Summary factsheet: Fundamental concepts of sub-seasonal forecasting

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What is sub-seasonal forecasting?

Sub-seasonal forecasting bridges the gap between short-range weather forecasts and seasonal climate forecasts, combining initial (atmospheric memory) and boundary (slow-varying oceanic influences) condition predictability. Once considered low in predictability, recent research shows some sources of predictability exist, allowing for skilful forecasts. ECMWF's Integrated Forecasting System (IFS) is a leading model, using ensemble forecasts and data assimilation from both the ocean and atmosphere. Sub-seasonal forecasts support decision-making in sectors such as agriculture, disaster preparedness, and water management, and help anticipate deviations from climatology, providing more actionable insights than long-term averages.

Drivers of sub-seasonal predictability

The key drivers of sub-seasonal predictability include the Madden-Julien Oscillation (MJO), stratospheric variability, and land-ocean interactions such as soil moisture, El Niño/La Niña, and the polar vortex. MJO phases strongly influence tropical cyclone activity and rainfall patterns; this factsheet focuses on the MJO.

Sub-seasonal forecasting process

Initialisation: massive observational datasets (satellites, ships, buoys, etc.) define the current atmosphere-ocean state. ECMWF, for example, uses around 60 million quality-controlled observations daily.

Ensemble generation: many forecast versions (e.g. ECMWF uses 101 members) run with varied initial conditions to account for uncertainty.

Model integration: coupled ocean-atmosphere-wave modules run forecasts up to 46 days ahead (e.g. ECMWF's IFS).

Forecast calibration: model biases are corrected by comparing forecast outputs with historical 'hindcasts'.

Tropical Cyclone Fieda — February 2025

This event demonstrated sub-seasonal forecasts in action. Forecasts 10-15 days ahead indicated an MJO in phases 3- but early forecasts underestimated cyclone risk. Later updates showed increased risk.

While MJO forecasts are valuable, they remain imperfect and there are still gaps in understanding and prediction – not all tropical cyclones can be forecast in advance.

Opportunities

- Forecast skill is improving – MJO prediction skill increased significantly between 2015 and 2022.
- Major centres like ECMWF now provide more data, including through AI tools.
- The tropics show higher forecast skill at longer lead times (day 5-7 onwards), offering potential for better cyclone prediction.
- Collaborative platforms such as ACACIA Testbed sessions help share real-time forecasts and refine interpretation.

Challenges

- Forecast skill (accuracy) varies by time and region.
- Interactions between predictability sources (e.g. MJO and El Niño) remain poorly understood.
- Models may not accurately represent these interactions.
- National Meteorological Services face technical barriers to processing large ensemble datasets.

ACACIA is funded by the European Union under Grant Agreement No. 101137847.