

# Syllabus

## Course Title

### Predictive models

#### General Information

*General description of the required education/training, outlining the main objectives and explaining the need for training at the organizational/country/regional level*

The course “Predictive Models” plays an important role in the training of PhD students in the field of climate services, as it enables a shift from the description of climate processes to their quantitative analysis and forecasting. In the context of global climate change, increasing extreme weather events, and the need for scientifically grounded decision-making on adaptation and mitigation, the role of predictive models is significantly growing. Such models are the main tool for assessing future changes in the climate system, the risks associated with these changes, and for developing effective management strategies.

The aim of the course is to equip students with knowledge and skills in the construction, evaluation, verification, and practical application of predictive models in the field of climate and environmental science. The course covers both basic concepts of mathematical modelling and modern approaches to developing models of varying complexity—from simple empirical models to complex numerical general circulation models of the atmosphere. Special attention is given to input data analysis, model calibration methods, uncertainty assessment, and interpretation of forecasting results for decision-making purposes.

The course will contribute to the training of specialists capable of applying predictive models in climate services practice. Such training is particularly relevant for modern Ukraine, which on the one hand faces the challenges of climate change, and on the other is undergoing post-war reconstruction, requiring the integration of science-based approaches to sustainable development planning, infrastructure recovery, and reduction of vulnerability to climate risks.

#### Audience

*Main target audience of the course and any secondary audience that may influence decisions regarding the structure or content of the course.*

*Expected level of knowledge and skills of the main audience (current or minimum required), as well as other factors (e.g., cultural characteristics, level of technical training, access to the internet) that should be considered when planning the course, as they may influence the choice of teaching methods, materials, and approaches to interaction with the audience.*

Main audience – PhD students of Ukrainian higher education institutions who are studying or conducting research in climate sciences, meteorology, geoinformatics, applied mathematics, or related disciplines.

#### 1. Level of knowledge and skills of the main audience

##### Basic academic background:

The course audience consists of PhD students with strong theoretical preparation in natural or technical sciences. They are already familiar with the basics of the climate system, atmospheric dynamics processes, and climate modelling. Previous experience in meteorology, geophysics, or environmental forecasting is an advantage.

##### Mathematical background:

PhD students are expected to have a solid command of mathematical tools sufficient for understanding and constructing differential models, statistical analysis, optimization methods, and processing large datasets. Knowledge of numerical methods and the ability to apply them to practical problems in climate sciences is expected.

##### Technical background:

The audience should be able to work with scientific software, use programming languages (Python, R, MATLAB, Fortran), digital meteorological models, and GIS tools. Experience with climate or atmospheric models (e.g., WRF, RegCM, GCM) is an advantage. Skills in independently accessing data repositories, processing NetCDF/GRIB files, and visualizing research results are expected.

English language level:

A recommended English proficiency level is B2 or higher, enabling students to work with scientific literature, publish research results in international journals, and use foreign online courses and model documentation.

**2. Other factors influencing course design:**

Inclusivity and accessibility.

Flexible delivery of materials, assessment, and communication will be provided, taking into account different learning styles and abilities.

Internet access:

The course is designed in a blended learning format with a significant online component. However, all learning materials (texts, presentations, model code, videos) will be available for download for offline self-study. This is critically important in conditions of unstable internet access due to military actions or technical limitations.

## Competencies

*Training needs at the individual or organizational/country/regional level, as well as a description of how these needs were identified and recognized as relevant.*

*Competencies targeted by the training.*

C1. Assessment of the impacts of climate change, climate variability, and climate extremes on different sectors (society, environment, economy, etc.) at various scales, taking into account the full range of interconnections within the climate system and transdisciplinary interactions with society.

## Learning outcomes and performance criteria

*Learning outcomes and performance criteria formulated taking into account the knowledge and skills to be acquired during the learning process.*

**Performance criteria:**

PC1. Perform search, selection, and preprocessing of climate model data.  
PC2. Assess possible impacts of climate change on natural and socio-economic systems.  
PC3. Conduct verification and quality assessment of climate model outputs.

**Learning outcomes:**

LO1. Explain the principles of climate system modelling, the structure of climate models, sources of climate data, and standards for working with climate information.  
LO2. Apply climate data, scenarios, and climate model outputs to analyze climate change and simulate its possible impacts.  
LO3. Evaluate the quality of climate model outputs using standard WMO verification methods, downscaling techniques, and bias correction methods.

## Course Content

*Provide a plan of content that corresponds to the objectives and learning outcomes. This may be a course outline as it will be presented to students, but it does not necessarily have to be a full curriculum.*

*Include a general list of all topics you consider necessary to cover. If it helps clarify, indicate what will NOT be covered.*

**Module 1: Principles of climate system modelling.** Basics of climate models and forecasting. Sources of climate data and data formats.

**Module 2: Modelling climate change impacts.** End-user needs and design of climate services.

**Module 3: Validation of climate models.** Verification and assessment of the accuracy of climate forecasts. Tools for accessing and processing climate data. Downscaling and bias adjustment.

### *Learning solutions and methods of their implementation*

*List the learning solutions (teaching methods) that will be used and explain why you chose them. For example: classroom learning, online learning, blended learning, workplace learning, online resources for self-study, coaching or mentoring, etc.*

For PhD students, it is advisable to use a blended learning format that combines online components with periodic face-to-face or synchronous consultations. This approach makes it possible to effectively combine the flexibility of individual learning with opportunities for in-depth discussion of complex scientific and applied aspects of climate services management.

Considering the specifics of PhD training, a significant portion of learning can take place online, mainly in an asynchronous mode. This allows PhD students to independently plan their study time, combining it with research work, dissertation preparation, and participation in scientific projects. PhD students generally have sufficient experience in independent work with scientific materials, time management skills, and a high level of motivation for learning.

At the same time, given the complexity and interdisciplinary nature of climate services management, regular discussion of theoretical concepts, methodological approaches, and practical examples of climate services application is essential. For this purpose, periodic meetings between PhD students and the instructor are planned in a synchronous format (online or offline), during which the results of studying course materials will be discussed, case studies of climate services will be analyzed, and research tasks will be carried out.

Asynchronous online learning involves working with video lectures, scientific articles, analytical reports, and other learning materials available on a learning platform (e.g., Moodle). The instructor will support the learning process through forums, online discussions, and consultations, ensuring continuous feedback between the instructor and PhD students.

At the end of the course, a final assessment of learning outcomes is *предусмотрено*, which may include the preparation of an analytical paper or a research project related to the analysis or evaluation of climate services. Upon successful completion of the course, PhD students may be awarded certificates.

Given the current challenging conditions in Ukraine, the course may also be delivered fully online using asynchronous materials with the possibility of synchronous online sessions.

The online format also creates additional opportunities to involve leading scientists and experts in climate services, who can deliver guest lectures or participate in discussions. This will contribute to broadening the scientific outlook of PhD students and familiarizing them with current international research and practices in climate services.

Particular importance in this format is placed on regular and purposeful communication between the instructor and PhD students, as studying climate services management requires in-depth analysis of climate, socio-economic, and institutional aspects. Such interaction will support the development of PhD students' ability to critically analyze scientific approaches, evaluate the effectiveness of climate services, and apply acquired knowledge in their own research.

### *Learning strategies*

*Consider which learning strategies you will use. Provide justification for why you intend to apply them, including reasons why they will help participants achieve the planned learning outcomes.*

*Combine different learning strategies to create a diverse learning environment that accommodates different learning styles of participants. This will increase learning effectiveness and help achieve the planned outcomes. In this section, it is not necessary to describe specific activities in detail.*

## **Learning strategies**

The learning process within the course is based on a combination of theoretical instruction, practical work with climate data, case-based analysis, and a project-oriented approach. This combination allows for the development of both fundamental knowledge and applied skills necessary for working with climate forecasts and climate services.

### **1. Lecture-based learning and work with scientific resources**

Lectures provide the theoretical foundation of the course and account for approximately 30% of the study time. During lectures, students are introduced to key concepts of climate forecasting, methods for evaluating the accuracy of climate models, sources of climate data, and modern approaches to developing climate services.

Lecture materials are supported by the use of scientific articles, technical reports from international organizations (in particular the World Meteorological Organization and the Copernicus Climate Change Service), as well as specialized online resources for working with climate data.

This strategy is aimed at developing students' systemic understanding of climate modelling processes, forecasting, and the use of climate information to support decision-making.

### **2. Practice-oriented learning (hands-on learning)**

Practical sessions account for about 30% of the course time and are aimed at developing skills in working with real climate data and predictive information.

During practical sessions, students work with modern digital tools and platforms, including:

- Copernicus Climate Data Store (CDS)
- Climate Explorer
- Climate4Impact
- Python libraries for working with climate data (xarray, climpred, pandas, matplotlib)

Practical tasks include:

- downloading and initial processing of climate data;
- analysis of seasonal and sub-seasonal forecasts;
- evaluation of the accuracy of climate forecasts;
- application of downscaling and bias correction methods;
- analysis of long-term climate scenarios.

This approach enables students to acquire skills in using tools that are widely applied in international practice in climate research and climate services.

### **3. Project-based learning**

Project work accounts for approximately 40% of the course time and is a central element of the learning process.

Students work in small groups to develop an applied climate forecast for a specific region and user (e.g., an agricultural enterprise, a municipal water utility, or local government authorities).

The project involves completing the full cycle of working with climate predictive information:

- identifying user needs;
- collecting and analyzing climate data;
- developing a forecast;
- assessing its accuracy;
- adapting results to user needs;
- preparing recommendations for decision-making.

The project concludes with a presentation of results and a group discussion, allowing students to receive feedback and critically evaluate different approaches to developing climate forecasts.

#### 4. Discussion and reflection strategies

Discussions and debates are conducted both during practical tasks and after project completion.

These discussions are aimed at:

- developing critical thinking;
- building skills for reasoned scientific discussion;
- analyzing different approaches to the use of climate forecasts;
- evaluating the limitations of climate models and uncertainties in forecasts.

#### 5. Self-directed learning and digital tools

Independent student work includes:

- studying scientific materials;
- completing practical tasks;
- preparing project work;
- taking self-assessment tests.

Digital platforms and online resources are used to support the learning process, providing access to climate data, software tools, and learning materials.

#### 7. Pedagogical logic of the course

The combination of lectures, practical sessions, case studies, and project work ensures a balanced learning process that aligns with two key principles of modern education:

**Flexibility** — the ability to adapt the learning process to different levels of student preparation and varying learning conditions.

**Diversity** — the combination of theoretical knowledge, practical skills, and analytical thinking.

The application of these approaches contributes to the development of professional competencies required for working with climate forecasts, analyzing climate risks, and developing climate services to support decision-making across different economic sectors.

### *Learning activities*

*Describe the main learning activities that will be included, such as lectures, readings, case studies, discussions, exercises, practical tasks, simulations, role-playing, etc.*

*Also describe the roles of instructors and students during these activities.*

The learning activities of master's students will consist of lectures, which will account for approximately 20% of the total course time. Practical sessions will be implemented in the form of various practical tasks (20% of the time), case studies (30%), and projects (30%). Case studies and project work will also include discussions, which will be conducted either after task completion or during its implementation. To assess knowledge of course sections, self-assessment tests and final assessment tests will be provided.

Lecture sessions will include the following topics:

**Lecture 1:** Fundamentals of climate modelling

**Lecture 2:** Standards and agreed frameworks supporting climate modelling

**Lecture 3:** From global climate models to regional applications

**Lecture 4:** Methodological approaches to impact modelling

**Lecture 5:** Access to climate data and tools for end users

**Lecture 6:** Validation of climate models and the ESMValTool

## **Lecture 7: Bias correction of climate models: methods, effectiveness, and limitations**

The practical session cycle is aimed at developing skills in working with climate predictive data, model verification, and the use of climate scenarios for assessing future climate change. The tasks are based on modern tools such as the Climate Data Store (CDS), Climate Explorer, Climate4Impact, Python libraries (xarray, climpred), as well as methods recommended by the World Meteorological Organization (WMO). The practical sessions are applied in nature and oriented toward real needs of climate services in supporting decision-making across different sectors.

### **Practical session 1: Downloading and initial processing of climate predictive data**

#### *Objective:*

To familiarize students with basic sources of climate predictive information and methods for structuring it for further analysis.

#### *Expected outcomes:*

Students will be able to locate and download data from open climate portals, perform basic quality checks, and visualize simple time series.

### **Practical session 2: Developing a sub-seasonal or seasonal forecast for a specific region**

#### *Objective:*

To train students to formulate a climate forecast considering the specifics of a selected region and seasonal climate variability.

#### *Expected outcomes:*

Students will produce a forecast of temperature or precipitation for a given period, analyze the spatio-temporal structure of anomalies, and present results in the form of maps or graphs.

### **Practical session 3: Forecast verification**

#### *Objective:*

To introduce students to methods of forecast evaluation by comparing predictions with observed data.

#### *Expected outcomes:*

Students will calculate key verification metrics (e.g., CRPSS, Brier Score), interpret their values, and draw conclusions regarding forecast quality.

### **Practical session 4: Downscaling and bias adjustment**

#### *Objective:*

To provide practical skills in applying simple methods of spatial downscaling and bias correction of climate models to improve the accuracy of regional forecasts.

#### *Expected outcomes:*

Students will apply statistical downscaling and bias-correction methods to real climate data and evaluate improvements in the results.

### **Practical session 5: Analysis of climate scenarios**

#### *Objective:*

To develop skills in working with long-term climate scenarios and assessing them for applied tasks.

#### *Expected outcomes:*

Students will compare SSP scenarios (e.g., SSP2-4.5 and SSP5-8.5), produce graphs of projected changes, and analyze potential impacts for a selected region or sector.

The group project will include research on the topic: "Development of a climate forecast and its adaptation to the needs of a specific user."

Group project will include research on the topic: “Development of a climate forecast and its adaptation to the needs of a specific user”.

**General description:**

This project is based on the application of climate forecasts (sub-seasonal, seasonal, or long-term) to solve practical tasks in the field of climate services. Students will work in small groups (2–4 persons) to create a forecasting product for a specific region and user—for example, an agricultural enterprise, a municipal water management service, or a municipality. Each team will carry out the full forecasting cycle: from climate data collection to their adaptation and presentation in a form understandable to the end user.

**Project aim:**

To provide students with practical experience in developing a climate forecast, assessing its quality, and adapting it to specific user needs. The project will promote interdisciplinary thinking, communication with simulated clients, as well as skills in visualization and presentation of forecasting information.

**Student tasks:**

Students analyze weather and climate conditions in a selected region, create and verify a forecast for one or more climate parameters (temperature, precipitation, etc.), and formulate a final forecast taking into account user needs (e.g., a farmer or municipal officer).

Each group:

1. **Select a region and a user (LO#1):** e.g., an agricultural producer in the Odesa region or the city administration of Kyiv..
2. **Collects relevant climate data (LO#1):** downloads seasonal or long-term forecasts from Copernicus CDS, Climate4Impact, Climate Explorer portals.
3. **Creates a climate forecast for the selected period (LO#3):** uses models or interprets forecast data; performs basic data processing.
4. **Verifies the forecast (LO#2):** compares it with observational data and calculates simple accuracy metrics (e.g., Brier Score, CRPSS).
5. **Produces an adapted forecast for the user (LO#1):** translates results into decision-oriented language, formulates risks, provides practical recommendations, and indicates time horizons.

**Expected results:**

- A completed forecast (graphs, maps, tables) for the selected region;
- A verification analysis with basic accuracy estimates;
- A user-adapted forecast (in the form of an explanatory note);
- **A presentation (10 minutes)** with conclusions, comments, and recommendations;
- **A short report (up to 5 pages)** in a structured format (introduction, methods, results, discussion, conclusions);
- Participation in a **group discussion** after the presentation for critical analysis of other teams’ approaches.

*Assessment of learning*

*Describe the assessment plan for participants before, during, and/or after the course, including tests, exercises, activities, and projects to be assessed.*

*Indicate whether self-assessment or peer assessment will be used. Explain how assessment is linked to the learning outcomes.*

Type of activity	Assessment description	Maximum score
Tests	Online tests after thematic modules to assess theoretical knowledge of climate models, data sources, forecasting methods, and climate scenarios	20 points
Practical sessions	Completion of individual practical tasks: working with climate data, developing forecasts, verifying them, applying downscaling methods, and analyzing climate scenarios	30 points
Discussions	Active participation in discussions during practical sessions and presentation of results, quality of argumentation, and ability to interpret analytical outcomes	10 points
Group project	Development of a climate forecast for a specific region and user, including data analysis, forecast verification, scenario use, and presentation of results	40 points

Group project assessment is carried out using a four-level scale: **excellent level, good level, satisfactory level, and insufficient level**. The maximum score for the project is **40 points**.

Learning outcome	Assessment criterion	Excellent level (A)	Good level (B–C)	Satisfactory level (D–E)	Insufficient level (F)	Max. score
<b>LO1</b> Develop sub-seasonal, seasonal, and long-term forecasts	Quality of the developed climate forecast and its adaptation to user needs	The forecast is developed correctly, using appropriate data and methods; uncertainty is considered; results are clearly adapted to the needs of a specific user	The forecast is generally correct, but uncertainty or user needs are only partially considered	The forecast is developed with noticeable methodological limitations; adaptation to user needs is superficial	The forecast is incorrect or missing; user needs are not considered	<b>15</b>
<b>LO2</b> Perform forecast verification	Use of standard verification methods (Brier Score, CRPSS, etc.)	Verification is performed correctly; several metrics are used; results are properly interpreted	One or two metrics are used; interpretation is somewhat limited	Verification is conducted superficially or with methodological errors	Verification is absent or performed incorrectly	<b>10</b>
<b>LO3</b> Formulate and apply climate scenarios	Use of scenarios and models in forecasting	Scenarios (e.g., SSP) are used correctly; radiative forcing, boundary conditions, and model limitations are explained	Scenarios are used, but their interpretation or explanation is partially limited	Scenarios are used formally or without sufficient explanation	Scenarios are not used or are used incorrectly	<b>10</b>
General research skills	Quality of presentation of results (visualization, structure, presentation)	Clear structure, high-quality maps and graphs, well-argued conclusions	The presentation is understandable but has some shortcomings	Visualization and explanations are partially unclear	The work is unstructured, and the results are difficult to interpret	<b>5</b>

### Learning storyboard (learning storyboard)

Use it to create a visual scenario of your blended learning activity

## Сторіборд курсу «Прогностичні моделі»: Баланс змішаного навчання

Підготовка фахівців до кількісного аналізу та передбачення кліматичних процесів у змішаному форматі

	Синхронно (Очне навчання)	Асинхронно (Онлайн-навчання)
<b>Модуль 1: Складання прогнозів</b> Фокус на основах моделювання, джерелах даних та початковій обробці.	 Тьюторіал (лекції про джерела та формати даних) та практичні вправи з завантаження та обробки даних у системі Copernicus Climate Data Store (CDS). <input checked="" type="checkbox"/> Групування <input checked="" type="checkbox"/> Оцінювання	 Самостійне читання профільних наукових праць та проходження тестів для самоконтролю знань. <input checked="" type="checkbox"/> Групування <input checked="" type="checkbox"/> Оцінювання
<b>Модуль 2: Верифікація</b> Оцінка точності прогнозів та методологія роботи з інструментами.	 Практичні вправи з розрахунку метрик точності (CRPSS, Brier Score) та відкрита дискусія щодо аналізу похибок моделей. <input checked="" type="checkbox"/> Групування <input checked="" type="checkbox"/> Оцінювання	 Тьюторіал з методології роботи з інструментами та програмним забезпеченням для обробки кліматичних даних. <input checked="" type="checkbox"/> Групування <input checked="" type="checkbox"/> Оцінювання
<b>Модуль 3: Сценарії та Прокст</b> Фіналізація моделювання, звстосування методів корекції та презентація результатів.	 Практичні вправи з даунскейлінгу та корекції зсуву (bias adjustment), а також фінальна презентація результатів проекту. <input checked="" type="checkbox"/> Групування <input checked="" type="checkbox"/> Оцінювання	 Самостійна робота над проектом: збір даних, безпосереднє моделювання та написання фінального дослідницького звіту. <input checked="" type="checkbox"/> Групування <input checked="" type="checkbox"/> Оцінювання

NotebookLM

### Learning resources and tools



Co-funded by the Erasmus+ Programme of the European Union

List the available resources that you will use for different types of learning activities and recommend to students.

Describe the technologies you will use to implement the learning solutions, including educational technologies and operational equipment (technical equipment, software, collaboration tools).

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11. Masson, D., & Reto Knutti. Climate model genealogy. *Journal of Climate*, 2011. <https://doi.org/10.1029/2011GL046864>
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