Cold: discomfort or danger? (Either, or ...)

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In this issue, we present what I believe to be an important discussion of flying in the cold. The primary article is supported with 6/7 sidebar discussions in more depth on specific topics for those who want to pursue. Additionally, Dr. Johnson gives links and search suggestions for further research on this topic.
— Editor

When our core temperature falls, ***everything s-l-o-w-s d-o-w-n****. For example, after the first 2018 altitude record flight of Perlan II on August 26, Chief Pilot Jim Payne remarked that he'd gotten cold, and shivered during descent. "I turned on my heated vest!"*

Later, I remarked to one of the team who'd been manning the capcom office that Jim had been cold. "Yes," Tim said, "His speech gets slow when he's cold."

This is very perceptive. The brain slows as it cools, all our proteins work more slowly, our internal clock rate slows, and we wrongly think we're at normal speed – but others who are used to our pace will notice this subtle change.

Eventually speech will become slurred and, later, responses inappropriate. (We need hardly point out that when the pilot is confused, risk is already firmly in the red zone. An emergency descent must be demanded from the ground if possible. **See:** "Charlton Stanley Wave Hypothermia.")

In a nutshell

In case you don't have time or inclination to read the details, here are the main points, to help you discern mere discomfort from actual danger:

Temperature: Check the dewpoint for thermal flight; check the forecast temps aloft for wave flight.

Preparation: Wear more insulation than you think you need, especially from the waist down; wear openable top garments. (Don't wear electric clothing next to the skin.)

Reassurance: You will *suffer*, but not freeze anything as long as the temperature is above +21 °F (-6 °C) without wind.

Early warning: Cold feet within insulated boots mean your temperature is falling. Do something about your upper body, like turn on the electric vest.

Late warning: Shivering means the high flight is over. Get warm.

Rehydrate: If you've been cold, drink a pint or two of sport drink, fruit juice, or soup broth on your way down.

Rescue: Use a hot tub for recovery if quickly available; if not, do what can be done as quickly as it can be arranged.

Injury: For frozen parts, thaw the part, then go to the ER and educate the staff, as diplomatically as possible.

Now let's trudge through some of the important details.

Discomfort

The hardest comfort issue in cold temperature activities is keeping your feet warm. This is because your legs and feet radiate heat to your surroundings and your feet are a long way from your heart. Veins flank arteries, so as hot blood goes toward your feet, it warms the returning blood in veins – which protects the core but brings cooled blood to your cold feet. (This is called "countercurrent exchange.")

The solution is to keep your entire body a *little* bit warmer than necessary (not enough to break a sweat), so that it sends blood out from the core to the extremities to be cooled. This brings hot blood to your feet.

The other important comfort issue when we cool down is that an uncomfortably full bladder happens in about an hour because our blood vessels constrict, and we have no storage tank for the extra fluid. So it goes out the front door. This tends to interrupt any activity – and if your cockpit relief system freezes .... **See:** "Cockpit relief systems in the cold."

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Charlton Stanley
Wave Hypothermia

Chuck was flying wave one cold day out of the late, lamented Black Forest Gliderport near Colorado Springs. He describes a flight he made in the early 1980s.

It was a clear and cold late winter morning at Black Forest. My flight plan was to challenge the powerful and potentially dangerous wave coming off the leeward side of Pike's Peak.

I wore multiple layers of severe winter weather gear. I was concerned about my face, because I knew the head can lose a lot of heat. I tried wearing a thick balaclava I bought at a ski shop, but it interfered with my vision and the A-14 oxygen mask.

The tow from Black Forest to the primary wave was eventful, to say the least. It took 40 minutes for the Super Cub to drag me the 22 miles from the gliderport to the primary wave.

Rotor turbulence was the worst I ever experienced. That should have been a warning this day was not going to be a routine wave flight.

After a 4,000 fpm rocket ride up the wave, I settled into the smooth air at altitude. I had the urge to set that ride to music, so Bach's "Toccata and Fugue in D Minor" played in my head.

I had a nice flight and was having fun teasing the last bit of lift out of that wave. Suddenly, one of the women on the desk came on the radio. She told me to return to the field and land. I didn't want to; I was having too much fun. She insisted, but I blew her off.

At that point, flight instructor Jim Foreman's voice crackled on the radio. In a command voice that would have made a Marine Sergeant Major envious, he barked, "Land. Right. Now!!"

Having no idea why I was so rudely ordered down, I complied anyway. The descent was almost as interesting as the ride up.

There was another lesson here. The canopy frosted over. It snowed in the cockpit. When a thick layer of ice formed on the canopy, I had no way to stay spatially oriented. Through my foggy brain, I realized the orange spot on the canopy was the sun.

I am an instrument rated pilot, so training kicked in. Keeping the bright sun blob in exactly the same place on the canopy, I kept the glider right side up and on course until the ice cleared at a lower altitude and I could see again.

Finally, I got lined up with the field. Forget the runway, I landed on the grass and did well to hit the field at all. Every wind sock was standing out stiff as stovepipes, each pointed a different direction. Some socks pointed in opposite directions.

Once I stopped, the strong gusting wind battered the glider, threatening to blow me across the road next to the field. Holding the glider on the ground, full forward stick, brake on, spoilers deployed, I waited for the ground crew.

Jim Foreman and his ground crew careened up in the jeep. As the guys secured the wings, I pulled off my glove and shook hands with Jim, the crusty old story teller. He made a wisecrack about almost sticking to me like a frozen flagpole. I could tell he was worried, but I thought I was FINE.

As a forensic neuropsychologist and member of the Aerospace Medical Association, I had the knowledge, but was too goofy to realize what had just happened.

I pulled finger-size icicles off my neck from where condensation had frozen them to my skin. I still have the frostbite scars. As the cobwebs began clearing shortly after, I realized I had been hypoxic and hypothermia was setting in.

I said to Jim later, "Thank you for saving my ass when I was too dumb and cocky to save it without help. You are the kind of guy I am proud to call friend."

One lesson we take from that experience is that I thought I sounded fine. I was unable to hear my voice becoming gravelly, and slurring my words on the radio. Jim Foreman and the ladies on the desk saved my life that day, when I was too out of it to realize I was in trouble.

Altitude and the wave can kill two ways, hypothermia and hypoxia. It killed experienced glider pilot David Bigelow on a flight over Mauna Loa. His last radio transmission was at 28,000 ft. Impact with the mountain was about 10,000 ft; his flight recorder showed him reaching a maximum altitude of 38,700.

Charlton Stanley, garbed for winter wave.

Clothing for extreme temperatures and temperature variation

The best thing you can do to prepare for extreme temperature flying (or any other activity) is to find someone with experience who is thoughtful, and ask two questions:

What clothing do *you* use in the temperatures I expect to encounter?

What has gone wrong for you with clothing, and why?

Layers

I expect that your mother taught you why to use layers. Having a collection of garments of varying characteristics allows you to build insulation for each flight relative to the expected conditions. Life and happiness linger best when we are somewhere between pleasantly cool and pleasantly warm.

Pre-flight and post-flight pilots may engage in real exertion. Then you should not be wearing the kind of insulation you'll need in the chaise longue of the sky, twiddling ankles and wrists. You might produce 200 watts of heat assembling, disassembling, and generally chasing whatever wild geese frustrate personal progress, but you produce only about 70 watts under the canopy. Since this essay is about cold, let's cover the layers you may choose.

1: Base layer. Whatever's next to your skin is a spacer for irritating clothing, wicks away sweat, and if thick, insulates a bit. If your skin does not mind wool, it's a fine base layer.

Cotton: cheap, comfortable, absorbs water enthusiastically and then is a conductor of heat.

Polyester: cheap, attracts odors, loses insulating value when wet. I prefer a light polyester base with optional wool outside.

Personally, I wouldn't be caught dead using either if the flight begins in warm weather. If sweat isn't going to happen, there's no issue. When I was a kid, cotton waffle-weave tights and flippy-flappy army surplus wool were the sole choice.

Silk: comfortable, warm if thick, tolerates a bit of moisture, doesn't adsorb body odors much. My preferred base layer for the feet.

Wool: Comfortable for most people, especially merino wool, which isn't as durable, but you're not stressing the fabric in the airborne chaise longue, are you?

2: Electric layer. If you fly through a particularly wide range of temperatures, heated underwear can allow you to safely reduce the bulk of insulating clothing. This is detailed in a separate sidebar.

3: Insulating layer(s). The number and thickness of layers is relevant to the conditions in which you fly and your own corpulence. Fat is insulating, so skinny people truly need thicker layers. You can, of course, wear lightweight underwear, but my own experience is that it lasts about eleven minutes in subzero Fahrenheit temperatures. Thick woolen or silk underwear over a light base layer, insulated trousers, thick woolen (not cotton) sweaters, and insulated snowmobile suits or flightsuits.

Wind protection. The wind does not of course blow through your cockpit, a blessing, but windproof trousers and jackets are much superior to added layers of thick insulation in blustering winter winds on the ramp.

4: Boots. Honestly, the warmest boots made are Baffin Boots. Within Baffin.com, look for "Expedition boots" and choose a temperature range. In a careful search, I was unable to find a competitor. No other brand is rated for as low a temperature. They are deeply insulated and cosset your feet in a tight hug. But they may feel a little awkward on the rudders, and you'll not be scuffing them in the footwell. Some pilots prefer down booties over boots to add insulation without weight.

Having said that, buy your footgear at least a size big, and fill them with wonderful, thick woolen socks with or without electric sock or insoles. In my experience, it's almost impossible for boots to be too warm when the temperature is below zero Fahrenheit.

5: Shoe covers. Search for "down booties" and "down boot socks" to find lightweight, down-filled overboots. These boots are not made for walking, but they'll do fine in the glider or the ice house.

But do remember that ***your feet can get painfully cold in the warmest boots if your core temperature drops***. For example, if you're cold enough to shiver, your feet *will* be cold because your body has shut down circulation to your extremities.

6: Hats. The consistently warmest cap I've found is the brand Turtle Fur, which is thick fleece, often inside a knit shell. I'm sure there are competitors. There are so many variations that I think you have to go to a ski shop or outdoor sports store and feel them.

7: Insulated flight suits. The Perlan pilots wear KiloYankeePapa, tailored, insulated, flight coveralls https://tinyurl.com/KYPcoveralls. You can't buy these in stores. And they also wear electrically heated base layers – socks, pants, and a vest that they can turn on and off as the temperature varies in their environment. Having said that, -70 °C/-90 °F is a challenge no matter what you're wearing.

My research on snowmobile gear indicates that Klim brand snowmobile bibs and pants are the default standard. One-piece suits such as made by Acteryx are expensive, and aren't easily openable at warmer altitudes. My own bias is to heavily insulate from the waist down, and use cap, gloves, and zip-up jacket (or backwards jacket a la Henry Combs) to add and subtract insulation as I fly through different temperatures. Most gliders don't have a clothes locker, so whatever we do, we have to adapt to that.

Experience. Your own experience will teach you what not to do again, and it's important to be willing to descend whenever you have any of the warning signs of hypothermia.

Danger

We'll emphasize hypothermia because it's insidious and impairs judgment, and because frostbite and freezing are rare.

Your brain and heart need to be warm in order to work well. As your core temperature drops, neither works as well. If you're gliding because your heart isn't FAA-certifiable, you or your heirs may discover why the FAA was cautious.

If you need your brain for sound, prompt decisions during urgent moments in flight, it's best to have it warm. Flying is easy as long as there's nothing special to do. But as we've all experienced, special moments often surprise us. You'll be slow, if not stupid, when cold.

It's not just wave – summer flights are often cold.

We can become hypothermic at any temperature below about 70 °F / 20 °C. Moisture, wind, sunlight, duration, and clothing are the main determinants.

We may be sweating as we assemble the glider in the summertime. We may swelter in the cockpit while waiting for tow, especially after having to close the canopy – but we prefer to spend our time near cloud base. Are you dressed for the desert or for cloud base? The cloud base temperature just happens to be at the surface dewpoint. Check that attentively each day. This temperature will surround you for hours. Prepare for it. In the summer you need clothing that opens and closes easily. (**See:** "Clothing for extreme temperatures and temperature variation.")

All high flights are cold.

Any flight, any time of year, anywhere, above about 10,000 ft MSL enters a cold environment. If you plan to fly high and linger there, it's important to insulate your body. This article reflects the experience of pilots who've spent all day in cold altitudes.

It's important to understand that you can be ***miserably cold*** without being ***dangerously cold***. (In fact, it's possible to become dangerously cold – hypothermic – without first being miserable, if exercising continuously. But that's unlikely in a glider.)

To repeat: Cold is "dangerous" when the actual temperature declines in our brain (the seat of judgment, if you have any) and the heart (the most vital organ). The protein systems that keep us functioning work well only within a narrow temperature range, and all reactions slow when cooled.

Our body has several intricate responses to cold that protect our "core temperature" – our *deep-inside* temperature. We are exquisitely sensitive to skin temperature, yet have no clear sensation of our deep-inside (core) temperature. Everyone makes clothing decisions based on skin temperature.

Some people clearly speak and act as if insulating their chest and abdomen protects their core temperature. Not so much! Your "core" sends hot blood to arms, legs, and head, and in cool surroundings receives from them chilled blood. You can protect your *core* temperature most effectively by insulating your *head and extremities*. You'll be surprised at how little you need around your trunk if you are well insulated from waist to feet.

Warning clues, prompt actions.

Since our body has no core-temperature thermometer, you'll want to understand the changes in your body that signal hazardous cooling. As our core cools, there are noticeable changes, especially in our extremities, that can warn us that this trend will affect our brain:

1: Cold feet and hands that develop **within boots** or gloves mean that your core temperature is falling, and whatever you have done to keep warm *isn't working* – it's time to shift goals, to making your *core* warmer a priority. *Treatment:* In this situation, turning on your electric socks will make your feet more *comfortable* – but has little effect on core temperature, and may actually drop it further by increasing the return of cool blood from your feet, while not actually decreasing heat loss from any other part of you. Warm your entire body at a warm altitude or hot bath. *Prevention: Insulation* is the key to comfort and safety: insulated boots, thick woolen long johns, plus knit cap, warm gloves or mittens, jacket. And big, roomy boots at least a size larger than your shoes, so that your thick woolen socks aren't compressed and blood can flow freely to your toesies.

2: Numbness and stiffness of fingers and toes, ears and nose, is the idiot light of *frostbite*.

They will *not freeze* if their surrounding temperature is more than -6 °C (21 °F). But you probably don't have thermistors in your socks, and can't know whether you're skirting this limit. *Action:* Numbness does mean that it's time to make warming up a priority. You must judge whether your core is warm. If you're toasty with cold hands or feet, they need more insulation (put that glove back on!). But if you feel generally cool, your whole body needs to be warmed pretty soon. It will willingly sacrifice a foot or finger to save the heart.

3: Shivering is the idiot light of hypothermia, a danger signal that your core temperature has already dropped enough to impair judgment and complex mental tasks. Either numbness or shivering means that getting warm is now your top priority, not whatever ambition got you into this trouble. *Action:* It's time to get warm (but not to land out). The average person has enough energy stores to shiver for 3 or 4 hours, but don't use that time to stay in wave!

Altitude and temperature.

As you know, the thermal that brings you up high cools at the dry adiabatic lapse rate, 5.4 °F (3 °C) / 1,000 ft.

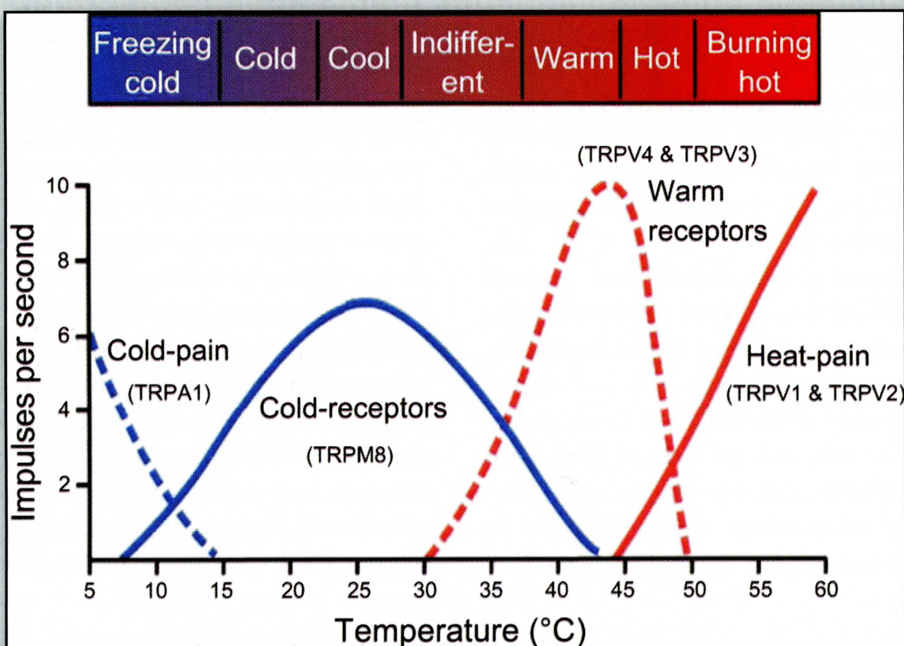
3,000 ft AGL is a fairly low cloud base for cross-country soaring. 10,000 ft AGL is a fantastic cloud base over the prairie. Twice that is feasible in the mountains.

Simple arithmetic (done here for you at no charge) means that at 3,000 ft AGL, the temperature will be 15 °F (9 °C) cooler than on the surface. And at 10,000 ft AGL, it is 54 °F (30 °C) cooler than on the surface. At 18,499 ft MSL, if that's 15,000 AGL, it is 80 °F (45 °C) cooler than the airport.

This means that we need to plan our garb and cockpit ventilation for the temperatures in which we plan to spend most of the flight. The shorts and T-shirt that were fine in the heat on the ground are dangerous at cloud base, as many naïve young men have discovered.

It also means that we need to plan for significant variation in cockpit temperature as we gain and lose altitude through the flight. As you have probably experienced, we may be uncomfortably cold while in the shade of a high cloud that's sucking air – and uncomfortably hot scratching around (interminably) at 1,000 or

The Sensation of Painful Temperatures



Sensitivity ranges of our 4 skin-temperature receptors.

We have 2 cold receptors and 2 heat receptors in our skin. This figure shows the response ranges of these. (The TRP abbreviations indicate types of Temperature-Receptor Proteins that conform to particular temperatures.)

By inspection, you can see that this corresponds with your experience: (These are *skin* temperatures, not air temperatures.)

- Painfully cold: below 15 °C (59 °F); maximal off the scale, around –6 °C (21 °F).
- Merely cold: Peaks at 25 °C (77 °F).
- Warm: 30°C (86 °F), peaks at 43 °C (109 °F).
- Painfully hot: begins at 45 °C (113 °F), goes off-scale.

This is why air above about 0 °F is merely cold, while air below 0 °F *hurts*. Below zero air cools the skin so rapidly that it quickly activates the painful-cold receptor proteins because our normal circulation cannot deliver heat fast enough.

2,000 ft AGL after we've missed the next thermal.

How can we best protect ourselves from the cold while cruising high – and yet manage the reality that, because thermals are invisible and the markers may have gone stale, we sometimes spend too many minutes downstairs in the furnace room?

A somewhat different challenge is that springtime soaring in northern areas, and wave or ridge soaring, often involves truly frigid temperatures well below freezing.

Areas of heat loss; What to do.

Our legs and feet, arms and hands, are designed to be radiators to permit heat loss. This is why we wear short-sleeve shirts, short pants, and sandals in hot weather. As us bald guys know, the scalp is also a radiator, and up to 25% of heat can be lost through the scalp. The body's great blood vessels are near the surface under the sternum and at the front of the neck, also an important area for heat loss or conservation.

This means that, in a cold environment, we should especially insulate legs and feet, hands and arms, head, neck, and upper chest. Insulate your feet and legs well, because they're tucked out of reach. For temps near 0 °F (-18 °C) and below, do use insulated boots. (Baffin boots are the warmest, partly because they are designed to minimize conductive loss to whatever cold object the boot is touching.) Down boot covers work well until you walk in them.

In the cockpit, several things affect heat gain and loss. How much ventilation you must have in order to keep the canopy clear is very important. The radiant gain or loss from being in sun or shade is also important.

For hands and arms, wear a long-sleeved undershirt and warm gloves that are easily slipped on and off for fine work (touchscreens come to mind), or get those super-insulated ski mittens with an interior fabric glove that can be released temporarily with a zipper.

If legs, arms, and feet are well insulated, we will be comfortable with *much* less around our trunk, and better able to adjust to the changing temperatures as we climb and descend by opening or closing our jacket or shirt and donning or doffing gloves and hat.

Obviously, we are not going to doff and don boots and pants or long johns after strapping in. Nor is there clothing with easily removed or opened sleeves. But we can very easily use stocking caps and jackets or sweaters with a full zipper front, and we can don or doff mittens or gloves.

Some pilots have room to keep a warm jacket within reach and pull it on backwards over their arms and upper front in the cold. (This works well, even if just a warm shirt, if there's a place to tuck it. I stuff mine behind one elbow.)

It is possible to purchase electrically heated clothing (produced for snowmobilers, ice fishermen, and motorcyclists) to reduce the amount of insulation we wear while scratching around low, while allowing protection up high in the cold. Be careful: skin burns can occur when the heating elements are next to the skin, and the wiring itself can cause skin pressure injury or pain if weight is borne across it. (**See:** "Electrically heated clothing.")

There is *no* need to run any electric clothing at a toasty-warm setting. It's much safer, more effective, and prolongs battery life when the goal is to be *comfortably cool.*

If you're going to spend more than an hour in frigid temperatures, buy and wear insulated clothing.

Other risks of temperature transition

The main risk of assembling and launching in the heat while dressing for the cold aloft is that we may drench our underclothing with sweat, destroying the insulating value of cotton or synthetic fabrics. (Wool retains insulating value when wet, though it's degraded if soaked.)

Another risk is that when we become cool, *cold diuresis* always occurs – even if we do not feel very cold. The extra urination this produces is merely an inconvenience unless you did not plan for it. The important safety point is that this is *lost blood volume* that you'll miss when you warm up.

We lose balanced salt and water during cold diuresis, and when we descend and scratch around, we lose further salt and water through sweating while our blood vessels dilate. This drops our blood pressure and reduces G-tolerance. If you are planning to cruise high and may have to scratch around low, please take Gatorade or equivalent as your rehydration solution and sip steadily as you descend and warm.

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Electrically Heated Clothing

If you plan to fly your glider in extreme cold, especially in wave, we recommend electrically heated clothing, as well as complete insulation. This is especially worthwhile if the ground temperatures are quite warm, for with heated underclothes you'll need less insulation bulk as long as the electrons flow. The goal is not to be toasty; it's to preserve brain function and good judgment.

It is much more effective – and safer – to keep you and your extremities *pleasantly cool* than to wait until you're shivering or your feet are numb before turning the heat on "high." If your legs are chilled, they contain much chilled blood. When you abruptly make the skin hot, the veins beneath are commanded to dilate. This causes cold blood to be dumped into your core, and if it's too low already, heart and brain dysfunction won't help you get home safely.

Don't try to be toasty-warm. It risks burns and wastes batteries. To avoid burns, use it over an unheated base layer, adding insulated clothing outside of it. If the heated piece is the outer piece, your cockpit will get uselessly warmer. If the heater is next to your skin, it can burn or be lumpy. A skin temperature of 60 °F/15 °C is comfortably cool and 80 °F/27 °C is comfortably warm and will prevent hypothermia.

Caution: this clothing can fail out of the box or during use. Check and recheck! Have a failure plan.

Battery-powered clothing is widely available, promoted to and manufactured for motorcyclists, ice fishermen, snowmobilers, and hunters. Search for "heated base layer" (*not* "pants" – that returns lingerie) or "battery-powered base layer" (or gloves or socks).

Some heated clothing is designed to be plugged into an alternator-driven electrical system. Find plugin clothing by searching for "12-volt motorcycle clothing" or "heated snowmobile clothing." **Do** check the current draw of each piece and add them up! Make sure that you have twice enough battery reserve for both avionics and clothing. (Do you know what your battery capacity is when chilled to freezing? It's low.) A review of such clothing shows that a particular entire kit requires about 200 amps in 8 hr, about 20 times the capacity of your typical avionics battery. (Thanks to Kempton Izuno for calculating a particular full kit. There are many vendors.)

More practical are battery-heated insoles for shoes, stockings (less durable), and vests. (Thanks to Jackie Payne for this judgment.) Research the battery type and expected duration at each warmth setting. Some can be plugged into ship's power. Look for variable power settings.

If you plan serious wave flight, monitoring external battery temperature as well as voltage increases safety, and adding a heater and insulation to any external battery will be worth the consumption cost.

Electrically heated garments:

- Socks
- Trousers
- Vests
- Shirts (some with heated arms)
- Gloves
- Caps

It's the Perlan experience that keeping the feet warm is the most challenging thing. This takes warm socks, electric insoles or socks, and a warm core with insulation and heated trousers and heated vest that can be turned on in severely cold temperatures.

(I mention Gatorade because the high-sodium version is the appropriate one to use when warming up. Obviously, any sport drink that has equivalent electrolytes is fine – read the labels – or you can make your own with about ¼ teaspoon of salt in about a quart of juice.)

Also do this if you are descending into a hot environment for landing, because you do not want to have poor blood flow to your brain while maneuvering in the pattern.

Thirst is a very reliable *water*-deficiency detector. It means that that you need *water* despite the cold diuresis that occurred early in flight. It is *fine* to use plain water for in-flight hydration when you are thirsty. **If you feel thirsty, you *do* need *water*.** (Has your water bottle frozen?)

On the other hand, there is no specific clue that you need **salt** – just headache or fatigue or lassitude. If you've been sweating or have urinated after being cool or cold, you will need some salt while rewarming. You're best off drinking sport drinks, fruit juice, or soup while descending and warming. Guesstimate the volume of urine you've passed, and drink at least that much fluid while you warm. If you're warming up and feel a headache or fatigue or lassitude, use a salty beverage. The *volume loss* that is caused by cold diuresis (or severe sweating) does not cause thirst, because it's a relatively balanced salt-and-water loss. *Only water lack* (or excess salt intake) *causes thirst.*

Discomfort vs Danger:

We can be utterly miserable and in pain without actually being in danger. The miseries *are* warnings, though, and worth understanding.

Clues you can use to avoid cold injury.

The research paper says blandly, *Decreased skin temperature leads to modified behavior prior to a decrease in core temperature.* Translated, this means, if our hands feel cold, we put on gloves before they freeze. When we feel miserable, we do something about it if we can. We are sentient, and we know what cold air means, so when we feel it, we do something about it. And we plan.

But how can we know if our plans are adequate?

We have internal clues that we can use to judge whether we are merely feeling discomfort or are being endangered by cold.

Cold hands, cold feet.

Two things cause vascular constriction, which decreases blood flow to hands and feet and makes them cold: touching cold surfaces and dropping core temperature.

1: *Touching something cold.* Cold air, cold metal, cold gasoline or water, cold handles. It's easy to tuck our hands up into our armpits or between our legs (one at a time, if flying or driving). Our feet are stuck where they are, under the panel, in the foot well.

When the skin of hands or feet touch a cold object, the *brain* commands constriction of veins and arteries, and blood flow decreases.

This is followed in 2 or 3 minutes by vascular dilation, and the skin pinks up. After this, if the cold contact continues, vasoconstriction returns, and hands or feet feel cold, especially to the person with whom you just crawled into bed: popsicle toes.

2: *Drop in core temperature.* As soon as our core body temperature drops, the brain commands decreased blood circulation to the extremities. This preserves central functions at the expense of those useful small parts on our hands and feet.

This will cause cold hands and feet even if they are well insulated.

Having cold hands and feet while wearing well-insulated boots and gloves is one important clue that we have not adequately protected ourselves from hypothermia. Worse is coming unless we correct the situation (turn on the glider's central heating, get into a hot tub, descend to a warm altitude [~5 °F / 3 °C per 1,000 ft]).

See "The Sensation of Painful Temperatures."

Cold injury.

On the road to frost, you will first feel pain somewhere around 55 °F (14 °C) that gets more severe and widespread until the temperature is too cold for the nerve endings to function. I found disagreement in research papers about

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Cockpit relief systems in the cold.

Gabriel Fahrenheit did not have sophisticated technology when he created his thermometer. He needed reproducible and consistent standards. He chose the innards of a live chicken as 100° and the temperature of saturated freezing salt water as 0°. (This coincidentally means that road salt will not melt ice below 0 °F.)

The freezing point of urine will vary according to how concentrated it is. If you have been hydrating vigorously, it will be little different than that of pure water. If you are dehydrated, the urine will be concentrated. Formal studies, now 60 years old, show the freezing point of urine to be depressed to as much as -2.2 °C (28 °F).

The bottom line is this: since you do not know whether your urine will be concentrated or dilute when flying in the cold, you can count on your glider's relief tubing plugging up with ice if the outside temperature is meaningfully below freezing. In a standard atmosphere, this is any altitude above 8,500 ft MSL.

Altitude (MSL)	Temp °F	Temp °C
1,000	55	13
8,000	30	-1
18,000	-5	-30
24,000	-27	-33
30,000	-48	-44
38,000	-70	-57

Standard atmosphere temperatures.

the numbness temperature, but it's clearly near the temperature at which skin freezes. At least, numbness is an idiot light for *frozen*.

1. Chilblains (pernio, trench foot, immersion foot).

Cold can injure, even without freezing. Prolonged exposure to moderate cold, especially damp cold, injures the skin. The temperature and duration required are vague. Cases have been reported with ambient temperatures between 60 °F (15 °C) and 31 °F (-0.5 °C) for several hours. My experience is that much longer exposure is required at the warmer temps.

The exposure may be for a few hours, or repeatedly for several days. The skin becomes red, puffy, tender, and – worse – itchy. This is traditionally called ***chilblains***, academically, ***Non-Freezing Cold Injury*** *(NFCI)*. This heals in about 2 weeks if excessive cold exposure can be avoided. Sometimes the affected part (usually hands or feet or ears) remains hypersensitive to cold for months. If your extremities are numb with cold for long, this will likely happen. It's uncomfortable but not dangerous.

2. Frostbite

Sometimes only the skin is frozen, not the underlying fat, ligaments, tendons, or bone. This is *frostbite*. Freezing requires a tissue temperature below -6 °C (21 °F). This means that if the air and the glider are warmer than 21 °F, you *will* be miserable, but you will not *freeze*.

3. Freezing

Some people differentiate between superficial and deep frostbite, others simply say ***frozen*** if fat, ligaments, or bone are involved. This is important to identify (and prevent!) in growing children, because if the bones' growth plates (epiphyses) are frozen, the bone no longer lengthens, resulting in crippling or unsightly finger or toe deformities.

The Dangerous Chill: Shivering

Shivering is the first clear sign of ***hypothermia***.

When our core temperature drops below about 95 °F (35 °C), our brain normally commands our muscles to begin shivering. Shivering can raise our body's metabolic rate 5- or 6-fold, and – unless you are starving, have exhausted your liver and muscle glycogen with prolonged exercise, or take your calories as alcohol – shivering can continue for 4 hours or so. You have time to make even a long descent. But get going, please; and remember that your brain has slowed. You cannot be conscious of this because your internal clock has also slowed. Your response time and thinking times will be slow.

Yet, shivering is a ***danger signal*** because it means that your personal keeping-warm strategy has failed – the situation will not improve without revision – requiring at least that you revise your ambitions to include a much lower altitude. Your insulation is simply not adequate. Your core temperature will continue to drop; your brain is not working up to its typical sharp brilliance. You need to get to a warm altitude or find a hot tub.

Recovery from hypothermia and frostbite.

The most effective treatment is the simplest: simply slide into a warm bath of 100 °F (38 °C) water, and add warm water continually to maintain this temperature, and stir it around. The frozen parts will thaw in two or three minutes, and the rest of you will warm up nicely. *Do not* permit refreezing. It's better to stay frozen.

Drink rehydration fluid while warming. Do *not* drink alcohol at this point, because it causes dilation of skin vessels that will cause central cooling.

Warming will hurt! Take 1,000 mg acetaminophen (paracetamol) plus 600 mg ibuprofen immediately. (This combination is as effective as narcotics – 5 mg of oxycodone or hydrocodone – without the risks.) Repeat every 6 hours if desired.

If the frozen parts blister, and there is any blood in the blisters, go to the hospital and instruct the emergency room physician to Google up "**State of Alaska Cold Injuries Guidelines**."

The most important treatment for frozen parts is that *anticoagulation* with intravenous heparin was shown in the early 1950s to dramatically reduce the risk of gangrene if given within 24 hours, and is *essential* to limit gangrene if there's any blood in the blisters that form.

Oral heparin-equivalent medication is now available. It of course has not been tested for this use, but can be taken promptly and does not require hospitalization. If I were faced with a frozen part, I'd give apixaban immediately during rewarming and every 12 hours for 2 or 3 doses. If going on a cold-environment expedition, I'd take a supply along in the rescue kit.

A hospital is useful because it's very damaging to walk on recently-thawed feet, and while there you're waited on hand and foot – and the professional staff should know what's best for you (or know how to look it up).

Summary

Loop back to the beginning. Read "In a nutshell."