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CASE STUDY · MARLUC SYNOPSIS

ECMWF AI Forecasting System (AIFS)

IMPLEMENTED 2023–2025 · GOVERNMENT AND PUBLIC SERVICES · GLOBAL · BAND C · PARTLY PROVED

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An intergovernmental forecasting centre put machine-learning weather models into daily production alongside its physics-based model, and reports lower forecast errors at a fraction of the energy.

ABOUT THIS SYNOPSIS

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NOTICE WORDING LAST UPDATED 16 NOVEMBER 2026

AT A GLANCE

Frontier case: AI used for a scientific, medical or engineering breakthrough. The transformation is potential and unproven; MarLuc grades what has changed in practice so far.

AI used: Machine-learning weather forecast models (graph neural network and transformer), trained on reanalysis data.

Implemented: 2023–2025. Grade: band C, Process change, Partly proved.

Headline result, as reported: AIFS Single (February 2025) and AIFS ENS (July 2025) run operationally; ECMWF reports medium-range error reductions typically of 5 to 15% against its physics-based forecasts

1 · The case

The facts, as reported by the 5 sources listed at the end. Where a source is silent, the field says "Not reported".

Organisation

European Centre for Medium-Range Weather Forecasts (ECMWF). Intergovernmental organisation producing global weather forecasts for its Member and Co-operating States. ECMWF describes working with and for 35 nations, per its 2025 news release. Canvas block: 4. Operations and process. Also 2. Technology.

Business challenge

The challenge. Not reported in these terms. ECMWF presents the AIFS as complementing its physics-based ensemble, which it says remains indispensable for high-resolution fields and coupled Earth-system processes.

How it was addressed. ECMWF built the AIFS, a graph neural network encoder and decoder with a transformer processor, trained on the ERA5 reanalysis. AIFS Single (deterministic) became operational on 25 February 2025. AIFS ENS, an ensemble of 51 forecasts with about 30 km resolution, became operational on 1 July 2025. Both use the physics-based system to produce their starting conditions. [1] [2] [3] [4] [5]

Who implemented it

In-house (In-house): ECMWF: Built and operates the AIFS, with the Anemoi framework developed with many of its Member States.
EuroHPC Leonardo supercomputer (Cineca) (University or research lab): Hosted the AIFS Single training runs on A100 GPUs.
The Anemoi framework is co-developed by ECMWF and many of its Member States, per the ECMWF annual report.

Technology (SEAM pillar E)

SEAM types: T5 Custom / fine-tuned models, T8 Predictive / ML models. Deployment: Not reported. Vendors and products: AIFS Single, AIFS ENS, Anemoi framework.

Where it was built in: Physics-based data assimilation in the IFS produces the starting conditions; the AIFS models then produce deterministic and 51-member ensemble forecasts that run alongside the IFS in daily production and are made available to users.

What changed

Before: ECMWF's operational forecasts came from the physics-based IFS. After: two machine-learning systems run daily alongside it. By ECMWF's account, AIFS ENS shows forecast improvements up to 25% in its scorecard, medium-range error reductions are typically 5 to 15%, and AIFS ENS needs about 1,000 times less energy than traditional ensemble forecasting. [1] [2] [3] [4] [5]

What it cost

Not reported as a total. ECMWF says the training run takes about three days on A100 GPUs on the Leonardo supercomputer, and a 10-day AIFS Single forecast takes about 2 minutes 30 seconds on one A100 GPU.

What it saved

ECMWF says AIFS ENS generates forecasts over 10 times faster and uses approximately 1,000 times less energy than traditional ensemble forecasting. That figure is ECMWF's own; no outside measurement was found. [1] [2] [3] [4] [5]

Governance and control

ECMWF reports verification against analyses and observations; its Technical Advisory Committee called the introduction a world-leading achievement and noted a small decrease in AIFS skill over the last 12 months. Accountable owner and fault processes: Not reported.

S2 · Accountable owner · Not reported
Not reported.

A1 · Safe use · Claimed
ECMWF says it provided verification and model characteristics to help users build trust, which its advisory committee welcomed. [2]

A2 · Human in the loop · Not reported
Not reported.

A3 · Monitoring and assurance · Evidenced
ECMWF publishes scorecards against analyses and observations and reports annual verification; its Technical Advisory Committee reviewed the results and noted a small decrease in skill over the last 12 months. [1] [2]

A4 · Vendor AI · Not reported
Not reported.

A5 · Agent controls · Not reported
Not reported.

A6 · Standards and regulation · Not reported
No regulatory standard for the use of machine-learning models in forecasting is described in the sources opened.

What worked, what did not, what is unproven

WORKED

– ECMWF reports AIFS ENS improved on IFS ENS for 2-metre temperature at all lead times against surface observations.

– ECMWF reports error reductions in the medium range typically of 5 to 15% for most upper-air and surface parameters, and smaller tropical cyclone track errors.

– ECMWF's Technical Advisory Committee congratulated the centre on both launches, called them world-leading achievements, and noted that the ML forecasts lead on skill for many parameters and are less jumpy.

DID NOT

– For 10-metre wind speed against surface observations, ECMWF says IFS ENS was more skilful than AIFS ENS at launch.

– Temperature at 100 hPa showed a degradation against IFS analyses.

– AIFS Single 1.0.0 had a precipitation forecast issue, corrected by AIFS 1.1.0 on 27 August 2025.

– ECMWF's advisory committee noted that tropical cyclone intensity errors are generally larger in AIFS because of a weak-intensity bias.

UNPROVEN

– Whether the 1,000-fold energy figure holds once data assimilation and the physics-based system that feeds the AIFS are counted; the sources describe the comparison as with traditional forecasting methods.

– Whether ML models can replace physics-based forecasting; ECMWF says the physics-based ensemble remains indispensable for high-resolution fields and coupled Earth-system processes.

Timeline

Oct 2023 Experimental AIFS forecasts begin running four times daily, with forecasts publicly available under ECMWF's open data policy [4]

Feb 2025 AIFS Single 1.0.0 becomes operational, replacing AIFS 0.2.1 [4]

Jul 2025 AIFS ENS, an ensemble of 51 forecasts, becomes operational [3]

Aug 2025 AIFS 1.1.0 released to correct a precipitation forecast issue in the first operational version [4]

2025 ECMWF's performance review of 2025 reports medium-range error reductions typically of 5 to 15% against the IFS [2]

2 · Grade and SEAM assessment

MarLuc's opinion, made on the evidence above. How cases are graded: marluc.co.uk/case-studies/how-we-rate

Level of change and impact

Claimed: A. Grade: C, Process change. Proof: Partly proved. Level of change: Process change.

Process change (Level 2, band C). Machine-learning forecast production now runs daily beside the physics-based system, with lower reported errors and energy use; the evidence is ECMWF's own, so the marker is Partly proved. Transformation of the field is claimed as potential and not proved.

Graded C, claimed A. The transformation is potential and unproven. ECMWF's forecast production now includes two machine-learning systems that run every day, and its own scorecards show lower errors for most upper-air and surface variables at much lower computing cost. That is a change to how the core product is made. The physics-based IFS still supplies the starting conditions and remains in operation, and the evidence is ECMWF's own verification, reviewed by its Technical Advisory Committee. The wider claim that machine learning will replace physics-based prediction is not shown.

The SEAM view and lessons learnt

The transferable idea is to run a new model beside the established one and publish scorecards, including where it is worse, before relying on it. The physics-based system still supplies the starting conditions, so this is a change to part of the process, not its replacement. Disclosed limits, such as wind speed and tropical cyclone intensity, tell users where to keep the older product.

1. Run the new model beside the old one and publish the scorecard, including the variables where it is worse.
2. Keep the proven system until the new one passes the checks that matter to users.
3. Treat the vendor's or builder's efficiency claim as unproven until someone outside measures it.

Evidence

Score 2 of 4. Self-reported by ECMWF with committee review: published verification scorecards and annual performance review; no independent peer-reviewed comparison opened.

Evaluation method. Self-reported company figures: ECMWF's verification scorecards, annual performance review and news release, with a review by its Technical Advisory Committee; no independent study opened.

Sources disagree. The Newsletter 185 article reports improvements up to 25% in its scorecard, the July 2025 news release reports gains of up to 20% for surface temperature, and the 2025 annual report and Newsletter 187 give typical medium-range error reductions of 5 to 15%. The figures describe different variables and measures.

Status. Ongoing: AIFS Single and AIFS ENS operational; AIFS 1.1.0 released in August 2025.

3 · Original sources

Read these in full. To challenge a fact or a grade, use the contact form at marluc.co.uk or the link on https://marluc.co.uk/case-studies/ecmwf-aifs-operational-forecasting

[1] ECMWF Newsletter 185: AIFS ENS becomes operational
https://www.ecmwf.int/sites/default/files/elibrary/102025/81687-aifs-ens-becomes-operational.pdf

[2] ECMWF Newsletter 187: Forecast performance 2025
https://www.ecmwf.int/en/newsletter/187/news/forecast-performance-2025

[3] EurekAlert (ECMWF news release, 1 July 2025): ECMWF - delivering forecasts over 10 times faster and cutting energy usage by 1000
https://www.eurekalert.org/news-releases/1088526

[4] ECMWF (Moldovan et al., arXiv): An update to ECMWF's machine-learned weather forecast model AIFS
https://arxiv.org/html/2509.18994v1

[5] ECMWF: Annual report 2025
https://www.ecmwf.int/sites/default/files/elibrary/062026/81739-annual-report-2025.pdf

European Centre for Medium-Range Weather Forecasts (ECMWF) website: https://www.ecmwf.int

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