0:00
My name is Daniel Gilford. I'm a postdoctoral associate at Rutgers University and I'm really excited to share with you pyPI, which is a tropical cyclone potential intensity calculator coded up in Python and now available as a Python package.

0:16
Tropical Cyclone potential intensity is effectively the speed limit that a tropical cyclone can spin at, given its environmental conditions and pyPI is designed to supply a freely available set of codes and algorithms to both calculate potential intensity and do some simple analysis on potential intensity. [The] potential intensity algorithm has been around since about the 1980s, and in 2002, there were sort of a new version of it in Bister and Emanuel (2002). But the code from that which was originally coded in Fortran and then in MATLAB has never been really fully documented, so one of the purposes of this Python package that I developed, was to fully document the potential intensity algorithm, and make it as transparent as possible for users within the tropical cyclone and meteorological communities. I also want to really demonstrate the usefulness and utility of potential intensity as a research tool and pyPI makes that really transparent and I'm excited to share it with you today, as I do, as I sort of show you what it's capable of and what its purpose is.

1:23
So let's just start off with what potential intensity is. It's fundamentally the speed limit of a tropical cyclone when we consider that it is a thermal heat engine. So it takes in energy it does work on the environment and it turns its potential energy into kinetic energy which is represented by the rotation of the wind, the wind speed of the tropical cyclone. And that maximum wind speed is really useful because we can compare it directly to actual intensity of tropical cyclones, and we can see there's a strong significant correlation between those two that is well documented in previous research.

2:01
And so what we can do is we can take environmental conditions, namely the temperature, water vapor, and sea surface temperatures, and also mean sea level pressures from an environmental profile---a single profile or we can take a gridded profile--and we can put those things together to calculate the potential intensity through the potential intensity algorithm. This is really exciting because you can take the potential energies from the environment convert them into kinetic energy you have some maximum speed at which the hurricane can spin, and you can learn a lot about the tropical cyclone that way; it's thermodynamic properties.

2:39
So if you're looking to calculate potential intensity one of the big questions you might ask, using pyPI, is how fast does this algorithm run. In the case of pyPI we are using numba to optimize potential intensity calculations; that's something that my colleague, Daniel Rothenberg helped me to set up within pyPI and I'm really grateful to him for his help, because it really has gotten

the runtime down; so that for climatological research application such as calculating potential intensity for an entire reanalysis grid, it does not take that long. It's about 13,000, or sorry, 13 seconds per 100,000 profiles. And so if you're looking at a quarter by quarter degree global grid of your ERA5 data---monthly ERA5 data---it takes about 27 minutes to run through the entire year. So we have included within the repository the algorithm to calculate potential intensity, some utility files, some sample run code and some example analysis that you can do in Jupyter Notebooks, which I'm going to go through the results of in just a second. One of the things I wanted to sort of impress upon you is how useful this can be from a research application standpoint, so I'll be showing those examples. Another thing I wanted to say is that I compared this directly to the MATLAB code output, and there is a very strong agreement between the two---with one small exception, which is that there was a there was a sort of mistake in the previous MATLAB code with one of the constants and we've updated that here. And so we have an improvement on that particular code.

4:20
Now we can calculate the potential intensity, and I've done so here, with some pretty coarse MERRA2 data for 2004 that I've averaged over the year to get the annual potential intensity across the globe, and that's what you're seeing here in this particular figure. Potential intensity is of course high at the equator where you have warm sea surface temperatures, which is an input to the potential intensity algorithm. You can also look at the outflow temperature which is an output of pyPI and the outflow temperature level, and you can see where there's warmer sea surface temperatures, of course you're going to have more instability in your profile with these warm low to the surface---low and then surface temperatures---and with that greater instability comes higher outflow and a higher level of neutral buoyancy. And the outflow temperatures tend to be colder right up until you hit the cold point tropopause in the tropics. And that's what we're seeing here with these darker colors being right next to the cold point tropopause, you can see the high outflow levels which are, you know, around 100 hectopascals typically in the tropics.

5:29
And one of the things that's interesting is you can take the sea surface temperature, and you can subtract off the outflow temperature and then normalize by the outflow temperature and you get something called the tropical cyclone efficiency, which is just the same as the efficiency of a thermal heat engine in the Carnot cycle. And this tells you a lot about how efficient the hurricane or the tropical cyclone is. And these actually tend to be very efficient tropical cyclones, very efficient things within nature, sometimes operating efficiency near 50%, which is kind of amazing. And this is a really interesting thing to explore from sort of an academic perspective, but it's one example of how we can use pyPI to explore tropical cyclone thermodynamics.

6:15
Another example is that we can look at just the seasonal cycle the of potential intensity, which is something I did in a 2017 paper, and this is a result using pyPI, it compares very favorably

with that earlier work. And one of the things you see if you just compare the red curve here for the North Atlantic to this blue curve for the western North Pacific, is that there's very low potential intensities in the boreal winter in North Atlantic whereas they're quite high in the boreal winter in the western North Pacific. The reason for that is because there's cold outflow temperatures in the western North Pacific, quite cold outflow temperatures in the western North Pacific in the boreal winter, and that drives up the potential intensity because it drives up the tropical cyclone efficiency. And then you get this damped out seasonal cycle that you're getting for the western North Pacific; it’s really interesting because it means that in the boreal winter you can sometimes have tropical cyclones---typhoons---that can spins upwards of 75 meters per second. And indeed we do see high-category five storms sometimes in the February and March months in the tropical Pacific. So this is pretty incredible result, and it's something that pyPI can tell you directly when you're looking at the thermodynamics of these storms.

7:32
Another thing you can do with pyPI, which I have been sort of been doing a cursory exploration of right now, is creating Jupyter Notebooks to use pyPI as a teaching tool in the classroom. So I'm starting to look at developing some of these tools for meteorological or climatological coursework, and I created a Jupyter Notebook here called efficiency.ipynb, which you can, you can visit by following this link, and see how I'm using pyPI to explore the concept of tropical cyclone efficiency. And this is something that I think could be adapted in your work, or your teaching if you're doing that, to look at tropical cyclone thermodynamics. So if that's something you're interested in more, please contact me.

8:20
Now how can you start looking at tropical cyclone potential intensity and doing these calculations yourself on whatever data you have available to you. If you are trying to study intensity of tropical cyclones. Well you can simply just go to your command line and type in “pip install tcpypi”, and you need to make sure you have the required dependencies. You can also use conda to install, I believe. And please contact me if you have any trouble with this.

8:52
Another thing I wanted to note is that the potential intensity algorithm and pyPI as a project has been very carefully documented each step of the way. And I submitted a paper to Geoscientific Model Development last year to look at this. It's currently being revised for publication---you can follow this this QR code to look at that paper---and I really welcome any comments that you have there as well.

9:19
Many thanks to Kerry Emanuel for supporting this project. Daniel Rothenberg for his numba optimization and others who have given me feedback so far. I hope you find pyPI useful. Thank you.

[Recording transcribed by https://otter.ai; lightly edited/formatted for readability/accessibility]