The System for Classification of Low-Pressure Systems (SyCLoPS): An All-in-One Objective Framework for Large-scale Datasets

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PCMDI Earth System Model Evaluation Project

Introduction

In response to the growing need for advanced impacts-relevant model and climate data analysis, objective feature detection has emerged as a key tool for detecting and tracking various meteorological features in large-scale datasets. Among all the features, Low pressure systems (LPSs), or cyclones, receive the most attention due to their potential destructiveness in high winds and extreme precipitation.

In this study, we propose an all-in-one detection and classification framework which we refer to as SyCLoPS. In essence, SyCLoPS combines multiple specialized LPS detectors into a single framework, which has the effect of improving classification performance for individual features through a comprehensive treatment of boundary cases. SyCLoPS is developed atop the TempestExtremes (**TE**; Ullrich & Zarzycki, 2017[a]) software package. It is tuned and subsequently applied to the **ERA5**[b] reanalysis (1979-2022). We demonstrate that SyCLoPS is valuable for investigating various aspects of LPSs in climate data, such as the evolution of a single LPS track, patterns of LPS frequencies, and precipitation or wind influence associated with a particular LPS class.

Key points

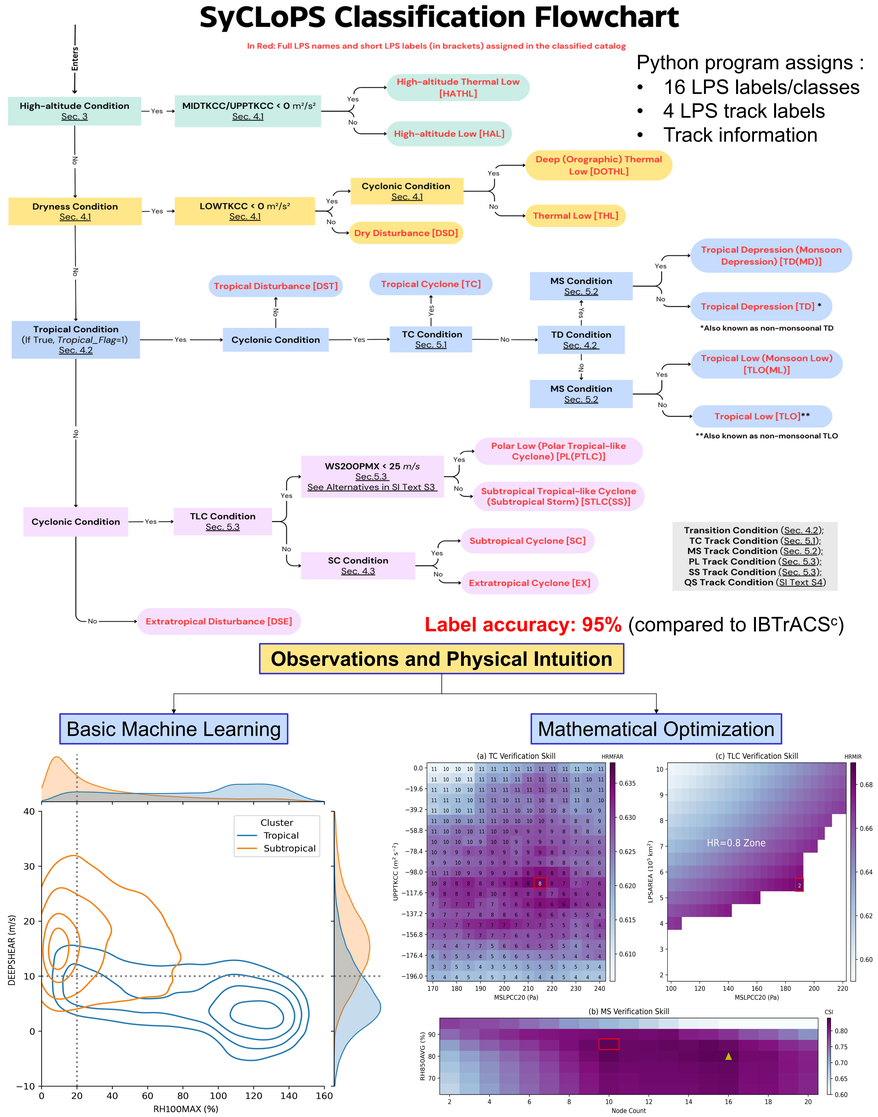
1. **SyCLoPS** is the first all-inclusive low-pressure system (LPS) detection and classification framework for global climate/weather data.
2. **SyCLoPS** substantially extends LPS track lengths while improving tropical cyclone detection skill and maintaining monsoonal system (MS) detection skill.
3. **SyCLoPS** is useful to study the frequency, structure, development, wind impact, and precipitation contribution of each type of LPS.
4. **SyCLoPS** proposes a new way to objectively and physically define tropical and non-tropical systems using 100 hPa level relative humidity and large-scale deep-layer wind shear to address the insufficiency of using warm-core criteria to disentangle tropical systems.
5. **SyCLoPS** features the first global tropical-like cyclone (subtropical storms and polar lows) detection scheme by detecting similar physical features to tropical cyclones among non-tropical system candidates.

Scan to view SyCLoPS paper on JGR-A

Scan to view SyCLoPS manual

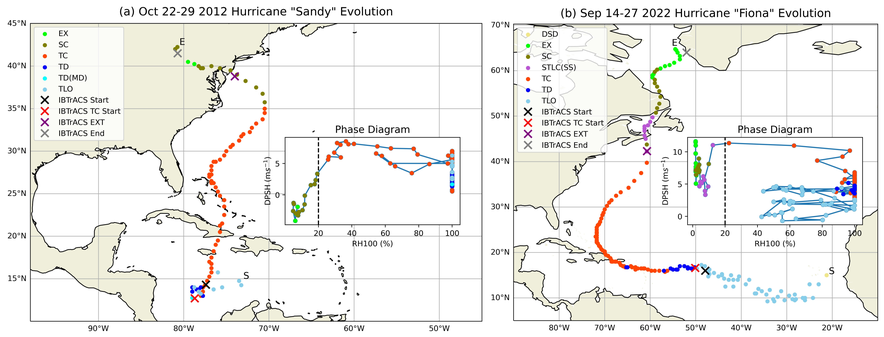
a. Ullrich, P. A. & Zarzycki, C. M. TempestExtremes: a framework for scale-insensitive pointwise feature tracking on unstructured grids. Geosci. Model Dev. 10, 1069–1090 (2017).
b. Hersbach, H. et al. The ERA5 global reanalysis. Quarterly Journal of the Royal Meteorological Society 146, 1999–2049 (2020).

Methods



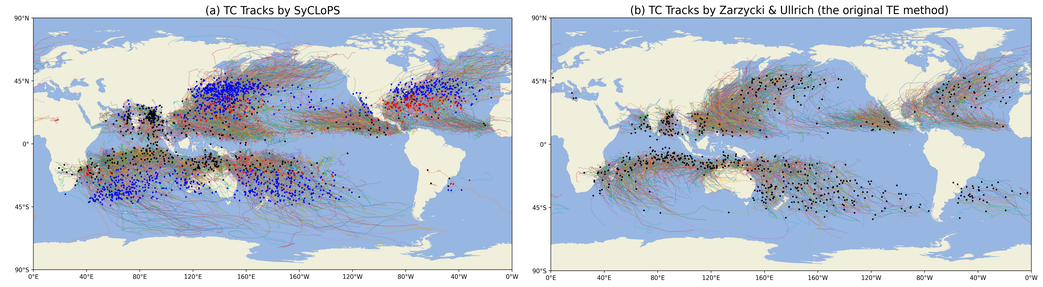
Results & Applications

i. LPS Evolution. Here shows two North Atlantic Tropical Cyclone (TC) cases



c. Knapp, K. R., Kruk, M. C., Levinson, D. H., Diamond, H. J. & Neumann, C. J. The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying Tropical Cyclone Data. Bulletin of the American Meteorological Society 91, 363–376 (2010).

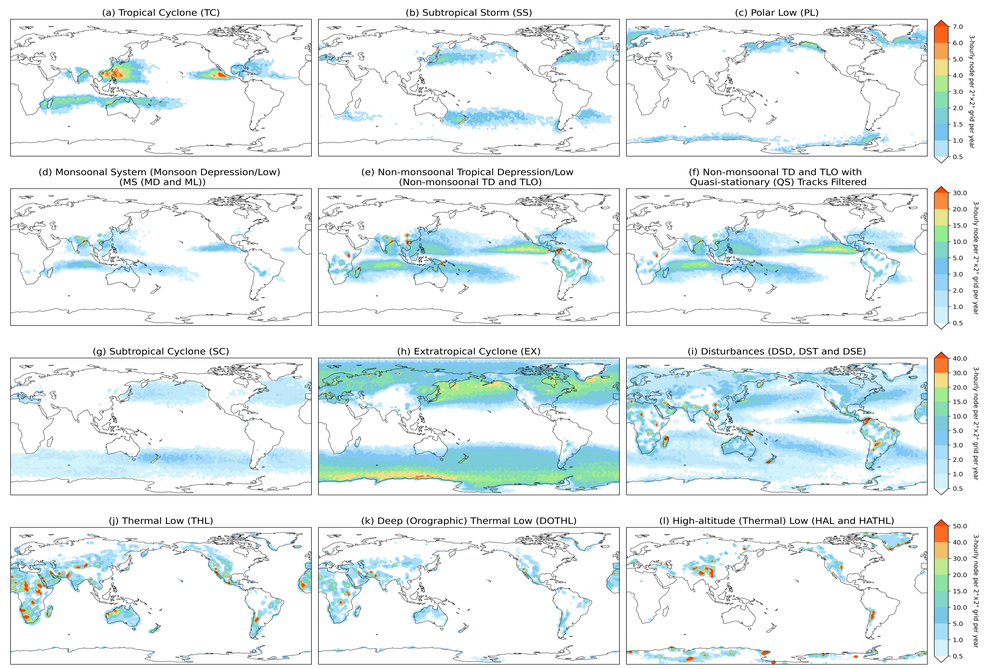
ii. TC Detection: Hit Rate 78.2% (+2% vs Old TE Method); False Alarm Rate: 14.6% (-5.5% vs Old TE Method)



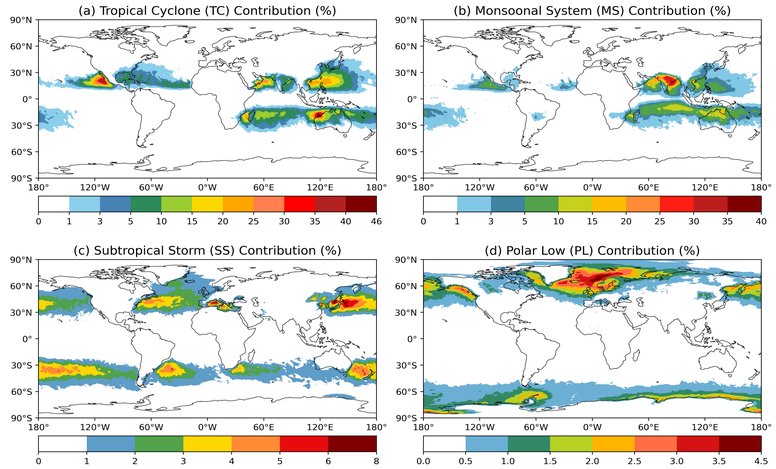
Track length extends on both ends by **136 hours** vs Old TE Method

Blue/Red Dot: Extratropical/Tropical transition point: median (mean) time error: **+6 (10) hours**

iii. 3-hourly LPS Frequencies per year:



iv. Precipitation Contribution by the four types of high-impact LPS (TC, MS, Tropical-like cyclones)



Using the SyCLoPS LPS labels to tag LPS blobs detected in the dataset and derive precipitation (or integrated kinetic energy) associated with a kind of LPS.

LPS precipitation blobs are detected via a cyclonic relative vorticity and precipitation rate threshold near a detected LPS node