LA-UR-15-25190
Approved for public release; distribution is unlimited.

Title: Multi-scale Atmospheric Modeling of Green House Gas Dispersion in Complex Terrain: Atmospheric Methane at Four Corners

Author(s): Costigan, Keeley Rochelle
Dubey, Manvendra Krishna

Intended for: Report

Issued: 2015-07-10

W13_ghgas Institutional Computing Annual Report

Multi-scale Atmospheric Modeling of Green House Gas Dispersion in Complex Terrain: Atmospheric Methane at Four Corners

June 2015

Keeley R. Costigan and Manvendra Dubey

Scientific and Technical Impact:

Methane (CH_4) is a potent greenhouse gas and ozone precursor. Quantifying methane emissions is critical for recognizing and mitigating changes to climate and air quality. However, identifying sources and understanding the CH_4 budget has been difficult. Under a previous LDRD DR project, LANL had established a test facility for monitoring CO_2 emissions from two large power plants in the Four Corners region of New Mexico, Colorado, Utah, and Arizona. The facility included both in-situ measurements and a remote sensing, ground-based Fourier Transform Spectrometer (FTS). These measurements were combined with satellite observations and numerical modeling of CO_2 and co-emitted species to study the emission, dispersion, and transport of CO_2, in the Four Corners region. Methane was among the other species sampled at the facility and we were intrigued that the concentrations were higher than expected in this rural location with relatively sparse vegetation. The CH_4 concentrations also showed a diurnal pattern that demonstrated a correlation with the local winds.

At the same time, collaborators at the University of Michigan and NASA's Jet Propulsion Laboratory had noticed a very strong CH_4 signature over the Four Corners region in satellite measurements. Our corroborating measurements were supporting evidence that the methane hot spot, which had consistently appeared over a number of years in the satellite measurements, was real. It is possible that the higher than expected methane concentrations are related to the natural gas and coal industries in the area. The w13_ghgas project provided the computational resources needed to further investigate this hot spot with simulations of methane emissions, dispersion, and transport in the Four Corners region and to determine what emissions rate is consistent with our atmospheric observations.

An unprecedented set of regional atmospheric simulations were carried out with the Weather Research and Forecasting Chemical (WRF-Chem) model for six separate six-day periods. The simulations were started two months apart, which was designed to cover the full range of seasonal dynamics. Simulations were performed of 2012 to match ground-based observations (which began in 2011), enabling both rigorous assessment of representativeness and direct simulation comparison with ground based observations. Telescoping nested grids allowed for

horizontal grid spacing of 600 m, in order to capture topographically influenced winds in the surrounding complex terrain. We performed forward model simulations of expected CH_4 enhancements (the hourly averaged value above the afternoon minimum) from the inventoried emissions sources in EDGAR v4.2.

Comparisons of the WRF-Chem simulated days in 2012 with FTS data from the same days and for all of 2012 demonstrated the robustness of the model results. Both measurements and simulations showed greater concentrations when winds were from an east-southeasterly direction. Further comparison of the model results with satellite observations showed that the model captures the observed spatial structure, and a significant linear relationship exists between model and observations. The enhanced methane concentrations were observed and modeled in all seasons. However, the model simulations, using the EDGAR emissions inventory, consistently predicted lower, by a factor of ~3.5, CH_4 enhancements than were observed in both the FTS and satellite measurements. Based on our finding of a large and consistent regional atmospheric CH_4 signal from 2003 onwards, we concluded that long-established fossil-fuel extraction in the Four Corners region likely has larger CH_4 emissions, and subsequent greenhouse gas footprint, than accounted for in current inventories. This study was published in Kort et al. (2014) and the accompanying slides include figures from the study.

Publications:

E.A. Kort, C. Frankenberg, K.R. Costigan, R. Lindenmaier, M.K. Dubey, D. Wunch, 2014: Four Corners: The Largest US Methane Anomaly Viewed from Space. *Geophys. Res. Lett., 41, 6898–6903, doi:10.1002/2014GL061503.*

Costigan, K., R. Lindenmaier, and M.K. Dubey, 2014: Modeling and Measurements of Atmospheric Methane at Four Corners, NM, American Geophysical Union Fall Meeting, 15-19 Dec 2014, San Francisco, CA.

Financial Impact:

The simulations carried out under this project have recently inspired us to submit a proposal to NASA. This proposal outlines a > $4M/yr project to develop a green house gas monitoring strategy that incorporates remote sensing measurements and modeling capabilities.

Los Alamos
NATIONAL LABORATORY
EST. 1943

Multi-scale Atmospheric Modeling of Green House Gas Dispersion in Complex Terrain: Atmospheric Methane at Four Corners

Keeley Costigan and Manvendra Dubey

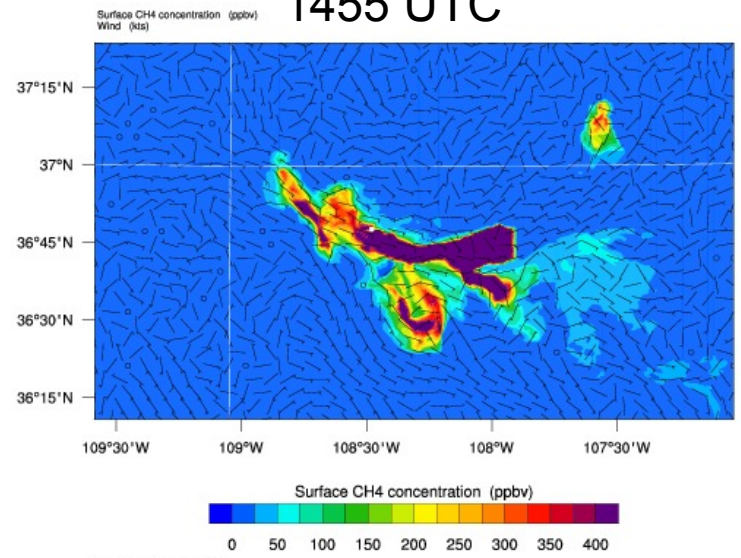
Earth and Environmental Sciences Division

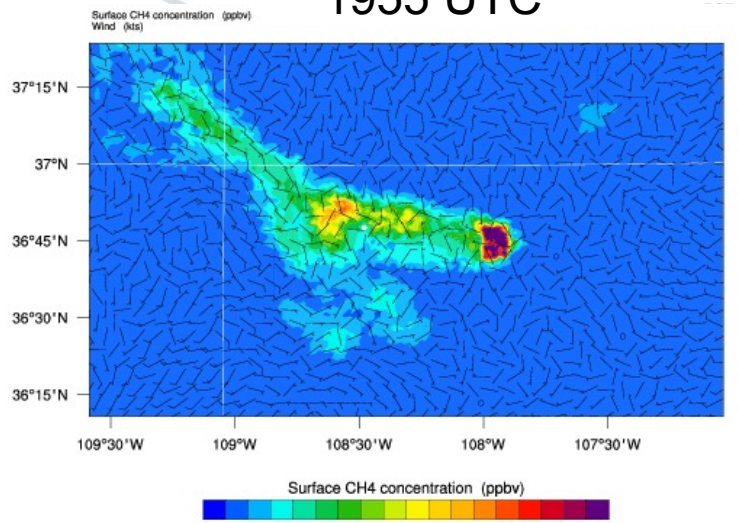
June 2015

Horizontal Plots of Simulated Domain 4 Surface and Column Integrated CH_4 Enhancements

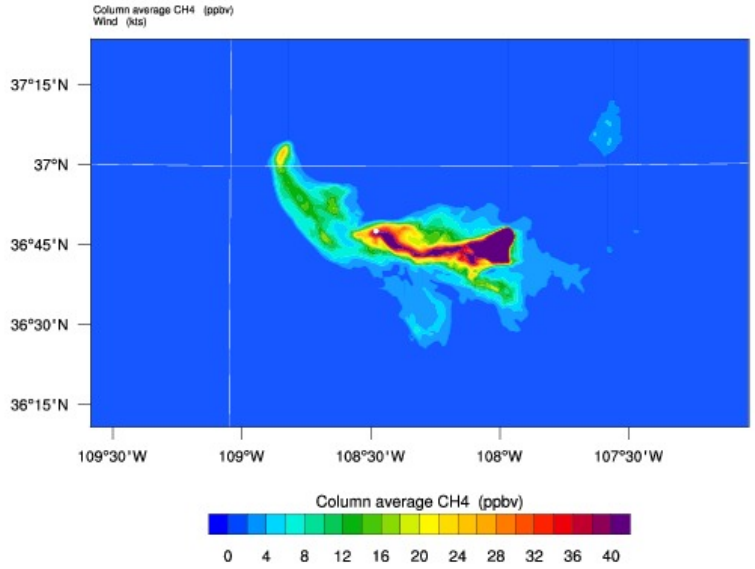
1455 UTC

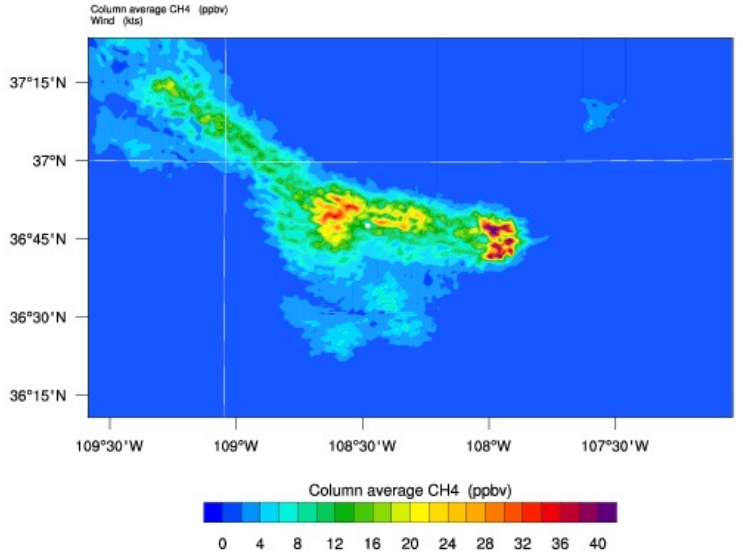
1955 UTC





Surface

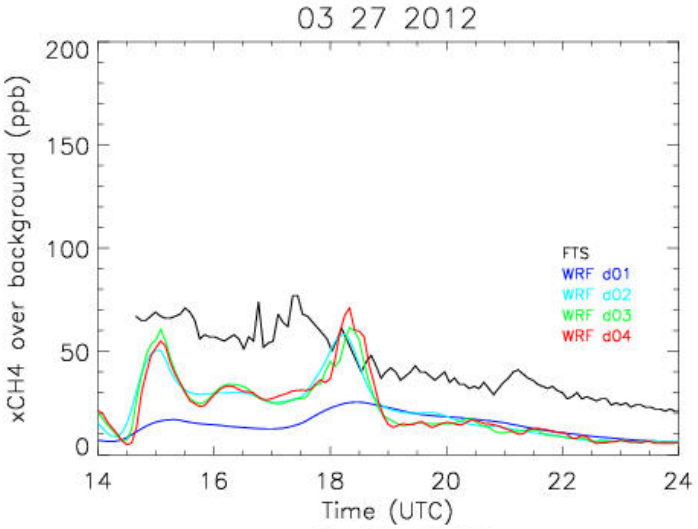


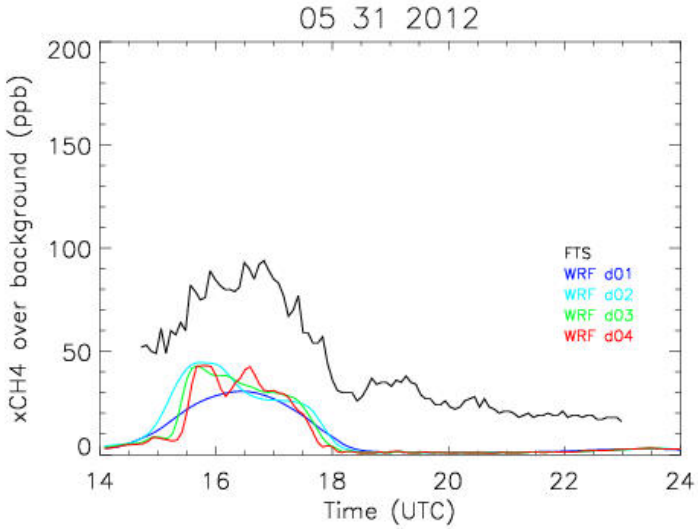


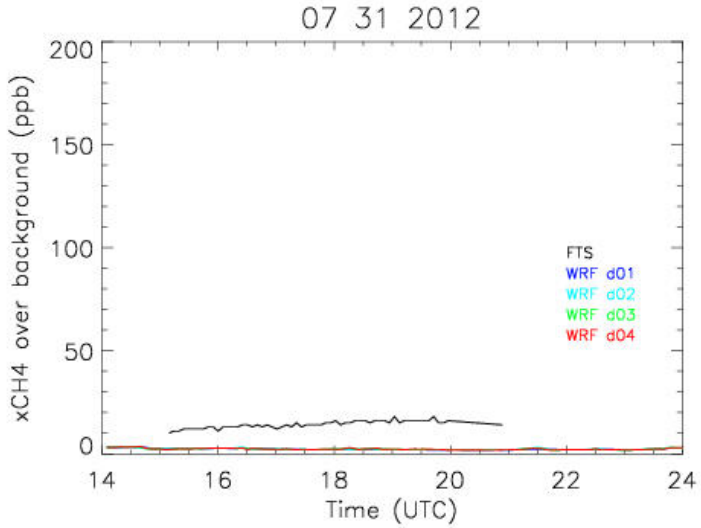
Column

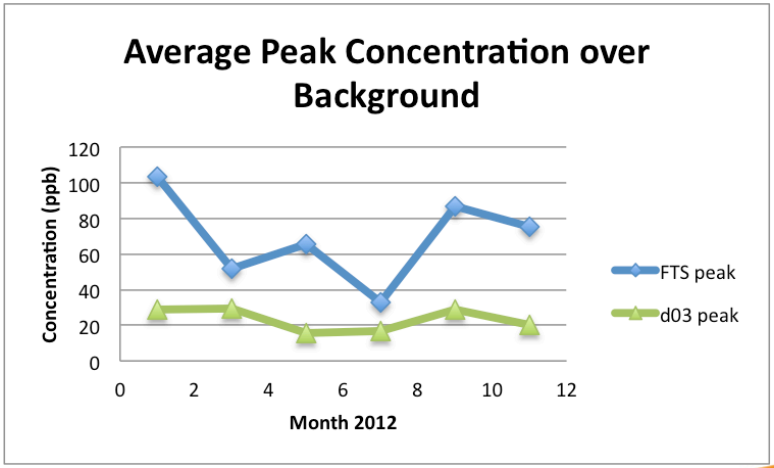
UNCLA

FTS and Simulated CH_4 Enhancement Diurnal Cycle for Three Example Days and Averaged



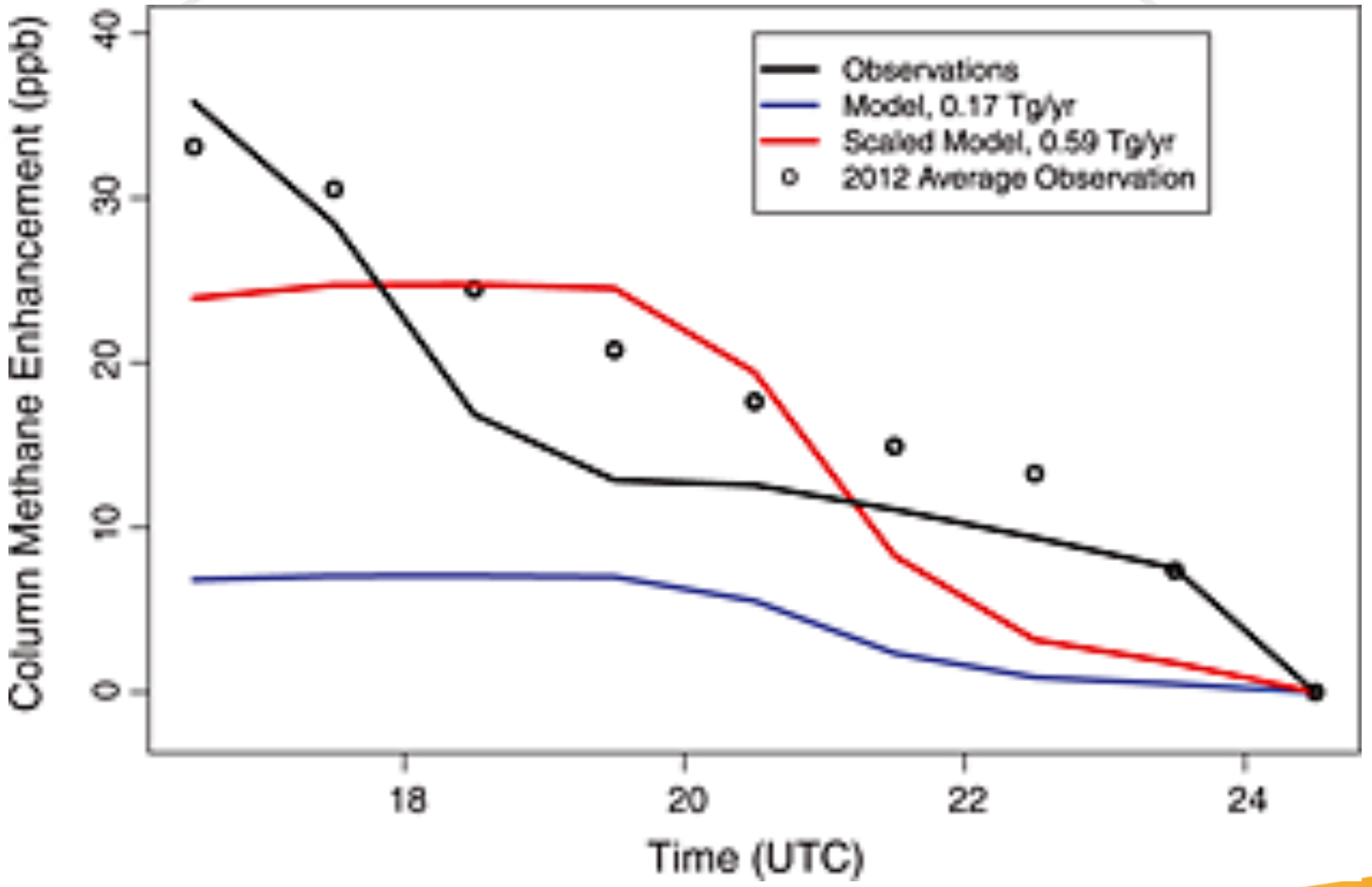




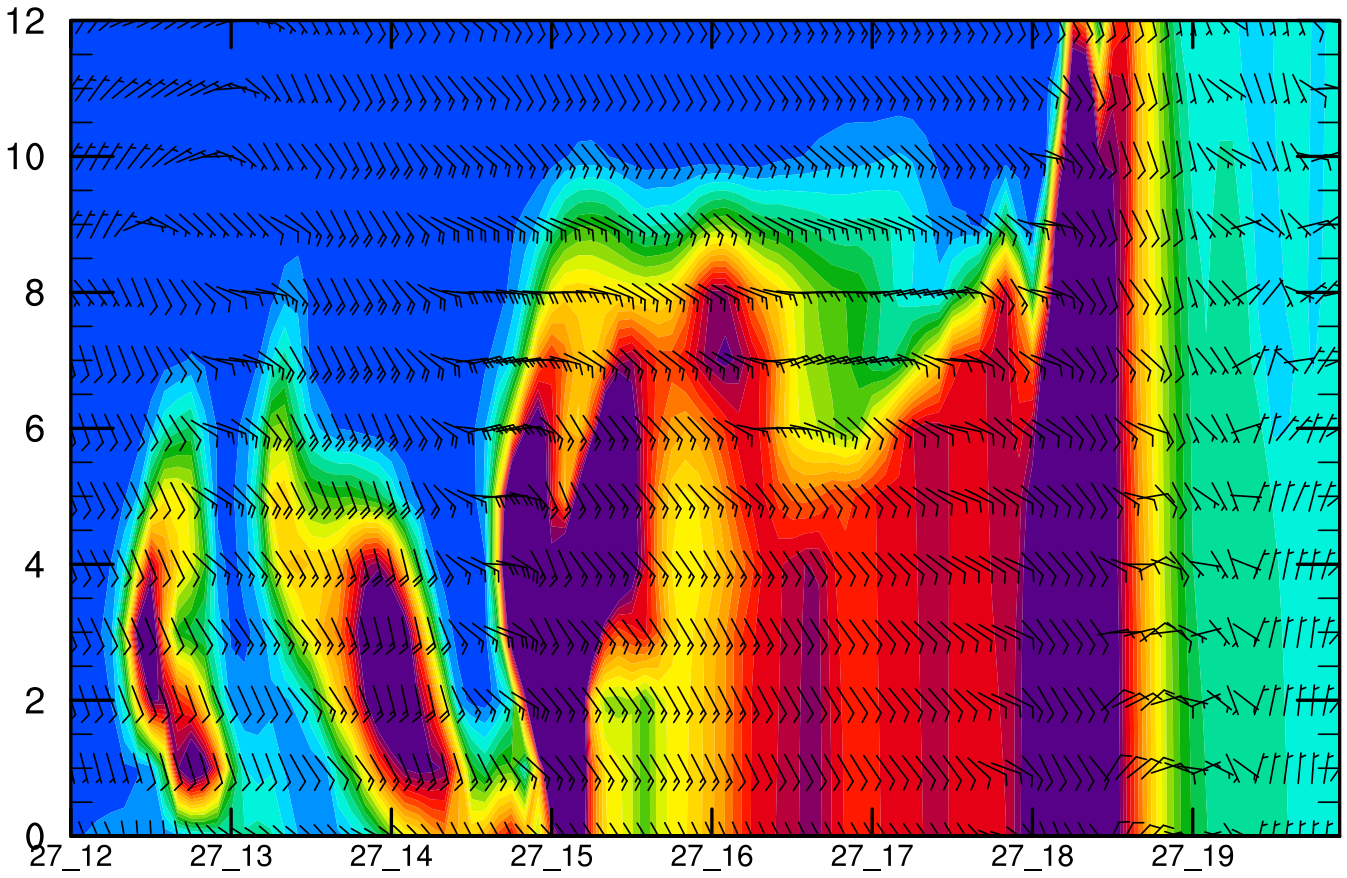


UNCLASSIFIED

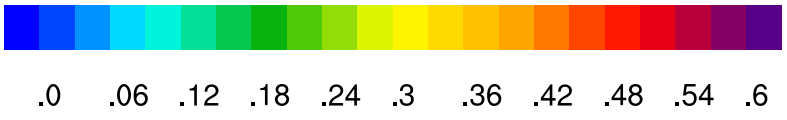
FTS Observed Enhancement for Simulated Days (black) and 2012 Average (circles) vs. Modeled Enhancement with EDGAR Emissions (blue) and Scaled by 3.5 (red)



Simulated Height (vertical axis) vs. Time (horizontal axis, from 1200-2000 UTC) of CH_4 and Winds for 27 March 2012



27 Mar 2012

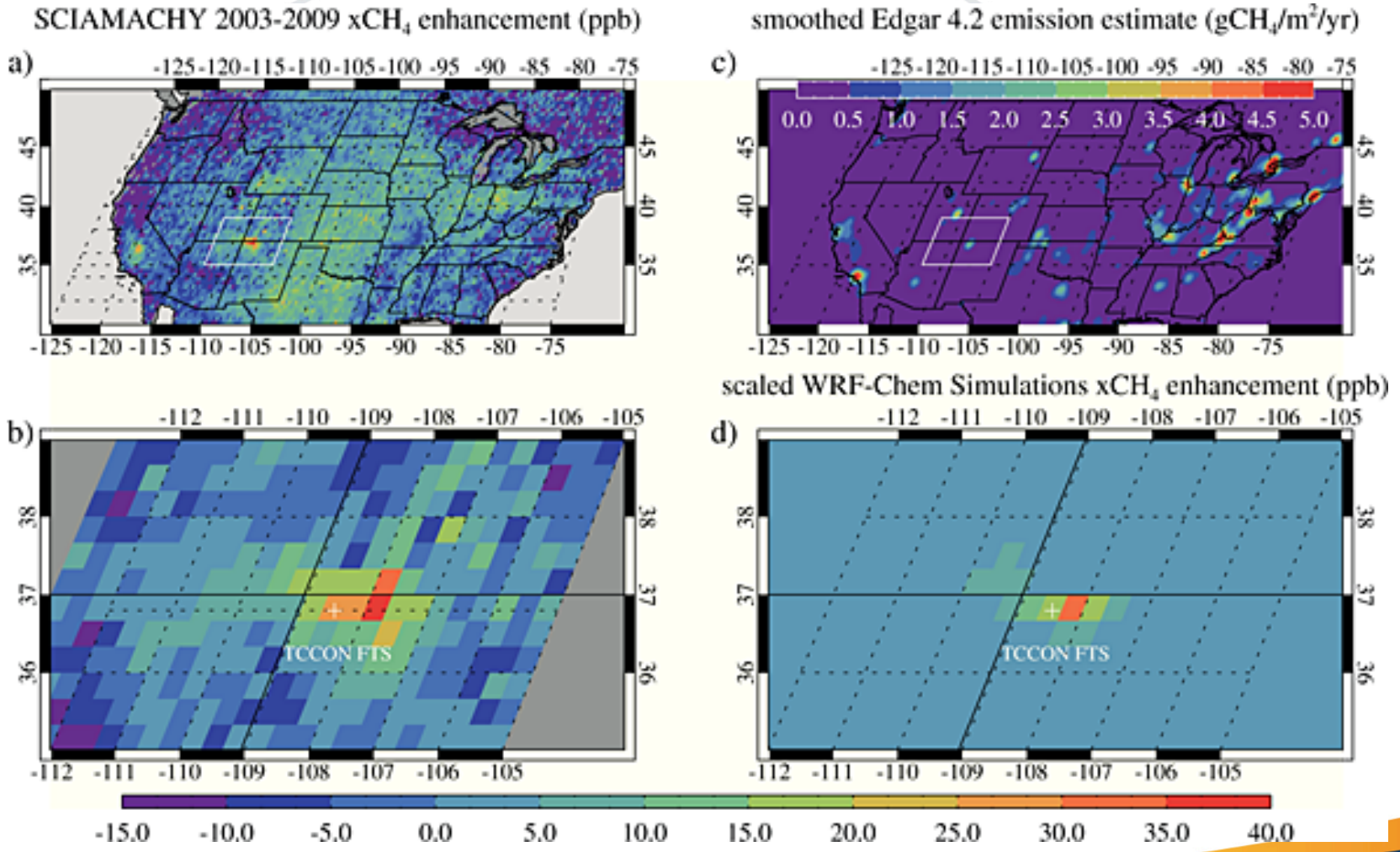


(ppm)

Wind barbs show the horizontal direction and speed (full barb = 3.3 m/s).

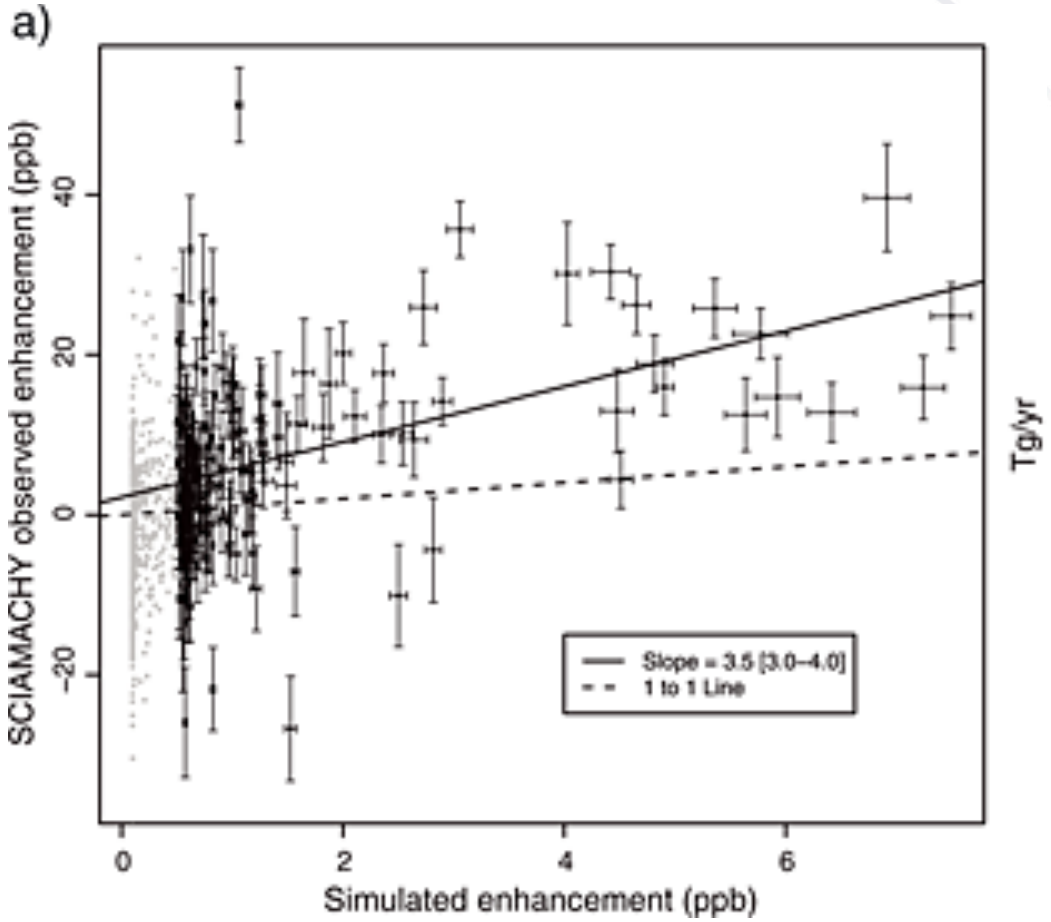
Shading indicates CH_4 excess concentration over background.

Column Methane Anomalies in Satellite Measurements (left, top and bottom), EDGAR Emissions (right top), and Simulations (right bottom)



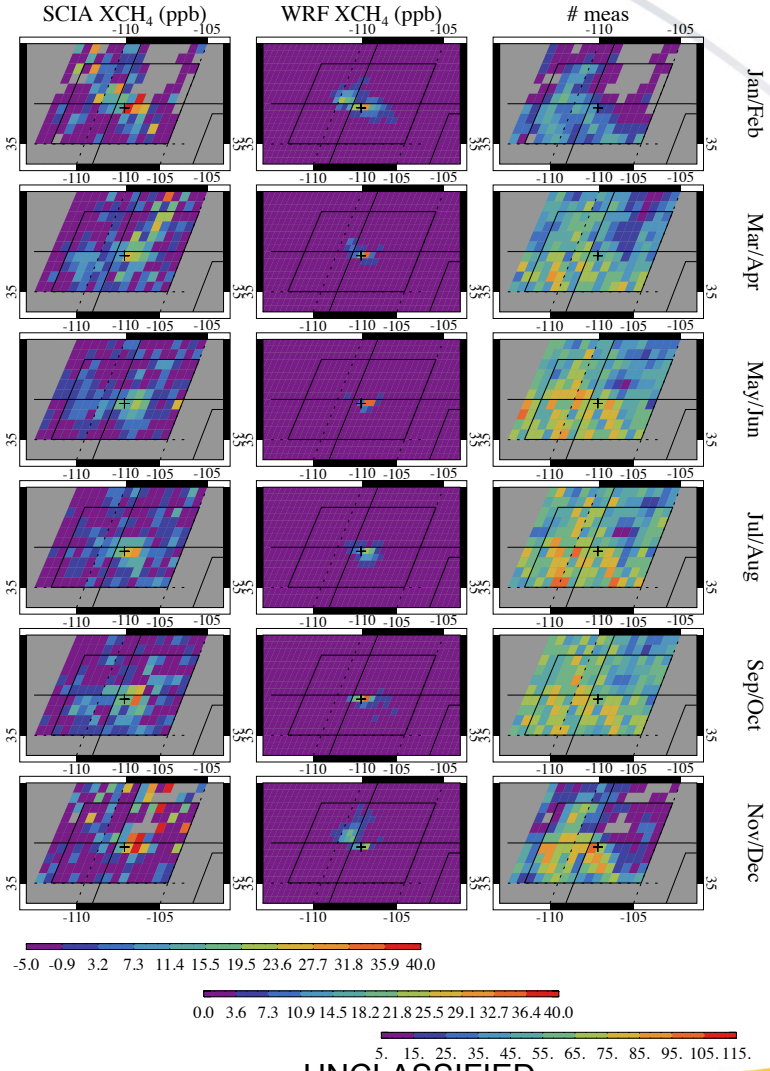
UNCLASSIFIED

FTS Observed vs. Simulated CH_4 Enhancement



UNCLASSIFIED

Satellite and Model Enhancements for Six Different Simulations



UNCLASSIFIED