Attributing methane and carbon dioxide emissions from anthropogenic and natural sources using AVIRIS-NG

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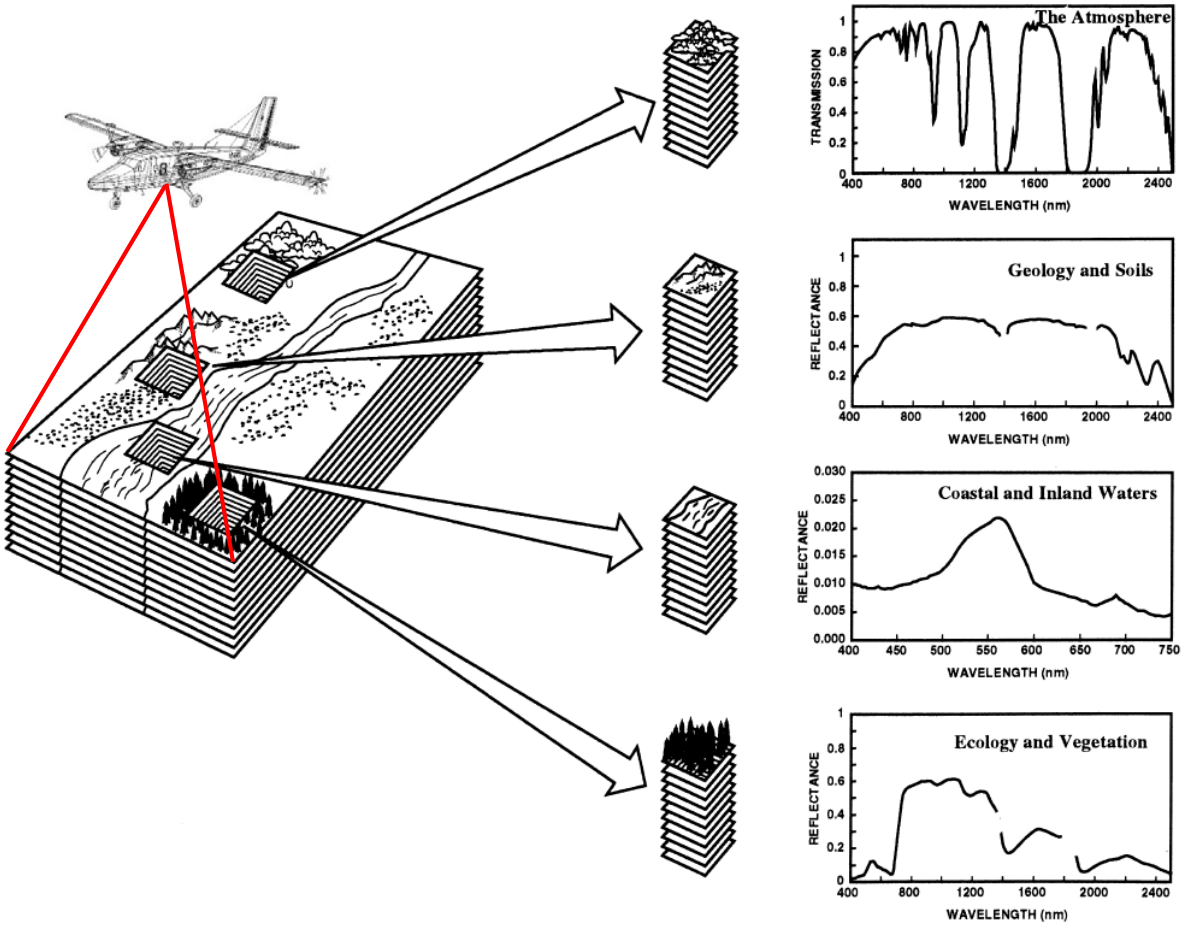
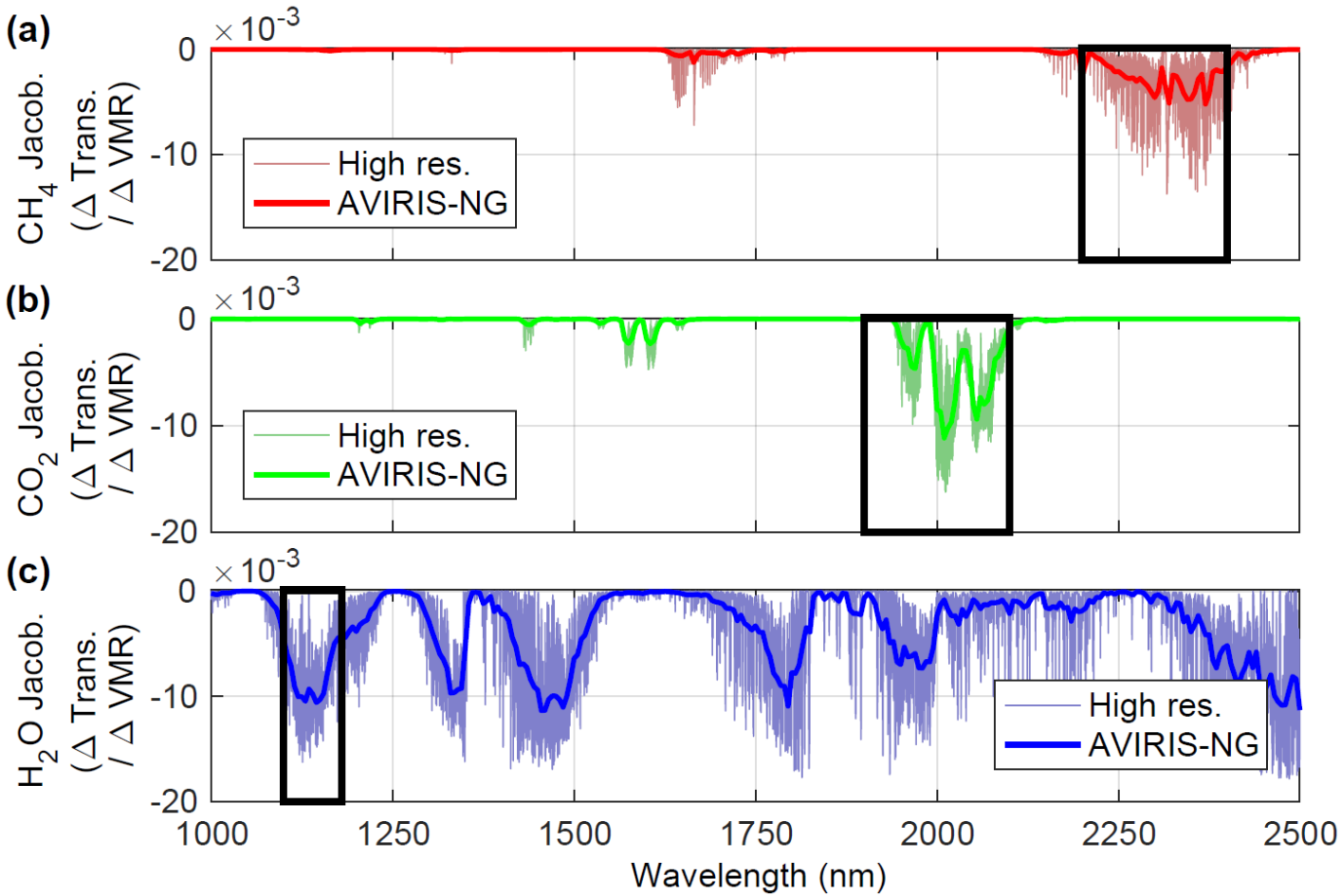
- AVIRIS-NG (Next generation Airborne Visible/Infrared Imaging Spectrometer)
  - Pushbroom sensor
  - 36° field of view
  - 380 to 2,510 nm
  - 5 nm spectral resolution
  - 427 spectral channels



Gas absorption features

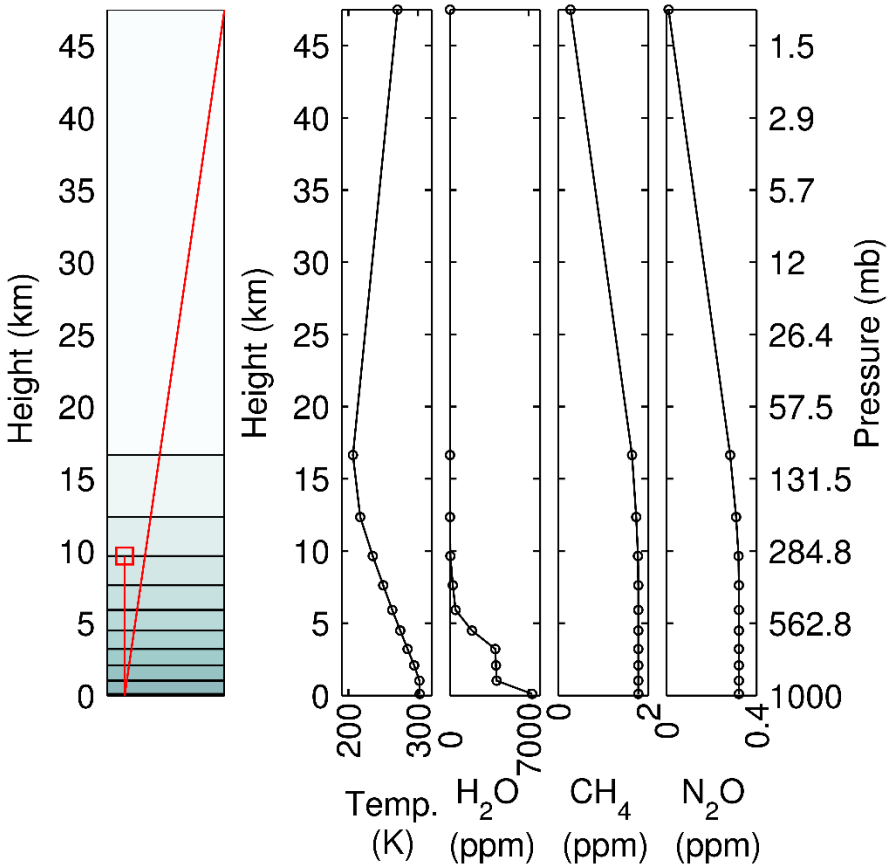
- CH_4, CO_2, and H_2O absorption features



Gas retrievals

- 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

CH_4 retrieval (Thorpe et al., 2014):



Motivation

32 x 22 km , 704 km^2 region:

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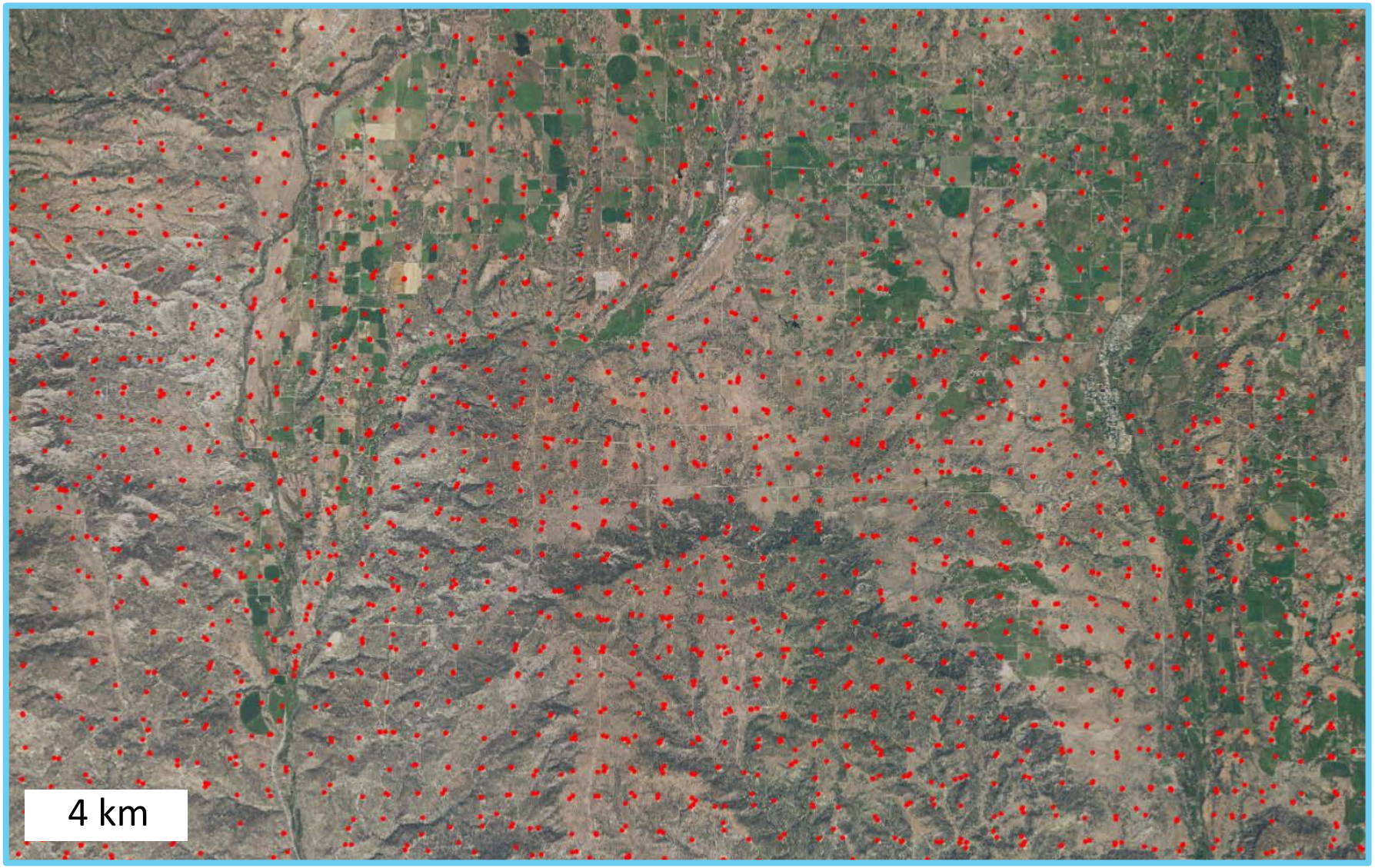

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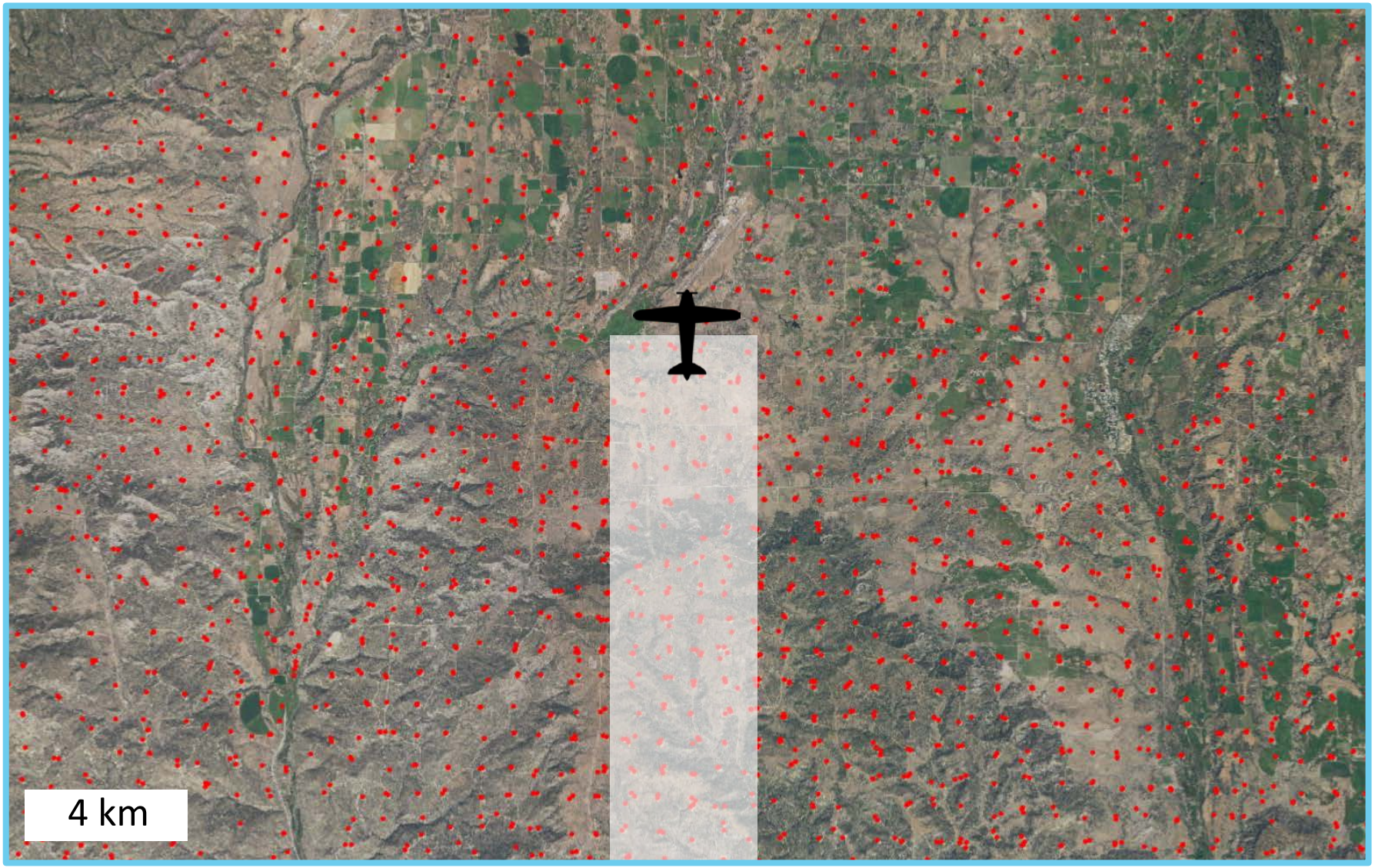
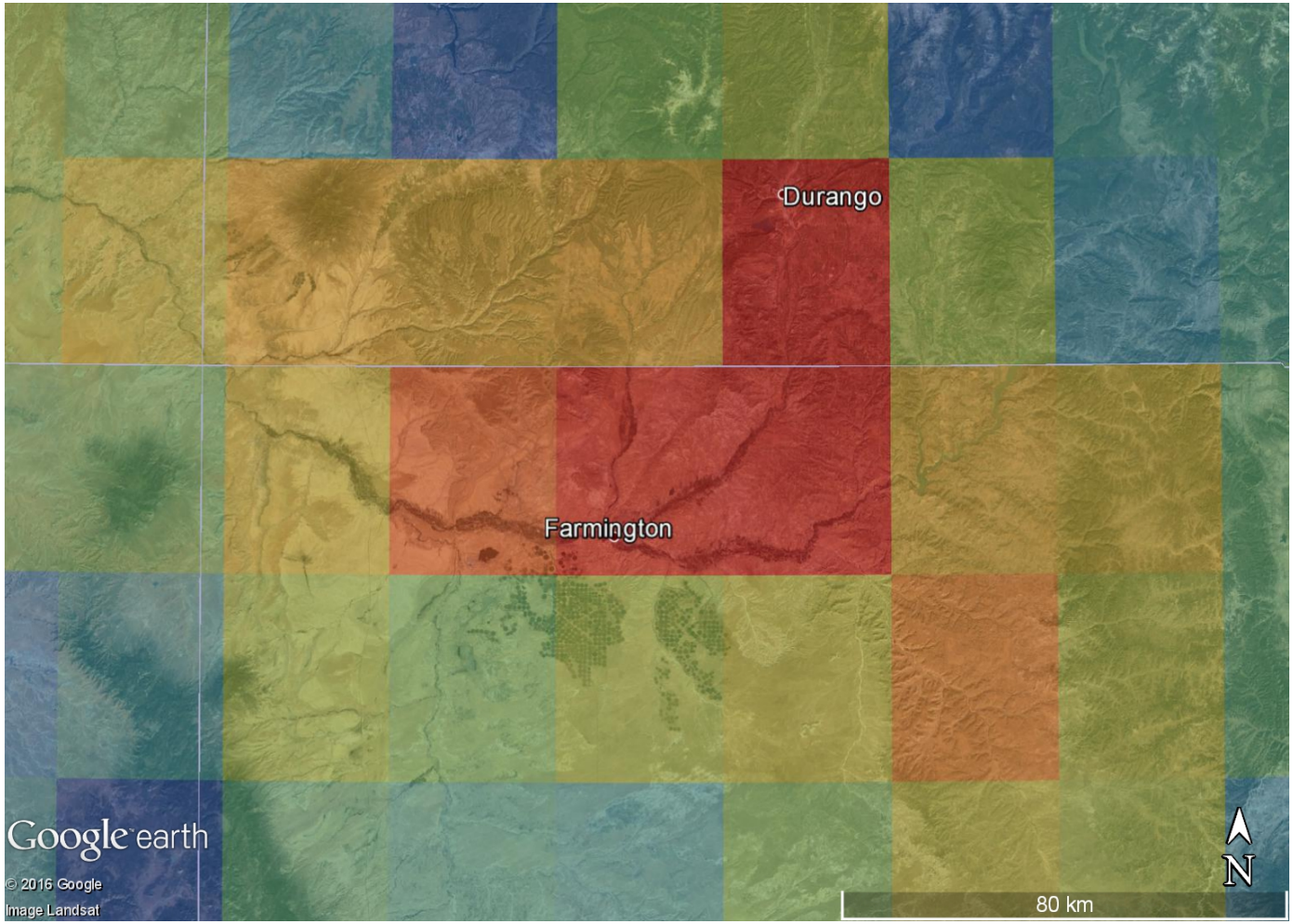


Study site

- San Juan Basin (Four Corner: Colorado, New Mexico)
  - Coal bed CH_4
  - 20,000 oil and gas wells

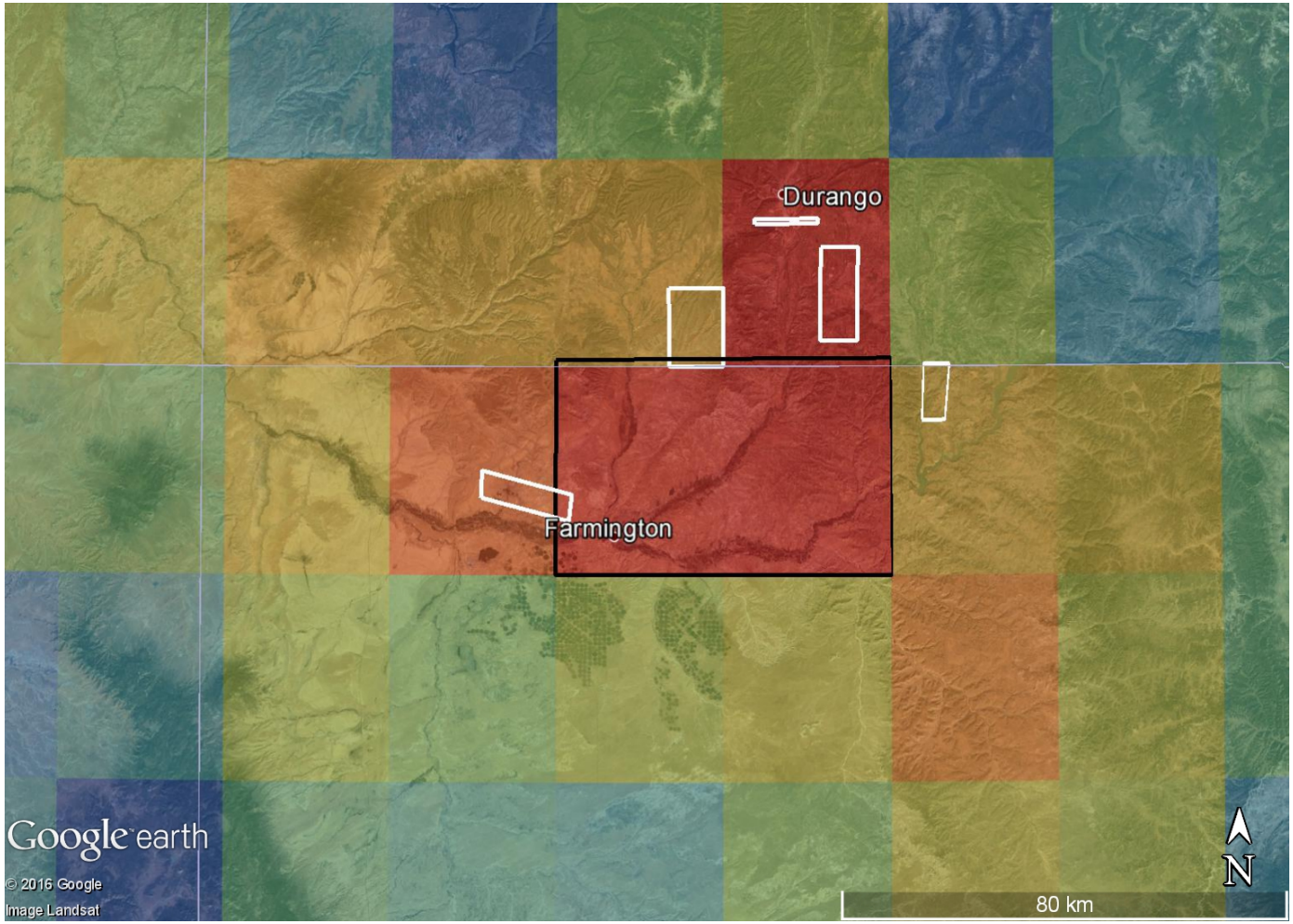
Study site

- CH_4 enhancement observed with SCIAMACHY satellite (Kort et al., 2015)



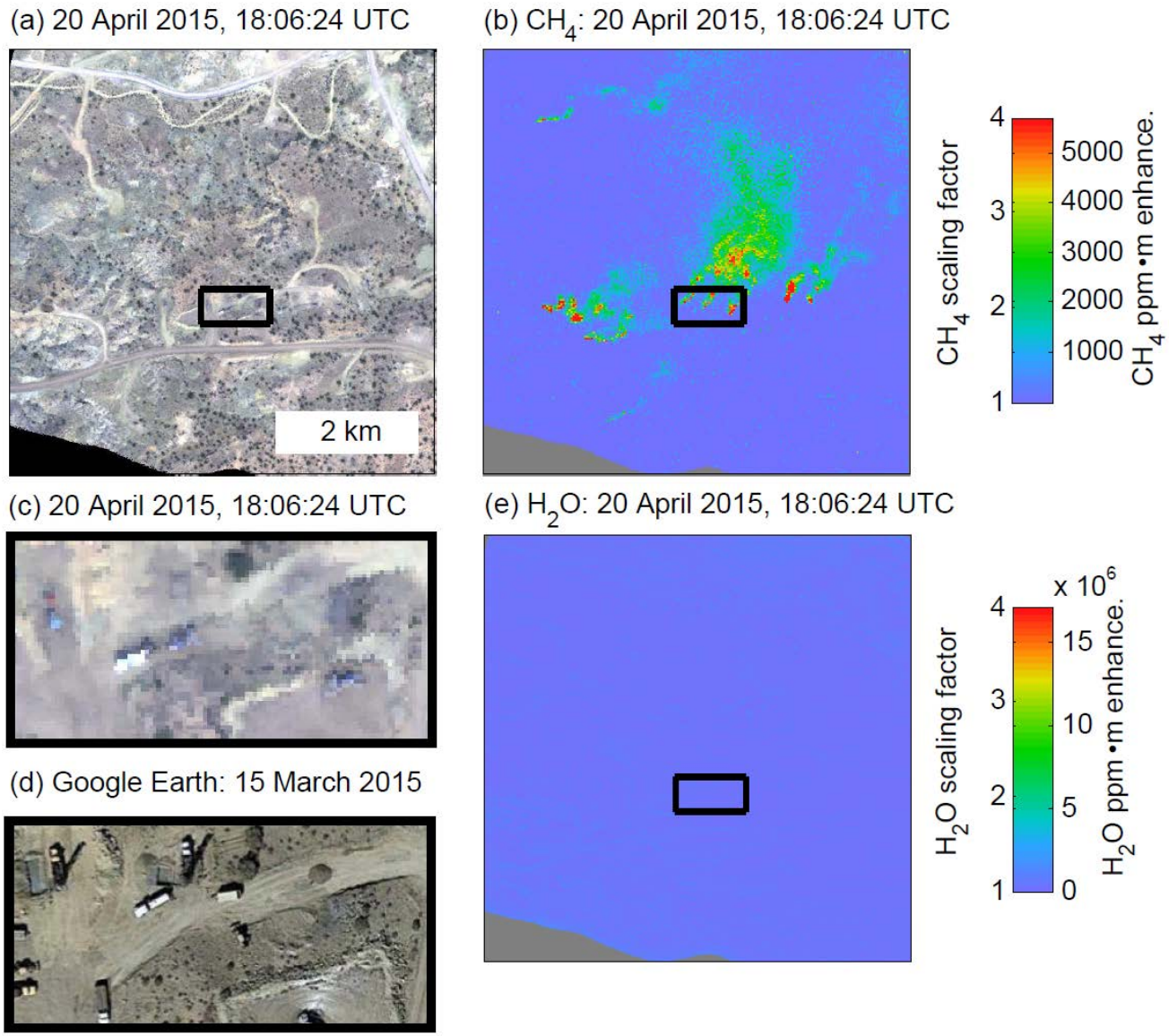
Study site

- 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)



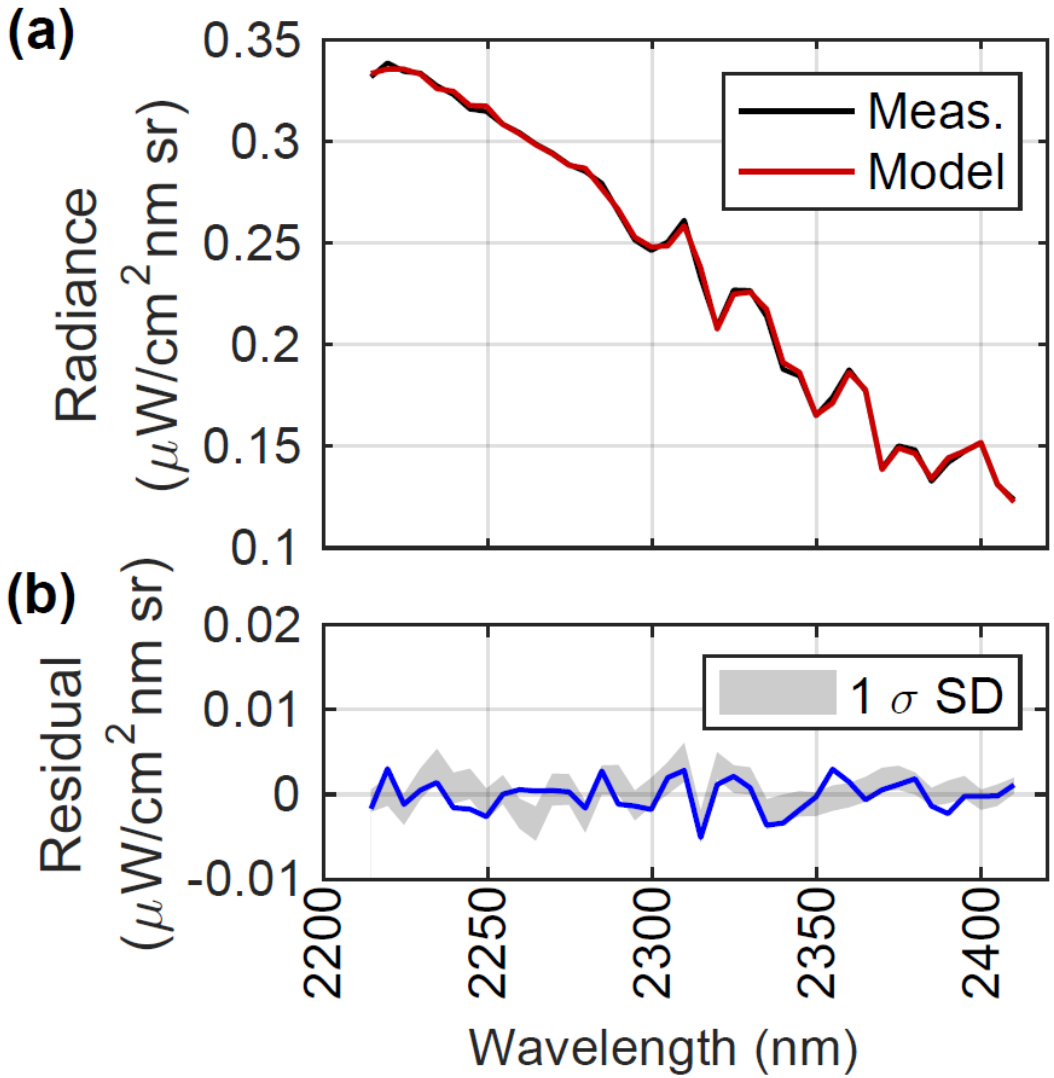
Results (CH_4)

- Example 1: Well completions



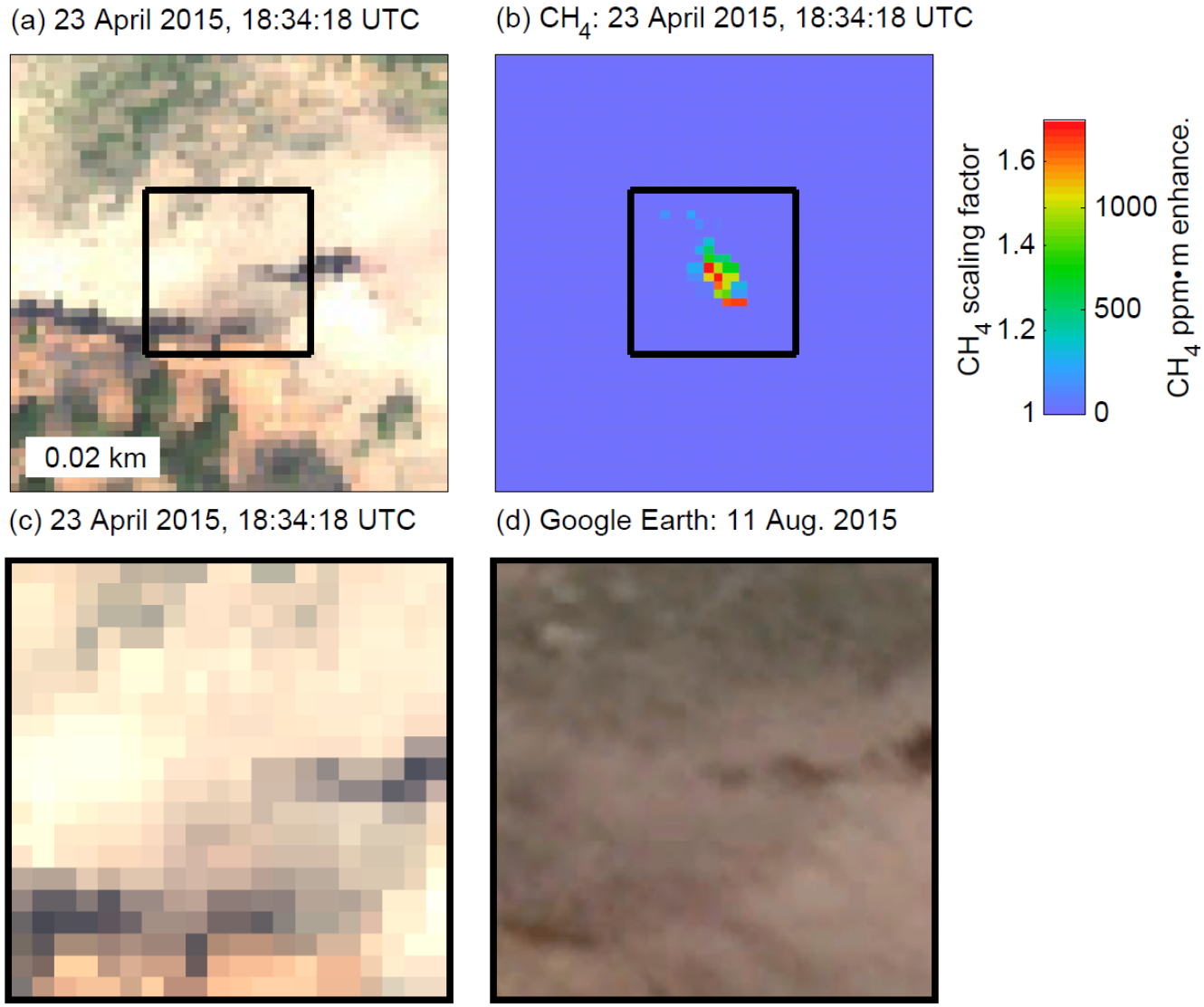
Results (CH_4)

- Example 1: CH_4 retrieval radiance fits



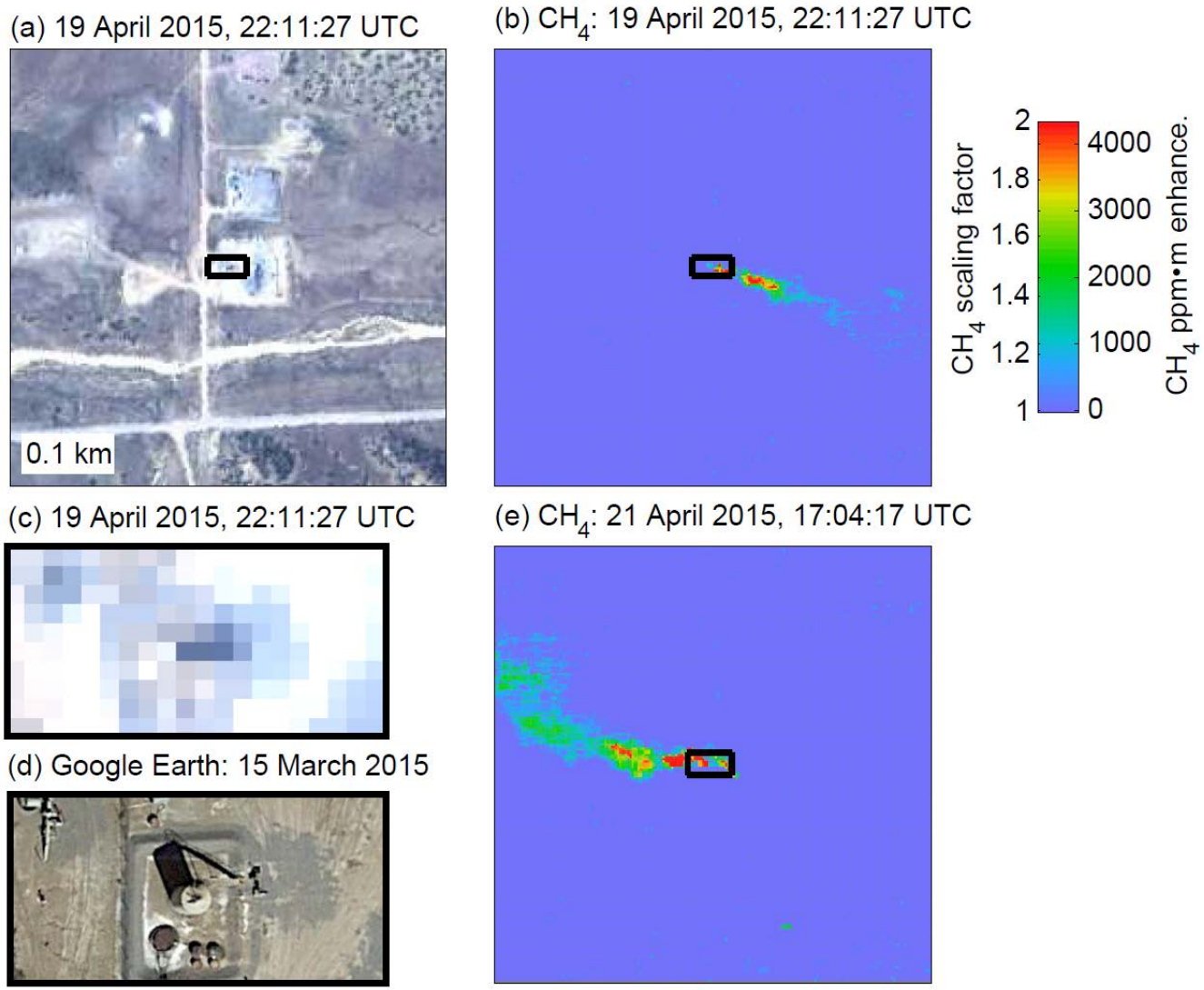
Results (CH_4)

- Example 2: Natural source at “Moving Mountain”



Results (CH_4)

- Example 3: Tank emissions



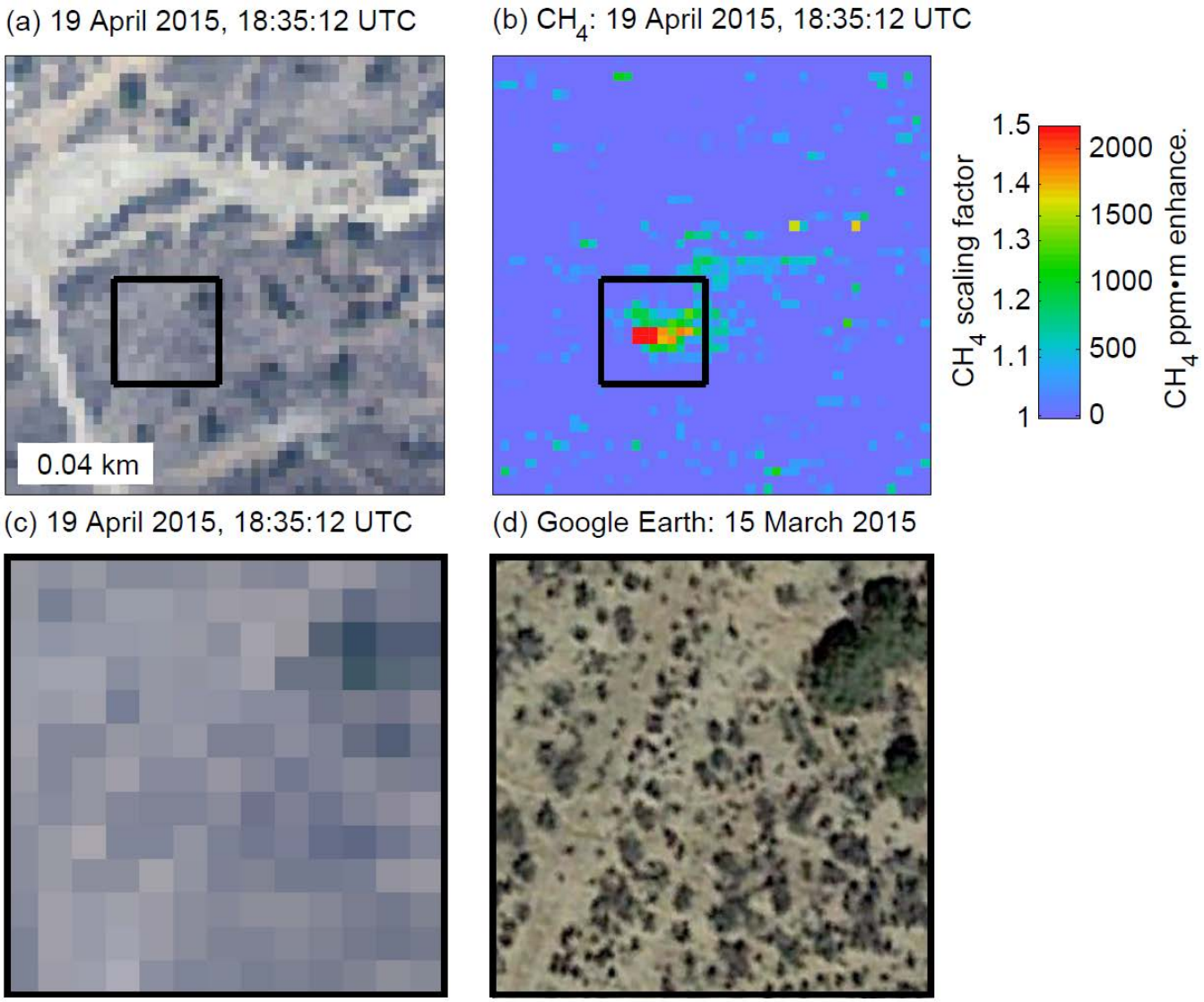
Results (CH_4)

- Example 3: Tank emissions (CH_4 thermal camera)

INSERT VIDEO

Results (CH_4)

- Example 4: Pipeline leak



Results (CH_4)

- Example 4: Pipeline leak (CH_4 thermal camera)

INSERT VIDEO

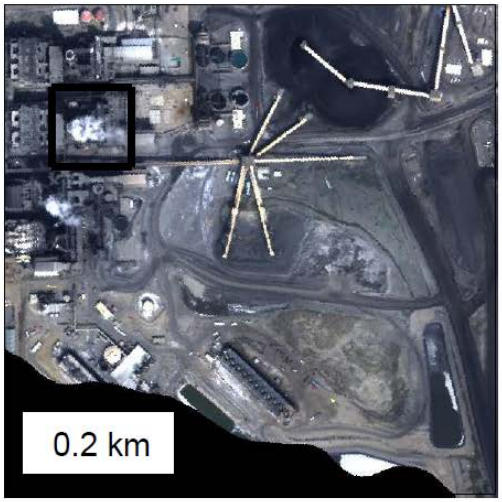
Results (CH_4)

- Example 4: Operators shut down pipeline

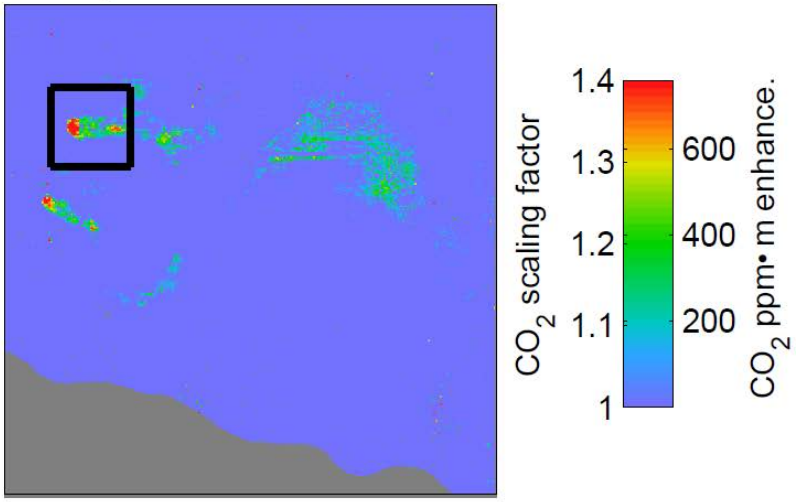
Results (CO_2)

- Example 5: Power plant

(a) 20 April 2015, 18:13:45 UTC

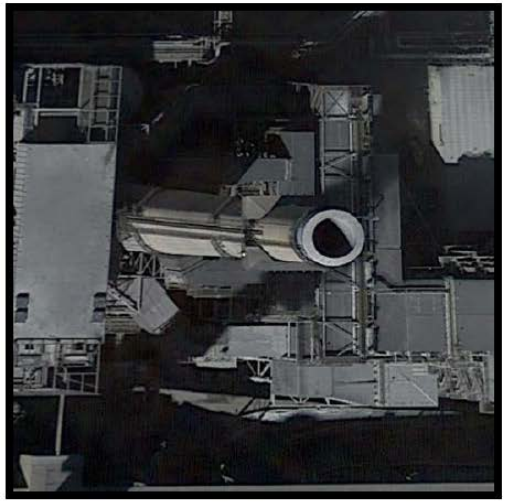


(b) CO_2: 20 April 2015, 18:13:45 UTC



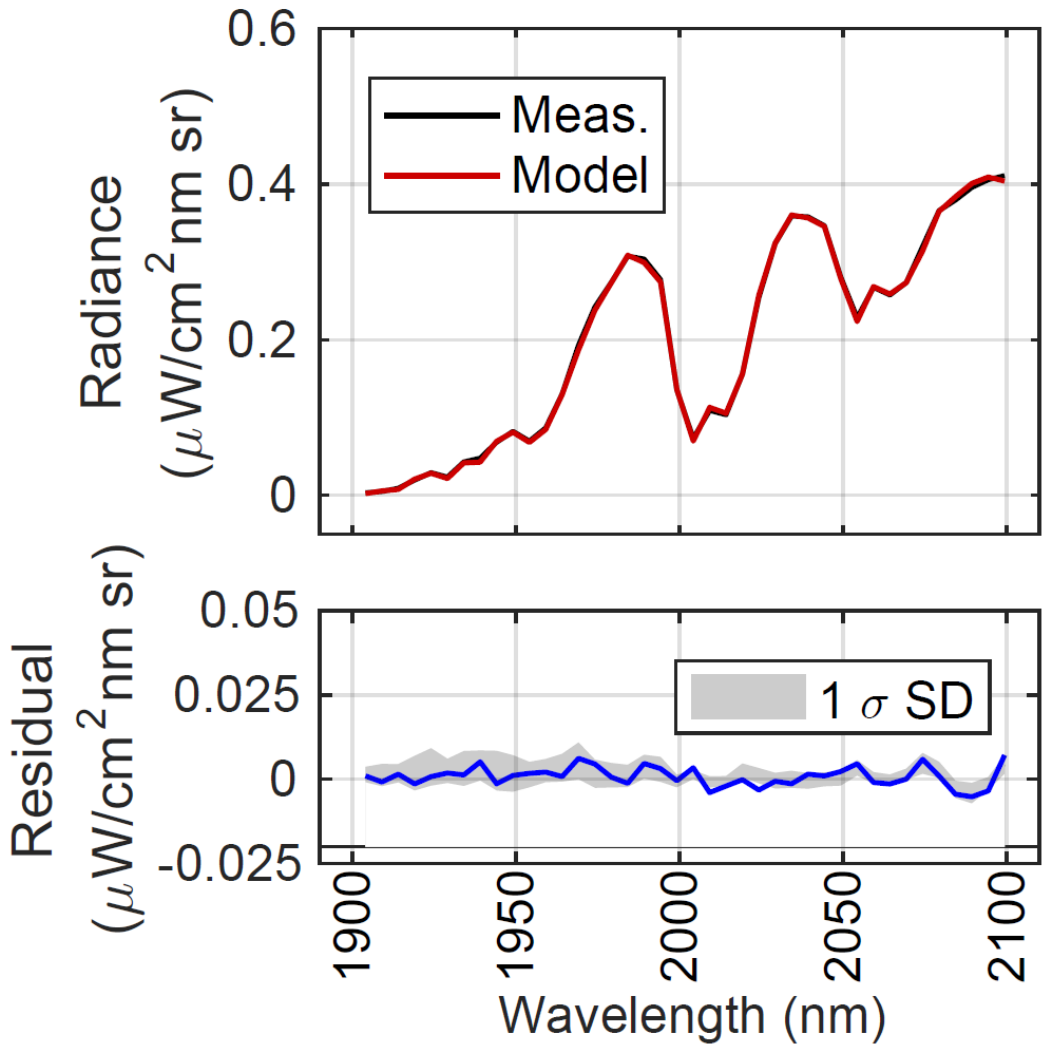
(c) 20 April 2015, 18:13:45 UTC

(d) Google Earth: 15 March 2015



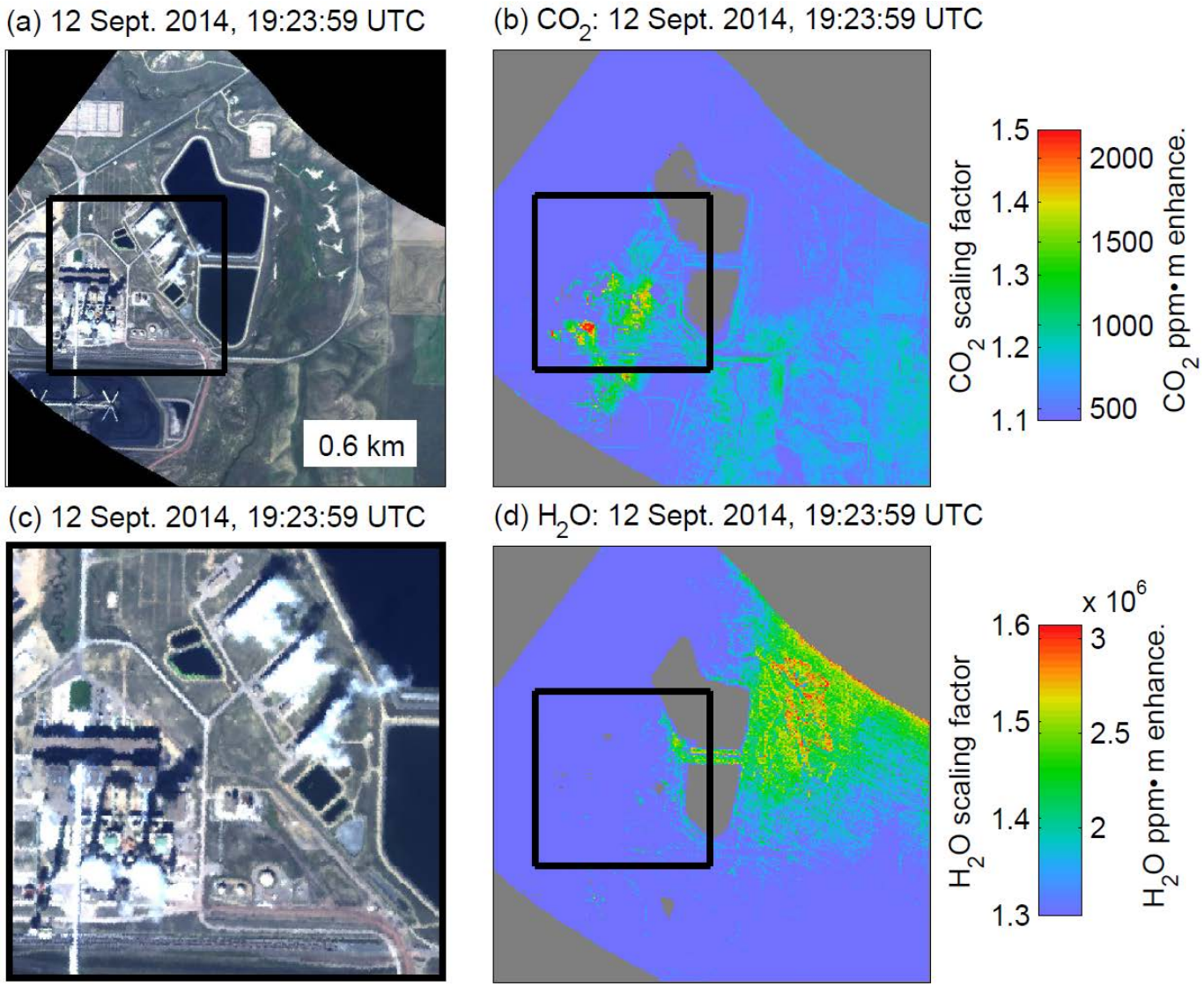
Results (CO_2)

- Example 5: CO_2 retrieval radiance fits



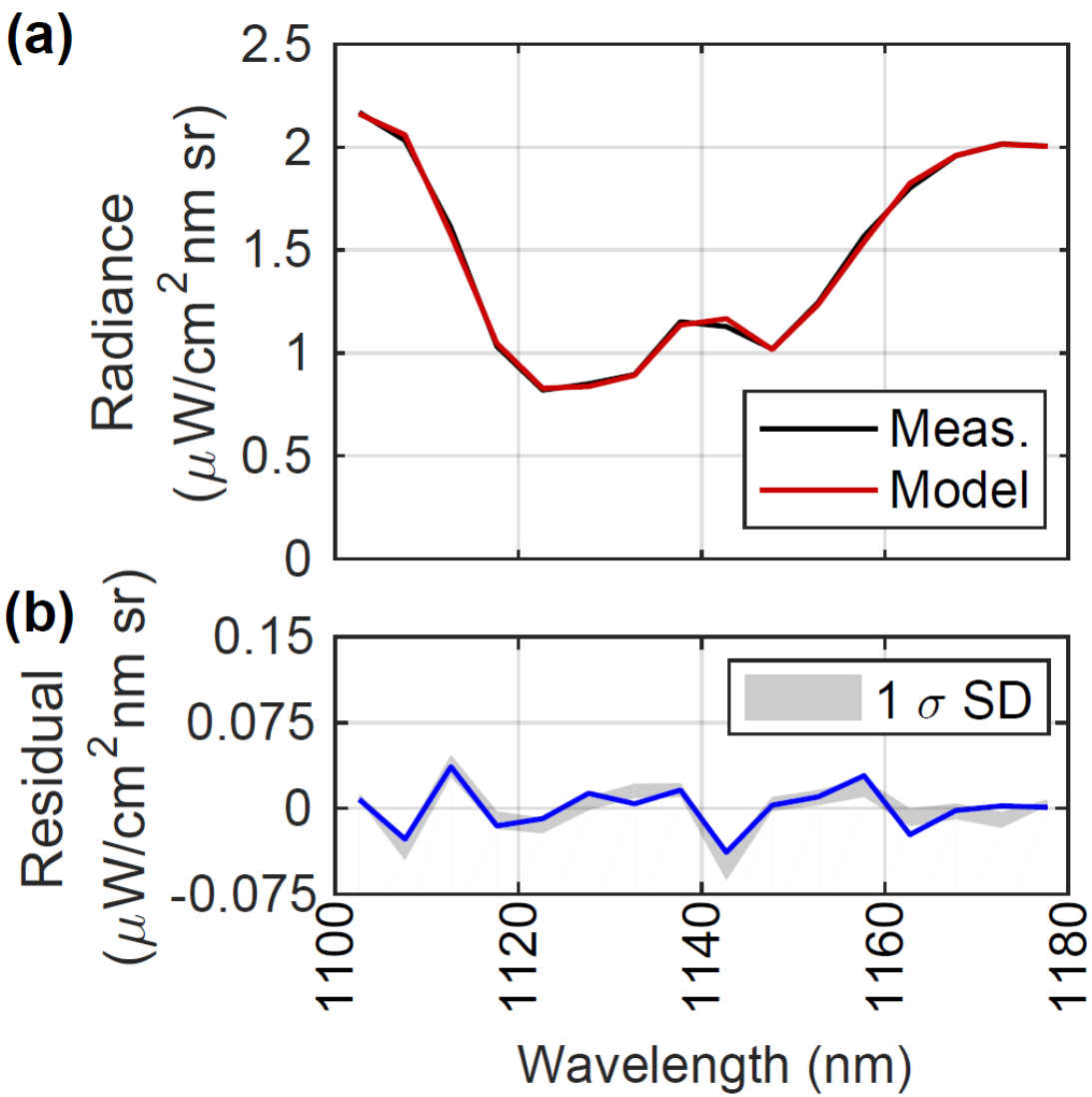
Results (CO_2, H_2O)

- Example 6: Power plant (2014 flight)



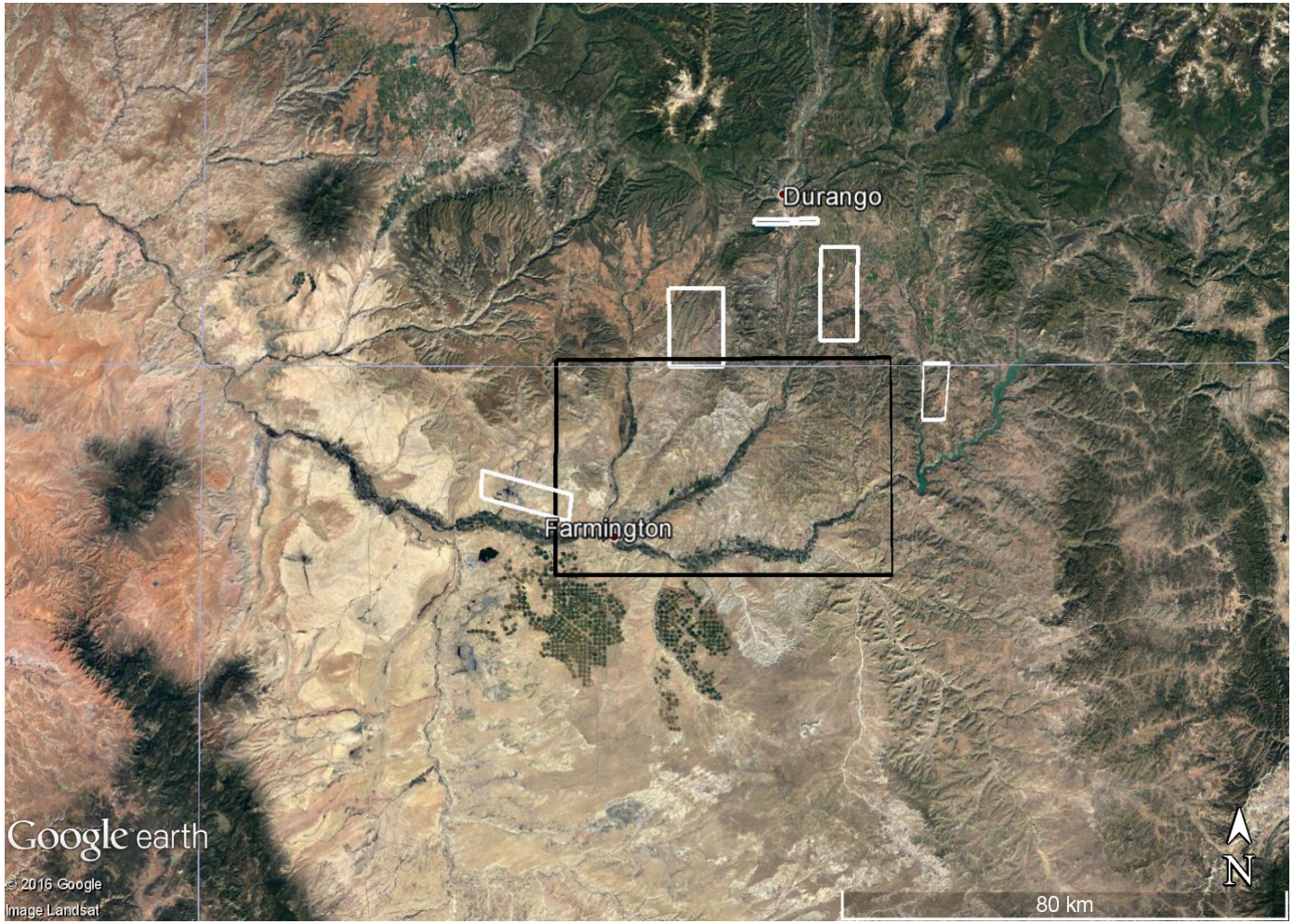
Results (H_2O)

- Example 6: H_2O retrieval radiance fits



Results

- Observed CH_4 plumes



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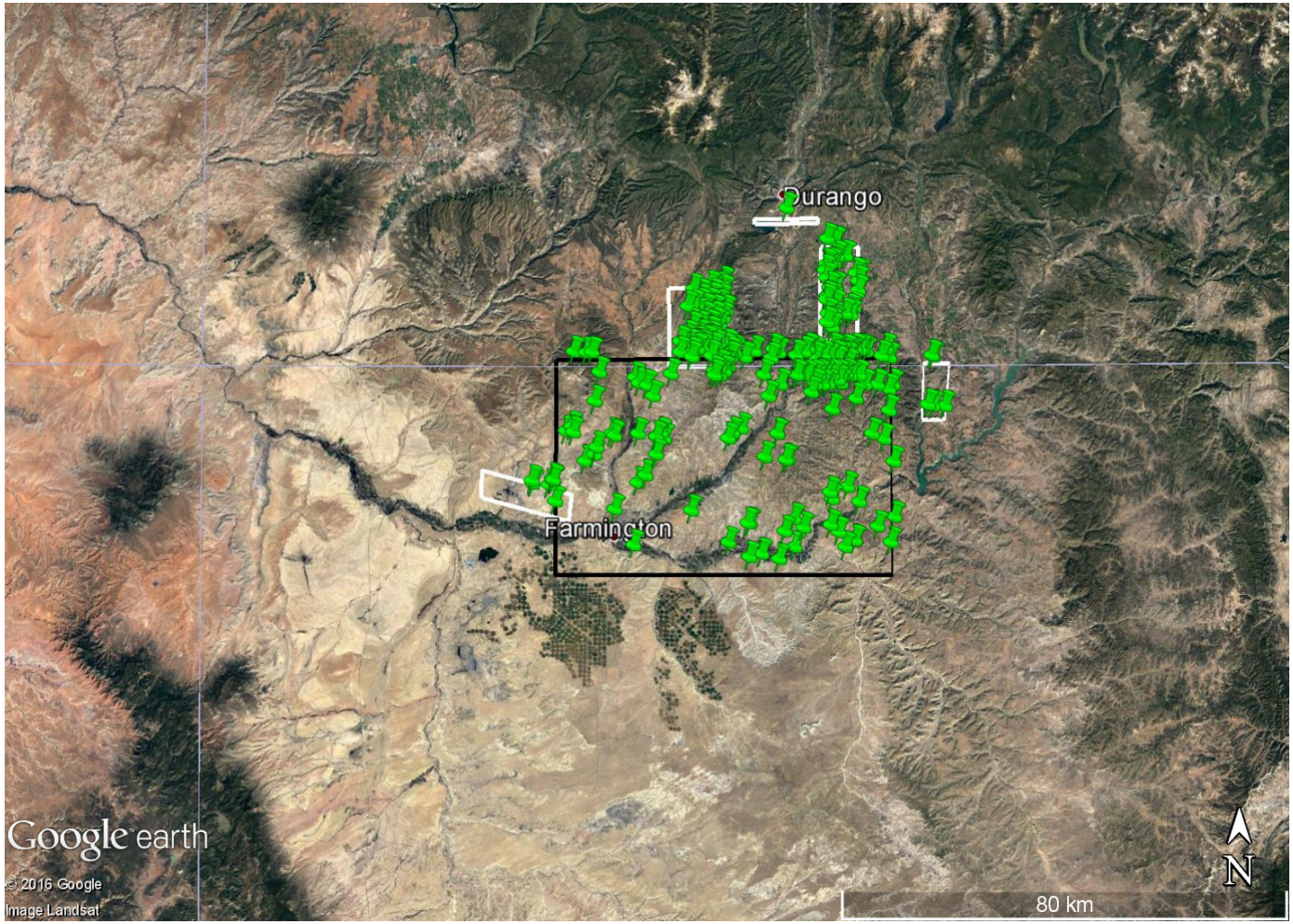

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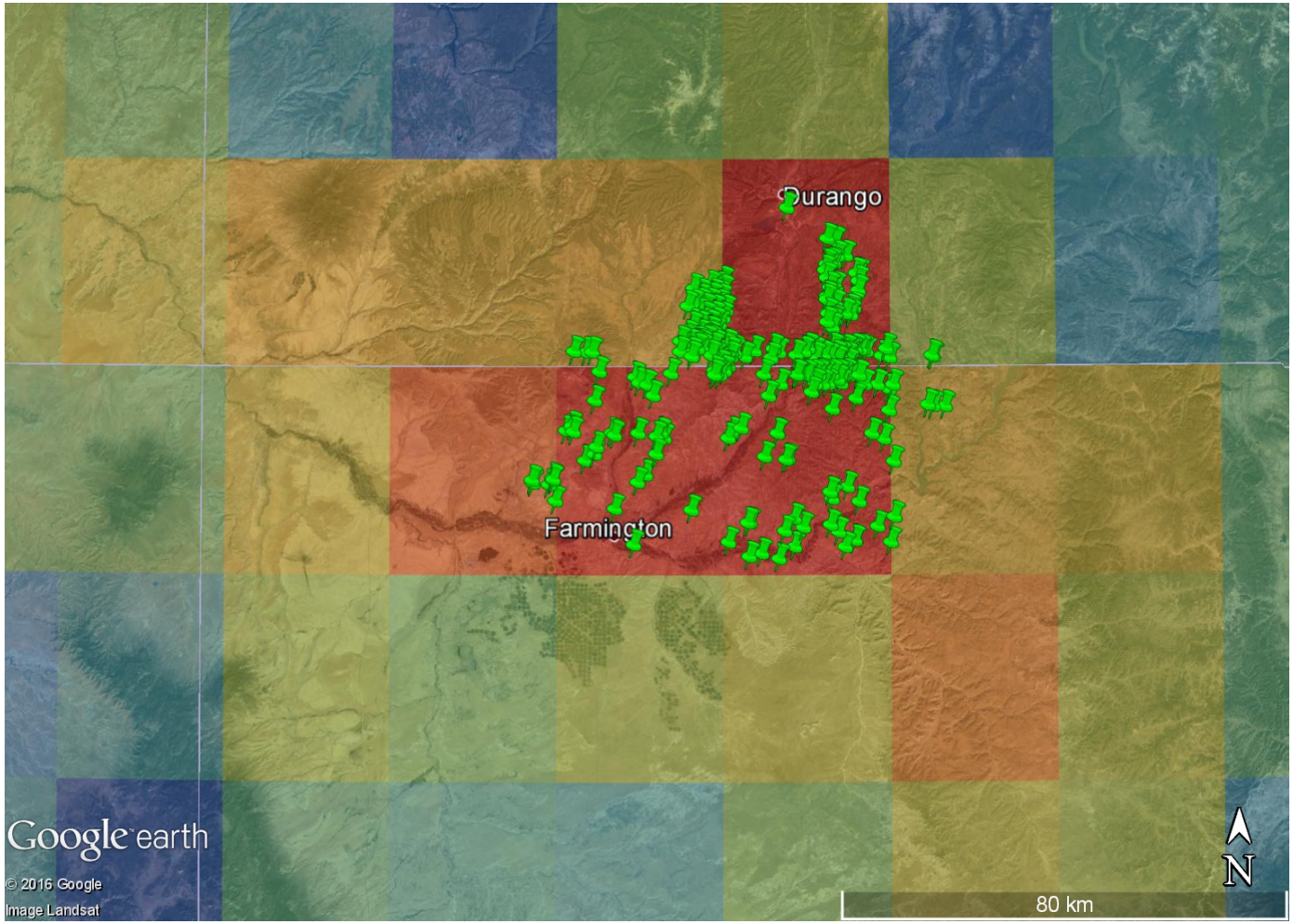


- Source categories

Total flight hours	Total ground coverage (km^2)	Source category	Specific source	Number of plumes	Percentage of total
9.2	2,530.8	Natural gas production	Well completions	10	3.9%
			Wellpad insfrastructure	135	52.5%
			Tanks	64	24.9%
			Gas processing plants	7	2.7%
			Unknown facility	15	5.8%
			Unknown infrastructure	2	0.8%
		Natural gas transmission	Buried natural gas pipeline leaks	3	1.2%
		Coal mining	Mine ventilation shaft	1	0.4%
		Geological (terrestrial)	Coal bed CH_4 seeps	2	0.8%
		Unknown		18	7.0%
		Total		257	100.0%

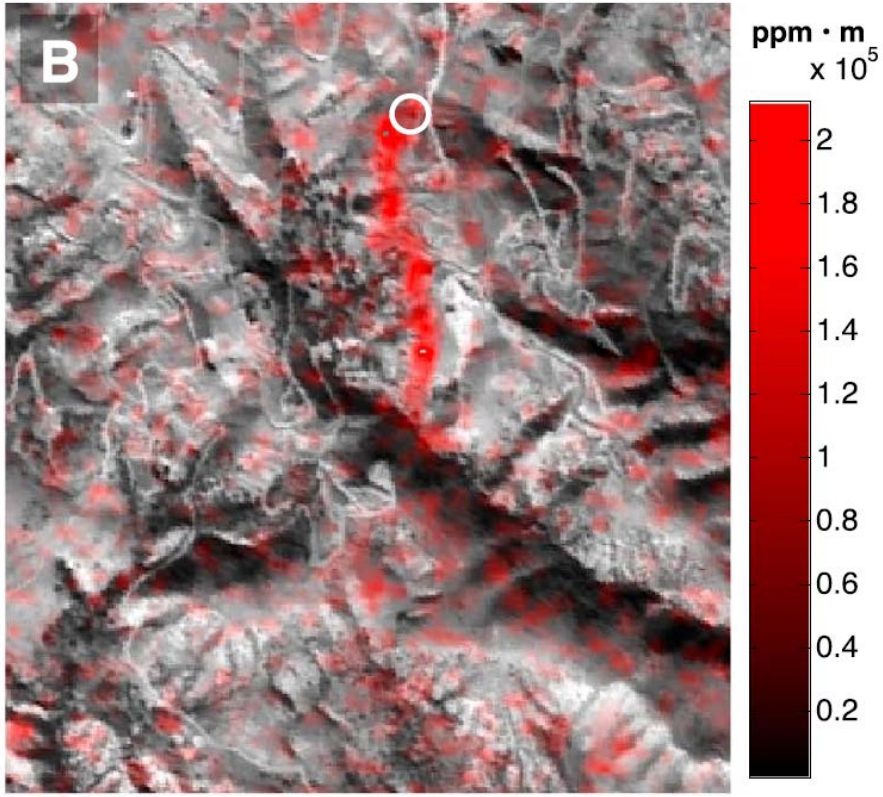
Results (Aliso Canyon)

- AVIRIS Classic (10 nm spectral resolution) observed Aliso Canyon gas leak

Results (Aliso Canyon)

- Orbital Hyperion instrument also observed CH_4 plume

Hyperion: 1/1/16, 16:39 UTC
Low Earth orbit



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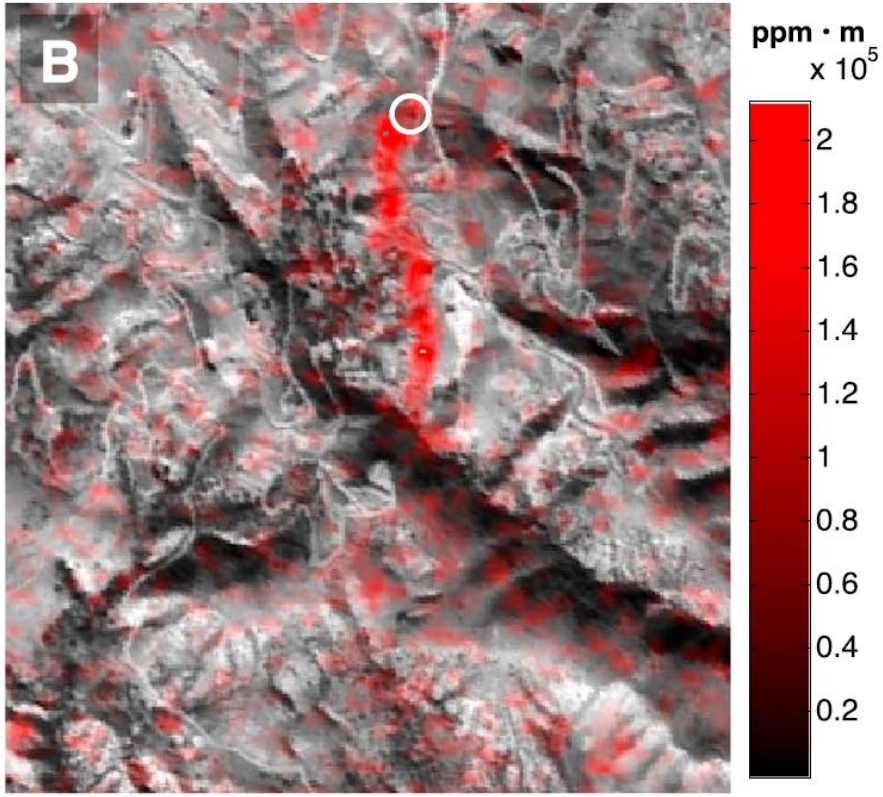
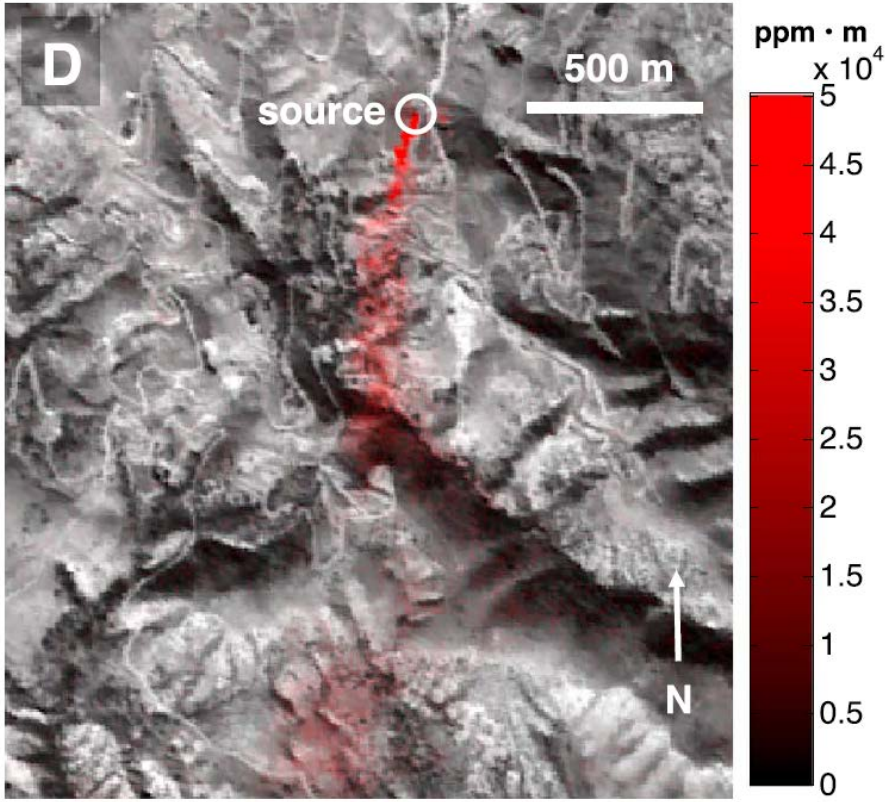
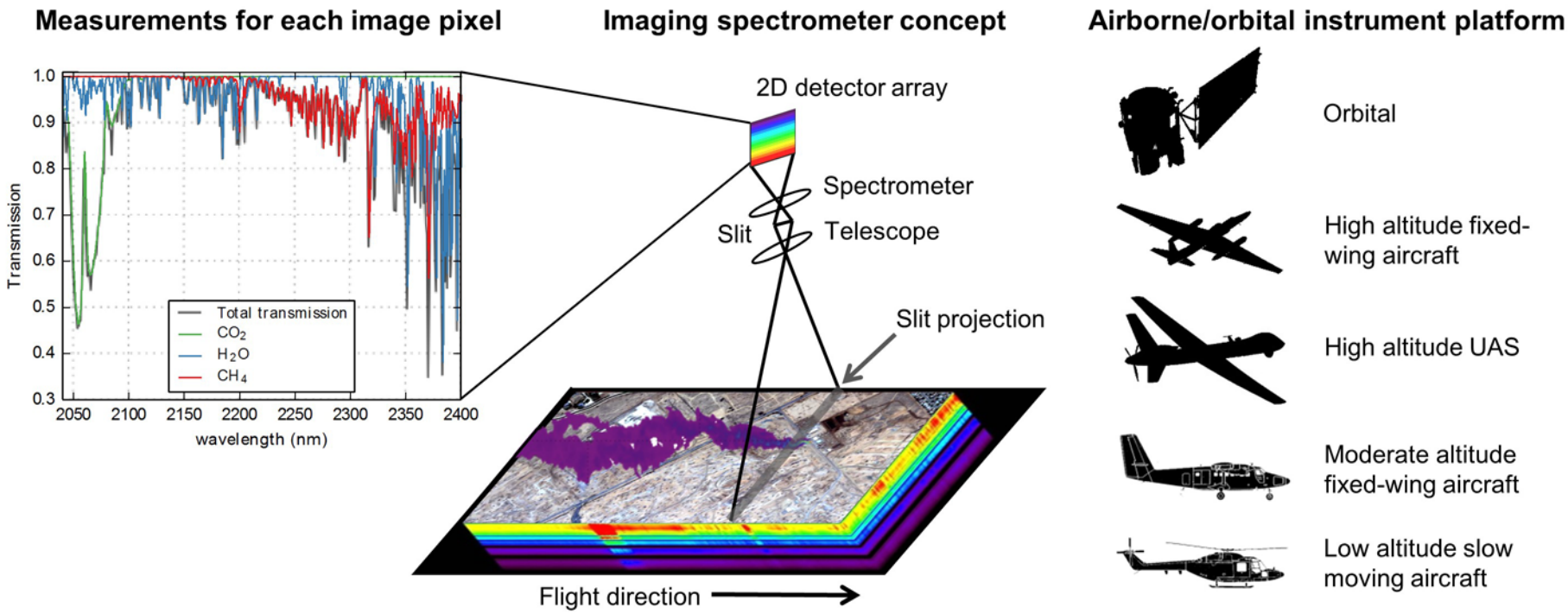


AVIRIS Classic: 1/12/16, 20:25 UTC
6.6 km above ground level



Future instrument design

- 1 nm spectral resolution for improved gas sensitivity
- Quantitative mapping of CH_4, CO_2, H_2O, CO, N_2O
- NRC RFI #2: Understanding anthropogenic methane and carbon dioxide point source emissions (Duren et al., 2016)



Conclusions

- AVIRIS-NG permits quantitative mapping of CH_4 and CO_2 emissions
- Hundreds of CH_4 plumes were observed as part of a campaign in Four Corners (CO, NM)
- Offers the potential to better understanding partitioning of anthropogenic and natural emission sources
- A dedicated instrument for greenhouse gas mapping would offer:
  - Improved gas sensitivity
  - Quantitative mapping of CH_4, CO_2, H_2O, CO, N_2O
  - Flexible instrument platform (aircraft/orbital)

Acknowledgments

- JPL:
  - AVIRIS/AVIRIS-NG team
  - Simon Hook and Bill Johnson (thermal camera)
- NASA:
  - Jack Kaye (Four Corners campaign)
- Hyperion team:
  - Elizabeth Middleton, Lawrence Ong, Stephen Ungar (NASA Goddard Space Flight Center)