

Mini-projects for Atmospheric Processes – 2024

Re-analysis (ERA5)

A re-analysis is a global multivariate climate data set covering decades (> 30 years) created using a given model and data assimilation scheme (hence constrained by many observations).

ERA5 is the ECMWF re-analysis product with a 30 km and 1h resolutions, from 1959 to present (<https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5>). Here we focus on surface variables.

List of proposed mini-projects:

ERA5-1. Arctic amplification: historical perspective. The objective here is to document from existing data the Arctic amplification. Surface variables over the Arctic region are provided.

ERA5-2. Evolution of snow cover and sea ice in Scandinavia and related processes (e.g., precipitation, temperature, precipitation type, ...)

Climate predictions (IPSL-CM)

IPSL is a French institution in Paris, running its Earth System model (<https://cmc.ipsl.fr/ipsl-climate-models/>) named IPSL-CM. LMDz is the general circulation model of IPSL-CM (<https://lmdz.lmd.jussieu.fr/>).

IPSL-CM / LMDz was used for CMIP6 (<https://pcmdi.llnl.gov/CMIP6/>), an intercomparison project involving 23 climate models. Predictions are based on scenarios proposed by IPCC : the 5 Shared Socio-economic Pathways (SSPs, see IPCC AR6, chap.1.6). Here we provide IPSL-CM predictions based on two SSPs:

- SSP2-4.5 corresponds to SSP2 (intermediate) and a radiative forcing of 4.5 Wm⁻².
- SSP5-8.5 corresponds to SSP5 (fossil-fuel intensive) and radiative forcing of 8.5 Wm⁻².

List of proposed mini-projects:

IPSL-1. Characterize the polar amplification in 2 climate scenarios (SSP2-4.5 and SSP5-8.5). The objective is to analyze and compare the respective evolution of the polar amplification in the Arctic or in Antarctica, according to the 2 scenarios.

IPSL-2. Investigate the evolution of at least two surface variables (temperature, precipitation, and many others) in different target regions for the 2 scenarios. The objective is to analyze and characterize the influence of the scenario on surface variables over at least two target regions.

MeteoSwiss Gridded Products

MeteoSwiss provides [long-term gridded products of various meteorological variables](#) to study and analyze the evolution of the Swiss climate.

The *Rhires* product is a gridded precipitation product obtained from precipitation gauges interpolated over Switzerland (since 1961). The spatial resolution is 1 km and we provide daily datasets.

TabsD, *TminD* and *TmaxD* are the gridded product of mean, minimum and maximum daily temperature.

List of proposed mini-projects:

MCH-1. Snow. How many days per year does it snow in Switzerland? Have the snowfall frequency and the amount of solid precipitation changed? Are these trends related to a variation in the number of precipitation events and/or to the generalized increase in surface temperature? Has the number of days with temperatures below °C changed? Disentangle the factors driving changes in the cryosphere. Data: *Rhires* and *Tabs/Tmin/Tmax*.

MCH-2: Drought. Hydrological droughts and heatwaves typically develop during periods without precipitation (meteorological drought). Has the number of consecutive days without precipitation increased over the past decades? Characterize precipitation deficits and relate them to the occurrence of heatwaves. Data: *Rhires* and *Tabs/Tmin/Tmax*.

Links to access the various data sets:

- ERA5 Monthly: <https://enacshare.epfl.ch/dZ4wV56hozFtnXKY3s8BU>
- Swiss Gridded: <https://enacshare.epfl.ch/dSXu8xbFGH7EfBQrZCwtJ>
- LMDZ Climate projections: <https://enacshare.epfl.ch/dxKpejGuHzNk9waAofqZC>
- Python codes to read the data : <https://enacshare.epfl.ch/d3SzaKjqtDnbV4fdQkGmW>

Weather forecasting (Josué)

In this project, you will learn the job of a meteorologist. You will analyse each Tuesday the forecasts for the following Monday for the western part of Switzerland. You will use forecasts from the European Centre for Medium-Range Weather Forecast (ECMWF). In your forecast, you will have to analyse the synoptic situation (e.g. identify the key weather systems at play and their effect on weather) and provide a forecast of some key meteorological variables (cloud cover, precipitation, temperature). To quantify forecast uncertainty, numerical weather prediction models compute multiple scenarios for the same forecast period, by slightly perturbing the initial conditions and the physics of the model. This process is known as ensemble weather forecasting. The key role of meteorologists is to interpret the different scenarios proposed by ensemble models to identify the most likely ones and also the potentially hazardous ones. In this project, you will use the ECMWF ensemble weather forecasts to provide probabilistic information in your forecasts. Every Tuesday, you will be able to verify your forecast and analyse what happened. The final report will include a summary and analysis of your forecasts describing what you have learnt in this process.

Boundary layer determination in orographic environments (BL)

The boundary or mixing layer is the layer of air closest to ground that usually carries the highest concentration of aerosol sources that provide the nuclei for forming droplets and ice crystals. Knowledge of the extent of this layer is critical for understanding the sources of particles that eventually “feed” cloud droplet formation. This project involves using observations of atmospheric turbulence and/or in-situ observations of aerosol and other properties to determine the height of the planetary boundary layer, its diurnal variability and

seasonality at an orographic environment (CHOPN and CALISHTO experiments) at Mt.Helmos, Greece. For more questions or information, please contact Prof.Nenes.

Suggested approach:

1. Read the Foskinis et al. (2024) manuscript outlining the approaches used to determine the height of the boundary layer, and if an orographic measurement site is in the boundary layer or the free troposphere and their application to the 2021 CALISHTO campaign. (<https://b.tellusjournals.se/articles/10.16993/tellusb.1876>).
2. Obtain the datasets of aerosol and gas-phase ammonia collected during the 2024 CHOPIN campaign (<http://go.epfl.ch/chopin-campaign>), provided by Prof. Nenes, and determine the timeseries where the Mt.Helmos HAC site is in the free troposphere and when in the boundary layer.
3. Determine a new criterion, based on the level of gas-phase ammonia concentration and a characteristic threshold, for understanding when the HAC2 site is in the Free troposphere and when in the Boundary layer.
4. How long is the HAC site in the boundary layer each day? Do you see a diurnal cycle? Does it depend on ambient temperature and day in the month?

Airmass analysis to understand sources of ice nuclei (AirINP)

Particles can transport over long distances before influencing clouds in certain regions. Understanding whether airmasses originate from marine (seasalt aerosols), desert (dust aerosols) or continental regions (pollution, bioaerosols) is very important for understanding the possible sources of cloud condensation nuclei (CCN) or ice nuclei (INP) that eventually “feed” cloud droplet formation. This project involves using back trajectory (<https://www.ready.noaa.gov/HYSPLIT.php>) analysis to understand the sources and types of airmasses involved and their importance for ice nuclei sampled at the orographic site of Mt.Helmos, Greece during the CHOPIN experiment. Conclusions obtained from backtrajectory analysis will be evaluated against in-situ (aerosol size distribution measurements) or remote sensing observations (lidar) to understand the robustness of backtrajectory analysis. More about CHOPIN can be found at <http://go.epfl.ch/chopin-campaign>. For more questions or information, please contact Prof.Nenes.

Suggested approach:

5. Read the Gao et al. (2024) manuscript outlining the airmass origin calculations with HYSPLIT taken place at Mount Helmos in the 2021 CALISHTO campaign. (<https://acp.copernicus.org/articles/24/9939/2024/>).
6. Learn to run the HYSPLIT model (<https://www.ready.noaa.gov/HYSPLIT.php>) for any period (backtrajectories, 2 days) to understand how to calculate backtrajectories.
7. Calculate the backtrajectories (2 days backward) and see where the ground-level aerosol that reaches Mt.Helmos during the CHOPIN October period (October 2024) comes from. Note that origin (e.g., continental Europe, Mediterranean, Sahara, Atlantic - or wind sector: N, S, E, W). Also note periods where there may be rain (very high level of humidity) and separate from periods where there is not much humidity.

8. See if you can see a correlation between particle concentrations observed at Mt.Helmos, and air mass origin. Discuss whether you think different aerosol sources (e.g., continental pollution, desert dust, marine aerosol) contribute to the results.

How well can ice nuclei be predicted? (INPErr)

This project examines the ability of parameterizations used to predict the concentration of ice nuclei (INP) and ice crystal number concentration, which is a major source of cloud prediction uncertainty in climate models. Quantifying this prediction uncertainty for different conditions of cloud formation (particularly the effect of different particle types, like dust and biological particles) is especially important and a topic of research. This project calls the student to evaluate the uncertainty of INP prediction parameterizations using ambient observations. For this, concentrations of ice nuclei sampled at Mt.Helmos, Greece during the CHOPIN and CALISHTO experiments are to be compared against predictions of ice nuclei from established parameterizations that use as input the aerosol size distribution and/or particle types (biological, dust). The parameterization ability is evaluated for different conditions of particle load and air mass characterization (dust vs, pollution, background, etc.) which is available from the ambient data or any other source (available upon discussion with Prof.Nenes). For more questions or information, please contact Prof.Nenes.

Suggested approach:

1. Read the Gao et al. (2024) manuscript outlining the parameterization of ice nuclei concentration (INP) from observations at Mount Helmos in the 2021 CALISHTO campaign. (<https://acp.copernicus.org/articles/24/9939/2024/>).
2. Code the parameterizations for calculating INPs as available in the manuscript.
3. Obtain the observations of INP concentrations observed at Mt.Helmos during the 2024 CHOPIN campaign (data will be provided by prof.Nenes in the next few days) and the aerosol concentration data from the WIBS and large particle concentrations.
4. Apply the parameterizations in step 2 using as input the aerosol data you have from step 3 and compare against the INP observations you have as well from step 3. Evaluate the ability of each parameterization to reproduce the INP data and suggest which formulation works the best.

Drivers of droplet formation in different environments (DRP-3)

The following projects involve understanding the drivers of droplet formation (i.e, is droplet formation mostly influenced by aerosol parameters or vertical velocity?). For this, the groups will utilize data collected from a number of ambient campaigns (Arctic, E.Mediterranean, orographic environments). Input parameters that are missing (e.g., hygroscopicity parameter or vertical velocity) can be estimated obtained from literature sources or provided additionally from Prof.Nenes in discussion with the groups. For more questions or information, please contact Prof.Nenes.

DRP-1. CALISHTO campaign (<https://calishto.panacea-ri.gr>)

DRP-2. CHOPIN campaign (<https://go.epfl.ch/chopin-campaign>)

DRP-3. ArcticCentury campaign (<https://swisspolar.ch/expeditions/arctic-century-expedition/>)

Suggested approach:

1. Read the Motos et al. (2023) manuscript outlining the approach used to use aerosol size distribution data together with observations of hygroscopicity and vertical

velocity to calculate droplet number and maximum supersaturation in clouds. (<https://acp.copernicus.org/articles/23/13941/2023/acp-23-13941-2023.html>).

2. Download (<https://enacshare.epfl.ch/fC3p7r4J9UbMfqzsuKe5aTExinHdWNh>) the cloud droplet calculation parameterization package, unzip it in a folder on your (Windows) laptop and learn to run the included example and interpret its output. The goal of this steps is to understand how to specify as input an aerosol size distribution, hygroscopicity parameter and vertical velocity so you can get as output the droplet number and supersaturation that correspond to the clouds that would form.
3. Obtain the observations corresponding to your project (DRP-1, DRP-2, DRP-3), provided by prof. Nenes. Understand what is in the input data and whatever is missing you can constrain from the literature (i.e., prescribed values from the class overheads or literature search values).
4. Apply the parameterizations to your data and examine the relationship between aerosol number, droplet number and supersaturation. Do polluted clouds exhibit the same response in aerosol perturbations as clean clouds? What are the levels of supersaturations developed? How do your results change if you assume weak updraft velocities (0.3 m/s) typical of stratocumulus clouds vs. stronger velocities (1m/s) typical of convective clouds?

Groups for mini-projects in Atmospheric Processes

- 4 students per group (5 for weather forecasting)
- Registration through the following googlesheet:

<https://docs.google.com/spreadsheets/d/1NLI0pGMN5XKyywiN8uV5nI6UbrAlf1-rXvGIMYTtdol/edit?usp=sharing>

- Each group indicates a single project number.
- The groups must be finalized by **Monday November 25th**.

Report guidelines

- Length: 8-10 pages.
- Names of all group members.
- Explanations about the data, methods and analyses.
- References from scientific literature.
- Figures illustrating the approach and the main obtained results.
- The contribution of each group member must be clearly stated.

Indicative structure of the report (max page size, font not larger than 11pt)

- Introduction-Motivation (~1 page)
- Literature review (~1 page)
- Methods/Analysis (~2-3 pages)
- Results (~2-3 pages)
- Conclusions (~1 page)
- References, group contributions (~1 page)

To be uploaded in Moodle by January 10 2025.

Evaluation criteria:

- Relevance and robustness of the employed methods.
- Quality of the presented analyses.
- Quality of the presentation (writing, illustrations, references).