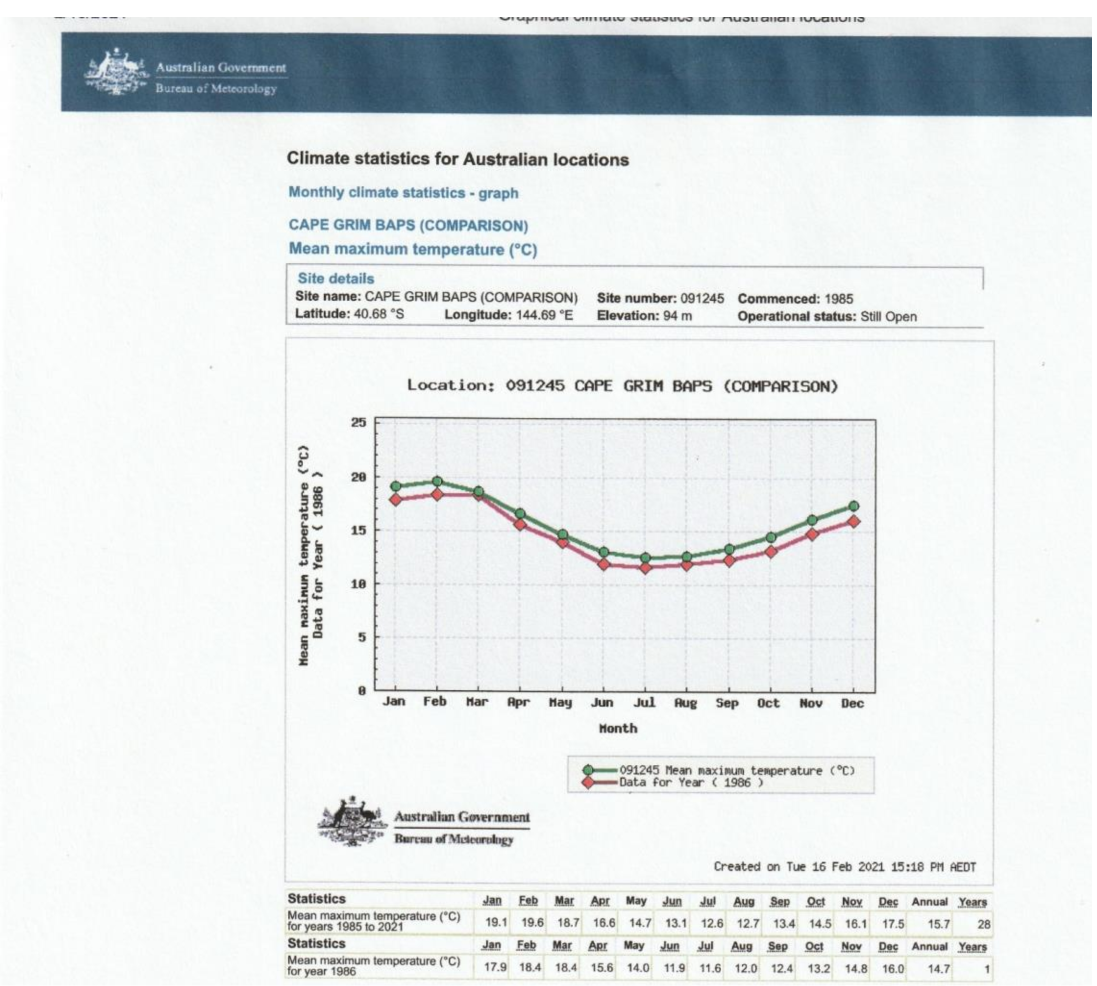
17.Cape Grim & Mauna Loa.

18.Mauna Loa Observatory.





19.Cape Grim.



Australian Government
Bureau of Meteorology

Climate statistics for Australian locations

Monthly climate statistics - graph

CAPE GRIM BAPS (COMPARISON)

Mean maximum temperature (°C)

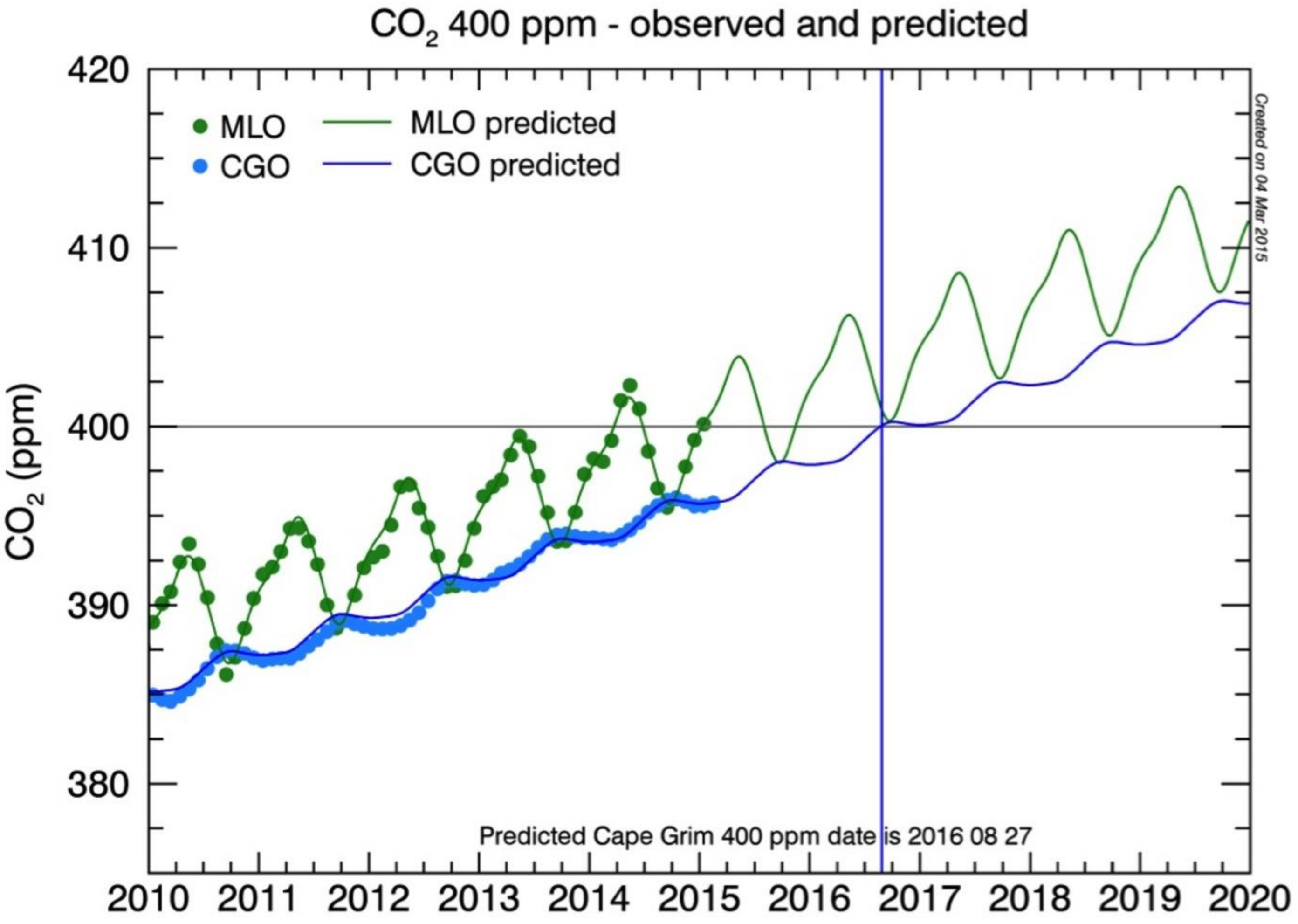
Site details

Site name: CAPE GRIM BAPS (COMPARISON) **Site number:** 091245 **Commenced:** 1985
Latitude: 40.68 °S **Longitude:** 144.69 °E **Elevation:** 94 m **Operational status:** Still Open

Created on Tue 16 Feb 2021 15:18 PM AEDT

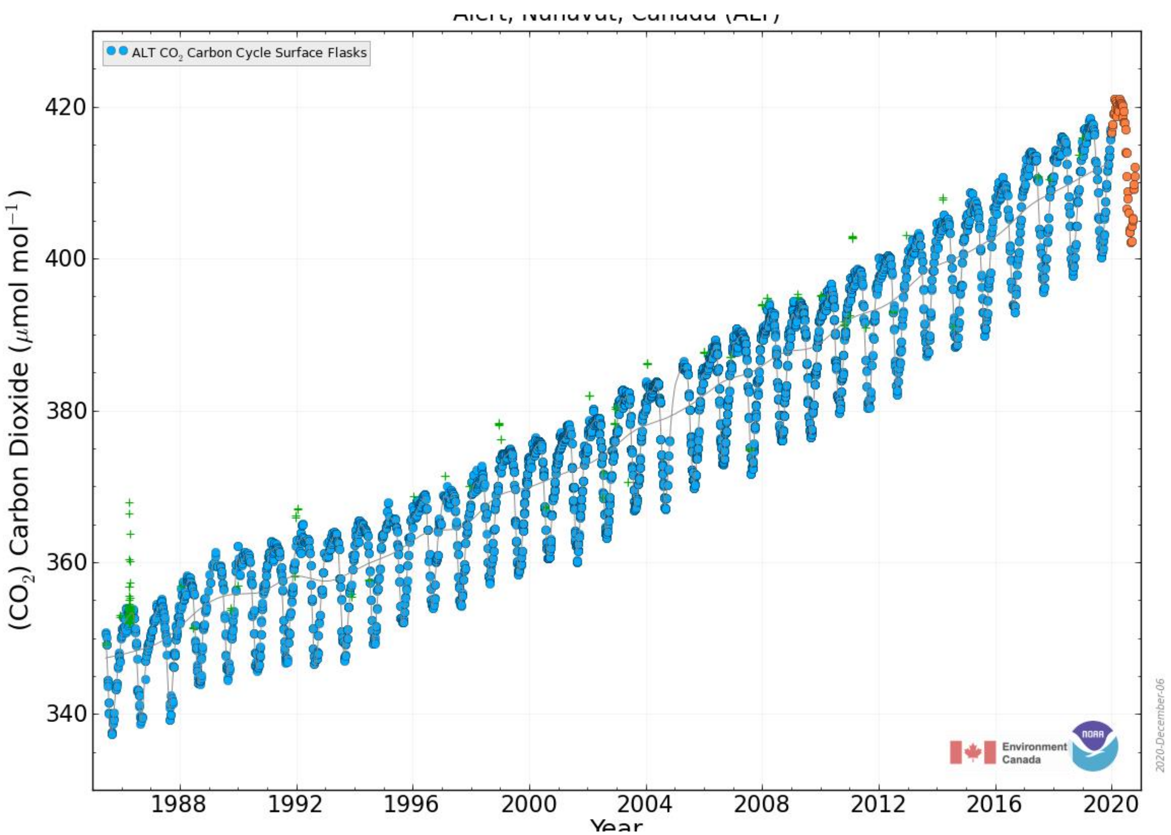
Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean maximum temperature (°C) for years 1985 to 2021	19.1	19.6	18.7	16.6	14.7	13.1	12.6	12.7	13.4	14.5	16.1	17.5	15.7	28

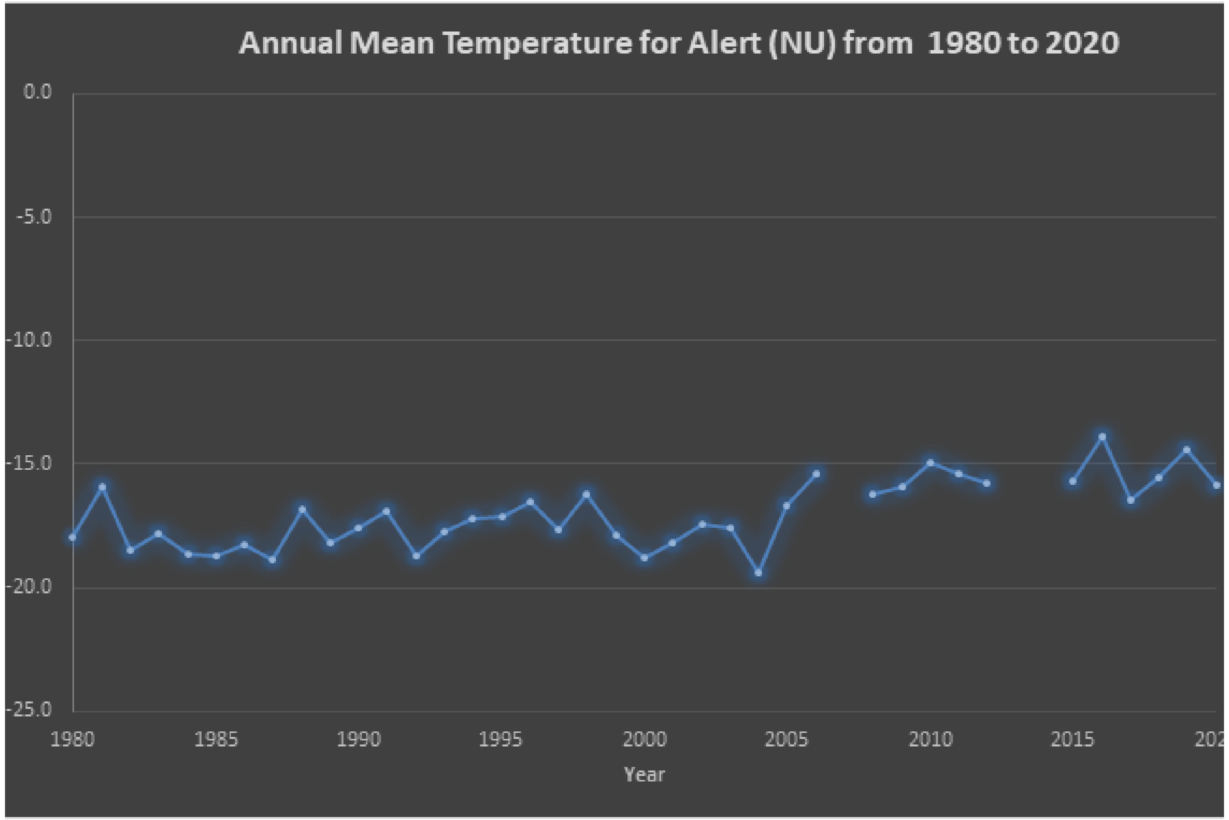
Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean maximum temperature (°C) for year 1986	17.9	18.4	18.4	15.6	14.0	11.9	11.6	12.0	12.4	13.2	14.8	16.0	14.7	1



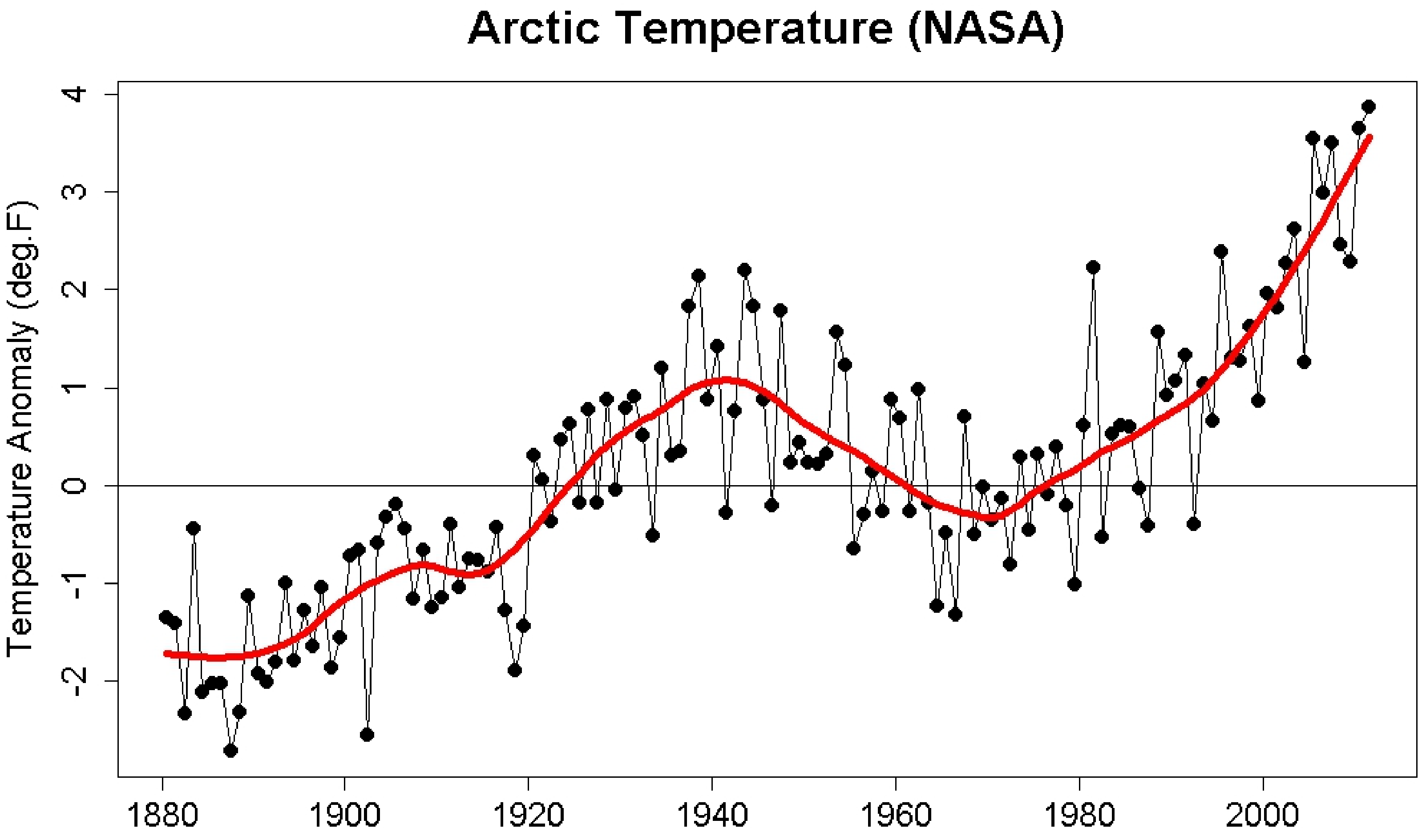
20.Cape Grim Solar Radiation.

21.Alert, Canada CO2 & Temperature.

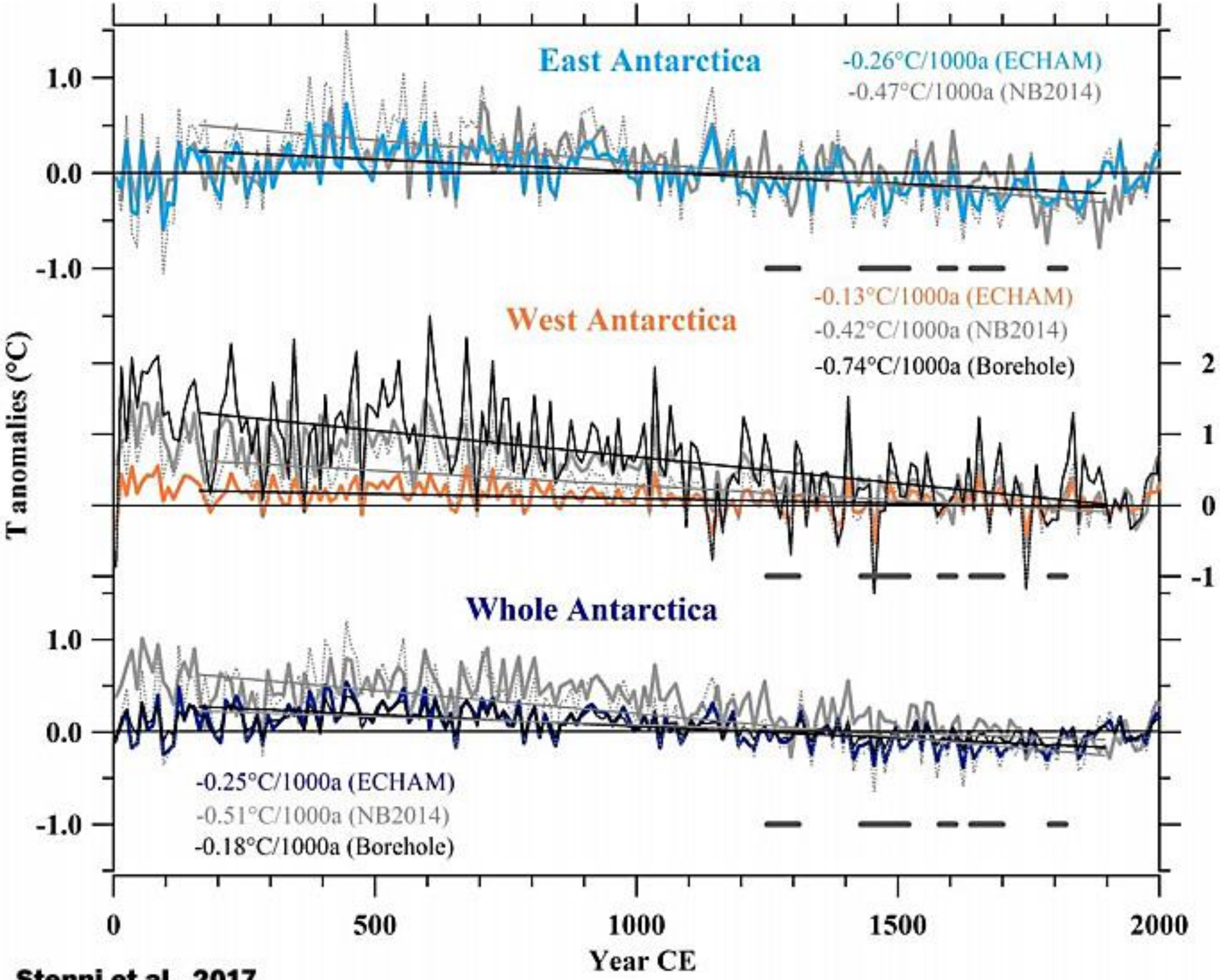




22.Arctic Temperature Increase.

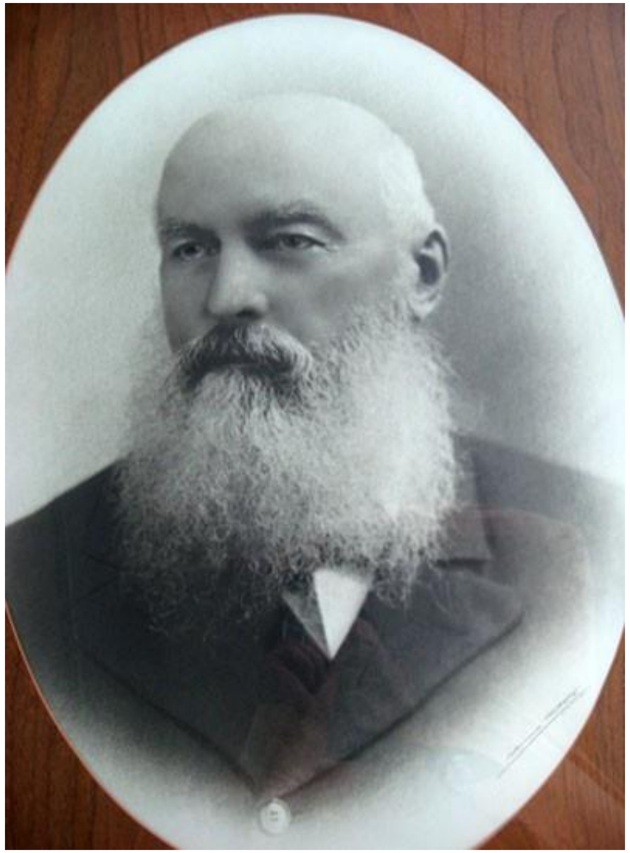


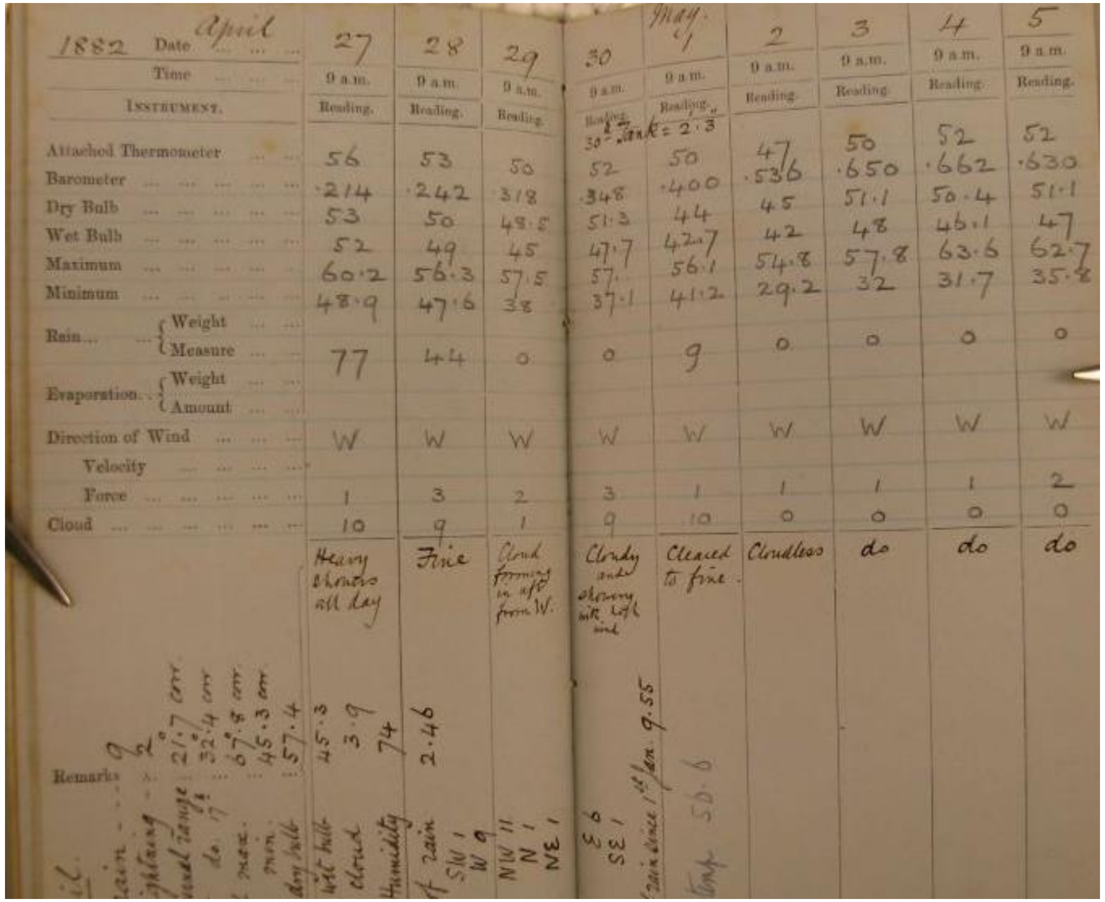
23.Antarctic Holocene.



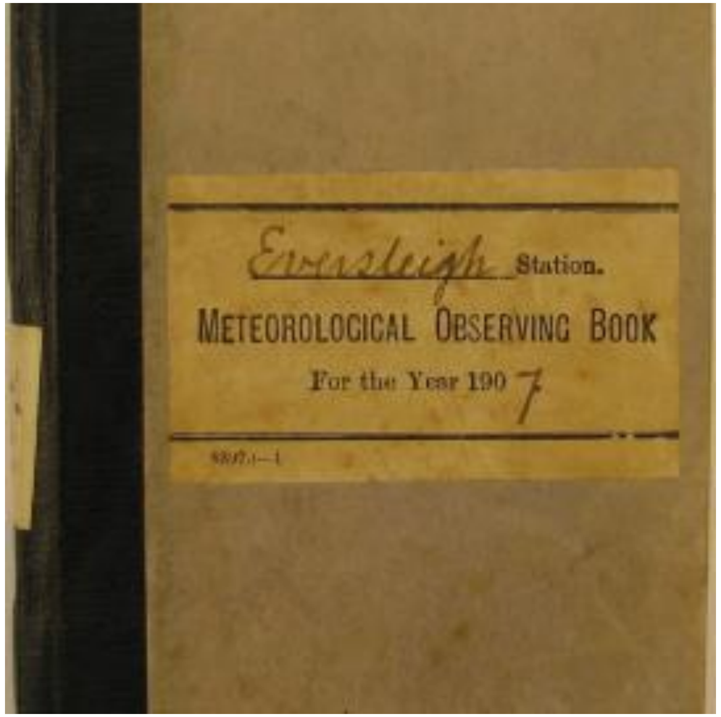
Stenni et al., 2017

24.Sydney Observatory H.C. Russell & A. Belfield.

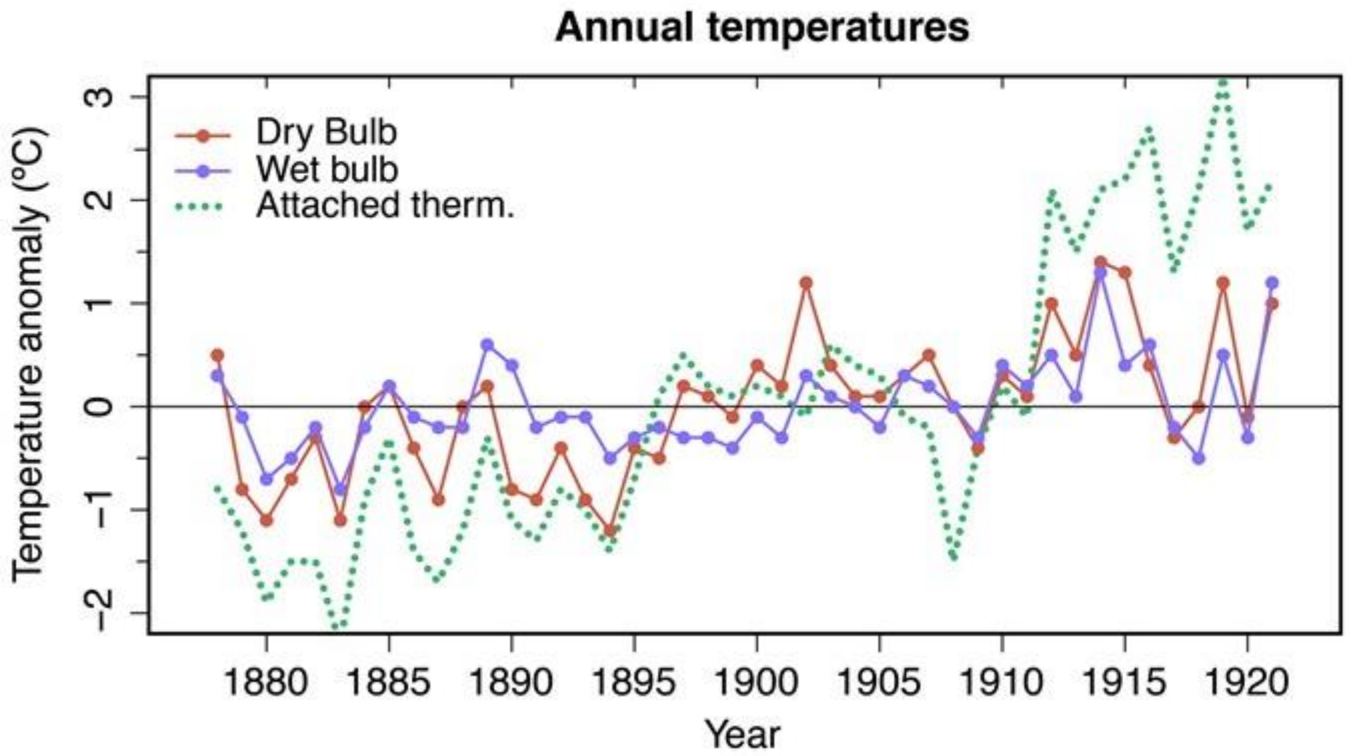




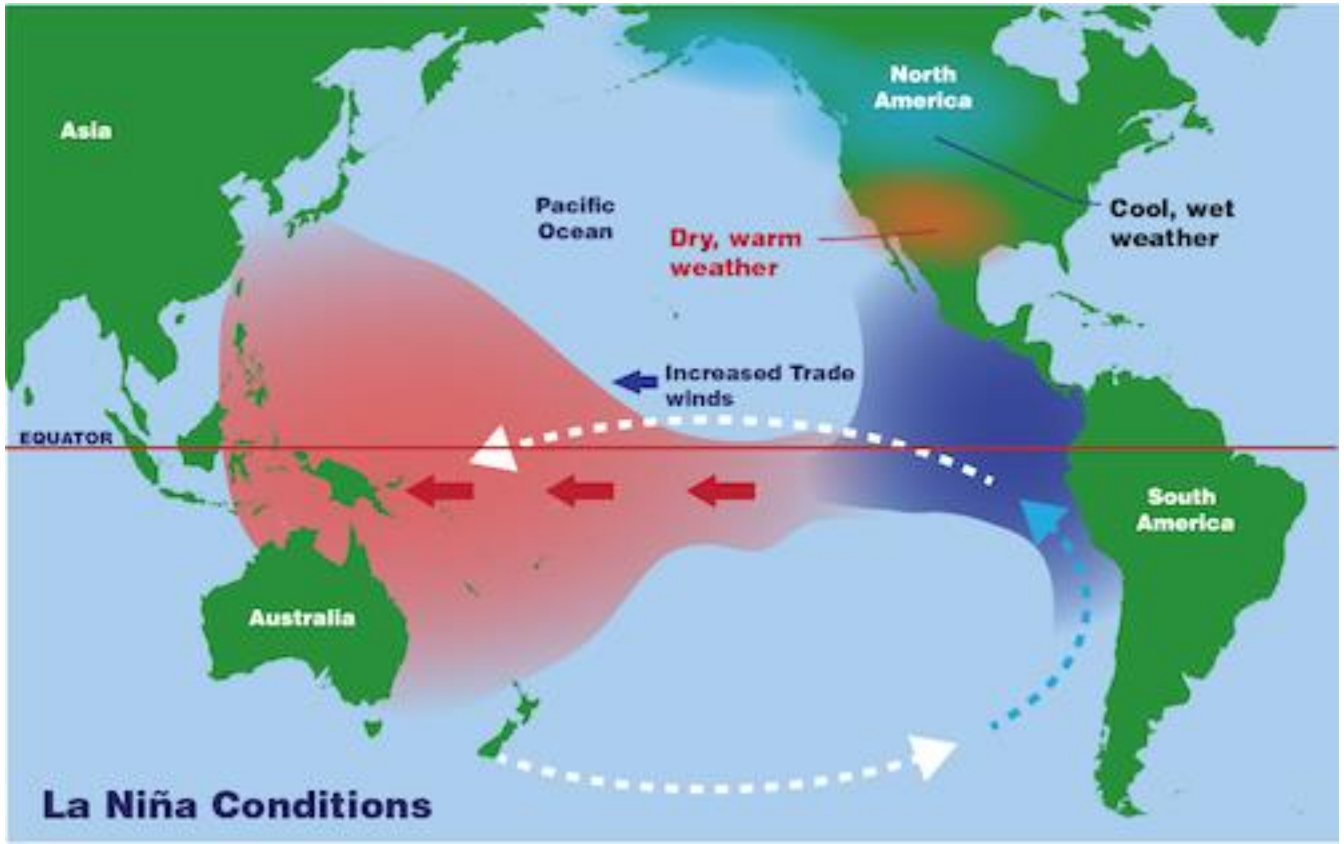
25.Eversleigh & Belfield Temperatures 1877-1922.

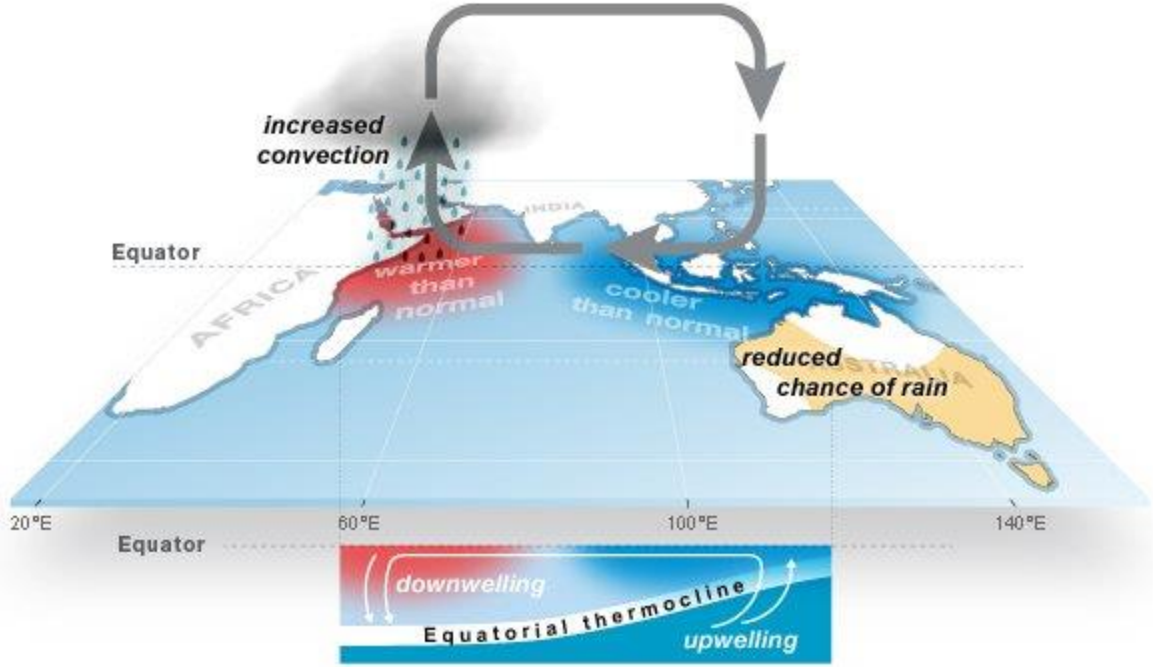


Meteorological observations for Eversleigh Station, near Armidale, New South Wales, Australia: 1877–1922



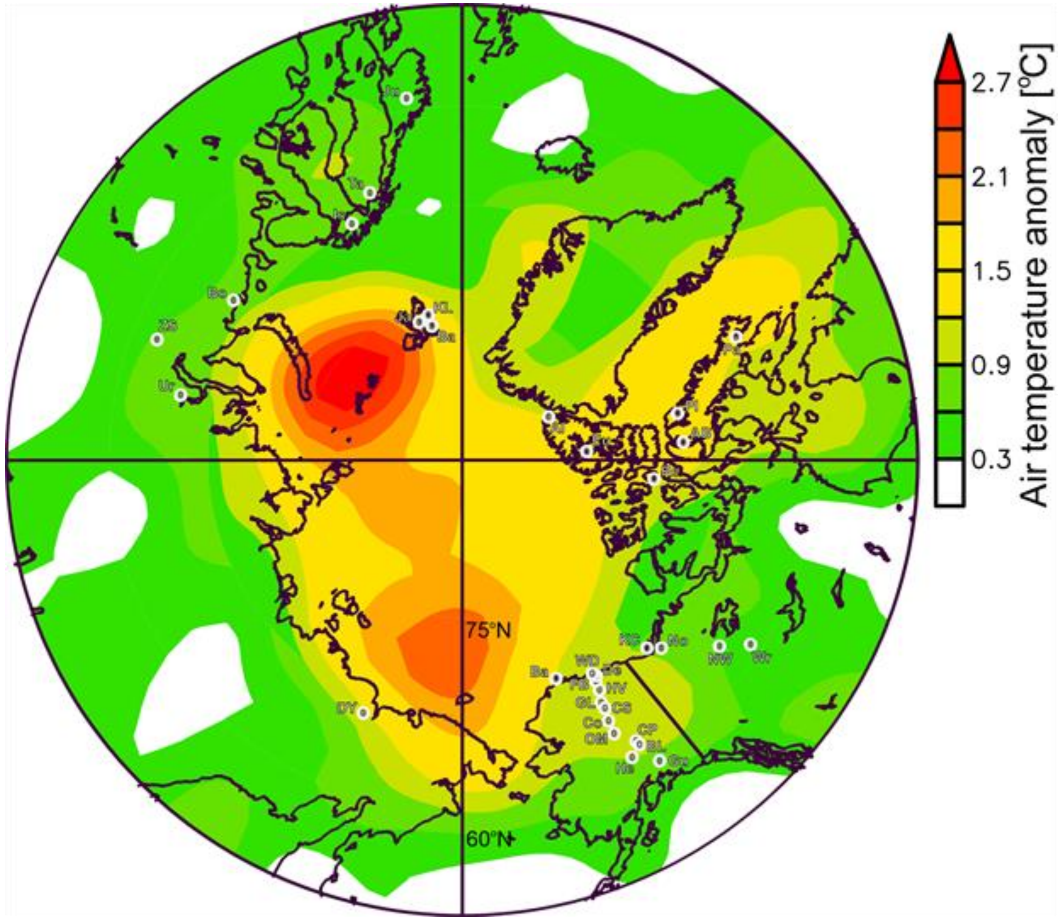
26.Indian Ocean Dipole, La Nina.



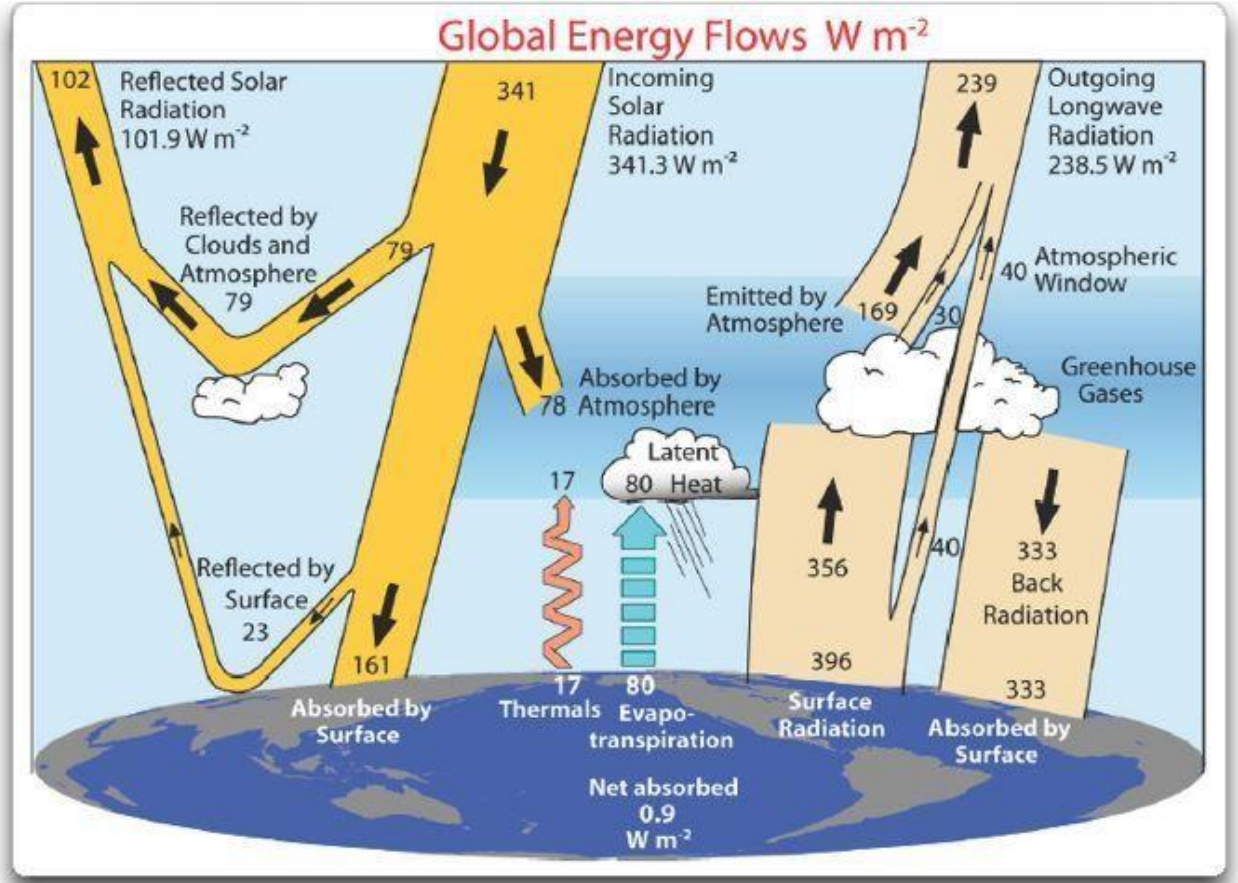


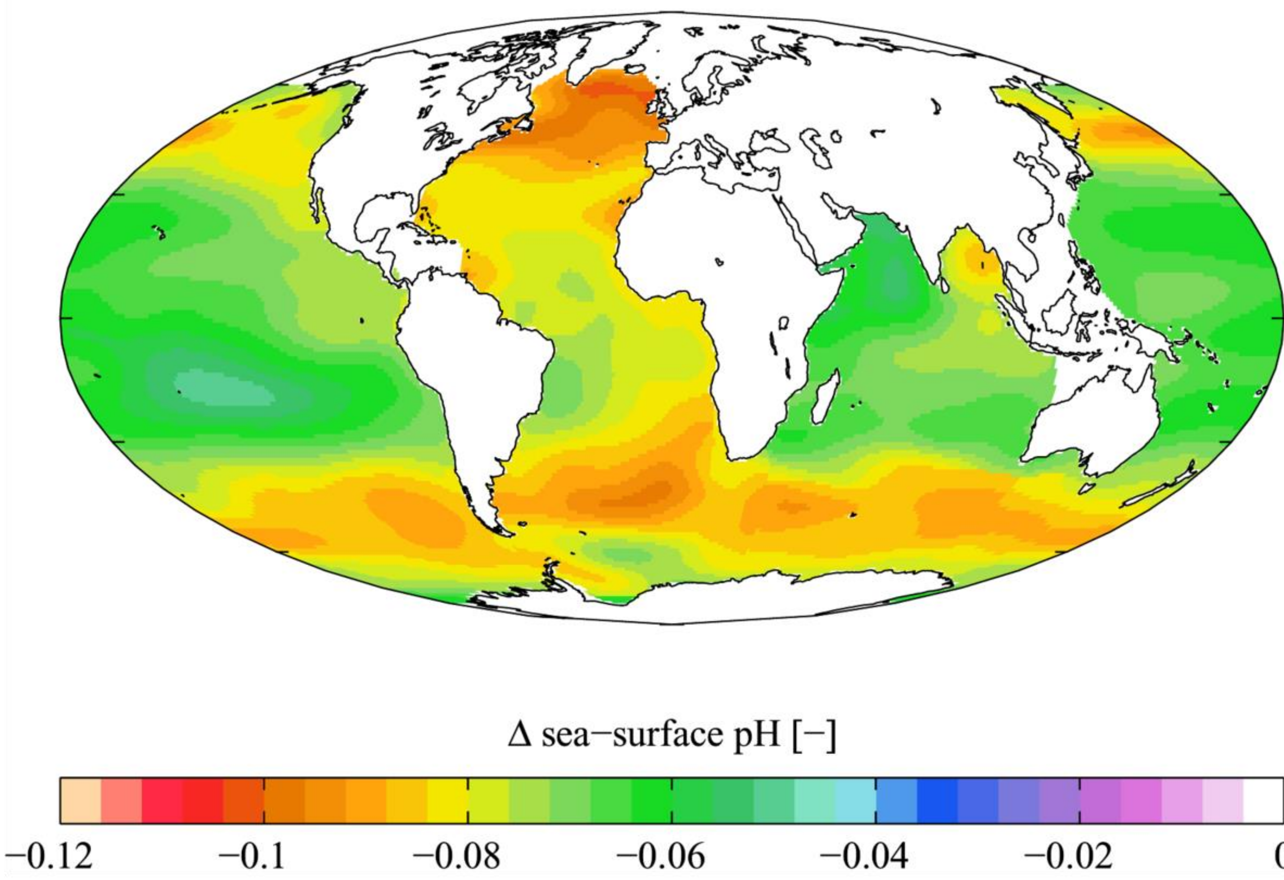
Indian Ocean Dipole (IOD): **Positive phase**

27.Arctic Permafrost & Alps Glaciers



28.Vertical Balance & Ocean Acidification.





29.Sydney University P N Russell Engineering School.(1933).

THE PETER NICOL RUSSELL SCHOOL OF ENGINEERING.

(Reproduced from an etching by Freeman.)

STAFF OF ENGINEERING SCHOOL, AND ALLIED PROFESSORS.

BACK ROW (left to right): Mr. W. H. Gibson (Mechanical), Mr. L. Hey Sharp (Electrical), Mr. K. R. M. Hart (Mechanical), Mr. C. R. Bickford (Civil), Mr. T. B. Nicol (Civil), Mr. T. D. J. Leech (Civil), Mr. H. J. Vogan (Civil), Mr. F. Danvers Power (Mining).

MIDDLE ROW: Assistant-Professor G. F. Sutherland (Mechanical), Professor O. U. Vonwiller (Physics), Professor H. S. Carslaw (Mathematics), Mr. D. T. Sawkins (Civil), Professor C. E. Fawsitt (Chemistry), Mr. E. F. Campbell (Electrical), Professor L. Wilkinson (Architecture).

FRONT ROW: Associate-Professor F. A. Eastaugh (Technology), Professor W. A. Miller (Civil), Sir Henry Barraclough (Dean), Professor J. P. V. Madsen (Electrical), Mr. J. Vicars (Civil).

ABSENT: Dr. J. J. C. Bradfield, Mr. R. L. Aston (Civil), Mr. C. A. Hodgson (Civil), Mr. H. M. Larkins (Civil), Mr. H. J. Swain (Mechanical), Mr. N. Hill (Technology).

Temperature & Constituents of the Upper Atmosphere 1935-2020.

Prepared by: R.W.Madsen, March 2021.

Slide 1. Introduction.

Between 1931 & 1939 the Australian Radio Research Board (RRB) under the Chairmanship of J P V Madsen (1879-1969) (Professor of Electrical Engineering at Sydney University) published 38 papers involving 15 researchers dealing mainly with radio propagation but also with further fundamental investigations as is the case here where D F Martyn (1906-1970) & O O Pulley (1906-1966) published in 1936 (Royal Society -received December 2, 1935 & RRB Report No.11) a paper on the "Temperature & Constituents of the Upper Atmosphere". In 1975 Sir Frederick White FRS (1905-1994) (Royal Society- Early Work in Australia, New Zealand & the Halley Stewart Laboratory, London) observed about this paper that remarkable deductions were made from very limited observations of the heights & ionization densities during July, August & September 1935. Absolute temperatures between E & F-regions were estimated from electron collision frequencies to be of the order of 1000K with high temperatures in both summer & winter attributed to absorption of solar radiation by ozone, & because of this it was believed that the ionization densities in E & F regions were correlated with barometric pressure at the ground. Martyn showed for the first time in this paper his remarkable acquaintance with possible physical mechanisms in the upper atmosphere. Some of the deductions, for example the high temperatures at the F-region heights, have turned out to be true but not for the reasons given in the paper (based on electron collision frequency). CSIROPEDIA has a lengthy entry on D F Martyn & his career with CSIR/CSIRO & his continuing involvement with the upper atmosphere, especially with his view to consider it as a whole. The Academy of Science biography refers to Martyn's postwar prediction that the Sun's corona has a temperature of 1,000,000 dg C calculated on base thermal radiation at metre wavelengths which subsequently was confirmed.

Slide 2. 1935 Royal Society Paper Sponsored by Lord Rutherford.

Whilst overseas for 6 months from July 1927 JPVM had been able to arrange with Lord Rutherford (1871-1937), Sir Henry Tizard FRS (1885-1959) & Sir Edward Appleton FRS (1892-1965) to form a selection panel to choose 3 researchers to come from the UK to join the Australian RRB in Sydney & Melbourne. JPVM had a scientific involvement with Rutherford in conjunction with Sir William Bragg (1862-1942) from 1905 & especially in 1911 on the structure of the nuclear atom. JPVM was alive to the need to have the significant papers of the RRB published internationally including the Royal Society & in the case of the Martyn & Pulley paper Rutherford was evidently sufficiently impressed to communicate it at once to the Royal Society as a very interesting discussion of the upper atmosphere. Peter Kapitza (1894-1984) referred to in this letter was a Russian pupil of Rutherford's who was to receive the Nobel prize in physics in 1978.. Rutherford was able to communicate the paper to the Royal on the 2nd of December 1935 the day before writing to JPVM & so was very prompt indeed. Oliver Pulley photo also shown here.(left).

Slide 3. D F Martyn & Temperature Graph. Noctilucence.

The co-author, Oliver Owen Pulley was born in Wellington NSW, Educated Orange High School, Sydney University BSc 1927, London University PhD 1934, AWA 1935-1939, Radiophysics Lab. 1939-1947, Atomic Energy UK, Harwell. 1947-1959. In 1935 Pulley returned to Sydney & built similar equipment as he had 1st made at Kings College in London & by June 1935 was providing routine ionograms for the Sydney RRB workers (White & Huxley 1974).

Martyn was born and educated in Scotland & obtained a PhD in science from the University of London.1928.

The temperature graph prepared by Martyn & Pulley in 1935 extends down from altitude 300 km from the F region of the ionosphere through five distinct temperature layers (Thermosphere 300-100 km, Mesopause 82 Km, Stratopause 60 Km, Tropopause 11Km & Earth surface) indicating absolute temperatures of 300-1,000+ dgs, 160 dg, 450dg, 200 dg & approx..290 dg respectively. In centigrade these temperatures calculate as: 27-727dg, -113 dg, 177 dg,-73 dg & 17 dg approx..These recordings were based on their own calculations using the radio pulse method of Breit & Tuve from a transmitter & receiver at the Elec Eng Dept of Sydney University (Lat. 33 dg S, 151 dg E) for altitudes above 100 Km & below this from recently published results on noctilucent clouds at 82 Km by principally William Jackson Humphreys (1862-1949)[1932-editor of the Weather Bureau, Washington] & at 60 Km relating to the ozone layer proposed by Gordon M B Dobson (1889-1976) at Oxford from 1924. Weather balloon data was used up to 35 Km & sound data records up to 50 Km.

Noticeably the stratopause temperature derived from the ozone work of G. Dobson (Applied Optics 1968) was calculated to be much higher than currently measured (Slide 4.) however the temperature based on noctilucent clouds has remained. Even now after satellite experiments it is unclear whether the water vapour to form the noctilucent clouds has come from seepage from the troposphere or oxidation of methane (in the image noctilucent clouds are seen from the ISS with the sun below the horizon- from Earth they are only visible at certain times between latitudes 50—65 dgs). Martyn & Pulley in considering the rise in temperature above 100 km suggested the presence of water vapour & a 2nd ozone layer as possibilities. (see slide 10-Composition of Earth's Atmosphere with elevation to 1,000 km). An interesting development during WW2 by Dobson was that it was found that the stratosphere was relatively dry. At 100km the atmosphere is very thin.

Slide 4. International Standard Atmosphere & NASA Upper Atmosphere.

The ISA mathematical model is used for aircraft engineering applications & is based on average conditions at mid latitudes & has a standard mean seal level temperature of 15 dg C using a hypothetical standard day. Up to 32 km ISA is consistent with the US Standard Atmosphere but for satellite use other models are used. The Stratopause at altitude 50-55 km is apparently currently at -15 dg C with an atmospheric pressure of 1/1,000 that at sea level. There are current indications that the mesopause has two boundaries, one at 85 km & another at 100 km involving the presence of carbon dioxide with temperatures at 173 dg K (-100 dg C).

A temperature inversion cap sitting over the troposphere from altitude 11km to 31 km marks conditions of great stability & acts as a ceiling preventing further upward convection & is generally the limit for cloud development.

The graphic of the Earth's Upper Atmosphere (NASA/ Naval Research Lab. J.Emmert 2017) depicts the temperature difference with increase in altitude & with solar minimum (night) & solar maximum (day) periods. The atmospheric penetration of the various spectral wavelengths entering the atmospheric system, the density of oxygen, nitrogen & carbon dioxide as altitude increases from Earth is shown also with the approximate height within the ionosphere of the D,E & F levels.

Slide 5. Electron Density Layers & Map of the Ionosphere.

The two graphs show the layers (D,E & F) of the ionosphere from 50 km to 500 km altitude & the electron density as electrons per cubic metre & cubic centimetre. Models of the ionosphere electron density are of great use in radio communications & especially OTH radar (Over the Horizon) such as

Jindalee which uses the JORN Profile Model of E & F layers. Appleton (1892-1965) had shown that free electrons & not ions are mainly responsible for the reflection of radio waves from the F region of the ionosphere.

Martyn & Pulley state for their calculations that the average number of free electrons during the night in a square centimetre column of the F region may be taken as 5 X 10^11. They also noted that all observations during the night show electron densities which are sensibly the same just after sunset as just before sunrise.

Slide 6. Magnetosphere & Properties.

The position of the Ionosphere is shown in relation to the Magnetosphere however Martyn & Pulley only state that the high temperatures found are attributed mainly to the absorption of solar ultra violet energy by ozone, in concentration of 1 part in 10^4. [In the post war period from 1947 Martyn published a series of papers on the electrodynamic effects at altitude 100 km being transmitted to much higher altitudes along magnetic lines as well as magnetic storm effects associated with auroral phenomena & radio emissions from the quiet Sun].

Slide 7. Ozone Holes & CO2 at 100 km Altitude.

The 2 NASA Antarctic Ozone hole images in the southern hemisphere Spring (October 2011) & Summer (January 2012) are in Dobson units. Susan Strahan & Natalya Kramarova (NASA scientists in 2017) explain that the hole is a seasonal depletion of the stratospheric ozone over Antarctica with the drop beginning in August & reaching a maximum between September & October because of the extremely low temperatures during the Antarctic winter between June & August allowing ice clouds to form in the stratosphere. The chemical reactions that occur on the ice particles process the chlorine from CFCs into a reactive form that destroys ozone & this continues until either all the ozone is destroyed or the air warms with the changing seasons & mixes with air from lower latitudes. In May 1985 in Nature 3 scientists (J.Farman, B.Gardiner & J Shanklin) from the British Antarctic Survey reported on their finding the ozone holes using Dobson Meters Nos 31 & 51 which led to the Montreal Protocol on CFCs in 1987 & CFC usage reductions since 1996 & a gradual healing since 2016, as the CFCs have a very long lifetime. By 2021 the WMO has reported the Antarctic Ozone hole closed.

The NASA image of CO2 concentration at altitude 100 km has been obtained from the ACE (Advanced Composition Explorer) satellite launched in 1997 & still functioning as late as 2019. It would appear that as for CFCs, CO2 becomes distributed throughout the atmosphere by turbulence.

Slide 8. Satellite Temperature Trend 1979-2005, Antarctic 1,000 years CO2 & CH4.

Results by C. MacFarling Meure et al of CSIRO Marine & Atmospheric Research (AGU Wiley 2006: Law Dome CO2, CH4 & N2O ice core records extended to 2,000 years BP) based on air samples from ice cores from Law Dome in East Antarctica & from air in the firn layer pumped into containers involving overlaps with contemporary air archive & firn records, compare well. (Firn represents the intermediate stage between fresh snow & glacial ice & is highly variable in depth & density). A notable feature of abrupt decreases in concentrations during the 16^{th} & 17^{th} centuries was the coincidence with a period of generally cooler northern hemisphere temperatures-the Little Ice Age (AD 1300-1850). The results show significant atmospheric concentrations during the last 200 years & mainly in the 20^{th} century with increases of CO2 (29%), CH4 (150%) & N2O (21%).

The NASA Atmospheric Temperature Trends, 1979-2005 (Images by J.Allen Remote Sensing Systems & information by C. Mears RSS et al at NASA Goddard Flight Centre) are based on microwave sounding units on NOAA (National Oceanic & Atmospheric Administration) weather satellites which had to be adjusted due to a drift in satellite orbits over time but once corrected revealed consistent data with surface observations. These images show temperature trends in 2 thick layers of the atmosphere measured by a series of satellite based instruments between January 1979 & December 2005. The top image shows temperatures in the middle troposphere centred around 5 km above the surface. The lower image shows temperatures in the lower stratosphere centred around 18 km above the surface. Oranges & yellow dominate the troposphere image indicating that the air nearest Earths surface warmed during the period. The stratosphere image is dominated by blues & greens indicating cooling.

Special attention needs to be made concerning warm spots in the stratosphere over Antarctica & the Arctic where temperatures can fluctuate wildly resulting in warming in the stratosphere by several tens of degrees Celsius in a few days & although more common in the Arctic a sudden stratospheric warming also occurred in the Antarctic stratosphere in 2002. The break down of vortex winds which circle the Poles is thought to contribute to these warmings.

Slide 9. The International Space Station Heat Rejection System. The Nile & Atmosphere at night.

The remarkable ISS (International Space Station) launched in 1998 orbits at an average altitude of 400 km (320-380 km) every 93 minutes with gravity at 90% of Earth. An array of insulation materials blanket the lining of the ISS which experiences a temperature range of 150 dg C to -150 dg C where the Sun facing side can soar to 121 dg C & the dark side down to -157 dg C. In 2010 there was a cooling Loop A (starboard) problem in Boeing equipment which was replaced. Panels of the Heat Rejection Subsystem are shown. The image of the Nile at night & the atmosphere band around Earth are shown from a NASA image of the day September 22, 2015.

Slide 10. Composition of the Atmosphere.

Data attributed to the NASA MSIS-E-90 atmosphere model (Rhett Allain Ass. Prof. Phys. Southeastern Louisiana University) suggests that up to 100 km the composition of the atmosphere is fairly "normal" consisting mostly of molecular Nitrogen N_2 & molecular oxygen O_2, with a small amount of Argon (0.93%) & traces of other gases (CO_2 etc). After 100 km the percentage of molecular nitrogen & molecular oxygen decrease sharply but with a sharp increase in monatomic & triatomic oxygen. By 200 km ozone dominates to about 650 km where helium takes over & at 1000 km is 93%.

Martyn & Pulley indicate that there was abundant evidence of molecular nitrogen, molecular oxygen, atomic oxygen & water vapour at altitudes 200-300 km.

Slide 11. Sunspot Cycle & Activity.

In 1935 sunspot activity was at a minimum & Martyn & Pulley do not make any reference to it in their experiments. Dr. David Hathaway of NASA has observed that sunspots themselves produce only minor effects on solar emissions but the magnetic activity that accompanies the sunspots can produce dramatic changes in the ultraviolet & soft x-ray levels. These changes over the solar cycle have important consequences for the Earth's upper atmosphere. Early records of sunspots indicate that the Sun went through a period of inactivity in the late 17th century however there is some doubt how accurate the observations were. This period of solar inactivity also corresponds to a climatic period called "The Little Ice Age" when rivers that are normally ice free froze & snow fields remained year round at lower altitudes. The connection between solar activity & terrestrial climate is an area of on going research. The Dalton minimum lasted from around 1796-1820 corresponding to solar cycle 4 to solar cycle 7. (In 1816 the year without summer, cool temperatures were due to the 1815 eruption of Mt Tambora in Indonesia, one of the largest in the past 2000 years.)

Slide 12. Global Mean Temperature since 1850.

The UK Met Office has produced a Global Mean Temperature Difference graph from 1850 to 2020 from various sources indicating an increase since 1980 of 0.7 dg C.

Slide 12. Australian Sea & Air Surface Anomaly Temperature Since 1910.

The Australian Bureau of Meteorology commenced in 1910 & the 2 graphs set 1980 as anomaly zero & show Australia since 1980 with an air temperature increase of 0.75 dg C (similar to the UK Met Office). The ten year sea surface temperature average is only slightly less than the air temperature & it is noticeable from the current BOM sea anomaly data that the Indian Ocean is warming (1.5-2.0 dg C) more than the east coast Tasman/ Pacific.

Slide 14. Surface & Satellite Temperatures since 1975.

The satellite temperatures 1980-2010 correlate closely with the surface temperature anomaly data showing an increase for tis period of 0.4 dg C & is consistent with the Met Office & Australian data (Slides 12 & 13).

The A-Train (A=Afternoon) group of satellites for weather observations (ozone, climate, water cycle, temperature etc.) operated at times by NASA, France & Japan comprises 4 satellites orbiting at 705 km a few minutes apart so that their collective observations may be used to build high definition 3 dimensional images of Earth's atmosphere & surface. The satellites cross the equator each day at around 1.30 pm solar time & again at night around 1.30 am at the night side. Since around 2000 there have been 8 satellites which have operated as part of the A-Train, many operating years beyond their original planned dates.

Slide 15. Martyn Surface Pressure & E-Layer Ionosphere Correlation.

The radio method used by Martyn & Pulley was based on the pulse technique used by Breit & Tuve in 1925 in Washington as a Carnegie Institution (Department. of Terrestial Magnetism) experiment to prove the existence of a conducting layer (the Ionosphere) as suggested in 1902 by Arthur Kennelly (USA) & Oliver Heaviside (UK). Tuve's idea of a radio echo sounding method involved using transmitter & receiver equipment at the Naval Research Laboratory (as shown in the slide). The radio echoes were received with a steady time delay variation consistent with a conducting layer in the upper atmosphere of variable distance.

The graphs from Martyn & Pulley's paper (Fig. 2) for the period July 9-20 ,1935 when an intensive study of ionization changes was made indicated that the ionization densities in the E & F regions were found to correlate directly & the height of the F region indirectly, with the barometric pressure at the ground (from 9.00 am barometric data at Sydney Observatory). This correlation was attributed to the temperature changes in the ionosphere occasioned by changes in ozone concentration.

Separate to the ionospheric work, the RRB for 6 months from July 1935 had a co-operative programme with the Commonwealth Meteorological Burau & was undertaken involving Hobart, Mt Stromlo & Watheroo to determine whether the atmospheric observations of the RRB had any potential value for meteorologists but after a further 6 months it was considered there was little value to be obtained.

Slide 16. Global Baseline Weather Stations.

In 1962 Martyn was invited by the United Nations to be Chairman of the body's Scientific & Technical sub-Committee on the Peaceful Uses of Outer space involving 28 nations. Martyn held this position until his death in 1970 during the latter time he had become acutely aware of apathy by Government officials & industry concerning the international contamination of the biosphere, the atmosphere, waterways & sea & realized that little or nothing would avert ultimate disaster.

Within UNESCO from 1950, the WMO (World Meteorological Organisation) which has origins back to 1873 for nations to exchange weather data, has a Global Atmosphere Watch (GAW) comprising 31 global stations including 3 greenhouse gas "intercomparison supersites" at Mauna Loa, Hawaii, Cape Grim, Tasmania (CSIRO) & Alert, in northern Canada chosen for their remoteness from industrial pollution & contamination & geographically spread (approx.. 60 dg latitude) from the equator to the extremes of the inhabited southern & northern hemispheres.

Slide 17. Cape Grim (CGO) & Mauna Loa (MLO) Observatories.

Cape Grim located on the north west corner of Tasmania which experiences winds coming from the south west sector across the southern ocean 9,000 km from South America, has operated since 1976 by CSIRO & the BOM. Much data is gathered from air samples concerning the composition & chemistry of the atmosphere (eg. CO2, aerosol gases & numerous other chemicals) as well as climate information such wind speed & direction, rainfall, temperature, humidity & solar radiation. CO2 has increased by 20% since 1976 to 410.6 ppm in Jan. 2021.

Mauna Loa's primary location is on the volcano at 3,397 metres & has been continuously monitoring CO2 since 1958 (316 ppm increased to the current 410 ppm). Adjustments to readings of CO2 have to be made to allow for gas emissions from the volcano.

Slide 18. Mauna Loa Observatory.

The temperature at MLO is evidently quite variable, however the CO2 readings consistently trend upwards. The Methane CH4 readings have increased from 1630 ppm in 1985 to 1880 ppm in 2020.

Slide 19. Cape Grim Observatory , Temperature & CO2.

The monthly mean comparison temperatures for 1986 compared to January 2021 average (red line compared to green line) indicate an increase in excess of 1 dg C. The prediction made in 2016 for the CO2 level in 2020 (408 ppm) is very close to the actual reading of 410.6 in Jan.2021. The estimated methane CH4 level at Cape Grim in 1995 was 1680 ppm (CSIRO "Baseline 1996"). [1985-1600ppm, 2013-1750 ppm].

Slide 20. Cape Grim Solar Radiation.

At Cape Grim a solar radiation monitor automatically tracks the Sun across the sky while other instruments measure the light which arrives indirectly from the Sun after being diffused through the atmosphere. Data is recorded for wavelengths of 368 nm, 500 nm, 778 nm & 868 nm. (The Ultra Violet wavelengths are 10-400 nm) .A typical BOM solar monitoring station is shown which measures Daily Solar Exposure (Mean, Annual, Month. Day) as MJ (mega joules). BOM data for Cape Grim average daily sunshine hours (annual) of 5-6 hours & Sydney 6-7 hours. The need for extensive solar irradiance data (16 BOM stations & 3 Qld stations) is required to forecast solar power forecasts & facilitating safe & reliable grid management. It appears that there has been a fall off in TSI (Total Solar Irradiance) starting in 2003-2005 to 1365 w/m^2.

Slide 21. Alert, Canada CO2 & Temperature.

Alert in far northern Arctic Canada has recorded CO2 increases similar to Cape Grim & Mauna Loa & has recently recorded 410 ppm. The mean annual temperature from 1980 to 2020 has been calculated by Environment Canada in Edmonton for the author & shows a warming from an average around -18 dg C in 1980, to -16 dg C in 2020 (3 data records were reported as missing).

Slide 22. Arctic Temperature Increase (NASA).

The NASA graph of Arctic Fahrenheit temperatures from 1880 to 2019 shows an increase of 5.5 dg F (3.05 dg C). An interesting feature of this graph is the cooling trend during the 1940-1975 period which had been reversed by 1980.

Slide 23. Antarctic Holocene.

Data over 2,000 years from sources including the European ECHAM climate model on the temperature anomalies in Antarctica indicate according to Barbara Stenni (Dept Environment Science Foscari Uni. Venice) in 2017 that there was a glacial readvance during the period of the Little Ice Age & recently that there has been rapid climate warming which has been observed in various regions of the Antarctic Peninsular, with glacial fronts retreating.

Slide 24. Sydney Observatory, H.C.Russell & A.Belfield.

Temperature & weather meteorology records at Sydney Observatory combined with astronomy observations were thoroughly reorganized in 1870 when Henry Chamberlain Russell (1836-1907) became Government Astronomer. Russell was born in West Maitland & educated at West Maitland Grammar School & at Sydney University (BA 1859). In 1886 Russell became the first graduate of Sydney University to become a Fellow of the Royal Society, London & was a Fellow of the Senate of the University of Sydney (1875-1907) & Vice Chancellor of the University (1891-92). Russell was also the first President of the Australasian Association for the Advancement of Science in 1888 & President of the Royal Society of NSW four times. Russell increased the number of weather stations from 43 to 50 in 1870 & by 1895 there were 1600 observers using equipment some of which he had designed himself eg. a portable anemometer. Russell pioneered a global approach to meteorology & thought comprehensively about the southern hemisphere.

It appears that in 1874 Russell went to Armidale (elevation 980 metres) to watch the Transit of Venus using the instruments of Algernon Henry Belfield (1839-1922). Belfield came to the Armidale district in 1856 aged 17 years working as a jackaroo having travelled from England in steerage class. Belfield was a remarkable scholar who had studied Latin & Greek at the Rugby School in England before coming to NSW & was later able to acquire property running with 19,000 head of sheep for wool. From 1877 to 1922 Belfield kept meticulous weather records based on observations at 9.00 am each day with accompanying notes & these have all been digitized & are in the process of being analysed internationally & are regarded as a very reliable continuous source of temperature & weather data during a period of significant industrialization in the northern hemisphere.

From 1907 to 1931 Henry Ambrose Hunt (1866-1946) was the first Director /Meteorologist of the Bureau of Meteorology who had been taught by Russell at Sydney Observatory & on taking up the position did a world tour to identify the most suitable methods to run the BOM. (Hunt was born in London & migrated to Sydney in 1884 & had spent 3 years in St Petersburg where his father had designed ships for the Tsar.)

Slide 25. Eversleigh & Belfield Temperatures 1877-1922.

The digitized temperature results from Belfield"s Eversleigh Meteorological Observing books are shown.

Slide 26. Indian Ocean Dipole & La Nina.

Temperatures in the eastern half of Australia are affected by the periodic (ie. periods of several years) cycles of the cooler La Nina conditions & the warmer El Nino conditions with the reduced chance of rain where there is anti-clockwise convection for El Nino. During the positive phase of the Indian Ocean Dipole there is reduced chance of rain in Australia compared to the negative phase when the direction of convection is reversed to anti-clockwise.

Slide 27. Arctic Permafrost & Alps Glaciers.

In the Northern Hemisphere there is great concern concerning rising temperatures in the Arctic & the thawing of permafrost which potentially is thought to release a vast amount of carbon as CO2 as a part of the permafrost carbon cycle.. The location of permafrost monitoring sites is shown & superimposed is the average surface air temperature anomaly for the period 2005-2016 (V. Romanovsky et. al. NOAA 2017 Arctic Report Card- Fairbanks AK) . In general the increase in permafrost temperatures observed since the 1980's is more substantial in the higher latitudes where the largest increase in surface air temperature is also observed.

The glacial retreat in the Swiss & German Alps has been occurring very rapidly since 1980 including the Jungfrau at 4158 metres.

Slide 28. The Vertical Balance Energy Budget & Ocean Acidification.

One aspect of Climate Change affecting Scandinavian countries is the distinctly stronger ocean acidification uptake of CO2 in the Arctic Ocean. The Wikipedia image uses data from the 1700's to 1990's as calculated by the Global Data Analysis Project.

A schematic has been prepared by NASA of the Earth's Energy Budget based on satellite data between 2005 & 2015 (& also as shown by Prof. Bob Mackay of Clark College, Vancouver, WA) based on the principle of conservation of energy. The NASA-CERES (Clouds & Earths Radiant Energy System) data shows on average 340 watts per square metre of solar energy arriving at the top of the atmosphere. The Earth returns an equal amount of energy back to space by reflecting some incoming light & by radiating heat (thermal infra-red energy). Most solar energy is absorbed at the surface, while most heat is radiated back to space by the atmosphere.

Slide 29. Sydney University P N Russell Engineering School (1933).

JPVM & Prof. O. Vonwiller (Physics) are shown in the PN Russell Engineering School at Sydney University in 1933. Martyn & Pulley at the end of their paper acknowledge the assistance given by other members of the RRB as well as other staff, including Physics, of the University. Sir Peter Nicol Russell (1816-1905) was born in Scotland & came to Van Dieman's Land in 1830 then to Sydney in 1838 involved with iron founding businesses. In 1896 he gave the University 50,000 pounds & in 1904 a further 50,000 with a additional 25,000 pounds from the NSW Government to construct buildings for an Engineering School at the University. Russell last visited Australia in 1886 & died childless in 1905.