Air Quality Data Analytics using Spark and Esri's GIS Tools for Hadoop

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Session: Discovery and Analysis of Big Data using GIS

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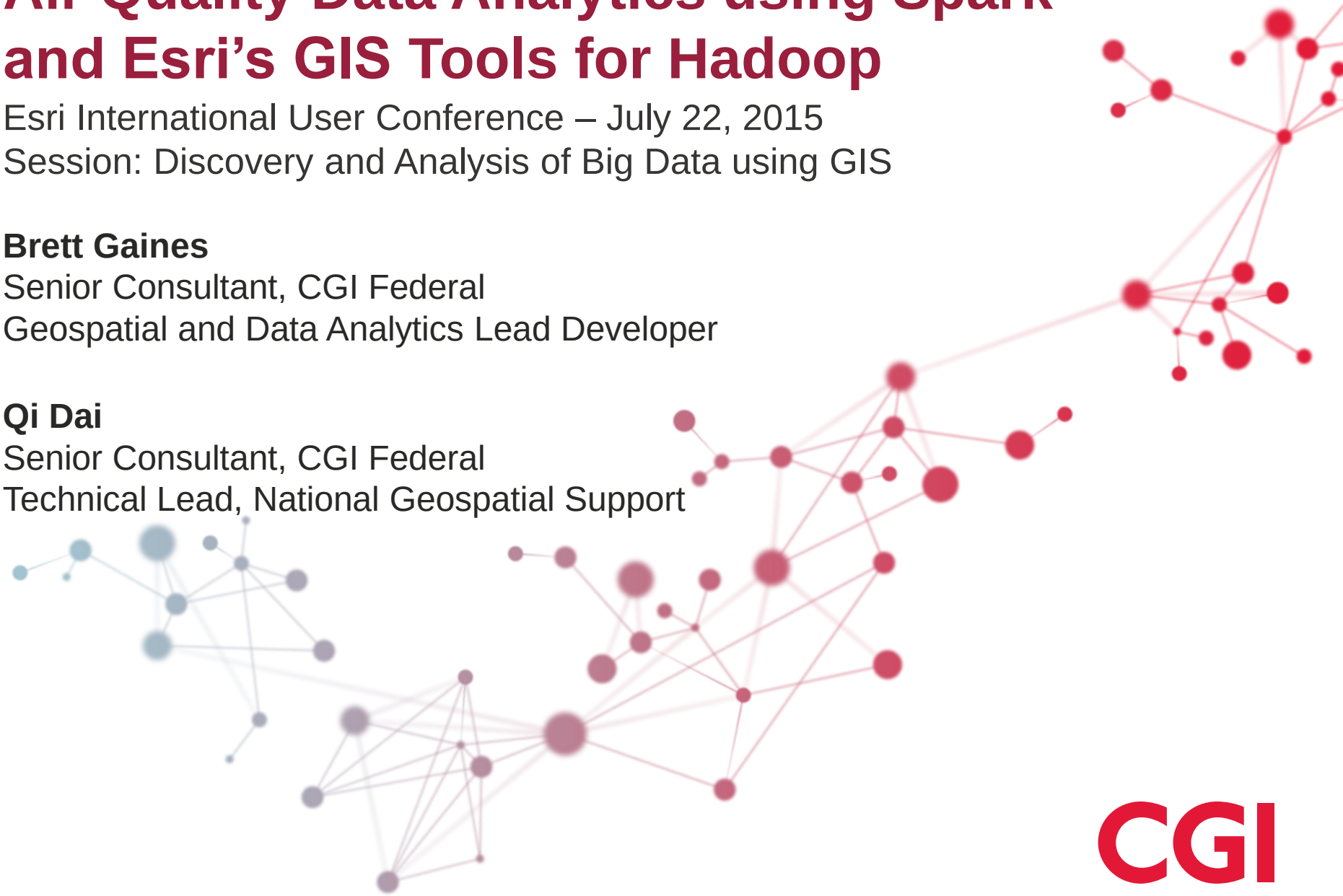

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Overview

- Goal of Analysis
- Data Sources
- Hardware Cluster
- Data Processing Steps
  - Anomaly Detection Methods (Statistics)
  - GIS Analysis
- Data Analytics Results and Mapping

Purpose Overview

Data Science

- Apply an anomaly detection algorithm on spatio-temporal static air monitoring pollutant data
- Data is collected hourly by thousands of monitors and contains data for multiple pollutants

Target Architecture

- Hadoop ecosystem & Spark for batch analysis
- Visualization of spatio-temporal results in Tableau and Esri
- Export anomaly datasets to on premise GIS servers & AGOL

Deployment

- Hortonworks Data Platform (HDP) cluster
- Esri GIS Tools for Hadoop (extended)

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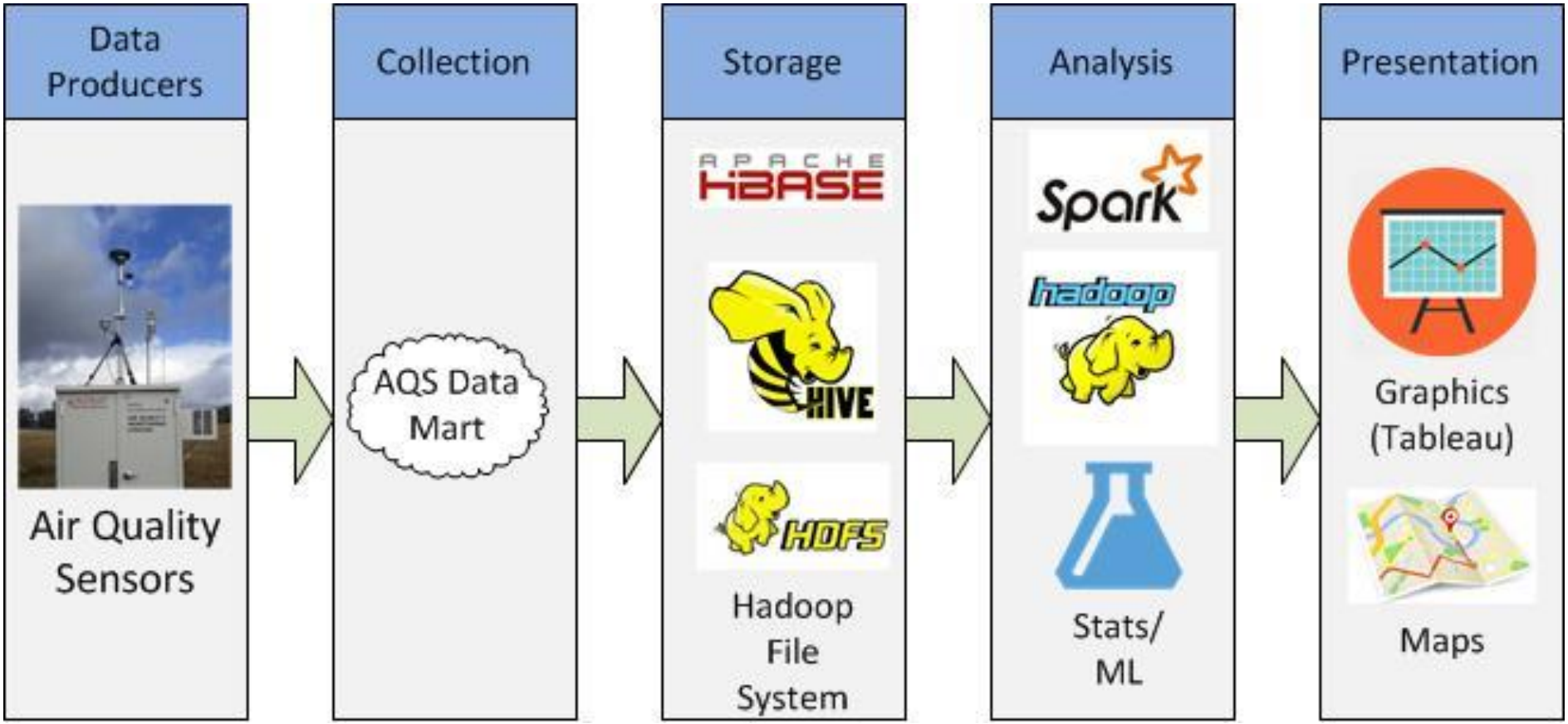
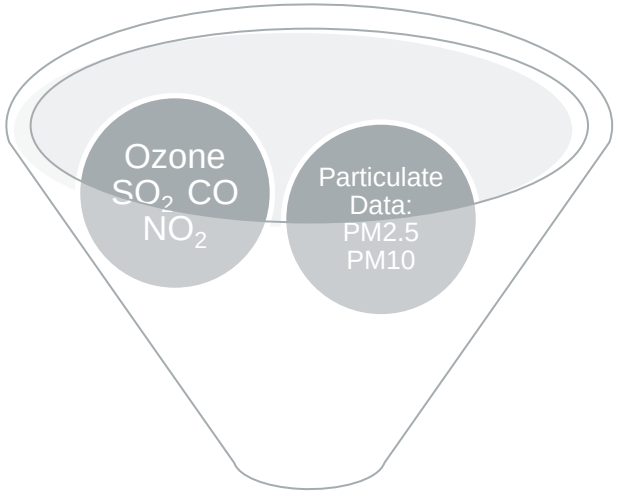
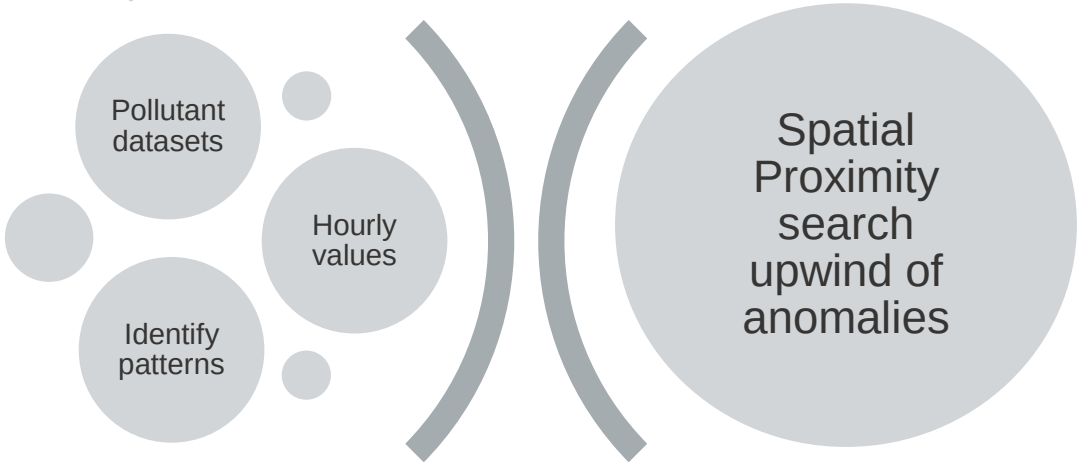
Workflow


Data Producers
Collection
Storage
Analysis
Presentation
Air Quality Sensors
AQS Data Mart
APACHE HBASE
HIVE
HDFS
Hadoop File System
Spark
hadoop
Stats/ ML
Graphics (Tableau)
Maps

Analysis Overview

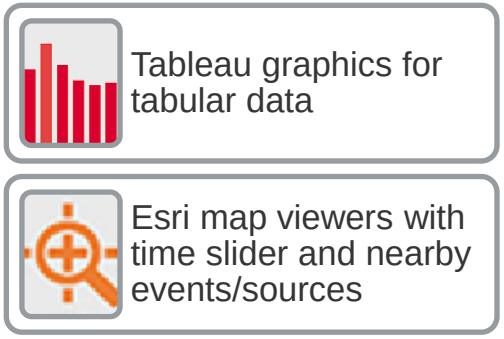


- Distributed spatial search with targeted vectors (wind speed and direction at hour and location of anomaly)
- Extending Esri's Geometry API and integration with Spark



Identify Anomalies

Locate Potential Cause



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Data Sources

- USEPA Air Quality System (AQS)
  - Stores data from >10,000 monitors - Annual, Daily, Hourly, Minute
- 2008-2013 for 6 pollutants
  - Ozone, SO2, CO, NO2, PM25 Non-FRM, PM10 Mass
    - Vary Seasonally and/or Daily
- Meteorological data and possible stationary emission sources

Hourly Data

Criteria Gases

Year	Ozone (44201)	SO2 (42401)	CO (42101)	NO2 (42602)
2014	hourly_44201_2014.zip 7,147,884 Rows 52,900 KB As of 2015-01-02	hourly_42401_2014.zip 2,861,454 Rows 19,046 KB As of 2015-01-02	hourly_42101_2014.zip 1,761,002 Rows 11,998 KB As of 2015-01-02	hourly_42602_2014.zip 2,433,435 Rows 18,323 KB As of 2015-01-02
2013	hourly_44201_2013.zip 9,096,192 Rows 67,040 KB As of 2015-01-02	hourly_42401_2013.zip 3,797,758 Rows 25,191 KB As of 2015-01-02	hourly_42101_2013.zip 2,498,904 Rows 16,893 KB As of 2015-01-02	hourly_42602_2013.zip 3,188,575 Rows 23,803 KB As of 2015-01-02
2012	hourly_44201_2012.zip 9,025,084 Rows 66,896 KB As of 2015-01-02	hourly_42401_2012.zip 3,770,826 Rows 25,073 KB As of 2015-01-02	hourly_42101_2012.zip 2,572,491 Rows 17,258 KB As of 2015-01-02	hourly_42602_2012.zip 3,081,439 Rows 22,857 KB As of 2015-01-02
2011	hourly_44201_2011.zip 8,878,649 Rows 65,644 KB As of 2015-01-02	hourly_42401_2011.zip 3,676,396 Rows 24,565 KB As of 2015-01-02	hourly_42101_2011.zip 2,612,976 Rows 17,500 KB As of 2015-01-02	hourly_42602_2011.zip 3,017,114 Rows 22,321 KB As of 2015-01-02
2010	hourly_44201_2010.zip 8,392,448 Rows 62,172 KB As of 2015-01-02	hourly_42401_2010.zip 3,661,150 Rows 24,041 KB As of 2015-01-02	hourly_42101_2010.zip 2,616,882 Rows 16,937 KB As of 2015-01-02	hourly_42602_2010.zip 3,111,967 Rows 22,388 KB As of 2015-01-02
2009	hourly_44201_2009.zip 8,201,693 Rows 59,443 KB As of 2015-01-02	hourly_42401_2009.zip 3,732,540 Rows 24,115 KB As of 2015-01-02	hourly_42101_2009.zip 2,753,380 Rows 17,597 KB As of 2015-01-02	hourly_42602_2009.zip 3,084,877 Rows 21,618 KB As of 2015-01-02
2008	hourly_44201_2008.zip 8,054,745 Rows 58,634 KB As of 2014-06-13	hourly_42401_2008.zip 3,963,631 Rows 25,656 KB As of 2015-01-02	hourly_42101_2008.zip 2,941,703 Rows 18,759 KB As of 2015-01-02	hourly_42602_2008.zip 3,187,823 Rows 21,976 KB As of 2015-01-02
2007	hourly_44201_2007.zip 8,005,170 Rows 58,479 KB As of 2014-06-13	hourly_42401_2007.zip 4,216,470 Rows 27,239 KB As of 2015-01-02	hourly_42101_2007.zip 3,036,390 Rows 19,309 KB As of 2014-06-13	hourly_42602_2007.zip 3,241,278 Rows 22,207 KB As of 2015-01-02
2006	hourly_44201_2006.zip 7,859,903 Rows 57,396 KB As of 2014-06-13	hourly_42401_2006.zip 4,206,488 Rows 27,119 KB As of 2015-01-02	hourly_42101_2006.zip 3,193,385 Rows 20,324 KB As of 2014-06-13	hourly_42602_2006.zip 3,334,127 Rows 22,912 KB As of 2015-01-02
2005	hourly_44201_2005.zip 7,762,599 Rows 56,660 KB As of 2014-06-13	hourly_42401_2005.zip 4,304,211 Rows 27,873 KB As of 2015-01-02	hourly_42101_2005.zip 3,407,244 Rows 21,699 KB As of 2014-06-13	hourly_42602_2005.zip 3,349,695 Rows 23,073 KB As of 2015-01-02

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Distributed Cluster Environment

- Hortonworks Data Platform (HDP) 2.2
  - RHEL 6.6 OS's
  - 16 CPUs Total
  - 40GB RAM Total
  - 2.5TB Disk Total

- And testing on Azure HDInsight

http://azure.microsoft.com/en-us/services/hdinsight/

Data Analysis – High Level Processing Steps

- Download raw data from Public AQS Data Mart
- Exploratory analysis in R
- Pre-process raw data with Python and ‘sed’
- Import to HDFS
- Create Hive schema-on-read HQL scripts
- Process Hive tables
- Spark jobs with Esri Geometry API (GIS Tools for Hadoop)
- Output from analysis into ArcGIS ecosystem

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Data Analysis – Anomaly Detection and QC

- Detect anomalies at scale and quickly identifiable
- Flag records with identical samples >3 hours in succession
- Check specifically for evening monitor QC samples
- Compare each site only to itself (distinctive “normals”)
- Using anomaly outputs, detect spatial autocorrelation of nearby monitors

Hive – Schema on Read

- Hive can either store a copy of the data or store reference to the data (EXTERNAL command)
- Esri GIS Tools for Hadoop provides Hive UDFs
  - ${env:HOME}/esri-git/gis-tools-for-hadoop/samples/lib/esri-geometry-api.jar
  - ${env:HOME}/esri-git/gis-tools-for-hadoop/samples/lib/spatial-sdk-hadoop.jar;
  - Function ST_Point as ‘com.esri.Hadoop.hive.ST_Point’;

```
1  DROP TABLE IF EXISTS hourly0813co;
2
3  CREATE TABLE IF NOT EXISTS hourly0813co (State_Code STRING, County_Code STRING, Site_Num STRING,
   Parameter_Code string, POC int, Latitude DOUBLE, Longitude DOUBLE, Datum string, Parameter_Name STRING,
   Date_Local STRING, Time_Local STRING, Date_GMT STRING, Time_GMT STRING, Sample_Measurement DOUBLE,
   Units_of_Measure STRING, MDL DOUBLE, Uncertainty STRING, Qualifier STRING, MethodType STRING, Method_Name
   STRING, State_Name STRING, County_Name STRING, Date_of_Last_Change STRING)
4  ROW FORMAT DELIMITED FIELDS TERMINATED BY ",";
5
6  LOAD DATA LOCAL INPATH '/home/bg20/hourly0813no2.csv' OVERWRITE INTO TABLE hourly0813no2;
7
```


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Anomaly Detection Methods

- Global and local maximas
- Mean, variance, standard deviation
- Support Vector Machines, Density-based (KNN), Neural Nets, Fuzzy Logic

- Median Absolute Deviation (ModZScore)
  - Implemented in PySpark
    - By site, by month, by hour
    - Threshold determined by ModZScore

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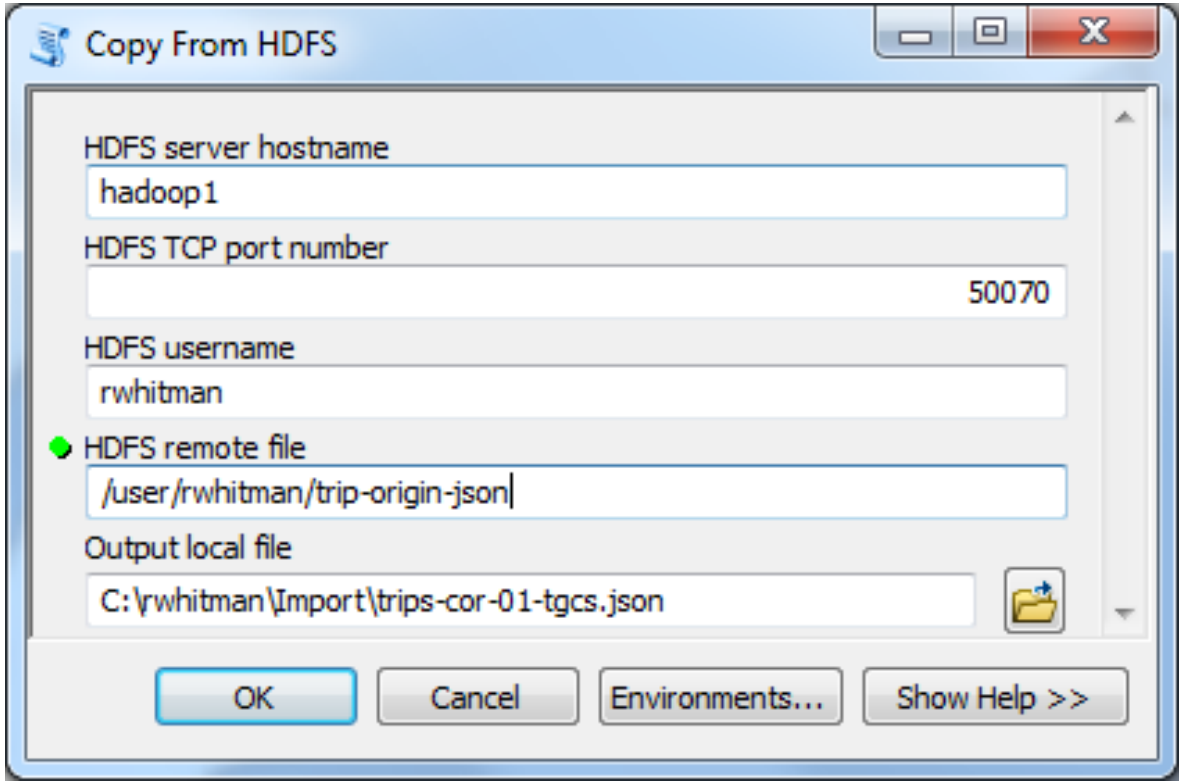
Anomaly Results in HDFS – Now what?

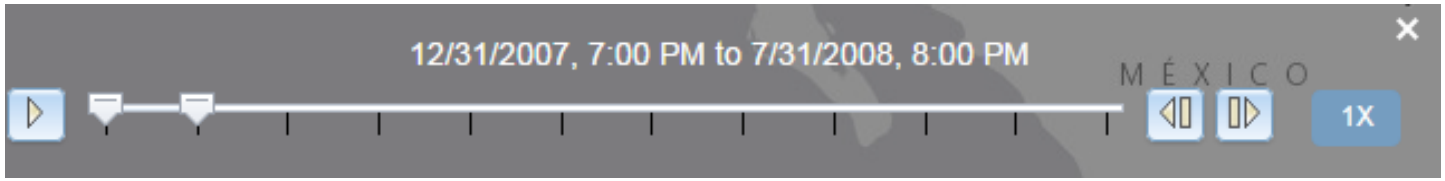
- Transfer output and perform spatial analysis on anomaly data



http://blogs.esri.com/esri/arcgis/2013/08/09/vehicle-trip-discovery-with-gis-tools-for-hadoop/

Time-series spatial correlation

- Checking if anomalies occur at same exact time for nearby monitors over 6 years
  - These monitors can be possible candidates for ‘buddy sites’
  - Time-series filtered buffer/intersect
    - Esri Geometry API in Spark Job:
    - Proximity2DResult.**getCoordinate**()
      - Returns the closest coordinate



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Directed Proximity Search on Anomalies

- Using wind speed/direction – search upwind of anomaly via targeted vector
  - Wildfires, oil spills, airports, industrial, road network, dust events, agriculture, etc. (mix of temporal and non-temporal datasets)
    - USCG NRC, USGS Fed. fires, EPA FRS, Esri Streets, EPA AQS (Wind), US Census Bureau, FAA NFDC
- One-to-Many with possible sources per anomaly time/location

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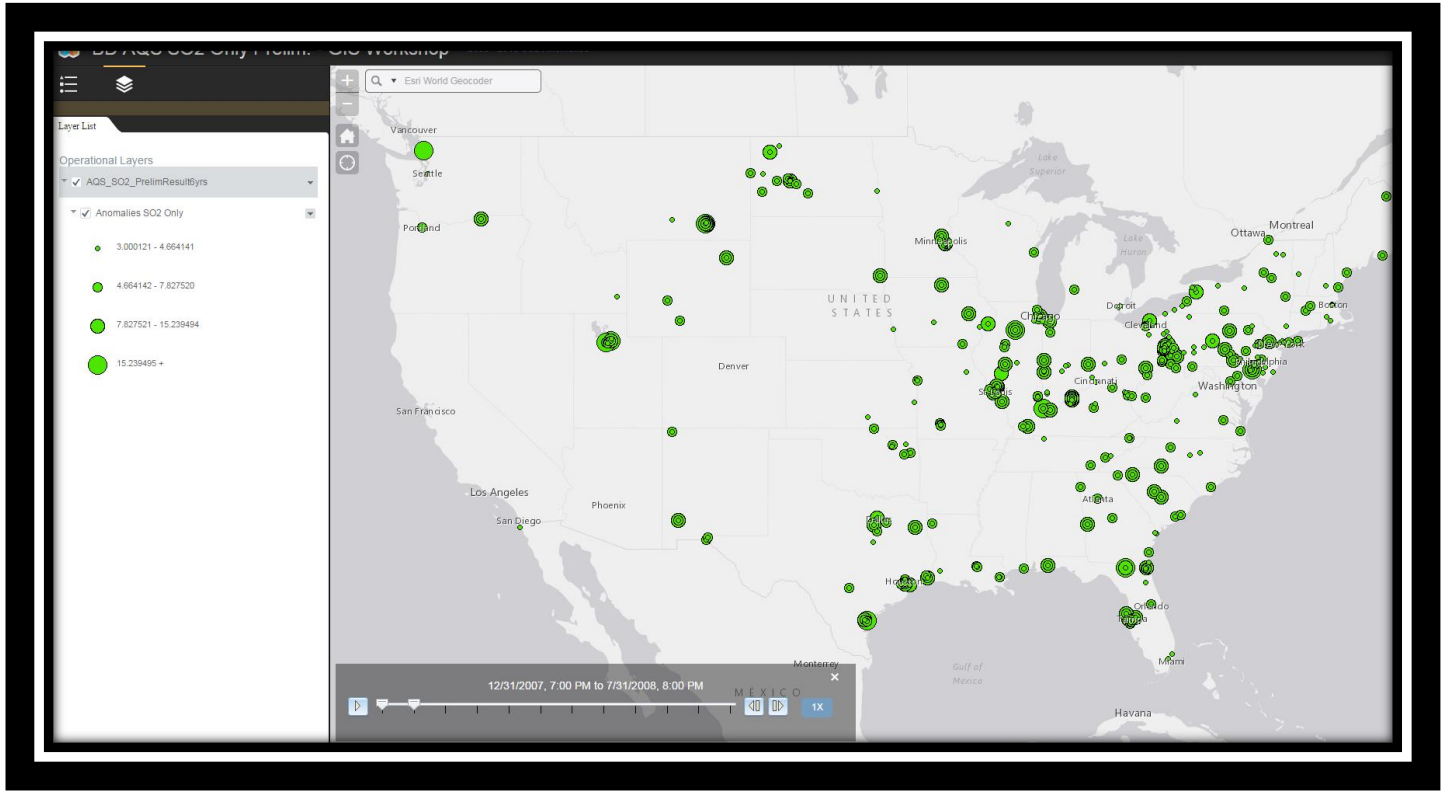
Visualizing the Results

- ArcGIS Server Map Services
- ArcGIS Online Webmaps and Web App Builder
- Tableau Desktop and Server

Web App Builder w/Time Slider Widget and Quantitative Z Scores



Several other GIS products produced to visualize the analysis results as well

Tableau Workbook and Dashboard Anomalies Per Month, Per Pollutant

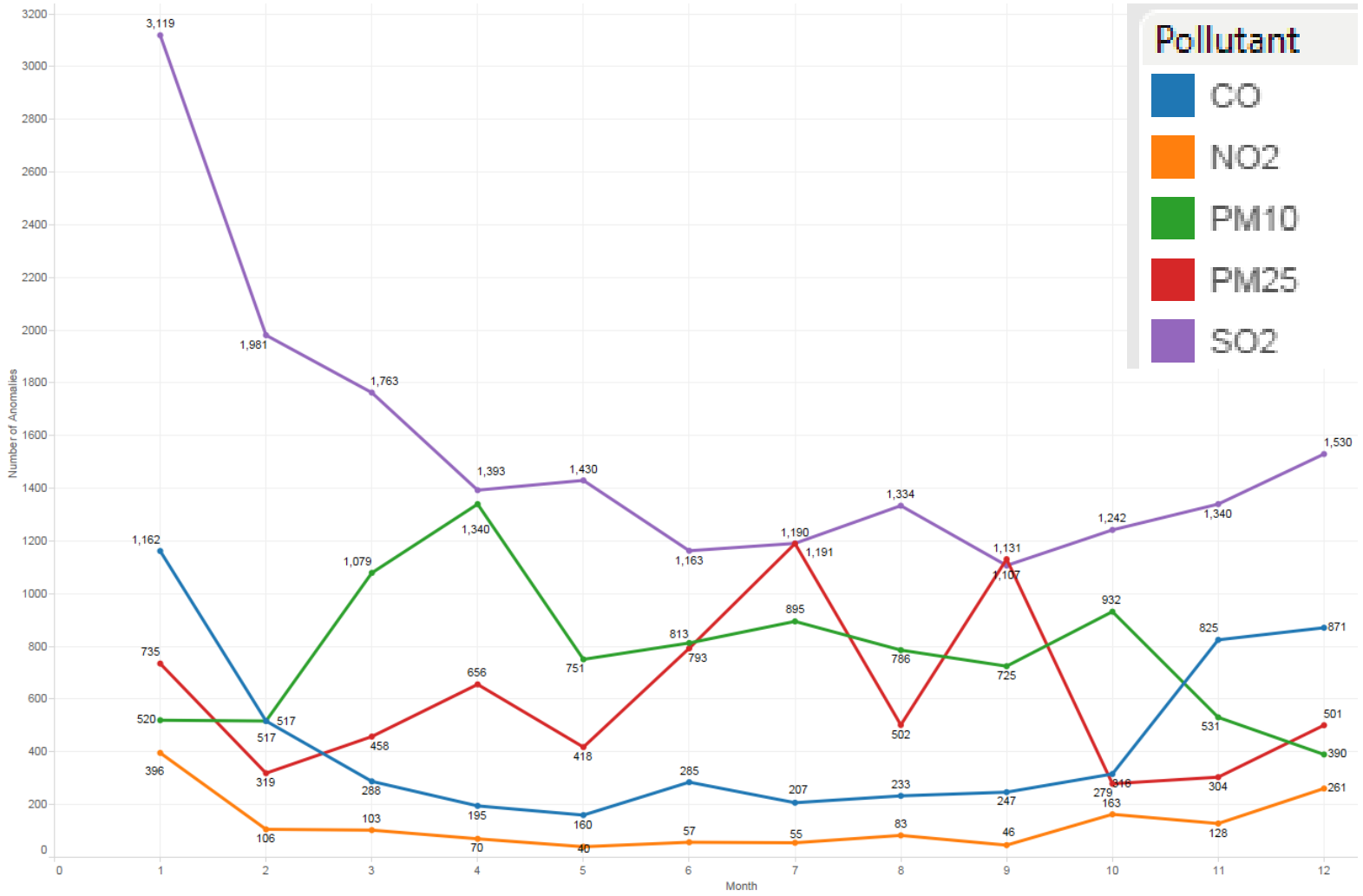
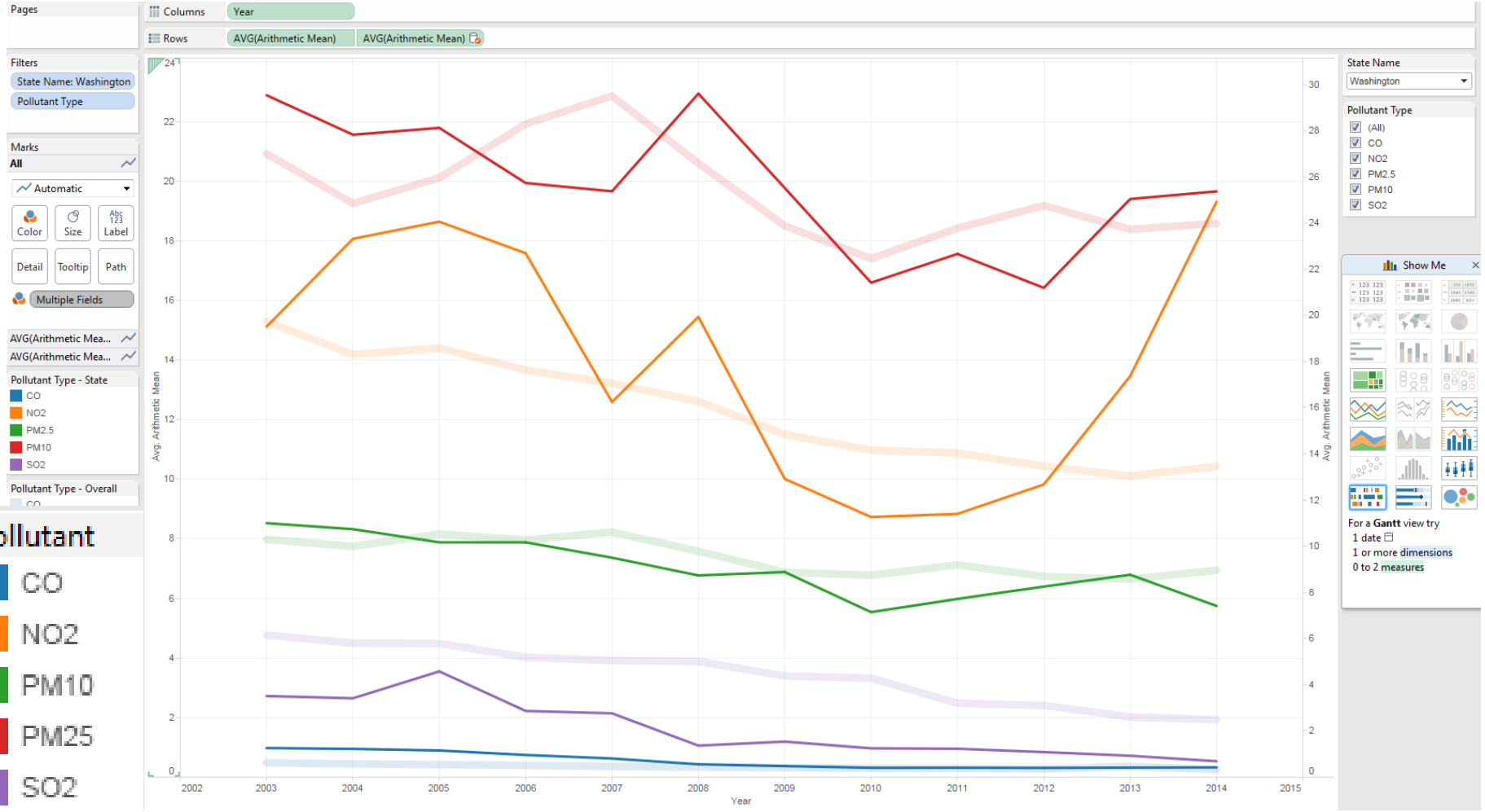


Tableau – Comparing states to national mean



Conclusion

- Esri's open source GIS Tools for Hadoop allows large-scale distributed computing on spatial data
  - Utilize via Spark, Hive, Traditional MR
  - Esri Geometry API for Java is easily customized and extensible for particular use-cases
- https://github.com/Esri/geometry-api-java

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Questions?

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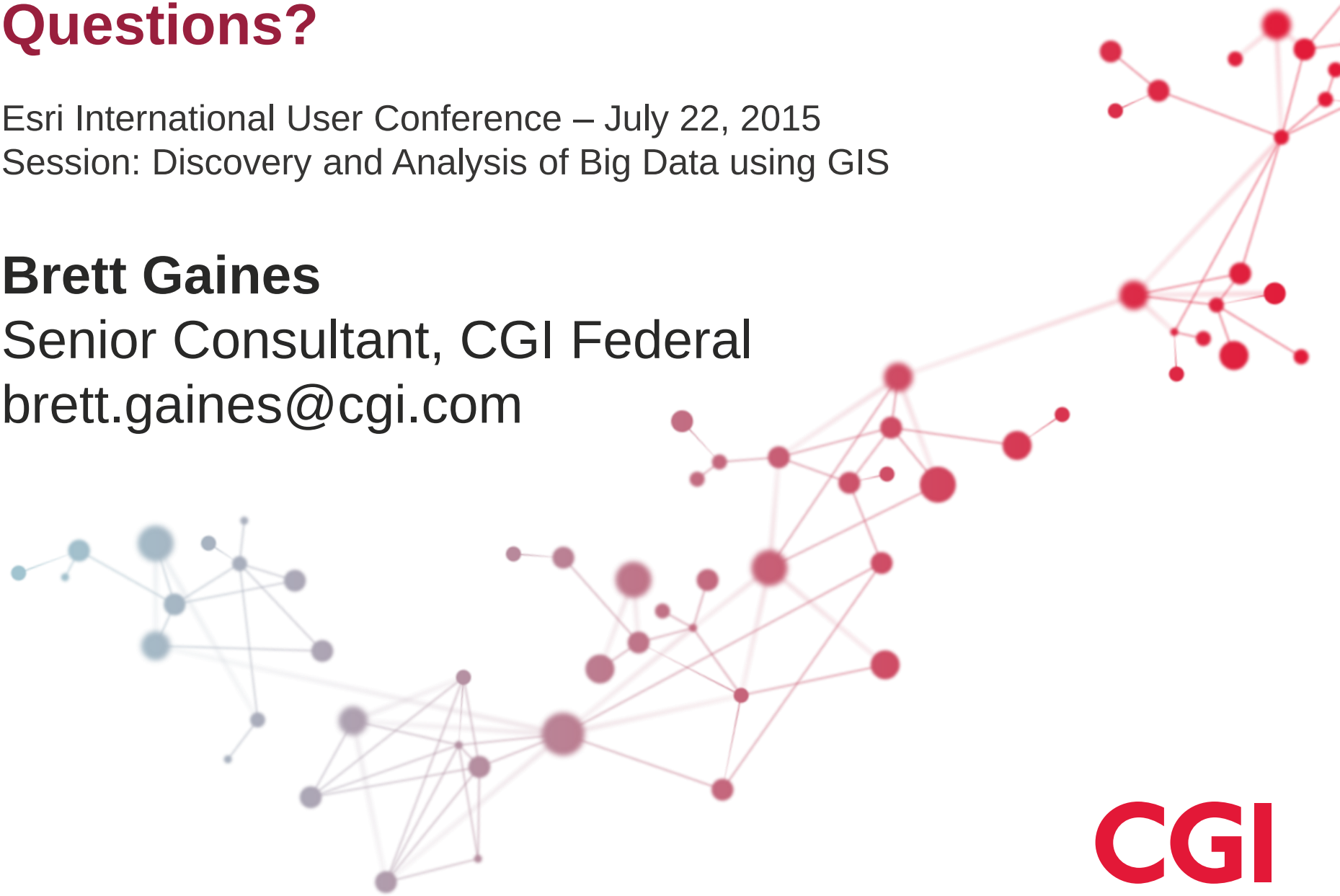

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