Jet Propulsion Laboratory
California Institute of Technology

# Spatial Aggregation of Level 2 OCO-2 Data via Geostatistical Interpolation

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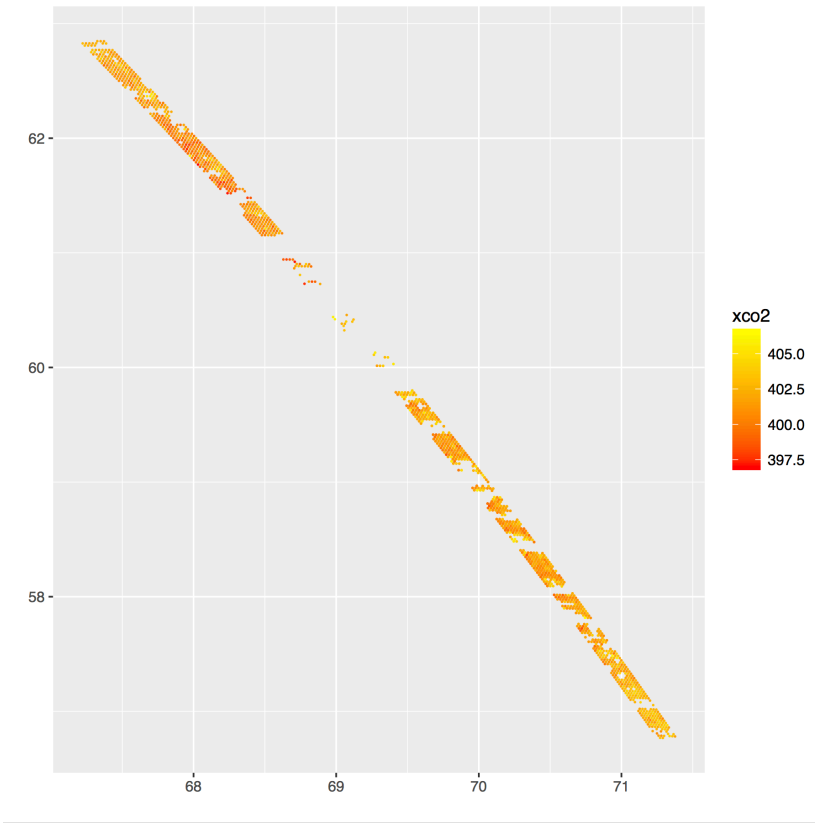
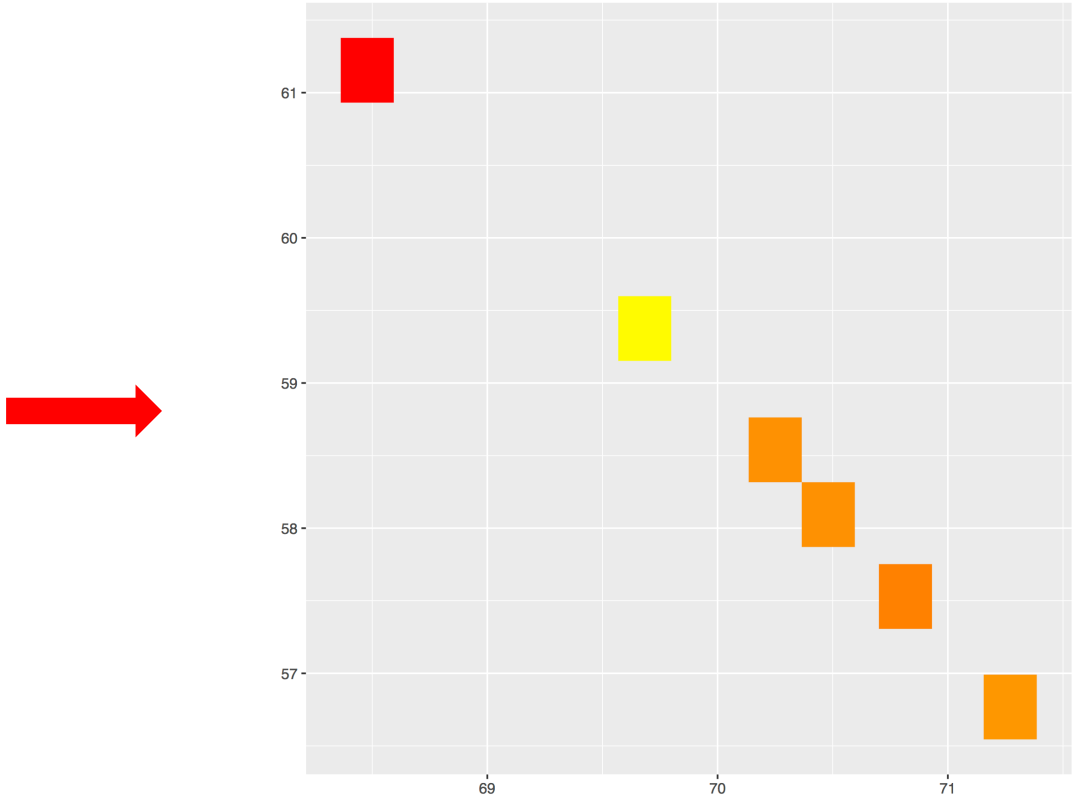
# Motivation: Objective

- Aggregating level-2 OCO2 Data into 1°x1° blocks for flux inversion

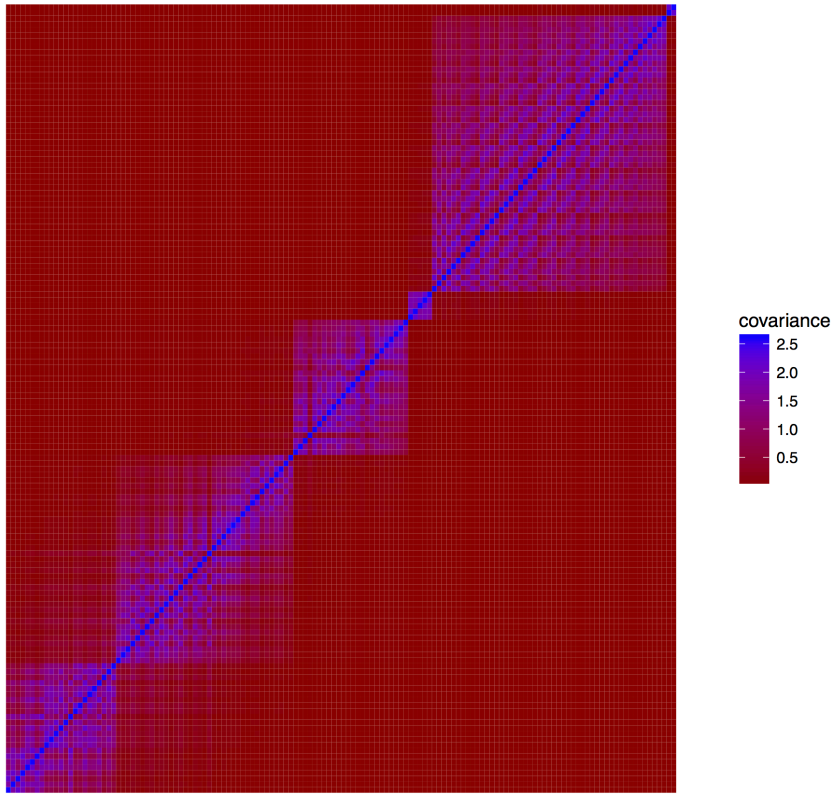


# Motivation: Why use spatial interpolation?

- Simple average is suboptimal
- Take advantage of underlying spatial structures
- Kriging is the Best Linear Unbiased Predictor (BLUP)
- Provides 1°-block uncertainty independent of individual retrieval uncertainties

Example of spatial covariance in $XCO_2$ bin



# Theory: Kriging Basics

- Kriging is a linear estimator of point value
- Coefficients determined by distance from interpolation point
- Founding principle: points that are closer in distance are more similar in value

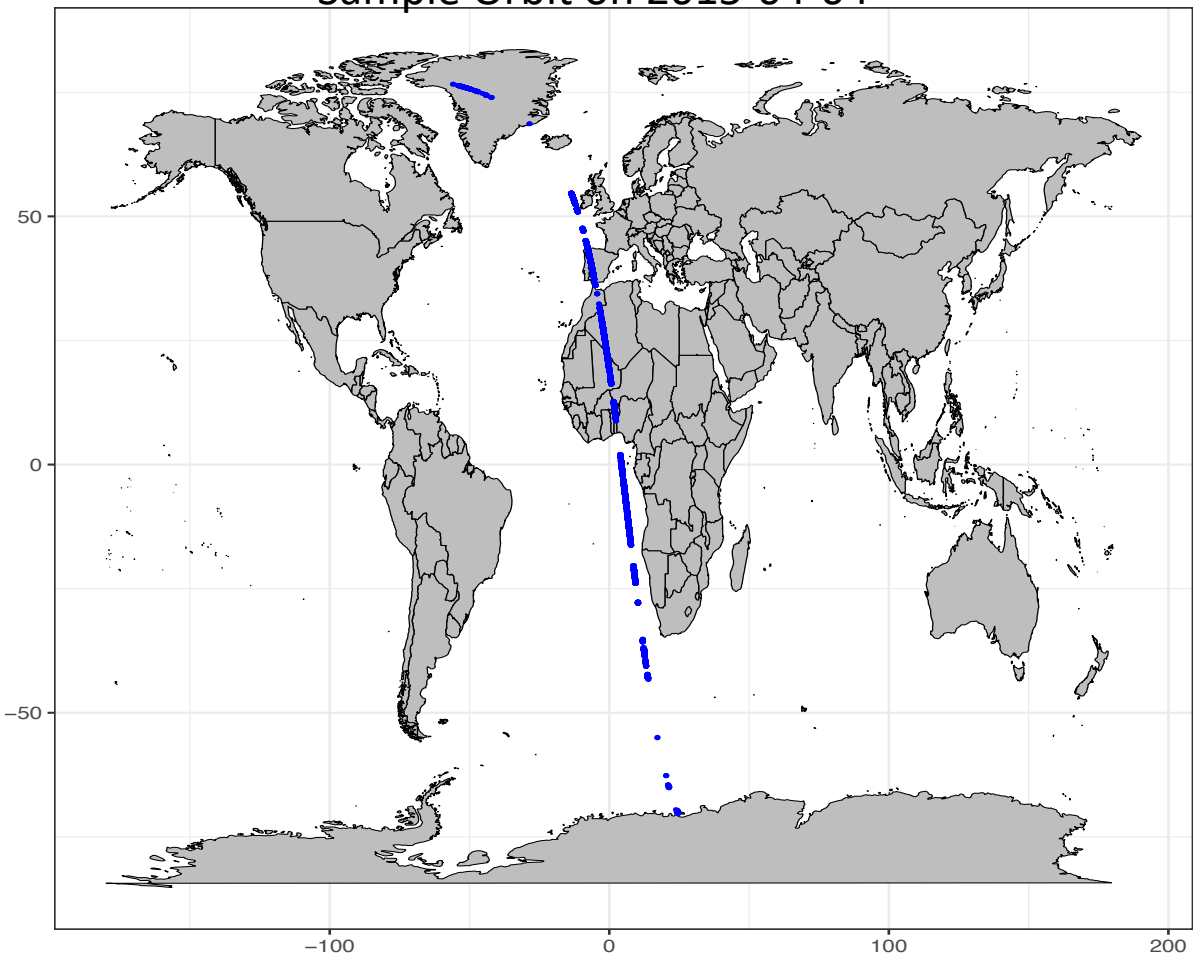
# Theory: Kriging

- Estimate covariance function $C(s_j, s_i)$ between points $s_j, s_i$ and covariance matrix $\Sigma$ as a function of $|\, s_j - s_i \,|$
- For mean $\mu$ and variance $\sigma^2 = C(s_0, s_0)$
- $a_i = C(s^*, s_i)\, \Sigma^{-1}$
- $\hat{Z}(s^*) = \mu + (\frac{1}{n})(a_1 Z(s_1) + \cdots + a_i Z(s_i) + \cdots + a_n Z(s_n))$
- $\widehat{\sigma^2}^* = \sigma^2 - a_i^T C(s^*, s_i)$
- Block Kriging:
  - $\hat{Z}(v) = \frac{1}{v}\int_v Z(s)ds,\ v \subset V, s \in V$
  - $\widehat{\sigma^*}(v) = \frac{1}{v}\int_v \sigma(s)ds,\ v \subset V, s \in V$

# Implementation: Overview of Kriging Aggregation Tool

- Krige by orbit
- 4 Step process:
  - Estimate and remove latitude-dependent trend
  - Define spatial field
  - Estimate local covariance
  - Krige

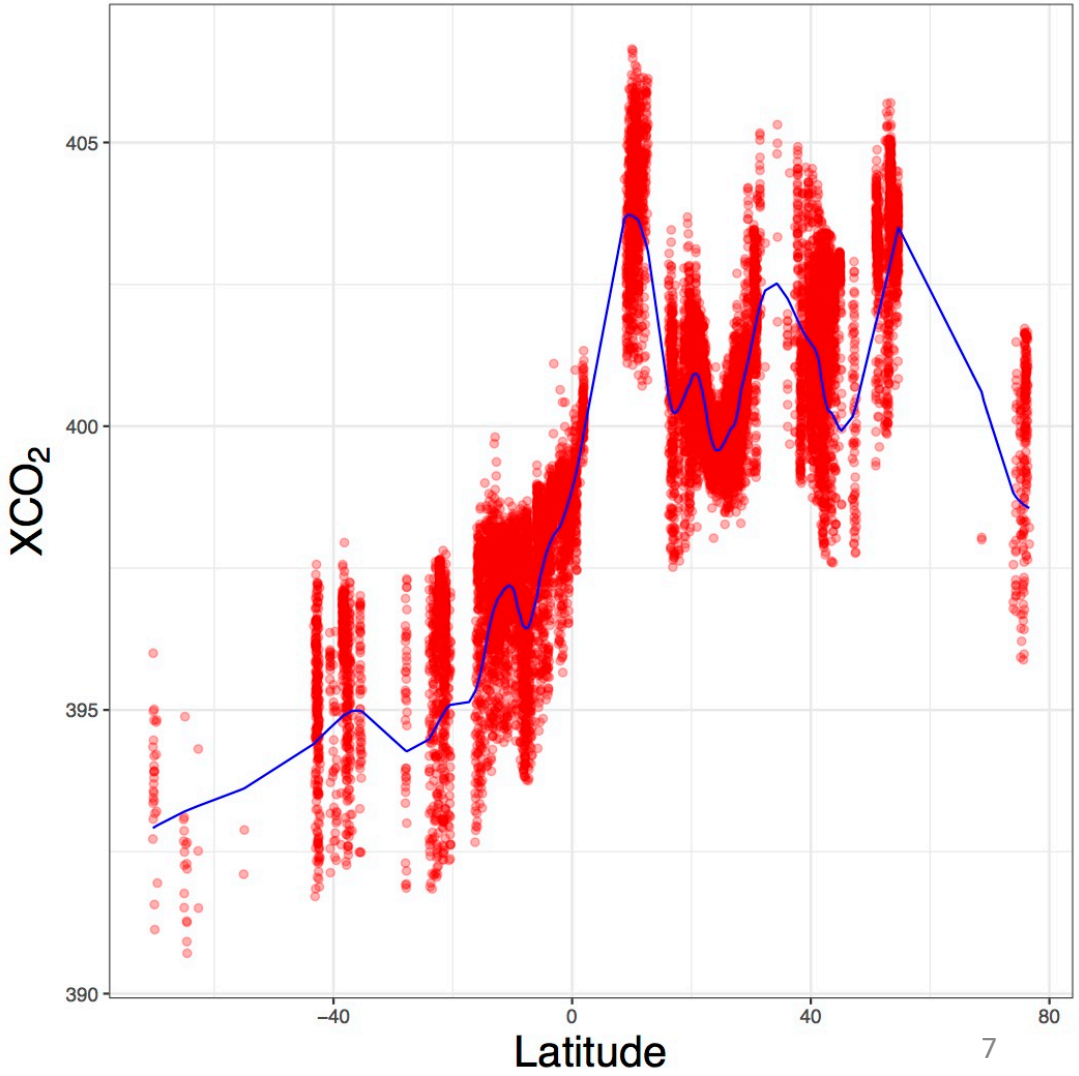
Sample Orbit on 2015-04-04



# Implementation: Detrending

- Kriging estimation requires stationary data
- De-trend $XCO_2$ with respect to latitude using LOESS
- Outlier removal

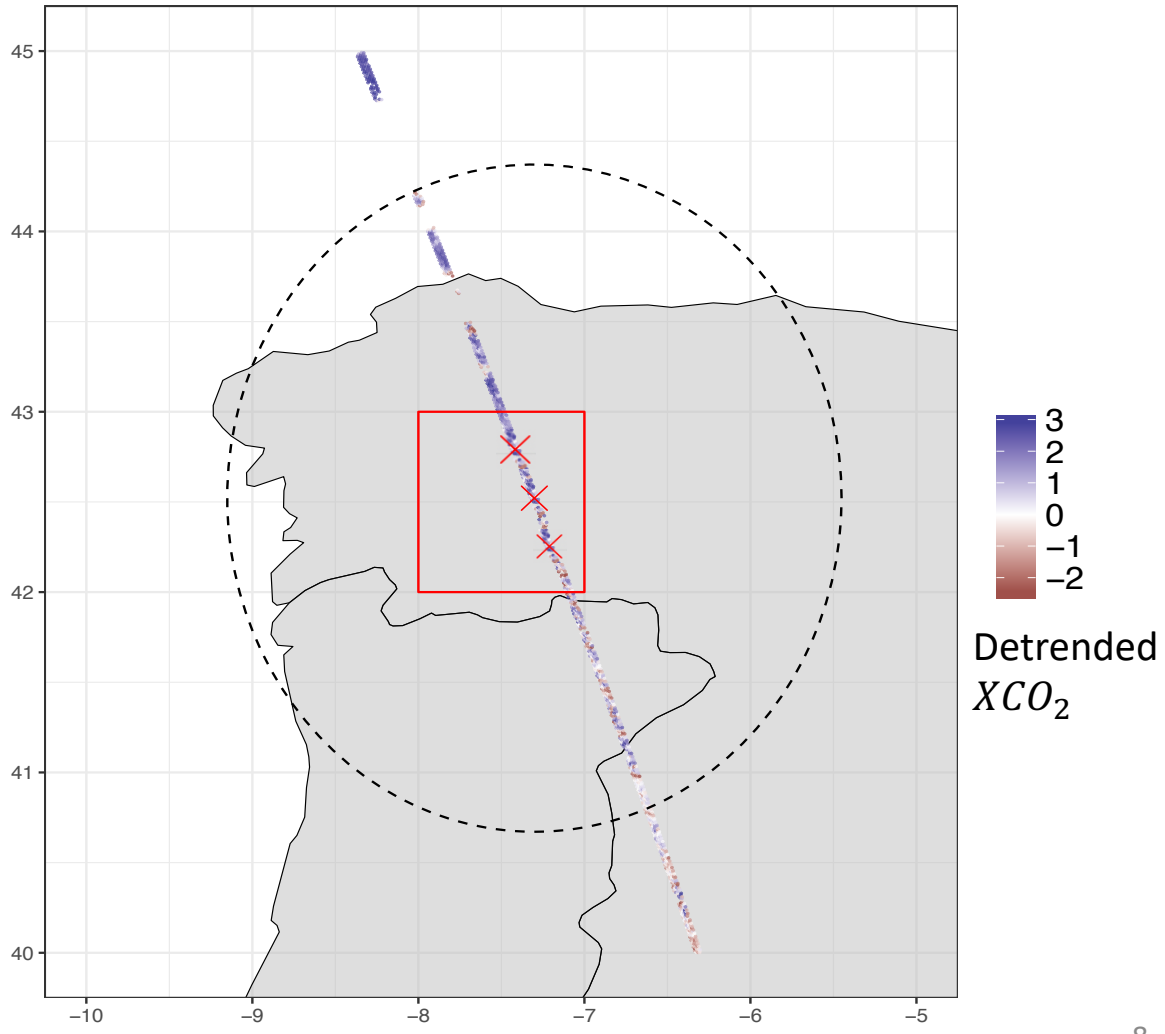
$XCO_2$ for all sample orbit footprints and latitude-dependent trend



# Implementation: Definition of Spatial Field

- Retrievals inside circle within ~200Km of center point
- Block Krige over degree box

Spatial field for sample degree box



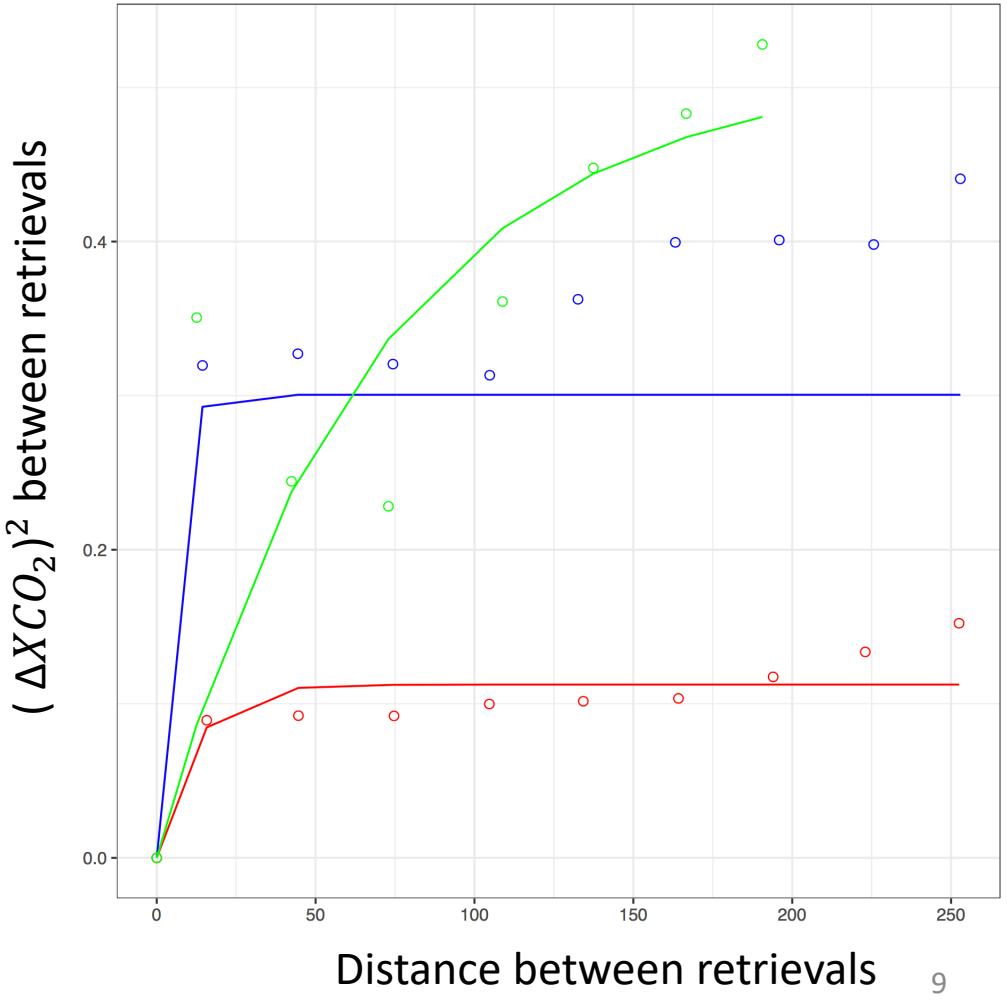
# Implementation: Empirical Covariance Estimation

- Estimate covariance from empirical variogram of spatial field
- Assume variogram ($\gamma$) has exponential form:
  - Bin squared difference in $XCO_2$ value against distance for each retrieval
  - Fit exponential regression
- Covariance:

$$C(h) = C(0) - \gamma(h)$$

where $h$ is the distance between two points

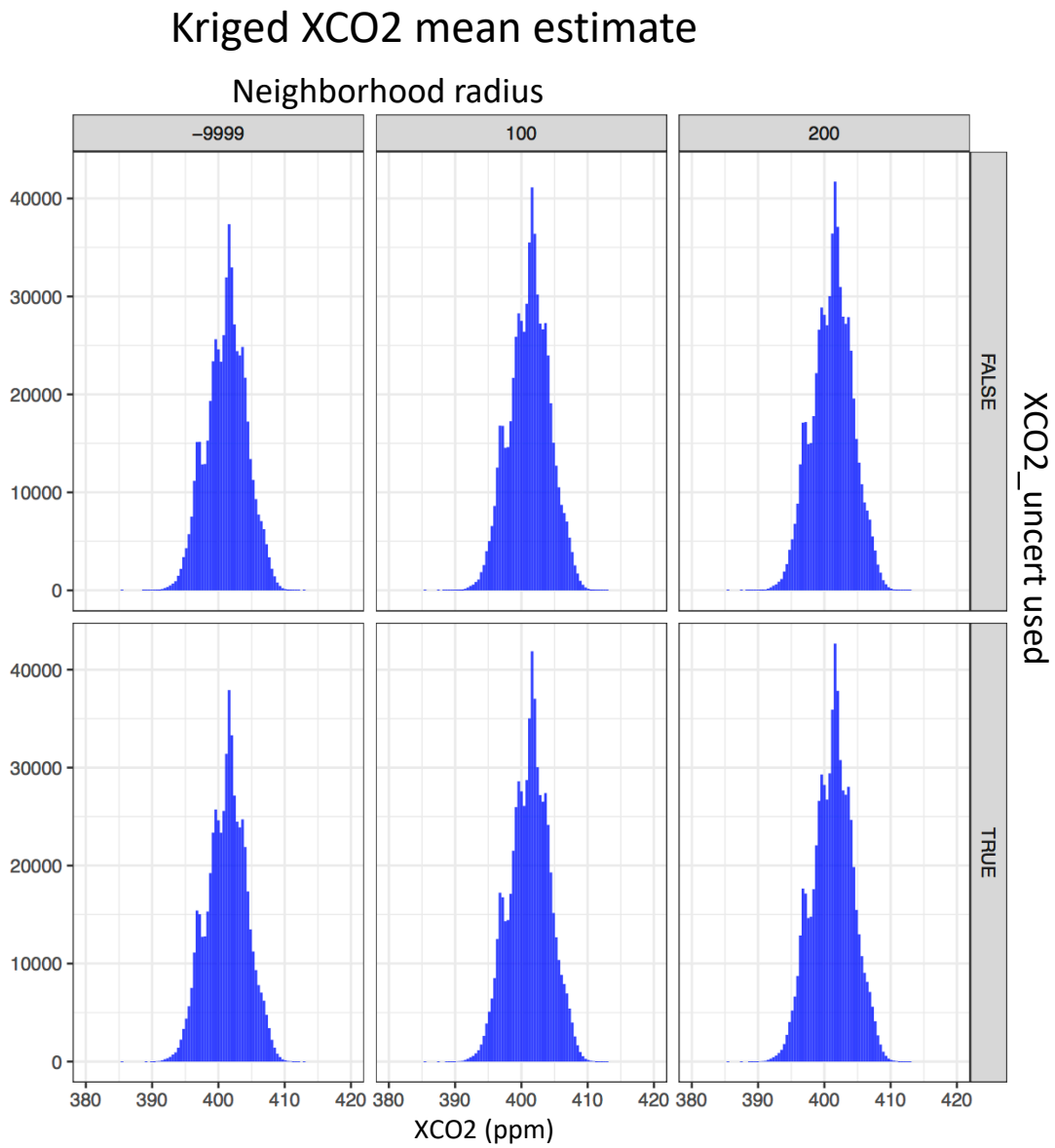
Fitted Empirical Variogram for different spatial fields

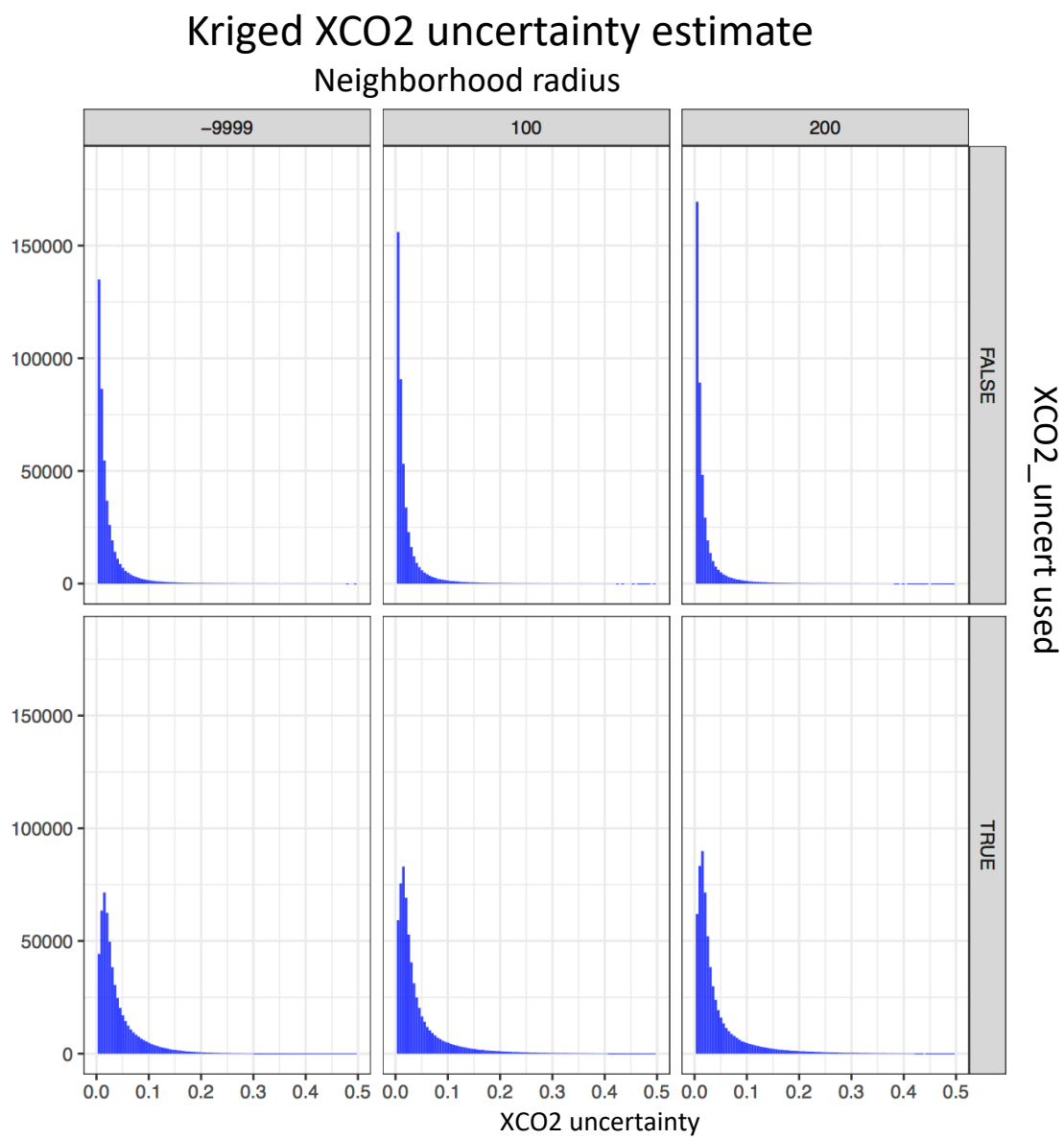


# Overview of Processed Results

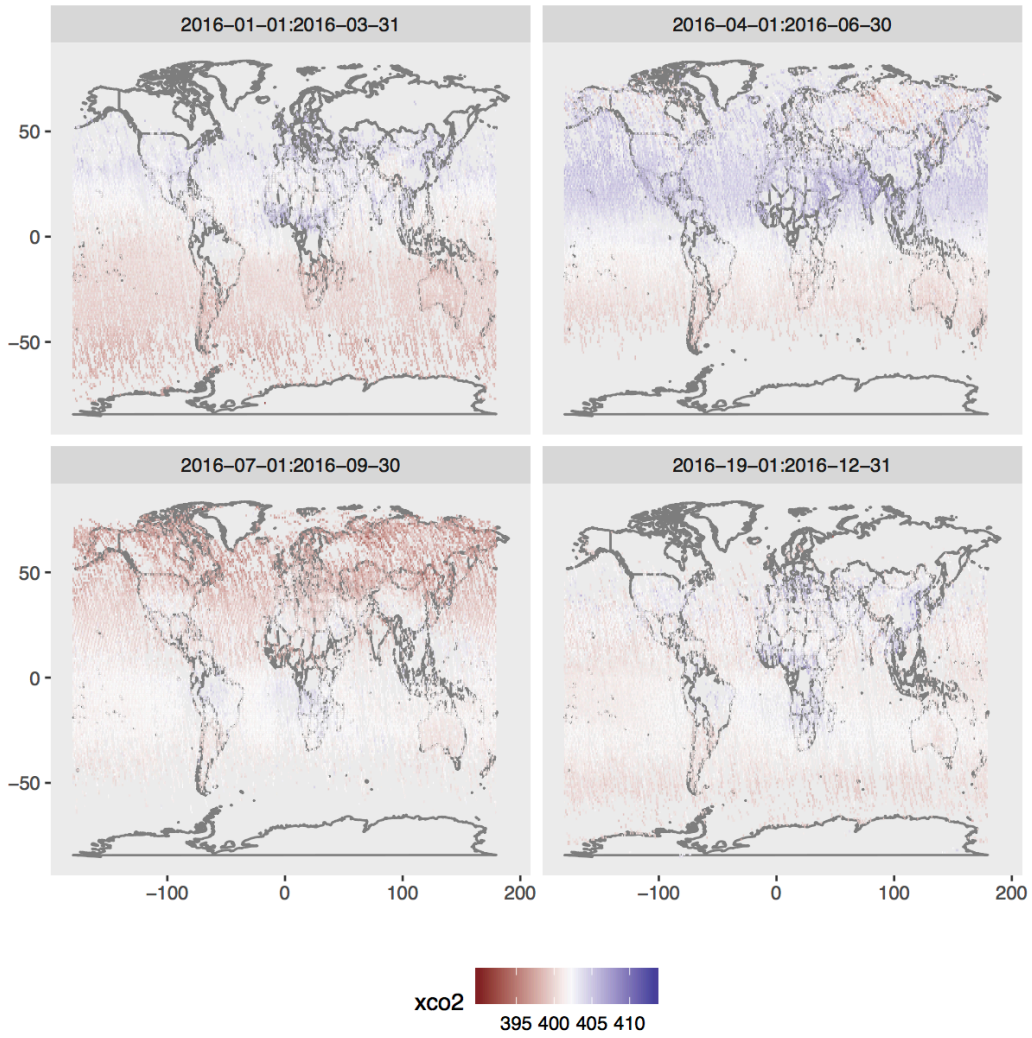
- All of 2014-2017 processed
- 6 different parameter settings:
  - Individual retrieval uncertainty value:
    - Zero
    - XCO2_uncert
  - Radius of spatial neighborhood:
    - 100Km
    - 200Km
    - Only Grid Box

# 2014-2017 Spatially Averaged Values



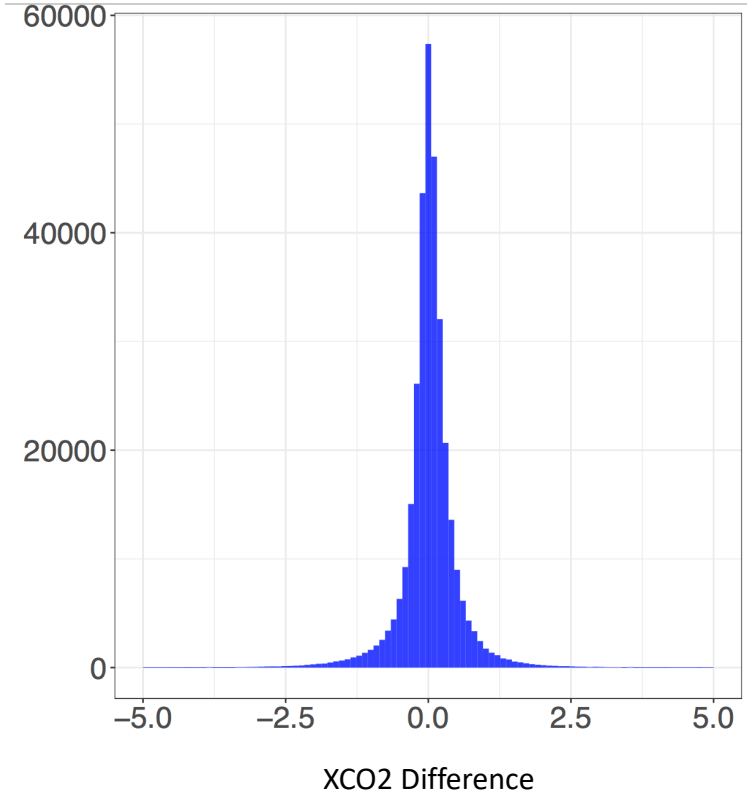



# 2016 Spatially Averaged Values, by season



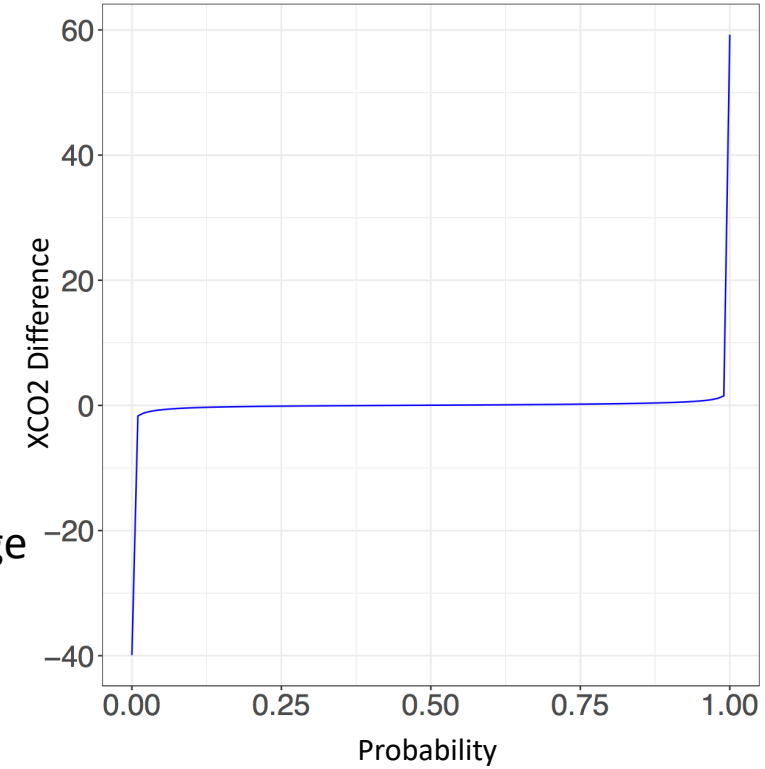
# Comparison with 10 Second Average

- Global 2016 values compared
- Matched by nearest integer coordinate
- 90% of XCO2 Difference within +/-0.6ppm
- 99% of XCO2 Difference within +/-2ppm
- Mean difference: 0.0272 ppm
- Variance difference: 0.151 ppm

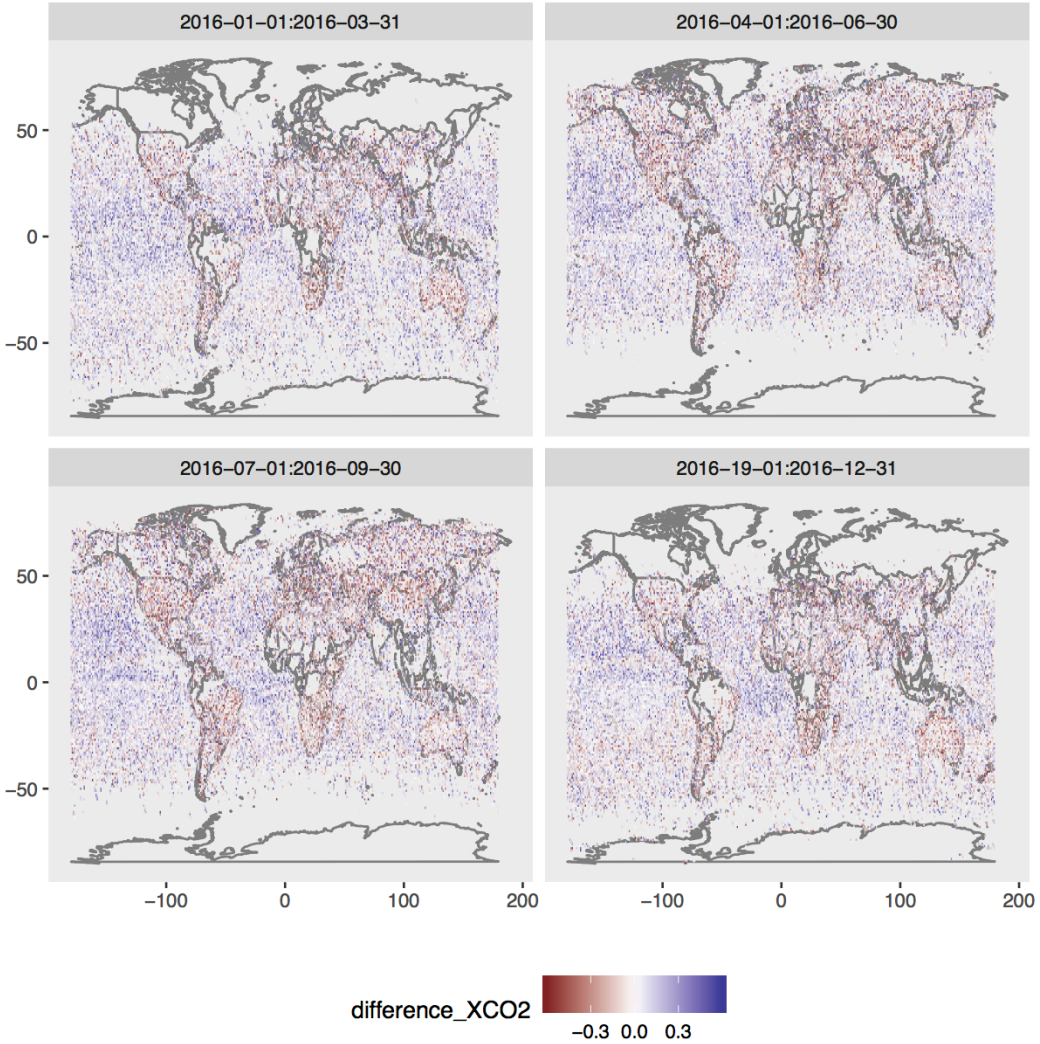



Spatial average – 10 second average

Spatial average – 10 second average CDF



# Comparison with 10 Second Average, by season




- Land/Ocean bias present
- Mean land difference: -0.0564 ppm
- Mean ocean difference: 0.0475 ppm

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