New insight into renewed methane increase: constraints by long-term evolution of ethane interhemispheric gradients

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INSTITUTE OF METEOROLOGY AND CLIMATE RESEARCH, ATMOSPHERIC ENVIRONMENTAL RESEARCH, IMK-IFU
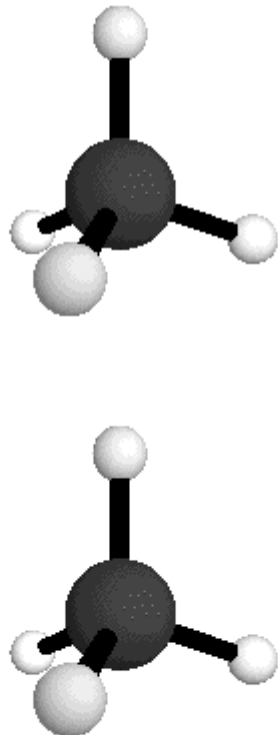REGIONAL CLIMATE SYSTEMS – Atmospheric Variability and Trends

KIT-Campus Alpin
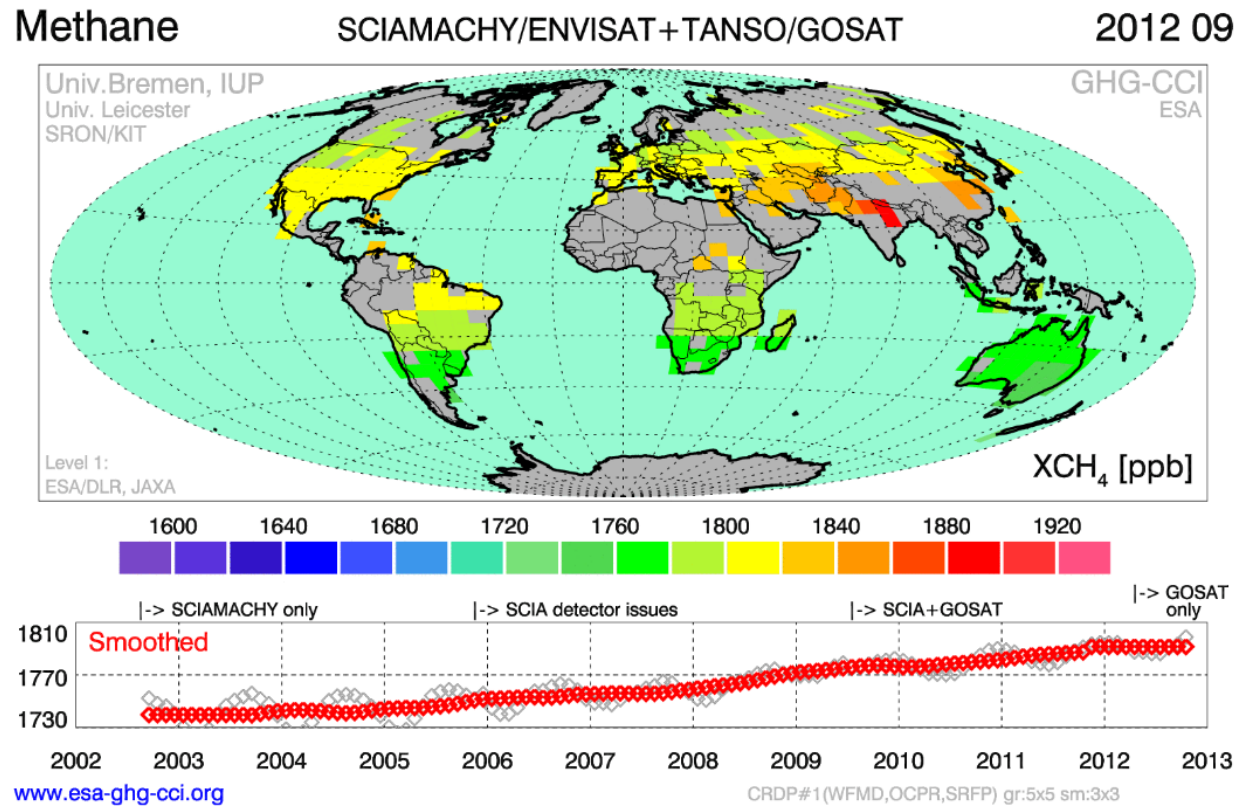IMK-IFU: Atmospheric Environmental Research

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Motivation – why look at methane?

IR-active vibrations

Long-term increase

www2.ess.ucla.edu

Methane sources – US shale gas revolution

US NATURAL-GAS PRODUCTION
Historical gas data and forecast from the EIA.

- Shale gas, other plays
- Shale gas, big four plays
- Alaska
- other than shale (including Alaska)
- conventional (excluding Alaska)
- not available

Shale gas has driven US production to record levels.

PROJECTED ▶

Inman, Nature, 2014

Bakken
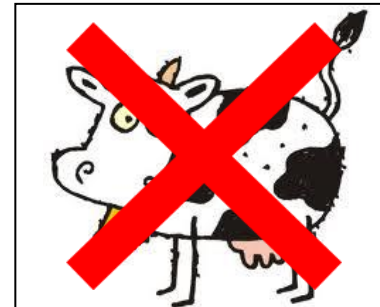
Marcellus

Eagle Ford

Schneising et al., 2014
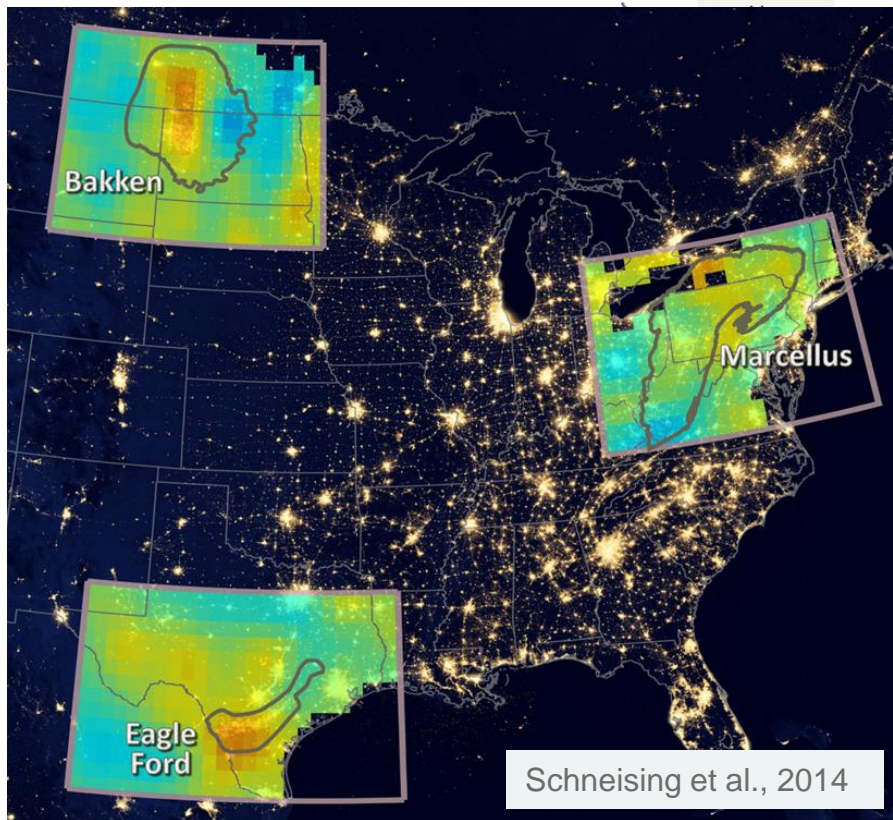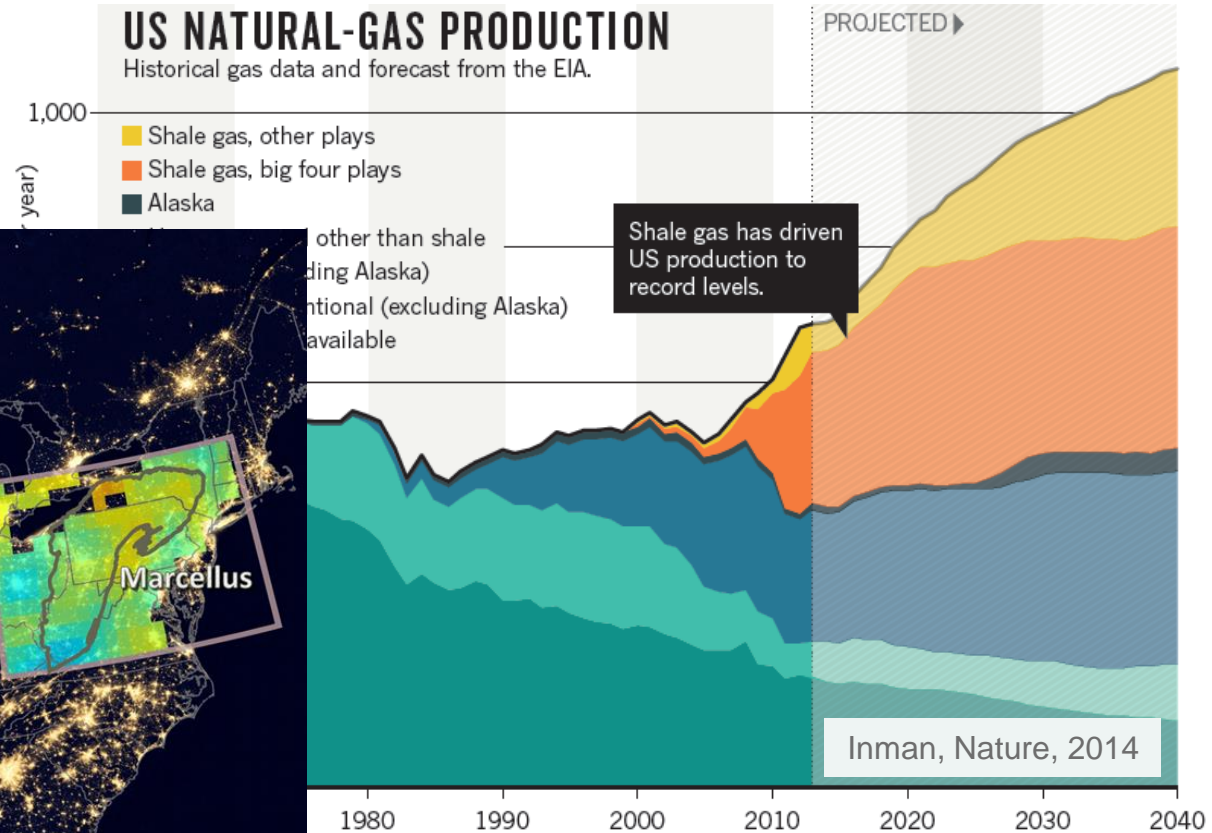
US CH$_4$ emissions underestimated + leakage rates highly uncertain

Methane sources – what does ethane tell us?

- shares major source with methane: fossil fuel production / distribution


- no significant biogenic ethane sources

→ C_2H_6 as valuable tracer for thermogenic methane

| Petra Hausmann, R. Sussmann, D. Smale; KIT/IMK-IFU, Garmisch

FTIR spectrometry – retrieval strategies

|	CH$_4$	C$_2$H$_6$
strategy	Sussmann et al., 2011	NDACC recipe, 2014
micro windows [cm-1]	2613.70 – 2615.40 2835.50 – 2835.80 2921.00 – 2921.60	2976.66 - 2976.95 2983.20 - 2983.55
interfering species	H2O, HDO, NO$_2$	H$_2$O, O$_3$, CH$_4$
line list	HIT00 + 2001 update	C$_2$H$_6$ pseudo-lines (Franco et al., 2015) other species: HIT08 + 09
regularization a priori profile	Tikhonov-L$_1$, DOFS ~ 2.0 WACCM v6	Tikhonov-L$_1$, DOFS ~ 1.6 WACCM v6

- spectral fitting code: PROFFIT v9.6
- station-to-station harmonization of regularization strength

Trends – Zugspitze and Lauder methane trend
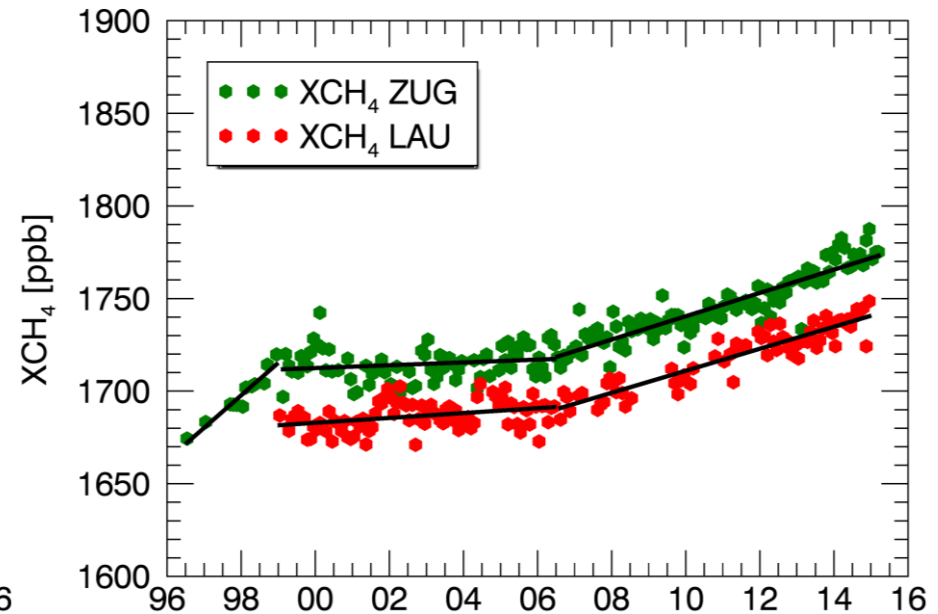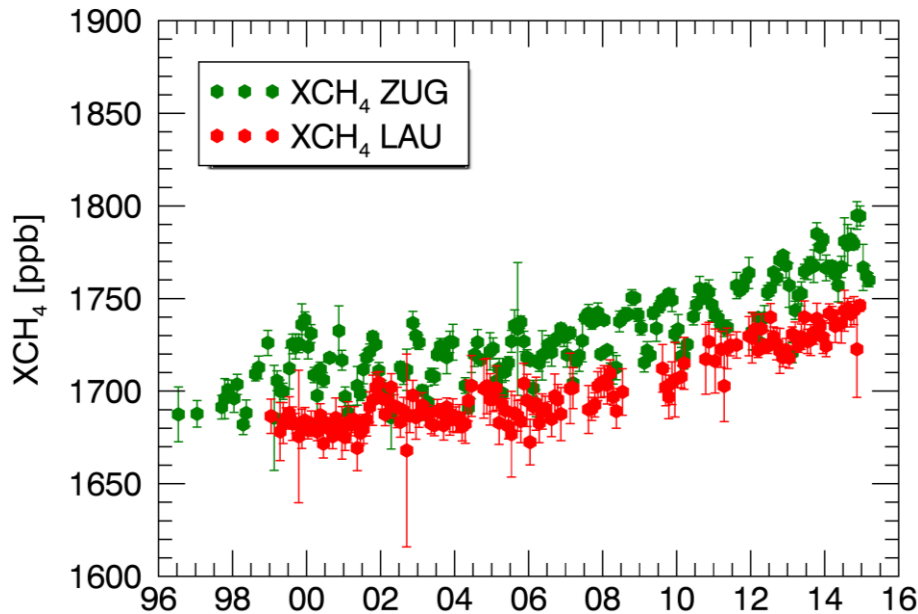
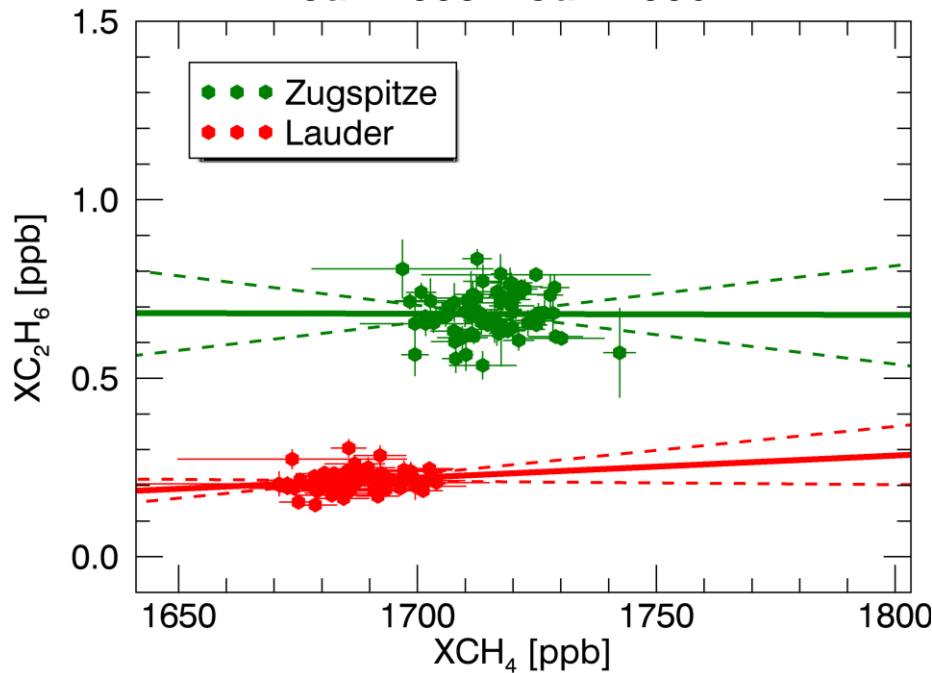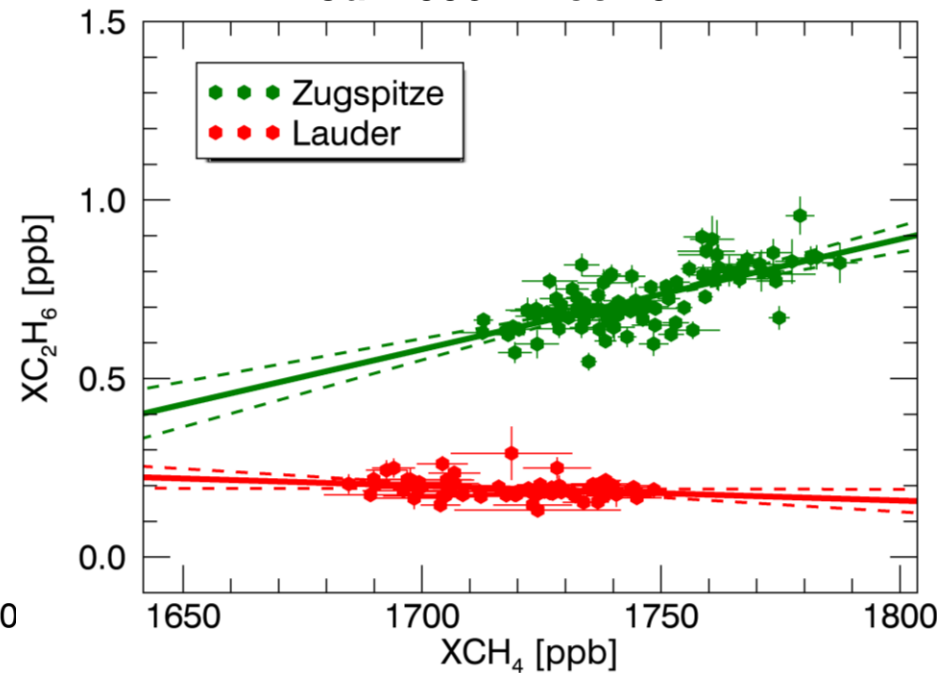|	trend [ppb/yr] Jan 1999 – Jun 2006	trend [ppb/yr] Jul 2006 – Dec 2014
Zugspitze (47° N)	0.76 [-0.14, 1.64]	6.29 [5.70, 6.87]
Lauder, NZ (45° S)	1.32 [0.61, 2.05]	5.94 [5.36, 6.52]

Trends – Zugspitze and Lauder ethane trend
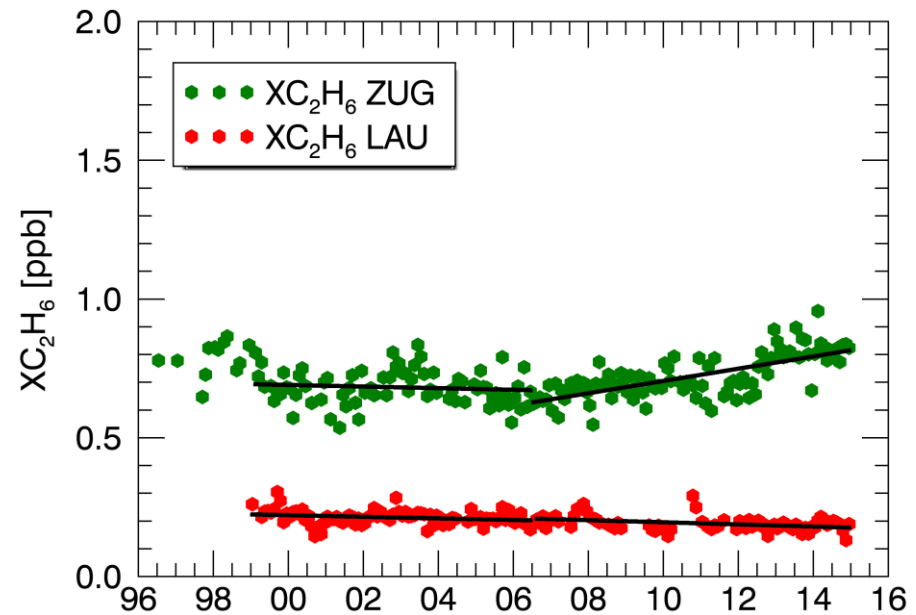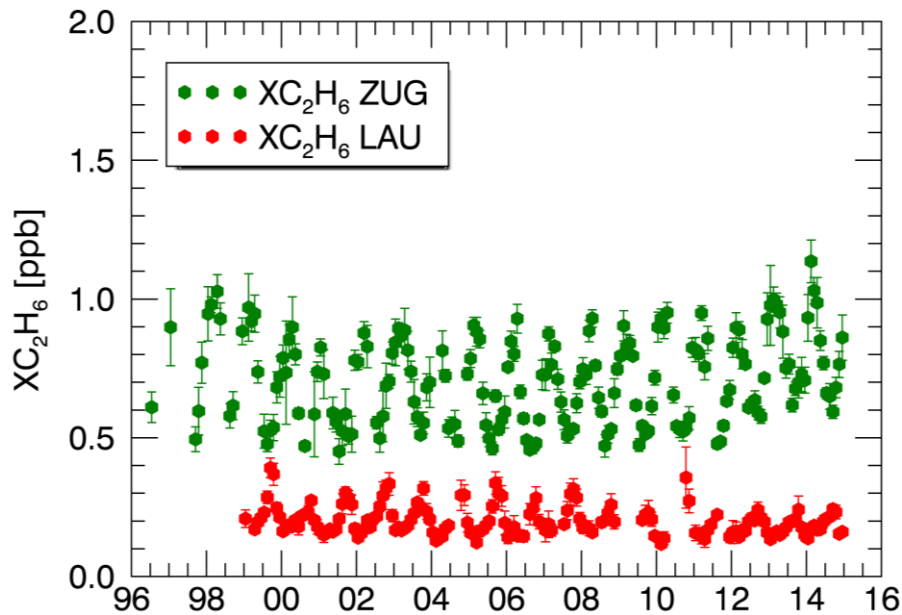
|	trend [10^{-2} ppb/yr] Jan 1999 – Jun 2006	trend [10^{-2} ppb/yr] Jul 2006 – Dec 2014
Zugspitze (47° N)	-0.29 [-0.91, 0.35]	2.21 [1.77, 2.66]
Lauder, NZ (45° S)	-0.29 [-0.53, -0.04]	-0.38 [-0.60, -0.17]

Trends – ethane-to-methane ratio

slope [%]	Jan 1999 – Jun 2006	Jul 2006 – Dec 2014
Zugspitze	-0.003 ± 0.161 (no)	0.309 ± 0.067 (yes)
Lauder	0.062 ± 0.072 (no)	-0.041 ± 0.039 (yes)

Trends – interhemispheric gradients

IHG (XCH$_4$) = XCH$_4$ (NH) – XCH$_4$ (SH)

IHG (XC$_2$H$_6$) = XC$_2$H$_6$ (NH) – XC$_2$H$_6$ (SH)
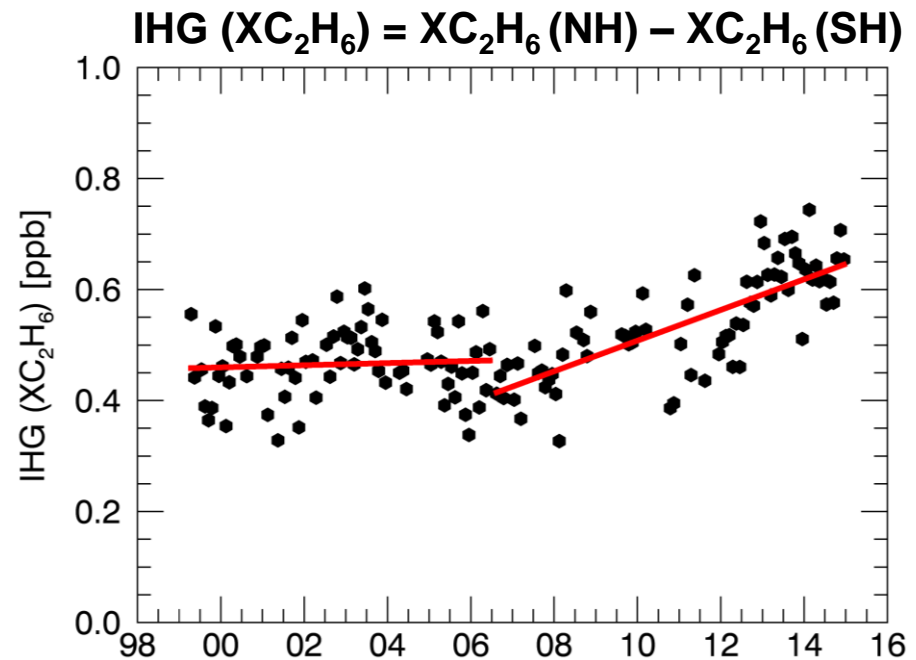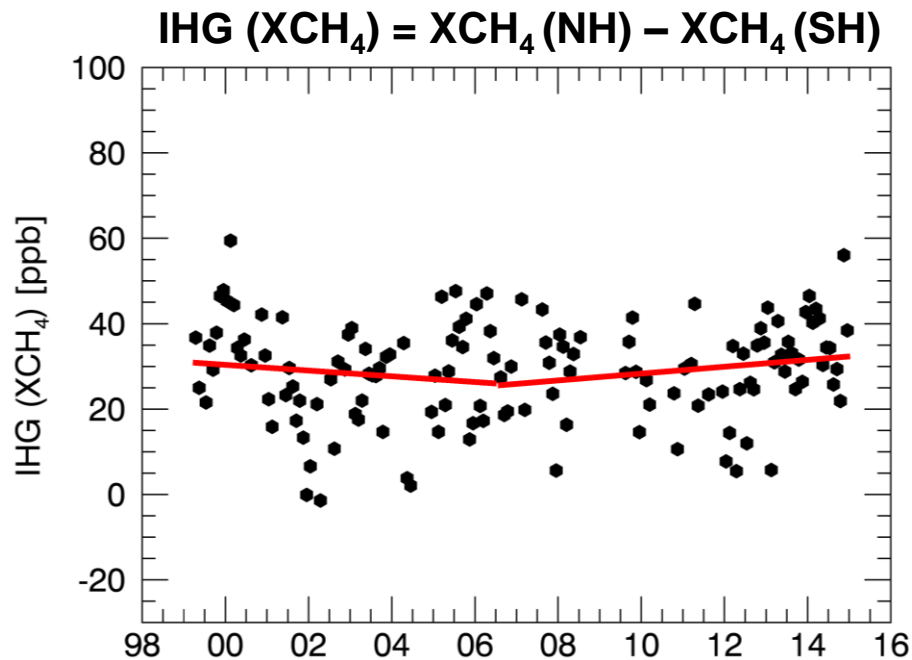
	Jan 1999 – Jun 2006	Jul 2006 – Dec 2014
IHG (XCH$_4$) [ppb/yr]	-0.67 [-2.01, 0.68]	0.80 [-0.18, 1.79]
IHG (XC$_2$H$_6$) [10^{-2} ppb/yr]	0.19 [-0.45, 0.83]	2.76 [2.20, 3.31]

Two-box model – global ethane budget
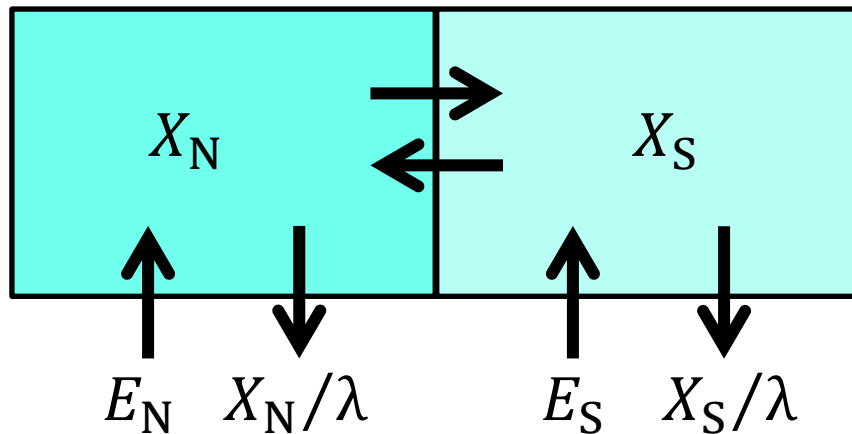
X_N, X_S column-averaged mole fraction [ppb]

τ_{ex} interhemispheric exchange time [yr]

E_N, E_S emission [Tg/yr]
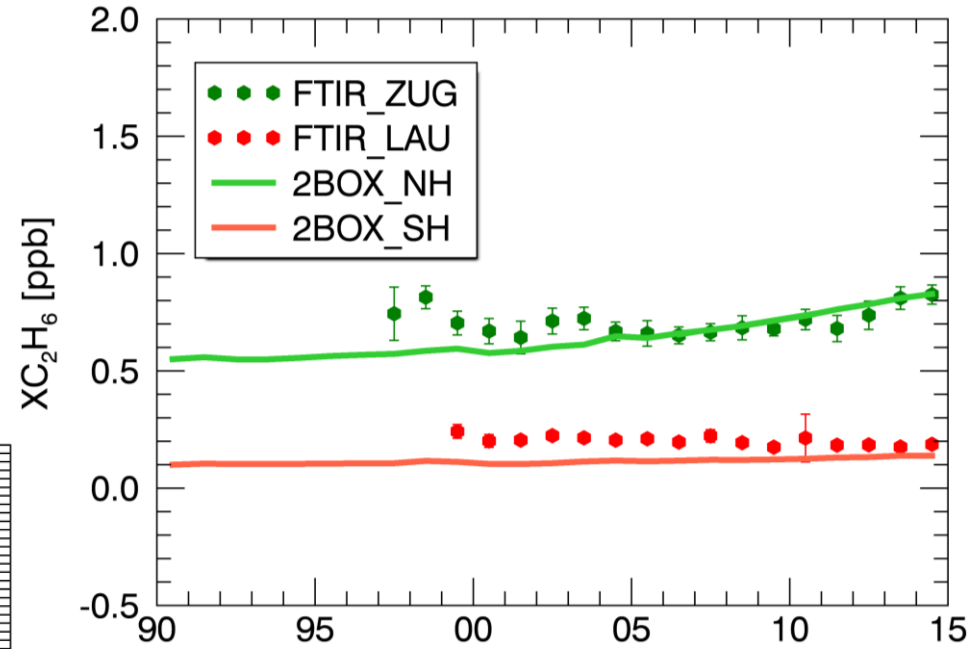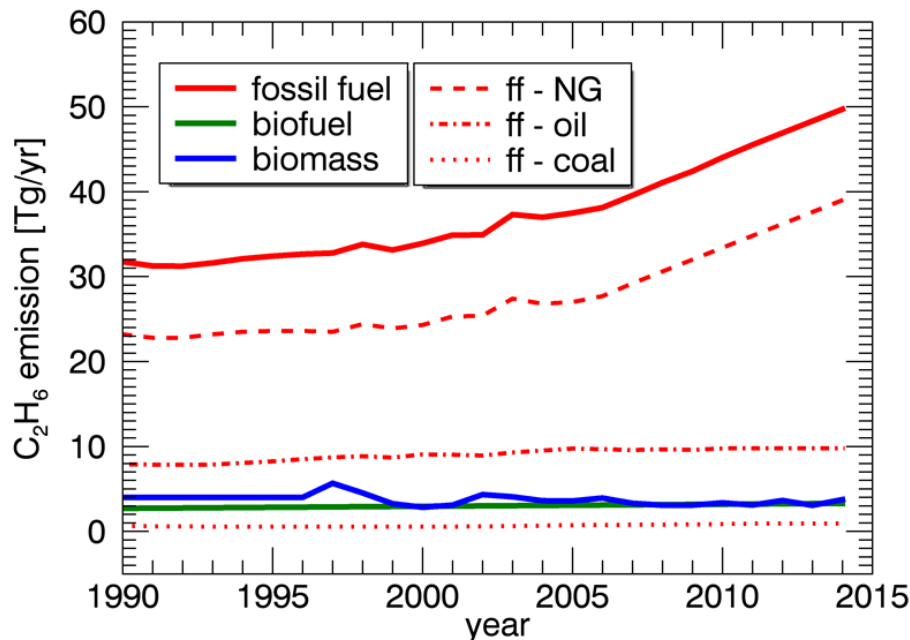
λ atmos. lifetime [yr]
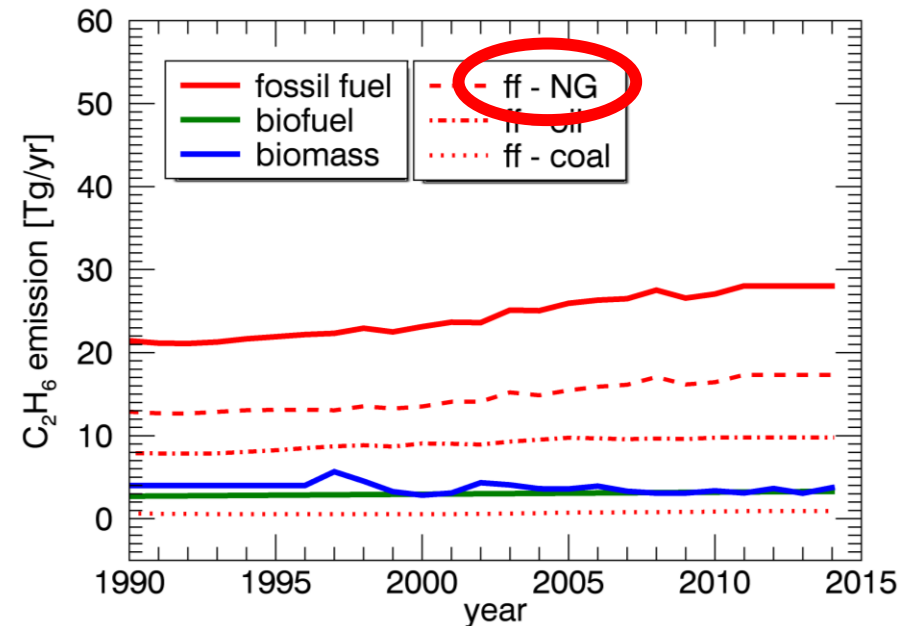
C_2H_6 emissions estimates:

- biomass burning (GFED4s)
- biofuel use × emiss. factor (Andreae and Merlet, 2001)
- fossil fuel prod. / distrib. (Schwietzke et al., 2014)

Two-box model – optimize ethane emissions

- minimize model-observation difference in XC_2H_6 trend from 2006 – 2014

- assumption: all "missing" emissions attributable to growing natural gas source

necessary change in C_2H_6 emissions from natural gas between 2006 and 2014: $\Delta E_{\text{gas}}^{\max} = 11.1\ [3.9, 24.7]\ \text{Tg/yr}$

Two-box model – renewed methane increase

Change in C_2H_6 natural gas emissions between 2006 and 2014 derived from ethane two-box model

⬇

Quantify associated methane emission change using reasonable CH_4-C_2H_6-ratio

⬇

Quantify natural gas contribution to total renewed methane increase applying analogous two-box model for methane

Summary and outlook

- Harmonized retrieval of methane and ethane for Zugspitze (47° N) and Lauder (45° S) time series

- Long-term trend analysis for methane and ethane (1995 - 2014):
  - Consistent renewed methane increase in both hemispheres
  - Significant ethane increase since 2006 in the northern hemisphere

- Two-box model for hemispheric ethane budgets:
  - Minimize model-observation difference of ethane trend since 2006
  - Optimize ethane emissions from natural gas production

- Methane two-box model: quantify contribution of fossil fuel emissions to renewed methane increase

Thank you for your attention!