



Airborne retrievals of methane, carbon dioxide, and water vapor concentrations at high spatial resolution: application to AVIRIS-NG

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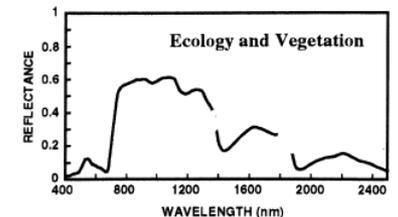
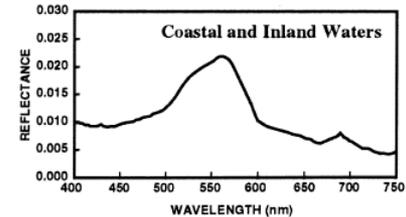
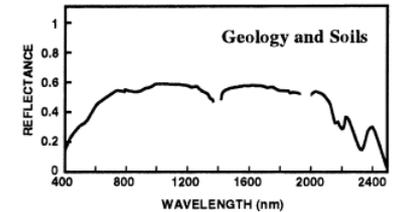
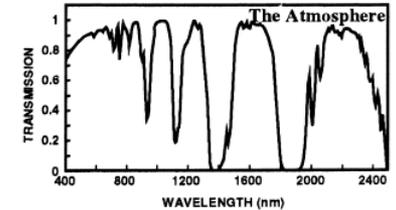
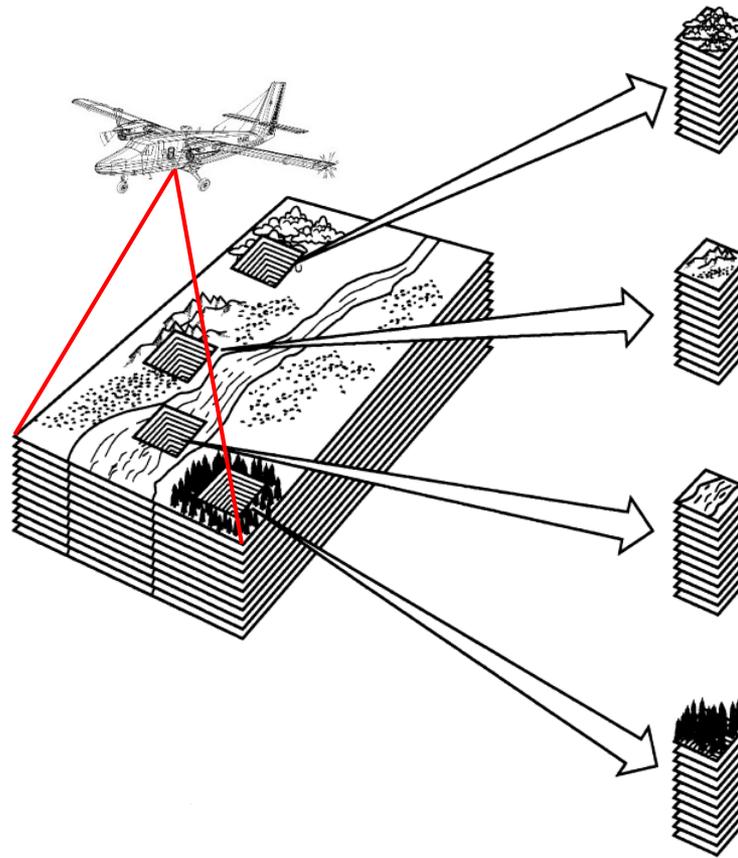
⁷ Scientific Aviation, 3335 Airport Road, Boulder, CO, United States

⁸ University of California, Santa Barbara, Santa Barbara, California, United States

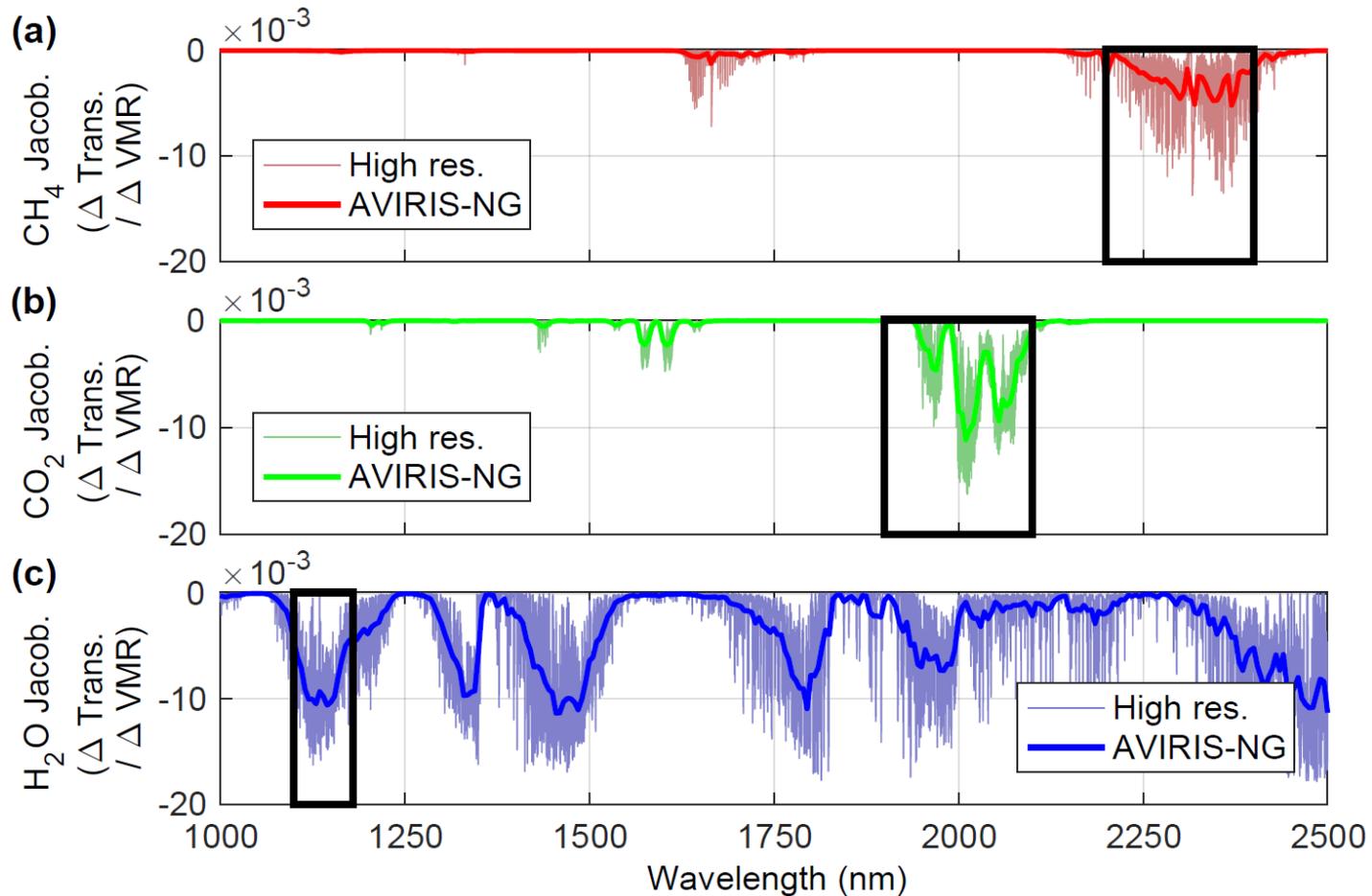
⁹ University of Utah, Salt Lake City, Utah, United States

- Next generation Airborne Visible/Infrared Imaging Spectrometer (AVIRIS-NG)

- Pushbroom sensor
- 36° field of view
- 380 to 2,510 nm
- 5 nm spectral resolution
- 427 spectral channels

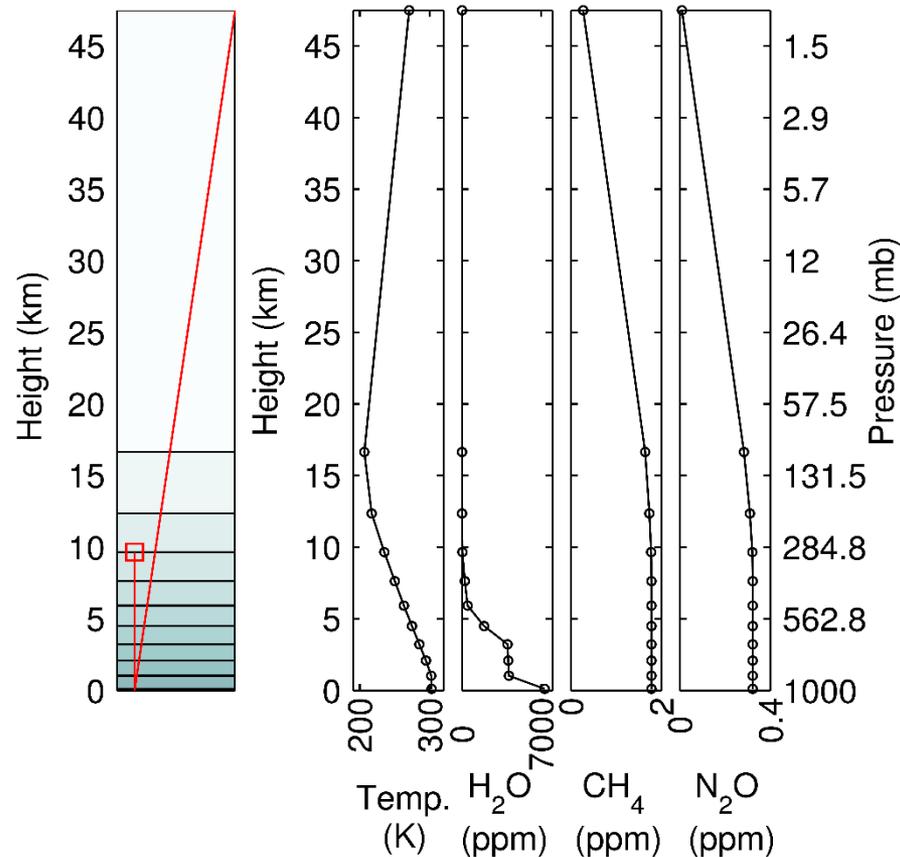


- CH₄, CO₂, and H₂O absorption features

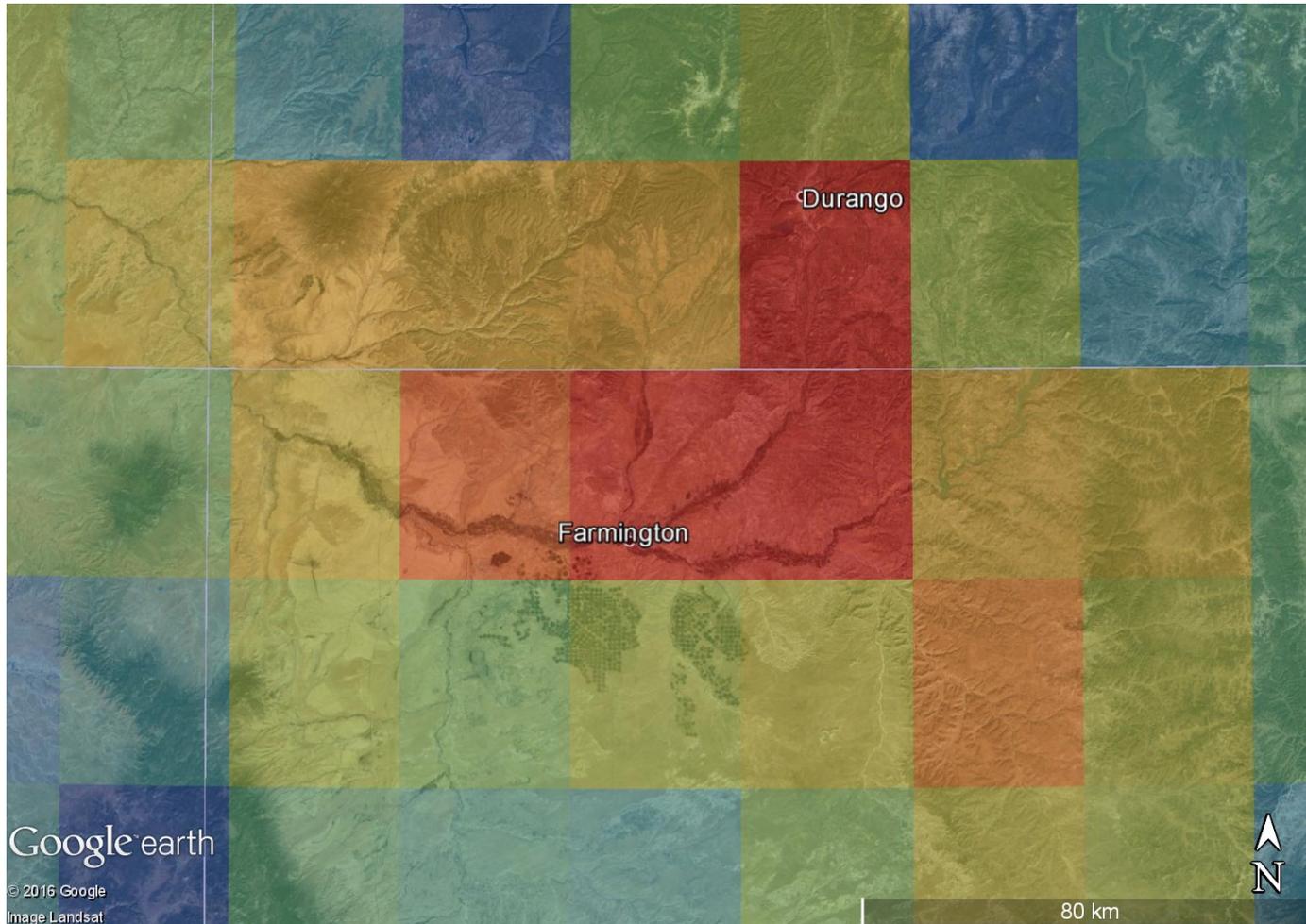


- Iterative maximum a posteriori-DOAS algorithm (Frankenberg et al., 2005)
 - Adjusts vertical column densities of multiple gasses until total optical density fits the observed measurement

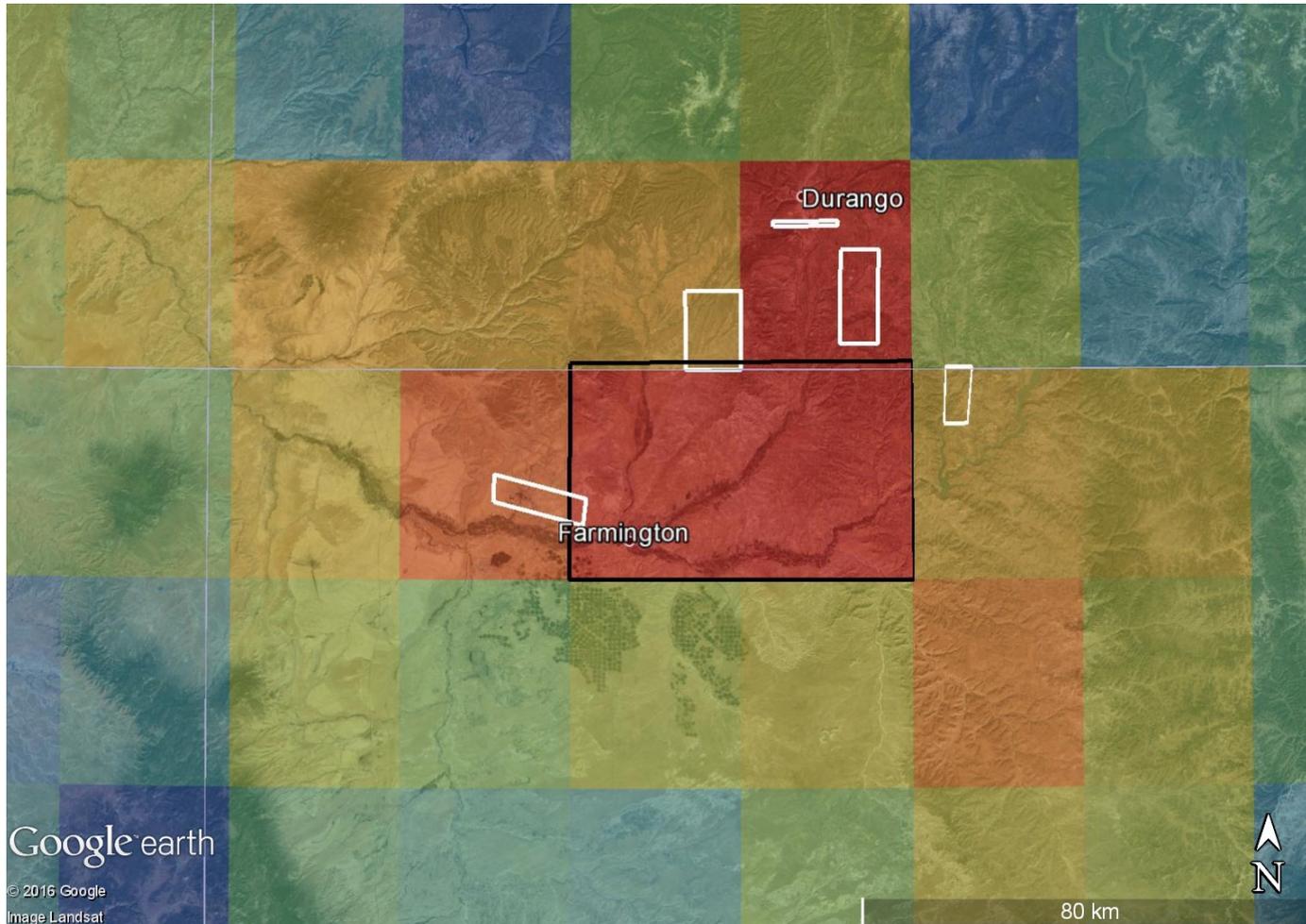
CH₄ retrieval (Thorpe et al., 2014):



- San Juan Basin (Four Corner: Colorado, New Mexico)
 - Coal bed CH₄
 - 20,000 oil and gas wells
 - CH₄ enhancement observed with SCIAMACHY satellite (Kort et al., 2015)

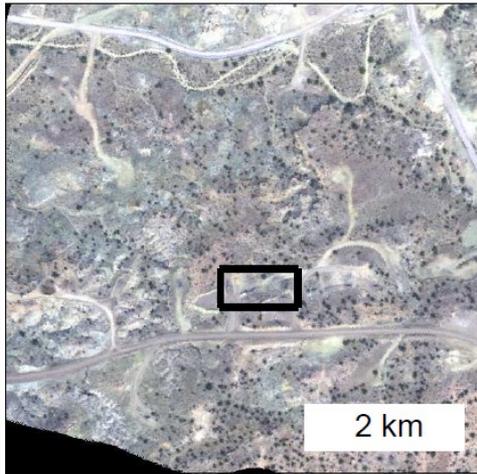


- AVIRIS-NG flight boxes target SCIAMACHY hotspot
 - Black: Survey (3 km above ground level, 3 m pixels)
 - White: Directed study (1 km above ground level, 1 m pixels)

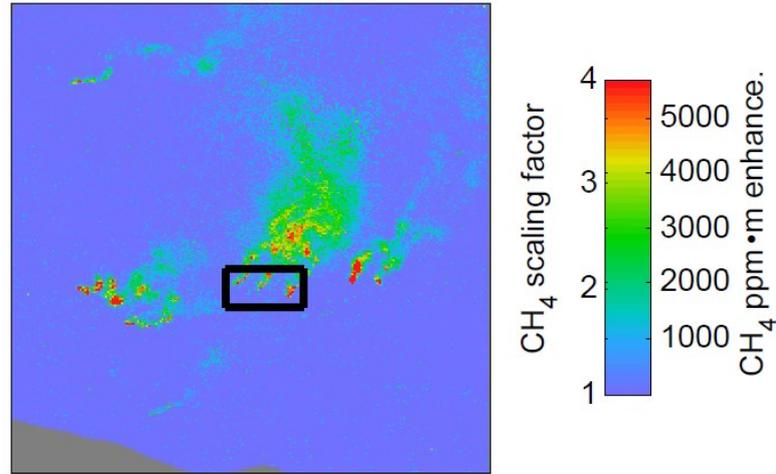


- Example 1: Coal mine ventilation shaft emissions

(a) 20 April 2015, 18:06:24 UTC



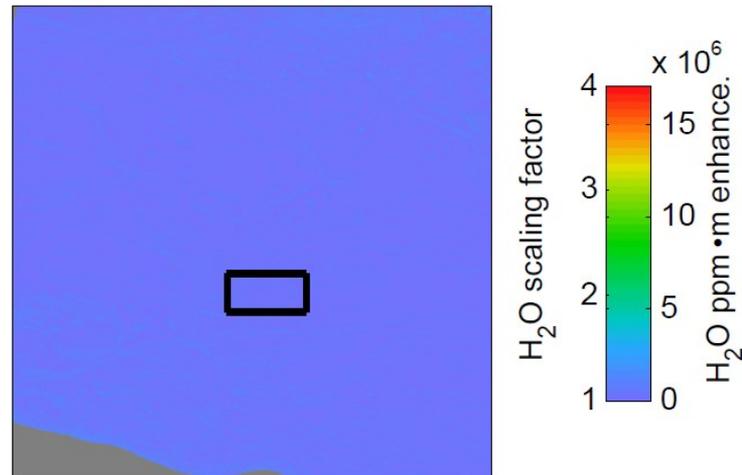
(b) CH₄: 20 April 2015, 18:06:24 UTC



(c) 20 April 2015, 18:06:24 UTC



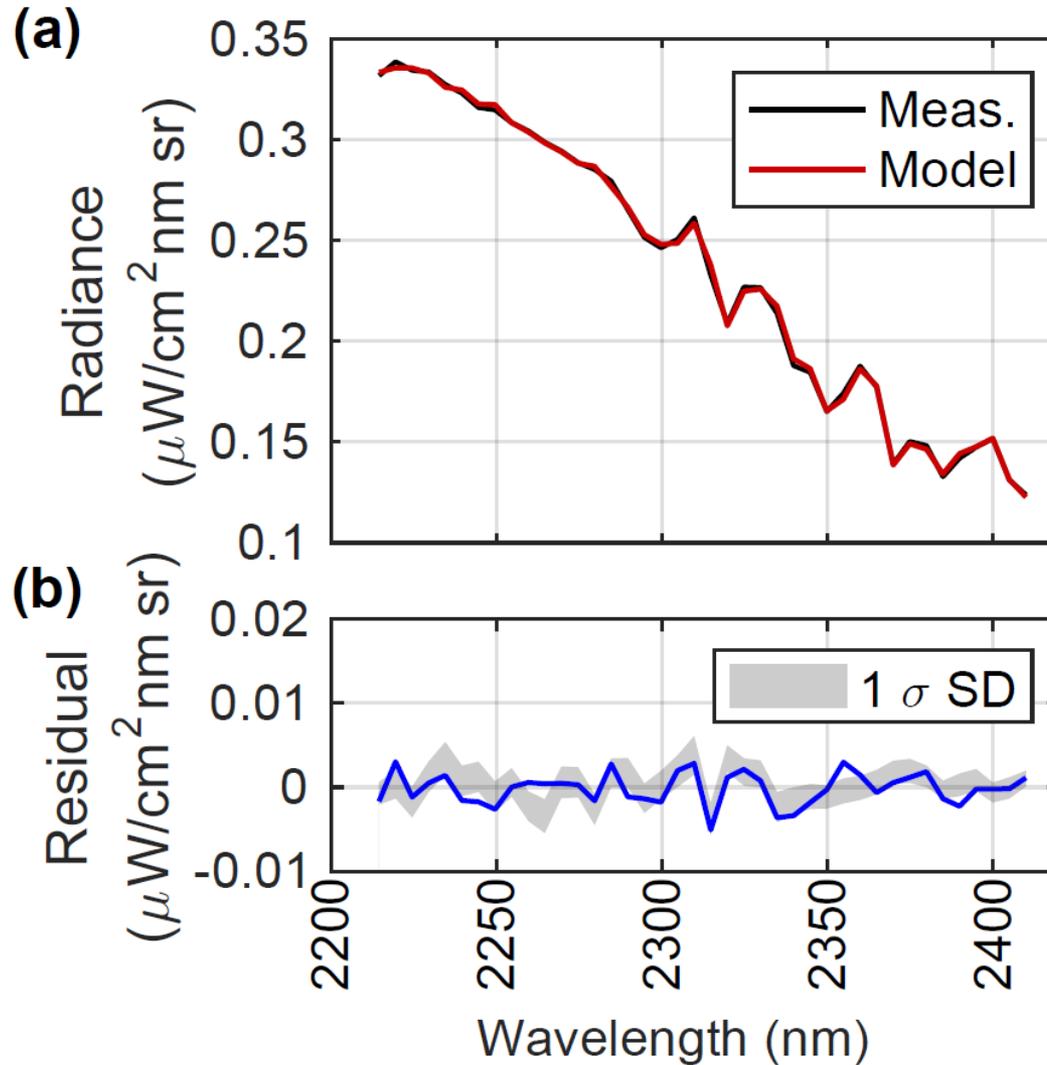
(e) H₂O: 20 April 2015, 18:06:24 UTC



(d) Google Earth: 15 March 2015



- Example 1: CH₄ retrieval radiance fits

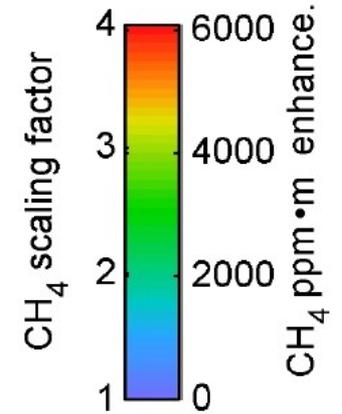
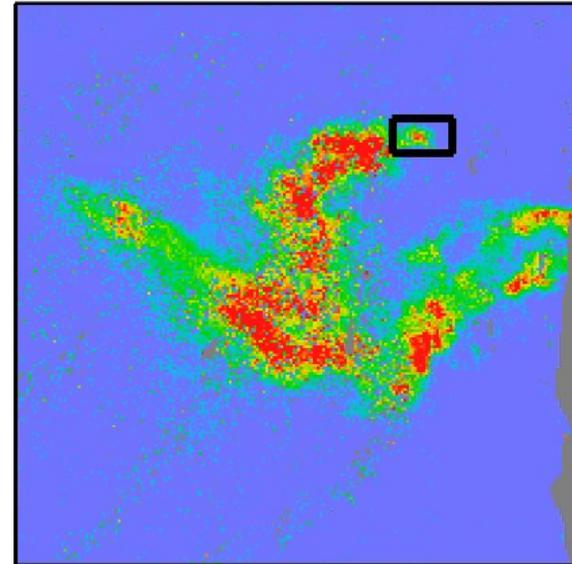


- Example 2: Gas processing plant

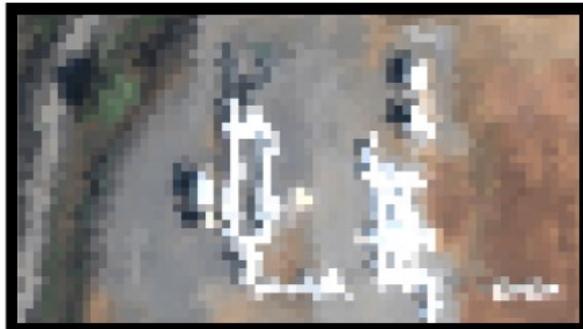
(a) 20 April 2015, 16:07:19 UTC



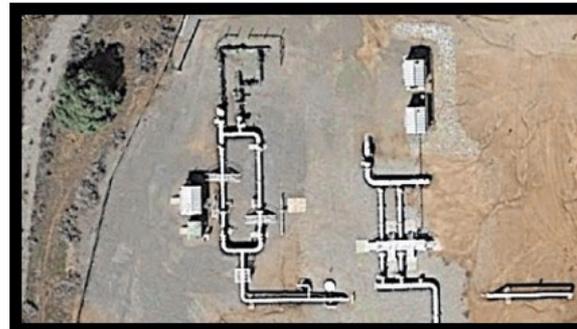
(b) CH₄: 20 April 2015, 16:07:19 UTC



(c) 20 April 2015, 16:07:19 UTC



(d) Google Earth: 16 March 2015

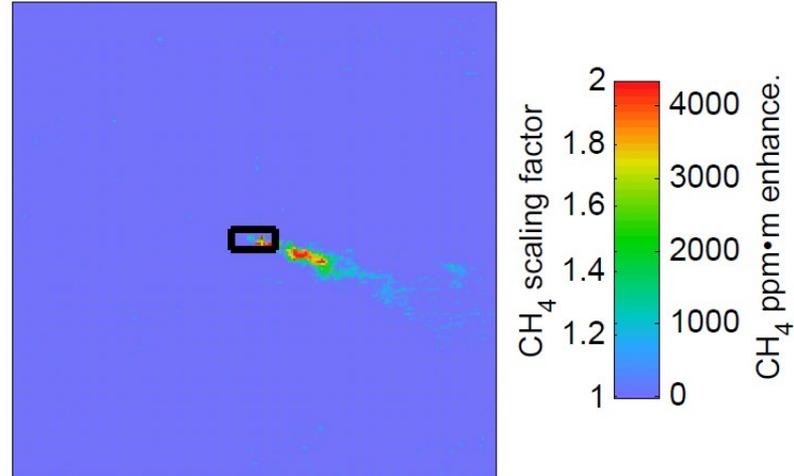


- Example 3: Tank emissions

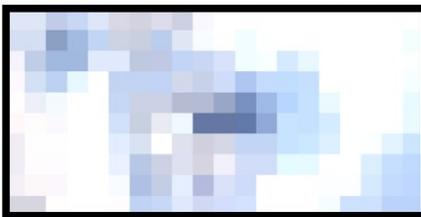
(a) 19 April 2015, 22:11:27 UTC



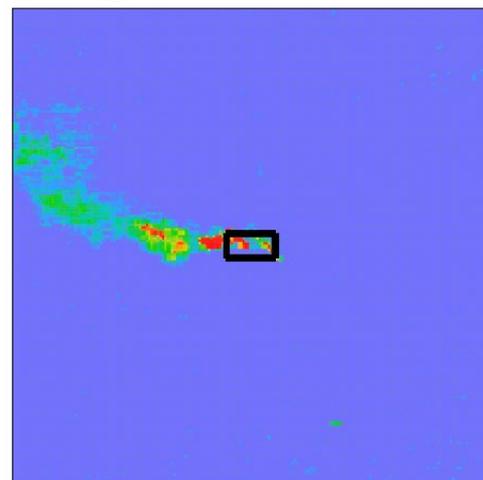
(b) CH₄: 19 April 2015, 22:11:27 UTC



(c) 19 April 2015, 22:11:27 UTC



(e) CH₄: 21 April 2015, 17:04:17 UTC

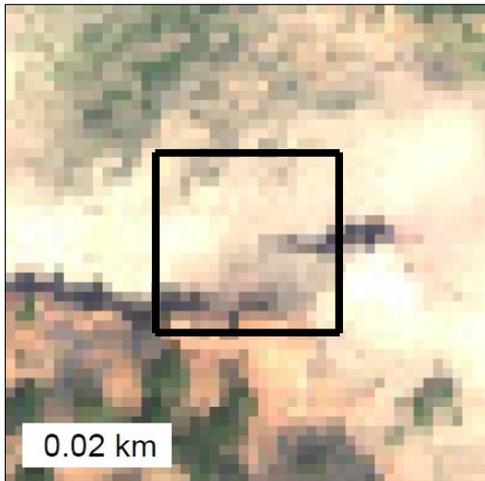


(d) Google Earth: 15 March 2015

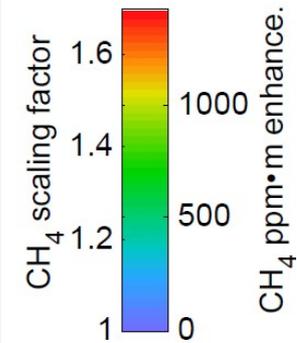
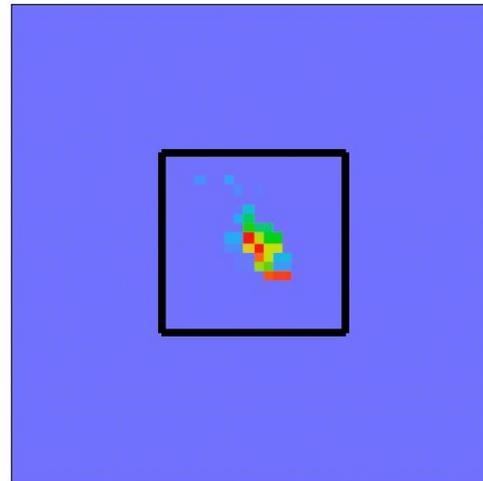


- Example 4: Natural source at “Moving Mountain”

(a) 23 April 2015, 18:34:18 UTC



(b) CH₄: 23 April 2015, 18:34:18 UTC



(c) 23 April 2015, 18:34:18 UTC

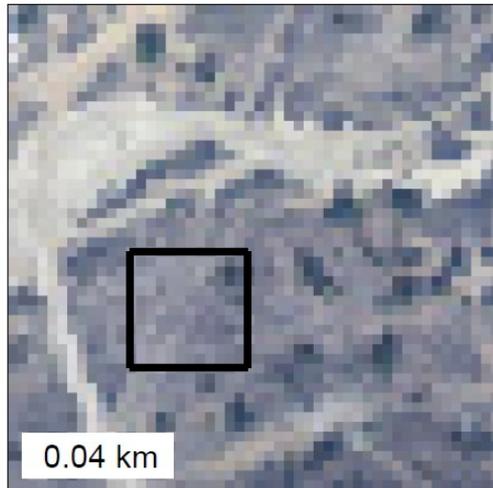


(d) Google Earth: 11 Aug. 2015

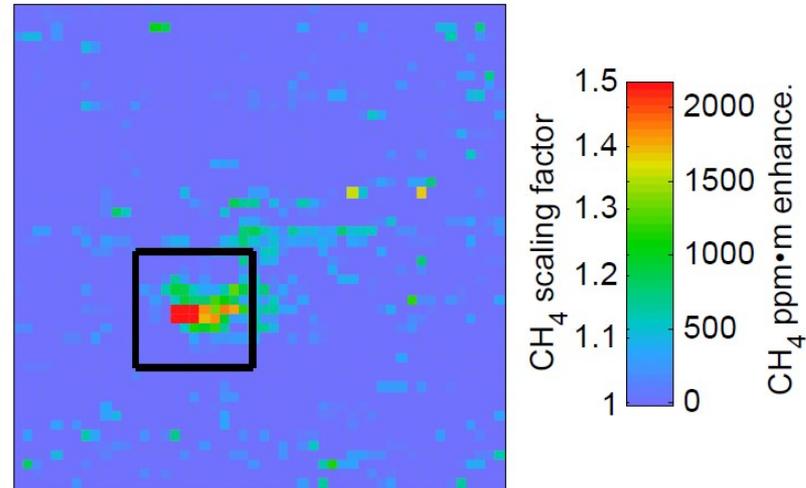


- Example 5: Pipeline leak

(a) 19 April 2015, 18:35:12 UTC



(b) CH₄: 19 April 2015, 18:35:12 UTC



(c) 19 April 2015, 18:35:12 UTC



(d) Google Earth: 15 March 2015

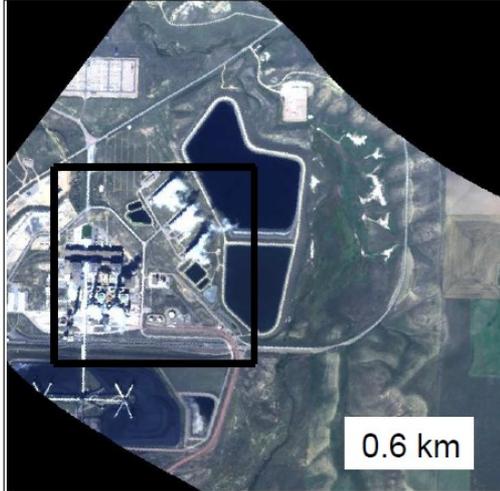


- Example 5: Operators shut down pipeline

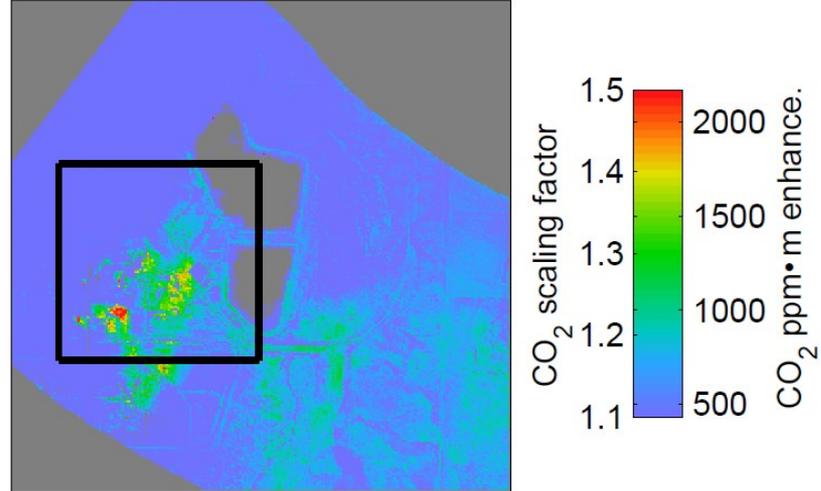


- Example 6: Power plant (2014 flight)

(a) 12 Sept. 2014, 19:23:59 UTC



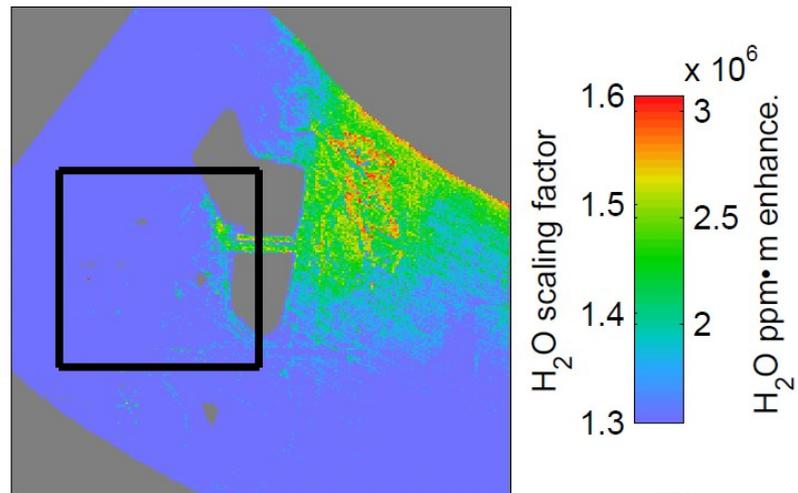
(b) CO₂: 12 Sept. 2014, 19:23:59 UTC



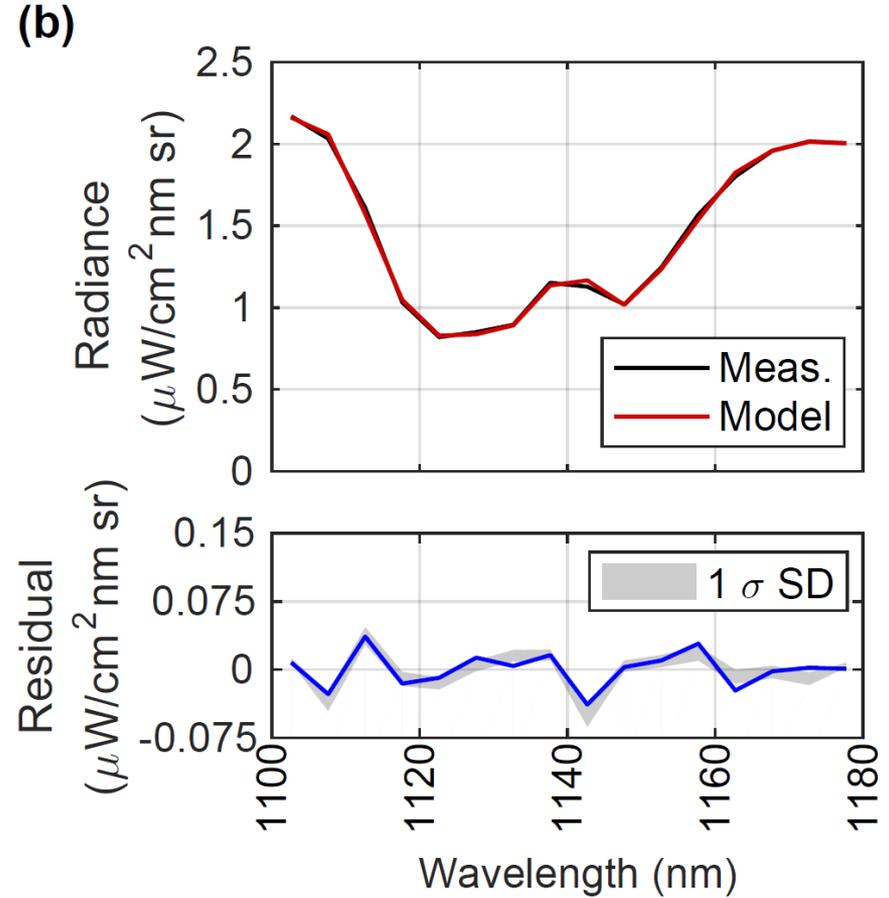
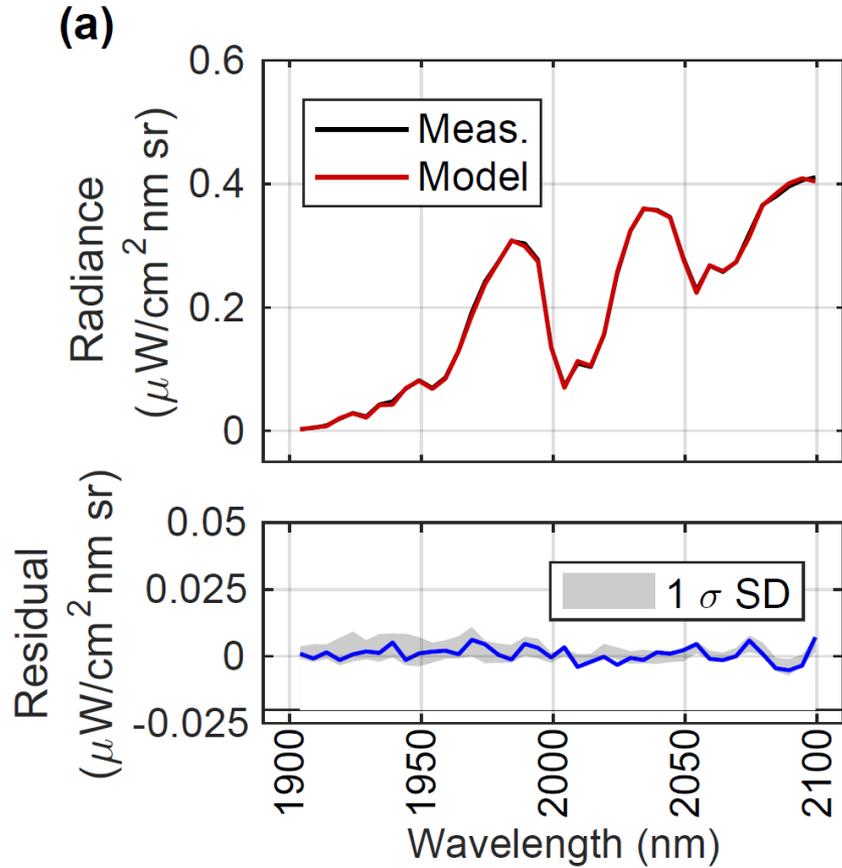
(c) 12 Sept. 2014, 19:23:59 UTC



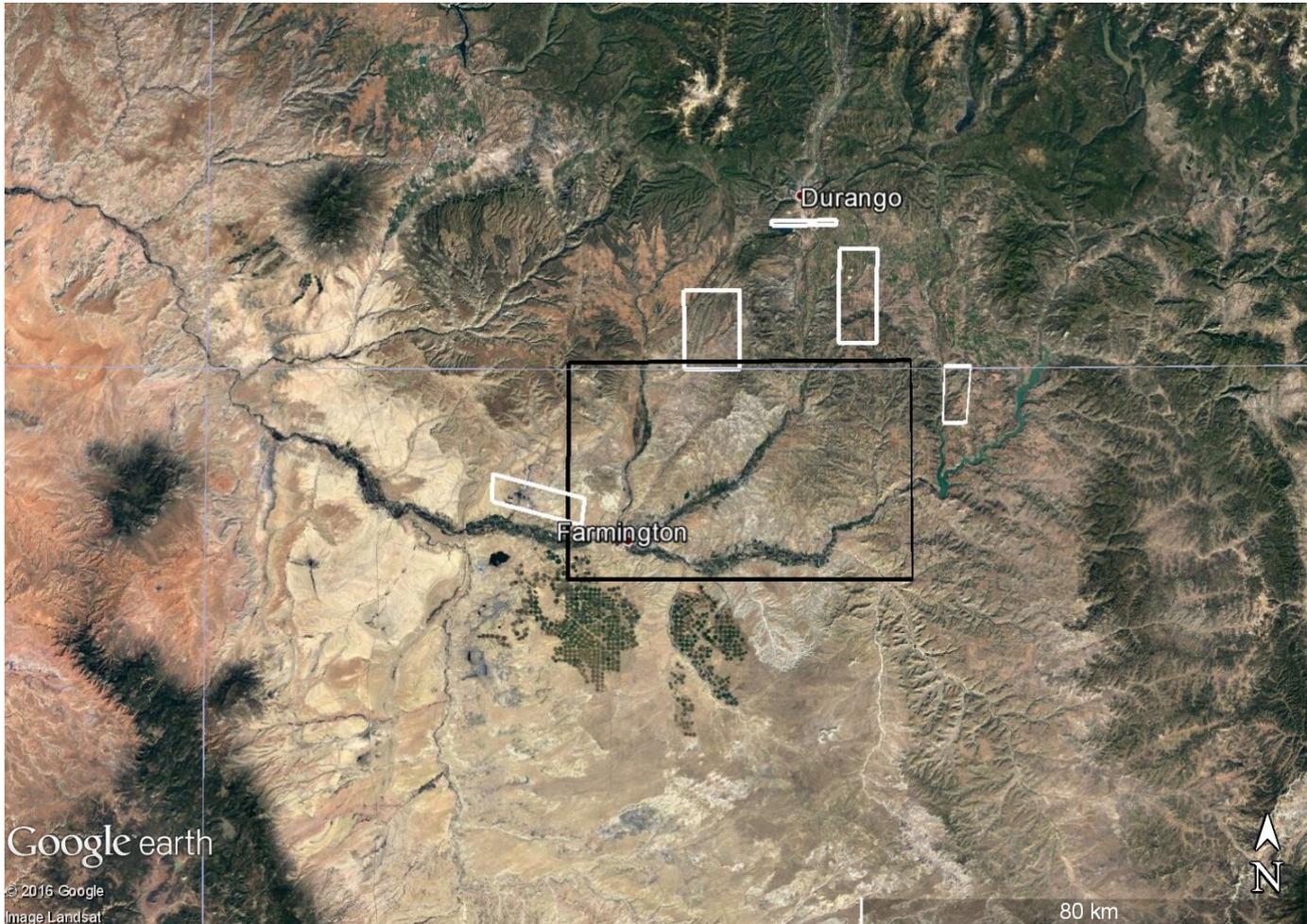
(d) H₂O: 12 Sept. 2014, 19:23:59 UTC



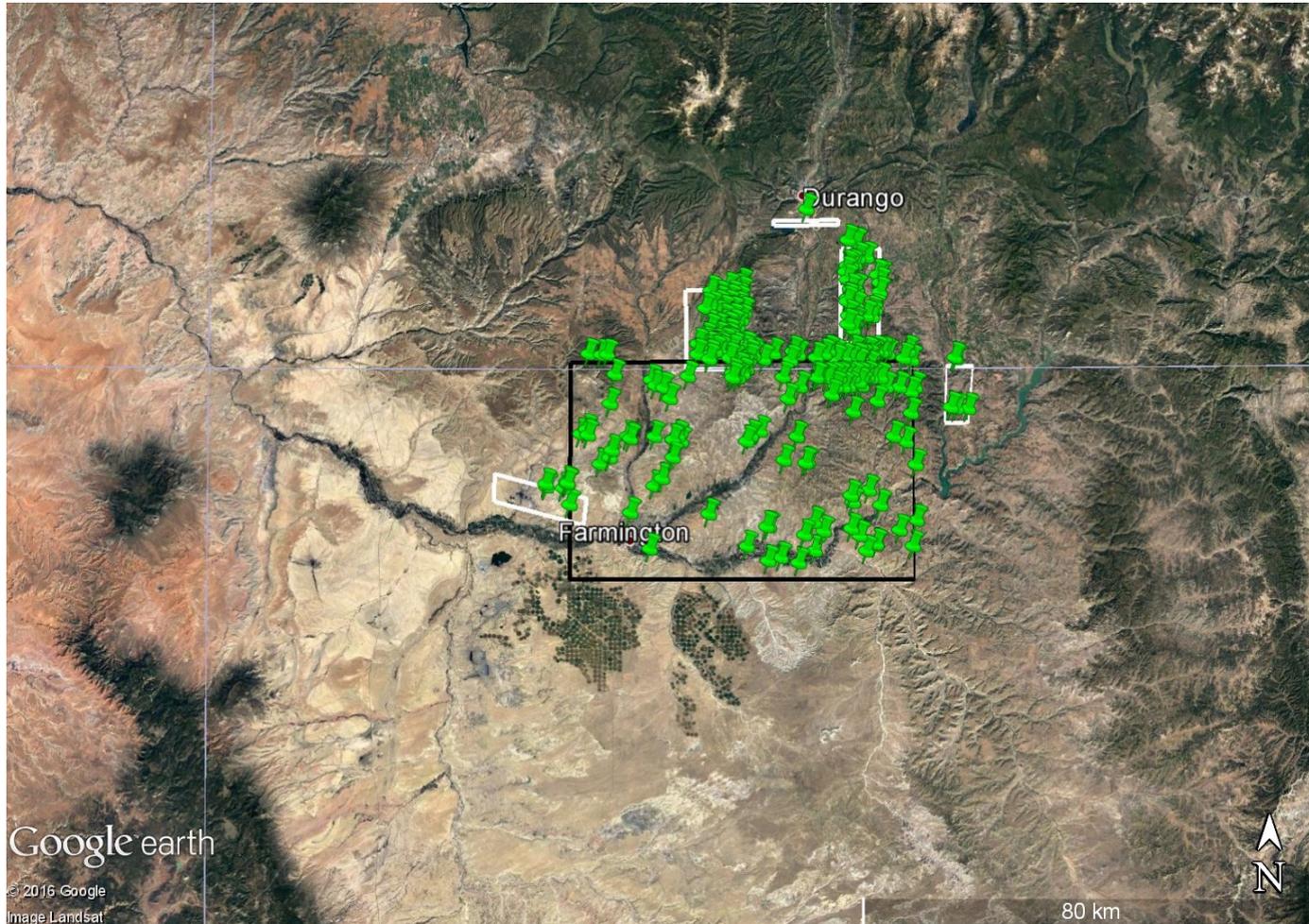
- Example 6: CO₂ and H₂O retrieval radiance fits



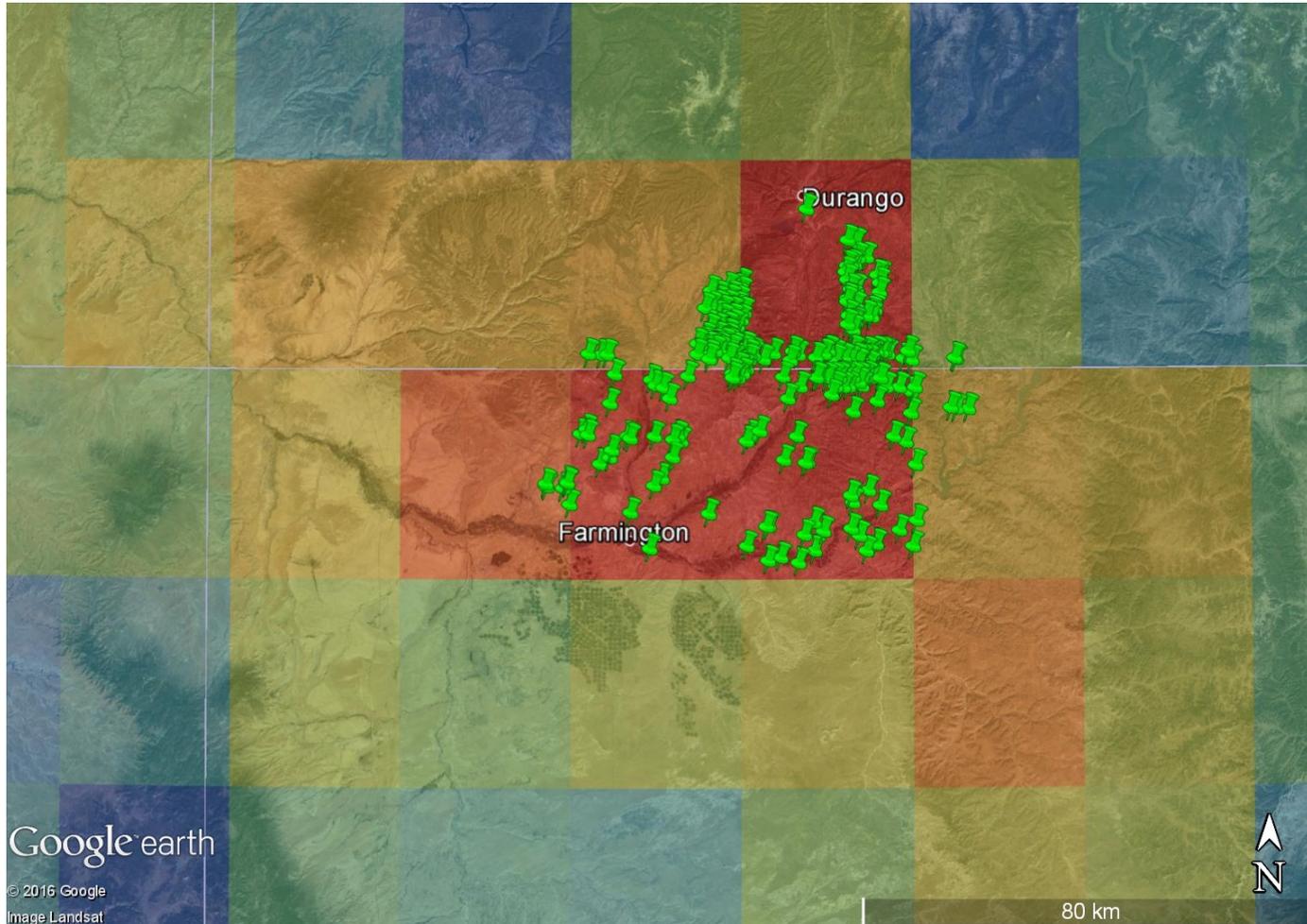
- Observed CH₄ plumes



- Observed CH₄ plumes (Frankenberg et al., 2016)



- Observed CH₄ plumes (Frankenberg et al., 2016)



- AVIRIS-NG permits quantitative mapping of CH₄, CO₂, and H₂O emissions
- Offers the potential to:
 - Map large areas rapidly
 - Identify unknown emission sources (i.e. natural gas pipeline leaks)
 - Better understand partitioning of anthropogenic and natural emission sources

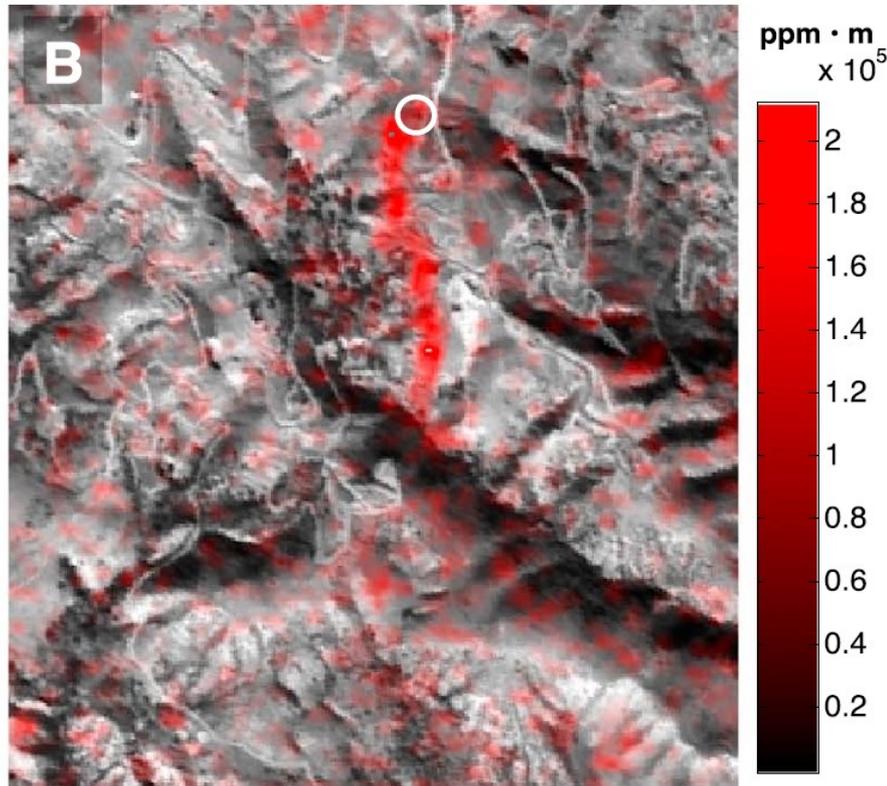


- JPL:
 - AVIRIS/AVIRIS-NG team
 - Simon Hook and Bill Johnson (thermal camera)

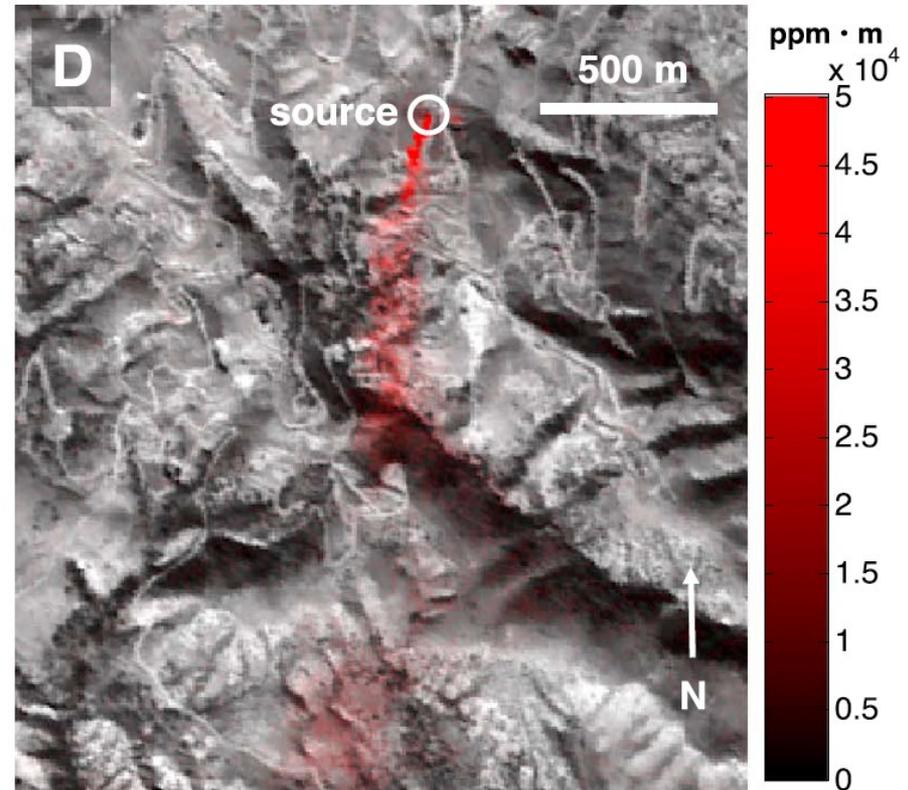
- NASA:
 - Jack Kaye (Four Corners campaign)

- Orbital Hyperion instrument and AVIRIS also observed CH₄ plume (Thompson et al., 2016)

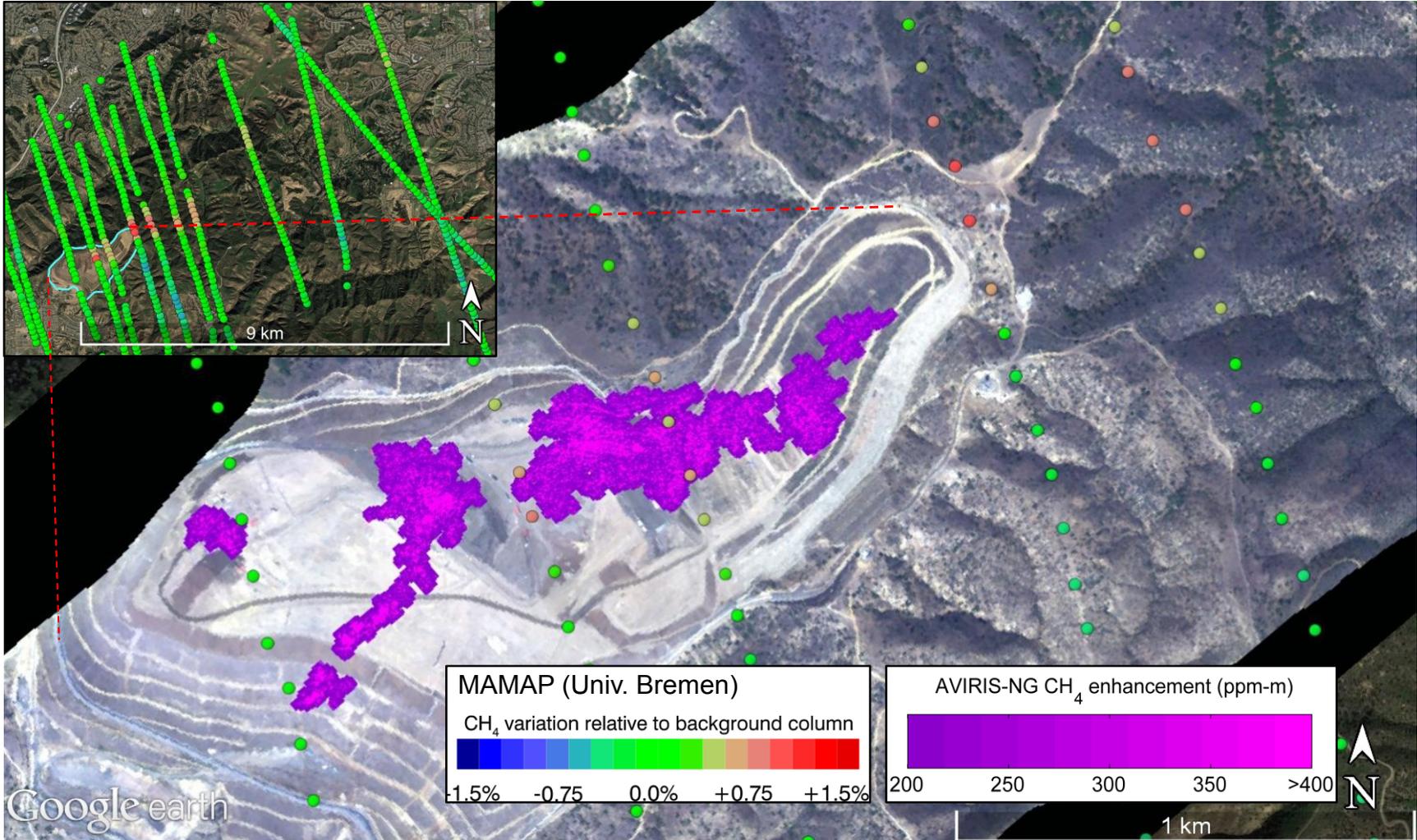
Hyperion (10 nm): 1/1/16, 16:39 UTC
Low Earth orbit



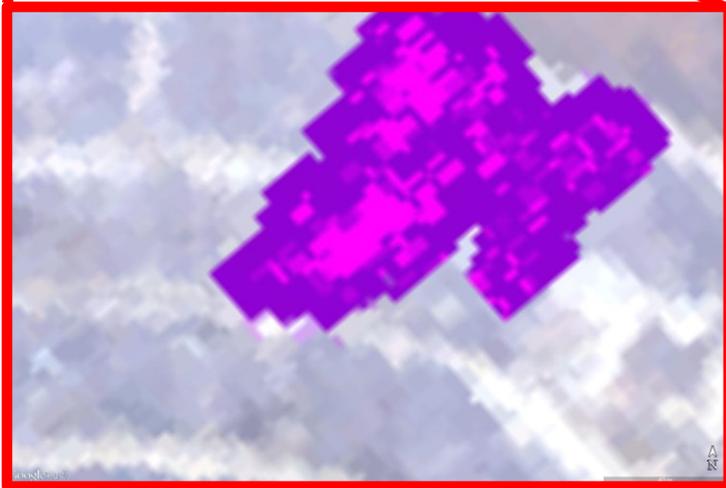
AVIRIS (10 nm): 1/12/16, 20:25 UTC
6.6 km above ground level



- CH₄ from Olinda Alpha Landfill (Krautwurst et al., 2017)



- CH₄ from Olinda Alpha Landfill



- 1 nm spectral resolution for improved gas sensitivity
- Quantitative mapping of CH₄, CO₂, H₂O, CO, N₂O
- NRC RFI #2: Understanding anthropogenic methane and carbon dioxide point source emissions (Duren et al., 2016)

