

WeatherFlow

AI-Powered Weather Intelligence Platform

Your Complete Visual Guide to
Professional Weather Forecasting,
Machine Learning, and Climate
Analysis

From Zero to Expert in Minutes
Train Models • Forecast Weather •
Analyze Climate

Comprehensive Visual Edition • January 2026

Welcome to WeatherFlow

The world's most comprehensive AI-powered weather intelligence platform, combining cutting-edge machine learning, real-world weather data, and intuitive visualization into a single, powerful application.

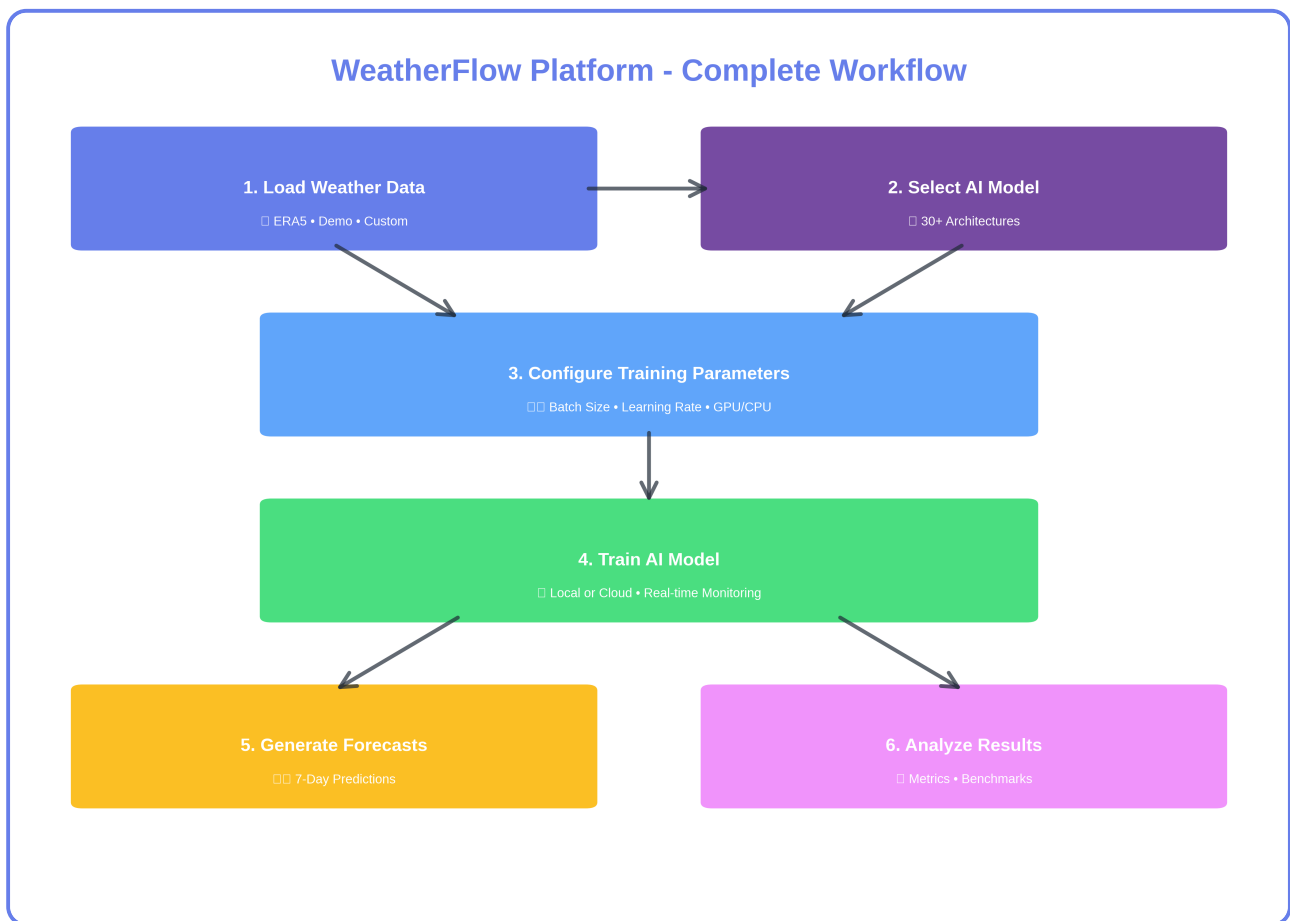


Figure 1: WeatherFlow End-to-End Workflow - From Data to Insights in 6 Steps

What Can You Do with WeatherFlow?

- **Train State-of-the-Art AI Models** - Use the same architectures as Google DeepMind (GraphCast), NVIDIA (FourCastNet), and other leading research labs
- **Generate Professional Forecasts** - Create 7-day weather predictions with publication-quality visualizations
- **Analyze Real Weather Data** - Work with ERA5 reanalysis data, the gold standard in weather observation
- **Plan Renewable Energy** - Calculate wind and solar power generation with real atmospheric data
- **Detect Extreme Events** - Identify heatwaves, atmospheric rivers, and extreme precipitation
- **Benchmark Performance** - Compare your models against published results using WeatherBench2

Platform Architecture

WeatherFlow provides access to 30+ state-of-the-art AI architectures from leading research organizations. Choose the right model for your specific forecasting needs.



Figure 2: 30+ AI Model Architectures Available in WeatherFlow

Model Categories

- **Transformer-Based:** FourCastNet, Pangu-Weather, ClimaX - Best for capturing global patterns
- **Graph Neural Networks:** GraphCast, MeshGraphNet - Highest accuracy, handles spherical geometry
- **Convolutional:** UNet, ResNet, MetNet - Fast and efficient, great for regional forecasts
- **Generative Models:** Flow Matching, GenCast, Diffusion - Uncertainty quantification
- **Hybrid Physics-ML:** NeuralGCM, PhysNet - Combines AI with atmospheric physics
- **Vision Models:** ViT, Swin, MaxViT - Transfer learning from computer vision

Weather Data Sources

WeatherFlow integrates multiple high-quality data sources to power your AI models and analyses. From quick demos to real-world ERA5 reanalysis data, we've got you covered.

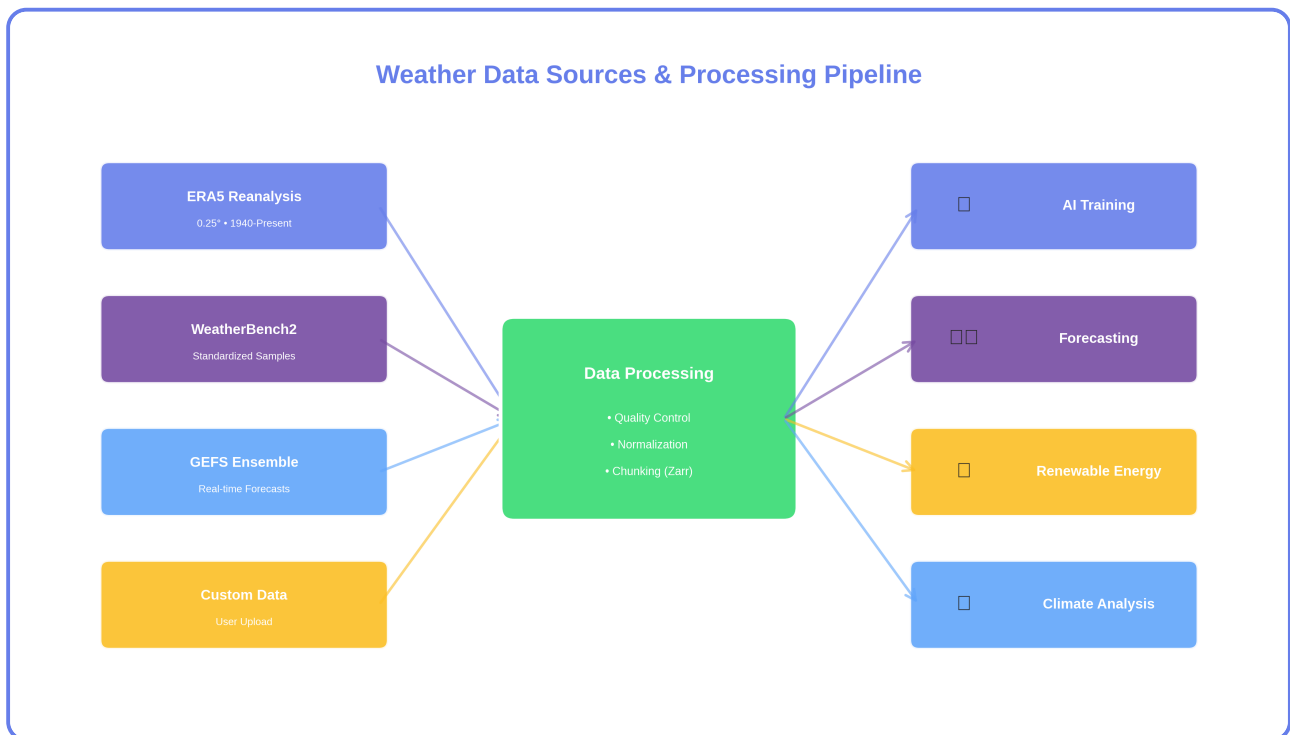


Figure 3: Data Sources and Processing Pipeline

| Data Source | Resolution | Coverage | Best For |
|-----------------|---------------|----------------------|----------------------------------|
| Quick Demo | Synthetic | Global, any time | Learning, testing, demos |
| ERA5 Reanalysis | 0.25° (~25km) | 1940-present | Research, real forecasts |
| WeatherBench2 | Various | Pre-packaged events | Benchmarking, standardized tests |
| GEFS Ensemble | 0.25-1.0° | Real-time + archives | Uncertainty quantification |
| Custom Upload | User-defined | Any | Specialized applications |

Pro Tip: Start with demo data to learn the interface, then move to ERA5 for production work. ERA5 is the gold standard for weather AI research, used by Google DeepMind, NVIDIA, and other leading labs.

AI Model Training Pipeline

Training a weather AI model involves multiple stages, from data preparation to model validation. WeatherFlow automates and streamlines this entire process.

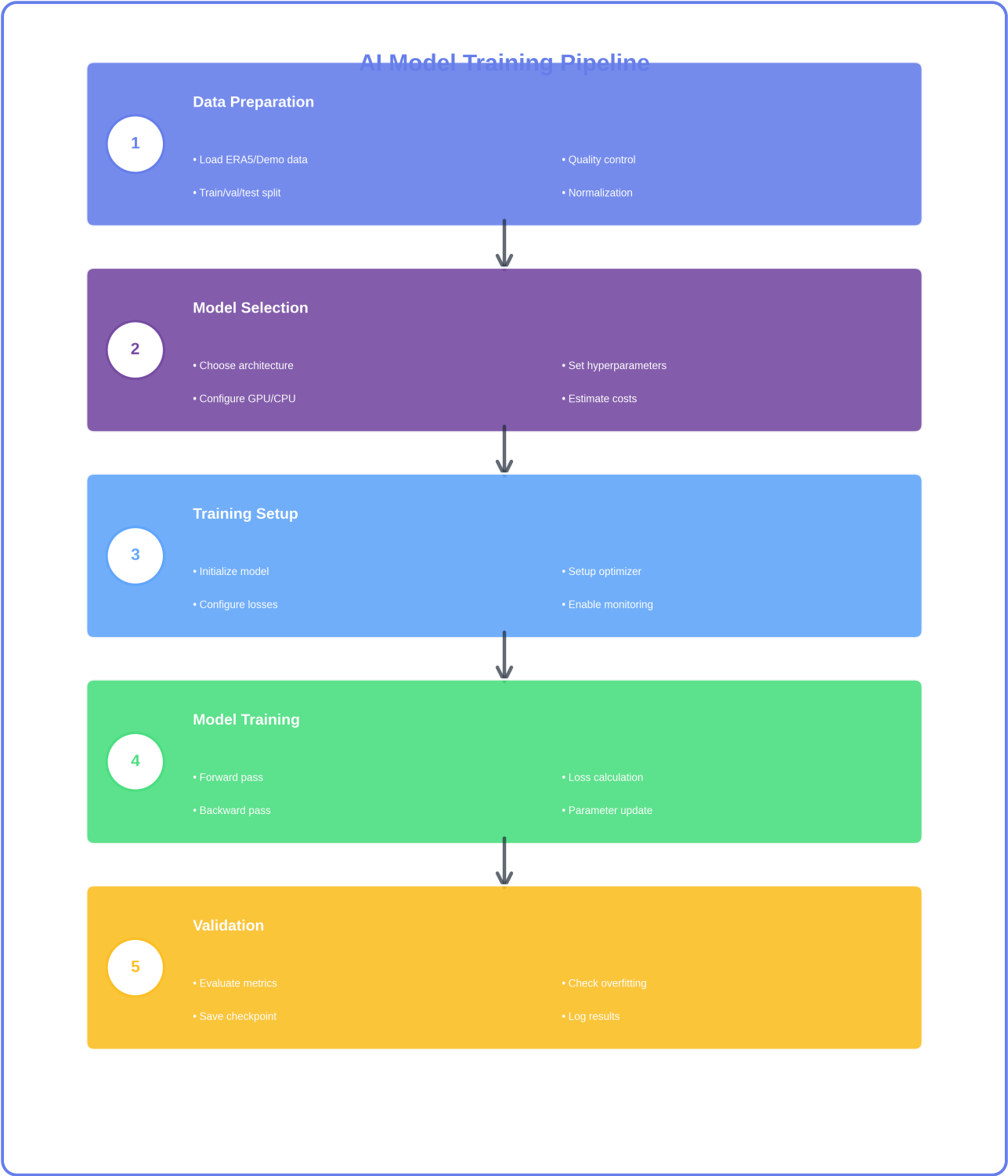


Figure 4: Complete AI Model Training Pipeline

Training Features

- **Cost Transparency:** See exact GPU costs before training - no surprises!
- **Real-time Monitoring:** Watch loss curves, GPU utilization, and time estimates
- **Physics Constraints:** Add conservation laws to improve model accuracy
- **Flexible Deployment:** Train on CPU, local GPU, or cloud (GCP T4/A100/H100)
- **Automatic Checkpoints:** Save your progress every N epochs
- **Mixed Precision:** 2-3x speedup with fp16 training

Quick Start Training

1 Load Data

Choose Quick Demo for instant start, or ERA5 for real-world data

2 Select Model

Pick from 30+ architectures or build your own custom model

3 Configure Parameters

Set batch size, learning rate, epochs, and physics constraints

4 Review Cost Estimate

See GPU memory needs, training time, and exact USD cost

5 Start Training

Monitor progress in real-time with live charts and metrics

Model Performance Comparison

Different AI architectures excel at different aspects of weather forecasting. Some prioritize accuracy, others speed. WeatherFlow lets you choose the right balance.

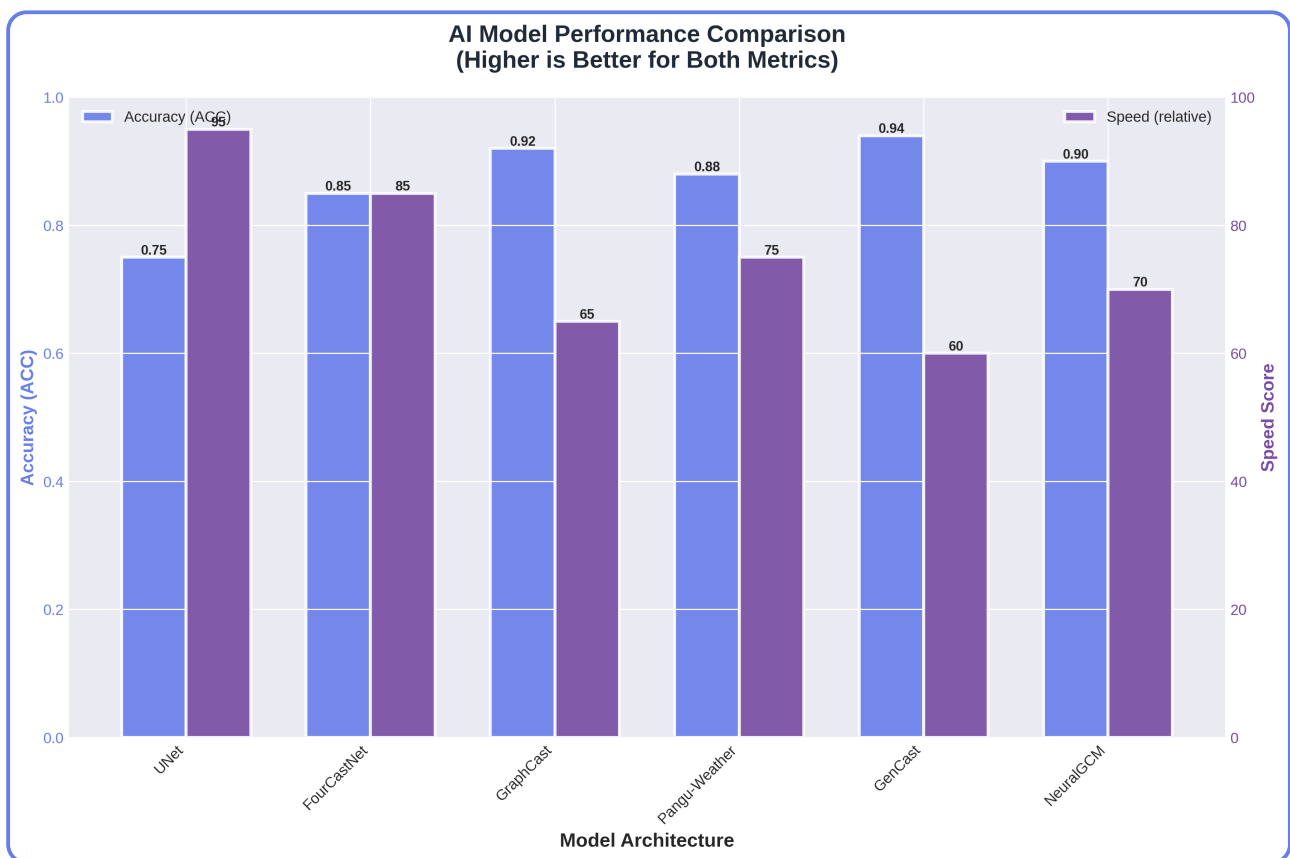


Figure 5: Accuracy vs. Speed Trade-offs for Popular Models

Choosing the Right Model

- **For Maximum Accuracy:** GraphCast, GenCast - State-of-the-art results, longer training
- **For Speed:** UNet, FourCastNet - Fast inference, good for real-time applications
- **For Balance:** Pangu-Weather, NeuralGCM - Great accuracy with reasonable speed
- **For Research:** Flow Matching, Custom models - Experiment with novel approaches

| Model | Organization | Accuracy (ACC) | Speed | Training Time |
|---------------|-----------------|----------------|-----------|---------------|
| GraphCast | Google DeepMind | 0.92 | Medium | Days |
| FourCastNet | NVIDIA | 0.85 | Fast | Hours |
| Pangu-Weather | Huawei | 0.88 | Medium | Hours-Days |
| UNet | Classical | 0.75 | Very Fast | Minutes-Hours |
| GenCast | DeepMind 2024 | 0.94 | Slow | Days |

Applications Across Industries

WeatherFlow is designed for diverse use cases, from scientific research to commercial applications. One platform, unlimited possibilities.



Figure 6: WeatherFlow Applications Across Multiple Industries



Weather Forecasting

Generate 7-day forecasts with professional meteorological visualizations. Perfect for weather services and meteorologists.



Renewable Energy

Forecast wind and solar power generation for energy planning and grid management. Optimize renewable investments.



Climate Research

Run GCM simulations, analyze climate trends, and study atmospheric dynamics. Publish-quality outputs.



Extreme Weather

Detect and analyze heatwaves, atmospheric rivers, and extreme precipitation events for risk assessment.



Education

Learn atmospheric dynamics through interactive lessons and hands-on experiments. Perfect for students and educators.



AI/ML Research

Experiment with novel architectures, run benchmarks, and publish research papers with reproducible results.



Agriculture

Plan crop cycles, predict frost events, and optimize irrigation based on weather forecasts.



Insurance & Risk

Quantify weather-related risks, model claims, and improve actuarial calculations.

Why Choose WeatherFlow?

WeatherFlow is the only platform that combines all these capabilities in one place. See how we compare to alternatives.

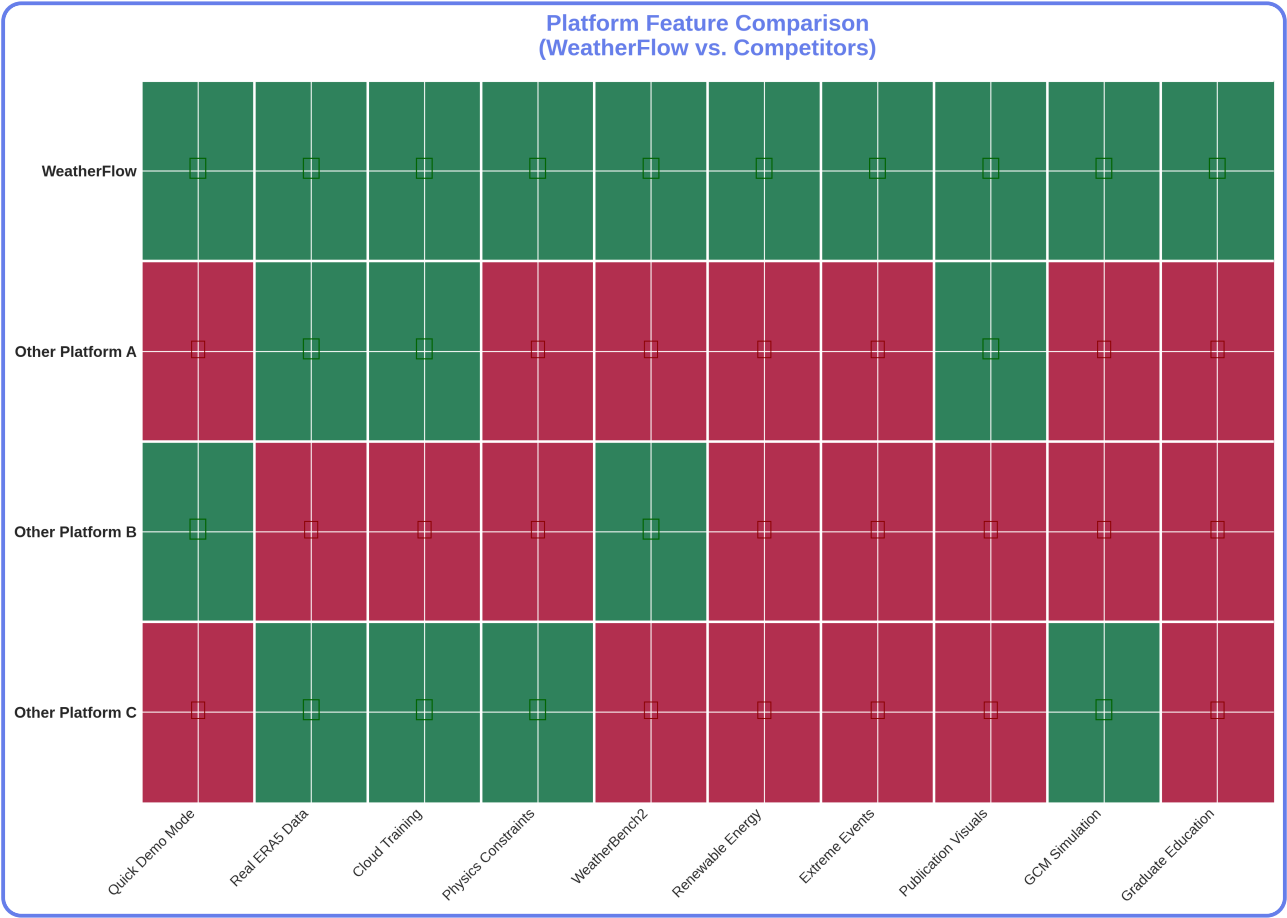


Figure 7: WeatherFlow Feature Comparison Matrix

Industry-Leading Features

WeatherFlow is the ONLY platform that provides:

- ✓ Quick Demo Mode + Real ERA5 Data in one platform
- ✓ Cloud Training with transparent cost estimates
- ✓ Physics-informed loss functions for improved accuracy
- ✓ WeatherBench2 integration for standardized benchmarking
- ✓ Renewable energy forecasting built-in
- ✓ Extreme event detection algorithms
- ✓ Publication-quality visualization tools
- ✓ Full GCM simulation capability
- ✓ Graduate-level atmospheric dynamics education
- ✓ 30+ pre-configured AI model architectures

Cost Transparency

Unlike other platforms that hide costs until you're committed, WeatherFlow shows you **exact GPU costs upfront**. Before starting any cloud training, you'll see:

- GPU memory required (GB)
- Estimated training time (hours)
- Cost per hour by GPU type (T4: \$0.35/hr, A100: \$2.50/hr, H100: \$4.50/hr)
- Total estimated cost in USD

No surprises. No hidden fees. Complete transparency.

Quick Start Guide - Your First Forecast in 5 Minutes

Step-by-Step Tutorial

1 Launch WeatherFlow

Open your terminal and run:

```
cd weatherflow
streamlit run streamlit_app/Home.py
```

Your browser automatically opens to `http://localhost:8501`

2 Load Quick Demo Data

Navigate to  **Data Manager** in the sidebar

Click " **Load Quick Demo Data**"

✓ Success message appears in seconds!

3 Train a Model

Navigate to  **Training Workflow**

Select "**Quick Demo Training**" mode

Click " **Start Training**"

🕒 Completes in 2-5 minutes on CPU

4 Generate Forecast

Navigate to  **Weather Prediction**

Select your trained model

Click "**Generate 7-Day Forecast**"

🎉 Professional weather maps appear instantly!

5

View Dashboard

Navigate to  **Live Dashboard**

See predictions vs. ground truth

Review performance metrics and error statistics



Congratulations! You just completed your first end-to-end weather forecasting workflow using AI. What takes professional meteorologists years to learn, you did in 5 minutes!

Key Features In Detail

1. Data Management



Data Manager - Your Data Hub

Quick Demo Data:

- Instant synthetic weather data generation
- Perfect for learning and testing
- No download required, works offline

Real ERA5 Data:

- 0.25° resolution global reanalysis
- 1940-present historical archive
- Pre-bundled samples: Hurricane Katrina, Heat Waves, Atmospheric Rivers
- Custom downloads with date/region selection

Data Quality:

- Automatic quality control checks
- Statistics and visualization before training
- Efficient zarr format for large datasets

2. Model Training

Training Workflow - From Novice to Expert

Beginner Mode:

- Quick Demo Training: 2-5 minutes on CPU
- Pre-configured parameters
- Instant feedback and results

Advanced Mode:

- Full hyperparameter control
- Physics-informed loss functions
- Multi-GPU distributed training
- Custom model architecture builder

Cloud Training:

- GCP integration (T4, A100, H100 GPUs)
- Exact cost estimates before launch
- Automatic checkpoint synchronization
- Real-time monitoring from anywhere

3. Forecasting & Prediction



Weather Prediction - Professional Forecasts

Forecast Generation:

- 1 to 10-day forecasts (model-dependent)
- Multiple atmospheric variables
- 6-hour, 12-hour, or 24-hour time steps
- Batch mode for multiple dates

Visualizations:

- Professional weather maps with pressure contours
- Wind barbs and arrows
- Temperature and precipitation colors
- Multiple map projections
- GIF animations for presentations

4. Renewable Energy

Wind & Solar Power - Energy Planning Tools

Wind Power Calculator:

- Multiple turbine types (Vestas, GE, Siemens, custom)
- Power curve modeling
- Wind farm configuration
- Capacity factor analysis
- Seasonal pattern visualization

Solar Power Calculator:

- Panel types (mono, poly, thin-film, custom)
- System configuration (tilt, azimuth, tracking)
- Temperature coefficient modeling
- Performance ratio calculation
- Energy yield estimates

5. Model Evaluation



WeatherBench2 Integration - Standardized Benchmarking

Metrics Available:

- RMSE (Root Mean Squared Error)
- ACC (Anomaly Correlation Coefficient)
- MAE (Mean Absolute Error)
- BIAS (Systematic error)
- SEEPS (For precipitation)

Comparison Features:

- Compare to published models (GraphCast, FourCastNet, etc.)
- Regional breakdown (Global, Tropics, Extra-tropics)
- Lead time degradation curves
- Variable-specific performance
- Leaderboard positioning

Advanced Capabilities

Physics-Informed Machine Learning



Physics Loss Functions

Improve model accuracy by incorporating atmospheric physics:

- **Divergence Loss:** Enforces mass conservation ($\nabla \cdot \mathbf{v} \approx 0$)
- **Energy Spectrum Loss:** Matches realistic atmospheric scales
- **Geostrophic Balance:** Physical wind-pressure relationships
- **Potential Vorticity Conservation:** Fundamental dynamics constraints

Toggle these on in the Training Workflow to prevent unphysical predictions!

Climate Modeling



GCM Simulation - General Circulation Model

Run a complete physics-based climate model:

- Configurable resolution (32×16 to 128×64 horizontal)
- 10-26 vertical levels
- Multiple time integration schemes
- CO₂ forcing effects
- Climate diagnostics (Hadley circulation, jet streams)

Educational Value: Compare AI forecasts to traditional numerical weather prediction!

Research Tools



Research Workbench - Build Custom Models

Mix and match components like LEGO blocks:

- **Encoders:** CNN, Vision Transformer, Graph Neural Network
- **Processors:** Transformer, GNN message passing, Recurrent
- **Decoders:** MLP, Transposed CNN, Graph decoder

Perfect for PhD students and researchers exploring novel architectures!

Education Module



Graduate Atmospheric Dynamics

Interactive calculators and lessons:

- Geostrophic wind calculations
- Rossby wave theory
- Potential vorticity analysis
- Thermal wind relationships
- Practice problems with solutions

Learn the physics behind weather forecasting while using AI!

Pro Tips & Best Practices

Getting Started Right

Do's

- Start with demo data to learn the interface
- Use pre-bundled samples before custom downloads
- Always check cost estimates before cloud training
- Save checkpoints frequently during long training runs
- Validate on held-out data (proper train/val/test splits)

Don'ts

- Don't train large models on CPU - use demo mode or GPU
- Don't skip data inspection - always check quality first
- Don't ignore physics losses - they improve generalization
- Don't over-fit - monitor validation loss, use early stopping

Optimization Strategies



Speed Up Training

- **Mixed precision (fp16):** 2-3x speedup on modern GPUs
- **Larger batch sizes:** Better GPU utilization
- **Data caching:** Pre-load to RAM if possible
- **Gradient accumulation:** Simulate large batches on small GPUs



Improve Accuracy

- **More data:** Use longer time periods from ERA5
- **Data augmentation:** Rotations, shifts for robustness
- **Ensemble models:** Average multiple trained models
- **Physics constraints:** Add conservation losses
- **Transfer learning:** Start from pre-trained checkpoints



Storage Tip: ERA5 data is large! A year of global data at 0.25° can be 100+ GB. Use zarr format for efficient access, download only needed variables, and cache preprocessed data.

Start Your Weather AI Journey Today

You now have everything you need to become a weather AI expert!

What You've Learned

- ✓ How to load and work with real weather data (ERA5)
- ✓ Training AI models with 30+ architectures
- ✓ Generating professional weather forecasts
- ✓ Applying weather AI to renewable energy
- ✓ Detecting extreme weather events
- ✓ Benchmarking with WeatherBench2
- ✓ Advanced features: Physics-ML, GCM, Research tools

Next Steps



Your Journey Continues

1. **Experiment:** Try different model architectures and compare
2. **Customize:** Build your own models in the Research Workbench
3. **Publish:** Share your findings with the community
4. **Collaborate:** Join forums and contribute to development



Join the Weather AI Revolution

WeatherFlow puts cutting-edge weather AI in your hands. Whether you're forecasting tomorrow's weather, planning a wind farm, or publishing breakthrough research, you have the tools to succeed.

The future of weather forecasting is here. Let's build it together.

Quick Reference Table

| Task | Page to Visit | Time Required |
|---------------------------|--------------------------------------|---------------|
| Quick demo forecast | Data Manager → Training → Prediction | 5 minutes |
| Train on real ERA5 data | Data Manager → Training Workflow | Hours-Days |
| Wind power estimation | Renewable Energy → Wind Power | Minutes |
| Detect heatwaves | Extreme Events | Minutes |
| Benchmark model | WeatherBench2 Metrics | Minutes-Hours |
| Create publication figure | Visualization Studio | Minutes |

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Built with care for the weather AI community

Start forecasting today!