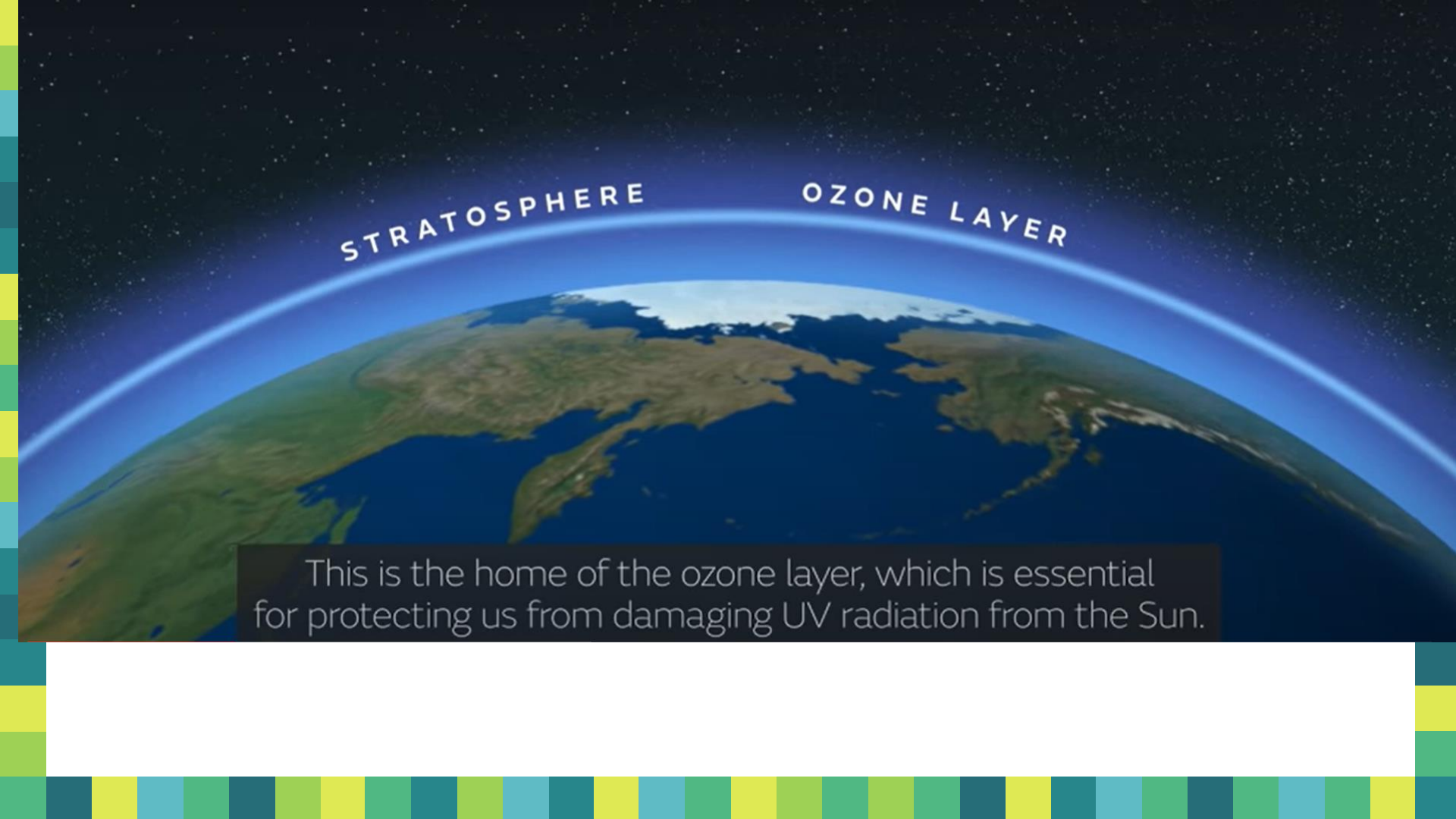


Sudden Stratospheric Warming

By

Sudarshan Gurjar

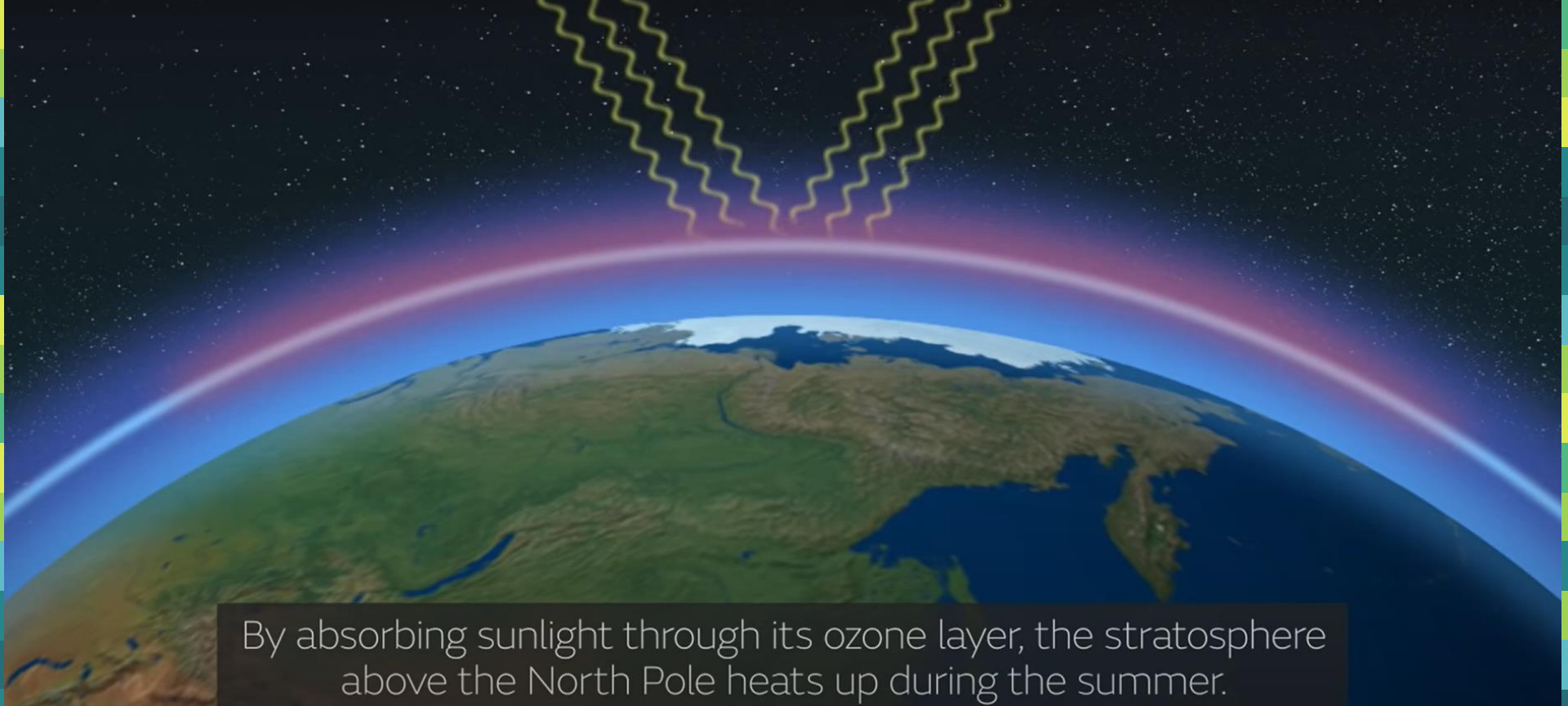
- Sudden Stratospheric Warming
- Record warm temperatures occurred above Antarctica in a phenomenon called "sudden stratospheric warming".

A view of Earth from space, showing the curvature of the planet. The surface is visible with green landmasses and blue oceans. Above the surface is a thin blue line representing the atmosphere. The background is a dark space filled with stars.

STRATOSPHERE

OZONE LAYER

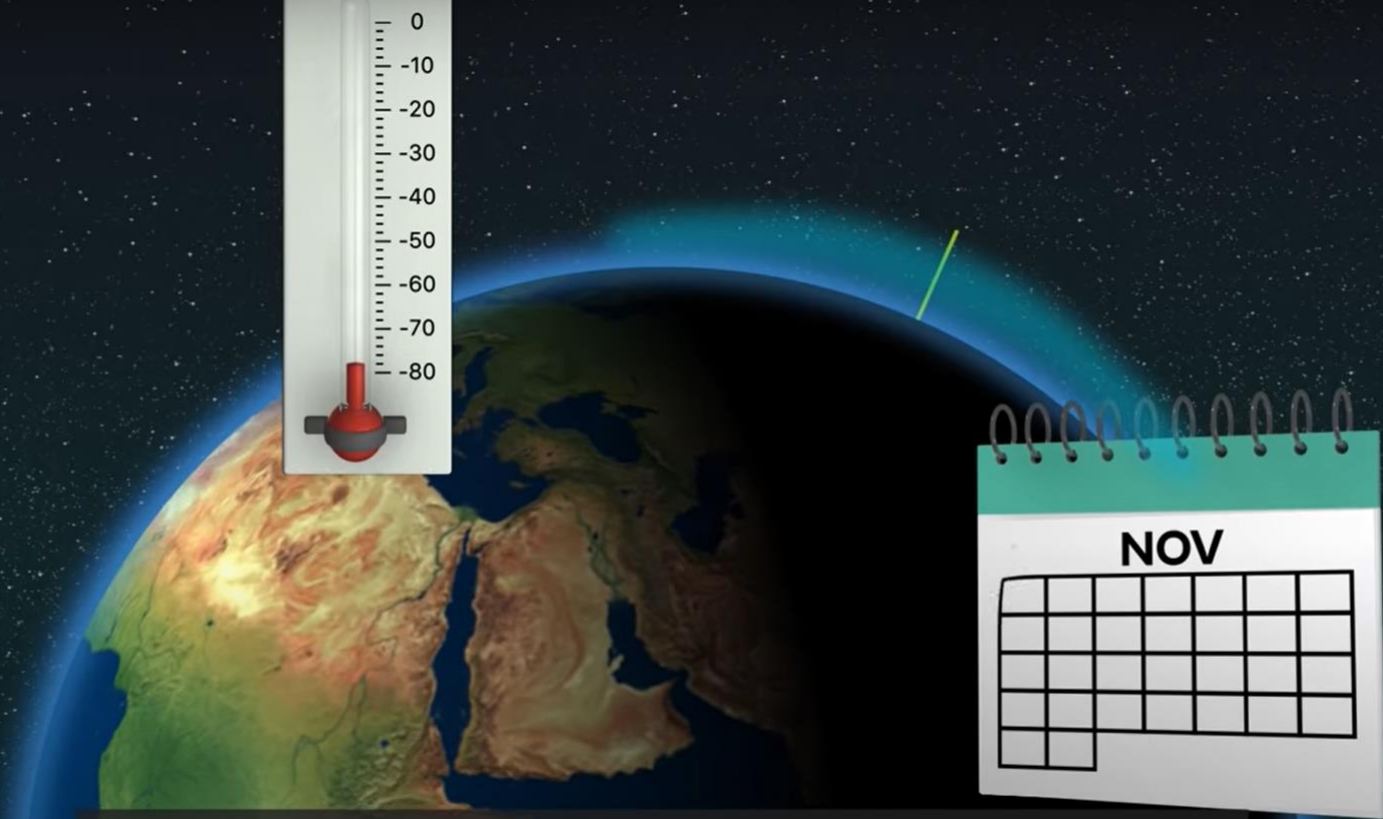
This is the home of the ozone layer, which is essential for protecting us from damaging UV radiation from the Sun.



By absorbing sunlight through its ozone layer, the stratosphere above the North Pole heats up during the summer.



Then, when the polar stratosphere tilts away from the Sun during the winter, the air above the pole becomes extremely cold...



...becoming as low as **minus 80 Celsius** by December.



Circulating around this cold pool is the **stratospheric polar vortex** with an area of low pressure at its centre.





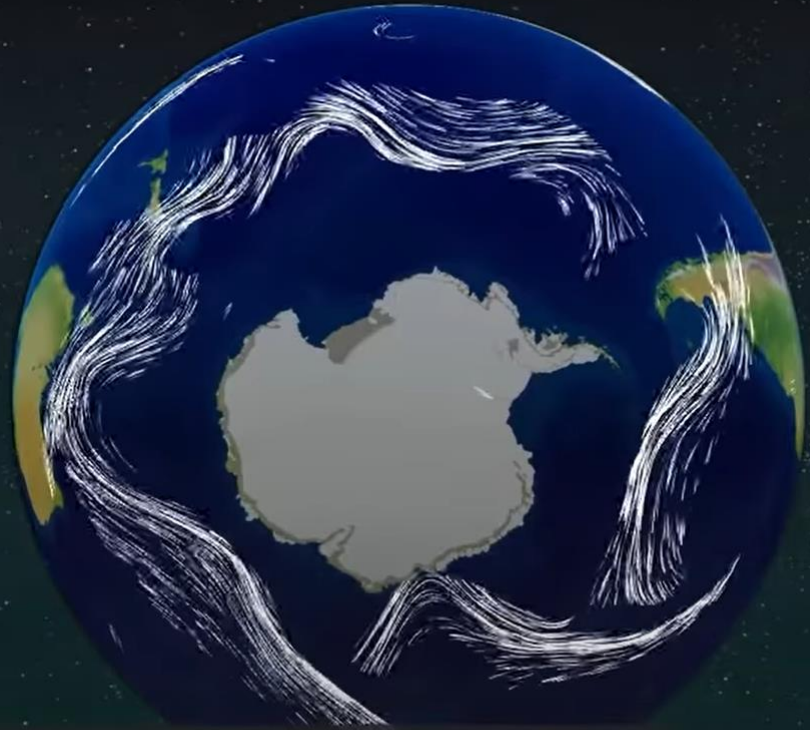
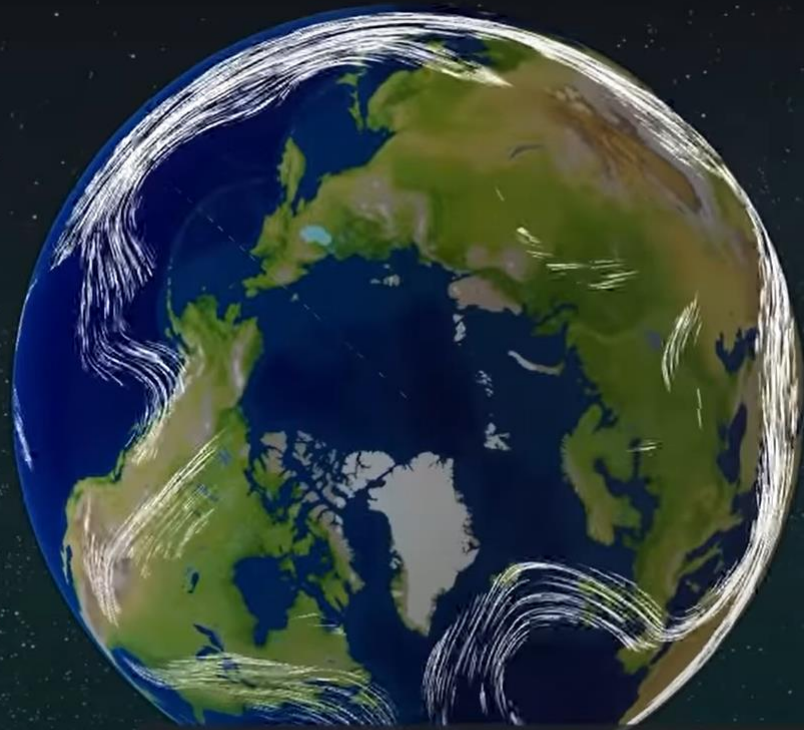
Due to the huge temperature difference between the cold polar air and the warmer air at mid-latitudes...



...a jet stream flows around the perimeter of the vortex,
known as the **Polar Night Jet**.



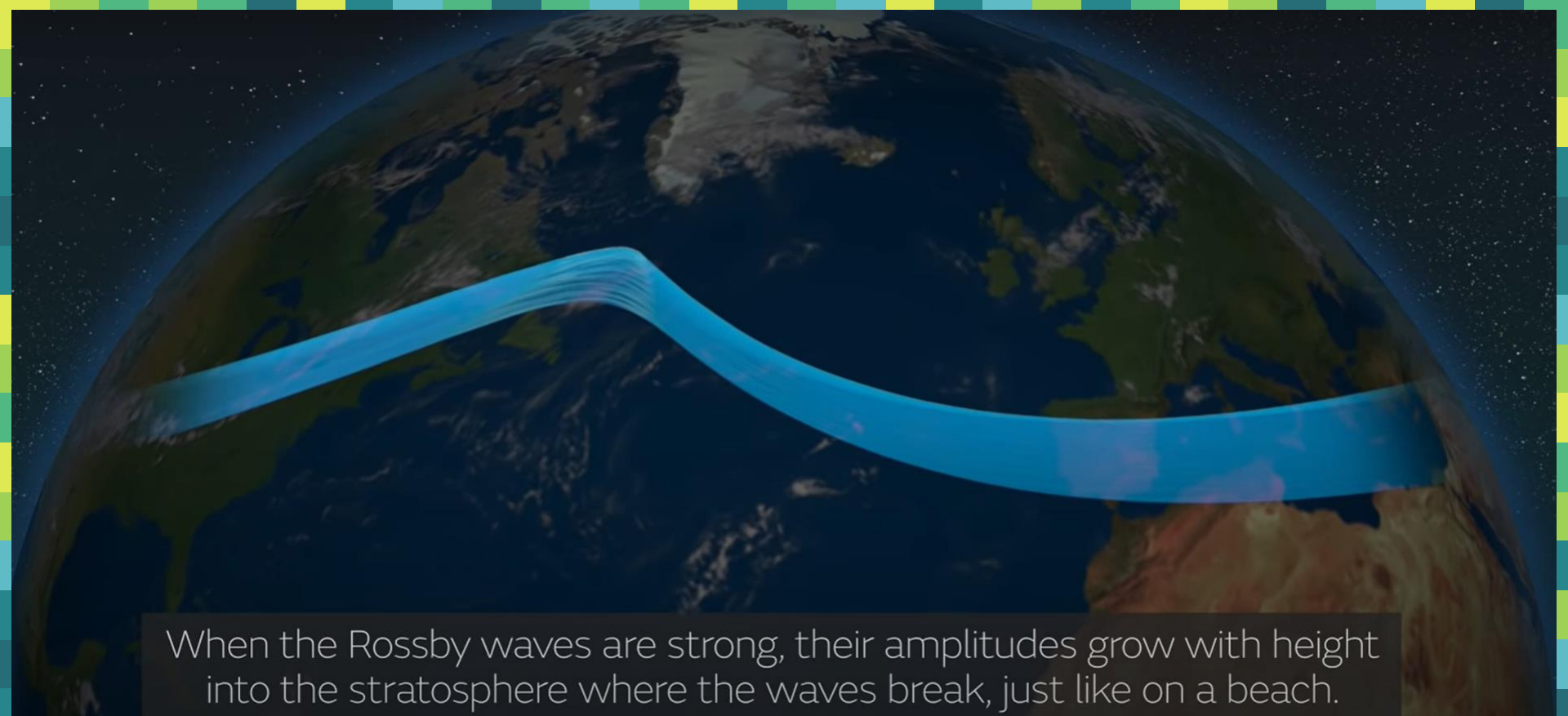
With a larger landmass in the Northern Hemisphere compared to the Southern...



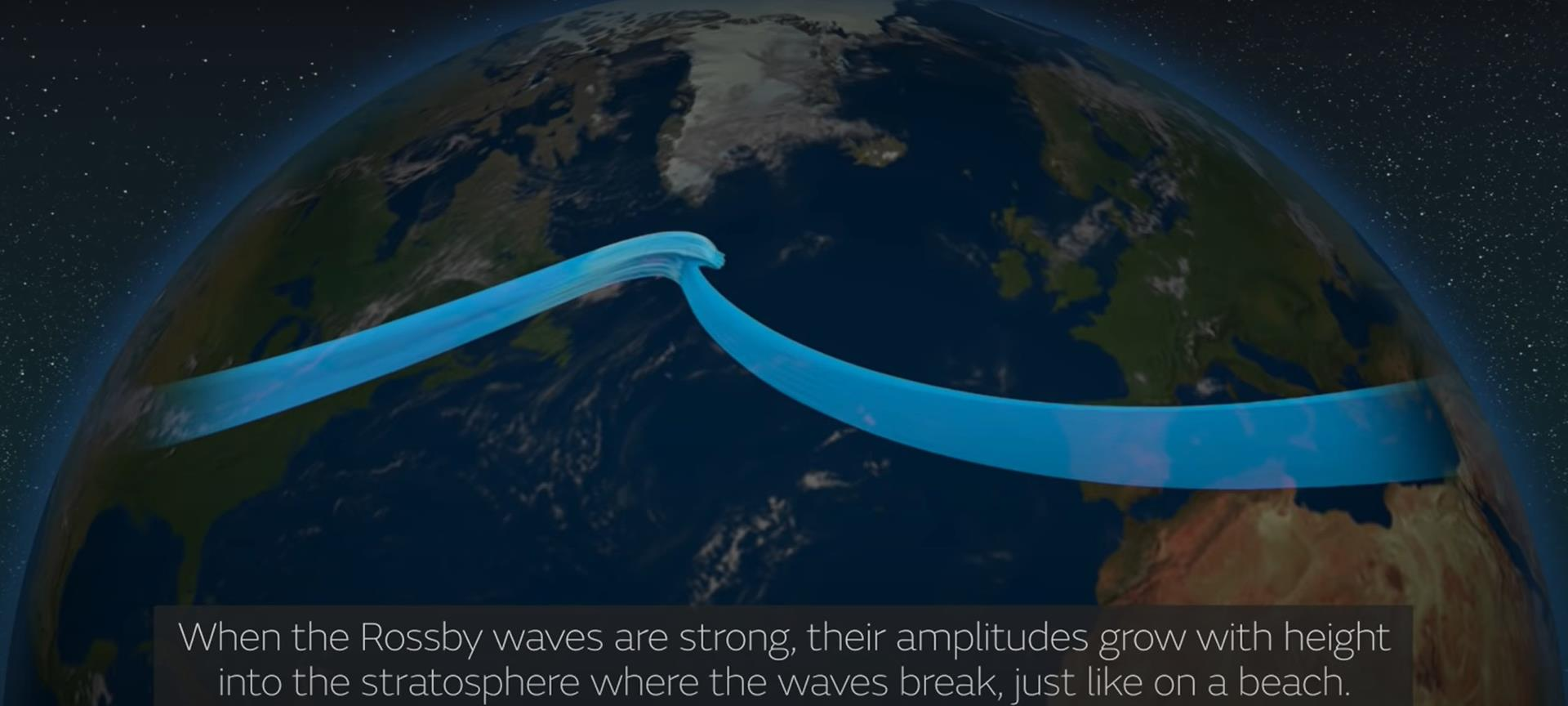
...this leads to more Rossby waves and so SSW events are largely a Northern Hemisphere-focussed phenomenon.



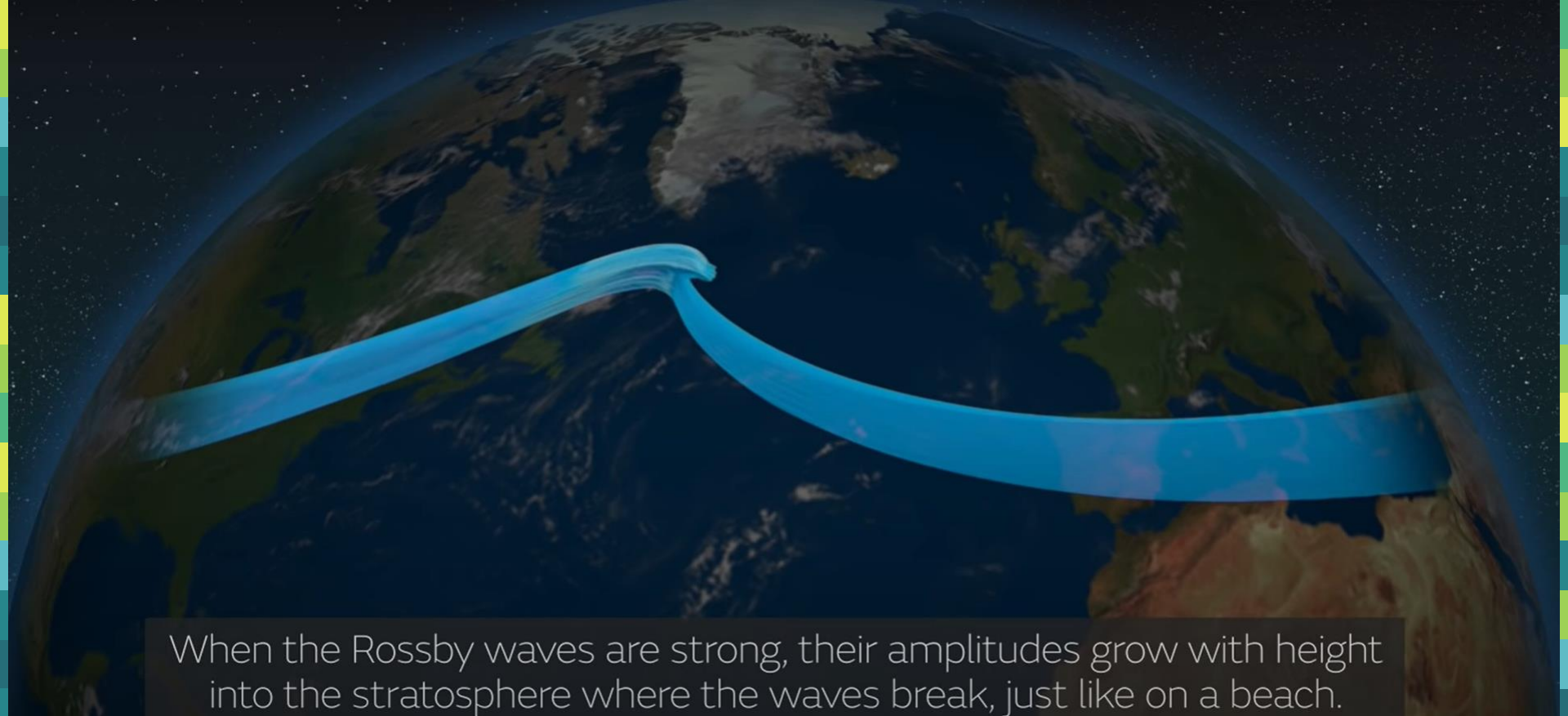
When the Rossby waves are strong, their amplitudes grow with height into the stratosphere where the



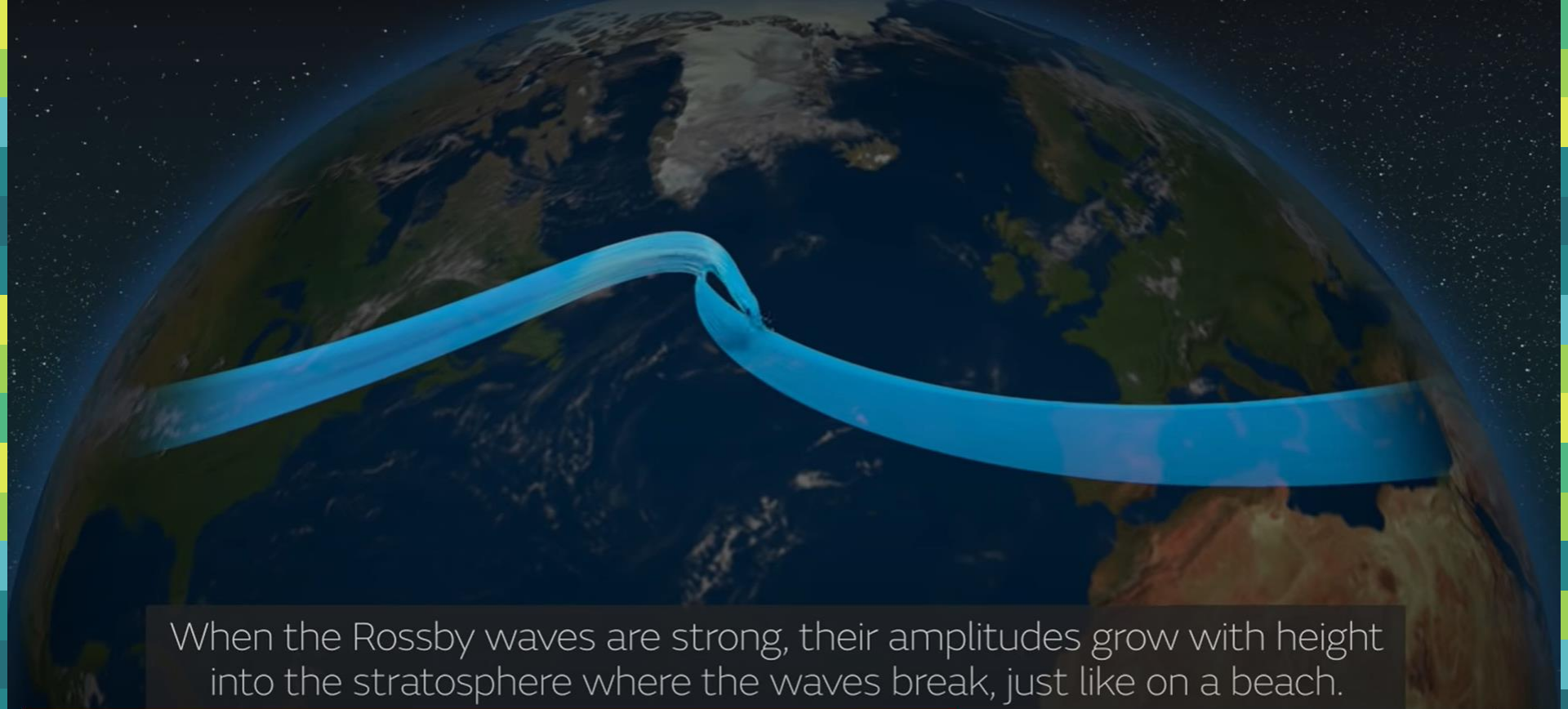
When the Rossby waves are strong, their amplitudes grow with height into the stratosphere where the waves break, just like on a beach.



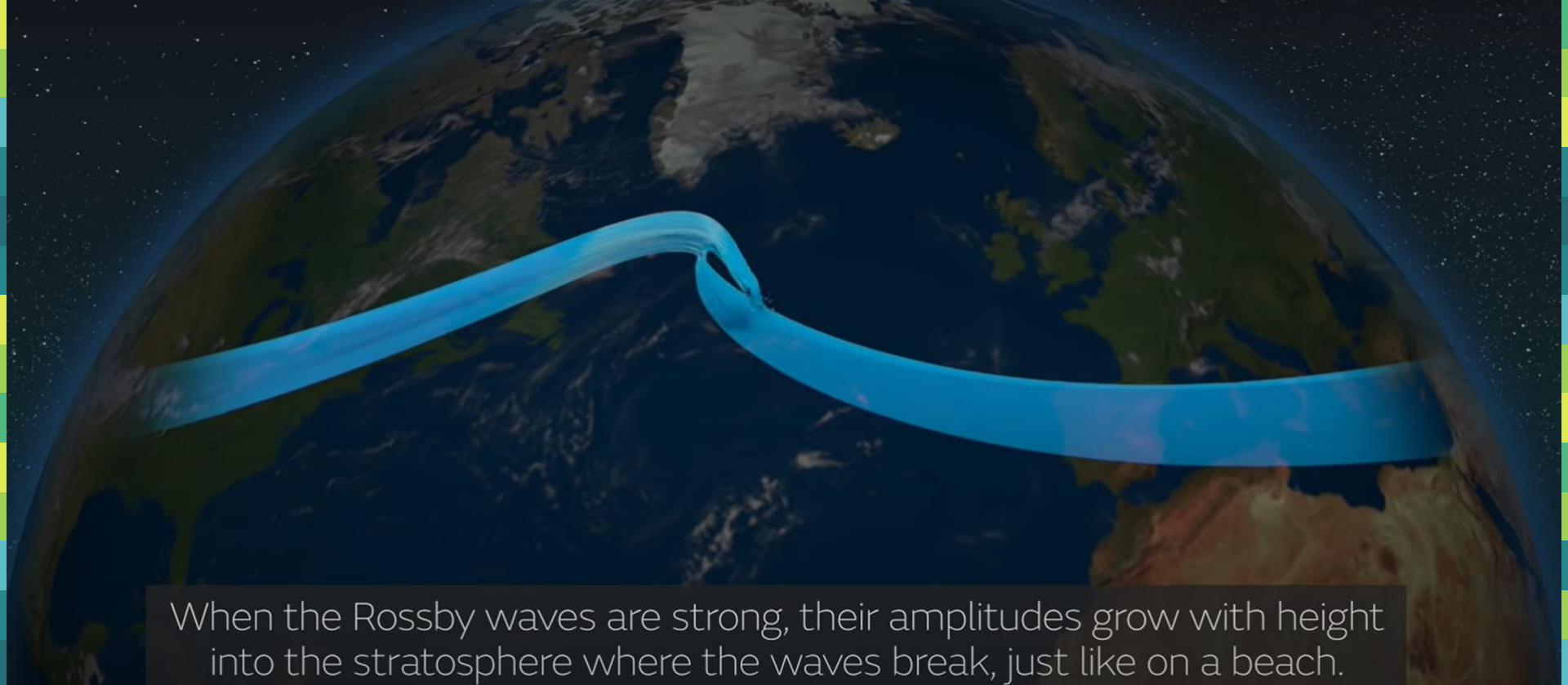
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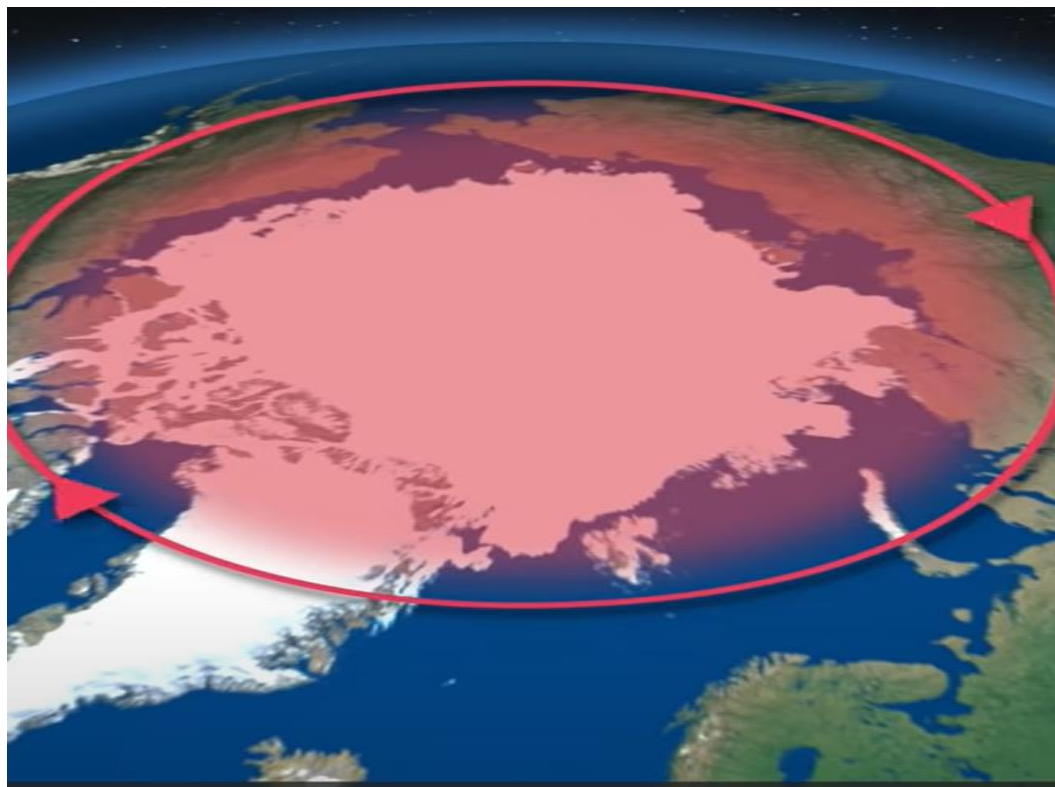
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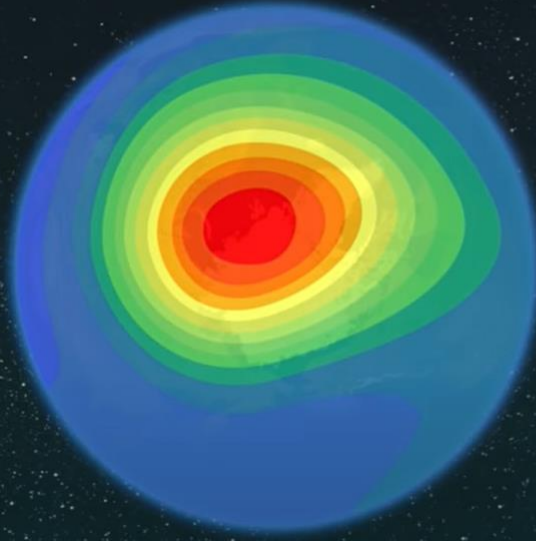
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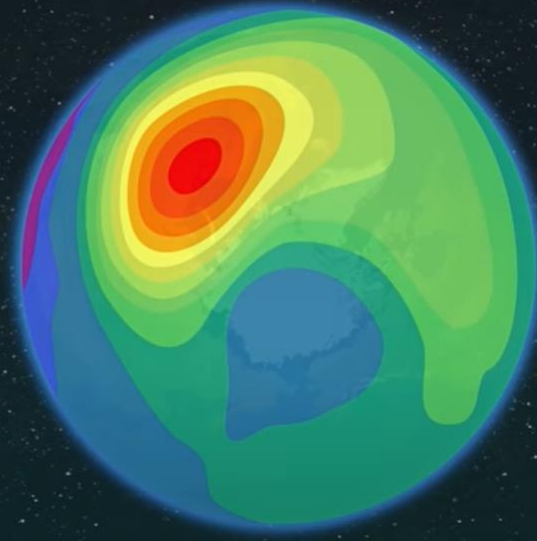
When the Rossby waves are strong, their amplitudes grow with height into the stratosphere where the waves break, just like on a beach.



Stable vortex



Displaced vortex



- In sudden stratospheric warming, the stratosphere high above the South Pole began rapidly heating.
- Every winter, westerly winds, often up to 200 km/hour, develop in the stratosphere high above the South Pole and circle the polar region.
- The winds develop as a result of the difference in temperature over the pole (where there is no sunlight) and the Southern Ocean (where the sun still shines).
- As the sun shifts southward during spring, the polar region starts to warm.

- This warming causes the stratospheric vortex and associated westerly winds to gradually weaken over the period of a few months.
- However, in some years this breakdown can happen faster than usual.
 - Waves of air from the lower atmosphere (from large weather systems or flow over mountains) warm the stratosphere above the South Pole.
 - This weakens or "mix" the high-speed westerly winds.
 - Very rarely, if the waves are strong enough they can rapidly break down the polar vortex, actually reversing the direction of the winds so they become easterly.

- Apart from warming the Antarctic region, the most notable effect of the phenomenon will be a shift of the Southern Ocean westerly winds towards the Equator.
- Tasmania, New Zealand's South Island, and Patagonia directly in the path of the strongest westerlies results in more storminess and rainfall, and colder temperatures.
- Subtropical Australia, which largely sits north of the main belt of westerlies, receives reduced rainfall, clearer skies, and warmer temperatures.

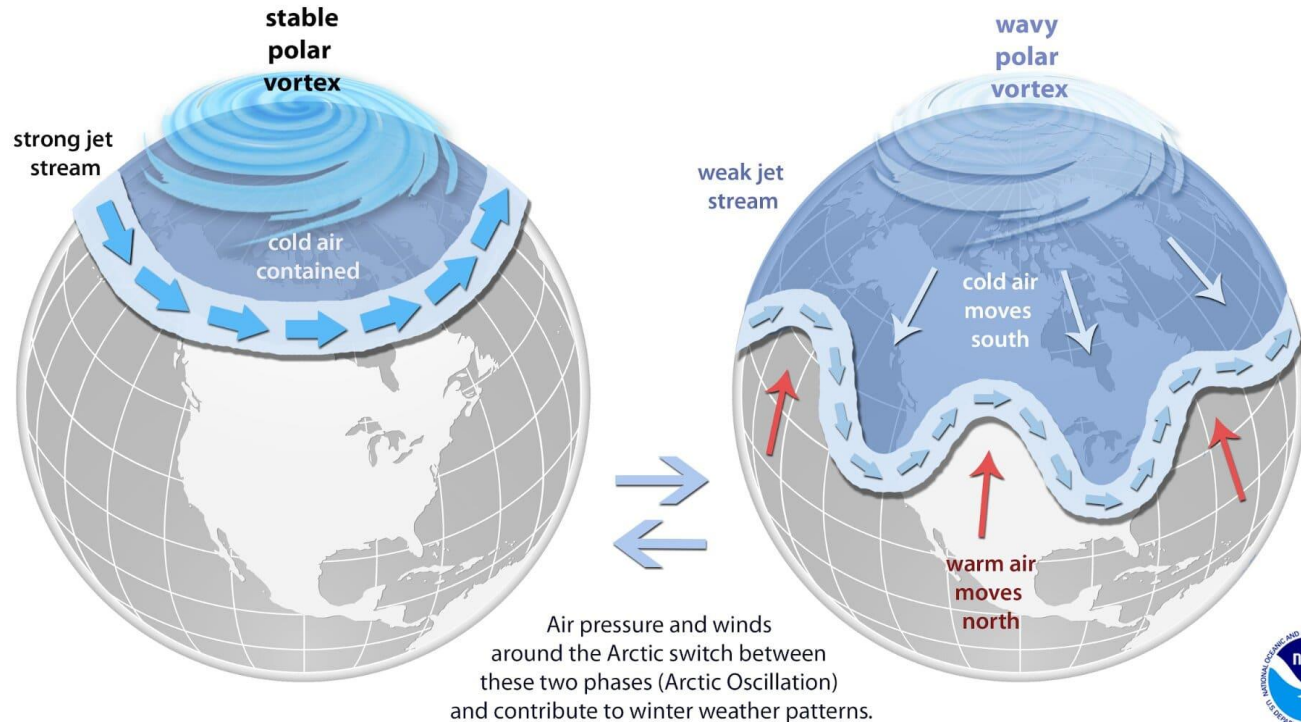
- The weather system causing the rapid rise of stratospheric temperatures also lead to weakening of the Antarctic polar vortex, a slowly-spinning pool of stratospheric air trapped by a ring of fierce westerly winds—the polar night jet—that emerges in the upper stratosphere during winter at the South Pole.

- The breakdown of the polar vortex helped the ozone hole in two ways. The early season warmth minimized further formation and persistence of polar stratospheric clouds. Because these clouds enable the chemistry that produces ozone-destroying substances, fewer clouds meant less ozone destruction. The weak polar vortex also allowed more ozone-rich air from lower latitudes of the Southern Hemisphere to mix into the polar stratosphere and partially patch the hole that had begun to form. The lingering warmth prevented it from reforming.
- This is the third time in the last 40 years that weather systems have caused warm temperatures that limit ozone depletion. Similar weather patterns in the Antarctic stratosphere in September 1988 and 2002 also produced atypically small ozone holes

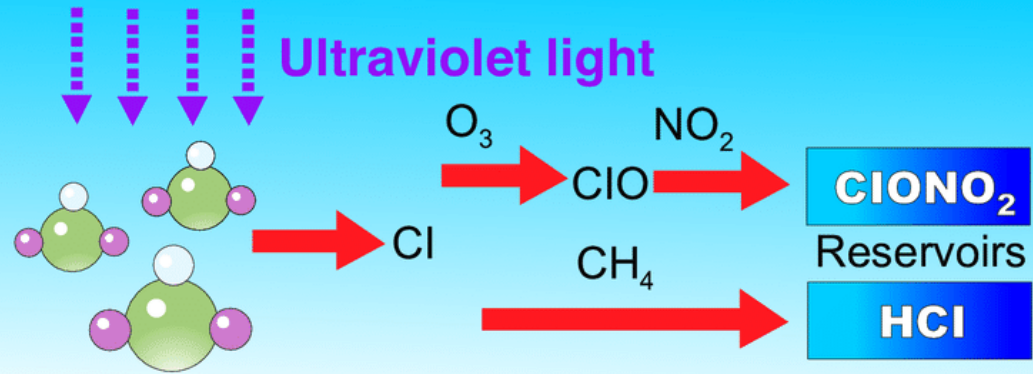
The Science Behind the Polar Vortex

The polar vortex is a large area of low pressure and cold air surrounding the Earth's North and South poles. The term vortex refers to the counterclockwise flow of air that helps keep the colder air close to the poles (left globe). Often during winter in the Northern Hemisphere, the polar vortex will become less stable and expand, sending cold Arctic air southward over the United States with the jet stream (right globe).

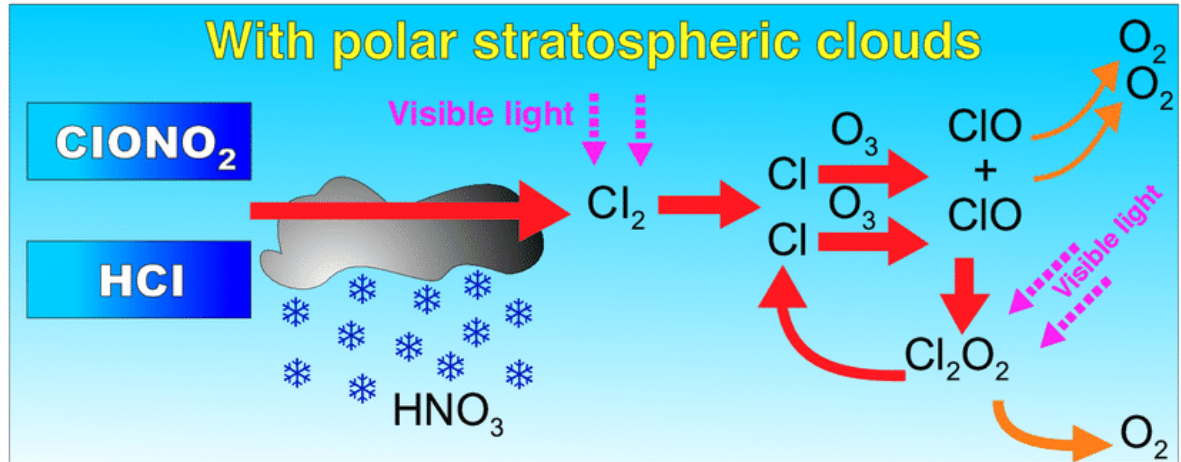
The polar vortex is nothing new — in fact, it's thought that the term first appeared in an 1853 issue of E. Littell's *Living Age*.



Without polar stratospheric clouds



With polar stratospheric clouds



Hypothesis: CFCs cause significant *and rapid* ozone depletion, with the help of polar clouds.

Nothing will affect CFCs in the lower atmosphere.



CFCs will eventually diffuse to the upper atmosphere.



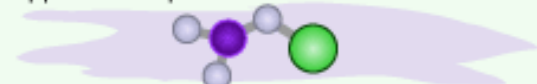
CFCs will release a Cl atom when exposed to solar radiation.



The catalytic sequence of reactions involving Cl and O₃ happen rapidly enough to cause significant O₃ depletion.



Nitrogen dioxide neutralizes some Cl in upper atmosphere.



Ice particles speed release of chlorine.



Ice particles keep nitrogen dioxide from neutralizing much chlorine.



Ozone Treaties

Ozone Depletion

- In the mid-1970s, scientists became aware that the ozone layer was threatened by the accumulation of gases containing halogens (chlorine and bromine) in the atmosphere.
- Then, in the mid-1980s, scientists discovered a ‘hole’ in the ozone layer above Antarctica – the region of Earth’s atmosphere with severe depletion.

What Causes Ozone Depletion?

- Man-made chemicals containing halogens were determined to be the main cause of ozone loss.
- These chemicals are collectively known as **ozone-depleting substances (ODSs)**.
- The most important are chlorofluorocarbons (CFCs), which at one time were widely used in air conditioners, refrigerators and aerosol cans.
- Other chemicals, such as hydrochlorofluorocarbons (HCFCs), halons and methyl bromide also deplete the ozone layer.
- Most of our computers, electronics and parts of our appliances were cleaned with ozone-depleting solvents.

How Is Ozone Destroyed?

- When a CFC molecule reaches the stratosphere, it eventually absorbs UV radiation, causing it to decompose and release its chlorine atoms.
- One chlorine atom can destroy up to 100,000 ozone molecules.
- Too many of these chlorine and bromine reactions disrupt the delicate chemical balance that maintains the ozone layer, causing ozone to be destroyed faster than it is created.

Vienna Convention

- The Vienna Convention for the Protection of the Ozone Layer was adopted in 1985 and entered into force in 1988.
- Nations that signed the Convention– called the parties– agreed to research and monitor the effects of human activities on the ozone layer and to take concrete action against activities that are likely to have adverse effects on the ozone layer.
- The Convention did not require countries to take specific actions to control ozone-depleting substances.
- The specific actions are spelled out by the Montreal Protocol.

Montreal Protocol

- The Montreal Protocol on Substances that Deplete the Ozone Layer (a protocol to the Vienna Convention for the Protection of the Ozone Layer).
- It is an international treaty designed to protect the ozone layer by phasing out ODS (Ozone Depleting Substances).
- It was agreed on 26 August 1987, and entered into force on 26 January 1989.
- The two ozone treaties have been ratified by 197 parties making them the first universally ratified treaties (legally binding) in United Nations history.

September 16th is observed as World Ozone Day. It is the day that marks the signing of the Montreal Protocol.

The Parties are aided by the Ozone Secretariat, which is based at the headquarters of the UN Environment Programme (UNEP) at Nairobi.

Multilateral Fund

- It provides financial and technical assistance to developing member countries whose yearly per capita consumption and production of ODSs is less than 0.3 kg.
- The activities of the Fund are implemented by four bodies:
 - UNEP
 - UN Development Programme (UNDP)
 - UN Industrial Development Organisation (UNIDO)
 - World Bank

1. Developing and developed countries have **equal but differentiated responsibilities**.

2. Developed Nation 2000 – CFC Phase out Methyl Chloroform 2005

3. Developing Nation 2010 – CFC

2010- HCFC

- The substances controlled by the treaty are listed in-
- Annex A – CFCs, halons
- Annex B – other fully halogenated CFCs, carbon tetrachloride, methyl chloroform
- Annex C – HCFCs
- Annex E – methyl bromide
- Annex F – HFCs

- Amendments have been made to the Montreal Protocol in
 - London- 1990
 - Copenhagen- 1992
 - Montreal- 1997
 - Beijing- 1999
 - Kigali- 2016 (Meeting of the Parties - 28)

Kigali Amendment

- The Kigali Amendment is an amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer.
- It was adopted in Kigali, Rwanda in 2016 and entered into force in 2019.
- It is legally binding.
- The Amendment adds powerful greenhouse gases hydrofluorocarbons (HFCs) to the list of substances controlled under the Protocol and which are to be phased down.
- HFC phase down is expected to avoid up to 0.5 degree Celsius of global temperature rise by 2100, while continuing to protect the ozone layer.

- The Agreement upholds the principle of Common but Differentiated Responsibilities and Respective Capabilities (CBDR & RC).
- Under the Amendment, Montreal Protocol parties are required to gradually reduce HFC use by 80-85 per cent by the late 2040s.

•It has divided the signatory parties into three groups-

1.The first group consists of rich and developed economies like USA, UK and EU countries who will start to phase down HFCs by 2019 and reduce it to 15% of 2012 levels by 2036.

2.The second group consists of emerging economies like China, Brazil as well as some African countries who will start phase down by 2024 and reduce it to 20% of 2021 levels by 2045.

3.The third group consists of developing economies and some of the hottest climatic countries like India, Pakistan, Iran, Saudi Arabia who will start phasing down HFCs by 2028 and reduce it to 15% of 2024-2026 levels till 2047.

India's Commitment Under Kigali Agreement

- **Baseline years-** 2024, 2025, 2026
 - **Freeze: 2028**
 - 1st step - 2032: 10%
 - 2nd step - 2037: 20%
 - 3rd step - 2042: 30%
 - 4th step - 2047: 85%
-
- India has agreed on a lenient schedule as it consumes only **3%** of HFCs as compared to the other nations like the **USA (37%)** and **China (25%)**.

The answer is HFO refrigerants. HFO stands for hydrofluoro olefin. HFC refrigerants are composed of hydrogen, fluorine and carbon atoms connected by single bonds between the atoms.



CFCs



HCFCs



HFCs



HFOs

High ODP
High GWP

Low ODP
High GWP

Zero ODP
High GWP

Zero ODP
Very Low GWP

ODP (Ozone Depletion Potential) GWP (Global Warming Potential)