TEXAS TECH UNIVERSITY™

Streamed Clustering of Lightning Mapping Data in Python Using scikit-learn

Eric Bruning
TTU Department of Geosciences
Atmospheric Science Group
@deeplycloudy

SciPy 2012
Wed, 26 June 2012
6:00-6:15 pm
Austin, TX

West Texas Lightning Mapping Array

OK

Thursday, June 27, 2013

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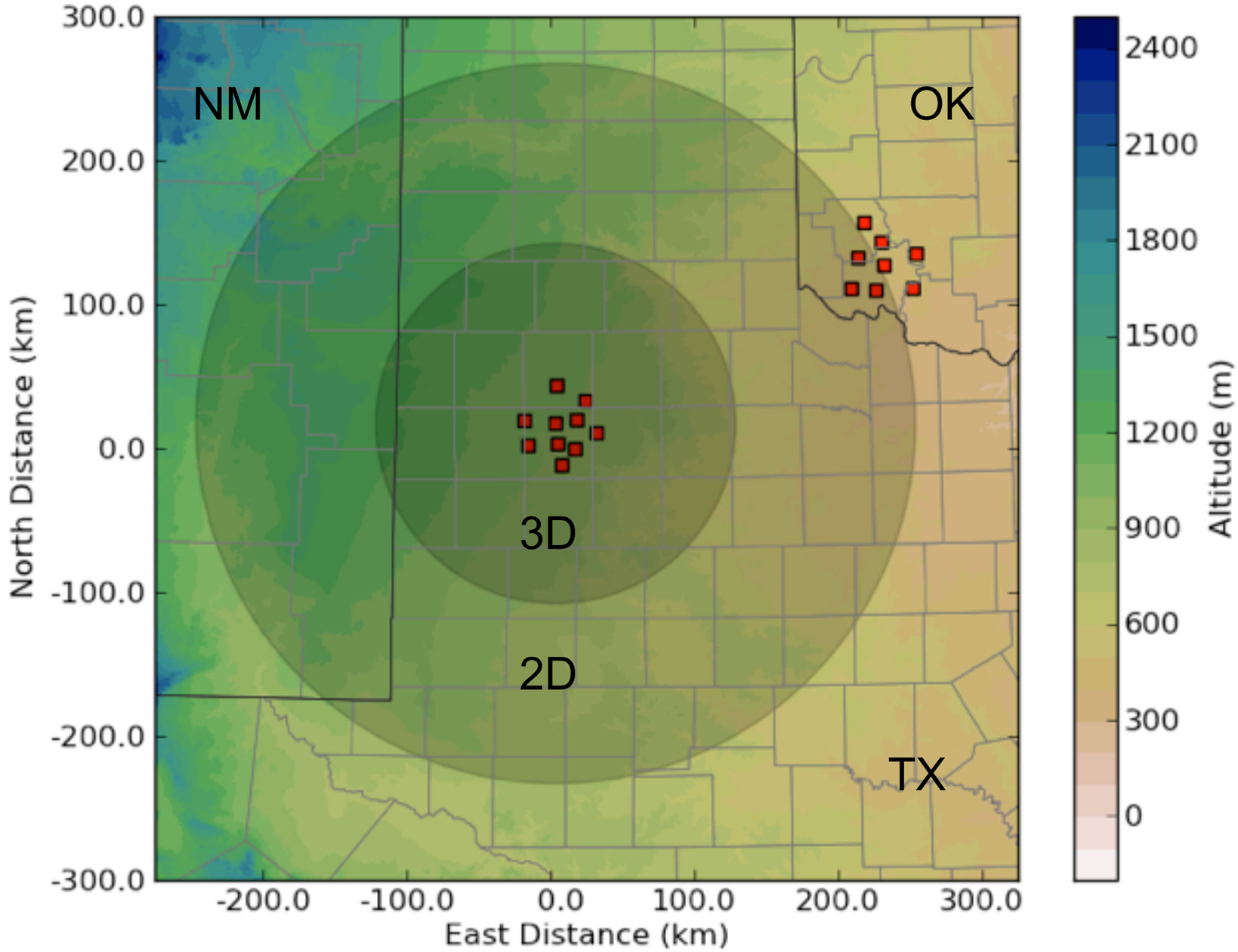

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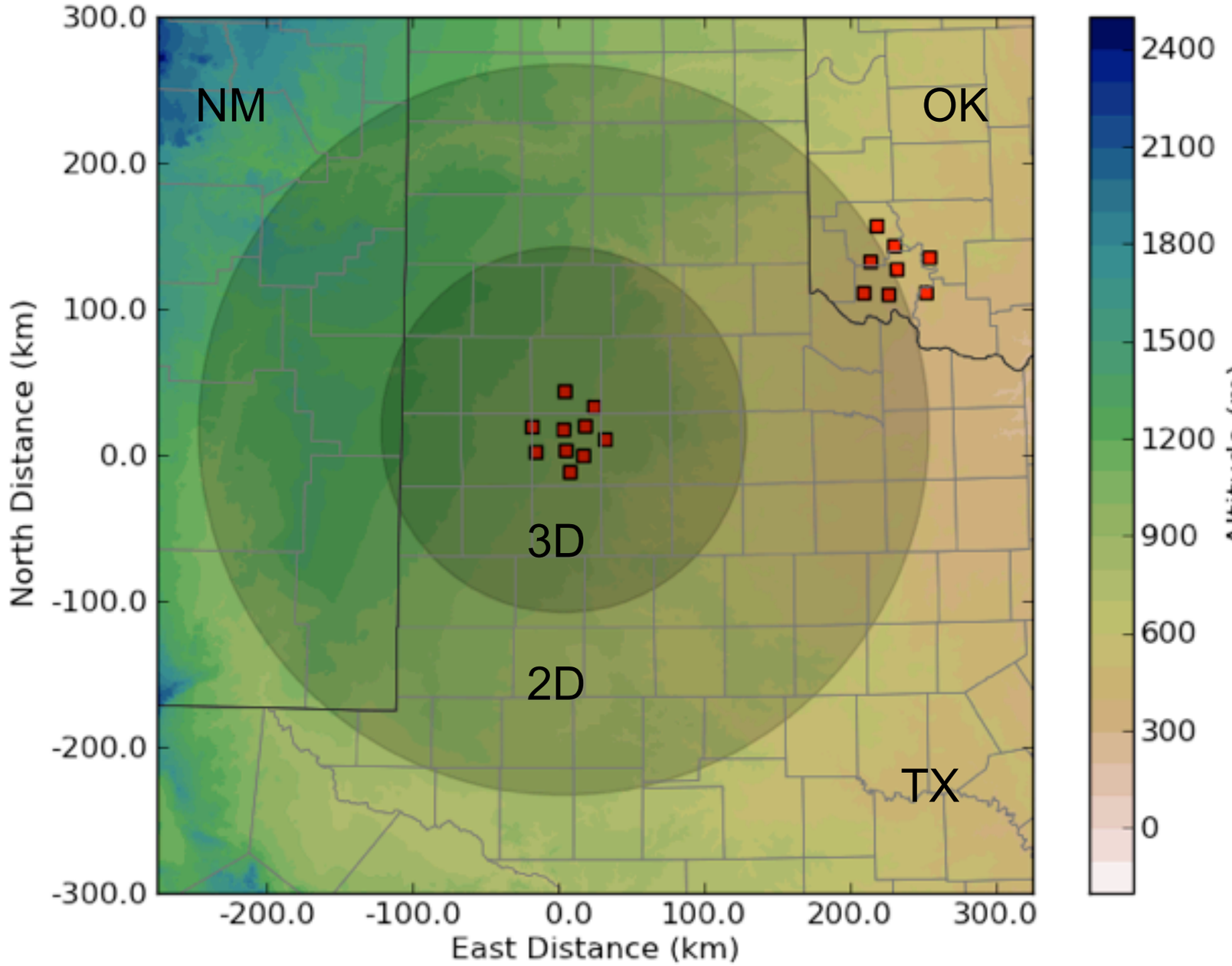

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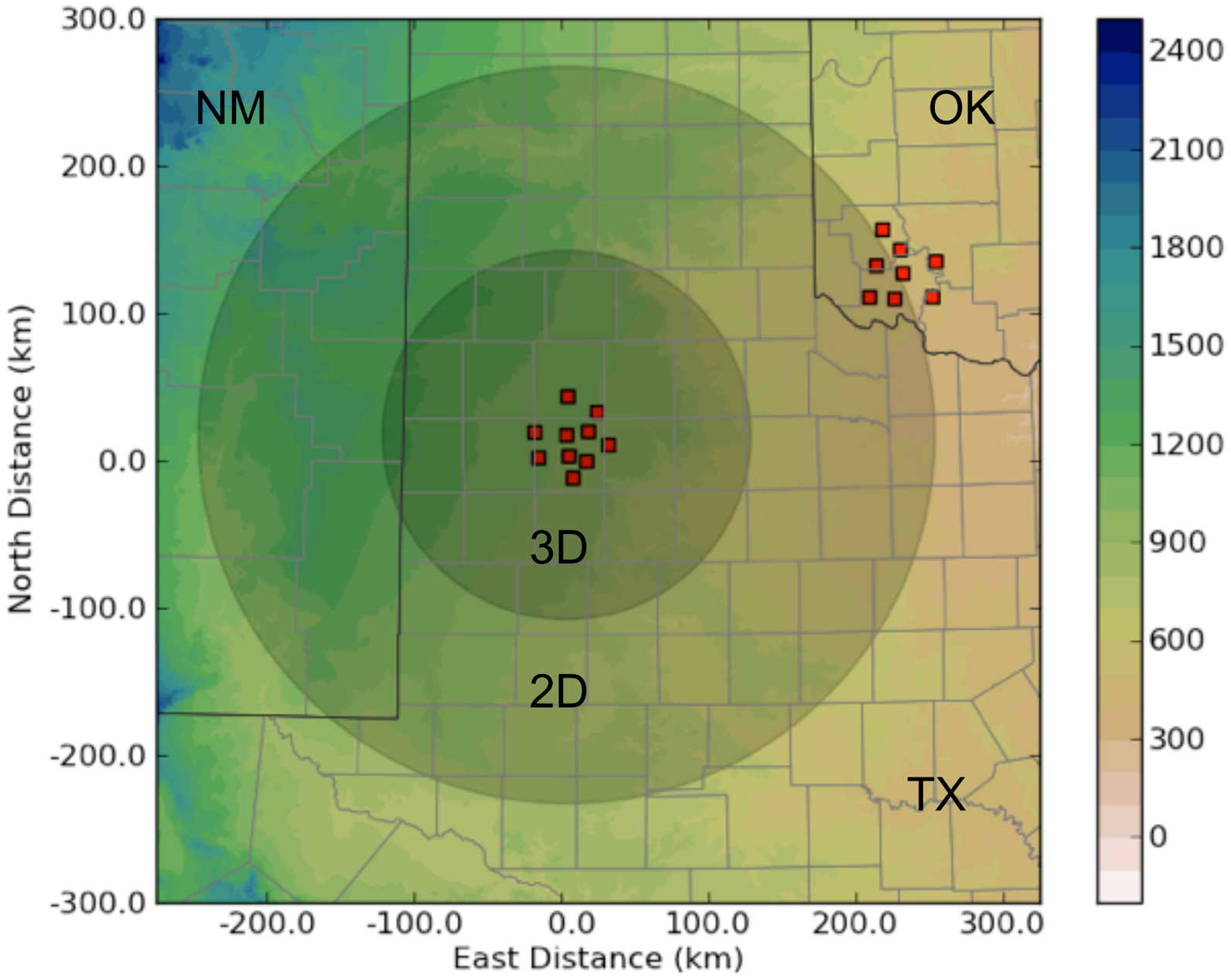
- Typical lightning flash: 100-1000 sources



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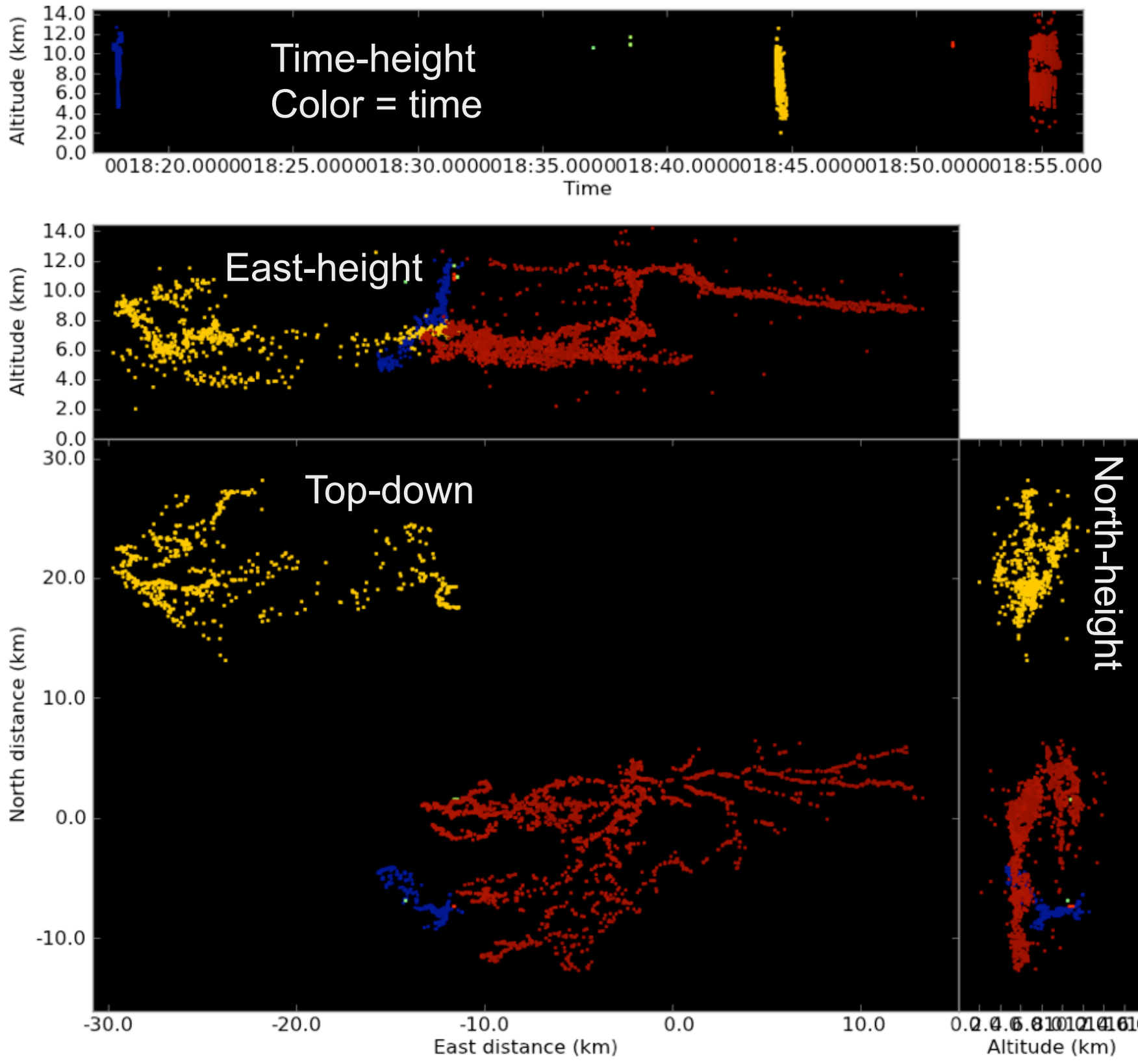

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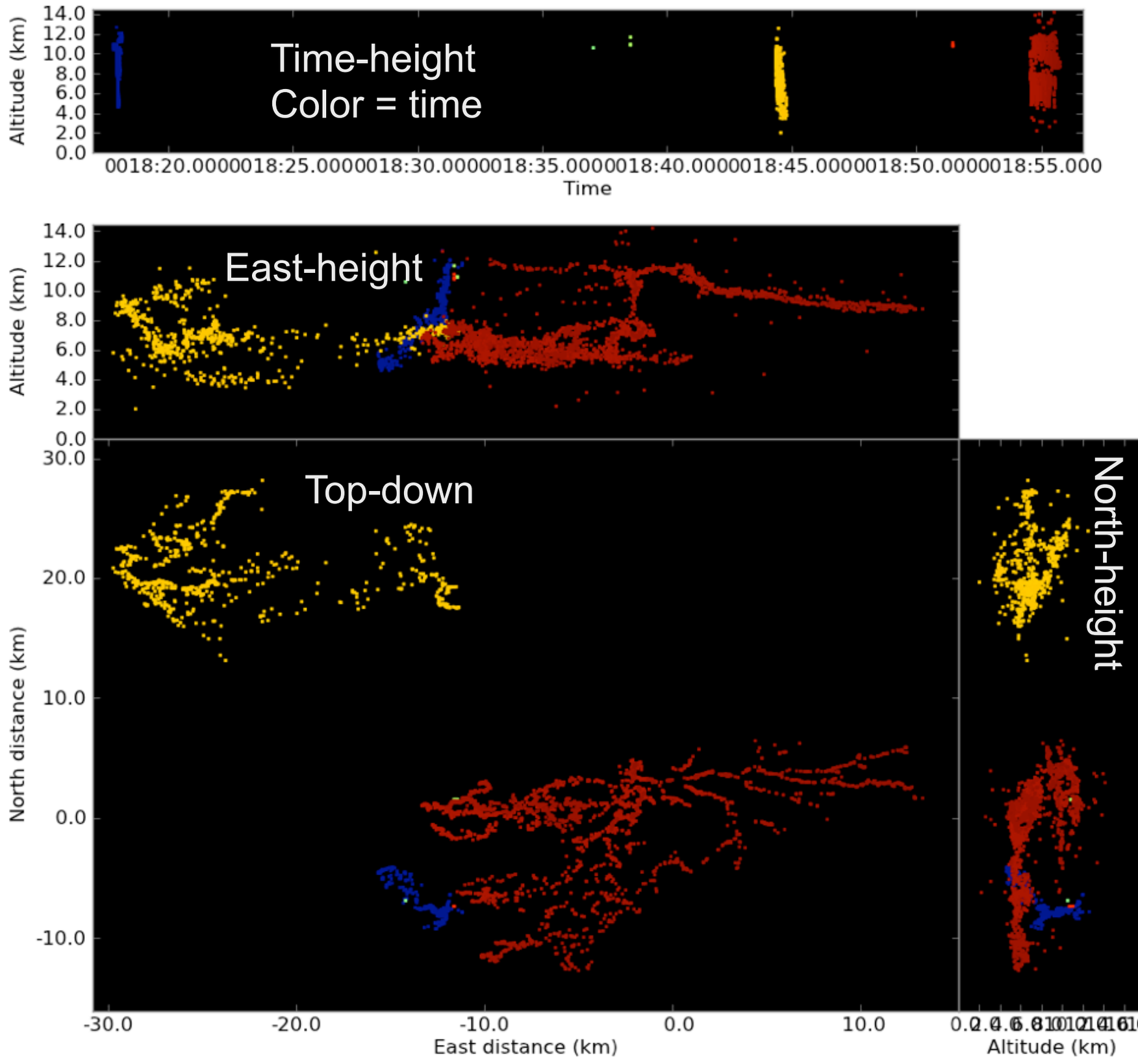

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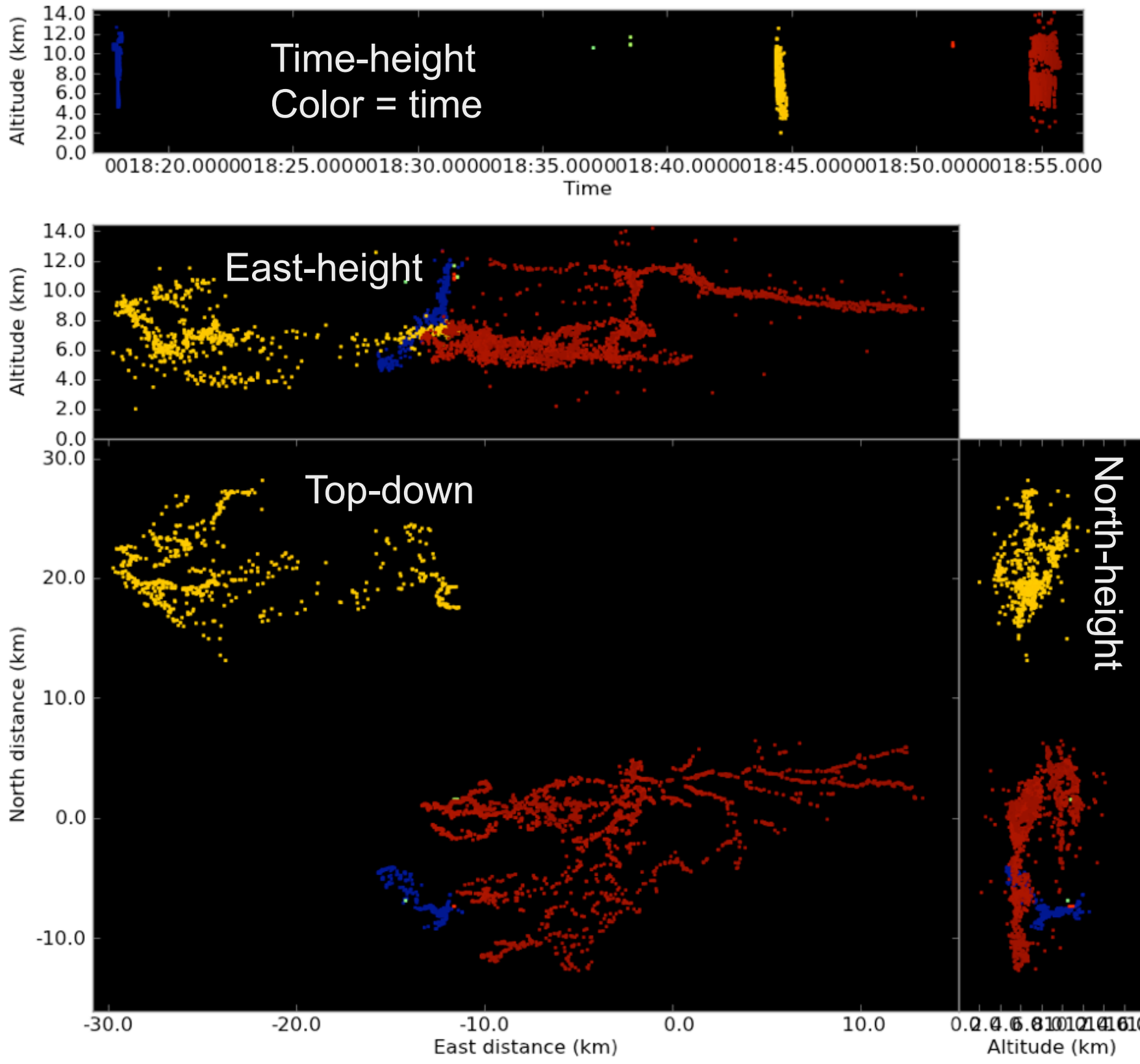

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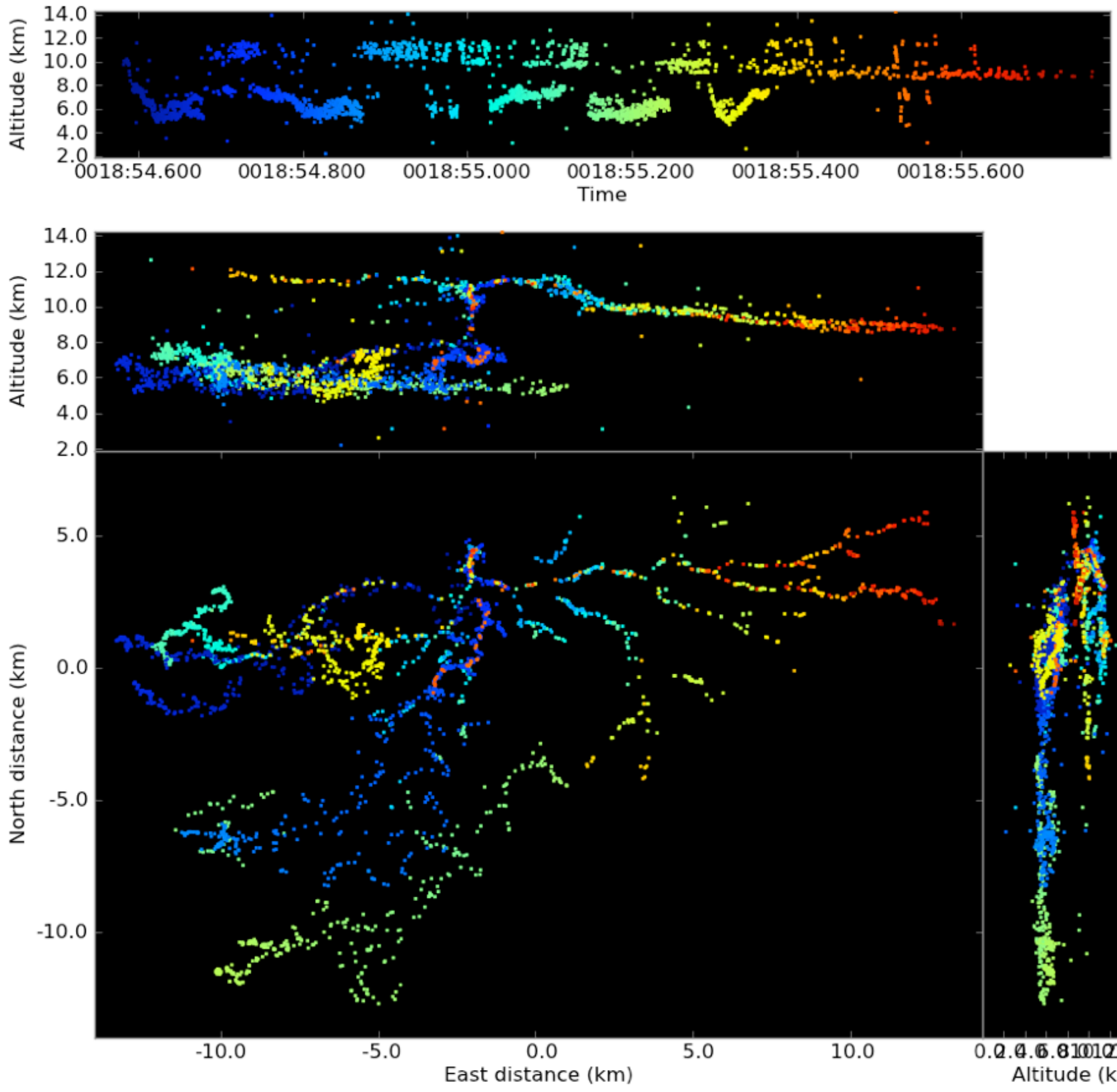

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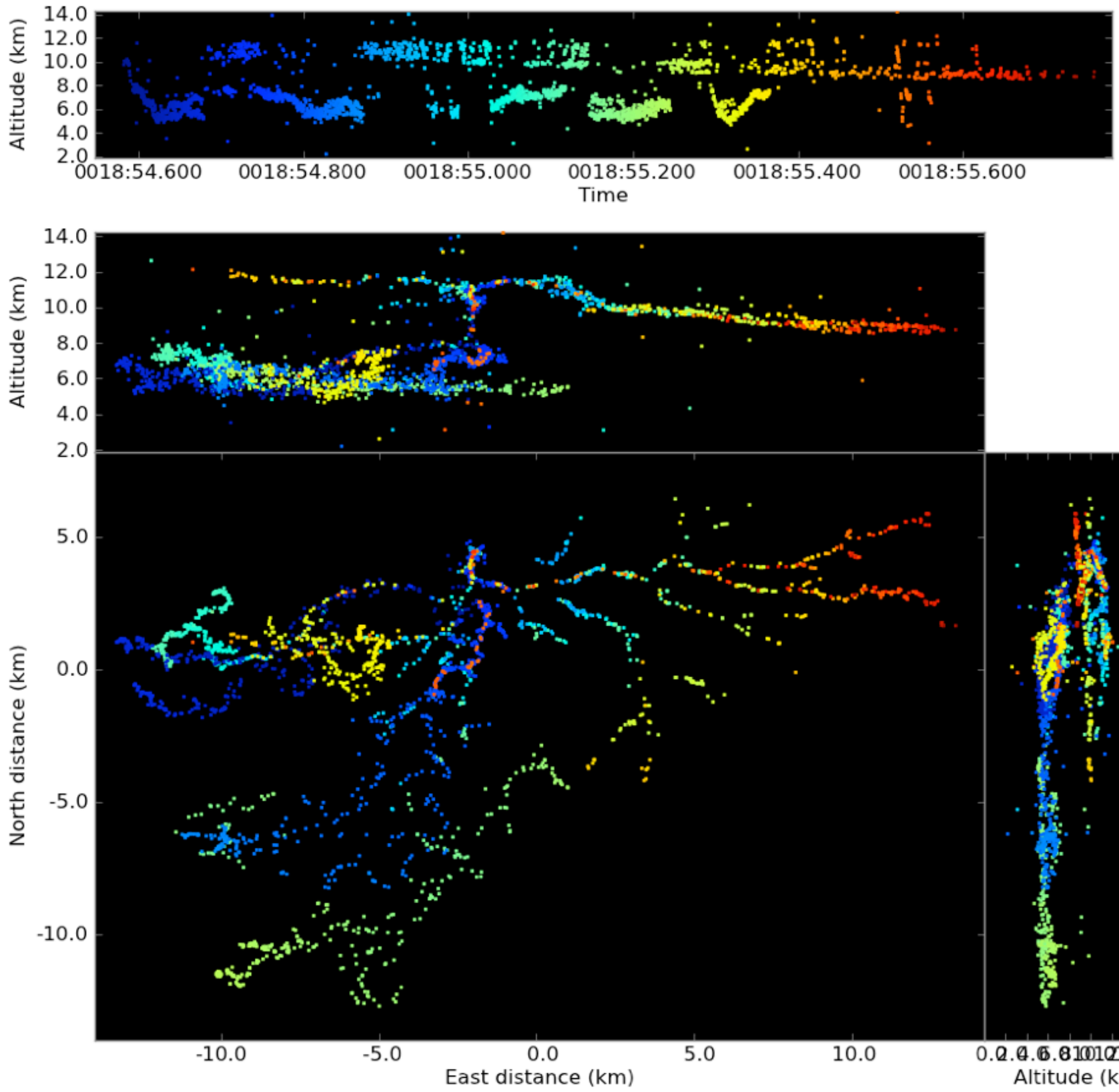

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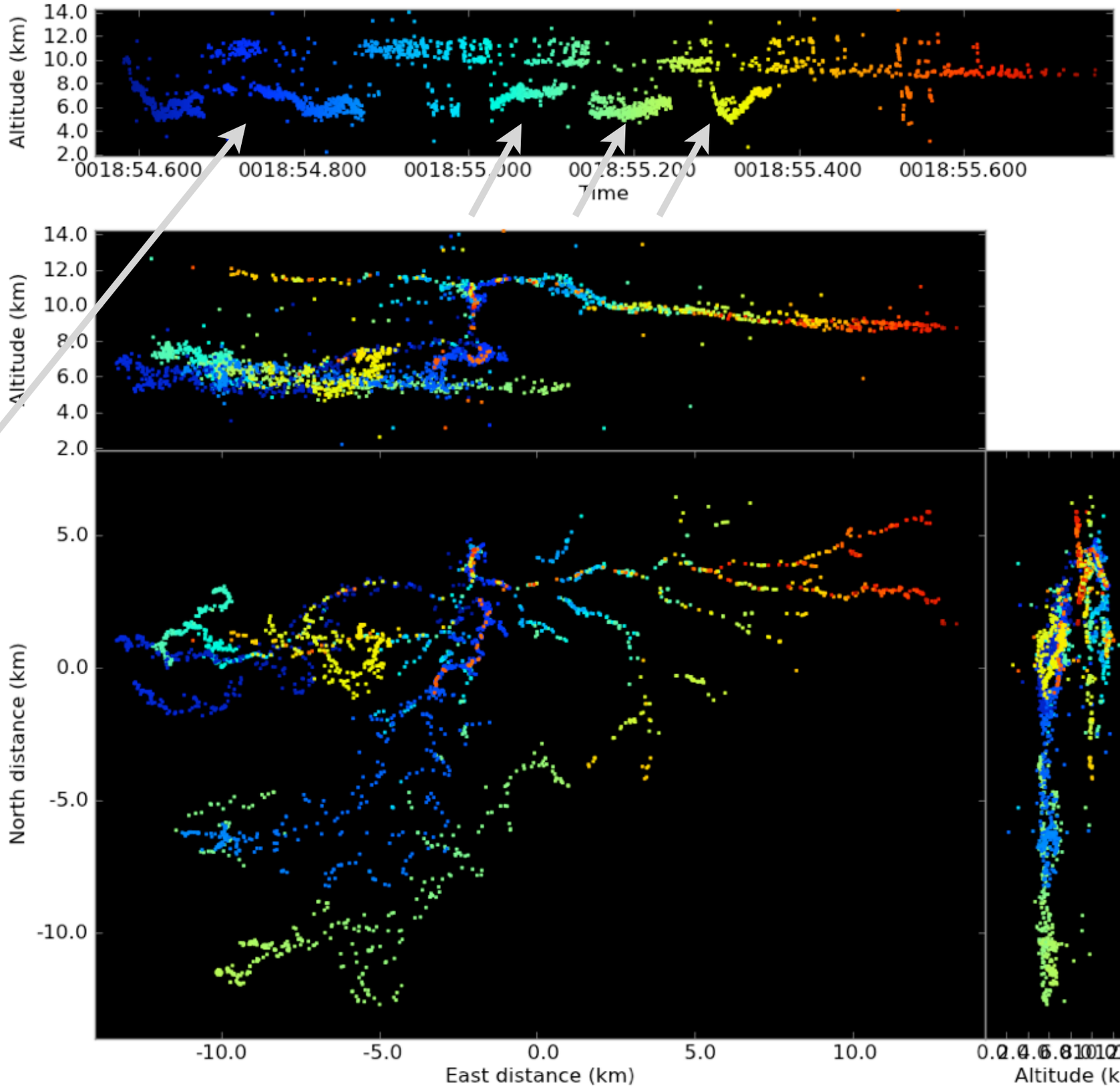

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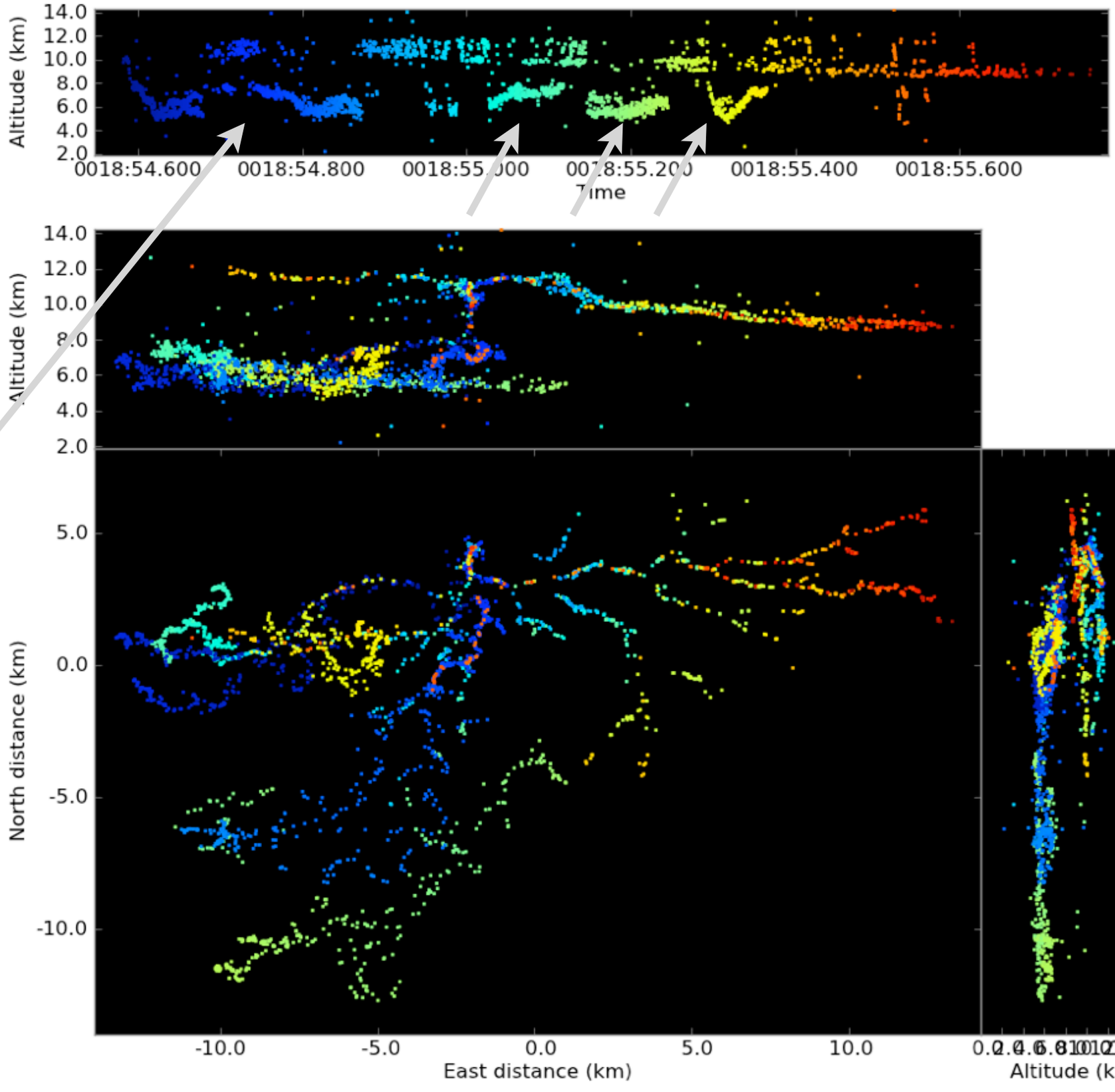

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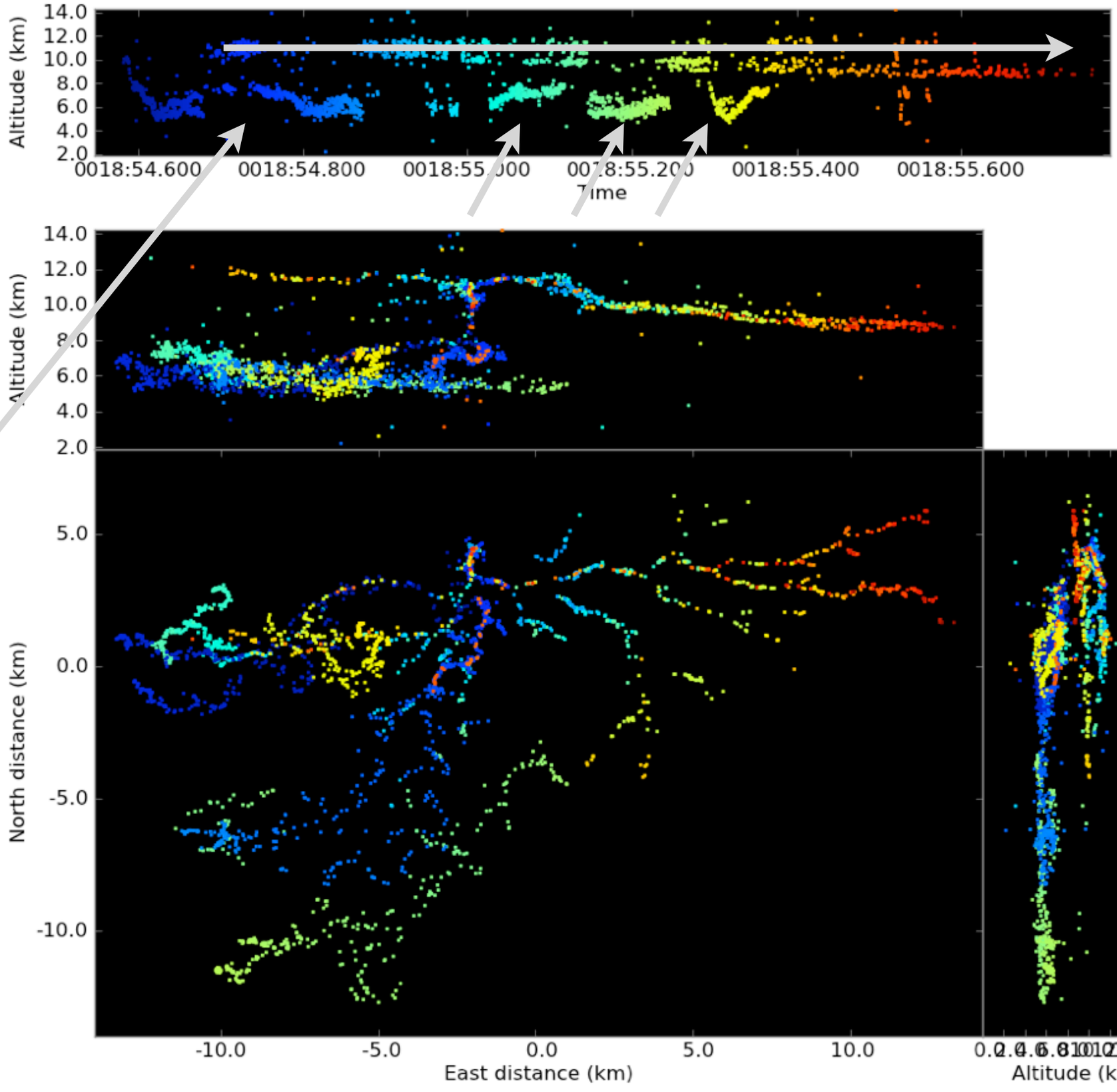

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  - *Maintains vertical coordinate*
  - *Project geographic data to/from (polar) weather radar coordinates*

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  - *Typical: 0.15 seconds, 3 km*

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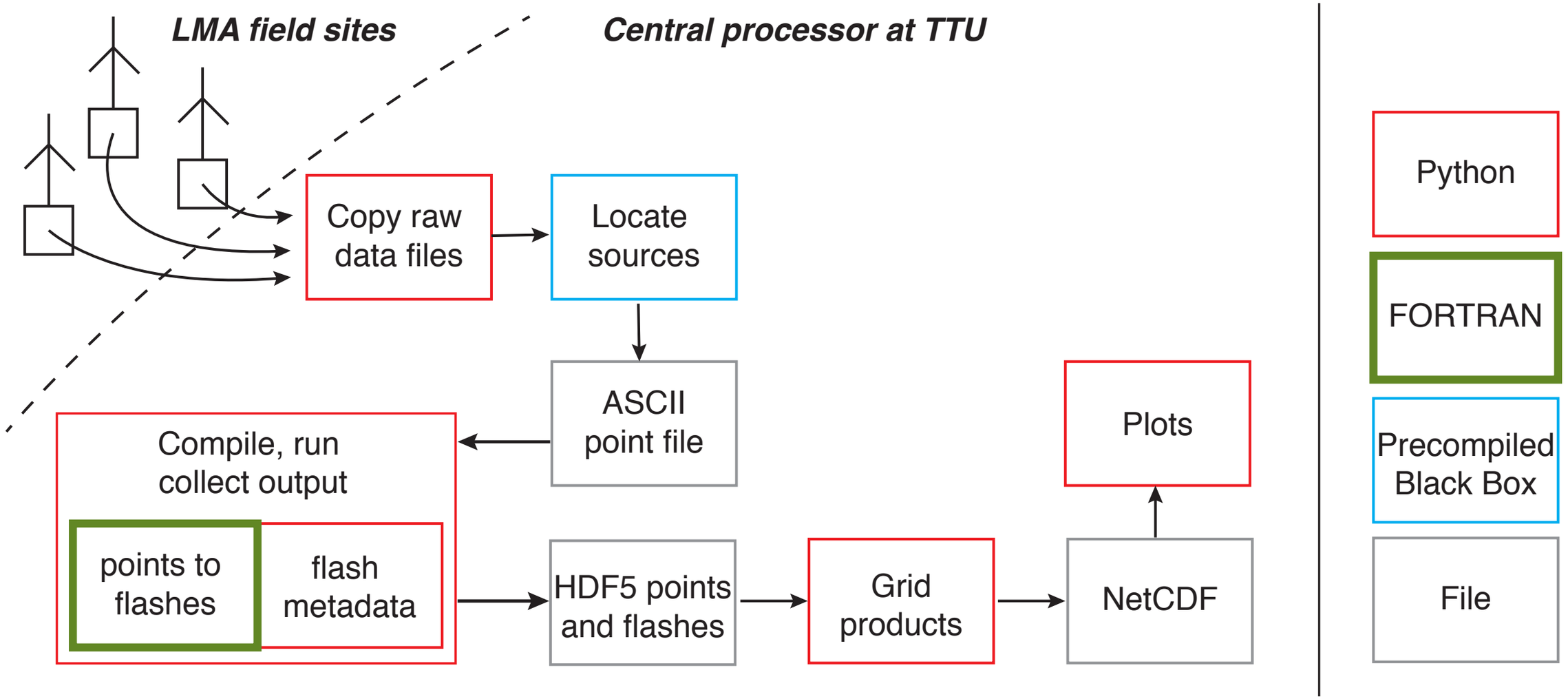

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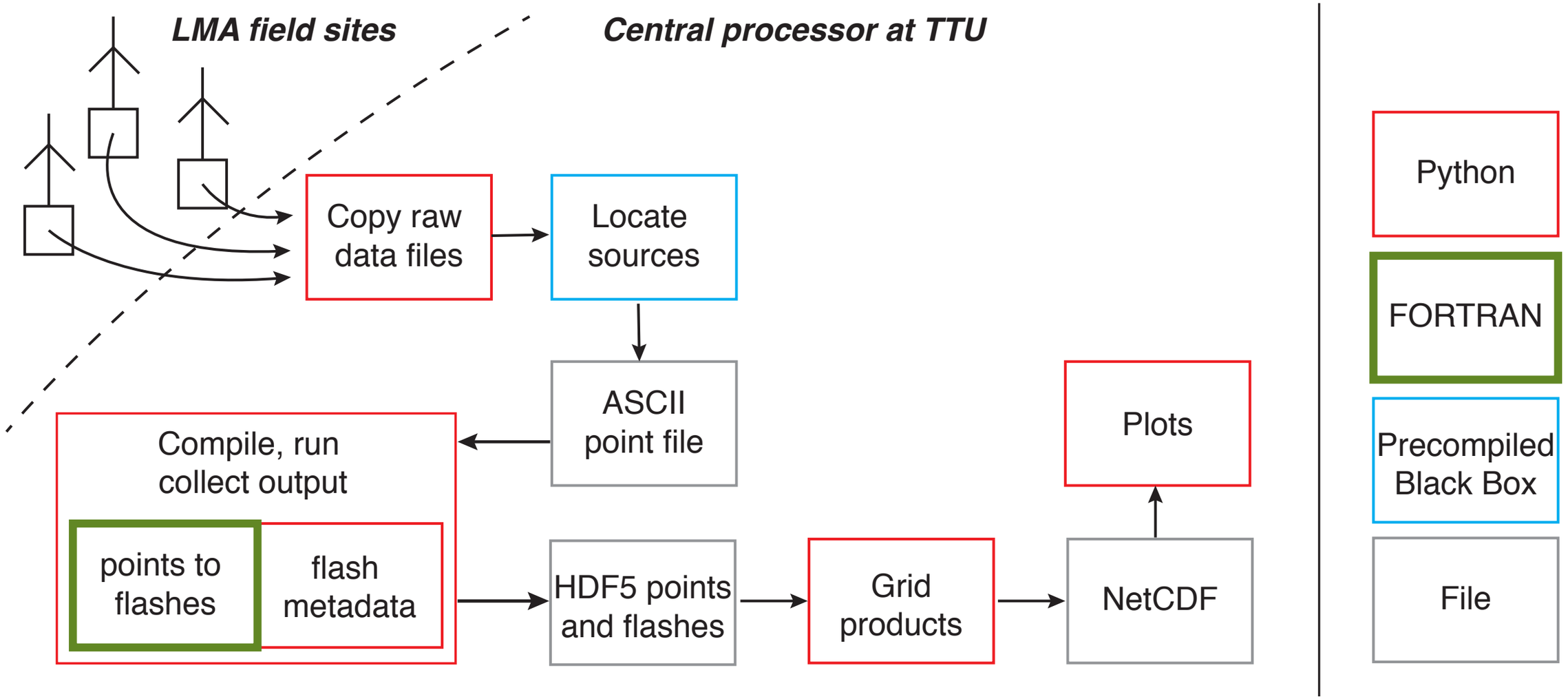

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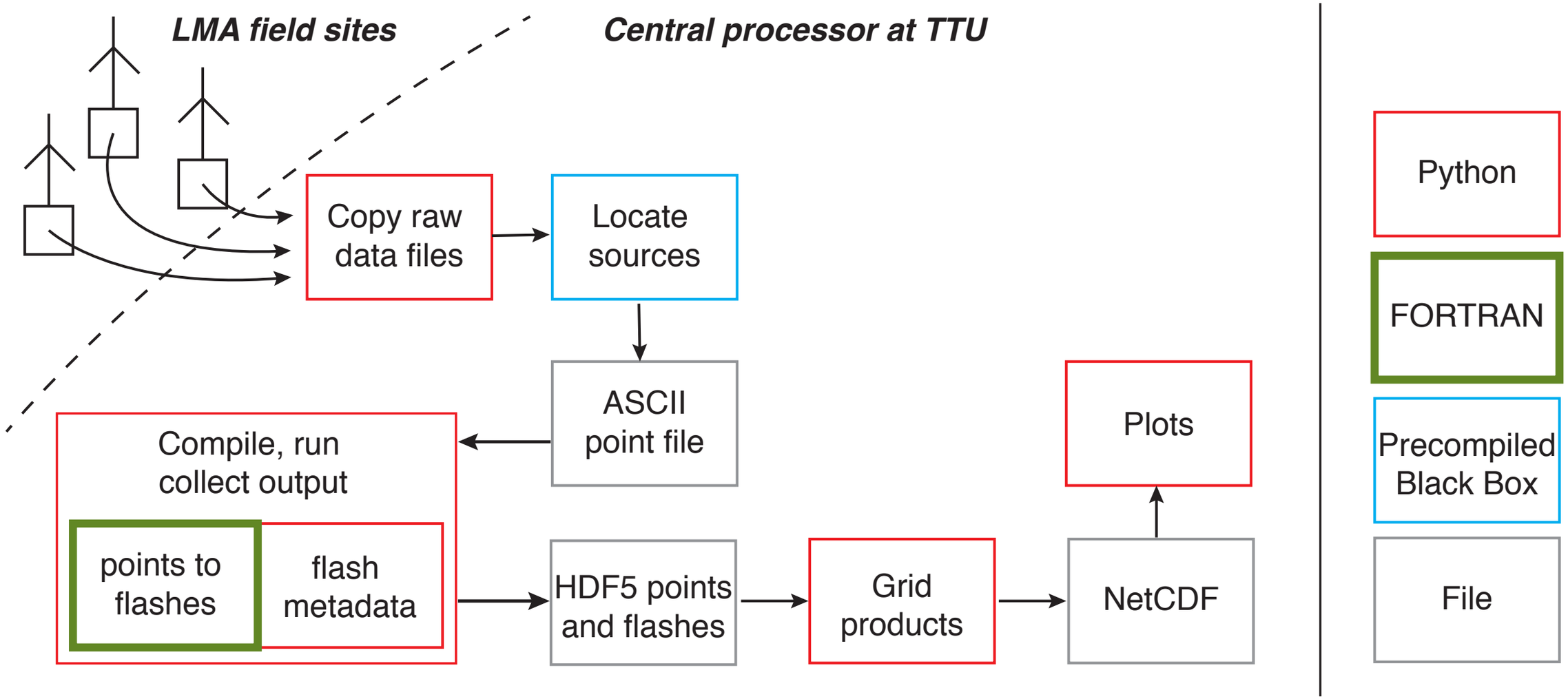

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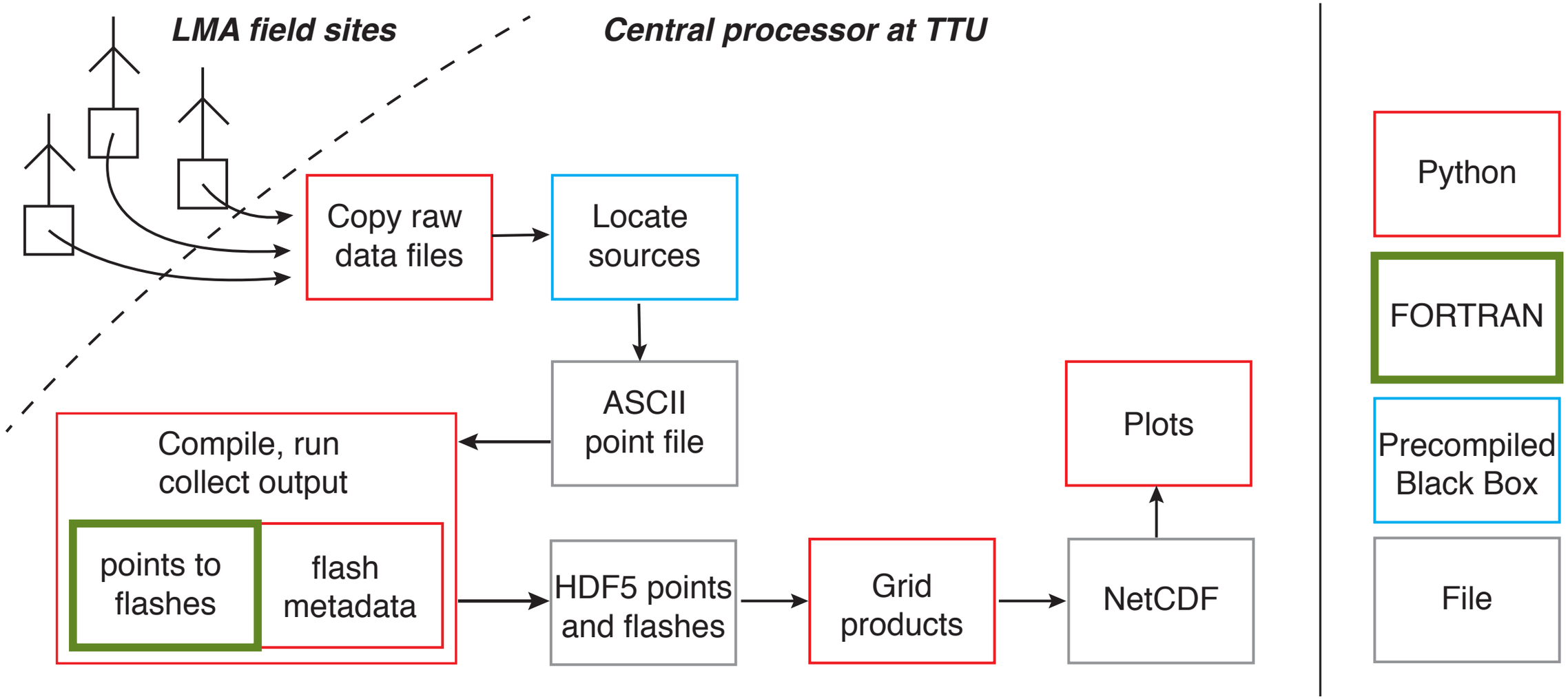

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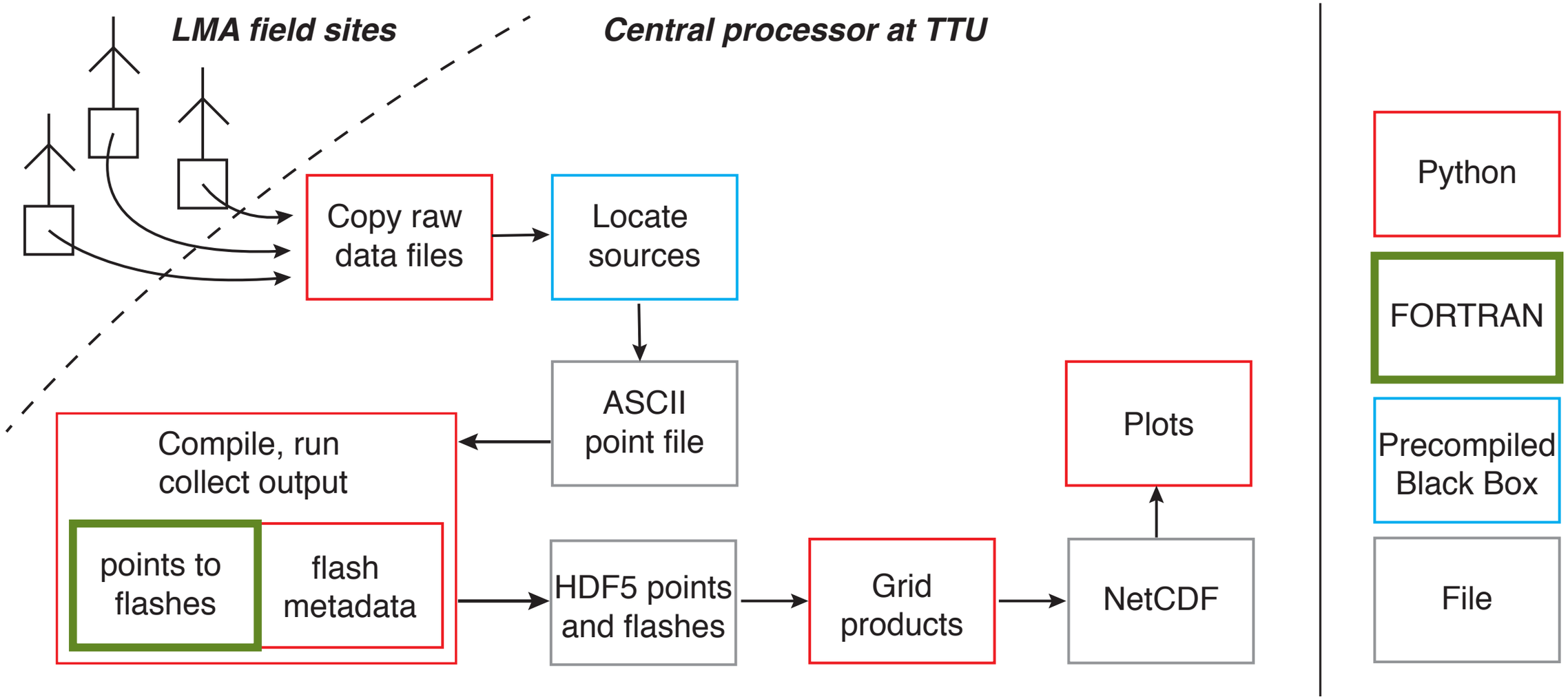

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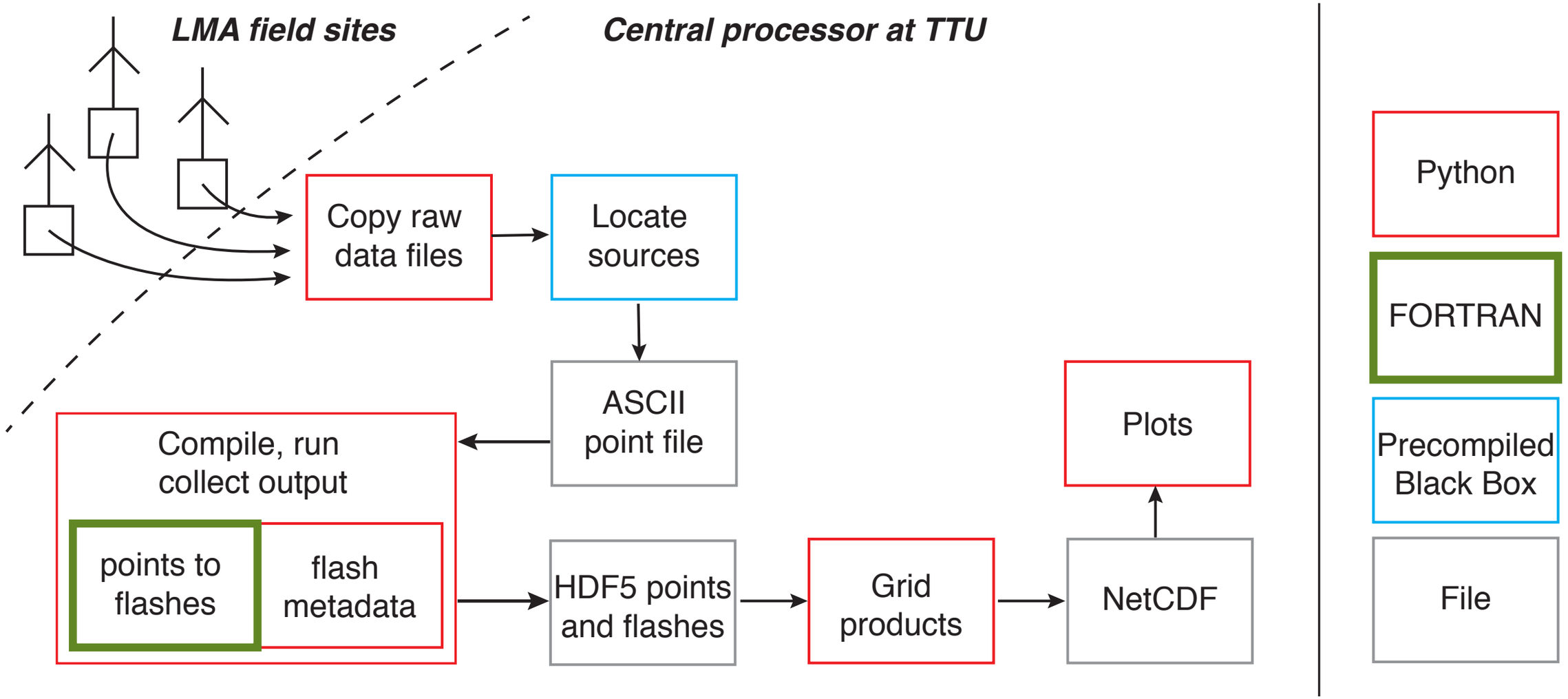

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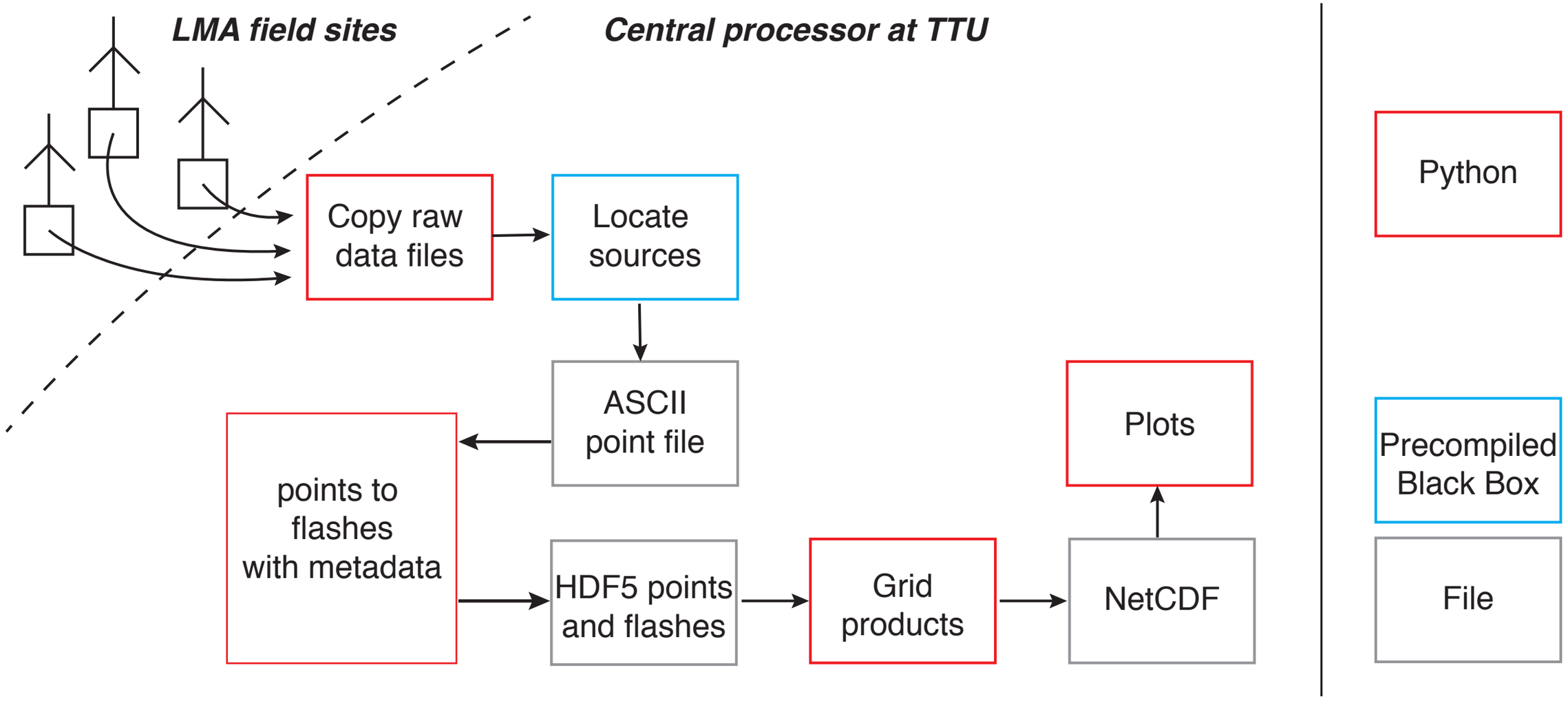

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- Exploit max flash duration (a few seconds) to do streamed, chunked processing

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Cycle 2

Cycle 3

...

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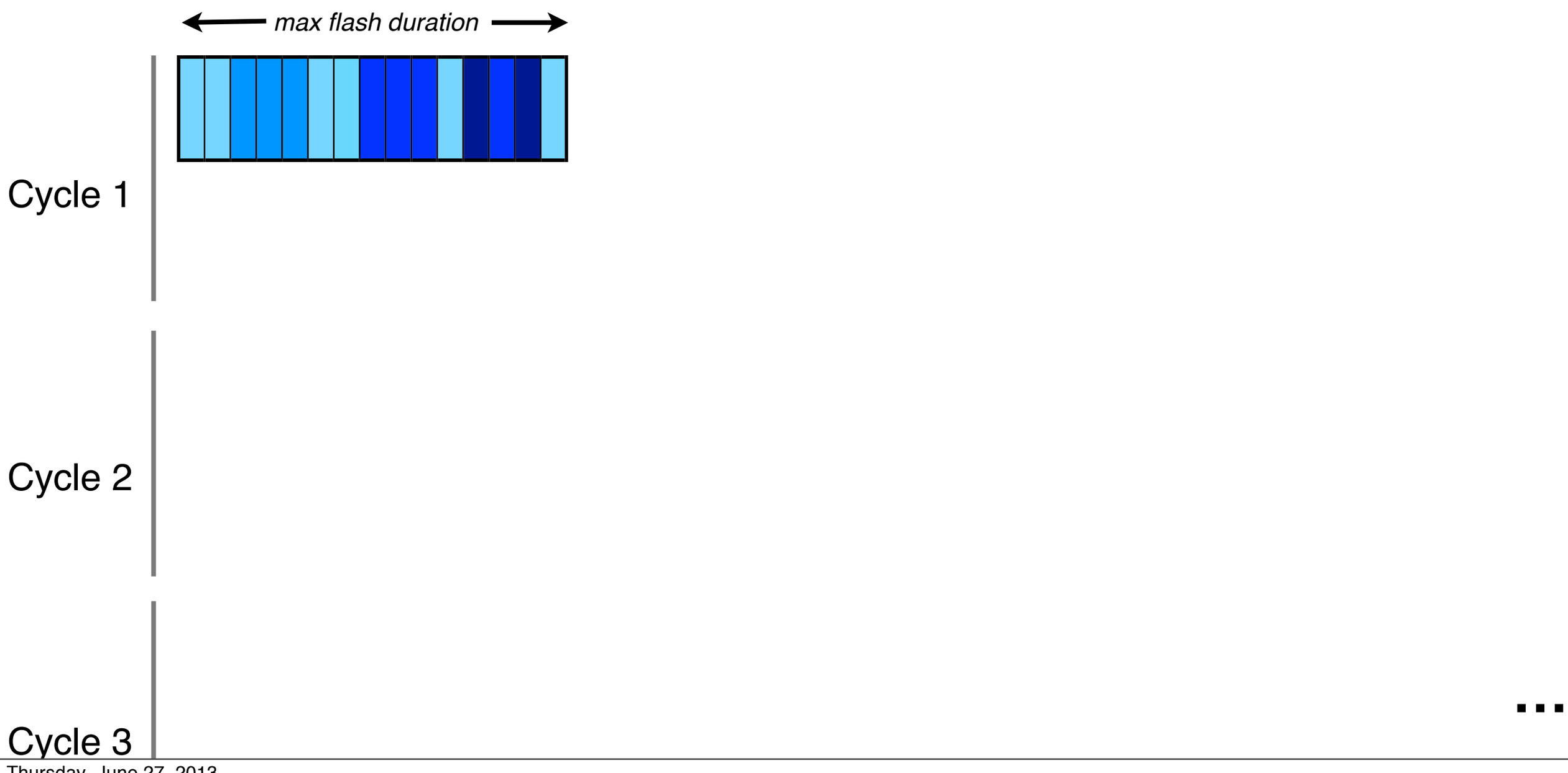

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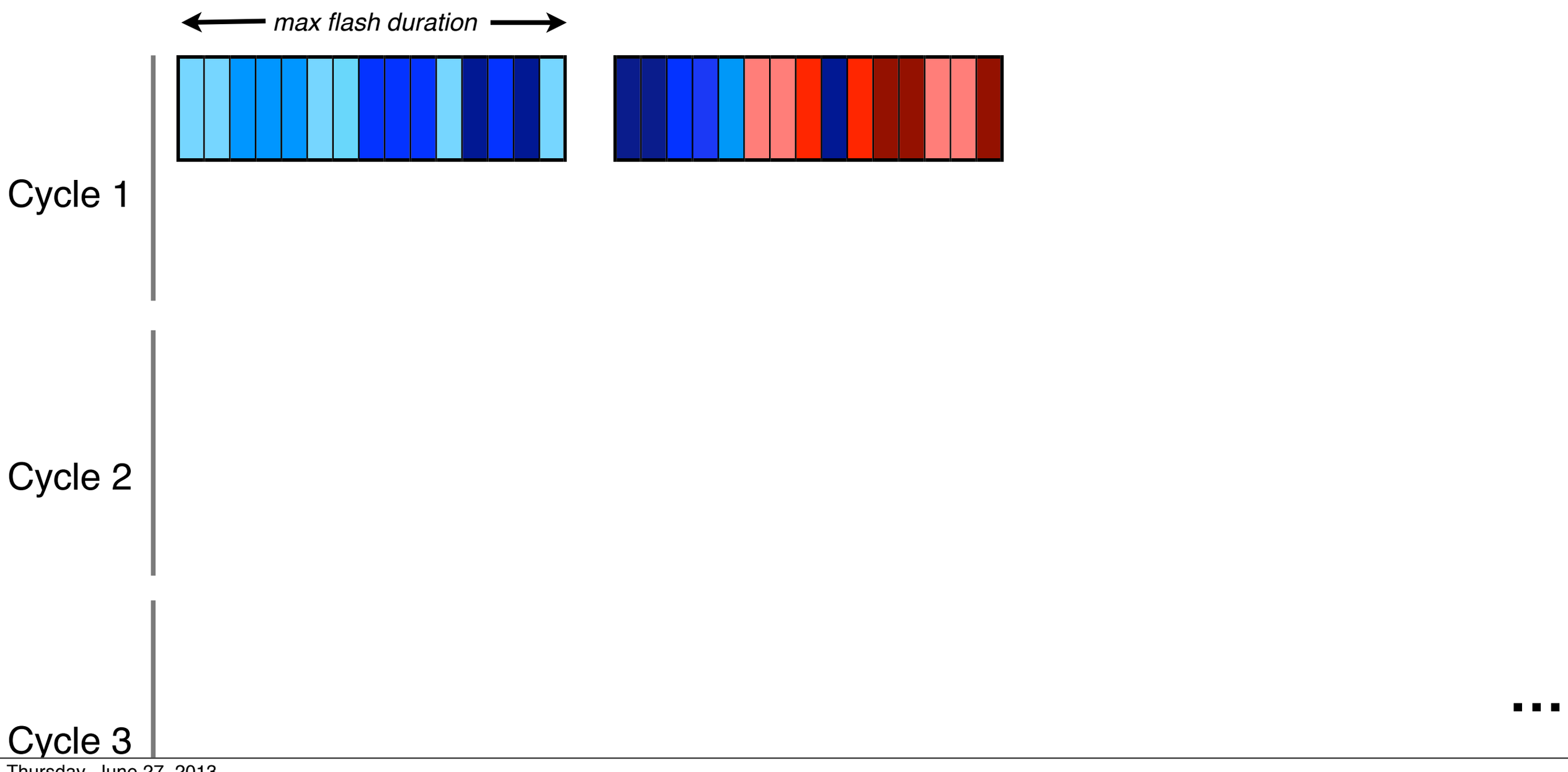

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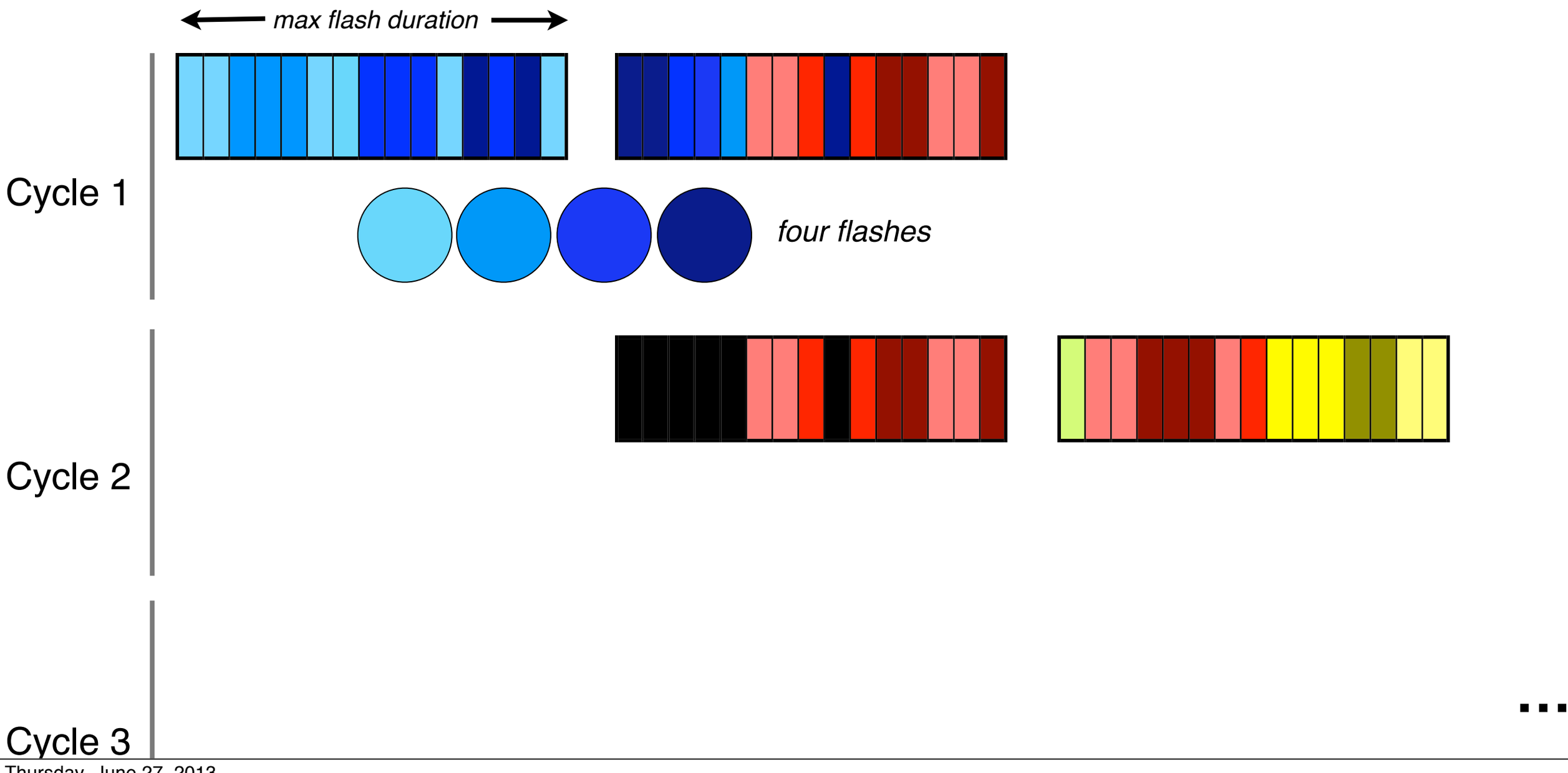

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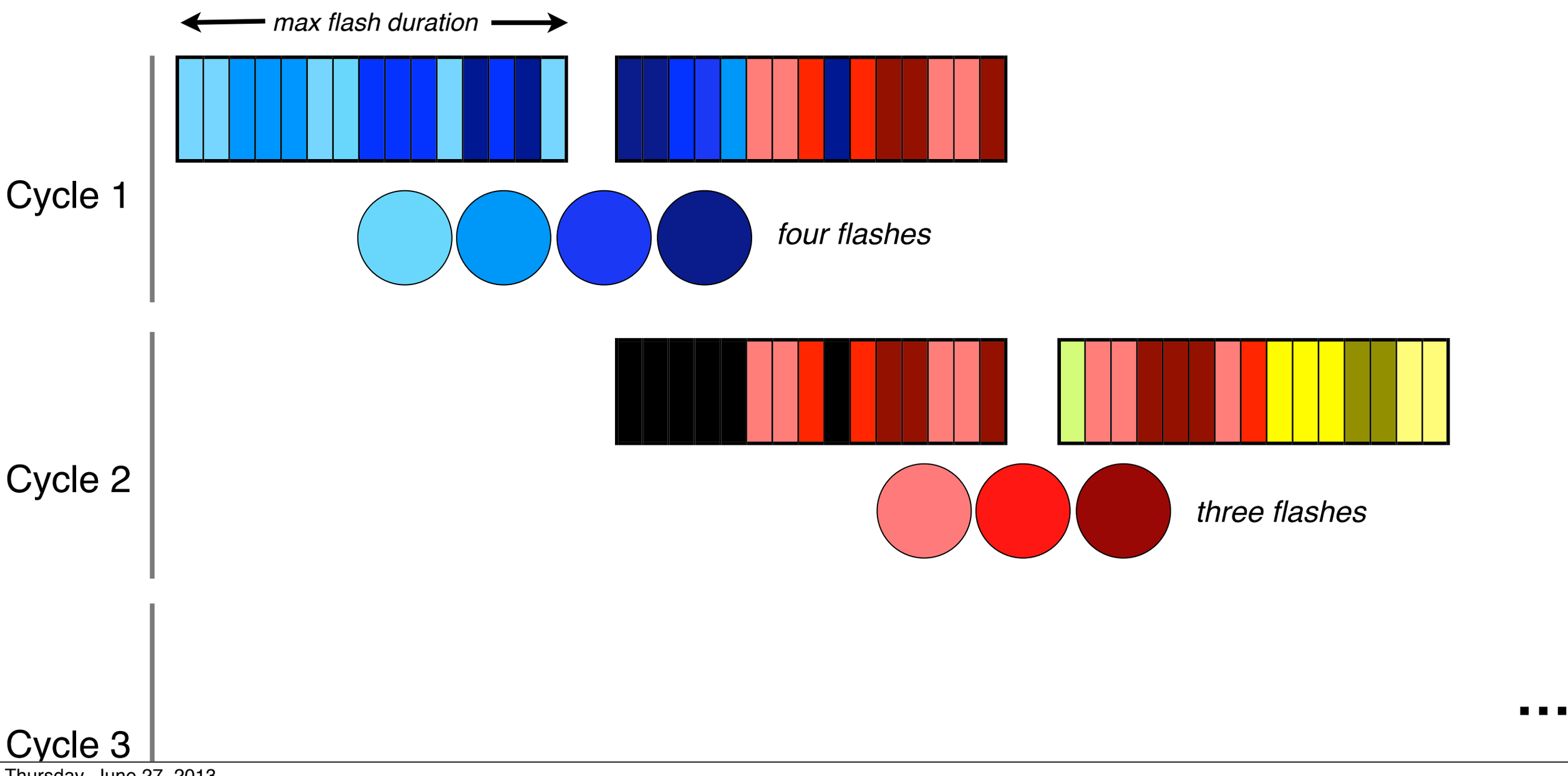

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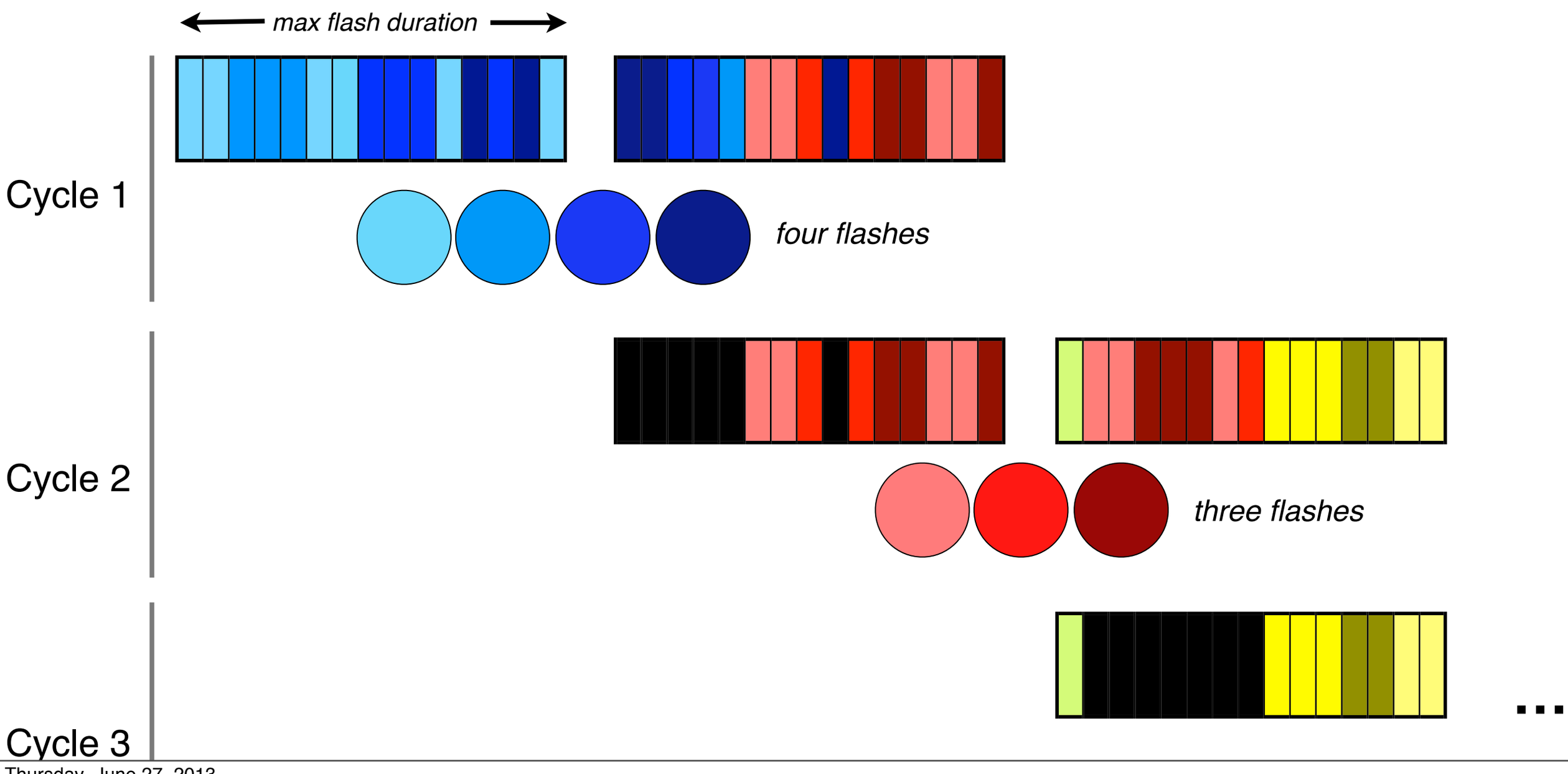


Pipeline based on coroutines: start with a stream of vectors

```
def stream(vec, target):
    for v in vec:
        target.send(v)
    target.close()

@coroutine
def chunk(start_time, max_duration, target, t_idx=-1):
    next_time = start_time + max_duration
    v_buffer = []
    try:
        while True:
            v = (yield)
            v_buffer.append(v)
            t = v[t_idx]
            if t >= next_time:
                target.send(np.asarray(v_buffer))
                v_buffer = []
                next_time = t+max_duration
    except GeneratorExit:
        target.send(np.asarray(v_buffer))
```

loop over array, send vectors

chunk **coroutine is the** target

setup

new (x,y,z,t) vector from stream

max possible duration?
send to the next step (clustering)

deal with leftovers

THE CLUSTERER

```
    @coroutine
def cluster_chunk_pairs(clustered_output_target, min_points=10):
    db = DBSCAN(eps=1.0, min_samples=min_points, metric='euclidean')
    chunk1 = (yield)
    try:
        while True:
            chunk2 = (yield)
            len1, len2 = chunk1.shape[0], chunk2.shape[0]

            # do stuff with chunk 1 and 2
            clusters = db.fit(np.vstack((chunk1, chunk2)))
            labels = clusters.labels_.astype(int)
            clustered_output_target.send((chunk1, labels[:len1]))

            # pull data out of chunk2 that was clustered as part of chunk 1
            chunk1_labelset = set(labels[:len1])
            if -1 in chunk1_labelset:
                chunk1_labelset.remove(-1) # remove the singleton cluster ID - retain these from chunk 2.
            label_iter = ( True if label in chunk1_labelset else False for i,label in enumerate(labels[len1:]) )
            clustered_in_chunk2 = np.fromiter( label_iter , dtype=bool)
            clustered_output_target.send((chunk2[clustered_in_chunk2], labels[len1:][clustered_in_chunk2]))
            residuals = chunk2[clustered_in_chunk2==False]

            # prepare for another chunk
            if len(residuals) == 0:
                residuals = chunk1[0:0,:] # empty array; preserves the number of dimensions in the data vector
            chunk1 = np.asarray(residuals)
    except GeneratorExit:
        clusters = db.fit(chunk1)
        labels = clusters.labels_.astype(int)
        clustered_output_target.send((chunk1, labels))
```

setup DBSCAN
get first chunk

get another chunk

do the clustering

figure out first chunk
for next round

process the leftovers

Final pipeline setup

```
def cluster(a_file, output_path, outfile, params, logger, min_points=1, **kwargs):

    ... preprocessing ...

    X, Y, Z, T = from_data

    D_max, t_max = 3.0e3, 0.15 # m, s

    X_vector = np.hstack((X[:,None],Y[:,None],Z[:,None])) / D_max
    T_vector = data['time'][:,None] / t_max
    XYZT = np.hstack((X_vector, T_vector-T_vector.min()))
```

preprocessing to get T; cartesian X,Y,Z from geographic data

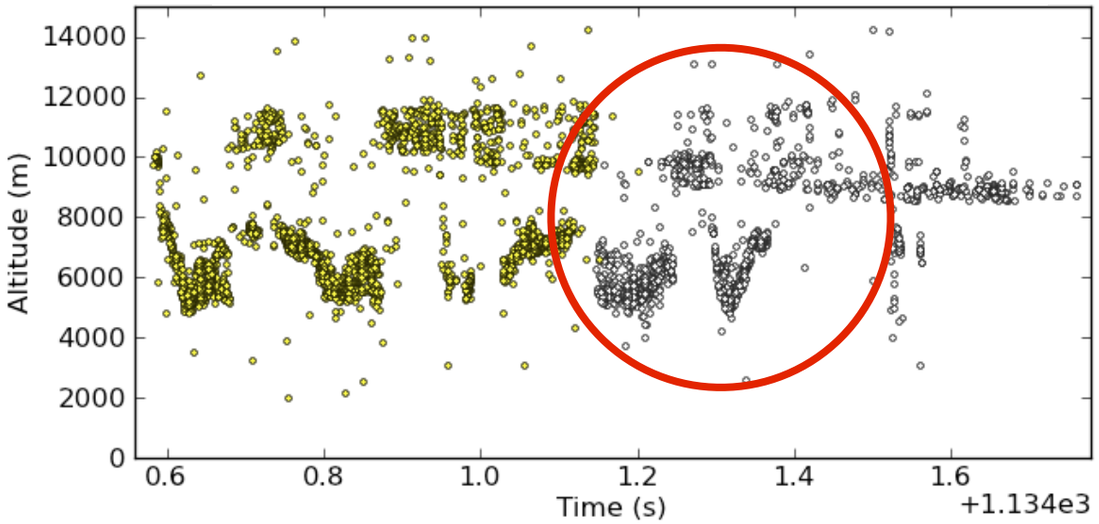
create a normalized vector

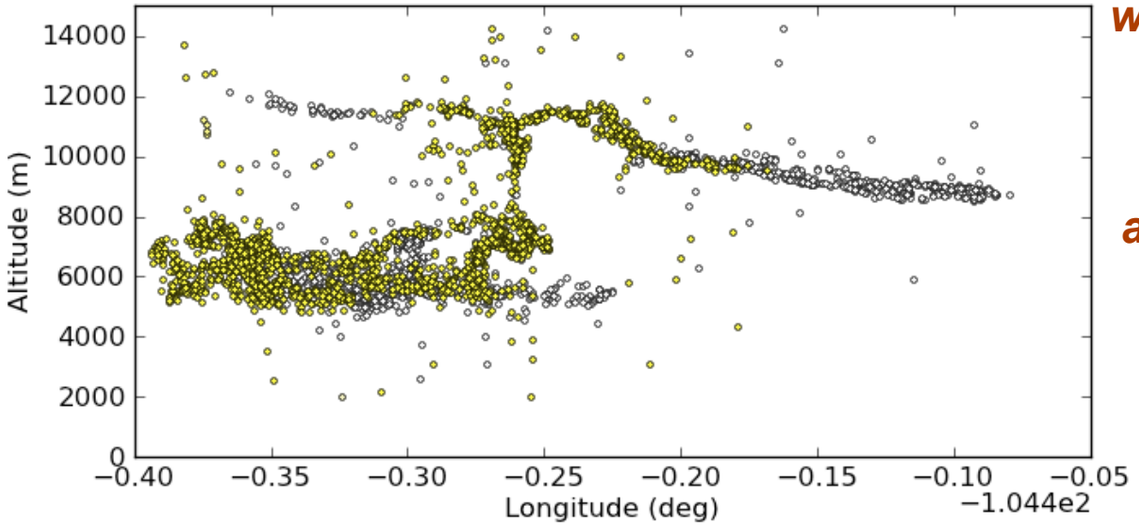
set up the pipeline: `stream ⇒ chunker ⇒ clusterer ⇒ label_aggregator ⇒ create_flash_objs`

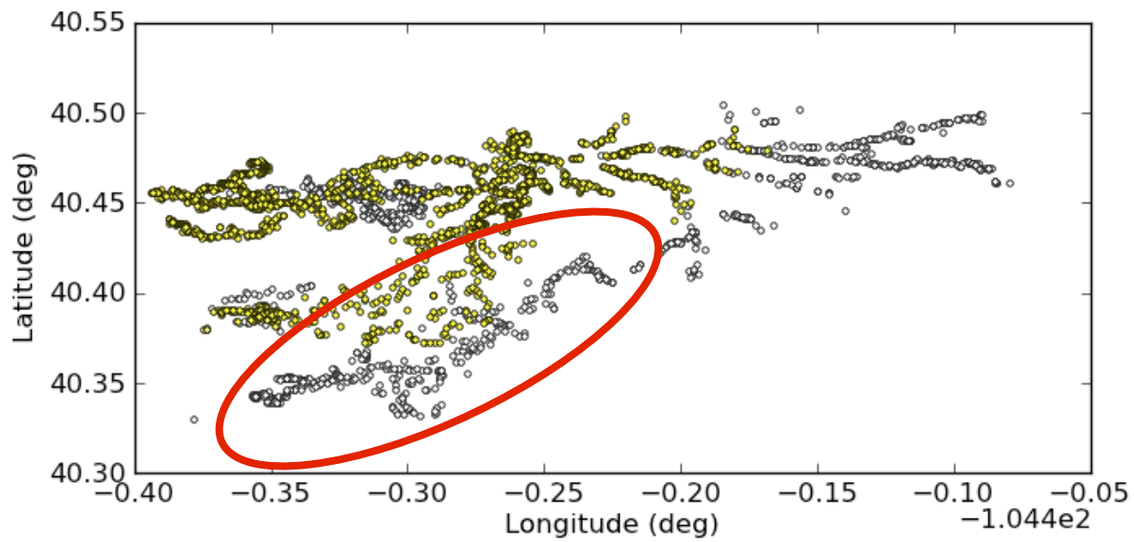
```
    label_aggregator = aggregate_ids(create_flash_objs(out, data))
    clusterer = cluster_chunk_pairs(label_aggregator, min_points=min_points)
    # Maximum 3 s flash length, normalized to the time separation scale
    chunker = chunk(XYZT[:,-1].min(), 3.0/.15,  clusterer)
    stream(XYZT.astype('float32'),chunker)
```

RESULTS: BOTH ALGORITHMS HAVE TROUBLE

Original —2 clusters

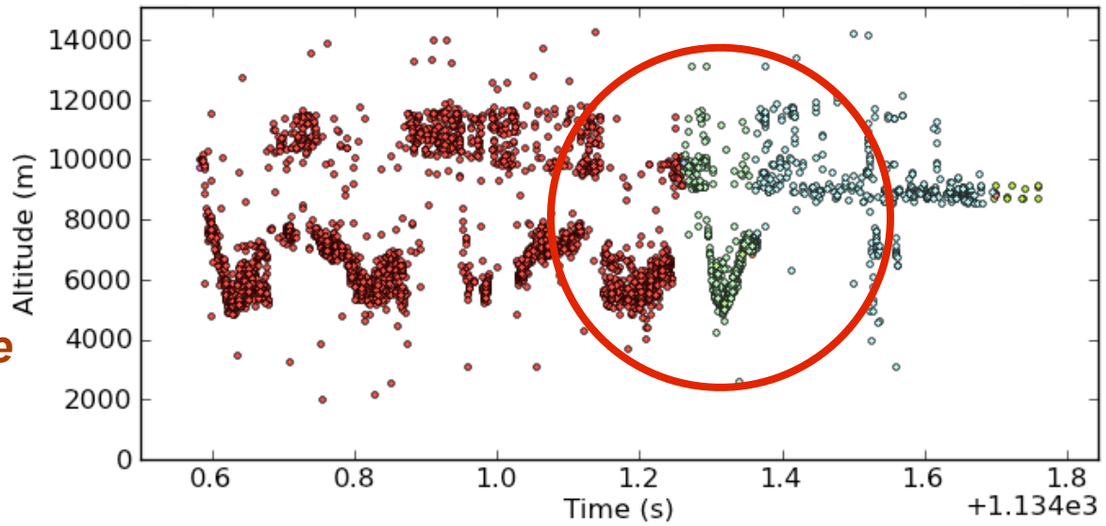


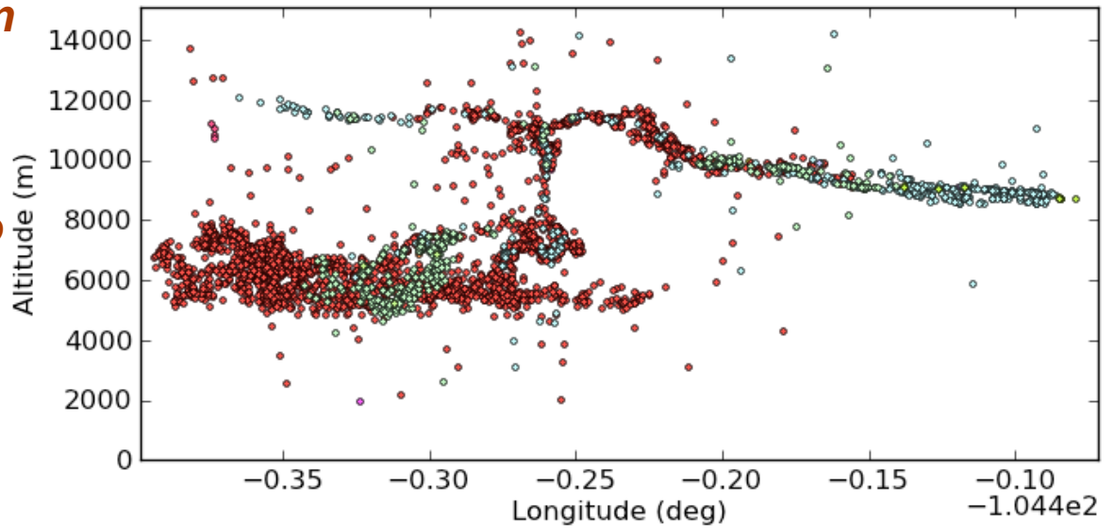


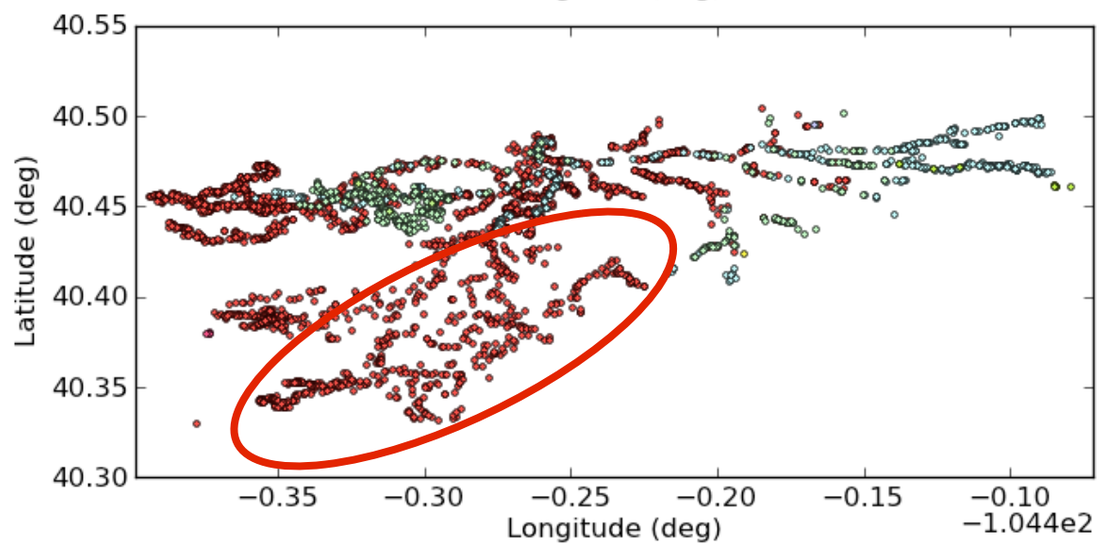


For this single flash, both algorithms have trouble with extension into areas that were previously active, but go quiet for a bit

sklearn —3 clusters







SUMMARY: NEW ALGORITHM

- At least no worse than old algorithm
  - *When it fails, it does so in similar ways*
  - *Point of this talk is not algorithm correctness*
- Advantages
  - *Clustering developed by algorithm professionals*
    - Algorithm (and not results using algorithm) has been peer reviewed
  - *Lets me focus on my area of expertise*
  - *No question about sharing with colleagues since built on open code*
- Python as a home for reference implementations of solved algorithms in computer science
  - *Minimizes time needed to field the right algorithm once it's identified*
    - dictionaries, arrays, machine learning, etc. …
    - reliable, obvious, documented

Multiple layers of open source

MULTIPLE LAYERS OF OPEN SOURCE

- New code shared with graduate student (Brody Fuchs) at Colorado State

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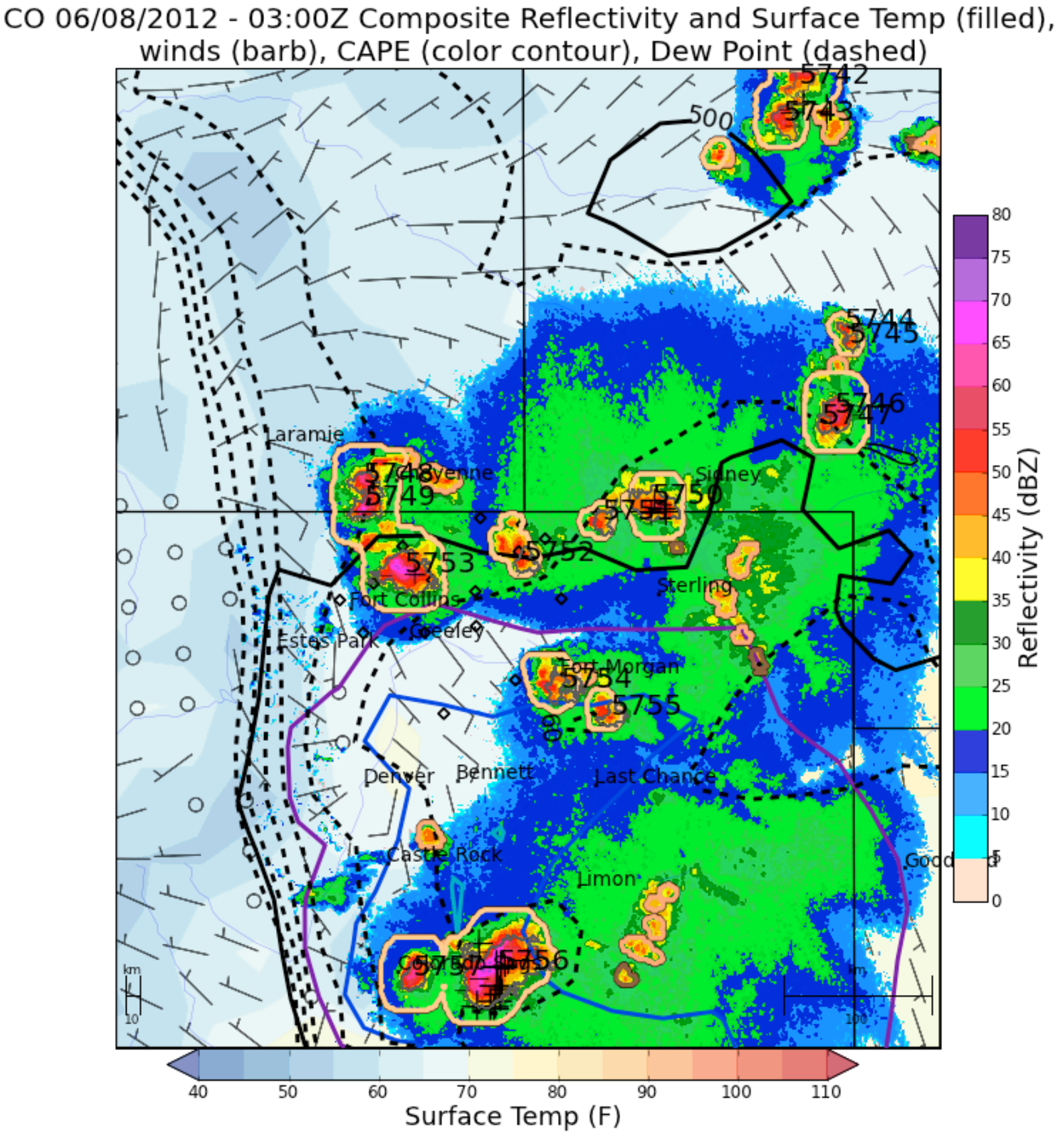
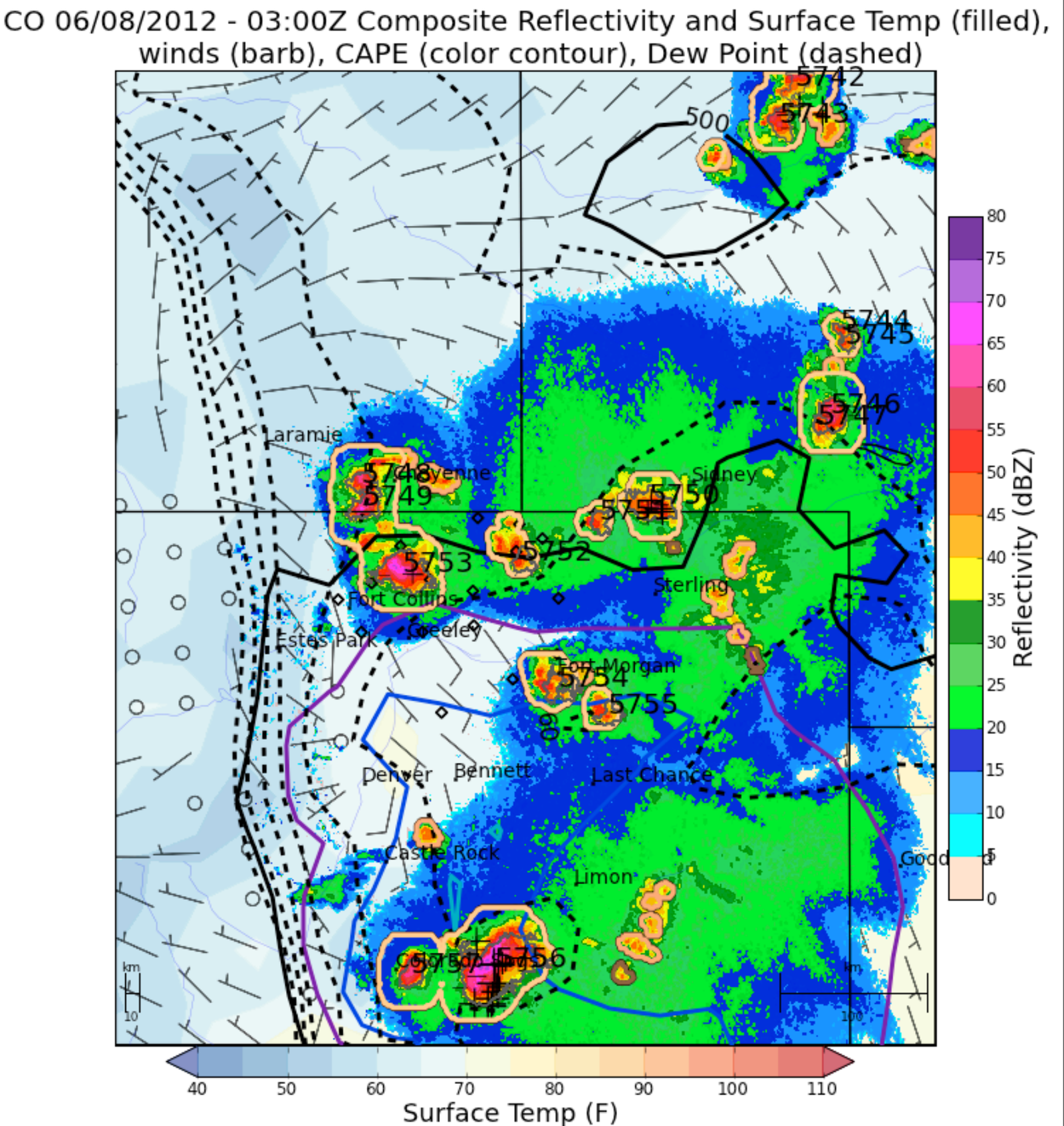
  - *Compared DBSCAN flash sorting to another (third) algorithm*



MULTIPLE LAYERS OF OPEN SOURCE

- New code shared with graduate student (Brody Fuchs) at Colorado State
  - *Compared DBSCAN flash sorting to another (third) algorithm*
  - *Within 10%*



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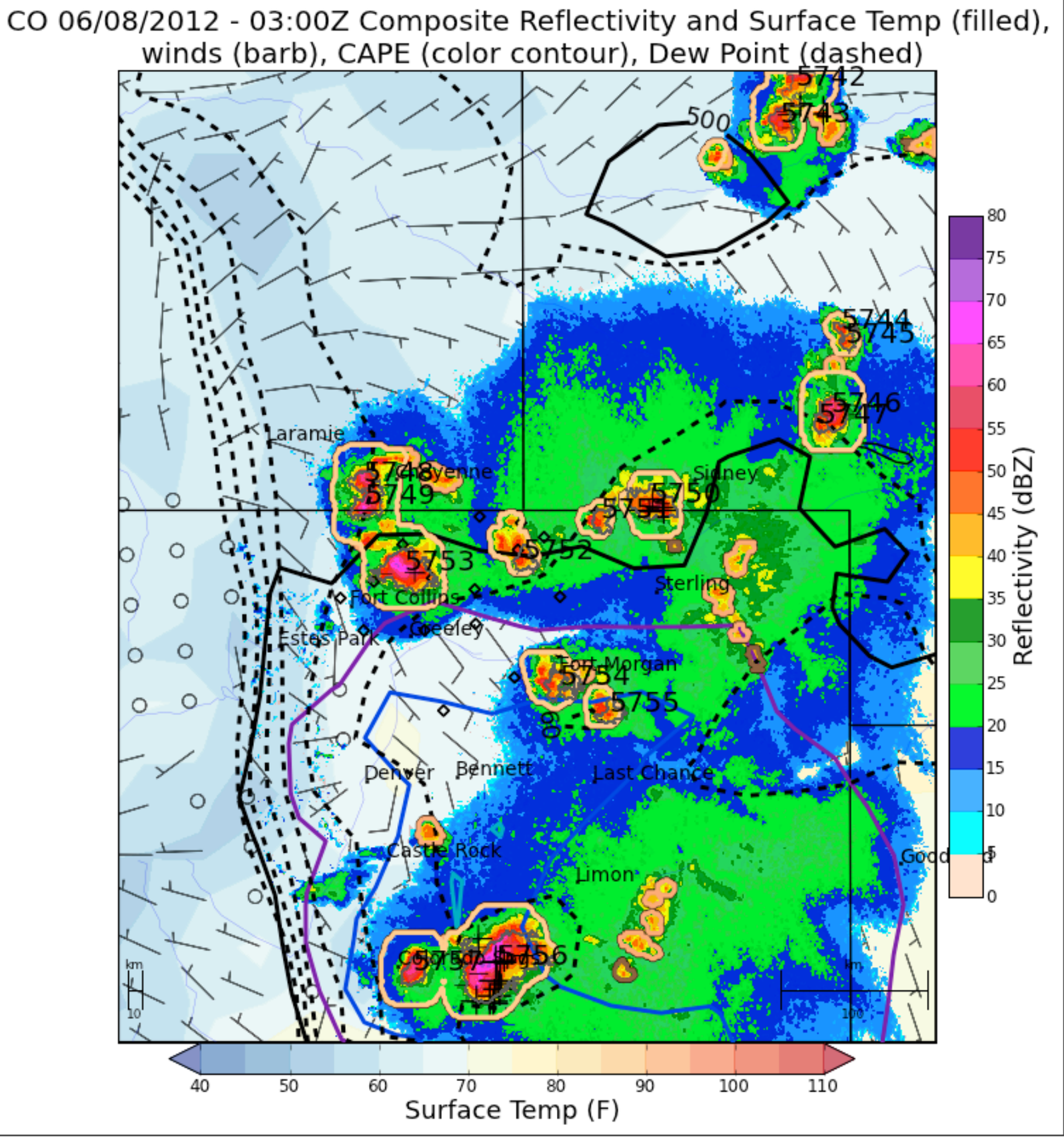

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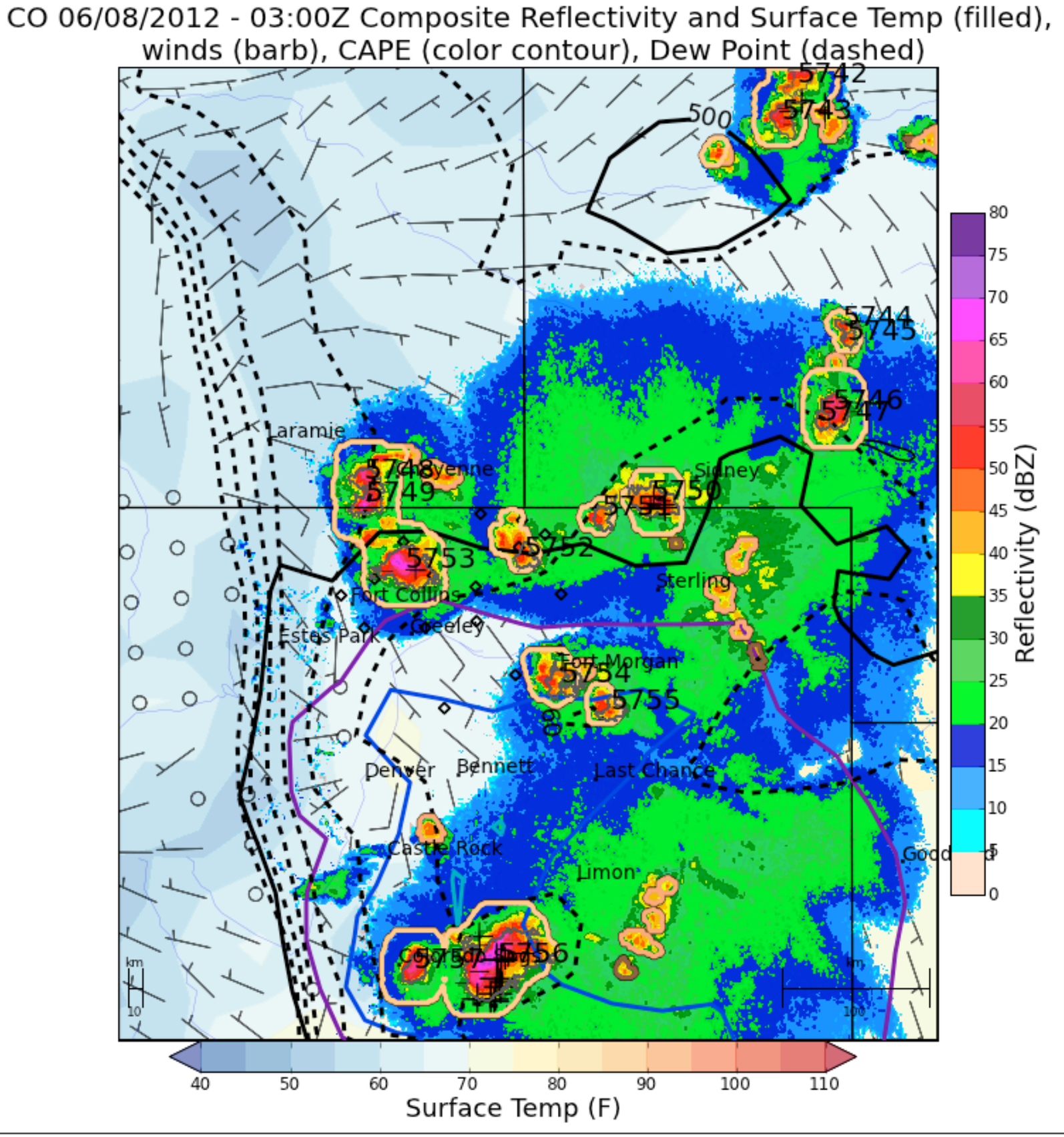

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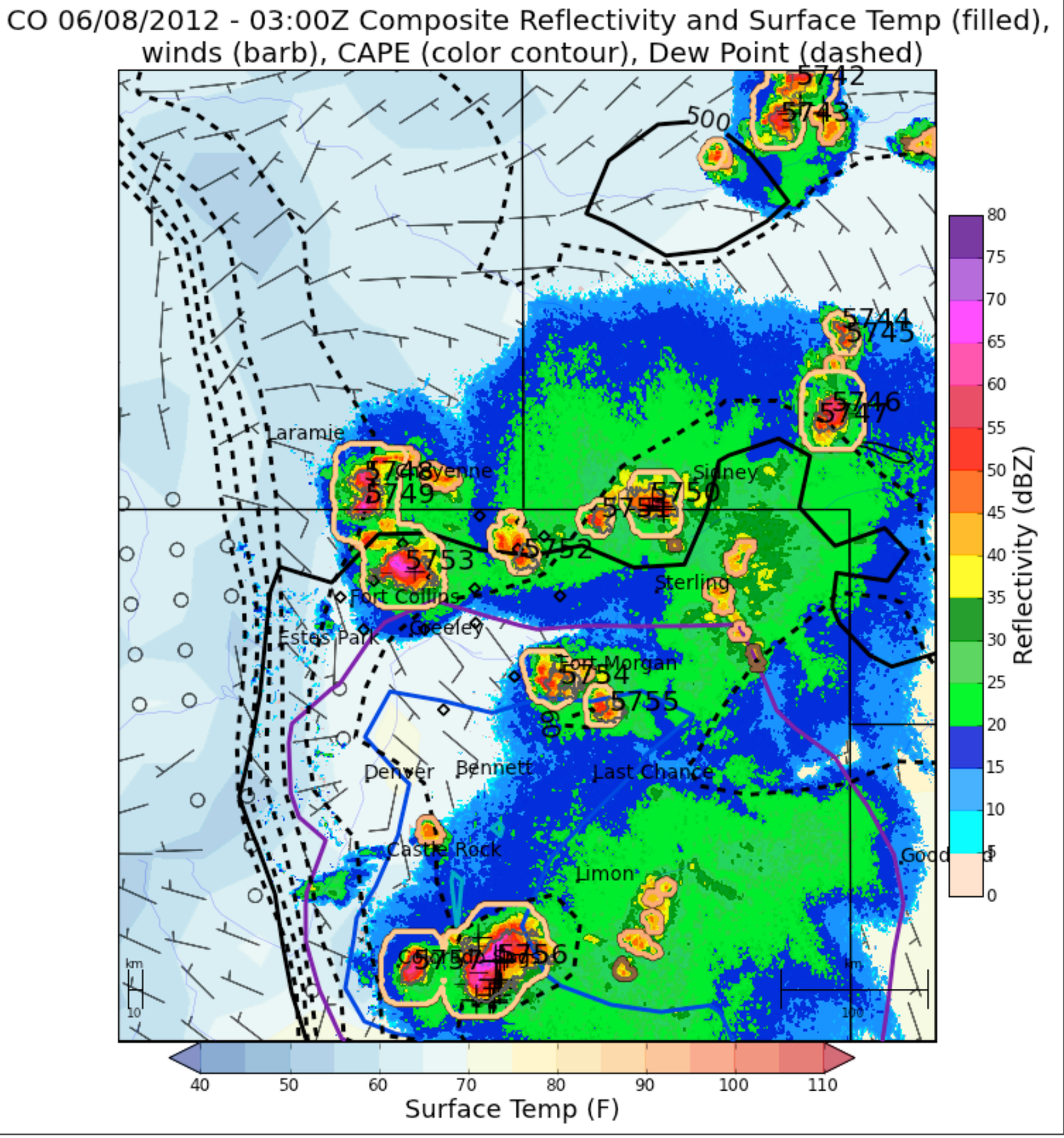
- New code shared with graduate student (Brody Fuchs) at Colorado State
  - *Compared DBSCAN flash sorting to another (third) algorithm*
  - *Within 10%*
- Modified my lmatools to work with his existing storm cell tracking code
  - *Identified some bad assumptions I made during implementation*
  - *Expect to integrate these generalizations to make lmatools more robust in the future*



PIPELINE EXTENSIONS

- More generally, the streaming pipeline can be triggered to do subsetting/re-transformation of data
  - *e.g., after adjusting one plot limits in two of four dimensions when panning a map view*
    - demo developed during last year's SciPy sprints
    - https://github.com/deeplycloudy/MPLIPy
    - my project for this week
- Datasets sit at the head-end of the pipe
  - *wait for message to trigger push of data*
- Pipeline can branch to multiple destinations
- Pipeline outlets are often "views" of data
  - *plots, data files, etc.*

References

Code shown in this talk:

- https://bitbucket.org/deeplycloudy/lmatools/
  - *stream and flashsort modules, coordinateSystems.py*

Coroutines

- Beazley, D. and B.K. Jones (2013): *Python Cookbook*, 3rd ed., 687 pp.