Introducing pyPI: Tropical Cyclone Potential Intensity Calculations in Python



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Description & Motivation

pyPI is a Python package developed to calculate/document tropical cyclone (TC) potential intensity (PI), adapted from the Bister and Emanuel (2002) algorithm.

pyPI Goals:

- Supply a freely available and validated Python PI calculator
- Document the PI algorithm and its Python implementation
- Demonstrate & encourage use of PI theory in TC analyses

What is Potential Intensity?

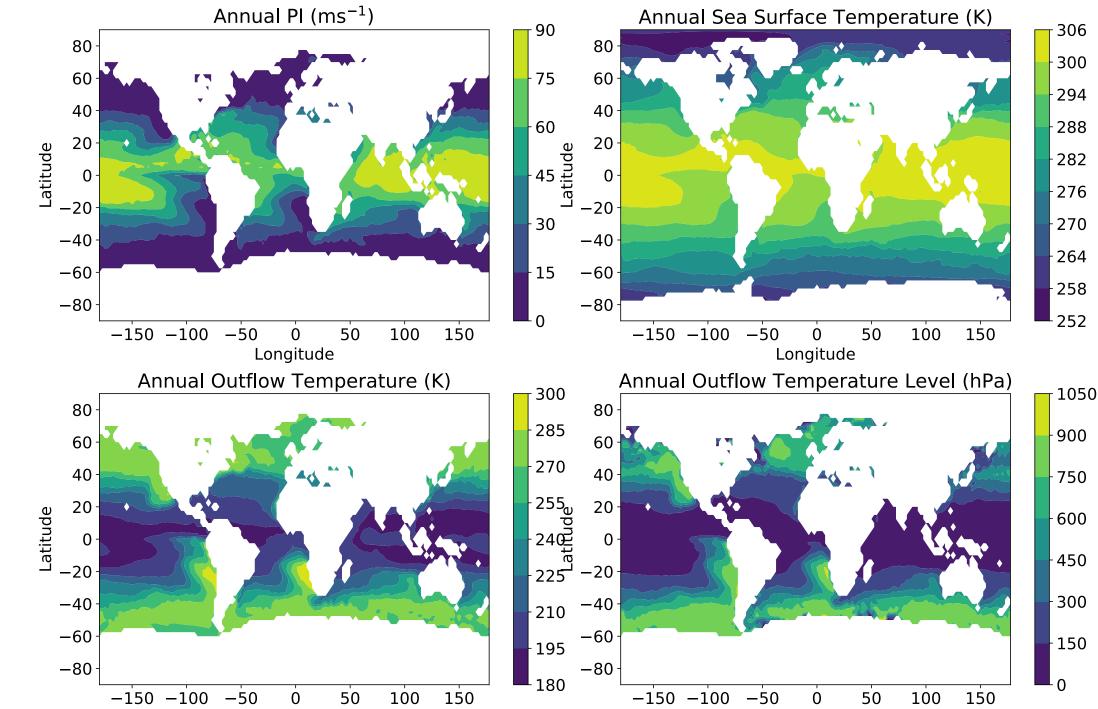
PI is a tropical cyclone's maximum wind speed, found by treating it as a thermal heat engine

Input Profile:

- Temperatures (T) and water vapor mixing ratios (r) on a pressure grid (p)
- Sea surface temperatures (T_s), and mean sea-level pressures (p_{msl})

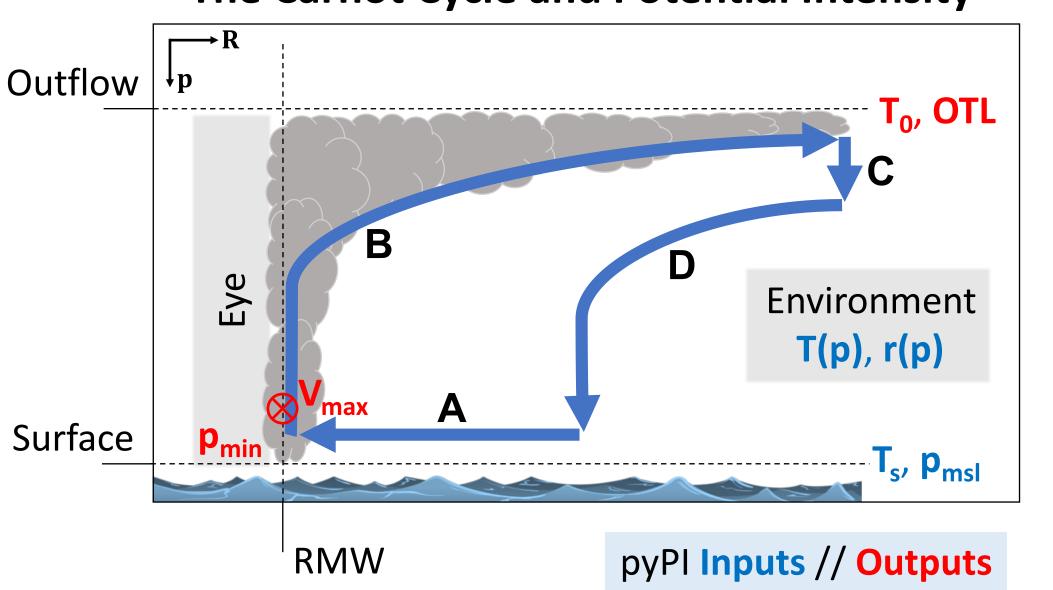
Example pyPI Analyses

2004 Annual Mean Outputs from 2.5° x 2.5° MERRA2 Input Profiles:



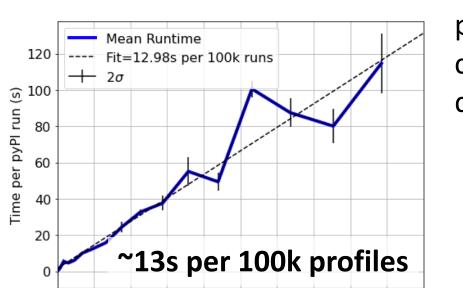
pyPl Outputs:

Potential intensity (V_{max}/p_{min}), outflow temperature (T₀) and level (OTL)



The Carnot Cycle and Potential Intensity

Codebase, Runtime, & Validation



pyPI uses **numba** to optimize PI computations; climatological PI may be computed on gridded data using the **xarray** package

Avg. runtime for one year of monthly 0.25° x 0.25° ERA5 data is ~27 mins.

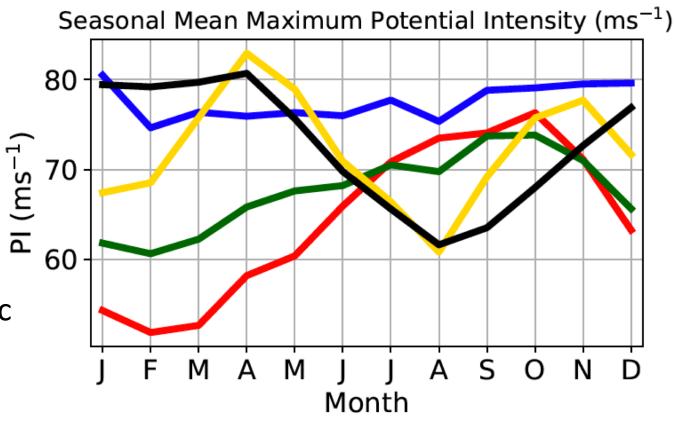
The pyPI Git repository includes the algorithm,

Longitude Longitude

Potential Intensity Seasonal Cycles:

Main Development Regions North Atlantic Western North Pacific Eastern North Pacific North Indian Southern Hemisphere

→ The Western North Pacific seasonal cycle is damped by warm boreal winter tropopause temperatures



see also Gilford et al. (2017)

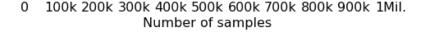
pyPl as a Teaching Tool?

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+ %				
	What is Tropical Cyclone Efficiency?			
	A key principle in treating a tropical cyclone as a thermal heat engine is the thermal maximum efficiency of the engine itself, n, which is given by the second secon	ven hv		
		ven by		
	$\eta = \frac{T_i - T_0}{T_0}$			
	so that the ratio of the sea surface temperature (T_s) and outflow temperature (T_0) is critical important to how efficient the storm is at convenergy from the sea surface into kinetic energy in the form of wind speed.	verting po	otentia	l
	In this notebook we explore the efficiency term by first calculating potential intensity and outflow temperature from ERA5 data, then analy the climatological nature of the efficiency term.	tically ar	nd em	pirically
	Setup			
In [1]:	import sys			
	<pre>sys.path.append(sys.path[0]+'/') import numpy as np</pre>			
	import xarray as xr			
	import matplotlib			
	<pre>import matplotlib.pyplot as plt # load PI calculation module</pre>			
	<pre>import matplotlib.pyplot as plt # load PI calculation module from pyPI import *</pre>			
	<pre>import matplotlib.pyplot as plt # load PI calculation module</pre>			

Combining Jupyter notebooks with pyPI, I am exploring the development of teaching tools for a Meteorology/Climatology course.

One such example can be found in the repository: <u>efficiency.ipynb</u>

Getting Started



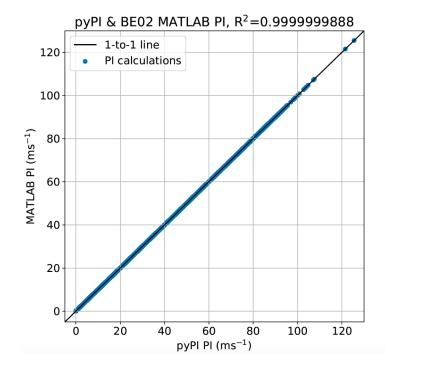
Validation:

utility files, sample run code, and example analyses in Jupyter notebooks

pyPI code improves on the Bister and Emanuel (2002) formulation by fixing minor errors and offering consistent handling of missing data

pyPI still strongly agrees with the original algorithm, R²>0.999...





Requirements and Dependencies

 pyPI requires Python version 3.7+, NumPy 1.18.1, and Numba 0.48.9 to run.

Installation

• Use the Python Package Index from the command line, type

> pip install tcpypi

If you have feedback on this project, please visit the Git repository or <u>email me</u>

Many thanks to Kerry Emanuel for encouragement & support for pyPI; Daniel Rothenberg for numba optimization; Dan Chavas, Jonathan Lin, and Raphael Rousseau-Rizzi for early feedback



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