Satellite Sensing of Greenhouse Gases from Space

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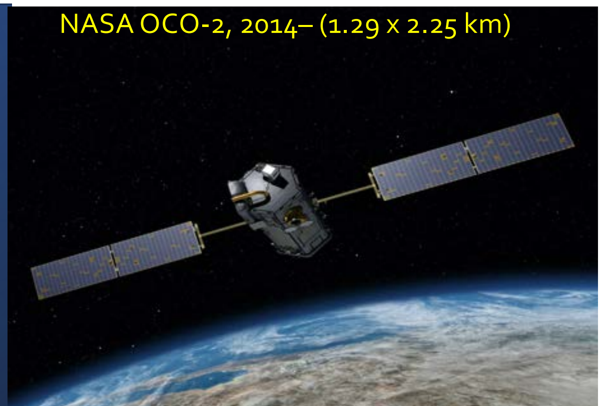
SCIAMACHY @ ESA Envisat, 2002–2012 (30x60 km²)

TANSO-FTS @ JAXA GOSAT (Ibuki)-2, 2009–
(10.5 km, 1000 km swath)

Acknowledgement: CERTAIN Seed Grant 2019–2020, David Cole, Tom Darrah

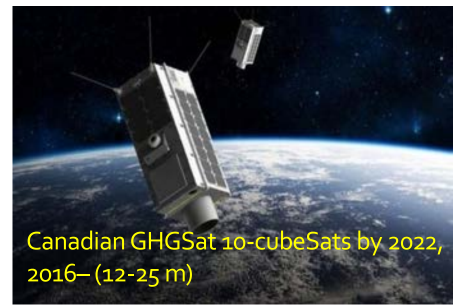
NASA OCO-2, 2014– (1.29 x 2.25 km)



TROPOMI @ESA Sentinel-5P, 2017– (7 km)

CSA TanSat (CarbonSat), 2016– (0.5 km, 400 km swath)

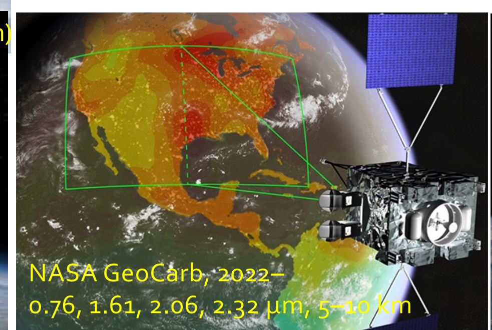
CO_2, CH_4, and other trace gas sensing from Space



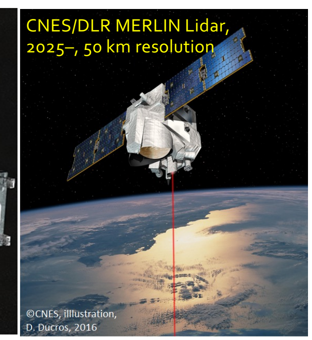
Canadian GHGSat 10-cubeSats by 2022, 2016– (12-25 m)

NASA ISS OCO-3 2019–, 2 km, 0.765, 1.61, 2.06 µm

Future Missions (MERLIN is a lidar mission)

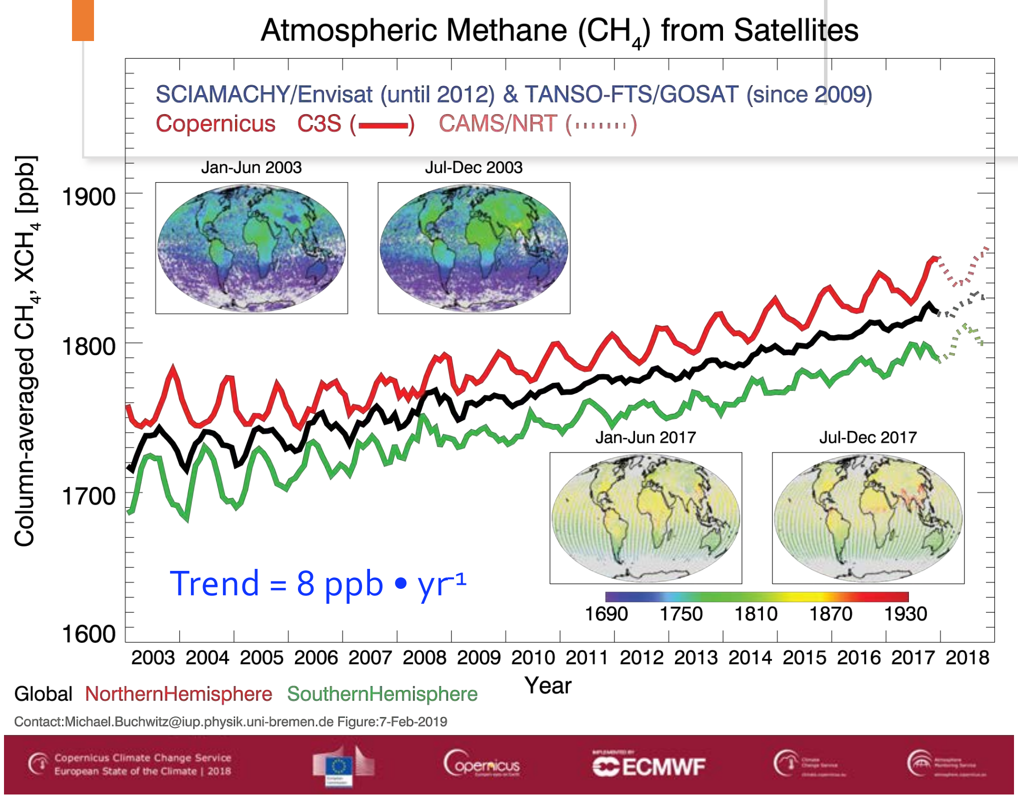


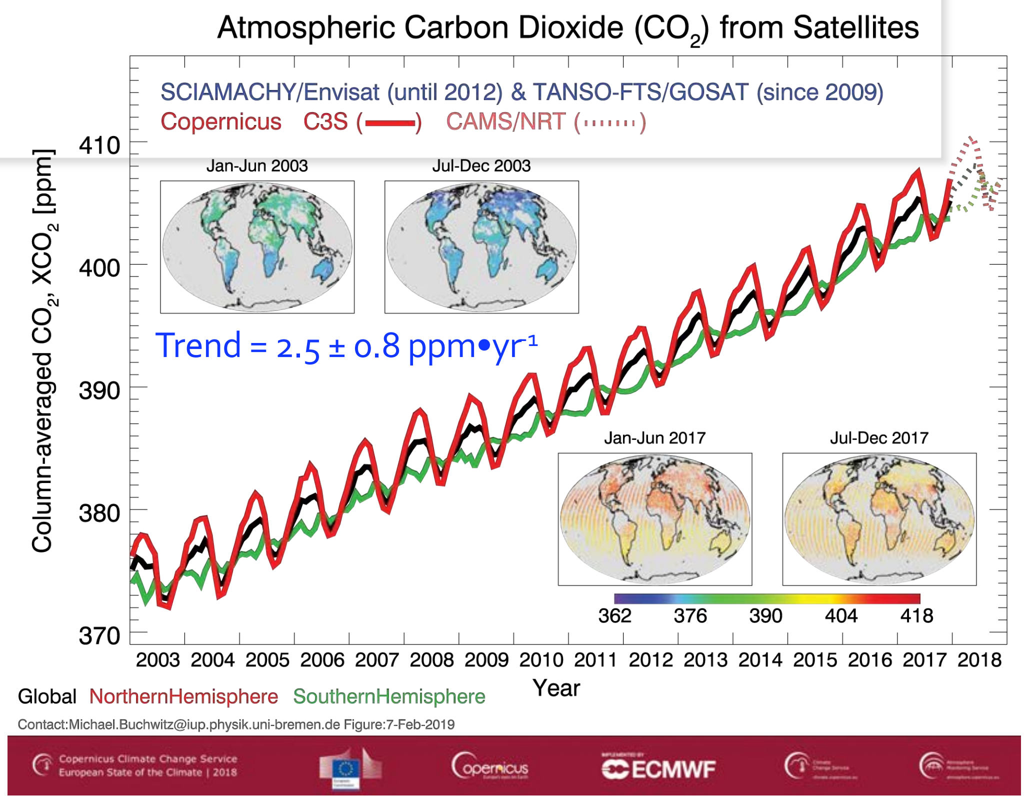
NASA GeoCarb, 2022–
0.76, 1.61, 2.06, 2.32 µm, 5–10 km



CNES/DLR MERLIN Lidar, 2025–, 50 km resolution

Satellite Monitoring of Global CO_2 & CH_4 concentrations



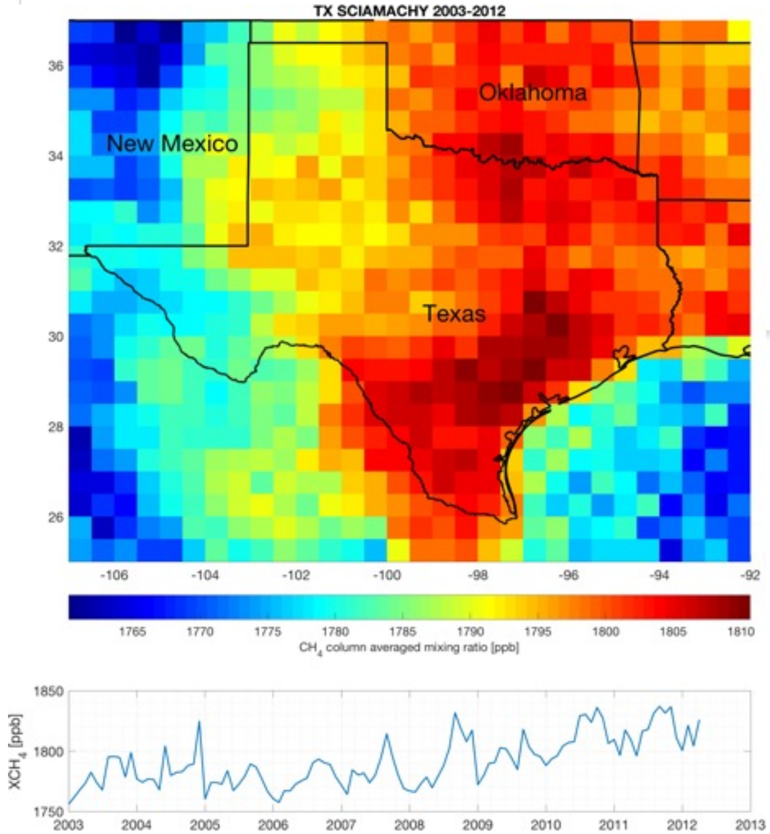


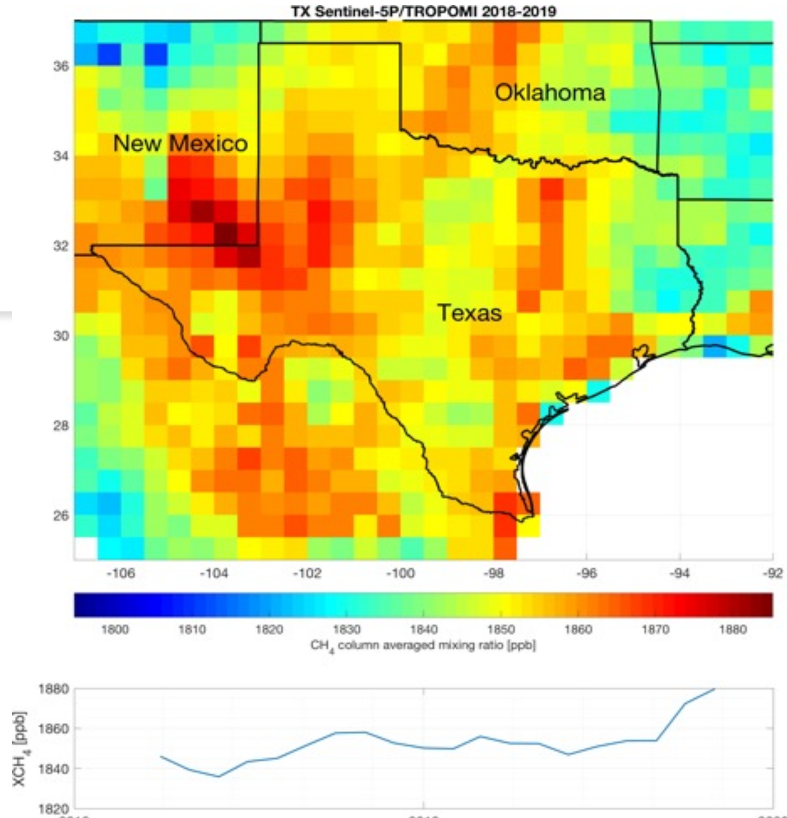
https://climate.copernicus.eu/greenhouse-gases

"X" denotes Satellite measurements

Credit: Copernicus Climate Change Service (C3S)/Copernicus Atmosphere Monitoring Service (CAMS)/ECMWF/Univ. Bremen

Satellite Monitoring of CH_4 Leakage: Eagle Ford Shale Fracking, Texas





Credit: Express News

Monthly Average, 2003–2012
XCH4 (*CH_4 column averaged mixing ratio*), **30x60 km² resolution)**

Monthly Average, 2018–2019
XCH4 (7 km resolution)

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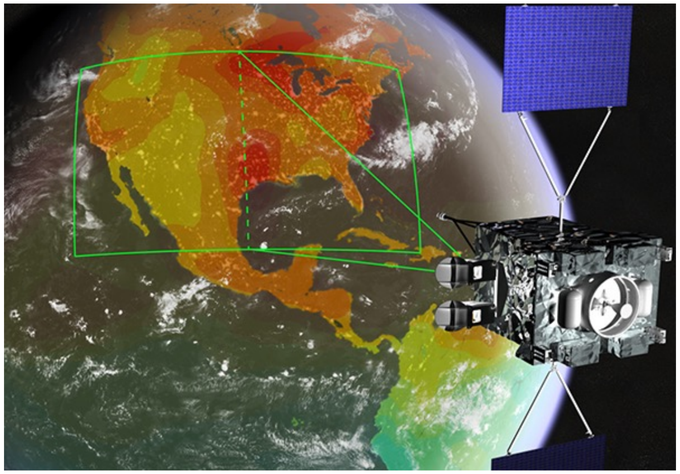
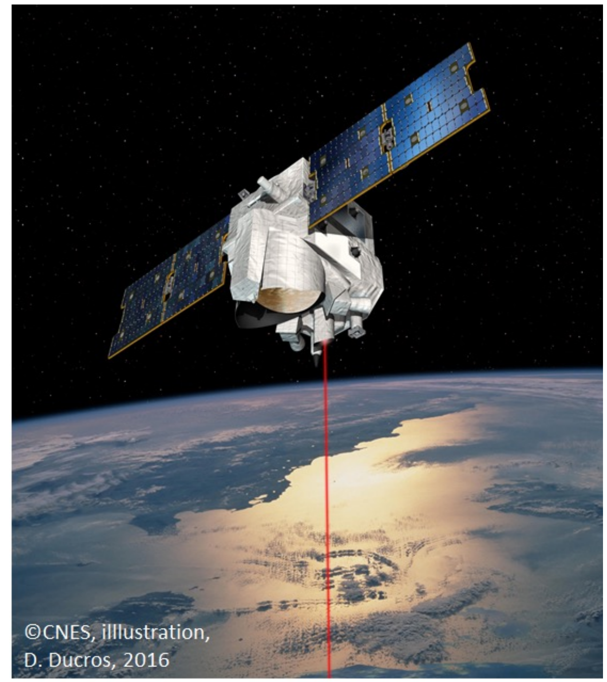


NASA Geostationary Carbon Cycle (GeoCARB) Observatory, 2022–, 5–10 km resolution, 0.76 μm, 1.61 μm, 2.06 μm and 2.32 μm [*Moore et al., Frontiers in Environ. Sc., 2018*]

NASA GSFC Lidar instrument development - nadir-viewing lidar that uses Integrated Path Differential Absorption (IPDA), to measure methane near 1.65 μm [*Riris et al.* ISCO, 2018]

Abdalati et al., Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space, *National Academy Report* [2018]



CNES/DLR MERLIN Lidar, 2025–, 50 km resolution

NASA Lidar Receiver/Detector Development Project (PI: Sanjay Krishna, OSU)

Quad Chart

Bandstructure Engineered Type-II superlattice Antimonide Avalanche Photodiodes (BETA-APD) for space lidar instruments

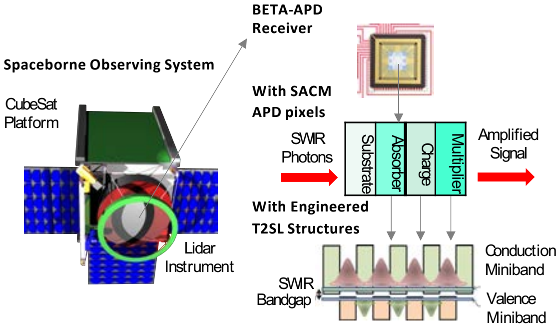
PI: Sanjay Krishna, The Ohio State University (OSU)

Objective

Develop and demonstrate a short-wave infrared avalanche photodiode (APD) with spectral coverage from 1-2 µm and high operating temperature for application in lidar receivers.

Design detectors to support spaceborne lidar receivers that monitor greenhouse gases (large-area detector) and provide high resolution topographic imaging (focal plane array).

Provide opto-electronic performance comparable to state-of-the-art with large coolers at an operating temperature ≥ 200 K. Enable reductions in size and weight by two orders of magnitude and power by factor of 3-4. Enable integration into small satellite platforms (e.g., CubeSats).



Approach

Engineer Type-II superlattice separated absorption, charge, and multiplication (SACM) APD based on III-V semiconductor materials to operate as either large area detector or imaging array:

- Validate BETA-APD design with predicted performance supported by models and preliminary experiments
- Design, grow, and test BETA-APD SACM material
- Integrate, package, and test BETA-APD as large-area detector and small-format array in lab environment

Co-Is: C. Ball (OSU), C. Grein (U. Illinois-Chicago), E. Fuller (SK Infrared LLC), TJ Ronningen (OSU), CK Shum (OSU)
Collaborator: X. Sun (NASA GSFC)

Key Milestones

1. Absorber Material Designed, Grown, Characterized 7/21
2. Multiplier Material Designed, Grown, Characterized 12/21
3. Custom packaging designed 11/21
4. BETA-APD validated design (TRL 3) 12/21
5. SACM first production design 2/22
6. SACM first growth 5/22
7. BETA-APD large-area detector tested (TRL 4) 12/22
8. SACM second production design 1/23
9. SACM second growth 5/23
10. BETA-APD small-format array tested (TRL 4) 12/23

TRL_{in} = 2

Earth Science Technology Office