Thank you for your interest in this survey!

This is an expert survey on weather forecasting accuracy and how it will likely develop in the future. The survey takes about 15 minutes to complete.

Before you can start the survey, please read the survey consent form below.

Consent to Participate in Research

You are being asked to participate in a research study. Your participation in this research study is voluntary and you do not have to participate. This document contains important information about this study and what to expect if you decide to participate. Please consider the information carefully. Feel free to ask questions before making your decision whether to participate.

Do you agree to participate in the survey?

- ○ Yes, I agree to participate in this survey
- ○ No, I do not agree to participate in this survey

Consent

Are you located in the European Union?

- ○ No
- ○ Yes

You indicated that you are located in the European Union. Please read the addendum to the informed consent document below:

General Data Protections Regulation (GDPR) Addendum to the Informed Consent Document for Research Subjects who are located in the European Union for Expert Elicitation on Opinions of Future Weather Forecast Accuracy

As described in the informed consent document for the research study named above (the "Study"), personal data pertaining to your participation in the Study will be generated and recorded. The

Do you agree to participate in the survey?

- ○ Yes, I agree to participate in this survey
- ○ No, I do not agree to participate in this survey

Introduction

Thank you for sharing your time and expertise!

We are interested in understanding expert views on future weather forecast accuracy for temperatures and precipitation.

To verify whether you qualify as an expert for the purposes of this study, please select all boxes that apply to you:

- [ ] I am at least 18 years of age.
- [ ] I work at an official national or international meteorological organization.
- [ ] I conduct meteorological research at a university or other research organization.
- [ ] Part of my job responsibilities include an aspect of weather forecasting or numerical weather prediction.

Introduction

For which location do you forecast or predict weather?

Locations could include your Weather Forecast Office, state, or other geographic region. If you forecast or predict weather for multiple locations, please respond with the location you would like to focus on for the survey.

All following questions will refer to the location that you have provided.

Throughout the survey, please answer the questions using your best expert judgement. You are welcome to consult outside resources including colleagues, organizational resources, and research in answering the survey.

You may choose to skip any survey questions that you do not want to answer, including if you feel a question is outside your area of expertise. You can also revise your answers later in the survey if you wish.

- ○ Alright, let's start!

Factors impacting forecast quality

In this first section, we are interested in understanding the factors that would lead to increases or decreases in overall forecast accuracy in the future.

Please think of **three-day-ahead 2 meter temperature forecasts**.

Briefly:

By 2050, what could make these forecasts more accurate?

By 2050, what could make these forecasts less accurate?

With respect to three-day-ahead 2m temperature forecasts generated by your organization, how do you view the potential for artificial intelligence (AI) to impact the accuracy of these forecasts in the next 10 years?

AI will _ _ _ _ _ _ _ _ _ _ forecast accuracy.

- ○ greatly increase
- ○ somewhat increase
- ○ not impact
- ○ somewhat decrease
- ○ greatly decrease

How do you view the potential for climate change to impact three-day-ahead 2m temperature forecasts generated by your organization in the next 25 years?

Climate change will _ forecast accuracy.

- ○ greatly increase
- ○ somewhat increase
- ○ not impact
- ○ somewhat decrease
- ○ greatly decrease

In terms of value of forecasts to society, do you believe that forecast quality or communication to the public and public officials is a larger constraint?

- ○ Forecast quality is a bigger constraint
- ○ Public communication is a bigger constraint
- ○ Forecast quality and public communication are both equal constraints

What do you believe are the biggest challenges for your organization in communicating weather

forecasts to the public and public officials?

To have a more positive impact for society, in your judgement are there any instances that a public meteorologist in your country might decide to issue a forecast skewed to a more extreme value to encourage people to take proper precautions based on the forecast?

- ○ Yes
- ○ No
- ○ Maybe

To what extent do you believe future forecasting advances will come from the public versus private sector in your country?

I believe future forecasting advances will come _ _ _ _ _ _ _ _ .

- ○ primarily from the private sector
- ○ somewhat more from the private than the public sector
- ○ equally from the private and public sectors
- ○ somewhat more from the public sector than the private sector
- ○ primarily from the public sector

How do you view the potential for future public funding for your organization to impact forecast accuracy in the next 10 years?

Future public funding will _ _ _ _ _ _ _ _ _ _ _ _ to future forecast accuracy.

- ○ not likely be a constraint
- ○ likely be a small constraint
- ○ likely be a moderate constraint
- ○ likely be a large constraint
- ○ likely be the main constraint

How do you view the potential for future staffing levels at your organization to impact forecast accuracy in the coming 10 years?

Future staffing levels will _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ in future forecast accuracy.

- ○ not likely be a constraint
- ○ likely be a small constraint
- ○ likely be a moderate constraint
- ○ likely be a large constraint
- ○ likely be the main constraint

If there was a ten percent increase in your organization's annual operating budget, what percentage of the additional budget would you allocate to each of the following categories to have the greatest increase in forecast accuracy?

Expand the number of highly skilled meteorologists	0	%
Increase computing power	0	%
Invest in increasing the numerical weather prediction model quality	0	%
Increase communication of forecasts to the general public	0	%
Increase communication of forecasts to public officials	0	%
Increase availability of high-quality weather observations	0	%
Increase collaboration with skilled public partners	0	%
Increase collaboration with skilled private partners	0	%
Other (please specify)	0	%
Total	0	%

If there was a ten percent increase in your organization's annual operating budget, what percentage (from 1 to 100%) of the additional budget would you allocate to each of the following categories to have the greatest positive impact from forecasts on the public?

Expand the number of highly skilled meteorologists	0 %
Increase computing power	0 %
Invest in increasing the numerical weather prediction model quality	0 %
Increase communication of forecasts to the general public	0 %
Increase communication of forecasts to public officials	0 %
Increase availability of high-quality weather observations	0 %
Increase collaboration with skilled public partners	0 %
Increase collaboration with skilled private partners	0 %
Other (please specify)	0 %
Total	0 %

Please make sure that for each question your answers total 100.

Temperature Forecasts

We will now ask you several quantitative questions regarding the accuracy of **three-day-ahead forecasts of 2m temperatures** that your organization produces for ${q://QID5/ChoiceTextEntryValue}.

We are interested in accuracy changes over relatively long time horizons of 25 to 75 years. We will also ask a set of questions about historic developments to compare the past with your expected future trajectories of forecast accuracy.

Please name the relevant forecasting product that your organization produces for 2m temperatures in ${q://QID5/ChoiceTextEntryValue}:

- If your organization produces *multiple relevant* forecast products, please report the product that is most widely disseminated or most relevant to the public.
- If your organization does *not produce* a relevant forecast product, please report the most relevant product issued in ${q://QID5/ChoiceTextEntryValue} for three-day-ahead

forecasts of 2m temperatures to the public.

For all following questions, please focus on this forecast product.

On what spatial resolution is this above product issued?

Please make sure to add a unit to your answer. Valid answers could be, for example, 9km or 0.25°. If the product has variable spatial resolutions, please list the most common resolution.

Please select if you will answer the following questions based on temperatures measured in ºC or in ºF.

- ○ ºC
- ○ ºF

Please select if you would like to answer the following questions regarding three-day-ahead 2m temperature forecast accuracy based on Mean Squared Error (MSE), Mean Absolute Error (MAE), or Root Mean Square Error (RMSE).

You can find full definitions of the statistics further below.

We are aware that other statistics might be used by your organization for verification of three-day-ahead temperature forecasts. To allow comparisons across responses we would like you to report accuracies using one of the three measures below. In case your organization uses neither the MSA, MAE, or RMSE for forecast verification, you will be able to indicate this on the next page.

- ○ Mean Squared Error
- ○ Mean Absolute Error
- ○ Root Mean Square Error

Definitions

The Mean Squared Error (MSE) is equal to the average of the square of the difference between the forecasted temperature (Fi) and the observed value (Oi) for each observation pair i:

Mean squared error - $MSE = \frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2$

Measures the mean squared difference between the forecasts and observations.

Range: 0 to ∞. **Perfect score:** 0.

The Mean Absolute Error (MAE) of the forecast is the average absolute value of the error between the forecasted temperature (Fi) and observed value (Oi) for each observation pair i:

Mean absolute error - $MAE = \frac{1}{N}\sum_{i=1}^{N}|F_i - O_i|$

Answers the question: *What is the average magnitude of the forecast errors?*

Range: 0 to ∞. **Perfect score:** 0.

The Root Mean Square Error (RMSE) is the square root of the Mean Squared Error from above.

Root mean square error - $RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2}$

Answers the question: *What is the average magnitude of the forecast errors?*

Range: 0 to ∞. **Perfect score:** 0.

How familiar are you with the ${q://QID9/ChoiceGroup/SelectedChoices} statistic for temperature forecast verification?

- ○ Not familiar at all
- ○ Somewhat familiar
- ○ Moderately familiar
- ○ Very familiar
- ○ Exremely familiar

Does your organization use ${q://QID9/ChoiceGroup/SelectedChoices} for verification of three-day-ahead 2m temperature forecasts?

- ○ Yes
- ○ No
- ○ I don't know

What metrics does your organization use for the verification of three-day-ahead 2m temperature forecasts?

What was the ${q://QID9/ChoiceGroup/SelectedChoices} of three-day-ahead 2m temperature forecasts that your organization produced for ${q://QID5/ChoiceTextEntryValue} in the years 2005 and 2020?

2005

2020

Now, we would like you to think about the future. What do you think the ${q://QID9/ChoiceGroup/SelectedChoices} of three-day-ahead temperature forecasts that your organization produces for ${q://QID5/ChoiceTextEntryValue} will be in the future?

Since the future is not certain, we ask you to provide a range of possible estimates based on the likelihood that each will occur.

- Worst-case means a less than 1% chance that the forecast accuracy will be worse than your stated answer.
- Median means that there is a 50% chance that the forecast accuracy will better/worse than the value you give.
- Best-case means a less than a 1% chance that the forecast accuracy will be better than your stated answer.

What do you think the ${q://QID9/ChoiceGroup/SelectedChoices} of three-day-ahead 2m temperature forecasts in ${q://QID5/ChoiceTextEntryValue} will be in 2050?

Worst Case

Median Case

Best Case

What do you think the ${q://QID9/ChoiceGroup/SelectedChoices} of three-day-ahead 2m temperature forecasts in ${q://QID5/ChoiceTextEntryValue} will be in 2100?

Worst Case

Median Case

Best Case

Your answers:

How confident are you about your answers to the above questions regarding future temperature forecast accuracy?

- ○ Not confident at all
- ○ Slightly confident
- ○ Somewhat confident
- ○ Fairly confident
- ○ Strongly confident

Now, instead of the forecast that your organization issues to the public, we would like to think about the **current and future accuracy of the European Centre for Medium-Range Weather Forecasts**' (ECMWF) numerical temperature predictions for ${q://QID5/ChoiceTextEntryValue}.

From 2005 until 2020, by how much has the ECMWF's three-day-ahead 2m numerical temperature prediction quality changed for ${q://QID5/ChoiceTextEntryValue}?

Quality has _ _ _ _ _ _ _ _ _ _ _ _ _ _ _.

- ○ greatly decreased
- ○ slightly decreased
- ○ remained the same
- ○ slightly increased
- ○ greatly increased

From 2024 until 2050, by how much will the ECMWF's three-day-ahead 2m numerical temperature prediction quality change for ${q://QID5/ChoiceTextEntryValue}?

Quality will _ _ _ _ _ _ _ _ _ _ _ _ _ _ _.

- ○ greatly decrease
- ○ moderately decrease
- ○ remain the same
- ○ moderately increase
- ○ greatly increase

Precipitation Forecast

Finally, we ask you to focus on the three-day-ahead **probability of precipitation (POP)** forecast that your organization produces for ${q://QID5/ChoiceTextEntryValue}.

Between today and the year 2050, by how much do you think the three-day-ahead POP forecast accuracy generated by your organization for ${q://QID5/ChoiceTextEntryValue} will change?

The accuracy of three-day-ahead precipitation forecasts will _ _ _ _ _ _ _ .

- ○ greatly decrease
- ○ moderately decrease
- ○ remain the same
- ○ moderately increase
- ○ greatly increase

Between today and the year 2050 and for three-day-ahead weather forecasts in ${q://QID5/ChoiceTextEntryValue}, will the accuracy of probability of precipitation forecasts improve more or less than the accuracy of temperature forecast?

Three-day-ahead precipitation forecast accuracy will improve _ _ _ _ _ _ _ _ _ _ temperature forecast accuracy.

- ○ significantly less than
- ○ somewhat less than
- ○ to a similar degree as
- ○ somewhat more than
- ○ significantly more than

Final Questions

While your responses to these questions are very helpful in our verification of your status as an expert, *all following questions are optional*. As highlighted in the consent form, your name and any potentially identifiable information will not be shared with individuals outside the research team.

To verify your status as an expert, what is your family (i.e., surname) name?

To verify your status as an expert, what is your given (i.e., first) name?

What meteorological organization do you currently work for?

What is your terminal degree related to meteorology?

- ○ Bachelors
- ○ Masters
- ○ PhD
- ○ [ ] Other (please specify)

How many years have you worked as a meteorologist? (Please round to the closest year.)

If you used any outside sources in the generation of your responses to this survey, please list them here:

If you have any additional comments or notes regarding your answers to this survey, please include them here:

If you would like a copy of your survey responses, please include your email address here: