Fake it 'till you make it

Zarr-like Access of Existing NetCDF4 Datasets

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The Problem

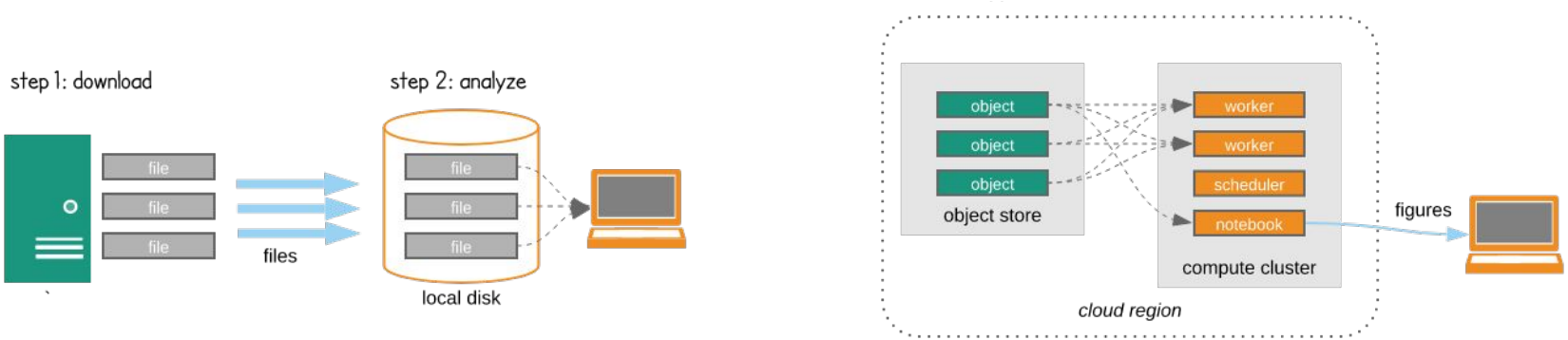
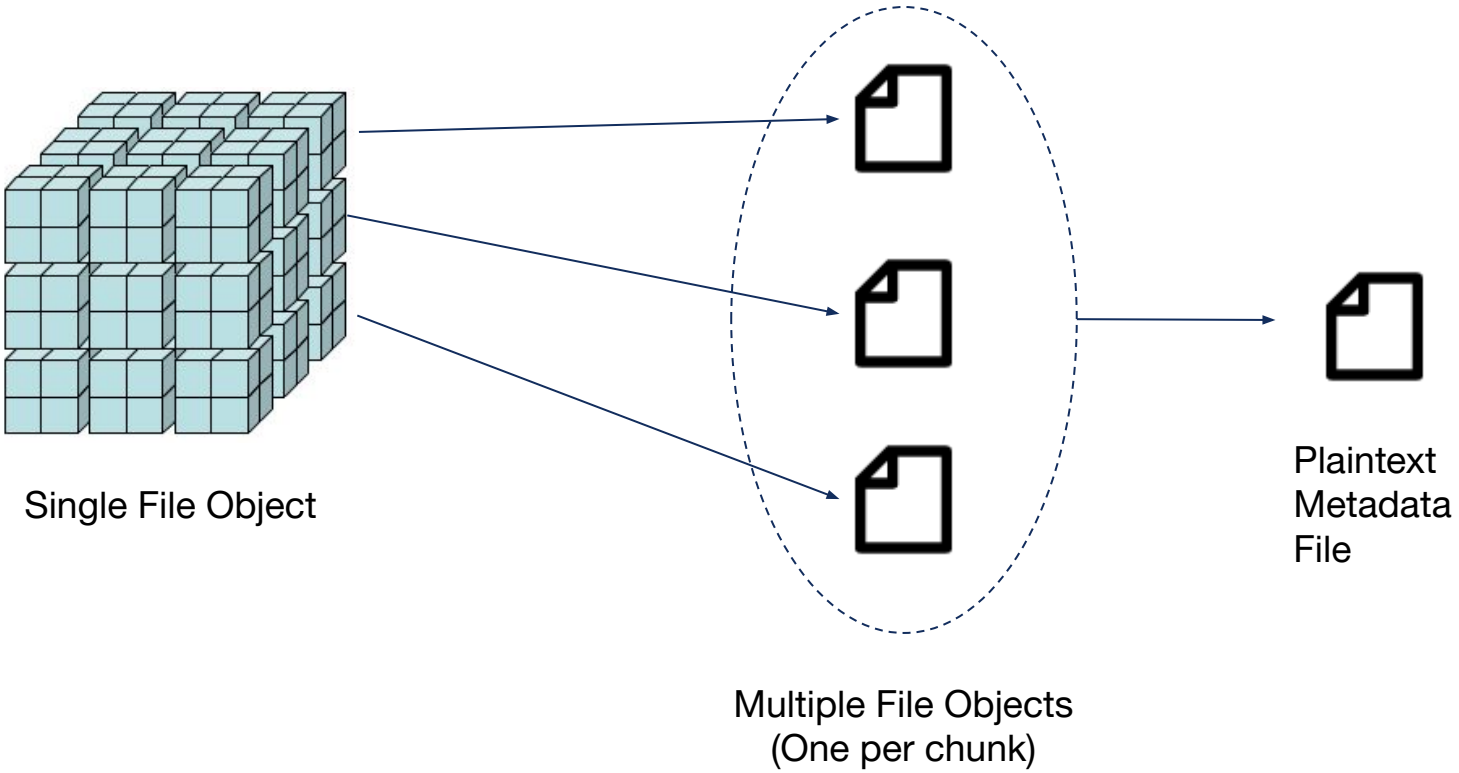


Image Source - Pangeo/Ryan Abernathy

- Peta(Exa?)bytes of geophysical data now available in the cloud
- Much of the data are in NetCDF4/HDF5 format
  - Not efficient for cloud computing

NetCDF vs Zarr

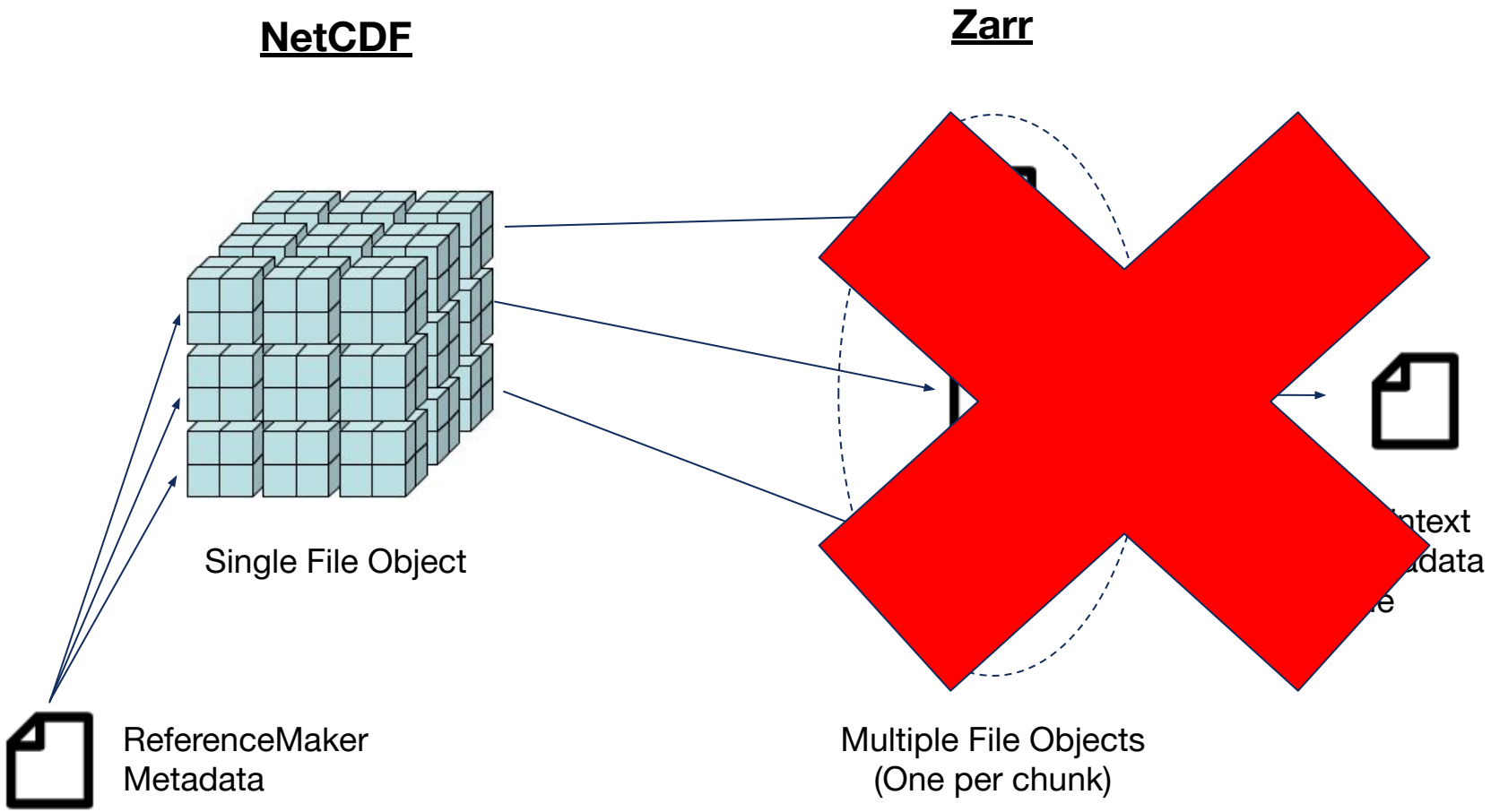


ReferenceFileSystem

ReferenceMaker/ReferenceFileSystem:

- Part of Intake group's **`fsspec`** project
- Access existing NetCDF/HDF files ***as if they are Zarr***
- Zarr-like Metadata files (few MB each)
  - Remote file address (Azure Blob, AWS S3, etc)
  - Data variable and chunking info
- Extracts byte-ranges for individual variables/chunks
  - Instead of individual chunk files in Zarr

ReferenceMaker



Creating JSONS

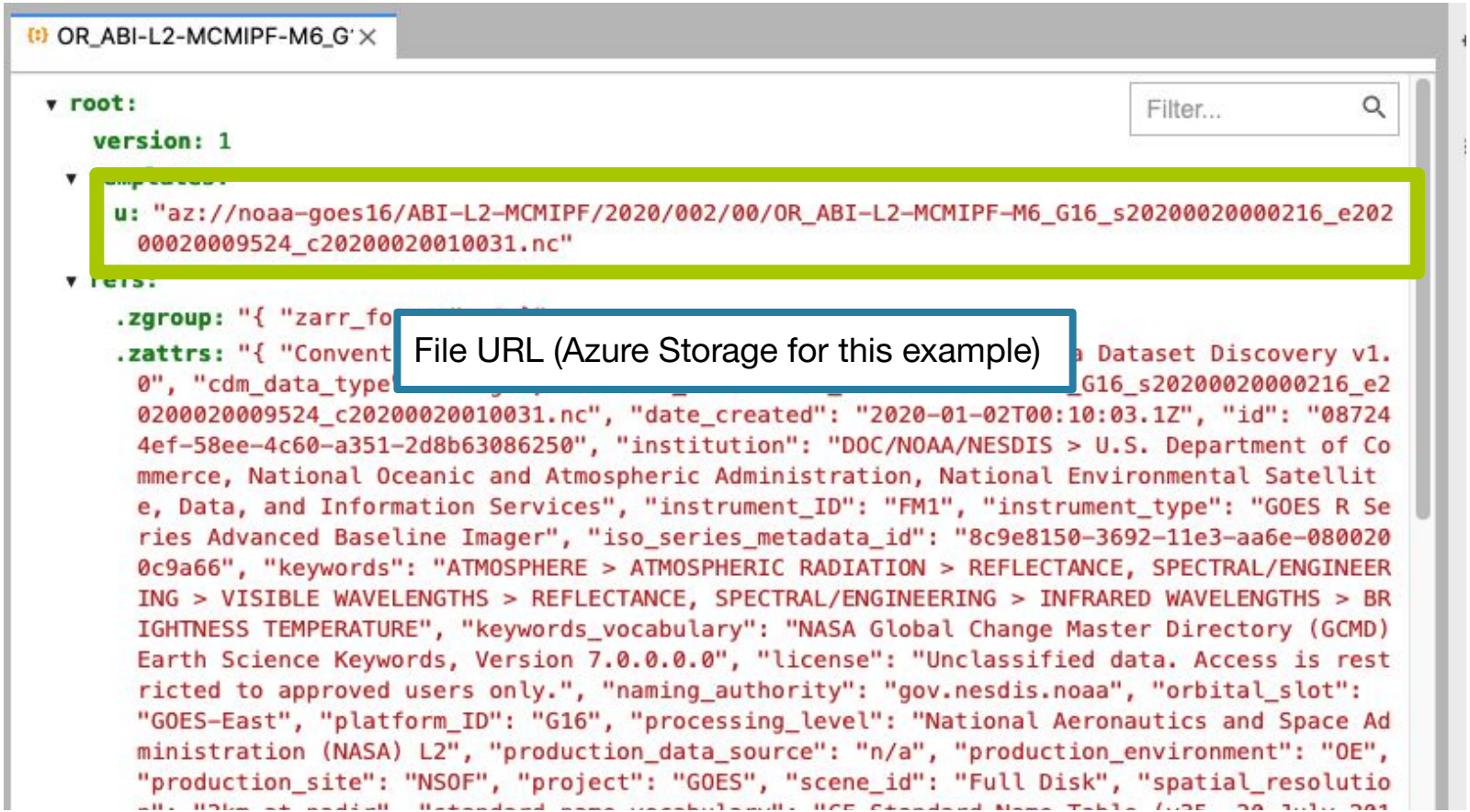
```python
@dask.delayed
def gen_json(url):
    so = dict(
        mode="rb", anon=True, default_fill_cache=False, default_cache_type="none"
    )

    outpath = './jsons/' + url.split('/')[-1].split('.nc')[0] + '.json'

    with fsspec.open(url, **so, account_name='goeseuwest') as inf:
        h5chunks = SingleHdf5ToZarr(inf, u, inline_threshold=300)

        with open("./reference.json", 'wb') as outf:
            outf.write(ujson.dumps(h5chunks.translate()).encode())
```

Easily distributed with Dask!

Read remote file and process chunks

Write metadata to file

Reference JSON Example



Reference JSON Example


```
ministration (NASA) L2", "production_data_source": "n/a", "production_environment": "OE",
"production_site": "NSOF", "project": "GOES", "scene_id": "Full Disk", "spatial_resolutio
n": "2km at nadir", "st                                    ame Table (v35, 20 July 201
6)", "summary": "Multip                                    ud and Moisture Imagery Pro
ducts are digital maps                                     ndows at visible, near-IR,
and IR bands.", "time_c                                    "time_coverage_start": "20
20-01-02T00:00:21.6Z", "timeline_id": "ABI Mode 6", "title": "ABI L2 Cloud and Moisture I
magery" }"
CMI_C01/.zarray: "{ "chunks": [ 226, 226 ], "compressor": { "id": "zlib", "level": 1 }, "dt
  ype": "<i2", "fill_value": -1, "filters": null, "order": "C", "shape": [ 5424, 5424 ], "z
  arr_format": 2 }"
CMI_C01/.zattrs: "{ "_ARRAY_DIMENSIONS": [ "y", "x" ], "_FillValue": -1, "_Netcdf4Dimid":
  0, "_Unsigned": "true", "add_offset": 0.0, "ancillary_variables": "DQF_C01", "cell_method
  s": "t: point area: sum (interval: 0.000028 rad)", "coordinates": "band_id_C01 band_wavel
  ength_C01 t y x", "downsampling_method": "average", "grid_mapping": "goes_imager_projecti
  on", "long_name": "ABI Cloud and Moisture Imagery reflectance factor", "resolution": "y:
  0.000056 rad x: 0.000056 rad", "scale_factor": 0.00031746001332066953, "sensor_band_bit_d
  epth": 10, "standard_name": "toa_lambertian_equivalent_albedo_multiplied_by_cosine_solar_
  zenith_angle", "units": "1", "valid_range": [ 0, 4095 ] }"
▾ CMI_C01/0.4: [] 3 items
    0: "{{u}}"
    1: 253643
    2: 468
```


Variable (CMI_C01) chunk info, compression, shape, etc

Single Chunk Byte Range

Reference JSON Example

Set “reference” filesystem and specify JSON file

```
fs = fsspec.filesystem('reference',
fo='reference.json',
remote_protocol='az',
remote_options={'account_name':'goeseuwest'},
simple_templates=True)
```

Specify remote file protocol (Azure here) and authentication

```
m = fs.get_mapper("")

ds = xr.open_dataset(m, engine='zarr')
```

Pass mapper to xarray and specify Zarr engine

GOES Workflow

Microsoft Azure

Data stored in same region as compute

4 CPU, 32 GB Memory,
8 Dask Workers

- Created a test workflow on Microsoft Planetary Computer
- Analysis of 24 hours of GOES data
- Test access to data stored in Azure in 3 formats:
  - NetCDF4
  - NetCDF4 + ReferenceMaker
  - Zarr

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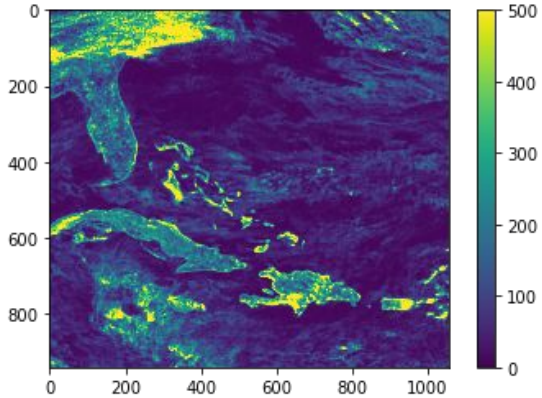

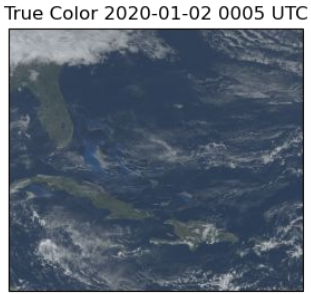

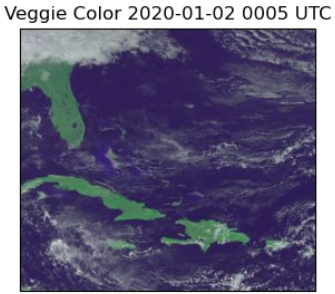

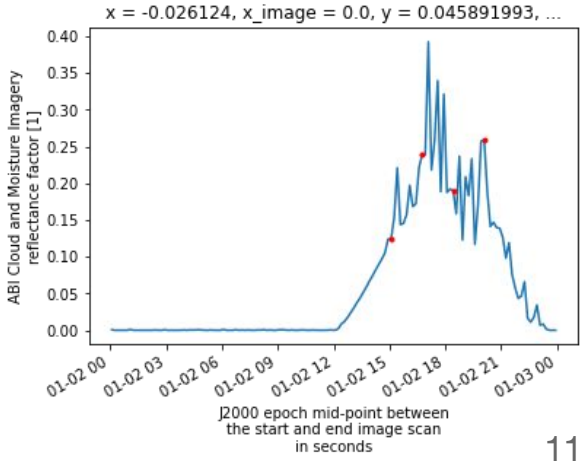

GOES Processing Times

For 24 hours of GOES-16 “ABI-L2-MCMIPF” product data

Format	**Preprocess Time**	**Data Open Time**	**Workflow Time**	**Extra Storage**
Remote NetCDF4	0 min	10 minutes	40 min	0 GB
Zarr	1 h 38 min	30 seconds	4 min	52 GB
ReferenceFileSystem	1 h 25 min	35 seconds	5 min 30 s	***416 MB***

- NetCDF has no upfront preprocess time cost
  - But very slow open and workflow times
- Zarr comes at cost of high storage costs (full data duplication)
- ReferenceFileSystem has speed of Zarr but ***<1% storage cost***
  - Reference file can be compressed further

The Implications

- ReferenceMaker/FileSystem harnesses the cloud-optimization of Zarr without converting any data
- Allows current institutions to cheaply make existing cloud-hosted data more optimized
- Reference files can be also created, hosted, and shared by third parties
- Automatable
  - e.g. Pangeo Forge

Future Work Needed

- Project is still in early development
- Test compatibility across different datasets
- Scale to larger datasets and compare performance to Zarr
- Test performance on a local parallel filesystem (like GLADE)

Acknowledgements

Thank you to the ReferenceFileSystem team!

- Special thanks to Martin Durant (Anaconda) and Rich Signell (USGS) for their help learning and contributing to this project
- https://github.com/intake/fsspec-reference-maker

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Thanks to the SIParCS team for working so hard to make a fully-online internship experience so successful

Thanks to Microsoft for providing credits for Planetary Computer

Link to site with interactive code examples, tutorials, resources, and contact info

https://lucassterzinger.com/2021-siparcs-poster/

Please feel free to reach out with questions lsterzinger@ucdavis.edu or twitter @lucassterzinger

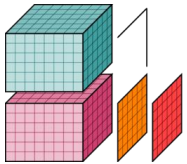
Community Matters

If you are a scientist that works with these tools

- Join the Pangeo community
- Talk to project maintainers about your workflow needs
- Open issues/bug reports on GitHub
- Submit pull requests, even if your code isn't 100% ready

PANGEO

Microsoft Planetary Computer



xarray

jupyter

Iris

DASK