That Vast Mass

Melting
is already
undoubtedly
and dramatically
underway.

Glaciers are spitting
icebergs into the ocean
and scurrying back up
their narrow fjords
like rats up drainpipes.

Giant lakes are forming
on the frozen surface,
sending torrents
of water plunging
through fissures
in the ice sheet
and thus, perhaps,
accelerating its slipping
and sliding seawards.

Over the past four summers,
Greenland has shed
an average of between
380 billion tonnes
and 490 billion tonnes
of ice each year —
on average 150
billion tonnes more
than it gains
in snow in winter.

That's a lot
of water.

To get the best overview
of the great Greenland meltdown,
you need to go to space
and look for gravity.

The Gravity Recovery

and Climate Experiment
(GRACE) is a pair of
US–German satellites
that orbit Earth
500 kilometres up,
one close behind the other.

Through constant
interchange of microwaves
the satellites measure
the distance between
them very precisely,
and that distance changes
as massive objects below
tug at the leader
and the follower
in slightly different ways
at any given instant.

The small discrepancies
so produced
can be used to calculate
a gravity map
for the planet.

As masses
move around,
that map will change.

Isabella Velicogna
of the University
of California, Irvine,
leads a group that takes
a large-scale approach
averaging the global
gravity numbers
provided by GRACE
for each 30-day period.

Her latest estimate suggests
that 211 billion
tonnes of ice
are being lost
each year,
mainly
from southern Greenland.

Scott Luthcke
of NASA's Goddard
Space Flight Center
in Greenbelt, Maryland
takes a different tack,
using the changing distance
between the satellites
to calculate the pull
of smaller mass
concentrations
on the ground
over time.

Including the 2017
melt season,
he gets preliminary
estimates of 154 billion
tonnes of ice lost per year.

GRACE is also providing
clues as to how
the situation varies
from year to year —
particularly for the last
melt season,
when surface temperatures
were 4–6 °C higher
than average
and during which
500 billion tonnes
of ice vanished.

That's 30% more
than the previous year,
and 4% more
than the previous record,
set in 2015.

“2017 was a shocking year,”
says Luthcke.

And GRACE's findings
are bolstered by observations
of dramatic ice losses
by other satellites.

Radar measurements,
for instance,
have shown that glaciers
in southern Greenland
are dumping ice
into the ocean
ever more quickly.

One reason why
extra information is needed
to supplement the data
from GRACE
is the problem of
'post-glacial rebound'.

As big as
Greenland's ice sheet
is today, in the
ice age it was just
part of something far bigger,
ice that reached
as far south as
the Ohio Valley
and as far east
as the Urals.

That vast mass
pressed the crust
beneath it down
into the denser
mantle below.

Although most
of the ice has long
since disappeared,
large parts
of the high-latitude
crust have yet
to recover from this
repressed position.

Scandinavia,
for instance,
rises 9 millimetres higher
every year
as the denser mantle

pushes the lighter
crust back up.

This ongoing bounceback
makes analysing the GRACE
data harder.

Help may soon come
from a system
of global-positioning receivers
that have just been installed
around Greenland to measure
how the bedrock is rising
over time.

The Greenland
GPS Network (GNET)
is one of the northern components
of a two-pole effort
called POLENET
to measure
post-glacial rebound
and other phenomena.

The GNET stations are strung
along the rocky margin
of Greenland mainly
in remote areas.

They require a lot
of battery capacity
to continue operating
throughout the winter months,
and links
to five of the stations
installed last summer
have already
gone down.

The GNET receivers
are expensive,
highly precise,
heavy and,
in principle,
durable.

Another monitoring strategy
takes the opposite tack;
it uses GPS equipment
cheap enough to lose,
embedded at the calving fronts
of some of Greenland's
most active
'outlet glaciers'.

These are
the thick streams
of ice that flow
through narrow fjords
into the oceans
surrounding Greenland.

A decade ago,
researchers thought that
these outlet glaciers
moved slowly,
creeping downward
from the high centre
of the ice sheet.

In recent years, though,
the glaciers have been doing
a veritable hokey-cokey
on their approach
to the ocean,
first advancing rapidly,
then pulling back.

“A decade ago, nobody
would have anticipated
one of Greenland's
biggest outlet glaciers
doubling its speed.”

Faster glacier movement
means more ice
dumped into the ocean,
and a thinning
of the central ice sheet
from which the glaciers feed.

The back-and-forth
of the outlet glaciers
has a lot to do with
the geometry of the fjords
the ice squeezes through.

The glaciers
inch forward
until their ends
finally break off,
calving icebergs
into the ocean.

This relieves stress
on the glacier,
which begins to surge,
much as removing
a buttress
holding up
a rickety old house
will cause the house
to collapse.

But the scenario
is not as clear-cut
as it might seem.

In the past, glaciers
advanced and then calved
off icebergs
when they got too long.

Now, the calving happens
while the glacier is advancing.

What this means
is unclear,
but it does suggest
that the glaciers
are behaving
in a fundamentally
different manner
than just a few years earlier.

The water that surrounds
Greenland has been there

forever.

More novel
is the increasing
amount of water which,
in summer,
sits on top of it.

What starts out in the winter
as cold white snow
ends up in the summer
as a landscape
of blue water,
as more than
1,000 shallow
melt lakes
up to 5 kilometres across
form on the ice.

It is like Minnesota —
but white.

2017 was a particularly
good year to study
this surface melting,
because there was
a great deal of it.

High-pressure
weather systems
throughout much
of the summer
kept storms away,
allowed the Sun
to beat down
on the ice
almost without cease.

The melt season
lasted 25–30 days
longer than average,
and 19,000 square kilometres
turned from ice to water.

The effect
was particularly noticeable

at higher elevations;
as warm air
swept ever higher,
the area that melted
at 2,000 metres or greater
was 150% larger
than normal.

Even in a normal
May to August
field season,
researchers have to make sure
that their instruments
stay anchored
on the ice sheet,
planting their poles
2–3 metres deep
to make sure
they can withstand
the melt.

It's not just the water
that makes things
difficult — it's the
unpredictability.

Melt lakes
have been known
to drain away tens
of millions of cubic
metres of water
in the space
of a day,
swirling down
some unknown drain
channel in the ice.

Huge waterfalls appear
and then disappear
overnight.

How exactly the water
gets from the top
of the ice
to its bowels
isn't known,

but understanding
the plumbing
could help illuminate
a crucial question —
does the water
that reaches
the bottom
of the ice sheet
lubricate it in a way
that encourages
movement and collapse?