Python and AI/ML for Weather, Climate and Environmental Applications

Let us enjoy playing with Python and AI/ML!

Five-Day Schedule Overview

Time	Day 1	Day 2	Day 3	Day 4	Day 5
09:00–10:00	Opening by ECMWF DG, Start: Coding & Science in the Age of AI	Neural Network Architectures	Diffusion and Graph Networks	MLOps Foundations	Model Emulation, AIFS and AICON
10:00–11:00	**Lab:** Python Startup: Basics	**Lab:** Feed-forward and Graph NNs	**Lab:** Graph Learning with PyTorch	**Lab:** Containers and Reproducibility	**Lab:** Emulation Case Studies
11:00–12:00	Python, Jupyter and APIs	Large Language Models	Agents and Coding with LLMs	CI/CD for Machine Learning	AI-based Data Assimilation
12:00–12:45	**Lab:** Work environments, Python everywhere	**Lab:** Simple Transformer and LLM Use	**Lab:** Agent Frameworks	**Lab:** CI/CD Pipelines	**Lab:** Graph-based Assimilation
12:45–13:30			**Lunch Break**		
13:30–14:30	Visualising Fields and Observations	Retrieval-Augmented Generation (RAG)	DAWID System and Feature Detection	Anemoi: AI-based Weather Modelling	AI and Physics
14:30–15:30	**Lab:** GRIB, NetCDF and Obs Visualisation	**Lab:** RAG Pipeline	**Lab:** DAWID Exploration	**Lab:** Anemoi Training Pipeline	**Lab:** Physics-informed Neural Networks
15:30–16:15	Introduction to AI and Machine Learning	Multimodal Large Language Models	MLflow: Managing Experiments	**The AI Transformation**	Learning from Observations Only
16:15–17:00	**Lab:** Torch Tensors and First Neural Net	**Lab:** Radar, SAT and Multimodal Data	**Lab:** MLflow Hands-on	**Lab: How work style could change**	**Lab:** ORIGEN and Open Discussion
17:00–20:00				Joint Dinner	

AI as Strategic Transformation

Artificial Intelligence is becoming a core component of the next-generation observation–forecast–service chain.

What changes

- Some components will be replaced by AI-driven methods
- Many will be hybridized for better efficiency and accuracy
- Some remain targeted classical methods — but AI supports their use, development and understanding

Strategic goal: enable scalable AI adoption without losing operational stability.

Key point

> ***AI transforms the full modeling ecosystem, not just single algorithms.***

Outcome

- faster cycles from idea to product
- stronger automation in workflows
- new products and interaction modes

AI as Tool of Discovery: From Ideas to Tested Systems

Discovery viewpoint

AI is not only about producing forecasts — it increasingly supports scientific discovery and systematic development.

What AI adds to science and engineering

- accelerate coding and refactoring of research and operational software
- help to formulate equations, losses, and constraints in a consistent way
- generate tests, validation scripts, and diagnostic plots automatically
- explore hypotheses: patterns, regimes, causal links in large datasets

Result

We move from isolated scripts to AI-supported workflows that iterate fast: idea → prototype → test → deploy.

Key takeaway

> ***AI becomes part of the scientific method:*** *hypothesize, implement, test, improve.*

Python Everywhere: The Universal AI Workflow Environment

Course principle

We learn AI techniques inside a Python-based workflow — because this is the environment that is adequate today for research and operations.

Python runs everywhere

- laptop development and rapid prototyping
- online + browser execution (cloud notebooks, collaboration)
- GPU training environments
- Linux + macOS daily engineering platforms
- HPC systems for scaling and operations

Practical consequences

- transfer skills across platforms with minimal friction
- the same toolchain supports research and operations
- consistent workflows: data, training, inference, plots

Key message

Python is mastering data, models, and operations.

We Use Git Heavily: Reproducibility, Collaboration, Traceability

Course principle

We use Git as the backbone for structured work — not optional, but essential.

Why Git matters

- reproducibility: exact versions of code + configs
- collaboration: branching, merging, review culture
- traceability: who changed what, why, and when
- safe experimentation: try ideas without breaking the main line

Operational viewpoint

Modern AI systems require controlled evolution: models, code, data interfaces and validation must co-evolve.

Key takeaway

Git makes individual work maintainable and save.

In this course

- clone / pull / commit daily
- structured repos for lectures + code
- CI/CD connection later in the week

Setup your own git repos!

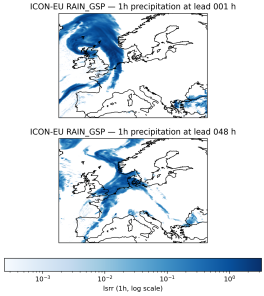
Domain Knowledge Stays Central: AI Needs Science

Message to classical modelers

AI does not replace domain expertise. Instead, domain knowledge becomes even more valuable : it determines what is physically meaningful, operationally relevant, and scientifically trustworthy.

Why expertise matters

- choose variables, scales, and constraints
- define loss functions and evaluation metrics
- identify artefacts vs. true signals
- judge extreme events and non-stationarity



Weather service viewpoint

Forecasting is not only a model: it is an ecosystem of **observation processing, modeling, validation, products and communication.**

Domain knowledge is central in

- services: impact products, warnings, tailored guidance
- forecasting: interpretation, uncertainty, plausibility
- development: model design, physics coupling, DA strategy

AI becomes powerful when grounded in science.