

Diagnostic Evaluation of Tropical Cyclone Genesis and Prediction Skill in S2S Models over the North Indian Ocean



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INTRODUCTION & MOTIVATION

- Tropical cyclones (TCs) over the North Indian Ocean (NIO) threaten densely populated coasts of South Asia.
- Subseasonal-to-Seasonal (S2S) forecasts (2 weeks to 2 months) bridge medium-range NWP and seasonal outlooks, offering actionable lead time for preparedness.
- S2S models show limited TC genesis skill beyond Week 1, partly due to constraints in detection algorithms.
- The Vitart & Stockdale (2001) algorithm applies fixed global thresholds (vorticity, warm core, geopotential thickness) to find TC-like vortices.

KEY GAP Are fixed global thresholds suitable for the NIO, with its distinct thermodynamic environment? This has not been evaluated.

OBJECTIVES

- Evaluate S2S model skill in detecting NIO TC genesis (2004–2016) at Week 1 and Week 2 lead times.
- Assess the ± 7 -day temporal window and 500 km spatial buffer for systematic errors.
- Analyse environmental parameters and the suitability of global thresholds for the NIO.

DATA & METHODOLOGY

Table 1 S2S models evaluated in the study. Validation against IBTrACS best tracks and ERA5 ($0.25^\circ \times 0.25^\circ$ resolution)

Model	Version	Forecast (days)	Resolution	Period	Ens.
ECMWF	CY49R1, 2024	0–46	Tco319 L137	2004–2023	11
KMA	GloSea6-GC3.2, 2025	0–60	N216 L85	1993–2016	7
ECCC	GEPS 8, 2024	0–39	0.25°, L85	2001–2020	4

1 Data inputs
S2S models, ERA5, IBTrACS

2 Detection
Vitart & Stockdale (2001) algorithm

3 Validation
 ± 7 -day window and 500 km buffer

4 Structural diagnostics
Environmental parameters

Temporal window
 ± 7 days

Accounts for timing bias around observed genesis

Spatial buffer

500 km

Radius from IBTrACS genesis point; captures position error

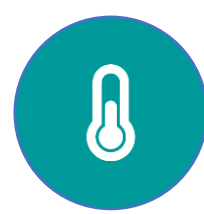
DETECTION ALGORITHM THRESHOLDS



Relative vorticity (850 hPa)

$> 3.5 \times 10^{-5} \text{ s}^{-1}$

Strong cyclonic rotation



Warm-core temperature (500–200 hPa)

$> 0.5^\circ \text{C}$ warmer

Confirmed within 2° of storm centre



Geopotential thickness (200–1000 hPa)

50 m threshold

Indicates deep structural integrity

OBSERVED NIO CYCLONES

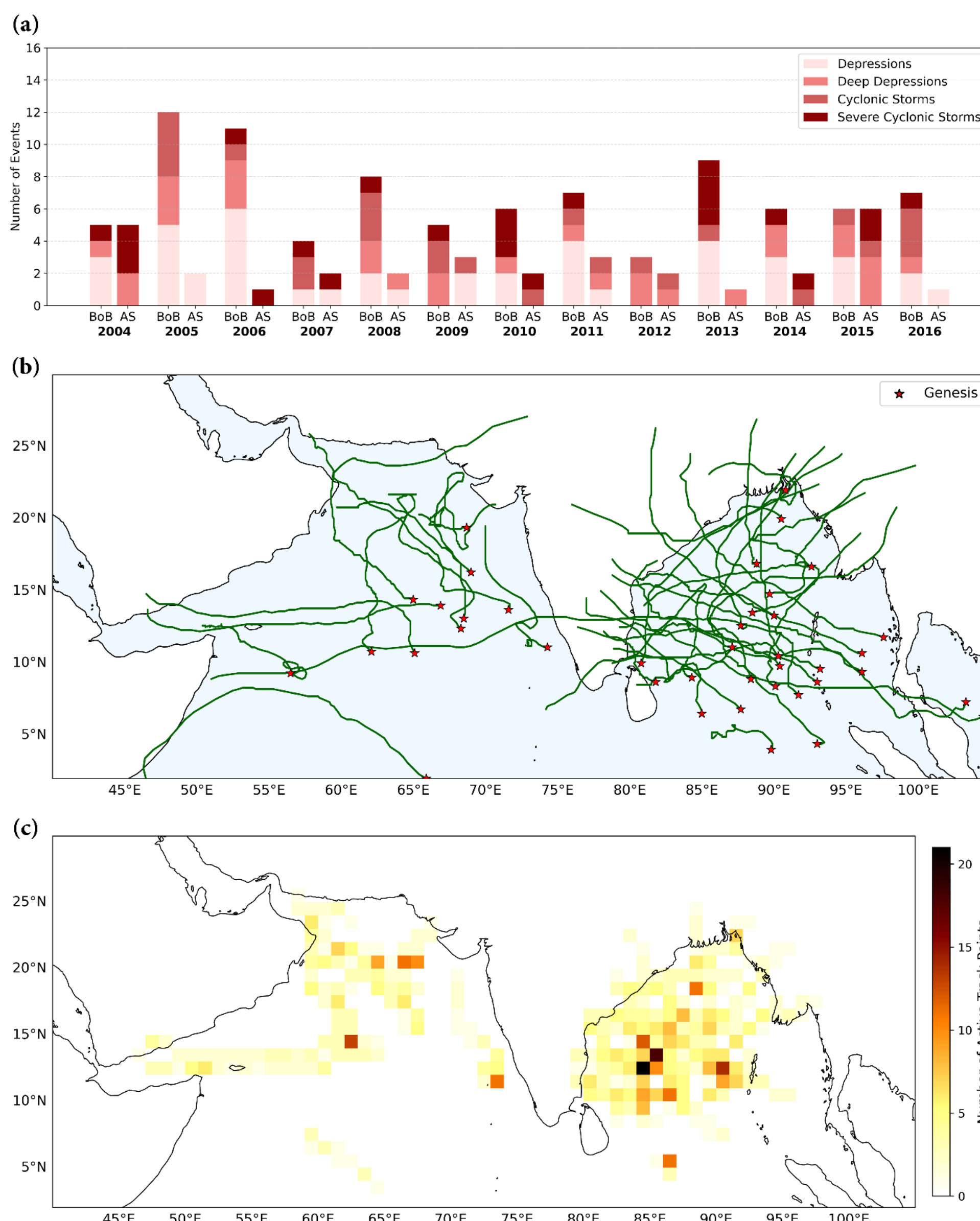


Fig. 1. IBTrACS-based NIO TC climatology (2004–2016): (a) interannual intensity distribution over BoB and AS, (b) genesis points and tracks of 40 observed TCs, and (c) spatial track density over the NIO

DETECTION SKILL

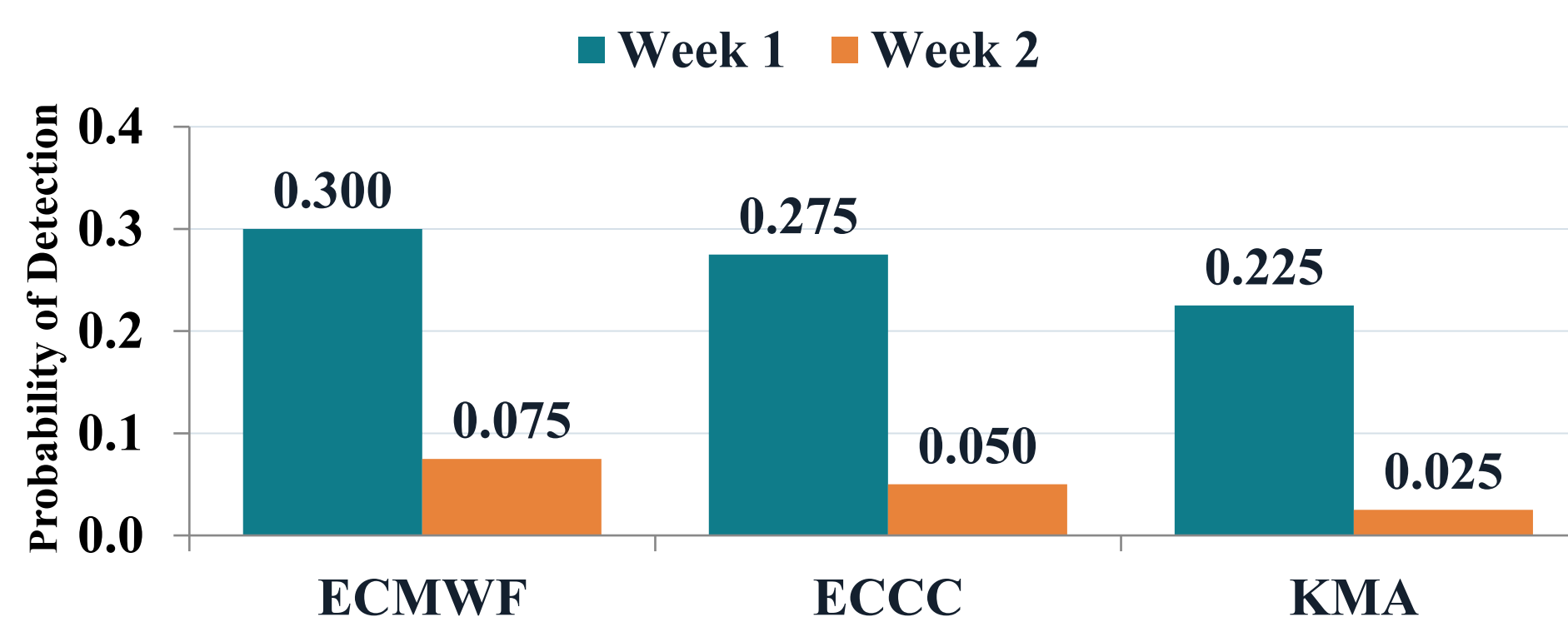


Table 2 Probability of detection for TC genesis across the NIO for S2S models: ECMWF, KMA, and ECCC for W1 and W2 lead times at $4^\circ \times 4^\circ$ grid box

Model	Week	Hits	Misses	POD	Ens. detections
ECMWF	W1	12	28	0.30	27–35
	W2	3	37	0.075	28–33
ECCC	W1	11	29	0.275	24–34
	W2	2	38	0.05	25–32
KMA	W1	9	31	0.225	26–33
	W2	1	39	0.025	24–32

TIMING & SPATIAL MATCHING

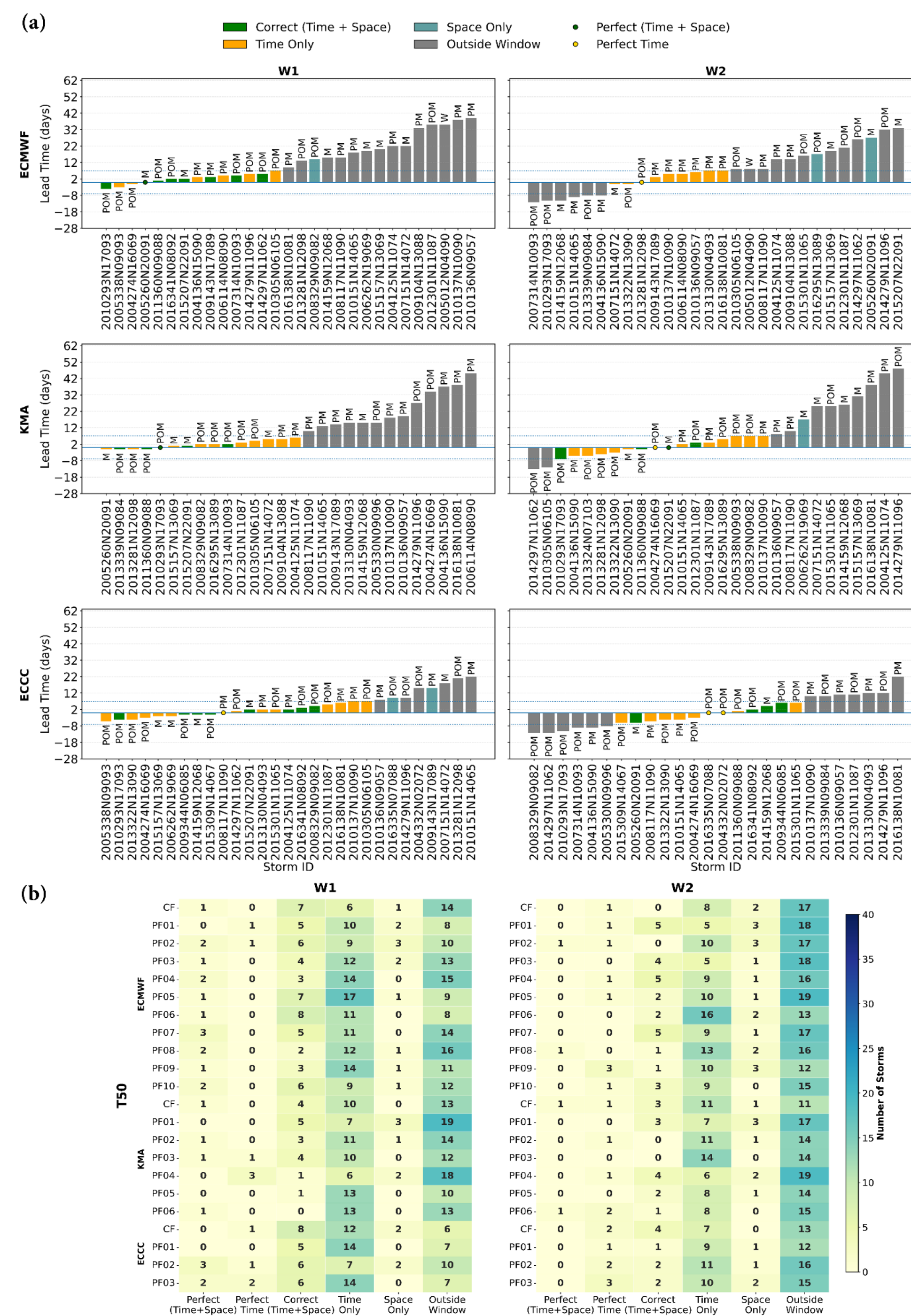


Fig. 2. Seasonal lead-time distribution of S2S-detected TC genesis events (a) and ensemble-wide spatiotemporal storm classification (b) for ECMWF, KMA, and ECCC at W1 and W2

WHY STORMS ARE MISSED

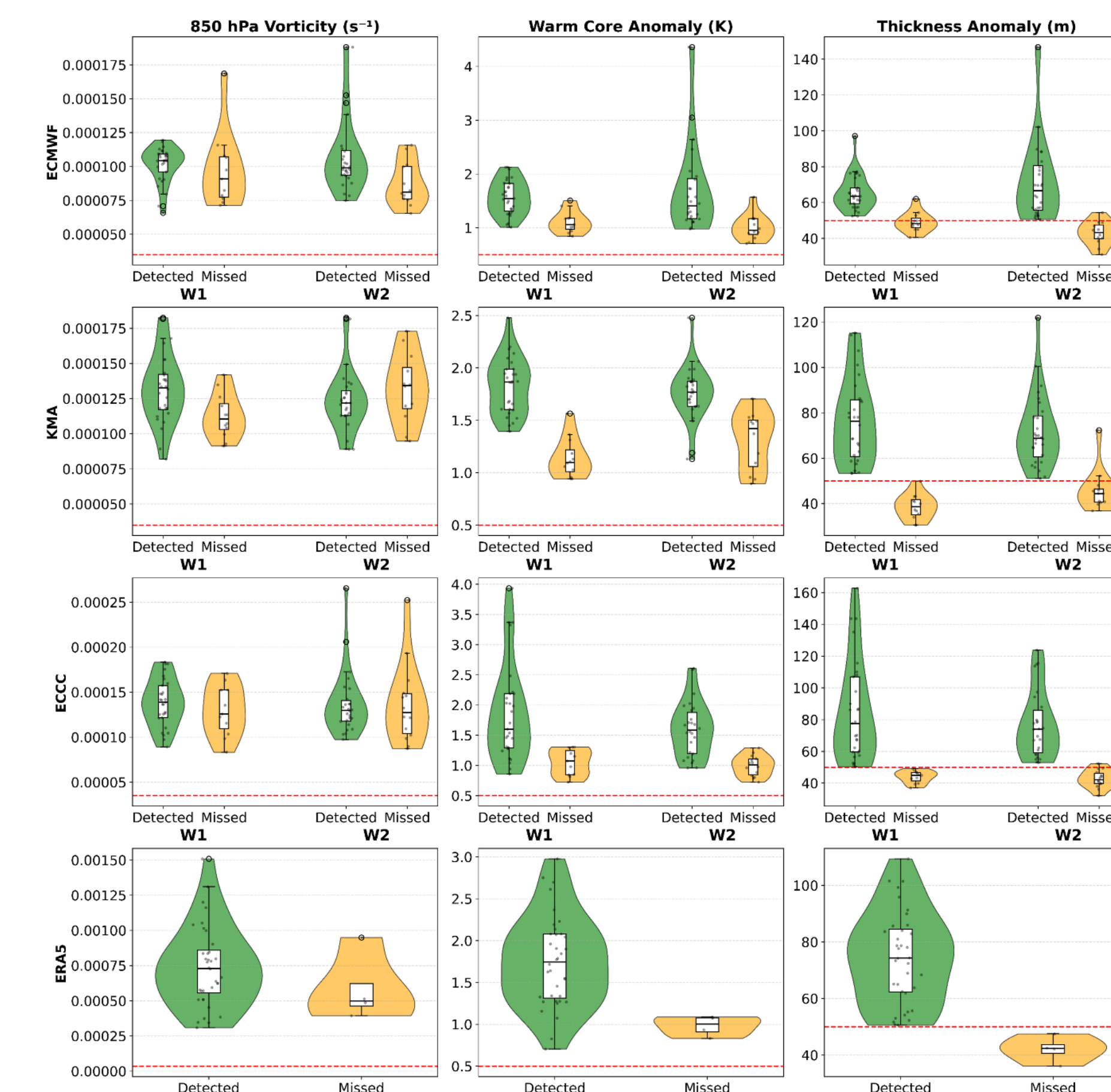


Fig. 3. Statistical distributions of the environmental parameters for detected and missed storms. Red dashed lines mark global thresholds used in the detection algorithm

CONCLUSIONS

- Skill drops sharply after Week 1: ECMWF leads (POD ~ 0.30 vs ~ 0.27 KMA, ~ 0.23 ECCC); all models fall to ≤ 0.075 in Week 2.
- Detection is delayed: Delayed detection tendency across all models, particularly affecting monsoon/post-monsoon seasons
- Fixed global thresholds fit the NIO poorly: Thickness anomaly often fails, even in ERA5; region-specific, flexible thresholds are needed.

References Vitart, F., & Stockdale, T. N.: Seasonal forecasting of tropical storms using coupled GCM integrations, Monthly Weather Review, 129, 2521–2537, 2001.

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