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Climate models and scenarios
part B

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INTERNATIONAL SUMMER SCHOOL: CLIMATE CHANGE IMPACTS ON THE MED-AGRO-FOOD CHAIN: FROM THEORY TO PRACTICE, SCHLOSS RAUISCHHOLZHAUSEN, HESEN, GERMANY
9-14/9/2019

Content of Part B

This part discusses:

1. Climate sensitivity and climate feedback processes
2. Recent scenarios for climate models
3. Energy – Balance Models – MAGICC
4. Regional Climate Models

Planets as black bodies

A **black body** absorbs all the radiation and during its heating it radiates all the absorbed radiation towards the environment with which it is in a thermal equilibrium.

The total amount of energy that radiates from a black body, to the unit of area and time, is given by the Law of **Stefan-Boltzmann**:

$$\mathbf{F = \sigma T^4}$$

where $\sigma^{=}$ 5.67*10^{-8} W m^{-2} K^{-4} the Boltzmann constant

Earth’s Effective Temperature

The solar energy that the Earth absorbs $(1\text{-}A)\,\pi\, R^2\, F_s$

The energy that the Earth emits as a black body in the same temperature $4\,\pi\, R^2\, F_L$

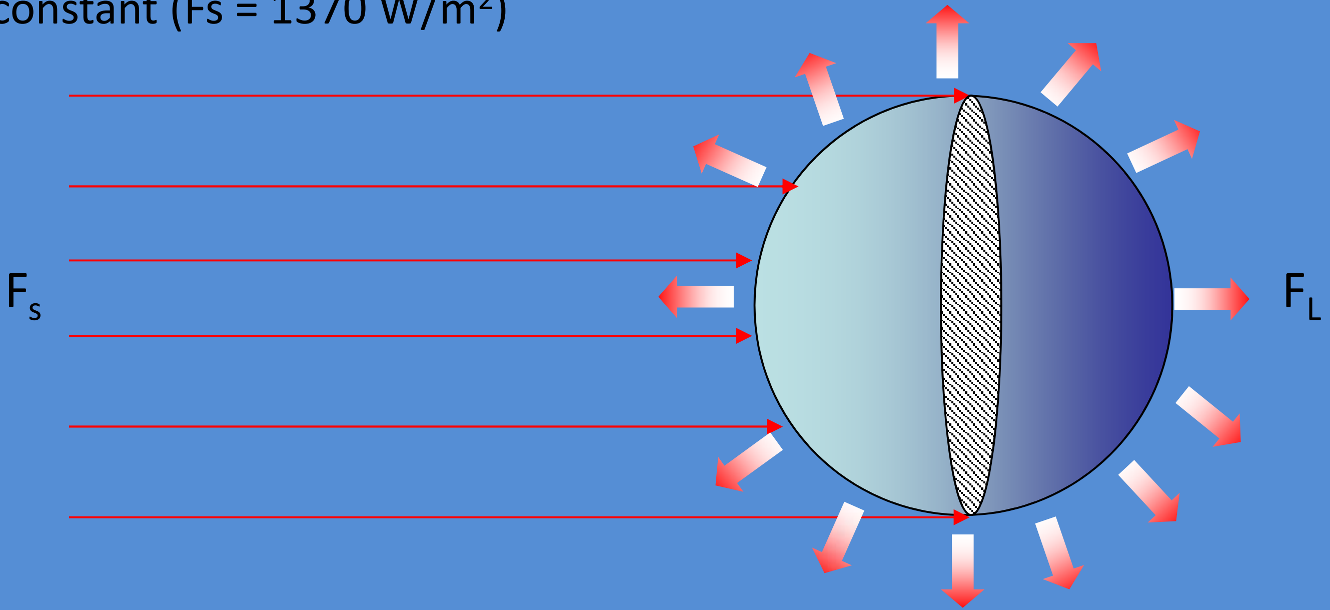
In equilibrium state they msut be equal!

$$(1\text{-}A)\,\pi\, R^2\, F_s = 4\,\pi\, R^2\, F_L$$

R Earth radius

A Albedo of the Earth-Atmosphere system (A= 0.3)

F_s solar constant (Fs = 1370 W/m^2)



Calculation of the Earth's Effective Temperature

According to the Law of Stefan-Boltzman

$$F_L = \sigma T_e^4$$

so

$$(1-A)\,\pi R^2 F_s = 4\,\pi R^2 \sigma T_e^4$$

$$\boxed{T_e = \left[\frac{(1-A)}{\sigma}\frac{F_s}{4}\right]^{\frac{1}{4}}}$$

T_e = 251 K

The effective temperature of a planet Te is the temperature at which a black body would emit the same constant flux F equal to the planet's radiation flux, which is ultimately emitted from its upper boundary to space.

0-D energy-balance climate sensitivity and feedback parameters

For the equilibrium state:

$F_s = F_L$

If there is a perturbation, then:

$\Delta F_{net} = \Delta Fs - \Delta F_L$

In order for the equilibrium to be restored, there must be a change in T_e, so that:

$\Delta T_e = \lambda\ \Delta F_{net} \leftrightarrow \lambda = \Delta T_e / \Delta F_{net}$

λ is the climate sensitivity parameter

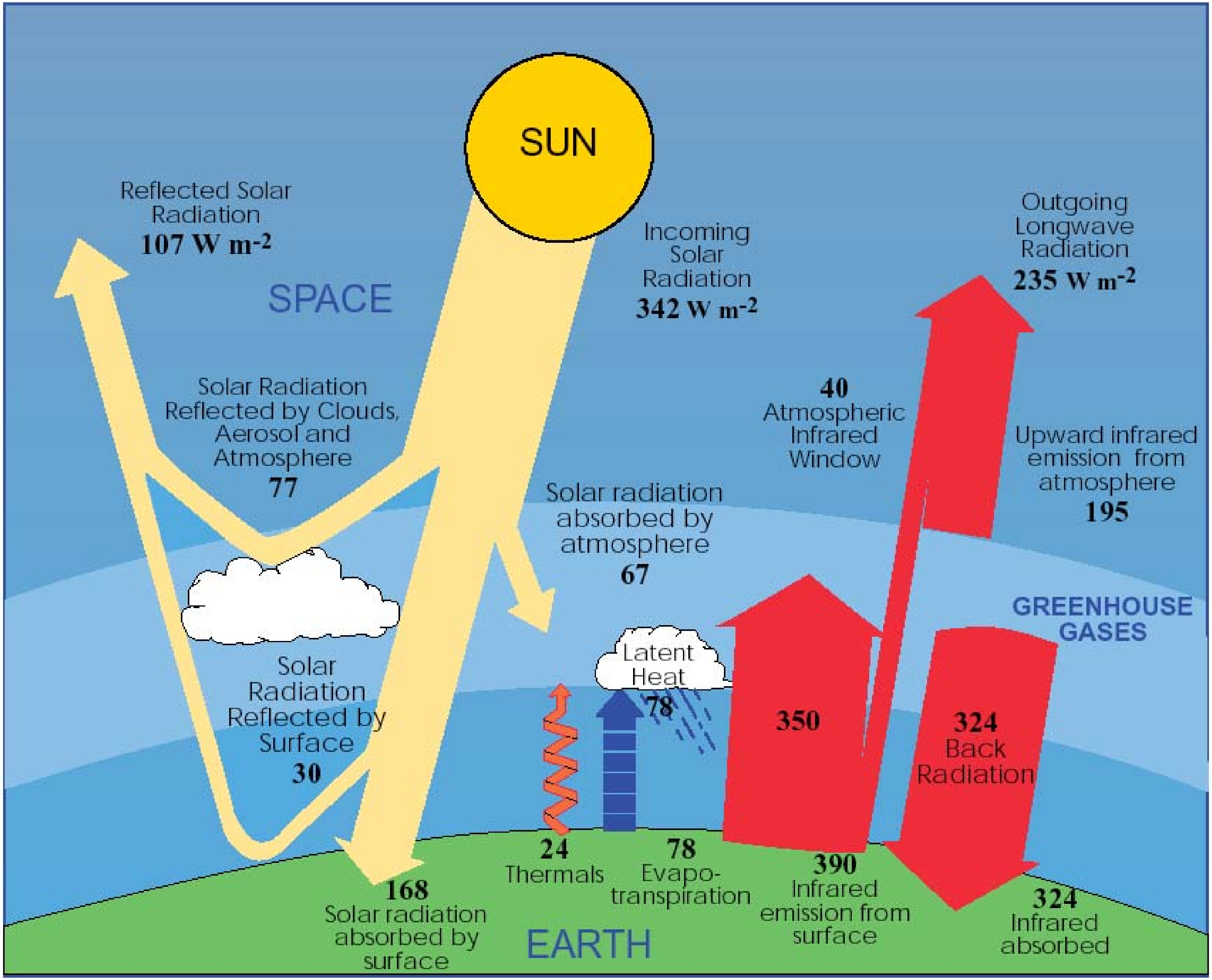
$$\lambda = \left(\frac{\partial F_L}{\partial T_e}\right)^{-1} = \frac{1}{4\sigma T_e^3} = \frac{T_e}{4F_L} \approx 0.3\ \mathrm{K}\ (\mathrm{W\ m^{-2}})^{-1}$$

and

$f = \lambda^{-1} = \Delta F_{net} / \Delta T_e = 3.75\ \mathrm{Wm^{-2}\ K^{-1}}$

f is the climate feedback parameter

Energy Flow in the Climate system:



The Greenhouse Effect

The difference between the temperature of the lower atmosphere and the effective temperature depends on the mass of the atmosphere and the ability of its compounds to absorb in the outgoing infrared (IR) part of the electromagnetic spectrum.

According to Eddington's relation for radiation equilibrium conditions where there are no energy losses, the change in temperature at various optical depths is given by the relationship:

$$T^4 = T_e^4\left(\frac{1}{2} + \frac{3}{4}\tau\right)$$

where ***τ*** is the atmosphere’s optical depth

Greenhouse Effect

I_o intesity of IR at the surface

I_t intesity of IR that passes through the atmosphere

τ optical depth in IR

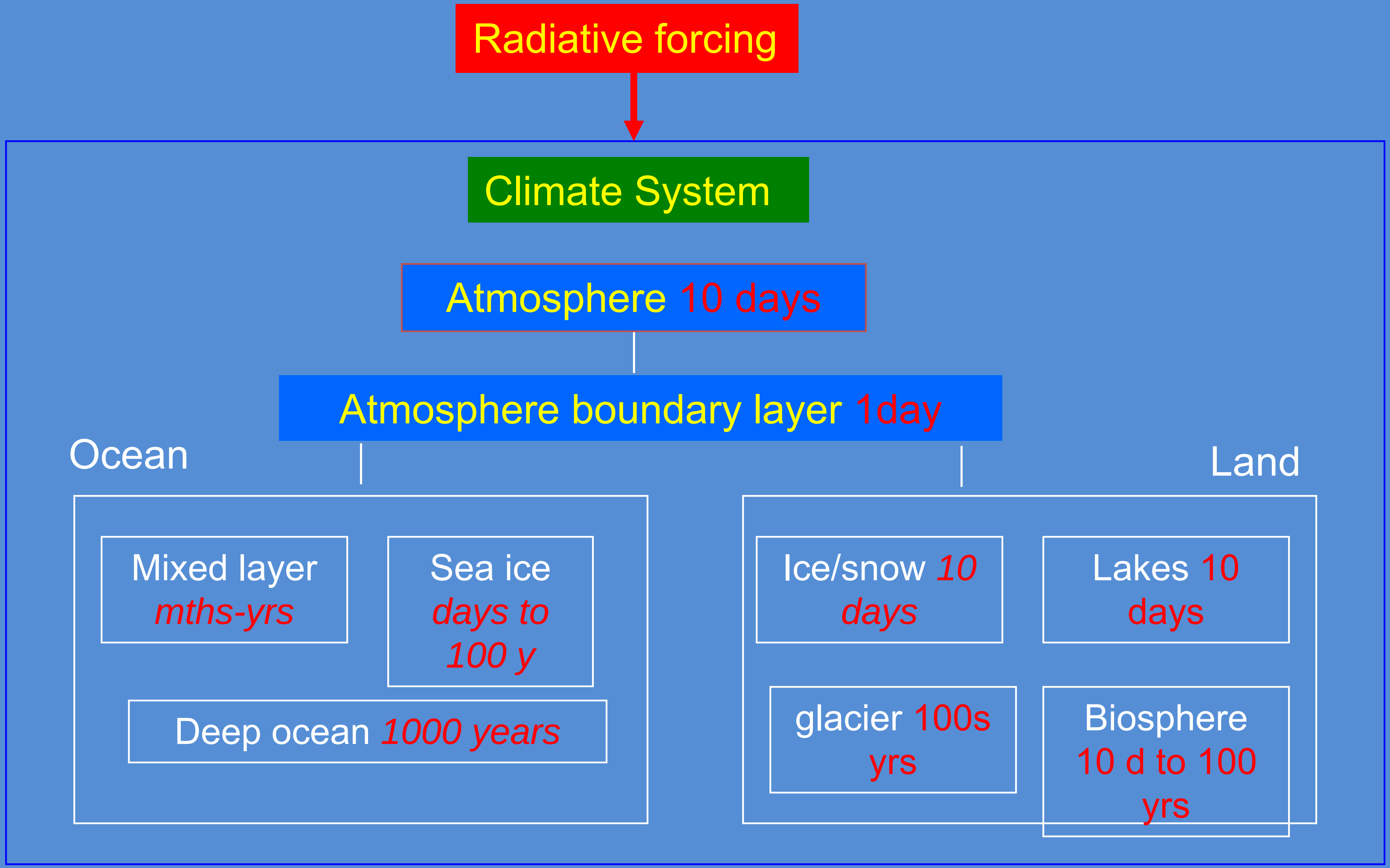
$$I_t = I_o \exp(-\tau)$$

From observations we know that $I_t/I_o = 0.2$, which means that about **80% of the intensity of the IR radiation is absorbed mainly by triatomic gases** (CO_2, H_2O, O_3)

$$\tau_\upsilon = -\ln(I_t/I_o) = -\ln(0.2) = 1.61$$

$$T^4 = T_e^4\left(\frac{1}{2}+\frac{3}{4}\tau\right)$$ ➡ T= 287 K

Equilibrium time scales of the climate system



Radiative forcing

Climate System

Atmosphere 10 days

Atmosphere boundary layer 1day

Ocean

Mixed layer *mths-yrs*

Sea ice *days to 100 y*

Deep ocean *1000 years*

Land

Ice/snow *10 days*

Lakes 10 days

glacier 100s yrs

Biosphere 10 d to 100 yrs

Climate sensitivity

How is climate sensitivity defined?

Climate sensitivity is typically defined **as the global temperature rise** following **a doubling of CO_2 concentration** in the atmosphere compared to pre-industrial levels. Pre-industrial CO_2 was about 260 parts per million (ppm), so a doubling would be at roughly 520 ppm. Current levels of atmospheric CO_2 have now exceeded 400 ppm, with the 520 ppm threshold expected in the next 50-100 years depending on future greenhouse gas emissions. In climate models, it is a measure of estimating the climate feedbacks.

There are several ways of defining climate sensitivity, depending on the timescales of interest. Two of those are:

Transient Climate Response (TCR): The temperature increase at the instant that atmospheric CO_2 has doubled (following an increase of 1% each year) gives us the TCR. This is useful as a gauge for what we might expect over the current century when atmospheric concentrations of CO_2 are changing.

Equilibrium Climate Sensitivity (ECS): The climate system will continue to warm for some time after the TCR point, largely as the oceans are very slow to respond. Therefore we can also consider the temperature increase that would eventually occur (after hundreds or even thousands of years) when the climate system fully adjusts to a sustained doubling of CO_2. The long timescales involved here mean ECS is arguably a less relevant measure for policy decisions around climate change.

In climate models, the estimation of ECS requires a long-term simulation, something that is not required for TCR. TCR is smaller than ECS due to the inertia of the oceans to heating.

Climate sensitivity

How can we estimate climate sensitivity?

Climate sensitivity cannot be directly measured in the real world. Instead it must be estimated and there are three main lines of evidence that can be used to do this:

Climate models: we can use climate models, which provide complex simulations of the Earth's climate system, to predict future climate sensitivity as we don't have observations for the future climate. These mathematical models are built around our understanding of the physics which underpin our climate system.

Historical climate records: instrumental records of warming since the mid-19thcentury, combined with estimates of greenhouse gas and aerosol emissions, can be used to assess the global temperature response to emissions of CO_2 by human activities to date.

Palaeoclimate records: ice cores and other records can be used to estimate natural changes in temperature and atmospheric CO_2 over thousands of years. These can be used for estimates of the past relationship between the two factors.

What would be the effect of doubling CO_2 on T_e?

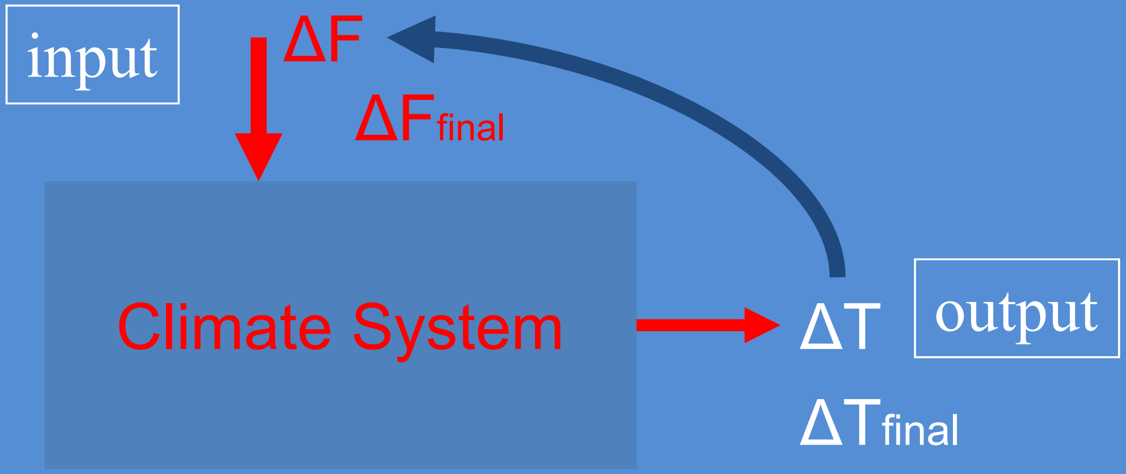
- It is estimated that a doubling of CO_2 will lead to $\Delta F_L = 4.6\ W\ m^{-2}$

- According to $\Delta T_e = \lambda\ \Delta F_{net}$ and considering $\lambda = 0.3\ K / Wm^{-2}$ this will lead to an increase in the effective temperature $\Delta T_e = 1.4\ K$ (a first estimate for ECS)

- This change in temperature is smaller than what is estimated for ECS by climate models (~2 to 4.5 K), that contain mechanisms of feedback, that eventually lead to the enhancement of the greenhouse effect.

Climate Feedback

Feedback is a circular causal process whereby some proportion of a system's output is returned (fed back) to the input.



input

ΔF

ΔF_{final}

Climate System

ΔT

output

ΔT_{final}

$\Delta F_{final} = \Delta F + \Delta F_{feedback}$

$\Delta F_{feedback}$ can be either negative or positive

$\Delta T_{final} = \Delta T + \Delta T_{feedback}$

Major Climate Feedback Mechanisms

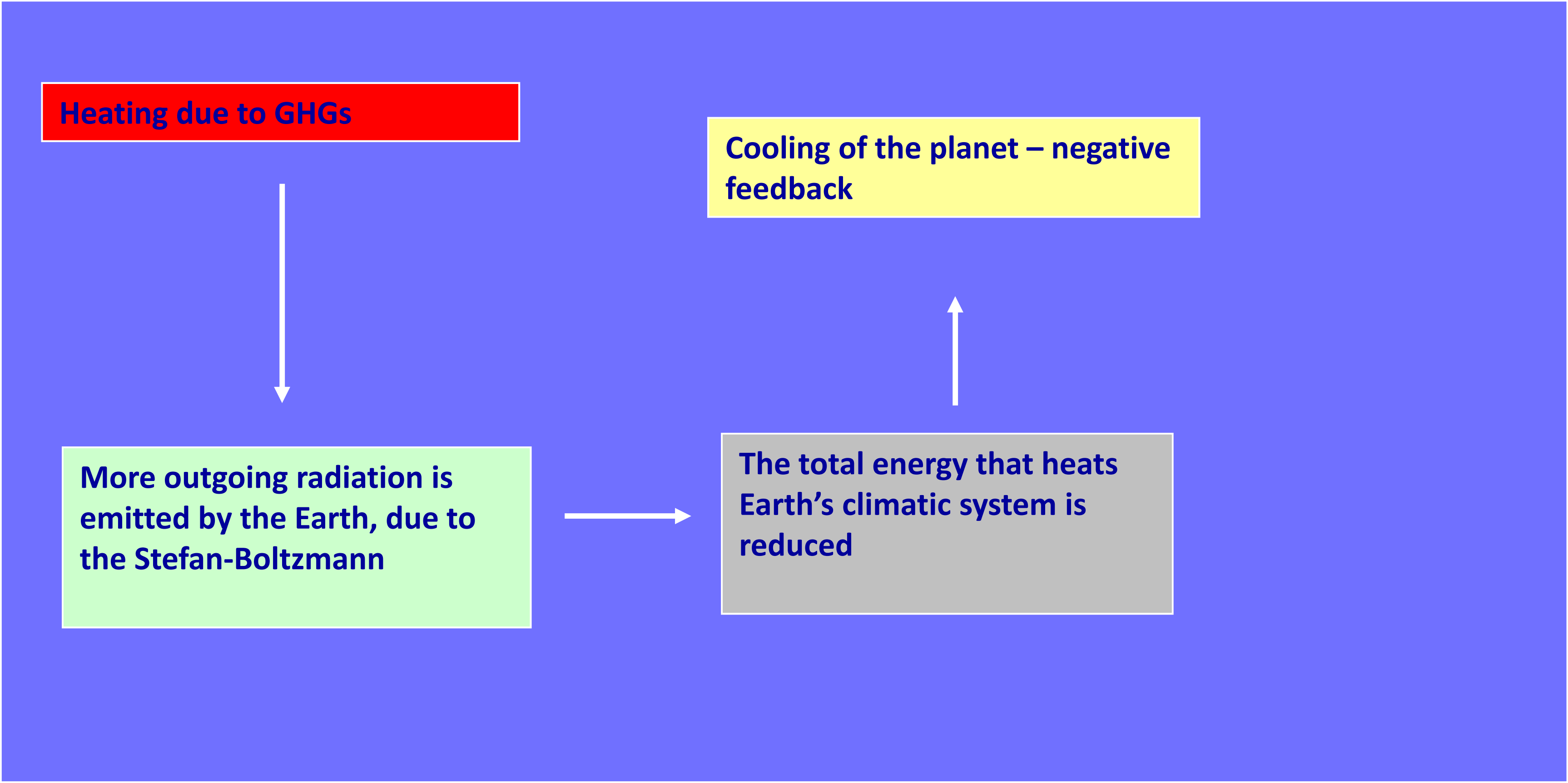
- **Stefan-Boltzmann Law (longwave radiation feedback) - negative**
- **Ice/snow-albedo feedback - positive**
- **Water vapour feedback - positive**
- **Cloud feedback – either positive or negative**
- **Lapse Rate Feedback - negative**
- **Climate – carbon cycle feedbacks- positive**
- **Climate – vegetation feedback - positive**

Negative Stefan-Boltzmann Law - longwave radiation feedback

Longwave outgoing radiation:

$F_L = \sigma T^4$

$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4} the Boltzmann constant



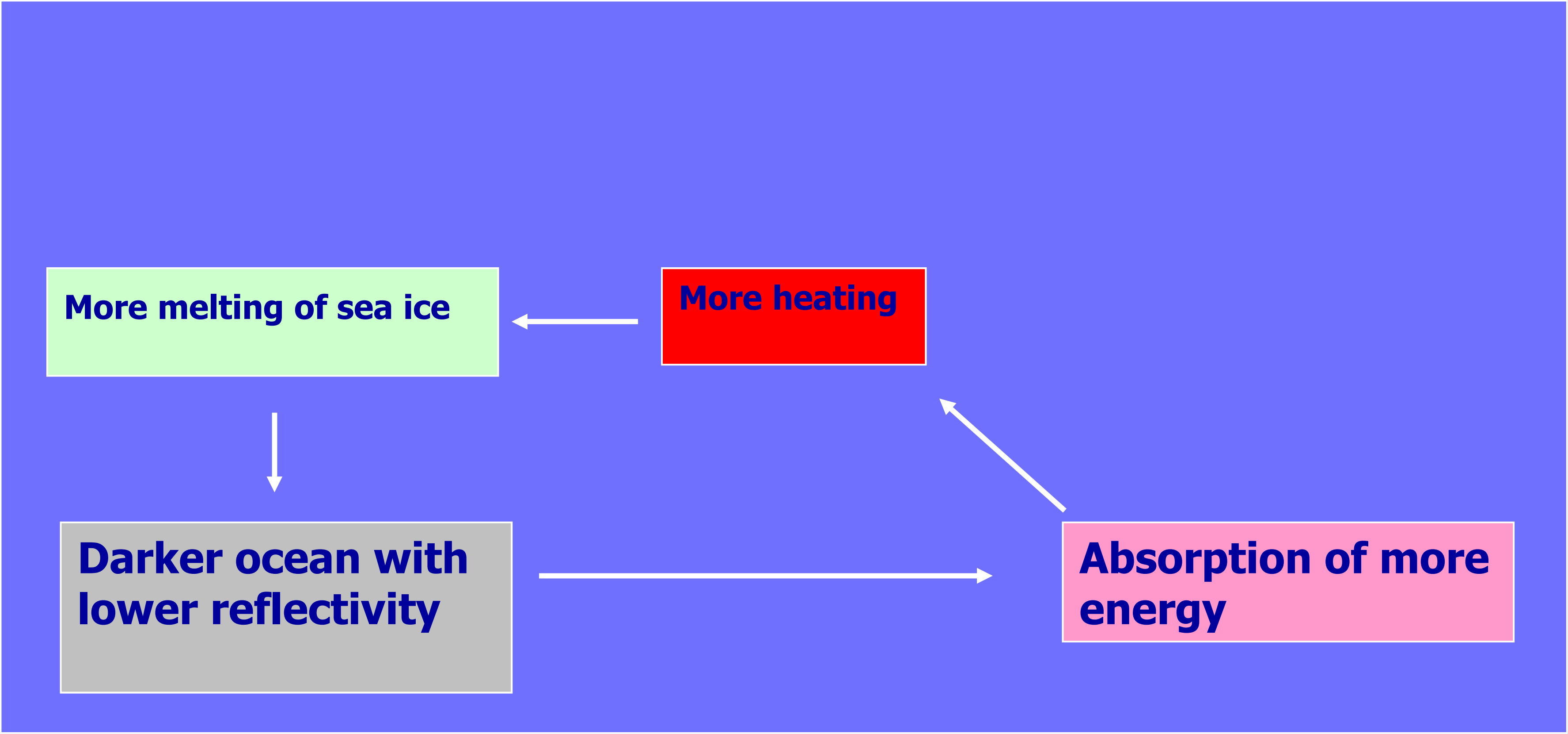
Heating due to GHGs

More outgoing radiation is emitted by the Earth, due to the Stefan-Boltzmann

The total energy that heats Earth's climatic system is reduced

Cooling of the planet – negative feedback

Positive Ice/snow-albedo feedback



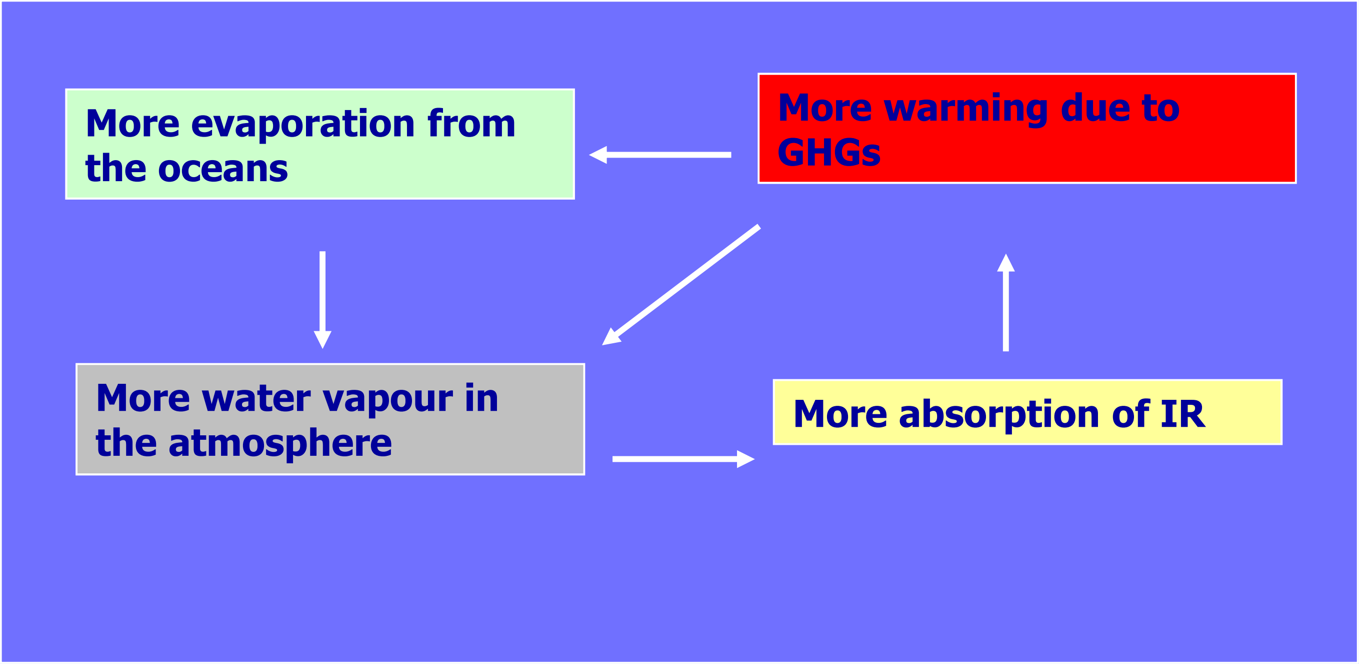
More melting of sea ice

More heating

Darker ocean with lower reflectivity

Absorption of more energy

Positive Water vapour feedback



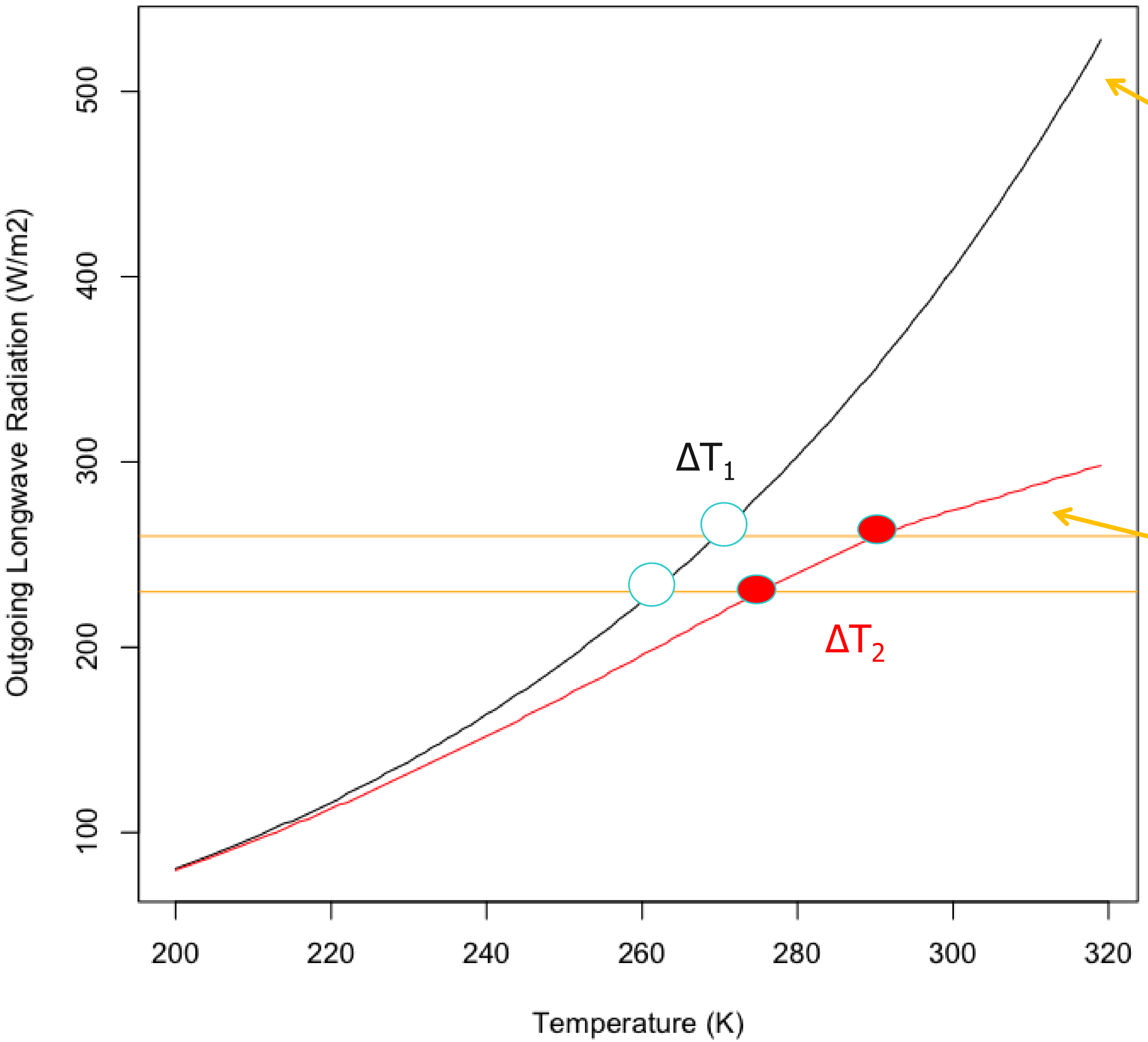
More evaporation from the oceans

More warming due to GHGs

More water vapour in the atmosphere

More absorption of IR

1) Water vapor (H_2O) is a strong greenhouse gas.
2) Increase of 1% in T will increase the saturation vapour pressure e_s through the Clausius-Clapeyron equation by 20%.
3) The maximum content of the atmosphere in water vapour increases with the increase of temperature, while the oceans consist a huge source of water vapor. Theoretical calculations display a maximum increase in water vapour of ~7% for every degree of heating near the surface and by a factor of 2-3 times larger in upper atmosphere.



Dry atmosphere

The distance among the two equilibrium positions is larger $\Delta T_2 > \Delta T_1$

With the vapour feedback

Cloud feedbacks

1. Clouds increase reflectivity, decreasing the shortwave radiation every year to -47 W m^{-2} in a global scale. Also, clouds hinder the outgoing IR radiation causing a mean increase to the radiation budget +30 W m^{-2}. The result is a decrease of -17 W m^{-2} on a global scale, that in recent climate leads to cooling. This fact does not provide information concerning cloud feedbacks, but it is indicative that it is difficult to calculate the total impact of the clouds from the subtraction of two large and competitive terms.

2. It is unclear what is the strength and even directions (negative or positive).

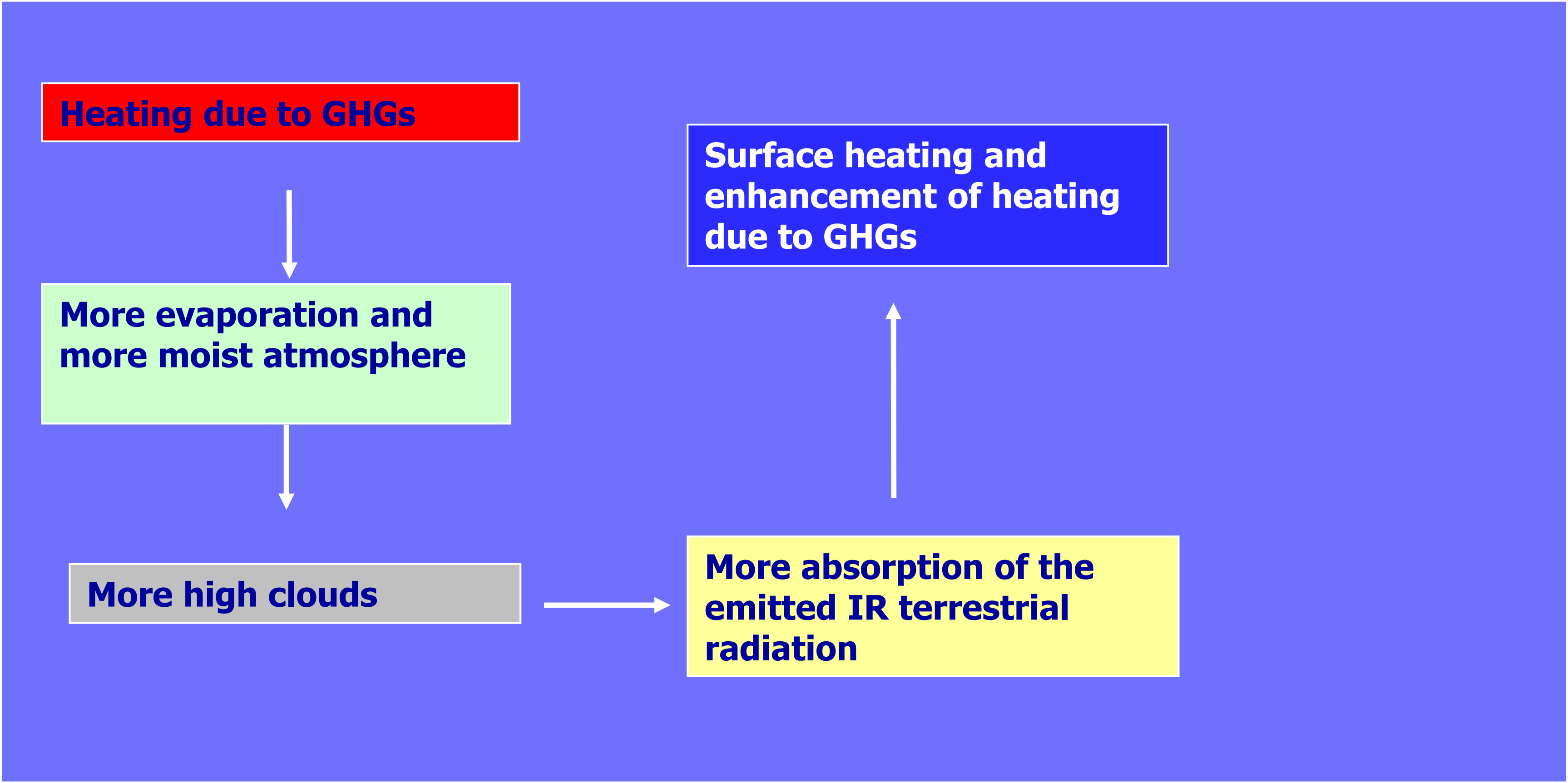
3. Low cumulus clouds (negative feedback) - High cirrus clouds (positive feedback)

4. It is uncertain whether an increased temperature will lead to increased or decreased cloud cover.

5. It is generally agreed that increased temperatures will cause higher rates of evaporation and hence make more water vapor available for cloud formation, but the form of additional clouds is much less certain.

6. Generally, cloud feedbacks are responsible for the large range of estimations of climatic sensitivity in climate models and hence, for the range of future climatic estimations.

positive cloud feedack



Heating due to GHGs

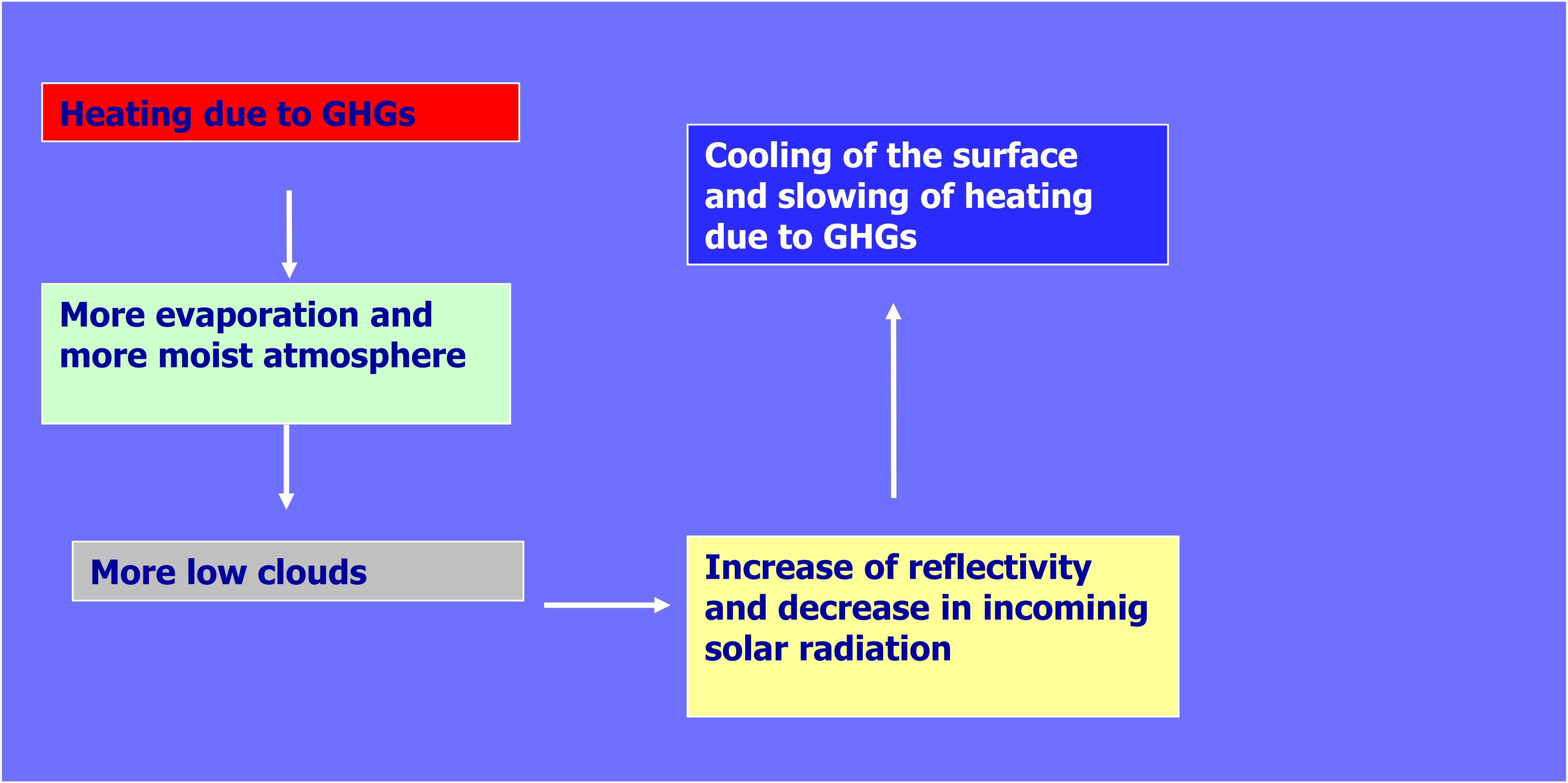
More evaporation and more moist atmosphere

More high clouds

More absorption of the emitted IR terrestrial radiation

Surface heating and enhancement of heating due to GHGs

negative cloud feedack



Heading due to GHGs

More evaporation and more moist atmosphere

More low clouds

Increase of reflectivity and decrease in incominig solar radiation

Cooling of the surface and slowing of heating due to GHGs

Negative Lapse Rate Feedback

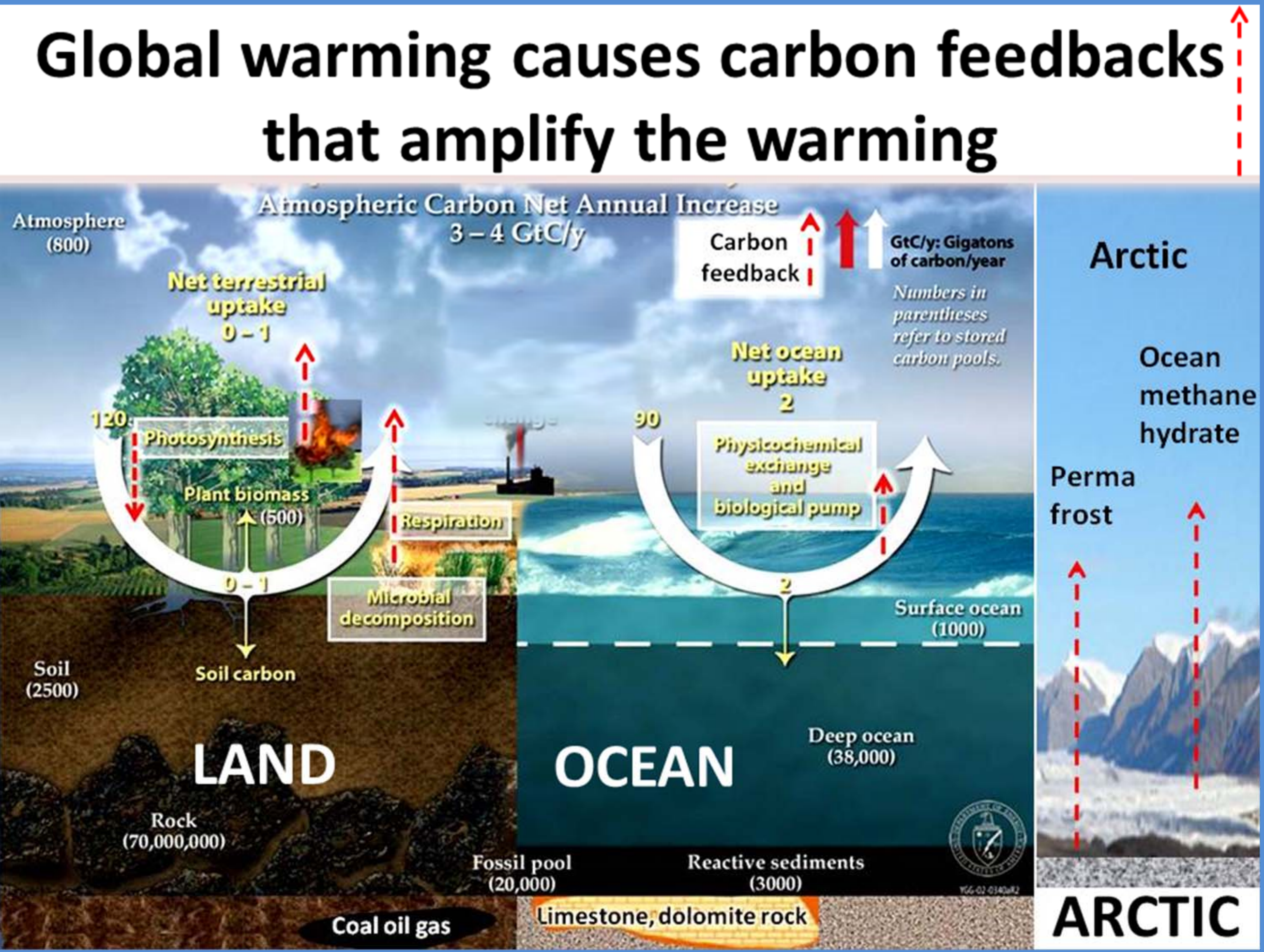
- As an ascending moist mass of air condenses, it releases latent heat and heats the air around it. A warmer air mass contains more water vapour in saturation, so it condenses more water vapour as it ascends and temperature decreases with height with a slower rate. This means that the moist adiabatic lapse rate, -dT/dz, decreases with the increase of temperature.

- The intensity of the greenhouse effect depends on the vertical distribution of temperature. The theory and the climate models show that global warming decreases the vertical laspe rate, creating a negative feedback and a weakening in the greekhouse effect.

- A larger emission of IR radiation in the upper troposphere means that the surface needs less temperature in order to reach equilibrium.

- The lapse rate feedback is more intense in the tropics.

Climate – carbon cycle feedbacks



Terrestrial feedbacks

o Increased decomposition and respiration by soil organisms in a warming soils.

o Heat waves and drought - reduce carbon uptake by green vegetation photosynthesis.

o Increased green plant toxic ground level ozone increase- reduced photosynthesis.

o Increased forest fires - emit black carbon, CO_2 and methane.

Ocean carbon feedbacks.

o Increased water temperature dissolves less CO_2.

o Increased ocean acidification dissolves less CO_2.

o Reduced phytoplankton growth reduces ocean photosynthesis.

o Impaired Capacity of shell bearing organization to make calcium carbonate.

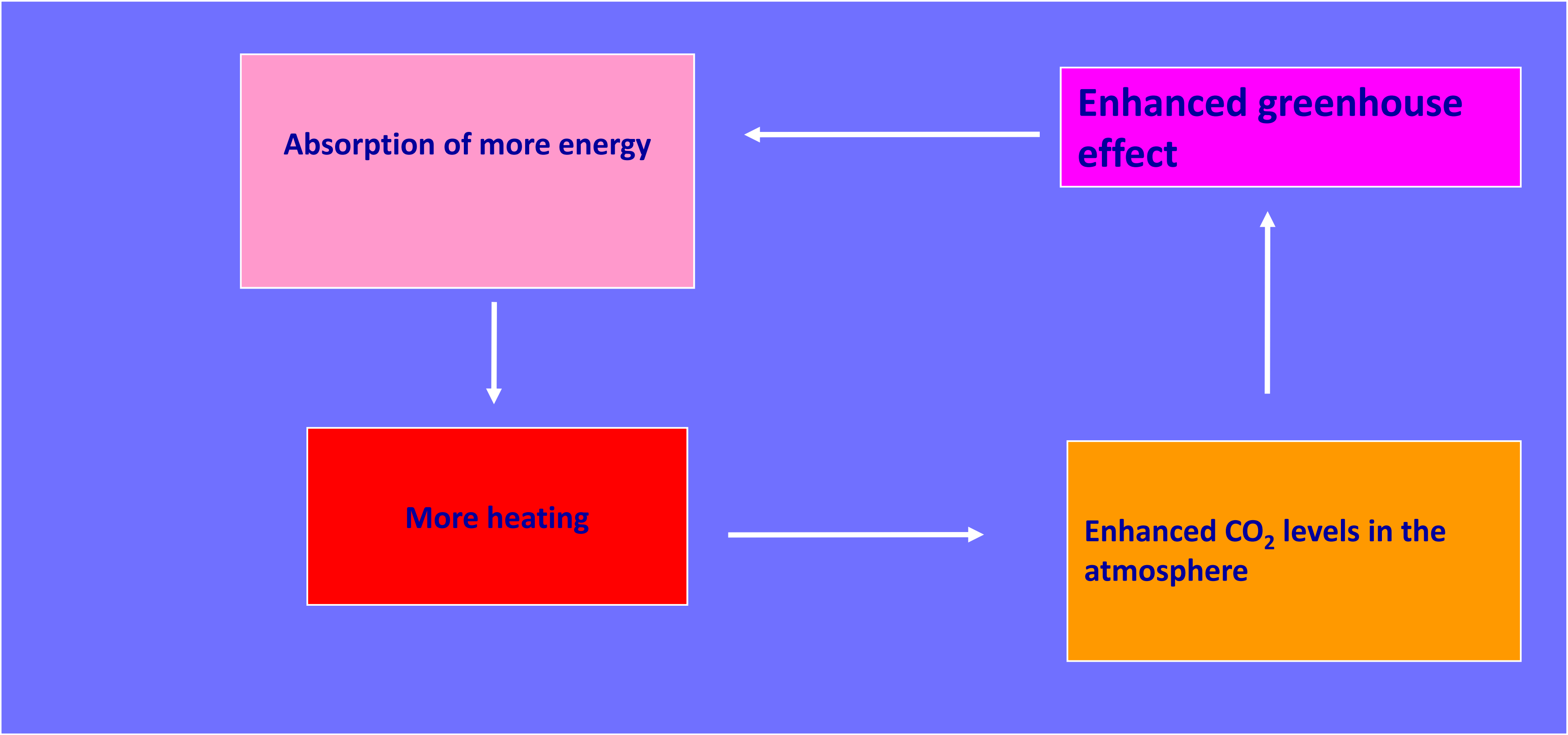
Arctic cryosphere carbon feedbacks

o Thawing permafrost

o Melting ocean floor methane hydrates

Feedback Mechanisms

Positive Feedback CO_2 - climate



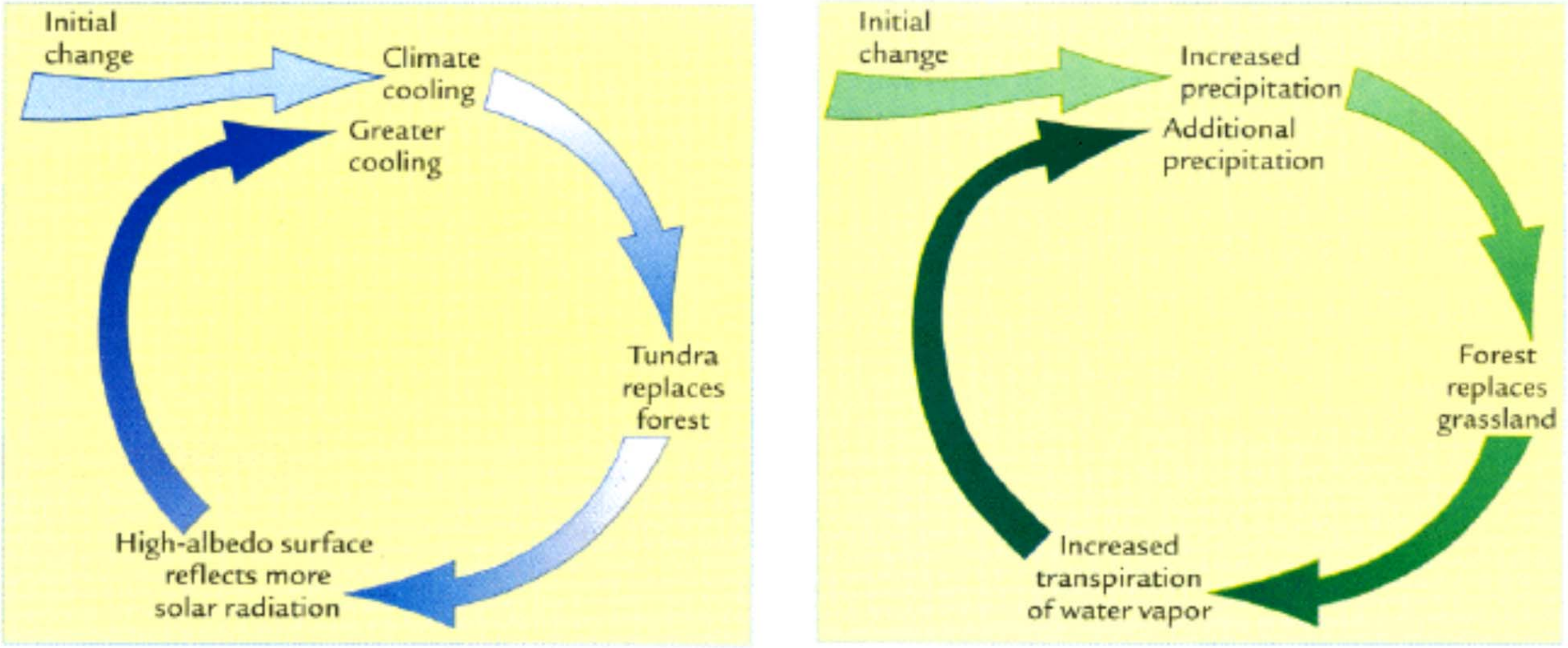
Absorption of more energy

More heating

Enhanced CO_2 levels in the atmosphere

Enhanced greenhouse effect

Vegetation-Climate Feedbacks



A Vegetation–albedo feedback

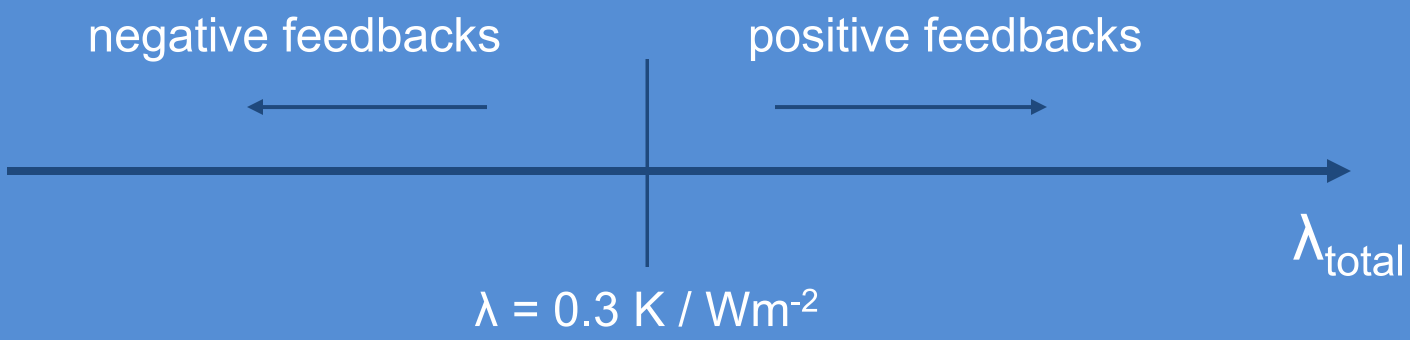
B Vegetation–precipitation feedback

(from *Earth' Climate: Past and Future*)

Total feedback

Feedback process	Feedback parameter f (Wm^{-2}K^{-1})
longwave	3.75
Water vapour	- 1 to -1.5
Ice/snow albedo	-0.1 to -0.9
clouds	uncertain

$\lambda_{total} = 0.7$ K / Wm^{-2} (with all feedbacks)



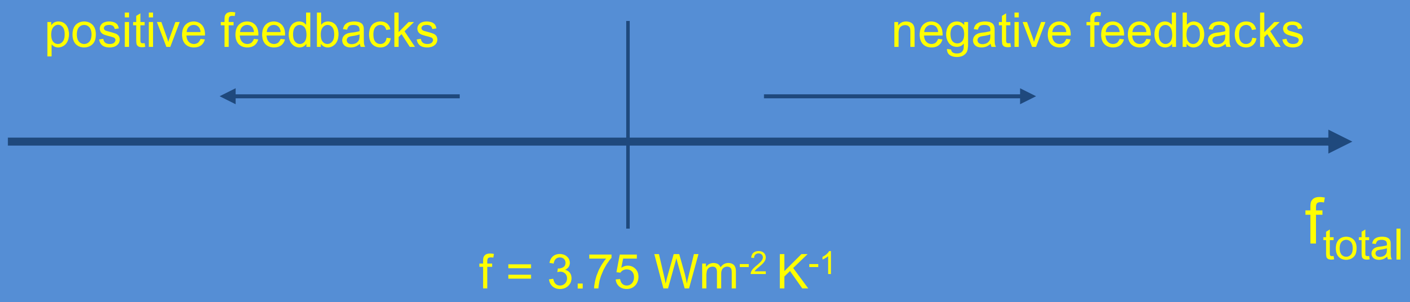
negative feedbacks

positive feedbacks

λ_{total}

$\lambda = 0.3$ K / Wm^{-2}

$f_{total} = 1.45$ Wm^{-2} K^{-1} (with all feedbacks)



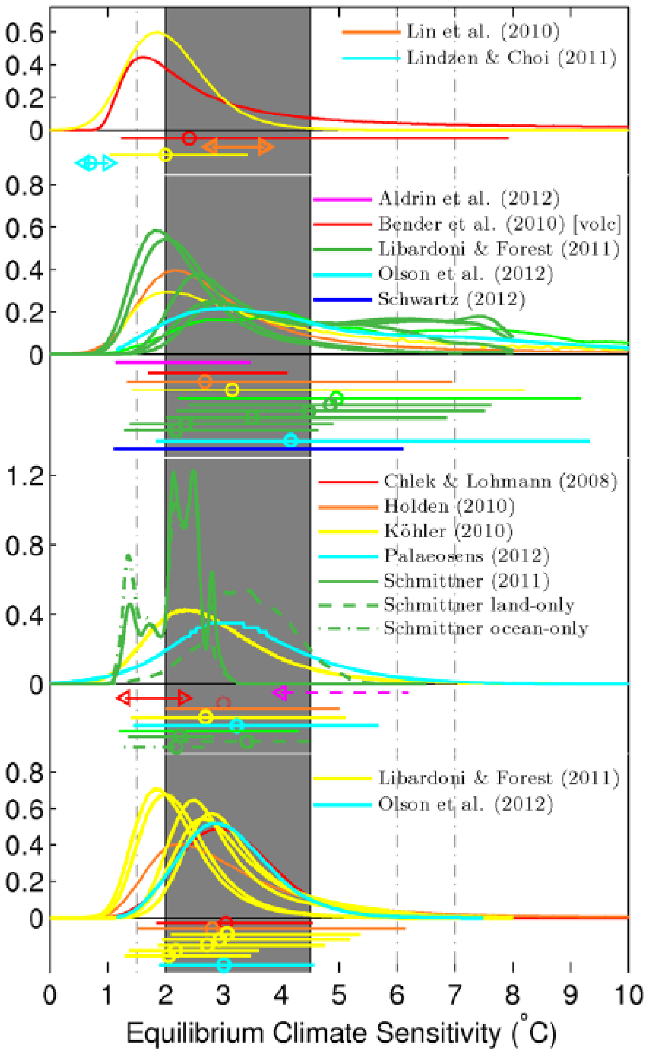
positive feedbacks

negative feedbacks

f_{total}

f = 3.75 Wm^{-2} K^{-1}

- So doubling of CO$_2$ and considering λ = 0.7 K / Wm^{-2} will lead to an increase in temperature $\Delta T = \lambda \Delta F_{net} = 0.7 \times 4.6 = 3.2$ K



	Similar climate base state	Similar feedbacks	Close to equilibrium	Uncertainties accounted for / known	Overall level of scientific understanding
Satelite period	🟩	🟩	🟥	🟨	🟨
20th Century	🟩	🟩	🟥	🟨	🟩
Palaeoclimate	🟥	🟥	🟩	🟨	🟨
Combination of evidence				🟨	🟨

The mean climatic sensitivity ECS extends from ~2 to 4.5 ^{0}C for a doubling of CO_2, and this range has not changes significantly the last decades.

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4. Regional Climate Models

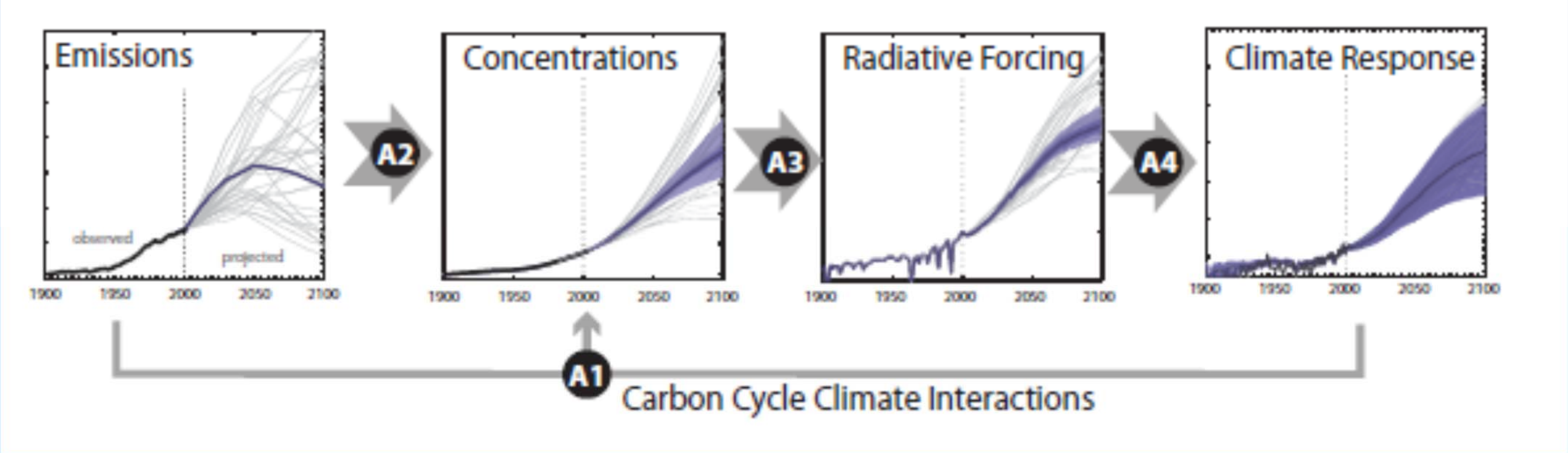


Figure. Schematic overview of MAGICC calculations showing the key steps from emissions to global and hemispheric climate responses. Meinshausen et al., Atmos. Chem. Phys., 11, 1417-1456, 2011 (https://doi.org/10.5194/acp-11-1417-2011)

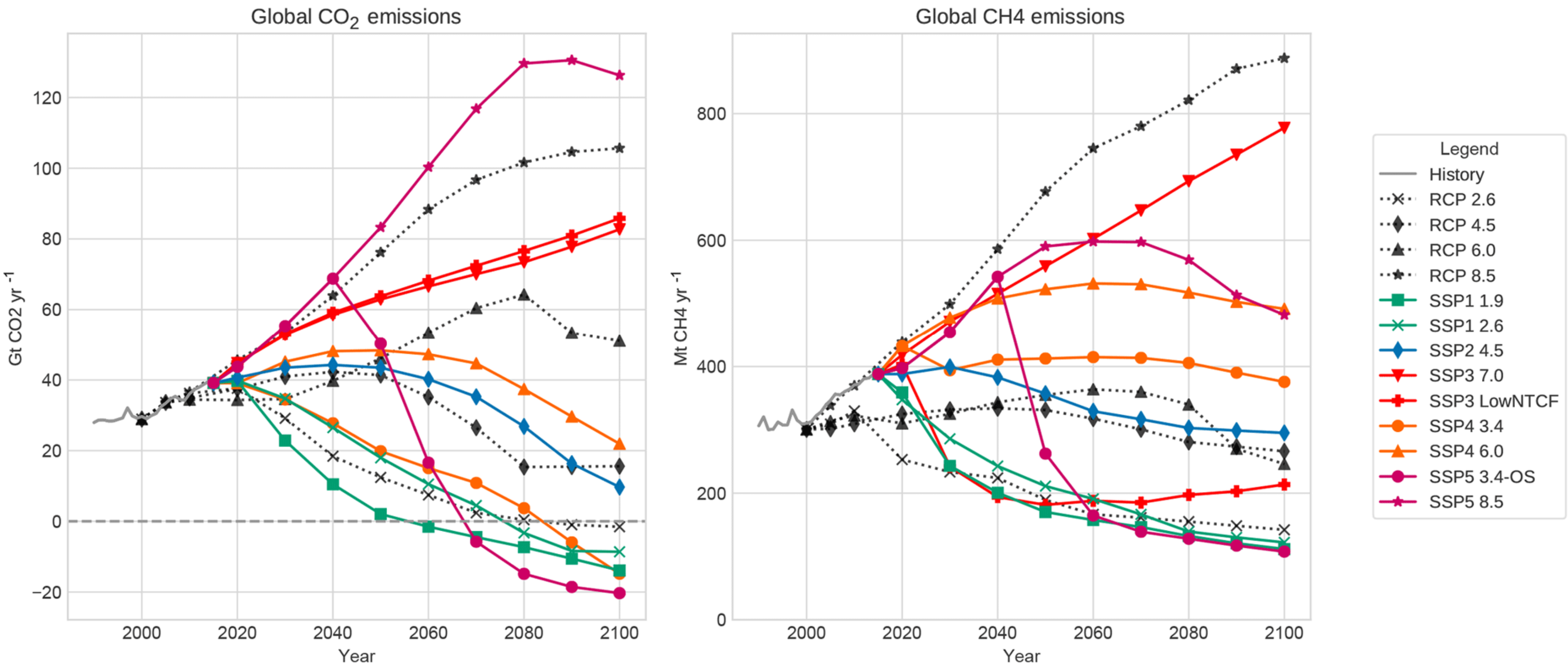


Figure: Trajectories of CO_2 and CH_4, primary contributors to GHG emissions, including both historical emissions, emissions analyzed for the RCPs, and all nine scenarios covered in this study. (Gidden et al., 2019, https://www.geosci-model-dev.net/12/1443/2019/)

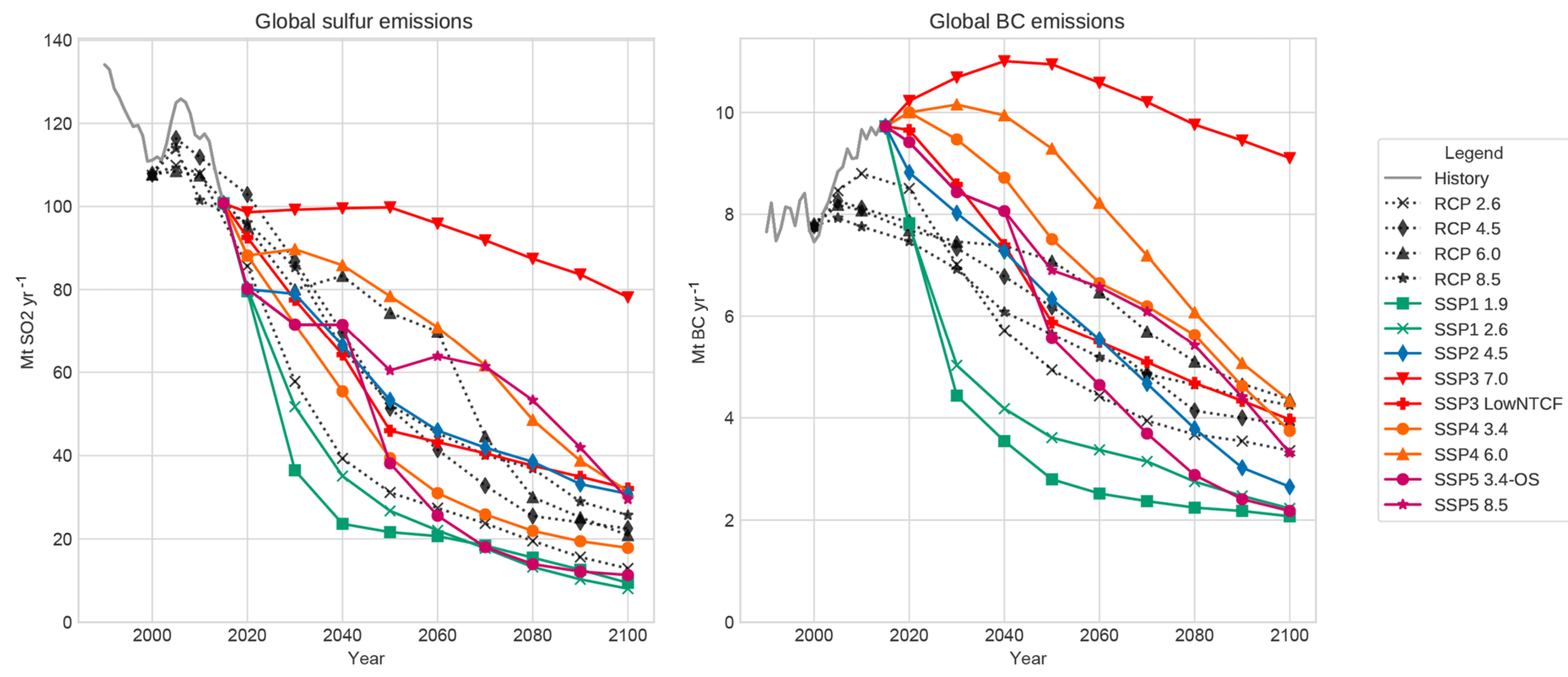


Figure: Emissions trajectories for sulfur and black carbon (BC), for history, the RCPs, and all nine scenarios analyzed in this study. SSP trajectories largely track with RCP values studied in CMIP5. A notable difference lies in BC emissions, which have seen relatively large increases in past years, thus providing higher initial emissions for the SSPs. (Gidden et al., 2019, https://www.geosci-model-dev.net/12/1443/2019/)

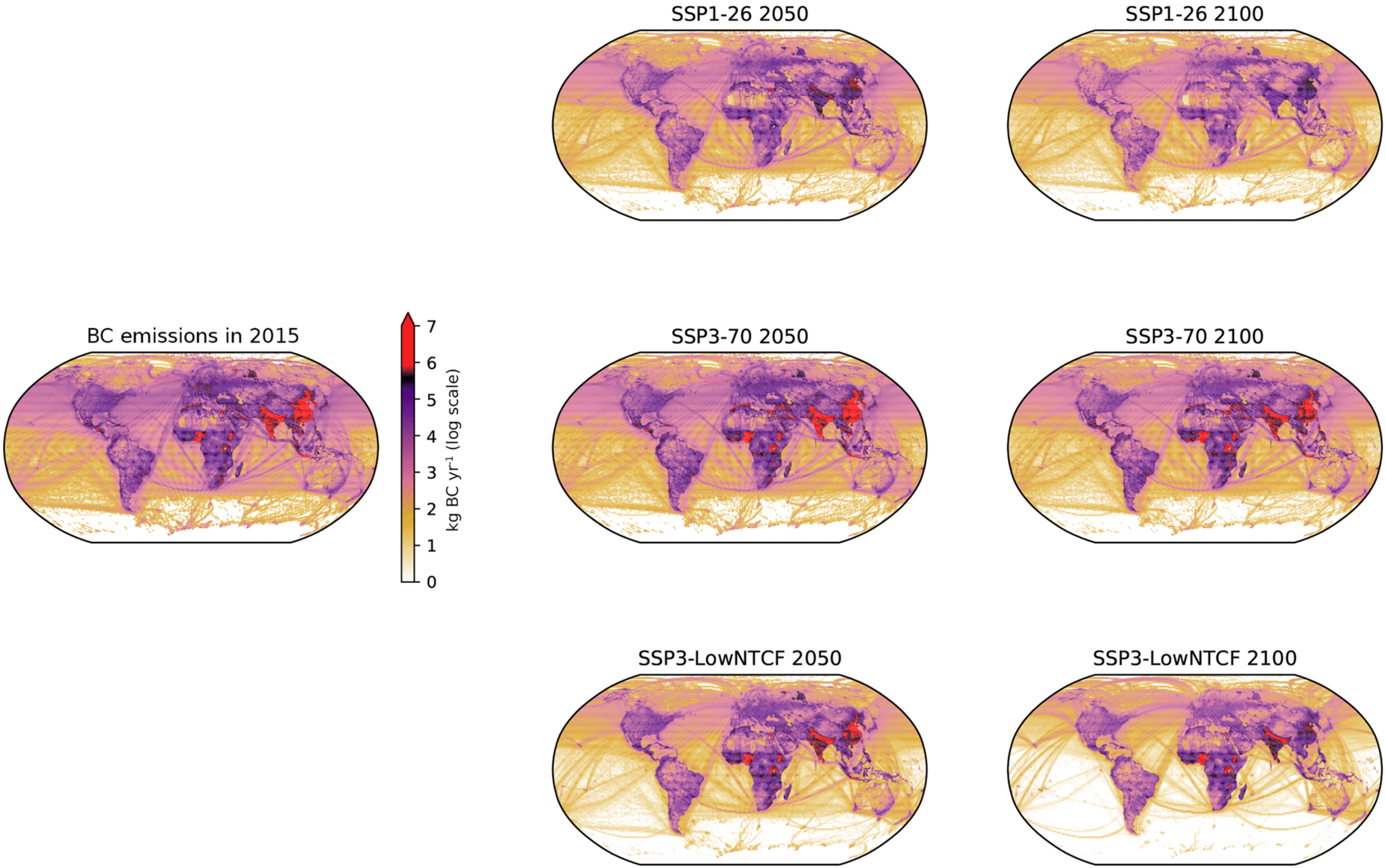


Figure : Downscaled and gridded emissions of black carbon at present and in 2050 and 2100 for SSP1-2.6, SSP3-7.0, and SSP3-LowNTCF.

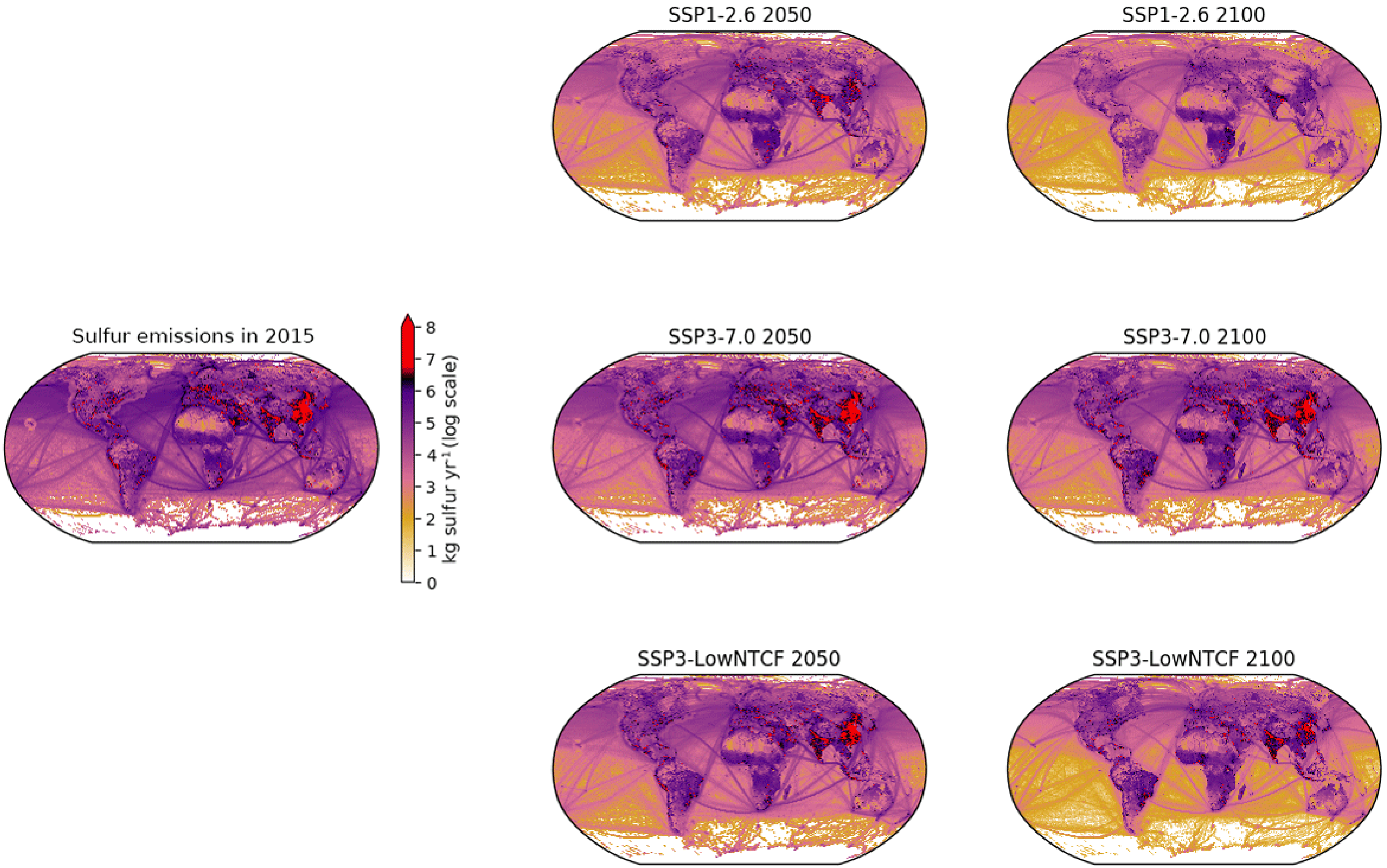
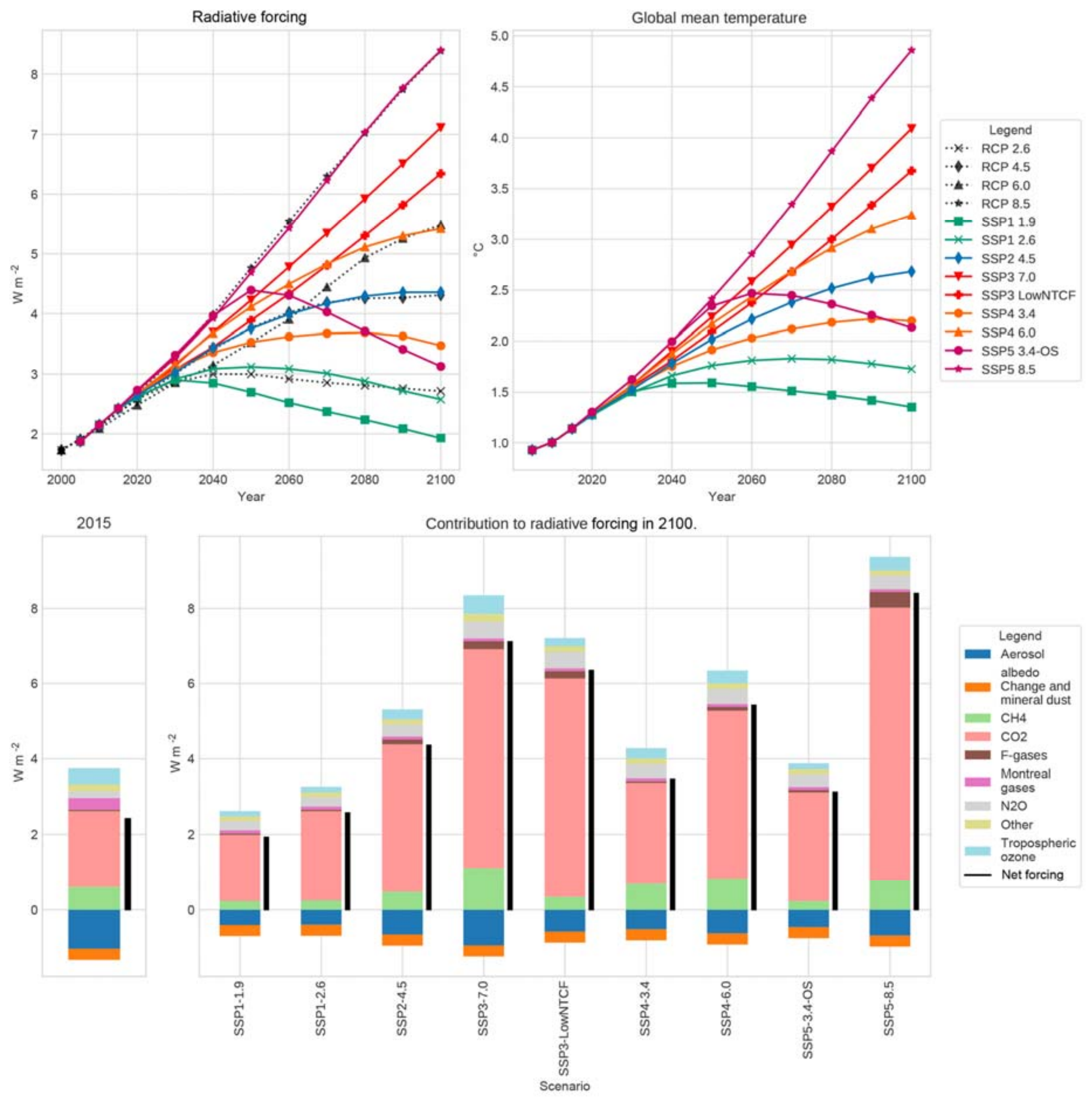


Figure: Downscaled and gridded emissions of sulfur at present and in 2050 and 2100 for SSP1-2.6, SSP3-7.0, and SSP3-LowNTCF.



Radiative forcing

Global mean temperature

2015

Contribution to radiative forcing in 2100.

Figure 2: Trajectories of RF and global mean temperature (above pre-industrial levels) are presented as are the contributions to RF for a number of different emissions types native to the MAGICC6 model. The RF trajectories are displayed with their RCP counterparts analyzed in CMIP5. For those scenarios with direct analogues, trajectories are largely similar in shape and match the same EOC forcing values. (Gidden et al., 2019, https://www.geosci-model-dev.net/12/1443/2019/)

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2. **Recent scenarios for climate models**
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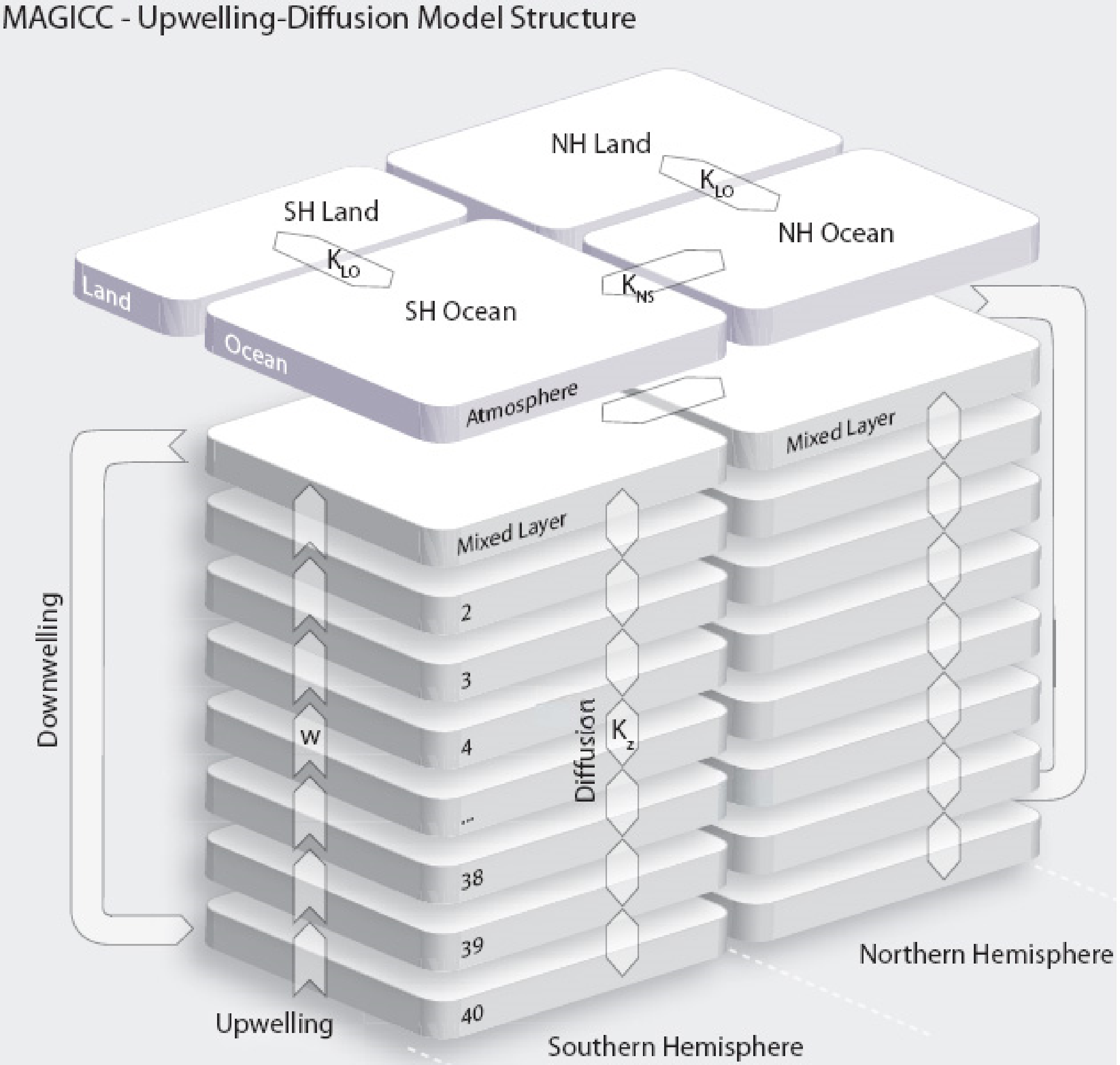
MAGICC

- MAGICC is coupled gas-cycle/climate model (MAGICC; Model for the Assessment of Greenhouse-gas Induced Climate Change). The climate model in MAGICC is an upwelling-diffusion, energy-balance model that produces global- and hemispheric-mean temperature output together with results for oceanic thermal expansion.

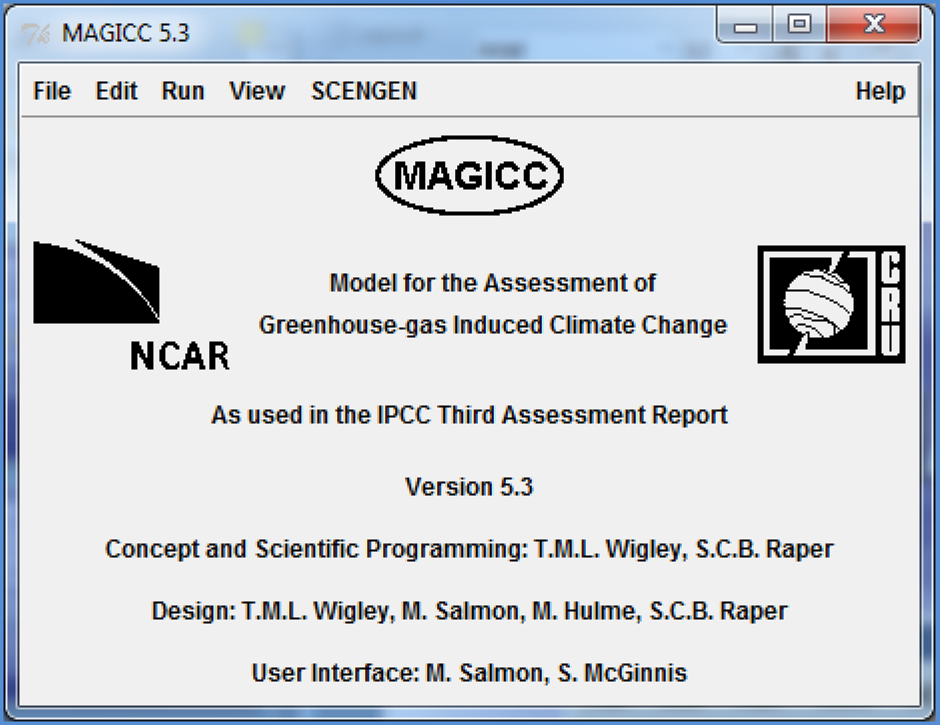
- MAGICC was one of the primary models that was used by IPCC since 1990, for the calculation of future projections of mean global temperature and the increase in sea-level.

- The MAGICC climate model is coupled interactively with a range of gas-cycle models that give projections for the concentrations of the key greenhouse gases. Climate feedbacks on the carbon cycle are therefore accounted for.

Structure of MAGICC


MAGICC - Upwelling-Diffusion Model Structure

Running MAGICC



Model for the Assessment of
Greenhouse-gas Induced Climate Change

As used in the IPCC Third Assessment Report

Version 5.3

Concept and Scientific Programming: T.M.L. Wigley, S.C.B. Raper

Design: T.M.L. Wigley, M. Salmon, M. Hulme, S.C.B. Raper

User Interface: M. Salmon, S. McGinnis

1. Installation

Download MAGICC 5.3 from the website http://www.magicc.org/. It is a zip file (SG53.zip), that contains a full index of folders. After unzipping, save your files in folder C:.

All files will be normally unzipped to your new folder, which is C:\SG53.

It is important that you choose the unzipping and creation of the new file directly to C:\SG53

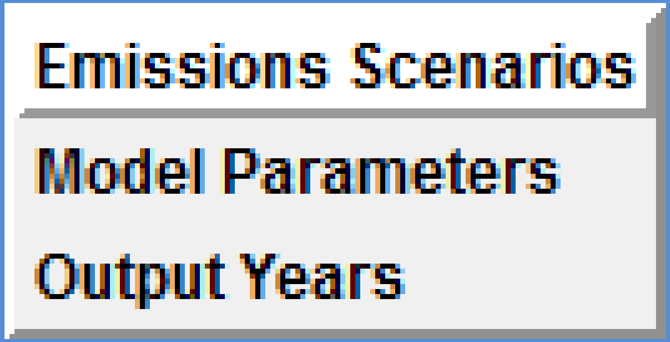
2. Execute (Run)

Start
c:\SG53\SCEN-53\magicc.exe

MAGICC: Choosing scenarios

3. click edit (press Edit)

You have the option of:
—Emission Scenarios,
—Model Parameters and
—Output Years (years of the outputs)

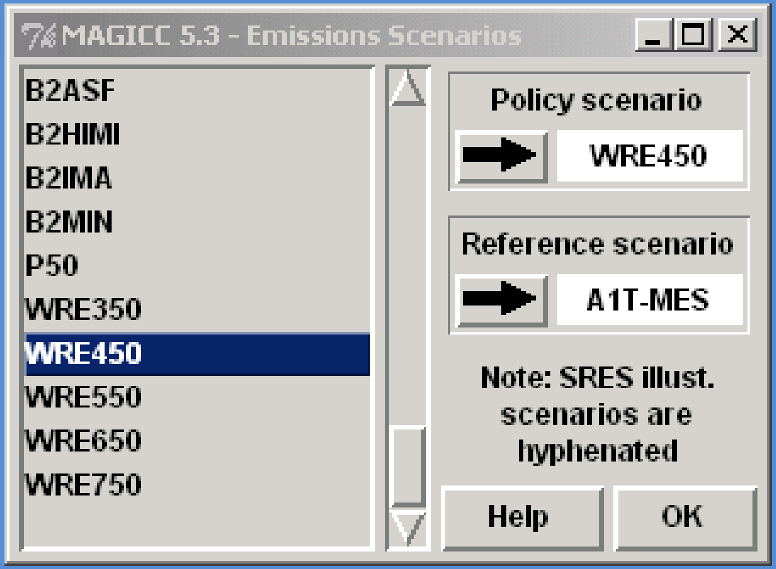


Emissions Scenarios
Model Parameters
Output Years

4. Under —Emissions Scenarios

The user can choose either a Reference scenario, or a Policy scenario. In the following example the A1T-MES is used, as a Reference scenario and WRE450 as a Policy scenario.
The A1T-MES is one of the six explanatory scenarios of SRES (Special Report on Emissions Scenarios). The WRE450 scenario uses CO_2 emissions that lead to the stabilization of the concentrations at 450.

Emissions for WRE450 are given until 2400. For A1T-MES they are given until 2100. The basic programming for MAGICC is to give results until 2100. If the user wants the calculation to be performed for another year, they can change the selection in the option "Output Year".



MAGICC 5.3 - Emissions Scenarios

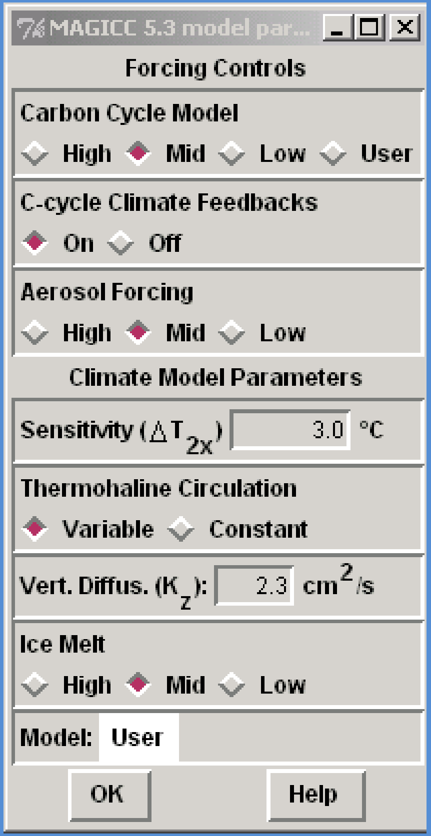
B2ASF
B2HIMI
B2IMA
B2MIN
P50
WRE350
WRE450
WRE550
WRE650
WRE750

Policy scenario: WRE450

Reference scenario: A1T-MES

Note: SRES illust. scenarios are hyphenated

MAGICC: Models Parameters Selection



Forcing Controls

Carbon Cycle Model
○ High ● Mid ○ Low ○ User

C-cycle Climate Feedbacks
● On ○ Off

Aerosol Forcing
○ High ● Mid ○ Low

Climate Model Parameters

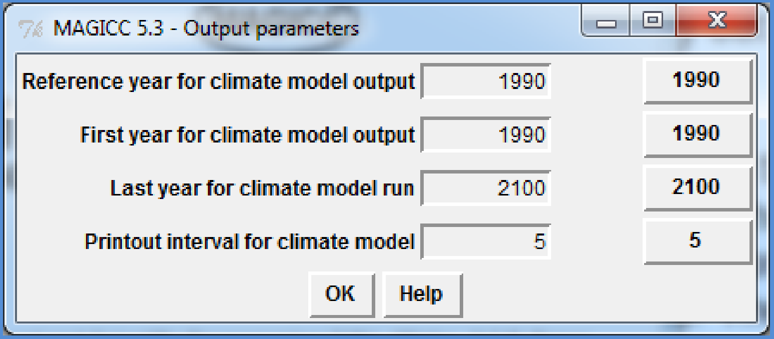
Sensitivity (ΔT_{2x}) 3.0 °C

Thermohaline Circulation
● Variable ○ Constant

Vert. Diffus. (K_z): 2.3 cm^2/s

Ice Melt
○ High ● Mid ○ Low

Model: User



Reference year for climate model output	1990	1990
First year for climate model output	1990	1990
Last year for climate model run	2100	2100
Printout interval for climate model	5	5

—Model Parameters

The range of options allows the user to carry out a variety of sensitivity studies. The sensitivity of the models (ΔT2x), is the magnitude of the increase in the average global temperature caused by the doubling of CO_2 concentrations with respect to its 18th century levels (~ 1750, pre-industrial age). Default values are 3 ºC - press OK to close the window (figure).

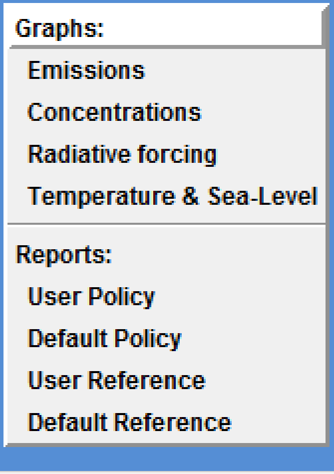
-Output Years

The -Output Year will display the -Output parameters window. The user can select the years to be displayed, as well as the years and the time step that will be used as data in the report files. The buttons on the right reset the default values. The choice of years for output files determines input data in the SCENGEN model. Most scenarios are only available until 2100, so choosing a longer year will not work. CO2 stabilization scenarios are available until 2400. This will also allow SCENGEN to calculate results by the year 2400. The default year is here in the year 2100 (figure). Select OK to close the window.

4. Click Run

After your choices are complete, press Run. After a short period of time, the climatic model begins.

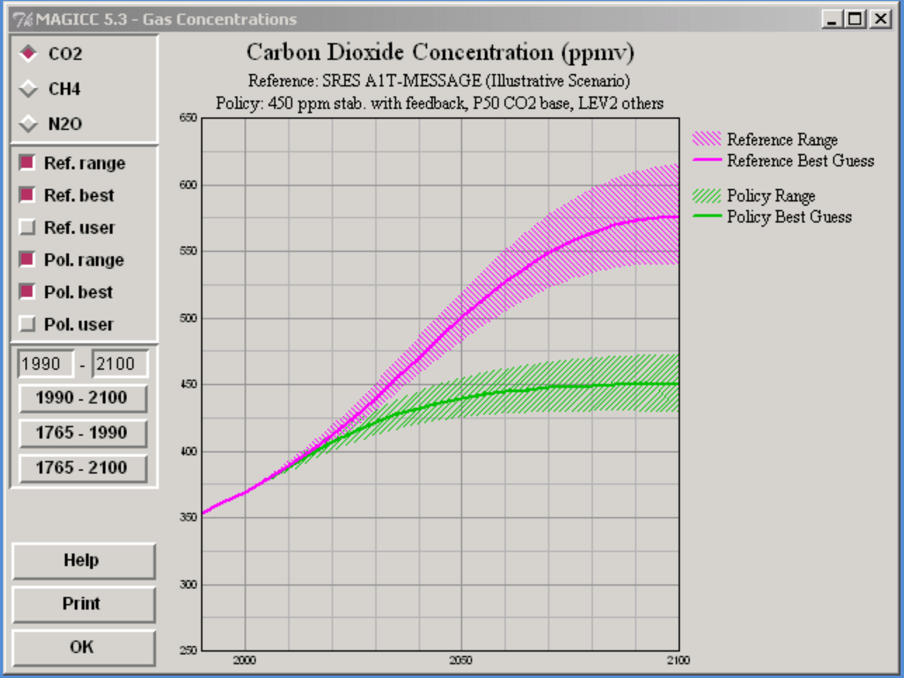
MAGICC: Graphical display

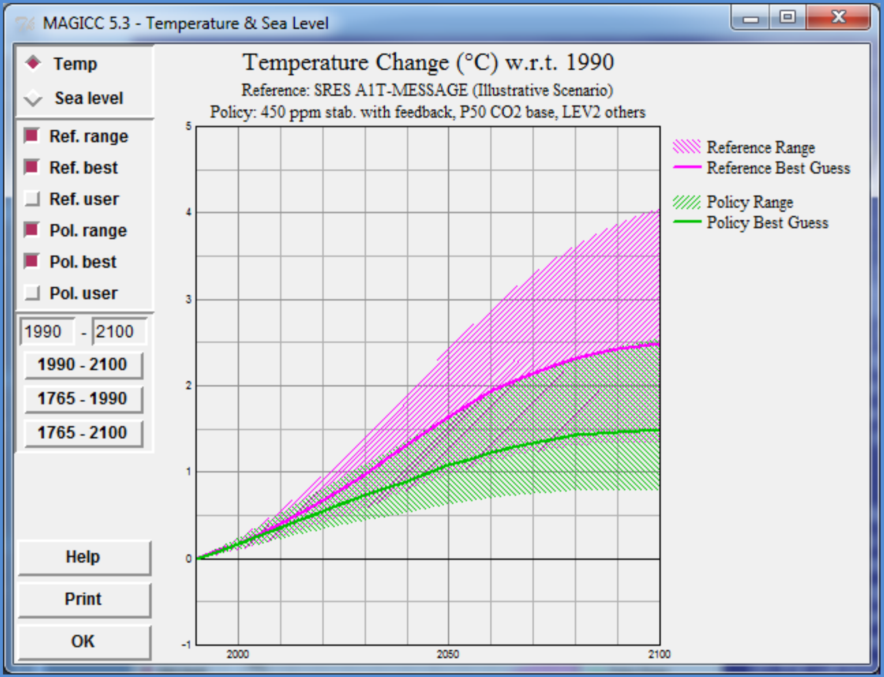


5. click View

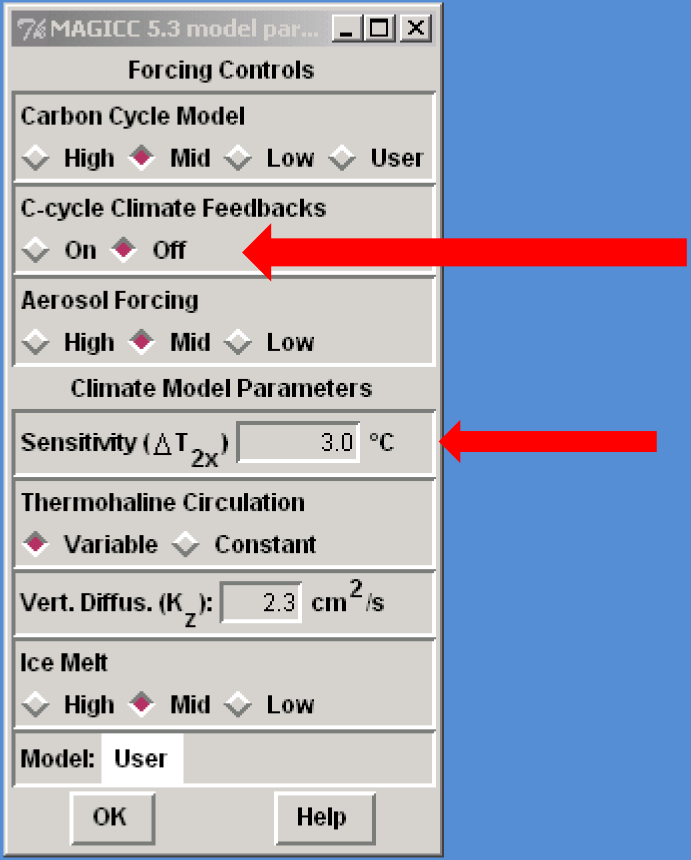
The user can select either to view graphical output, or, in the Reports files, to access much more detailed tabulated output. Each Report file gives results for (default) sensitivity ΔT2x = 1.5, 3.0, 6.0 ºC, as well as user-selected sensitivity. Output data for sea level combine low sensitivity with low ice melting, and high sensitivity with high melting.

Example figures are shown using the WRE450 policy scenario and the A1T-MES reference scenario. In a similar way we can show results of other emission, concentration and radiative forcing parameters.





MAGICC: Carbon cycle climate feedbacks



Forcing Controls

Carbon Cycle Model
○ High ● Mid ○ Low ○ User

C-cycle Climate Feedbacks
○ On ● Off

Aerosol Forcing
○ High ● Mid ○ Low

Climate Model Parameters

Sensitivity (ΔT_{2x}) 3.0 °C

Thermohaline Circulation
● Variable ○ Constant

Vert. Diffus. (K_z): 2.3 cm^2/s

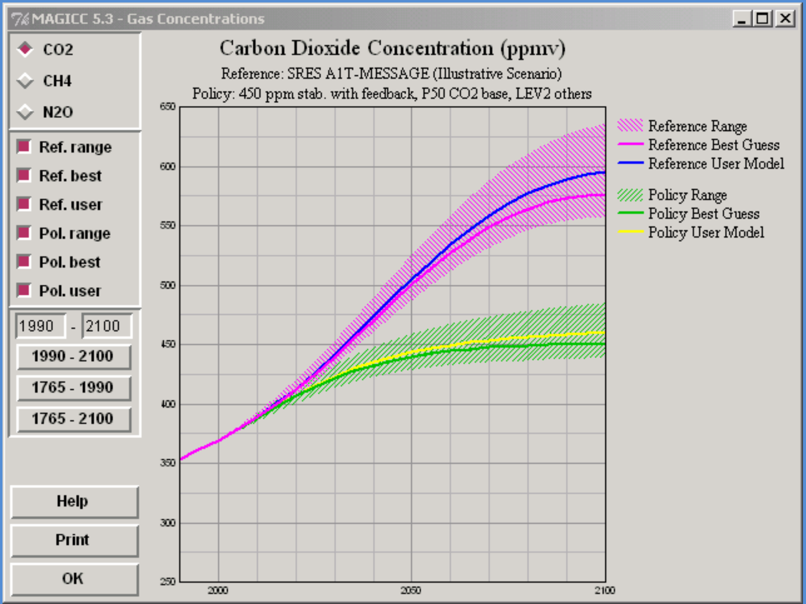
Ice Melt
○ High ● Mid ○ Low

Model: User

A key component of CO_2 projections is the feedback on the carbon cycle due to global warming. This is really a complex set of different feedbacks operating on a regional scale, some positive and some negative. On balance, however, these climate feedbacks are positive leading to significantly higher concentrations than would be the case if they were absent.

We can illustrate the importance of these feedbacks with some specific examples either by turning of the C-cycle Climate Feedbacks box or by changing the Sensitivity parameter.

The figure below shows an example by increasing sensitivity to 4.5 ºC



● CO2
○ CH4
○ N2O

☑ Ref. range
☑ Ref. best
☑ Ref. user
☑ Pol. range
☑ Pol. best
☑ Pol. user

1990 - 2100

Excercise

Starting from the basic MAGICC model,
Use
- as a reference scenario: A1Bnew
- WRE450 policy scenario.

Consider that the other parameters keep the default values.
You can make the display of the average global temperature by the year 2100 for both scenarios (Reference and Policy).
What are the differences? Comment on your results.

Check the effects of carbon cycle climate feedbacks on global temperature by increasing the climate sensitivity parameter to 5.

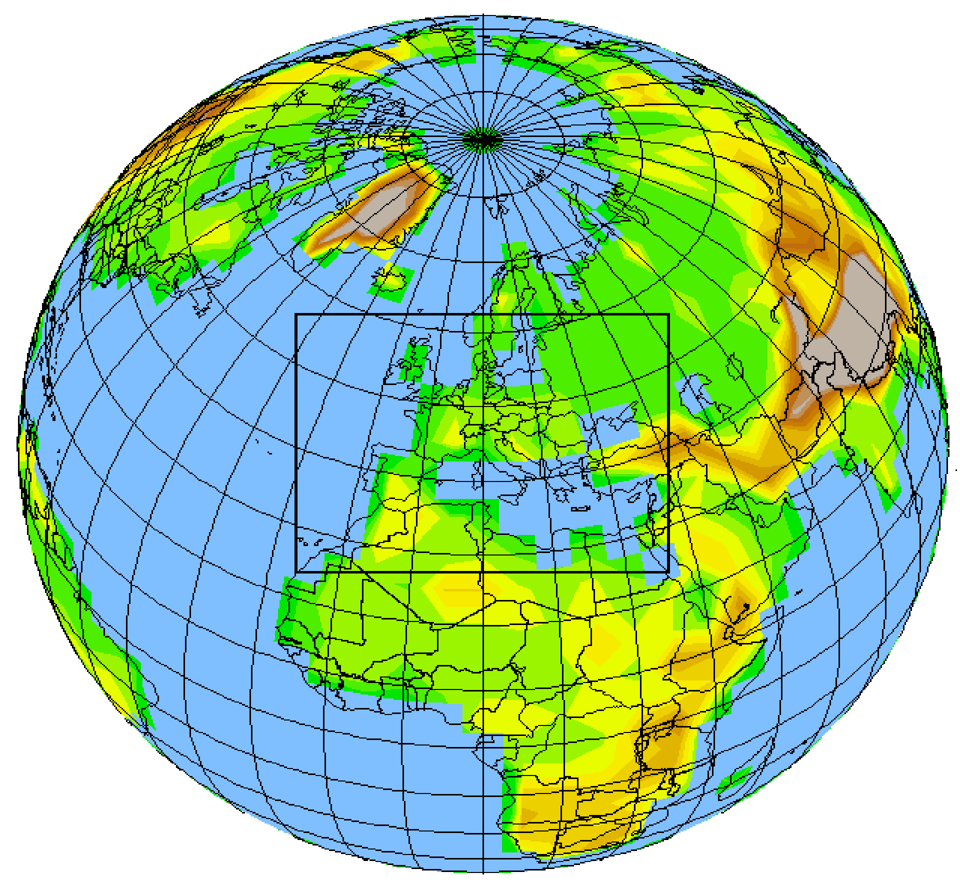
Content of Part B

This part discusses:

1. Climate sensitivity and climate feedback processes
2. Recent scenarios for climate models
3. Energy – Balance Models – MAGICC
4. Regional Climate Models

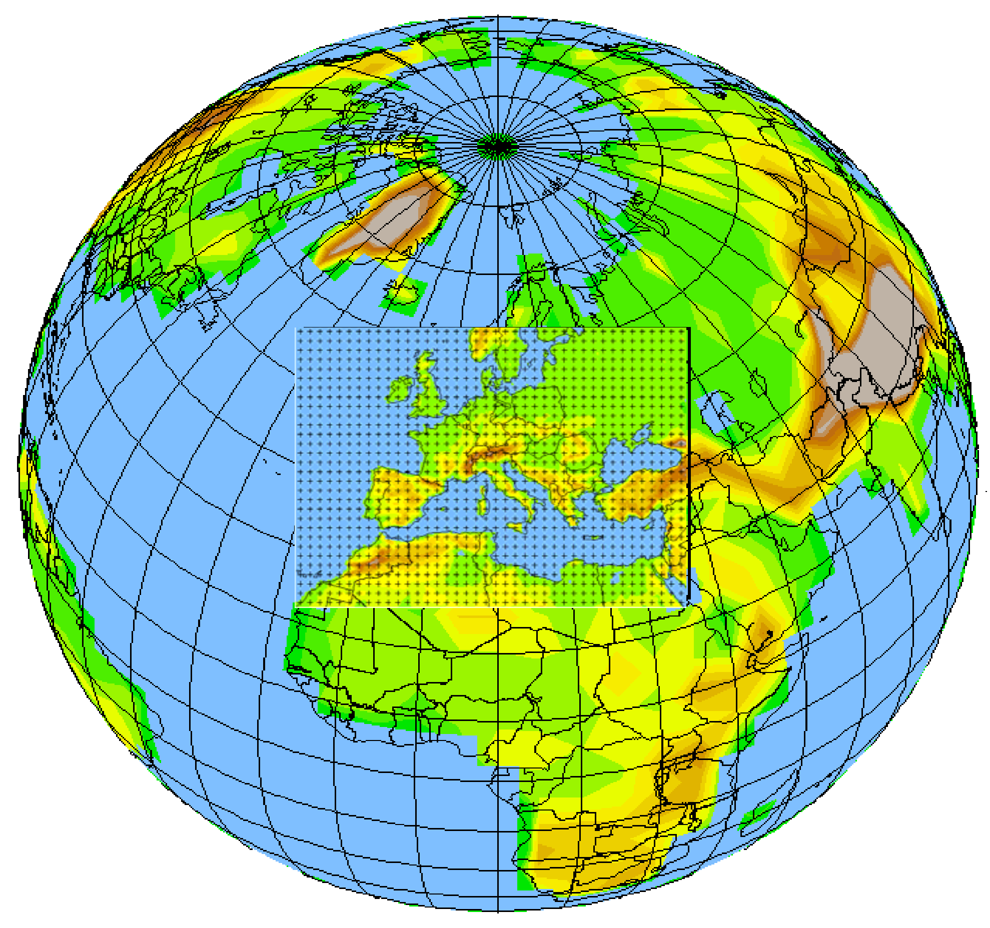
Global Climate Models

- Coupled AOGCMs are the most advanced tools today available for climate simulation
- The resolution of present day AOGCMs (100 – 300 km) is still too coarse to provide fine scale regional climate information useful for impact studies.

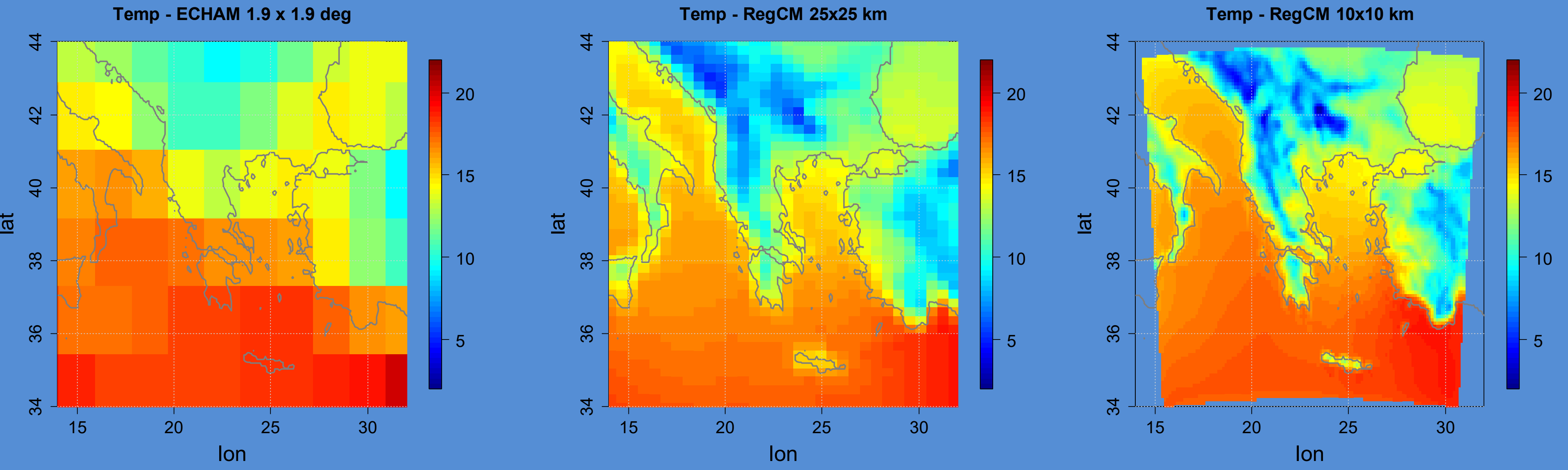


Regional Climate Models

- Technique: A "Regional Climate Model" (RCM) is "nested" within a GCM in order to increase the resolution of a climate simulation.
  - Initial conditions (IC) and lateral boundary conditions (LBC) for the RCM are obtained from the GCM.
- Strategy: The GCM is used to simulate the response of the general circulation to large scale forcings, while the RCM is used to simulate the effect of sub-GCM-grid scale forcings and to provide fine scale regional information
  - The RCM is intended to only enhance the GCM information
- Technique inherited from NWP



Modelled temperature climatology (1975-2000) based on GCMs and RCMs: The effect of resolution



Climate on islands, mountains and coastal areas changes very differently around the Mediterranean Sea and it can only be properly highlighted using a RCM

Source: Zanis et al., A transient high resolution regional climate simulation for Greece for the period 1960-2100: Evaluation and future projections, Climate Research, 64: 123–140, doi:10.3354/cr01304, 2015

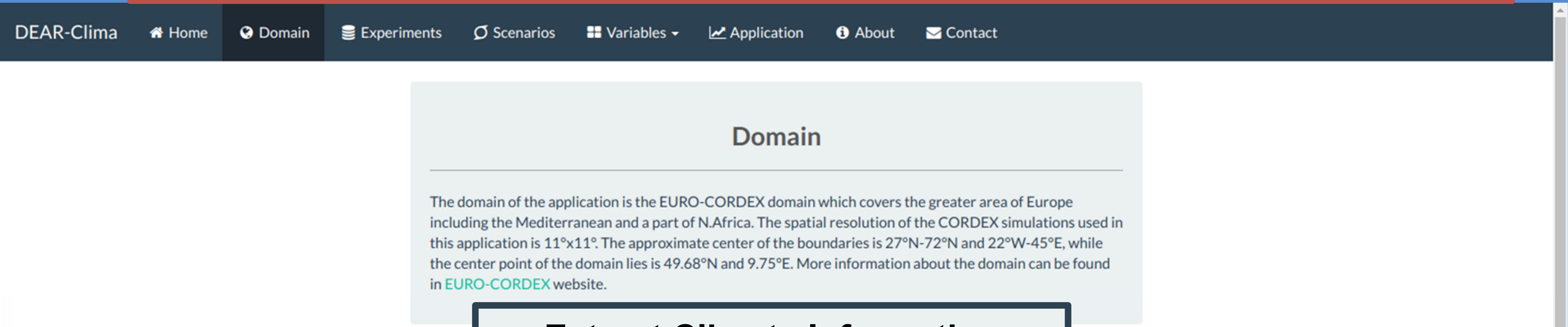
Aristotle University
of Thessaloniki

DEAR-Clima

A Data Extraction Application for Regional Climate

http://meteo3.geo.auth.gr:3838/ or http://datahub.geocradle.eu/dataset/dear-clima

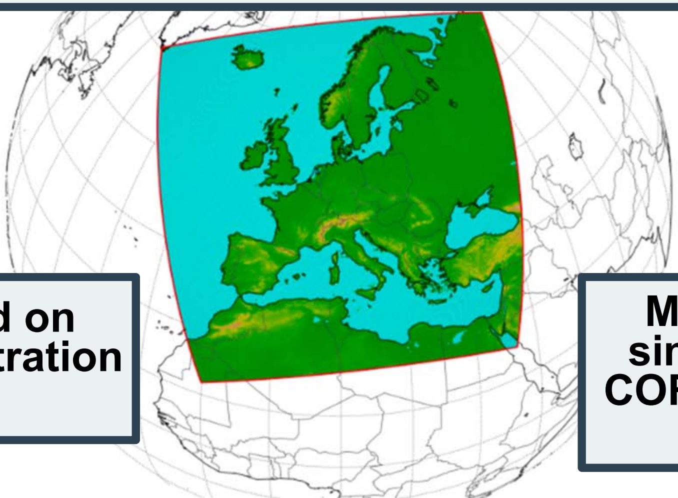
- **DEAR-Clima is a user friendly dynamical web application tool that extracts, visualizes and provides time series of essential climate variables and climate indices**



Domain

The domain of the application is the EURO-CORDEX domain which covers the greater area of Europe including the Mediterranean and a part of N.Africa. The spatial resolution of the CORDEX simulations used in this application is 11°x11°. The approximate center of the boundaries is 27°N-72°N and 22°W-45°E, while the center point of the domain lies is 49.68°N and 9.75°E. More information about the domain can be found in EURO-CORDEX website.

Extract Climate Information above Europe and N.Africa (EURO-Cordex Domain) in ~12 km resolution.



Future Projection are based on three Representative Concentration Pathways (RCPs)

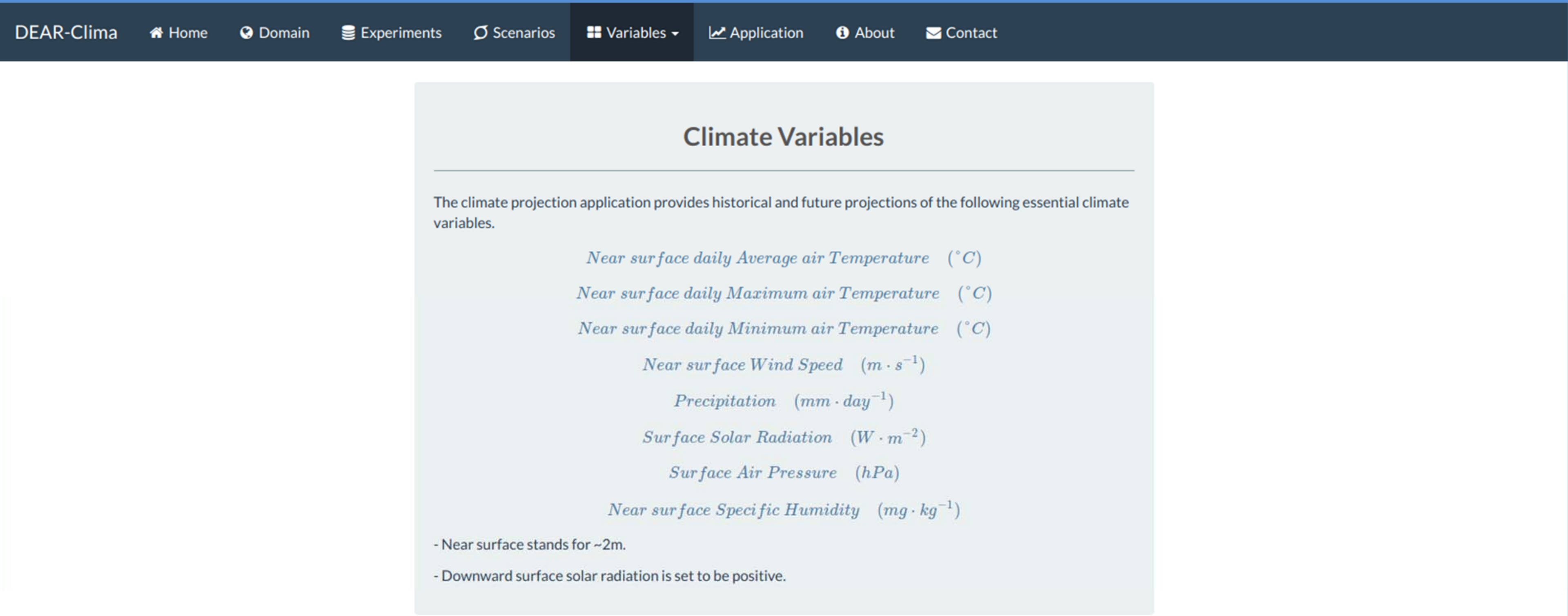
More than 32 regional climate simulations to choose from the CORDEX experiments ranging for the period 1950-2100.

Aristotle University
of Thessaloniki

DEAR-Clima

A Data Extraction Application for Regional Climate

http://meteo3.geo.auth.gr:3838/



Climate Variables

The climate projection application provides historical and future projections of the following essential climate variables.

$$Near\ surface\ daily\ Average\ air\ Temperature\quad (^{\circ}C)$$

$$Near\ surface\ daily\ Maximum\ air\ Temperature\quad (^{\circ}C)$$

$$Near\ surface\ daily\ Minimum\ air\ Temperature\quad (^{\circ}C)$$

$$Near\ surface\ Wind\ Speed\quad (m\cdot s^{-1})$$

$$Precipitation\quad (mm\cdot day^{-1})$$

$$Surface\ Solar\ Radiation\quad (W\cdot m^{-2})$$

$$Surface\ Air\ Pressure\quad (hPa)$$

$$Near\ surface\ Specific\ Humidity\quad (mg\cdot kg^{-1})$$

- Near surface stands for ~2m.

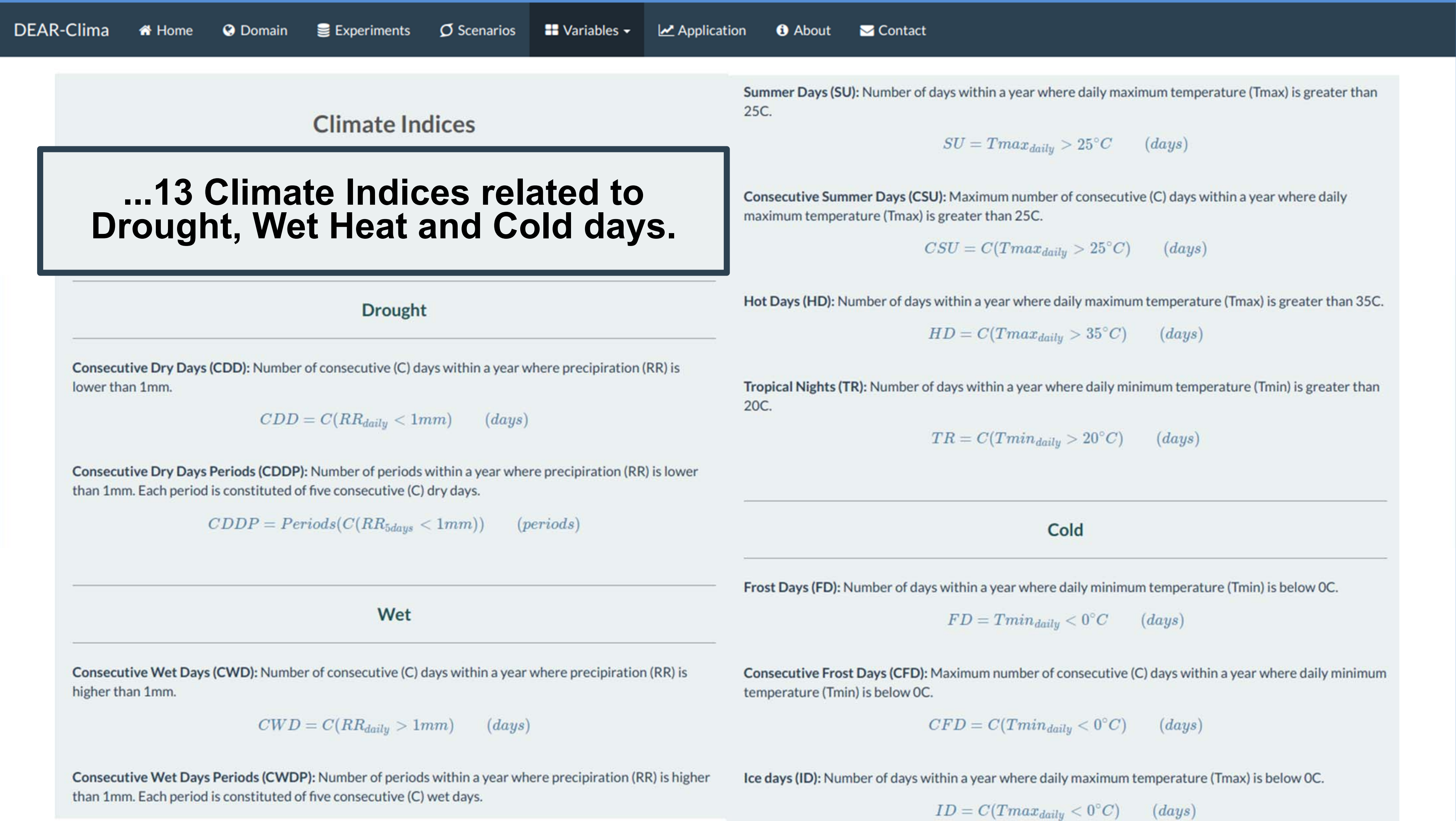
- Downward surface solar radiation is set to be positive.

8 Essential Climate Variable to extract and...

DEAR-Clima

A Data Extraction Application for Regional Climate

http://meteo3.geo.auth.gr:3838/



Climate Indices

...13 Climate Indices related to Drought, Wet Heat and Cold days.

Drought

Consecutive Dry Days (CDD): Number of consecutive (C) days within a year where precipitation (RR) is lower than 1mm.

$$CDD = C(RR_{daily} < 1mm) \qquad (days)$$

Consecutive Dry Days Periods (CDDP): Number of periods within a year where precipiration (RR) is lower than 1mm. Each period is constituted of five consecutive (C) dry days.

$$CDDP = Periods(C(RR_{5days} < 1mm)) \qquad (periods)$$

Wet

Consecutive Wet Days (CWD): Number of consecutive (C) days within a year where precipitation (RR) is higher than 1mm.

$$CWD = C(RR_{daily} > 1mm) \qquad (days)$$

Consecutive Wet Days Periods (CWDP): Number of periods within a year where precipiration (RR) is higher than 1mm. Each period is constituted of five consecutive (C) wet days.

Summer Days (SU): Number of days within a year where daily maximum temperature (Tmax) is greater than 25C.

$$SU = Tmax_{daily} > 25^{\circ}C \qquad (days)$$

Consecutive Summer Days (CSU): Maximum number of consecutive (C) days within a year where daily maximum temperature (Tmax) is greater than 25C.

$$CSU = C(Tmax_{daily} > 25^{\circ}C) \qquad (days)$$

Hot Days (HD): Number of days within a year where daily maximum temperature (Tmax) is greater than 35C.

$$HD = C(Tmax_{daily} > 35^{\circ}C) \qquad (days)$$

Tropical Nights (TR): Number of days within a year where daily minimum temperature (Tmin) is greater than 20C.

$$TR = C(Tmin_{daily} > 20^{\circ}C) \qquad (days)$$

Cold

Frost Days (FD): Number of days within a year where daily minimum temperature (Tmin) is below 0C.

$$FD = Tmin_{daily} < 0^{\circ}C \qquad (days)$$

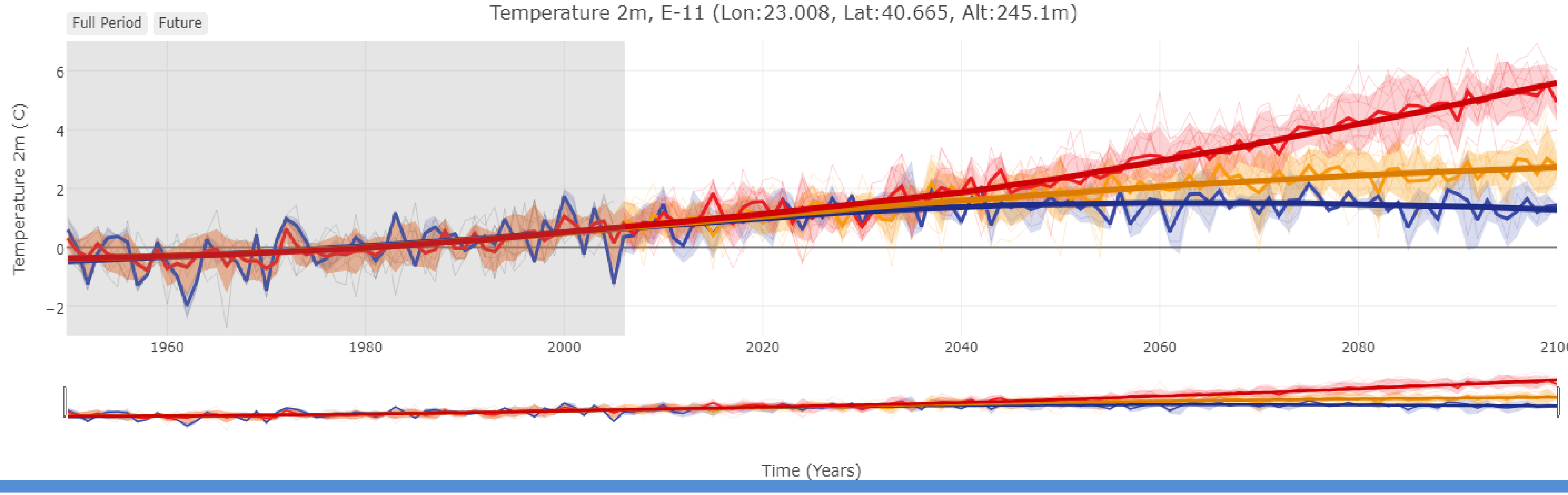
Consecutive Frost Days (CFD): Maximum number of consecutive (C) days within a year where daily minimum temperature (Tmin) is below 0C.

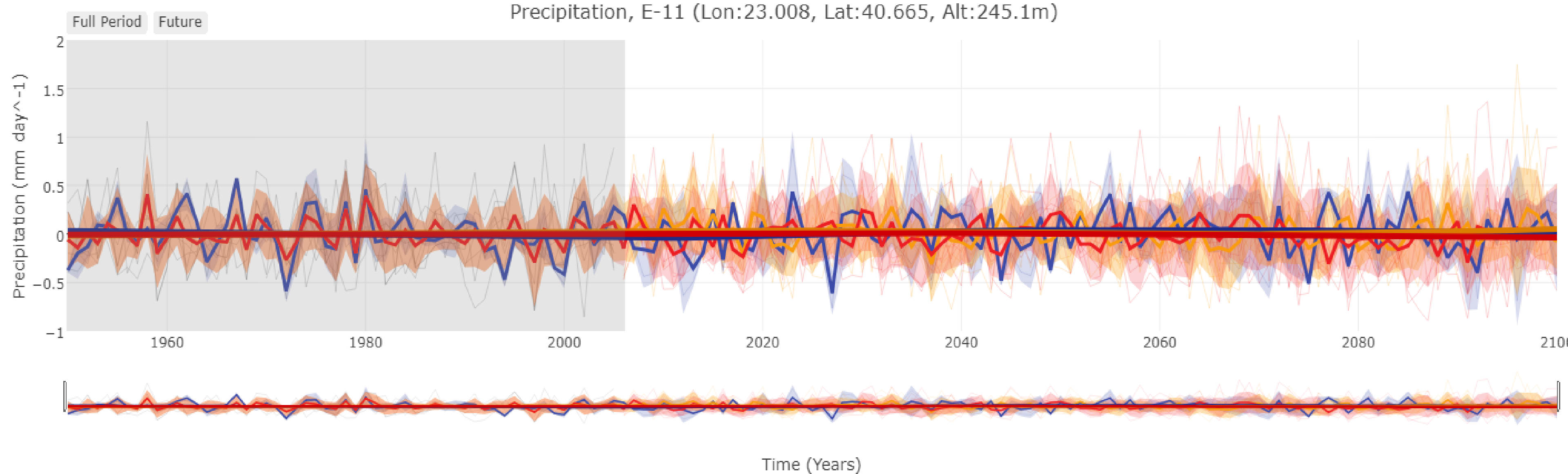
$$CFD = C(Tmin_{daily} < 0^{\circ}C) \qquad (days)$$

Ice days (ID): Number of days within a year where daily maximum temperature (Tmax) is below 0C.

$$ID = C(Tmax_{daily} < 0^{\circ}C) \qquad (days)$$

Temperature change at Thessaloniki

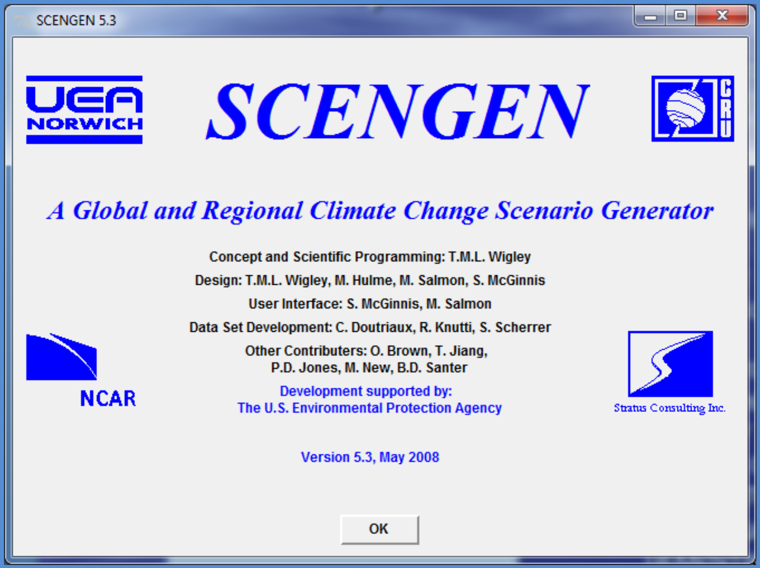




Thanks for your attention

SCENGEN

- Global-mean temperatures from MAGICC are used to drive SCENGEN (SCENario GENerator). SCENGEN uses a pattern scaling method to produce spatial patterns of change from a data base of atmosphere/ocean GCM (AOGCM) data. The pattern scaling method is based on the separation of the global-mean and spatial-pattern components of future climate change, and the further separation of the latter into greenhouse-gas and aerosol components.



SCENGEN

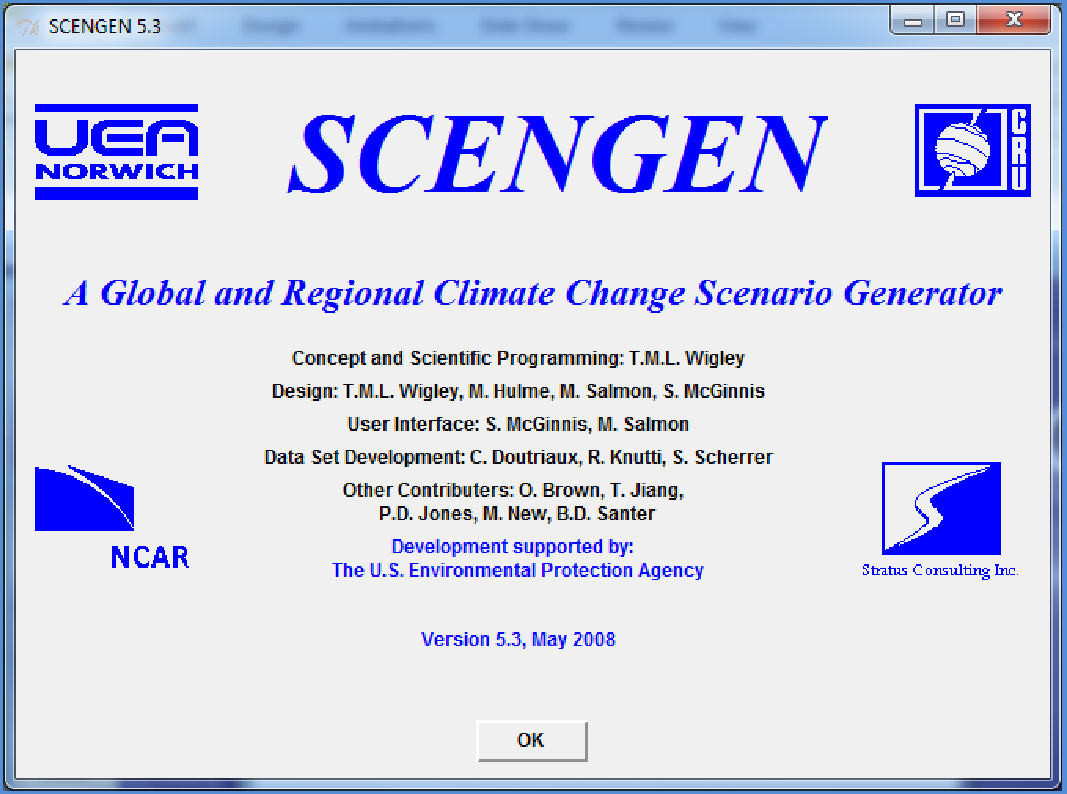
A Global and Regional Climate Change Scenario Generator

Concept and Scientific Programming: T.M.L. Wigley
Design: T.M.L. Wigley, M. Hulme, M. Salmon, S. McGinnis
User Interface: S. McGinnis, M. Salmon
Data Set Development: C. Doutriaux, R. Knutti, S. Scherrer
Other Contributers: O. Brown, T. Jiang,
P.D. Jones, M. New, B.D. Santer
Development supported by:
The U.S. Environmental Protection Agency

Version 5.3, May 2008

- In SCENGEN 20 GCMs are used
- Results:
  - Changes from model to model
  - Mean change
  - Standard deviation between models
  - Changes in variability
  - Depiction of current and future climate on a 5 x 5° grid.

Use of SCENGEN


SCENGEN 5.3

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The U.S. Environmental Protection Agency

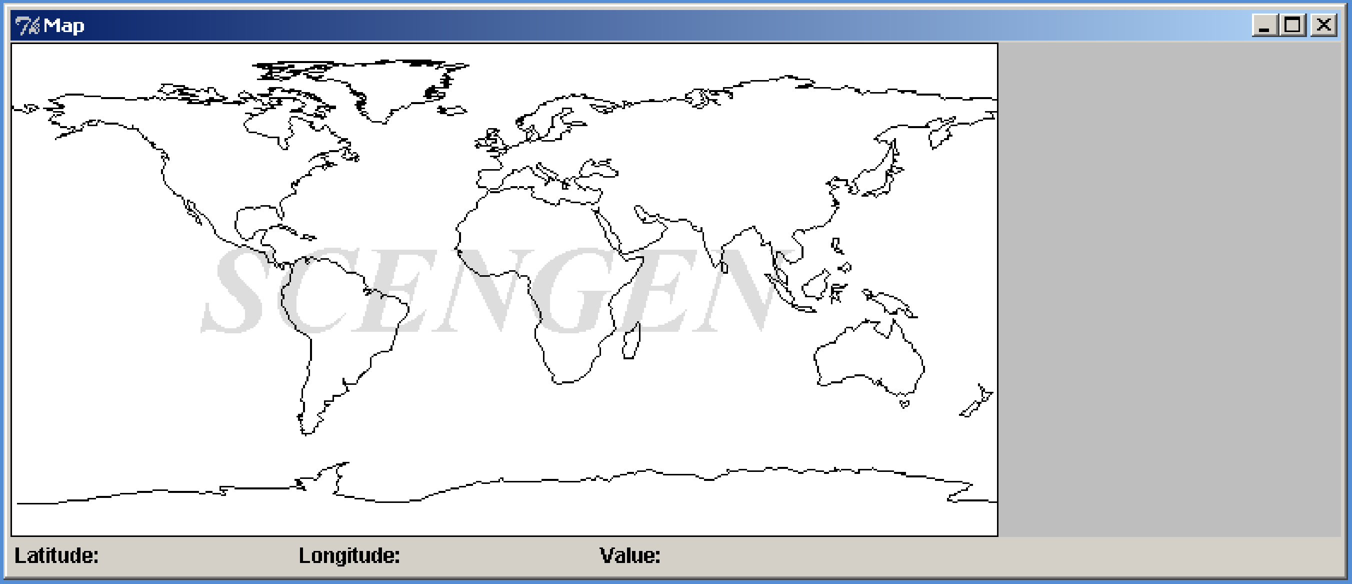
Version 5.3, May 2008

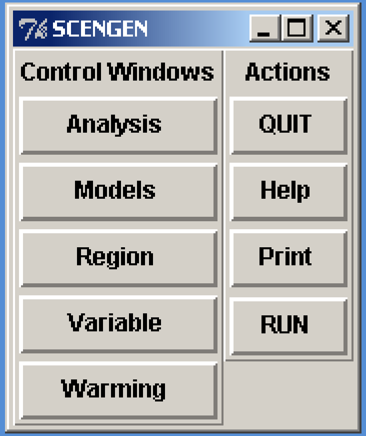
6. Run SCENGEN

The next step is to return to the MAGICC main control window, select the SCENGEN key and the -RUN SCENGEN option. This will display the SCENGEN title window.

Use of SCENGEN

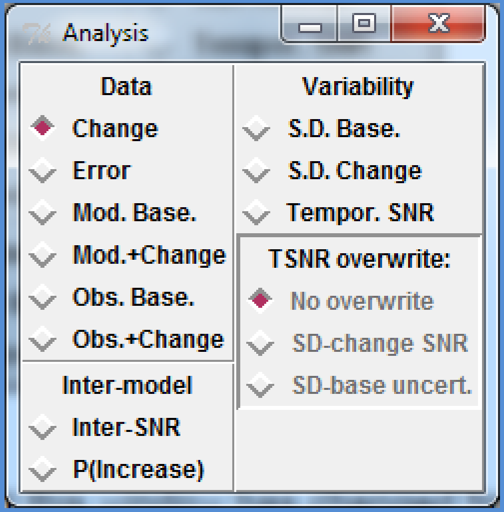
7. Pressing the OK button will display an empty map and the SCENGEN Options Menu





SCENGEN: Example

The example gives a comparison of the results of different models for changes in spatial distribution of mean annual rainfall. The results of the MAGICC calculations described above, ie the A1T-MES as the baseline scenario and the WRE450 as a policy scenario, are used.



Data
● Change
○ Error
○ Mod. Base.
○ Mod.+Change
○ Obs. Base.
○ Obs.+Change

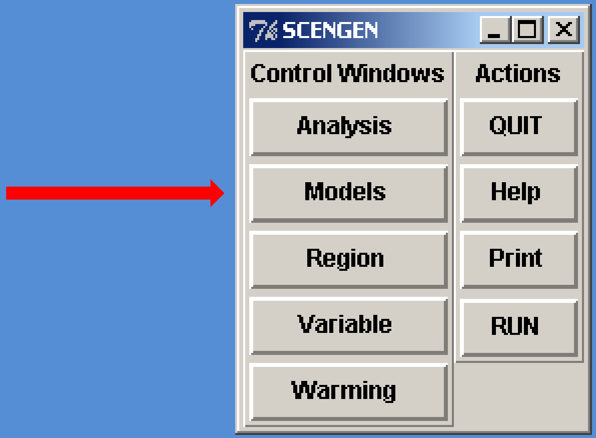
Inter-model
○ Inter-SNR
○ P(Increase)

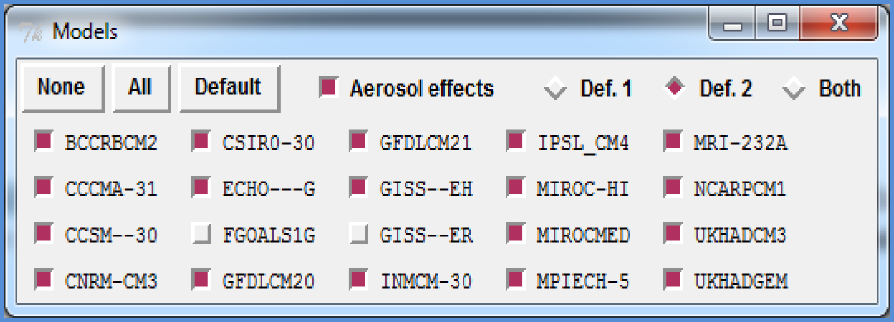
Variability
○ S.D. Base.
○ S.D. Change
○ Tempor. SNR

TSNR overwrite:
● No overwrite
○ SD-change SNR
○ SD-base uncert.

8. The first step: selecting -Analysis in the SCENGEN window. The -Analysis options window will appear.
In the -Data option, the default is -Change, that is, the analysis will give us the changes in the average value of each variable.

SCENGEN: Choose models





☑ Aerosol effects ○ Def. 1 ● Def. 2 ○ Both

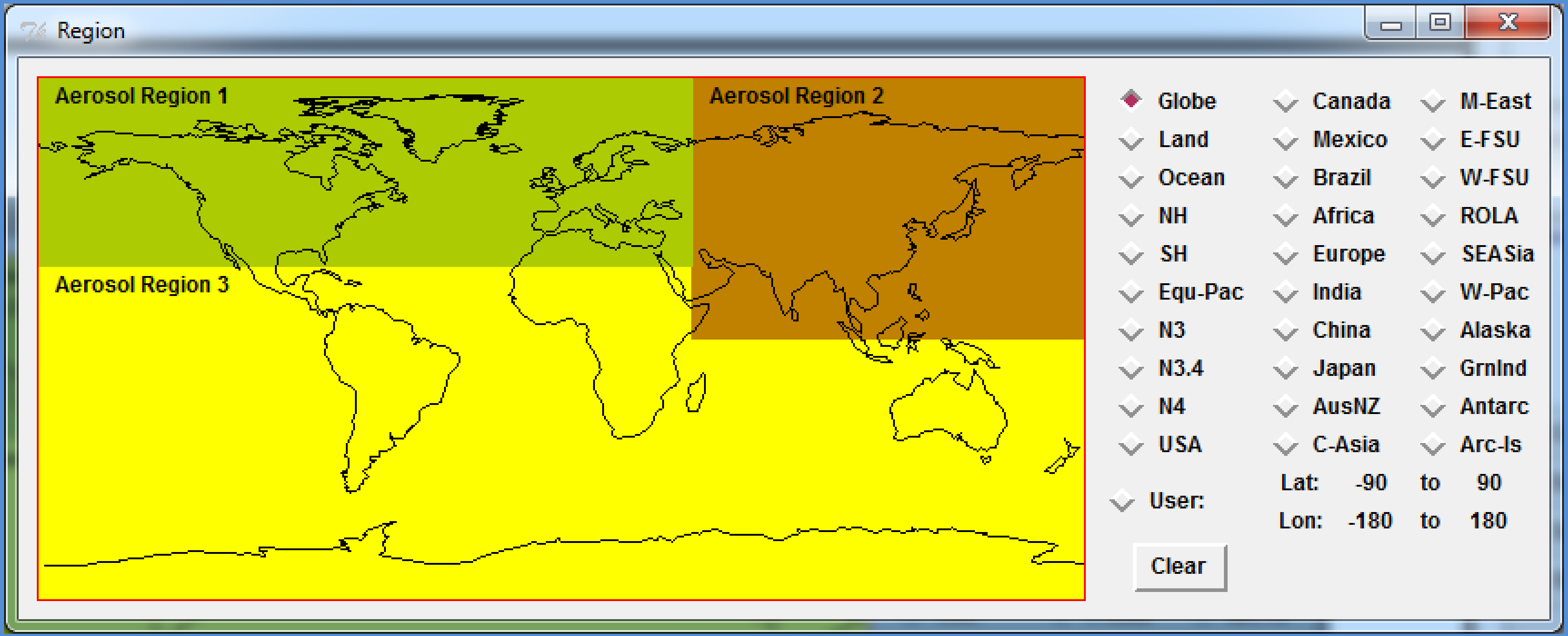
☑ BCCRBCM2	☑ CSIRO-30	☑ GFDLCM21	☑ IPSL_CM4	☑ MRI-232A
☑ CCCMA-31	☑ ECHO---G	☑ GISS--EH	☑ MIROC-HI	☑ NCARPCM1
☑ CCSM--30	☐ FGOALS1G	☐ GISS--ER	☑ MIROCMED	☑ UKHADCM3
☑ CNRM-CM3	☑ GFDLCM20	☑ INMCM-30	☑ MPIECH-5	☑ UKHADGEM

9. Next step: (always in the SCENGEN window) select the -AOGCMs models to use (the results shown are for the average status of the selected models). Important: SCENGEN calculates average values of normalized model results so that each distribution has the same weight as the rest, and the effect is not affected by the participation of models with different climatic sensitivity. In the example we use all models except FGOALS and GISS -ER.

Next, the user has the option of using Definition 1 or Definition 2 changes. Def. 1 uses the difference between the start and end of a perturbation experiment. Def. 2 uses the difference between the perturbed state and the control climate at the same time. If a model has any spatial drift (and most models do) then Def. 2 is a way of removing this drift (under the justifiable assumption that the drift is approximately common to both the perturbed and control runs) – normally one should use Def. 2.

Next, the user must decide whether or not to include the spatial effects of aerosols. Normally, these effects should be included (which is done by clicking on the "Aerosol effects" button). The option not to include aerosol effects is to allow the user to determine how important these effects are. The "Models" window shown above corresponds to these selections.

SCENGEN: Choose a region



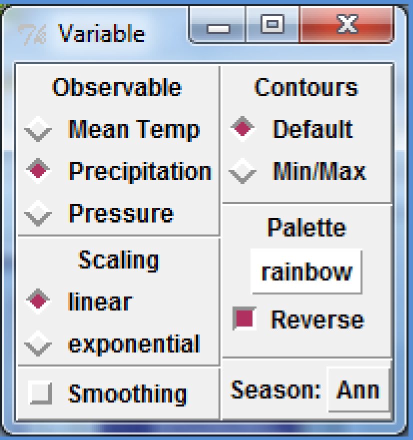
● Globe

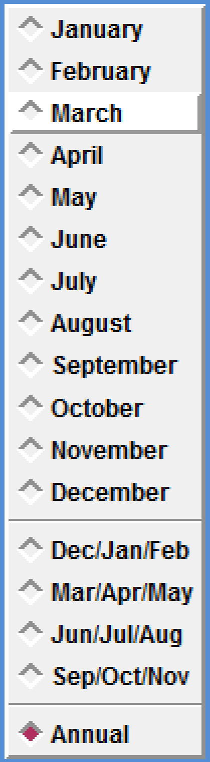
Lat: -90 to 90

Lon: -180 to 180

10. Next, return to the SCENGEN window and click on “Region”. The map shown in the figure will appear, which shows the areas used to calculate SO_2 emissions in the MAGICC emission records. Next you see the areas that can be selected. The default is the whole world, and this is used in our example.

SCENGEN: Variable Selection





11. Return to the SCENGEN window and select “Variable”.

The -Variable window (as in the figure) will appear. We chose the -Precipitation (ie atmospheric precipitation), and we will use this variable in our example. Note that the red-back option is displayed because the color scale for the precipitation (ie red for low values and blue for high) is inverse.

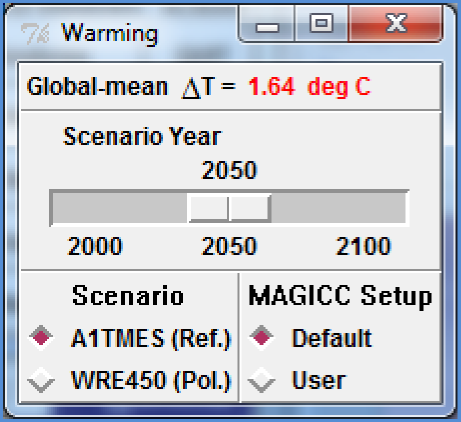
The -Ann button allows us to select seasonal or monthly changes. We return to -Ann.

The Scaling window provides the option of using linear or exponential interference when calculating and constructing maps from the grid points of the climate models. In our example we use the linear one, although it is preferable to use the exponential for rainfall variations.

Selection of spatial smoothing: This option replaces all our output files (our data) with a smoothed field calculated from 9 neighboring boxes (the area-weighted method). The choice of spatial smoothing means that if, for example, we have chosen a single grid of 2.5^0 x 2.5^0 as an area, the results will be the average values of the nine grid boxes contained in our main grid.

To change the color scale, press the rainbow button.

SCENGEN: Chosing a scenario

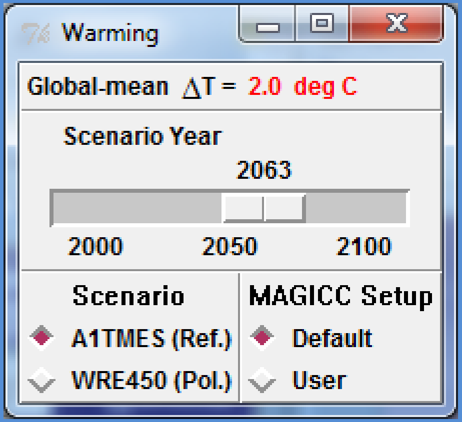


Global-mean ΔT = 1.64 deg C

Scenario Year 2050

Scenario
● A1TMES (Ref.)
○ WRE450 (Pol.)

MAGICC Setup
● Default
○ User



Global-mean ΔT = 2.0 deg C

Scenario Year 2063

Scenario
● A1TMES (Ref.)
○ WRE450 (Pol.)

MAGICC Setup
● Default
○ User

12. Return to the SCENGEN window and open the “Warming” option.

Here the user can follow the following steps for his/hers choices:

(1) the emission scenario, ie either the Reference or the Policy.

(2) The year for which the calculations will be performed, based on the scenario selected in step (1) (i.e., the central year for the calculation of the climatic average *, as indicated by the length of the rolling bar, is selected.) The default year Is 2050, as in the figure)

* Climate averages are calculated as an average of 30 years.

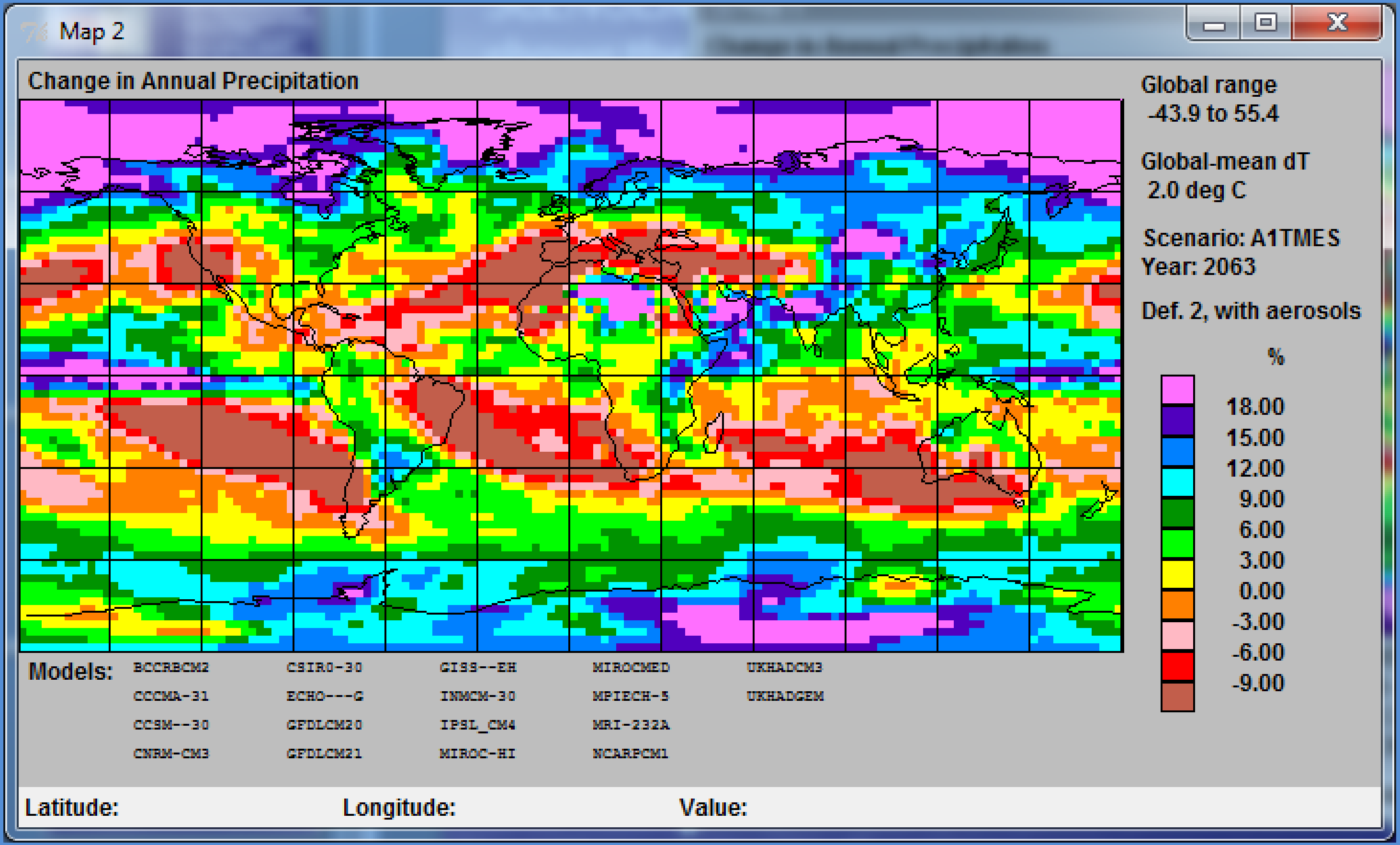
(3) a specific configuration in the MAGICC model, the default value (i.e., the "best guess"), or the User option, where the User chooses.

The above factors determine the average global temperature change value from 1990 to 2050 (the deg C value displayed in red at the top of the window in our case). This value is used to construct maps based on normalized values with an appropriate scale.

In our example, we use the default emission scenario, ie the A1T-MES, the Reference scenario that we have previously defined, and the default parameters from MAGICC. We also move the rolling bar to the year 2063 to reach a global average heating value of 20C, as shown in the figure.

SCENGEN: Mapping

13. Return to the SCENGEN window: Press -RUN to start. The map will appear shortly (in the figure below). Our map now shows the changes in the average annual precipitation for the 30 year period we chose with a central year in 2063 for the A1T emission scenario and the MAGICC climate parameter for the best estimation (ie the default). The result has been calculated as an average of 18 AOGCMs (of the Atmospheric-General Traffic Models).



Change in Annual Precipitation

Global range
-43.9 to 55.4

Global-mean dT
2.0 deg C

Scenario: A1TMES
Year: 2063

Def. 2, with aerosols

Models:
BCCRBCM2
CCCMA-31
CCSM--30
CNRM-CM3
CSIRO-30
ECHO---G
GFDLCM20
GFDLCM21
GISS--EH
INMCM-30
IPSL_CM4
MIROC-HI
MIROCMED
MPIECH-5
MRI-232A
NCARPCM1
UKHADCM3
UKHADGEM

Latitude:
Longitude:
Value:

Excercise

Starting from the basic MAGICC model,
Use
- as a reference scenario: A1Bnew
- WRE450 policy scenario.

Consider that the other parameters keep the default values.
You can make the display of the average global temperature by the year 2100 for both scenarios (Reference and Policy).
What are the differences? Comment on your results.

Continuing with the SCENGEN model
Follow the steps in the example and:
Describe changes in the spatial distribution of mean annual rainfall with SCENGEN (you can use both the Reference and Policy scenarios) for the time frame 2071-2100 using any of the AOGCMs you want. What are the differences in Europe and the Mediterranean? Comment on your results.

MAGICC/SCENGEN:

More Information

You can get more information about using the model and other user options from the User_Manual file, the User Manual that is included in your notes.

- More about the model
- http://www.cgd.ucar.edu/cas/wigley/magicc/