NASA Air Quality Applied Sciences Team

Earth Science Serving Air Quality Management Needs

Aura Observations of Trace Gases and their Application for Studying Air Quality near Oil and Natural Gas Operations

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EOS Aura Science Team Meeting
15-18 September 2014, College Park, MD

NASA Air Quality Applied Science Team (AQAST) FY14 Tiger Team Activity

Project Description:

Air Quality Managers (AQM) in regions affected by rapidly ONG extraction are working to address these questions:

- (1) What is the burden of CH_4, NOx, non-methane hydrocarbons [NMHC], and byproducts (eg, HCHO, CO) being released by new mines and wells?
- (2) Can we verify modified emissions inventories that AQM are developing based on increased ONG sources?

Collaborator	Stakeholder Roles
Julie McDill (MARAMA)	New emission inventories using oil & gas well & production data
Tad Aburn (MDE)	Support Marcellus aircraft flights
Theresa Pella (CenSARA) / Margaret Robertson (OK DEQ)	Liaison for CenSARA: Assessment of Oil and Gas (O&G) emissions inventory based on satellite NO2, CH4 and HCHO distributions / Liaison to OK DEQ
Gail Tonnesen (US EPA Region 8)	Liaison for EPA Region 8: Comparison of satellite HCHO/NO2 ratios to EPA model results
Patrick Reddy / Gordon Pierce (CDPHE)	Liaisons to CDPHE (Colorado Dept Public Health & Environment)
John Lyon (BLM)	Liaison to BLM (Bureau of Land Management)

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Approach:

- For Question #1: (1) Satellite maps and trends will be derived for regions affected by newer ONG activity: Marcellus (OH, WV, PA, MD), Bakkan (ND), Barnett/Woodford (TX-OK), and Utah-Colorado-Wyoming region (UT-CO). Products and trends from different sensors will be compared as each satellite product has inherent limitations. (2) We will compare satellite products with available ground and aircraft CH_4, NMHC, NO_x data in each region.
- For Question #2: (1) AQM are using emissions inventories with models to predict impacts of ONG emissions. We will partner with these activities to support model validation using our combined satellite and in-situ datasets.

Focus Areas for Analyzing Satellite Signatures of Trace Gases Associated with US Oil and Gas Extraction

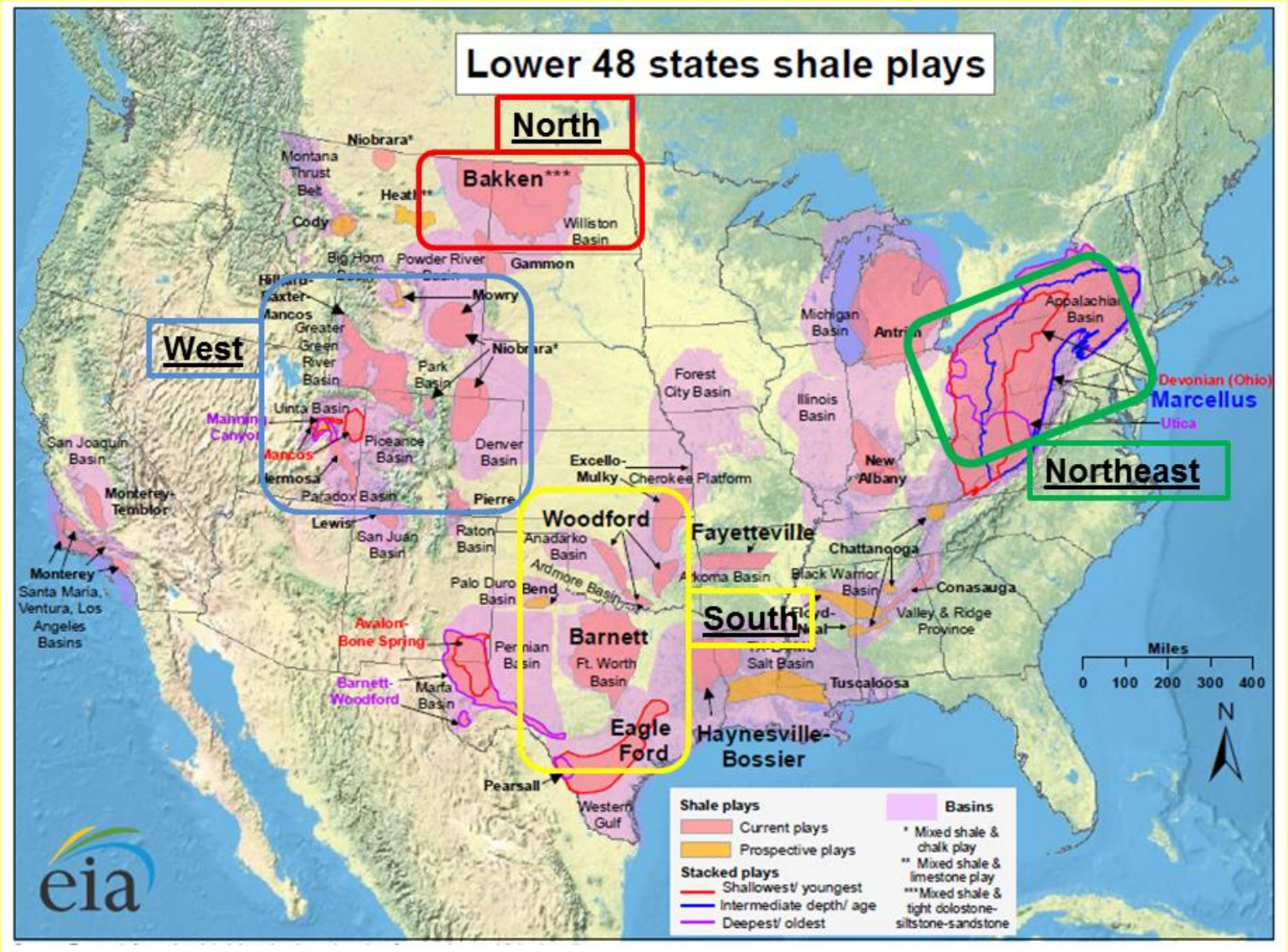


Figure adapted from http://www.eia.gov.

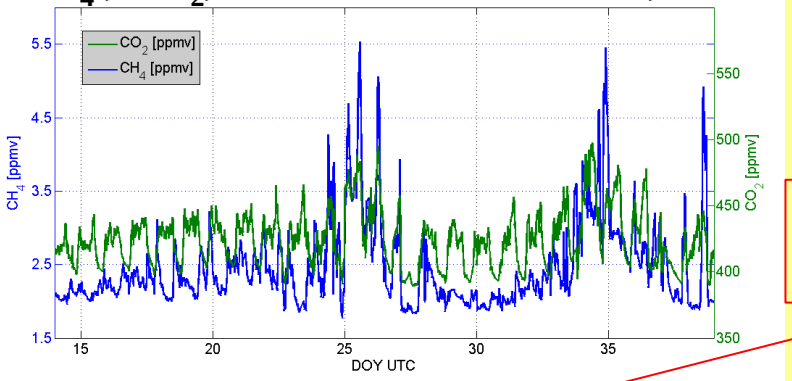
Satellite methane and other trace gas burdens for comparison to O&NG emissions:

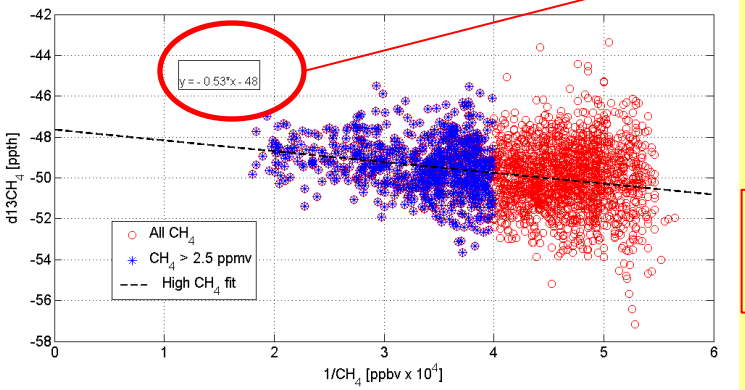
- **Objectives:**
  - (1) Determine regional changes in CH_4 and related carbon gases near O&NG activities in Eastern and Western US based on satellite and in situ measurements.
  - (2) Work with AQ stakeholders, such as MARAMA and CenSARA, to compare satellite observations with emissions inventories and air quality modeling.
- **First step:** Validate satellite observations with ground/aircraft measurement (ie. NASA DISCOVER-AQ 2011-MD, 2013-CA/TX, and 2014-CO provide in situ ground and aircraft measurements perfect for validation.)
- **Second Step:** Analyze satellite carbon gas time series to characterize regional trends and compare to inventories and AQ modeling (ie. TES can provide mid-tropospheric trends in CH_4 near and downwind of O&NG operations [background] and locate regional hotspots in CH_4.)

NATIVE Methane & δ^{13} C Isotope: Porterville, CA vs. Smith Point, TX

- **Porterville:** Weak correlation between CO_2 and CH_4 (**top left**) provides evidence to support that local traffic is not the dominant source for large CH_4 peaks as it is for CO_2. Oil and/or natural gas operations are more likely a source for CH_4 with an intercept of -48‰ (ie. -35 to -50‰ is range for natural gas) on the Keeling plot (**bottom left** - $\delta 13CH_4$ vs $1/CH_4$).
- **Smith Point:** Intercept (-59‰) for Keeling plot (**bottom right**) shows source of the >2.5 ppmv enhancements of CH_4 likely wetland (biogenic) emissions.

CH_4 , CO_2, and δ^{13} C at Porterville, CA

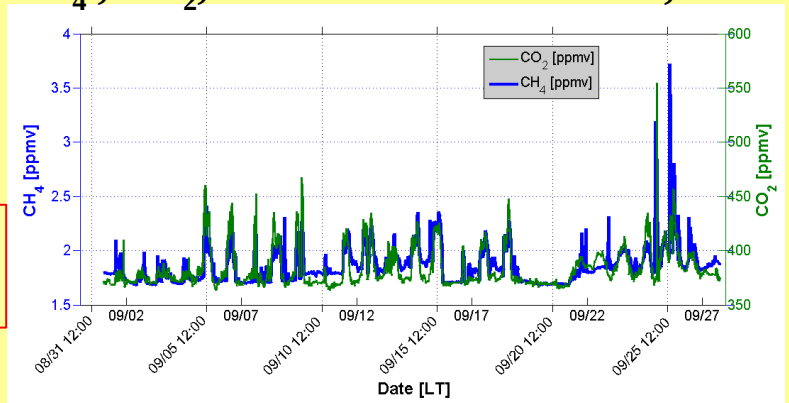


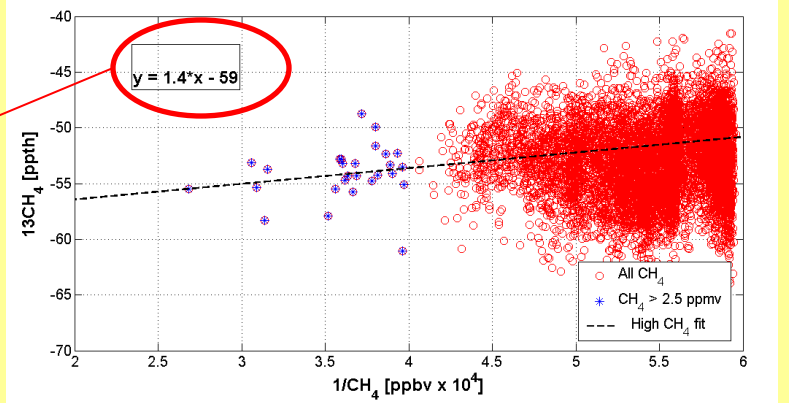


Sources with δ^{13} C of -48‰

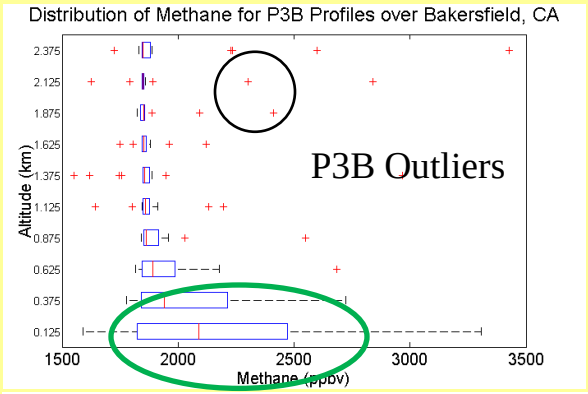
Sources with δ^{13} C of -59‰

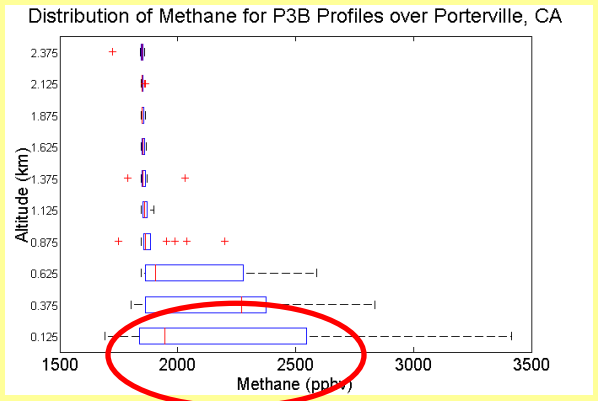
CH_4 , CO_2, and δ^{13} C at Smith Point, TX

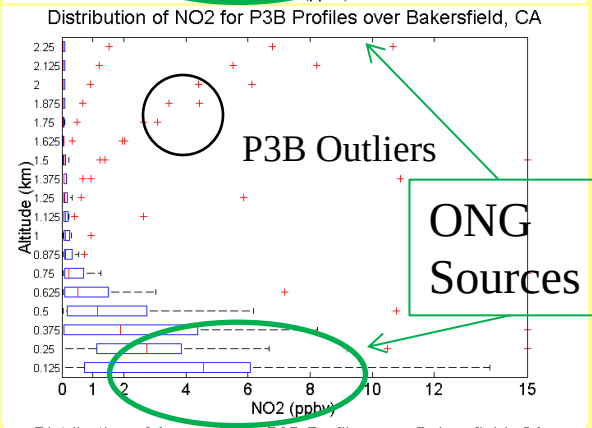


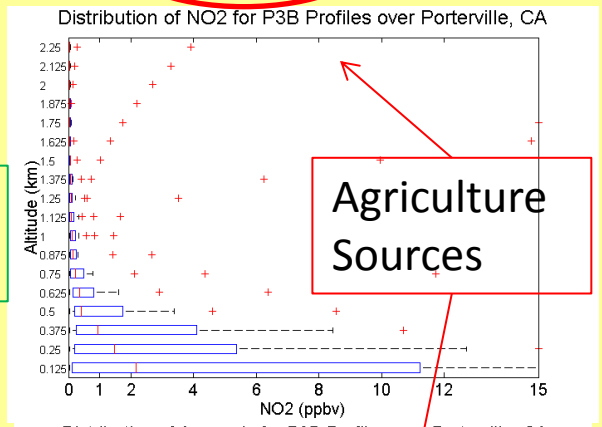


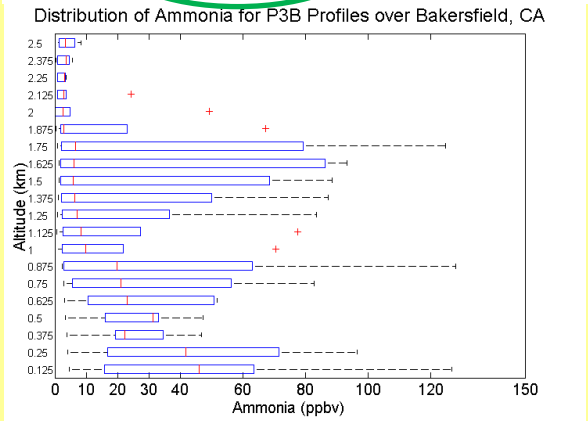
2013 DISCOVER-AQ CA:
P3B Profile Variability

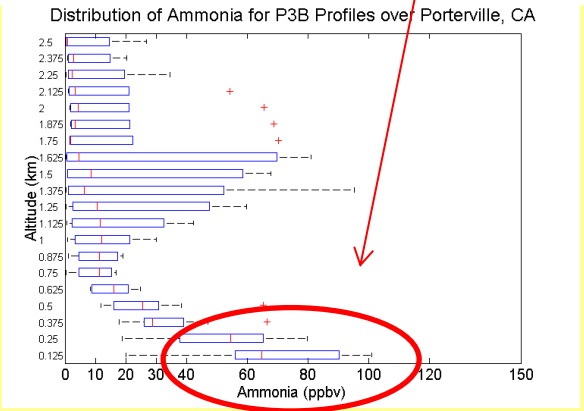


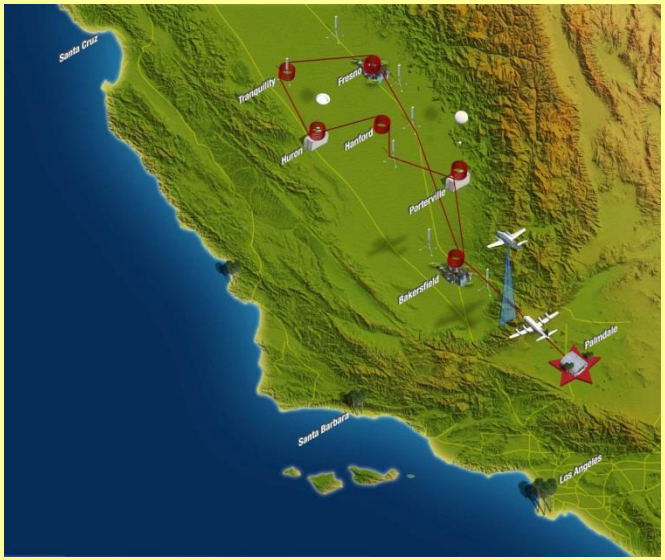






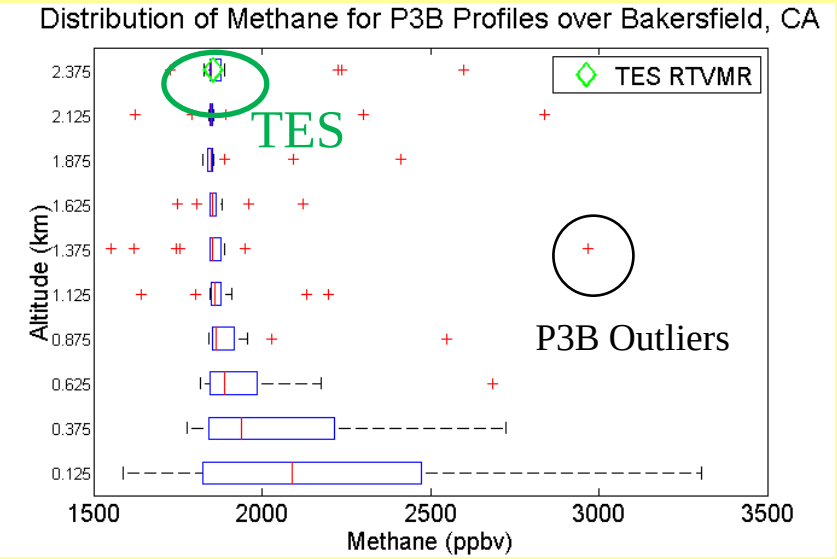


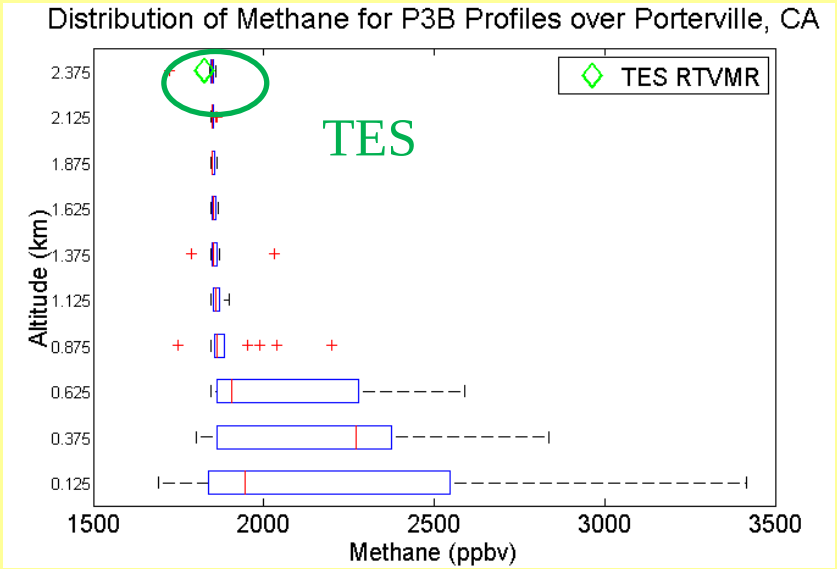


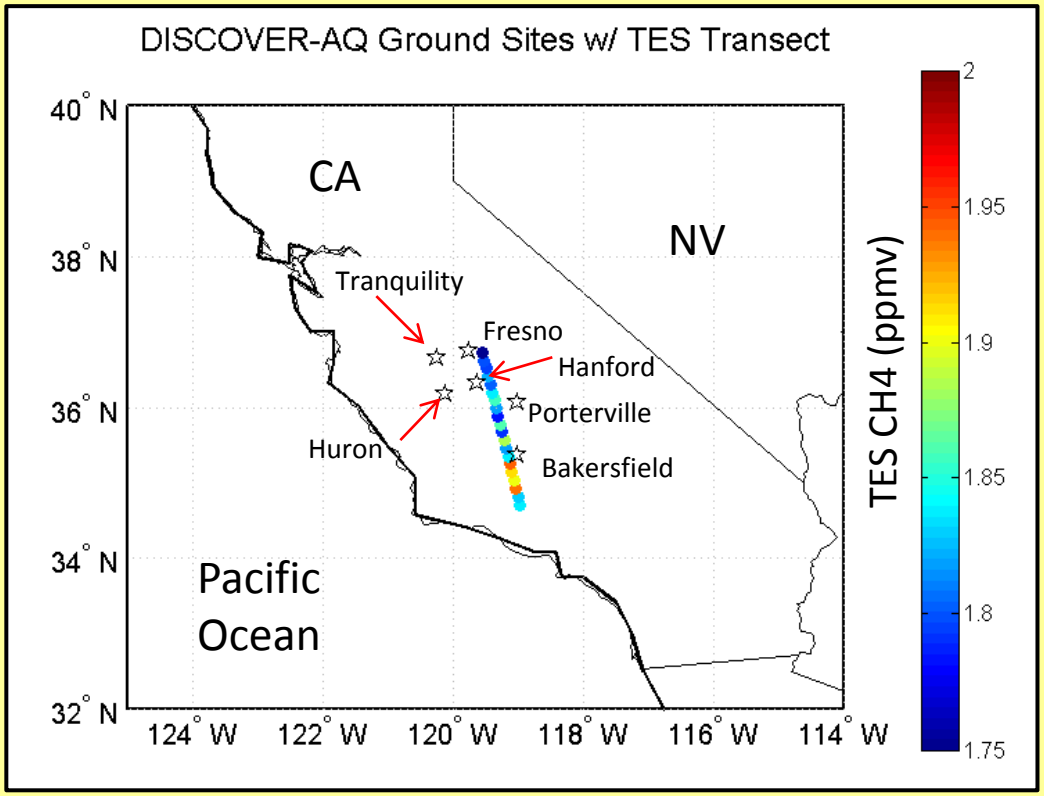


- Higher near surface NO_2 and CH_4 at Bakersfield vs Porterville suggests more of an ONG operational and emissions influence.
- High Ammonia concentrations at Porterville (vs Bakersfield) indicate the source of CH_4 as more likely agriculture.

2013 DISCOVER-AQ CA: Profiles vs. Satellite

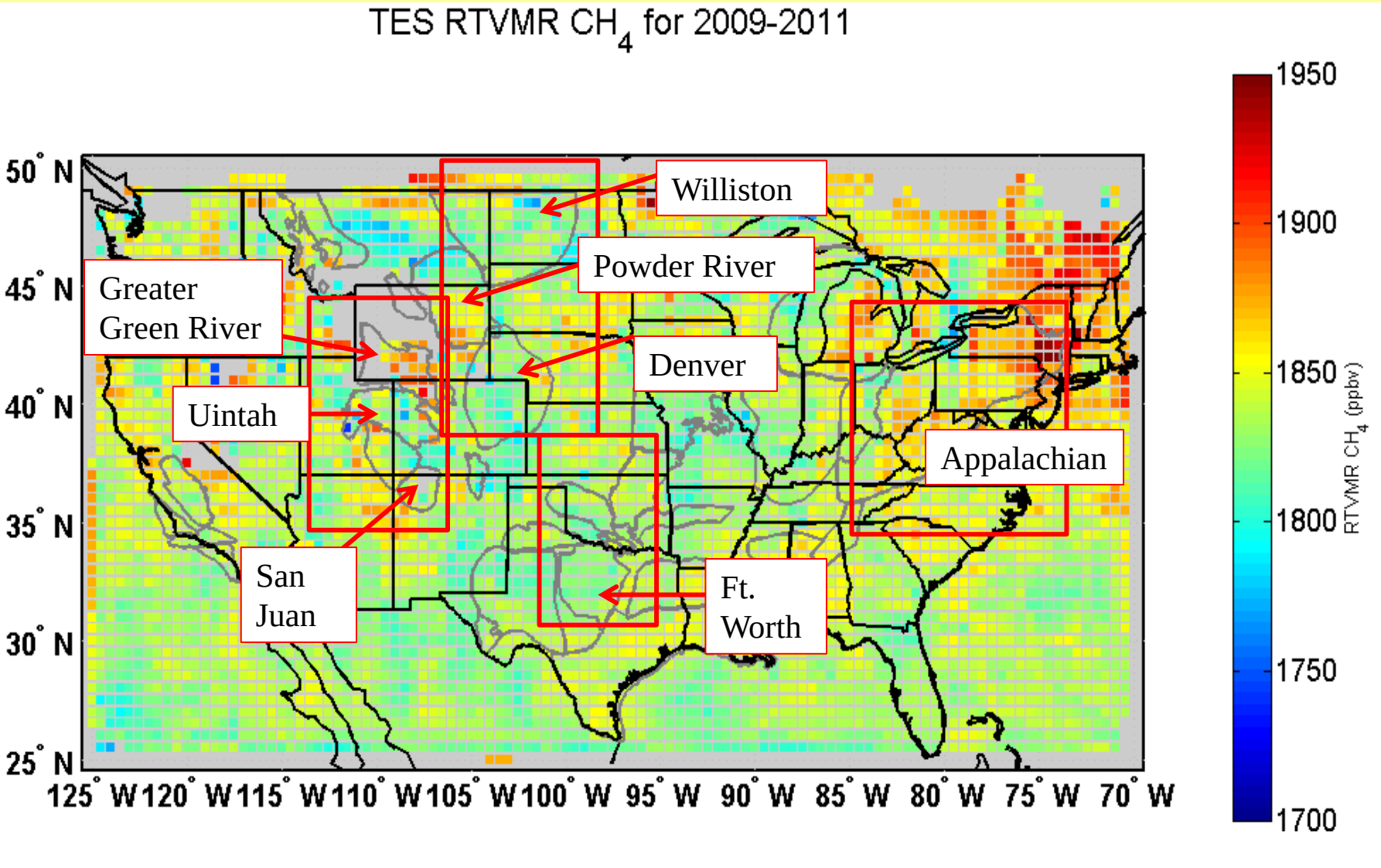






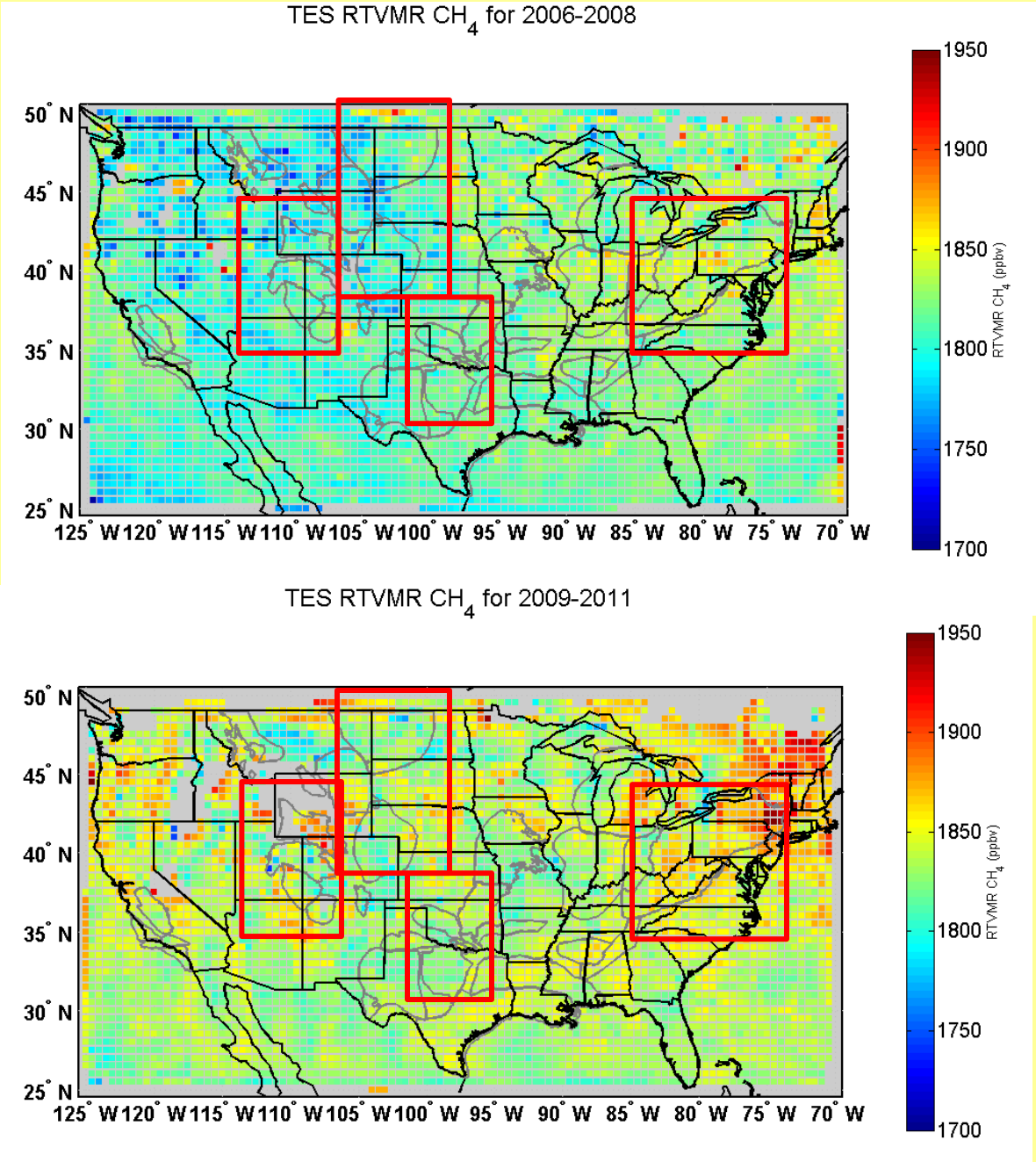
- Although TES cannot see the surface, it consistently retrieved elevated CH_4 concentrations in the mid-troposphere near Bakersfield, CA (Figure above) where oil and gas wells are concentrated.
- TES and P3B profiles show reasonable correlation above the boundary layer.

TES CH4 RTVMR over US from 2009 to 2011



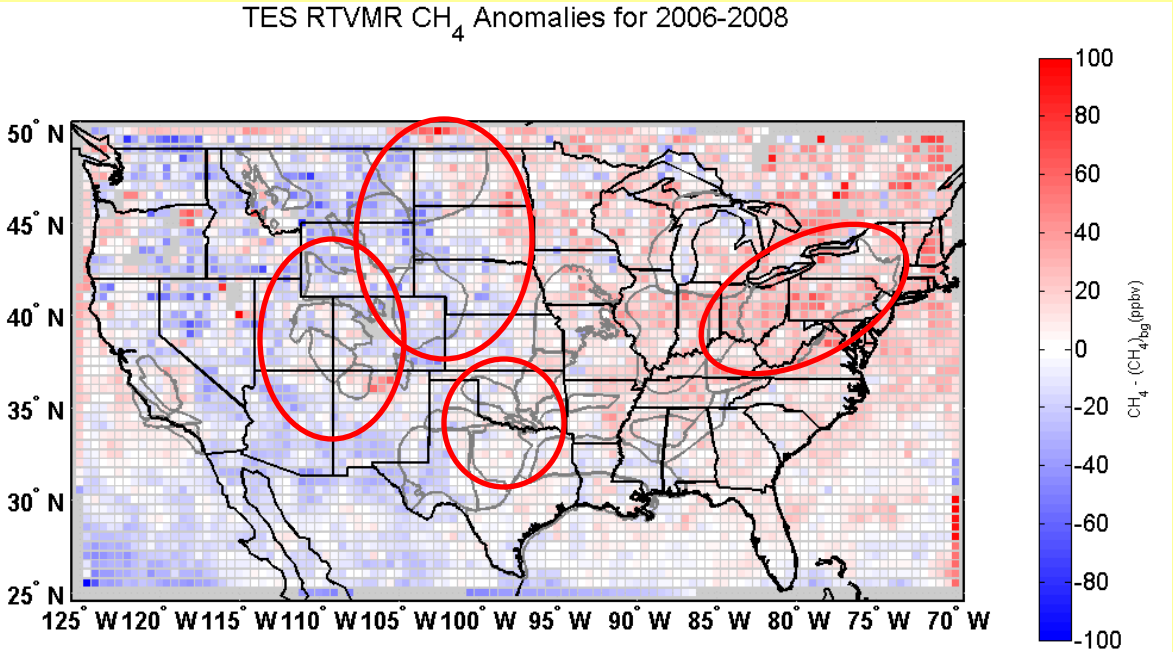
US. Basins, listed above, have active oil & natural gas extraction sites.

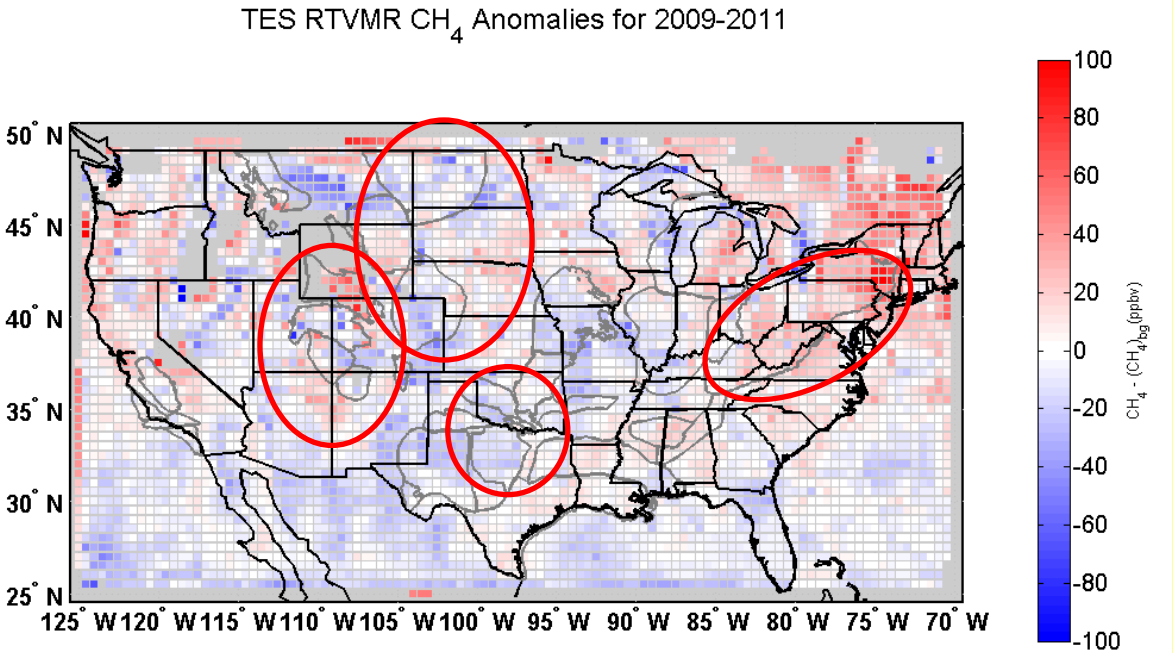
TES CH4 RTVMR over US from 2006 to 2011



- To show growth in methane and to account for the limited sampling from TES, we chose two study periods 2006-2008 and 2009-2011.
- All of the previously highlighted US Basins have enhancements in methane from the first period to the second.

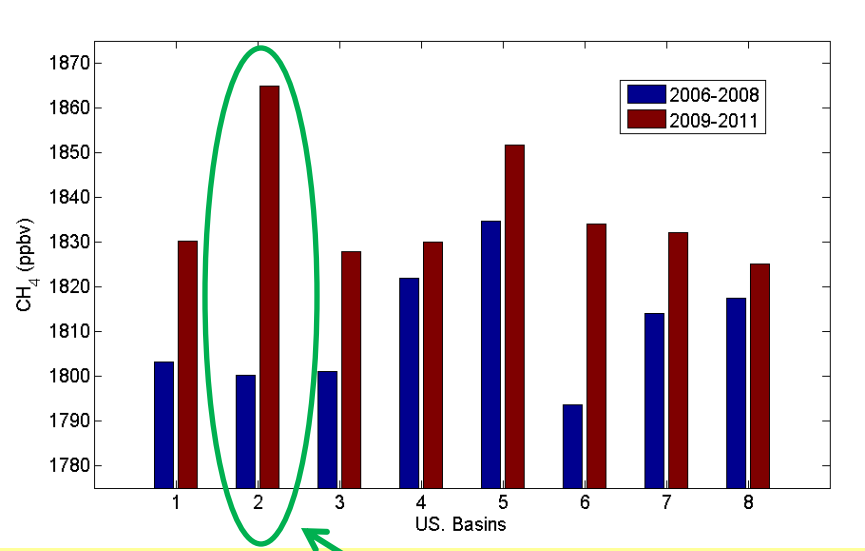
TES CH4 Anomalies over US from 2006 to 2011

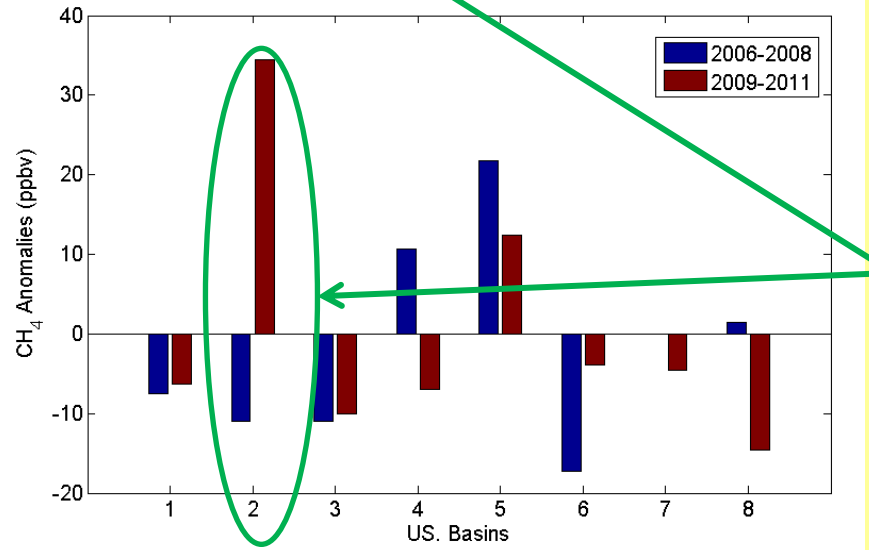


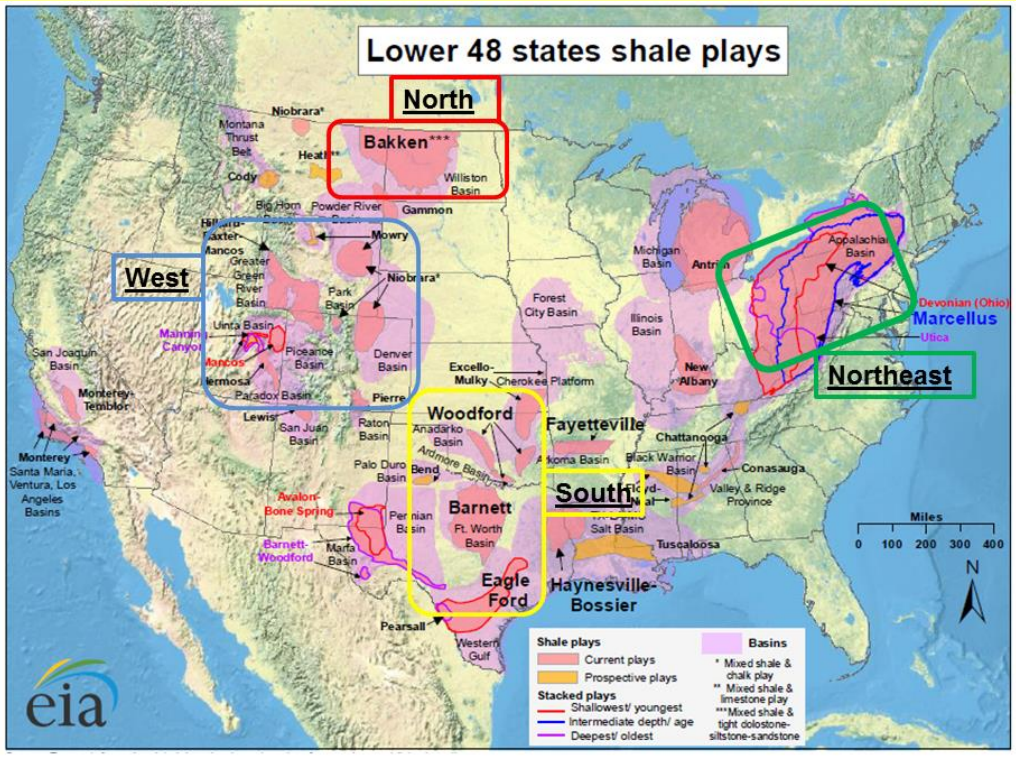


- Several basins have reduced methane anomalies (difference between concentration and background value in ppbv) from 2006-2008 to 2009-2011.
- Exceptions to that include the Greater Green River Basin where several hotspots are clearly above the background.

TES CH4 and Anomalies over US from 2006 to 2011: Statistics of the two study periods







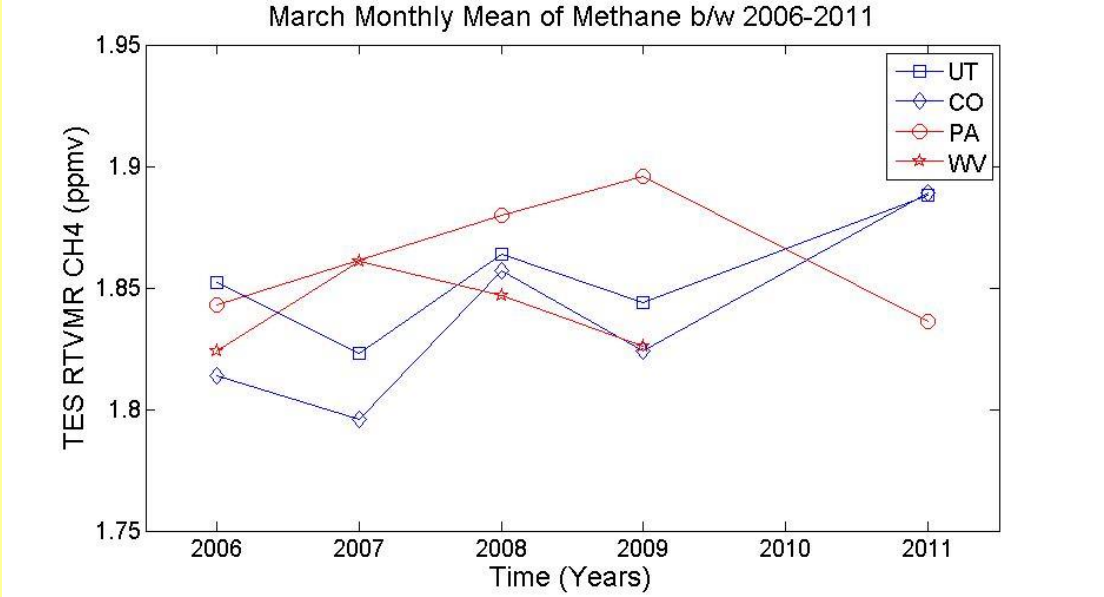
Basin with highest methane change between two time periods.

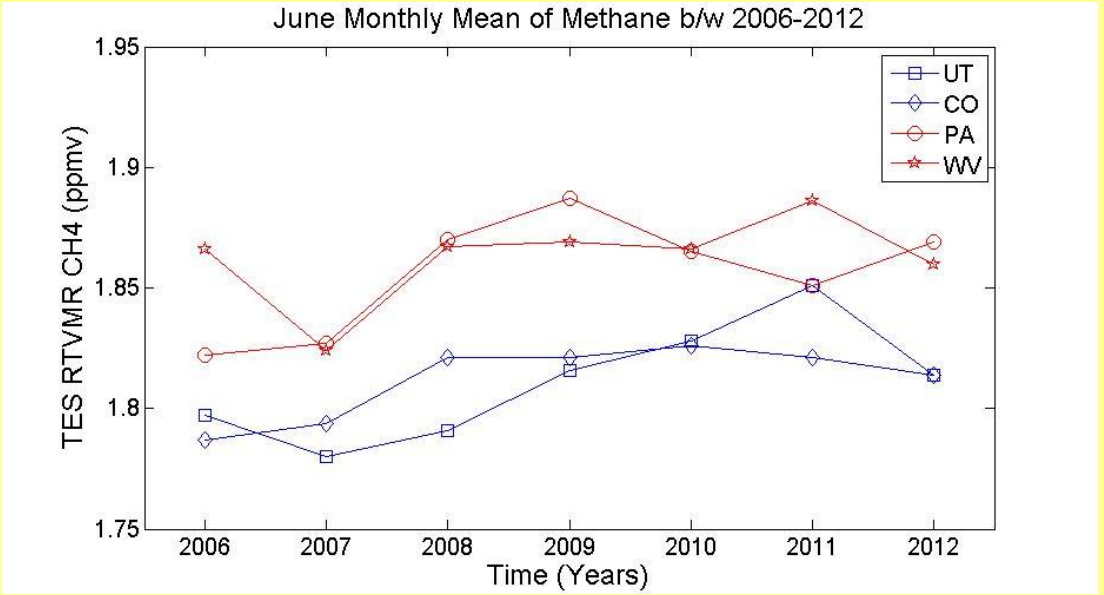
List of US. Basins

1. Williston Basin
2. Green River Basin
3. Denver Basin
4. San Juan Basin
5. Appalachian Basin
6. Powder River Basin
7. Uinta Basin
8. Ft. Worth Basin

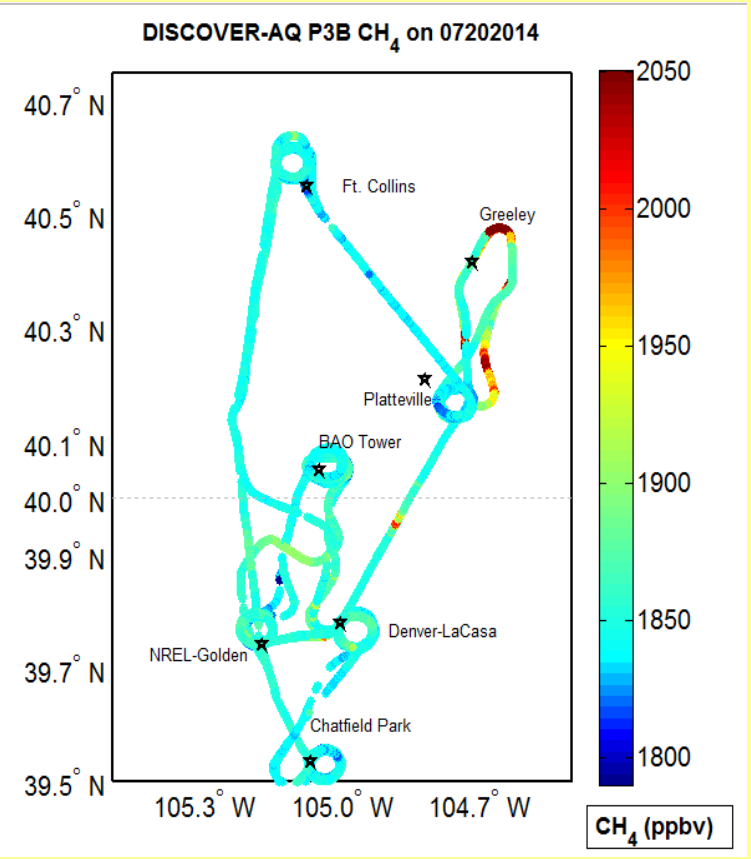
TES Monthly Mean CH4 from 2006 to 2011: Time series over Eastern and Western States

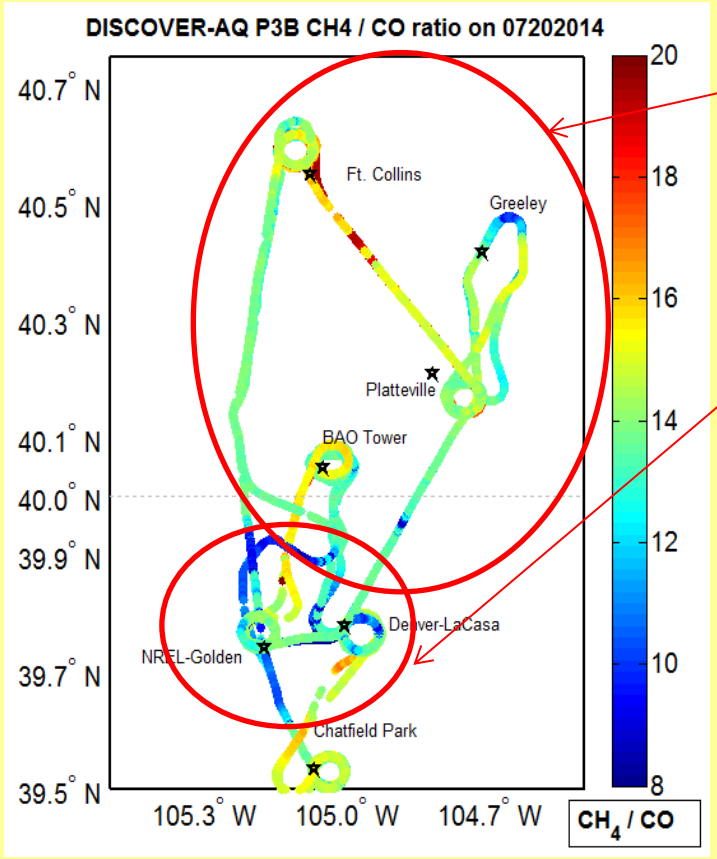
- During spring, the western states continue to have increasing CH4 burdens.
- During the summertime, methane concentrations in the free troposphere have become almost constant across the four states from 2008 onward.





Trace gas correlations near oil & gas operations





Oil & Gas Activities

Urban pollution

P3B DACOM CH4 and CO preliminary data from DAQ Colorado via Glenn Diskin.

- Next, both satellite and aircraft CH4/CO ratios will be analyzed near and downwind of oil & gas operations.
- The addition of NH3 will also identify agriculture sources of methane.

Tiger Team Project Summary

- **Progress:**
  - Past **DISCOVER-AQ campaigns in MD (2011) and CA (2013)** serve as validation for carbon gas products from the Tropospheric Emission Spectrometer (TES) and others. So far, there is good correlation between aircraft measurements and satellites.
  - Comparisons of **2006-2008 vs 2009-2011 from TES** demonstrate increasing CH_4 burdens overall with anomalies varying between regions. Carbon gas correlations and NMHC measurements will assist with source attribution in these regions.
- **Additional Team Progress:**
  - Analysis of **GOSAT CH_4** shows sensitivity to ONG basins.
  - **OMI HCHO** oversampling can identify regions with NMVOC emissions from ONG operations.
  - Preliminary comparisons of **OMI NO_2** and modeled emissions inventories show reasonable spatial correlation in urban areas and some ONG basins.
- **Recent Activities: July-August FRAPPE/DISCOVER-AQ mission in Denver/Front Range targeted O&G emissions and Air Quality impacts using extensive airborne, ground-based, and mobile van measurements.**
  - **PSU NATIVE trailer and *PI Anne Thompson*** was at Platteville, CO conducting in situ trace gas/hydrocarbon measurements and launching ozonesondes.
  - **UW-Madison SPARC trailer (*B. Pierce*)** was at NOAA BAO tower (Erie, CO) conducting remote trace gas and aerosol measurements and launching radiosondes.
  - **NCAR (*D. Edwards & G. Pfister*)** is the Team's liaison to FRAPPE and its measurements.
- **Acknowledgements: NASA AQAST, TES Science Team, and DISCOVER-AQ Science Team.**