# Python: Solving Large Network Problems

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2018 **Esri DEV**Summit **Conference** | Palm Springs, CA

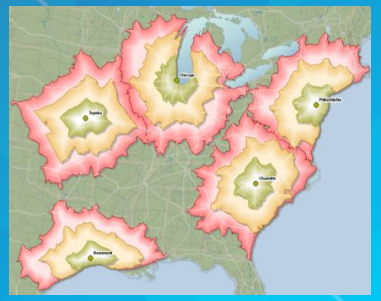
Code and slides:

# http://esriurl.com/ds18pyslnp

# ArcGIS Network Analyst Extension

## for transportation analysis

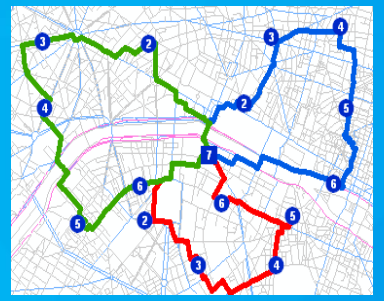
### Coverage



Service Area

### Optimization

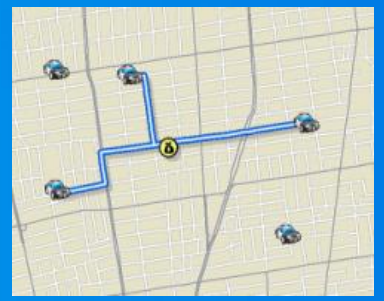
Location-Allocation



Vehicle Routing Problem

### Point-to-point routing

Route



Closest Facility

Origin-Destination Cost Matrix

# What is a large problem?

- Can’t be solved in one calculation
  - Memory limits
  - Service limits
  - Unreasonable calculation time
- Large number of inputs
- Large number of outputs
  - number of origins x number of destinations
  - 1000 x 1000 = 1,000,000

Examples

- Calculate drive time for all patients to all medical clinics within 100 miles
- Calculate the network distance from every parcel to every other parcel

# Today’s goal

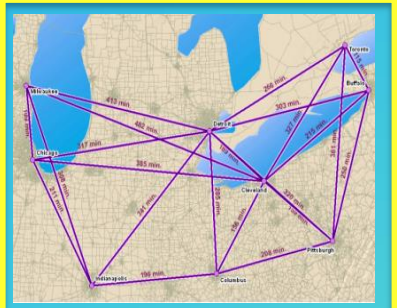
Solve large OD Cost Matrix

- Any number of origins and destinations
- Using local data or a service
- With or without a time/distance limit
- Output a single feature class

## Point-to-point routing

Route

Closest Facility



Origin-Destination Cost Matrix

# Network Analyst workflow

Local network dataset

1. Make analysis layer
2. Add locations
3. Solve
4. Work with output

Remote service

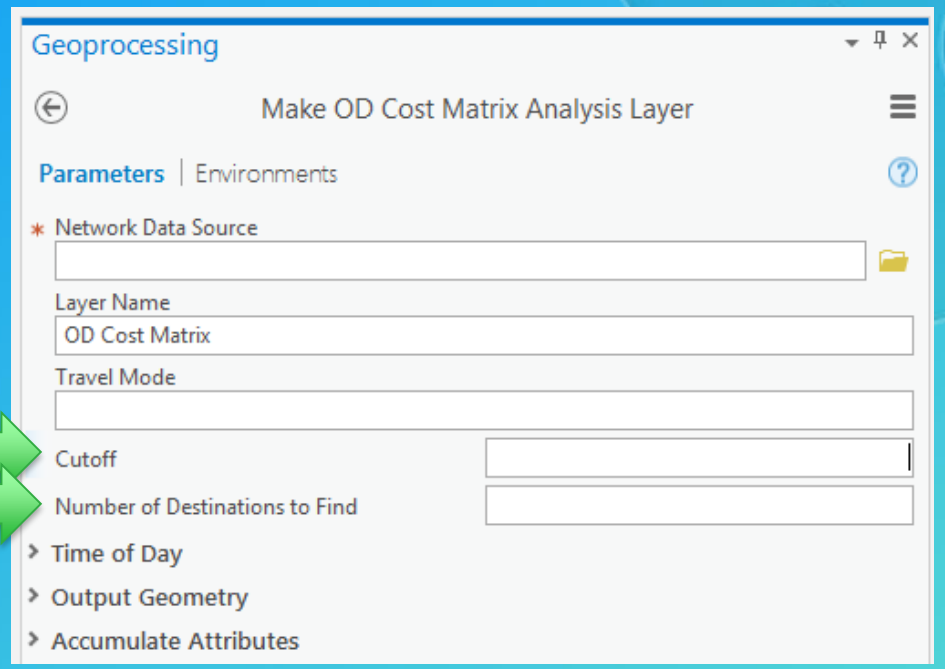
1. Call service
2. Work with output

# How to optimize solving a large problem

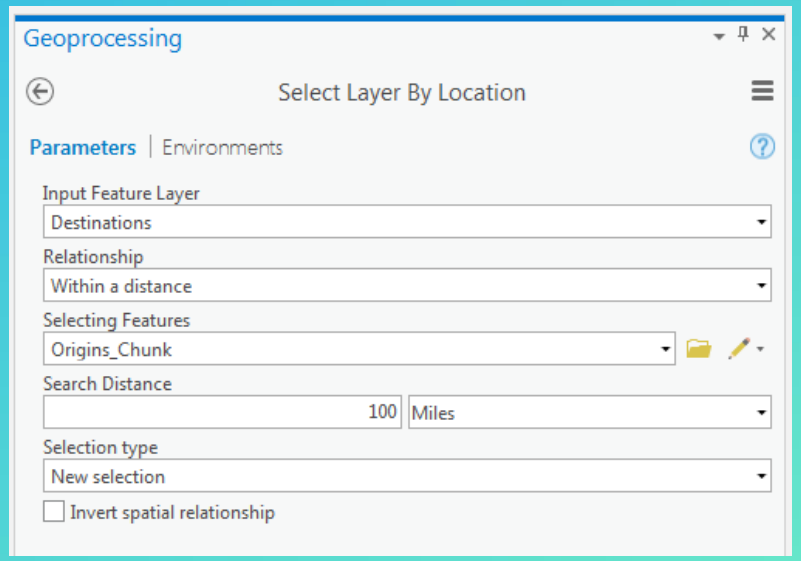
- Reduce problem size
- Chunk data
- Spatially sort data
- Solve in parallel
- Pre-calculate location fields
- Use network dataset layer

# Reduce problem size

- Use a time/distance limit
- Find only the K nearest
- Use only destinations within a reasonable straight-line distance of origins
  - Watch out for the case where none are selected




```
result = arcpy.management.SelectLayerByLocation(self.input_destinations_layer, "WITHIN_A_DISTANCE_GEODESIC",
                                                self.input_origins_layer, "{} Miles".format(cutoff),)
# If no destinations are within the cutoff, skip this iteration
if not result.getOutput(0).getSelectionSet():
    msg = "No destinations found within the cutoff"
    self.logger.warning(msg)
    self.job_result["solveMessages"] = msg
    return
```



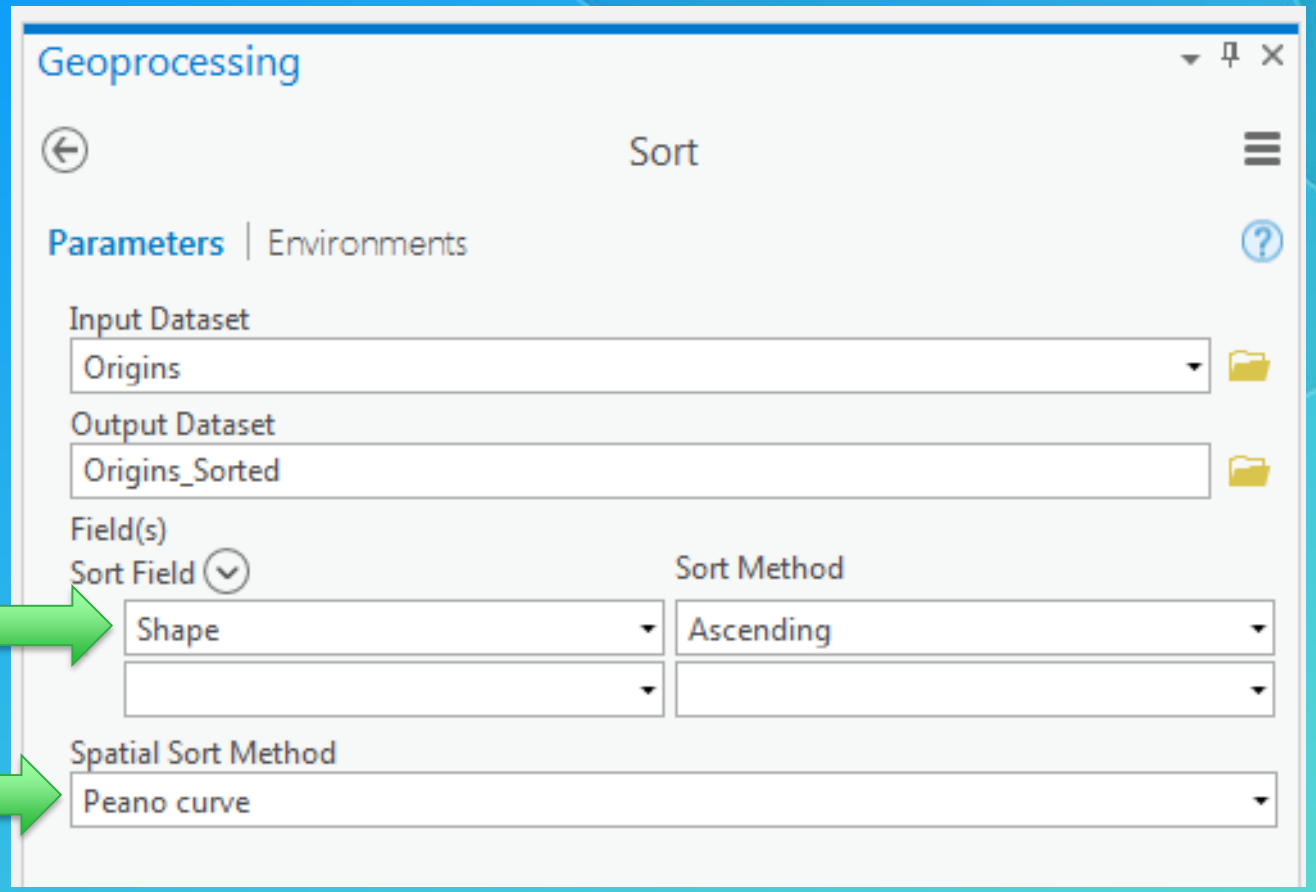
# Chunk data

- Break up origins and destinations into chunks of reasonable size
- Iteratively solve each chunk
- Chunk size depends on service limits or memory limits
- Consider number of origins x number of destinations

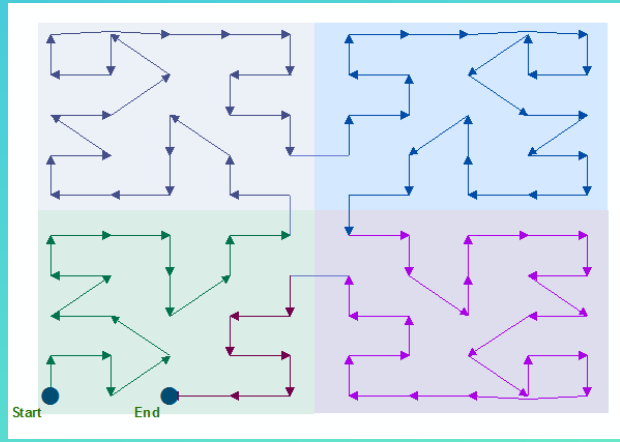
```
# Select the origins and destinations to process
origins_where_clause = "{} >= {} And {} <= {}".format(self.origins_oid_field_name, origins_criteria[0],
                                                      self.origins_oid_field_name, origins_criteria[1])
arcpy.management.MakeFeatureLayer(self.origins, self.input_origins_layer, origins_where_clause)
```

# Spatially sort data

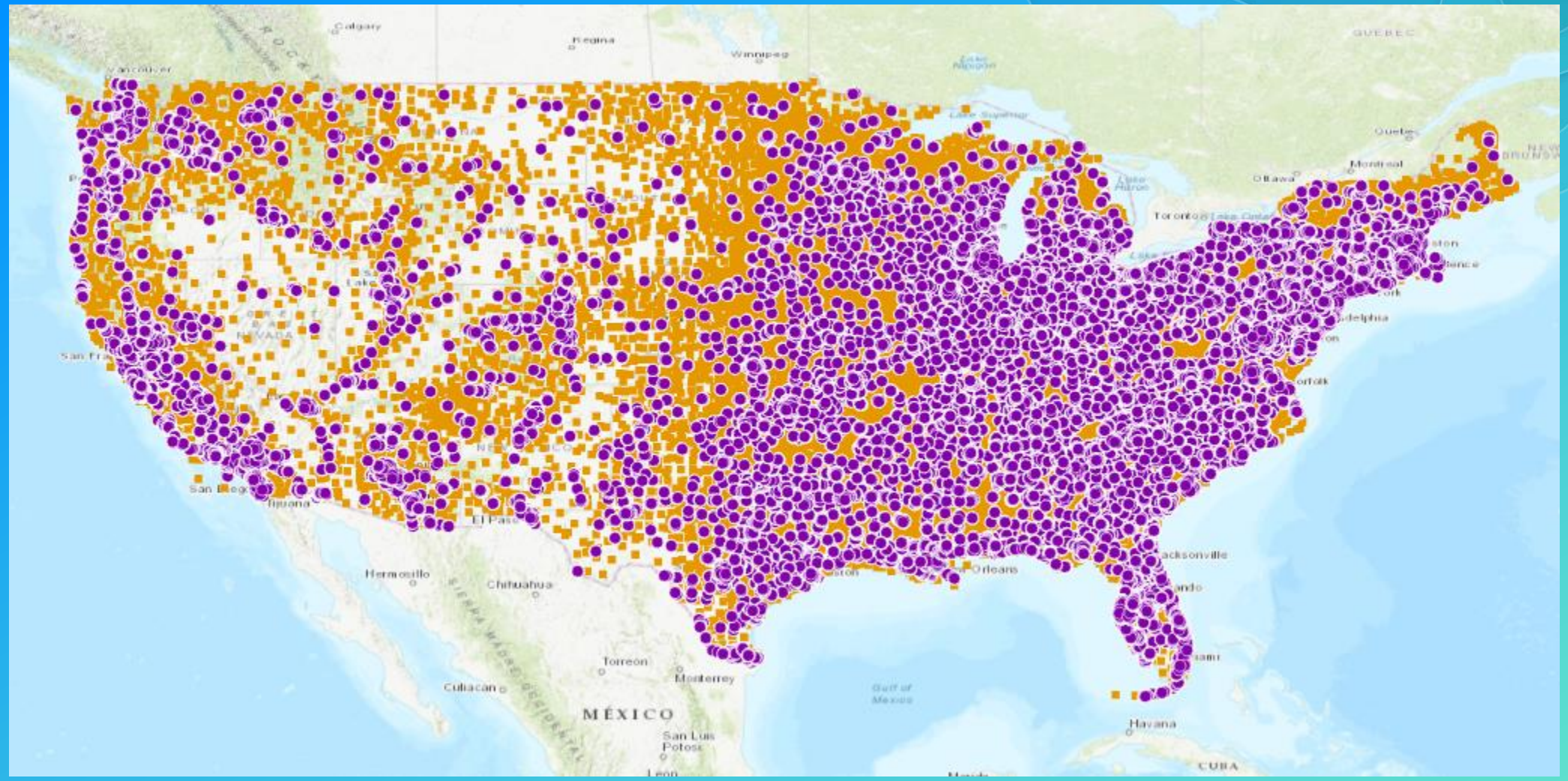
- Sort geoprocessing tool
- Sort by Shape field using Peano curve
- Requires Advanced license




```
# Spatially sort input features
logger.debug("Spatially sorting %s", input_features)
result = arcpy.management.Sort(input_features, output_features,
                               [[desc_input_features.shapeFieldName, "ASCENDING"]], "PEANO")
```

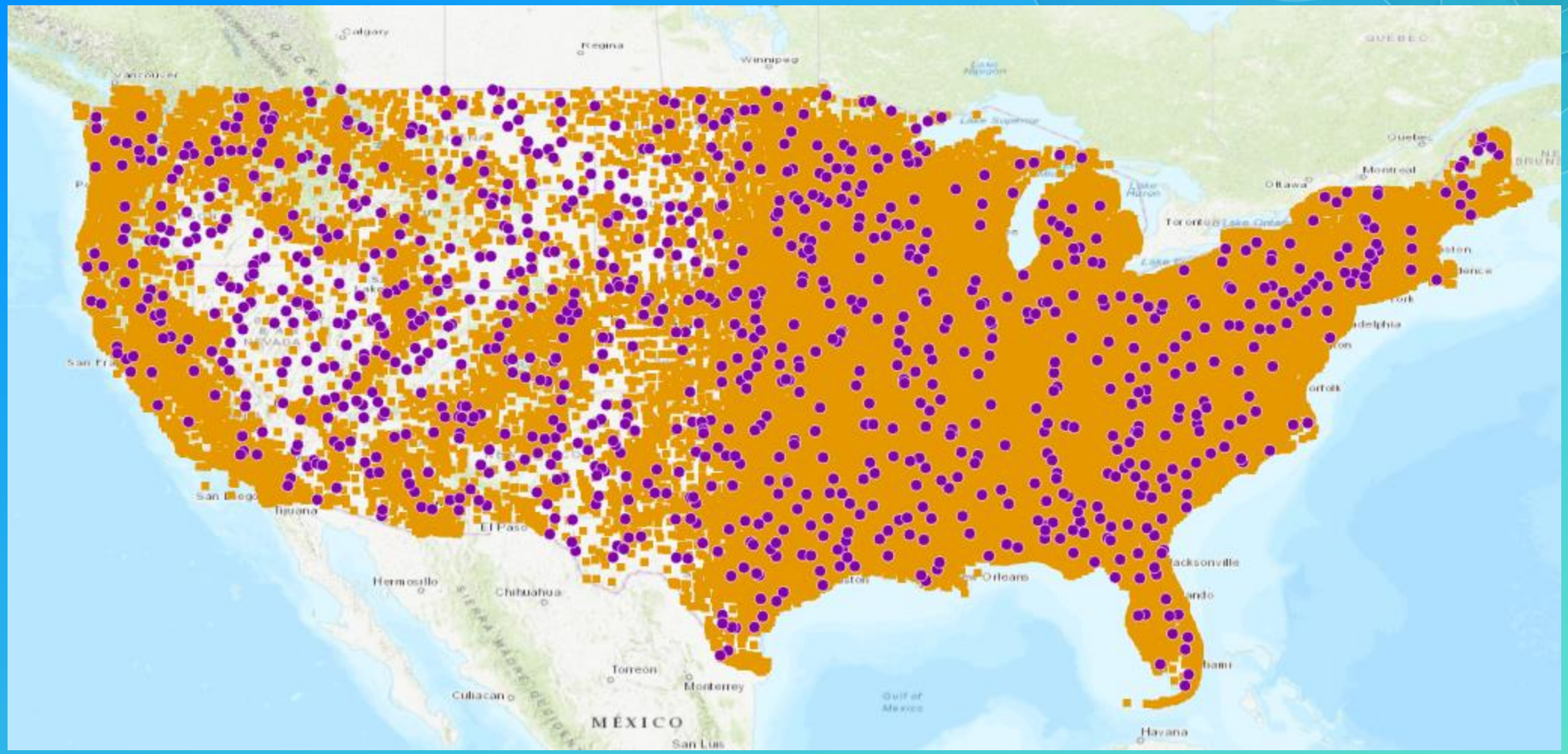


# All origins and all destinations

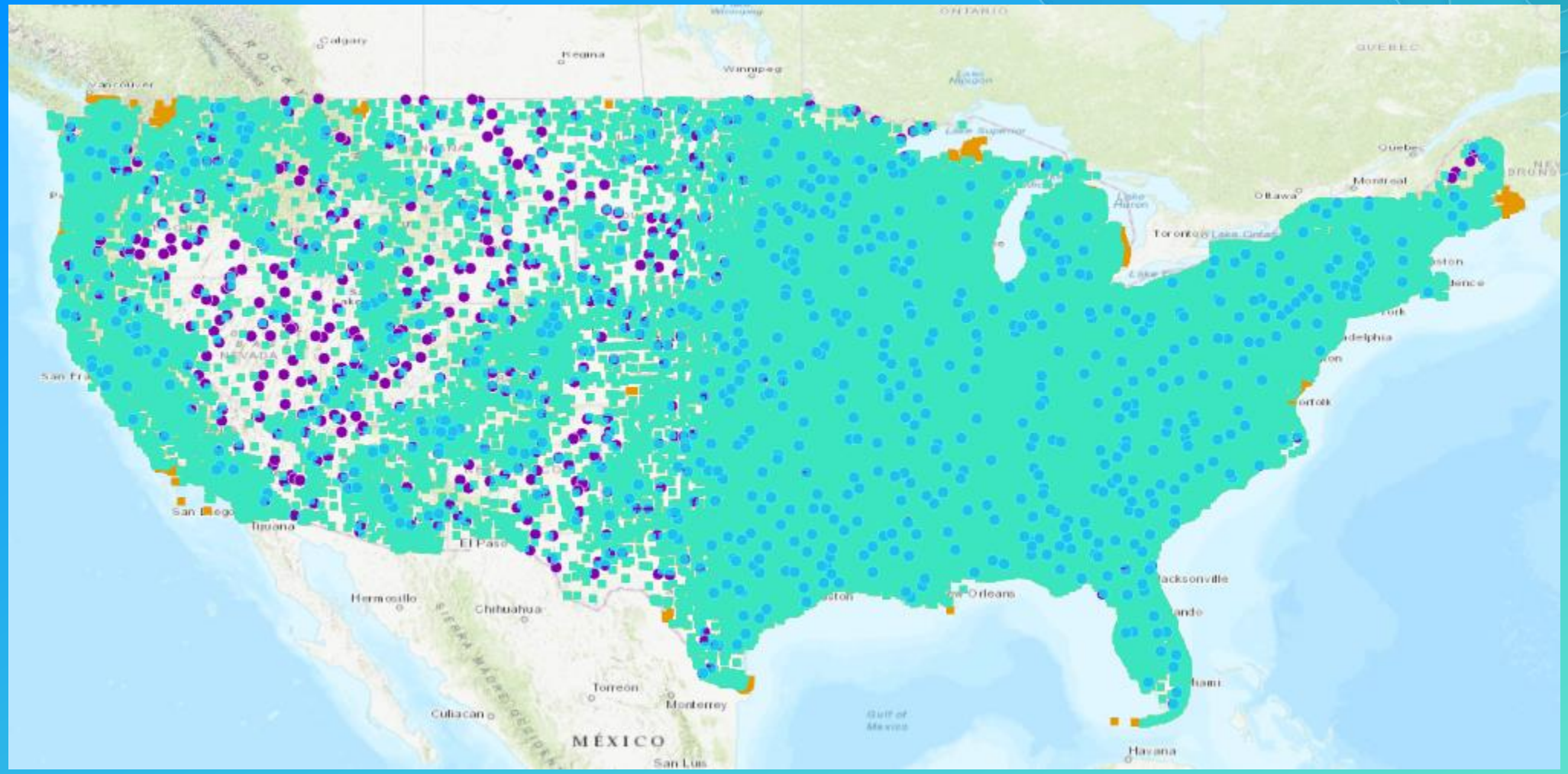



26 million origins, 220k destinations

# Chunk of 1000 unsorted origins

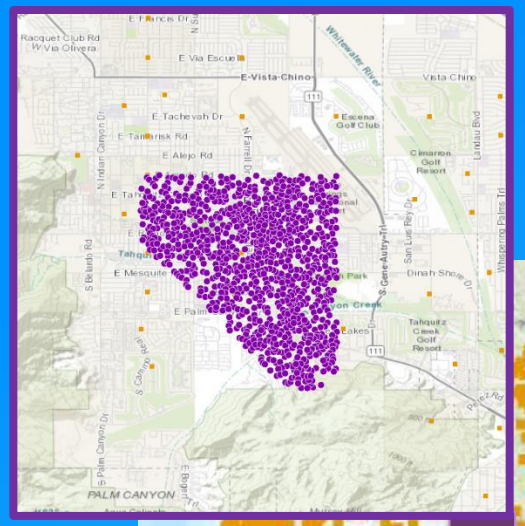


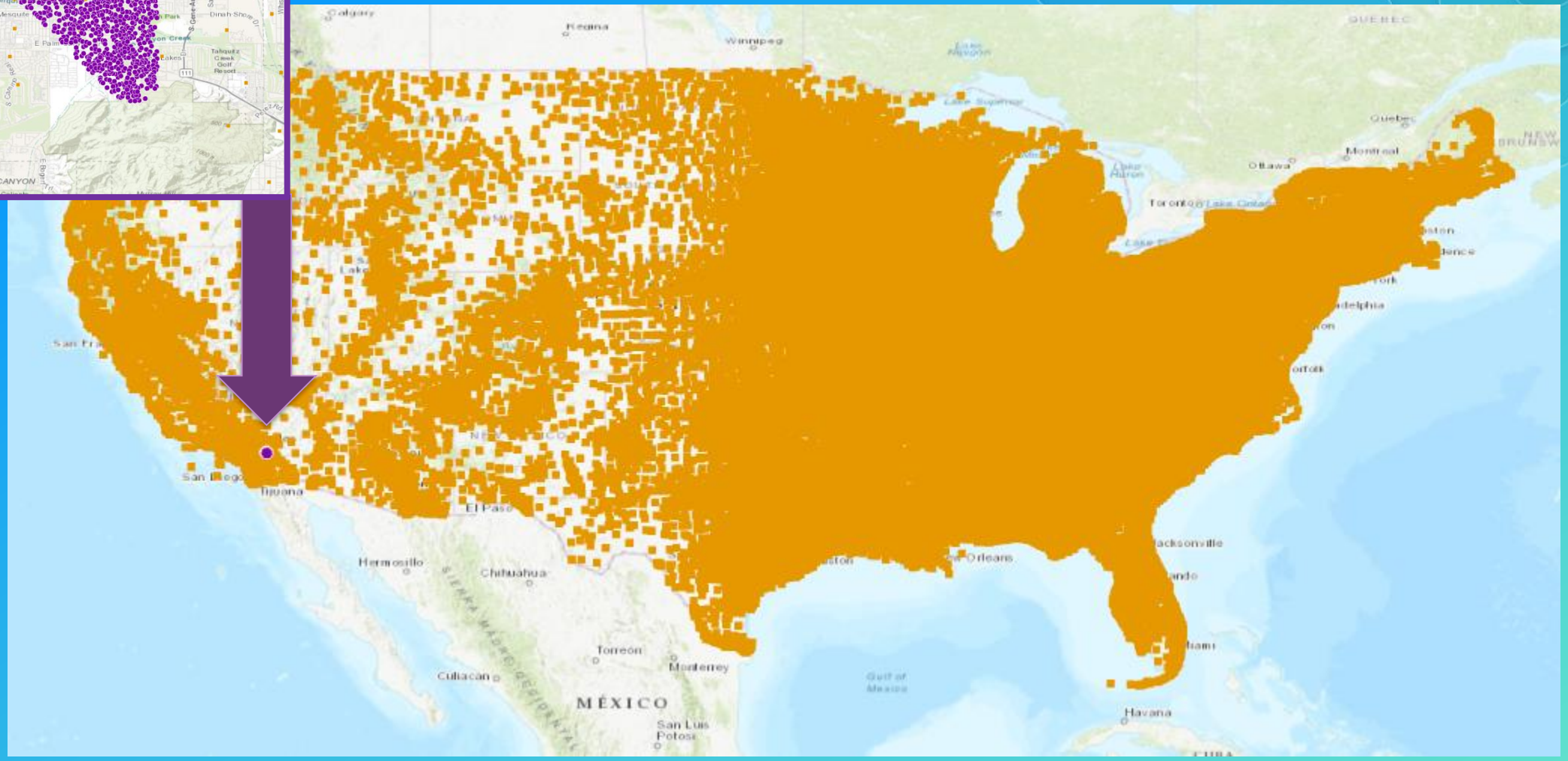
# Destinations within 100 miles of 1000 origins



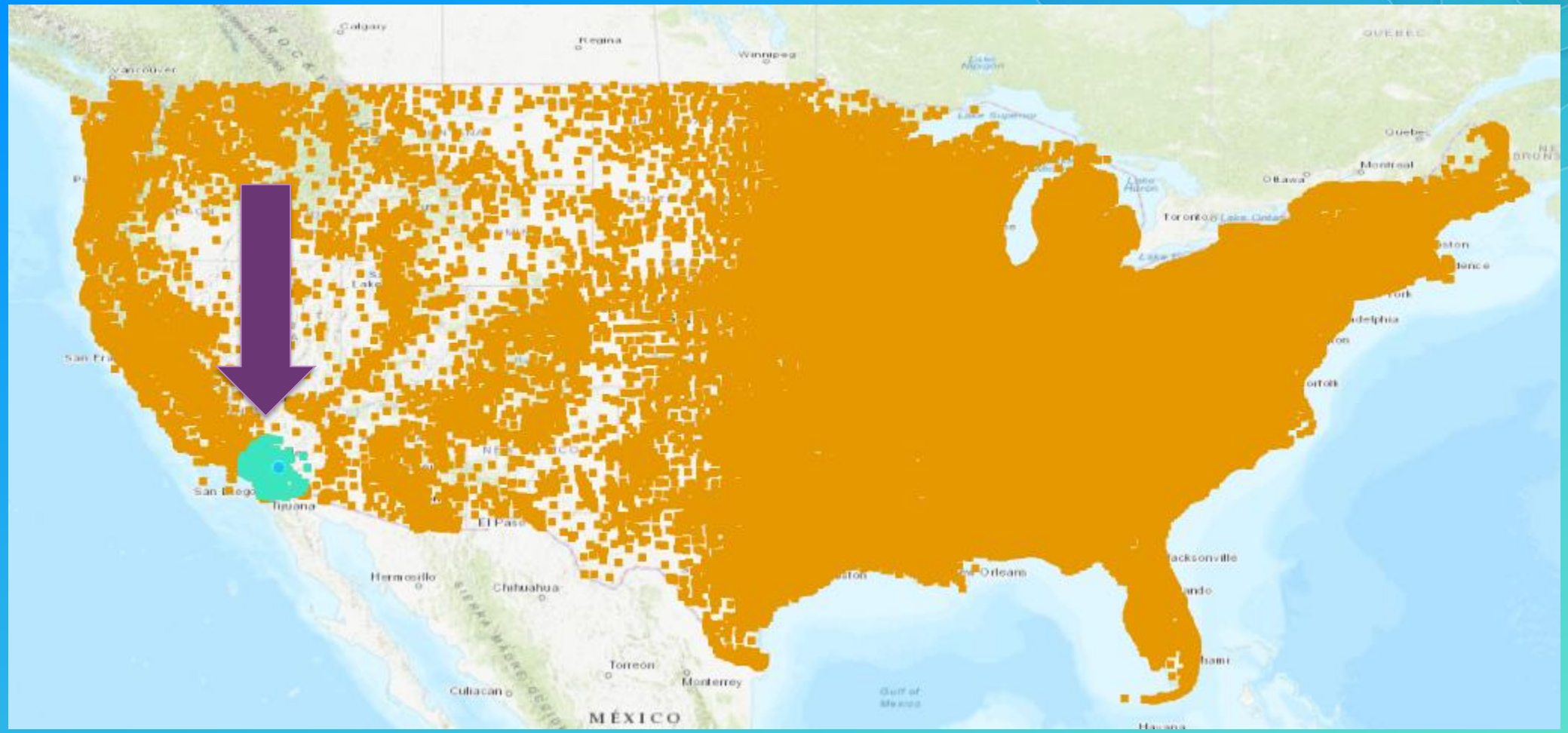

214,449 destinations selected (98%)

# Chunk of 1000 sorted origins



# Destinations within 100 miles of 1000 sorted origins




5,653 destinations selected (3%)

# Solve in parallel

- concurrent.futures

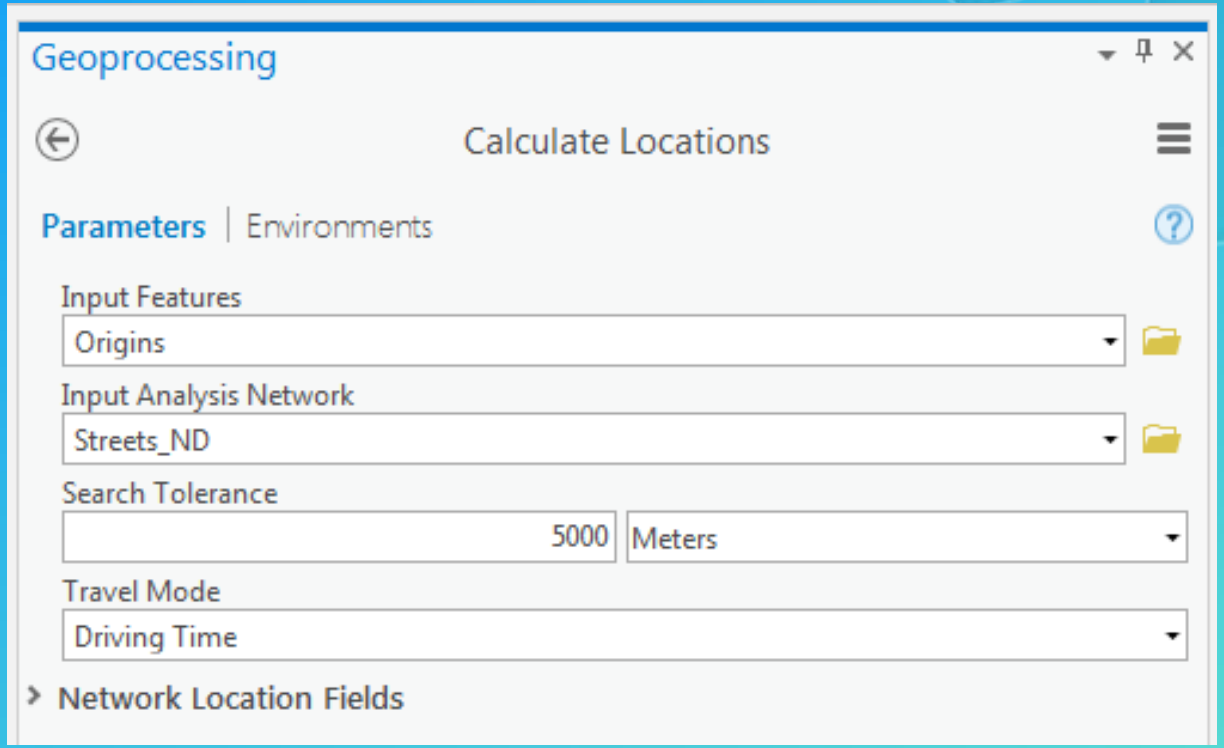
```
from concurrent import futures
```

- Multiprocessing: Spin up multiple processes and run solves on multiple cores
  - Better choice!
  - Can only run from standalone python
  - Can’t write to same gdb from multiple processes
  - Can’t share NA layer across processes
- Multithreading: Use multiple threads in the same process
  - Not good for CPU-intensive problems
  - Does not work with arcpy
  - Only use if:
    - Writing a script tool to run in the app
    - Calling a service

```
with futures.ProcessPoolExecutor(max_workers=inputs["workers"]) as executors:
    results = executors.map(solve_od_cost_matrix, inputs_iter, ranges)
```

# Pre-calculate location fields

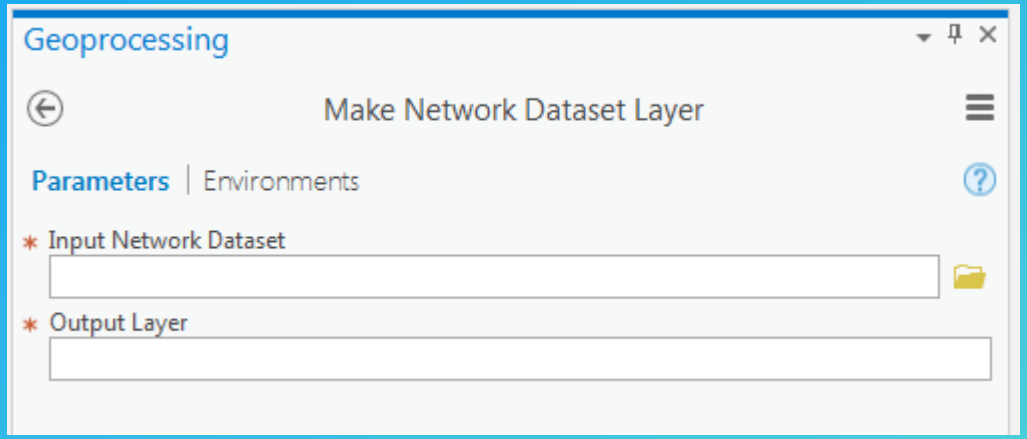
- Define how a point snaps to the network
- Calculate them in advance if you're using your points more than once
- Use field mapping in Add Locations to use existing location fields
- Only works for local data. Not for services.




```
logger.debug("Calculating network locations for %s", input_features)
result = arcpy.na.CalculateLocations(output_features, network_data_source, "20 Miles",
                                     ODCostMatrix.get_nds_search_criteria(network_data_source),
                                     travel_mode=travel_mode)
```

# Use network dataset layer

- Opening from catalog path is slow
- Even slower for licensed data or data on UNC path
- Open once by making a Network Dataset Layer; then use the layer.




```
self.logger.debug("Creating network dataset layer")
arcpy.na.MakeNetworkDatasetLayer(self.network_data_source, self.nds_layer_name)
```

# Outline of today’s code

Goal: Solve OD of any size using local data or a service, write it out to a single feature class

- Components:
  - Preprocessing
    - Sorting spatially
    - Calculate network locations
  - Solving
    - Chunking
    - Solving in parallel
  - Post-processing
    - Merging results

```python
# Compute OD cost matrix
od_line_fcs = []
job_folders_to_delete = []
# Run on multiple processes or threads when solving large ODs
if origins_count * destinations_count > inputs["max_od_size"]:
    if ODCostMatrix.is_nds_service(inputs["network_data_source"]):
        max_workers = os.cpu_count() // 2
        pool = futures.ProcessPoolExecutor
    else:
        max_workers = (os.cpu_count() // 2) - 1
        pool = futures.ProcessPoolExecutor

    with pool(max_workers=max_workers) as executors:
        results = executors.map(solve_od_cost_matrix, inputs_iter, ranges)
        for result in results:
            if result["solveSucceeded"]:
                od_line_fcs.append(result["outputLines"])
                job_folders_to_delete.append(result["jobFolder"])
            else:
                logger.warning("Solve failed for job id %s", result["jobId"])
                logger.debug(result["solveMessages"])
```

# Let’s look at some code!

# Wrap-up

- Reduce problem size
- Chunk data
- Spatially sort data
- Solve in parallel
- Pre-calculate location fields
- Use network dataset layer

**Code and slides:**

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