Making decisions with probabilistic forecasts

Environmental Modelling in Industry Study Group
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Challenge summary

We are making more and more use of probabilistic forecasts in flood forecasting. A side effect of this is that it complicates decision making for staff involved in incident response. There is always a cost linked to making the wrong decision. We are looking for mathematical tools that can help practitioners make the right decision when given a probabilistic forecast.

Background

Flood forecasting is an uncertain process. So, in recent years, forecasters have moved towards probabilistic forecasting. Now, instead of saying that it will rain tomorrow, we might say that there is a 70% chance of rain tomorrow.

This allows forecaster to be more honest about the uncertainty in their predictions and to give more advanced warning times of low probability but high consequence events, like severe floods.

Problem

Probabilistic forecasts have been an important and useful step forward. However, if you are an incident manager, you can't take probabilistic actions. If you receive a warning that says there is a 30% chance it will flood, should you act or not? Every action has a cost. But deciding not to act could be even more costly.

Types of decisions

Simple binary decision

An example of this is whether or not to evacuate. Evacuation itself poses a risk to life, but it is preferable to widespread severe flooding of people. An example of this decision is represented in the table below. For simplicity, the numbers in the boxes represent impacts on a 1 to 10 scale. However, it could be any other measure of impact such as damage measured in £ or number of lives lost.

	Evacuate	Don't Evacuate
Will flood 30%	6	10
Won't flood 70%	4	1

Multiple forecast outcomes

Often there is more than two possible forecast outcomes. For example, the Met Office's MOGREPS system is an ensemble forecast based on 24 different members. In this situation there would be many more rows to the table presented above. The example below shows what the table could look like with 3 rows.

	Evacuate	Don't Evacuate
Big flood 30%	6	10
Small flood 50%	4	3
No flood 20%	4	1

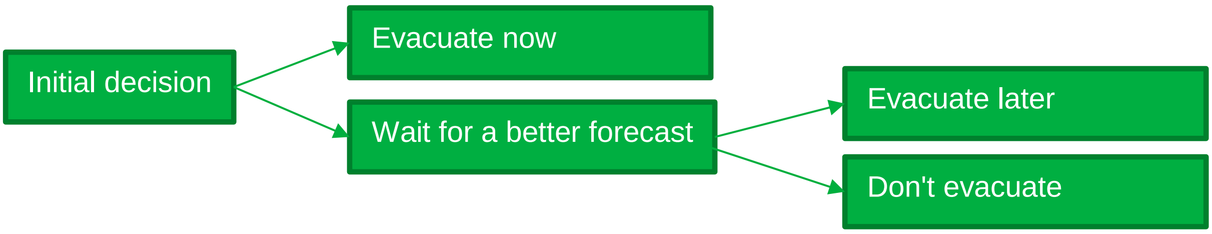
Multiple decision options

Decision makers rarely have just one way to respond to a flood incident. Often there is a portfolio of measures they can draw on. Their challenge is to pick the right measure or mix of measures that is the best fit for the current incident. The effect this would have on the table above is to add more columns. So for example, the table might look like the one below.

	Evacuate	Don't Evacuate	Temporary defences
Big flood 30%	6	10	10
Small flood 50%	4	3	2
No flood 20%	4	1	2

Branching decisions

Sometimes decision makers prefer to delay a decision until they have better information. For example, waiting for the forecast confidence to improve before making a decision. Alternatively, they might decide to take a small action early on to give them more options later. For example, they might increase stock of sand bags at a local depot in preparation for a possible flood. This type of decision is different from the multiple options described above because the probability of the flood occurring changes as you progress along the decision tree in an unknown way. An example of a branching decision is shown below.



Environment Agency

What do we need from Maths Foresees study group?

We are looking for tools that will help staff involved in flood incidents make confident decisions based on probabilistic forecasts. The tools should be able to help with all 4 of the types of decisions discussed above.

There are two specific cases we would like you to consider:

Routine decisions

These decisions include things like whether or not to issue a flood warning and whether or not to close a flood barrier. These decisions are usually made by an individual who is trained and experienced in making that decision. The decision maker already has a set of tools designed to advise them when they make the decision.

So any additional tools for these types of decisions should be considered in that context. It means that tools for this work can be complex to set up - if necessary. The key issue is that they must be quick and easy to run during an incident.

Reactive decisions

Many of the decisions that have to be made during an incident are unique to that incident. For example, should we destroy a bridge that is restricting flow on a river and putting homes at risk?

In these cases, decision makers don't have the opportunity to pick up a new tool and learn how to use it. They definitely don't have time to calibrate the tool for each new situation that occurs.

So we need a generalised set of advice that can be given to decision makers for use during an incident. These could include

- Rules of thumb. For example, if the probability is less than 10%, assume it is 0%.
- A flow chart that describes a set of simple steps to work through.
- A look up table that describes for the preferred decision based on a range of probabilities (10%, 20%, 30%, etc) and the impacts of making a decision.