PILOT WEATHER

FROM SOLO TO THE AIRLINES

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To all of our students of weather…

Capped Cumuliform Clouds at Sunset
—Photo by Scott Dennstaedt

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PILOT WEATHER

FROM SOLO TO THE AIRLINES

A Thunderstorm is Born Over Rock Hill, South Carolina
—Photo by Scott Dennstaedt

PREFACE

While you may master one or more musical instruments you may never compose a score or even write a single line of music. Similarly, you may never know enough meteorology to become a professional forecaster, but you can learn enough to be a better pilot.

The Internet has now become a rich source of weather guidance for pilots. Pilots almost have too many choices. Online resources for pilots have continued to blossom to the point where so many more useful weather guidance and tools has emerged that it has become difficult for pilots to know what guidance to use and how to integrate that information successfully into their preflight planning ritual.

You don't have to be a pilot very long to know weather will disrupt your flying activity more than any other physical factor. Instrument rated pilots have a few more doors of opportunity, but learning to decipher what is behind these doors is typically more challenging. Adverse weather such as thunderstorms, turbulence, airframe icing and fog are the heavy hitters when it comes to developing a plan to limit your exposure to adverse weather.

Learning to fly requires the pilot master many, many disciplines and techniques. A pilot's formal and recurrent training is heavily weighed on stick and rudder skills, in other words, how to *fly* the aircraft. Additionally, instructors place a lot of emphasis on instrument procedures and avionics and how to negotiate safely within the National Airspace System (NAS). Once we get our certificate or additional ratings, we hear the ubiquitous statement that it is a beginning, not an end to our learning.

As a result, we practice landings and takeoffs until we can impress our friends and relatives. We practice instrument approaches to minimums until we're tired of wearing those not-so-flattering scratched-up "foggles." Except for the occasional magazine article, most pilots rarely attempt to advance their core knowledge of weather and weather planning. Moreover, it is rarely done in concert with any one-on-one coaching from a weather savvy instructor who is equipped to take you beyond the basics.

Many low-time pilots feel that as they accumulate flying experience it will somehow all just fall in place and someday they will acquire the weather knowledge they were always missing. According to an NTSB safety study, this is not the case:

"It appears that pilots generally require formal training to obtain weather knowledge and cannot be expected to acquire it on their own as they simply gain more flight experience."

In the end, Mother Nature doesn't discriminate; she doesn't care how many hours are in your logbook. While experience is important, education is the key to a long flying career.

Congratulations on buying your complete A-to-Z weather book, written for American pilots. Whether you are starting from hour zero or you've amassed thousands of hours as an airline pilot, this will be the book you keep during your entire aviation career. It covers a gamut of aviation weather topics, from the ins and outs of weather theory to the reading and interpretation of aviation weather reports. True, this is *the* weather book for American pilots, but it also caters to the air traffic controller, the flight service specialist, the new upstart flight dispatcher, or the Canadian pilot wanting to brush up on weather south of the border.

The intent of this book is not to teach weather so you can pass the test, but to teach it so you will comprehend it.

Cumulus Turret Racing Toward the Flight Levels
—Photo by Scott Dennstaedt

LETS GET STARTED...

*This Cirrus icon denotes **SCOTT** speaking in first person.*

*This generic airliner represents **DOUG** conversing in first person.*

*This symbol reflects **WEATHER FACTS** and **TRIVIA**.*

*This symbol symbolizes **WEATHER RELATED ACCIDENTS**. Fortunately, it has been sparsely used.*

Twilight Approach
—Photo by Erik Ritterbach

CHAPTER 31

SPACE WEATHER AND "OVER-THE-TOP" OPERATIONS

Until recently, a roly-poly man with a white beard and red suit flew the only scheduled polar flight—and even then it was only once a year. But the opening of Russian airspace in the late 1990s created new opportunities. Now, many international airlines launch daily "over the top" flights. By flying a polar route, airtime can be reduced by 60 to 90 minutes. This means huge fuel savings! Duty time for aircrew is also lessened. Duty time may not seem like a big issue, but it easily enters the equation if a less-productive route is flown. Additionally, turbulence is less prevalent on polar flights because jet streams are corkscrewing around the globe farther south. There are no weather fronts to contend with—and rarely any thunderstorms! But this newfound flight path comes with many restrictions and new meteorological and environmental considerations.

Flights operating north of 78° North latitude are deemed "polar" flights; thus, special procedures and policies associated with polar operations come into play.

SPACE WEATHER HURDLES

Polar flights present some unique obstacles, especially when it comes to space weather. Space weather is defined as the ***conditions created on Earth from activity on the surface of the sun.*** But non-solar sources, such as GCR (***Galactic Cosmic Rays),*** can also fall under the umbrella of space weather, since they substantially affect conditions near or on Earth.

Erik Ritterbach's photo

Our Sun: Solar activity fluctuates in cycles. During the peak period, ***solar max***, a great number of solar flares and CMEs (***Coronal Mass Ejections***) are produced. Coronal mass ejections are massive clouds of hot gases and magnetic force fields. You will soon learn that these ejections actually ***reduce*** radiation emanating from outside our solar system. Wherever CMEs go, cosmic rays are deflected, as the CMEs "push" the GCRs away from Earth. Occasionally, the CMEs are strong enough to increase the dose of radiation Earth receives, but it is rare.

Solar Cycle and Sunspots: The number of sunspots fluctuates over time in a somewhat consistent 11-year cycle called the ***solar or sunspot cycle***—the exact length of the cycle can vary. More sunspots mean increased solar activity. Sunspots are the source of the solar flares and coronal mass ejections that send charged particles hurtling toward Earth, ***which can damage satellites, produce power grid surges, and cause aircraft radio blackouts.***

Sunspots are temporary intense magnetic activities that appear as dark spots on the sun. About every 11 years, the sun starts to look like it has a case of bad acne, as sunspots break out all over. Midway through the cycle, the blotches vanish.

On a lighter note, the increased sunspot activity produces dazzling displays of auroras above our planet. The duration of these storms is on the order of days, with the strongest storms persisting for almost a week. The highest number of sunspots in any given cycle is designated the ***solar maximum,*** while the lowest number is the ***solar minimum***.

Figure 31-1: Nick Czernkovich's photo, taken north of Yellowknife, Northwest Territories. He captured a dazzling display of vibrant green aurora borealis (northern lights)—a perk of northern flight.

Galileo and other European astronomers observed sunspot activity over 400 years ago. They described the spots as blemishes on the sun's surface and even speculated about their origin. Over the years, sunspots have become a standard reference point when discussing the sun's variability and activity.

Solar Minimum: According to NOAA (National Oceanic and Atmospheric Administration) and NASA (National Aeronautics Space Administration), the sunspot cycle hit an unusually deep bottom from 2007 to 2009. In fact, in 2008 and 2009, there were almost ***NO*** sunspots. Due to the weak solar activity, ***galactic cosmic radiation*** on Earth was at record levels!

The sun's activity varies over an 11-year cycle. Many think that increased solar activity means higher radiation. In reality and counterintuitively, the opposite happens. When the sun is active, it shields the inner solar system. When the sun is inactive, the Earth receives more cosmic radiation. At solar minimum, the GCR flux increases by about a factor of three near the earth.

Solar Maximum: The sun's record-breaking period of inactivity ended in 2010. We are now in Solar Cycle 24, which peaked in 2014. When it arrived, the peak of the 11-year sunspot cycle brought more solar flares, CMEs, and geomagnetic storms. However, this cycle produced a lower number of sunspots than the average of previous cycles.

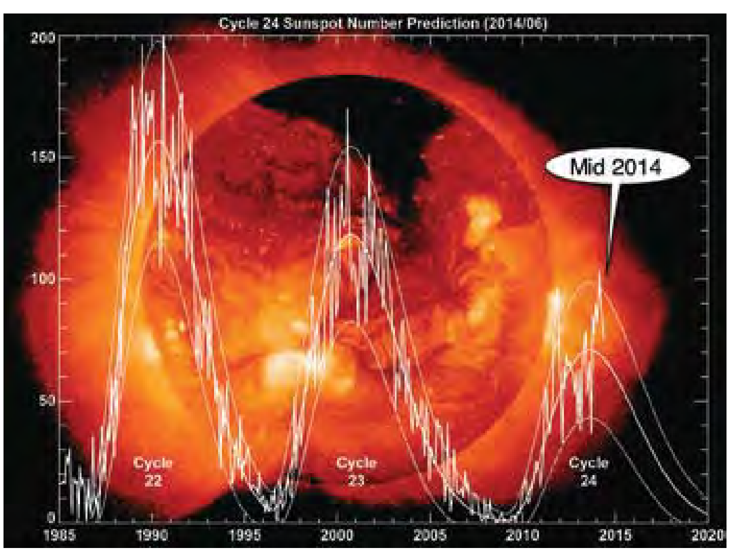


Figure 31-2: Solar cycles and sunspot activities. We are on cycle 24, which peaked April 2014, but proved to be the tamest cycle in 100 years. The vertical axis depicts the number of sunspots, with years shown on the horizontal axis. Note: Galactic cosmic radiation is at a minimum on Earth during solar maximum, but during solar minimum more radiation can reach the earth! (NASA's photo.)

Electromagnetic Radiation: The sun's electromagnetic radiation spans the radio: infrared, visible, ultraviolet, X-ray spectrum and beyond. Electromagnetic radiation moves at the speed of light, and begins to affect the Earth's atmosphere around ***eight minutes*** after it leaves the surface of the sun.

Solar Radiation: In addition to electromagnetic radiation, the sun ***constantly*** ejects clouds of matter in the form of subatomic particles known as ***solar protons***. You may see the term ***SPE*** (Solar Proton Event), but because these events include other nuclei like helium ions and lots of electrons, the event is commonly deemed a ***solar particle event****.* The collective term for these clouds of streaming particles is the ***solar wind,*** and it is always present to some degree. The solar wind generally travels at speeds well below the speed of light, taking two to four days to reach the earth. During periods of increased activity, this speed increases, and the strength and direction of the earth's magnetic field changes. The polar auroras (northern and southern lights) become larger and more vivid, but the ability of the ionosphere to propagate HF (High Frequency) radio signals is reduced, and GPS navigation accuracy may be impacted. This proton invasion is of insufficient energy to contribute to the radiation field at aviation altitudes. However, on occasion, proton particles are produced with sufficient energy to penetrate the earth's magnetic field and enter the atmosphere. Such events are comparatively short lived and vary with the 11-year solar cycle; they are most frequent at solar maximum. Polar routes may not be practical during these events, since navigation and communication may be affected, plus the presence of proton particles produces a higher risk to human health. In most situations, protection is provided by three phenomena: ***the sun's magnetic field, the earth's magnetic field,*** **and** ***the earth's atmosphere.***

Galactic Cosmic Radiation (GCR): Radiation emanates from outside the solar system, exposing us to other sources besides the sun. In fact, most of the radiation that hits the earth does not come from the sun. Cosmic rays ***(GCR) are supercharged subatomic particles originating from exploding stars and black holes; these rays greatly surpass the sun in terms of violence.*** When a primary cosmic ray produces many secondary particles, we call this a ***cosmic-ray air shower***. Cosmic rays ***can't*** be completely stopped by any known shielding technology. At commercial jet aircraft operating altitudes, the percentage of GCR in the skies at solar minimum is 20% to 100% higher than it is at solar maximum; GCR increases with altitude and latitude.

Solar protons, unlike GCR, are relatively easy to stop with materials such as aluminum or plastic; their interaction with other particles may generate highly energetic secondary particles that provide a dose of radiation —but this is rare. Radiation ***may*** increase beyond recommended human dosage levels, but this will probably only occur during a SPE and not just from solar wind alone.

Cosmic radiation makes up, on average, about 17% of the natural background radiation to which we are all exposed. The rest consists of radon gas (50%), radiation from minerals in the soil (20%), and radiation in our bodies from food and water (13%). These numbers vary, with altitude and latitude being big players. But don't give up on being a pilot and become a train engineer to avoid the cosmic risk! You would have to fly 100 one-way flights between New York and Los Angeles to acquire the same exposure as you get from other sources of natural background radiation in one year!

At jet aircraft altitudes during solar minimum, GCR is 2.5 to 5 times more intense in polar regions than near the equator.

Most of the cosmic radiation that may possibly affect crew members and frequent flyers originates from galactic cosmic rays—outside of our solar system. The activity of the sun can reduce or increase this flux of particles from space, but the sun itself is a weak source of cosmic radiation.

Units and Dosage: Radiation absorption is measured in Sievert units, usually ***millisieverts (mSv) and microsieverts (μSv).*** The mSv is used for yearly exposure measurements, whereas the μSv (a thousand times smaller) is a more practical unit for hourly radiation dose. The FAA's maximum recommended annual dosage increases to 20 mSv for people occupationally exposed, such as medical workers and NEWs (Nuclear Energy Workers). This recommended amount of radiation can be averaged over a 5-year period, with a maximum of 50 mSv in any one year. Pilots flying about 900 hours annually (at North American latitudes) will typically receive a total annual dosage of 2 to 4 mSv.

Aircrew and passengers run a slightly higher risk of cosmic radiation exposure at higher flight levels, and this risk increases toward the poles. Four factors affect the potential dose of cosmic radiation: ***latitude, altitude, solar activity, and flight duration. The atmosphere offers less protection at higher altitudes, with protection also lessening toward the poles.***

The atmosphere is thinner at the poles, and the Earth's protective magnetic field also decreases poleward. Less atmosphere means stronger particles, as it is atmospheric interaction that protects against penetrating radiation.

Incoming cosmic radiation is redirected by the Earth's magnetic field; in general, radiation shielding is greatest at the equator and decreases as one goes north or south. The magnetic field that forms a cocoon around the earth is called the ***magnetosphere.*** However, near the magnetic north and south poles, the magnetic field points directly towards the ground. A resultant funnel-shaped hole develops, called a ***polar cusp***, allowing particles from space to infiltrate toward the surface more easily.

As mentioned, protection decreases progressively by a factor of two to three toward the poles, to reach a minimum protection in Canada's north in relation to the equator. In Russia, protection is present much further north, because the magnetic pole is significantly skewed toward our side of the planet in Northern Canada. As a result, Canadian domestic airspace is similar to the polar regions in terms of the weakness of its magnetic protection.

Magnetic North is moving northwest about 40 miles a year towards Russia (Siberia). Presently, it is nearing the geographic North Pole. You'll notice that runway numbers change now and again to compensate for this shift. I soloed on runway 24 in Halifax 38 years ago, but several years ago it was renamed runway 23.

The second source of radiation protection is the ***atmosphere***. The more you have above you—the better. Atmospheric interference can reduce the intensity of the GCR by a factor of 100 depending on its thickness. In general, ***ambient radiation increases by approximately 15% for each altitude increase of around 2,000 feet*** at the same latitude.

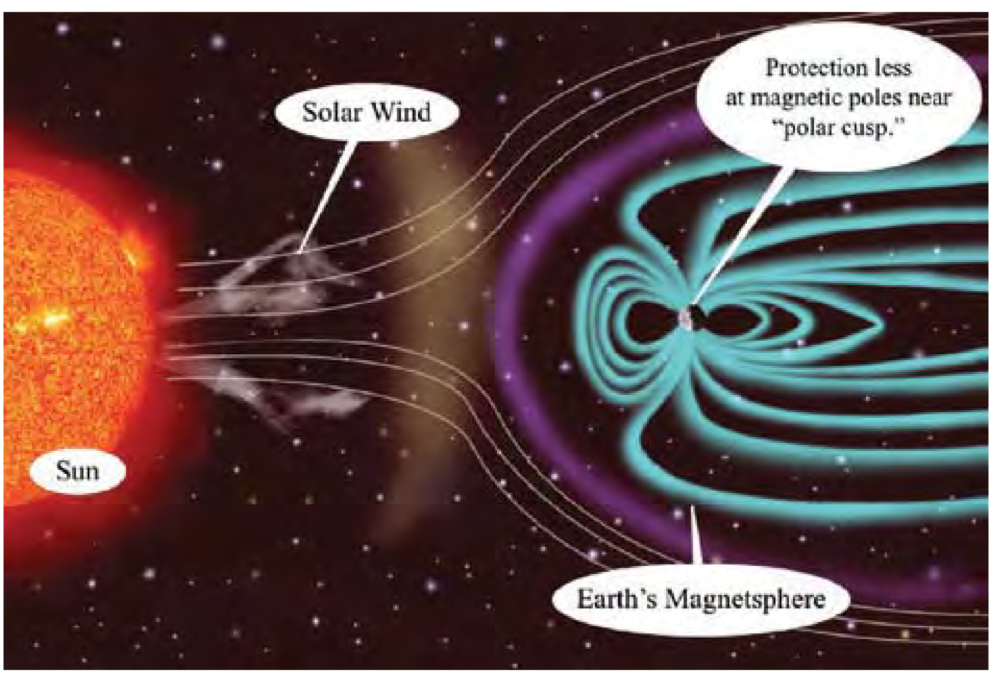


Figure 31-3: shows how the earth's magnetic field provides protection, which diminishes as the lines of magnetism become vertical at the magnetic poles. (NASA's photo.)

The atmosphere is a huge buffer against cosmic radiation, so it's something to take into consideration when taking your "biz jet" up to FL 470. Even though fuel burn decreases with altitude, cosmic radiation increases! And if you plan on moving from near sea level to take up basket weaving in Nepal nestled in the Himalayans, you will be exposed to more radiation there, too.

There is a popular fallacy which insists that flights over the polar routes receive more radiation. But a recent ACPA (Air Canada Pilot Association) study showed that Boeing 777 pilots that fly the polar routes have the lowest average dose rate, of 4.5 µSv/hour, compared to an Embraer crew which clocks in at 6.5 µSv/hour. One explanation has to do with altitudes. When Doug flew the polar routes, it would take nearly ten hours for the aircraft to be light enough to climb to maximum cruising altitude. At lower altitudes, the air above offered protection, even though the flight was over the pole. As flights fly south into Russian airspace, more and more protection is obtained as the magnetic pole gets further away. As a result, longer domestic flights, and transcontinentals or "Transcons" on the Embraer and Airbus A320, wind up with higher dose rates. Doug flew hundreds of Transcons on the Airbus A320.

The intensity of radiation due to solar activity is much smaller than that caused by higher altitudes or higher latitudes. There is about a 40% decrease in intensity from solar minimum to solar maximum conditions.

Cosmic Radiation Myths

It does not matter if you fly day or night, and for passengers, it does not matter if you sit in a window or aisle seat. GCR penetrates the aircraft from the top, sides and below. The only way to truly escape GCR is to fly in a concrete or lead enshrouded aircraft—and even then, the shield would have to be extremely thick. Remember that the substance in question is cosmic radiation and not ultraviolet radiation. Cosmic rays and charged particles occur in different ranges on the electromagnetic spectrum, hence different frequencies, wavelengths and most importantly, energies.

Of all of the sun's emissions, it is actually UV rays that pose the greatest risk to human health i.e. potential skin cancer especially melanoma. Wearing a baseball cap, sunscreen lotion, and a long sleeve pilot shirt with huge sunglasses will not stop cosmic radiation, but will provide needed protection from UV rays.

If a pilot accumulated a cosmic radiation dose of 5 mSv per year over a span of 20 years, his likelihood of developing cancer would increase by 0.4%. The overall risk of cancer death in the western population is 23%; thus, cosmic radiation exposure raises that risk from 23% to 23.4%. At least, so says one study found floating amongst the cosmic universe of the Internet. ☺

Monitoring Cosmic Radiation

There are third-party companies that assess estimated radiation exposure to pilots. One such company, the Ottawa-based PCAire (***P***redictive ***C***ode for ***Ai***rCrew ***R***adiation ***E***xposure), allows Doug to log onto their site to determine his exposure for each flight flown. Passengers, especially frequent flyers, can also log in and set up an account.

My dose report for the last twelve months was 3.5 mSv.

These services measure the full range of radiation from both primary (sun) and secondary (outer space) sources. By using flight plans, years of measurements from onboard flights, and observations of the sun's activities, a fine-tuned value for an individual's radiation exposure can be determined.

Pilots that fly at low altitudes (in unpressurized aircraft) are exempt from these readings because flights below 15,000 feet receive negligible radiation exposure and are omitted from the reporting data. That Twin Otter job, island-hopping in the Caribbean wearing Bermuda shorts, sounds more and more appealing. ☺

The SST (Supersonic Transport) Concorde entered service in 1976, retiring in 2003. From the outset, cosmic radiation (both galactic and solar) was known to present a hazard at cruising altitudes of 50,000 to 60,000

feet. The Concorde came installed with permanent radiation monitoring equipment, amassing tons of data. But keep in mind: the time this model spent exposed to higher values was less because of its speed.

Route	Average Dose Rate (μSv/hr)
Domestic < 1.5 hr	3.2
Domestic > 1.5 hr	6.2
California	5.6
Florida	5.0
Caribbean	4.8
Mexico	4.8
Asia	4.5
Europe	5.8
Southern Hemisphere	3.7

Figure 31-4: Dose rates per hour for various destinations from a recent study. The good news is that these rates were observed during low solar flare activity in 2009 (which results in higher cosmic radiation). Consequently, one can expect that in most years the exposure should be less than these values. In comparison, the average dose rate for the SST Concorde was 12 to 15 μSv per hour.

A typical annual dose for an airline pilot is 2 to 4 mSv. A chest X-ray is 0.4 mSv, a mammogram is 0.7 mSv, and a CAT scan of the chest is 8 mSv—almost two to three years of airline flying. An angioplasty (heart study) may be as high as 57 mSv!

NOAA categorizes the potential impact of electromagnetic and solar radiation by ranking these levels on a severity scale from S1 to S5. The National Oceanic and Atmospheric Administration's (NOAA) Space Environment Center (SEC) operates a worldwide network of sensors, maintained primarily through satellite data. S1 and S2 allow for a safe journey, whereas an S5 is equal to about 100 chest X-rays. Forecast levels of S4 and S5 prohibit polar flights (above 78°N), with S3 imposing lower altitudes or a more southerly polar route.

Solar Radiation Storm Scale
S5 (Extreme) High radiation hazard to commercial jets (equal to 100 chest X-rays), loss of some satellites, no HF communications in polar regions.
S4 (Severe) Radiation hazard to commercial jets (equal to 10 chest X-rays), satellite tracker orientation problems, and blackout of HF radio at polar cap for several days.
S3 (Strong) Radiation hazard to jet passengers (equal to 1 chest X-ray), permanent damage to exposed satellite components, degraded HF at polar cap.
S2 (Moderate) Infrequent satellite event upsets, slight effect to navigation and HF at polar regions. **For this level and higher pregnant woman are particularly susceptible.**
S1 (Minor) Small effect on HF radio in the polar region.

NOAA's Space Environment Center (SEC) operates a worldwide network of sensors that continuously observe conditions between the earth and the sun. Their website offers excellent real-time information on electromagnetic and solar radiation. ***The frequency of occurrence for an S5 (extreme) is less than 1 per 11-year cycle; S4 (severe), 3 per cycle; S3 (strong), 10 per cycle; S2 (moderate), 25 per cycle; and S1 (minor) 50 per cycle.***

Another element of flight impacted by space weather is radio reception. Again, NOAA broadcasts a five-level range of severity. High-frequency (HF) aircraft radios work by bouncing transmissions off the ionospheric layers, allowing for long-distance communications. A R5 rating means radio communication will not be possible for hours. Luckily, FANS (Future Air Navigation Systems) work through satellites, lessening the reliance on HF. FANS played a major role in making polar flights a reality.

The "extreme" R5 occurs nearly once in the 11-year solar cycle and blacks out the entire sunlit side of the earth for hours. The more common "strong" R3 blackouts occur at a rate of 175 per solar cycle and cause roughly a 1-hour communications blackout. The least problematic condition, a minor R1 radio blackout, occurs at a rate of 2,000 per 11-year solar cycle, resulting in a degraded or lost ability to communicate for several minutes. For long-range flights that implement HF radio for communication and position reports, flight routes will be altered.

Radio Blackout Scale
R5 (Extreme) Complete HF radio blackout on the entire sunlit side of the earth for a number of hours, navigational outages on sunlit side for many hours. Satellite navigation errors will ensue as well.
R4 (Severe) One to two hour HF blackout on sunlit side of Earth, minor satellite navigation disruptions.
R3 (Strong) Wide area of HF blackout, loss of radio contact for mariners and en route aviators for about an hour, low-frequency navigation degraded.
R2 (Moderate) Limited loss of HF radio, some low-frequency navigation signals degraded.
R1 (Minor) Minor degradation of HF, minor low-frequency navigation signal degraded.

Yet another feature of space weather is the ***geomagnetic storm scale***, which measures worldwide disturbances of the earth's magnetic field. It, too, is ranked from 1 to 5. A G1 rating indicates slight power grid fluctuations and minor impact to satellites, whereas a G5 is extreme and denotes possible power grid collapses, damaged transformers, and radio blackout in many areas for one to two days. During a G5, the unreliability of satellite navigation and communication, coupled with possible ground-level power outages, puts a halt to polar operations.

Geomagnetic Storm Scale
G5 (Extreme) Power grids can collapse, transformers are damaged, spacecraft will see extensive surface charging, HF radio blackout in many areas for one to two days, low-frequency radio outage for many hours, aurora seen as low as the Tropics! Other systems: Satellite navigation maybe degraded for days. Even pipelines can be affected, with hundreds of amps running through them. Typically, a **G5-level storm occurs at a rate of 4 per 11-year solar cycle.**
G4 (Severe) Voltage stability problems in power systems, satellite orientation problems, induced pipeline currents, HF radio propagation sporadic, low-frequency radio disrupted, satellite degradation for several hours.
G3 (Strong) Voltage corrections required on power systems, false alarms triggered on protection devices, increased drag on satellites, low-frequency radio navigation problems, aurora seen as low as mid-latitudes, intermittent satellite and HF problems. **G3s occur at a rate of 200 per cycle.**
G2 (Moderate) High-latitude power systems affected, drag on satellites effect orbit, HF radio propagation fades at higher altitudes, aurora seen at latitudes of 50 degrees.
G1 (Minor) Slight power grid fluctuations, minor impact to satellites, aurora seen at high latitudes (60 degrees).

Adapting to Space Weather

What can be done about space weather? Airlines using polar routes have adopted the policy that flights will ***not*** be conducted if solar radiation, radio blackout, or geomagnetic storm activity is at level 4 or 5. Solar radiation

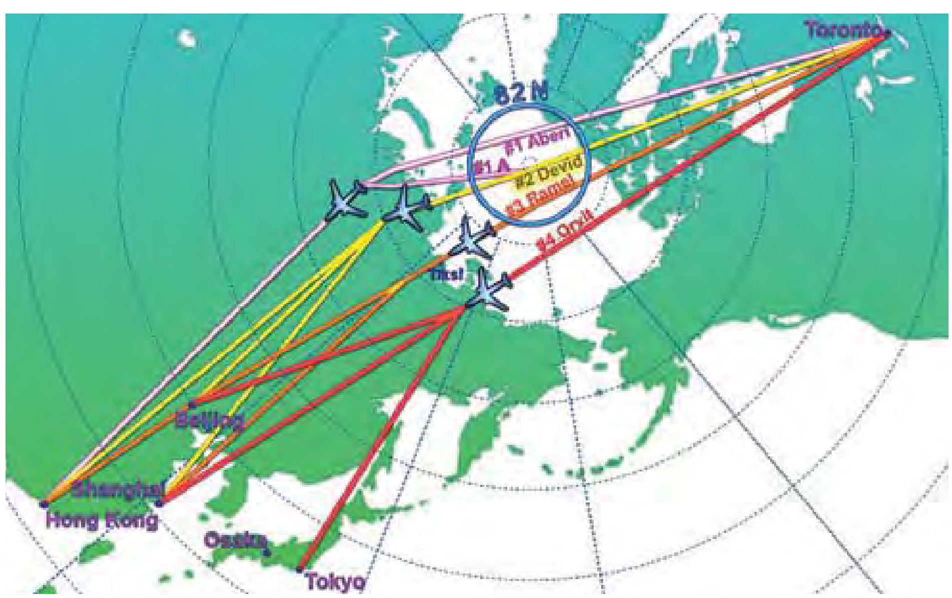


Figure 31-5: The "original" four polar routes. Polar route #2 is the closest to the North Pole—about 60 nautical miles away. No polar route goes directly over the pole. Because travel "over the top" has increased exponentially in recent years, there are now TEN polar routes.

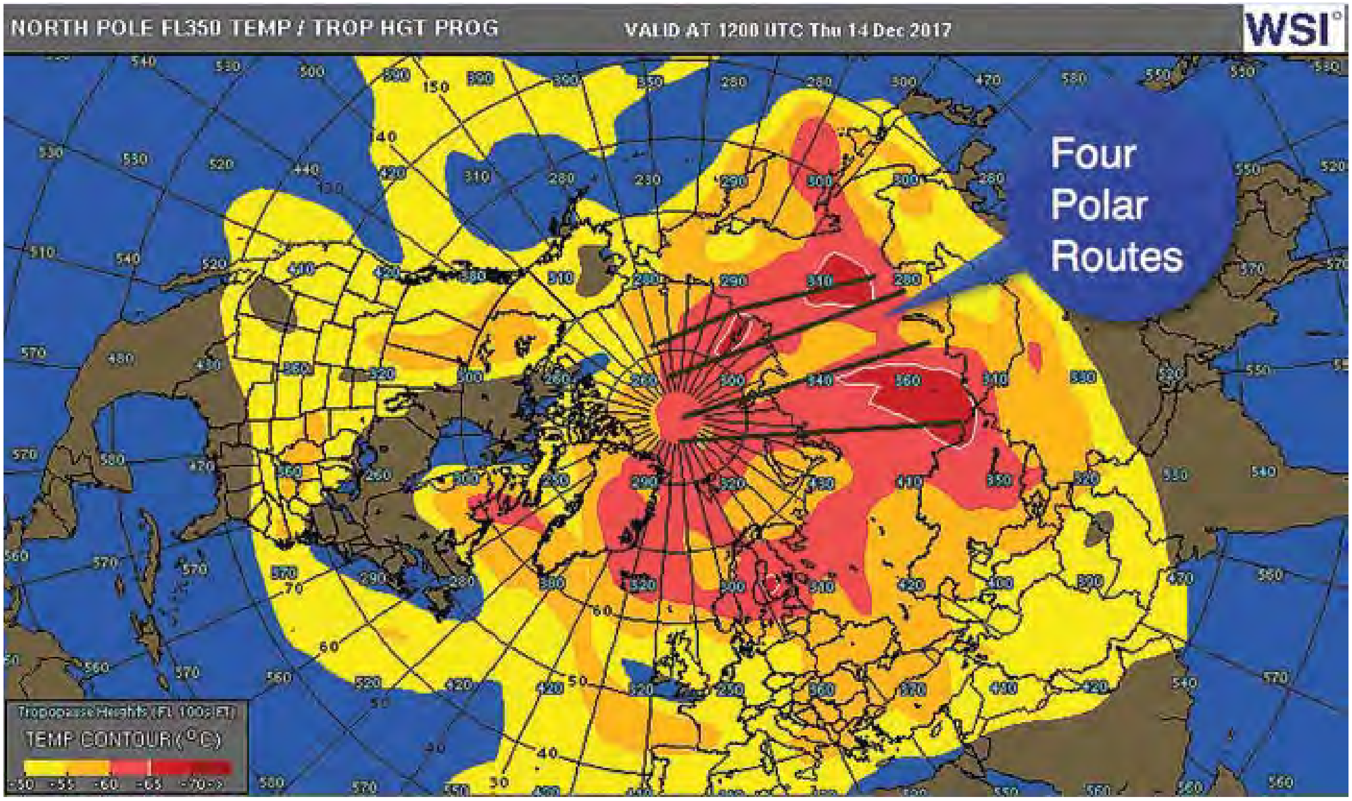


Figure 31-6: A Flight Level 350 temperature depiction of the North Pole and northern latitudes. The four "original" polar routes are superimposed on the chart. (WSI chart).

at level 3 requires polar flights to be conducted at FL310 or below. Hours before each polar flight, flight dispatch determines whether space weather is deemed safe. Sometimes varying the route or changing the cruising altitude guarantees a safe flight.

Electronic components of aircraft avionic systems are also susceptible to damage from cosmic rays, solar particles and the secondary particles generated in the atmosphere.

If for some reason your flight takes you directly over the North Pole, you should exercise caution due to the possibility of aggressive autopilot maneuvers when the heading fluctuates from north to west to east to south.

Extreme Climate

The extreme cold found in northern Canada and Siberia also has an impact on polar flights, as it can potentially freeze fuel. Flights into areas of −65°C must be restricted to 90 minutes or less. Depending on the aircraft, engine type, and type of jet fuel, the fuel on board may be analyzed and the actual-fuel-freeze point determined. Flight dispatch may data-link this actual-fuel-freeze temperature to the flight deck after the flight is airborne.

Years ago, while on a polar flight, this very problem came up for me: the jet fuel cooled to below −40°C, triggering a caution advisory in the fuel-temperature-monitoring system. Our fuel had a freezing threshold of −47°C, making immediate action unwarranted. If the conditions had persisted, procedures would have required us either to descend into warmer air or increase speed. Speeding up increases adiabatic compression (heating) and surface friction hence TAT (Total Air Temperature) but the effect is marginal. (Remember: these flights are over the North Pole, so finding warmer air below is also highly unlikely in the middle of winter). Descending burns more fuel, as does increasing speed. Luckily, temperatures were forecast to warm up—and they did!

Flight dispatch monitors space weather websites daily for polar-destined flights. On most polar routes, the flight dispatcher will add comments on the flight plan. For example: 1. No fuel-freeze issue 2. No solar issues expected 3. HF conditions reported fair.

Suitable Alternate Airports

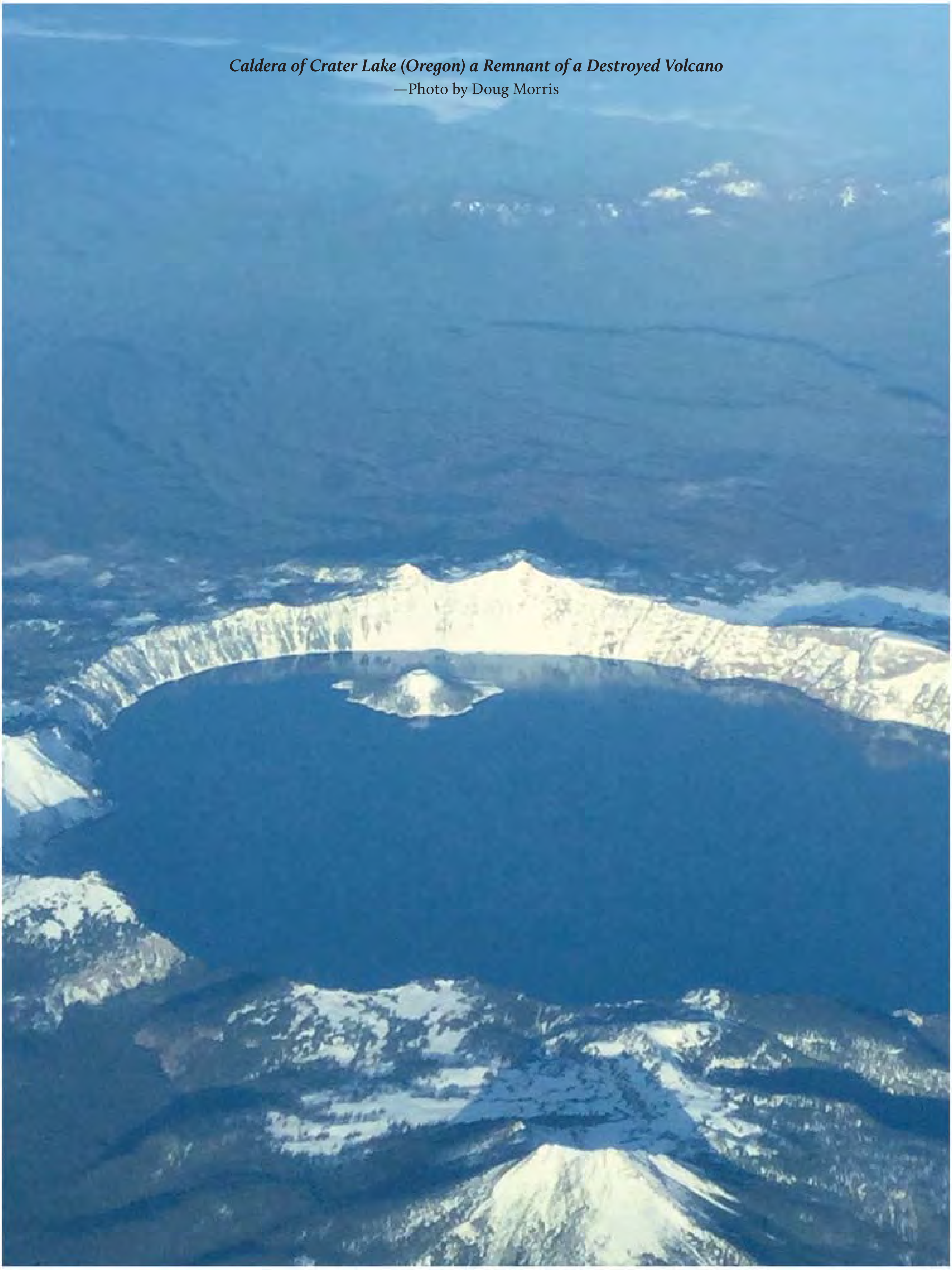
Yet another consideration is the availability of suitable airports in case of a serious medical situation or other emergencies, particularly in Arctic winters. Two Arctic survival suits, along with other environmentally appropriate clothing (boots, gloves, hats) are on board in case one has to exit the airplane to coordinate services after landing. (Rest assured, the junior pilot will be delegated this task). But think about it—landing a fully loaded airliner with over 450 passengers and crew in a remote airport in harsh weather conditions is an emergency in itself. No wonder many airlines remind pilots of this, and caution them to land in the polar regions only in dire situations.

One airport in close proximity of the transpolar routes is Tiksi, Russia. Briefing notes highlight the fact that it lies in the coldest region of the northern hemisphere, with temperatures possibly reaching as low as −50°C (−58°F)!

It takes six hours to reach the North Pole from Toronto. From Toronto to London, England, the flight is only six hours and thirty minutes. It's a big country to the north! Keep in mind as well that, for polar flights, six to ten hours of fuel burn is necessary for a long-haul aircraft to be light enough to reach optimum cruising altitude. Chicago to Hong Kong is about 16 hours.

THINGS YOU SHOULD KNOW...

- Higher solar activity actually means a ***lower*** dose of radiation. Cosmic radiation reaching the earth is ***more intense during a solar minimum***.
- Solar radiation is ranked from S1 to S5. Polar flights are banned during radiation ratings of S4 and S5.
- Geomagnetic storms and radio blackouts are also ranked in severity from G1 to G5 and R1 to R5, respectively.
- Four factors affect radiation levels:
    7. Altitude (the lower, the better),
    8. Latitude (the further south, the better),
    9. Solar activity (the higher the activity, the lower the cosmic radiation).
    10. Duration of flight (the shorter, the better).
- Radiation absorption is measured in units of Sievert and fractions thereof: millisieverts (mSv) and sometimes microsieverts (μSv).
- Our Earth is continuously bathed in high-energy radiation known as GCR (Galactic Cosmic Radiation) emanating from outside the solar system.
- We are also exposed to sporadic bursts of energetic particles from the sun known as SPE (Solar Proton Events).
- Coronal mass ejections are massive clouds of hot gases and magnetic force fields. These ejections actually ***reduce*** radiation emanating from outside our solar system.



Caldera of Crater Lake (Oregon) a Remnant of a Destroyed Volcano
—Photo by Doug Morris

CHAPTER 32

VOLCANIC ASH

Although it's not directly related to weather, we decided to include a chapter on volcanic ash because it is an environmental challenge to aviation.

The 1980 eruption of Mount St. Helens in Washington State brought the perils of volcanic ash to the forefront. A three-engine Boeing 727 and a four-engine DC-8 encountered windshield damage along with damage to other systems, but both aircraft managed to land safely.

Figure 32-1: While flying north from Los Angeles to Vancouver, Doug managed to get some great pictures of Mount St. Helens. Its summit went from 9,677' ASL to 8,365' MSL on the morning of May 18th, 1980. The eruption killed 57 people.

Two years after Mount St. Helens erupted in 1982, British Airway's Boeing 747 Flight 009 experienced a four-engine flameout due to volcanic ash over Java, Indonesia while in Jakarta-controlled airspace.

The skipper of Flight BA 009 sure personified calmness to the nth degree in his announcement to the passengers: "Ladies and gentlemen, this is your captain speaking. We have a small problem. All four engines have stopped. We are doing our damnedest to get them under control. I trust you are not in too much distress." Capt. Eric Moody, BA Flight 009

In 1989, yet another four-engine flameout occurred, this time on KLM's Flight 867 in a Boeing 747 on approach into Anchorage, Alaska. The flight, from Amsterdam to Tokyo, had a scheduled fuel stop in Anchorage. On descent through 25,000 feet, the aircraft entered a thick plume of ash from recently erupted Mount Redoubt, about 100 miles southwest of the airport. Ash and volcanic gas entered the flight deck and cabin. The crew increased power to climb above the ash cloud, but it was too late—the ash intake caused a four-engine failure. Advancing the thrust levers only exacerbated the situation; it is recommended to decrease power, not increase it, during volcanic ash encounters. As the airplane descended, the crew frantically attempted to restart the engines. After a harrowing experience, they successfully got two engines under way, and then all four, at a breathtakingly low altitude of 12,000 ft. The airplane continued to Anchorage for a safe landing. Observers on the ground said it looked like the airplane had been sandblasted. The B747, which was only six months old, cost US $80 million to repair.

During my weather classes, I play the tapes of KLM's flight 867. The female first officer's voice escalates several octaves—and rightly so, as they had just turned into one huge glider! "KLM 867, we have flame out... all engines...and we are descending now." "KLM 867 heavy, we are descending now...we are in a fall!"

ABOUT THE AUTHORS

DOUG

DOUG MORRIS is an Air Canada Boeing 787 (Dreamliner) captain who has amassed nearly 24,000 hours of flight time. To put this in perspective for those starting off in the industry, this would be equivalent to driving from New York to Boston (or Los Angeles to San Francisco) and back again… daily… for over six years! Doug did most of his training and initial flight-hour accumulation on Canada's East coast, where weather is a major player in flight operations. He has experienced a huge range of weather phenomena not only on the temperamental eastern seaboard, but throughout the world. He has contended with Pacific typhoons, ferocious jet streams corkscrewing both hemispheres, space weather while transiting the North Pole, wicked crosswinds at London Heathrow Airport, and low visibility approaches flying into smog-prone New Delhi, India. Plus, he has flown into America's top 20 busiest airports with many having unique weather.

Part of his career also saw Doug venture into meteorology when things were lean in the aviation world.