which has already occurred would be expected during the 21

century

Based just on the established physics of the amount of heat CO

absorbs and emits, a doubling of

[Figure ]

.

Warming due to the addition of large amounts of greenhouse gases to the atmosphere can be understood

ampliﬁcation by any other effects, cause a global average temperature increase of about 1 °C (1.8 °F).

in terms of very basic properties of greenhouse gases. It will in turn lead to many changes in natural

However, the total amount of warming from a given amount of emissions depends on chains of effects

climate processes, with a net effect of amplifying the warming. The size of the warming that will be

(feedbacks) that can individually either amplify or diminish the initial warming.

experienced depends largely on the amount of greenhouse gases accumulating in the atmosphere and

hence on the trajectory of emissions. If the total cumulative emissions since 1875 are kept below about

900 gigatonnes (900 billion tonnes) of carbon, then there is a two-thirds chance of keeping the rise in

global average temperature since the pre-industrial period below 2 °C (3.6 °F). However, two-thirds of this

figure .

If emissions continue

amount has already been emitted. A target of keeping global average temperature rise below 1.5 °C (2.7 °F)

on their present trajectory, without

would allow for even less total cumulative emissions since 1875.

either technological or regulatory

abatement, then the best estimate

2

is that global average temperature

atmospheric CO

concentration from preindustrial levels (up to about 560 ppm) would by itself, without

2

will warm a further 2.6 to 4.8 °C

(4.7 to 8.6 °F) by the end of the

century (right). Land areas are

projected to warm more than ocean

areas and hence more than the

The most important amplifying feedback is caused by water vapour, which is a potent greenhouse gas. As

expected to decrease with additional warming,

global mean. The ﬁgure on the left

CO

increases and warms the atmosphere, the warmer air can hold more moisture and trap more heat in

leading to faster increases in atmospheric

2

shows projected warming with very

the lower atmosphere. Also, as Arctic sea ice and glaciers melt, more sunlight is absorbed into the darker

CO

and faster warming. Models vary in their

aggressive emissions reductions.

underlying land and ocean surfaces, causing further warming and further melting of ice and snow. The

projections of how much additional warming

The ﬁgures represent multi-model

estimates of temperature averages

biggest uncertainty in our understanding of feedbacks relates to clouds (which can have both positive and

to expect, but all such models agree that the

for 2081-2100 compared to

negative feedbacks), and how the properties of clouds will change in response to climate change.

overall net effect of feedbacks is to amplify

1986–2005. Source: IPCC AR5

Other important feedbacks involve the

carbon cycle. Currently the land and oceans

together absorb about half of the CO

emitted

2

from human activities, but the capacities of

land and ocean to store additional carbon are

2

the warming.

Climate Change

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st

cal or regulatory abatement, then warming of 2.6 to 4.8 °C (4.7 to 8.6 °F) in addition to that

Very conﬁdent. If emissions continue on their present trajectory, without either technologi-

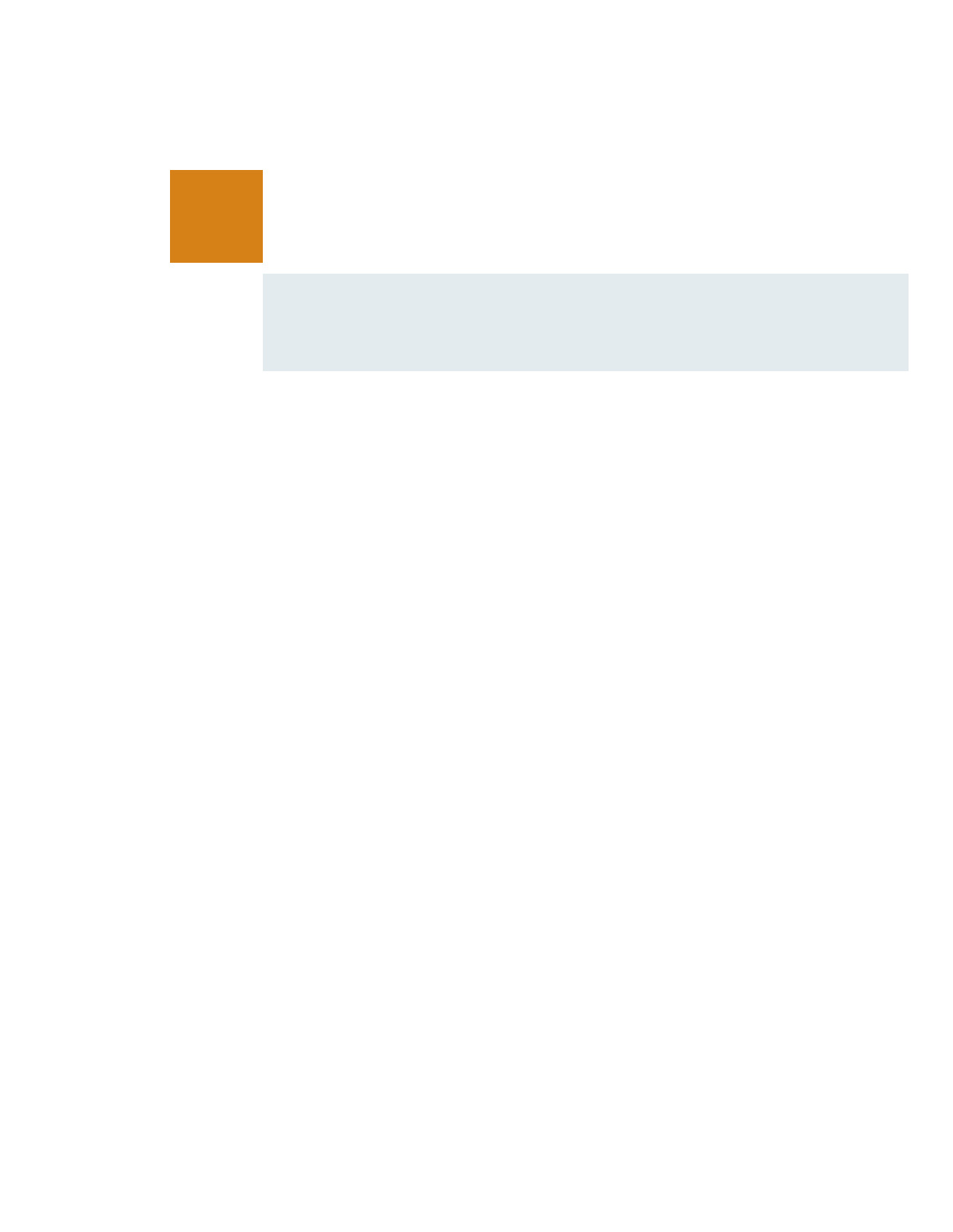
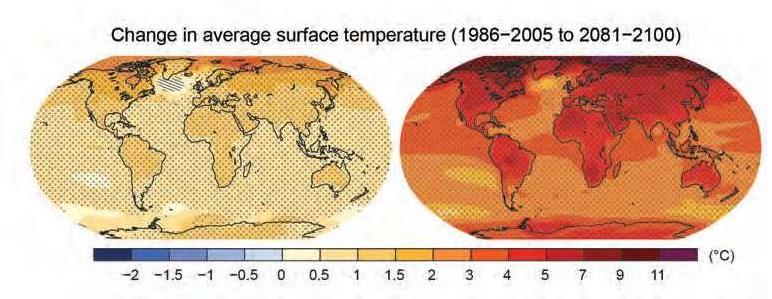
coming century?

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Earth will warm further over the

How confident are scientists that

n Q& A



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Evidence & Causes 2020

continued

of active research.

regional-to-local spatial scales and cloud responses to climate change, which are all areas

Examples include natural climate variations on decadal-to-centennial timescales and

Nevertheless, understanding of certain aspects of climate change remains incomplete.

greenhouse gases is robust and has been conﬁrmed by a growing body of evidence.

prediction. The prediction of a long-term trend in global warming from increasing

Science is a continual process of observation, understanding, modelling, testing, and

understanding of the climate system?

18

address key uncertainties in our

What are scientists doing to

adapt, posing greater risks in areas vulnerable to more intense extreme weather events and rising sea levels.

mean that less time is available to allow for adaptation measures to be put in place or for ecosystems to

at which this warming occurs is also important (see Question 6). Rapid human-caused climate changes

It is not only an increase of a few degrees in global average temperature that is cause for concern—the pace

long-term consequences overall will be disruptive.

living in low-lying areas. Even though certain regions may realise some local beneﬁt from the warming, the

freshwater supplies, coastal infrastructure, and especially the welfare of the huge population currently

These impacts are expected to increase with greater warming and will threaten food production,

have become heavier, and snowpacks (an important source of freshwater for many regions) are decreasing.

record low temperatures, wet areas are becoming wetter as dry areas are becoming drier, heavy rainstorms

coastal inundation and storm surge). Already, record high temperatures are on average signiﬁcantly outpacing

extreme weather events, ocean acidiﬁcation, melting glaciers, and rising sea levels (which increases the risk of

over land than oceans, moistening of the atmosphere, shifts in regional precipitation patterns, increases in

Both theory and direct observations have conﬁrmed that global warming is associated with greater warming

natural world.

as sea level rise and storm surge) will have serious impacts on human societies and the

with increases in some types of extreme weather events. These and other changes (such

with widespread changes in regional and local temperature and precipitation as well as

5 °C (7 to 9 °F) colder than now. Global warming of just a few degrees will be associated

sound like much, global average temperature during the last ice age was only about 4 to

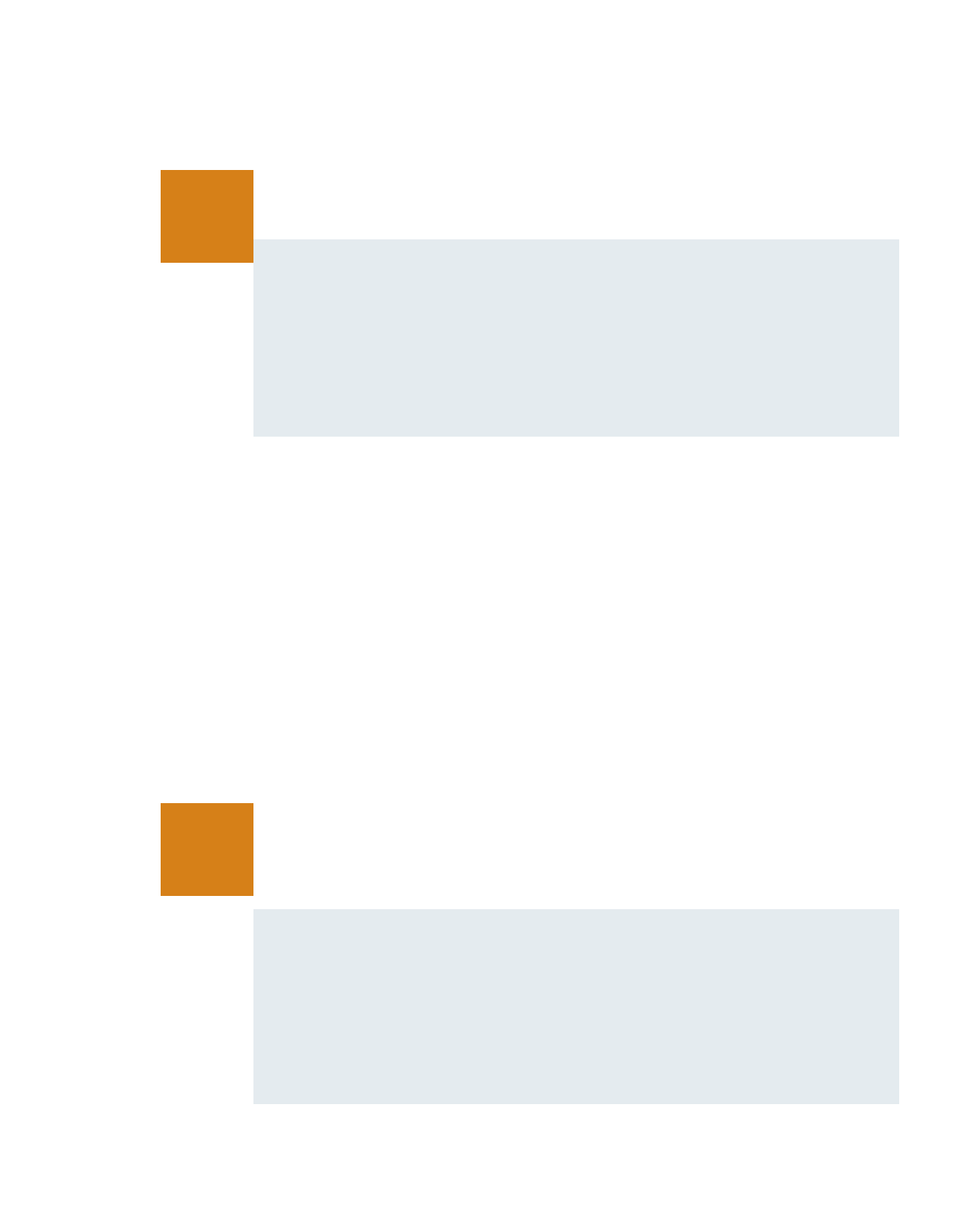
Yes. Even though an increase of a few degrees in global average temperature does not

17

a cause for concern?

Are climate changes of a few degrees

Q& A n



models are capable of performing reliably under a wide range of conditions.

way of checking that we understand how different processes work and that

Studying how climate responded to major changes in the past is another

mechanisms.

that are robust and that can be interpreted in terms of known physical

models help scientists to identify aspects of climate change projections

change. Additionally, large archives of results from many different

estimates to be made of the uncertainties in projections of future climate

can focus on the relevant processes. Differences among models allow

diagnosing the causes of differences among models, so that research

in bringing out the strengths and weaknesses of various models and

and with observations. Such opportunities are of tremendous beneﬁt

world’s major Earth-System Models and compare them with each other

and scientists are now able to analyse results from essentially all of the

Dozens of groups and research institutions work on climate models,

of these processes to be resolved in the new generation of models.

models can resolve. Greater computer power is already allowing for some

and the many cloud processes occur on scales smaller than most current

in part because different cloud types have different impacts on climate,

warming remains one of the major challenges for global climate models,

Simulating how clouds will change with warming and in turn may affect

regional and local scales important for policy decisions.

climate change and associated changes in severe weather, especially at the

and transport of heat into the oceans. This is critical for accurately simulating

of key processes in them, especially those associated with clouds, aerosols,

to advance models of Earth’s climate system and to improve representation

Together, ﬁeld and laboratory data and theoretical understanding are used

surprises.

the present rapid rate of increasing atmospheric CO

has

interactions among them. The most comprehensive

2

no precise analogues in the past, nor can it be properly

climate models, Earth-System Models, are designed

understood through laboratory experiments. As we are

to simulate Earth’s climate system with as much detail

also unable to carry out deliberate controlled experiments

as is permitted by our understanding and by available

on Earth itself, computer models are among the most

supercomputers.

important tools used to study Earth’s climate system.

Climate models are based on mathematical equations

since the 1960s. Using physics-based equations, the

that represent the best understanding of the basic

models can be tested and are successful in simulating

laws of physics, chemistry, and biology that govern the

a broad range of weather and climate variations, for

behaviour of the atmosphere, ocean, land surface, ice,

example from individual storms, jet stream meanders,

and other parts of the climate system, as well as the

El Niño events, and the climate of the last century.

The capability of climate models has improved steadily

Their projections of the most prominent features of the

long-term human-induced climate change signal have

remained robust, as generations of increasingly complex

models yield richer details of the change. They are also

used to perform experiments to

isolate speciﬁc causes

of climate change

and to explore the

consequences of

different scenarios of

future greenhouse gas

emissions and other

inﬂuences on climate.

Clim ate Change

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land, and ice—is therefore critical, as the climate system may be full of

The future evolution of Earth’s climate as it responds to

monitoring of the entire climate system—the atmosphere, oceans,

study climate change?

our understanding. This helps to set priorities for new research. Vigilant

Why are computer models used to

well-understood and, at the same time, reveal uncertainties or gaps in

Comparisons of model predictions with observations identify what is

n Q& A

