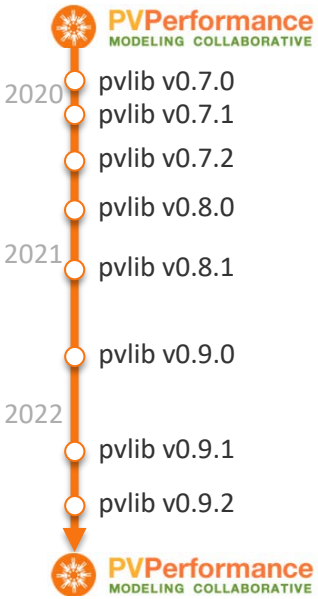



# pvlib python 2022 update

Kevin Anderson (NREL)
Will Holmgren (DNV)
Cliff Hansen (Sandia)
Mark Mikofski (DNV)
Adam R. Jensen (DTU)
Anton Driesse (PV Performance Labs)

PV Performance Modeling and Monitoring Workshop
Salt Lake City, Aug 23, 2022

# Contents

# What is pvlib?

A python library for PV performance modeling that is **community-driven**, **free**, **open-source**, and **well-documented**

## Modeling Toolbox

Stand-alone models for:

| | |
|---|---|
| Atmosphere | Snow |
| Solar position | Soiling |
| Transposition | Shading |
| Bifacial | I-V curves |
| Temperature | Inverters |
| Clear-sky | IAM |

…and more!

## System Energy Yield

Weather-to-power following the PVPMC workflow

Customizable end-to-end PV system modeling (ModelChain)

Completely scriptable and automatable by design

## Data I/O

Batteries-included data import:

| | |
|---|---|
| TMY | SURFRAD |
| EPW | SOLRAD |
| NSRDB | MIDC |
| PVGIS | BSRN |
| CAMS | UO SRML |
| ECMWF MACC | NOAA USCRN |

Online documentation: https://pvlib-python.readthedocs.io

# New models (v0.7.0 – v0.9.2)

## pvlib.bifacial
- infinite_sheds

## pvlib.iam
- martin_ruiz
- martin_ruiz_diffuse
- marion_diffuse

## pvlib.temperature
- faiman
- fuentes
- ross
- noct_sam
- prilliman transient model

## pvlib.snow
- Marion model

## pvlib.soiling
- Kimber model
- Humboldt State model

## pvlib.shading
- sky_diffuse_passias

## pvlib.inverter
- fit_sandia
- sandia_multi
- pvwatts_multi

## pvlib.ivtools
- fit_sde_sandia
- fit_sdm_cec_sam
- fit_sdm_desoto
- fit_pvsyst_sandia
- fit_desoto_sandia

## pvlib.spectrum
- spectrl2

## pvlib.scaling
- Wavelet variability model

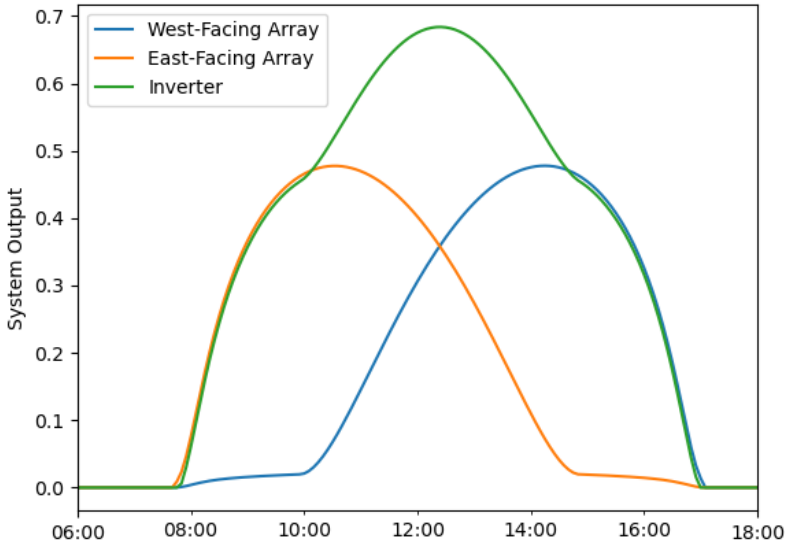
## pvlib.tracking
- slope-aware backtracking

Full details: https://pvlib-python.readthedocs.io/en/stable/whatsnew.html

# ModelChain: Multi-Array Systems (v0.9.0)

Major refactor for non-homogeneous systems, e.g.:

- **Different subarray orientations**:
  - Multiple orientations (e.g. rooftop)
  - Part tracking, part fixed-tilt
- **Different subarray electrical properties**:
  - e.g. part 300W, part 305W
- **New classes**:
  - Array
  - FixedMount, SingleAxisTrackerMount




Thanks to Will Vining!
https://github.com/wfvining

# Google Summer of Code 2021: pvlib.iotools

GSoC project adding data import for:

- **BSRN**: global ground station network (WRMC)
- **CAMS**: satellite-based irradiance
- **McClear**: satellite-based clear-sky irradiance
- **PVGIS**: various satellite/reanalysis data

- **MERRA2**: reanalysis weather (NASA)
- **ERA5**: reanalysis weather (ECMWF)

Thanks to Adam Jensen!
https://github.com/adamrjensen/

Google Summer of Code

- Participants work with an open-source organization on a 10 week programming project
- Good fit for students, but any open-source beginner can apply
- https://summerofcode.withgoogle.com/
- Get in touch for 2023!

# Other Code Changes (v0.7.0 – v0.9.2)

- pvlib.forecast was deprecated in v0.9.1
  - To be removed altogether in some future release

- Partial model reorg by modeling topic
  - pvlib.iam, pvlib.inverter, etc

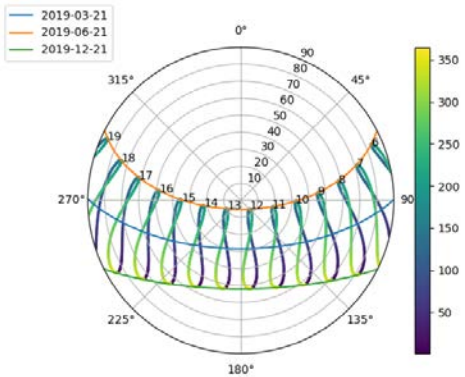
- Consistency improvements, especially in pvlib.iotools

… and many other enhancements and bug fixes

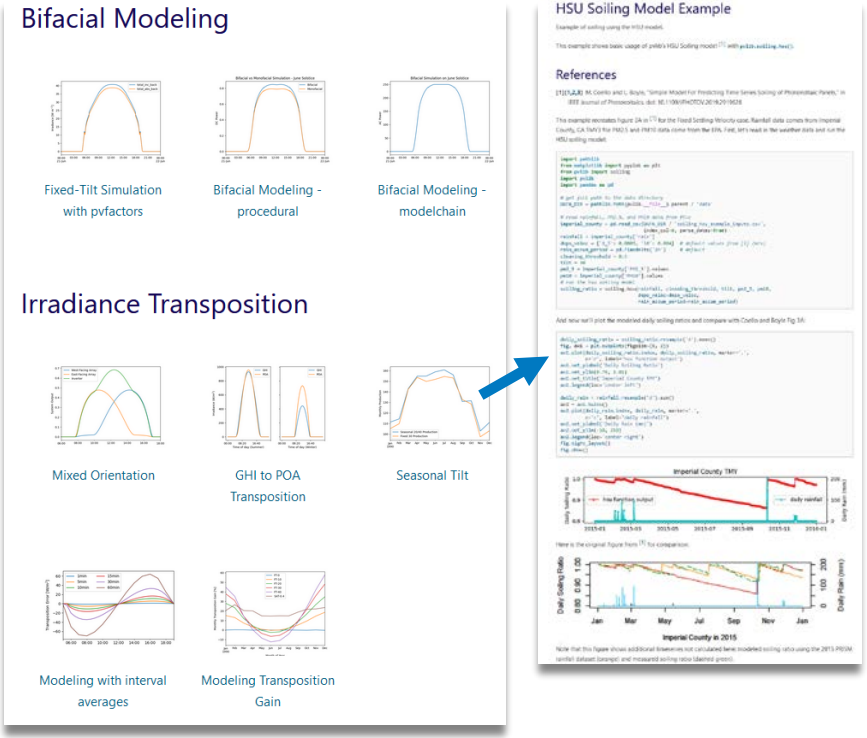
Full details: https://pvlib-python.readthedocs.io/en/stable/whatsnew.html

# Documentation: Example Gallery

pvlib “cookbook” -- small self-contained scripts for various modeling tasks, intended as a starting point for your own code.




Wanna make cool plots like this one?
Go check out the example gallery!



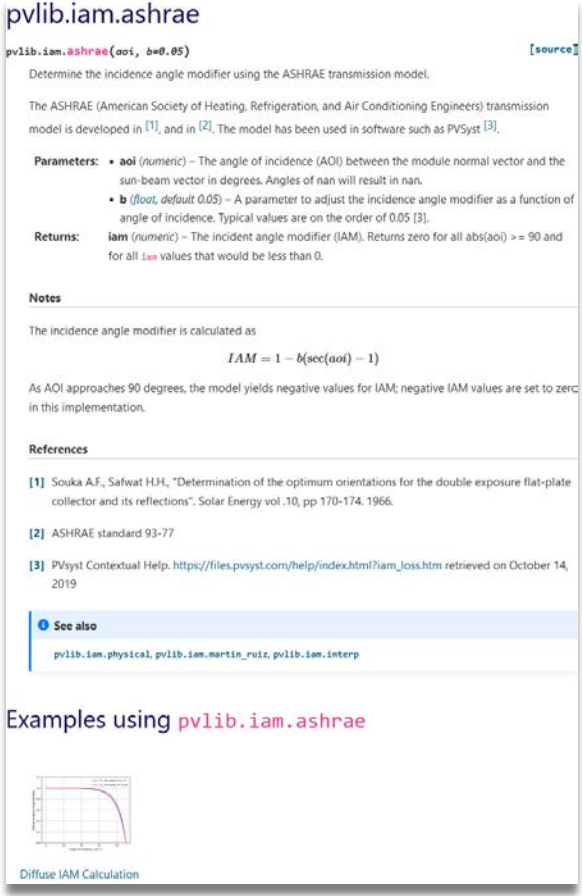

https://pvlib-python.readthedocs.io/en/stable/gallery/index.html

# Documentation: Model Descriptions

Each model function has a page with:

- Brief model description
- Inputs: description, data types, units
- Outputs: description, date types, units
- Published reference(s) for the model
- Links to other relevant functions
- Links to relevant gallery examples
- Other notes as needed

Several hundred model-level pages, all built automatically from in-code documentation!



## pvlib.iam.ashrae

pvlib.iam.ashrae(aoi, b=0.05) [source]

Determine the incidence angle modifier using the ASHRAE transmission model.

The ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers) transmission model is developed in [1], and in [2]. The model has been used in software such as PVSyst [3].

**Parameters:**
- **aoi** (*numeric*) – The angle of incidence (AOI) between the module normal vector and the sun-beam vector in degrees. Angles of nan will result in nan.
- **b** (*float, default 0.05*) – A parameter to adjust the incidence angle modifier as a function of angle of incidence. Typical values are on the order of 0.05 [3].

**Returns:** **iam** (*numeric*) – The incident angle modifier (IAM). Returns zero for all abs(aoi) >= 90 and for all iam values that would be less than 0.

**Notes**

The incidence angle modifier is calculated as

$$IAM = 1 - b(\sec(aoi) - 1)$$

As AOI approaches 90 degrees, the model yields negative values for IAM; negative IAM values are set to zero in this implementation.

**References**

[1] Souka A.F., Safwat H.H., "Determination of the optimum orientations for the double exposure flat-plate collector and its reflections". Solar Energy vol .10, pp 170-174. 1966.

[2] ASHRAE standard 93-77

[3] PVsyst Contextual Help. https://files.pvsyst.com/help/index.html?iam_loss.htm retrieved on October 14, 2019

**See also**

pvlib.iam.physical, pvlib.iam.martin_ruiz, pvlib.iam.interp

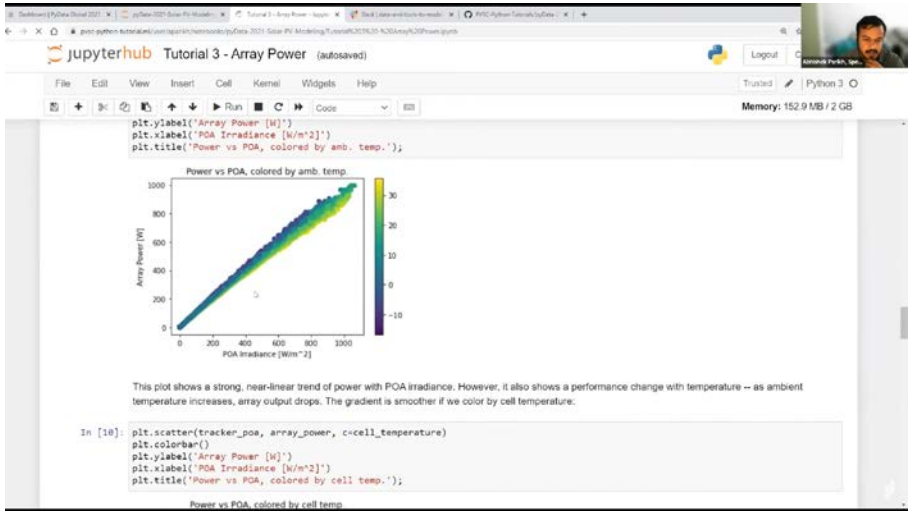
## Examples using pvlib.iam.ashrae

Diffuse IAM Calculation

# Documentation: Tutorials

Interactive tutorials for PV system performance:
- Modeling concepts
- Implementation in pvlib
- Previous tutorials at PVSC and PyData Global

The next one is here, tomorrow afternoon!
Led by Silvana Ovaitt, don't miss it!



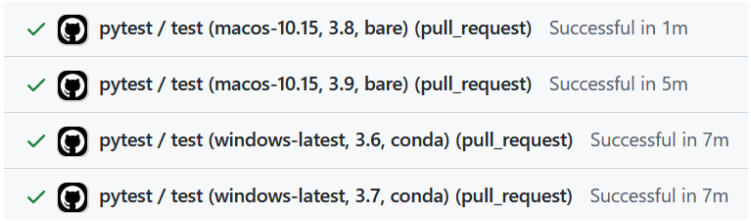

**PVSC 2021**
Source material: https://github.com/PVSC-Python-Tutorials/PVSC48-Python-Tutorial

**PyData Global 2021**
Youtube recording: https://www.youtube.com/watch?v=sweUakFg3I8
Source material: https://github.com/PVSC-Python-Tutorials/pyData-2021-Solar-PV-Modeling

# Automated Testing

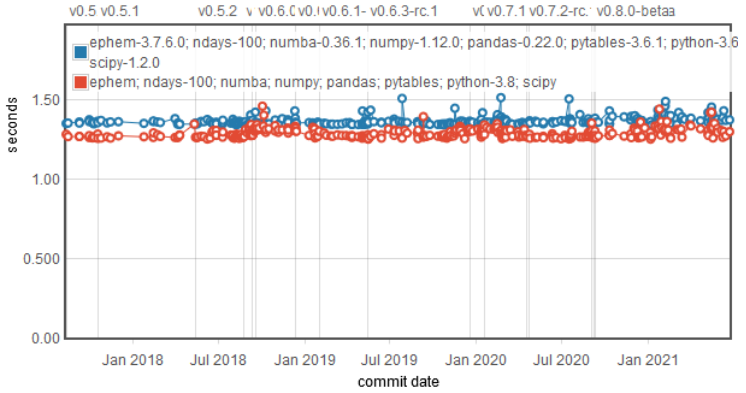
## Correctness Testing

- Comprehensive coverage of the entire package
- Essential to avoid accidentally introducing bugs in development
- pvlib has >10k LOC for testing alone


## Speed Benchmarks

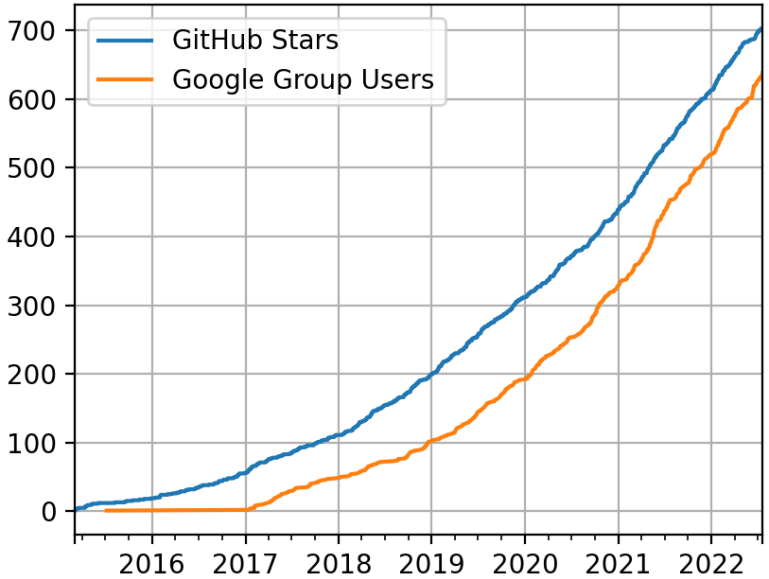
- Monitor execution speed of test cases to detect performance regressions over time
- Uses airspeed velocity (asv): https://asv.readthedocs.io
- Benchmark Results:
  - https://pvlib-benchmarker.github.io/pvlib-benchmarks/



# Community Growth

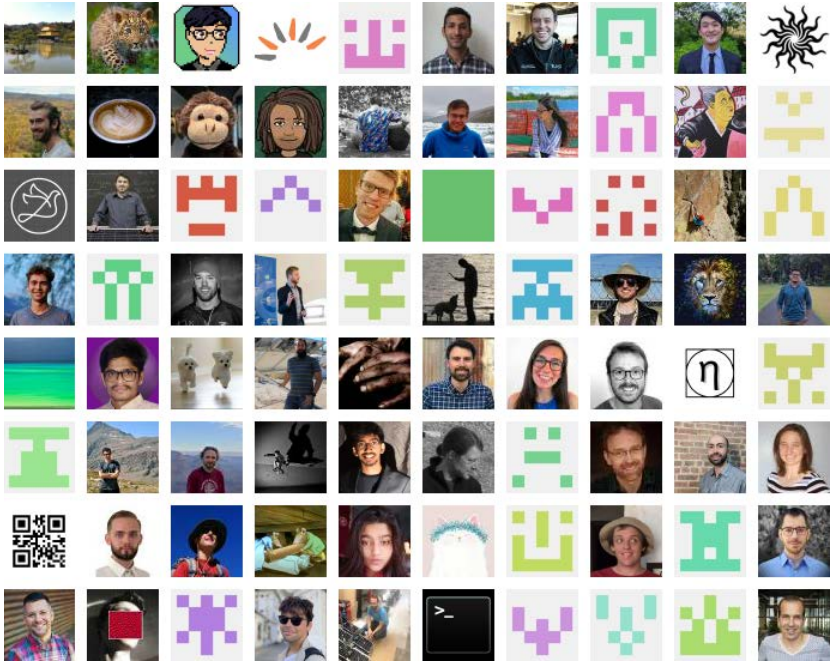
**Google Group** (user discussion, announcements)
- 650+ members
- Roughly quadrupled since 2019 workshop
- https://groups.google.com/g/pvlib-python

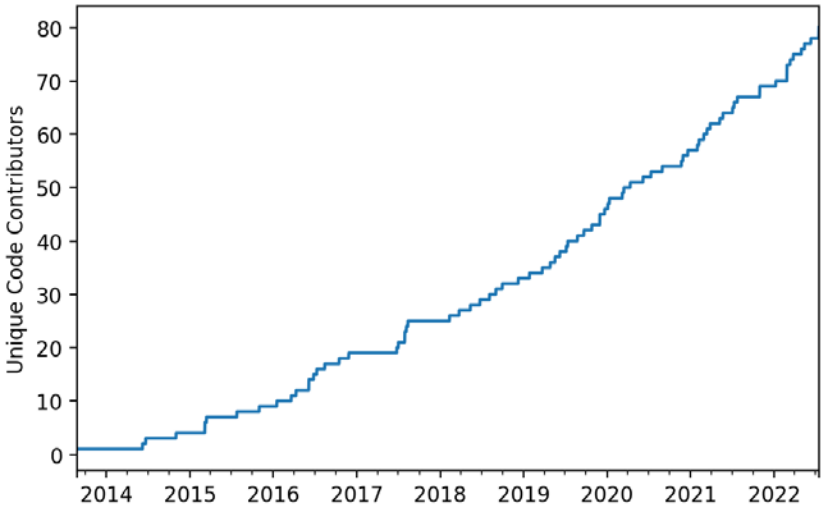
**GitHub** (code development)
- 700+ pull requests
- Code contributions from 80+ people
- https://github.com/pvlib/pvlib-python




Numbers as of 2022-07-20

# GitHub Contributors






*Not all contributions are code!

**This software is made possible by contributions from people like you. You can help!**

https://pvlib-python.readthedocs.io/en/stable/contributing.html

# pvlib 1.0?

## Does 1.0.0 come right after 0.9.*?

- No. Expect 0.10.0 to come next. There is no ETA for pvlib 1.0.0 yet ☺

## What does 1.0 mean?

- A declaration that pvlib is no longer “beta” (whatever that means)
- Mostly, no more changes that break people’s code (until 2.0, anyway)

## What needs to happen before 1.0?

- Change all the things we want to change:
  - Package-wide consistency in naming (mostly there already, but still room for improvement)
- Fill in some modeling gaps: transformer losses, direct shading, etc
- Rewrite/reorg the docs to follow an intentional strategy instead of the current ad-hoc “pile of info”
- **What else? We’d love to get your feedback!** Come to the pvlib user discussion tomorrow, 3pm



# Thank You

www.github.com/pvlib/pvlib-python
https://pvlib-python.readthedocs.io

NREL/PR-5K00-83420

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