

# Climate change impacts on Nordic icing climate

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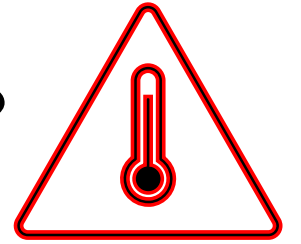
WinterWind 2023



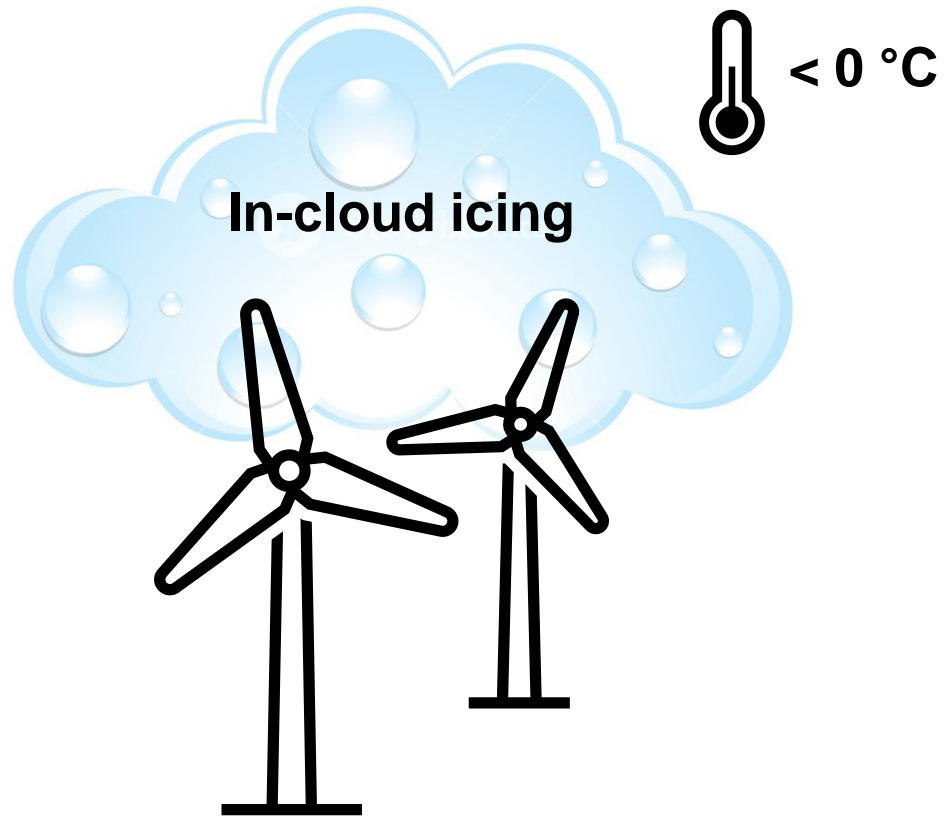
More of this ↓ ?



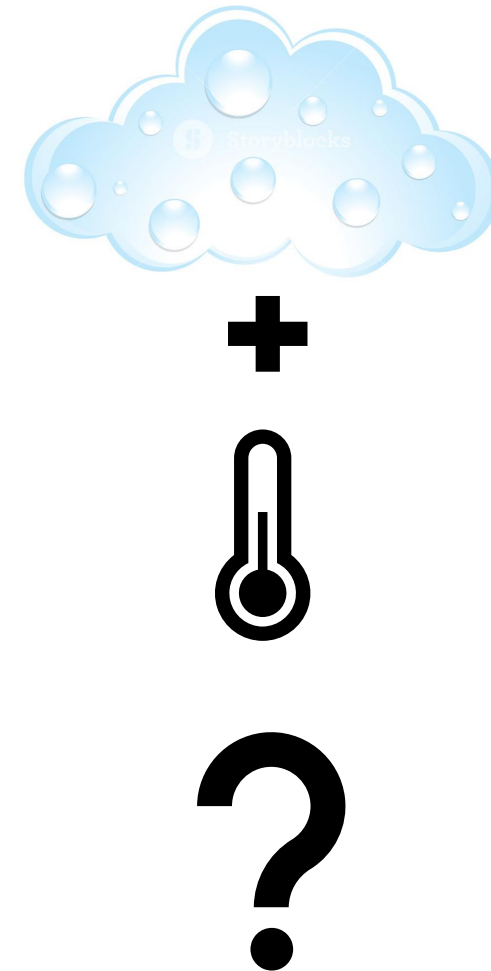
or more of this ↓ in the future?



# What causes icing?

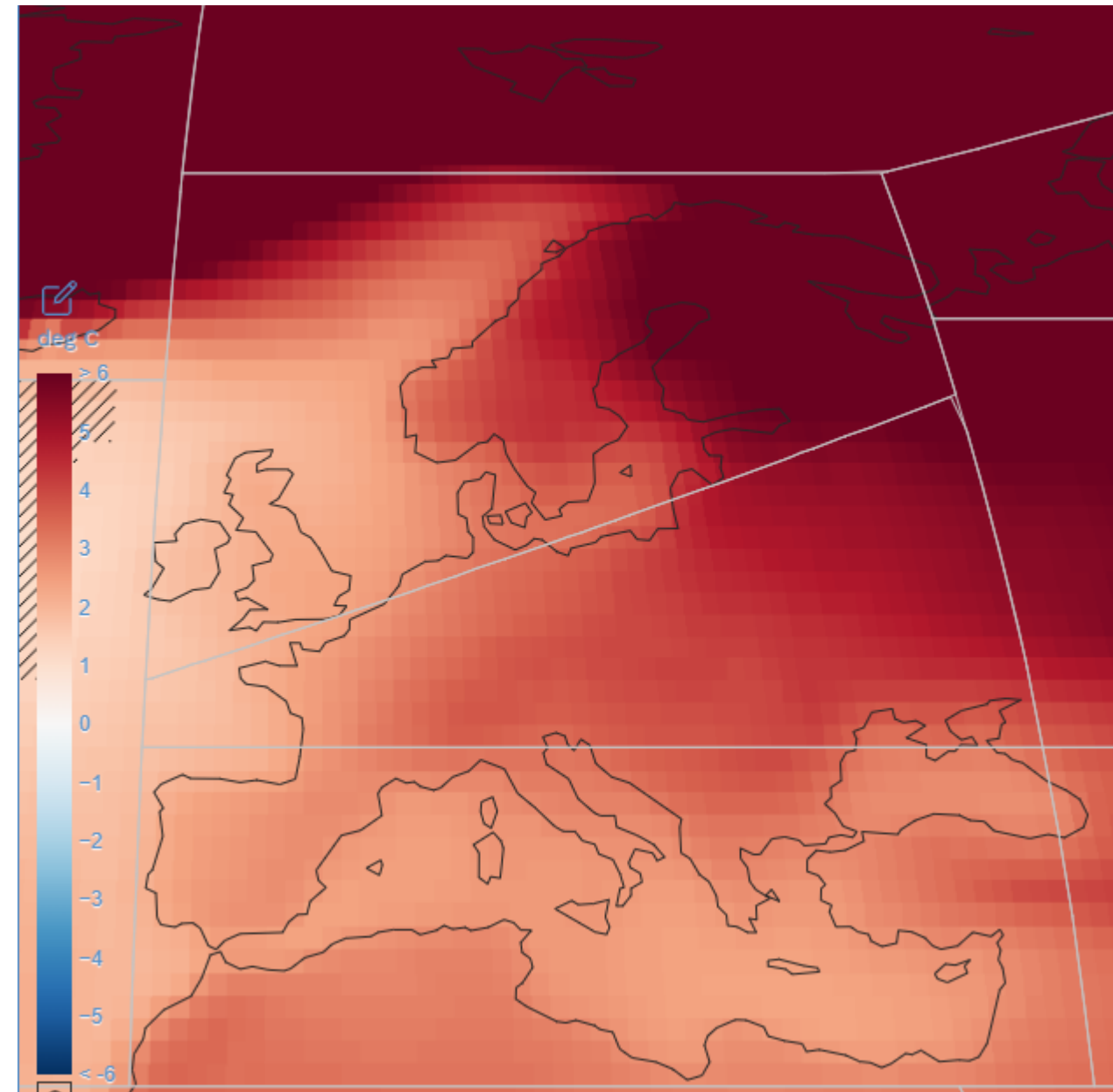


# What will happen in the future?



# It will get warmer...

- ▶ Mean temp. change
- ▶ 2081-2100 rel. to 1850-1900
- ▶ Dec – Feb
- ▶ 34 climate models
- ▶ Middle of the road scenario SSP2-4.5

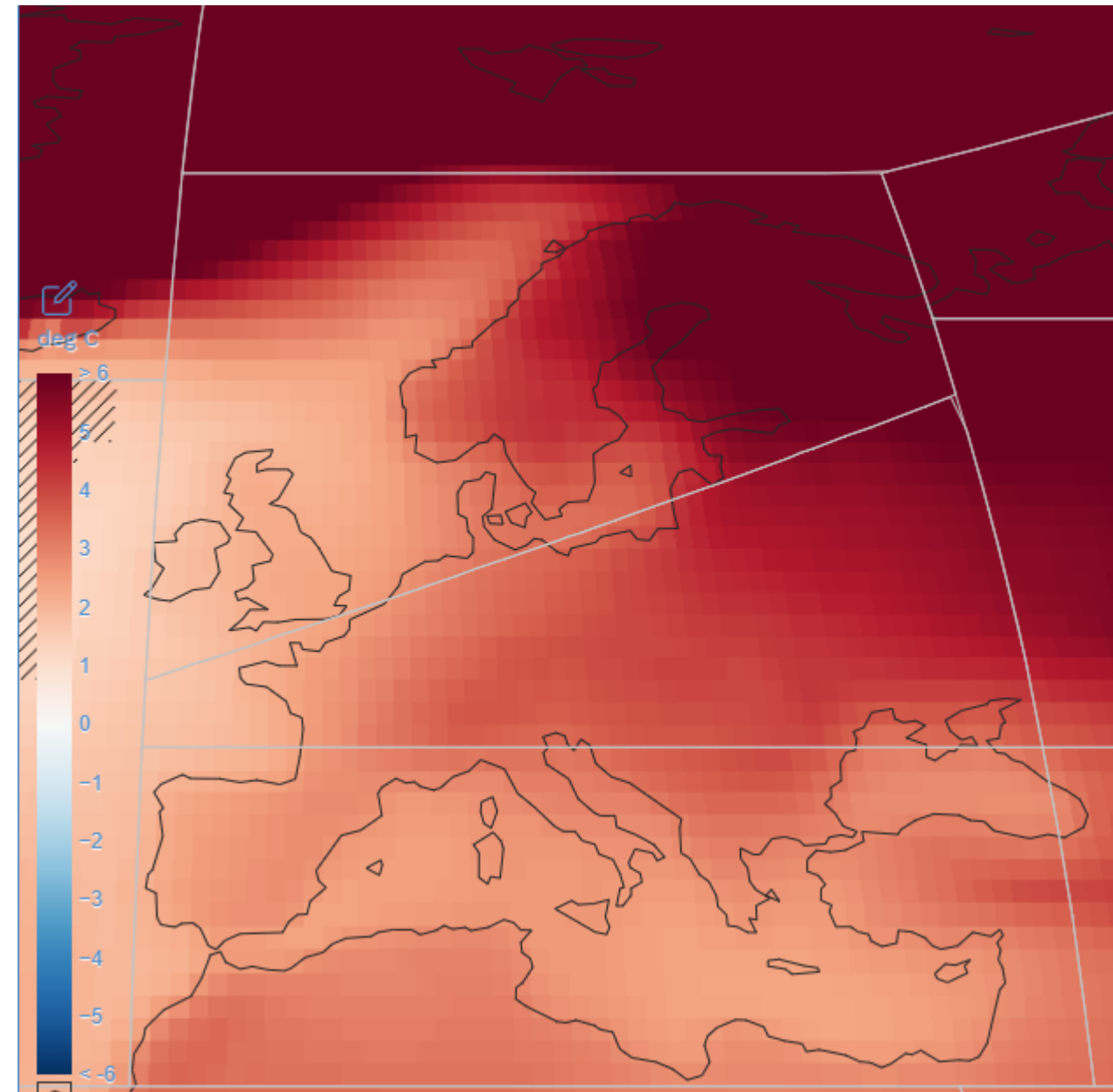
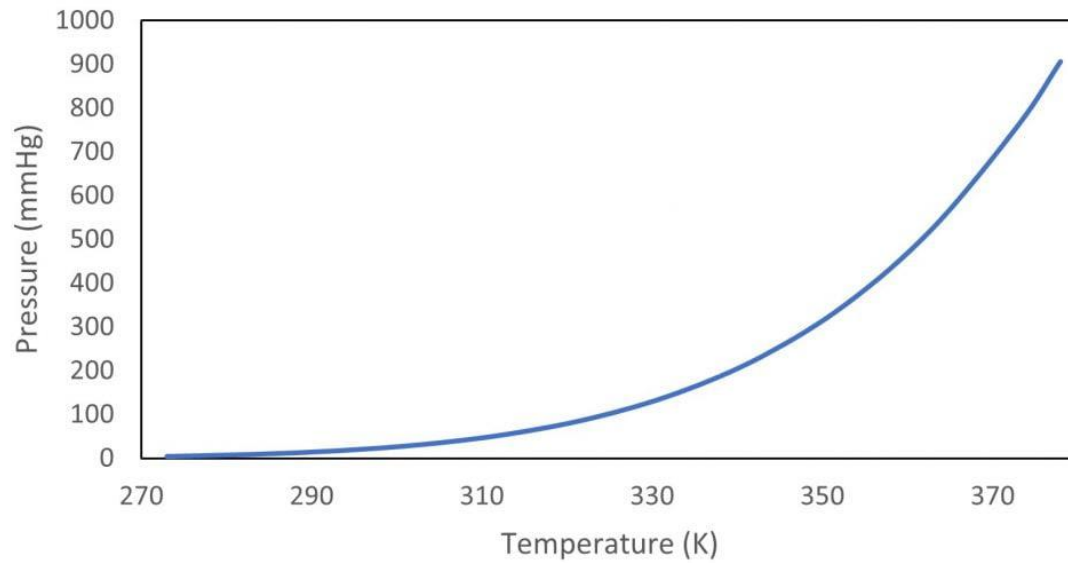


# It will get warmer...

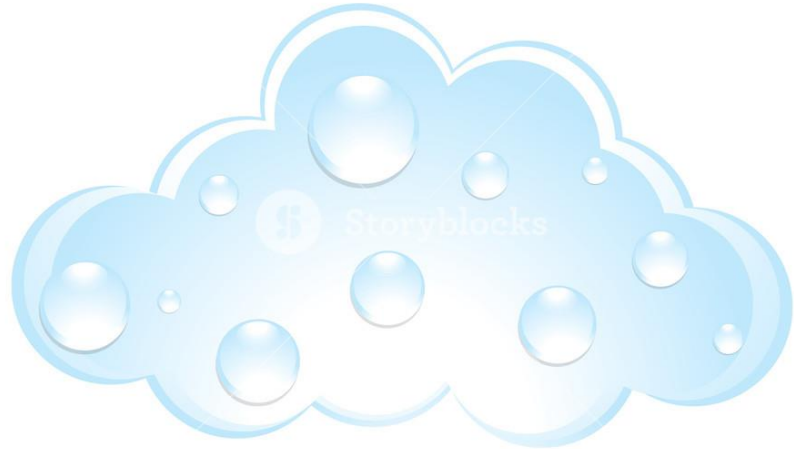
Clausius-Clapeyron:

Also more moisture in the air!

Vapor Pressure of Water



# Clouds are still the largest uncertainty in climate models...



# How to answer this more accurately?





Voss, Norway, in April 1961. Photo: Olav Wist. Rights: Kjeller Vindteknikk.

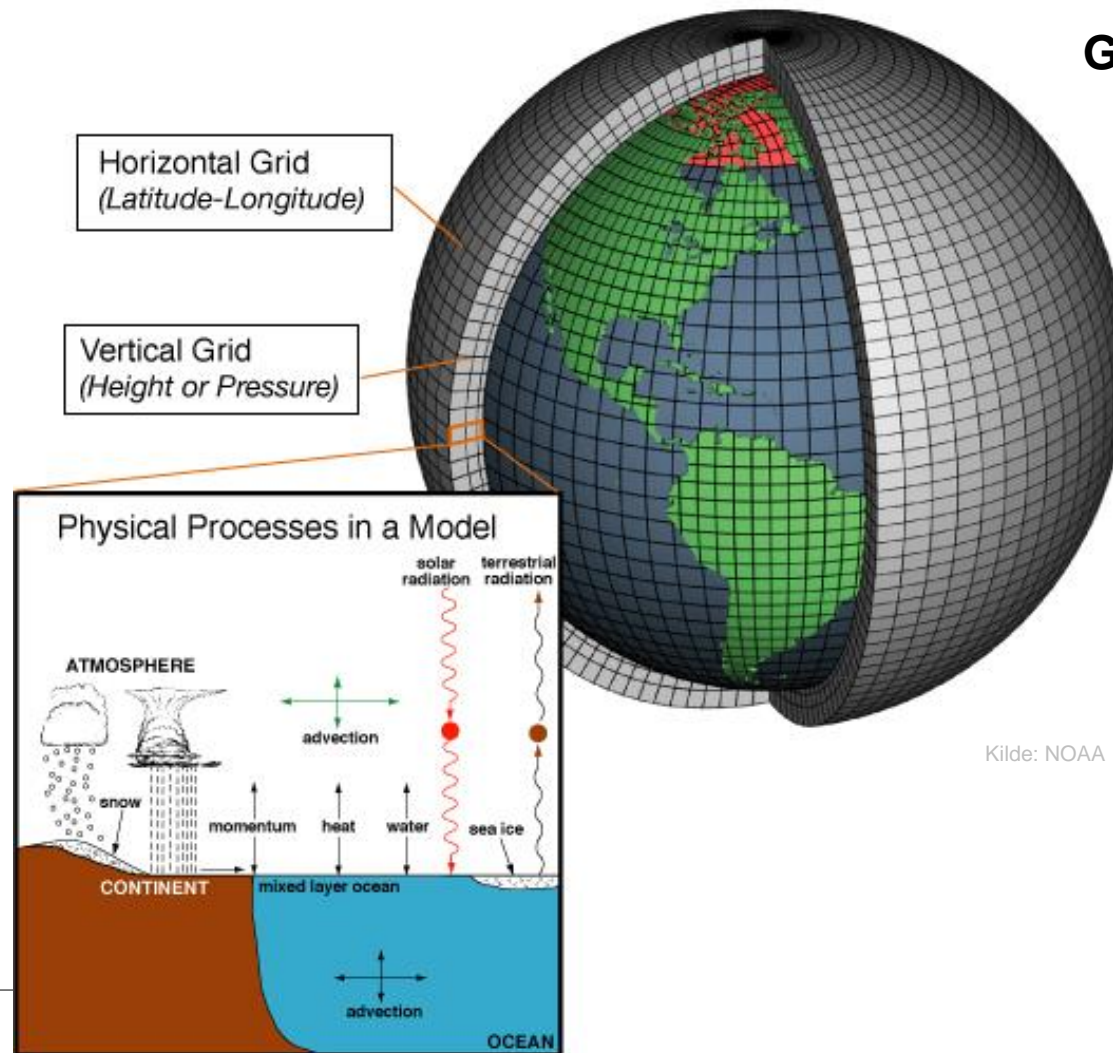


Ålvikfjellet, Hardanger. Foto: Statett



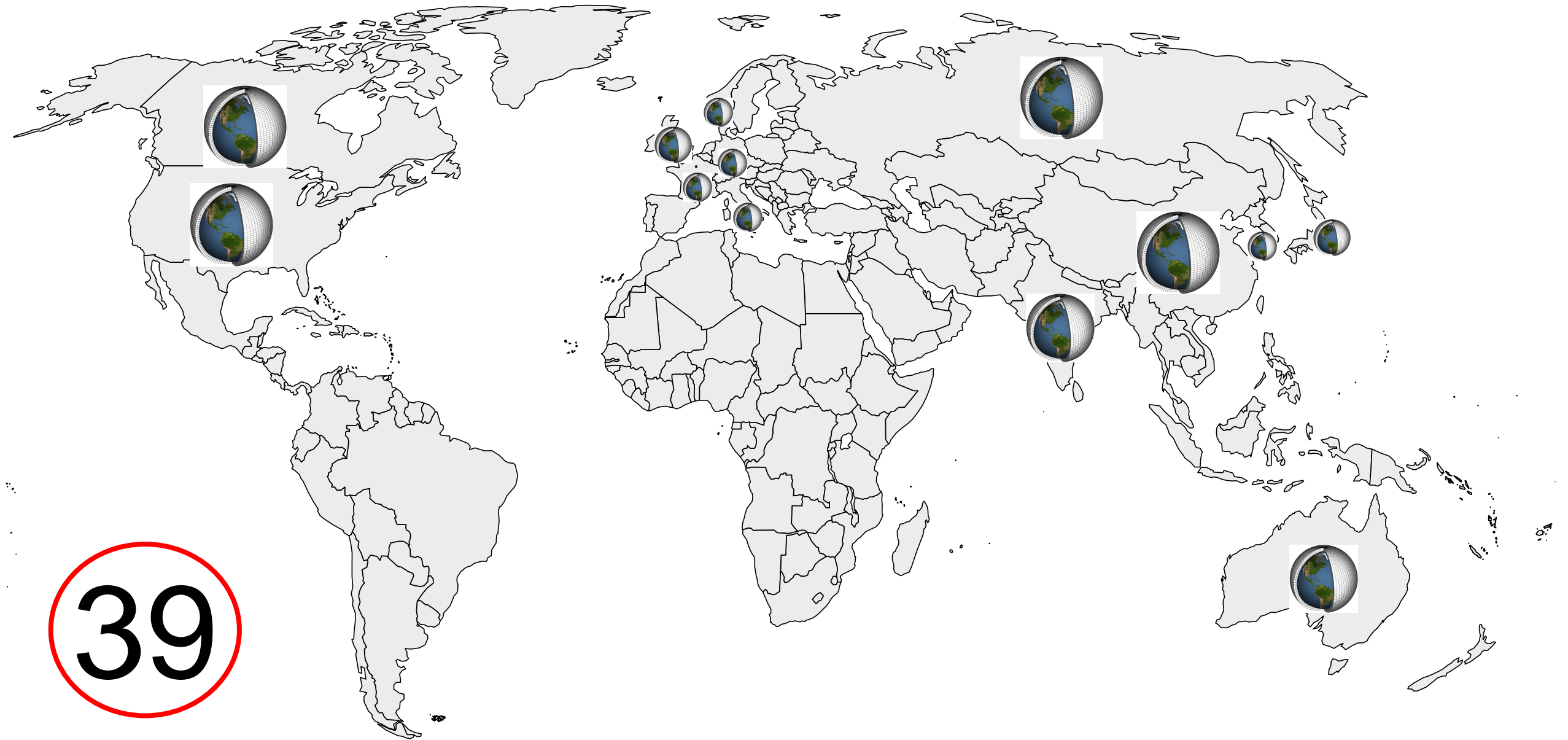
# What tools are available?

## Global climate model



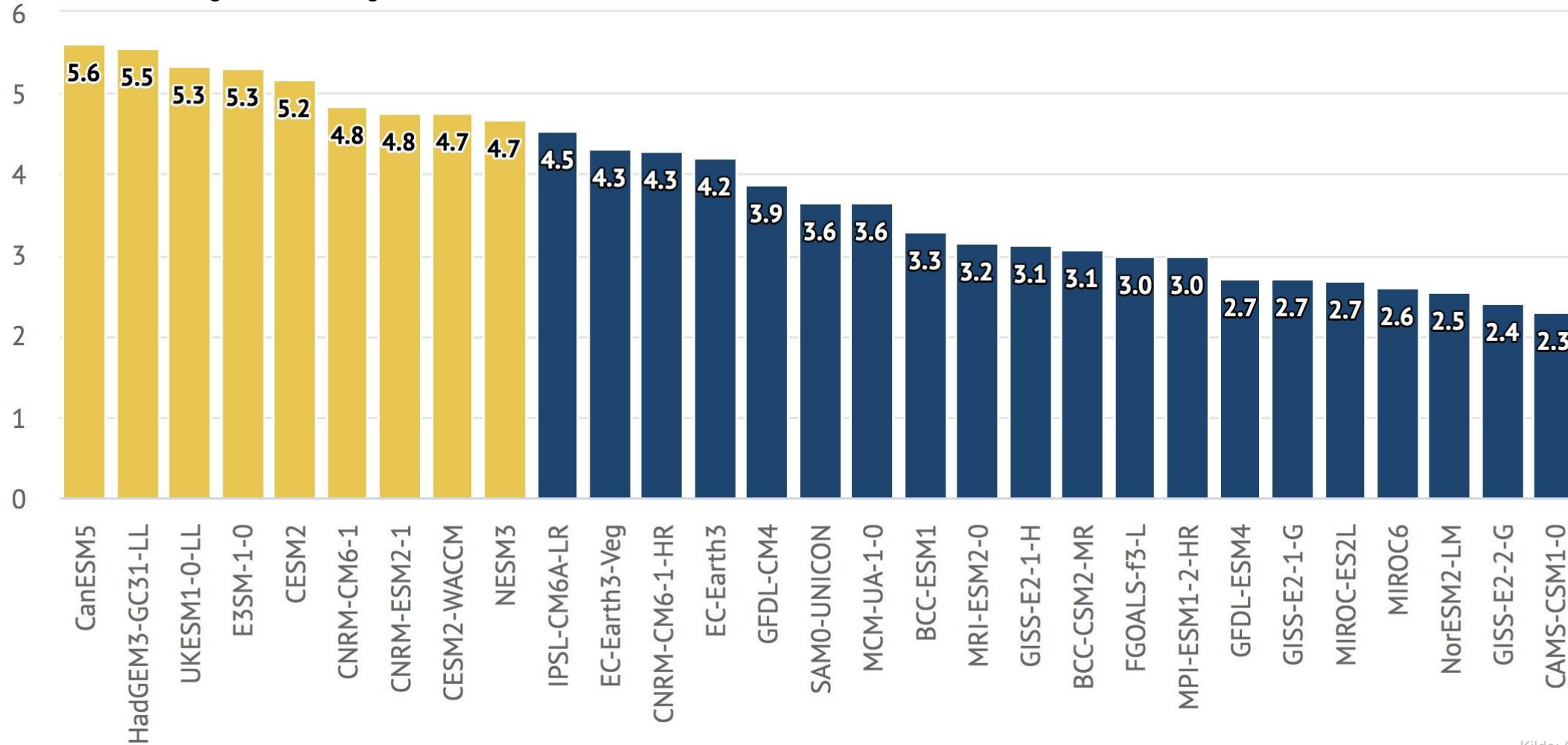
Kilde: NOAA

39



# Climate projections from the different models are different

Global warming after a doubling of CO<sub>2</sub>



Kilde: Carbon Brief

# What tools are available?

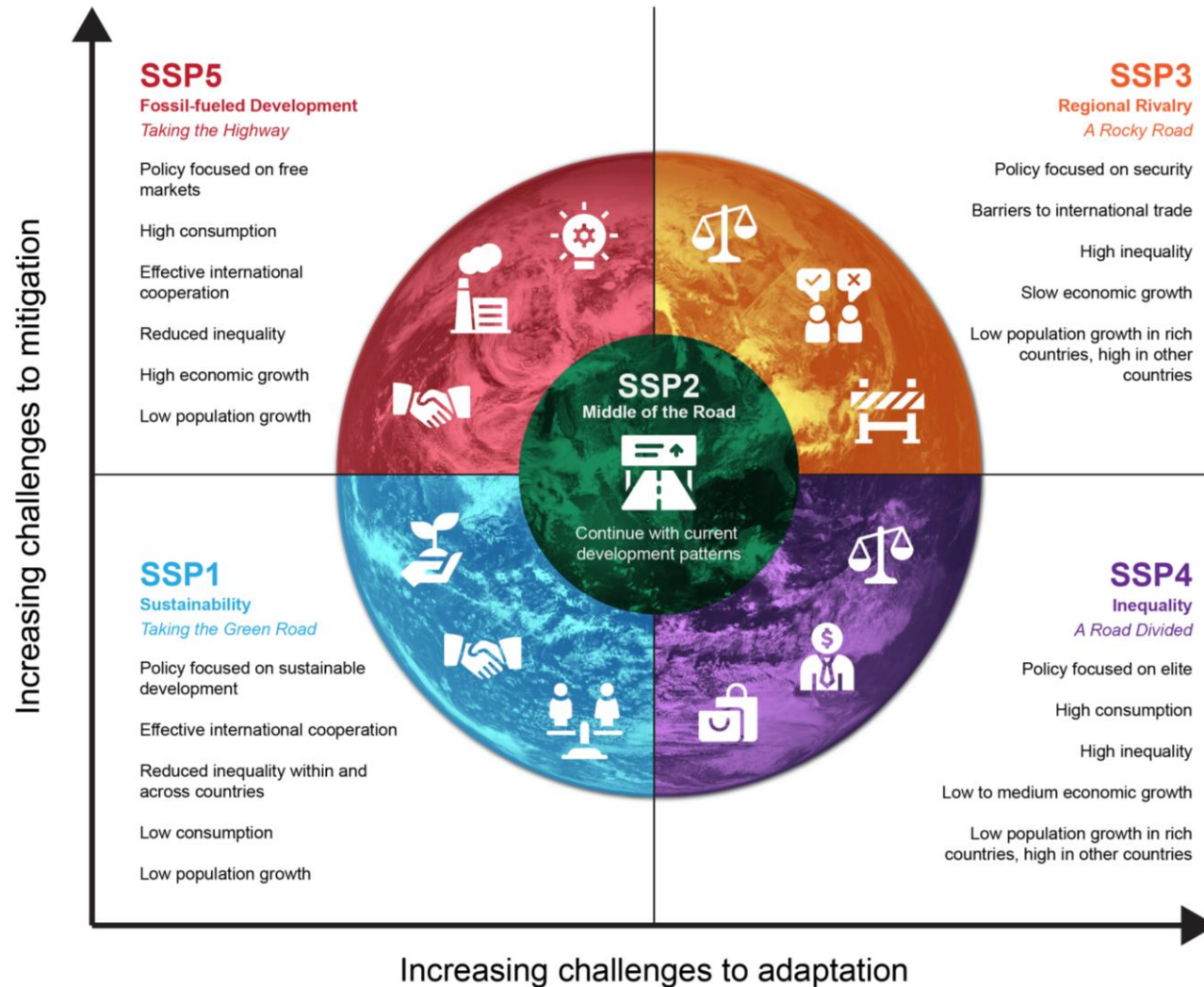
Climate model



Input about the future

# Input about the future:

## Scenarios on socioeconomic world development

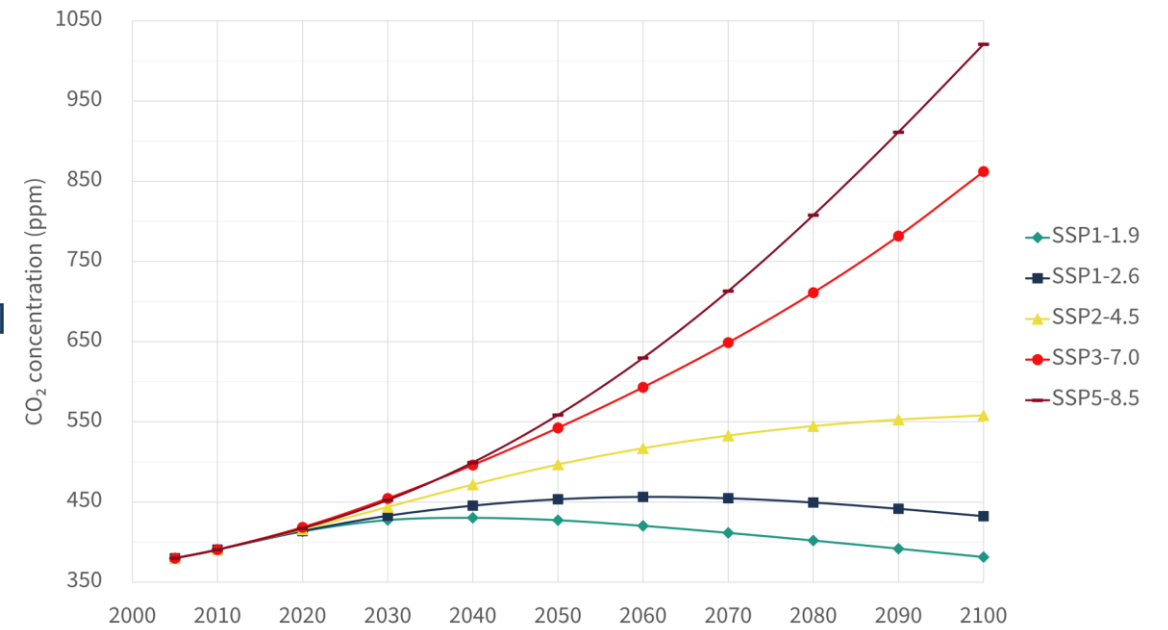


# What tools are available?

Climate model



Future scenarios

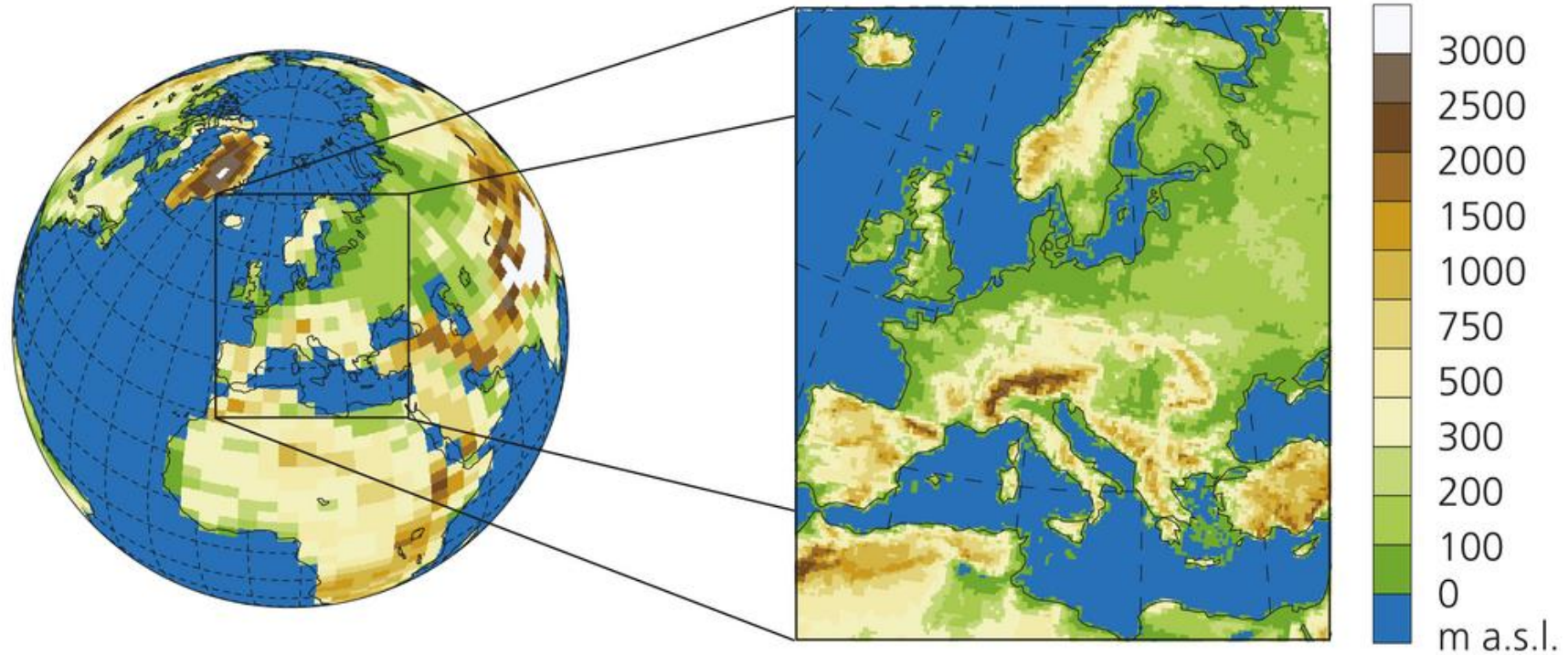
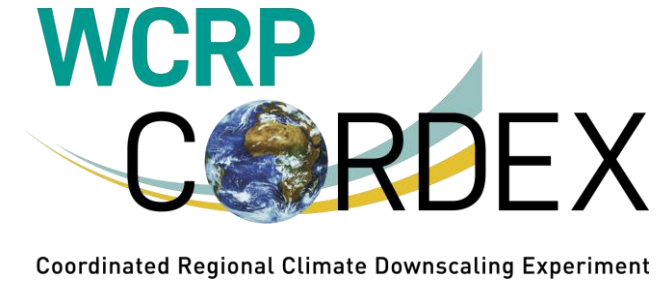


# What tools are available?

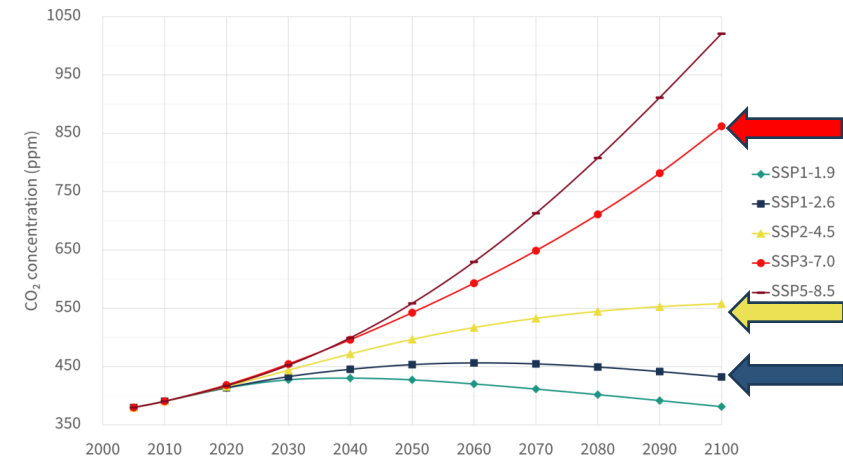
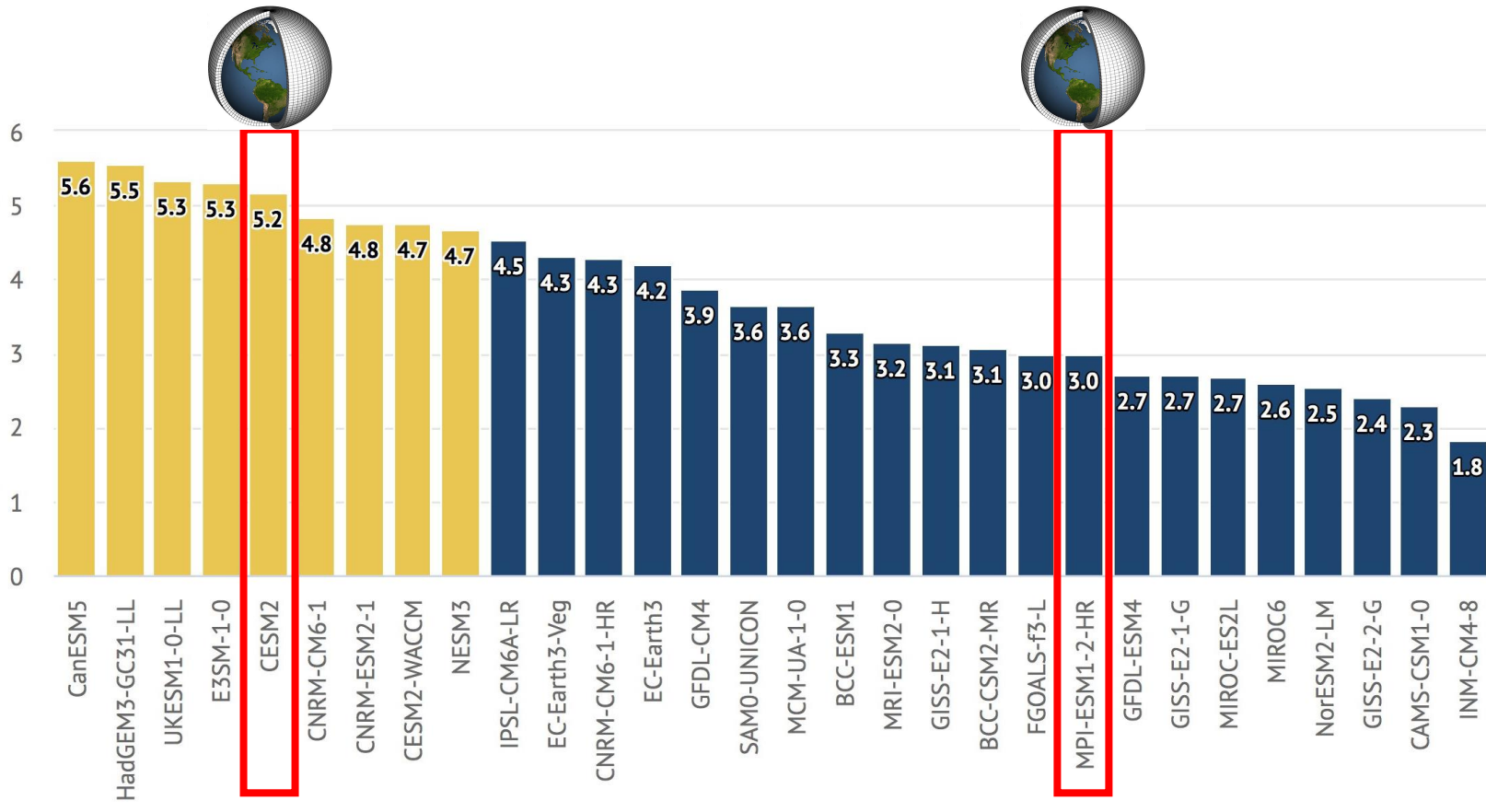
## “Downscaling”

Global Climate Model

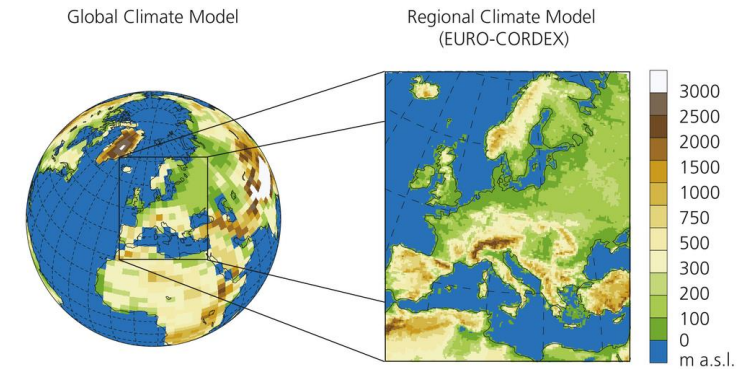
Regional Climate Model



We chose two climate models,  
and three future scenarios,



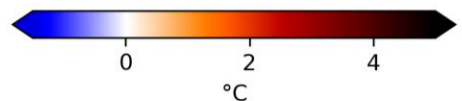
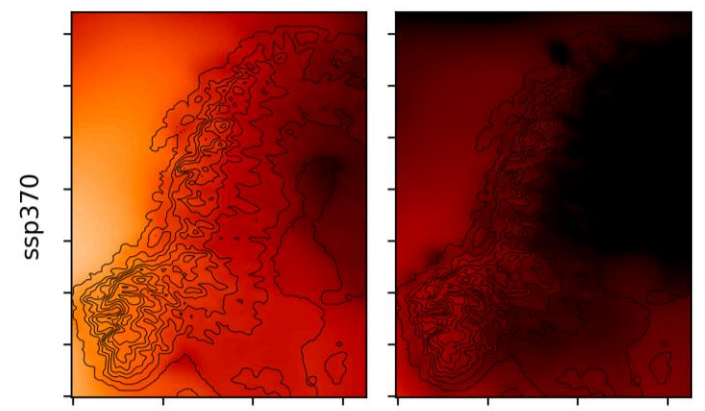
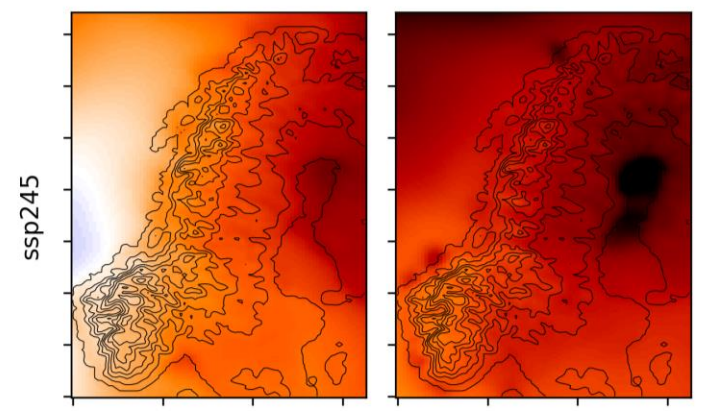
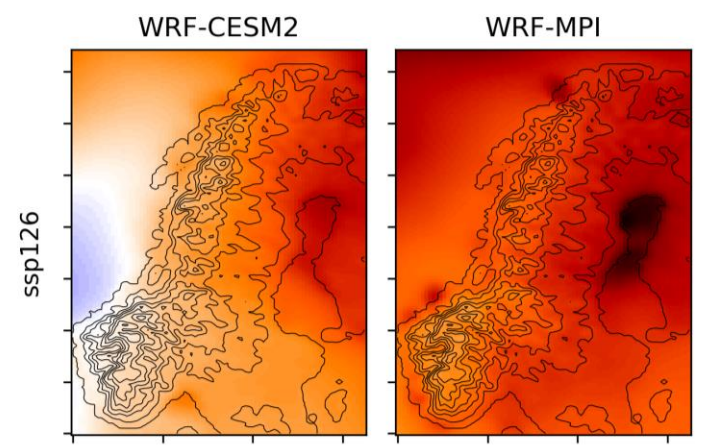
and performed downscaling



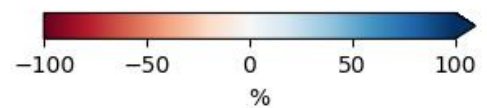
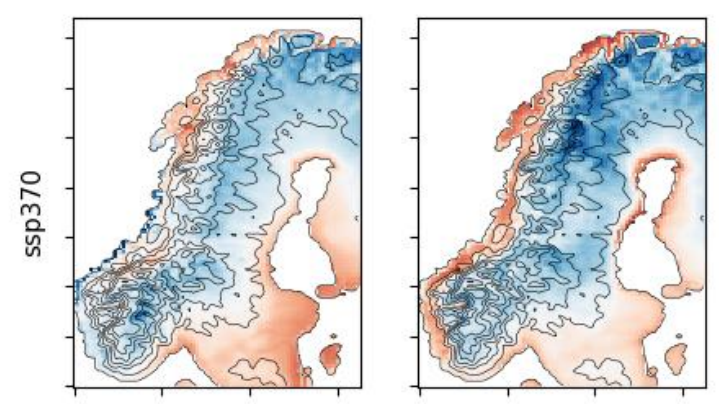
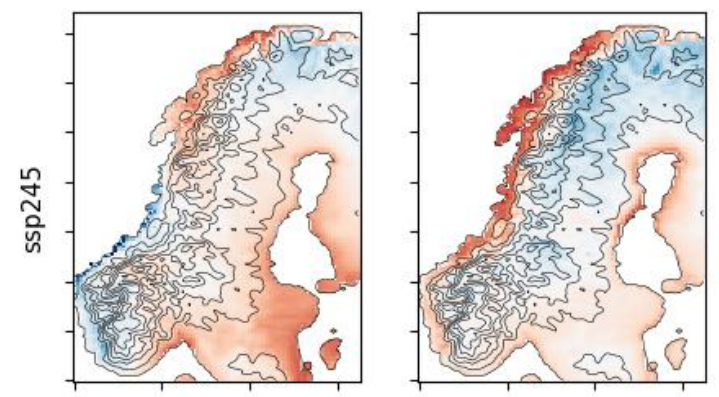
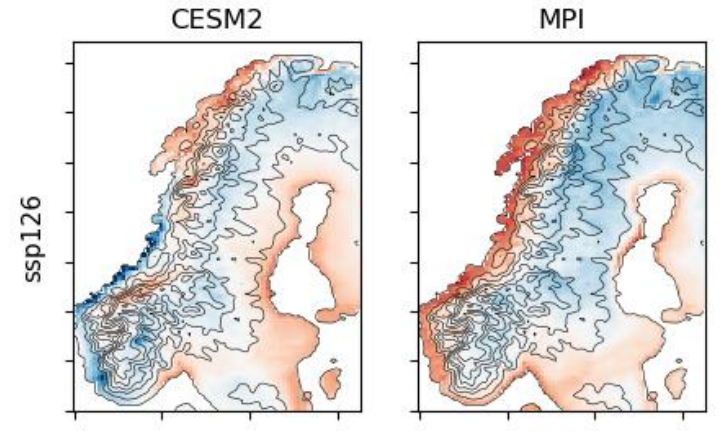


# Results

Change 2075-2100 rel. 1990-2014



## Icing?



# Perform icing calculations on the future data

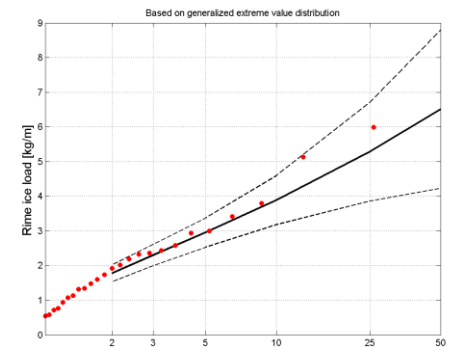
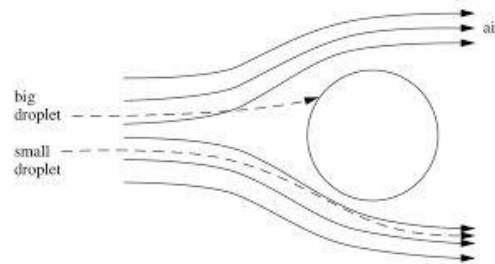
3 scenarios  
X  
2 climate models  
=  
6 datasets



Icing model:  
Standard vertical  
cylinder  
«Makkonen model»



Extreme value  
estimation  
(10 year RP)

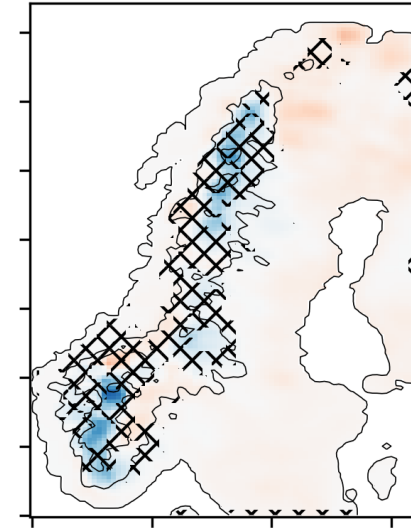
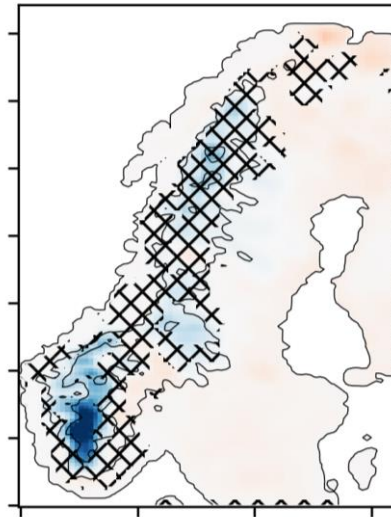
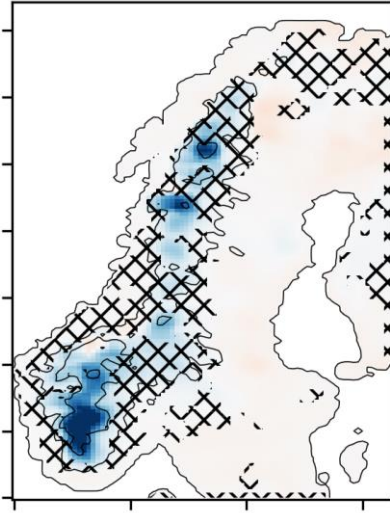


SSP126

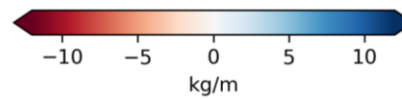
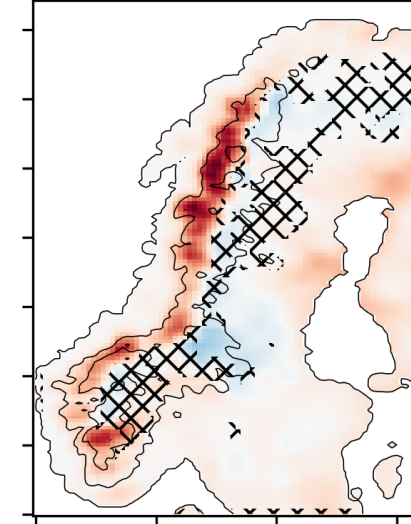
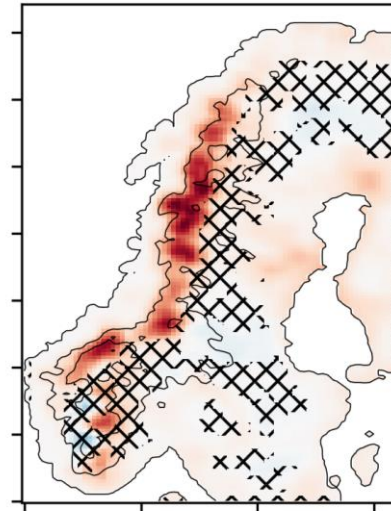
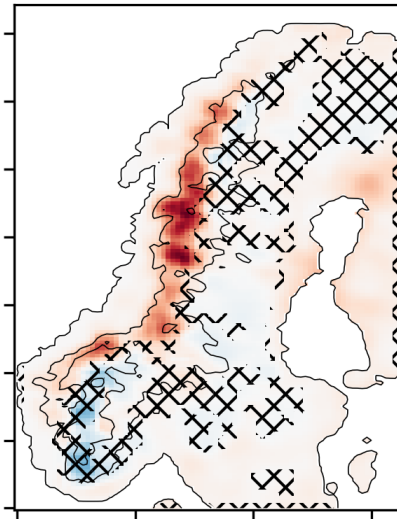
SSP245

SSP370

CESM2



MPI



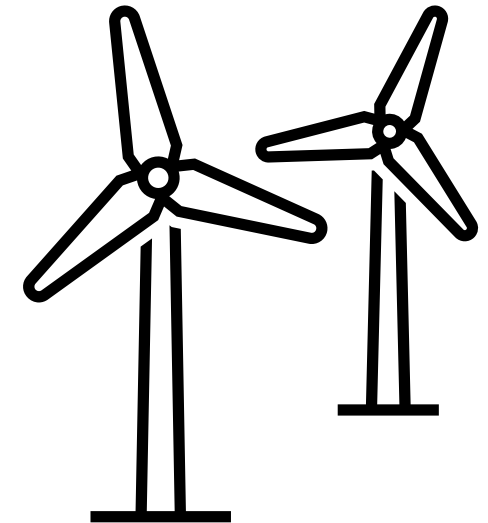
ACCESS-ESM1-5  $\Delta T=3.5$ AWI-CM-1-1-MR  $\Delta T=3.5$ BCC-CSM2-MR  $\Delta T=4.2$ CAMS-CSM1-0  $\Delta T=3.9$ CanESM5  $\Delta T=4.8$ CESM2  $\Delta T=0.56$ CESM2-WACCM  $\Delta T=2.2$ CMCC-CM2-SR5  $\Delta T=4.2$ FGOALS-g3  $\Delta T=2.3$ FIO-ESM-2-0  $\Delta T=3.3$ MIROC6  $\Delta T=3.4$ MPI-ESM1-2-HR  $\Delta T=2.8$ MPI-ESM1-2-LR  $\Delta T=2.7$ MRI-ESM2-0  $\Delta T=2$ NESM3  $\Delta T=4.2$ EC-Earth3  $\Delta T=3.8$ EC-Earth3-Veg  $\Delta T=3$ FGOALS-f3-L  $\Delta T=3.3$ IPSL-CM6A-LR  $\Delta T=4.2$ KACE-1-0-G  $\Delta T=4.2$ GFDL-ESM4  $\Delta T=2.5$ INM-CM4-8  $\Delta T=1.6$ INM-CM5-0  $\Delta T=3.8$ KIOST-ESM  $\Delta T=3.2$ ACCESS-CM2  $\Delta T=4.3$ 

Temperature change 1990-2009 rel. 2090-2099 ( $^{\circ}\text{C}$ )  
SSP245



# Take-aways:

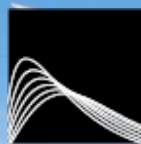
- ▶ Our models indicate decreasing loads in large parts of Sweden, and increasing loads close to the Norwegian boarder.
- ▶ Use as many climate models as possible in a climate change impact study!
- ▶ Future changes in extreme values of in-cloud icing are uncertain based on only two models.
- ▶ Also due to large uncertainties in climate models.



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**Thank you!**



**KJELLER**

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