psf-weather-station:

realistic inputs to atmospheric PSF simulations

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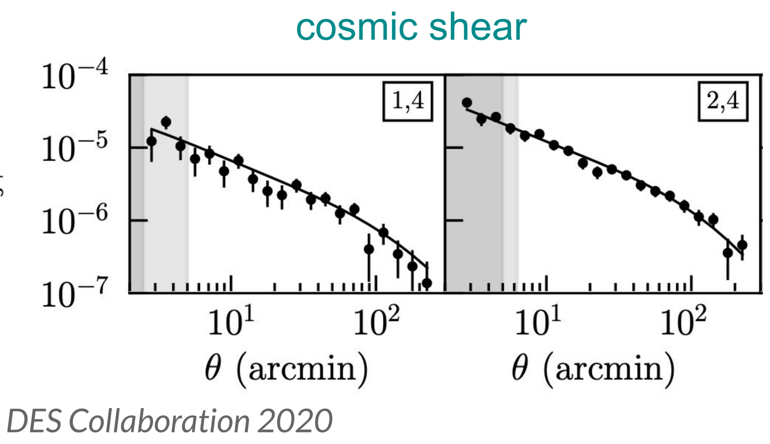
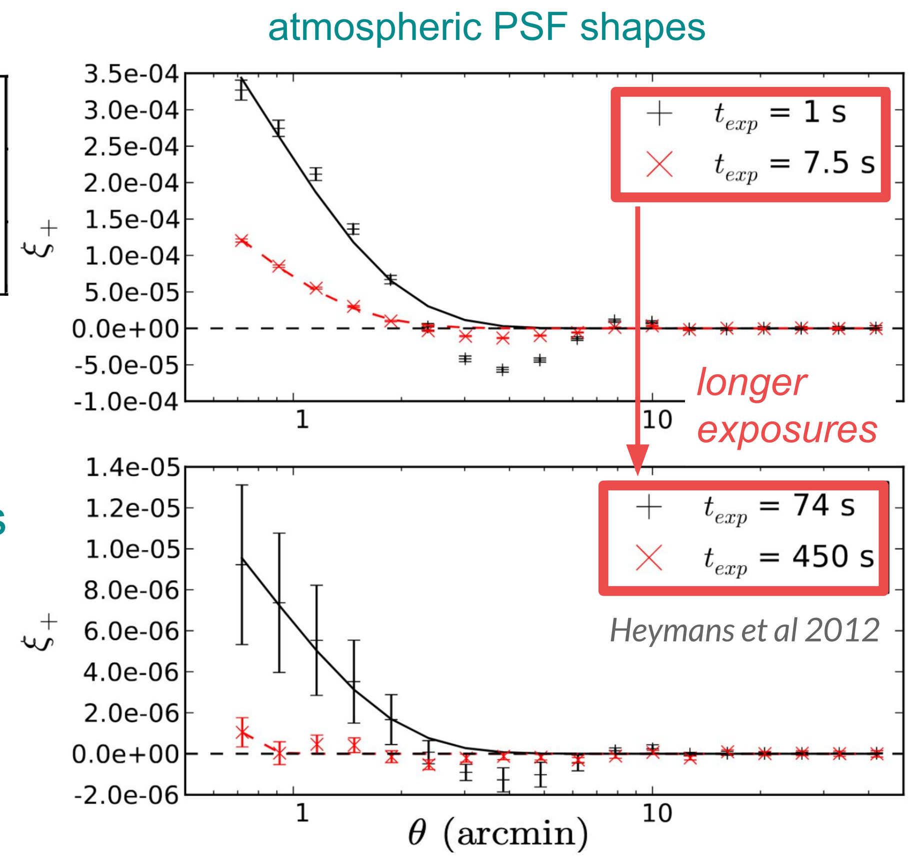
Correlations in the Rubin PSF

- A point-spread function (PSF) determines how light from a point source will spread when imaged through an atmosphere and instrument.
- The atmospheric component of a PSF is *spatially correlated*; magnitude of PSF shape correlations are significant when compared to correlations in observed galaxy shapes (cosmic shear signal).





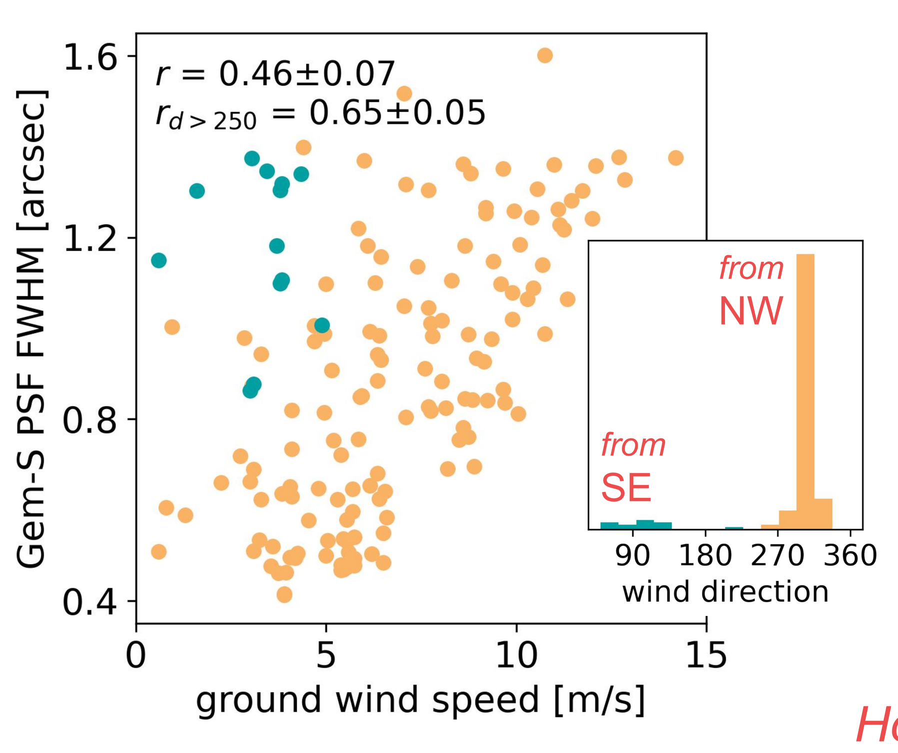
Up: Cosmic shear measurements from the Dark Energy Survey

Right: measurements of PSF shape correlations from CFHT

Note different range on the x-axes

- Due to persistent weather conditions, spatial correlations in the PSF are themselves likely to be *temporally correlated*.
- For accurate and unbiased weak lensing measurements, PSF modeling and correction algorithms must be robust to both of these correlations.
- This poster presents a work-in-progress test of current PSF modeling algorithms (e.g. PIFF) and leverages knowledge of Rubin's environment.

Telescope environment



- Data from Gemini-South (<2km from Rubin):
  - Weather tower wind measurements
  - 30-sec PSFs extracted from Zorro speckle imager data
- Very dominant wind direction
- Possible correlation between speeds, directions, and seeing

How will this affect the PSF at Rubin?

Atmospheric PSF simulations

- Approximate turbulent layers as von Kármán phase screens.
- Screens drift across the field of view during a simulated exposure.
- Photons accrue phase changes as they travel through these screens, resulting in nonuniform wavefronts at the aperture.

Input environmental parameters:

- Turbulence profile
- Number of screens
- Phase screen altitudes
- Wind velocities
- Outer scale L_0
- Fried parameter r_0

How do we choose representative values for these parameters?

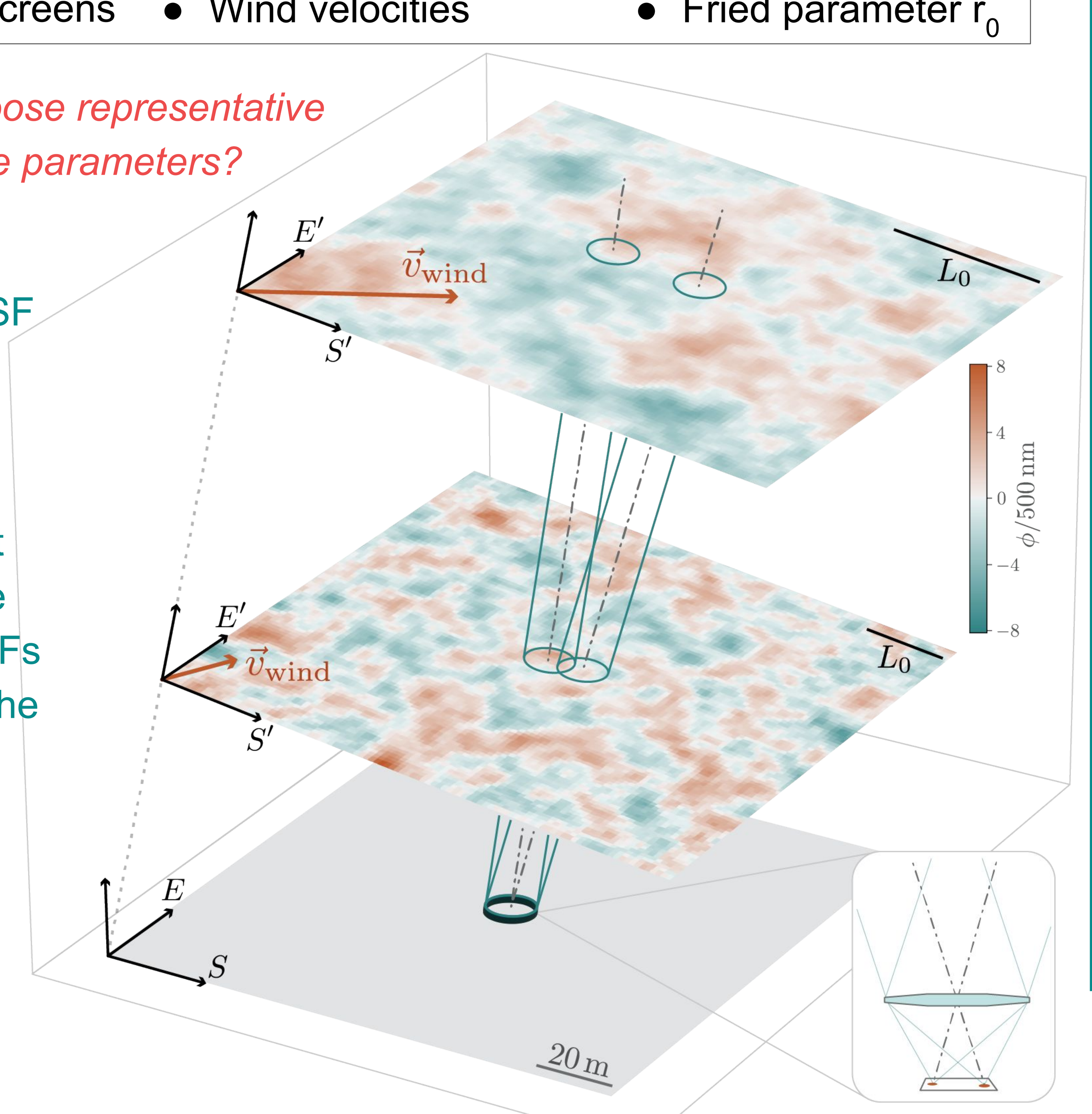


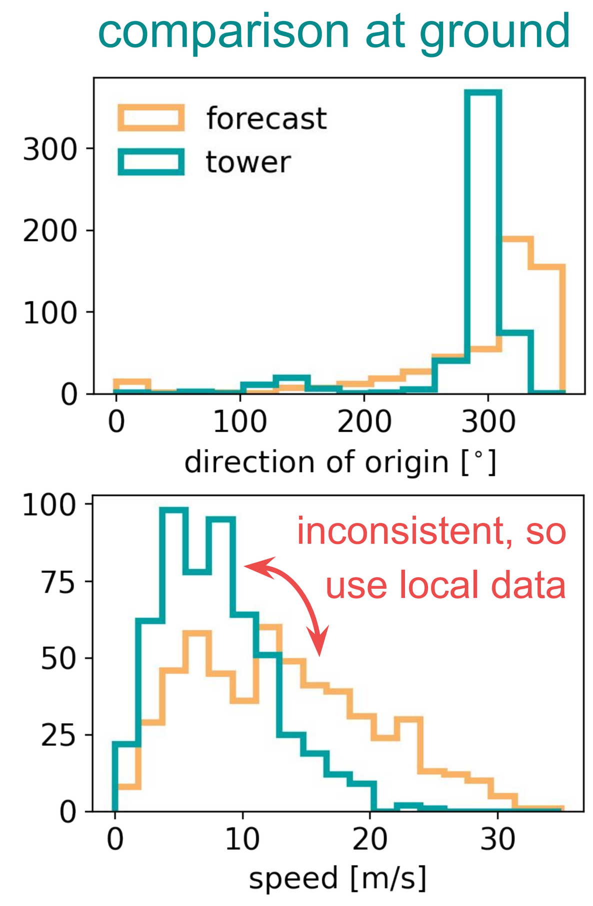
Illustration of atmospheric PSF simulation with two phase screens.

Columns depict the atmosphere sampled by PSFs on extrema of the FoV.

E'-S' plane is orthogonal to telescope axis.

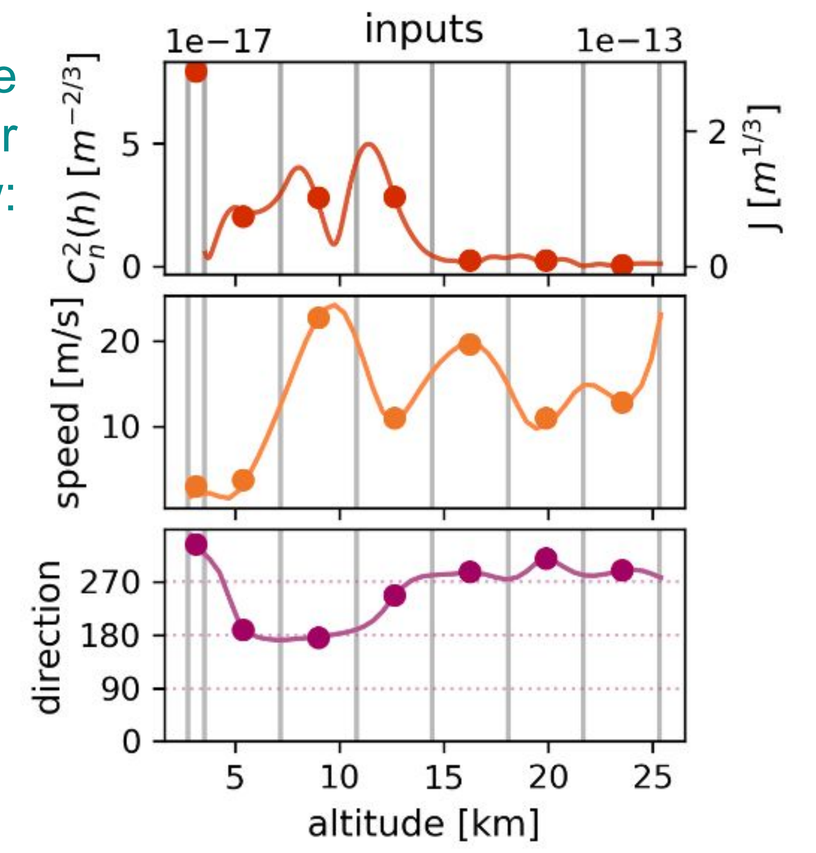
psf-weather-station

A data-driven software package that delivers environmental input parameters for realistic atmospheric PSF simulations.

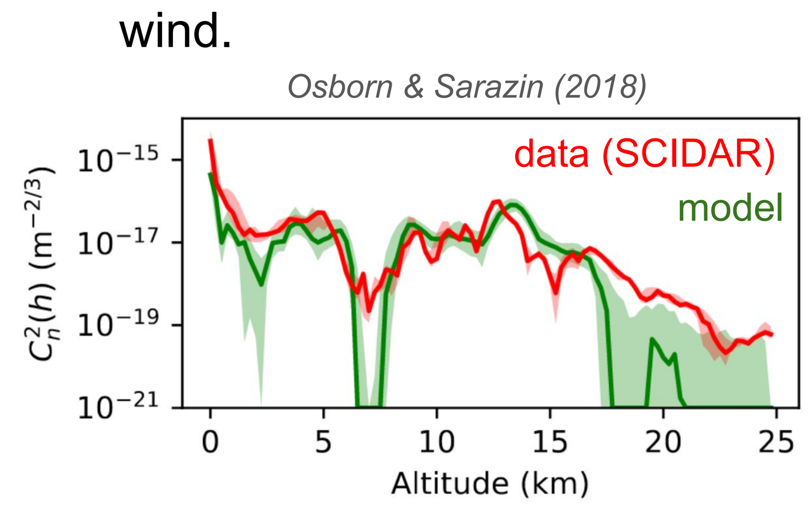


- Data sources (configurable):
  - **Weather forecasts**: analysis datasets from European Center for Medium-range Weather Forecasting (ECMWF).
  - **Local wind data**: weather tower at Gemini-S.
  - Log-normal distributions of **ground and upper atmosphere seeing**: parameters from Tokovinin et al 2004, fit to MASS/DIMM data.

Example parameter draw:



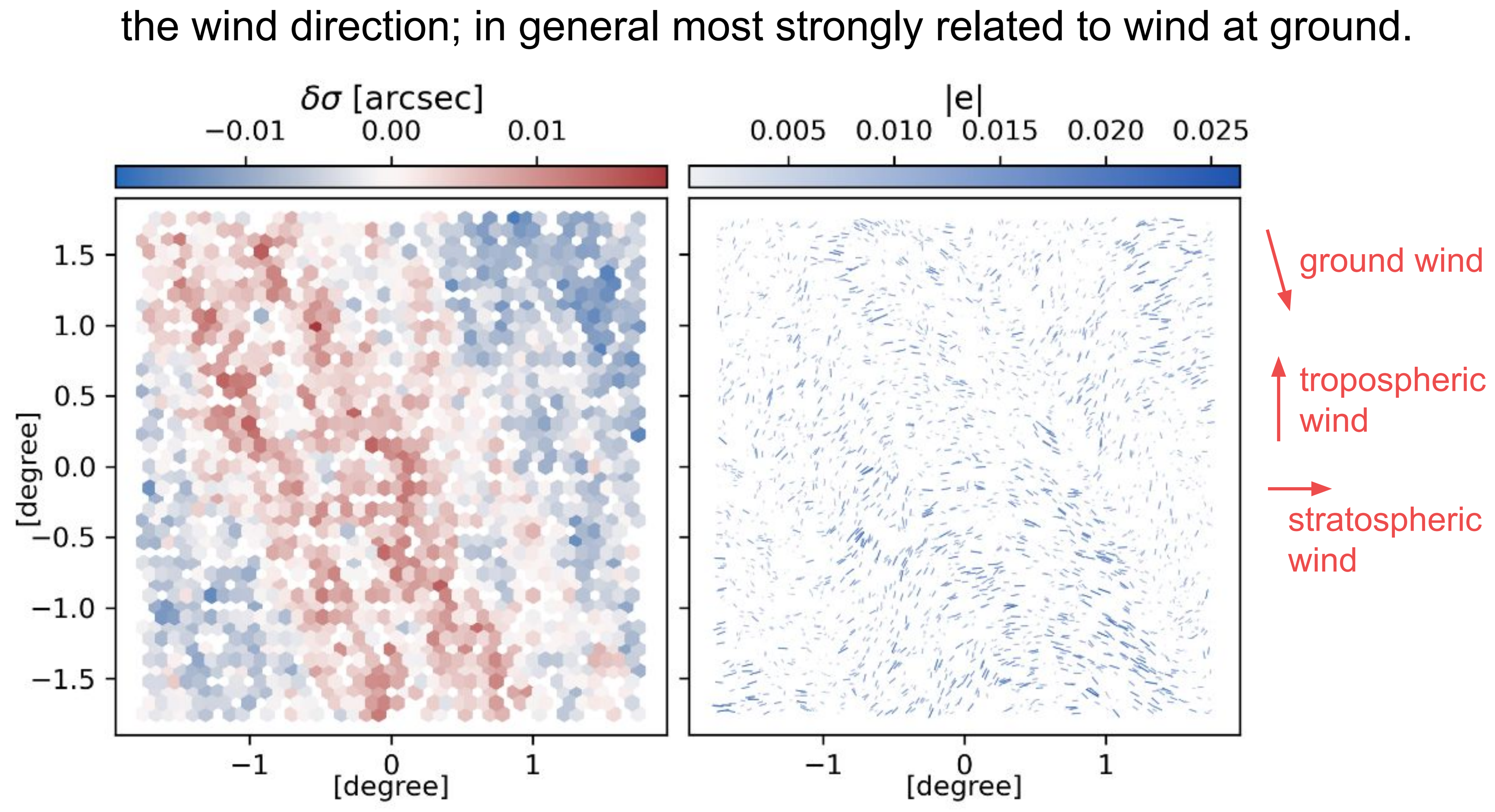
- Empirical models:
  - Osborn & Sarazin (2018) estimate optical turbulence profile from forecast data. Use wind shear as driver of turbulence (not valid near ground).
  - Optional method includes nonzero correlation between seeing and wind.



Paper coming soon; see QR code for psf-weather-station on github.

Example simulation

- Rubin-like simulation run using the GalSim software package and the psf-weather-station inputs displayed above.
- Resulting PSF sizes and shapes show directional patterns that match the wind direction; in general most strongly related to wind at ground.



What's next?

- *See **Mya Do**'s poster for a validation study.*
  - *Mya compares simulations run with psf-weather-station vs "random" (ImSim-like) input parameters.*
  - *Spatial correlations of PSF ellipticity have a more consistent anisotropy in psf-weather-station simulations than those with randomly set inputs.*
- Continue validation: compare simulations to PSF catalogs from DES.
- Simulate AuxTel/ComCam PSFs based on local telemetry, compare PSFs measured during commissioning with predictions.
- Use psf-weather-station to evaluate the impact of realistically correlated atmospheric PSFs on Rubin cosmology constraints:
  - Simulate an ensemble of LSST-like atmospheric PSFs; run state-of-the-art PSF modeling + correction.
  - Propagate residuals through weak lensing analysis to estimate the impact on cosmological parameters.
  - Use this framework to estimate whether any residual bias is averaged away in the co-adding process.

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