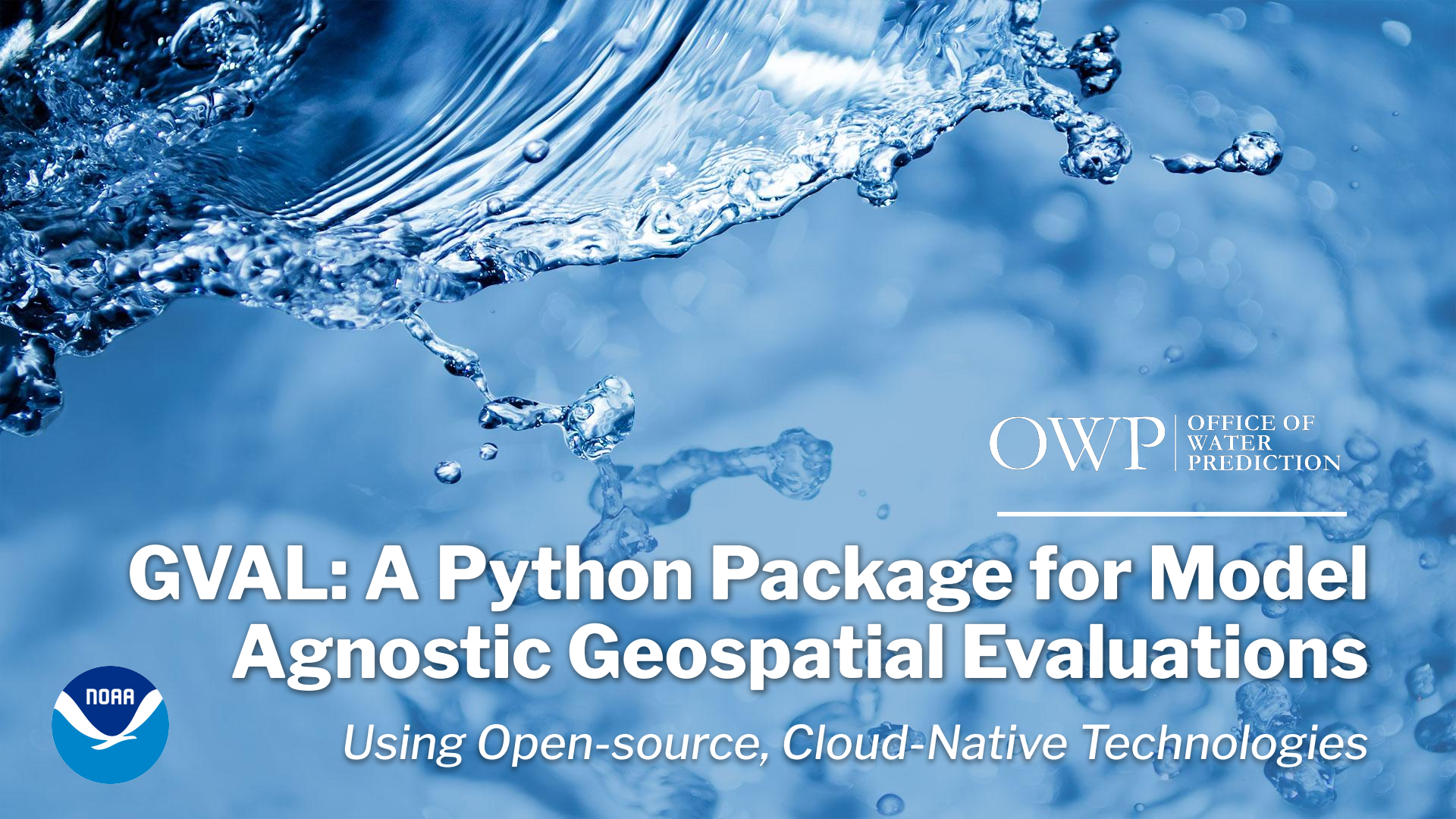
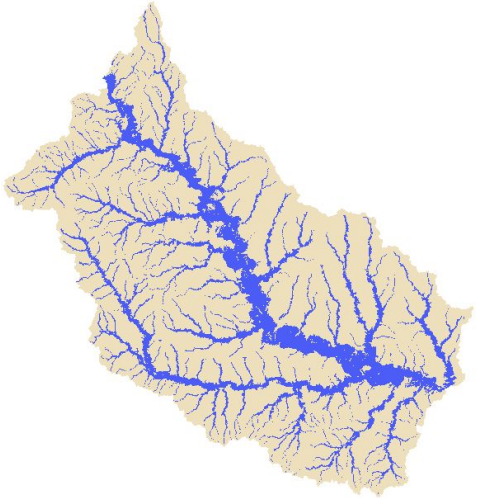


GVAL: A Python Package for Model Agnostic Geospatial Evaluations

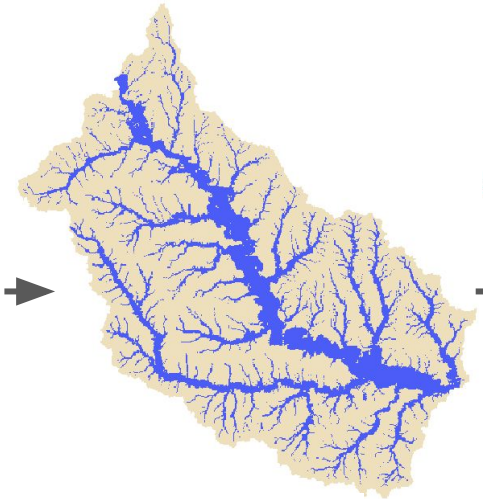
Using Open-source, Cloud-Native Technologies

Problem

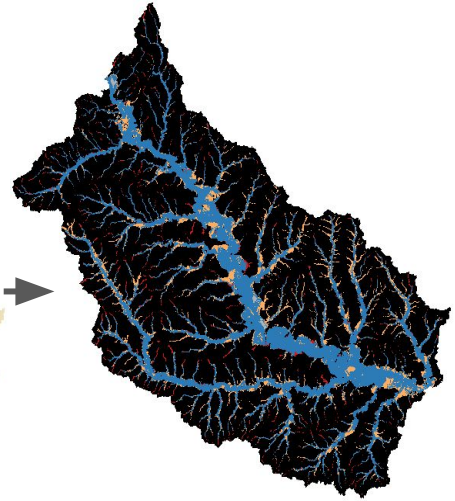
Evaluating Geospatial Datasets



Modeled/Simulated



Observed/Benchmark/ Validation



Agreement

Critical Success Index

Root Mean Square Error

Equitable Threat Score

Mean Absolute Percentage Error

F1-Score

Many more …

Agreement Metrics

Problem:

Geospatial ***Variable*** of Interest

inundation extents, depth, velocity, precipitation, water quality, soil moisture, overland roughness, temperature, etc

Data sources

Models: physics-based, empirical, stochastic, coastal, fluvial, etc

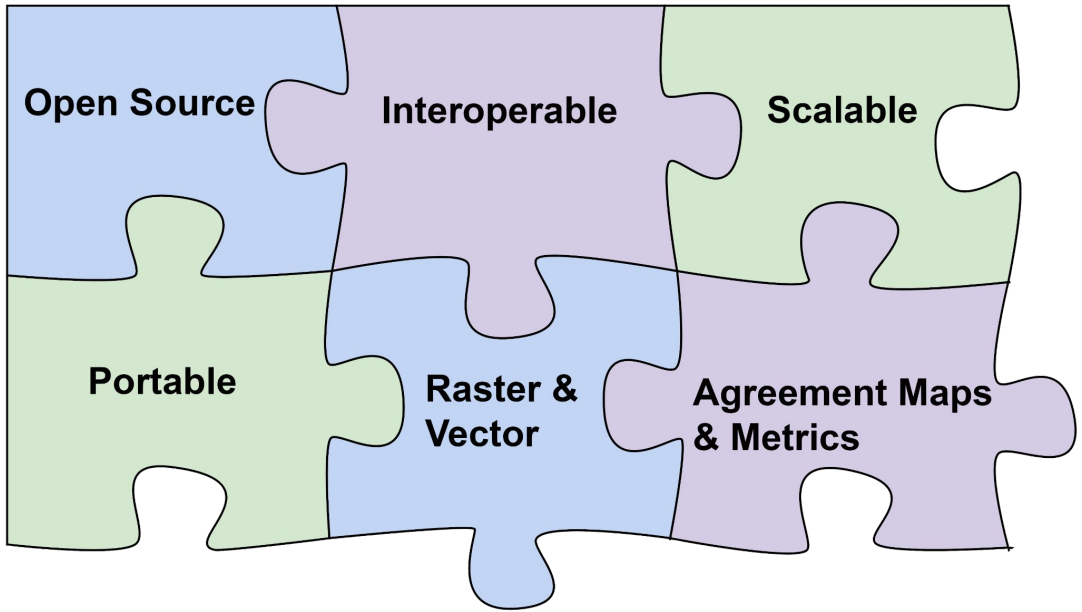
Other geospatial data sources

Designing a Solution

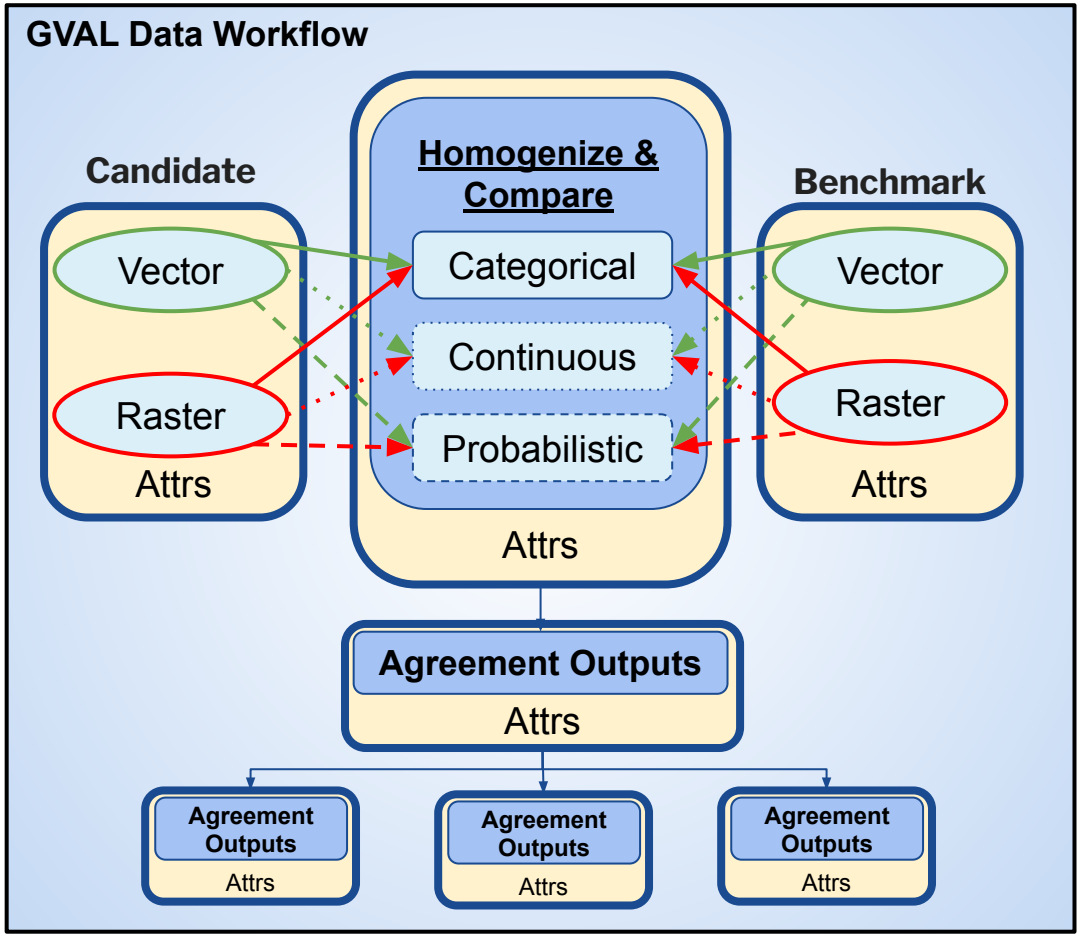
A Modern Approach

GVAL
GEOSPATIAL EVALUATIONS

To address these problems, we developed a python software package that we call **GVAL**.



General Workflow



Software Design

Core Libraries

GVAL uses accessors to run operations on commonly used libraries in the pangeo community.

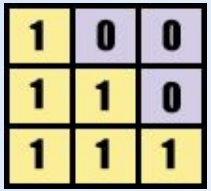
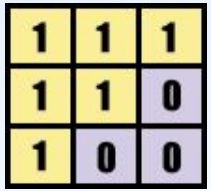
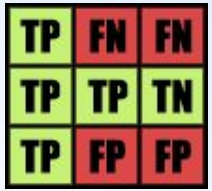
- Raster operations extend Xarray
- Vector operations extend Pandas/GeoPandas

Currently all processing is done in raster space

Data Sources

- Locally
- Direct AWS S3 Storage
- POSTGIS Service
- STAC Service

Supported Statistical Data Types

Type	Candidate	Benchmark	Agreement	Example Metrics
Categorical			 *TP = True Positive* *TN = True Negative* *FP = False Positive* *FN = False Negative*	* True Positive Rate * False Discovery Rate * Accuracy * F-Score * Critical Success Index * Equitable Threat Score
Continuous				* Mean Absolute Error * Mean Squared Error * Mean Percentage Error * Root Mean Squared Error * Coefficient of Determination
Probabilistic	Ensemble 1 & 2 			* Receiver Operating Characteristic * Brier Score * Continuous Ranked Probability Score * Discrimination * Reliability

Using GVAL

Categorical Comparisons

GVAL GEOSPATIAL EVALUATIONS

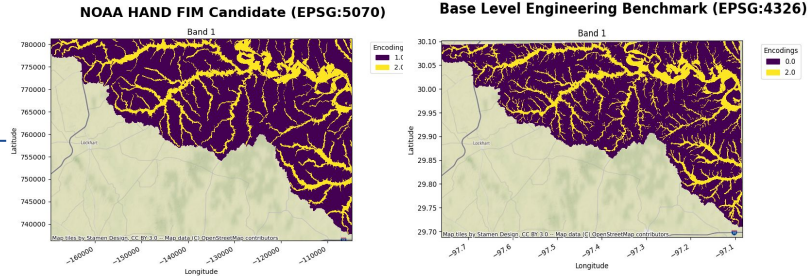
Two-class Categorical Comparisons

GVAL categorical evaluations can be run with minimal code:

```
import rioxarray as rxr
import gval

candidate = rxr.open_rasterio(
    'candidate_map_two_class_categorical.tif', mask_and_scale=True
)
benchmark = rxr.open_rasterio(
    'benchmark_map_two_class_categorical.tif', mask_and_scale=True
)

agreement_map, crosstab_table, metric_table = candidate.gval.categorical_compare(
    benchmark,
    positive_categories=[2],
    negative_categories=[0, 1]
)
```

*Input

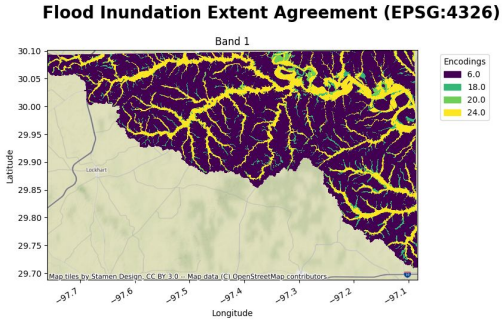
Candidate and Benchmark Maps



GVAL

*Output

Agreement Map



Cross Tabulation Table

	band	candidate_values	benchmark_values	agreement_values	counts
0	1	1.0	0.0	6.0	10345720.0
1	1	2.0	0.0	20.0	512277.0
2	1	1.0	2.0	18.0	639227.0
3	1	2.0	2.0	24.0	2473405.0

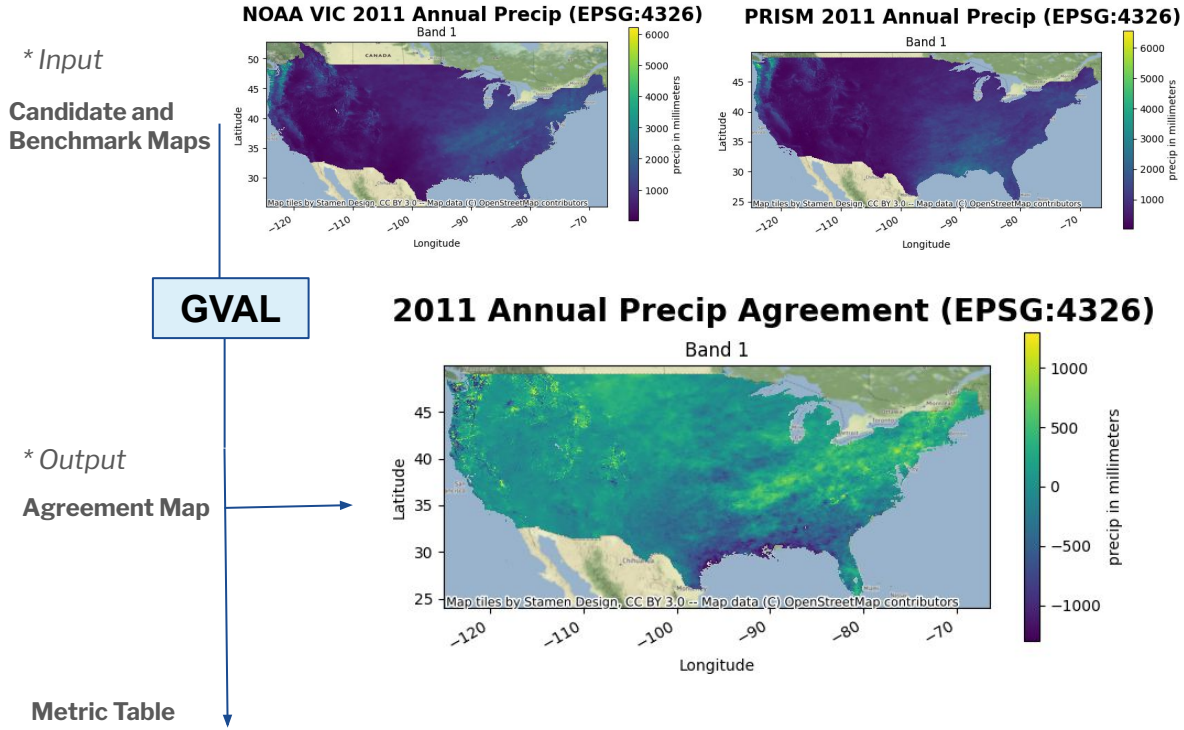
Metric Table

	band	fn	fp	tn	tp	accuracy	critical_success_index	f_score	false_discovery_rate	false_negative_rate	...
0	1	639227.0	512277.0	10345720.0	2473405.0	0.917577	0.682336	0.811177	0.171578	0.205365	...

Continuous Comparisons

Similarly to categorical evaluations, the following runs continuous evaluations:

```python
import rioxarray as rxr
import gval

candidate = rxr.open_rasterio(
    './livneh_2011_precip.tif', mask_and_scale=True
) # VIC
benchmark = rxr.open_rasterio(
    './prism_2011_precip.tif', mask_and_scale=True
) # PRISM

agreement, metric_table = candidate.gval.continuous_compare(
    benchmark,
    metrics=[
        "coefficient_of_determination",
        "mean_absolute_error",
        "mean_absolute_percentage_error",
        "mean_normalized_mean_absolute_error"
    ]
)
```



	band	coefficient_of_determination	mean_absolute_error	mean_absolute_percentage_error	mean_normalized_mean_absolute_error
0	1	0.685261	216.089706	0.319234	0.267845

Catalog Comparisons

GVAL can run evaluations on catalogs of maps:

```python
import pandas as pd

from gval.catalogs.catalogs import catalog_compare

candidate_continuous_catalog = pd.read_csv(
    './candidate_catalog_0.csv'
)
benchmark_continuous_catalog = pd.read_csv(
    './benchmark_catalog_0.csv'
)

arguments = {
    "candidate_catalog": candidate_continuous_catalog,
    "benchmark_catalog": benchmark_continuous_catalog,
    "on": "compare_id",
    "map_ids": "map_id",
    "compare_type": "continuous",
    "compare_kwargs": {
        "metrics": (
            "coefficient_of_determination",
            "mean_absolute_error",
            "mean_absolute_percentage_error",
        ),
    },
    "open_kwargs": {
        "mask_and_scale": True
    }
}

agreement_continuous_catalog = catalog_compare(**arguments)
```

GVAL GEOSPATIAL EVALUATIONS

Catalog Comparisons

Candidate and Benchmark Catalogs

*Input

	map_id	compare_id	agreement_maps
0	./candidate_continuous_0.tif	compare1	./agreement_continuous_0.tif
1	./candidate_continuous_1.tif	compare2	./agreement_continuous_1.tif

	map_id	compare_id
0	./benchmark_continuous_0.tif	compare1
1	./benchmark_continuous_1.tif	compare2

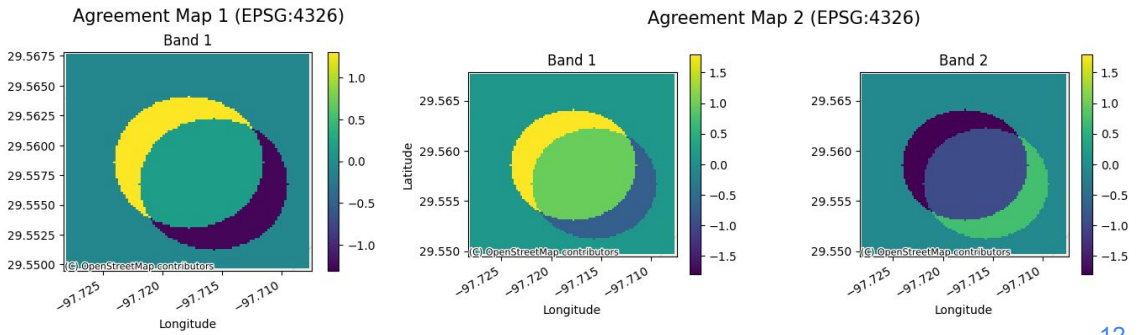
GVAL

*Output

Catalog Result Table

	0	1	2
map_id_candidate	./candidate_continuous_0.tif	./candidate_continuous_1.tif	./candidate_continuous_1.tif
compare_id	compare1	compare2	compare2
agreement_maps	./agreement_continuous_0.tif	./agreement_continuous_1.tif	./agreement_continuous_1.tif
map_id_benchmark	./benchmark_continuous_0.tif	./benchmark_continuous_1.tif	./benchmark_continuous_1.tif
band	1	1	2
coefficient_of_determination	-0.06616	-2.829421	0.10903
mean_absolute_error	0.317389	0.485031	0.485031
mean_absolute_percentage_error	0.159568	0.202235	0.153235

Agreement Maps



Additional Functionality

Additional Functionality

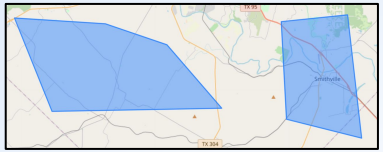
Subsampling

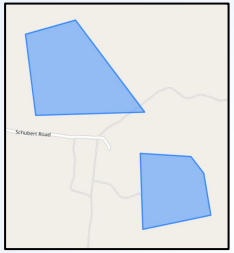
Type

Inclusionary

Exclusionary

Regions



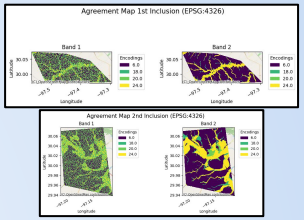


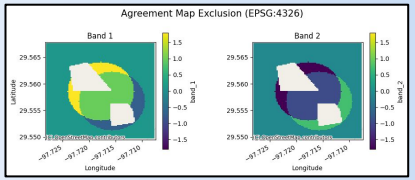
Metric Tables

	0	1	2	3
band	1	1	2	2
subsample	1	2	1	2
fn	201953.0	182389.0	68239.0	58638.0
fp	761242.0	397531.0	43646.0	65967.0
tn	762262.0	398338.0	1479858.0	729902.0
tp	201936.0	181301.0	335650.0	305052.0
accuracy	0.50026	0.499879	0.94195	0.892541
balanced_accuracy	0.500157	0.499506	0.901198	0.877941
critical_success_index	0.173316	0.238171	0.749997	0.70999

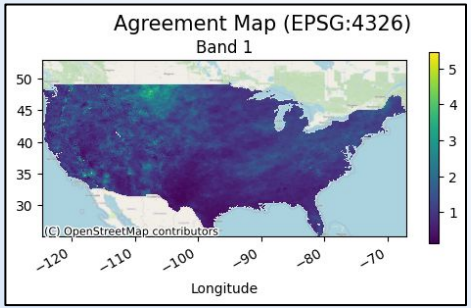
	subsample	band	mean_percentage_error
0	1	1	0.125928
1	1	2	-0.111844
2	2	1	0.167116
3	2	2	-0.143187

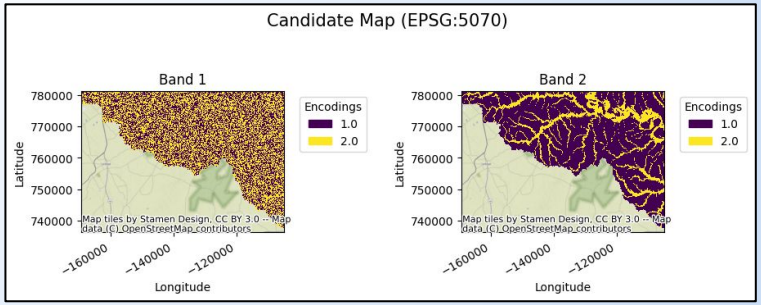
Agreement Maps





Visualization





Additional Functionality Continued

Registering Custom Statistical Functions

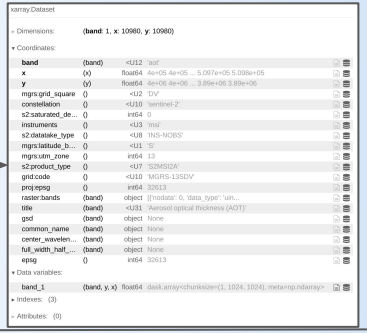
```python
from gval import CatStats

@CatStats.register_function(name="error_balance", vectorize_func=True)
def error_balance(fp: Number, fn: Number) -> float:
    return fp / fn
```

```python
metric_table_register = crosstab_table.gval.compute_categorical_metrics(
    negative_categories= None,
    positive_categories = [2],
    metrics=['error_balance']
)
```

	band	fn	fp	tn	tp	error_balance
0	1	639227.0	512277.0	NaN	2473405.0	0.801401

Stac API Client IO

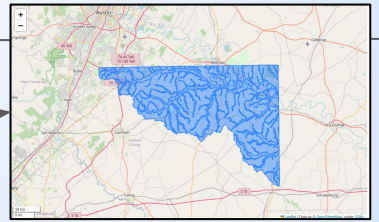
```python
from gval.utils.loading_datasets import dataset_from_stac

data = dataset_from_stac(
    url="https://earth-search.aws.element84.com/v1",
    collection="sentinel-2-l2a",
    time="2020-04-01/2020-05-01",
    bands=["aot"],
    time_aggregate="mean",
    bbox=[-105.78, 35.79, -105.66, 35.90]
)
```

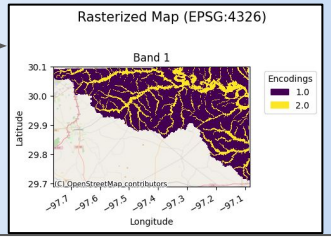


Rasterization/ Vectorization

```python
raster_candidate = vector_candidate.gval.rasterize_data(
    reference_map=benchmark, rasterize_attributes=["values"]
)
```

```python
vector_candidate = candidate.gval.vectorize_data()
```





Use and Contribution

- Documentation:

  https://github.com/NOAA-OWP/gval

- GitHub Issues:

  https://github.com/NOAA-OWP/gval/issues

- Main GitHub Page

  https://noaa-owp.github.io/gval/

GVAL
GEOSPATIAL EVALUATIONS

Acknowledgements

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Fernando Salas [1]

[1] NOAA

[2] NOAA Affiliate

[3] Lynker

Thank You!

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