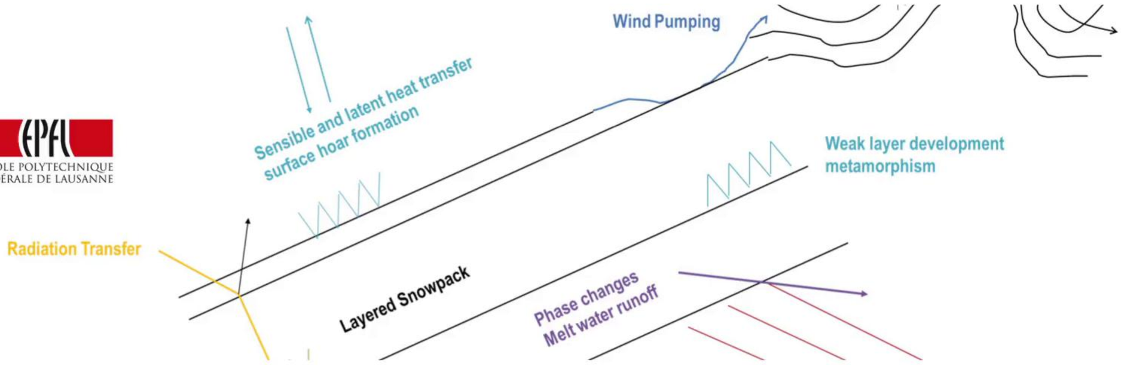

Snow and Avalanche Forecasting and Climate Modeling

A Resilient Future: Science and Technology for Disaster Risk Reduction

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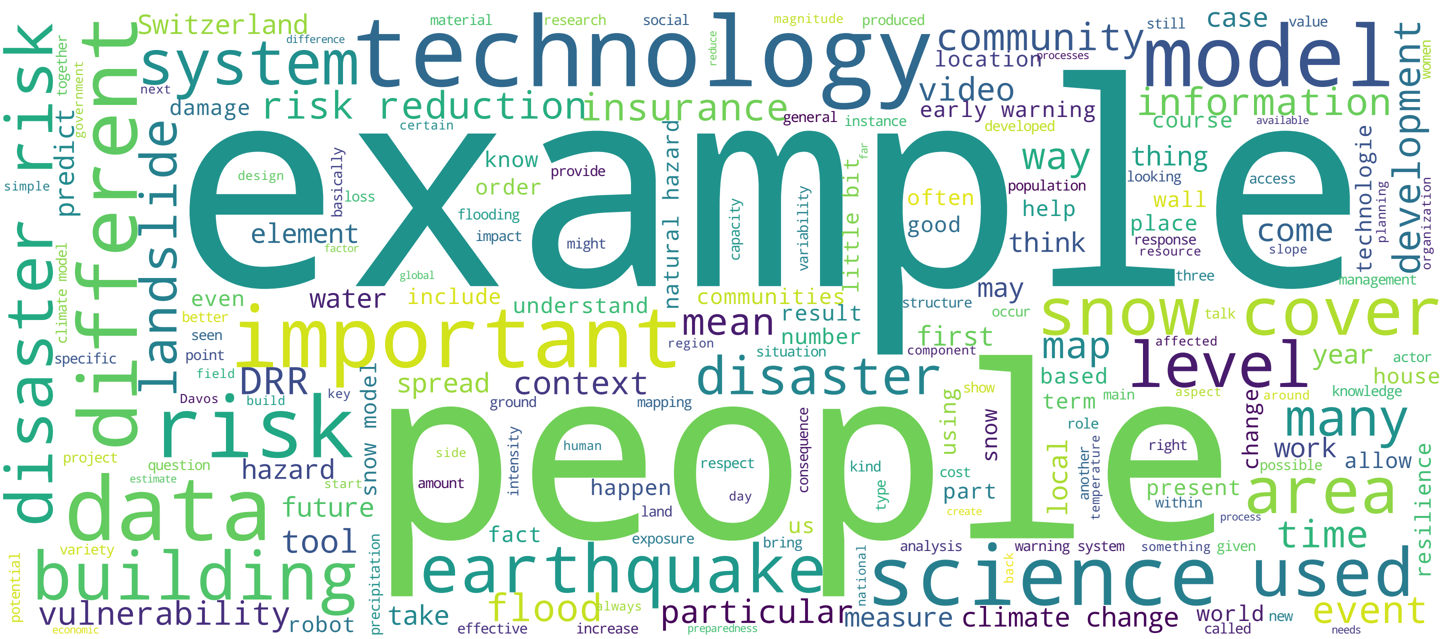

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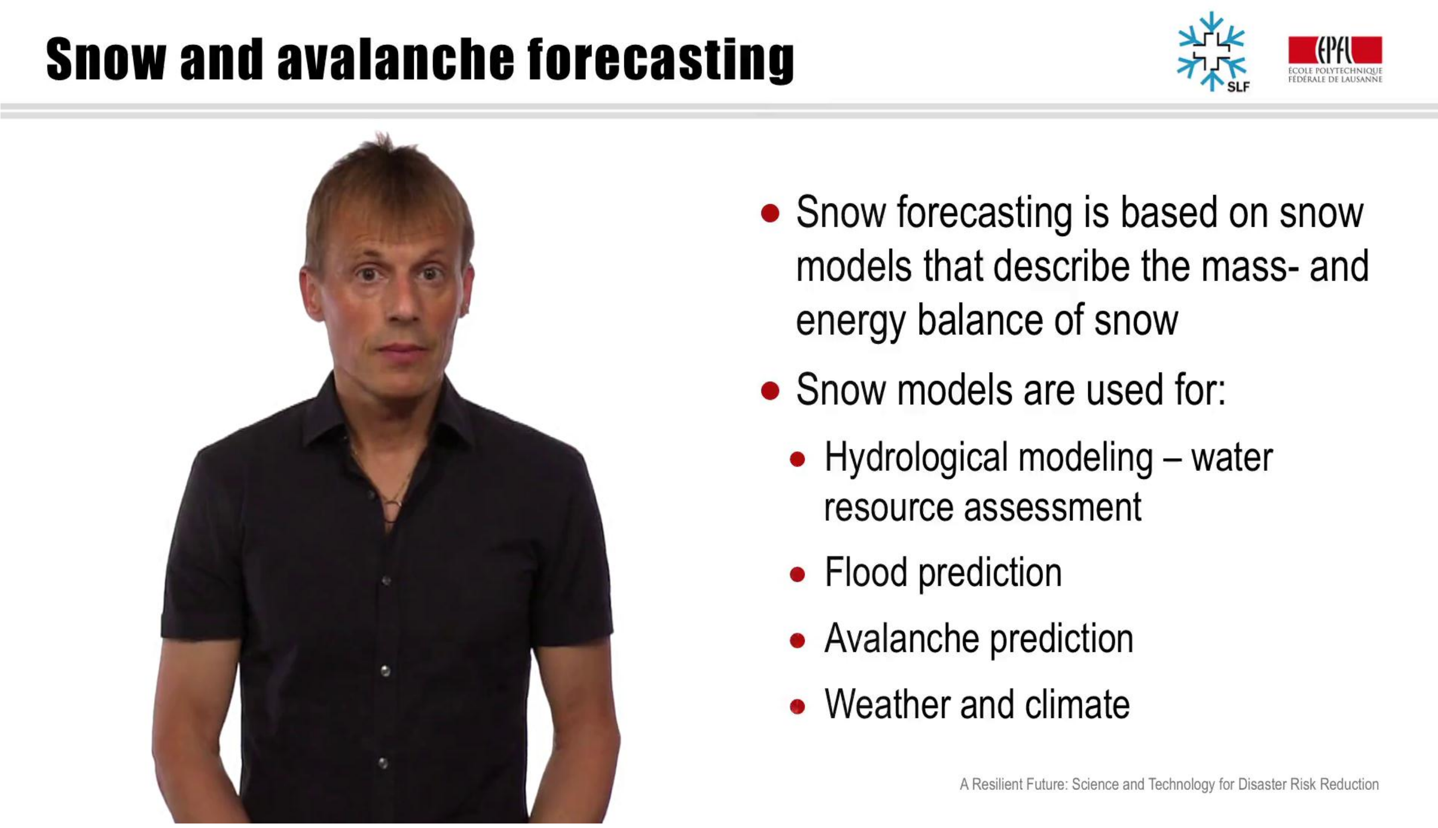


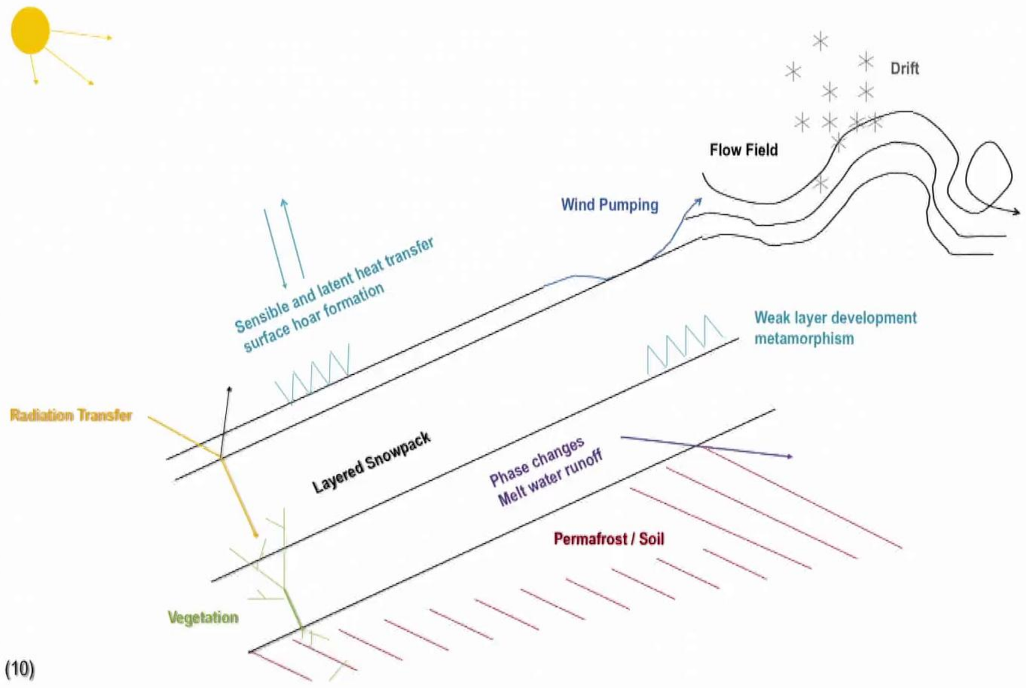
In the context of hydrological modeling, in particular in mid latitudes, the snow model is very important. So let's take a look at snow models in particular. Snow models are useful for hydrological modeling, but also for assessing the avalanche danger, and they are an important part of climate models as well.

Notes

Summary

0m 05s

SNOWPACK – The SLF snow model



(10)

- Seasonal snow cover simulations worldwide
- Includes snow – atmosphere – vegetation

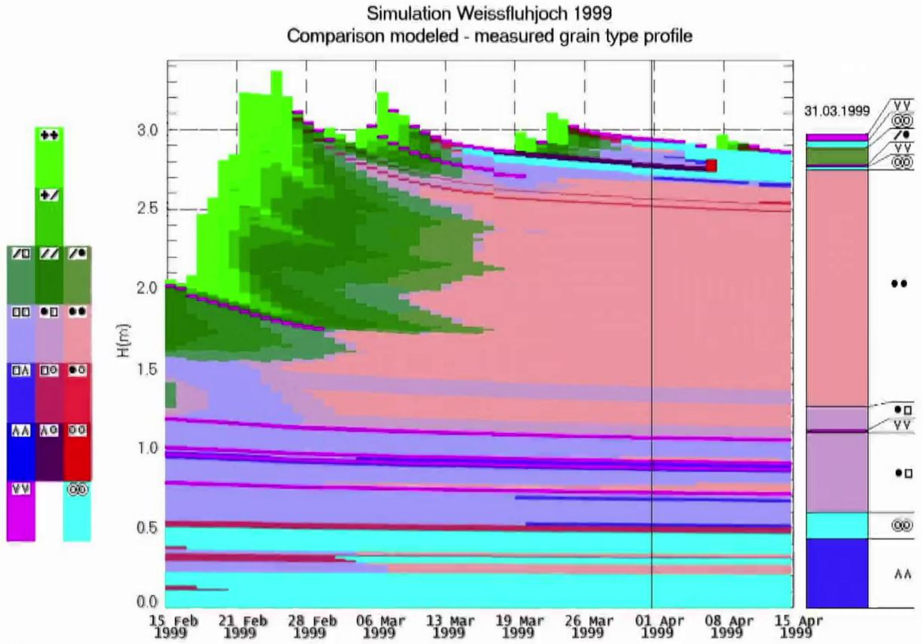
The numerical SNOWPACK model that has been developed at SLF in Davos, is a detailed snow model that is used worldwide for a variety of purposes. It is used for snow cover simulations, for avalanche warning, but it's also used in the context, again, of hydrological predictions. It contains representation of the following processes: The core of the model treats a layered snowpack. The layered snowpack comes into existence by individual precipitation events. If there is vegetation present, then vegetation that may be below the snow, but there may also be trees, also this is treated by the model. The layered snowpack resides on a module that treats permafrost or in general soil. Water that is produced within the snow by melt processes can run into the soil, but also the snow itself may undergo metamorphosis, and change its texture and its structure. The model treats incoming radiation, and allows to simulate in how far the shortwave radiation penetrates into the snow. The formulation of sensible and latent heat transfer at the snow surface allows for the generation of surface hoar, which may then become a weak layer once buried by new snow layers. The model has also modules for treating more spatial effects, such as drifting and blowing snow, or the redistribution of snow once on the ground.

Notes

Summary

0m 26s

SNOWPACK – The SLF snow model



- Time development of layers and grain types for the avalanche winter 1999
- For comparison, an observed profile is shown for March 31 (right column)
- The detailed representation is needed for avalanche forecasting, hydrological response or even climatological assessment

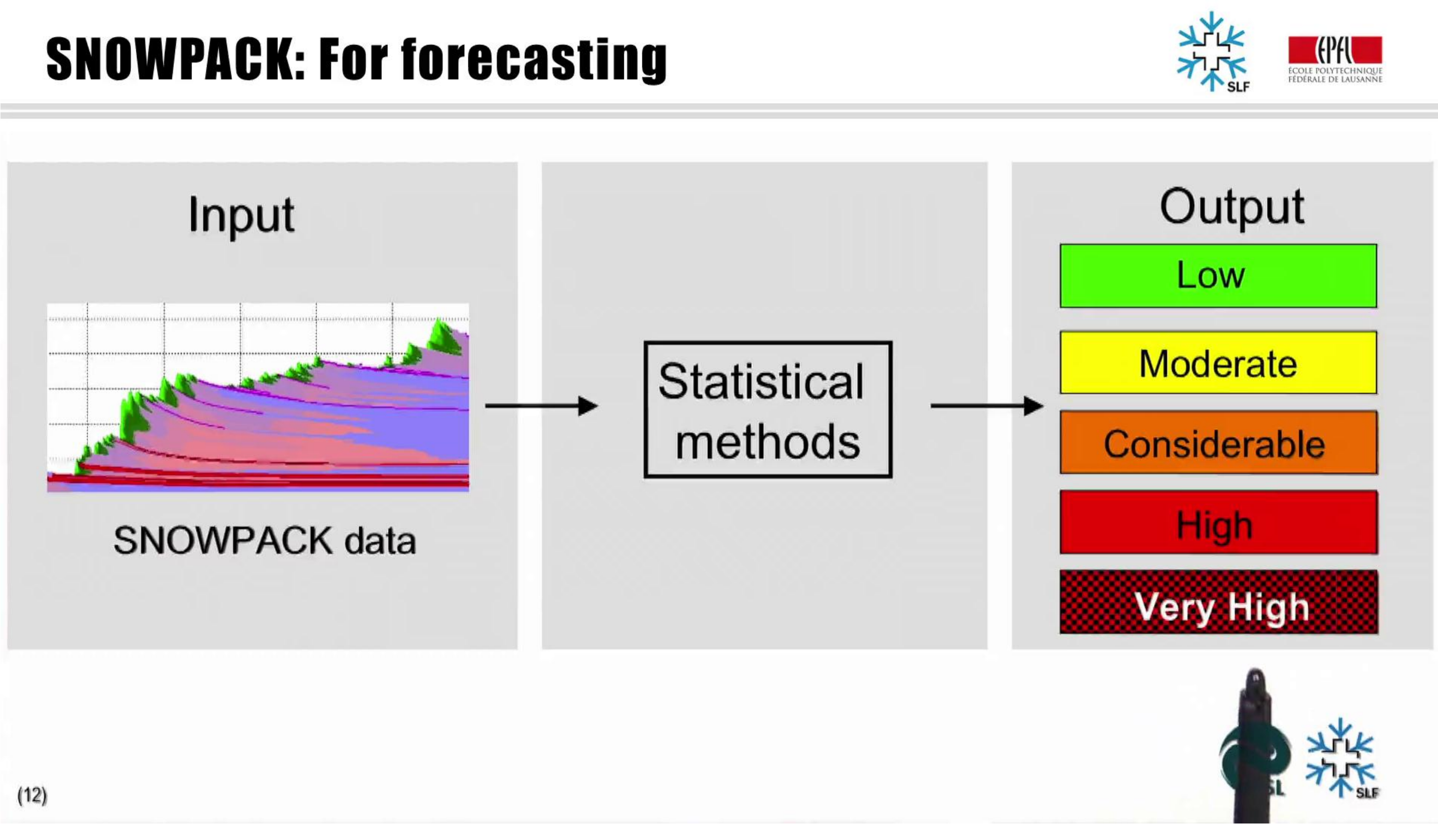
(11)

The SNOWPACK model gives you a very detailed assessment of individual layers in the snow cover. What you can see on this graph is the time development between the 15th of February, 1999, to the 15th of April, 1999, of the snow cover at the Alpine site Weissfluhjoch, in Davos. You can see major precipitation events. You can see that as the snow cover increases here, and then later on this snow develops into different types of snow. We don't have the time to go through the individual grain types here, but it's important to realize that there's many different grain types represented in the snow profiles. There is crusty snow here. There is surface hoar snow. There are facets and depth hoar crystals in the simulations. And all of these, they also occur in comparison to an observed profile, which you can see in the column on the right-hand side. The profile here corresponds to the simulated profile at this location, where you can see the black vertical line. So by comparison, you can judge how well the model actually represents the observations.

Notes

Summary

2m 05s



How is SNOWPACK used for avalanche forecasting? Well the link between a particular structure in snow to an avalanche danger is not a trivial one. So what is often attempted is to use a statistical link, and to use the simulated profile as an input, and then a variety of statistical methods to come up with a danger estimation. In Switzerland, and in all of the European mountains, the five-degree danger scale is used.

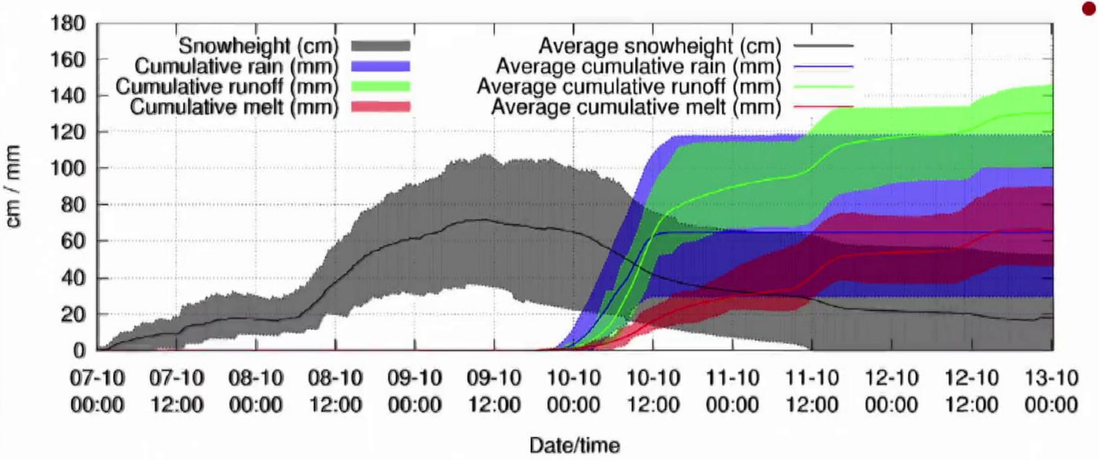
Notes

Summary

3m 13s

SNOWPACK: Runoff forecasting for flood prevention

Flood event in October 2011



- Total runoff exceeds precipitation
- Melt response may be such that runoff concentration can occur

(13)

But also, for flood forecasting, the snow model details are of use. What you see here is a devastating flood that happened in October, 2011, in Switzerland, where warm rain was falling on a snow cover that had just been dumped the days before. What the graph shows you is the total water produced, and the snow height, in grey here. The black curve and the grey shadow here gives you the variability of snow depths within the area investigated. What you can also see is, then, the water that would have been produced by rain only, in blue. This is the blue part, here. And then the cumulative runoff that has been produced by the combined effect of snow melt and of this rain input. First of all, it is important to realize that if rain falls into snow cover, the snow cover will first retain some of the water. But as time goes on, and as melt becomes more vigorous, the total water released by the snow cover may exceed the particular rain amounts. And this has happened in this event. That is seen, that this green band is actually exceeding the amount of rain that fell within that period. Cumulative melt part is shown in red, here. So all together, the full-time dynamics of the combined rain input and snow melt determines how severe a flooding event may become, in the case of this particular situation, where you have rain on a pre-existing snow cover.

Notes

Summary

3m 44s

A note on climate modeling

- Despite the long-term unpredictability of weather, climate change can be forecasted
- The world will be getting warmer
- Weather will be more extreme
- Sea level will rise
- Risks will change and in many cases, increase

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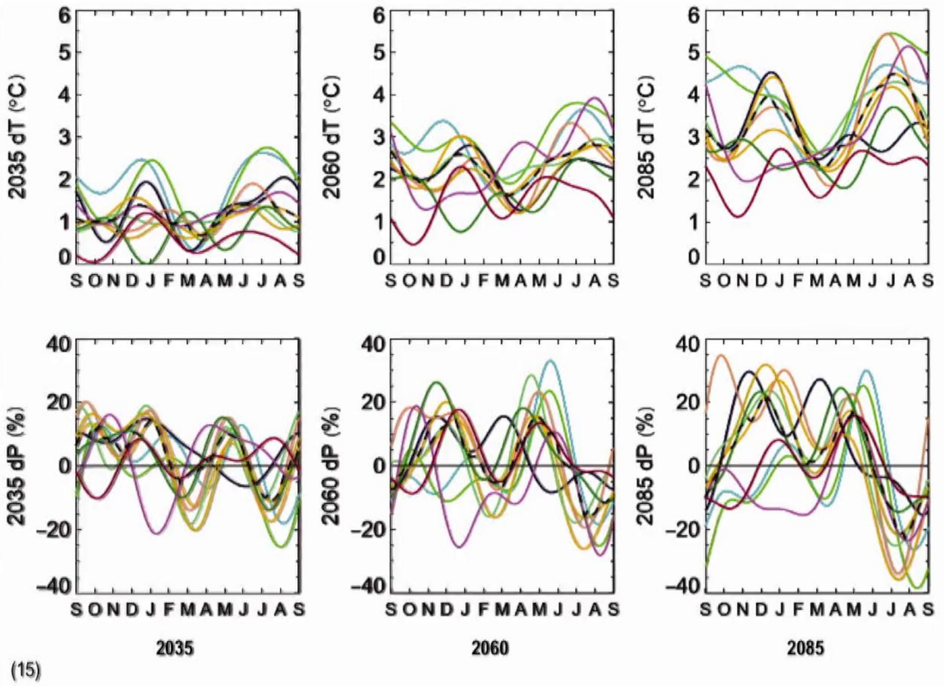
In discussions about climate change, you often hear the argument, "How can you predict the climate change over centuries, when you can't do a reliable weather forecast that extends over a week?" This is an argument that can be better understood if you look at the particular situation of a boiling pot of water. While you cannot predict where the next bubble will come up from this boiling pot, you can well predict that if you add heat to water, it will start boiling at some point, and this is exactly what happens with the climate system. We cannot predict the weather over centuries, but we can predict in general that the world will be getting warmer, that the weather will be more extreme, that the sea level will rise, and that, as a result of all of this, risks will change, and in many cases increase.

Notes

Summary

5m 30s

Climate change scenarios from IPCC / CH2011



- Large spread of predictions from different climate models
- Trend in temperature is clear for Switzerland
- Precipitation changes are less certain

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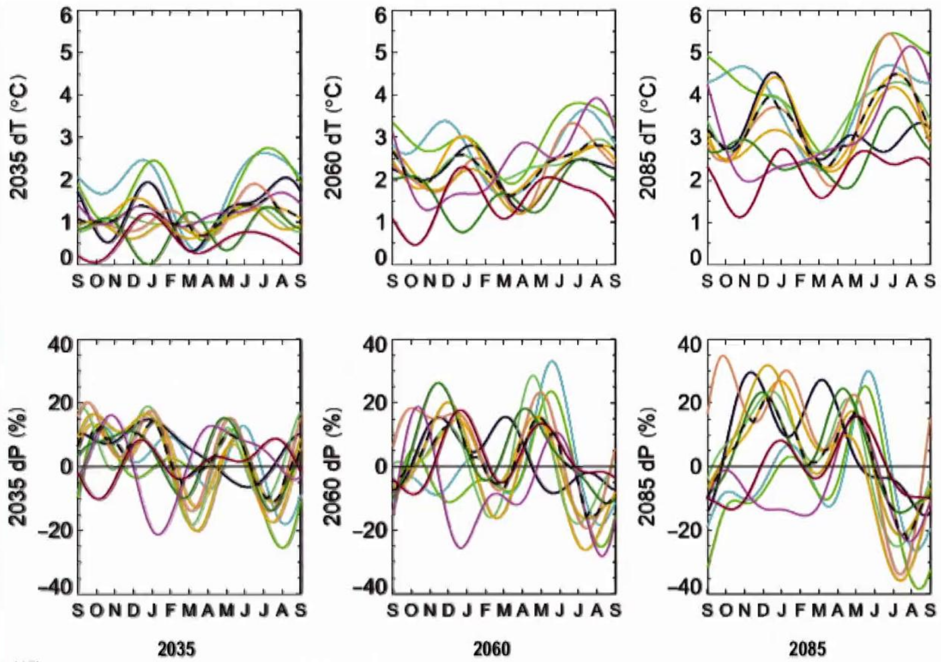
Let's return to the question how numerical models are used in the context of climate change prediction. What you can see here is a panel of graphs that has been produced in particular for Switzerland, and shows you the changes in temperature, on the upper row, and precipitation, on the lower row, for Switzerland, as forecasted by a variety of climate models. This is now different from the ensemble runs in weather forecasting that we've looked at, but you could sort of also see that as an ensemble simulation. Here, the spread in the individual curves comes more from the individual models, from the differences in the models, than from disturbed initial conditions. So it also allows you to estimate a little bit the uncertainty of these climate change scenario simulations. On the upper panel, you can see that despite the fact that the spread between the individual models is quite significant, in all these forecasting periods-- the first column is for 2035, the second column for 2060, and the third column for 2085-- despite the fact that the *Delta T*, the forecasted difference in temperatures is quite significant, and the spread between the model simulations is much, much larger than the mean effect.

Notes

Summary

6m 23s

Climate change scenarios from IPCC / CH2011



- Large spread of predictions from different climate models
- Trend in temperature is clear for Switzerland
- Precipitation changes are less certain

(15)

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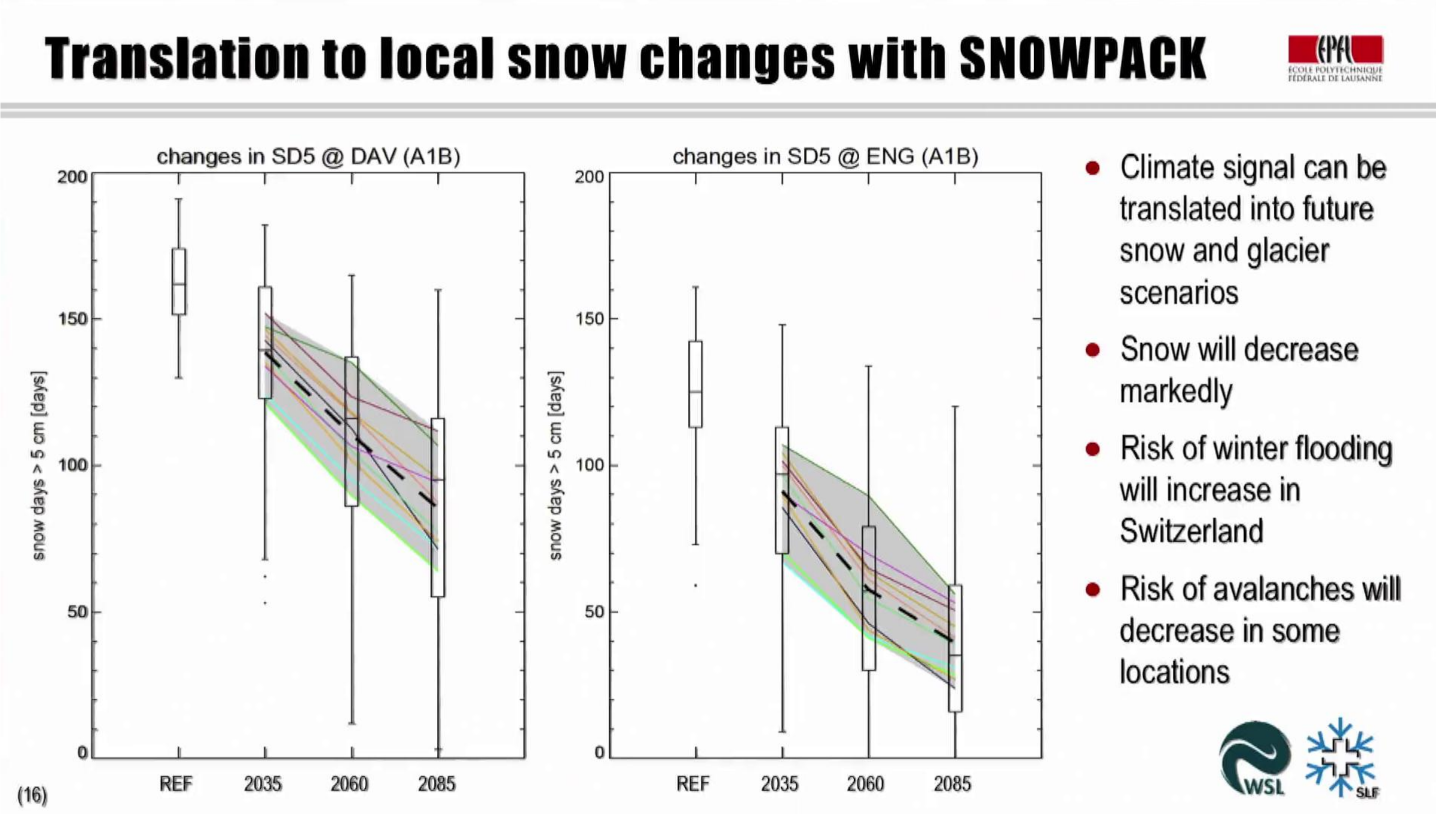
So the world gets warmer. In that result, all of these models agree. With precipitation, the situation is a little bit different, so the percentage change that is displayed in the lower row here is not quite as certain as it is for temperature. In fact, what you could say is, from looking at the spread in the models, and with respect to zero, that precipitation changes are highly uncertain, and it's not clear whether the general trend that is observed-- with a little bit more precipitation in the winter, and a little bit less precipitation in summer-- will actually become true. So it remains to be seen in how far these predictions will actually become true.

Notes

Summary

7m 51s

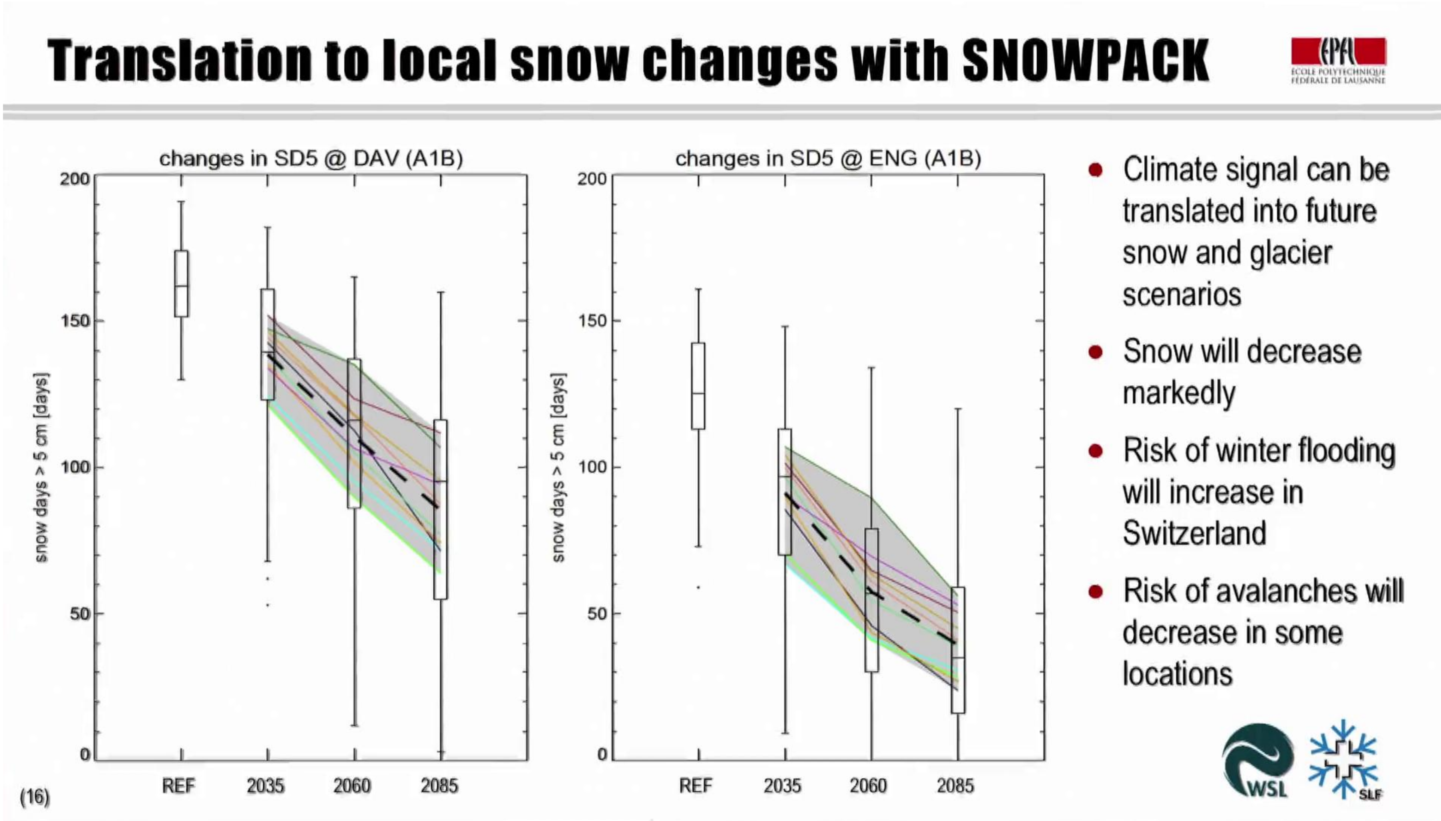


Nonetheless, we can use those climate model predictions to see what it actually means with respect to processes at the earth's surface. The climate models, because of their simplifications, are quite reliable with respect to saying what the mean temperature in Switzerland will do, but they will not be able to tell you in detail how the snow cover, for example, in an alpine resort, will evolve, or will look like in the future. Therefore, we again combine now the climate model result with our snow models to predict what the snow cover will look like in the future. On this slide what you can see is for two selected stations in the Swiss Alps, one is Davos and one is Engelberg, how we predict that the snow will diminish. In particular what we look at here is the changes in days that have a snow cover of 5 cm or more. Why is this an important parameter? This is an important parameter because a 5 cm snow cover will make the landscape look white. It is also important for snow removal, for example, and starts slowly to become important for the tourism industry. So this is why the snow days with a snow cover of more than 5 cm is a suitable index of how the snow climate will change in the future.

Notes

Summary

8m 43s

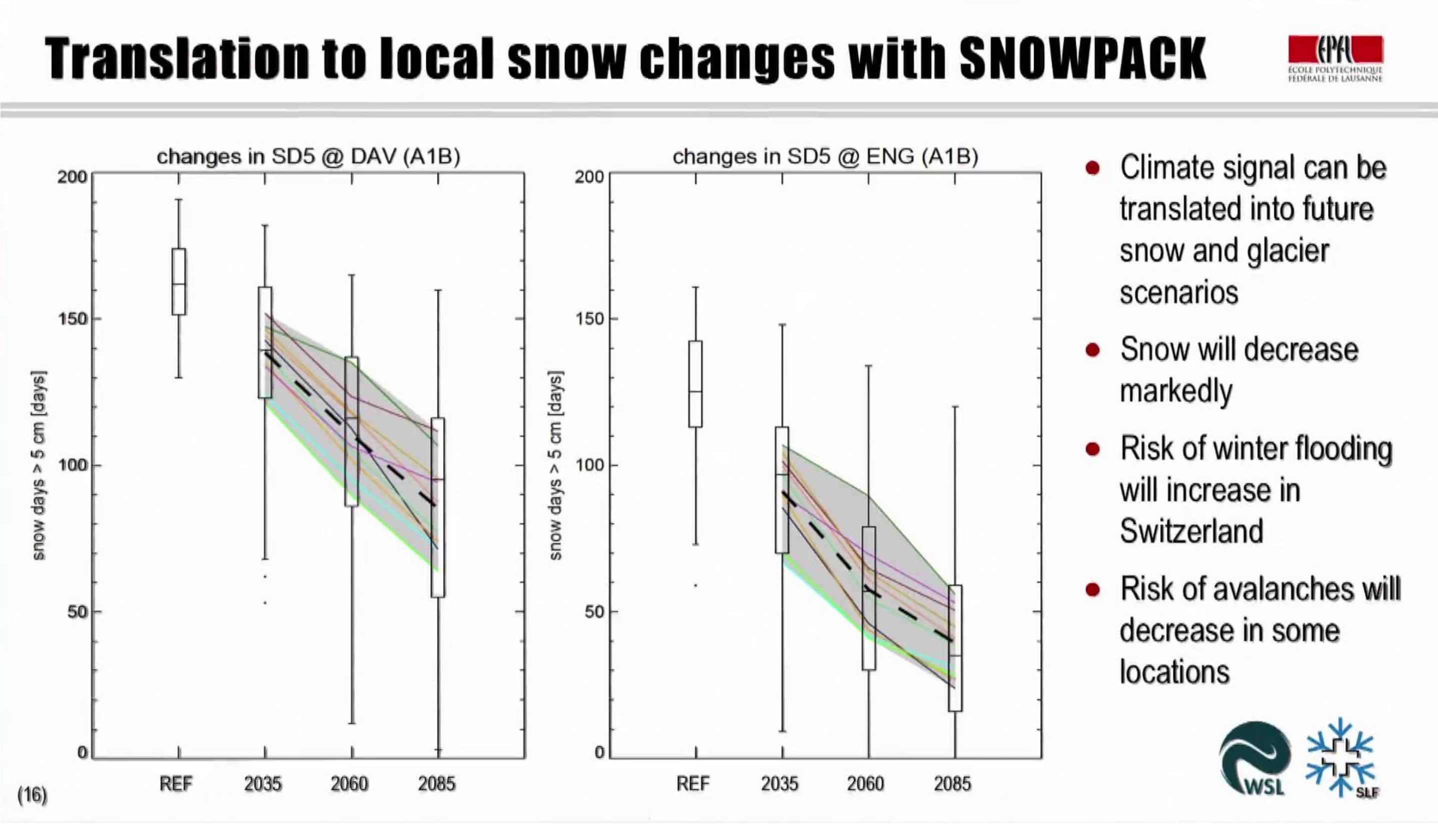


On these two panels what you see is that, in general, the number of these snow days decreases significantly at both locations. What you also see is the spread, or the variability that is forecasted, and in this particular picture, a nice way to visualize the spread is that the spread between the model runs, that we saw also in the previous slide, is given by this grey area here in the forecasts-- again, the forecasts are done for the times of 2035, 2060 and 2085-- and the variability that comes from the model, again, is contained in this grey bar, and is compared to the variability that is inherent in the time series at the locations. And the inherent time variability from year to year, for example, is represented for the present, in this first box plot-- it is the correct technical term for this way to visualize the result-- and it gets quite larger for the future, but is, in principle, in the same order of magnitude than the uncertainty that comes from the models. What you can read here is that snow will decrease markedly in the future, and as a result of that, you can easily imagine when you have less snowfall in the winter, but the same amount of total precipitation, then much more of the precipitation will fall as rain, which increases the risk of winter flooding.

Notes

Summary

10m 12s



It will also mean that, for example, the risk of avalanches will decrease in some of the areas we looked at, and the cost for snow removal will decrease.

Notes

Summary

12m 03s

Main point

Future climate predictions and the assessment of future changes in risks are completely dependent on numerical models

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I hope this video has convinced you that numerical models are indispensable tools of risk management for natural hazards. On the basis of weather models, natural hazards such as floods, but also landslides and avalanches, can be predicted. With respect to climate change scenarios, and the changing risks in many of these natural hazards, we do completely rely on numerical weather forecasts, numerical climate forecasts, because we don't have any other tool to help us in assessing these changes and risks.

Notes

Summary

12m 16s

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Notes

Summary

12m 52s

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(12) Schirmer, M., Lehning, M., and J. Schweizer (2009) Statistical forecasting of avalanche danger using simulated snow cover data, Journal of Glaciology, 55/193, 761-768.

(13) Wever, N., Jonas, T., Fierz, C., and M. Lehning (2014) Model simulations of the modulating effect of the snow cover in a rain-on-snow event. Hydrology and Earth System Sciences, 18, 4657-4669. This article is published in an open-access journal (license CC BY 3.0).

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Notes

Summary

12m 55s