Scaling biodiversity data processing and analysis workflows with Apache Beam

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Software Workflows and Tools for Integrating Remote Sensing and Organismal Occurrence Data Streams to Assess and Monitor Biodiversity Change

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WHY?

“improving the ease with which the biology and ecology communities can understand, select and use appropriately NASA remote sensing data.”
● Types of biodiversity data
● Combining biodiversity data with remote sensing products
● Existing tools for data fusion
● Scaling with Beam
Types of biodiversity data
- Observation / occurrence
- Expert range maps
- Local Inventories
- Gridded surveys
- Regional checklists
- Distribution model predictions
Movement data
... and more movement data.
Combining biodiversity data with remote sensing products
Environmental niche modeling

Species presence → Environment → Model → Prediction

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Biodiversity data $\cap$ Environmental data
Not trivial ...
Existing tools for data fusion
Advantages

- Well documented
- Extensible
- Well integrated with other tools and systems
- Large community of developers and users
- What biology and ecology communities use and understand

Limits

- Requires everything (imagery and data) to be local
- Can’t scale beyond local resources
Advantages

- Large catalog of public imagery
- Kept up to date
- Specifically designed for annotating movement data

Limits

- Slow (hours - days)
- Not extensible
- No support for raster upload
- No support for spatial or temporal aggregation
Google Earth Engine

Advantages

- Large and growing catalog of imagery
- Kept up to date
- Abstracts complexity away (scales compute, manages tasking)
- Full spatial analysis API - supports aggregation in space-time

Limits

- High vendor lock-in / low portability
- Limited interoperability with traditional tools
- Very limited server-side logging (difficult to debug)
- Quota limited per user
- Fixed node size
- Mediocre performance across large vector datasets.
Big-data frameworks

Advantages

● Ultimate flexibility
● Ultimate scalability

Limits

● Harder to use, less accessible to non-technical users
● Often limited documentation and support for spatial analysis
Bridging the divide with Apache Beam
An advanced unified programming model

Implement batch and streaming data processing jobs that run on any execution engine.
# sample images and apply spatiotemporal reducers

```python
samples = (features
    | 'sample_pixels' >> beam.ParDo(sample_region, args, asset)
    | 'applyReducers' >> beam.CombinePerKey(ReducePixels(args))
    | 'formatReducer_output' >> beam.ParDo(format_reducer_output)
    | 'groupByLocation' >> beam.GroupByKey()
)
```

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Cloud Dataflow features

Live pipeline monitoring

Detailed logging

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Autoscaling

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Drawbacks

- Very new
- Need high availability access to pixel data (high QPS API or local to compute node)
- Cloud runners (DataFlow) have ~6 minute startup cost
- Less suitable for small requests
- Exotic environments difficult to support and scale
- Google Cloud Dataflow only full-service option
Architecture: Environmental annotation of biodiversity occurrence data

Google Cloud Platform

Batch
- Raw occurrence
  - Cloud Storage
- Processed occurrence
  - BigQuery

Streaming
- Sensor data
  - Cloud Pub/Sub

Batch & Streaming
- Environmental data API
  - Earth Engine
- Source imagery
  - Cloud Storage

Annotation pipeline
- Cloud Dataflow

Analytics
- BigQuery

Enriched CSV
- Cloud Storage

Species distribution modelling
- Cloud ML

Visualization
- Map of Life

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Project deliverables

- Open source Apache Beam code to run data fusion requests on local and API accessible datasets
- HTTP API to manage data fusion requests on the Google Cloud Dataflow pipeline runner
- Command-line interface to interact with API
- Web front-end
- Suite of 1km products suitable for conservation science (1km daily temperature and precip)