Future Scenarios for Central Europe

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please note that this lecture builds on concepts and uses terminology introduced by Prof. Schulz and other lecturers in previous classes.

you can find this lecture and more information on: www.climod.eu

János Tordai and Brigitta Hollosi turned the content into readable slides and helped via fruitful discussions – just as Sebastian Wagner, Eduardo Zorita and Hans von Storch who all contributed a lot through their advises.
Part two: probable future climates in Europe

from past climate reconstructions (discussed last week) to potential future climate evolutions (aka ‘projections’). Example: WATER RESSOURCES (lakes)

Example: Lake Surface Temperatures (LSTs) 1880-2100: clearly visible: industri. aerosol cooling masking the anthropogenic GHG-effect until the mid-1980s – i.e. once international ‘clean air acts’ came into effect the aerosol cooling was reduced and the anthropogenic GHG kicked in and took control → strong LST (!) warming (Matulla et al. 2018).
In order to generate scientifically consistent scenarios of future climates we need to know about the climate system, the processes within and in between its spheres and the forcings. Prof. Schulz has taught you the way solar, short wave energy is received by the system and how it is passed through the spheres by different sorts of processes evening out differences in the energy budgets between the poles and the equator before the energy is finally released back to space as long wave infrared radiation. The involved processes are described by mathematical formulas which may be solved numerically. All time dependent information on the state of the climate system ‘the Earth’ can be modelled and (simply put) computer programs offering this functionality on a coarse spatio-temporal scale are called Global Climate Models (GCMs). So, GCMs are driven by the forcings and calculate the meteorological variables depending on space and time. GCMs results are valid on coarse scales (for the entire globe, hemispheres, continents, but not on smaller scales) -- meaning seen from the moon (as a picture, a comparison 😊) all is fine. In case you are interested in the climate of a particular region (e.g. the European Alps) further analysis steps are needed, which are summarized by DOWNSCALING. So, this step of transferring information from a coarse grid (spacing e.g. 150 km) down to a small region or even to stations is called ‘DOWNSCALING’. Now we’ll: (i) repeat Climate System’s features that are mimicked by GCMs – this gives us an idea what GCMs are and do; (ii) discuss potential pathways of mankind, (iii)‘Downscaling’ and (iv) Climate Change Impacts.
Climate system, Spheres, Processes, Forcings

• The climate system consists of five spheres (atmosphere, hydrosphere, biosphere, lithosphere, cryosphere). The energy driving processes within and in between these spheres comes almost entirely from the Sun.

• So, the climate system is driven by the sun and as such by the way the energy reaches the planet. This depends for instance on the activity of the sun and the movement of the earth around the sun (you have heard that already).

• There are other drivers: volcanic activity or the greenhouse gas concentrations in the atmosphere, industrial aerosols, mountain ranges, the distribution of the continents (impacting e.g. oceanic and atmospheric circulation), the biosphere, land use, etc.

• The way the atmosphere and the ocean convey the incoming solar energy around the globe plays an important role for all climates around the planet.

warming the system
solar activity, greenhouse gases, ...

cooling the system
volcanic ashes (for some years if ash enters the stratosphere)
industrial aerosols, ...

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Weather and Climate

• Climate is the *statistics of the weather*. (there is quite some content in this statement: ranging from descriptive methods to statistical inference, probability theory and statistical modeling;

• → histograms, probability density functions – mean, variance, higher moments of distributions; description of climate features by variables representative for states of the climate system (temperature, precipitation, sunshine duration, cloudiness, pressure...);

• Climate Changes are changes in the statistical measures (mean, variance, kurtosis, excess and higher moments). So, climate change is rather natural BUT depending on: how quick, how much change takes place and how persistent these changes are: these changes turn un-natural when they start leaving the range of climate’s natural variability!
What characterizes the climate of a certain place on the globe?

You may say: the climate of a region is the statistics of the weather this region experiences over some decades and that’s right – but how many decades do we have to take into account? The WMO pragmatically decided that (at least) 30 years should be considered (this is reasonably from a plain statistical view). So, when people speak about climate they always think of periods containing three decades: 1961-1990, for instance, is called the ‘climate normal period’. And when speaking about ‘climate change in the near future’ then people often think of the period 2021-2050 compared to e.g. 1961-1990. 30 years are meaningful when considering e.g. temperature etc. However there are some variables which require more decades to properly picture their natural variability: e.g. storms.

Matulla et al. 2008
drivers: the Sun and its 'not so constant' solar constant S

Since the 'Sun's birth' the luminosity of the Sun has increased about 30% in 4.6 billion yrs. (left panel).

Over the past 7000 yrs the amount of stellar Energy/s, which receives the Earth from the Sun, varied little (0.3%) – the term: 'solar constant' is obviously misleading, since there is variation with time (see the upper panel). Much variation can be assigned to changes in so-called 'sun spots' which have been observed by Galileio already.

Nevertheless – the stellar energy input into our climate system of the Earth does not change much over short periods of time (that will be different when the star starts to die in about $4.6 \times 10^9$ yrs). However, over the bygone three centurie(s) we have observed a comparable large increase in stellar activity (right panel). The well-known 11 yrs. 'sun-spot' cycle is clearly visible although somewhat masked by mulitdecadal variations.

Changes in W/m$^2$ received at the Earth’s surface varied from 340.5 to 342 W/m$^2$ over the past 7000 yrs! This will be important for our discussion of socio-economic scenarios (RCPs) later.
drivers: **GHGs** – greenhouse gases \(\text{H}_2\text{O}, \text{CO}_2, \text{CH}_4, \text{O}_3\)

- **Carbon Dioxide vs Temperature:** past 400,000 years

  - Please recall: (top,left) \(\text{CO}_2\) – temperature evolution throughout the past 1000,000 yrs. (\(\text{CO}_2\) content: >190 and <290 ppm)

- **CH\(_4\) und \(\text{N}_2\text{O}\)**

  - Top, right: GHG concentrations in the atmosphere over the past 500 yrs. -> there is a significant rise in CO2/CH4 concentrations during the bygone 170 yrs. (note the scales) since the industrial revolution.

  - The famous Keeling curve (bottom, left) depicts the increase in CO\(_2\) content in the atmosphere -- presently more than 400 ppm

  - So far all efforts to reduce worldwide CO\(_2\) emissions have not shown sustainable success.

  - Since we have already learned that it is not possible to reproduce the observed evolution of global temperatures across the 20th century without considering manmade greenhouse gases we know that *manhood turned into a driving force of the Earth’s climate* e.g. by changing the chemistry of the atmosphere (GHG uploading).
drivers: **Volcanoes** weak/strong eruptions > ashes $\varepsilon$ Tropo/Stratosphere

You know by now that the severity of volcanic explosions turns the scales (decides) whether their emissions remain in the Troposphere (where they’ll be whashed out to the ground within some days/weeks by regular weather processes) or whether their particles make it into the Stratosphere where no cloud/precipitation processes can bring them back to Earth, but just Gravitaition. This, however, takes a considerably longer time and thus volcanic eruptions entering the Stratosphere remain there for some years (and not for just a few days) – where they can block off the incoming stellar insolation (hampering the climate systemto uptake energy) and thus cool the planet. Hence, such events can have an impact on the development of climate – particularly during periods of time within which volcanic eruptions appear frequently, like during the Little Ice Age (LIA – Tambora, 1815 & the Year without Summer, 1816,...). Please note that we’ve already discussed the combined forcing made up by solar (previous slide) and volcanic forcings (first lecture; see the Figure on the right : the red curve in its top & remember the first lecture : when we discussed how to reconstruct global temperatures in the 20th century without & with anthropogenic GHGs, etc.)!
drivers: aerosols

Aerosol data depict here (up, left) cover somewhat more than 200 years. In fact there are more proxy data sources on hand, allowing to reconstruct volcanic eruptions (see the Volcanic Explosivity Index – VEI) farther back in time. The Figure on the right (which we have displayed already) shows such a reconstruction of aerosol & sun-insolation back to 100 A.D. VEI is a relative measure for the explosive-ness of volcanic activities, reaching from 0 to 8 (by now), which refers to ‘mega-collosal’ explosions, coming with ejected volumina of matter above 1000 km^3 (!) Tambora (1815) was the latest in history whose ejecta volumina amounted up to these values ‘year without summer’ (1816) with a plume of more than 20 km (see for instance https://en.wikipedia.org/wiki/Volcanic_Explosivity_index). Anyway, the above Figure depicts aerosol concentrations from ice core data (Colle Gnifetti) and snow-cover measurements (Sonnblick).

After a continuous and accelerated rise in aerosol loads until 1980 (‘global dimming’) an abrupt and substantial decrease in aerosol loads is to be found. This sharp decrease in aerosol pollution is a result of international measures to combat air pollution on global scales, showing that international acts and efforts can result in substantial changes (‘global brightening’). However, ever since the atmosphere was cleared from (industrial) aerosols – see the Figure on the right, which had a cooling effect on the climate system (blue circle) – the warming effect of anthropogenic greenhouse gas emissions stood out and hence global warming gained pace (red curve).
**drivers: an overview and an integral**

Here we see now a picture showing the effect of GHGs, aerosols, volcanoes and of course the Sun together. ‘Land use Change’ is of less importance in comparison. It refers to changes of the Earth’s surface (e.g. rain forest clearing, farming, agriculture, herd keeping, sealing, urbanization, etc.). The net forcing has visibly increased from early stages of the industrial revolution up to now – mainly due to uploading the atmosphere with GHGs.

Volcanoes whose eruptions enter the Stratosphere yield to intermediate (a few years) cooling.
processes : feedback cycles (are very important in climate system’s economy)

A change in external forcing causing the temperature of a body to rise, increases the radiation away from the body (here: our planet). This counteracts the warming. Stefan Boltzmann states that it takes much energy to increase a body’s temperature and consequently maintain it’s the energy released by the body growths with the fourth power of its temperature. ‘lapse-rate feedback’

A change in external forcing enhancing surface temperatures reduces the amount of snow/ice on the ground (of our planet) and uncovers darker surfaces (ocean, land). This in turn increases the amount of energy taken up by the climate system yielding higher temperatures again and amplifies the snow/ice melt. ‘ice/albedo feedback’
GCMs are computer models simulating processes taking place within the climate system (CSPF). GCMs are substitutes for the Earth. Within GCMs the physical equations are solved on a 3D grid (that intersperses the atmosphere and the ocean). Results can be interpreted on the scale of continents but not below (von Storch et al. 1993) – skillful scale (~8 times the grid-distance). GCMs do have different spatio-temporal resolutions. The higher the resolution, the longer it takes supercomputers to calculate the climate evolution with time.
The increasing resolution of GCMs allows for a more and more realistic picture of topography too.

Evolution of climate models through time - there are constantly more processes, interactions and features, integrated.
GCMs: substitutes for the Earth’s climate system (CSPF) reconstructions – can we trust GCMs’ results?

GCMs, which are based on the physics of the climate system (spheres and processes, ...), can reproduce past climate states through time when being driven by (known) forcings.

Reconstructions of: solar and volcanic forcings (red), CO$_2$ (blue) and CH$_4$ (green) are found close to the top of the Figure. These forcings are used to drive the GCM: ECHO-G - curves in the lower part depict resulting runs of global temperatures Erik (black) and Columbus (yellow) and 100 yrs. trends (pink).

Zorita et al. 2004
GCMs: substitutes for the climate system (CSPF) of the Earth:

- detection of mankind’s fingerprint on climate

Manhood: from being threatened by climate to being a hazard to climate

Not long ago there were considerable discussions on mankind’s part in climate change: if man actually influences the climate of the planet and if so, when it’ll be possible to detect that. This was at the turn of the century (!). Only a few years later it was possible to prove man’s impact on the run of global temperature in the following way: based on all that was known about the past behaviour of the forcings (we discussed that last time – proxies!) they were split into ‘natural forcings’ and ‘all forcings’. ‘Natural forcings’ contained everything but the anthropogenic Greenhouse-gases (GHGs released into the atmosphere by human activity) and land-use induced changes in the surface’s albedo (land-use changes assignable to manhood). These two setups were used to drive GCMs (there are about 10 climate computing centers around the globe that are capable of carrying out such experiments). It was found that ‘all forcings’ reproduced the observed run of global temperatures (top panel), but ‘natural forcings’ could not reproduce increasing global temperatures from the mid-1980s onwards. Hence, manhood’s activities are needed to model observed global temperatures throughout the 20th century. That - of course - didn’t come as a surprise. However, it had to be demonstrated to become an undeniable fact.
It’s good to know what’s around the corner

It is always important to know what the future holds in stock since it helps to be prepared and allows you taking an active position. You, for instance, are partly responsible yourself what problems you will have to manage in the future and you can choose from a set of possible paths to approach them. In such cases it is good to know the consequences of your behaviour (e.g. you do not put your hand a hot stove as you know that this will hurt and seriously burn your skin ... 😊). In this respect climate research and impact research try to answer ‘if ... then’ questions. If mankind behaves this or that way the climate system in the future will perhaps look like

Can we turn back time? No - so, what can we do in terms of looking into the future? • We know the principles of the climate system (CSPF). This knowledge can be formulated by physical equations that can be translated in GCMs. • GCMs, picture the climate and produce results that are valid on global & continental scales (von Storch et al. 1993). • If regional scale information is desired Downscaling (transferring information between the scales) is to be applied (von Storch 1995). These steps: • drawing possible pathways of mankind, • computing its consequences in terms of global/continental-scale climate via GCMs, • applying Downscaling to derive results valid on regional/local scales: help us to access consequences of our actions and foresee climate driven impacts – based on this knowledge we can: • decide which pathway to take • mitigate consequences • adapt to them – get prepared.
how to set up future pathways of mankind - how to formulate scenarios?

a silly Example:

- If you want to know your weight in a year or ten years from now – you should have an idea how you are going to change your diet. It is also of importance to know what sport (if any) you are going to practice.
- If you don’t know – make some opposing assumptions like that you may turn into an ascetic living person or that you discover your need for very rich meals.
- That covers quite a range of possibilities.

So, what is a Szenario?

- A scenario is a consistent description of a probable evolution of what mankind may go through.
- A scenario does not have to be very likely.
- If there is no clue of what will take place – choose very different scenarios that cover a variety of future developments. This gives you a good chance cover the actual evolution.

What are scenarios good for?

- They allow to lay out ideas of what society may want to reach out for. Important: scenarios should never narrow down our sight of the range of possibilities. They are just (to our best scientific knowledge) answers to, IF -- THEN’ questions.
- As such they permit for future evolutions that are desired by the majority of our society or by dictators.
- The development of scenarios should be led by the idea of covering a broad window of possible developments, so they allow to span a reasonable fraction of the range of possibilities.
• man turned into a driving force concerning the climate system – thus, the development of climate (significantly in fact at least since the industrial revolution) depends (visibly) on the evolution of manhood.
• climate modeling (GCMs + pertaining methods) provides us with the ability revealing the consequences of man’s activities to the climate of the planet / by calculating the impact of different pathways of manhood in the future that is used to drive GCMs.
• Pathways of manhood ‘scenarios‘ are drawn up by groups of experts from several fields including: sociology, politics, economy, labour, agriculture, philosophers, etc. Associated scenarios were called ‘IS92a,d,…‘ in the 1990s, SRES (Special Report on Emission Scenarios) in the 2000s and RCPs Representative Concentration Pathways) in the 2010s (see www.ipcc.ch for more detail).
• here we focus on two of them, which are considered in all designs so far: ‘business as usual‘ and another more ‘climate friendly‘ scenario/pathway of manhood.

“SRES” Scenarios SRES = IPCC Special Report on Emission Scenarios

A1 a world of rapid economic growth and rapid introduction of new and more efficient technology.

A2 a very heterogeneous world with an emphasis on family values and local traditions.

B1 a world of “dematerialization” and introduction of clean technologies.

B2 a world with an emphasis on local solutions to economic and environmental sustainability.

IS92a “business as usual” scenario without aerosols (1992).
“RCPs” = IPCC 2013 Representative Concentration Pathways

4.5, 8.5 W/m² – is that a lot? • Sun’s output: 3.8*10²⁶ W • distance Sun-Earth: 150*10⁶ km in this distance (radius) from the Sun (center) 1368 W are received per m² • the Sun’s rays striking the circle of the Earth have to be transferred to the sphere of the Earth giving : 342 W are received by m² of the Earth. So, 1.3%, 2.5% more energy available per square meter and second on the Earth’s surface is meant by RCP4.5 and RCP8.5. A lot considering the short period until 2100 and the ‘solar constant’ that varied just ~ 2 W/m² in the past 7ka!
Entwicklungspfade der Menschheit und Klimaprojektionen

Global: +2.1° bis +4.7° bis 2100

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Global, projections of the future temperature as produced with a **GCM** (based on the A2 and B2 scenario) validity of GCMs: on global to continental scales (see e.g. von Storch et al. 1993, von Storch 1995)

Source: DKRZ
hemispheric projections of the future temperatures produced with GCMs driven by different scenarios

Source: DKRZ/MPI

mankind decides which path to take – there are significant differences between different pathways concerning climate changes towards 2100.

skilful scale – describes the spatial scale on which model results are valid (von Storch et al. 1993)
continental scale projections of future temperatures and precipitations produced with GCMs driven with RCPs

**Downscaling (Empirical Statistical ESD, Dynamic DD)**

was introduced into climate research by e.g. von Storch in the early 1990s and stands for all techniques bridging the gap between the large scale and the local scale relevant for impact research. DD’s skillful scale: 8 times 8 grid-points (just as in case of GCMs) – see E.g. von Storch et al. 1993.
Downscaling (ESD, DD) means cascading down the information from the GCM scale (skilful scale 8 times 8 GCM grid-points) to the regional scale (DD - skilful scale 8 times 8 RCM grid-points) as well as the regional and local scale (ESD). ESD - Empirical (right panel) and DD dynamical (left panel) Downscaling.

DD uses Regional Climate Models (RCMs) nested in GCMs over limited geographic areas (e.g. Europe). RCMs feature smaller scale climate processes than GCMs as they runs on finder grids (e.g. 10 km grid-distance). Their skilful scale is (just as in case of GCMs) 8 x 8 grid-points. Below that their results are not valid.

ESD derives statistical relationships which are then applied to GCM scenarios to generate regional to local-scale climate change projections.
Downscaling ESD and DD

Dynamical downscaling is the application of physical based models Regional Climate Models (RCMs) that account for smaller scale processes to the output of GCMs. No historical information is needed besides the physics of the system, which have been derived from observations. Unlike GMCs, RCMs do not reproduce the observations satisfactorily by now. In practice statistical methods are applied to render nature.

Statistical methods use observations on the local scale one desires to model and the GCM scale to set up functions as e.g. in a linear form \( f(x,t) = ax(t) + e(t), \) \( e \sim N(0,1) \). The models derived from observation are to be validated using data independent from those utilized for calibration. When searching for a statistical model for a relationship between two parameters there are some fundamental principles to have in mind/to follow. One is the ‘law of insufficient cause‘ meaning that unless you have no strong reason (e.g. from experiment, experience or other sources) you shouldn’t start with fancy functions just for fun or the desire to appear ingenious 😊. As such often linear models are the first step to start modeling with. Here we have another reason as well to assume linearity – the statistics of climate variables. It is rather hard to demonstrate that atm. fields (e.g. pressure fields in 850 hPa, temp. readings at stations) over long enough periods of time (some days) are not distributed (i.e. have a non-normal pdf) Gaussian. A linear transformation conserves statistics, which is certainly very important. Imagine the problems arising from destroying features of the Sigma algebra living on probability spaces. We cannot afford the destruction of measure theory for stupidity and vanity (integration breaks down etc.).
The evolution of uncertainty

Starting from a particular emission scenario the uncertainty grows with every step that is necessary to derive different adaptation measures to mitigate the impact of climate change (schematic diagram). Source: after Viner 2002.
GCM projections downscaled to Austria


Änderung der Häufigkeitsverteilung der Temperatur:
an ensemble of downscaled temperature projections used in CliPDaR (DWD-ZAMG-CEDR)

One possibility to illustrate the findings from an ensemble of projections (a multi model ensemble for A1B). The panels show the increase in the number of hot days per year. The left two panels refer to the 15th and 85th percentile for the n.f., the right two the same for the r.f. Source: DWD (www.dwd.de/klimaatlas, Imbery et al. 2013).
an ensemble of projections used to study changes in risk of threats (DWD-ZAMG-CEDR)

**Figure:** The Figure shows the change in counts of frost days ($T_{\text{min}} < 0^\circ\text{C}$) for the period 2021-2050 (first row) or 2071-2100 (second row) relative to the past (1961-1990). The left hand side panel refers to the 15th percentile. The others are assigned to the 50th and the 85th percentile. Given we have 100 projections sorting them from cold to warm than the left panel would be the 15th warmest while the right panel the 85th warmest panel. So 70% of the projections are in between them, giving a hint on the accordance or discordance of the ensemble of the projections. The middle panel is the median. Numbers in brackets below each panel are min and max values.

Matulla, Hollosi et al. 2017
an ensemble of projections used to study changes in risk of threats (DWD-ZAMG-CEDR)

**Figure:** The Figure shows the change in counts of summer days ($T_{\text{max}} \geq 25^\circ C$) for the period 2021-2050 (first row) or 2017-2100 (second row) relative to the past (1961-1990). The left hand side panel refers to the 15th percentile. The others are assigned to the 50th and the 85th percentile. Given we have 100 projections sorting them from cold to warm than the left panel would be the 15th warmest while the right panel the 85th warmest. So 70% of the projections are in between them, giving a hint on the accordance or discordance of the ensemble of the projections. The middle panel is the median. Numbers in brackets are min and max values.

Matulla, Hollosi et al. 2017
an ensemble of projections used to study changes in risk of threats (DWD-ZAMG-CEDR)

Probability distributions of the first EOF’s appearances throughout the past (black, solid line) the near future (colored dashed lines) and the remote future (solid, colored lines). Red lines refer to the A2, green lines to the A1B.
Downscaled temperature increases

Austria (IS92a, near future ESD)

Matulla et al. 2002
Downscaled temperature increases Austria (RCPs, near and farther future DD)


Chimani et al. 2016, ÖKS15 – ACRP Project
Downscaled precipitation changes in Austria (RCPs, near and farther future DD)

Chimani et al. 2016, ÖKS15 – ACRP Project
saisonal temperature and precipitation developments at Wien Hohe Warte (1948-2100). Curves referring to the future represent ensembles of local-scale climate change projections, which are derived from GCM scenario runs driven by the RCP8.5 (so-called 'business as usual') and the RCP4.5 (so-called 'climate-friendly') pathways of manhood. Ensembles are made up of more than 60 members (about 30 for each scenario). RCP8.45 : red; RCP4.5 : blue.
Lake Surface Temperature increases based on the ensembles just shown (RCPs until 2100)

$+10^2$ yrs.: Impact – Lake Surface Temperature (ALAWA)

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LV 816342 „Possible Impact of Climate Change on Water Resources“

Matulla, Tordai, Schlögl et al. 2018
potential future composition of Austria’s forests are of interest


Das Ökosystem Wald ist sehr komplex. Starker Impact kann das Gleichgewicht im Wald vielfältig stören.

„Service-Funktionen“: neben seiner Rolle in der Holzwirtschaft, schützt Wald vor Lawinen, Steinschlag, Muren und stellt sauberes Trinkwasser sicher. Ökosystemschutz ist hier besonders wichtig.

Klimastress wirkt sich direkt auf verschiedene Baumspezies unterschiedlich aus, aber es gibt auch zahlreiche indirekte Auswirkungen wie etwa über den Borkenkäfer oder Waldbrände, deren Auftreten sich im Klimawandel potentiell deutlich verändern.

Hanewinkel et al. 2012; Lexer et al. 2001, 2002
Phenological processes are of interest too

Scheifinger, Matulla et al. 2008
So, putting up the present frame

- human made *climate change is real* and cannot be stopped. It can be eased off by reducing of the emission of greenhouse-gases into the atmosphere (or catching them, or, or, ...).
- presently climate change is visible in temperature related parameters (not in e.g. storms)
- climate change is to unfold more and more clearly in the decades to come (perhaps it is then better visible in other than temperature related quantities too)
- climate and weather is already dangerous and is going to stay so in the future
- along with increasing temperatures heat stress (particularly in cities; impacting healthcare-systems, agriculture, farming, ...) and cooling demand will rise
- **higher temperatures affect** • agriculture and forestry • heat stress and droughts • danger of pest infestations • changes productivity of forest productivity changes with available CO₂ • extend vegetation-periods
- **floodings are complex and depend on various** factors (within complex structured orography – flash floods while in rather flat terrain spatial extensive events prevail (and are physically differently triggered): precipitation ≠ floodings -- precipitation + land-use + river construction = flooding events
- **heavy precipitation events** • up to now no comprehensive statements about future behaviours of sporadic, local, convective events are possible • statements concerning large-scale, long-lasting precipitation events are to be treated with caution.
Mitigation, Adaption, Protection

• a complete fulfillment of the so called Kyoto protocol would have delayed the process of climate change to an unreasonable period of time (some weeks).

• COP21 is different! 😊 it is serious and considerable efforts are required to attain this goal: limiting increases of global temperatures 2100 to +1.5°C above ‘pre-industrial’ (i.e. 1835-1865) temperature levels.

• As there is no way to stop climate change, we have to cope with climate change and how to deal with impacts. This means mitigation and adaption. Until recently there were only a few scientists aware of that and honest about that. Now, since it is obvious this attitude has spread. Well, better late than never! So, check ‘experts’ – see their actual contributions to science – don’t believe everything: think yourself!

see e.g. von Storch and Stehr 2010
What you should know?

• That temperatures before the instrumental period are reconstructed by proxies and at least three of them;
• The run of temperature in Europa during the past 10ka;
• The components of the climate system;
• The forcings, some processes within and in-between the components of the climate system;
• The production of scenarios;
• The skilful scale of GCMs;
• The two possible ways of Downscaling;
• The creation of input data for impact modeling.
Thank you for your attention! and good luck in your further endeavours!
Past GAR temperature

Since 1950: intense impact of the living us on the atmosphere via aerosols and greenhouse gases.

Until 1950: mainly natural climate variations – human impact not restricted to menschlicher Einfluss marginal, largely via forest clearance (pushing the albedo to higher values and therefore reasoning a small cooling).
GAR temperature compared to the run for the NH temperature

Similar temperature evolution in different GAR-subregions

but: a less pronounced NH temperature (CRU)
Natural and anthropogenic forcings

The interplay of the climatic drivers throughout the past 160 years

Temperature development globally, since 1855

- solar + Volcanism
- GHGs
- Sulfur

IPCC 2007

Slide by R. Böhm
The reduction of light in favour of darker surfaces in the end of a process chain always yields a positive feedback.

The same is true for greenhouse gases. If, at the end of a process chain, greenhouse gas densities are enhanced, temperatures increase.
processes: feedback cycles (are very important in climate system’s economy)

‘water vapour feedback (sometimes called cloud feedback’): it is physically obviously meaningful that the greenhouse effect warms the atmosphere and that a warmer atmosphere is capable of carrying larger amounts of water than a colder one. Water vapour turns into clouds, which act in two possible ways: water vapour traps the outgoing infrared radiation from the Earth and at the same time reflect the incoming stellar radiation back to space. The first effect warms the climate system while the second one cools it. Presently observations suggest that the reflection of short wave radiation outweighs the trapping effect of the infrared radiation > clouds reduce the energy balance by about 20 W/m².

another dampening cycle: plant growth and CO₂ content of the atmosphere.

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