# THE ATMOSPHERE

As plotted from sea level to the exosphere People have long sought to understand, map, and occupy Earth's atmosphere. The Atmosphere: A Guide depicts some human influences on the sky and the accumulated traces left there-whether chemical, narrative, spatial, or political.

Recent efforts to visualize scale owe a debt to Kees Boeke and his 1957 book Cosmic View: The Universe in 40 Jumps. Preceding the first photograph of the Earth taken from space by two years, Cosmic View shares some zooming qualities with the bird's-eye perspective of satellite imagery. Boeke's book is a humane essay on scale, using a sequence of photographs and drawings to jump in steps from the relative size of the human body up to the scale of the universe and then back to the scale of the atom. Boeke also developed sociocracy, a model for consent-based pedagogy. Cosmic View influenced two films made in 1968; Cosmic Zoom by Eva Szasz and A Rough Sketch for a Proposed Film Dealing with the Powers of Ten and the Relative Size of the Universe by Ray and Charles Eames.

Which sky?

How do science, social attitudes, economics, and politics intersect in the atmosphere? The intangibility of the atmosphere and much of its composition of gases make it appear resilient and

forgiving of anthropogenic damage. However, the future of the atmosphere is altered by how people understand, consider, and act upon it in the present. Current and historic visions of the atmosphere frame our relationship to it and send ripples towards the rights of future people to a familiar climate.

Towards a new map

Which atmosphere is it? The biogeochemical or the geopolitical? A global commons or militarized space? Does the difficulty of human occupation of the atmosphere produce a space for projection and speculation? A space of indeterminacy? The Atmosphere: A Guide charts some atmospheric politics and their downward influences.

### LAYERS OF THE ATMOSPHERE

## **EXOSPHERE**

### 600-10.000 KM/375-6.200 MI

The exosphere is the uppermost layer of the atmosphere It is composed mostly of thinly distributed hydrogen and helium, the lightest gases. There is some atomic oxygen near the bottom of the exosphere, which is called the exobase. In the exosphere, satellites can orbit the Earth with little atmospheric drag.

There is no clear boundary between the exosphere and



### WHAT PEOPLE SHOULD KNOW

"One of the reasons I study the atmosphere is because it's critical to life. But it's a very, very thin veneer on the surface of the planet. You can go anywhere in the world and take an air sample in what you think is the cleanest place on earth, and it's full of human-produced compounds. We can see all these things that were never there before in the history of the planet. And we can measure it. And so the stuff that people dump into the atmosphere doesn't disappear, doesn't escape to space. And this is relevant for the greenhouse effect, it's relevant for stratospheric ozone depletion, it's relevant for just air pollution in general."

**YOU ARE HERE** 

- Robert Rhew, geochemist, UC Berkeley



**POLLUTION** 

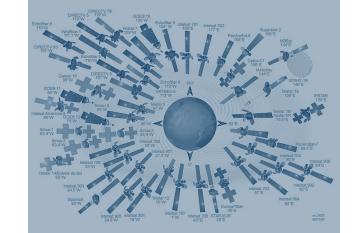
### SPACE JUNK + CO<sub>2</sub>

In 2012, the Swiss Space Center announced plans to launch CleanSpace One, a robot spacecraft that will grab inactive satellite parts and bring them back to Earth.

"Research since the early 1990s has led to the suggestion that increasing carbon-dioxide emissions, from power stations and other terrestrial sources, are increasing the orbital lifetimes of defunct satellites and debris in the lower-altitude orbits. Observations and modeling support the theory that CO<sub>2</sub> emissions have led to a cooling of the thermosphere (at altitudes between 85 and 600 km) and a consequent reduction in density, which reduces the frictional effect on orbiting objects. The hypothesis is that thermospheric cooling could continue for the next hundred years, despite CO<sub>2</sub> emission controls, by which time the effect would be comparable with that of solar variability.

- Mark Williamson, Space: The Fragile Frontier

### **SPATIAL POLITICS**



### SATELLITES

the public interest might be defined."

"Investigate satellites, learn their names, who owns them, what they do, how they have been used. There is a need for more satellite literacy. Contest the militaristic and corporate appropriation of satellites with more art, activism, dreaming, and experimentation. Imagine how the use of satellites in

> - Lisa Parks, Ph.D. Film and Media Studies UC Santa Barbara

**REMOTE SENSING** 

### SATELLITE REMOTE SENSING

Remote sensing satellites use sensors to observe the Earth from the exosphere. Remote sensing has become increasingly important for monitoring human impacts on the global environment. Environmental applications include tracking the effects of climate change on glaciers, sea ice, and for-

From 2003 to 2009, NASA's ICESat satellite measured ice sheet mass balance, cloud and aerosol heights, topography, and forest cover. When ICESat's primary sensor failed in 2001, it was crashed by "de-orbit burn" over the Barents Sea and replaced by IceBridge, an airborne survey of Earth's polar ice. In 2009 and 2011, two of NASA's Earthobserving satellites, Glory and the Orbiting Carbon Observatory (OCO), intended to further climate research efforts, crashed during their respective launches. This was a major setback for improving the accuracy of climate models. The

launch of ICESat-2 is planned for 2016.

# **CLIMATE CHANGE**



### THE SPECULATIVE

Scenarios are images of the future, or alternative futures. Used to explore possible ways the climate may change in the future in a range of time scales, climate scenarios predict how "temperature, precipitation, sea level, and other climatic variables may change" over time as a result of human and natural climate drivers. Climate scenarios also factor in human beliefs about the climate and how attitudes towards the future impact the future climate and atmosphere.

While it would be difficult to sum up the total impact of human worldviews on the atmosphere, anthropogenic greenhouse gas concentration might be a crude metric. In January 2011, the atmospheric concentration of carbon dioxide was 391 parts per million (ppm). What will the climate be like in 100 years? In 1,000 years? Uncertainty is high.

**AIRSPACE** 

**OUTER SPACE TREATY OF 1967** 

The Treaty on Principles Governing the Activities of States in

the Exploration and Use of Outer Space, Including the Moon

and Other Celestial Bodies, or the Outer Space Treaty,

forms the basis of international space law. It forbids govern-

ments from claiming rights to, or control over, resources

beyond the Earth's atmosphere, as the "common heritage

of humankind." It also stipulates free access to all areas of

celestial bodies. While signatories to the treaty are not

allowed to make claims of sovereignty by occupation of

celestial bodies, a state retains control over artificial objects

it has launched. States are also liable for damage or

pollution caused by their activities in space. The treaty bars

signatories from putting weapons of mass destruction in

Earth's orbit, on the Moon, or in outer space. It also limits the

use of the Moon to peaceful purposes, barring military

bases, training, testing, or occupation. However, it does not

ban the placement of conventional weapons in Earth's orbit.



**ELECTROMAGNETIC SPECTRUM** 

### THE SOUND OF SPACE WEATHER

Stephen P. McGreevy has been recording very low frequency (VLF) and extremely low frequency (ELF) electromagnetic (radio) wave signals in remote areas since the 1990s. "Unlike sound waves, which are vibrations of air molecules that our ears are sensitive to, natural radio waves are vibrations of electric and magnetic energy which-though occurring at the same frequencies as sound-cannot be listened to without a fairly simple radio receiver to convert the natural radio signals directly into sound," says McGreevy, who has a significant body of recordings of auroras, meteor showers, and VLF "whistlers," which McGreevy defines as "bursts of ELF/VLF radio energy initiated by lightning strikes which 'fall' in pitch," archived online at auroralchorus.com. Of the photo above, he says "Listening to whistlers at Lee Flat in the smoky desert that morning was eerie-usually we have such good desert visibility-the smoke made it feel like the world had closed in...

### **THERMOPAUSE**

## **THERMOSPHERE**

90-600 KM / 56-375 MI

and free-floating electrons.

The thermosphere is technically the warmest layer of the atmosphere. Influenced by solar activity, it expands and contracts daily. Here, gases can heat to 2,500°C (4,530°F) in daytime. But heated gas molecules are so thinly dispersed

that their influence on air temperature is negligible.

The ionosphere is an ion-rich area of the upper atmosphere, extending across the mesosphere, thermosphere, and exosphere from 60 to 300 km (37 to 190 miles) above the Earth's surface. In the ionosphere, the sun's energy, as ultraviolet radiation, breaks up air molecules to create plasma, made up of ions (atoms with missing electrons)

The International Space Station orbits in the upper thermosphere. The upper thermosphere and exosphere meet at the thermopause, also called the exobase.

### **ENMOD**

Operation Popeye was an American military cloud-seeding operation intended to extend the monsoon season over Laos during the Vietnam (American) War. Crafted in response to Operation Popeye, the 1976 Environmental Modification Convention (ENMOD) prohibits any hostile use of environmental modification techniques.

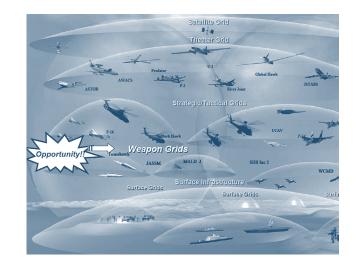
As defined in Article II of the Convention, "environmental modification techniques' refers to any technique for changing-through the deliberate manipulation of natural processes-the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space." The Convention entered



### SHRINKING SKY

Although CO<sub>o</sub> emissions cause warming in the lower atmosphere, they can cause the thermosphere to cool. Cooling is already reducing the density of the thermosphere, causing an overall contraction.

Since the 1940s, the thermosphere, which warms and expands significantly by day and cools and shrinks at night,

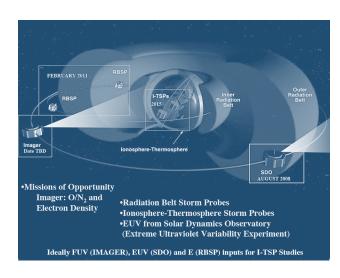


### **WEAPON GRIDS**

While difficult to inhabit, the atmosphere is occupied and controlled. From symbols of state power and cooperation, to spheres of remote control, the atmosphere is divided by maps, networks, and weapon grids.

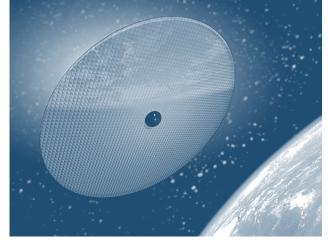
These include American attempts to exercise military control in the upper and lower atmosphere, such as the never-fullydeveloped Strategic Defense Initiative (Star Wars), which was to include space-based weapons, and the now-defunct Distant Early Warning (DEW) Line, a Cold War system of radar stations positioned in the Canadian High Arctic.

As represented in the above 2007 U.S. Department of Defense rendering, networked "weapon grids" are a vision of total militarization of the atmosphere, extending from the exosphere to sea level.



### IONOSPHERE-THERMOSPHERE PROBES

Delayed from a planned 2012 launch by NASA, a pair of lonosphere-Thermosphere Storm Probes (I-TSP) may eventually "study distributions of ionospheric and thermospheric densities, geomagnetic disturbances, and ionospheric irregularities" by bouncing high-frequency (HF) radio waves off the ionosphere. The ionosphere is broken into four regions: D, E, F1, and F2. The D region (50-90 km), which readily absorbs AM radio waves, disappears at night, along with the E (90-120 km) and F1 (150-210 km) regions. Only the F2 (210-800km) region is present 24 hours of the day, making it the most important region for HF radio propagation. If launched, the I-TSP probes will orbit near peak ion density (400-450 km), taking "measurements of plasma density, drifts, irregularities, neutral densities, and winds." These properties of the ionosphere-thermosphere impact communication, guidance, and spacecraft orbits, and poten-



### **GEOENGINEERING**

Geoengineering is the deliberate "rearranging [of] the Earth's environment on a large scale to suit human needs." This includes proposed and largely untested climate-altering technologies such as pumping sulfur into the stratosphere, liquefying and sequestering carbon dioxide in the deep sea, "fertilizing" oceans with iron to produce plankton blooms, and positioning a giant mirror in orbit over Greenland to reflect sunlight with the aim of stopping ice from melting.

Geoengineering is often promoted as an opportunity to utilize large-scale technology to slow or stop climate change. At the same time, these technologies have unpredictable and potentially irreversible implications. With weather modification as a potential weapon, they may contravene the 1976 UN Environmental Modification Convention (ENMOD). In addition, geoengineering legitimates continued extraction and



### KÁRMÁN LINE (100 KM / 62.1 MI)

and thus a lack of drag.

The Kármán line is an internationally designated altitude boundary used to define where space begins. Named for engineer and physicist Theodore Van Kármán, the Kármán line is the minimum height at which free fall and

orbiting is possible. It is also the upper atmospheric limit for

air sports, separating aeronautics from astronautics. While

aeronautics need the presence of sufficient atmosphere to

be viable, astronautics instead need a lack of atmosphere,

### Auroras are light displays in the upper atmosphere that occur mostly from 100 km to 300 km, high above polar regions. They resemble shifting red or green transparent arcs or rippling curtains that appear to hang from and move across the sky. Auroral glow is created by high-energy particles from the sun striking Earth's atmosphere as solar wind, colliding with, exciting, and ionizing oxygen atoms. Red oxygen aurora (150 km+) are above green oxygen aurora (100 km-150 km). The strength of the solar wind determines the intensity of the aurora. Earth's magnetic field is much stronger near the magnetic

north and south poles, which attracts charged particles, and makes it far more common to witness auroras there. A daily forecast of expected geomagnetic activity is provided by the Geophysical Institute at the University of Alaska Fairbanks at www.gi.alaska.edu/AuroraForecast.

### MESOPAUSE

### MESOSPHERE

50-90 KM / 31-56 MI

Sahara Desert.

Cold and dry, the mesosphere is the least researched layer of the atmosphere. It is the coldest layer of the lower atmosphere, where temperatures drop with increasing altitude to a low of around -100°C (-130°F), creating conditions that freeze water vapor into ice clouds. The mesosphere is very dry-one hundred million times drier than air from the



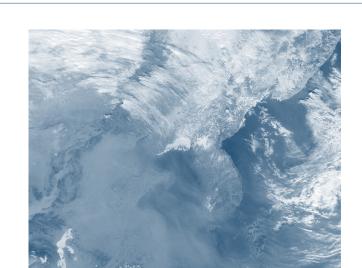
### NOCTILUCENT CLOUDS

Noctilucent or "night-shining" clouds can occasionally be seen very high in the sky at sunset, if sunlight hits them when the sun is four to sixteen degrees below the horizon. The clouds consist of tiny ice crystals about the size of the particles in cigarette smoke. Considered by some a symptom of a changing climate, noctilucent clouds (also known as Polar Mesospheric Clouds) begin to occur at a height upwards of 80 km (50 mi) in the mesosphere. They were first observed in 1885, about two years after the eruption of Krakatoa shot plumes of volcanic ash up to 80 km high. At that time, the clouds were only seen in latitudes above 50°, in places like Scandanavia, Russia, and Britain. More

recently, they have been seen as far south as Utah and

Colorado. In the northern hemisphere, noctilucent cloud

season runs from mid-May to the end of August.



**GENEVA CONVENTION ON AIR POLLUTION** 

The 1979 Geneva Convention on Long-Range Transboundary Air Pollution was a response to industrial emissions from central Europe causing acid rain in Scandinavia and a broader scientific understanding in the 1970s that air pollution could be transported thousands of miles from where it was emitted. The aim of the Convention was that "parties shall endeavor to limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution."

Since it came into force in 1983, the Convention has been extended by eight protocols that identify measures to be taken to cut emissions of specific air pollutants, including heavy metals, nitrogen oxides, volatile organic compounds,

and persistent organic pollutants.



**SCIENCEWASH** 

Dual-use technology describes technologies and goods that share peaceful scientific and military applications. Northrop Grumman Corporation's Global Hawk drone is a high-altitude unmanned aerial vehicle (UAV) that can stay aloft for more than 30 hours. NASA has used the Global Hawk in a project to verify measurements by its auroral atmospheric research satellite. The Global Hawk has also been utilized by the United States military in both the Afghanistan and Iraq Wars. As early as 2010, 7,000 UAVs were in use by the U.S. military across Iraq and Afghanistan for military reconnaissance, surveillance, and for the remote-controlled launch of missiles and bombs from the air.



tially affect ozone and climate.

AERONOMY OF ICE IN THE MESOSPHERE

The Aeronomy of Ice in the Mesosphere (AIM) satellite was launched in 2007 by NASA to research noctilucent, or "polar mesospheric" clouds (PMCs). The primary research goal of AIM has been to assist scientists' understanding of why these clouds form, and their relationship to Earth's climate. The satellite's instruments measure the spatial distribution, particle size, and abundance of PMCs, and gather data on temperature and atmospheric chemistry. Since 2007, AIM has revealed that mesospheric ice occurs in a continuous layer of clouds from below 83 km up to 90 km. However, the most significant early finding was that the "startling similarity between the PMC structure observed...and that seen in tropospheric clouds suggests that the mesosphere may share some of the same dynamical processes responsible for weather near Earth's surface." AIM was extended from 2009–2012 to further study the clouds' possible connection



ATMOSPHERIC & CLIMATE JUSTICE

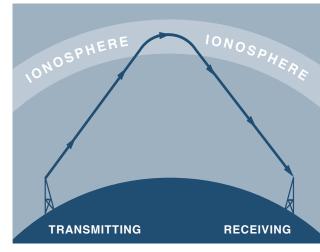
"We are shocked by the level of corruption that the United Nations Framework Convention on Climate Change has reached in allowing corporations to take over the political space and process of climate negotiations." - Alicia Muñoz of Via Campesina in Chile Climate Justice Now! Network Joint Statement Poznań, Poland, 2008



**CLIMATE MODEL** 

Climate models mathematically simulate the interactions of the atmosphere, oceans, land surface, and ice. Climate models can be global, showing general atmospheric circulation, or regional. Multiple climate models are considered simultaneously to provide a predictive range for projected impacts of climate change.

Both simple and complex mathematical scenarios are used by organizations like the Intergovernmental Panel on Climate Change (IPCC) during climate negotiations and in policy recommendations. In 2012, North Carolina's Senate passed a bill restricting the use of predictive modeling of coastal sea level rise scenarios by state planning officials



SKYWAVE (IONOSPHERIC REFRACTION)

Vital for shortwave radio communication, the ionosphere refracts HF radio waves well, making it possible for a receiver to pick up distant signals without satellites or other infrastructure. High frequency (HF) radio signals transmitted at sea level travel up to the ionosphere, where they are reflected back down, allowing radio communication over

Signals can skip many times between the Earth and ionosphere, in a process called multihop propagation. Both signal strength and multihop length can vary, influenced by electromagnetic interference and changes in the ionosphere from day to night. Lower levels of the ionosphere disperse at night, making higher reflected, longer distance bounces possible, and allowing AM and shortwave radio signals to be heard at long distances. HF radio frequencies are from 3 to 30 megahertz (MHz).

# **STRATOPAUSE**

# STRATOSPHERE

20-50 KM / 12-31 MI The stratosphere has stable atmospheric conditions, largely

lacking the weather, clouds, and air turbulence found in the The ozone layer occupies much of the stratosphere, and varies in height worldwide. It is thinner near the equator and thicker over polar regions. The ozone layer traps UV rays, causing the temperature to rise with increasing altitude towards the top of the stratosphere, creating temperatures



**JOSEPH KITTINGER (19.5 MI)** "There is a hostile sky above me. Man may live in space,

but he will never conquer it." In 1959, Joseph Kittinger made a solo jump in a pressurized suit from the Excelsior III balloon at 102,800 feet (19.5 miles) as part of military research on the impacts of high-

tailspin to the depressurization of a glove in mid-descent. In 2012, Felix Baumgartner jumped from a specialized helium balloon 128,100 feet (24 miles) above the Earth,

altitude bailout. He made two other high-altitude jumps over

the next year, from 76,400 and 74,700 feet. Each project

had mid-fall incidents, from an uncontrollable high-speed

breaking the sound barrier while in free fall. Joseph Kittinger

was his primary radio support during the upward journey.



**ARCTIC AIR POLLUTION TRANSPORT** Wind currents transport synthetic pollutants like PCBs

of endocrine-disrupting toxins found on the higher end of

(polychlorinated biphenyls) and the pesticide DDT Joseph Kittinger (dichlorodiphenyltrichloroethane) to the Arctic from areas of industrial production including China, the United States, Canada, and Europe. These pollutants are responsible for the high concentration

> The blood and fat tissues of Inuit (The People) and other people of the Canadian Arctic and subarctic, who eat a largely traditional diet of fish and sea mammals high in the food chain, contain among the highest concentrations of PCBs and other persistent organic pollutants of any people

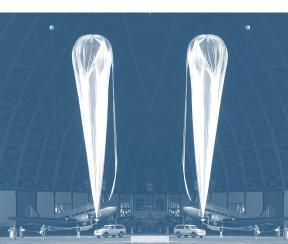


# WAR IN THE LOWER ATMOSPHERE

"Mr. Speaker, thick clouds of black smoke from the well fires have been spewing into Kuwaiti skies for over a month, obscuring the sun with air pollutants estimated at 10 times the amount produced by all the industrial and electric generating plants in the United States combined ....Atmospheric pollution on this scale has not occurred in our history. The Environmental Protection Agency has detected some air pollutants attributed to the gulf fires halfway around the world at its Mauna Loa station in the

Hawaiian Islands.

- Congresswoman Nancy Pelosi Excerpt from the Congressional Record April 16, 1991



# DRIFTSONDE

to climate change.

A driftsonde is a specialized high-flying balloon used to gather environmental data from remote parts of oceans that are otherwise inaccessible. The balloon expands to full size as it ascends to 60,000-65,000 feet in the upper stratosphere. It then drifts with prevailing winds for up to a

Dropped from an airplane mid-flight, driftsondes carry instrumentation to collect data on pressure, temperature, and humidity. Instrument packages, called dropsondes, are dropped from the driftsonde, repeatedly relaying information via satellite as they descend. Like radiosondes, driftsondes provide data for weather and climate



# OZONE $(0_3)$

"Ozone is an interesting compound. Many people view it as the central molecule in terms of atmospheric chemistry. In the lower atmosphere, ozone is considered a pollutant because it's harmful to human health and plant life, and it's a major component of smog. In the background atmosphere, though, ozone is essential to form radicals that clean the atmosphere of all its pollutants. So ozone in the troposphere can be considered as a pollutant and as a critical cleaner of the atmosphere. And when you go up into the stratosphere, it's critical to life on this planet, because it absorbs incoming ultraviolet radiation which would otherwise

cause damage to DNA of the cells of living organisms." - Robert Rhew, geochemist, UC Berkeley

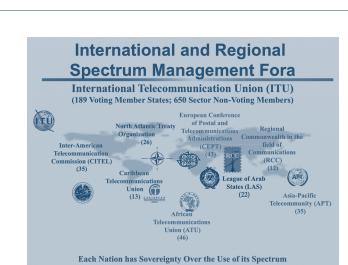


# **DIVERSIONS**

Many countries impose demands on airplane flights that overfly their territory. These include fees levied for "flyover

"These fees vary from country to country," says air traffic legal expert Ronald Schmid, quoted in Spiegel Online. "That's why, for instance, routes from Frankfurt sometimes take a zigzag course to Buenos Aires, Argentina, in order to avoid territories with high fees."

In 2007, the United States Department of Homeland Security proposed a requirement for Canadian airlines to hand over passenger lists 72 hours before flights that travel in the path of U.S. airspace, even if the plane and passengers did not intend to land there.



# **SPECTRUM**

The electromagnetic spectrum includes all frequencies of electromagnetic radiation, including radio waves, microwaves, visible and infrared radiation, and gamma waves. By selling permits for exclusive use of a band of the spectrum, spectrum privatization converts the electromagnetic

spectrum to property, restricting the ability to propagate

radio and other electromagnetic waves on certain frequen-

Experiments in spectrum autonomy have included the launch of Russian amateur radio satellite ARISSat-1 into low Earth orbit (2011-2012), as part of an educational project, and as-yet-unrealized plans for a Hackerspace Global

Grid, including a distributed ground station.

# TROPOSPHERE

0-20 KM / 0-12 MI The troposphere is the lowest part of Earth's atmosphere. It contains up to 80 percent of its gases, and most of its mass and water vapor. It is composed mostly of nitrogen (78 percent) and oxygen (21 percent), along with trace

gases. The bottom part of the troposphere is the only part of the atmosphere that is breathable. The troposphere is turbulent, and, in contrast to the other layers of the atmosphere, is warmest nearest the Earth's surface. It varies in thickness from 8 km over the poles to 16 km over the Equator.



# **ARCTIC BALLOON EXPEDITION OF 1897**

In 1897, balloonist S. A. Andrée led a failed Swedish expedition to the North Pole. They intended to steer their hydrogen balloon by a system of drag ropes to the Pole by way of Svalbard across the Arctic Sea. Their aircraft crashed on pack ice, weighted down by ice accumulation on top of the balloon. Andrêe and his travel companions, including playwright August Strindberg's nephew, Nils, died while attempting to trek back across the pack ice. Their disappearance was a mystery until 1930, when the remains of their last camp were discovered on White

Island (Kvitøya), near Svarlbard.



# TRANSBOUNDARY AIR POLLUTION

"At least one-third of California's fine particulate pollution -known as aerosol-has floated across from Asia,' says Steve Cliff, an atmospheric scientist at the University of California at Davis. 'In May this year, almost all the fine aerosol present at Lake Tahoe [300 km east of San Francisco] came from China,' says Tom Cahill, a UC Davis emeritus professor of atmospheric sciences. 'So the haze that you see in spring at Crater Lake [Oregon] or other remote areas is in fact Chinese in origin."

- Seth Zuckerman, Worldchanging Blog





Christmas Island Area, 210 kilotons at 6,970 ft. Atmospheric nuclear bomb tests from 1954 to 1963 produced a persistent cloud of carbon-14 (a radioactive isotope of carbon) that traveled the Earth. Beside doubling the amount of carbon-14 in the atmosphere, atomic weapons testing left markers of atmospheric militarism



around the world. As a result of eating fruit from trees with

increased carbon-14 uptake, people born in the 1950s

carry more carbon-14 in their brain cells than people born

The High Frequency Active Auroral Research Program

(HAARP) is an ionospheric research station. Its site, north

of Gakona, Alaska, was chosen for its location in the auro-

ral region, above which geographically limited ionospheric

features occur. These include the auroral electrojet, an un-

predictably occurring high-powered electrical current. Re-

search at HAARP includes "active or interactive" experi-

ments utilizing high frequency (HF) transmitting and "pas-

sive monitoring." With an array of 180 antennas, "the most

prominent instrument at the HAARP Station is the Iono-

spheric Research Instrument (IRI), a high-power radio fre-

quency transmitter facility operating in the HF band." Co-

managed by the U.S. Office of Naval Research and the

University of Alaska on U.S. Air Force property, HAARP is

the subject of ongoing speculative and popular interest,

owing to its size and funding and because stated research

goals include projects such as "ionospheric enhancement technology for radio communications and surveillance."

after the 1963 Partial Nuclear Test Ban Treaty.



**RADIOSONDE** A radiosonde is a balloon-borne instrument platform with radio transmitting capabilities. Like driftsondes, radiosondes carry pressure, temperature, and humidity instrumentation. These sensors gather and send back data about atmospheric conditions during an upward

flight. Data from daily flights are aggregated for a broader picture of changing atmospheric conditions. Radiosondes are launched twice daily near the Oakland airport by a private contrator for the National Weather Ser-

LIDAR (LIGHT DETECTION & RANGING)

Lidar is similar to radar, utilizing the length of time from trans-

mission of a signal to the detection of the reflected signal

to determine the distance to an object, but using laser light

clouds and other phenomena in the middle atmosphere.

instead of radio waves. Lidar is used to study noctilucent

"This image has beams from two lidar systems, one that does

Rayleigh scattering from all atmospheric gases and one that

is tuned to resonate with sodium atoms (which come from me-

teors ablating in the upper reaches of the atmosphere). The

systems are located at the Sondrestrom Upper Atmospheric

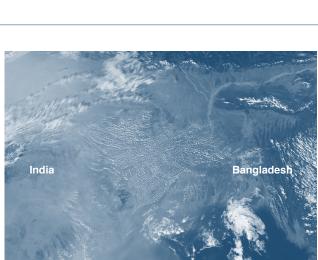
Research Facility in western Greenland. In addition to the

two lidar beams, you can also see optical domes that house

various camera systems to measure the aurora borealis and

a (blurry, moving) radar antenna also collecting information

- Craig Heinselman, Scientist, Stanford VLF Group



ATMOSPHERIC BROWN CLOUDS Atmospheric brown clouds (ABCs) are regional scale plumes of brownish air pollution that appear cyclically, particularly over parts of Asia, Southern Africa, and the Amazon Basin. They contain soot (black carbon), sulphates, and other aerosol components from the combustion of fossil fuels and biomass. ABCs block the Sun's rays, reducing the amount of sunlight reaching Earth's surface by 10 to 15 percent. They also reduce rainfall. Aerosols have the ability to enhance nucleation, so more water vapor is able to stay aloft in clouds and less falls as rain. The light absorbing and scattering impact of these aerosol-laden clouds is complex, contributing to atmospheric solar heating while masking other aspects of climate change. ABCs also decrease the Indian summer

monsoon rains, damage human health, increase surface ozone, and decrease crop production in affected areas.

The smokestacks of container ships traveling in and out of

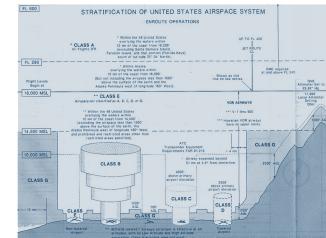
the San Francisco Bay leave long exhaust trails of conden-

sation in their wakes. The cloud trails, called ship tracks, can

be seen trailing graphically downwind from ships, resembling

Sulfur dioxide and other pollution particles in these ship

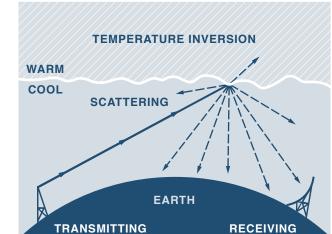
emissions "seed" cloud droplets and influence marine cloud



# **VERTICAL EXTENT OF SOVEREIGNTY**

A "complex, crafted network invisible to the spectator on the ground," airspace is divided into three-dimensional regions, which are organized into a series of standardized classes based on access restrictions. There is no international agreement on the vertical extent of sovereign airspace.

The United States has suggested that anyone or anything passing more than 50 miles (80 kilometers) high does not need to request permission to overfly other nations. The Kármán line, at 62 miles (100 kilometers) high, has also been recommended as the vertical limit of a nation's



**PUBLIC RADIO** 

Frequency: 100-108 FM

Aerial: 1-1.5 Extendable

Input: Twin CD and Mixer or Mike

Output: Minijack for headphones or to amplifier

Above, the *Pirate Radio Briefcase* by British anarchitects

the Space Hijackers is "a complete pirate radio station in

a case. Hold parties wherever you want." This mobile

radio transmitter contains "a fully operational pirate radio

station complete with twin CD players, mixer, amplifier,

speakers, transmitter, and aerial." Also available from

Space Hijackers, the *Pirate Radio Jacket*–"dapper dress

SKYWAVF

for pirate radio mischief making rude boys."

Size: Briefcase

**TROPOSCATTER** Troposcatter is a way to communicate across long distances using microwave radio signals. It utilizes the tropospheric scatter phenomenon, by which a signal directed at the tropopause in a tight beam is refracted and randomly scattered while passing through the moist, turbulent troposphere. Most of the transmitted information is lost through scattering, so a high-gain dish antenna or a billboard antenna is used. Troposcatter can be utilized for long-distance communication when supported by fixed or mobile relay stations from 180 to 300 miles apart, but it can also cause interference. Troposcatter was developed during the Cold War for long distance, point-to-point information transmission when high capacity and reliability were required. It has

largely been replaced by satellite comunication but may be

revived because of orbital and spectral congestion.

0 KM / 0 MI

Sea level is the average ground height of the sea. The atmosphere has significant variations in pressure and temperature with altitude, which define a number of atmospheric layers. The boundaries between these are marked by abrupt transitions, known as the tropopause, stratopause, mesopause, and thermopause.



SF-BAY AREA AIR BASIN "The San Francisco Bay Area Air Basin is comprised of a single district, the Bay Area Air Quality Management District, and consists of Napa, Marin, San Francisco, Contra Costa, Alameda, San Mateo, and Santa Clara counties, the southern portion of Sonoma County, and the western portion of Solano County. The air basin currently exceeds both the 24-hour and the annual State PM10

standards (particles smaller than 10 micrometers in diam-

eter), as well as the State annual PM2.5 standard."

- California Air Resources Board

Society and technology together push back against the missteps: new little solar

of space is hampered by pollution in the

### LAYERS OF THE **ATMOSPHERE** 1. Cloud Code Chart. United States. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administra tion. National Weather Service. 1972 2. NWS JetStream. srh.noaa.gov/jetstream/atmos/layers.htm

**MESOSPHERE** 

aftermath, opened to the public in 2008.

THE DONORA SMOG

of air pollution.

The 1948 Donora smog was a deadly ground-level smog

caused by a combination of particulate pollution from

smelting at Donora Zinc Works and fog trapped by an air

inversion. The smog sat over Donora, Pennsylvania, for

five days, darkening the skies. It sickened 6,000 of the

town's 14,000 residents and killed twenty people. Anger

at the widespread illness and deaths caused by the smog

spurred the first movement for air quality regulation in

the United States. It culminated in the Clean Air Act in

1963. The act established funding for study and cleanup

The Donora Smog Museum (donorasmog.com), a store-

front collection of artifacts documenting the smog and its

THERMOSPHERE windows2universe.org/earth/ Atmosphere/thermosphere.html. YOU ARE HERE WHAT PEOPLE SHOULD KNOW Image: Found photographic slide. Image: View from the Thermosphere Thunderstorms Over Brazil. 1984.

NASA Visible Earth

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Image: Special Report: The USA's February 1, 2007. **SCIENCEWASH** 1. Cone, Marla. Silent Snow: The Arctic

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SHIP TRACKS

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> Image: Hampton University/Emily Hill Designs/NASA 1. NASA, AIM Mission. aim.hamptonu.edu. DRIFTSONDE Image:Terry Hock, NCAR. 1. UCAR, Background on Driftsondes. **RADIOSONDE** Image: Radiosonde Launch, Oakland CA, 2009. Amy Balkin.



Sondrestrom Upper Atmospheric

Image: Korda & Menzies. H.G. Wells.

of the Potential Consequences of

Research Facility /SRI/NSF.

**CLIMATE CHANGE** 

(1936). Thinas To Come.

THE SPECULATIVE

**AIR RIGHTS** 

Image: Langelle/GJEP-GFC. Protest at United Nations Climate Change Conference (COP13), Bali, 2007.

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mage: Ship Tracks off the California

Schmaltz, LANCE/EOSDIS MODIS

Rapid Response Team at NASA GSF

Coast NASA Farth Observatory/ Jeff

SHIP TRACKS

CIIMATE MODEL

Air rights are a component of zoning height regulations

for built structures. Air rights give the property owner the

If a building is shorter than the maximum height, the

difference can be sold or otherwise transferred to another

property owner, allowing them to exceed the zoning

permission to build to the upper height limit allowed.

limitation by that same amount, when permitted.

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**SUPPORTED BY** Exploratorium, The James Irvine Foundation, The Andy Warhol Foundation for the Visual Arts and Grants for the Arts/San Francisco Hotel Tax Fund Susan Schwartzenberg, Peter Richards, Josh On, and Elizabeth Terzakis

LL-06

# paradoxically, obscures the the complex of

political and technological projects at work above us. Only when those projects are fully visible will they be reconciled as the agents of cultural and political effect that they are. Until then, we will not be at home is changing because of pollution in the with the sky, much less at home up in it. 

lower atmosphere. Peaceful exploration

**CHARTING THE SKY** 

The 1967 Outer Space Treaty designated

space as a site for peaceful purposes. It

weapons in space, following the detonation

of atomic bombs in the atmosphere in the

banned the testing and deployment of

early 60s. Yet after the treaty, geopolitical space to transit. use of the sky continued onward in a similar spirit. Satellites have been used for Then a range of activities reached into espionage since their first launches in space: explorers, scientists, militaries, 1957 and 1958. By the late twentieth businesses, and lawyers all went to work century, they were being used to conduct up there, extending their spheres of war itself remotely. influence into the atmosphere. The satellite era allowed the sky to be charted Telecom war is far more subtle than and better understood. Science laid out bombs in flight. We can now hide war in the sky; a transparent place has become a its lavers: troposphere, stratosphere. mesosphere, thermosphere, exosphere. curtain. The curtain of transparency,

touch. As we have explored, we have tried to assimilate the sky as an added realm of our geography. It was a new "place," but it defies our previously understood notions of place. Its transparency let us see the stars above, so it seemed to be an empty

Since 1783, hot air balloons, airplanes,

Within each layer lies a cultural legacy of

missteps and discoveries, intertwined.

Missteps leave footprints that press

down on us from above. The climate

sively higher reaches of the sky to our

and finally satellites have opened progres-

sails, first flown in 2010, may be able to haul space junk out of orbit. Pushback against climate destabilization is a challenge of a greater order. First, our idea of the sky must be reconciled with what we do in it. Our actions there mapped and charted. The sky itself must be woven into the fabric of our societal sense of place. Megan Prelinger

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**CHARTING THE SKY** By Megan Prelinger

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