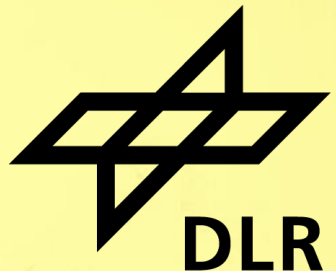


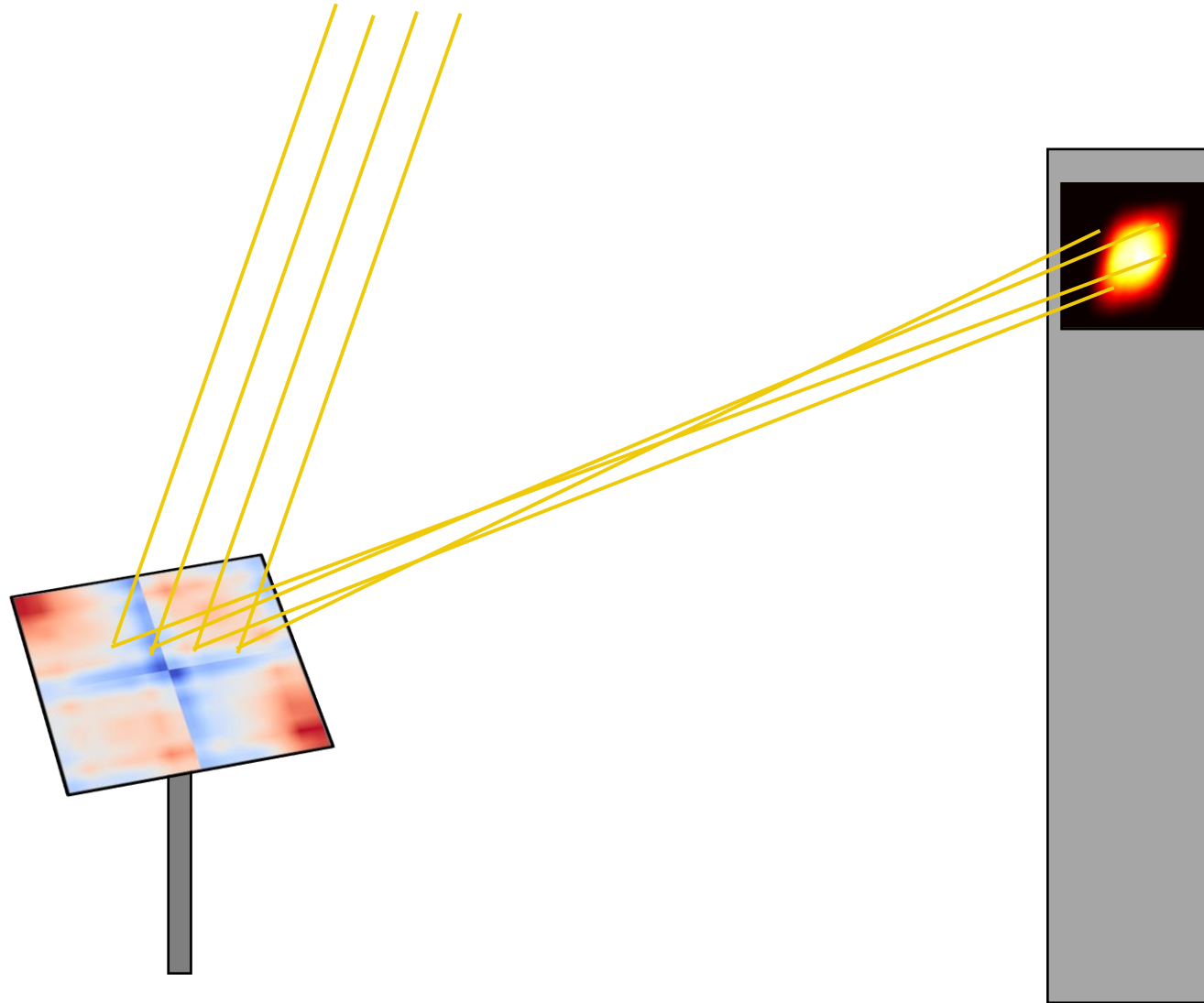
UNCERTAINTY QUANTIFICATION FOR INVERSE DEEP LEARNING RAYTRACING

SolarPACES Conference 2025, 25 September 2025

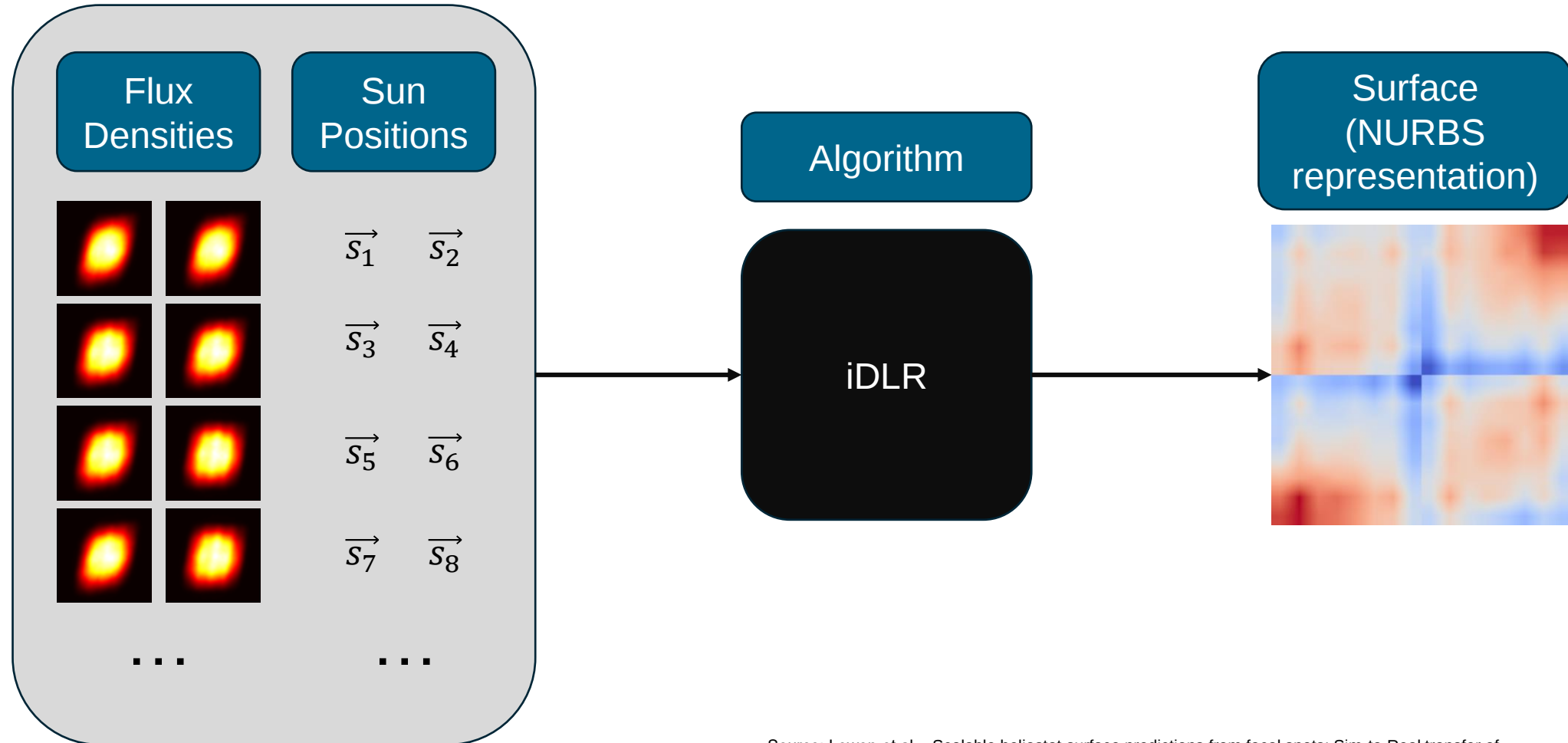
Leon Sievers, DLR Institute of Solar Research



Flux Density Prediction



Flux Density Prediction with Inverse Deep Learning Raytracing (iDLR)



Source: Lewen et al., „Scalable heliostat surface predictions from focal spots: Sim-to-Real transfer of inverse Deep Learning Raytracing“, Solar Energy, Vol. 300, Nov. 2025

Uncertainty and its usefulness

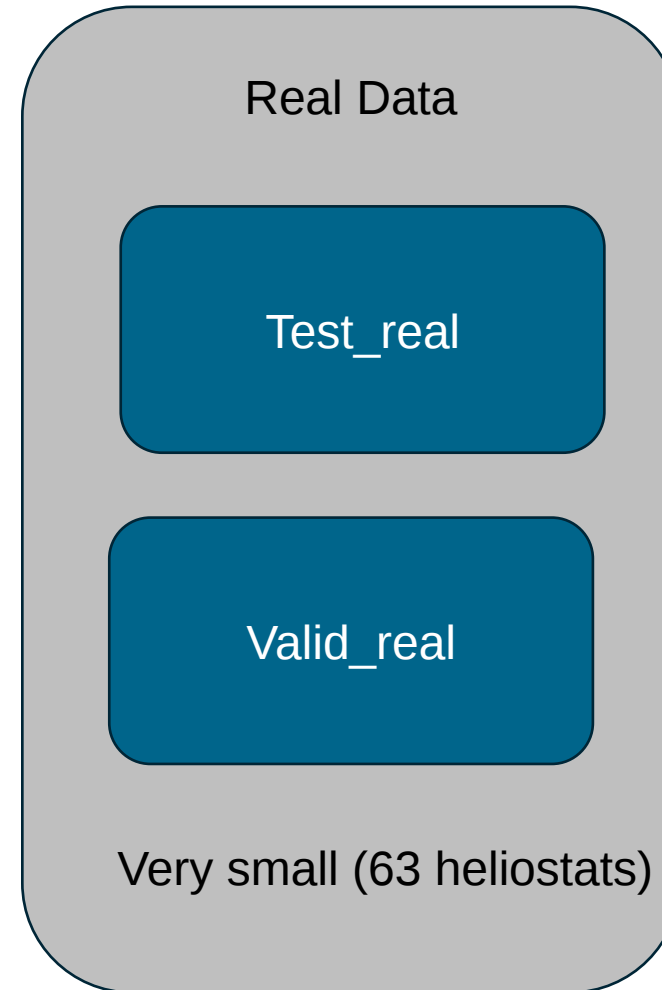
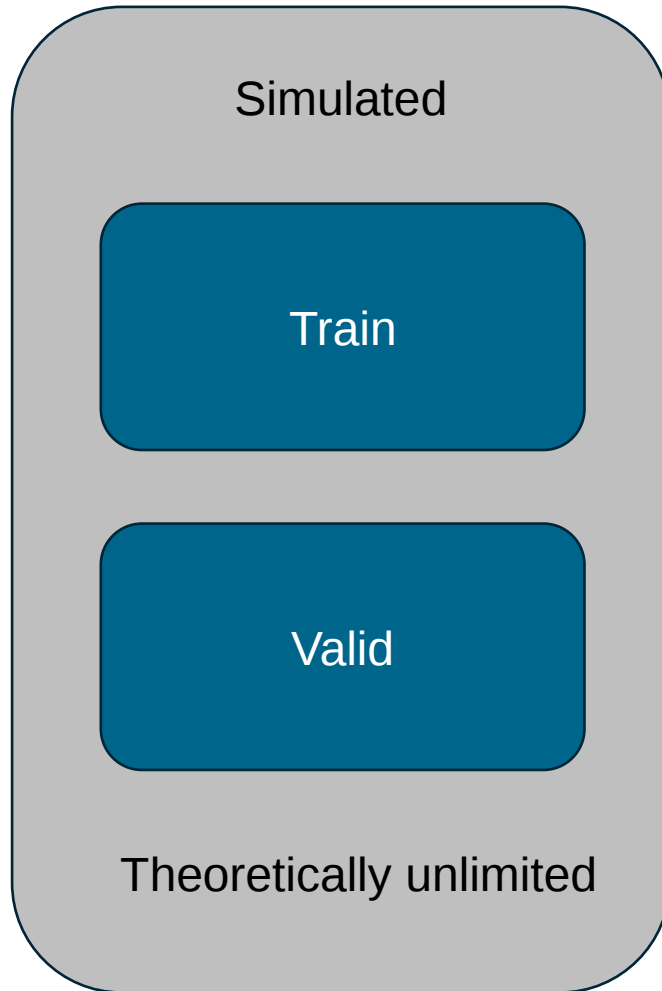


Not a well-defined term, but a umbrella concept.
Hints at likelihood of prediction accuracy.

Construction of metrics that are predictors for success of an algorithm.
No correction of the algorithm's prediction is intended!

iDLR: find features in surface / flux density prediction that help discern good predictions from bad ones.

Datasets

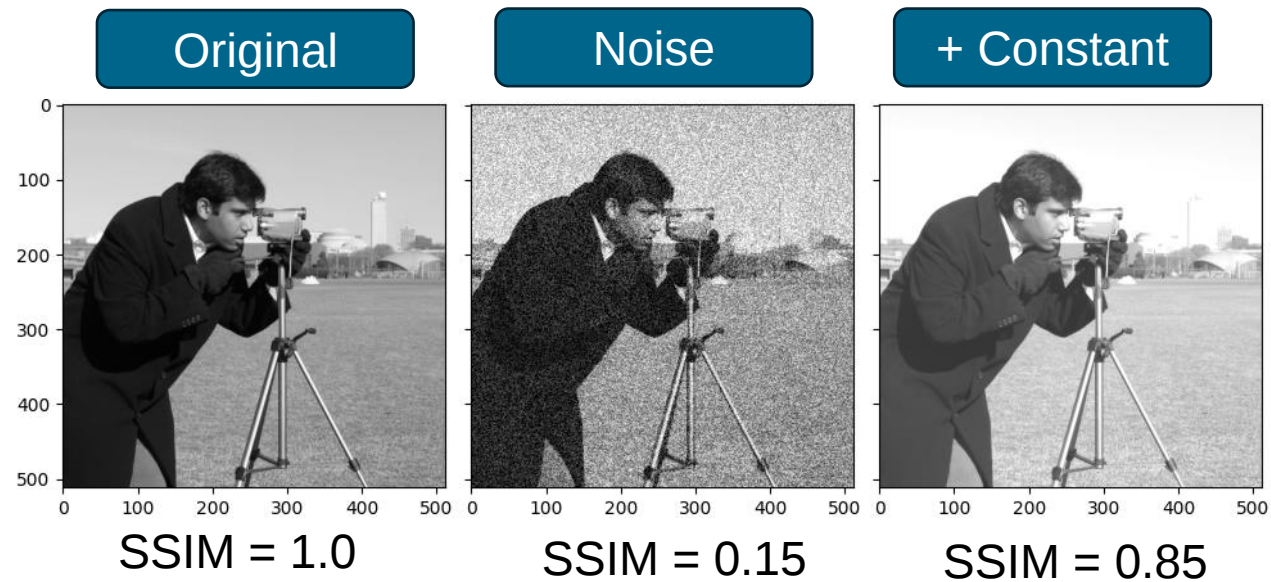


Metrics

Flux Accuracy:

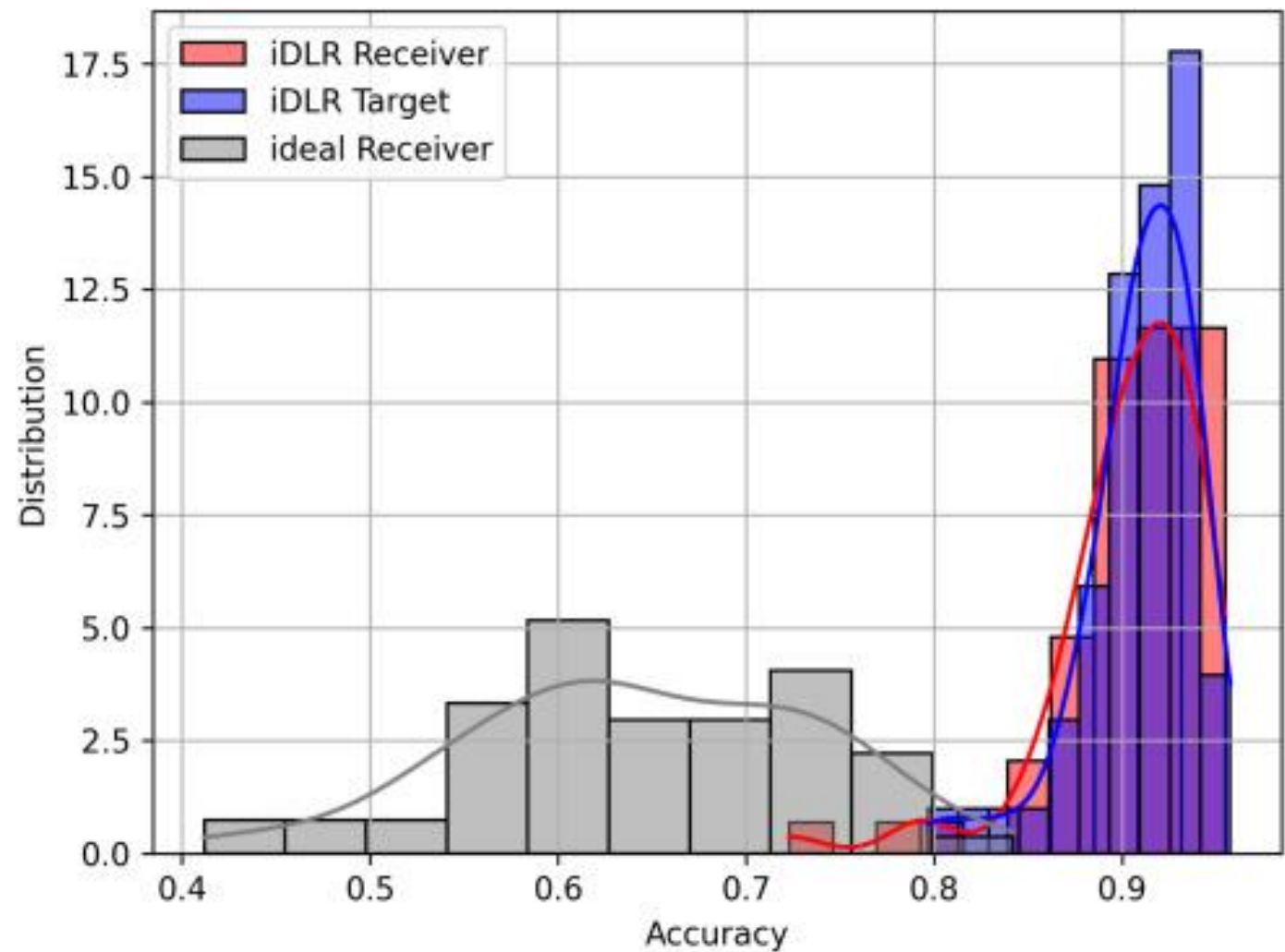
$$\frac{\sum | \text{GT} - \text{Pred} |}{\sum | \text{GT} |}$$

Surface SSIM:
(Structural Similarity Index)



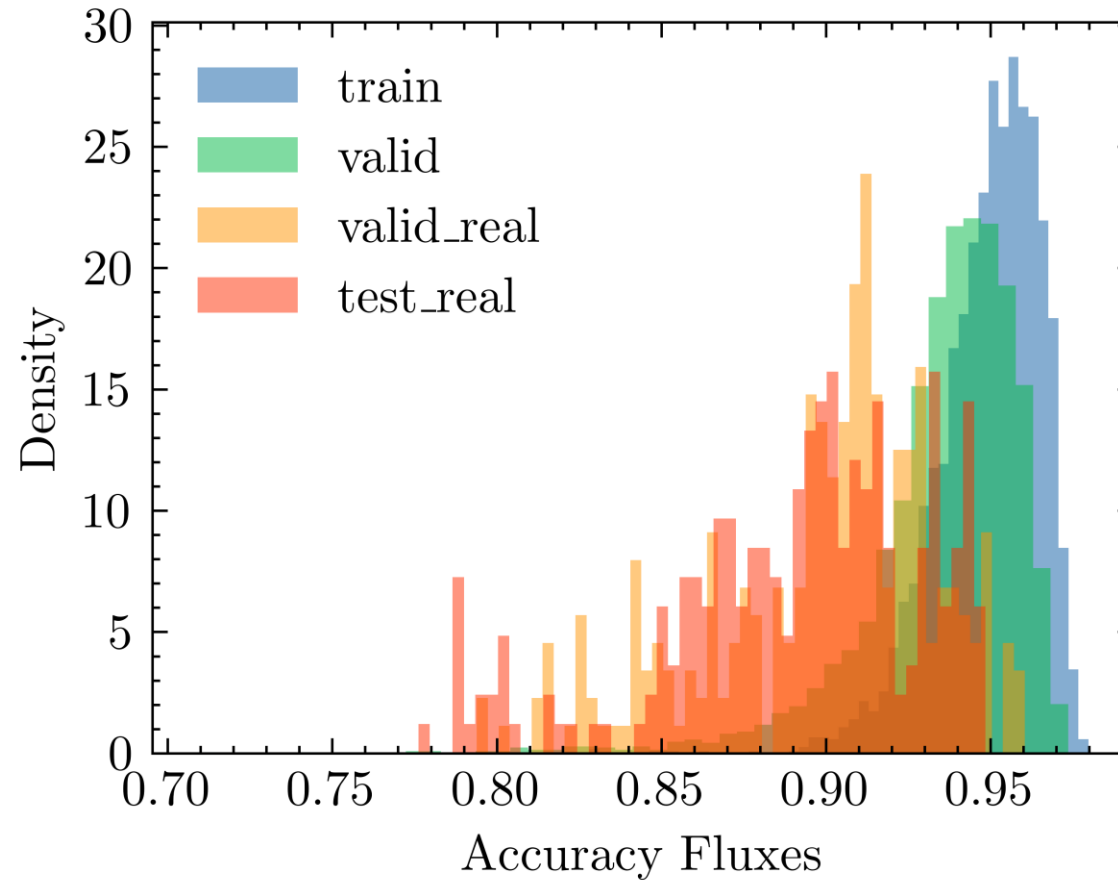
Source: https://scikit-image.org/docs/0.25.x/auto_examples/transform/plot_ssim.html

Metrics - Accuracy

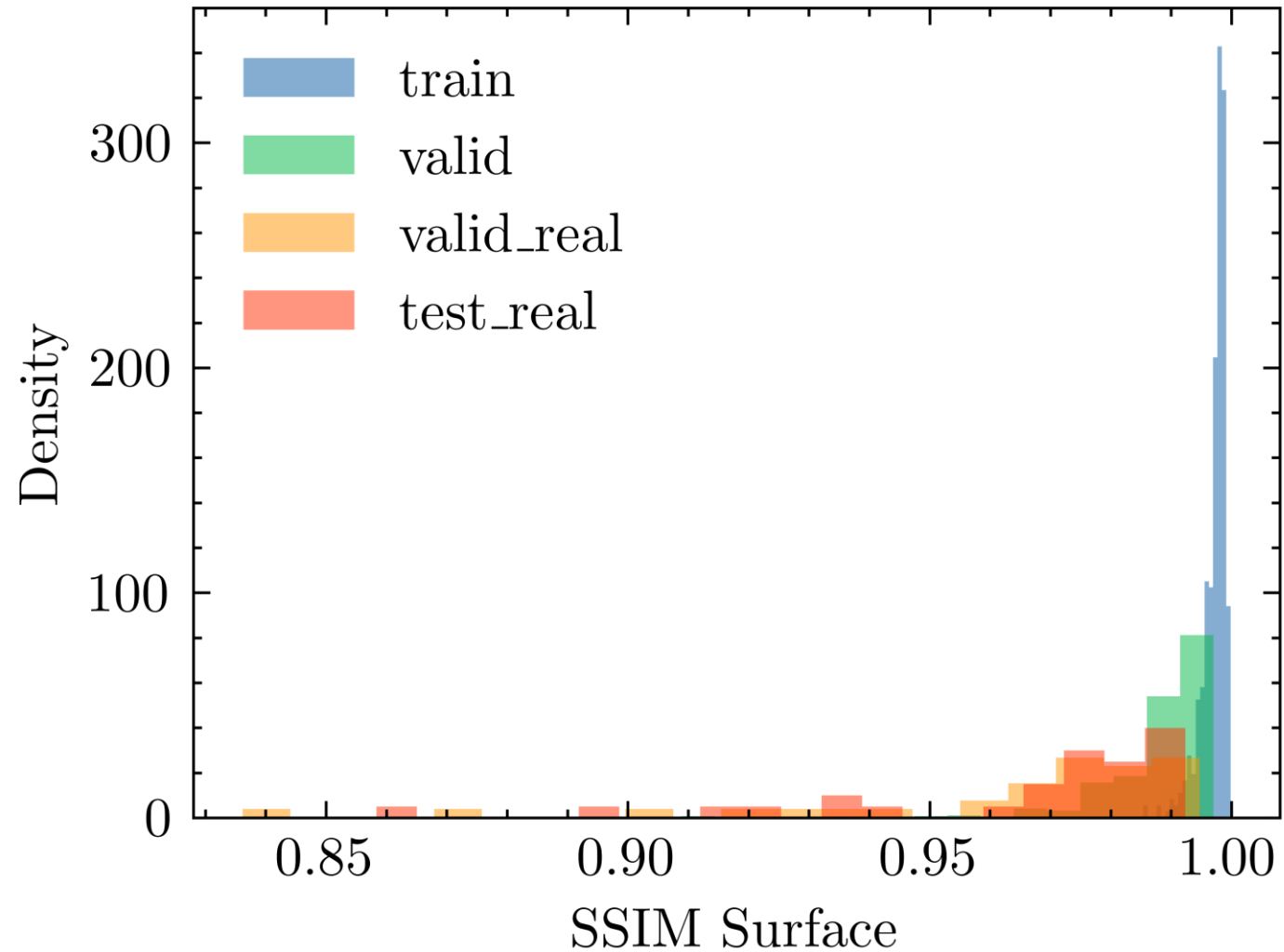


Source: Lewen et al., „Scalable heliostat surface predictions from focal spots: Sim-to-Real transfer of inverse Deep Learning Raytracing“, Solar Energy, Vol. 300, Nov. 2025

Metrics – Flux Accuracy: Generalization Error and Sim-to-Real gap



Metrics – Surface SSIM



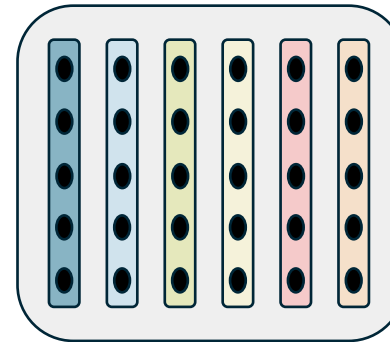
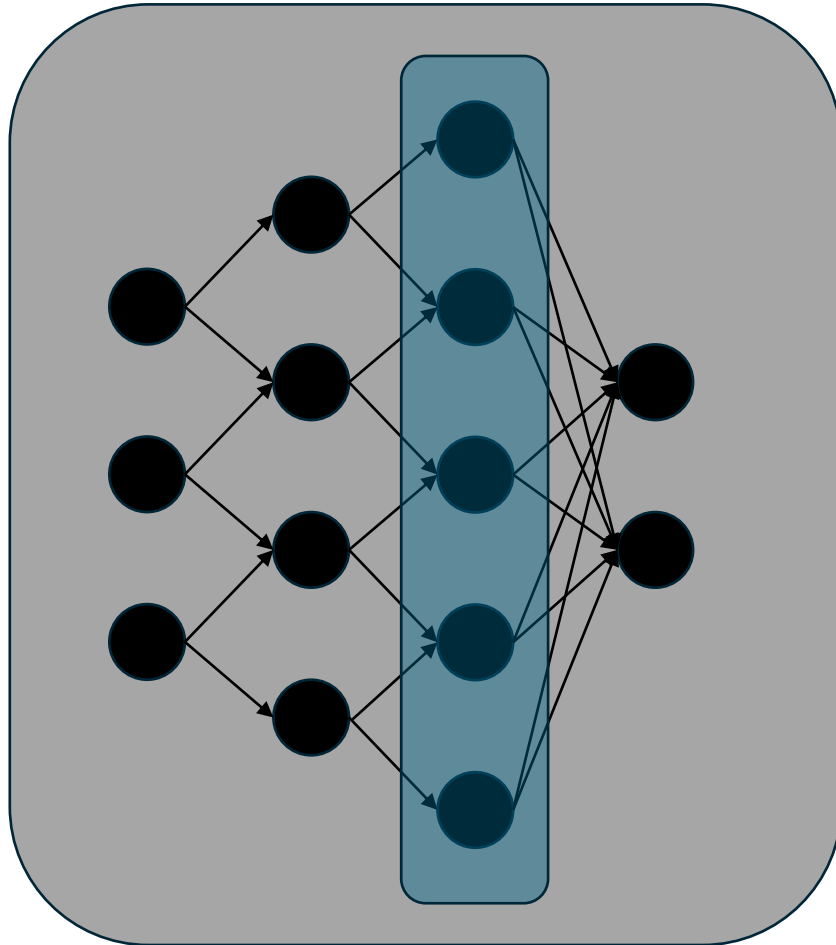
Research Question



How can we guarantee that the flux density prediction is better than under a flat heliostat assumption?

Find features that help discern good predictions from bad ones.

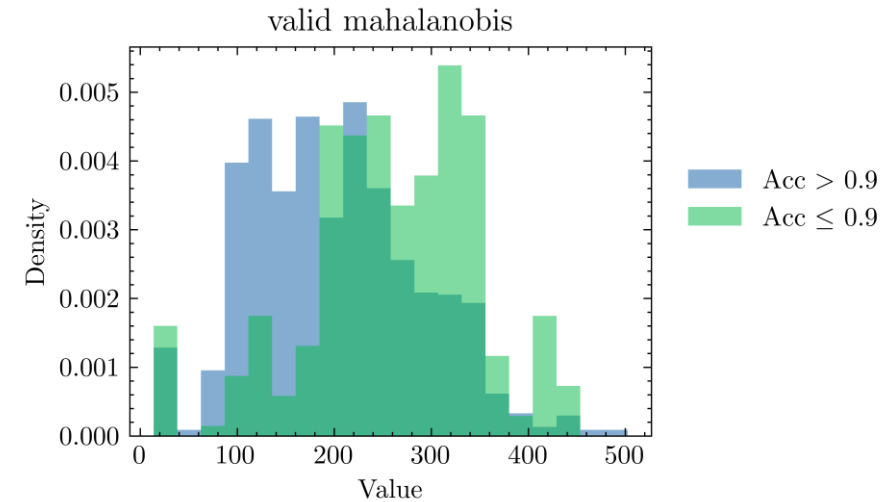
Mahalanobis distance of penultimate features



μ, Σ

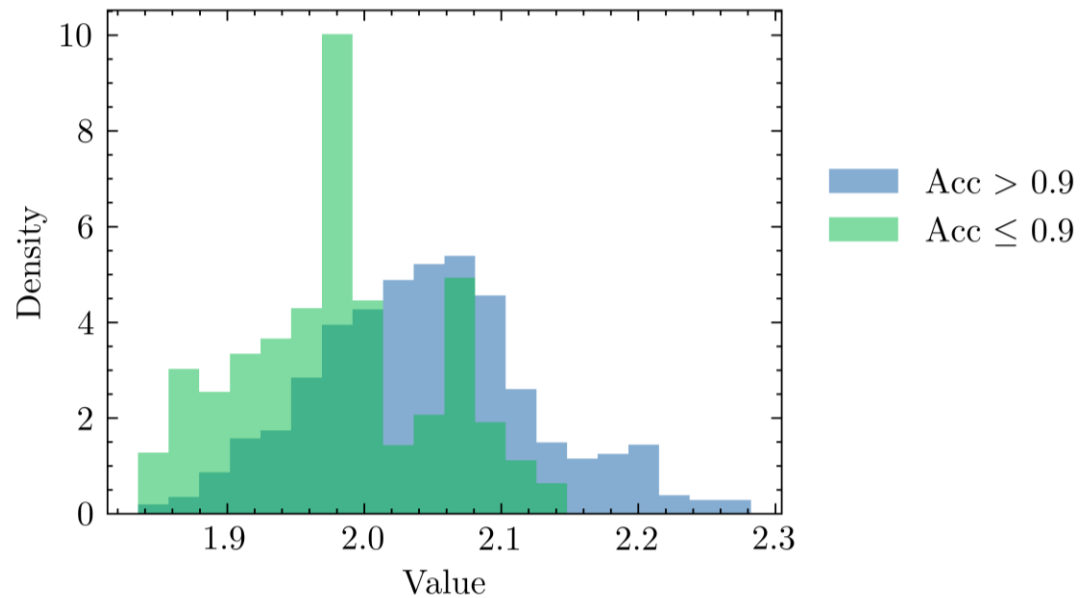
mean, covariance

$$d(x) = \sqrt{(x - \mu)\Sigma^{-1}(x - \mu)^T}$$

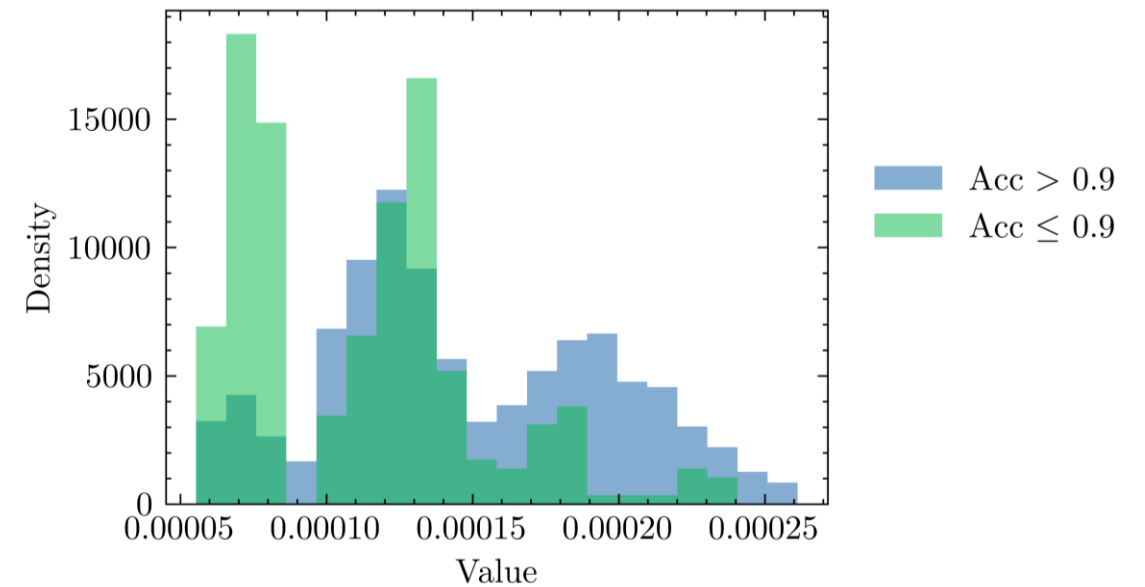


Statistics of penultimate features

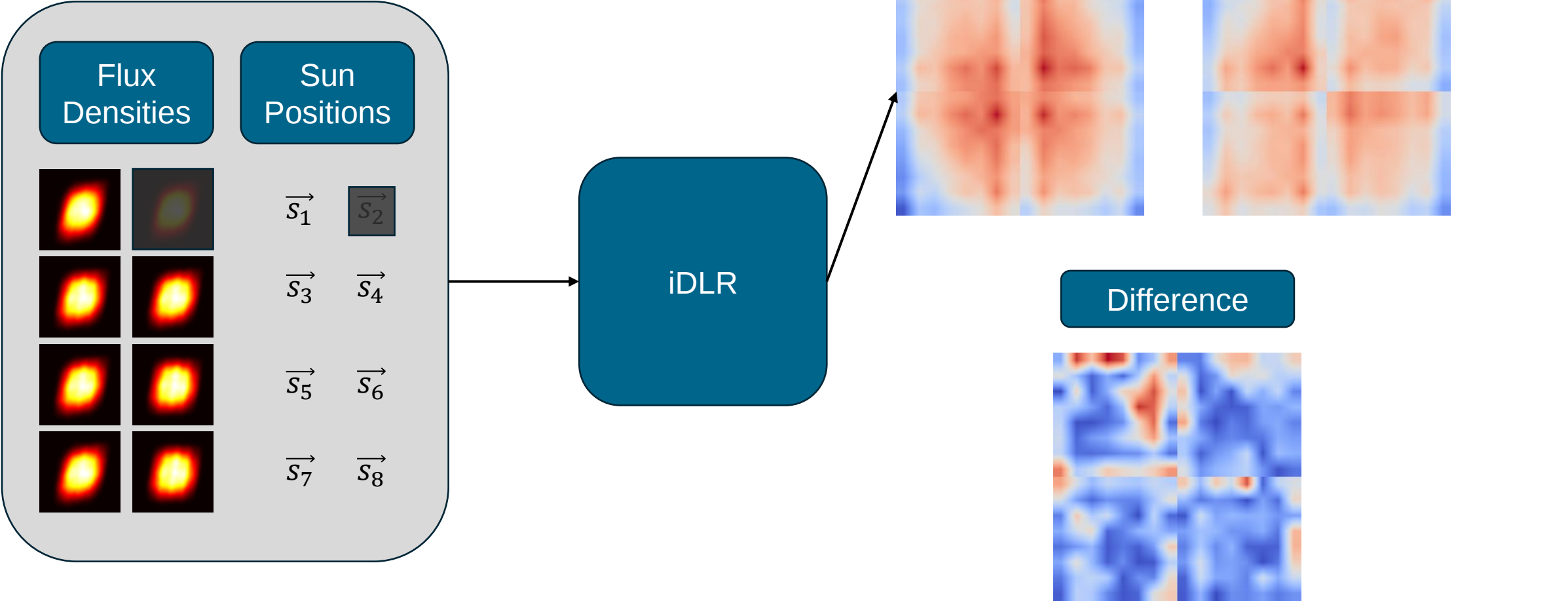
Skew of penultimate features
on valid dataset



Variance of penultimate features
on valid dataset

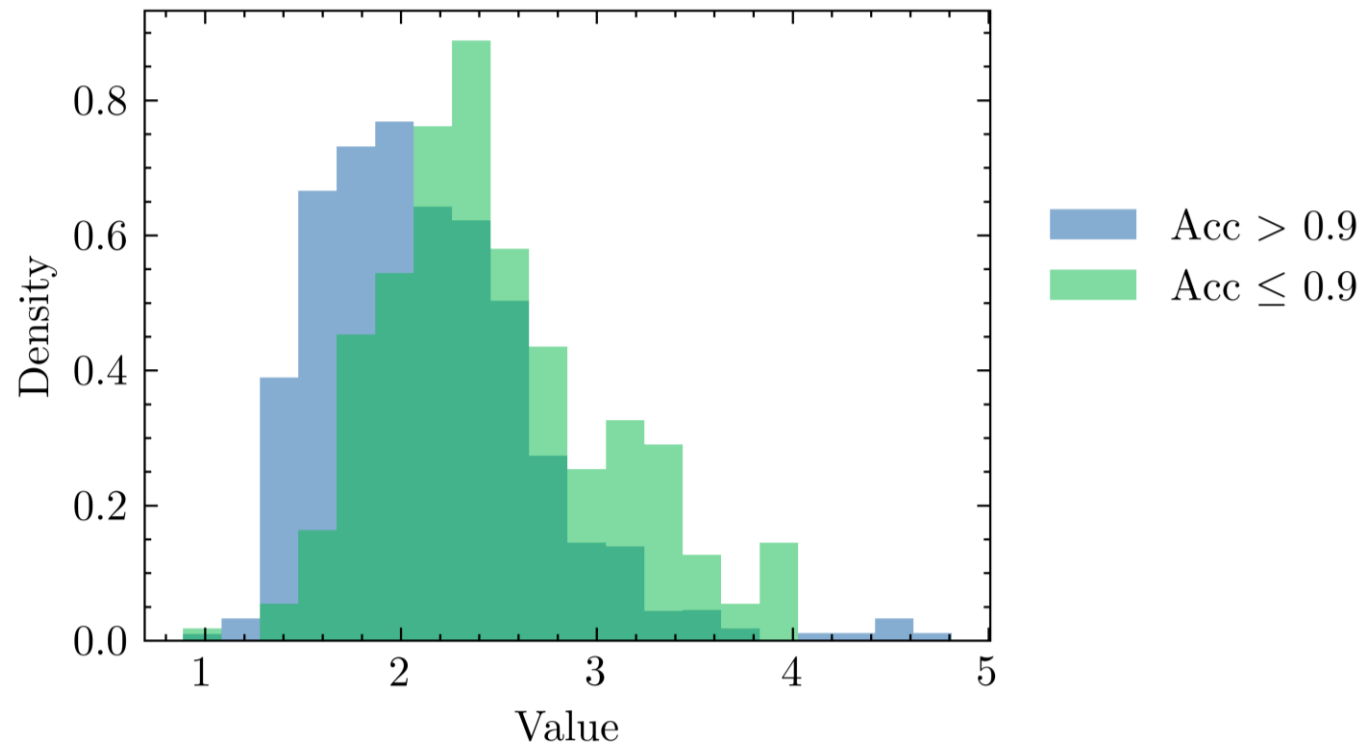


Incomplete Inference

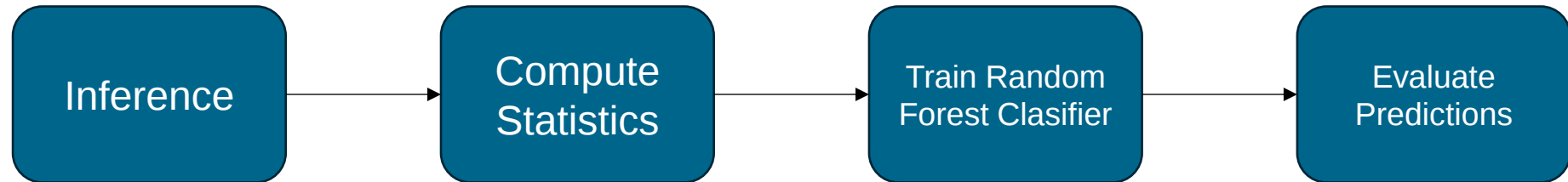


Incomplete Inference - Statistics

Skew of the difference maps between
regular and incomplete inference



Classification



Classification - Results



k-fold Cross Validation

Classifier	F1	Precision	Recall	Acc	TN	FP	FN	TP
Logistic Regression	47%	50%	43%	90%	207	10	13	10
Gradient Boosting	62%	68%	57%	93%	211	6	10	13
Support Vector Classifier	46%	44%	48%	89%	203	14	12	11
XG-Boost	51%	46%	57%	90%	202	15	10	13