**Introduction:**

The land-sea breeze system, a fundamental component of coastal climates, results from the differential heating between land and ocean surfaces. The land-sea breeze system is crucial for regional climate, influencing temperature, humidity, and local weather patterns. Various studies have highlighted its importance (M. Aparna et al., 2005; Chen et al., 2016; Clancy et al., 1979; Davis et al., 2019; Hamza & Babu, 2007; Hill et al., 2010; Kilpatrick et al., 2017; Miller et al., 2003; Pielke, 1973; Rani et al., 2010; Short et al., 2019; Woodson et al., 2007; Zhu et al., 2017). While most research has concentrated on how sea breezes affect inland areas, the impact of land breezes on offshore regions has been less studied, partly due to the scarcity of in-situ data from these areas (Athulya et al.2022). Also the studies often limited to large tropical islands, relied primarily on reanalysis/model outputs, and overlooked the diurnal variation in moist static energy (MSE), crucial for understanding tropical convection dynamics.

**A note on the influence of landmass width and topography on Land sea breeze:**

When two sea breeze systems form on opposite sides of a narrow landmass, the interactions that result when they converge at the center of the landmass are partially determined by the ***width of the landmass*** [Xian and Pielke, 1991]. The thermal forcing over a narrow peninsula or island (width <100 km) is insufficient for developing a deep, well-organized mesoscale circulation, and both sea breeze systems are weak. For landmasses with widths between ***100 and 150 km*** the thermal forcing is strong enough to develop deep systems, and the landmass is still narrow enough so that the two opposite systems converge at the center and produce a region of deep convection. Landmasses >150 km across are too wide for the two opposing systems to reach each other before sunset, and the associated convergence region in the center of the landmass is weakened [Xian and Pielke, 1991]. When the two opposing sea breeze systems reach each other during the evening hours (when the ambient atmosphere is stable), undular bores may result [Clarke, 1984].

Complex terrain, with or without nonzero synoptic-scale flow, may produce several separate sea breeze systems along different portions of the coastline. The appearance of these independent systems may not be simultaneous, and they may not ultimately reach the same intensities. Inland topographic features channel the low-level flow, creating areas of enhanced convergence and upward vertical motion. Upward vertical motion is also enhanced where different sea breeze systems converge at points inland [Melas et al., 1998, 2000].

**Details of the sites and area of Island:**

Two DOE-ARM sites in the near-equatorial western Pacific, Manus (4 m elevation, 2.06°S 147.43°E), and Nauru (7 m elevation, 0.52°S 166.92°E) are represented by white dots. Note that, the area of Manus (2100 km2) and Nauru (21 km2) is much smaller than Sumatra (475,808 km2), Borneo (748,168 km2), and Papua New Guinea (462,840 km2).

Add all the datasets that might be useful.

**Proposed work:**

This study analyzes the composite structure of land-sea breeze and MSE, and explores the most intense individual events. Based on the case studies of various meteorological phenomena including land-sea breeze (Brownlee et al. 2019; Tan et al. 2021) and MJO (Ray et al. 2009; 2010; 2011; Tan et al. 2020, 2022), we will categorize land-sea breeze events into different strength categories and explore how vertical profiles of wind, MSE, humidity, and temperature differ across these categories. To our knowledge, there has been no prior effort in the TWP to use high-frequency datasets to identify the underlying physical mechanisms driving such differences. **This knowledge can be applied to the AI/ML, along with adapting the already established classification systems (synoptic and mesoscale systems) based on Random forest and Neural Network.**

So essentially we need to create a model that learns how to identify the sea-breeze from given conditions and the based on given input conditions

1) There is nothing much to train here. Ideally we need cases of land-sea breezes and the environmental conditions to train the model. The model will understand what a land sea breeze is and using the model to detect land sea breeze in the smaller islands (we don't have that)

2) This is more of a development of an algorithm that combines everything and creates a new index for land-sea breeze.

Another way is to create a land-sea breeze dataset based on this conditions (like we can take larger islands create a dataset by manually checking for land sea breezes) and we can also give this same conditions as constraints to the model and predict the sea-land breeze in smaller islands

**Rough Methodology - Workflow:**

1. Use existing methodology to classify the events over a region (possibly a region large enough + have a vertical profile of wind and related environment conditions)
2. Train the model (with time, spatial aware network; LSTM) using column values/averages/frequencies (we need to find which levels we need) and predict the land sea breeze events
3. The input data should contain the spatial information, this can be done in multiple ways eg;
   1. The spatial topography around the point as a 2D data while all others are as a filled 2D (single value filled over 2D space)
   2. Create/find classifications based on the topography/elevation e.t.c
   3. This also means we have train the model in different terrain structures to effectively capture the spatial information
4. Detect the land-sea breeze conditions for smaller island

| Preliminary Analysis | Just using algorithms | AI/ML techniques |
| --- | --- | --- |
| 1. Plotting the wind direction anomalies. 2. Analyzing the background wind and surface temperatures. 3. Doing a FFT analysis to see the diurnal amplitude. 4. Calculation of SBI index:    1. Using the standard equation (Review paper).    2. Using vertical wind profile alone (proposed index using the insitu point observations) | Another approach for synoptic vs local that might be a consideration relates to clustering algorithms:  Classification of synoptic and local-scale wind patterns using k-means clustering in a Tyrrhenian coastal area (Italy): <https://link.springer.com/article/10.1007/s00703-022-00871-z>  ***Whether algorithms have been built to address sea breezes on a long coast such as the Florida coast vs. islands.*** |  |

Abstract v1.0

**A Deep Learning-based Physics-aware Model for Detecting Land-Sea Breeze over Tropical Islands**

Land-sea breeze circulation is one of the most prominent and well-observed meteorological phenomena in coastal zones. While the land-sea breeze and its influence is well-documented and observable using mesoscale-resolving operational NWP models over larger islands, it is typically much weaker and more challenging to detect over smaller islands due to their limited land mass that are unable to generate strong pressure gradients between land and ocean. We use high-resolution observations from a Department of Energy - Atmospheric Radiation Measurement (DOE-ARM) site on Manus island (1639 square km) in the tropical western Pacific to detect signatures of land-sea breeze circulations. These signatures demonstrate a nonlinear relationship between the land-sea breeze circulations and the spatial structure of the island and surrounding environmental conditions. Leveraging this nonlinear relationship, we develop a spatial-aware deep learning model to detect land-sea breeze circulations. The model is trained over different land structures to detect circulation in the atmosphere, irrespective of the size of the landmass. The work is extended to another DOE-ARM site on Nauru island (21 square km), smaller than Manus, to advance our understanding of the land-sea breeze dynamics.

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