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A TALK ABOUT CLIMATE CHANGE

Bjørn Aune

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A talk about climate change

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SAMMENDRAG

The report is the text of a talk about climate change given for the Comité Eurpéen des Assurances at the Plenary Meeting in Oslo 27. May 1997 of the Fire/Theft Committee.

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Bjørn Aune
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COMITÉ EUROPÉEN DES ASSURANCES

FIRE/THEFT COMMITTEE
Plenary meeting
OSLO - 26/27/28 May 1997

CLIMATE CHANGE

by

Bjørn Aune

Norwegian Meteorological Institute

DNMI

27. May 1997

Climate Change

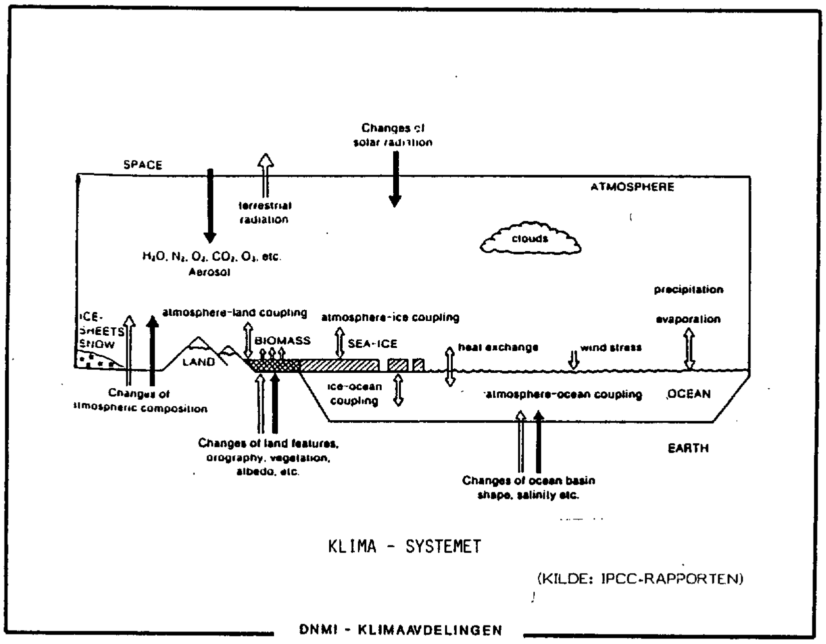
by
Bjørn Aune, Norwegian Meteorological Institute, Climatology Division

The weather is part of our daily life and affects our activities in different ways. Extreme weather conditions may lead to loss of human life and destruction of large economic values. Despite its instability the weather follows, however, a main pattern which is called *the atmospheric circulation*. The atmospheric circulation is the combined result of all forces that affects the atmosphere. An understanding of these forces makes it possible to plan for security, economy and comfort.

Climate is the statistical description of the weather. The basis for a climatological description is systematic weather observations through so many years that extreme single values do not have significant effects on the statistics.

The climate at a place is usually described by mean values of the weather elements and the variation around the means. The most known mean values are *the international standard normals* which are mean values for the 30-year periods 1901-1930, 1931-1960 and the presently used 1961-1990 period.

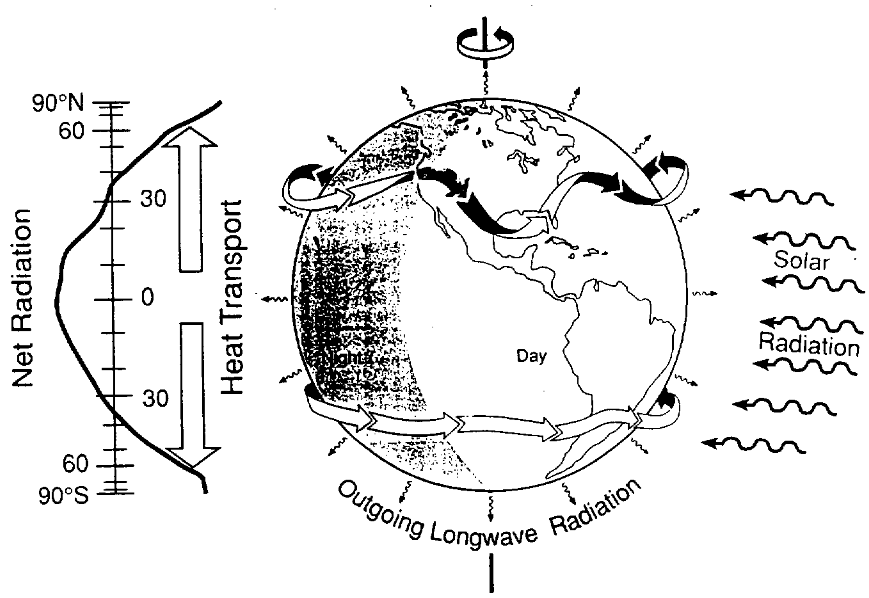
The normals and the variability around them, extreme values and other parameters together provide a systematic statistical description of common and possible weather conditions at a place.



The climate system

The atmosphere is a large and complex system where all elements interact with each other. The earth and the atmosphere receives energy from the sun and radiate the same amount of energy back to space. This equlibrium is necessary for keeping a mean constant temperature of the globe as a whole.

The areas around the equator receive more solar energy than areas at higher latitudes. The earth and the atmosphere below 38° receive more energy from the sun than they radiates back to space and therefore have a positive energy balance. The areas above 38° have an average negative energy balance. That means that nearly all of Europe has a negative average solar energy balance.



The energy balance (after IPCC Climate Change 1995)

The difference in energy balance from the equator to the polar regions and the resulting fall in air temperatures, create horisontal pressure differences and thereby instabilities in the atmosphere. The atmosphere tries to restore stability through large wind systems, referred to as the atmospheric circulation.

One may therefore say that the weather we experience is the result of the atmosphers efforts to reach equilibrium, a goal that it never will reach because of the earths rotation around the sun and the earths daily rotation around itself which gives a continuous change in the distribution of the incoming solar radiation energy.

The oceans have larger storage capacity for thermal energy than dry land. The solar energy is better distributed to greater depths and the surface temperatures are more stable. The currents therefore affect the temperature of the air above the ocean surface. The impact of solar energy upon the oceans that cover 71% of the earths surface is therefore of vital importance to the climate of the earth.

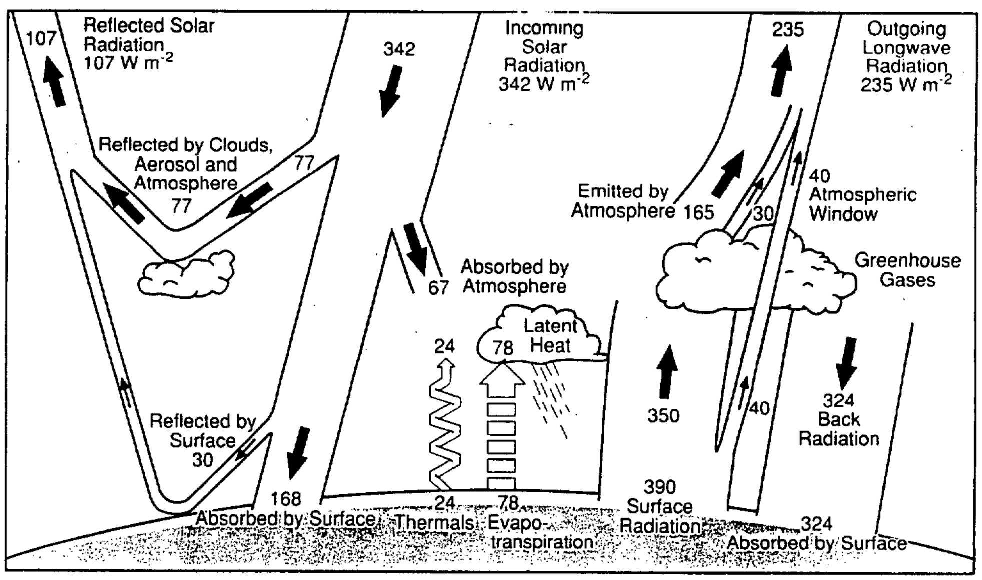
The movement of water between ocean, atmosphere and land is called *the hydrological cycle.* Through this constant cycle the land is continuously supplied with fresh water which is necessary for humans, animals and vegetation. But because the pattern of the atmospheric circulation and the earths topography the distribution of precipitation is uneven both geographically and in time.

The greenhouse effect

The earth has, as mentioned earlier, an energy balance with space and radiates back to space as a body with a temperature of -18°C. The mean air temperature on the earths surface however is 15°C because the atmosphere does not slip all backradiated energy through directly. Vater vapour, carbon dioxide, methane, nitrous oxide and other *"greenhouse gases"* in the atmosphere absorb longwave radiation and warm the lower atmosphere.

This so called "greenhouse effect" is a natural effect and has been there all the time. There is also a natural carbon dioxide cycle.

It is the greenhouse effect that makes it possible for life, as we know it, to exist on the earth. So the question is not if we create a greenhouse effect, but if we change it in a way that affects the weather and climate on the earth. This is a difficult question to answer, and no one has found it yet. There are some that very loudly and clearly state that they have the answer, and most of those are in opposition to the work done by the Intergovernmental Panel on Climate Change (IPCC).



The earth's radiation and energy balance. Some radiation is absorbed by the atmosphere producing av greenhouse effect (after IPCC Climate Change 1995)

IPCC

The Intergovernmental Panel on Climate Change (IPCC) which is set up by the United Nations (WMO and UNEP) evaluates the work that is being done, and

assess available scientific information on climate change
assess the environmental and socio-economic impact of climate change
formulate response strategies

IPCC depend on the work of numerous scientists and other experts world-wide. It is not correct that IPCC is a group of politicians. It can of cource be argued that the UN system for making reports like the IPCC reports, is not a good one. It depends very much on concensus, and does not show divergent theories and opinions. But in this case has there been a lot of scientific discussions and evaluations beforehand. At least is this the case for the scientific report. I must admit that I know less about the one dealing with response strategies, where of course the politics of countries and different interest groups comes in.

The IPCC report is therefore the most authoritative source when we seek information about the question of climate change and how climate will most probably develop in the future.

The main difficulty with the IPCC report is however not the scientific aspect, but that it is to complicated and comprehensive to be easy reading for policymakers, media and the general public. Especially is the media more happy with a simple theory that forecasts a not to dangerous catastrophy in the not to near future. The present weather is also important for the media interest. Hot weather that will be hotter, cold weather that will be colder, wet weather wetter and dry weather dryer.

Natural climate variations

The natural climate is not constant and has never been that. There is a natural climate variability which results from both internal fluctuations and from external causes such as solar variability or volcanic eruptions.

To understand recnt and future climatic change, it is necessary to document how climates have varied in the past. Such information is necessary, for instance, to determine whether the changes and variations found are likely to reflect natural rather than human-induced climate variability. Some measure of this natural variability can be deduced from instrumental observations, but these are restricted for the most part to less than 150 years. Longer records of climate variations are required to provide a more complete picture of natural climate variability against which anthropogenic influences in the observed climate record can be assessed.

Climates from before the recent instrumental era must be deduced from paleoclimatic records. These includes tree rings, pollen series, faunal and floral abundances in deep-sea cores, isotope analysis from coral and ice cores, and diaries and documentary evidence. There are however great difficulties in transforming these informations into general climatological information. That is one of the reasons that one when looking at for example temperature series see no small scale variations in earlier times. Modern research indicates now that rapid climate changes has occurred also earlier and they are all natural and not human induced changes. Much information about rapid climatic changes has recently been obtained either from a refined interpretation of existing records or from new ice, ocean and continental records from various parts of the world. Of particular significance are those concerning the North Atlantic and adjacent continents such as central Greenland ice cores, numerous deep-sea core records from the North Atlantic and continental records (lake sediments, pollen series etc) from Western Europe and North America. These records provide descriptions of the last glacial period and the following deglaciation. The observed rapid changes are often large in magnitude, and thus there is considerable confidence in their reality.

These rapid events are relevant to understanding current climate because they affect on the human time-scales important climatic variables on a large geographic scale. However,at least some of these abrupt changes have been attributed to the instability of an ice sheet which does not exist in today's world. Abrupt regional events also occurred in the past 10.000 years. These changes have been smaller and smoother than those during the previous glacial period. Such events are perhaps more relevant to the estimation of the possible speed of natural climate variations in the current climate. It seems unlikely, given the smaller regional changes, that global mean temperatures have varied by 1°C or more in a century at any time during the last 10.000 years.

I am not going to bore you with a long travel through millions of years of climate, but only mention a few highlights. The last ice age ended in Europe approximately 9000 years ago. The development from then was not even and continuous, there were great variations in the climate between warmer and colder periods. During a period 8000 - 5000 years ago the summer temperatures in Northern Europe were 2 - 3°C higher than today. Later there are the Medieval Warm Period between 9th and 14th century and the Little Ice Age during 1650 - 1850.

Recent studies have demonstrated that the two periods, the Mediveal Warm Period and the Little Ice Age, were geographically more complex than previously belived. It is not yet possible to say whether, on a hemispheric scale, temperatures declined from the 11-12th to the 16 -17th century. **However, it is clear that the period of instrumental record began during one of the cooler periods of the past milliennum.**

Two views of the temperature record of the last century are possible if this record is viewed with the longer perspective provided by the paleoclimatic data (Figure next page).

On one hand, the long-term change of temperature could be interpreted as showing a gradual increase from the late 16th century, interrupted by cooler conditions in the 19th century.

Alternatively, one could argue that temperatures fluctuated around a mean somewhat lower than the 1860-1959 average (puntuated by cooler intervals in the late 16th, 17th and 19th century) and then underwent pronounced and unprededented (since 1400) warming in the early 20th century.

Whichever view is considered, mid-late 20th century surface temperatures appear to have been warmer than any similar period of at least the last 600 years. In at least some regions

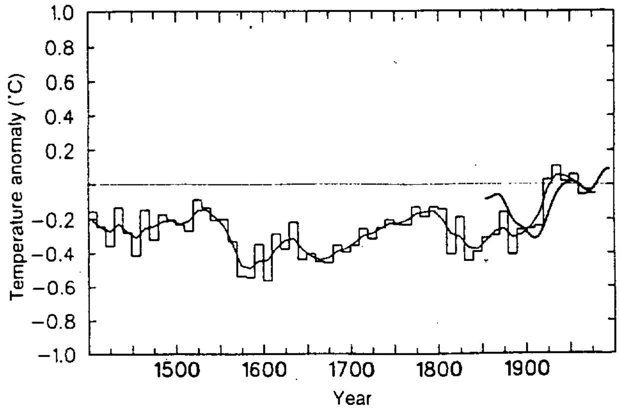


Figure 3.20: Decadal summer temperature index for the Northern Hemisphere, from Bradley and Jones (1993), up to 1970-1979. The record is based on the average of 16 proxy summer temperature records from North America, Europe and east Asia. The smooth line was created using an approximately 50-year Gaussian filter. Recent instrumental data for Northern Hemisphere summer temperature anomalies (over land and ocean) are also plotted (thick line). The instrumental record is probably biased high in the mid-19th century, because of exposures differing from current techniques (e.g., Parker, 1994b).

(After IPCC Climate Change 1995)

20th century temperatures have been warmer than any other century for some thousands of years.

Other regional changes are for example that the recent warming has been greatest over the midlatitude countries in winter and spring, with a few areas of cooling, such as the North Atlantic Ocean. Precipitation has increased over land in high latitudes of the Northern Hemisphere, especially during the cold season.

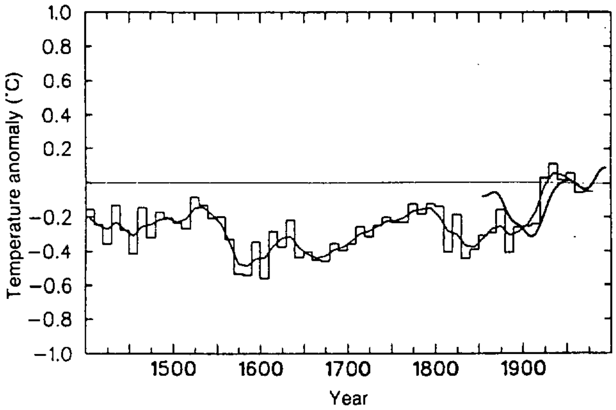
Global mean surface air temperature has increased by between 0.3°C and 0.6°C since late 19th century; the additional data available since 1990 have not significantly changed this range of estimated increase.

Figures on the next page shows temperature curves for Europe for 1890 - 1996.

Resent years have been the warmest since 1860, i.e. in the period of instrumental record, despite the cooling effect of the 1991 Mt. Pinatubo volcanic eruption.

Is the changes in climate during the last hundred years natural or human-induced? Or in other words: Is the human activities grown so much from the industrial revolution than we now influence the climate on a global scale. Humans have influenced the climate locally and regionally for decades. Examples are the clearing of forests in Europe for agriculture, building of cities and of large industrial areas. But until for some years ago one thought that the global atmospheric system was so large and strong that it absorbed these activities. Climatologists have warned earlier. The Swedish professor Svante Arrhenius first estimated rise in global temperatures due to carbon dioxide in 1896. But few people responded until new knowledge and the introduction of climate models that forecasted future climate caught media interest, when we got some winters with unusual weather 10 -15 years ago. The interest spread to environment protection groups and politicians. But more normal weather and cost estimates of measures for reducing climate affecting activities, seems now to have dampened the enthusiasm of many politicans.

The discharges of climate gases or greenhouse gases into the atmosphere from human activities has increased since pre-industrial times. The atmospheric



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Do human activities affect the climate?

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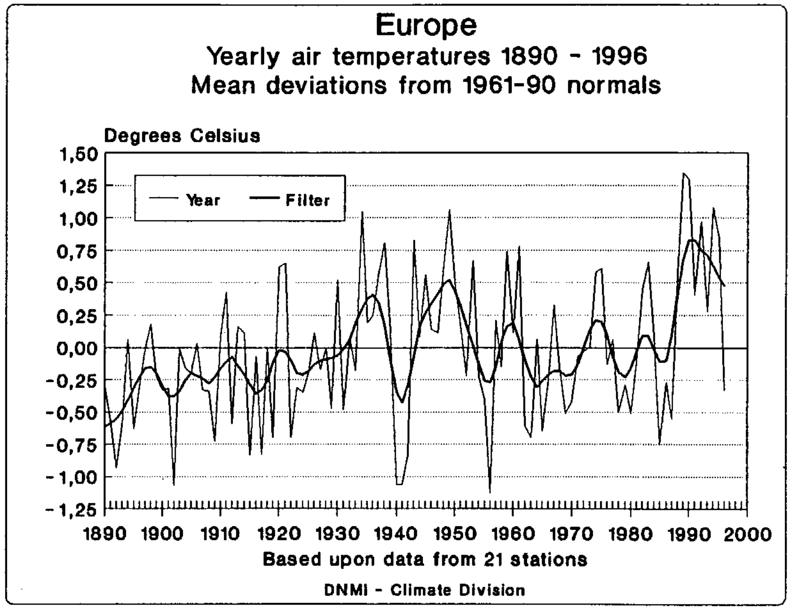
Europe
Yearly air temperatures 1890 - 1996
Mean deviations from 1961-90 normals
Degrees Celsius
Year
Filter
1,50
1,25
1,00
0,75
0,50
0,25
0,00
-0,25
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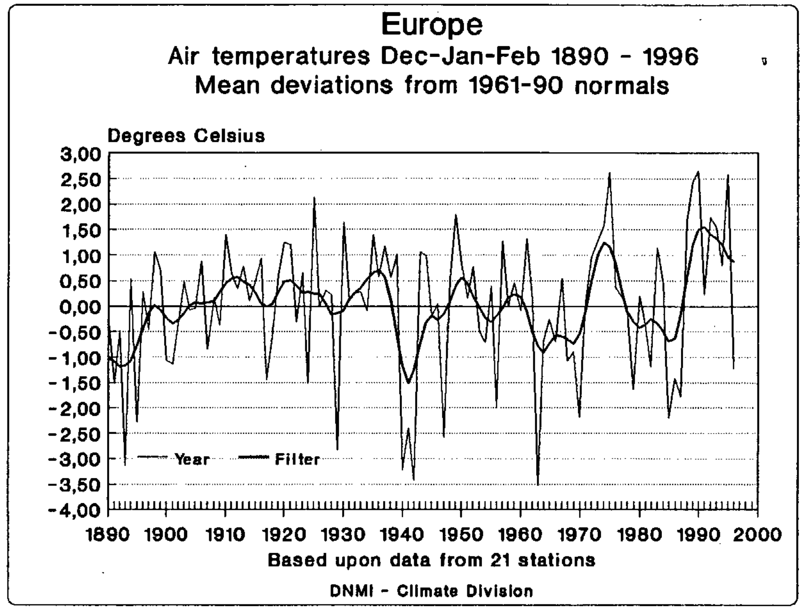
-1,00
-1,25
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Based upon data from 21 stations
DNMI - Climate Division


Europe
Air temperatures Dec-Jan-Feb 1890 - 1996
Mean deviations from 1961-90 normals
Degrees Celsius
Year
Filter
3,00
2,50
2,00
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-1,00
-1,50
-2,00
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-3,00
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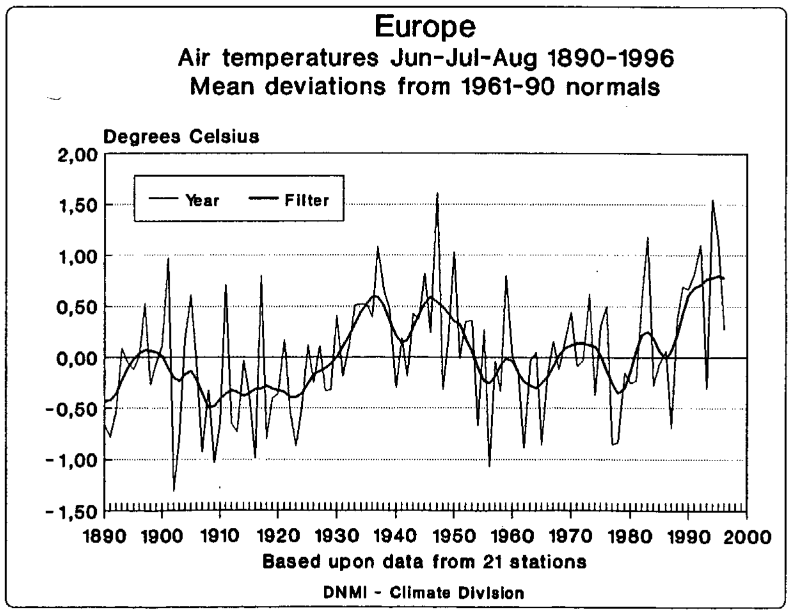
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Based upon data from 21 stations
DNMI - Climate Division


Europe
Air temperatures Jun-Jul-Aug 1890-1996
Mean deviations from 1961-90 normals
Degrees Celsius
Year
Filter
2,00
1,50
1,00
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-0,50
-1,00
-1,50
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000
Based upon data from 21 stations
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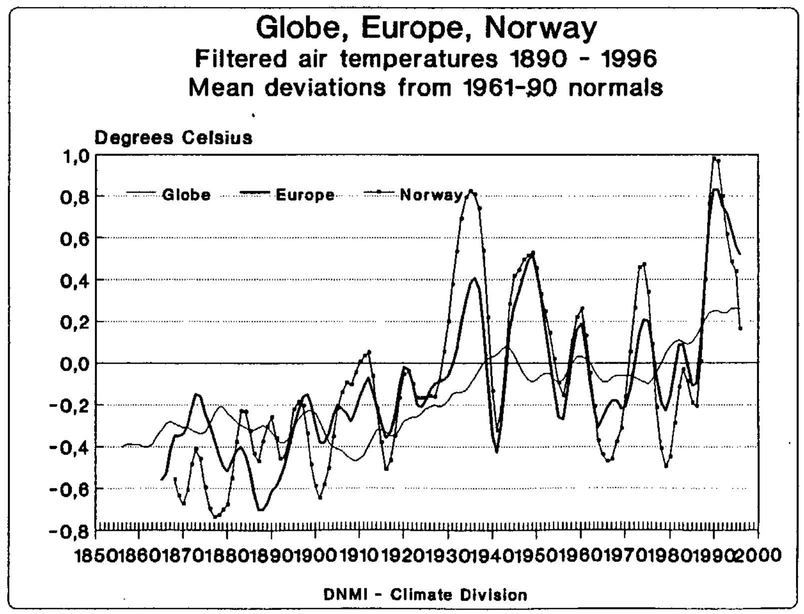

Globe, Europe, Norway
Filtered air temperatures 1890 - 1996
Mean deviations from 1961-90 normals
Degrees Celsius
Globe
Europe
Norway
1,0
0,8
0,6
0,4
0,2
0,0
-0,2
-0,4
-0,6
-0,8
1850186018701880189019001910192019301940195019601970198019902000
DNMI - Climate Division

The discharges of climate gases or greenhouse gases into the atmosphere from human activities has increased since pre-industrial times. The atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have grown sigificantly: by about 30%, 145% and 15 % respectively (1992). These trends can be attributed largely to fossil fuel use, land-use change and agriculture. Many greenhouse gases remain in the atmosphere for a long time, decades to centuries, and hence they affect the radiative forcing on long time scales. If carbon dioxide emmissions were maintained at near current (1994) levels, they would lead to a nearly constant rate of increase in atmospheric consentrations for at least two centuries, reaching approximately twice the pre-industrial consentration by the end of the 21th century. So if we want to stabilise the consentration at a certain level, for example to-days level, we will first have to reduce the emissions.

Any human-induced effect on climate will be superimposed on the background "noise" of natural climate variability, which results both from internal fluctuations and from external causes such as solar variability or volcanic eruptions. Detection and attribution studies attempt to distinguish between anthropogenic (man-made) and natural influences. *Detection of change* is the process of demonstrating that an observed change in climate is highly unusual in a statistical sense, but does not provide a reason for the change. *"Attribution"* is the process of establishing cause and effect relations, including the testing of competing hypotheses.

Considerable progress have been made during the last years in the attempts to distinguish between natural and antropogenic influences on climate. The most important results related to the issue of detection and attribution are:

** The limited available evidence from proxy climate indicators suggests that the 20th century global mean temperature is at least as warm as any other century since at least 1400 A.D. Data prior to 1400 are too sparse to allow the reliable estimation of global mean temperature.

** Assessments of the statistical significance of the global mean surface temperature trend over the last century have used a variety of new estimates of natural internal and externallyforced variability. These are derived from instrumental data, palaeodata, simple and complex climate models, and statistical models fitted to observations. **Most of these studies have detected a significant change and show that the observed warming trend is unlikely to be entirely natural in origin.**

** More convincing recent evidence for the attribution of a human effect on climate is emerging from pattern-based studies, in which the modelled climate response to combined forcing by greenhouse gases and anthropogenic sulphate aerosols is compared with observed geographical, seasonal and vertical patterns of atmospheric temperature change. These studies show correspondance in increase with time, as one would expect as an anthropogenic effect (or signal) increases in strength. Furthermore, the probability is very low that these correspondences could occur by chance as a result of natural internal variability only. The vertical patterns of change are also inconsistent with those expected for solar and volcanic forcing.

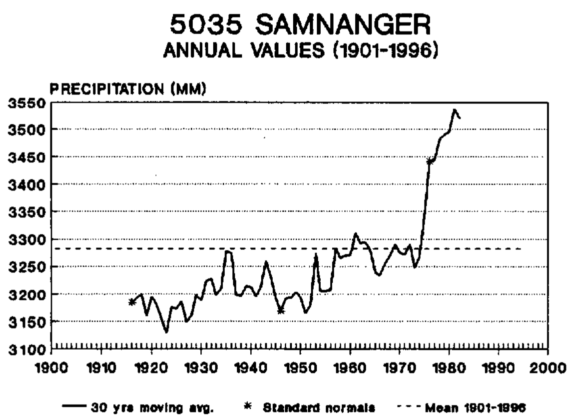
** Our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors. These include the magnitude and patterns of long term natural variability, the time-evolving pattern of forcing by, and responce to, changes in concentrations of greenhouse gases and aerosoles, and land surface changes.

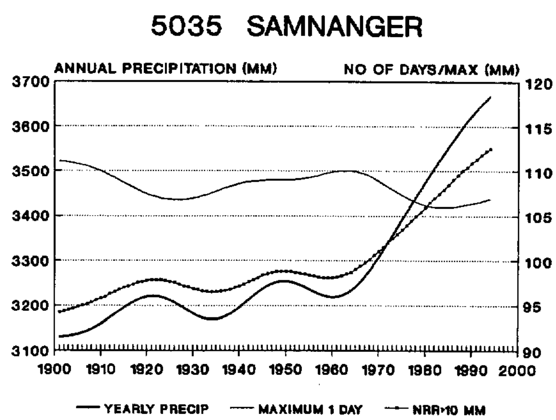
Nevertheless, the balance of evidence suggests that there is discernible human influence on global climate.

Extreme events

The data on climate extremes and variability are inadequate to say anything about global changes, but in some regions where data are available, there has been *decreases or increases* in extreme weather events and variability.

There have been few studies of variations in extreme precipitation events and flood frequency. In some areas with available data there is evidence of increases in the intensity of extreme rainfall events, but no clear, large-scale pattern has emerged.





The figures above show that the precipitation station Samnanger in the western part of Norway has had a great increase in precipitation during the last decade (The left figure shows moving 30-year averages). In this part of the country where we have had such increase in precipitation, we have not had an increase in short-time rainfall extremes (Right figure). The increase has come in more days with precipitation, and an increase in days with above medium to heavy, but not extreme, precipitation. I expect, however, that in other areas which are dominated by convective rainfall during the summer half of the year, an increase in precipitation together with an increase in temperature, will include an increase in extreme events.

In 1995 we had the second largest spring flood in history in the eastern part of Norway. This flood was not the result of extreme rainfall, but of an unfortunate combination of on their own non-extreme meteorological factors.

This last winter we had extreme snow depths in parts of northern Norway, and the people living their felt that it was the hardest winter ever experienced. And in especially one city that was worst hit, the expenses for roadclearing became enormous compared to the budget. But again the reason was an unfortunate combination of on their own non-extreme meteorological factors. And of course, a winter lasting 8 months has a great psychological effect.

There is some evidence of recent (since 1988) of increases in extreme extra-tropical cyclones over the North Atlantic. But less than 10 years is a very short period in climatology. Storms in the North Sea and in the Norwegia Sea has been studied by professor Lamb, UK. He has shown that there have been several short storminess periods, and before 1988 was a period with fewer storms.

Storms that make much damage are also so rare that sampling for statistical studies are difficult. The storm in Norway January 1. 1992 had wind gust values with an estimated return period of more than 200 years. How often will we experience a storm like that one?

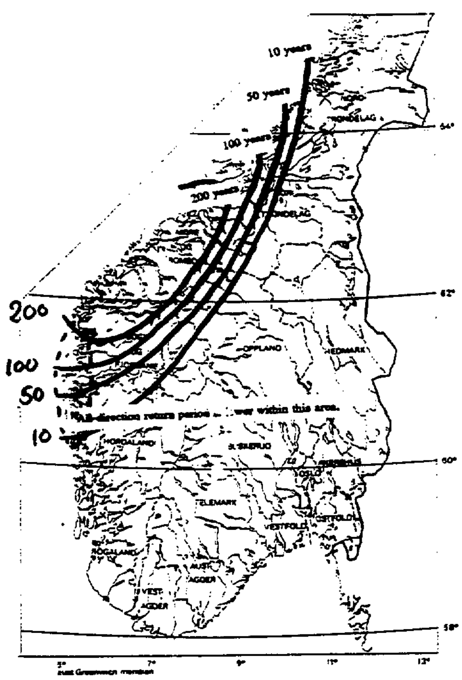
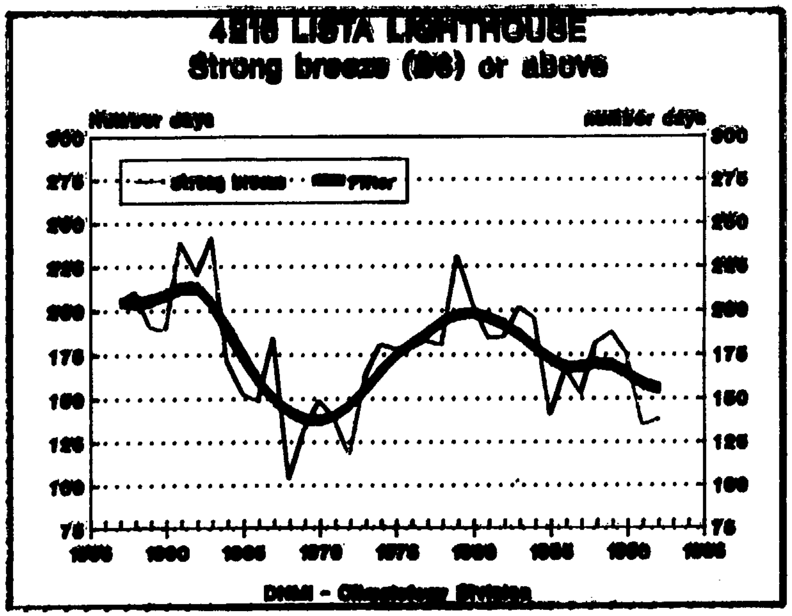
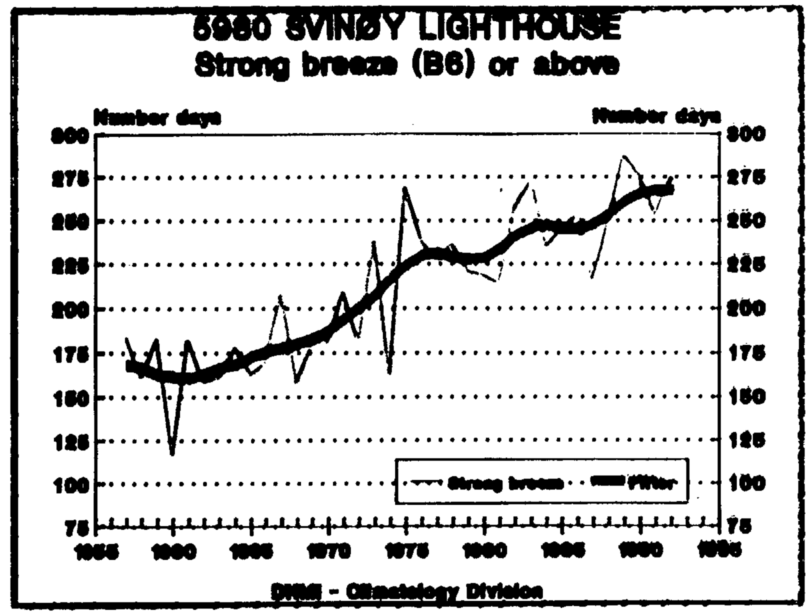
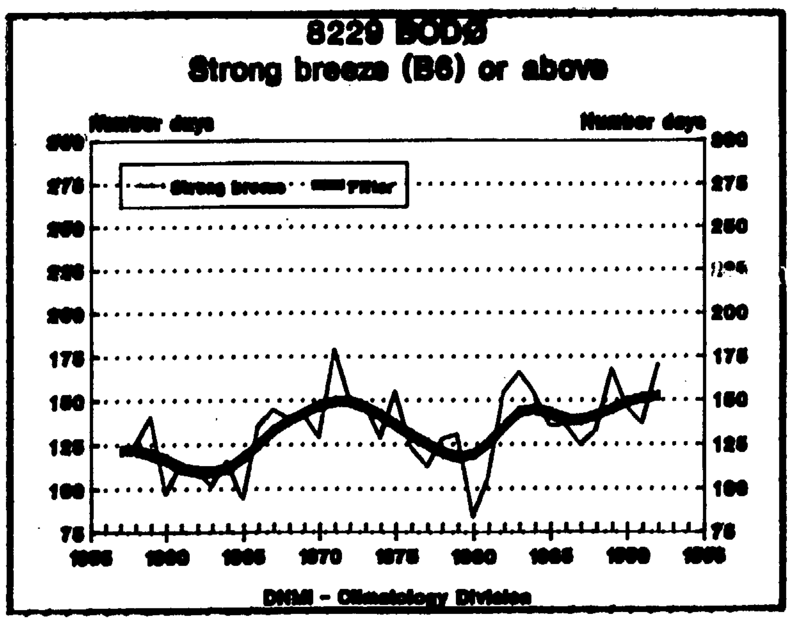


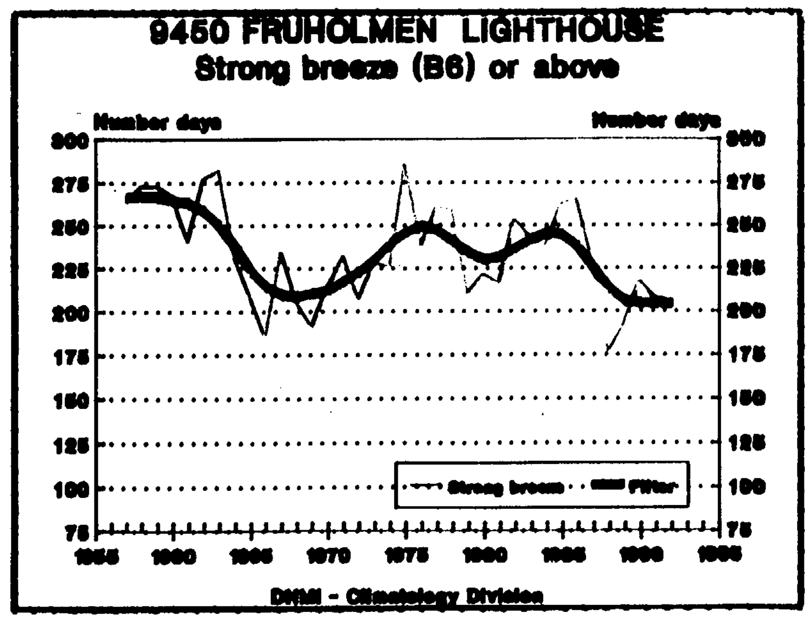
Figure 7. Geographical distribution of the gust return periods for areas exposed to wind fields from southwest to west, January 1. 1992.

In Norway some single stations along the coast shows opposite trends. So one has to sample over a large area. This shows that statistics for extreme storm events has to be sampled from large areas and not from specfic stations only. The figures on the next page shows number of days with strong breeze and above for four stations, Lista in southern Norway, Svinøy on the west coast, Bodø in northern Norway and Fruholmen on the coast north of Norway.


LISTA LIGHTHOUSE
Strong breeze (B6) or above
Number days
Strong breeze
Filter
DNMI - Climatology Division


5960 SVINØY LIGHTHOUSE
Strong breeze (B6) or above
Number days
Strong breeze
Filter
DNMI - Climatology Division


8229 BODØ
Strong breeze (B6) or above
Number days
Strong breeze
Filter
DNMI - Climatology Division


9450 FRUHOLMEN LIGHTHOUSE
Strong breeze (B6) or above
Number days
Strong breeze
Filter
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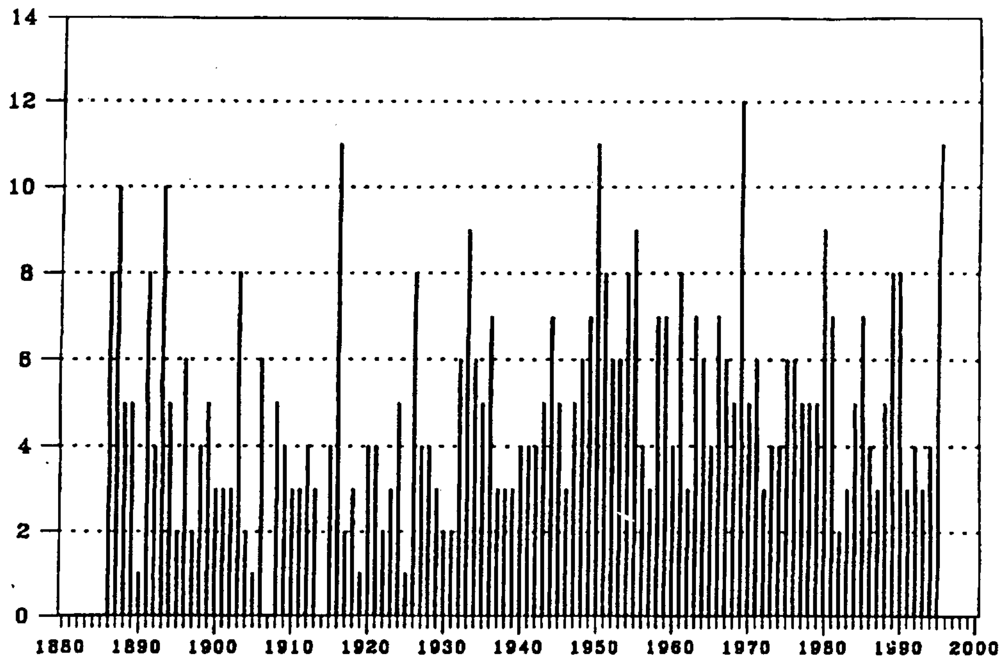
Intense tropical cyclones activity in the North atlantic has decreased over the last few decades, although the 1995 season was more active than recent years. But the figure below shows that that can not be taken as a change in climate!



Yearly number of Hurricanes in the North Atlantic Ocean 1886-1995.
(From Climate Monitor Vol. 24 No. 5, UEA)

There has been a clear trend to fewer extremely low minimum temperatures in several widely separated areas in recent decades. Widespread sigificant changes in extreme high temperature events have, however, not been observed.

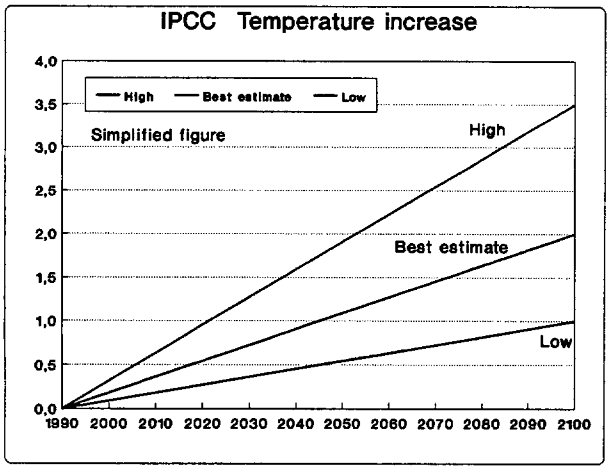
Global sea level has risen by between 10 and 25 cm over the past 100 years and much of the rise may be related to increase in global mean temperature. The termal expansion is estimated to be 2 - 7 cm, enhanced melting of glaciers and ice caps is estimated to be 2 - 5 cm.

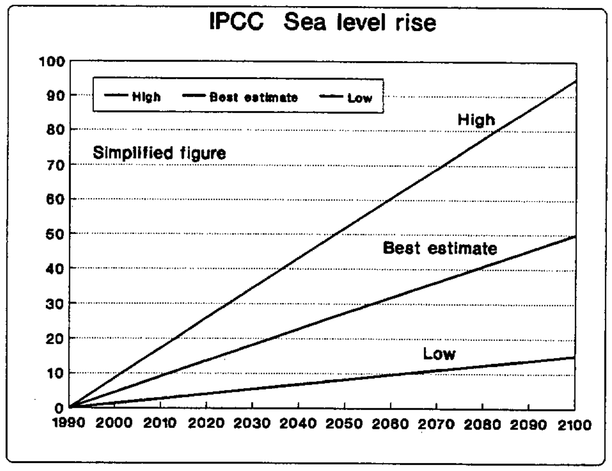
Climate is expected to continue to change in the future.
The IPCC has developed a range of scenarios of future greenhouse gas and aerosol precursor emissions based on assumptions concerning population and economic growth, land-use, technological changes, energy availability and fuel mix during the period 1990 to 2100. Through understanding of the global carbon cycle and of atmospheric chemistry, these emissions can be used to project atmospheric consentration of greenhouse gases and the pertubation of natural radiative forcing. Climate models can then be used to develop projections of future climate.

** the increasing realism of simulations of current and past climate by coupled atmosphere-ocean climate models has increased our confidence in their use for taken into account in the full range of projections of global mean temperatures and sea level change.

** For the mid-range IPCC emission scenario assuming the "best estimate" value of climate sensitivity and including the effects of future increases in aerosol, models project an increase in global mean surface air temperature relative to 1990 of about 2°C by 2100. This estimate is approximately one third lower than the same estimate in 1990. This is primarily due to lower emisioń scenarios, incusion of aerosols, and improvements in the treatment of the carbon cycle. The correponding low value is an increase of 1°C by 2100 and the corresponding high walue is an increase of 3.5°C by 2100.

In all cases the average rate of warming would probably be greater than any seen earlier in the last 10.000 years, but the actual annual to decadal changes would include considerable natural variability. Regional temperature changes could differ substantially from the global mean value. Because of the thermal inertia of the oceans, only 50-90% of the eventual thermal equilibrium change would have been realised by 2100 and temperature would continue to increase beyond 2100, even if concentration of greenhouse gases were stabilised by that time.





** Average sea level is expected to rise as a result of thermal expansion of the oceans and melting of glaciers and ice-sheets. In the "best estimate" models predict an increase of about 50 cm from the present to 2100. This estimate is approximately 25% lower than earlier "best estimate" (1990) due to the lower temperature projection, but it also reflects improvments in the climate and ice melt models. The correponding low value is 15 cm increase and the corresponding high value is 95 cm. Sea level would continue to rise at a similar rate in future centuries beyond 2100, even if consentrations of greenhouse gases were stabilised at that time. Regional sea level changes may differ from the global mean value owing to land movements and ocean current changes.

** Confidence is higher in the hemispheric-to-continental scale projections of coupled atmosphere-ocean climate models than in the regional projections, where confidence remains low. There is a great demand for climate predictions at a detailed regional level from those who are studying the potential impacts of climate change. Several climate modelling centres and others are carrying out experiments, but with limited success so far. In many regions special effects will have major influences on the local climate.

** There is at the moment more confidence in the temperature projections than in the hydrological ones.

** On the west coast of Norway will an eventual change in the main wind direction have great impact on future precipitation. More westerly winds at higher temperatures will lead to a significant increase, and most probably to a decrease in eastern Norway. If we get more southerly winds, the changes will be in the same direction at both locations, and with more southeasterly winds we will get decreased precipitation in western Norway. These options will be studied in more detail in the coming years.

** All model simulations show the following features:
greater surface warming over the land than over the ocean in winter;
a maximum surface warming in high nothern latitudes in winter;
little surface warming over the Arctic in summer;
an enhanced global mean hydrological cycle;
increased precipitation and soil moisture in high latitudes in winter. All these changes are associated with identifiable physical mechanisms.

** In addition, most simulations show a reduction of the strength of the circulation in the North Atlantic ocean and a widespread reduction in diurnal range of temperature. These features can also be explained in terms of identifiable physical mechanisms.

** Extreme weather events are important aspects of climate. Current climate models lack the accuracy at smaller scales, and except may be for precipitation, there is little agreement between models on change in extreme events. However, by reasoning from physical principles, or by using downscaling techniques and looking at patterns such as mid-latitude storm tracks from which extremes can be inferred, or by making time-slice experiments with high resolution models some tentative assessments concerning extreme events may be made:

** Small changes in the mean climate or climate variability can produce relative large changes in the frequency of extreme events;
small changes in the variability have stronger effects than similar changes in the mean.

** A general warming tends to lead to an increase in extremely high temperatures and a decrease in winter days with extremely low temperatures.

** Several models suggests an increase in the precipitation intensity, suggesting a possibility for more extreme rainfall events. In some cases models also predict more frequent or severe drought periods in a warmer climate.

** Extreme wind events

Mid-latitude storms
There is little agreement between models on the changes in storminess that might occur in a warmer world. Conclusions regarding extreme storm events are obviously even more uncertain.

Tropical cyclones
It is not possible to say wether the frequency, the area of occurrence, time of occurrence, mean intensity or maximum intensity of tropical cyclones will change.

Many factors currently limit our ability to project and detect future climate change. In particular, to reduce uncertainties further work is needed on the following priority topics: estimation of future emmissions of greenhouse gases and their behaviour, representation of climate processes in models, especially feddbacks from clouds and oceans, systematic collections of long-term instrumental and proxy observation of climate variables.

Future unexpected, large and rapid climate system changes as have occurred in the past, are by their nature difficult to predict. This implies that future climate changes may also involve *"surprises"*. In particular these arise from the the non-linear nature of the climate systems. When rapidly forced, non-linear systems are especially subject to unexpected behaviour. Examples of such non-linear behaviour include rapid circulation changes in the North Atlantic and feedbacks associated with terrestrial ecosystem changes.

As I said earlier, the climate system is complicated and there are still much we do not know about it. That means again that we do not have a certain knowledge of how the climate will change in the future. But it is clear that humans now affects the climate on a global scale. Climatologists will continue to better their knowledge both on past and future climate in the years to come. The challenge now is to act in advance where it is possible to act, because when we know for sure it may be too late.