



COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES

SPHERES

Edition 13 • 2021

Pandemic leaves its mark

Some air pollutants drop

Yes, coronavirus
spreads by aerosol

Quarantine can't
stop science education

Navigating the New Arctic

Banned gas back
on the decline

Scientists track
old smoke, firestarters

What's in the air
at your workout?



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ON THE COVER:

A food delivery worker waits to pick up his next order. Photo: Adobe Stock



NSIDC research scientist Kevin Schaefer stands above melting ground ice in front of the Alaska pipeline on the North Slope. More news from the Arctic, pages 20-26. Photo: Roger Michaelides/Colorado School of Mines

SPHERES

A publication of the Cooperative Institute for Research in Environmental Sciences

CIRES, a partnership of the University of Colorado Boulder and NOAA, conducts innovative research that advances our understanding of the global, regional, and local environments and the human relationship with those environments, for the benefit of society. Our environmental scientists explore many aspects of Earth system science: the atmosphere, cryosphere, hydrosphere, geosphere, and biosphere. These spheres of expertise give our magazine its name.

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SPHERES

by the numbers

97%

of home-threatening wildfire ignitions are human-caused (PAGE 19).

2,000

geoscientists participate in the Community Surface Dynamics Modeling System, now 13 years old (PAGE 13).

Five

sedentary people can emit the same amount of body-generated chemicals as one sweaty exerciser (PAGE 14).

>43

free libraries built by Russ Schnell and placed around the West, in Missouri, Canada, and now Antarctica (PAGE 33).

417.1

ppm of carbon dioxide in Earth's atmosphere in May 2020— the highest-ever monthly level recorded (PAGE 4).

12th

place ranking in size of the 2020 Antarctic ozone hole over the past 40 years (PAGE 7).

7,000+

pageviews of CIRES E&O's Science@Home webinars between April 2020 and March 2021 (PAGE 30).

1.44 mill.

square miles of sea ice in the Arctic on Sept. 15, 2020—the second least recorded (PAGE 6).

Briefs



Wolverines den and breed in snowpack at higher elevations, and warming temperatures likely won't threaten wolverine denning and breeding through mid-century, according to a CIRES-led study. Photo: Pixabay

CLIMATE

Snow projections keep wolverines off endangered species list

Wolverines rely on mountain snow: breeding females typically den in snow banks in late winter and spring. A CIRES-led study predicts snowpack through mid-century will be enough for wolverines in the contiguous United States to den and breed, even as temperatures rise. The U.S. Fish and Wildlife Service considered this study in their decision to not list the wolverine under the Endangered Species Act. The October 2020 study in *Earth's Future* evaluated the future of springtime snowpack at higher elevations in Glacier National Park, Montana and Rocky Mountain National Park, Colorado, through 2050. According to lead author and CIRES and NOAA scientist **Joe Barsugli**, lack of snow at high elevations likely won't be an impediment to wolverine conservation in that period of time.

bit.ly/wolverines-snowpack

Rise of carbon dioxide unabated

In May 2020, levels of atmospheric carbon dioxide (CO₂) reached their highest-ever

monthly reading on Earth: 417.1 parts per million (ppm), according to NOAA and the Scripps Institution of Oceanography. That's 2.4 ppm higher than the May 2019 peak; both were recorded at NOAA's Mauna Loa Observatory. CIRES researchers working in NOAA's Global Monitoring Laboratory play key roles in NOAA's CO₂ measurements, including collecting and analyzing air samples from baseline observatories, tall tower sites, on aircraft, and at sea and land surface sites around the world.

bit.ly/CO2-unabated

Pliocene patterns point to weaker Indian monsoon rainfall

Climate researchers often look to the past to anticipate the future. So when CIRES post-doctoral researcher **Jody Wycech** wanted to understand how a warming climate may impact the tropical Pacific Ocean and related rainfall patterns, she turned to the Pliocene. During that epoch (5.3-2.6 million years ago), the concentration of atmospheric carbon dioxide may have been similar to today's. Using a statistical approach, Wycech and her colleagues

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reconstructed sea-surface temperature maps for the equatorial Pacific. The team found that the eastern equatorial Pacific Ocean was 3–6° C warmer, much as it is during big El Niño events today. Indian summer monsoon rainfall is often low during El Niño years. Pliocene rainfall over India was 37 percent weaker than it is today, the team inferred, consistent with a weakening monsoon over the past 30 years as the globe has warmed and carbon dioxide has risen. Wycech is now a chemist with the U.S. Geological Survey.

bit.ly/Pliocene-El-Ninos

Grad student refines paleoclimate tool

CIRES Ph.D. candidate **Lina Pérez-Angel** uses liquid chromatography to isolate bacterial lipids from soils from the Eastern Cordillera of Colombia. These lipids, which are tiny compounds or remnants from bacteria, record past temperatures in the region, and when Pérez-Angel and her colleagues combined their new records with existing data, they refined a tool for reconstructing past temperatures in the tropics, reducing its uncertainty by more than two times. Her next step is to apply this new calibration to geologic samples from the Eastern Cordillera that date from Pliocene time, when the Earth at middle to high latitudes was

several degrees warmer than today. Her goal is to test whether the tropics also were warmer at that time than today.

bit.ly/Colombian-lipids

BIG DATA

Sound: Another way to ‘look’ at the sea

Studying underwater sound can help scientists understand what species live in marine environments and what noise is contributing to the ocean soundscape. Through the spring of 2022, a project called SanctSound is recording the sounds of marine animals, wind and waves, and human activities in the National Marine Sanctuary System. These sounds and other observations, including vessel tracking and scuba surveys, will help researchers better understand sound in water and establish acoustic baselines. So far, CIRES and NCEI researchers have archived over 70 TB of passive acoustic data for the NOAA and U.S. Navy project.

In a related collaboration, Google has developed AI models that can identify humpback whale calls in underwater recordings collected by NOAA’s Pacific Islands Fisheries Science Center. CIRES and NCEI have archived the 15-year dataset, now publicly available through Google Cloud.

bit.ly/underwater-sound



To see a video of Pérez-Angel at work with sample liquids during her investigation of bacterial lipids, see her [Twitter post at bit.ly/LPA-at-work](#). Photo: Lina Pérez-Angel/CIRES

Briefs

near real-time data

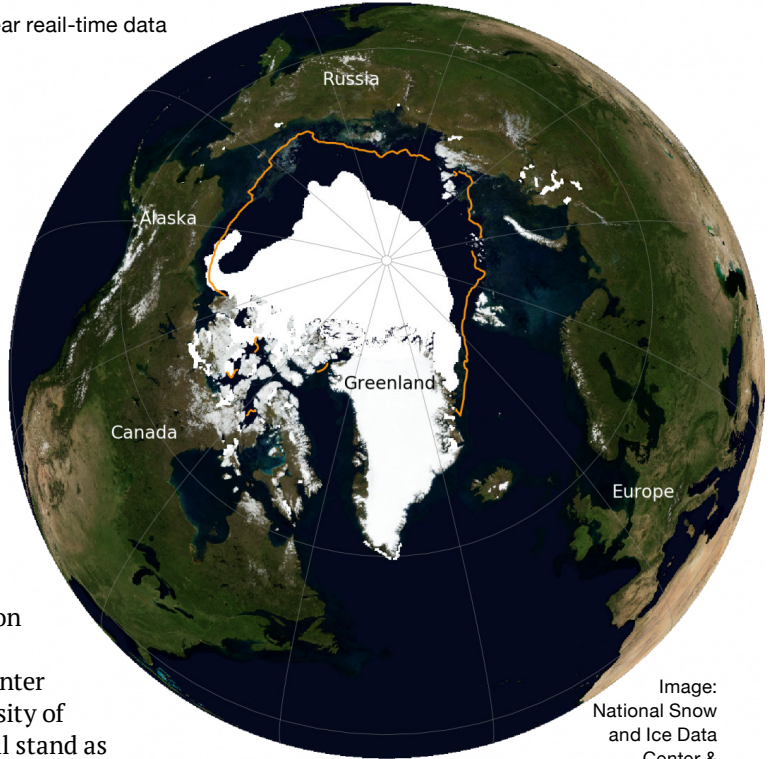
CRYOSPHERE

2020 Arctic sea ice minimum pounds 'another nail in the coffin'

The 2020 Arctic sea ice minimum was the second lowest in the nearly 42-year satellite record. On September 15, 2020, Arctic sea ice reached its minimum extent at 3.74 million square kilometers (1.44 million square miles), according to scientists at the National Snow and Ice Data Center (NSIDC), part of CIRES at the University of Colorado Boulder. "The year 2020 will stand as an exclamation point on the downward trend in Arctic sea ice extent," said NSIDC director **Mark Serreze**. "We are headed towards a seasonally ice-free Arctic Ocean, and this year is another nail in the coffin."

The sea ice maximum on March 5, 2021, was only the 7th lowest on record, according to NSIDC, but still fell well below the long-term average. Interestingly, there is no correlation between sea-ice maxima and subsequent sea-ice minima, the center reported. That is, a relatively ice-rich spring does not necessarily mean an ice-rich fall.

bit.ly/2020-sea-ice-min



15 September 2020
■ median ice edge 1981-2010

Image:
National Snow
and Ice Data
Center &
NASA Earth
Observatory

Greenland meltwater flows in winter, too

It's often assumed that Greenland's under-ice drainage system lies dormant during winter when standing water freezes, but CIRES-led research suggests otherwise. As a graduate student at UCLA, CIRES Visiting Fellow **Lincoln Pitcher** used ground-penetrating radar to survey the rivers draining five Green-

CONTINUED ON PAGE 7



Researchers use an auger to test for water flowing beneath river ice during winter in southwest Greenland. Photo: Lincoln Pitcher/CIRES

CONTINUED FROM PAGE 6

land outlet glaciers. He and a colleague found slowly flowing meltwater at one of these sites. The discovery is important for understanding meltwater and ice dynamics on the Greenland Ice Sheet, including impact on sea-level rise. And it underscores the need to do this kind of research in dark Arctic winters, not just summers.

bit.ly/Greenland-meltwater

ATMOSPHERIC CHEMISTRY

Colder, windier South Pole triggers larger-than-average ozone hole

The 2020 Antarctic ozone hole spanned nearly 9.6 million square miles at its September peak—the 12th largest in 40 years of satellite records. Persistent cold and winds at the South Pole spurred its formation in the stratosphere. NASA and NOAA scientists said under the same conditions, the hole would have been much bigger a couple decades ago, before the Montreal Protocol began regulating ozone-depleting chemicals. Monitoring Antarctica’s seasonal ozone hole remains an international effort, with CIRES researchers in NOAA’s Global Monitoring Laboratory playing an integral part.

bit.ly/12th-largest

Methane hotspot or not?

Recent CIRES and NOAA research sheds light on a mysterious methane cloud looming over the U.S. Southwest, caught by satellite in 2014. It wasn’t a persistent “hotspot” as headlines initially suggested, but a nightly build-up of polluted air that trapped methane emissions near the ground. Researchers from CIRES, INSTAAR, and NOAA used instrumented aircraft and vans to attribute the region’s methane

emissions to coalbed methane, oil and gas production, and other sources. The buildup was largely due to atmospheric conditions that concentrated pollution overnight; daytime winds later dispersed the gas. The findings underscored the value of coordinated field measurements and real-time data, said CIRES lead author **Gabrielle Pétron**.

bit.ly/methane-hotspot

PUBLIC INFORMATION

Drought.gov features new content, interactivity

In January 2021, NOAA’s National Integrated Drought Information System (NIDIS) launched a redesigned U.S. Drought Portal to better serve stakeholders, decisionmakers, the media, and the public. The new website, Drought.gov, features updated content and a new interactive design to provide actionable, shareable information, and easy-to-understand graphics describing current drought conditions and forecasts by city, county, state, ZIP code, and at watershed-to-global scales.

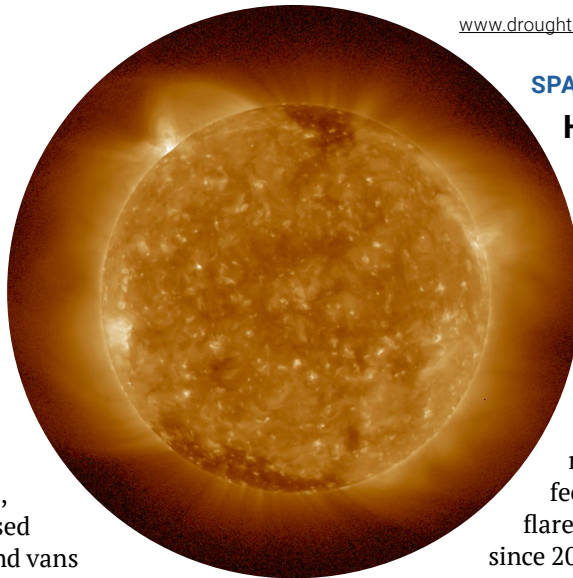
Drought.gov aggregates and presents drought impact data for economic sectors such as agriculture, energy, water utilities, tourism, and recreation. Nearly a dozen CIRES experts work in NIDIS, partnering with the National Centers for Environmental Information for the support and development of Drought.gov.

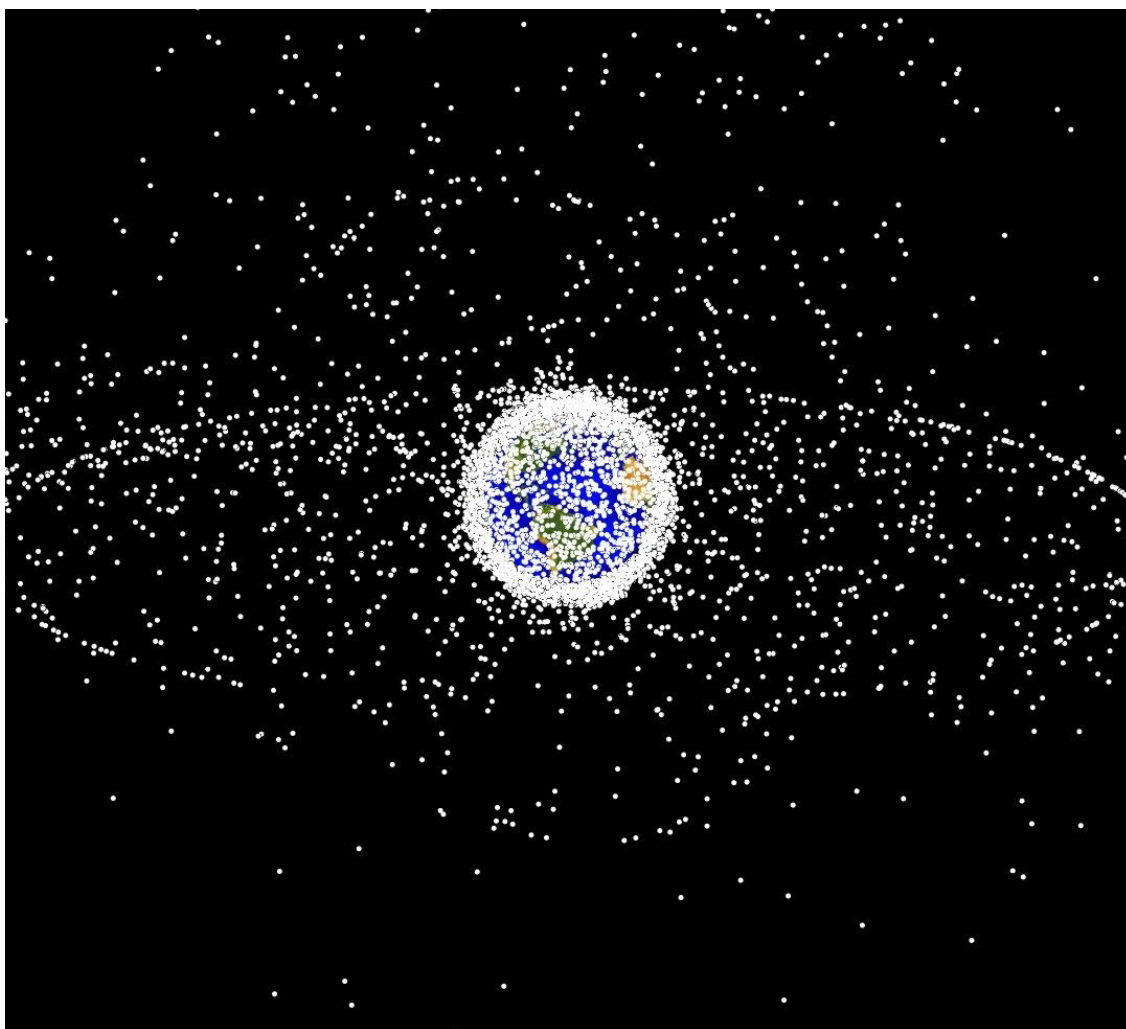
www.drought.gov

SPACE WEATHER

Hello, Solar Cycle 25!

NOAA’s GOES Solar Ultraviolet Imager (SUVI) captured the first significant solar eruptions of Solar Cycle 25, after a long period of inactivity. On May 29, 2020, NCEI and CIRES scientists monitoring the SUVI feed spotted two solar flares, the largest observed since 2017—a sign that the new solar cycle was ramping up.





A computer-generated image representing space debris in low-Earth orbit. Image: NASA

Orbital fees could solve space junk problem

ECONOMICS Space junk is a growing problem. An estimated 20,000 objects—including aging satellites and space debris—crowd low-Earth orbit, and launching new satellites adds to the collision risk. What’s the most effective solution? It’s not a technological fix like capturing debris or deorbiting old satellites. Rather, it’s economic: An international agreement to charge operators “orbital-use fees” for every new satellite put into orbit.

CIRES Fellow and environmental economist **Matthew Burgess** and colleagues made the case for orbital-use fees last year in a paper in the *Proceedings of the National Academy of Sciences*.

“Space is a common resource, but companies aren’t accounting for the cost their satellites impose on other operators when they decide whether or not to launch,” said Burgess, also an assistant professor of environmental studies at CU Boulder. “We need a policy that lets satellite operators directly factor in those costs.”

Orbital-use fees could also boost the long-run value of the space industry, the economic study found. By reducing future satellite and debris collision risk, an annual fee rising to about \$235,000 per satellite would quadruple the value of the satellite industry by 2040, the researchers estimated.

bit.ly/junk-in-orbit

How climate killed corals

CLIMATE

A squad of climate-related factors is responsible for the massive Australian coral bleaching event of 2016, according to recent CIRES research. The culprits: A marine heatwave that brought excessive warmth to Northern Australia's Coral Sea and a terrestri-

al heatwave that exacerbated the warming.

“When the Great Barrier Reef bleached severely back in 2016, some speculated it was global warming, others thought it was El Niño,” said **Kris Karnauskas**, a CIRES Fellow, associate professor at

CONTINUED ON PAGE 10



Bleached coral in the Maldives. Photo: The Ocean Agency

Marine heatwaves becoming more intense, frequent

CLIMATE

When thick, the surface layer of the ocean acts as a buffer to extreme marine heating, but a 2021 study shows that this “mixed layer” is becoming shallower each year. As this armor thins, the ocean becomes easier to warm and more susceptible to rapid swings in temperature.

“Marine heatwaves will be more intense and happen more often in the future,” said **Dillon Amaya**, a CIRES Visiting Fellow and lead author on the study published in the *Bulletin of the American Meteorological Society’s* special report, “Explaining Extreme Events.”

“And we are now understanding the mechanics of why. When the mixed layer is thin, it takes less heat to warm the ocean more,” he said.

Amaya and his colleagues from NOAA, the National Center for Atmospheric Research, and CU Boulder used a combination of ocean observations and models to estimate the depth of the mixed layer back to 1980, and also to project out into the future. During the last 40 years, the layer has thinned by nearly 9 feet (3 meters) in some regions of the North Pacific, they found. By 2100, the mixed layer will be 12 feet (4 meters) thinner—30 percent less than what it is today. This thin mixed layer combined with warmer global temperatures will set the stage for drastic swings in ocean temperatures, leading to much more frequent and extreme heating events, the researchers reported.

bit.ly/marine-heatwaves



Volcanic strata surround the Ice Lakes Basin in the San Juan Mountains in Colorado. Photo: Alison Barwell/CIRES

Geologic forensics explain midcontinental volcanism

GEOCHEMISTRY

Colorado has plenty of evidence of volcanic history, including Table Mountain in Golden and much of the San Juan Mountains. But it's been tricky for scientists to explain exactly how volcanism occurred so widely mid-continent, far from the places where geologic plates meet. One idea is that an oceanic plate subducted very shallowly under the West before diving deeper into the mantle, inspiring volcanism. Now, there's new support for this theory.

CIRES Fellow **Lang Farmer** and his colleagues have assembled a chain of evidence, starting with strangely "intermediate" tantalum-to-thorium (Ta-to-Th) ratios in southwestern volcanic rocks. The most likely explanation for the oddball ratios goes like this: Shallow subduction

squeezed water from oceanic crust, hydrating the lithosphere above and precipitating minerals in a way that concentrated both Ta and Th. Then, when subduction stopped (about 40 million years ago), the "hydrated" region was warmed by upwelling hot mantle below. Ta- and Th-rich areas dissolved and melted, eventually creating the unique intermediate Ta/Th ratios found in mid-continent volcanic rock.

This type of hydration is likely a "fundamental Earth process," Farmer said, responsible for other areas of volcanism in continental interiors, such as on the Tibetan Plateau and in the eastern Mediterranean. Farmer also serves as Divisional Dean for Natural Sciences at CU Boulder.

bit.ly/subductiontheory

Corals

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CU Boulder, and author of the May 2020 study in *Geophysical Research Letters*. "The actual roles of those two forces have not really been disentangled."

To determine what caused the excessively warm water that led to the coral bleaching event, Karnauskas used satellite observations and a mathematical technique to fingerprint what phenomena led to what amount of warming, and when.

El Niño initially caused a spike in sea-surface

temperature by shifting sun-blocking clouds away from the region. Global warming raised the background temperature, increasing the intensity of this marine heatwave and extending it by several months, the study found. Then, a land-borne heatwave moved across eastern Australia and spilled out over the ocean as the first phase of the marine heatwave was ending.

"Climate variability and change can lead to marine impacts in surprising, compounding ways," Karnauskas said. "We need to double down on efforts to understand these complexities."

bit.ly/climate-killed-coral

Commercial airline data: Ozone pollution increasing

AIR QUALITY

How can aircraft making international flights help scientists studying ozone? In a recent study, CIRES researchers used ozone data collected by commercial aircraft to show that over the past 20 years, levels of the pollutant increased across the Northern Hemisphere in the lower part of Earth's atmosphere. That's even as tighter controls on emissions of ozone precursors lowered ground-level ozone in some places, including North America and Europe.

Ozone in the troposphere—from Earth's surface up to 12-15 km (7-9 miles)—is a greenhouse gas and air pollutant that, at high levels, can harm people's lungs and damage plants. Previous studies couldn't draw firm conclusions on Northern Hemisphere ozone trends, because there are too few long-term monitoring locations and because new satellites with near-global cov-

erage provide conflicting results.

So a CIRES/NOAA research team turned to aircraft data from Europe's In-Service Aircraft for the Global Observing System program (IAGOS). Between 1994 and 2016, commercial aircraft captured more than 55,000 ozone profiles above 11 polluted regions across the Northern Hemisphere. In an August 2020 *Science Advances* paper, the team noted the greatest ozone increases in the tropics and concluded that ozone exported from that region may be driving increases above other parts of the Northern Hemisphere.

"That's a big deal because it means that in order to limit our pollution locally, we need to act as a worldwide team," said **Audrey Gaudel**, a CIRES scientist working in NOAA's Chemical Sciences Laboratory and the study's lead author.

[bit.ly/20years-of-ozone](https://www.noaa.gov/press-release/2020/08/2020-08-20-01)



This map shows routes of the commercial aircraft collecting ozone profiles for IAGOS between 1994 and early April 2021. Image: www.iagos.org/

Banned ozone-depleting gas emissions decline again

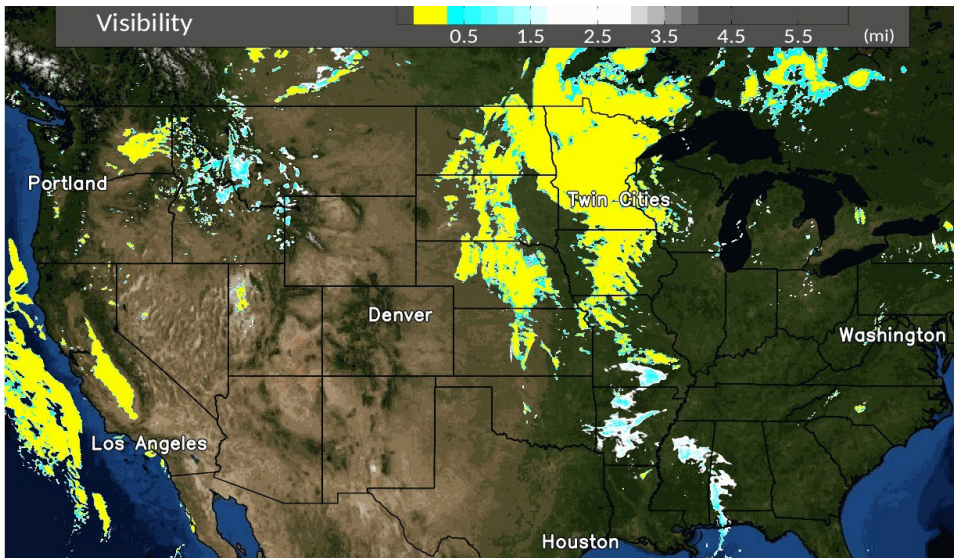
ATMOSPHERIC CHEMISTRY

A few years ago, NOAA and CIRES atmospheric watchdogs spotted something strange. Global emissions of an ozone-depleting chemical called CFC-11, which should be dropping, were in fact rising. The scientists tracked some of that global CFC-11 jump—more than a 25 percent increase in 10 years—to eastern Asia, and follow-up work by

international colleagues suggested much of the increase came from eastern mainland China.

Following two papers and international investigations, CFC-11 is back down again. A recent NOAA-led study, with scientists from the U.S., U.K., and Australia, found that from 2018 to 2019, CFC-11 emissions decreased globally by 26 percent. NOAA's global monitoring network and

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In this HRRR forecast, yellow indicates areas where visibility is predicted to be less than a half mile, which significantly slows air traffic arrivals and departures. Image: NOAA Global Systems Laboratory

Weather workhorse serves aviation, energy, fire safety

MODELING

In December, NOAA’s High-Resolution Rapid Refresh (HRRR) weather model made its final transition into National Weather Service operations. Developed by federal, CIRES, and CIRA scientists in NOAA’s Global Systems Laboratory and originally intended to help forecast aviation hazards, HRRR has evolved into a workhorse of a model with a remarkable resume of research accomplishments. HRRR can:

- ◆ improve forecasts for aviation, including icing, fog, and other short-term hazardous weather;
- ◆ improve predictions of atmospheric rivers, precipitation from long trains of Pacific storms vital to California’s water supply;

- ◆ better forecast low-level winds in complex terrain, leading to more efficient wind energy production;
- ◆ help public health officials, emergency operations, and wildland firefighters visualize the extent and spread of wildfire smoke across the country during fire season.

“The HRRR is so useful in a myriad of forecast applications because it does such a good job representing all aspects of the weather—wind, precipitation, clouds, thunderstorms, even smoke—and how they evolve together in the atmosphere,” said CIRES Fellow **Stan Benjamin**, a NOAA senior scientist and a principal developer of the HRRR.

bit.ly/HRRR-model

CFC-11

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an independent one, the Advanced Global Atmospheric Gases Experiment, both detected the turnaround. A companion regional analysis by a second international team found that a decline in emissions from eastern China accounted for about 60 percent of the global changes.

The twin papers, published in *Nature* in February 2021, documented the effect of actions taken to address the first known substantive violation

of the Montreal Protocol, an international treaty tasked with ensuring stratospheric ozone layer recovery.

“This was a major test of the Montreal Protocol, and it appears to have passed,” said **Stephen Montzka**, a NOAA scientist, CIRES Fellow, and lead author of the 2018 and 2021 *Nature* papers. CIRES scientists working in NOAA’s Global Monitoring and Chemical Sciences laboratories were co-authors on both papers.

bit.ly/CFC11-decline

AWARDS AND ACHIEVEMENTS

Happy 13th birthday, CSDMS

When the Community Surface Dynamics Modeling System, CSDMS, began 13 years ago, the geoscientists involved imagined a suite of open access modeling tools, continually improved by the community, to help them study the complicated dynamics of water and sediment. The group has done much more. Now more than 2,000 strong, CSDMS (“systems”) geoscientists around the world share code, technical expertise, ideas, and friendship. “CSDMS may have set out to build software, but it ended up building a community,” CIRES Fellow **Greg Tucker** wrote in a blog post about the effort he has led since 2017.

bit.ly/CSDMSblog

Congrats

- ◆ The Heterodox Academy awarded CIRES Fellow and environmental economist **Matthew Burgess** with its 2020 Open Inquiry Award for teaching.
- ◆ The Department of Commerce recognized several NOAA science teams in Boulder with Gold, Silver, and Bronze awards for outstanding scientific research and service in 2020. Since CIRES team members cannot win these awards, they’ll receive similar CIRES medals.
- ◆ And several CIRES and NOAA scientists are recognized as 2020 Highly Cited Researchers (by Clarivate Analytics).

There’s no way we could cover all our people’s awards here. Check out our [announcements](#) for kudos and follow CIRESnews on [Facebook](#) and [Twitter](#)!

cires.colorado.edu/announcements



We miss you, Koni

Former CIRES Director **Konrad Steffen**, better known as Koni, died in Greenland in 2020, a tragic victim of one of the many crevasses that have opened up at his field site as the ice sheet has warmed. He was 68, a giant in the field of glaciology, and a friend and mentor to many. CIRES and CU Boulder have established the Konrad Steffen Climate Legacy Fund in his memory, to support the kinds of environmental research and researchers he long championed.

bit.ly/konrad-steffen-climate-legacy-fund

Photo: Jim Kastengren

Sweat + bleach = something new

Intense workouts, cleaners change chemicals in the air

AIR QUALITY

One sweaty, huffing exerciser emits as many chemicals from their body as up to five sedentary people, according to a 2020 CIRES study. And notably, those human emissions, including amino acids from sweat and acetone from breath, chemically react with bleach cleaners to form new airborne chemicals with unknown impacts on indoor air quality.

“Humans are a large source of indoor emissions,” said **Zachary Finewax**, CIRES research scientist and lead on the *Indoor Air* study. “And chemicals in indoor air don’t just disappear, they linger and react with other chemicals.”

In 2018, the CU Boulder team outfitted a weight room in the Dal Ward Athletic Center—a campus facility for student athletes—with a suite of air-sampling equipment. Instruments measured a slew of airborne chemicals in real time before, during, and after workouts of the athletes. The team found the athletes’ bodies produced 3-5 times the emissions while working out, compared to when they were at rest.

Many gyms use chlorine bleach-based products to sanitize sweaty equipment. While these cleaning products work to kill surface bacteria, they also react with emissions from sweat to form a new cocktail of chemicals.

The team was the first to observe chemicals in a group called N-chloraldimines—produced by bleach reacting with amino acids—in gym air. The impacts of these N-chloraldimines on indoor air quality are not yet clear, but chemically similar reaction products can be harmful to human health.

“Since people spend about 90 percent of our time indoors, it’s critical we understand how chemicals behave in the spaces we occupy,” said **Joost de Gouw**, CIRES Fellow and CU Boulder Professor of Chemistry. Although the researchers collected all data for this study pre-pandemic, the team says their results illustrate that a modern gym with low occupancy and good ventilation may still be relatively safe for a workout, especially if masks are used.

bit.ly/sweatbleach



CU Boulder cheerleaders work out in the Dal Ward Athletic Center in 2018. Photo: Katie Weeman/CIRES



CU Environmental Engineering assistant professor Cresten Mansfeldt collects sewage samples on the CU Boulder campus during the fall 2020 semester. Photo: Katy Human/CIRES

Sewage microbes tell stories

Class dips underground to learn more about behavior, COVID

MICROBIAL RESEARCH

Sometimes, the best way to study a community of living things is by looking at its leftovers. Just as wildlife biologists study scat to learn what a pack of predators is eating, a team of student microbiologists at CU Boulder studied the dark, slimy sewers beneath the university's campus to learn more about what people are doing above.

"Sewage systems are a unique ecosystem we don't always think about: an underground river network connecting buildings," said **Noah Fierer**, CIRES Fellow, Professor of Ecology and Evolutionary Biology, and Director of CU Boulder's Center for Microbial Exploration. "Studying the microbes in sewage allows us to monitor human populations unobtrusively."

During the fall 2020 semester, a group of Ph.D. students played the part of microbial explorers. During the student-led graduate course, the team investigated sewage samples in an open-ended, 'choose-your-own adventure' biology study. The group pored through sequenced DNA from sewage sludge, looking for patterns in the complex collage of human, plant, bacterial, and viral genetic material. They developed research questions as patterns in the samples revealed themselves.

Sewage research can uncover changes in people's diets, trends of viral transmission, or even antibiotic resistance patterns in bacteria, the team said. "You get waste matter from toilets, outflow from showers and sinks, and even

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CIRES teams expand academic opportunities for Tribal groups

EDUCATION & OUTREACH

Two new CIRES programs

established in 2020 aim to strengthen the CU Boulder's connections with Native American Tribes.

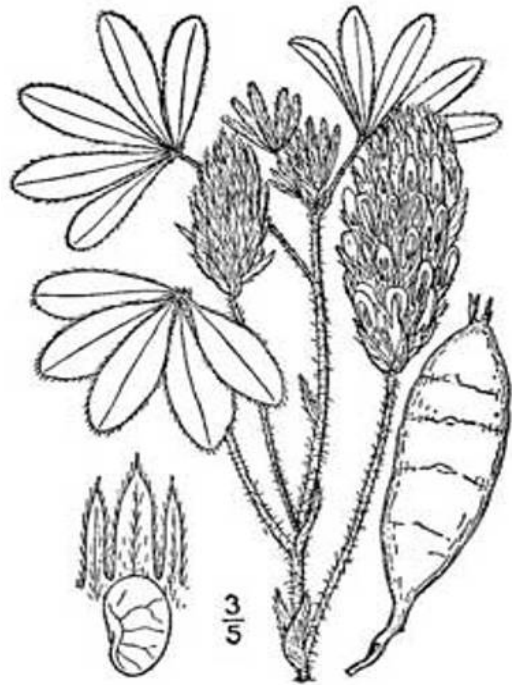
Tribal Climate Leaders Program

CIRES' North Central Climate Adaptation Science Center (NC CASC), which is a partnership with the U.S. Geological Survey, created the TCLP to support Native American students pursuing graduate degrees in fields related to climate adaptation science.

The program helps tribal student leaders “see the multiple ways in which this climate science, data, and technology can advance their leadership as tribal resource managers of the 21st century,” said **James Rattling Leaf**, a partner in the NC CASC and member of the Rosebud Sioux Tribe in South Dakota.

Will Crawford, a Dakota and enrolled tribal member, became a TCLP fellow in August 2020 to pursue a master's degree in Environmental Studies. Crawford's work involves researching past and present locations of *tipsiŋna* (prairie turnip or *Psoralea esculenta*), a perennial plant native to the original homelands of the Dakota. Historically and today, tribal members collect the plant's nutritious and protein-rich tuberous root, which can be dried and stored for future use. *Tipsiŋna* grows in unturned, rocky soils and has become more difficult to locate, especially in areas leased for agriculture and grazing. Crawford intends to use his research experience to help guide land management policies together with tribal leaders.

The relatively small amount of research being done on tribal lands has surprised Crawford, and he said he appreciates the opportunity to collaborate and share ideas with fellow Native American students. Furthermore, Crawford emphasized the importance of kinship within his Tribe, including kinship with extended family and the land itself; remote learning has given him the



Will Crawford, a graduate student in the Tribal Climate Leaders Program, is investigating the range of *tipsiŋna* or “prairie turnip.” Image: U.S. Dept. of Agriculture

advantage of remaining near the ancestral homelands that are central to his culture and research.

bit.ly/tribal-climate-leaders

Earth data science skills open doors to new careers

It can be hard to find a great earth data science skills course at some Tribal colleges and smaller schools. Yet a prerequisite for many STEM careers today is expertise in working with data. This lack of training opportunity can contribute to the lack of diversity in the technology sector.

“While there is great demand in the job market for technical earth data science skills, there is not equal access to these skills across communities and institutions,” said **Leah Wasser**, Director of Earth Analytics Education at Earth Lab, which

CONTINUED ON PAGE 17



One of the student projects for the 2020 cohort of the Earth Data Science Corps examined factors that might contribute to urban Emerald Ash Borer infestations in Minnesota. EDSC projects can be accessed here: bit.ly/EDSC-project-page. Photo: americanforests.org

Opportunities

CONTINUED FROM PAGE 16

is part of CIRES. “Many smaller institutions—which often serve underrepresented groups—suffer from the same gap we see in the workforce, where there is a lack of faculty skills to teach earth data science.”

Enter the Earth Data Science Corps (EDSC) program, funded by the National Science Foundation. EDSC increases earth data science capacity at institutions that want to offer these skills to their students but aren’t quite there yet. The program includes a combination of online data skills training for students and faculty, career-focused webinars, and project-based learning. All training materials are shared on an open education portal (<https://www.earthdatascience.org>).

In 2020, Earth Lab experts guided two dozen earth data science undergraduates from diverse backgrounds through an immersive summer internship. In addition to the training itself, the program sought to expand awareness of career pathways in earth data science, and support and boost student confidence in their new skills. This first EDSC cohort explored topics such as quantifying the impacts of flooding on tribal lands, assessing the effects of the invasive Emerald Ash Borer on urban trees, studying the South Platte River corridor to assess growing season changes due to climate change, and improving access to COVID-19 data for tribal communities.

Partner institutions include United Tribes Technical College, Oglala Lakota College, Front Range Community College, and Metropolitan State University of Denver.

bit.ly/earth-data-science-corps

Sewage

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organisms and chemicals from outdoor soil,” said Fierer.

The team took advantage of samples collected just a couple weeks earlier by **Cresten Mansfeldt**, CU Boulder Environmental Engineering assistant professor. During fall 2020, Mansfeldt and his colleagues pulled up samples daily from 20 locations across campus to look for COVID-19 in the wastewater.

In Fierer’s graduate class, one research team investigated viruses, finding that sewage from different buildings harbored distinct viral communities.

“Sewage microbes, including viruses which we studied, are still largely underexplored,” said **Corinne Walsh**, a CIRES Ph.D. student in that working group. “There’s so much left to learn.” Walsh calls the sewage samples the team studied “grab bags”—each with its own complex mix of microscopic information, with endless possibilities to explore.

John Sterrett, a CU Boulder Ph.D. student, and his group investigated bacteria in the sewage, specifically the kinds commonly found in human feces. Intuition may suggest that the more people use toilets in a building, the more fecal bacteria might be present, Sterrett said. But his team found more bacteria where fewer people lived. It appears that COVID-19 shutdowns resulted in stagnant water in some places, providing a place for certain bacteria to multiply.

bit.ly/sewage-samples



A DC-10 air tanker releases fire retardant over the 2018 Woolsey Fire near Los Angeles, California. Photo: Peter Buschmann/U.S. Forest Service

More burning issues

Researchers track smoke pollution, firestarters

New estimates of old smoke help refine atmospheric models

You may not be able to see it, but there's smoke in the air.

Globally, wildfires, agricultural burns, and residential fires contribute roughly 37 million tons of smoke particles to the atmosphere each year. Those particles block incoming sunshine from reaching the Earth's surface, influence cloud formation, and modulate climate. However, it's been tricky to see, let alone measure, smoke in the atmosphere once it dissipates downwind of fires.

"We found that, although we were often-times thousands of kilometers from active fires, one-quarter of the aerosol particles in the remote lower atmosphere originated from a fire," said **Gregory Schill**, a CIRES scientist who works in NOAA's Chemical Sciences Laboratory (CSL). Schill was one of many CIRES and NOAA scientists involved in NASA's Atmospheric Tomogra-

phy (ATom) mission from 2016-18. The team flew a DC-8 loaded with highly sensitive measuring devices on four pole-to-pole campaigns over the Atlantic and Pacific oceans. The researchers sought accurate measurements of smoke and other climate-influencing pollution in the atmosphere and then used this data to calibrate satellite estimates of the smoke and improve the skill of climate models. The goal was to better quantify our current climate and predict impacts of climate change.

Their results indicated that smoke in the background atmosphere is very dilute, but it is so widespread that its impact on the Earth's energy balance equals that of all the thick, fresh smoke plumes from active fires.

NOAA scientist **Dan Murphy**, CSL's Cloud and Aerosol Processes program leader, said the research might help us better understand possible impacts from a warmer, drier future. "If we're going to look at climate effects from wildfires and

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Burning issues

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biomass burning,” Murphy said, “we can’t ignore the dilute smoke.”

bit.ly/old-smoke

Wildfire smoke plumes rich in pollution-forming nitrous acid

Another study published in 2020 found wildfires cause a spike in nitrous acid in the atmosphere, which drives increased ozone pollution and harms air quality. “We found nitrous acid levels in wildfire plumes worldwide are two to four times higher than expected,” said CIRES Fellow Rainer Volkamer. “The chemical can ultimately drive the formation of lung- and crop-damaging ozone pollution downwind of fires.”

Nitrous acid, while abundant after wildfire, degrades quickly in sunlight, and is thus exceedingly difficult to study globally. So CIRES and CU Boulder researchers worked with European colleagues to combine two sets of data: global measurements from a satellite instrument, and those from a 2018 wildfire study in the Pacific Northwest during the BB-FLUX campaign. The team was able to compare near-simultaneous measurements made within minutes by the satellite looking down on a plume, and an aircraft-based instrument looking up into the same plume from below.

With the comparison in hand, the team could then scrutinize satellite data from wildfires in all major ecosystems across the planet to assess

nitrous acid emissions. The discovery of nitrous acid spikes and related chemistry “helps us to better keep track as photochemistry rapidly modifies emissions downwind,” Volkamer said.

bit.ly/nitrous-acid-spike

‘Smokey Bear needs to move to the suburbs’

Over the last 24 years, one million homes sat within the boundaries of wildfires, according to an analysis by EarthLab, part of CIRES. That’s five times previous estimates. And nearly 59 million more homes lay within a kilometer of fires.

The analysis didn’t just focus on proximity to fire as a threat; it found that the humans who came along with the houses caused 97 percent of home-threatening wildfires, through debris burning, equipment use, arson, and other activities. Further, most human-caused wildfires were relatively small (less than four square kilometers) but were responsible for 92% of homes threatened. About half of fire suppression costs went to protecting houses, and while the wildland-urban interface represents only 10% of U.S. land in 2010, 32% of all wildfire ignitions occur there.

The analysis dug into 1.6 million government records of wildfire ignition between 1992 and 2015; Earth Lab’s own compilation of 120,000 incident reports; and 200 million housing records from real estate database Zillow.

“Smokey Bear needs to move to the suburbs,” said lead author Nathan Mietkiewicz, a postdoc in Earth Lab. “If we can reduce the number of human-caused ignitions, we will also reduce the amount of homes threatened by wildfires.

bit.ly/smoky-suburbs



The ATom team poses in front of the mission’s DC-8 at NASA Armstrong Flight Research Center in Edwards, California upon its return from a sampling flight in 2018. Photo: Lauren Hughes/ NASA

Scientists, communities team up to navigate a new Arctic

Indigenous knowledge, social science, natural science come together in National Science Foundation's 'Big Idea'

Climate change is warming the Arctic more than twice as fast as the rest of the planet, creating great challenges for the regional communities—food security and sovereignty, coastal erosion, increased shipping traffic, and more. Now, CIRES' National Snow and Ice Data Center and Education & Outreach Program are part of a National Science Foundation-funded team connecting scientists and Arctic communities to address the region's biggest climate-related threats.

“Arctic change will fundamentally alter climate, weather, and ecosystems globally in ways that we do not yet understand but that will have profound impacts on the world's economy and security,” NSF wrote.

Navigating the New Arctic, or NNA, is one of 10 priority “Big Ideas” for the agency, and in 2021, the agency funded Alaska Pacific University

in Anchorage, the University of Alaska Fairbanks, and the University of Colorado Boulder to run the NNA's “community office,” dubbed NNA-CO.

“This office will bring people together to identify new ways to understand the holistic nature of Arctic systems, to learn from Arctic peoples who are adapting on the front lines of change, and to envision new and creative approaches to sharing knowledge across cultures and world-views,” said **Matthew Druckenmiller**, director of NNA-CO and a scientist at the National Snow and Ice Data Center.

In the five-year, nearly \$5-million cooperative agreement among three universities, NNA-CO activities will support several dozen projects, all involving:

- ◆ Co-production of knowledge with Indigenous Peoples

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The Nome River meets the Bering Sea outside of Nome, Alaska. Photo: Mwita Chacha

FROZEN LANDSCAPES

'New Arctic'

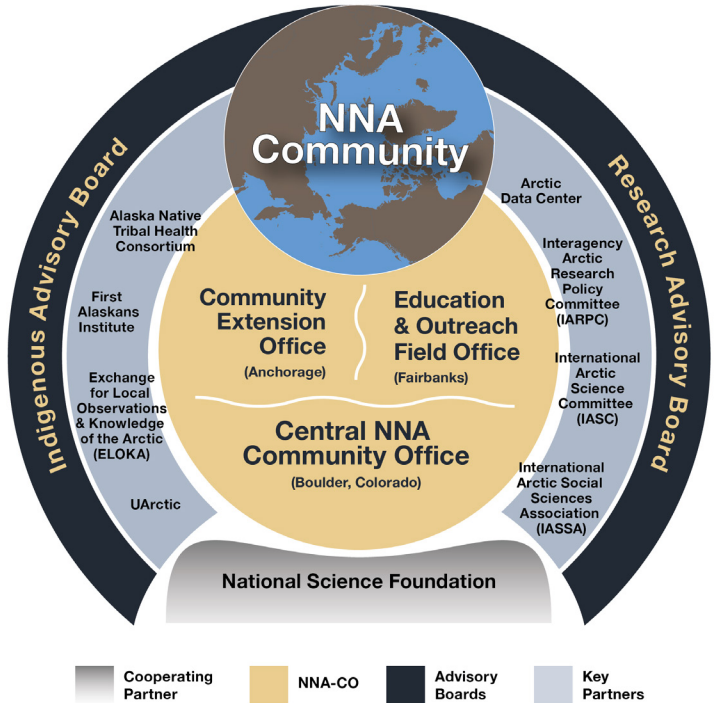
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- ◆ Convergence research, an approach to research that relies on the merging of ideas from different areas of expertise, including Indigenous knowledge
- ◆ Culturally responsive education and outreach and open science for greater integrity
- ◆ Data sharing and reproducibility across decision-making communities

For example, one of the funded projects involves CU Boulder's Institute for Arctic and Alpine Research (INSTAAR), the Yukon River Inter-Tribal Watershed Council, Northern Social-Environmental Research, the University of Alaska Fairbanks, CIRES, and CU Mechanical Engineering. Together, the team is planning to examine changes in permafrost thaw lake environments. As permafrost thaws, it releases carbon into the atmosphere and alters the landscape. Lakes can form, some emitting methane, a greenhouse gas, from the

underlying lakebeds. This creates a feedback loop of even more global warming and can put local communities at risk, rapidly shifting factors that affect subsistence hunting, drinking water quality, travel, and local economies.

[NNA-CO website: nna-co.org](http://nna-co.org)
bit.ly/permafrost-thaw



Indigenous Arctic knowledge program earns continued NSF support

In 2021, the National Science Foundation (NSF) renewed funding for five more years of the [Exchange for Local Observations and Knowledge of the Arctic \(ELOKA\)](#), a program at the National Snow and Ice Data Center (part of CIRES). ELOKA works with Indigenous organizations, community partners, and researchers across the Arctic to facilitate the collection, preservation, exchange, and use of Indigenous Knowledge and community-based observa-



tions of the Arctic. The funding will allow ELOKA to meet community information needs through new and enhanced digital tools, collaborative research, and network building, and to improve the usability of data products.

ELOKA members and their partners will engage community members, researchers, and Indigenous students in exploring options for community data management that uphold Indigenous data sovereignty.

Ice disappears, north and south

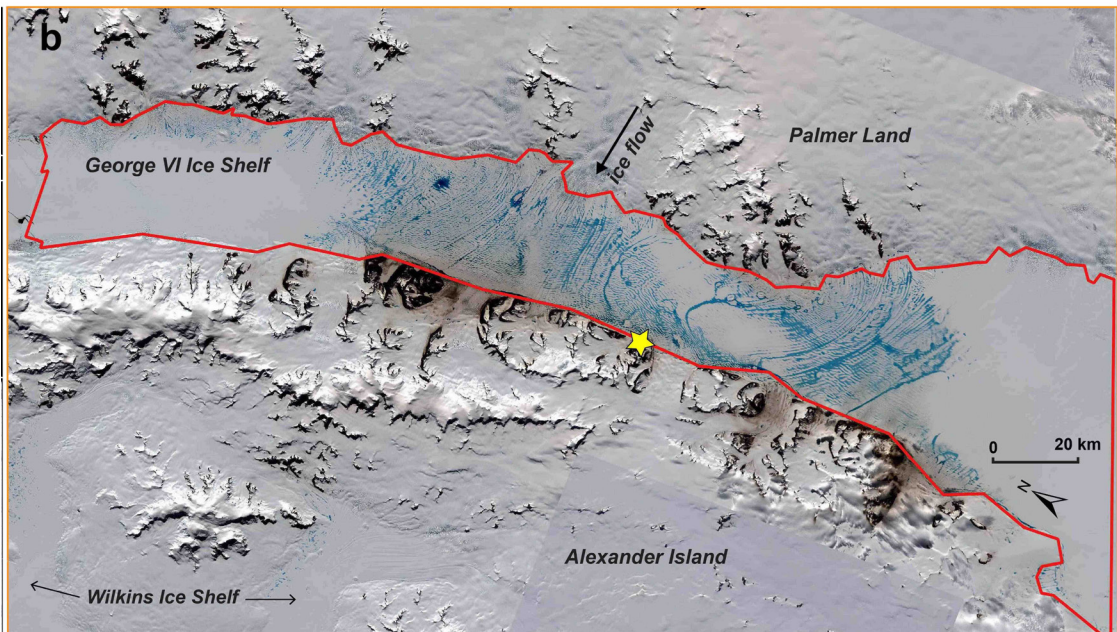
Greenland: Ice sheet mass loss reshapes coast

The shapes of the Greenland Ice Sheet edge and coastal Greenland are changing dramatically as ice loss has accelerated over the past two decades. In an October 2020 study in the *Journal of Geophysical Research: Earth Surface*, NSIDC’s **Twila Moon** and her co-authors concluded these changes could have far-reaching impacts on the local community and ecosystems.

“We can now see many signs of a transformed landscape from space. And as the ice sheet edge responds to rapid ice loss, the character and behavior of the system as a whole is changing, with the potential to influence ecosystems and people who depend on them,” said Moon.

Compiling satellite data from NASA, the U.S. Geological Survey, and other resources from 1985 to 2015, the researchers compared ice position, ice sheet surface elevation, and glacier flow. They found ice edge retreat across the entire

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A mosaic of satellite optical images taken in January 2020 shows blue surface meltwater ponds covering 23 percent of the study area in Antarctica. Image: Alison Banwell/CIRES and co-authors in bit.ly/32yr-record

Antarctica: Record-setting melt forebodes possible ice shelf breakup

Antarctica’s northern George VI Ice Shelf experienced record melting during the 2019-2020 summer season, coinciding with record-setting stretches when local surface air temperatures were at or above freezing, a CIRES-led study found. CIRES research scientist **Alison Banwell** and her co-authors—from CU Boulder,

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Researchers set up instrumentation that can detect ice in the deposits of the Flat Creek glacier detachments. Photo: Lia Lajoie/University of Montana

Glaciers may detach as climate warms

On August 5, 2013, deep in Alaska’s remote Wrangell-St. Elias National Park, a 500-yard tongue of the Flat Creek glacier broke off, unleashing a torrent of ice and rock. The debris rushed more than six miles downstream into the wilderness of the park. After a National Park Service geologist documented a similar event in 2015, he recruited CIRES Ph.D. student **Mylène Jacquemart** to investigate. “We started out thinking we were investigating a regular landslide,” Jacquemart said. “Then we noticed that the entire glacier was missing.” Her team’s results, published in *Geology* in 2020, indicate the Alaskan detachments occurred at the height of summer melt and suggest these destructive events could occur more frequently in a warming world.

bit.ly/glacier-detachment

Greenland Ice Sheet

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Greenland Ice Sheet—even in the coldest, northernmost regions.

Moon and her colleagues also observed glaciers within the same area behaving differently. Co-author **Alex Gardner** from NASA JPL attributed this to differences in ocean water properties, bedrock, and till that lie below the ice, and

how meltwater runoff is routed beneath. “Understanding the complexity of individual glacier response is critical to improving projections of ice sheet change and the associated sea-level rise that will arrive at our shores,” he said. The team’s work is bringing these complexities to light, revealing detailed changes across the full ice sheet.

bit.ly/ice-sheet-reshaping

Record-setting melt

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NSIDC, NASA Goddard, and international institutions—studied the ice shelf’s melt season using a variety of satellite observations that can detect meltwater on top of the ice and within the near-surface snow.

Surface meltwater ponding is potentially dangerous to ice shelves because when those lakes drain, the ice fractures and can trigger ice-shelf break-up. The George VI Ice Shelf buttresses large glaciers on the Antarctic Peninsula. “So if this ice shelf breaks up, ice that rests on land would flow more quickly into the ocean and contribute more to sea level rise than any other ice shelf on the Peninsula,” said Banwell, lead author of the February 2021 study published in *The Cryosphere*.

After 31 summers of dramatically less melt, the 2019-2020 melt season was the longest for the northern George VI Ice Shelf. And as air temperatures continue to warm, increased melting on this and other Antarctic ice shelves may trigger ice-shelf break-up events and ultimately sea-level rise.

bit.ly/extreme-melt

'An astonishing collection of data'

Scientific surprises, logistical challenges mark year-long international climate research project in the Arctic

For nearly 12 months, the German icebreaker *Polarstern* drifted with Arctic sea ice while scientists onboard collected petabytes of data describing the ocean, ice, and atmosphere. They built research stations on the ice, dipped nets, deployed buoys, and flew drones. Speaking more than a dozen different languages, they worked toward the same goal: Better understanding how dwindling Arctic sea ice influences the region's climate system and how those changes ripple around the world.

"We knew the ice was thinning, but it was still far more dynamic than we thought," said

Matthew Shupe, CIRES/NOAA atmospheric scientist and co-coordinator of the international Arctic mission. "The unpredictability of the Arctic is one of its characteristics right now. And we were right there in the middle of that."

On October 20, 2020, more than 380 days after leaving for the central Arctic Ocean from Tromsø, Norway, *Polarstern* returned to its home port in Bremerhaven, Germany. Local ships escorted the Alfred Wegener Institute's research vessel as it entered the harbor.

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Atmospheric scientists Alex Schulz and Sandro Dahlke deflate 'Miss Piggy', a weather balloon used to deploy instruments that help the scientists understand atmospheric properties like temperature and turbulence. Photo: Lianna Nixon/CIRES and CU Boulder



MOSAic scientists begin to dismantle and move instruments out on the melting ice during the latter part of the expedition. Photo: Lianna Nixon/CIRES and CU Boulder

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U.S. scientists on the German-led mission, dubbed MOSAic—the Multidisciplinary Drifting Observatory for the Study of Arctic Climate—said they will spend years, possibly even decades studying the data they collected from their year on the ice.

For some, those data tell a story of dynamism: The sea ice moved more than expected, fracturing into long, narrow cracks hundreds of miles long, then closing, ridging, and generally creating a messy, rough icescape. **Jennifer Hutchings**, a sea ice expert from Oregon State University, said she and her colleagues will gain new insight into the tricky physical dynamics of how sea ice fractures under the forces of wind and ocean motion. That’s significant, because “sea ice is one of the most important components of the Arctic climate system. It modulates the ‘talking’ between the ocean and the atmosphere,” Hutchings said.

For other scientists, the surprise was the relative calm: When the ice began melting in the

spring, for example, gases trapped in the ocean below didn’t immediately diffuse out into the air, as expected. Instead, lenses of cold freshwater several feet thick capped the seawater, restricting the upward movement of some gases. “This certainly took us by surprise,” said **Steve Archer**, a biogeochemist with Bigelow Laboratory for Ocean Sciences in Maine. “We expected to see a big peak in gas flux rates in the spring. We think it didn’t happen, and this is a feature of the central Arctic that we did not appreciate.”

The National Science Foundation was the lead U.S. funder of MOSAic, supporting dozens of researchers with about \$27 million, putting it among the agency’s largest Arctic research initiatives. The U.S. Department of Energy invested nearly \$10 million and provided the largest suite of atmospheric instruments for the research mission.

“Direct observations and physical samples collected during the MOSAic expedition represent

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CIRES/NOAA scientist Matt Shupe drives a snowmobile toward one of the expedition's research sites on the ice.
Photo: Lianna Nixon/CIRES and CU Boulder

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a quantum leap in our understanding of natural processes and cycles in the central Arctic Ocean across all seasons,” said **Frank Rack**, NSF’s Arctic Research Support and Logistics Manager. Winter

Permafrost thaw releases mercury, affecting fish

In Alaska, thawing permafrost may release so much mercury into the environment that by 2050, fish in the Yukon River may exceed EPA’s human-health-based standards for the toxin. That’s one consequence of unrestrained greenhouse gas emissions, according to a September 2020 study led by NSIDC’s **Kevin Schaefer**. Arctic warming is already thawing permafrost, and that can release mercury currently frozen in soils into the air and water—and eventually, into tissues of fish—at dangerous levels. Under a high emissions scenario, annual releases of mercury into the atmosphere could rival global anthropogenic emissions by 2200.

measurements are especially valuable because they’re so rare, Rack added.

Data sets that researchers imagined would be continuous for the entire year do have some gaps, however. Polar bears occasionally disrupted research on the ice, delaying instrument repairs or atmospheric balloon launches. Storms broke up scientific “cities” on the ice that required relocation or repair. Most significantly, the ship had to leave the ice for about a month last spring, to exchange staff while responding to the challenges of the global coronavirus pandemic.

Some systems remained on or below the ice, autonomously collecting data. Other projects paused briefly. “We lost all our June data,” said **Jeff Bowman**, an ecologist and oceanographer at the Scripps Institution of Oceanography, University of California San Diego. “But considering the global disruptions, when all is said and done, it will still be an astonishing collection of data.”

MOSAIC data will “aid in the development of improved models, forecasts and future predictions,” said NSF’s Rack. All MOSAIC data will be available for free to researchers around the world.

bit.ly/MOSAIC-ends



Photo: Shutterstock

Pandemic leaves its mark: airborne spread, air quality

Initial work on coronavirus-related shutdowns suggests decreases in some air pollutants

When global COVID-19 shutdowns and economic slowdowns reduced car and air travel, shipping, manufacturing and more, CIRES and NOAA researchers tuned their instruments to look at the impacts on greenhouse gases and common air pollutants.

Some results are in already: Levels of ozone pollution in the lower atmosphere fell by seven

percent across much of the Northern Hemisphere, according to one paper, for example. Researchers from the German weather service Deutscher Wetterdienst, with CIRES and NOAA scientists, analyzed ozone data collected from balloon soundings and remote sensing instruments during the shutdowns. They published

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Paolo Wilczak, a pilot with Scientific Aviation, flies an air sampling mission over Groton, Connecticut, as part of the East Coast Outflow experiment on April 25, 2020. Credit: Paulo Wilczak/Scientific Aviation

Impacts

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their work in an early 2021 *Geophysical Research Letters* paper.

Another team of NOAA and CIRES scientists found COVID-19 shutdowns contributed to decreases in most air pollutants. The researchers analyzed 200 peer-reviewed papers that examined post-lockdown changes in levels of common pollutants, including PM_{2.5}, nitrogen oxides, and ozone, and published their review in an April 2021 *Elementa* paper.

Other studies are ongoing. Researchers in NOAA's Global Monitoring Laboratory, which has continued to capture almost all of its normal long-term observations, sampled the air over several large East Coast cities in the spring of 2020 to measure changes in greenhouse gas emissions, including carbon dioxide and methane.

And in NOAA's Chemical Sciences Laboratory, scientists are observing how a smaller, later rush hour in Boulder could affect air quality by changing the composition, timing, and quantity of emissions.

NOAA's National Centers for Environmental Information will archive observations and findings generated by these research efforts.

bit.ly/COVID-environment

bit.ly/COVID-econ-slowdown

Fewer commercial airplanes in the sky last year caused a dip in weather model accuracy

Weather observations from commercial aircraft are key to short-range weather prediction over North America. But in mid-2020 during the COVID-19 pandemic, disruptions in air travel cut these routine aircraft observations by about 75 percent.

Researchers from CIRES and NOAA's Global Systems Laboratory examined how those missing data affected forecast accuracy for NOAA's short-term weather model, the Rapid Refresh model. The team found a reduction in short-range forecast skill of about 12 percent across summer and winter, with temperature, winds, and relative humidity factored in. NOAA's National Weather Service said official forecast accuracy wasn't affected. That's because meteorologists rely on several weather prediction models for their forecasts, plus observations from weather stations, radar, satellites, weather balloons, and ocean buoys.

The October 2020 study was published in the *Journal of Applied Meteorology and Climatology*.



An unmasked Swedish choir singers practices outdoors near Stockholm City Hall as churches are closed during the COVID-19 epidemic. Photo: Shutterstock

Yes, COVID spreads by aerosol

Research showing airborne transmission is crucial to curbing more infections

When the coronavirus pandemic began in early 2020, people faced a constant barrage of decisions: How dangerous is it to teach or attend class? To march in a demonstration? Governments and leaders faced choices, too: Require face masks? Close schools?

Recognizing the desperate need for reliable information, CIRES Fellow and atmospheric

chemist **José-Luis Jimenez** pivoted his work to the field of viral transmission. To him and other experts, it seemed the virus was moving around in a recognizable way: as an aerosol, a tiny particle in the air. Cigarette smoke, composed of similarly small particles, was a good analogy: If a person a few steps away was smoking, could you smell the smoke? Then you're too close for COVID-19.

Developing tools

Within three months, Jimenez and colleagues could pin numbers on their growing understand-

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Webinars, toolkits, mentoring, workshops sustain learning

CIRES Education & Outreach experts meet the quarantine-inspired demand for virtual science education from home

“Now what?”

When quarantine restrictions descended in March 2020, educators and students were thrust suddenly into fully remote learning. The CIRES Education and Outreach team (E&O) pivoted to serve the new needs of teachers and homebound families, dishing up digital resources and other content to help keep science education engaging and fun.

The transition to online platforms also expanded E&O’s reach to students and teachers who might not have been able to participate before. More participants from more places could take advantage of high-quality, low-cost education and enrichment offerings in STEM through the following CIRES E&O programs.

Science@Home

Within weeks of COVID-19-related school shutdowns across the country, E&O quickly organized and launched bi-weekly webinars as a virtual tour of the science done at CIRES. CIRES, NOAA, and other local scientists discussed their research and how they became scientists, followed by live Q&A sessions with classrooms, kids, and families in webinars from April through December 2020. Each webinar presentation was supported by educational resources (lessons, activities, supplemental videos, etc.) for different age levels, and in the fall, half the seminars were in Spanish.

The series was a hit: Between 25 and 50 kids, adults, and classrooms attended the webinars live, and many more watched the recordings. As of March 2021, Science@Home English webpages had logged more than 7,000 pageviews; Science@Home Spanish tallied 2,300; and the

videos on YouTube have amassed nearly 1,500 total views.

The series is expected to return in 2021.

bit.ly/CIRES-science-at-home

bit.ly/CIRES-ciencia-en-casa

Virtual Ocean Bowl

Since 1999, E&O has hosted the National Ocean Sciences Bowl (NOSB), a regional competition for high school students studying oceanography and related topics. In 2021, NOSB went virtual as students competed in their knowledge around Polar Oceans.

Although fewer teams competed overall, the new format allowed some teams to enter for the first time. “Teams could compete at no cost and with no travel, which really opened up our ability to recruit new teams from further away,” said **Amanda Morton**, former regional coordinator for the NOSB. “In fact, the team that won was a first-time team from Gillette, Wyoming.”

E&O is applying lessons learned from developing this virtual competition to provide more opportunities for rural and out-of state teams.

bit.ly/ocean-bowl

Climate Literacy and Energy Awareness Network (CLEAN)

With the explosion of virtual education, an increasing number of teachers have turned to CLEAN, a toolkit of more than 700 activities focused on climate topics. CIRES curates the collection, reviewing new entries for quality and scientific accuracy as well as for effectiveness and classroom readiness. E&O experts also run webinars to help teachers understand the

CONTINUED ON PAGE 31



The 2020 RECCS cohort meets during summer 2020 via Zoom.

Participants include:

Top row, left to right: Aislynn Connell/Pikes Peak Community College; Anne Gold/E&O Director; Alicia Christensen/ E&O Program Manager; Crystal Gonzalez/ Community College of Aurora. Second row: Kokolah Sherzad/

Community College of Denver (CCD); LeAnna Warren/Front Range Community College (FRCC); Magdalena Franchois/Red Rocks Community College; Matthew Martinez/Arapahoe Community College. Third row: Meliah Dubus/FRCC; Christina Waddle/University of the Ozarks, Arkansas; Mai

Abdelrahman/CCD; Daniel De Souza/Northeastern Junior College, Sterling, Colorado (NJC). Fourth row: Sydney Crites/NJC; Riley Breshears/FRCC; Elizabeth Mathews/Lamar Community College; Kyle Greaves/FRCC. Bottom row: Joshua Morlan/Otero Junior College, La Junta; Bec Batchelor/E&O Associate.

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resources. “When before we’d typically have at most 50 people registered, we started seeing registration numbers jump to more like 75-100 people,” said **Katie Boyd**, the CLEAN program manager. The CLEAN resource collection saw more than 65,000 visits each month in 2020.

bit.ly/CLEAN-network

Research Experience for Community College Students (RECCS)

Normally, CIRES hosts 15 community college students every summer, giving them paid, hands-on research experiences in the field. In 2020, students could participate virtually in a condensed, two-week experience and then defer full participation until 2021 as well. During the shorter virtual program, the students each

worked with a mentor to analyze data and synthesize their research into a scientific poster. They said that their participation influenced their research skills, understanding of the research process, and their intent to proceed in STEM fields.

Moreover, program staff became more confident in creating a supportive and engaged cohort virtually. Applying what the RECCS team learned during 2020, they will offer online training in summer 2021, and most student projects will include both in-person and virtual research. “We can serve students who may not have been able to participate in the full in-person experience due to a lack of child care, transportation, or other barriers,” said RECCS Program Manager **Alicia Christensen**. “This program model really opens up the research experience to a lot more

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Education

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students, which helps us diversify the geosciences with people from a wide variety of backgrounds.”

bit.ly/CIRES-RECCS

Teacher Professional Development Workshops

Each year, E&O typically holds in-person professional development workshops for educators around Colorado. That wasn't possible during pandemic restrictions, but shifting to virtual

platforms opened up the opportunity for teachers from across the country to participate. For example, “Arctic Feedbacks” and “Exploring the New and Old Arctic,” curricula developed around the MOSAiC expedition, engaged participants from every U.S. time zone (including Alaska and Hawaii) and several other countries. Webpages for these curricula drew more than 2,500 pageviews and curriculum documents were accessed more than 1,500 times.

Curriculum developer **Jon Griffith** said he is looking forward to “creating new partnerships as we connect classrooms to high quality climate curricula via in-person and virtual formats.”

bit.ly/teacher-PDW

Aerosol

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ing of aerosol transmission, releasing a “COVID Aerosol Transmission Estimator” to help individuals and institutions understand risk. The free model lets users tweak inputs to ask, for example, what's my risk if I wear a cloth mask vs. a perfectly fitting N-95? Get on a bus vs. sing with friends outdoors?

Since its 2020 release, the Estimator has served hundreds of thousands of users. Jimenez and his colleagues update the model and a list of answers to Frequently Asked Questions as scientific understanding of the COVID virus evolves.

The case of the choir

In March 2020, one person with mild COVID-19 symptoms attended choir practice in Skagit Valley, Washington. In the weeks that followed, more than 50 other people from that rehearsal would contract the disease, and two died. Participants had sanitized hands and did not touch each other, but they sang for more than two hours indoors, unmasked.

CU Boulder's **Shelly Miller** (an expert on air quality indoors and outdoors), Jimenez, and several other colleagues came together to assess the superspreader event. Their findings challenged the assertion that transmission of the coronavirus is primarily through fomites (infectious droplets on surfaces) or ballistic droplets (large

droplets from sneezing or coughing)—neither could explain the Skagit Choir cases. Aerosol transmission could.

Taking action

Jimenez and his colleagues became advocates for science, asking organizations like the World Health Organization and the U.S. Centers for Disease Control and Prevention to acknowledge aerosol transmission. The distinction is critical: If a disease is spread primarily by fomites or large droplets, cleaning, handwashing, and distancing can be highly effective against spread. But if the disease is transmitted primarily by aerosol, masks, ventilation, and other protocols would better protect people. CDC acknowledged in October 2020 that aerosol transmission could occur, but did not change recommendations for workplace safety. In February 2021, Jimenez and his colleagues urged the Biden administration to take smarter action against airborne transmission of the virus. And in an April 2021 assessment in the medical journal *Lancet*, Jimenez and other experts outlined the consistent, strong evidence that SARS-CoV-2 is predominantly transmitted through the air. Their “10 Reasons Why...” paper drew widespread attention around the world.

[Airborne Transmission Tool: tinyurl.com/covid-estimator](https://AirborneTransmissionTool.tinyurl.com/covid-estimator)

FAQs on protecting yourself from aerosol transmission: tinyurl.com/faqs-aerosol

bit.ly/case-of-choir

Lancet paper: bit.ly/10-reasons-why-airborne



One for the books

How do you upcycle an old four-poster bed? Russ Schnell has an answer for you.

Resident researchers at the South Pole can battle *Deranged Killer Monster Snow Goons* with Calvin and Hobbes; flip through *How to Win at Gin Rummy* to dominate the next card game; imagine Nigeria through Chinua Achebe’s classic *Things Fall Apart*; or relive the campfire scene in *Blazing Saddles* via DVD, all thanks to CIRES senior scientist Russ Schnell.

These are offerings inside the Little Free Library that Schnell built and shipped to NOAA’s Atmospheric Research Observatory in Antarctica. The library, a wooden cupboard, functions as a kind of serendipitous medicine cabinet for readers. The prescriptions are books and other media, shared among anyone at the facility, no checkout lists, no late fees.

The observatory’s Little Library is one of more than 43 Schnell built, including libraries scattered about Colorado’s Front Range and the CU Boulder campus; at the Cree First Nation Reserve and other locations in Alberta, Canada; Swansea, Wales; St. Louis and University City, Missouri; the Warrnambool Art Gallery in Warrnambool, Australia; Bolinas, California; and near Mt. Fuji, Japan. As of this writing, he has four more libraries awaiting installation, including one in Gula, Uganda, and three under

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Russ Schnell poses with a library he installed on a First Nations Reserve in Maskwacis, Alberta, in September 2019. A local retired teacher keeps it filled with her many boxes of children’s books. All photos courtesy Russ Schnell



The Little Library Schnell shipped to NOAA’s Atmospheric Research Observatory at the South Pole shares space with an instrument that measures human-made atmospheric trace gases that destroy ozone.



Libraries await delivery to Canada (two), California (one), and northern Colorado (four in this photo and two under construction) in December 2020. Schnell is continually fielding requests for more and began searching out the recycled material to construct them.



Above left: Books aren't all the libraries have to offer: Schnell converted this small, non-working refrigerator into a Little Free Pantry to offer food to people in need due to fallout from the COVID pandemic. The pantry is in his Boulder front yard beside a busy sidewalk, and neighbors help keep it stocked.



Above, right: Yukiko Dokiya, a retired Japanese professor, anticipates transporting this Little Library to Mount Fuji in the summer of 2021 or when logistics and weather permit. Its destination will be the Mount Fuji Research Station near the top of the mountain, 12,388 ft. above sea level. Schnell built and delivered the library to Japan in September 2019.

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construction. Schnell has begun collecting materials for three more.

Schnell builds the libraries exclusively from recycled materials, with the exception of about 100 new screws each to hold them together. One library takes 20-40 hours to build. Once, a woman relocating to a senior living facility gave him her old four-poster bed in exchange for helping her move some of her belongings. He constructed three libraries from its lumber.

He built his first Little Library for his daughter, Alicia, who wanted to get books into the hands of kids in her St. Louis neighborhood who might not have them otherwise. Alicia can fill a shopping cart for \$15 on “media day” at Goodwill. She sets out 30-40 books at a time, and anyone can help themselves—including the trick-or-treaters who opted for a good read with their candy.

During his non-Little Library-building career, Schnell’s research has included biological ice nucleants, black carbon measurements at the South Pole, ozone destruction

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TO FIND OUT MORE about how you can build, install, support or sponsor your own Little Free Library, check out littlefreelibrary.org.

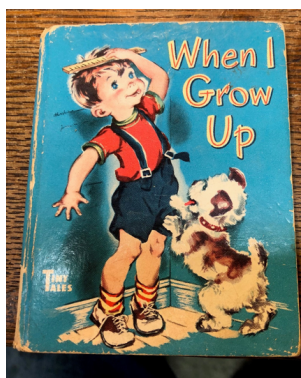


Children display the books they selected on opening day at a Little Library installed at an elementary school yard in South St. Louis, Missouri; Schnell's daughter Alicia regularly stocks it.

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in Antarctica, and global atmospheric gas and aerosol measurements. His association with CIRES began in 1979, and he was a CIRES Fellow from 1985 through 1991. From 1992 to 2019, he worked with NOAA as director of the Mauna Loa Observatory, Hilo, Hawaii, served as associate director of the Global Monitoring Division/Laboratory, and is now back with CIRES.

Because sharing books has become a passion with Schnell, we asked him what book was his



favorite. His response:

“The one book that I remember the best and that has the most meaning to me still, is probably the only book with color pictures I had as a child. It is titled *When I Grow Up*, measures 3” x 4”, has 20 color pages showing drawings of careers such as autogiro pilot, uniformed elevator operator, a man who nails shoes, a boy selling papers on a street, and a fireman. I had passed it on to a younger

sister when I left home, who gave it back to me 65 years later.”



Algae help melt snow

CLIMATE CHANGE AND CRYOSPHERE

Red and green algae growing on snow on the Antarctic Peninsula absorb more sunlight than the white snow itself, and cause significant extra melt, according to research led by Alia Khan, an affiliate scientist at CIRES' National Snow and Ice Data Center and assistant professor at Western Washington University. Antarctic snows are expected to see more and more algal blooms as the planet continues to warm, and that will further exacerbate seasonal snowmelt, the team concluded in a 2021 paper in *The Cryosphere*. The phenomena will let ice-free areas in the Antarctic Peninsula expand, they wrote, and could have serious impacts on regional climate, snow and ice melt, and freshwater availability. Photo: Bob Gilmore/NSIDC

bit.ly/antarctic-algae

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