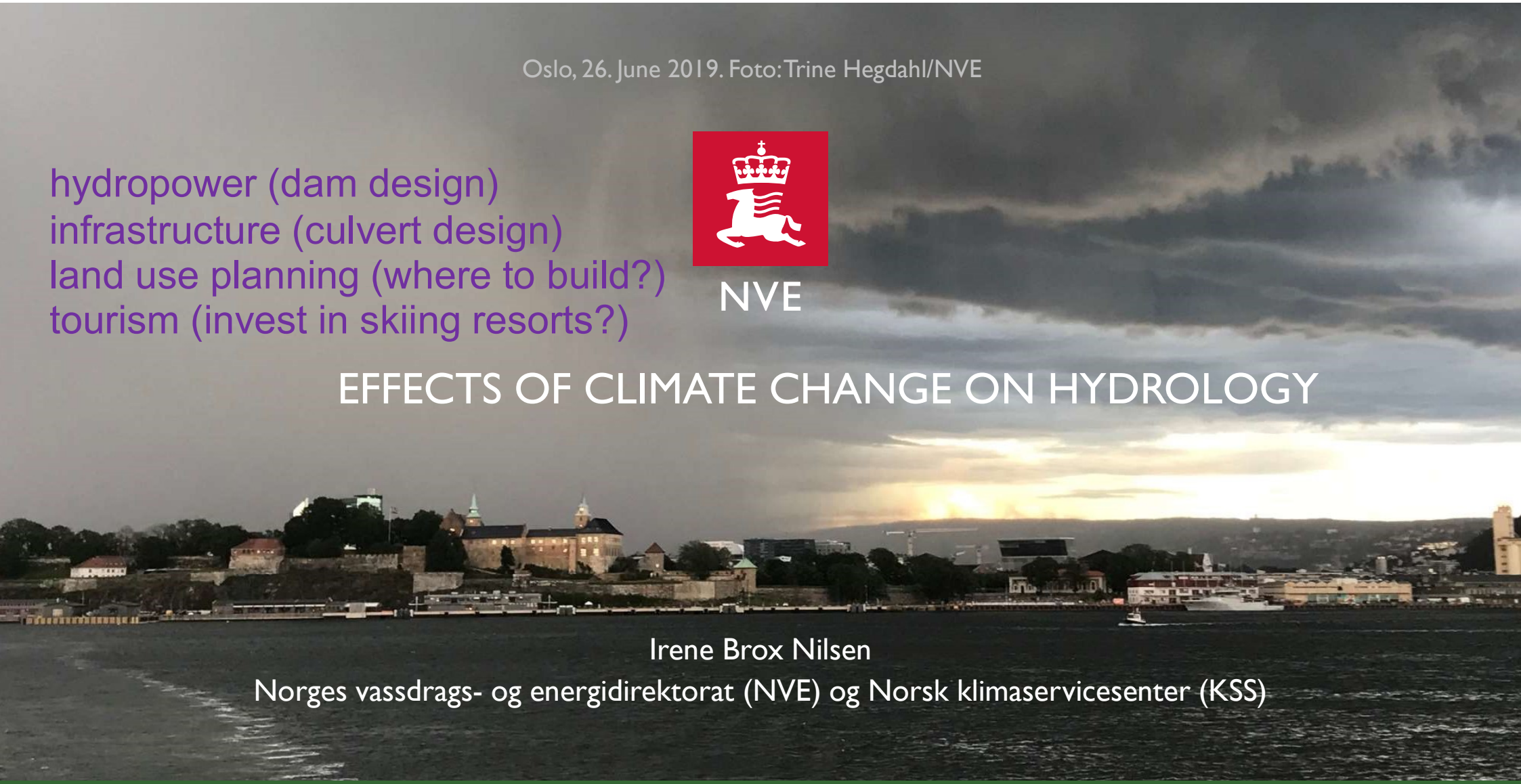

hydropower (dam design)
infrastructure (culvert design)
land use planning (where to build?)
tourism (invest in skiing resorts?)

NVE

EFFECTS OF CLIMATE CHANGE ON HYDROLOGY

Irene Brox Nilsen
Norges vassdrags- og energidirektorat (NVE) og Norsk klimaservicesenter (KSS)

NORSK KLIMASERVICESENTER

Meteorologisk institutt

Norges vassdrags- og energidirektorat

NORCE

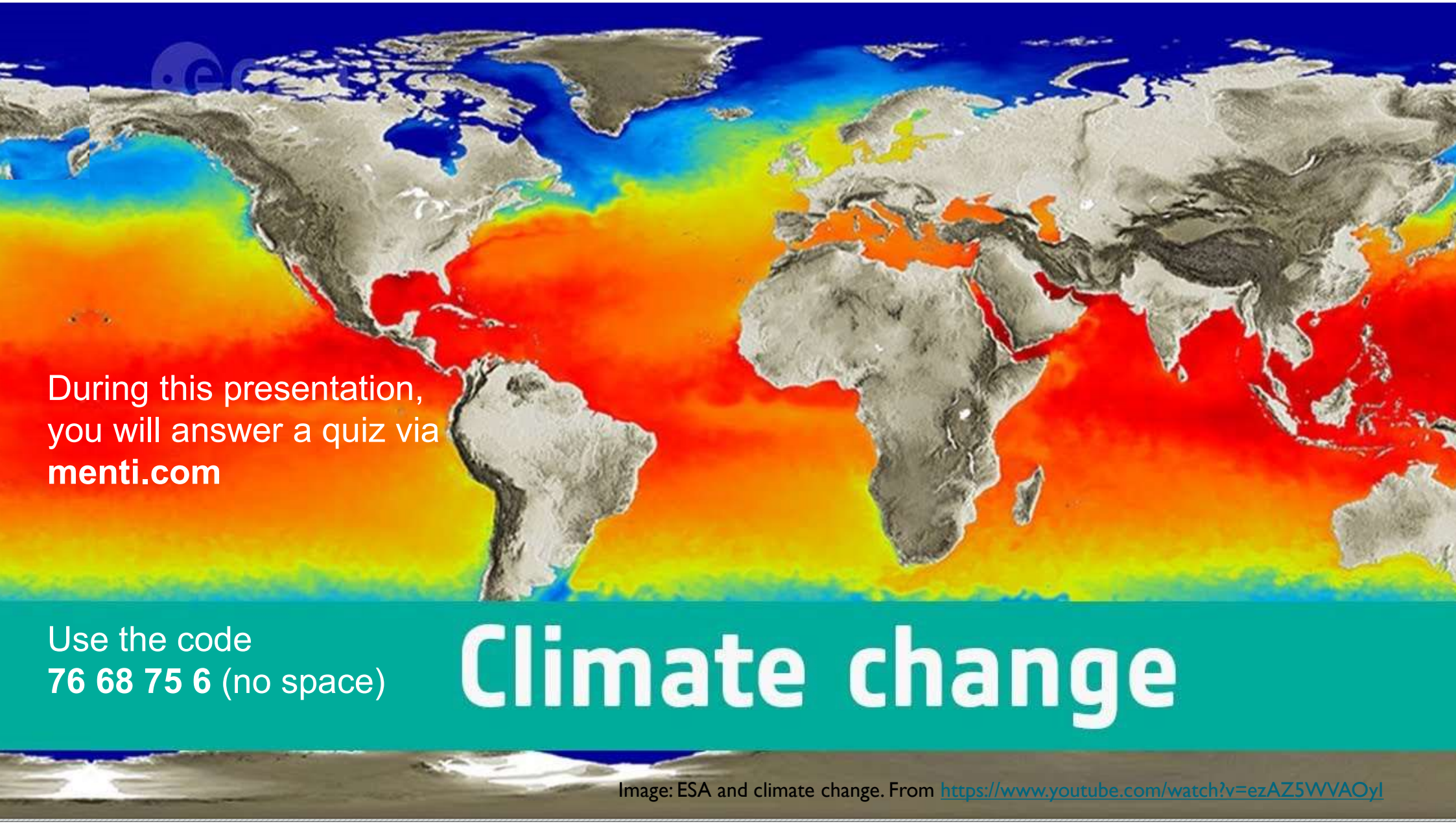

Image: ESA and climate change. From https://www.youtube.com/watch?v=ezAZ5WVAOyI

Q1: How much warming has Norway experienced compared to the global average warming (for the last three decades)?

A) There has been an equal warming for Norway and the global average
B) The warming for Norway has been greater than the global
C) The global average warming has been greater than that for Norway

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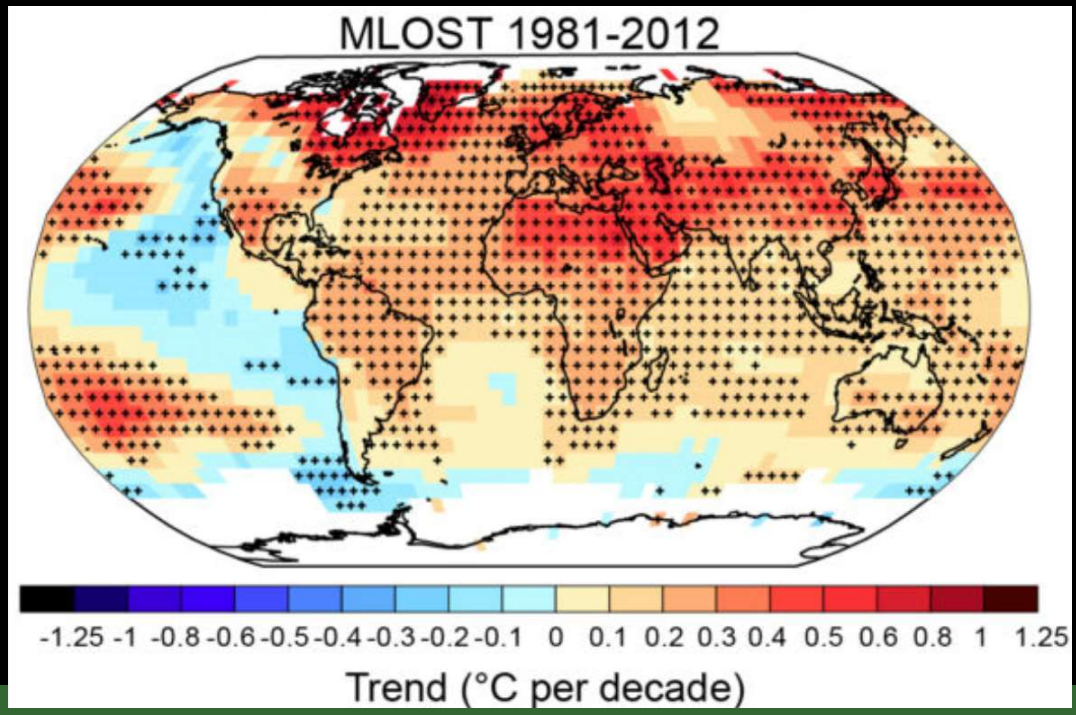
Q1: How much warming has Norway experienced compared to the global average warming (for the last three decades)?

A) There has been an equal warming for Norway and the global average
B) The warming for Norway has been greater than the global (correct)
C) The global average warming has been greater than that for Norway

Changes in snow and ice is one of the **causes** of the accelerated warming in Norway

Further changes in snow and ice conditions is one of the **consequences** of it.
-> feedback



IPCC, AR5, figure 2.22

Spørsmål 1: Hvor mye har temperaturen i Norge økt sammenlignet med resten av verden (i løpet av de siste tre tiårene)?

A) Det har vært større oppvarming i Norge (riktig svar)
B) Det har vært mindre oppvarming i Norge
C) Oppvarming i Norge og resten av verden har vært like stor

Endringer i snø og is er en av **årsakene** til den store oppvarmingen i Norge

Ytterligere endringer i snø- og isforhold er en av **konsekvensene** av den store oppvarmingen i Norge

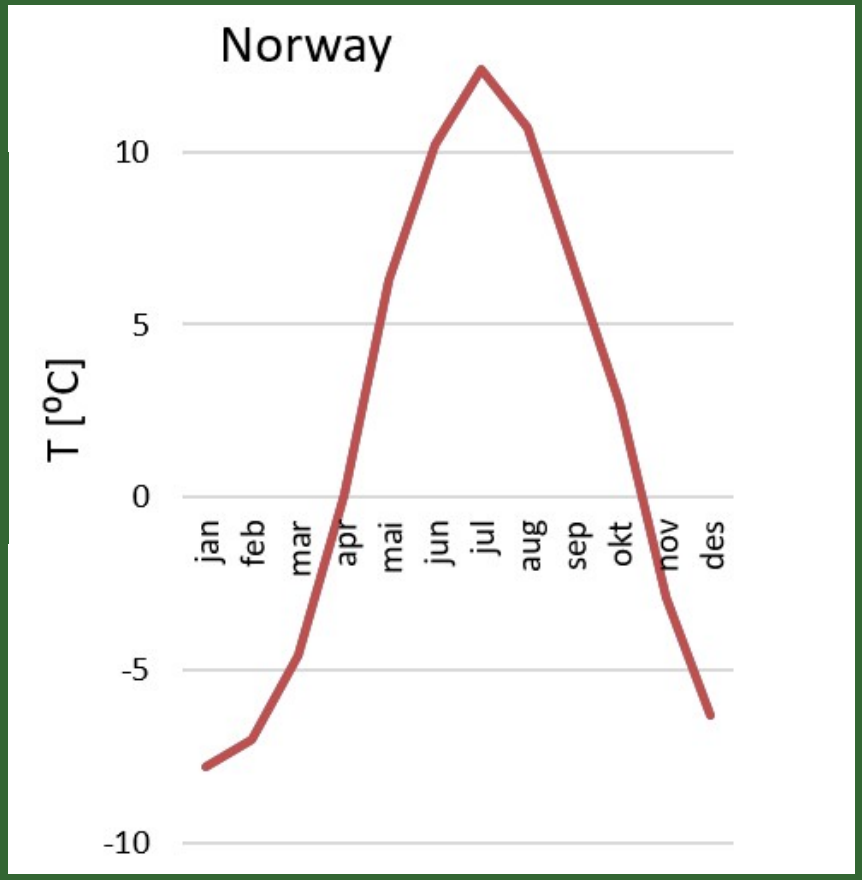
Fra IPCCs, femte hovedrapport, figur 2.22

Poll 1: Will I need an umbrella this afternoon?

<– Initial conditions

Forcing –>

Poll 2: Will I need to pack a warm jacket for my christmas holiday?



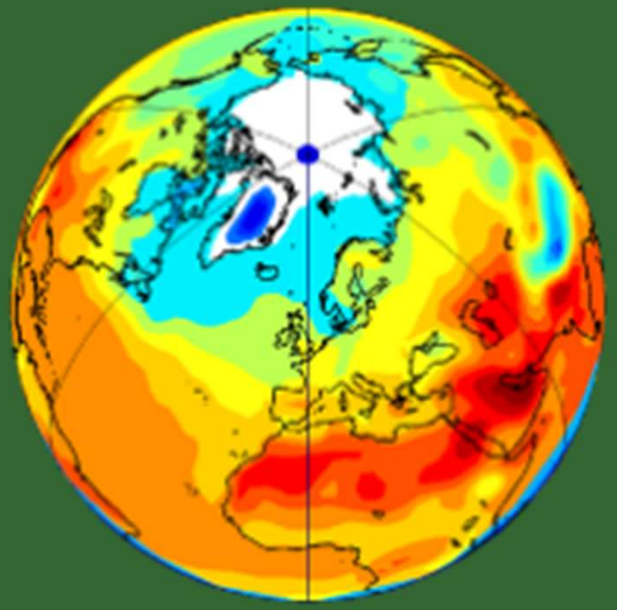
Q2: What is the difference between a weather foreast model and a climate model?

Although weather forecast models and climate models consist of the same physical equations, their purpose are different

Weather forecast models tell you when events happen,
1-10 days in advance

<– Initial conditions

Forcing –>



Climate models tell you about long-term weather statistics (anomalies).
They are more predictable on longer time scales.

Climate Change

Weather and climate models 1

Since many people mix the terms weather and climate, we first explanation the differences.

Weather consists of the short-term (minutes to months) changes in the atmosphere. Weather is described in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure, as in high and low pressure. In most places weather changes from minute-to-minute, hour-to-hour, day-to-day, and season-to-season. Weather is predictable up to about 2 weeks ahead in the mid-latitudes and in the tropics somewhat longer.

Climate is the description of the long-term pattern of weather in a particular area. Climate is the average weather for a particular region and time period, and the probability of extremes. Usually a period of 30-years is used to describe the climate. Examples of described climate variables are precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hail storms.

In the following slides we will explain the difference between weather and climate models.

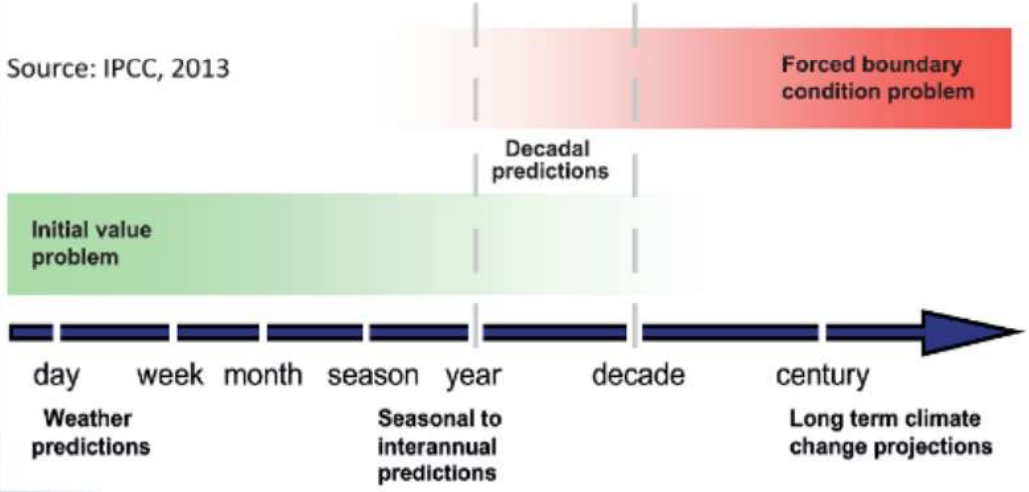
ECMWF Copernicus Europe's eyes on Earth European Commission

Climate Change

Weather and climate models 2

Weather and climate models are based on the same basic laws of physics, fluid motion, and chemistry.

A **weather forecast model** provides forecasts from a few hours to about 15 days ahead, while a climate projection covers a much longer time range and can go up to hundreds of years ahead. In a weather model, we care about **when and where** a storm or front occurs. Since the weather of tomorrow depends strongly on the weather of today, the initial conditions for the simulation of the weather are very important *(***initial value problem**).



Model-based weather forecasts are generally less reliable beyond a week, because the atmosphere is an inherently chaotic system. Small changes in observed conditions, which are fed to the model regularly, can produce completely different weather forecasts a week into the future, because the atmosphere is very dynamic.

Seneviratne et al., 2010

Q2: Which of the arrows show the greenhouse effect?

A) Solar radiation down (SW down)

B) Reflected solar radiation (SW up)

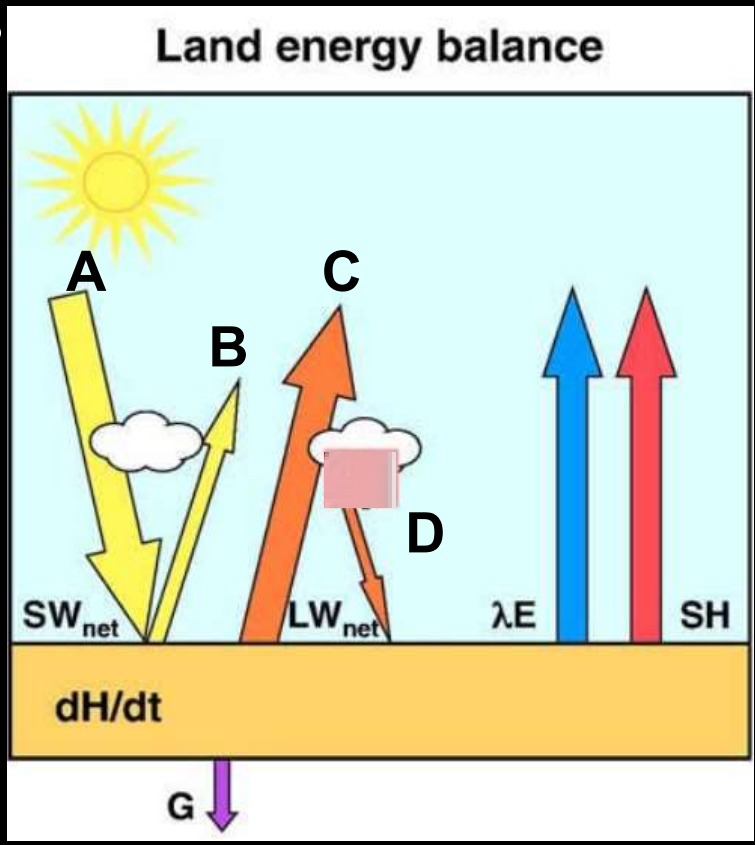
C) Longwave radiation up (LW up)

D) Longwave radiation down (LW down)

E) Latent heat (λE)

F) Sensible heat (SH)

G) Grund heat (G)



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Seneviratne et al., 2010

Q2: Which of the arrows show the greenhouse effect?

A) Solar radiation down (SW down)

B) Reflected solar radiation (SW up)

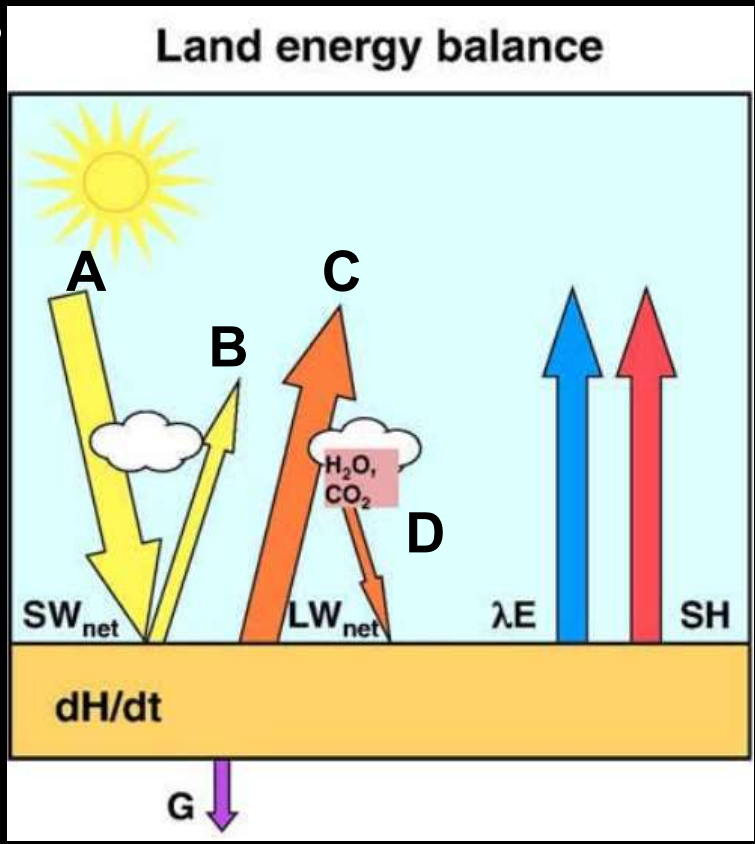
C) Longwave radiation up (LW up)

D) Longwave radiation down (LW down) (correct)

E) Latent heat (λE)

F) Sensible heat (SH)

G) Grund heat (G)



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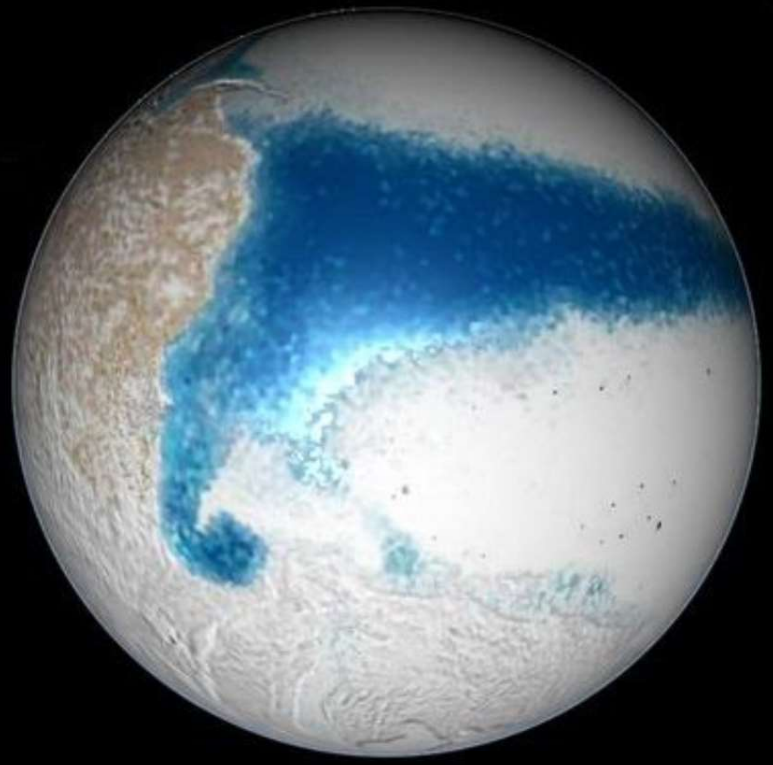
Q3: What would the mean temperature be if the globe was covered in ice?

A) 0 °C

B) –18 °C

C) –40 °C



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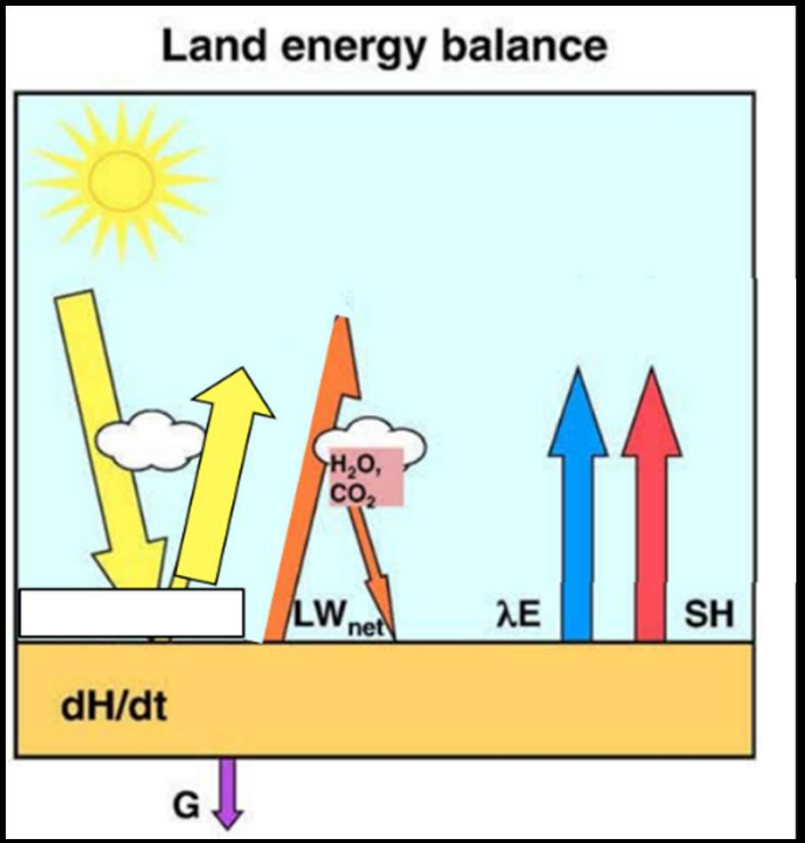


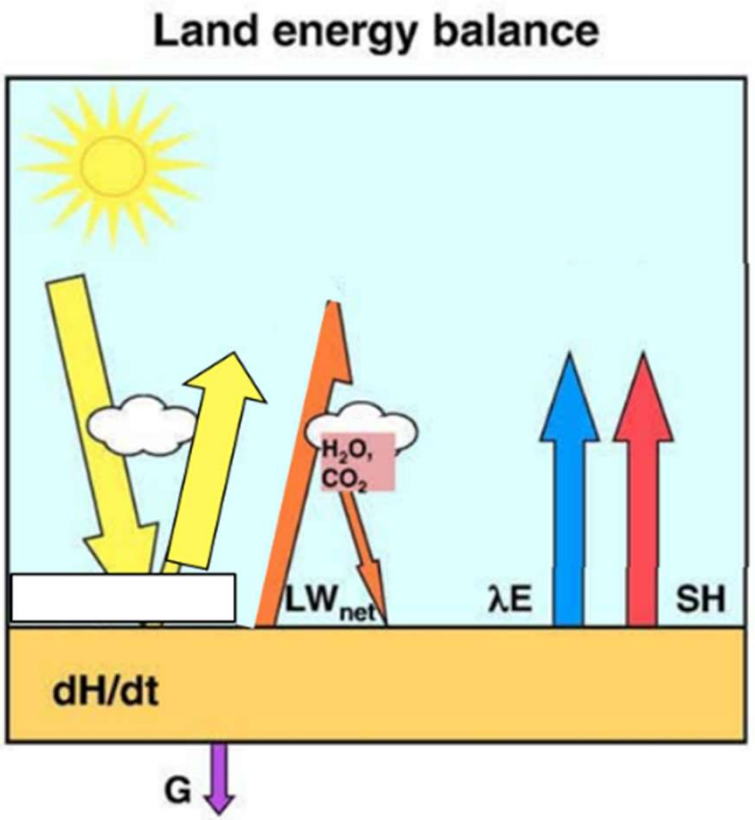
Seneviratne et al., 2010

Hva hadde middeltemperaturen på jorda vært…?

Middeltemperatur = +15 °C

Middeltemperatur **uten drivhuseffekt** = **–18 °C**

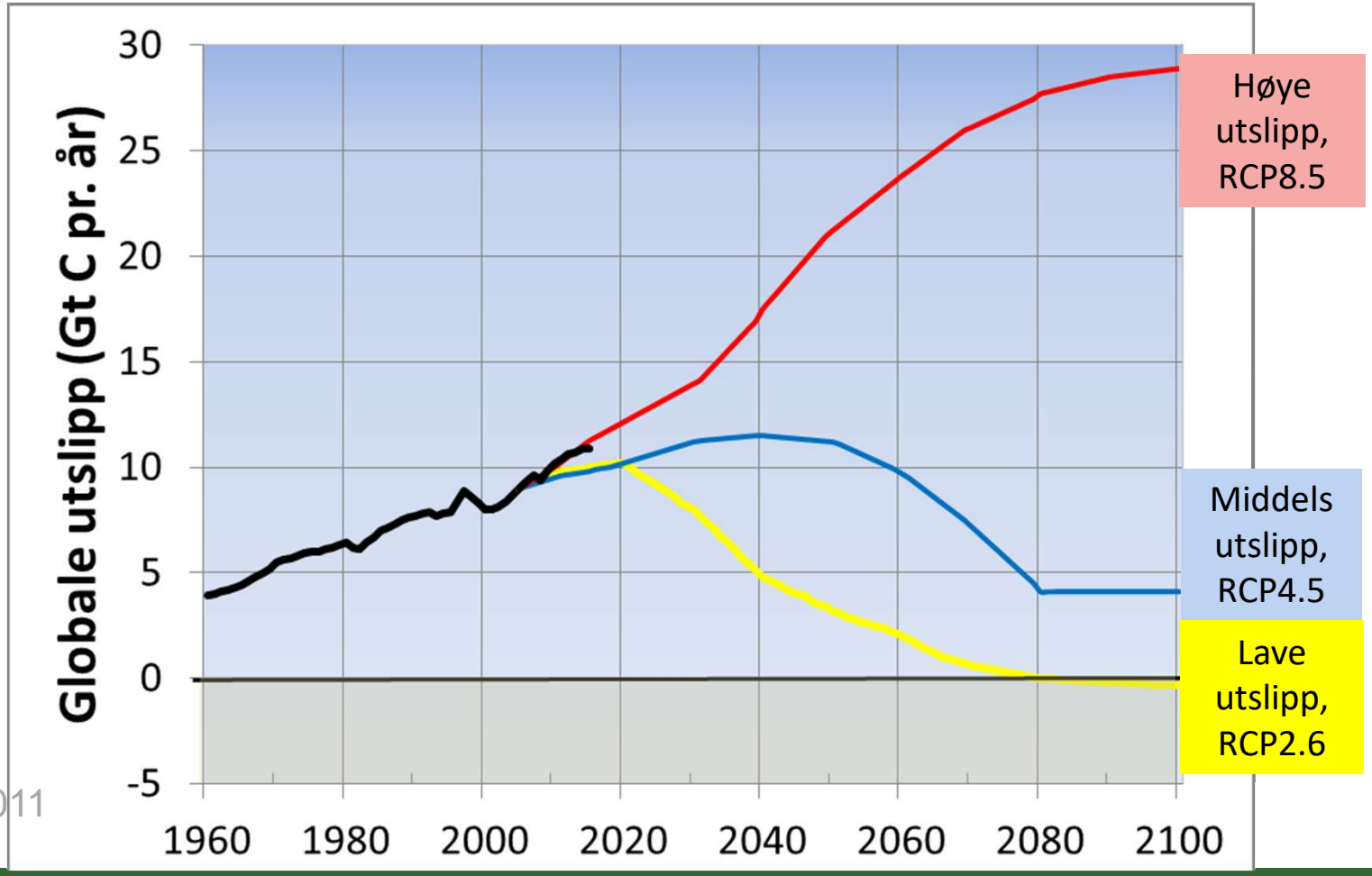
Middeltemperatur **om jorda var dekket av is/snø** = **–40 °C**



Q4: Do winter and summer temperatures in Norway change equally much towards the end of the century?

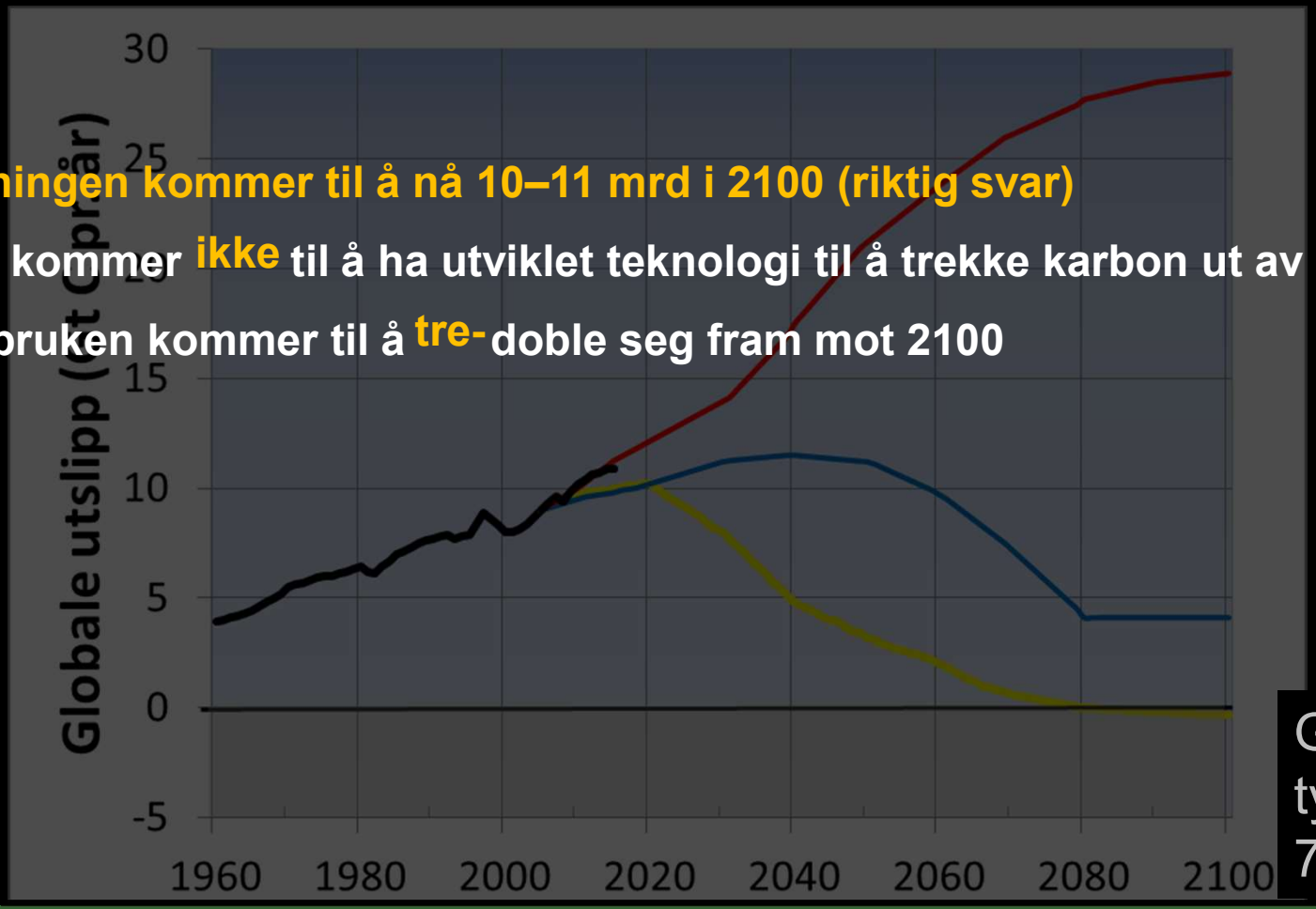
A) summer temperatures increase most
B) winter temperatures increase most
C) summer and winter temperatures increase equally much

Climate scenarios depend on assumptions on future population, technology and energy consumption



Van Vuuren et al., 2011

Spørsmål 5: Hvilke antakelser ligger bak det høye utslippsscenariet?



A) Befolkningen kommer til å nå 10–11 mrd i 2100 (riktig svar)

B) Verden kommer ikke til å ha utviklet teknologi til å trekke karbon ut av atmosfæren

C) Energibruken kommer til å tre- doble seg fram mot 2100

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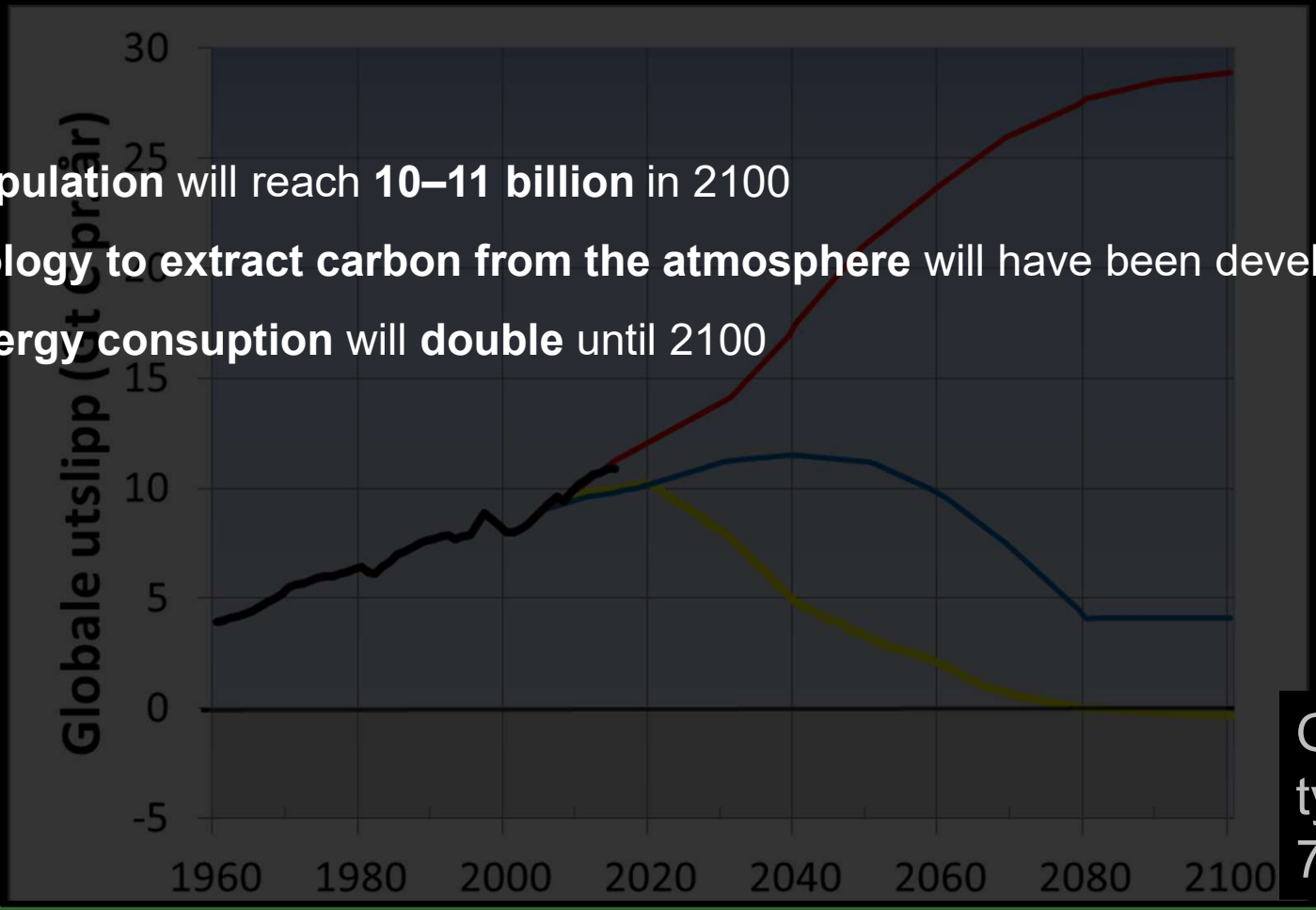
Q4: Which assumptions lie behind the high emission scenario?



A) The population will reach **10–11 billion** in 2100

B) Technology to extract carbon from the atmosphere will have been developed

C) The energy consuption will **double** until 2100

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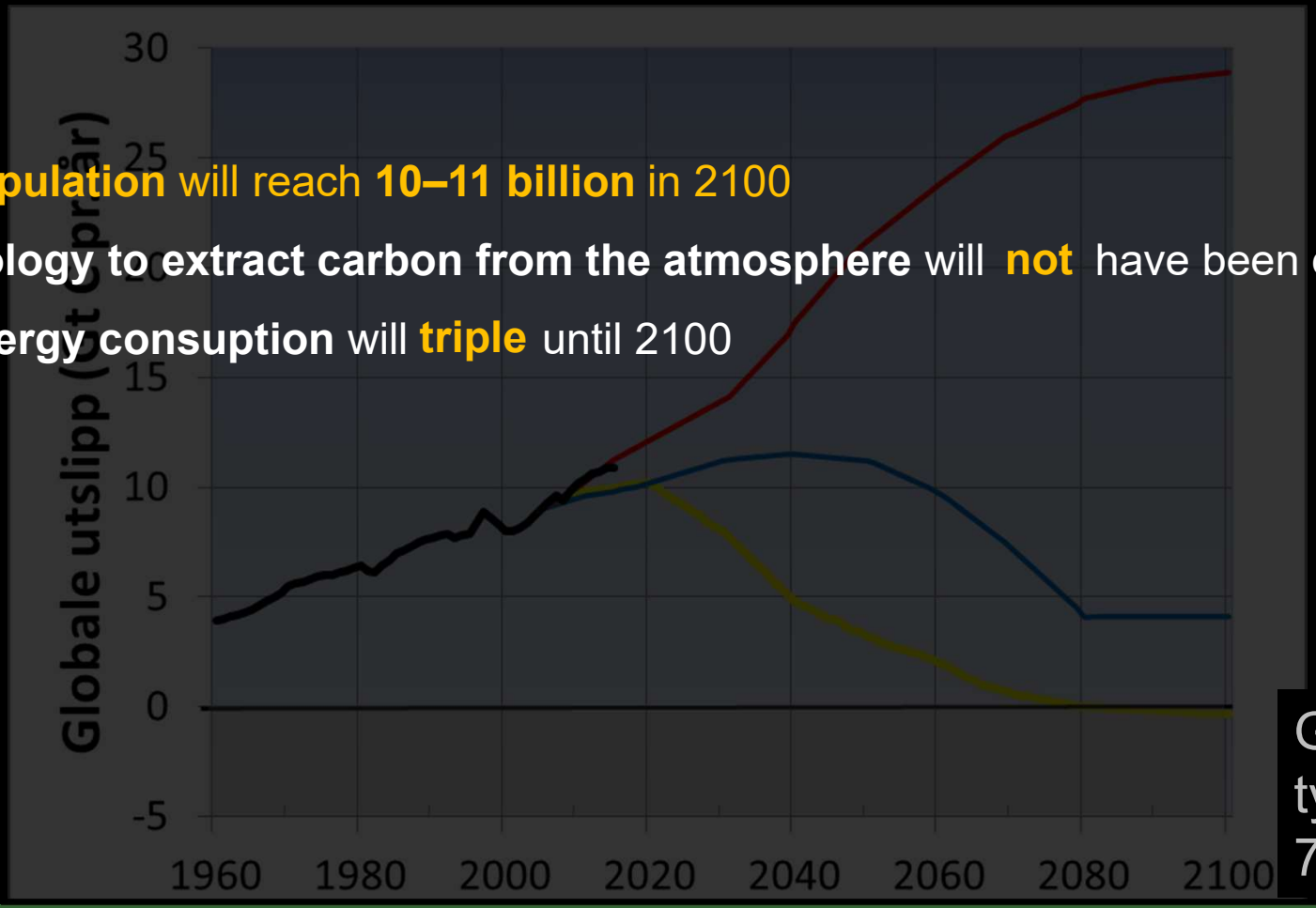
Q4: Which assumptions lie behind the high emission scenario?



A) The population will reach **10–11 billion** in 2100

B) Technology to extract carbon from the atmosphere will **not** have been developed

C) The energy consuption will **triple** until 2100

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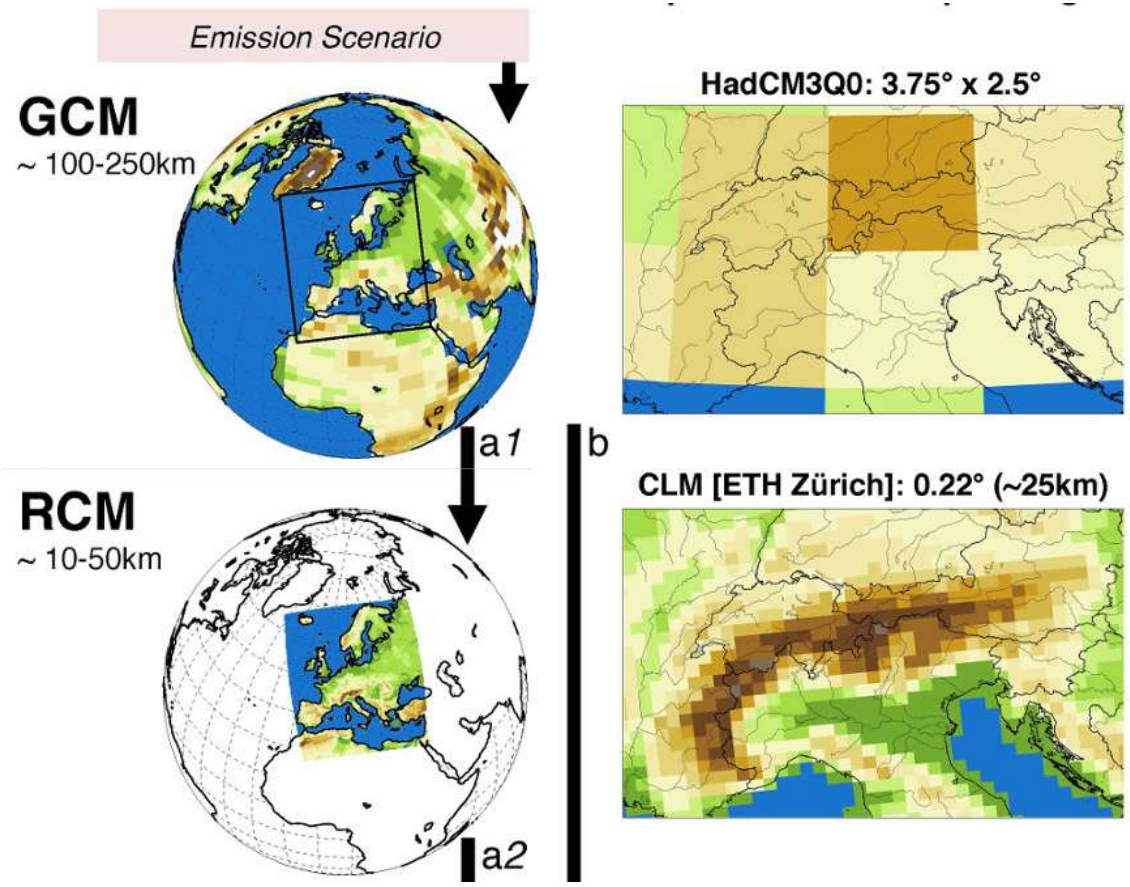
Global climate models have a coarse resolution, and cannot be used directly for local climate adaptation



Rajczak et al., 2016, ETH

Q5: Why do climate models have to be global (and thus coarse-resolution?)

Because…

A) IPCC require that they present results for the whole globe

B) they are driven by global emission scenarios

C) they need to calculate changes in fast and slow hydrological storages

(Water stays in the atmosphere for 10 days and thousands of years in glaciers/oceans).

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Spørsmål 6: Hvorfor må globale klimamodeller være globale (og derfor grove?)

A) Fordi de må kunne gi resultater fra alle deler av kloden til neste IPCC-rapport

B) Fordi de må kunne beregne endringer i raske og langsomme hydrologiske lagre

Vann har en oppholdstid på 10 dager i skyer; og tusen år i havtransport og breer.

C) Fordi drivdataene er globale utslippsscenarier (ingen grenseflatebetingelser)

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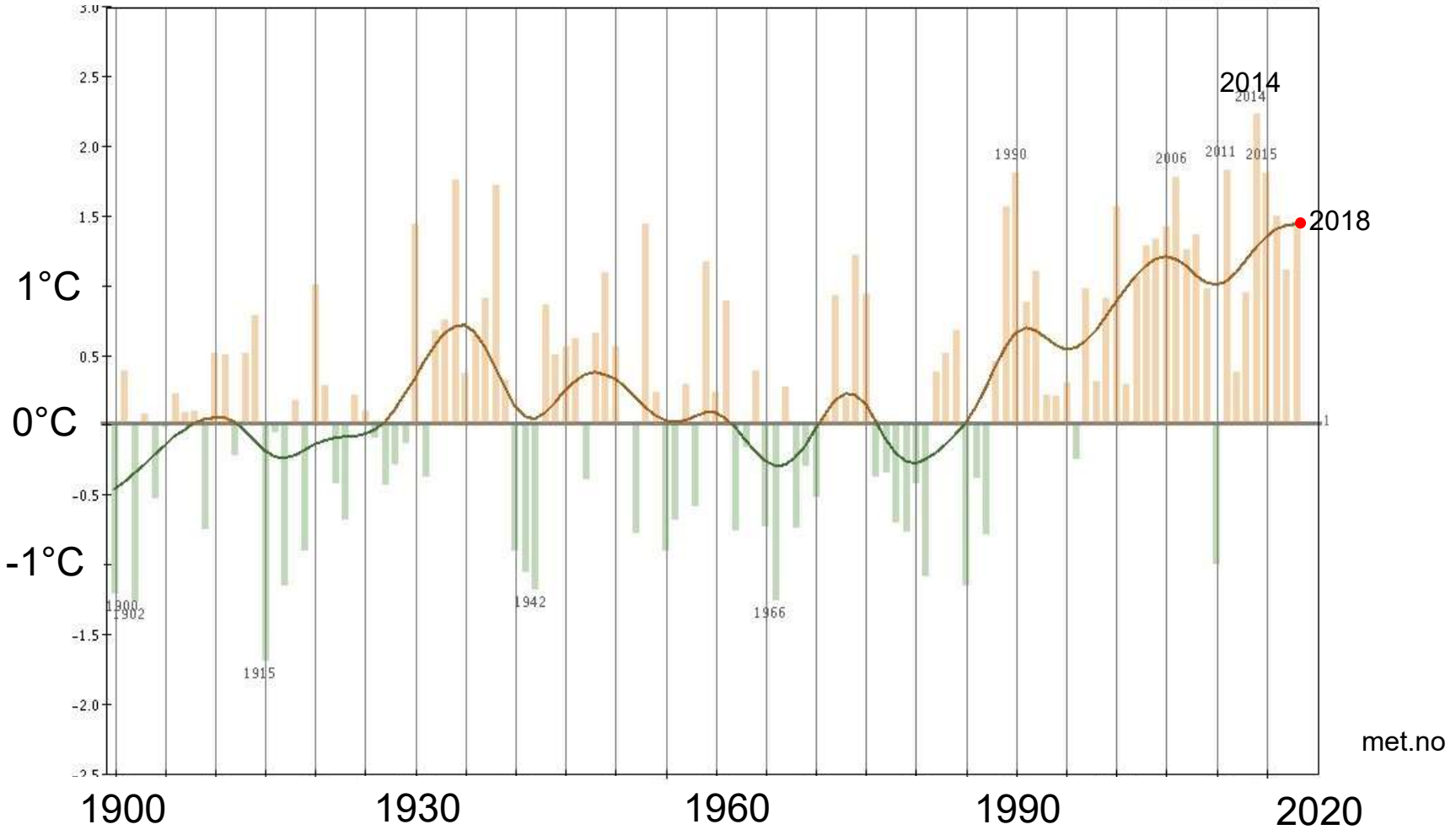
The annual temperature in Norway has increased



met.no

Q6: How much did Norwegian glaciers retreat, on average, in 2019?

A) 0 m

B) 10 m

C) 25 m

D) 50 m

Engabreen 1889: Anders Beer Wilse/ Norsk Folkemuseum.
Engabreen 2: Oskar Puschmann / NIBIO

Kilde: Naturiendring.no

Go to menti.com
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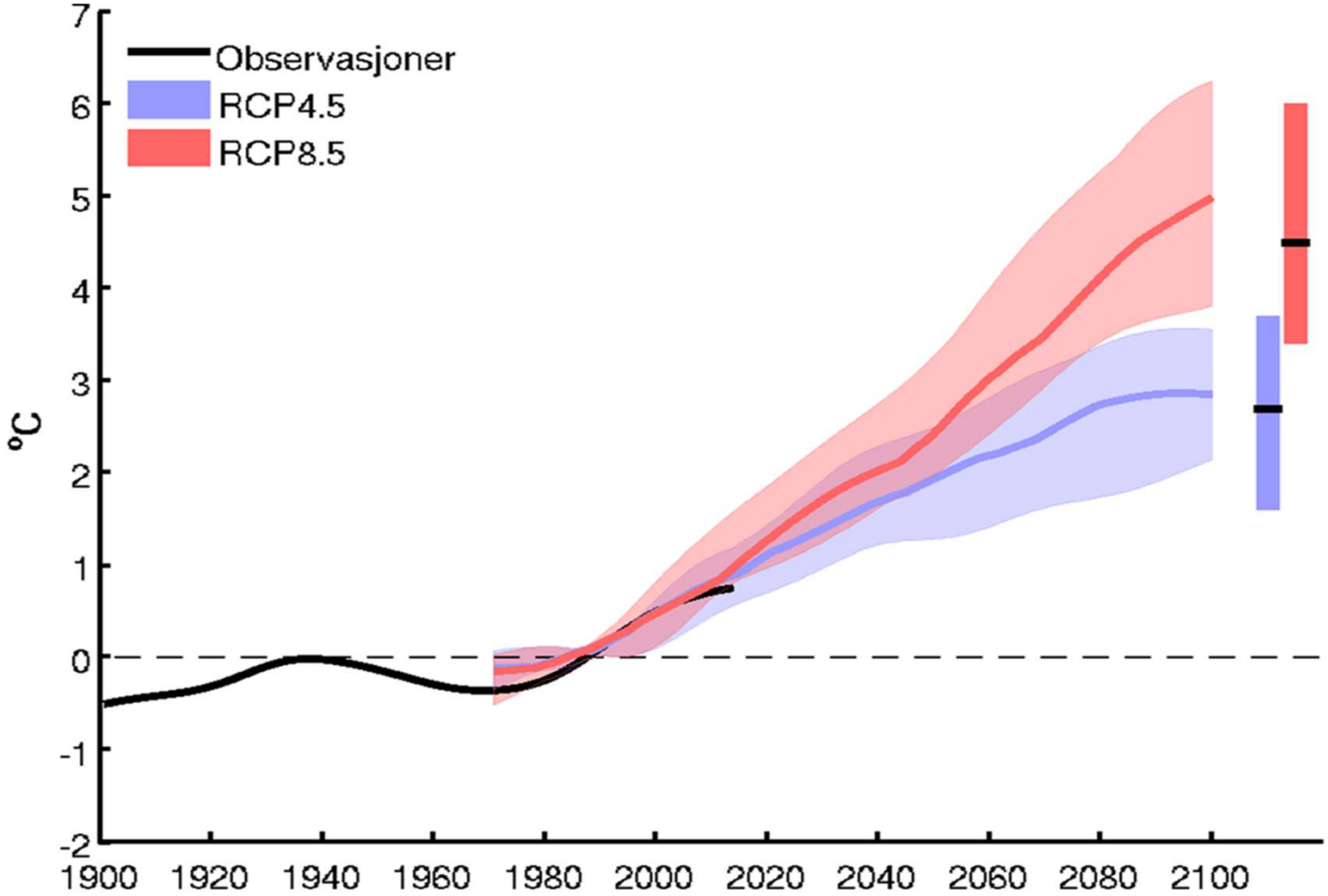
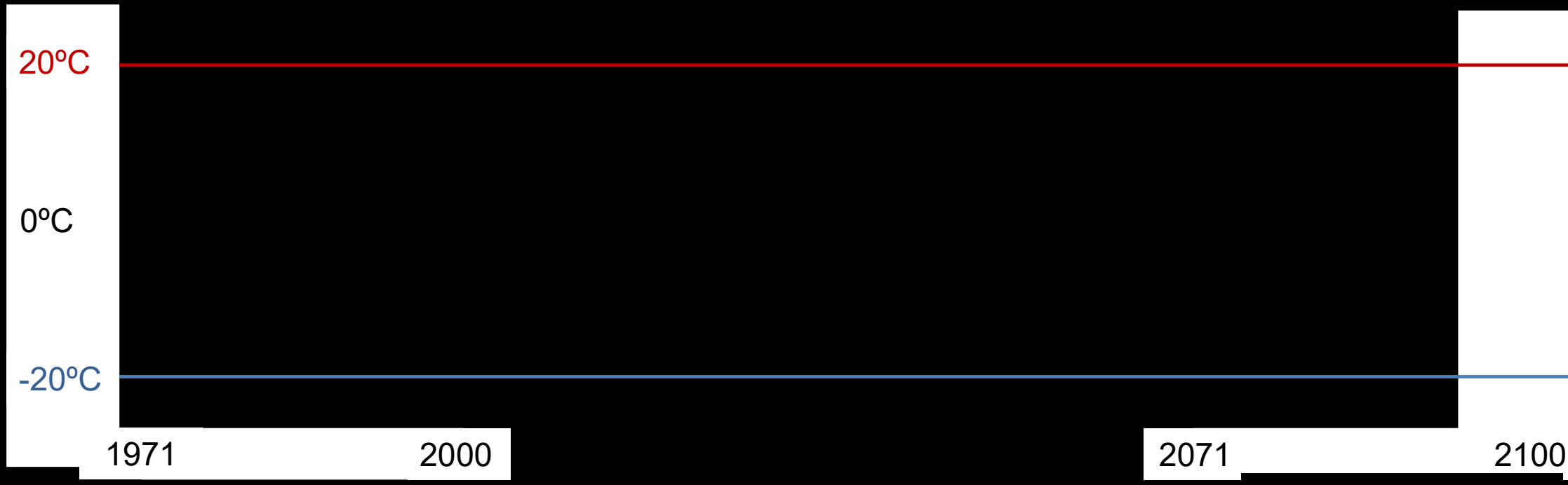
Engabreen 1889: Anders Beer Wilse/ Norsk Folkemuseum.
Engabreen 2: Oskar Puschmann / NIBIO

Kilde: Naturiendring.no

… and is expected to increase by another 4,5 °C by 2100



Spørsmål 3: Endres sommer- og vintertemperaturen ved Blindern like mye fram mot slutten av århundret (anta høye utslipp)?



A) sommertemperaturen øker mest
B) vintertemperaturen øker mest (riktig sv
C) sommer- og vintertemperaturen øker lik

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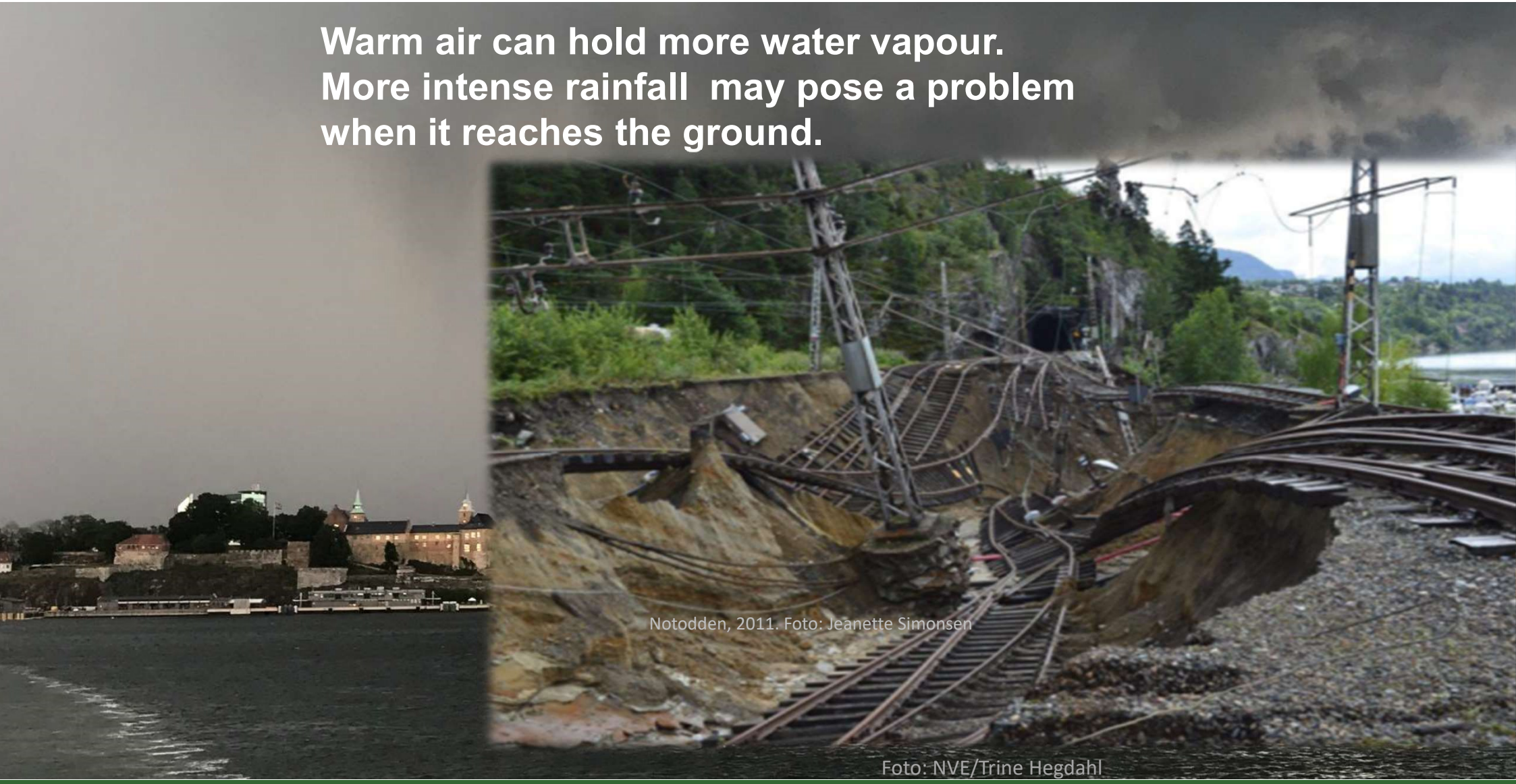
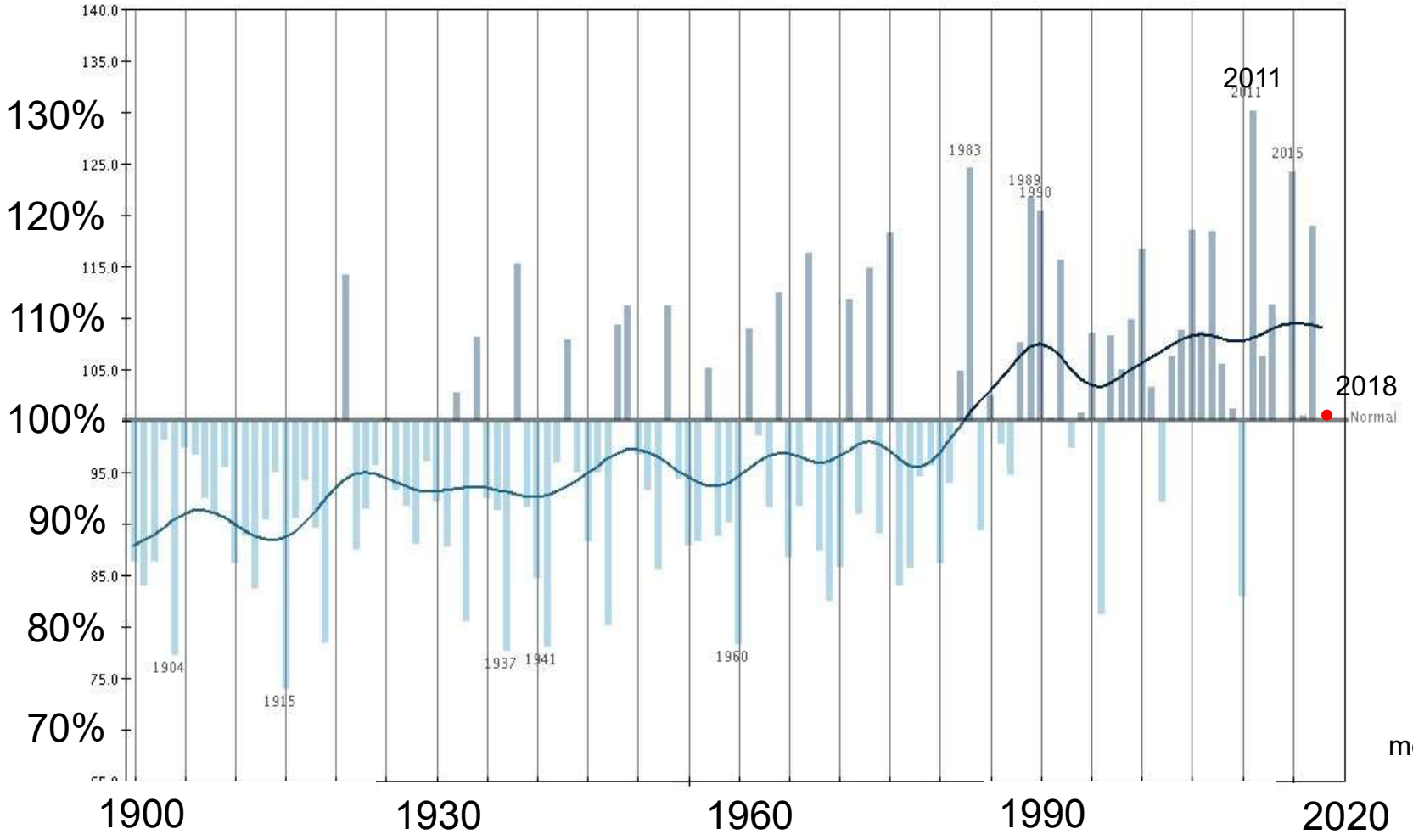
Warm air can hold more water vapour.
More intense rainfall may pose a problem when it reaches the ground.



Notodden, 2011. Foto: Jeanette Simonsen

Foto: NVE/Trine Hegdahl

Preciptation in Norway has increased



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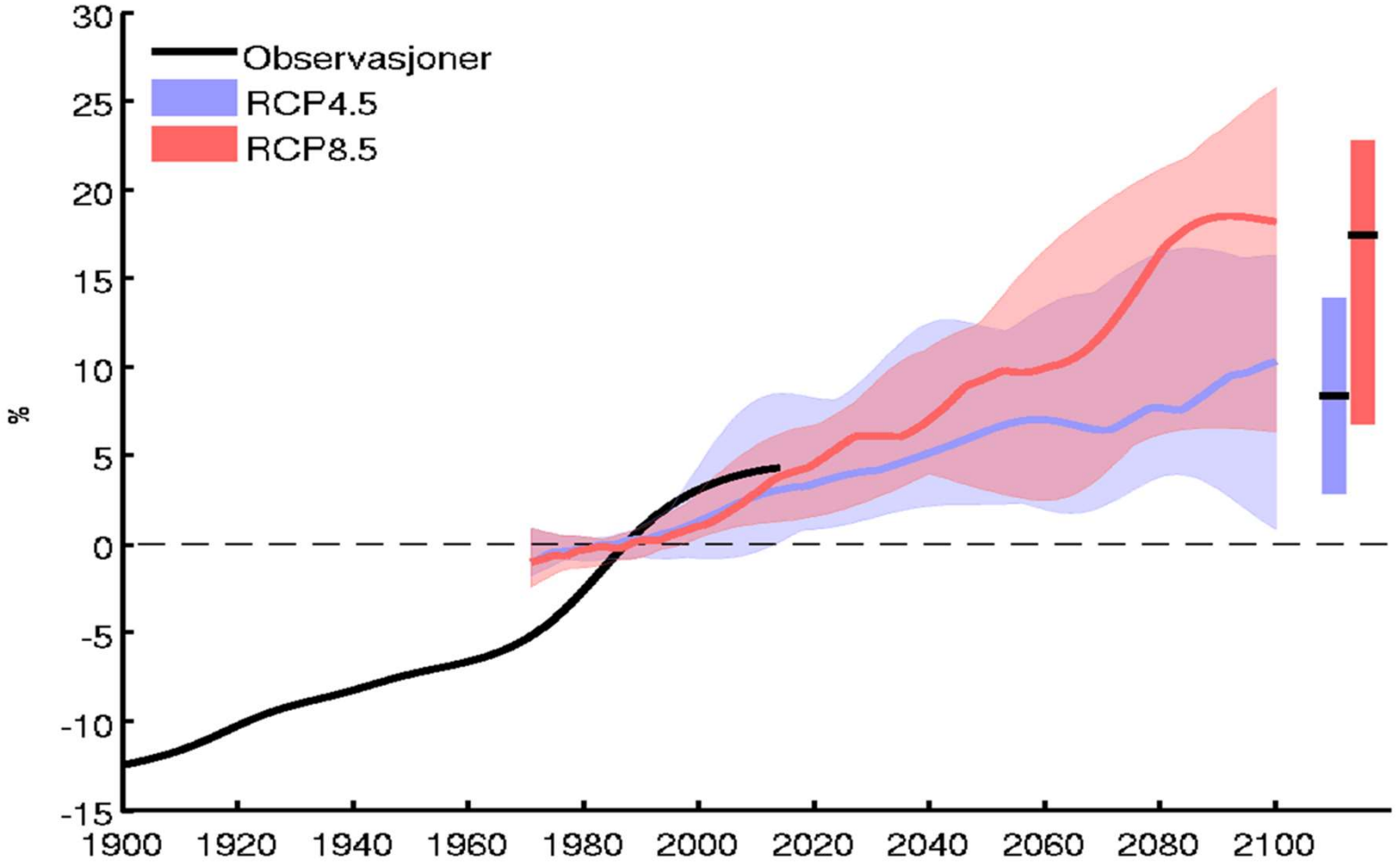
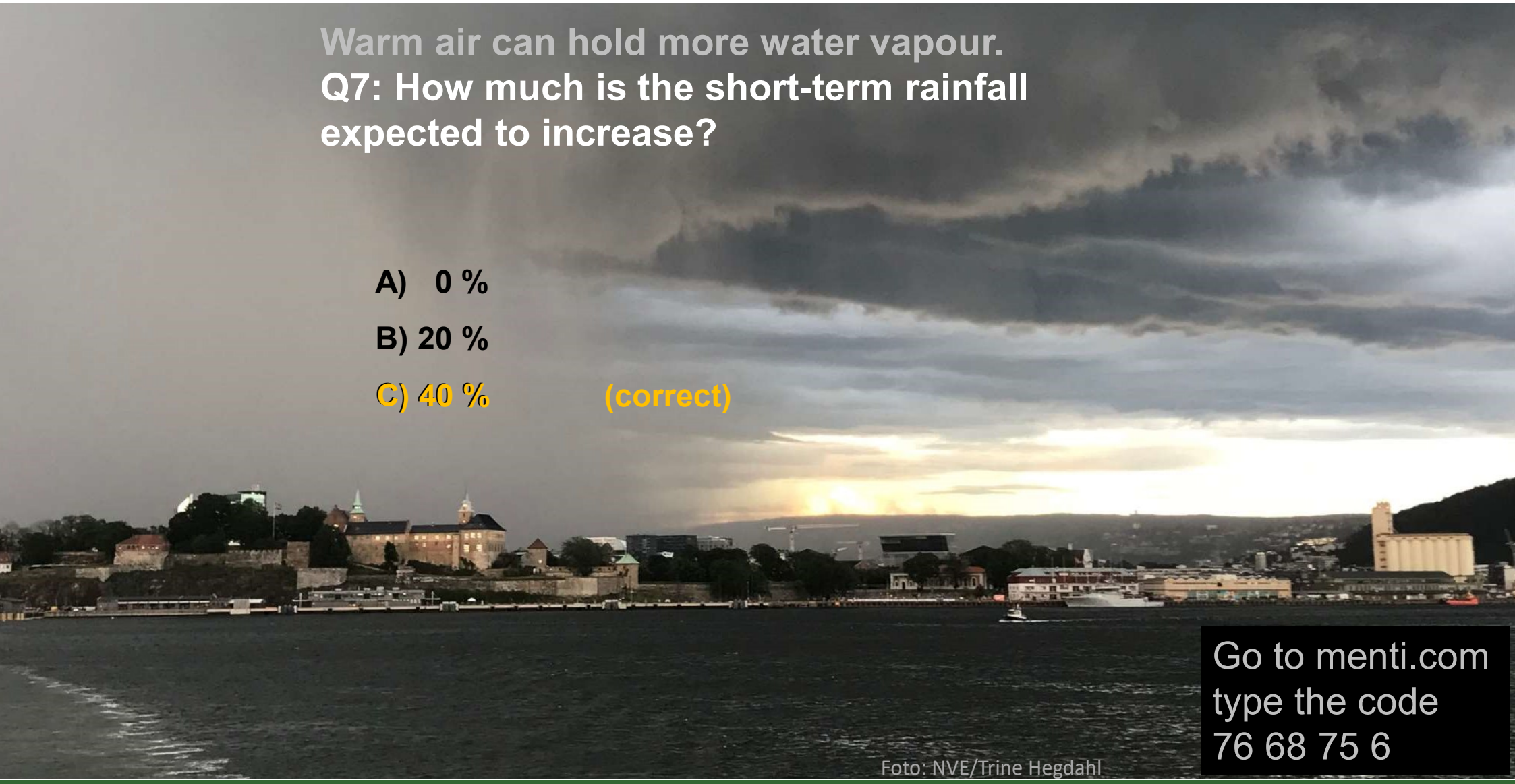
Precipitation has increased and is expected to increase by another 20 %





Warm air can hold more water vapour.

Q7: How much is the short-term rainfall expected to increase?

A) 0 %

B) 20 %

C) 40 % (correct)

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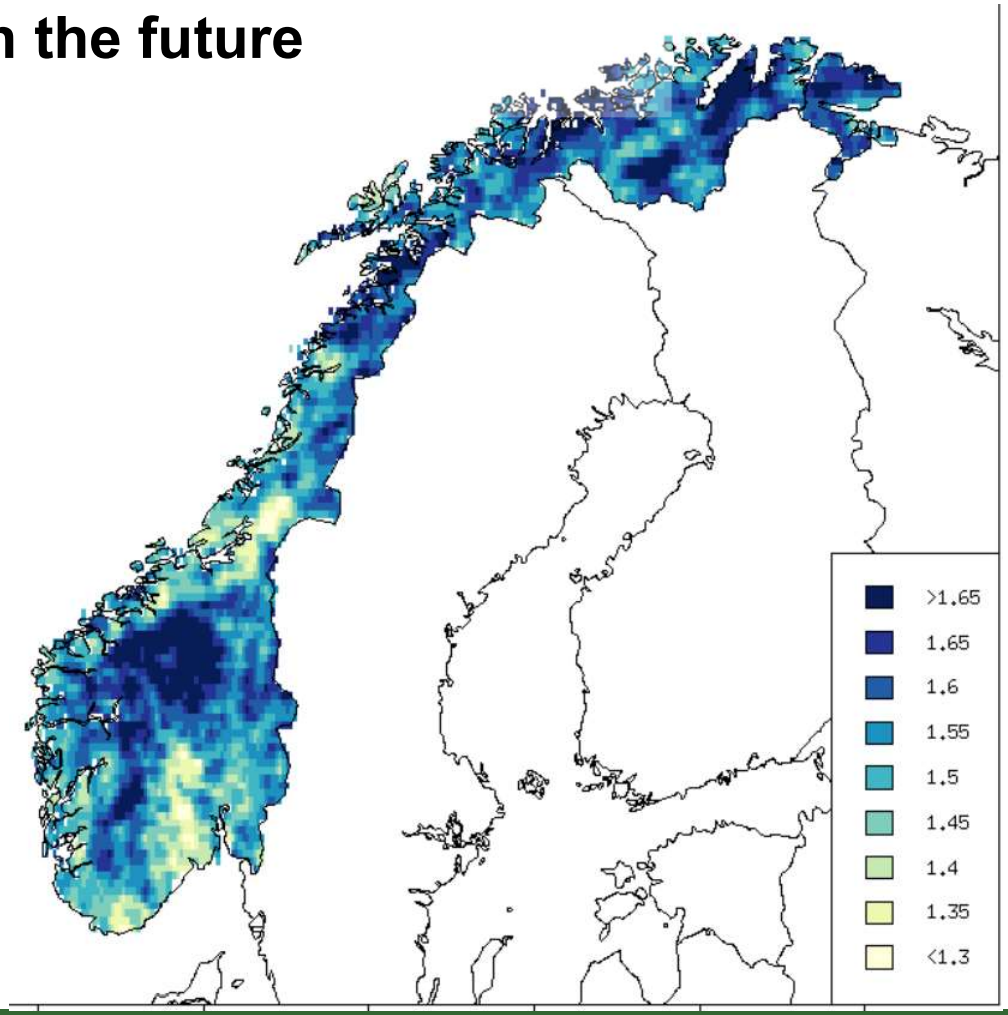
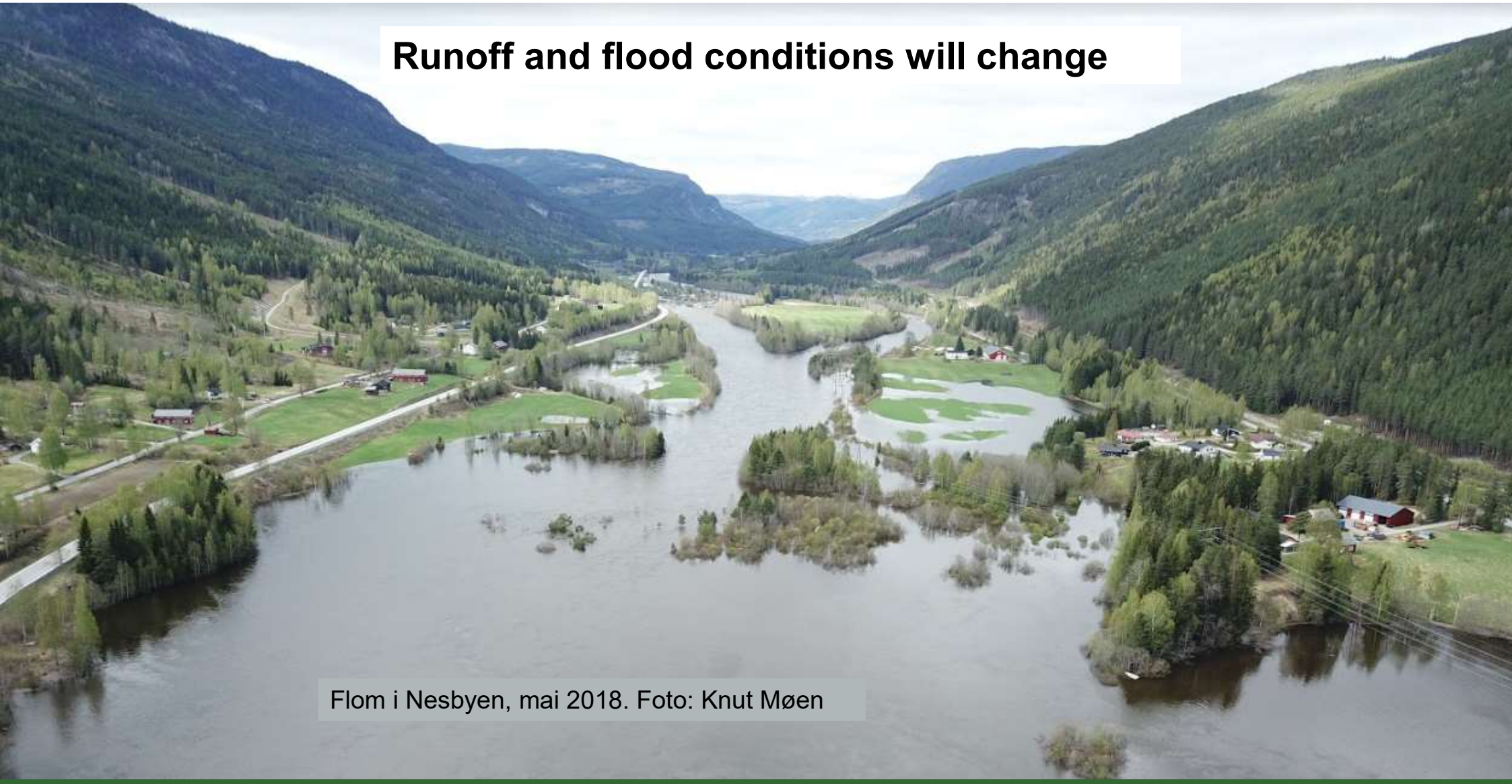
Foto: NVE/Trine Hegdahl

We have to prepare our sewage systems to handle 40 % more water during extreme events in the future

Kvinesdal 2015. Foto: Rolf Kristoffersen



Runoff and flood conditions will change



Flom i Nesbyen, mai 2018. Foto: Knut Møen

Q8: How do we expect runoff regimes (including floods) to change under climate change?

A) A stronger seasonality towards **more winter runoff, smaller snowmelt floods in spring**

B) Larger flood magnitudes in **all rivers**

C) Larger flood magnitudes in **large rivers**

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Q8: How do we expect runoff regimes (including floods) to change under climate change?

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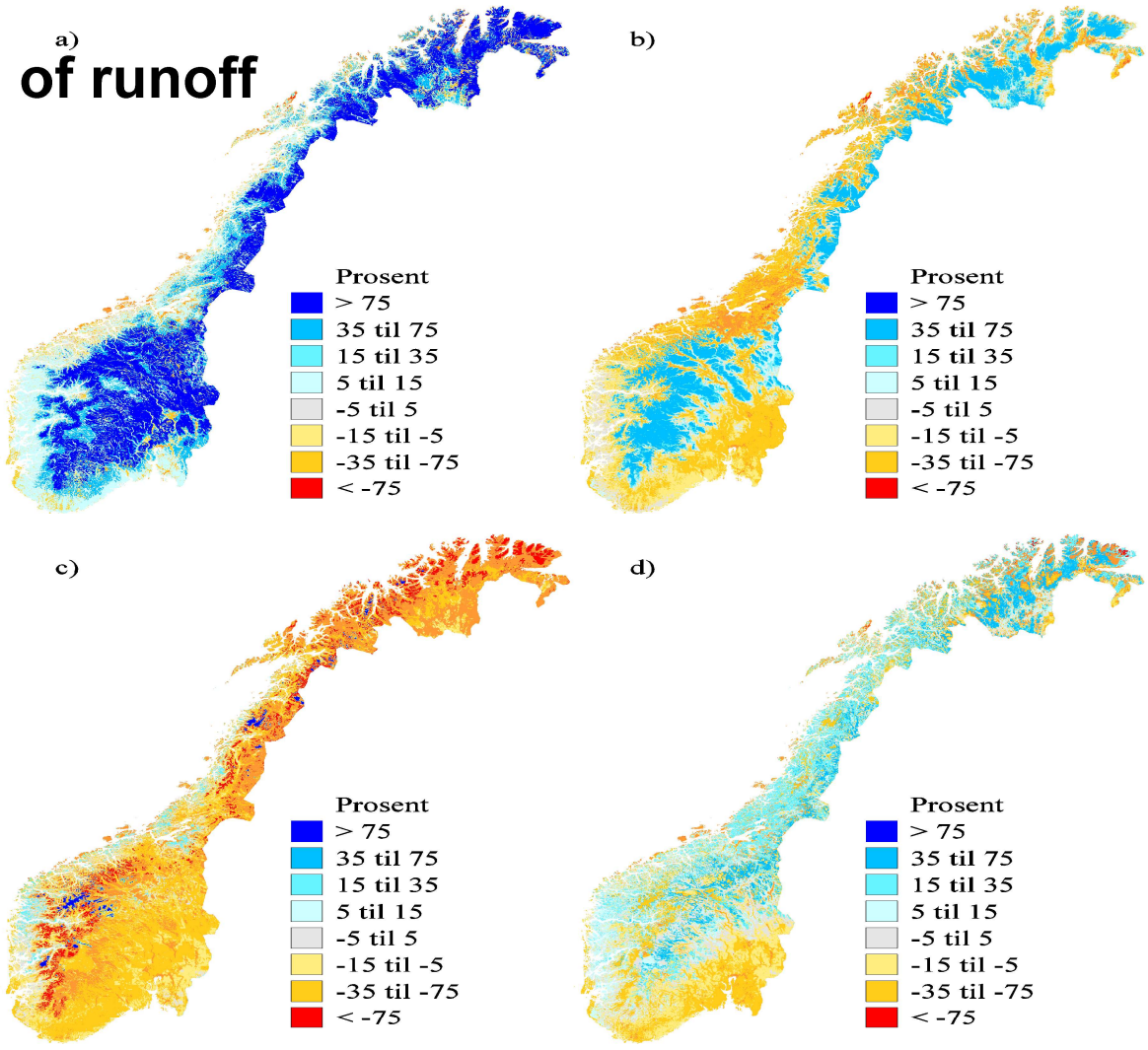
We expect changed seasonality of runoff

a) Vinter: +

b) Vår: fjellet +, lavlandet –

c) Sommer –

d) Høst: ~ 0

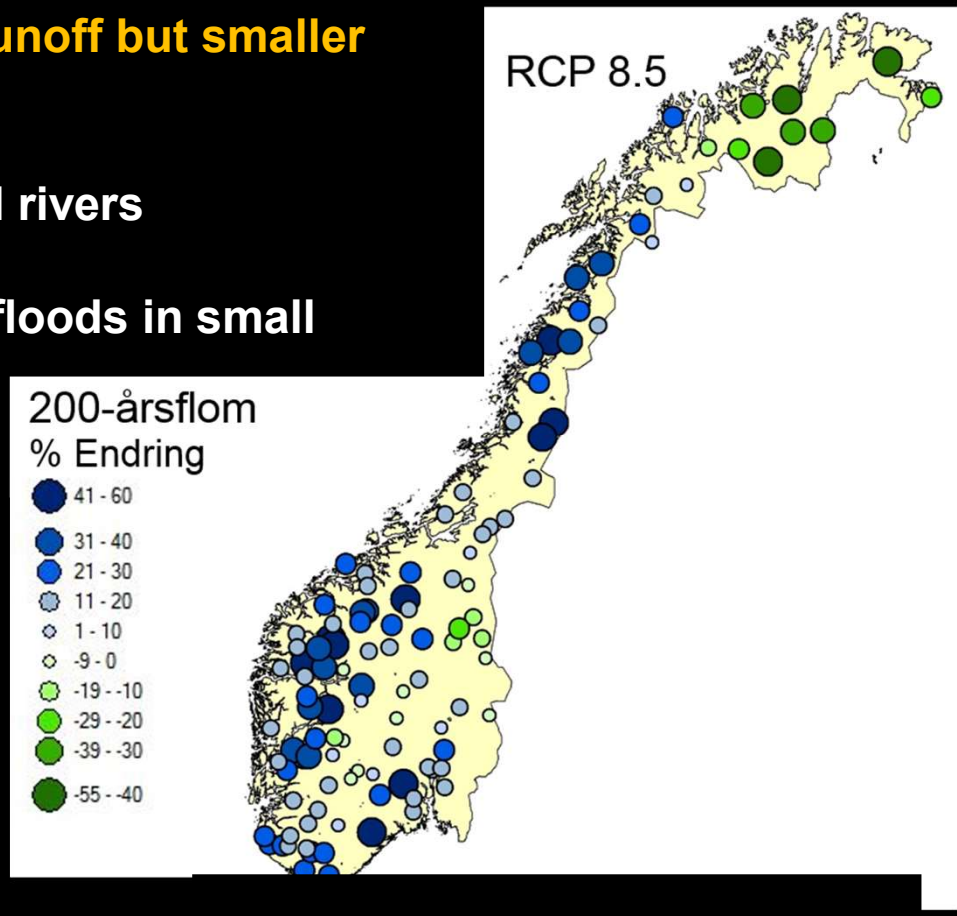


Q5: How do we expect runoff regimes (including floods) to change under climate change?

A) A stronger seasonality towards more winter runoff but smaller snowmelt floods in spring (correct)

B) More runoff and larger flood magnitudes in all rivers

C) More floods in large rivers and fewer/smaller floods in small rivers



Reduction

– In large catchments dominated by snowmelt floods

Increase

– In catchments where rainfall floods dominate in the future
– All small catchments reacting quckly to rainfall

Spørsmål 4: Hvis både nedbøren i Norge øker, OG snømengdene reduseres, hvordan endres flommene da?

A) Regnflommene øker og snøsmelteflommene minker (riktig svar)
B) Det blir flere og større flommer i alle elver
C) Det blir flere og større flommer i store elver, men ikke i små

Reduksjon

- Store nedbørfelt dominert av snøsmelteflommer

Økning

- Nedbørfelt hvor regnflommer vil dominere i fremtiden
- Alle små nedbørfelt som reagerer raskt på regn

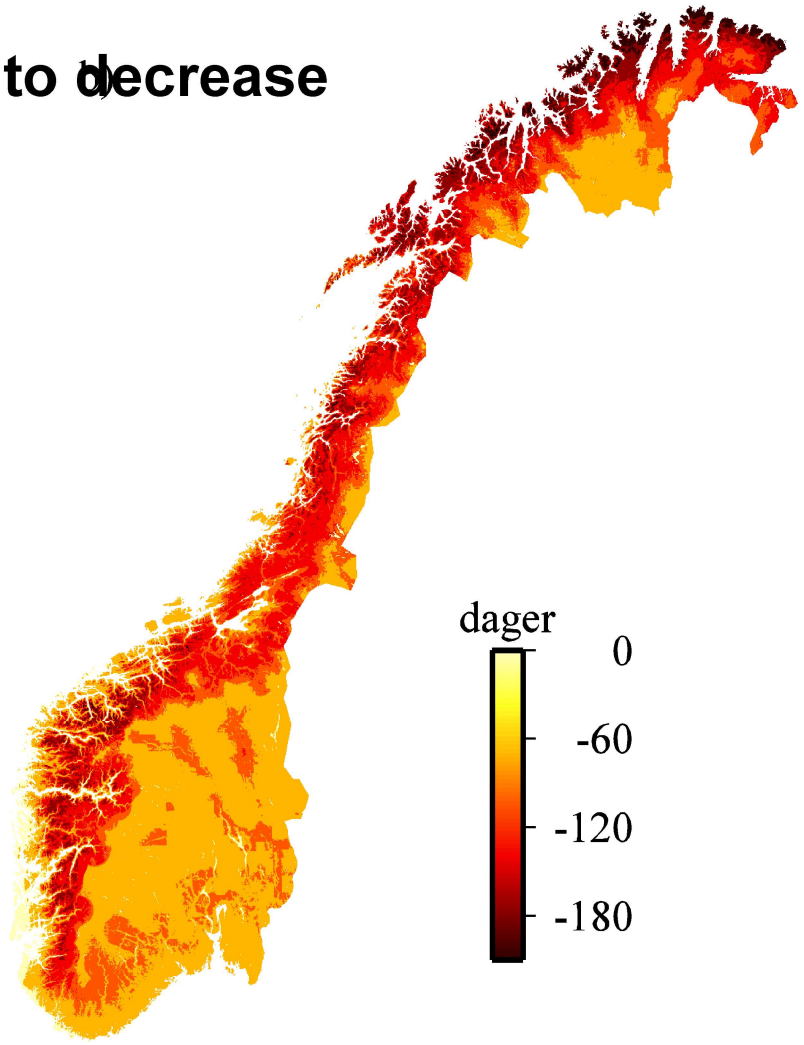
Natural hazards change with climate change. Thus, houses that were built on safe areas may not be considered safe in the future.

That's why climate adaptation is important - so that you can be safe

Kvam i Gudbrandsdalen 2011
Håkon Mosvold Larsen, NTB scanpix

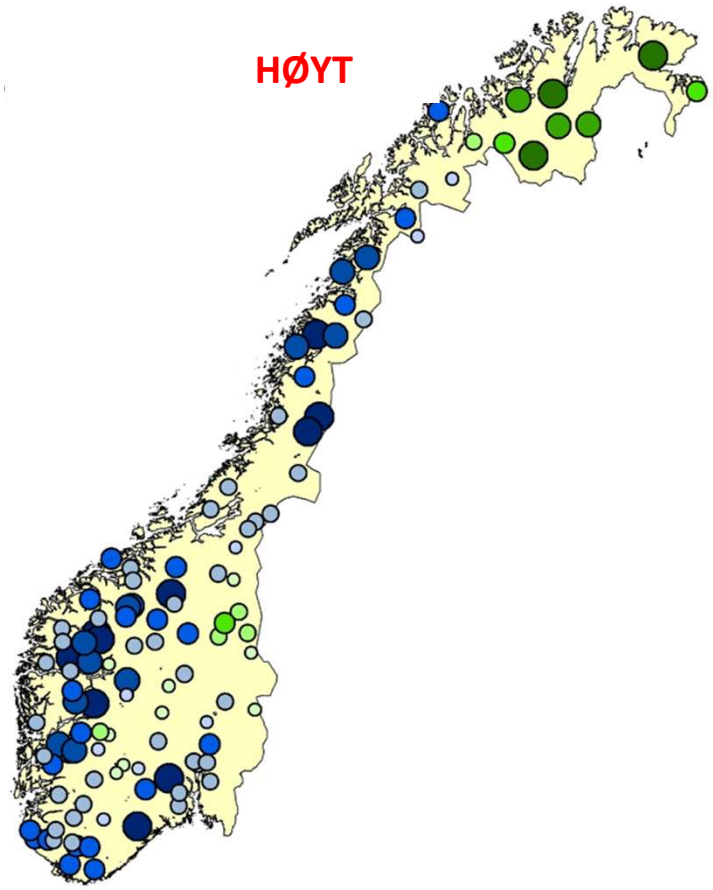
The length of the snow season is expected to decrease

Largest reduction in regions having winter temperatures just below 0 °C



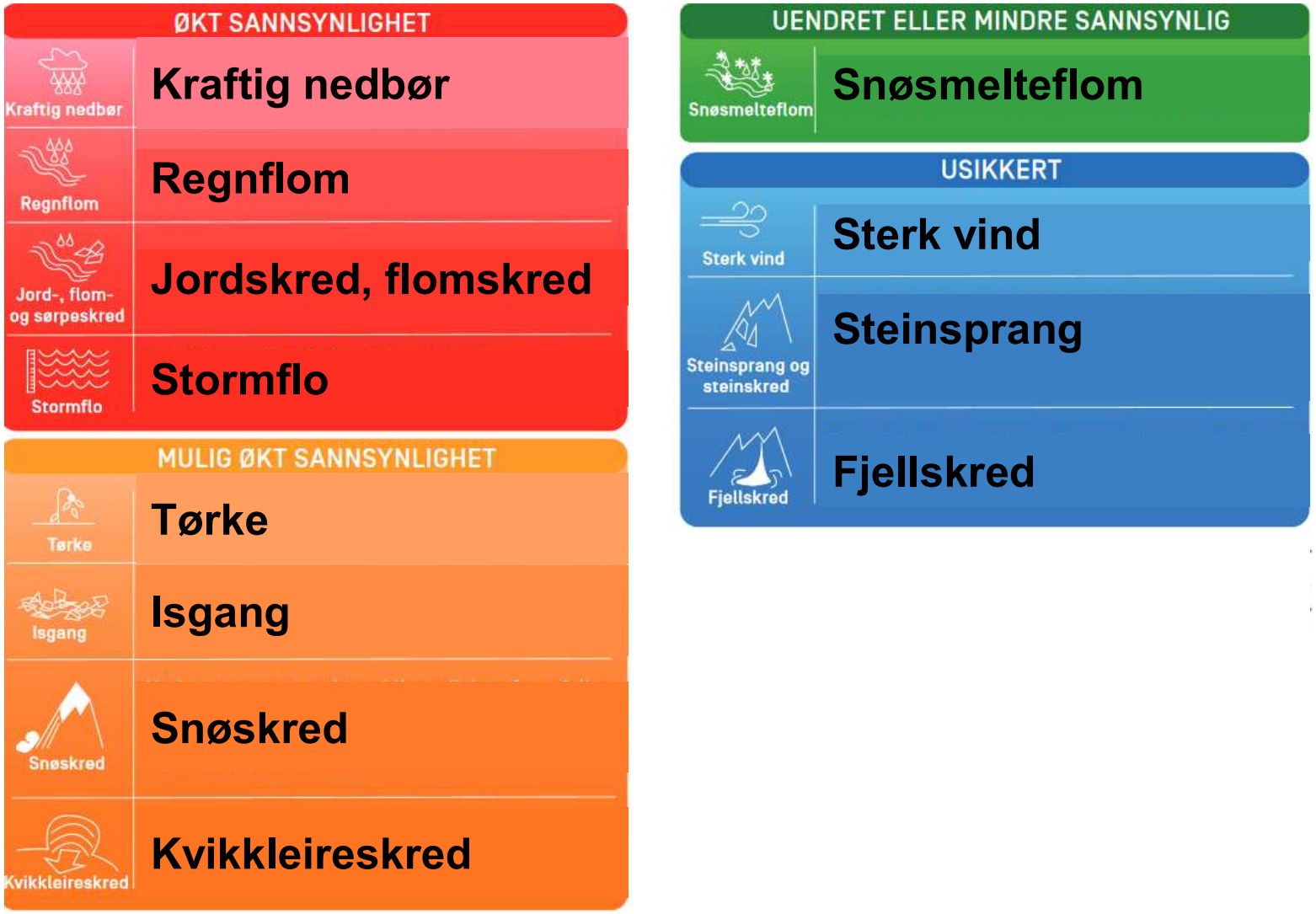
Flom

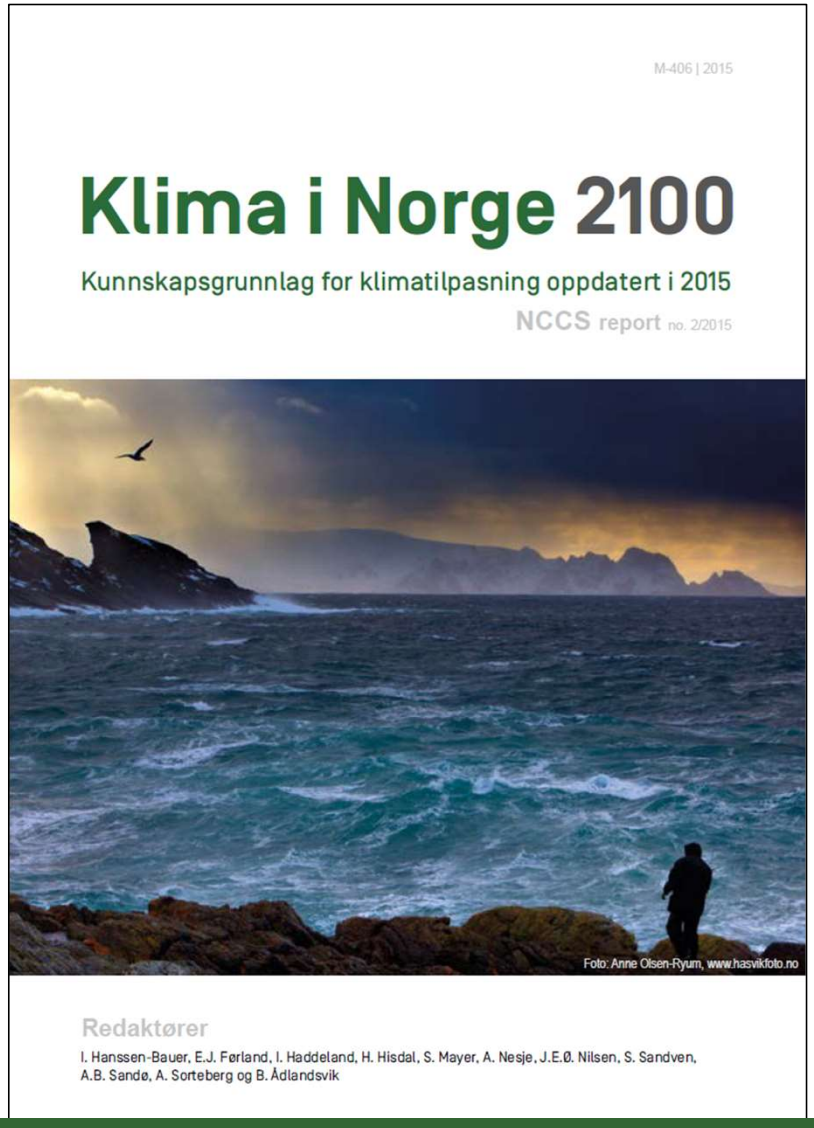
- **Reduksjon**
  - Store nedbørfelt dominert av snø-smelteflommer
- **Økning**
  - Nedbørfelt hvor regn-flommer vil dominerer i fremtiden
  - Alle små nedbørfelt som reagerer raskt på regn



Mot slutten av dette århundret – i hele Norge blir det:

- Varmere
- Våtere
- Lengre vekstsesong
- Kortere snøsesong
- Mer overvann i byer og tettsteder
- Flere og større regnflommer
- Færre og mindre snøsmelteflommer
- Økt sannsynlighet for tørke om sommeren
- Økt fare for jord-, flom- og sørpeskred
- Havnivåstigning
- Mindre breer


ØKT SANNSYNLIGHET
Kraftig nedbør
Kraftig nedbør
Regnflom
Regnflom
Jord-, flom- og sørpeskred
Jordskred, flomskred
Stormflo
Stormflo
MULIG ØKT SANNSYNLIGHET
Tørke
Tørke
Isgang
Isgang
Snøskred
Snøskred
Kvikkleireskred
Kvikkleireskred
UENDRET ELLER MINDRE SANNSYNLIG
Snøsmelteflom
Snøsmelteflom
USIKKERT
Sterk vind
Sterk vind
Steinsprang og steinskred
Steinsprang
Fjellskred
Fjellskred



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