# High resolution inverse modeling of methane sources in North America using satellite observations (SCIAMACHY, TES, GOSAT)

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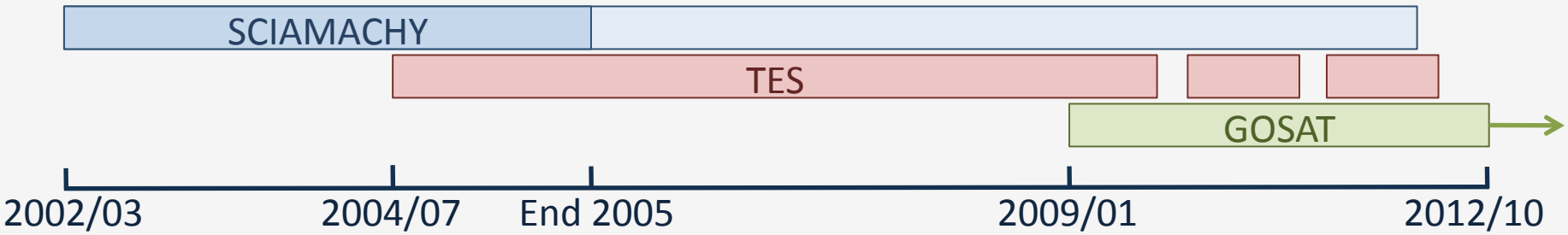
# Observing North America Methane from Space and Aircraft




SCIAMACHY

GOSAT

- NIR (~1.6 µm)
- column average
- day only
- few ocean obs

TES

- TIR (~7.6-8.5 µm)
- free troposphere
- any time of day
- any surface cover

INTEX-A

July – Aug 2004

Not yet used for $CH_4$ sources

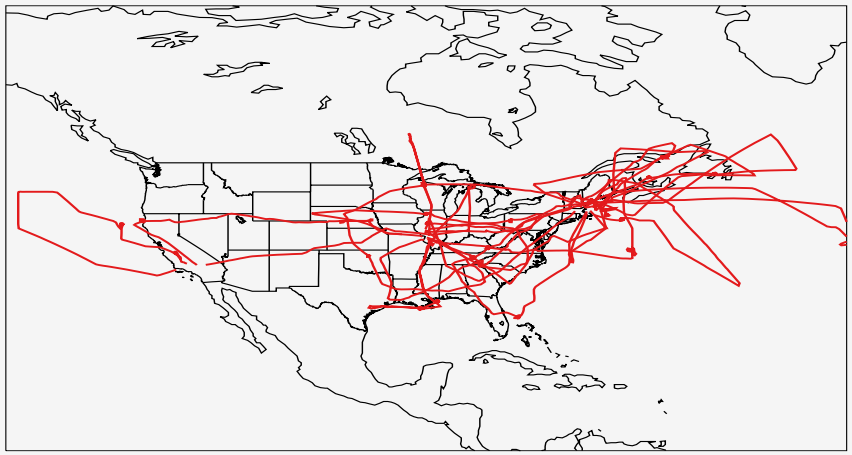
HIPPO 1-5

Jan 2009 – Sep 2011

North America

- Bottom-up inventories inconsistent with obs
- GEOS-Chem nested grid (0.5° x 0.67°)

INTEX-A Fligthpaths



Recent emissions of particular interest

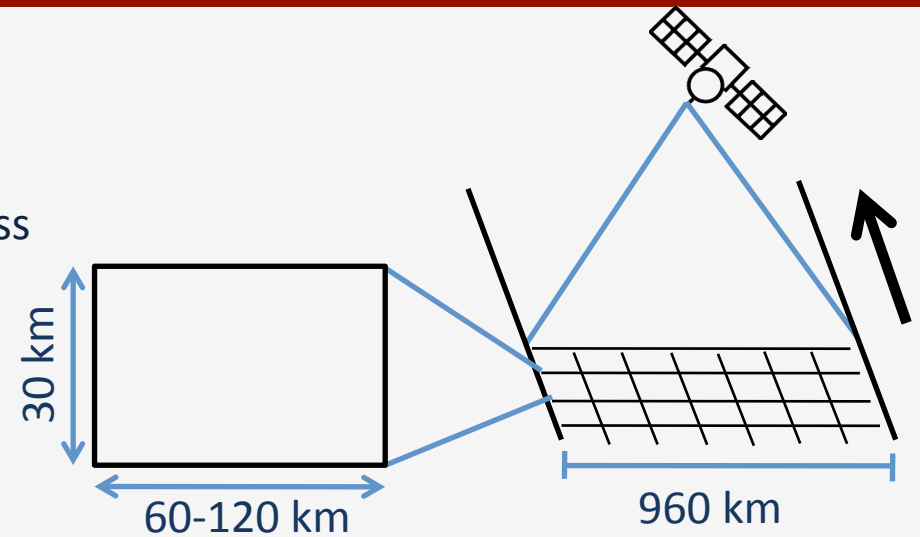
- Athabasca oil sands
- US shale gas production

**SCIAMACHY inversion methods will be applied to GOSAT + TES inversion in recent years.**

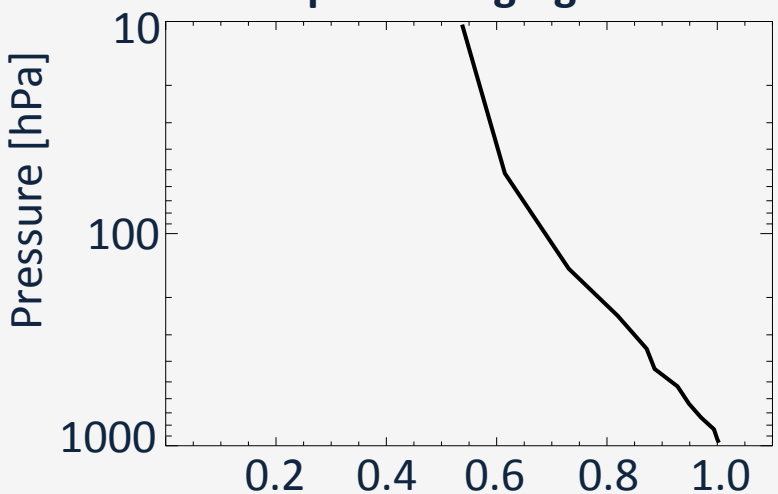
# SCIAMACHY Methane 2003 – 2005

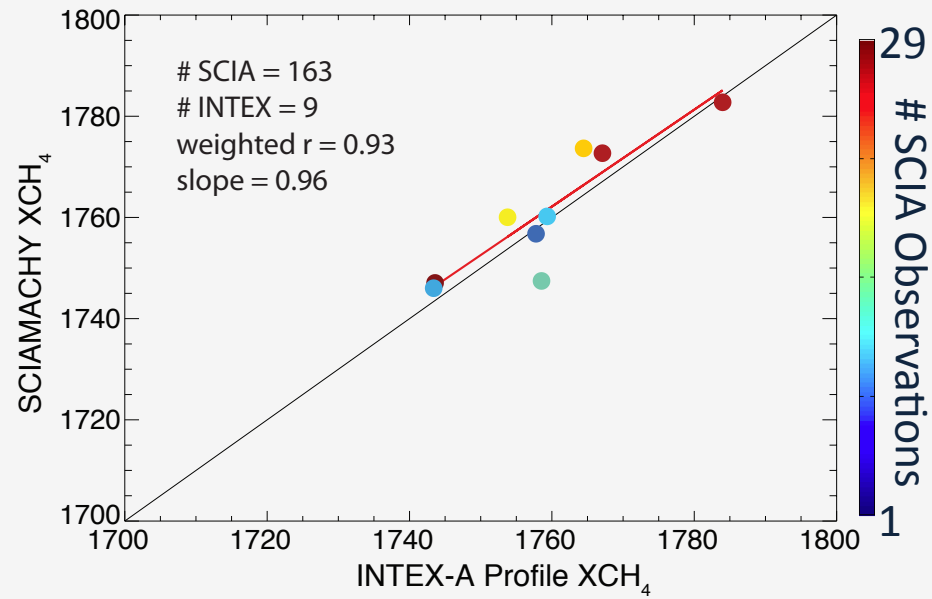
**SCIAMACHY Summary**

- Solar backscatter
- Sun-synchronous orbit, ~10:45am overpass
- Methane retrieval 1.630 – 1.670µm
- 30 x 60 km horizontal resolution
- global coverage achieved every 6 days
- Validation using INTEX-A profiles




**Sample Averaging Kernel**



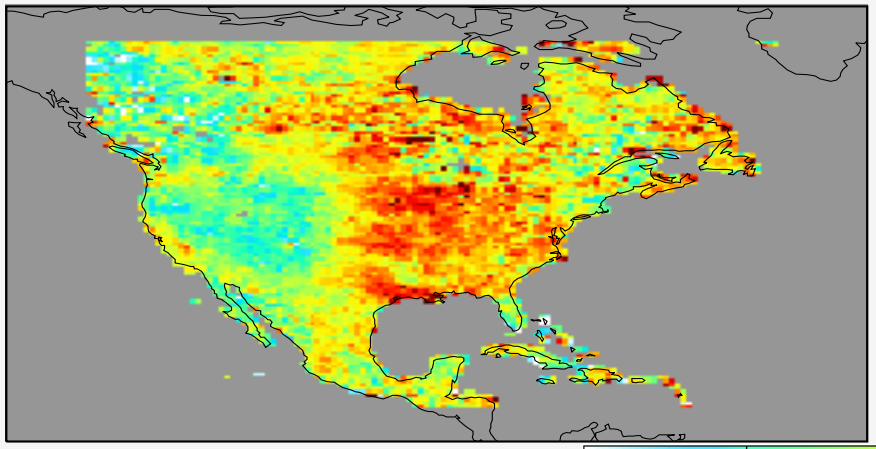




**SCIAMACHY is validated and ready for assimilation into adjoint inverse modeling framework.**

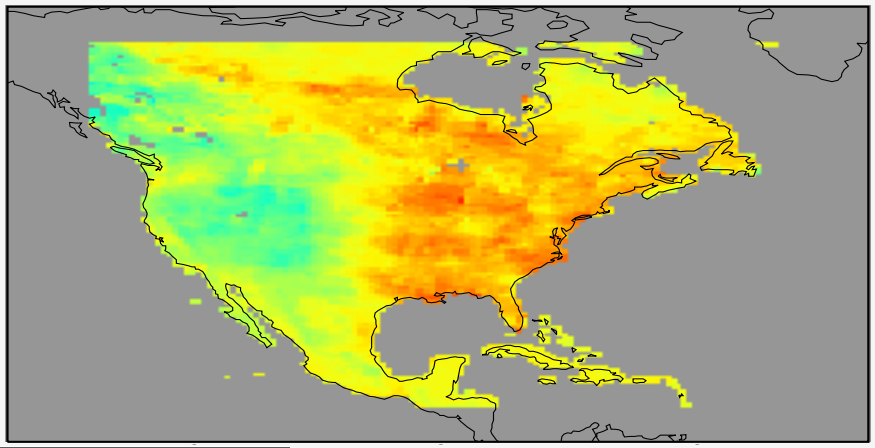
# Model vs. Observations: A priori

Assimilation period: 1 July – 14 August 2004

SCIA $XCH_4$

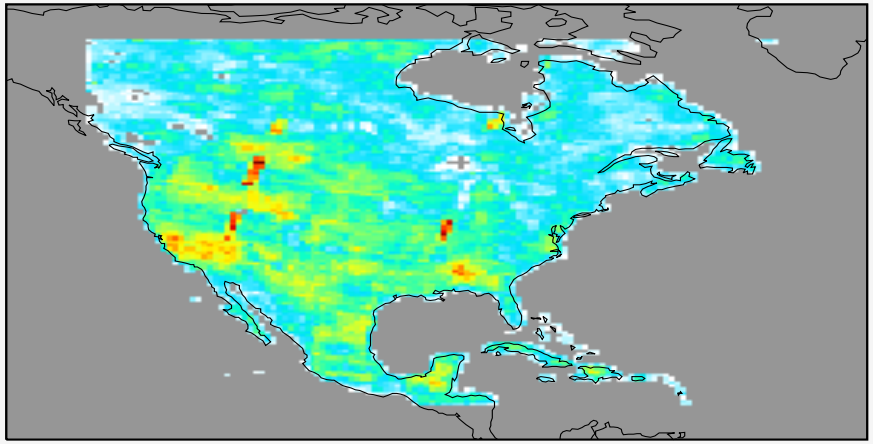


Model $XCH_4$



1700 ppb 1800

# Observations



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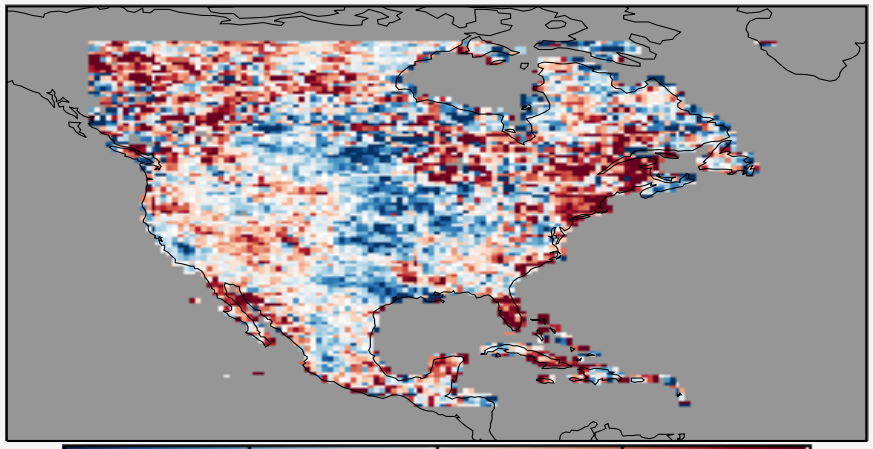
Model – SCIA $XCH_4$



-20 ppb 20

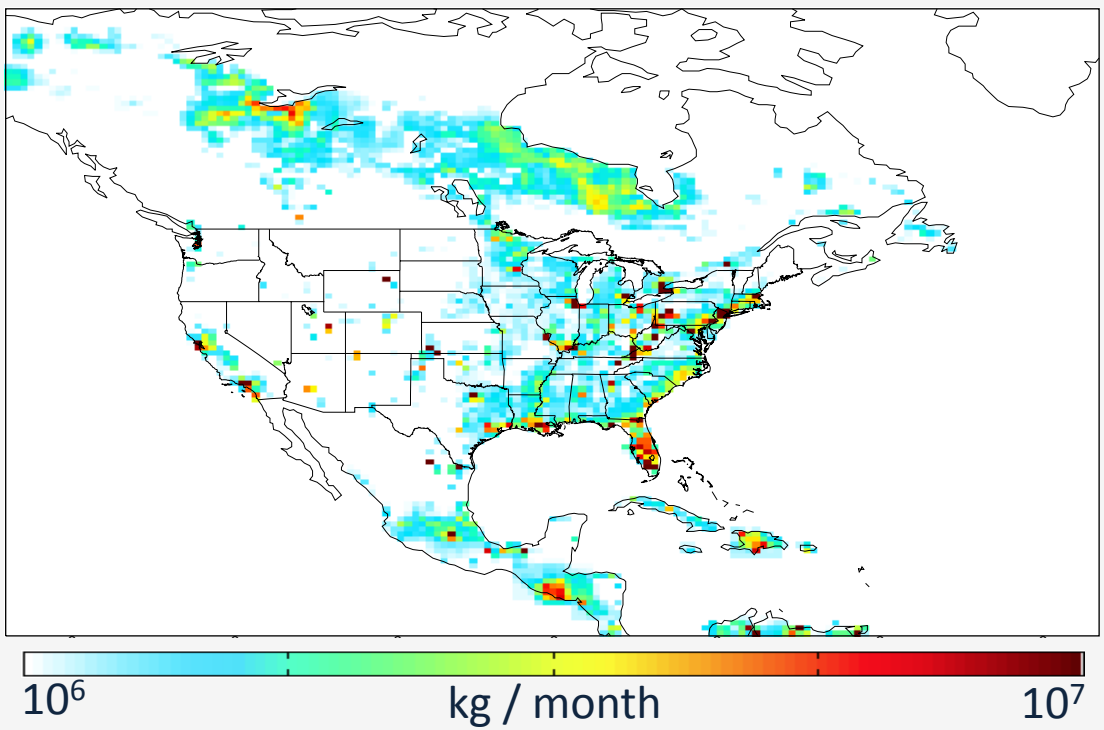
**Model – observation differences suggest corrections to be achieved through inverse modeling.**

# Nested Adjoint (4D-Var) Inversion

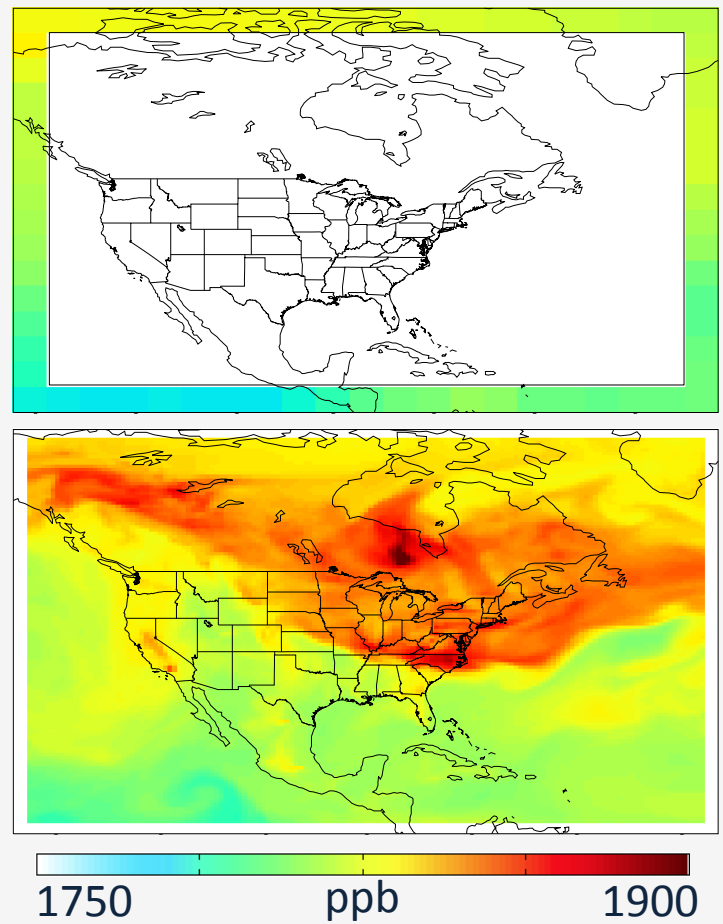
Model vs. observation differences are formally attributed to uncertainties in:

- Emissions
- Boundary Conditions
- Initial Conditions

GEOS-Chem emissions July – August 2004




Boundary conditions (top) and initial conditions (bottom) of GEOS-Chem high resolution domain

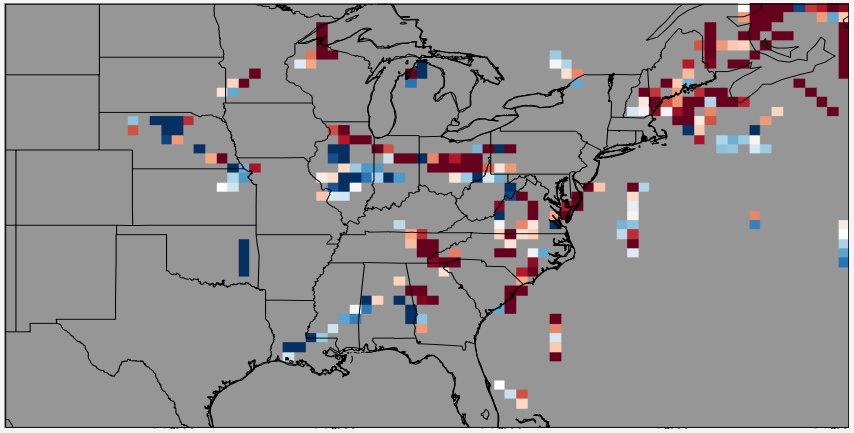



**Simultaneously optimize nested boundary conditions, initial conditions, and emissions.**

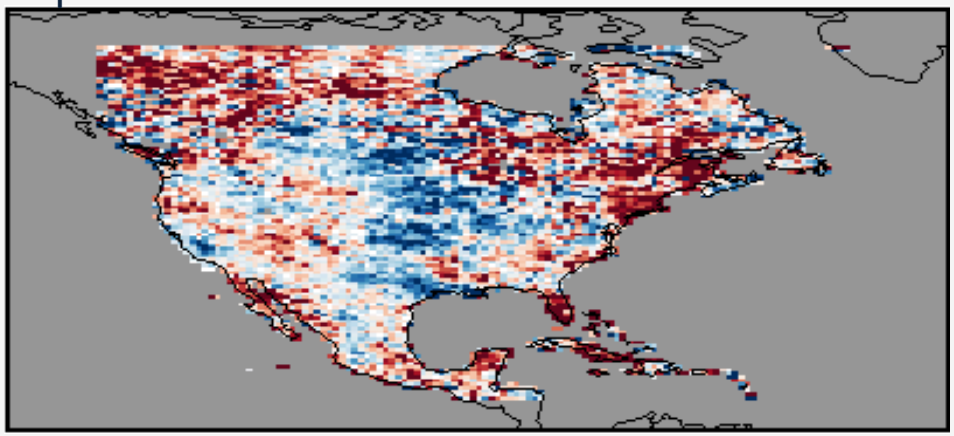
**BC optimization solves IC problem and effectively corrects for model errors in OH.**

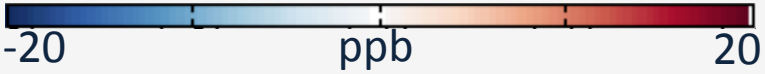
# Nested Adjoint Inversion – Preliminary Results

GEOS-Chem – INTEX-A difference



A priori GEOS-Chem – SCIAMACHY difference





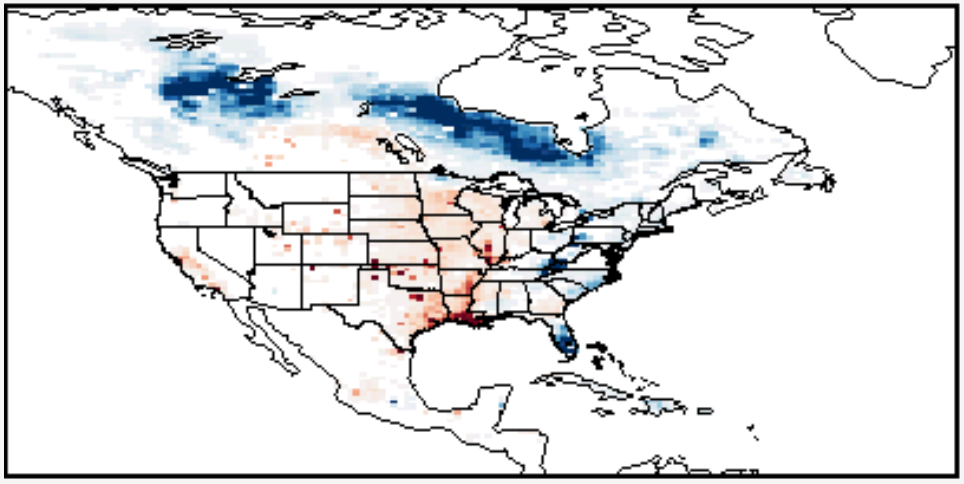

Prior emissions:

- too low: natural gas, livestock
- too high: natural wetlands, coal mining

Future Work:

- Dimensionality reduction of emissions through hierarchical clustering.
- Improve boundary conditions using independent data.

Optimized Emission Scaling Factors



**Differences consistent with INTEX-A data. Need to refine inversion methodology.**

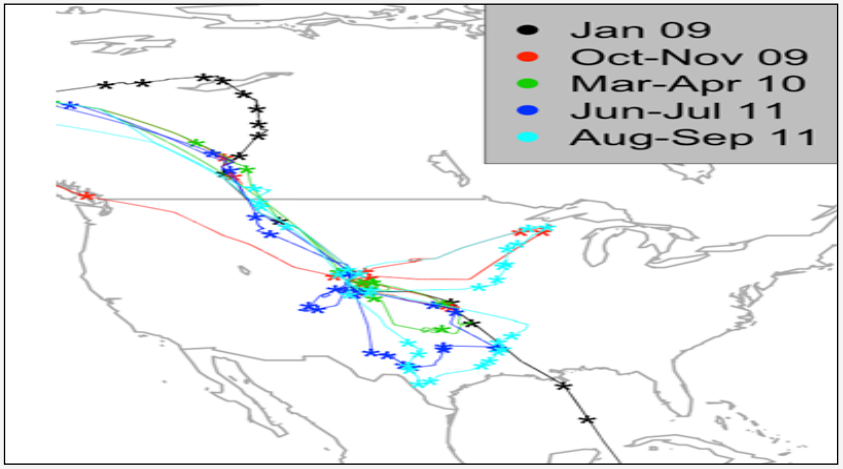
# GOSAT and TES Inversion – 2009 - 2011

GOSAT $XCH_4$
- $CO_2$ proxy method
- NIR (sensitive to total column)

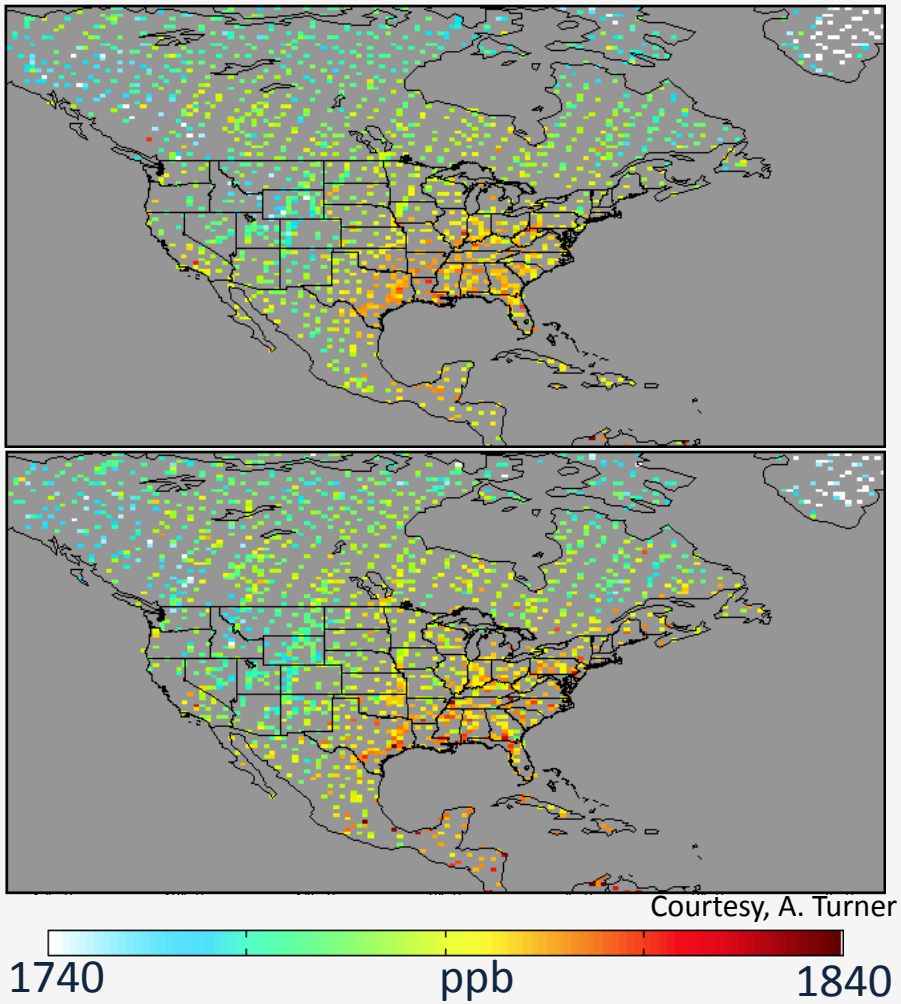
TES $CH_4$
- Extensively validated
- TIR (sensitive to free troposphere)
- Obs at night, over ocean (good for BCs)

Ground Based and aircraft observations
- HIPPO, NOAA, TCCON

Aircraft flightpaths from HIPPO




GOSAT $XCH_4$ 2010
MAM (top) and JJA (bottom)




Courtesy, A. Turner

**TES and GOSAT provide complementary vertical information.**