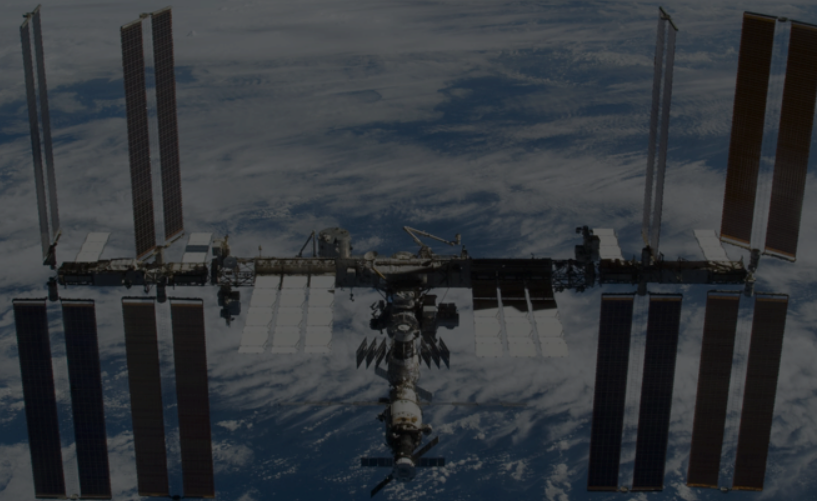# observing CO_2 hotspots from space: the OCO-2 experience and OCO-3 new capabilities

CO$_2$-Urban Synthesis &Analysis Workshop
24-25 October 2018 (Salt Lake City, UT)

thomas p kurosu, ANNMARIE ELDERING, ryan pavlick, brendan fisher, greg osterman, brian knosp, and The OCO-3 Team

jet propulsion laboratory, california institute of technology

Jet Propulsion Laboratory
California Institute of Technology

Orbiting Carbon Observatory 2/3

OCO-2

➤ launched 02 July 2014

➤ sun-synchronous orbit, ~1330h equator crossing time

➤ observed species:
- CO_2 dry-air column (XCO_2)
- solar-induced fluorescence (SIF)

➤ observation modes
- nadir
- glint
- target

OCO-3

➤ built as the OCO-2 spare

➤ launch date* 17 February 2019, International Space Station (ISS)

➤ observed species:
- CO_2 dry-air column (XCO_2)
- solar-induced fluorescence (SIF)

➤ observation modes
- nadir
- glint
- target
- city/area

➤ ground footprint size 4 km^2 to 6 km^2

*the recent Soyuz launch failure is not expected to significantly impact the OCO-3 launch date

OCO-2/3 – take-home messages

I. OCO-2 data enable the next step in quantifying fossil fuel CO_2 emissions impacts with space based data, at 1 ppm precision.

II. OCO-3 on the ISS will complement and continue the OCO-2 data record , with a dedicated new observation mode to map city areas.

III. OCO-3 pre-flight instrument performance tests and simulations indicate that XCO_2 and SIF data quality from OCO-3 will be similar to OCO-2.
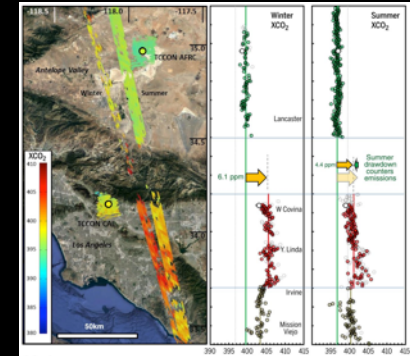
notable OCO-2 science
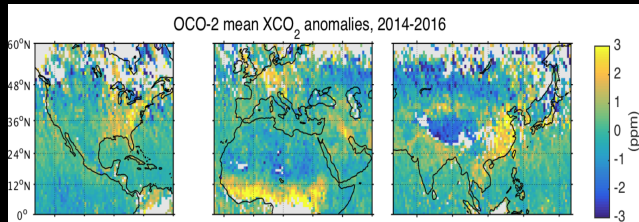
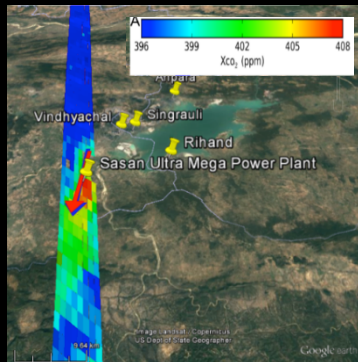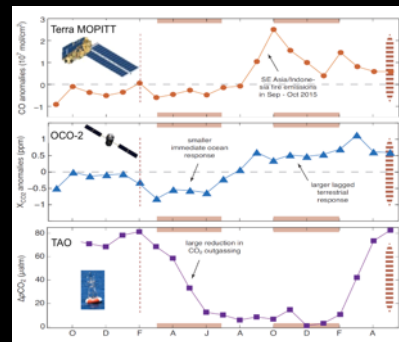Large-Scale Anthropogenic Emissions
(Hakkarainen *et al*, GRL, 2016)
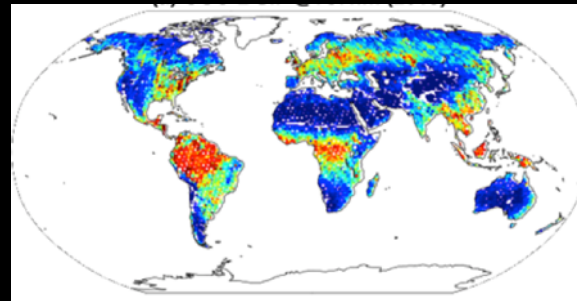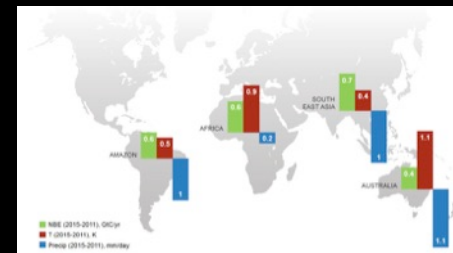
Global SIF Measurements
(*Sun et al*, Science, 2017)

Detection of Urban&Volcanic Emissions
(Schwandner *et al*, Science, 2017)

Ocean Response to
2015-16 El Nino
(Chatterjee et al,
Science, 2017)

Quantifying Power Plant Emissions
(Nassar *et al*, GRL, 2017)

Tropical Response to 2015-16 El Nino
(Liu *et al*, Science, 2017)

OCO-2 and Los Angeles

Aggregate sources: Megacities

- **Problem**: How well can OCO-2 X_{CO2} measurements quantify the increase in X_{CO2} from fossil fuel burning?

- **Results**: In the Los Angeles region, differences of ~6 ppm were seen from a single orbit of data. The overall statistics show that difference of 1 ppm can be quantified from the data.

- **Significance**: The OCO-2 data enable the next step in quantifying fossil fuel CO_2 emissions impacts with space based data.

- Figure from Schwandner et al., Science, 2017
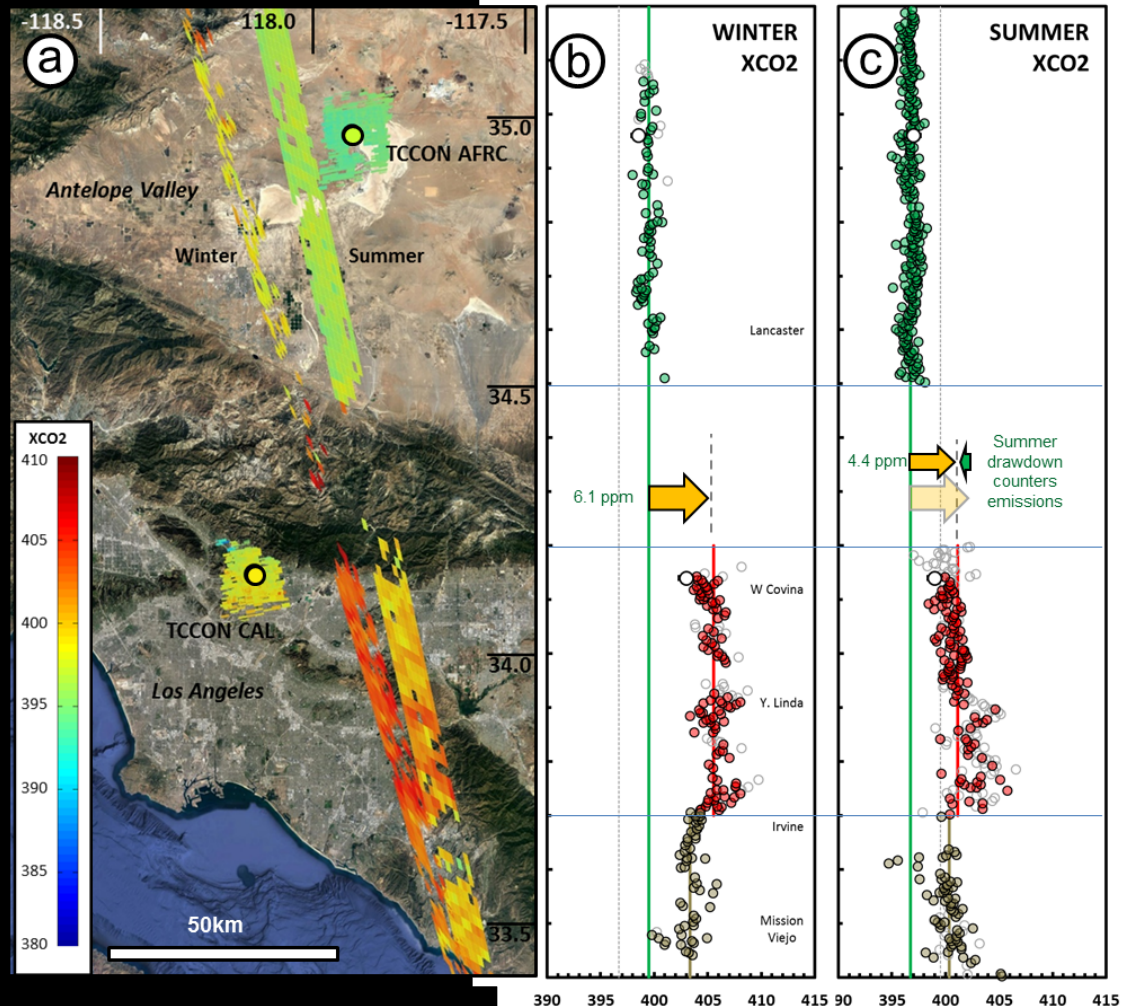
quantifying CO_2 emissions from power plants with OCO-2

Ray Nassar (Environment and Climate Change Canada, ray.nassar@canada.ca)

Direct overpasses or close flybys of mid- to large-sized coal power plants reveal XCO_2 enhancements and demonstrate a technique to estimate emissions from point sources from space.
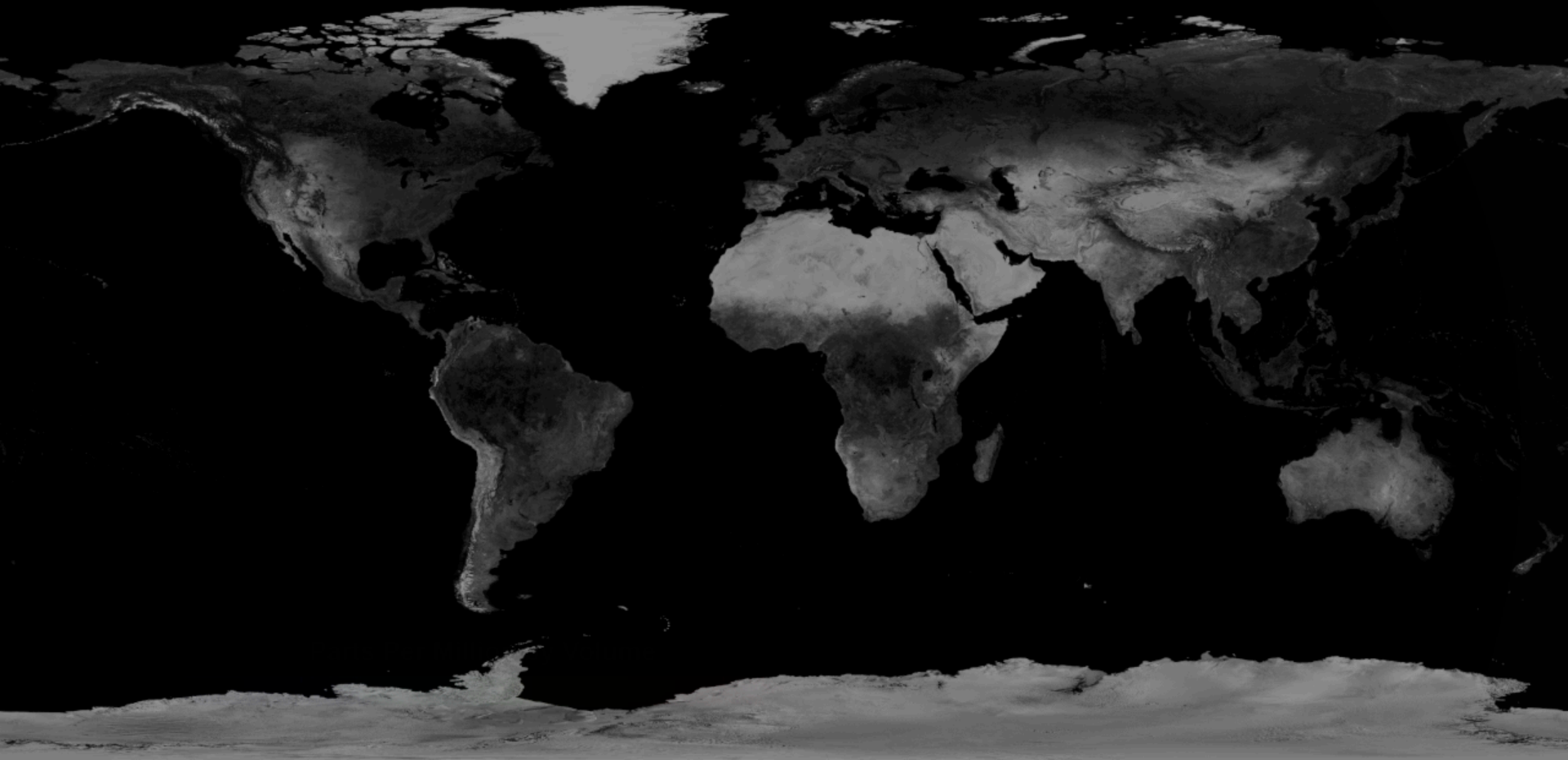

https://doi.org/10.1002/2017GL074702
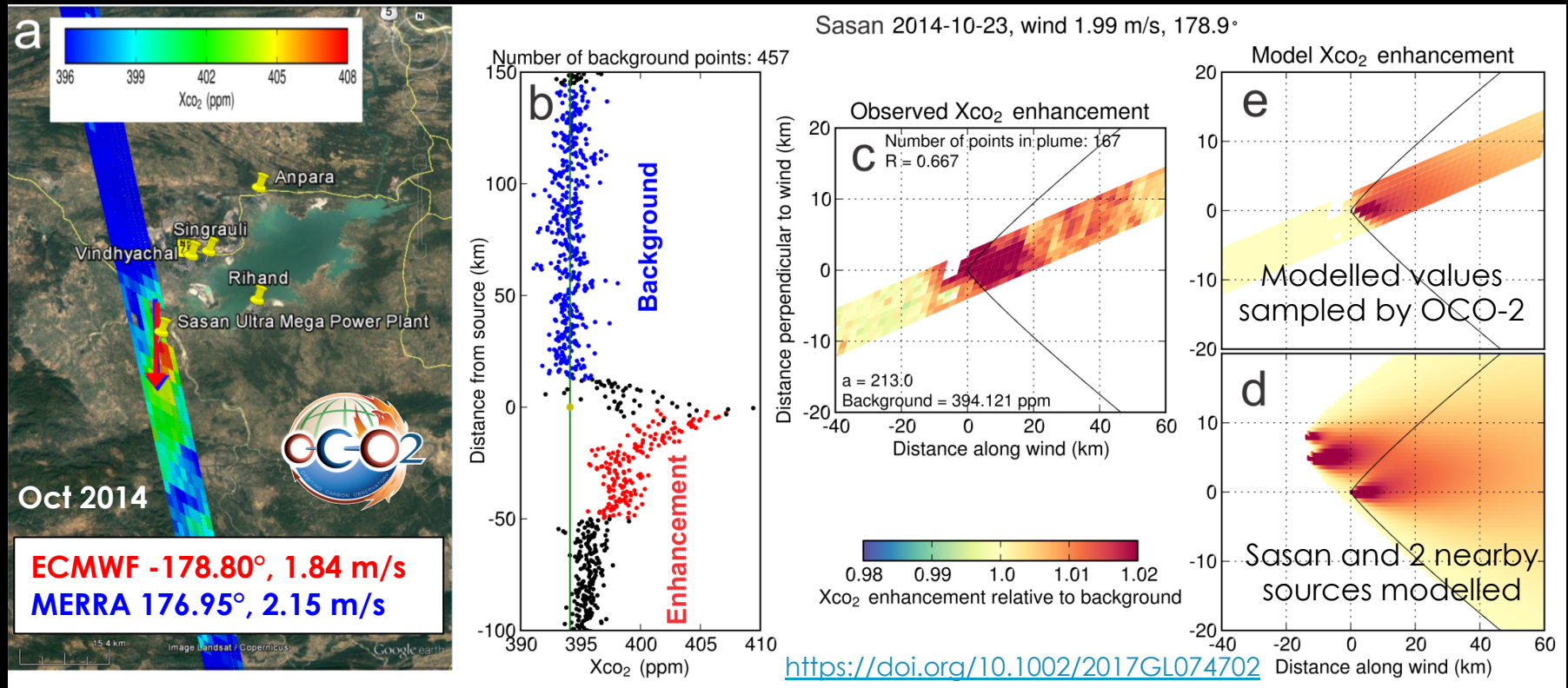
Demonstrated on US power plants with emissions from EPA, then applied to India & S. Africa
Sasan reported annual value equivalent to **60.2 kt/day** and we estimate **67.9±10.0 ktCO$_2$/day**

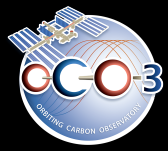# OCO-2 global XCO$_2$ – 3-year animation

Orbiting Carbon Observatory - 2
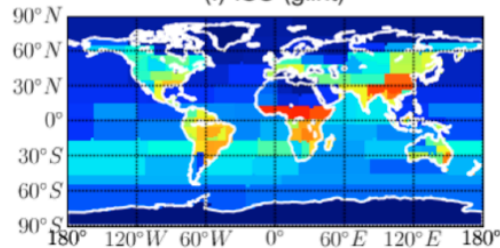Atmospheric Carbon Dioxide Concentration (09/06/14 - 07/30/2017)
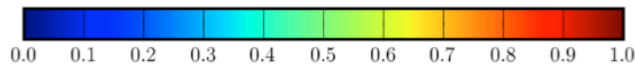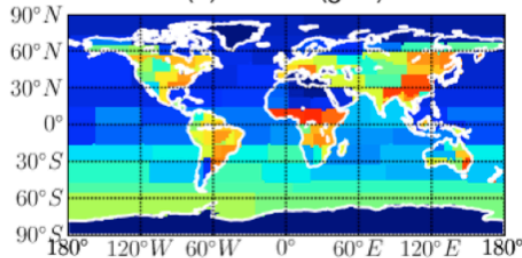
OCO-3 science overview

Continued Global CO$_2$ Flux Estimates
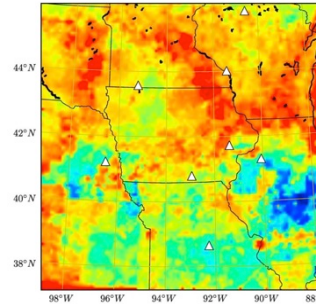
OCO-3 on
(f) ISS (glint)

(b) OCO-2 (glint)

Flux error improvement for January
Palmer et al., 2011

Unique Science Opportunities with OCO-3

Midwest Carbon Flux
From Schuh et al., 2013
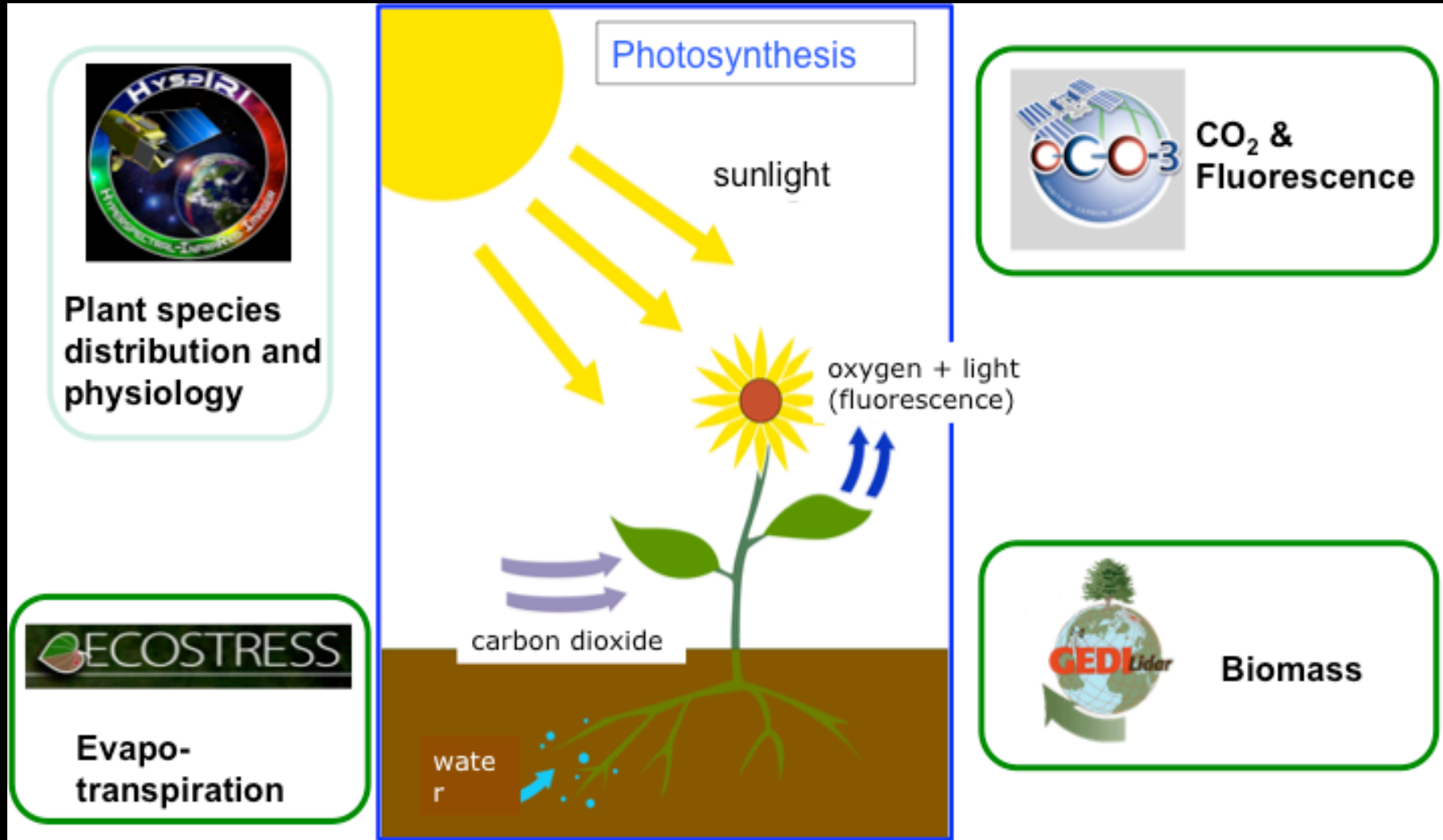
Terrestrial Carbon Cycle
Process studies enabled by measurements at all sunlit hours, including SIF. ISS will contain complementary instrumentation.
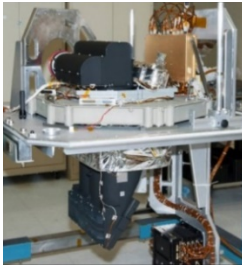

Anthropogenic Emissions
Enabled by enhanced target mode using pointing mirror assembly

OCO-3, ECOSTRESS, GEDI:
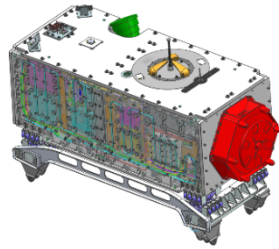# the ISS carbon cycle opportunity

OCO-3 mission architecture
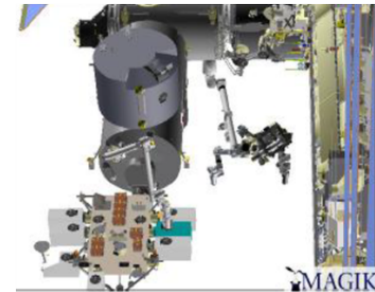

Spare OCO-2 Instrument
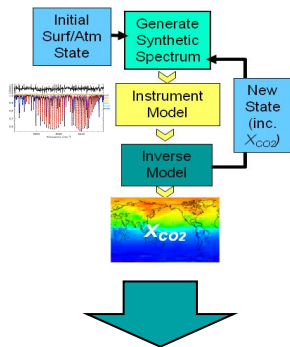
OCO-3 Payload

SpaceX Dragon Transfer Vehicle

Falcon-9 LV
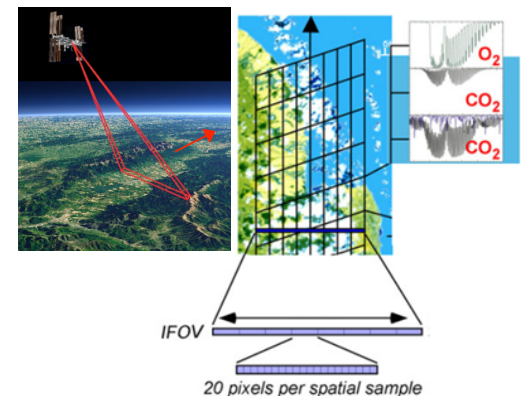
Installation on ISS JEM-EF

MAGIK

Science Data Processing

Initial Surf/Atm State

Generate Synthetic Spectrum

Instrument Model

New State (inc. X_{CO2})

Inverse Model

X_{CO2}

Command and Data Flow

TDRSS

ISS

Uplink commands

Downlink housekeeping / science data

JPL
Payload Control & Data Processing

TDRSS Ground Station

JSC
Payload Testing / Training
ISS Payload Program Office

MSFC
Payload Operations Integration Center

KSC
Launch Facility

Data Archiving & Distribution

Science Data Collection

O_2

CO_2

CO_2

IFOV

20 pixels per spatial sample

EOL Payload disposal via Dragon Trunk re-entry
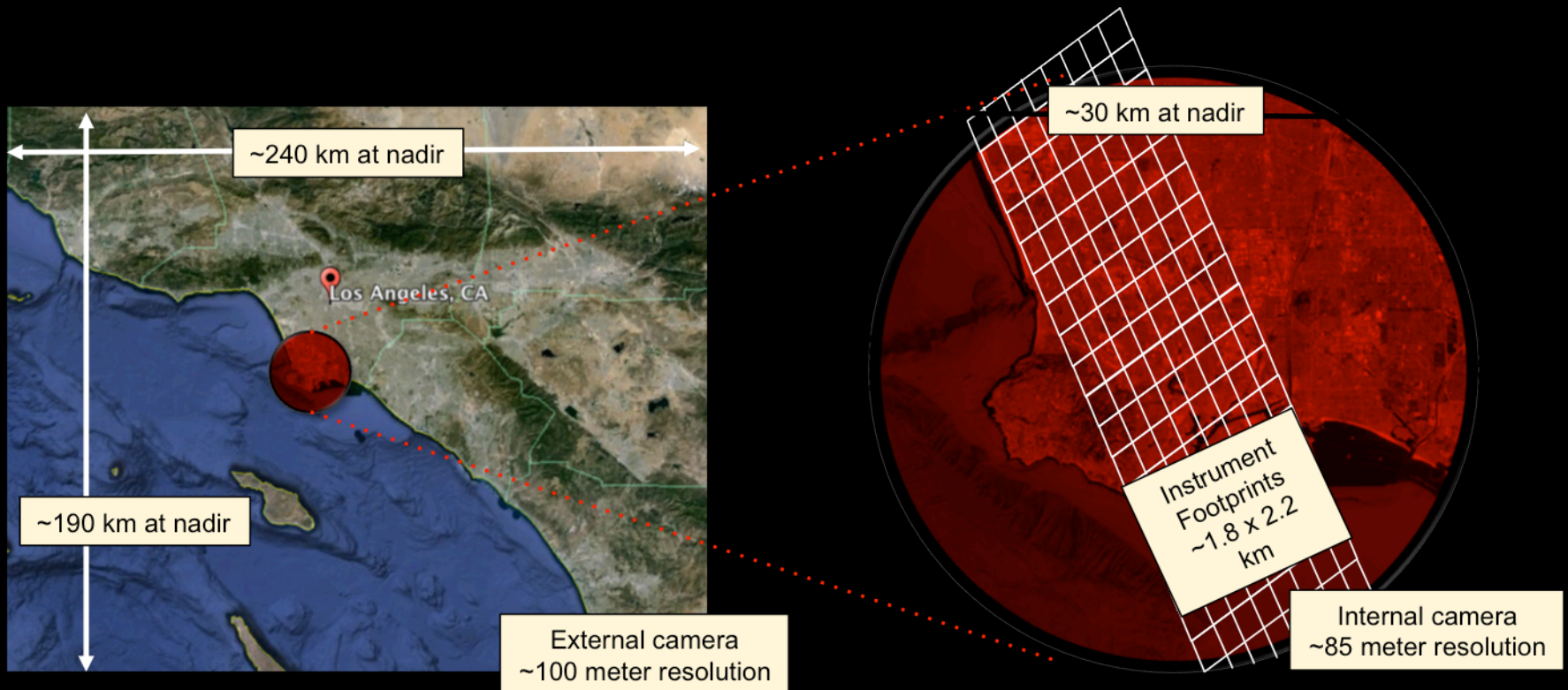
# OCO-3 context cameras

➤ Internal context camera (red image) specifically for geolocation.
(Gold mirrors will alter the color balance of the image.)

➤ External context camera (left) will collect a large image in false color.

~240 km at nadir

Los Angeles, CA

~190 km at nadir

External camera
~100 meter resolution

~30 km at nadir

Instrument
Footprints
~1.8 x 2.2
km

Internal camera
~85 meter resolution

OCO-3 area mode – challenges of pointing automation

o list of 1000 city/area targets world wide, based on the ODIAC emissions data base, plus TCCON, volcanoes, validation

o OCO-3 plans ~100 area observations per day

o instrument pointing must be automated

o challenges – must consider

  • ISS keep-out zones
    (obstructions, reflective surface)
  • ISS approach angle
    (apex, ascending, descending)
  • target location
    (east/ west of ISS track)
  • scan direction
    (toward/away from ISS track)

U.S. west coast

U.S. east coast

OCO-3 viewable

Europe

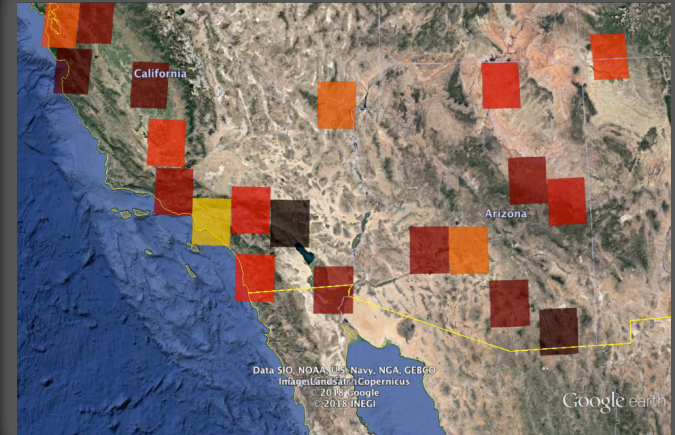Asia
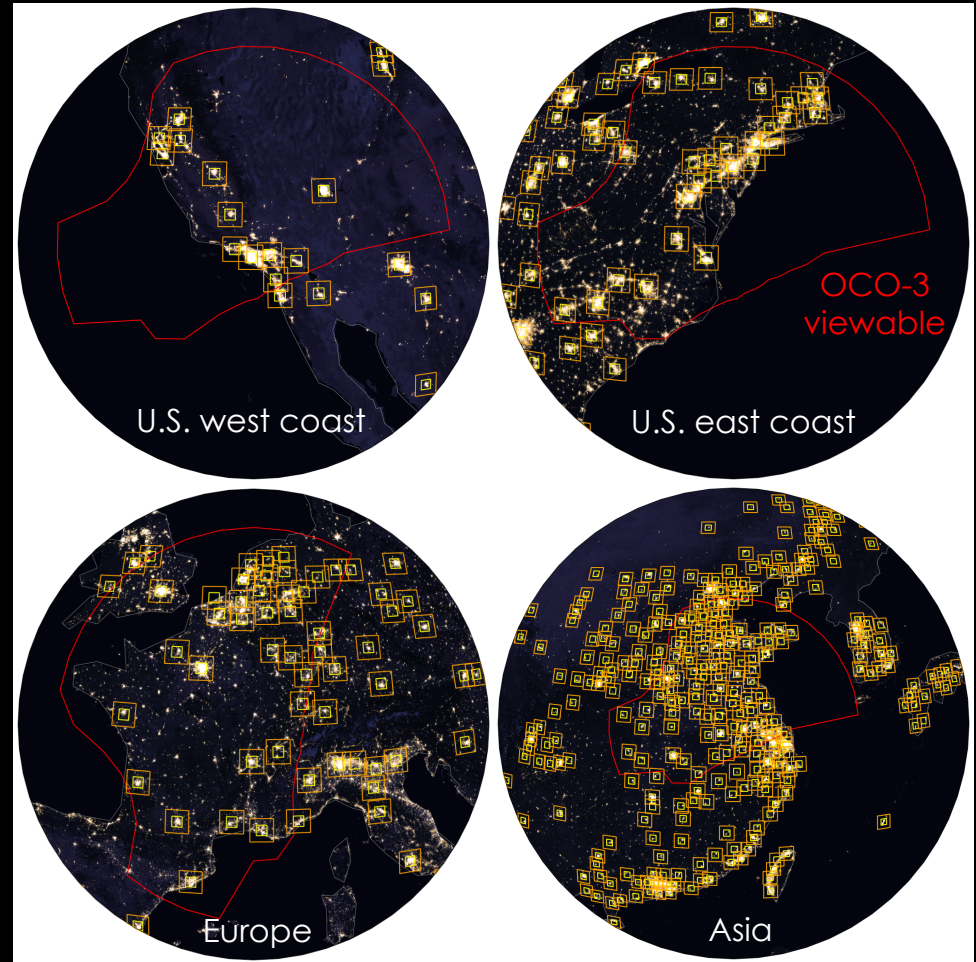
OCO-3 area mode – target selection and prioritization

OCO-3 area target selection will be based on continually updated prioritization lists

Q1: is the target observable?

? in view of OCO-3
? illuminated
? reasonably cloud-free

ODIAC targets,
colored by emission intensity

Q2: does the target have high enough priority?

? TCCON station = high priority
? importance of target for reducing uncertainties in global emissions
? number of times target was observed previously
? cloud cover conditions
? special targets (validation campaigns, OCO-2 coincidences, volcanoes, *etc.*)

OCO-3 expected observations – 2015-12-19 simulation

the following slides show
simulated OCO-3 observations for a day in 2015
performed with the
OCO-3 in-flight pointing control software

Jet Propulsion Laboratory
California Institute of Technology
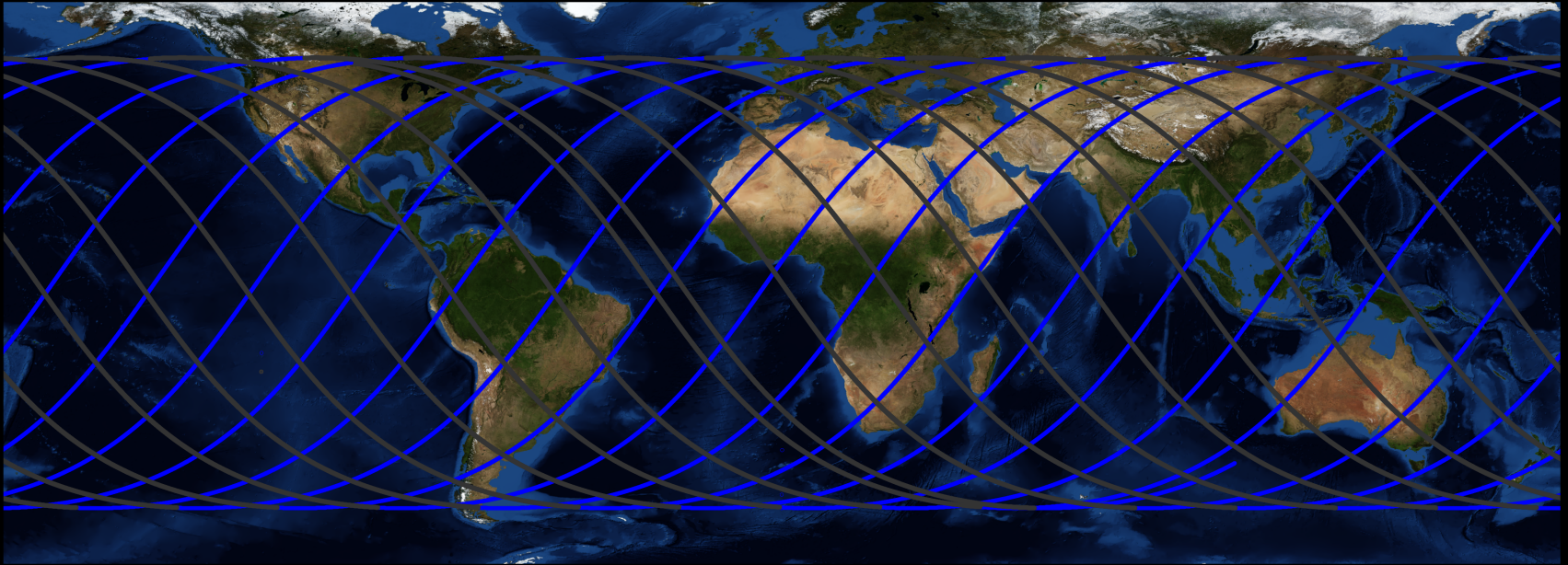
ISS track (partial) – 2015-10-19 simulation

flight direction
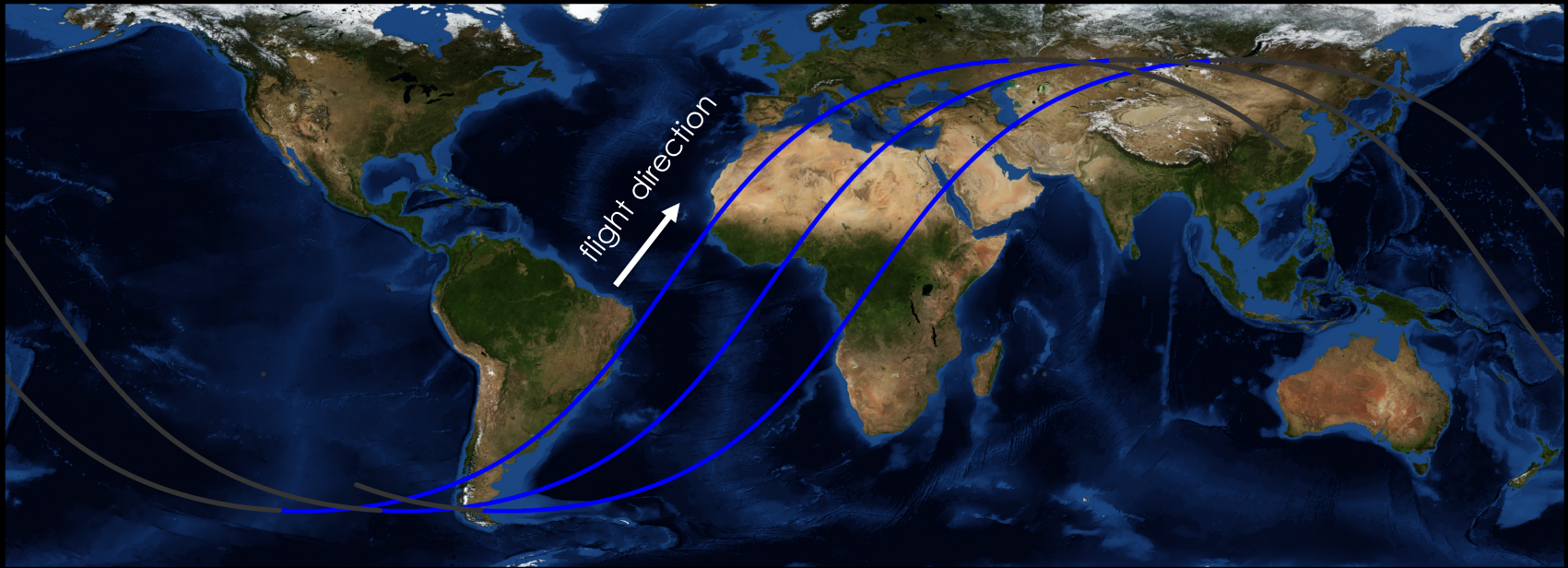
daytime
nighttime

ISS latitudinal coverage: 52˚S – 52˚N

ISS track (full) – 2015-10-19 simulation

daytime
nighttime
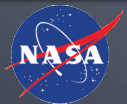
ISS latitudinal coverage: 52°S – 52°N

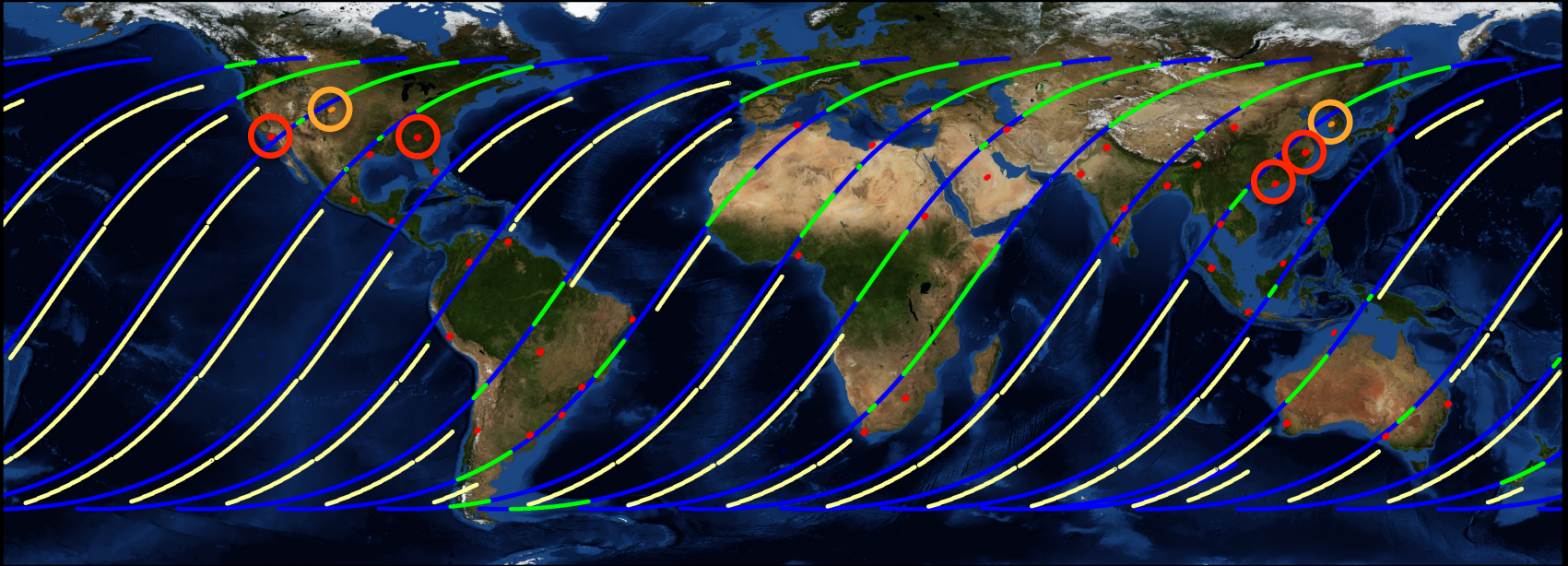# OCO-3 measurement modes – 2015-10-19 simulation
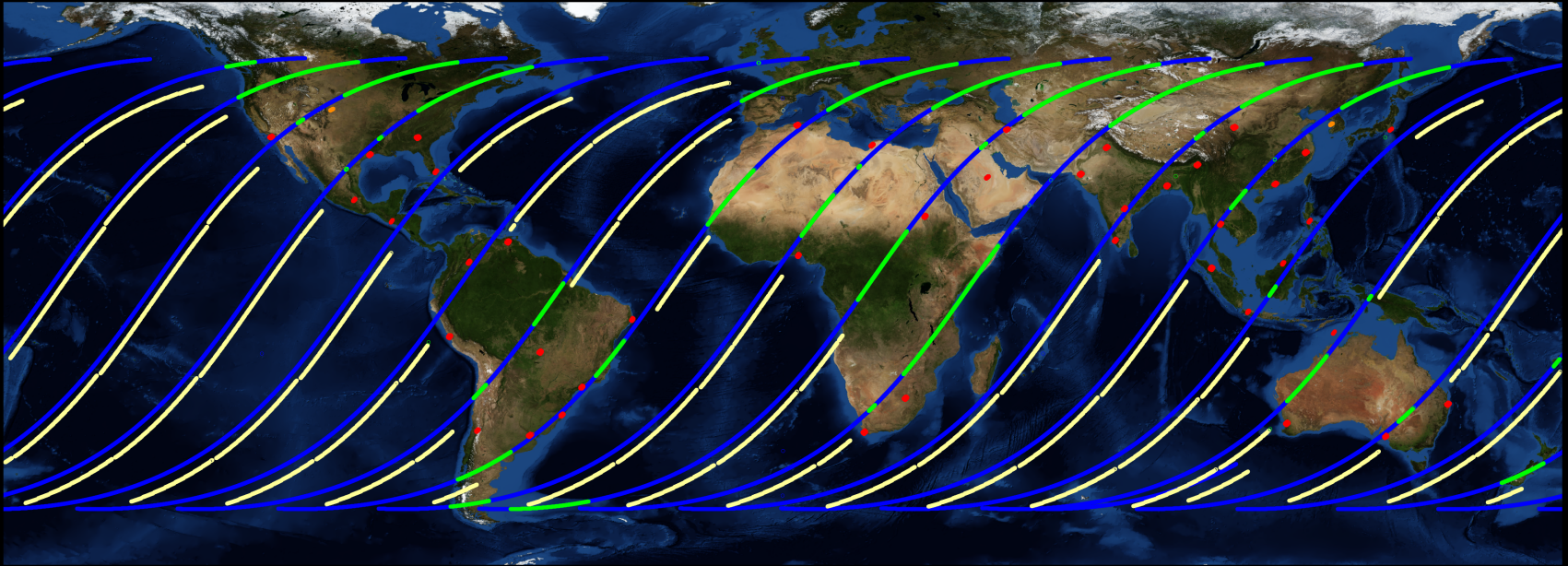
ISS track
OCO-3 glint mode
OCO-3 nadir mode
OCO-3 target mode
OCO-3 city/area mode

OCO-3 measurement modes – 2015-10-19 simulation
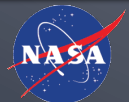

ISS track
OCO-3 glint mode
OCO-3 nadir mode
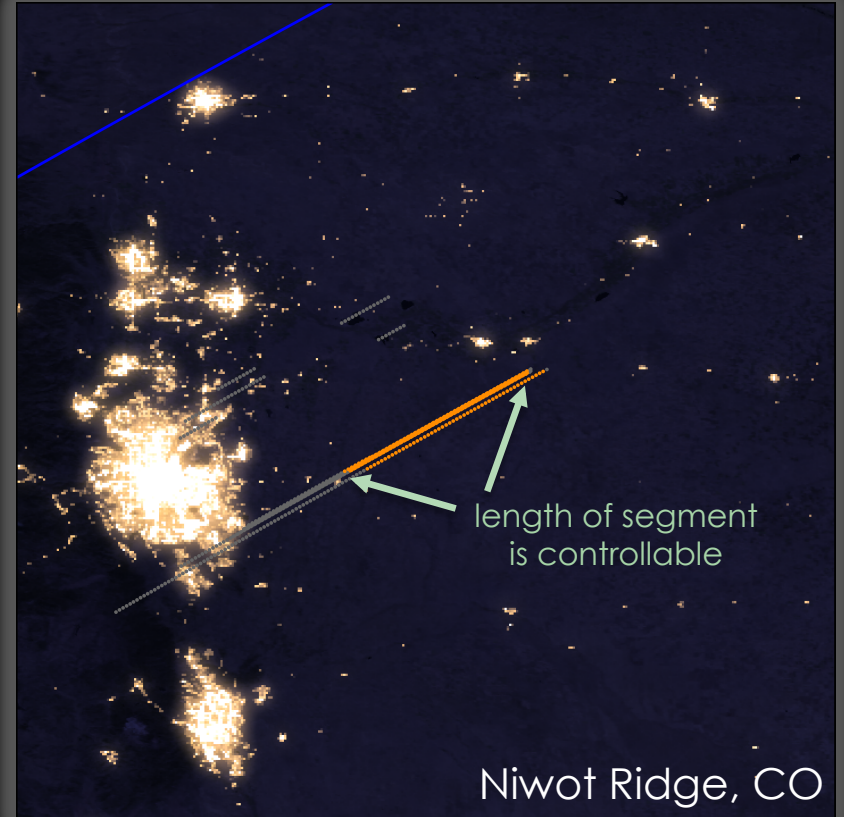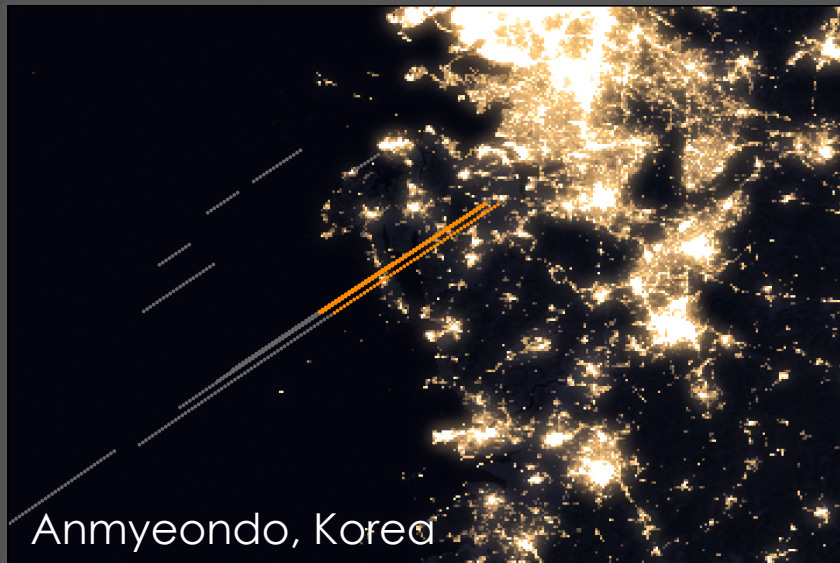OCO-3 target mode
OCO-3 city/area mode

⭕ zoom in on select target/
⭕ area observations

OCO-3 target mode simulation – Colorado, Anmyeondo
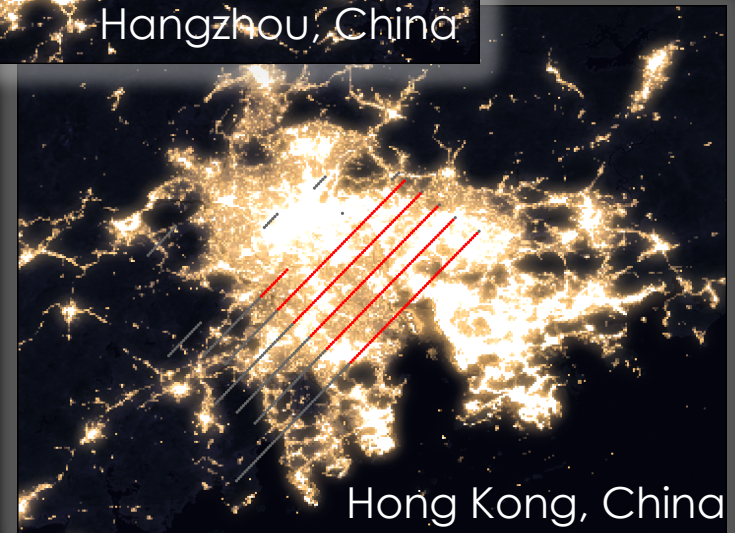

Anmyeondo, Korea

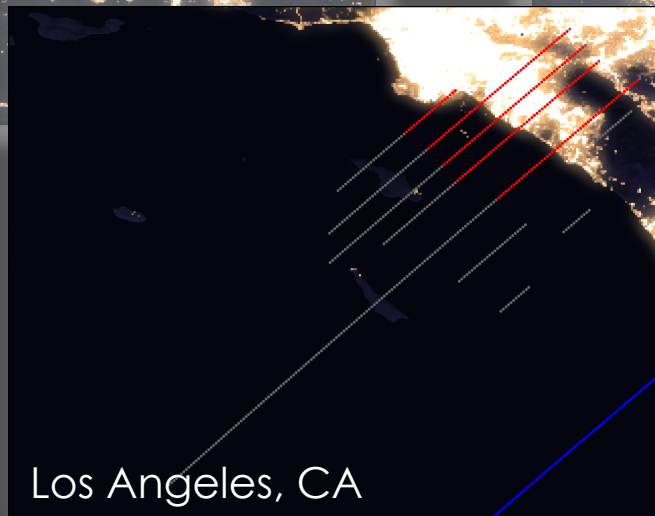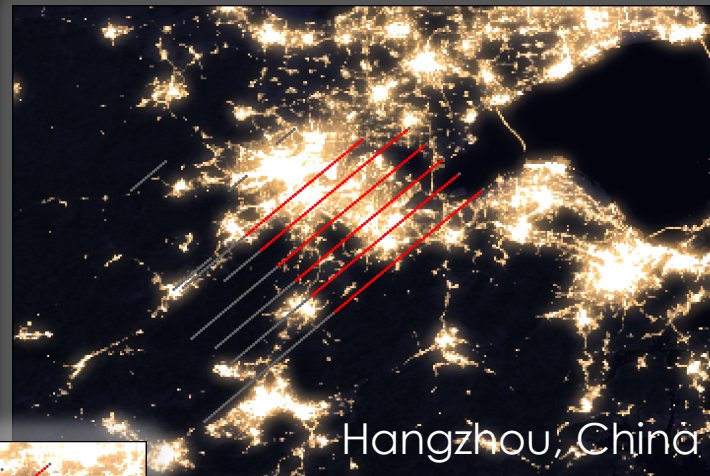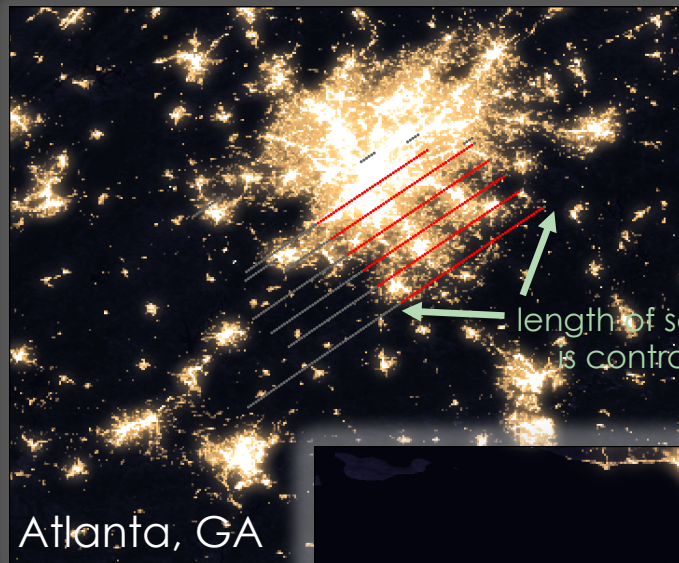
length of segment is controllable

Niwot Ridge, CO

ISS track
OCO-3 target mode
OCO-3 retarget mode

center footprints only; cross-track coverage not shown

OCO-3 city mode simulation – U.S., China

length of segments is controllable

Atlanta, GA

Hangzhou, China

Los Angeles, CA

Hong Kong, China

ISS track OCO-3 city mode OCO-3 retarget mode
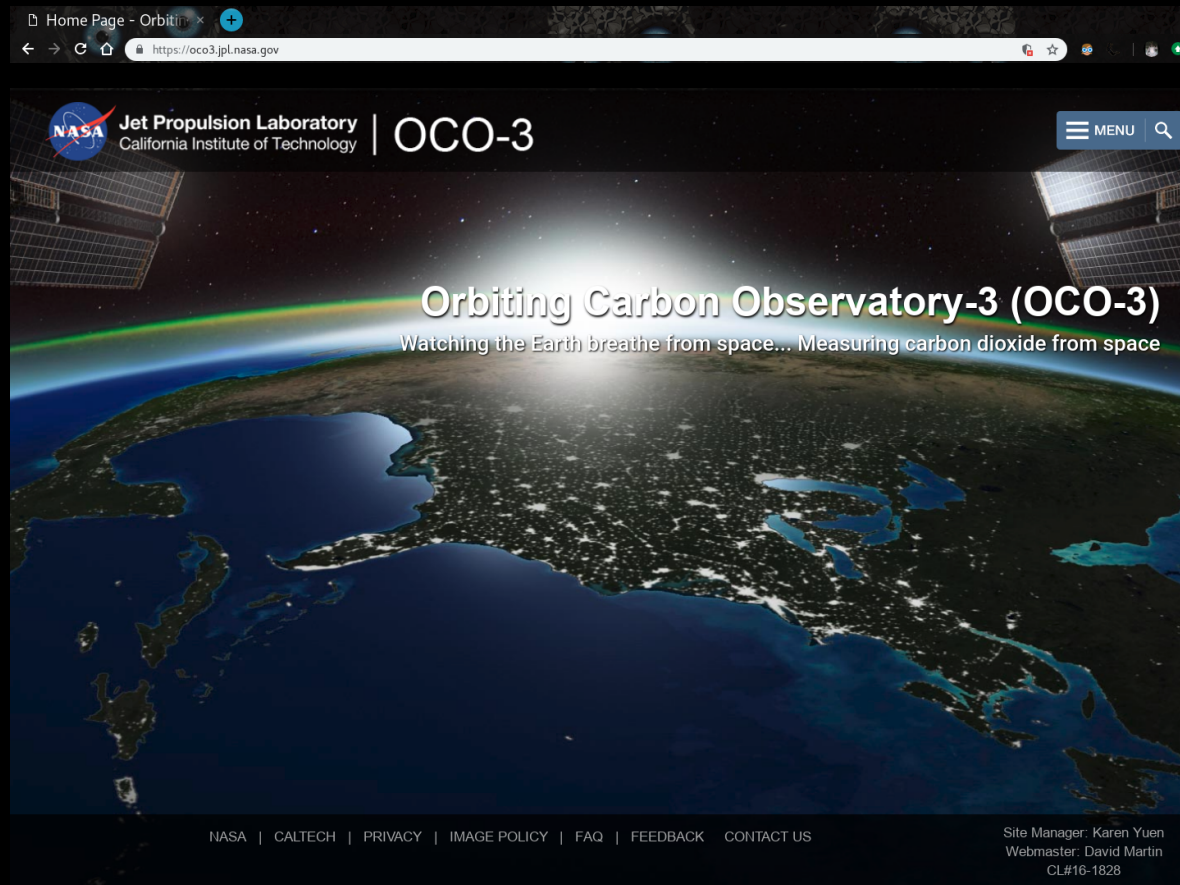center footprints only; cross-track coverage not shown

OCO-3 city mode coverage – Los Angeles

Los Angeles, CA
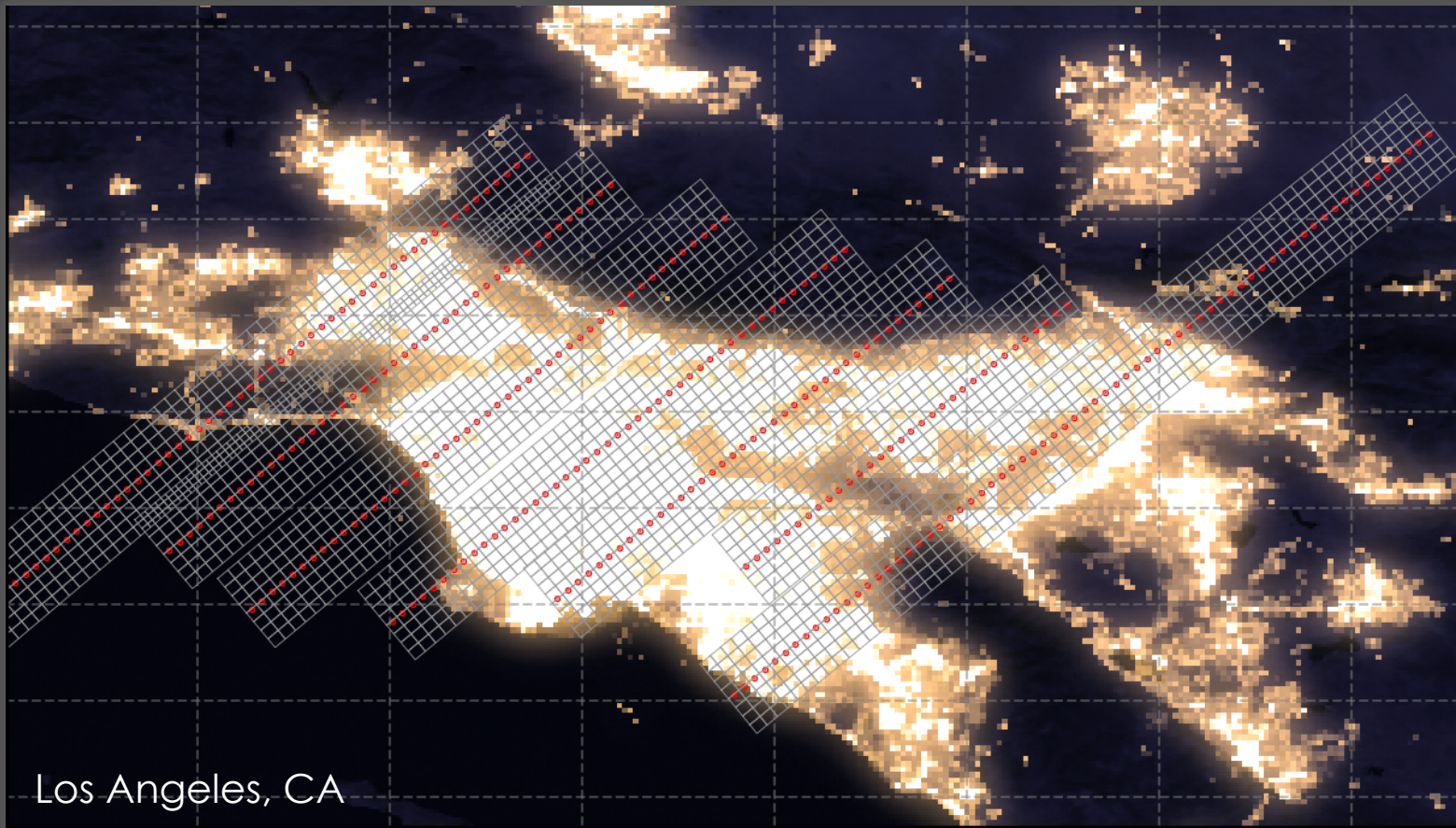
OCO-3 center footprints
OCO-3 cross-track pixels: ~14km width; 8 pixels. (image rotation pending)

oco3.jpl.nasa.gov

contact: annmarie.eldering@jpl.nasa.gov
thomas.kurosu@jpl.nasa.gov

check website for updates closer to launch
17 February 2019

thank you

Jet Propulsion Laboratory
California Institute of Technology