A journey from climate information to decision-making: a tale of two worlds?

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A tale of two worlds?

Introduction
A tale of two worlds?

Introduction

Source: https://www.gfcs-climate.org/about-gfcs/
"To enable better management of the risks of climate variability and change and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale."

Source: https://www.gfcs-climate.org/about-
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Introduction

Five Pillars

(I) Monitoring and Observations

(II) Research Modelling and Prediction

(III) Climate Service Information System

(IV) User interface Platform

(V) Capacity Development
Earth System Services

A tale of two worlds?

Introduction

Earth System Services

Bringing air quality and climate research to society

We develop our activities based on the five pillars of WMO’s Global Framework for Climate Services (GFCF)

PILLAR I  MONITORING AND OBSERVATIONS
- State-of-the-art research in the development of the atmospheric-chemical transport models and Earth System models
- Capacity to manage earth system big data obtained from national, international and global databases

PILLAR II  RESEARCH, MODELLING AND PREDICTIONS

PILLAR III  CLIMATE SERVICE INFORMATION SYSTEM
- Generation of climate information and products tailored to users from different sectors (energy, agriculture, water management, insurance, etc.)

PILLAR IV  USER INTERFACE PLATFORM
- Multi-sectoral platform development together with users through a co-creation process involving continuous dialog

PILLAR V  CAPACITY DEVELOPMENT
- Information and knowledge transfer to enhance a particular user understanding and capacity to apply climate services

TARGET USERS
A tale of two worlds?
First round
A tale of two worlds?

First round

(1) Grape-vine grower:
“Open to new strategies to optimise profits & expenses. I have 5ha for testing (out of 20ha)”

Risk aversion: Moderate
Farmer

(2) Water Resource Manager:
“We cannot afford public water restrictions”

Risk aversion: High
Public Institution

(3) Weather Derivatives trader:
“We have to take advantage of the predictions to maximise profit. We can hedge with other products.”

Risk aversion: Low
Business
We are at the end of February. Our region is a semi-arid extra-tropical area with hot and dry summers. The rainy season is spring. Each one of our users has to take a context-specific decision based on the March-April-May rain by the 1st of June. This decision, if taken in advance, could be advantageous (but also detrimental, depending on the final spring-rain outcome).
In this **first round** we only need that you discuss three **items**:

- What kind of **predictions** would you **choose** to look at? **Deterministic** or **probabilistic**? Why?
- What do you understand by ‘**risk aversion**’ in decision-making?
- What is a ‘**risk**’?
A tale of two worlds?
First round
A tale of two worlds?

First round

What kind of forecast would you look at? **Deterministic** or **probabilistic**?
A tale of two worlds?
First round

Seasonal forecasts

Past
Today
Century

Forecasts

DIAGNOSTIC
FORECAST
PREDICTION
PROJECTION

March
April
May
June
A tale of two worlds?
First round

Probabilistic

Past
Today
Hours
Days
Weeks
Months
 Seasons
Years
Decades
Century

DIAGNOSTIC
FORECAST
PREDICTION
PROJECTION

March
April
May
June
A tale of two worlds?

First round

- Initial value problem
- Seasonal predictions
- Decadal predictions
- Forced boundary condition problem

- Day
- Week
- Month
- Season
- Year
- Decade
- Century

Weather predictions
Seasonal to interannual predictions
Long term climate change projections
A tale of two worlds?

First round

**The Butterfly Effect.**
A tale of two worlds?
First round

### Example for the farmer

<table>
<thead>
<tr>
<th>Weather forecast</th>
<th>Climate predictions</th>
<th>Climate projections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-15 days</td>
<td>Sub-seasonal</td>
<td>Siting, choice of scion variety and rootstock.</td>
</tr>
<tr>
<td>10-60 days</td>
<td>Seasonal</td>
<td>Assessment of water needs</td>
</tr>
<tr>
<td>1-15 months</td>
<td>Decadal</td>
<td></td>
</tr>
<tr>
<td>2-30 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-100 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Siting, choice of scion variety and rootstock.**
- **Assessment of water needs**
- **Grow cycle management**
- **Pathogen pressure, abiotic stresses**
- **Crop forcing**
- **Productivity, quality**
- **Wine style**
- **Harvest date and duration**

*Adapted from: Antonio Graça, SOGRAPE VINHOS SA, 2014*
<table>
<thead>
<tr>
<th>Time</th>
<th>Weather forecast</th>
<th>Climate predictions</th>
<th>Climate projections</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-15 days</td>
<td>Sub-seasonal 10-60 days</td>
<td>Seasonal 1-15 months</td>
</tr>
</tbody>
</table>

**DETERMINISTIC**

- **Pathogen pressure, abiotic stresses**
- **Productivity, quality**
- **Harvest date and duration**
- **Grow cycle management**
- **Siting, choice of scion variety and rootstock**
- **Assessment of water needs**
- **Crop forcing**
- **Wine style**

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### PROBABILISTIC

#### First round

<table>
<thead>
<tr>
<th>Time</th>
<th>Weather forecast: 1-15 days</th>
<th>Sub-seasonal: 10-60 days</th>
<th>Seasonal: 1-15 months</th>
<th>Decadal: 2-30 years</th>
<th>Century: 20-100 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Siting, choice of scion variety and rootstock</td>
<td></td>
<td></td>
<td>Manage water needs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pathogen pressure, abiotic stresses</td>
<td></td>
<td></td>
<td>Crop forcing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Productivity, quality</td>
<td></td>
<td></td>
<td>Harvest date and duration</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from: Antonio Graça, SOGRAPE VINHOS SA, 2014
What do we understand by ‘risk aversion’ in decision-making?
When facing a **decision**, risk aversion is a preference for the option that maximises **certainty** and minimises **negative** outcomes (even if there are other options with higher potential gains).
A tale of two worlds?

First round

What is a ‘risk’ in a decision-making context?
Although the exact language depends on the framework, in general the ‘risk’ equation for any event can be defined as:

\[
\text{Risk} = \text{Likelihood} \times \text{Consequences}
\]
The ‘likelihood’ of any event can be determined through predictions, whereas the ‘consequences’ are an information that can vary on a decision-case basis.

Risk = Likelihood x Consequences
A tale of two worlds?
Second round
A tale of two worlds?

Second round

(1) Grape-vine grower:
“Open to new strategies to optimise profits & expenses. I have 5ha for testing (out of 20ha)”

Risk aversion: Moderate
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At the **beginning** of each **month**, each user will be told about the **probability** of having a **dry** spring. Then, the user will decide to either: ‘**wait and see**’ or ‘**insure**’. Consequently, in this second round we will give you three more **information** items:

- The **probability** to have a **dry** spring (it is a **negative** outcome for each of the users).
- The **cost** of **insuring** against a **dry** spring (in views of the **June deadline**).
- The **losses** that would **incur** if there is **no insurance** and a dry spring happens.
In this **second round** we will repeat the process for two or three years, and see what is the final remaining budget for each of the groups. After that, we will **discuss**:

- What **drove** your **decision-making**? Which were the most important **factors** that you **considered**?
A tale of two worlds?
Second round

<table>
<thead>
<tr>
<th>100000 Tokens (initial budget for insuring/support losses)</th>
<th>1st March</th>
<th>1st April</th>
<th>1st May</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Insurance Cost</td>
<td>Losses</td>
<td>Insurance Cost</td>
</tr>
<tr>
<td>Water Resource Manager</td>
<td>16000</td>
<td>25000</td>
<td>18500</td>
</tr>
<tr>
<td>Grape-vine grower</td>
<td>7500</td>
<td>15000</td>
<td>9000</td>
</tr>
<tr>
<td>Weather Derivatives Trader</td>
<td>2000</td>
<td>5000</td>
<td>3000</td>
</tr>
</tbody>
</table>
A tale of two worlds?
Second round
A tale of two worlds?
Second round

Did you find any **systematic** approach to try to **maximise** the **outcomes**?
We have the cost/loss model approach (i.e. Richardson D.S., 2000):

\[ p > \frac{C}{L} \]
Consider the situation where we do not have any forecast information. We have two systematic options. The first one is to always take de ‘protective’ action. The mean expense per time step in that case would be:

\[ E_{\text{always}} = C \]

Conversely, the second option would be to never take any protective action. In that cases, we would incur in losses each time the event happens. Consequently:

\[ E_{\text{never}} = \frac{n}{N}L = p_{\text{clim}}L \]
The **optimal** systematic strategy in that **situation** would be to take the **action** if:

\[ E_{\text{always}} < E_{\text{never}} \]

And, **consequently**:

\[ C < p_{\text{clim}} \rightarrow \frac{C}{L} < p_{\text{clim}} \]
## A tale of two worlds?

### Second round

<table>
<thead>
<tr>
<th>50000 Tokens (initial budget for insuring / support losses)</th>
<th>1st March</th>
<th>1st April</th>
<th>1st May</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/L</td>
<td>C/L</td>
<td>C/L</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Role</th>
<th>1st March</th>
<th>1st April</th>
<th>1st May</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Resource Manager</td>
<td>64 %</td>
<td>72 %</td>
<td>80 %</td>
</tr>
<tr>
<td>Grape-vine grower</td>
<td>50 %</td>
<td>60 %</td>
<td>70 %</td>
</tr>
<tr>
<td>Weather Derivatives Trader</td>
<td>40 %</td>
<td>60 %</td>
<td>90 %</td>
</tr>
</tbody>
</table>
A tale of two worlds?
Third round
A tale of two worlds?

Third round

(1) Grape-vine grower:
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In this **third** and final **round**, we will introduce **tercile** forecasts (more complete information), so we will have **three** different scenarios for spring rain: above normal, normal and below normal. This time our focus will be on making the decision at the **beginning** of **March**.
This time we will focus only in the ‘farmer’ user. He will have to choose from three different decisions which, at the same time, will have 9 different possible outcome scenarios (depending on the coincidence or not of the prediction and observation). And he wants to ‘maximise’ its outcome.

The question that we want to answer here will be: according to the farmer’s context, at what probability threshold does they have to make a decision?
### Grape-vine grower

<table>
<thead>
<tr>
<th>Decision Scenario 1</th>
<th>Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3</td>
<td>4880</td>
</tr>
<tr>
<td>A2</td>
<td>-1200</td>
</tr>
<tr>
<td>A1</td>
<td>-1200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decision Scenario 2</th>
<th>Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>N3</td>
<td>0</td>
</tr>
<tr>
<td>N2</td>
<td>0</td>
</tr>
<tr>
<td>N1</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decision Scenario 3</th>
<th>Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>B3</td>
<td>-5800</td>
</tr>
<tr>
<td>B2</td>
<td>-3200</td>
</tr>
<tr>
<td>B1</td>
<td>3200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Observation</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>Above Normal</td>
</tr>
<tr>
<td>N</td>
<td>2</td>
<td>Normal</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>Below Normal</td>
</tr>
</tbody>
</table>
We can analyse, within each decision scenario, which are the relationships between hits, errors and expected outcome. A question to answer: what is the minimum percentage of hits we need to have a positive outcome in that scenario? (Vigo et al. in rev. Climate Services)

<table>
<thead>
<tr>
<th>Counts</th>
<th>Decision Scenario 1</th>
<th>Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>A3</td>
<td>4880</td>
</tr>
<tr>
<td>D2</td>
<td>A2</td>
<td>-1200</td>
</tr>
<tr>
<td>D3</td>
<td>A1</td>
<td>-1200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prediction</th>
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<tr>
<td>B</td>
<td>1</td>
<td>Below Normal</td>
</tr>
</tbody>
</table>

\[ D_1 x + D_2 y + D_3 z \geq 0 \rightarrow D_1 \geq -\frac{D_2 y + D_3 z}{x} \]

\[ D_1 + D_2 + D_3 = 100 \]
If we go for the minimum:  
\[ D_1 x + D_2 y + D_3 z = 0 \rightarrow D_1 = -\frac{D_2 y + D_3 z}{x} \]

In this category \( y = z \rightarrow D_1 = -\frac{y}{x} \cdot (D_2 + D_3) \)

\[ D_1 = -\frac{1200}{4880} \cdot (D_2 + D_3) \approx 0.245 \cdot (100 - D_1) \]

\[ D_2 + D_3 = 100 - D_1 \]

\[ D_1 = \frac{25}{1.25} = 20\% \rightarrow D_1 \geq 20\% \]

This number is lower than what we would obtain with climatology!! (33%)
A tale of two worlds?
Third round

<table>
<thead>
<tr>
<th>Decision Scenario 2</th>
<th>Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>N3</td>
<td>0</td>
</tr>
<tr>
<td>N2</td>
<td>0</td>
</tr>
<tr>
<td>N1</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Observation</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<td>N</td>
<td>2</td>
<td>Normal</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>Below Normal</td>
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\[
D_1 x + D_2 y + D_3 z \geq 0 \rightarrow D_1 \geq -\frac{D_2 y + D_3 z}{x}
\]

\[
D_1 + D_2 + D_3 = 100
\]

This is the BaU scenario \(x = y = z = 0\) → no profits / losses expected in comparison to what is already applied.
Here we have two equations with 3 variables, so we will have a ‘free’ variable. Let’s try to set a range of possible / likely values.
What is the minimum percentage of hits we need to have a positive outcome in scenario 3?

\[ D_1 x + D_2 y + D_3 z \geq 0 \rightarrow D_3 \geq -\frac{D_1 x + D_2 y}{z} \]

If we go for the minimum:

\[ D_1 x + D_2 y + D_3 z = 0 \rightarrow D_3 = -\frac{D_1 x + D_2 y}{z} \rightarrow D_3 = 1.81 D_1 + D_2 \]

**First situation** \( D_1 = 0 \) (Best scenario)

\[ D_3 = D_2 \]

\[ D_3 = \frac{100}{2} = 50 \% \]

**Second situation** \( D_2 = 0 \) (Worst scenario)

\[ D_1 = \frac{D_3}{1.81} \]

\[ D_3 + \frac{D_3}{1.81} = 100 \rightarrow D_3 = \frac{1.81}{2.81} \cdot 100 \approx 64.4 \% \]
In a real working scenario, nor $D_1$ or $D_2$ will be 0. Although both cumulated $D_1$ & $D_2$ are equiprobable, their relative impact is not, $\frac{x}{y} = 1.81$, and so the weighted mean of both impact scenarios gives us a more realistic view to what is the probable minimum $D_3$ needed to attain value for the user:

$$D_3 \geq \frac{1.81 \cdot 64 + 50}{2.81} = 59\%$$
Are we **missing** something? (In the second and third round discussions)
We are assuming that the forecast probability (computed from the ensemble) is equivalent to the observed climatic probability, $p_{\text{clim}}$.

Can we do this?
... only if the forecast is **perfectly reliable**. That is, that the forecast probabilities match the **observed probabilities** (and this includes $P_{\text{clim}}$).

That is to say, if the event happens 60% of the time in our time-series, when the forecast system gives us a probability of 60%, this means that for every 10 times the model gave a 60% probability, 6 times the event actually happened.
A tale of two worlds?
Or maybe three…
A tale of two worlds?
Or maybe three...

The models have uncertainties!
The models have uncertainties!

Risk = Likelihood x Consequences
The models have uncertainties!

The ‘trust’ on the likelihood of an event is highly dependent on the quality of the forecast.
The quality (or skill) of climate predictions varies with:

<table>
<thead>
<tr>
<th>TEMPORAL HORIZON</th>
<th>REGION</th>
<th>MONTH/SEASON</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEATHER PREDICTIONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUB-SEASONAL PREDICTIONS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEASONAL PREDICTIONS</td>
<td></td>
<td>November</td>
</tr>
</tbody>
</table>

Correlation for temperature predictions from August start date

A tale of two worlds?
Or maybe three…
A tale of two worlds?
Or maybe three...

Science
We can give you predictions months ahead.

End-Users: 💫🎉
Wow!
A tale of two worlds?
Or maybe three...

We can give you predictions months ahead.

End-Users: Weather forecast skill!!
Actually, the skill is much lower. But, statistically, it can still be valuable.

End-Users: How much lower?
A tale of two worlds?
Or maybe three...

Science
It means seasonal predictions are not that specific and might be wrong many times. In the long run, however, they could still be worthy, depending on the decision.

End-Users: 😐 😐
A tale of two worlds?
Or maybe three...

End-Users:
They are not for us...
Skill vs. Value

This gap between end-users and scientific providers involves the concepts of quality and value.

- A forecast is of high quality if it successfully predicts the conditions observed according to some objective criterion.

- A forecast has value if it helps the user to obtain some kind of benefit from the decisions it has to make.
Given a prediction, the optimal strategy changes depending on the user, specific context and decision-making.

<table>
<thead>
<tr>
<th>Predicted Probabilities</th>
<th>Range of skill values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Average</td>
<td>Skill \leq 0 worse than past observations</td>
</tr>
<tr>
<td>Normal</td>
<td>Skill &gt; 0 better than past observations</td>
</tr>
<tr>
<td>Below Average</td>
<td>Skill = 1 perfect forecast</td>
</tr>
</tbody>
</table>

When to make a decision?
A tale of two worlds?
Or maybe three…

Climate Information

CLIMATE SERVICES
Co-development
scientists/end-users

User needs

Science world

Climate Informed Decision-Making

Users’ world
Take Home Messages

• Any **decision-making** considers the **relationship** between the **likelihood** of an event and its **consequences**.

  Likelihood x Consequences

• Need to **balance** the request for **confidence** from the users (for effective decision-making), with the intrinsic **uncertainty** of the **predictions** (that it is unavoidable at climate prediction time-scales).
A tale of two worlds?
Or maybe three...

Take Home Messages

• There are different strategies to maximise the performance of the predictions (bias correction, downscaling, multi-model, impact-based indicators...). However, they are highly specific, so to reach a sufficient level of 'performance' (so as to be value-effective), co-production and communication play a big role (to identify the critical features for the user).

• Adaptation and facilitation of decision-making can only be achieved if the product provided answers the particular needs of the user, and so the specific tailoring and co-development has to be performed at its 'production scale level'.
A tale of two worlds?
Or maybe three...
THANK YOU!

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- dragana.bojovic@bsc.es