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Attempt to estimate historical methane emissions from the oil and natural gas sector

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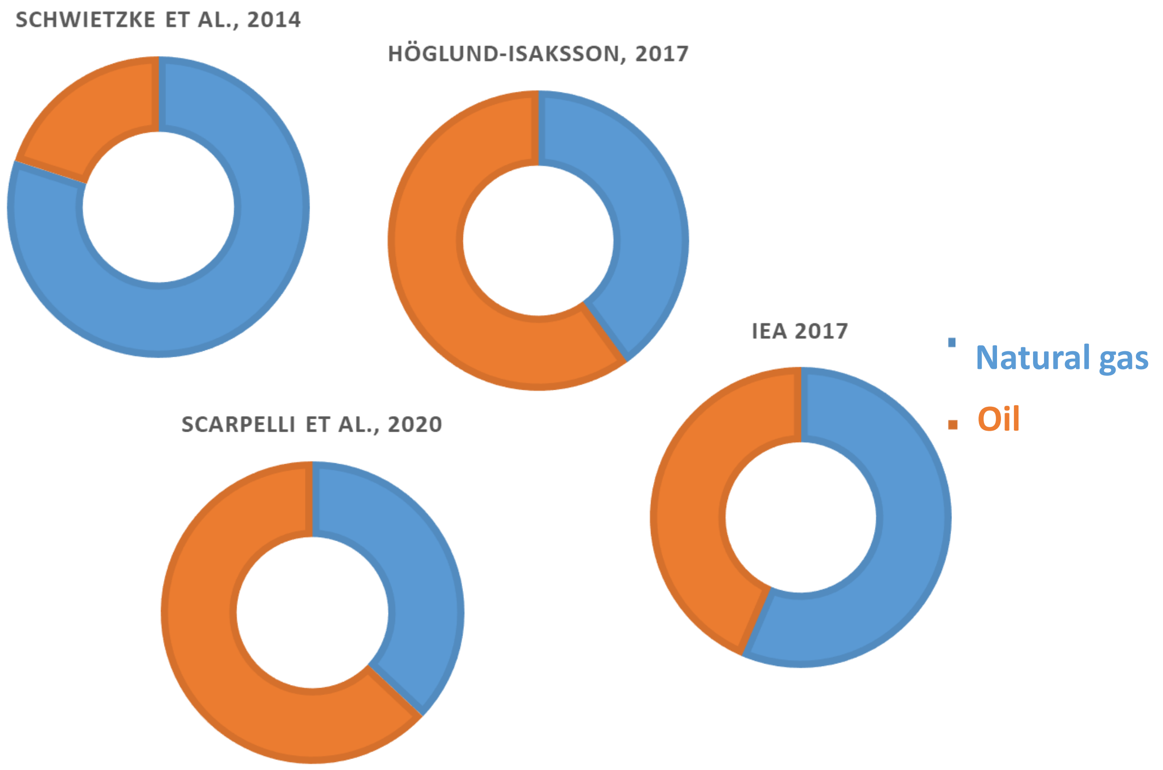
Methane emissions from the oil and natural gas sector vary greatly in different global inventories



According to Schwietzke et al. (2014) the vast majority (about 80%) of the methane emissions of the O&G sector are related to the natural gas industry. Höglund-Isaksson (2017), found only 40% and suggested that the majority of these methane emissions are related to the oil sector. According to Scarpelli et al. (2020), global emissions for 2016 are 41.5 Tg for oil, 24.4 Tg for gas. The International Energy Agency (IEA) assigns about 60% to the natural gas sector, however, their database is not accessible.

Höglund-Isaksson, L., 2017, Bottom-up simulations of methane and ethane emissions from global oil and gas systems 1980 to 2012: Environmental Research Letters, v. 12, no. 2, p. 024007.

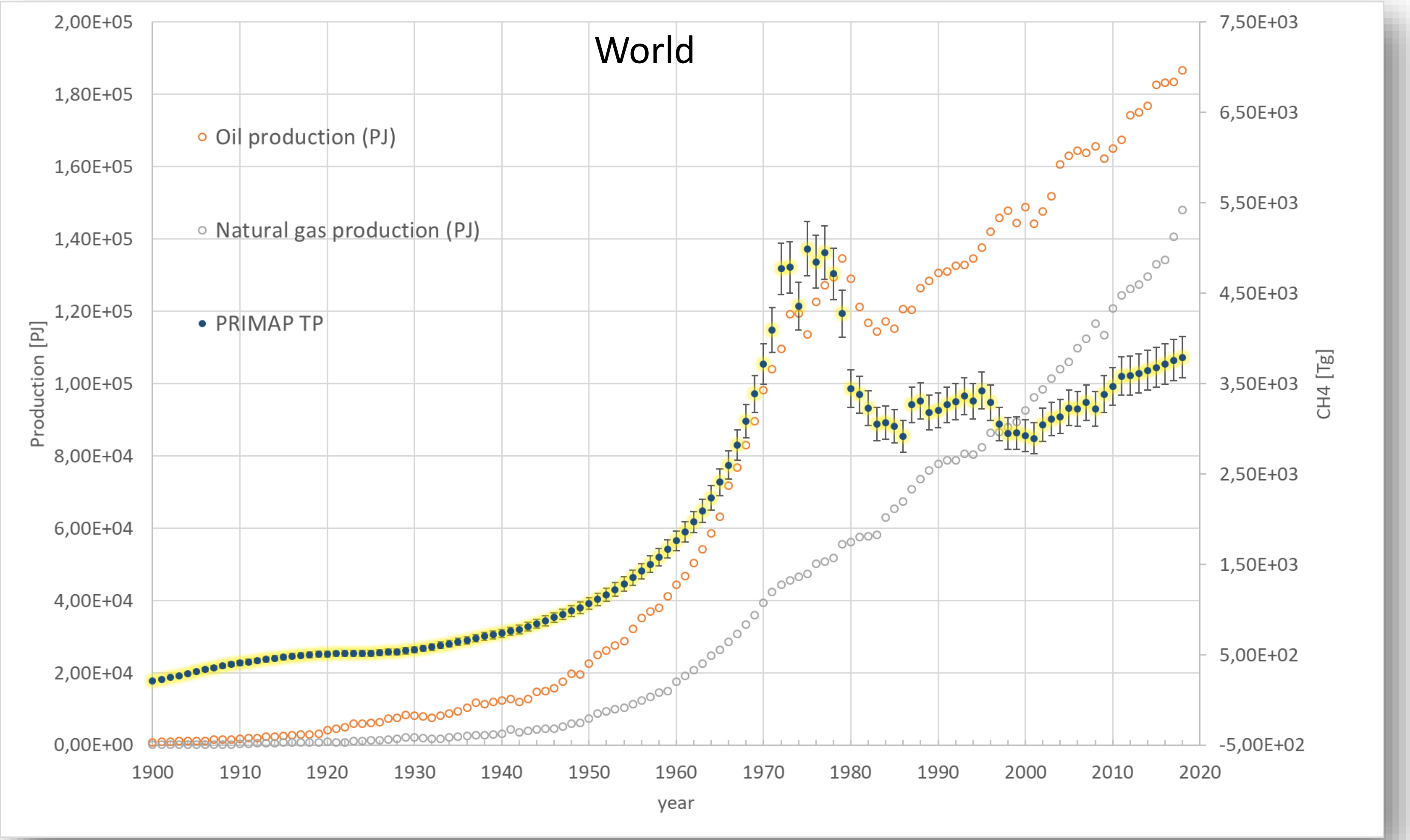
International Energy Agency, 2017, World Energy Outlook (WEO), Chapter 10: The environmental case for natural gas, p. 399-436.

Scarpelli, T. R., Jacob, D. J., Maasakkers, J. D., Sulprizio, M. P., Sheng, J. X., Rose, K., Romeo, L., Worden, J. R., and Janssens-Maenhout, G., 2020, A global gridded (0.1° × 0.1°) inventory of methane emissions from oil, gas, and coal exploitation based on national reports to the United Nations Framework Convention on Climate Change: Earth Syst. Sci. Data, v. 12, no. 1, p. 563-575.

Schwietzke, S., Griffin, W. M., Matthews, H. S., and Bruhwiler, L. M. P., 2014, Global Bottom-Up Fossil Fuel Fugitive Methane and Ethane Emissions Inventory for Atmospheric Modeling: ACS Sustainable Chemistry & Engineering, v. 2, no. 8, p. 1992-2001.

Approach of this study

Here we use BGR's worldwide database on natural oil and gas production and consumption, dating back to 1900, and compare it to the global bottom-up methane emission inventory PRIMAP v1.0.



Globally oil production globally initiated earlier with respect to than natural gas production (~1950ies). We test the correlation of O&G production with methane inventories using regression models for global and regional data.

PRIMAP: Gütschow, J., Jeffery, M.L., Gieseke, R., Gebel, R., Stevens, D., Krapp, M., and Rocha, M., 2016, The PRIMAP-hist national historical emissions time series: **Earth Syst. Sci. Data**, v. 8, p. 571-603.

TP - HISTTP: In this scenario third party data (CDIAC, FAO, Andrew, EDGAR, BP) is prioritized over country reported data (CRF, BUR, UNFCCC)

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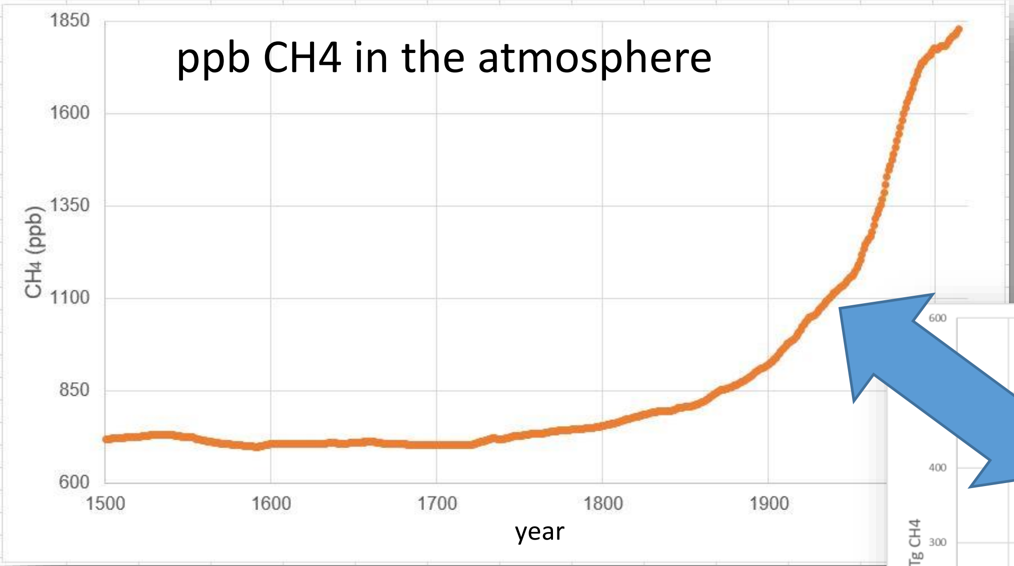
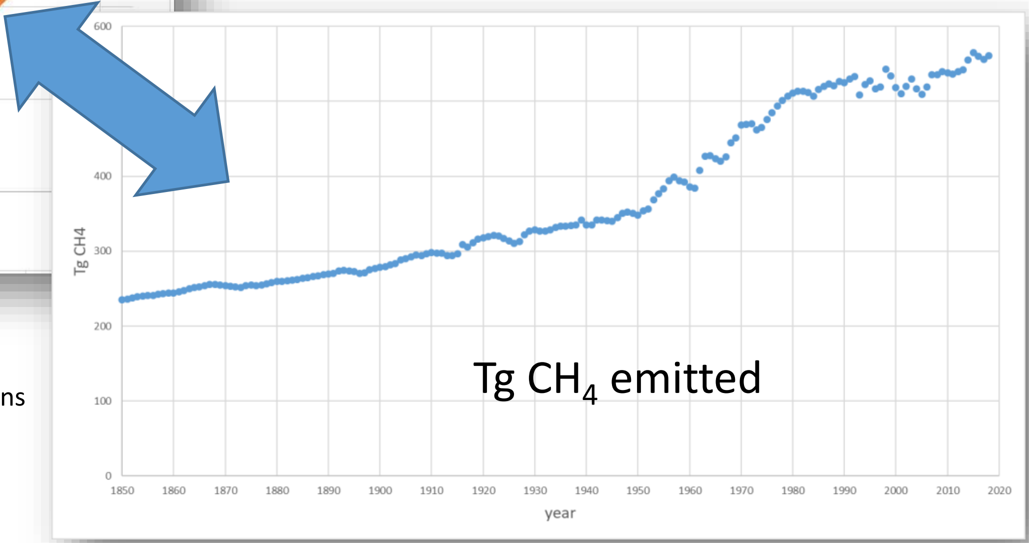
Calibration of inventory by using the atmospheric methane budget





ECH4: Meinshausen et al., 2017, Historical greenhouse gas concentrations for climate modelling (CMIP6): Geosci. Model Dev., v. 10, p. 2057-2116 and NOAA 1994-2018 (Ed Dlugokencky (303 497 6228; ed.dlugokencky@noaa.gov))

Global Mass Balance (Box model, in analogy to Schwietzke et al., 2014):

$$\frac{dC_{CH_4}}{dt} = Emissions_{CH_4} - \frac{1}{\tau} C_{CH_4}$$

C Concentration

$\tau =$ 9,5 a

(Lifetime of CH_4 (range of 9.1−9.7 years), Schwietzke et al. 2014)

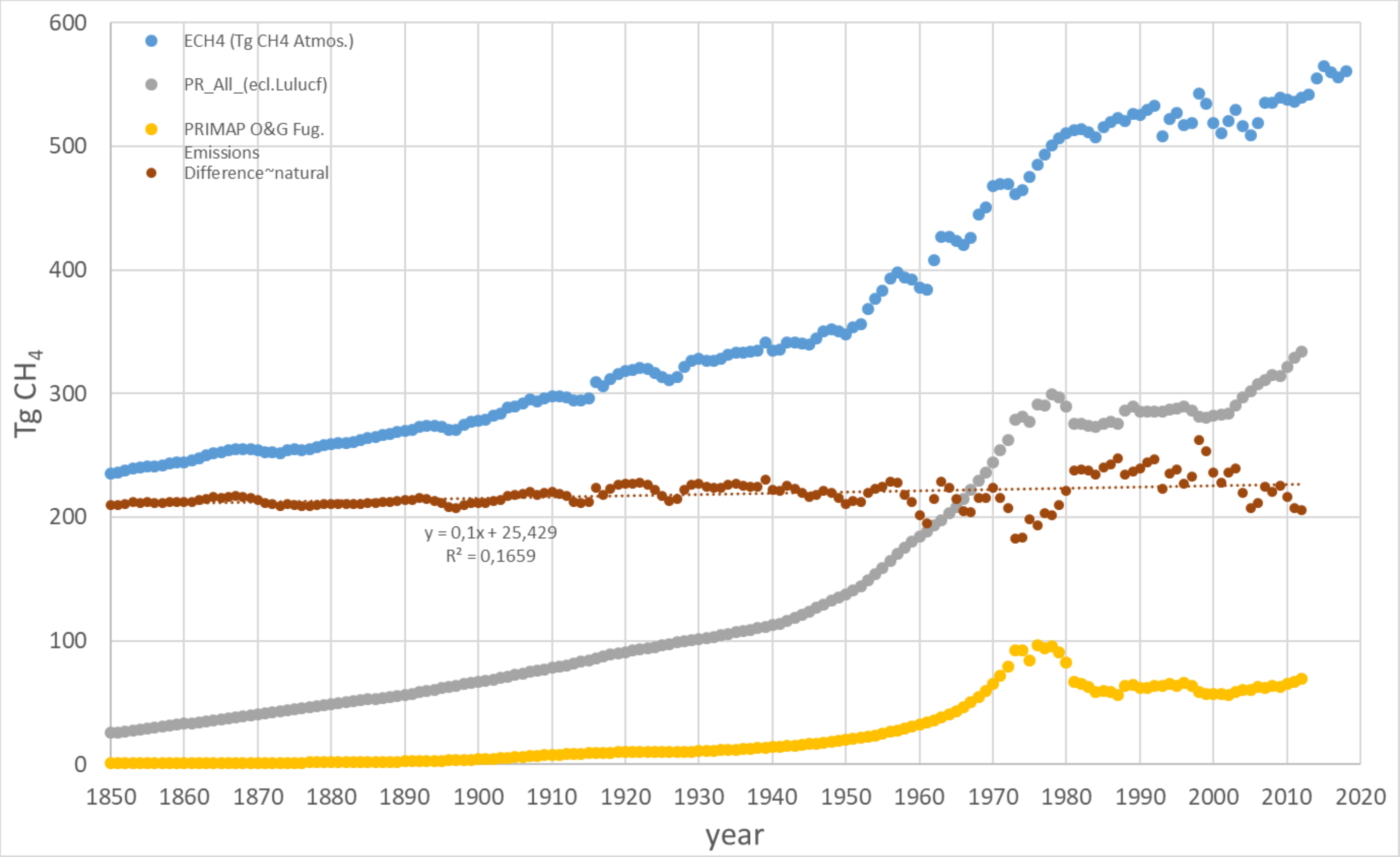
Conversion factor 2,767 Tg CH_4/ppb, in order to convert mole fractions to mass units for the global atmosphere, (according to Schwietzke et al. 2014)

Meinshausen et al., 2017, Historical greenhouse gas concentrations for climate modelling (CMIP6): Geosci. Model Dev., v. 10, p. 2057-2116.

Schwietzke, S., Griffin, W. M., Matthews, H. S., and Bruhwiler, L. M. P., 2014, Natural Gas Fugitive Emissions Rates Constrained by Global Atmospheric Methane and Ethane: Environ Sci Technol, v. 48, no. 14.

How reliable is the historic emission data base?

Comparizon of atmospheric methane with the PRIMAP inventory: **Difference should reflect natural methane emissions**



According to this box model, average pre-industrial atmospheric CH_4 = 208 Tg (years 1001-1849)

PRIMAP: Complete antropogenic methane emissions except Land Use, Land-Use Change and Forestry (LULUCF).

Natural sources, according to IPCC (Ciais et al. 2013), for 2000-2009:

Bottom up: 238-484 (median 347) [Tg]

Top down: 179-273 (median 218) [Tg]

Median 1980-1999: 193-182 Tg (TD)

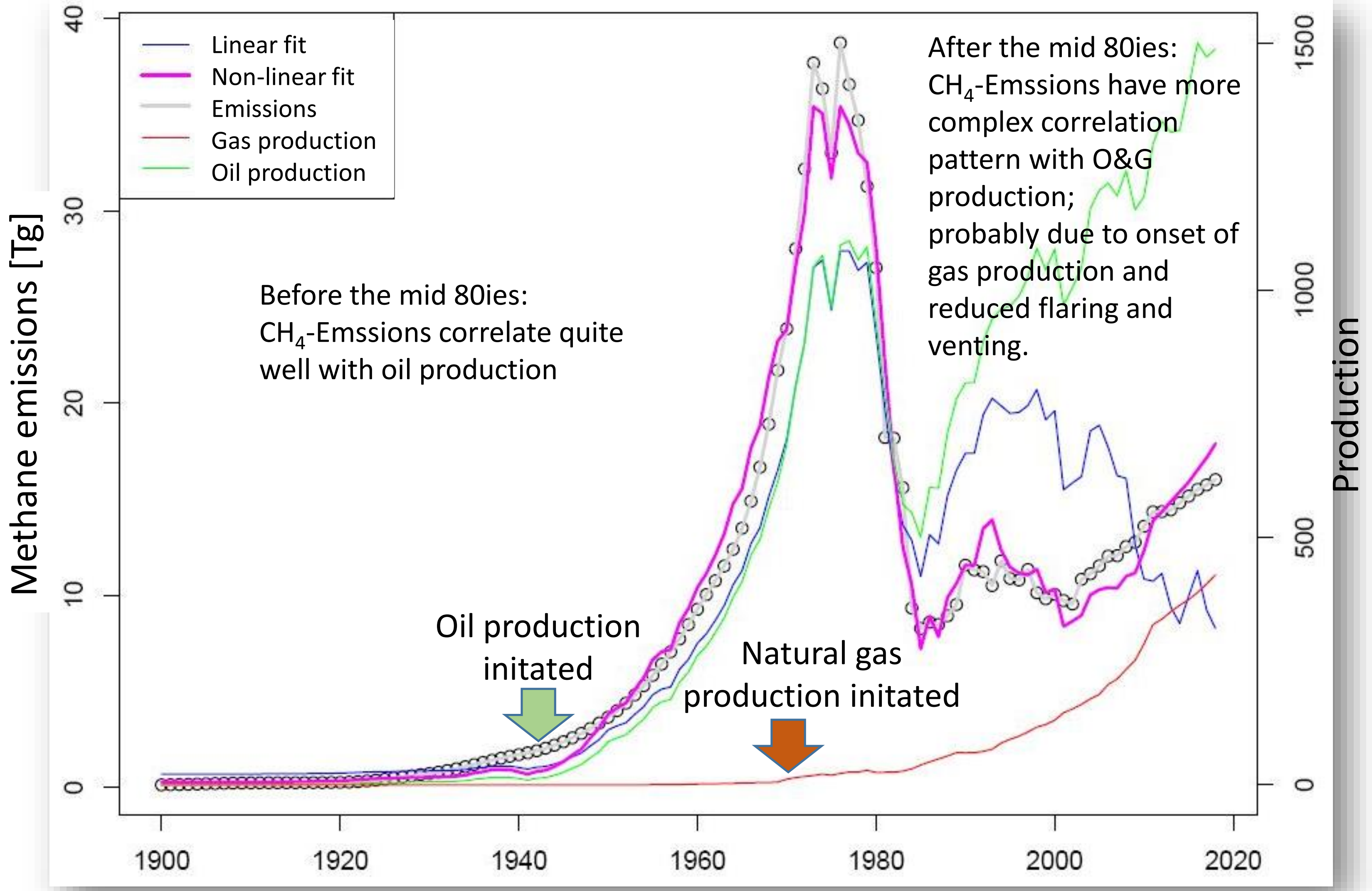
355-336 Tg (BU)

Janardanan et al. (2020) estimate 232.5 Tg CH_4/yr global natural methane emissions.

Ciais et al. 2013, Carbon and Other Biogeochemical Cycles, in Stocker, T. F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex , P.M. Midgley ed., Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

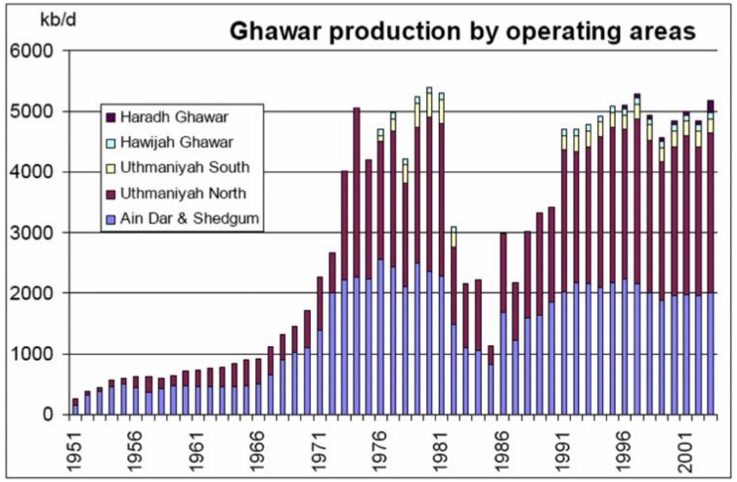
Janardanan et al., 2020, Country-Scale Analysis of Methane Emissions with a High-Resolution Inverse Model Using GOSAT and Surface Observations: Remote Sens., v. 12, no. 375.

Example for a regional approach: Middle East



The mid-80ies production decrease originated mostly from Saudi Arabia and there from the giant oil field Ghawar.

"The flaring and venting of natural gas were curtailed dramatically after the Saudi government took full control of the company in 1980" (Krane 2014; Saleri 2018).



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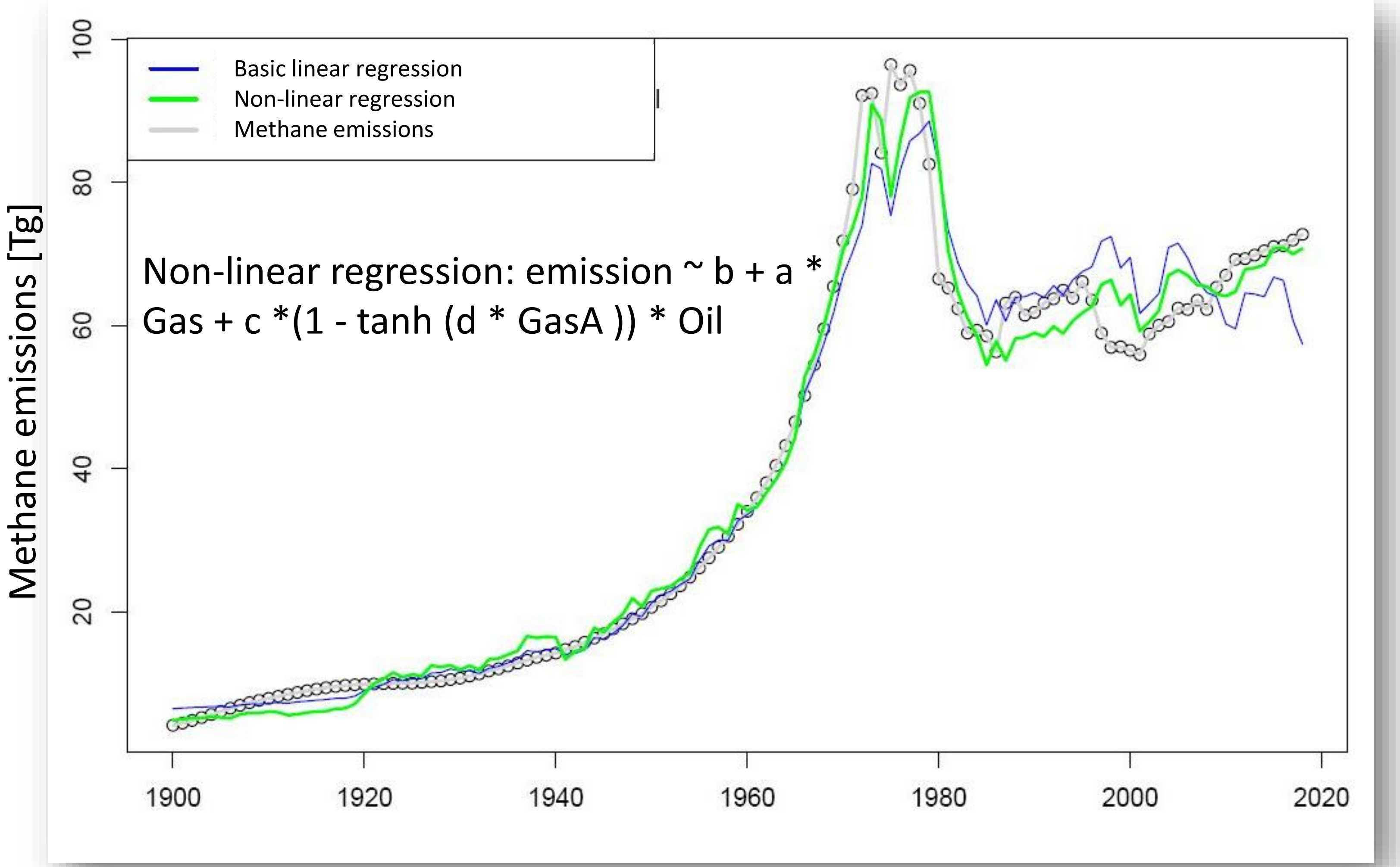
Preliminary result: Global linear regression models



Basic linear regression (~ b + a * Gas + c * Oil, blue line) failed over the whole time scale. Additionally bad is the negative *a* (b = 5.7, a = -0.053, c = 0.041)

Approach (green line):

Decreasing emissions from oil production, once natural gas is also produced (GasA = gas/oil production ratio).

This is, however, a non-unique solution.

(Input of oil and natural gas production numbers in (Tera)gramm. 93 % percent methane in natural gas is assumed. Calculations are performed using „R“)

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Summary

A simple global mass balance of atmospheric methane is compared to the global emission inventory PRIMAP. Subtracting the inventory from the box model results in a reasonable value of natural methane emissions, mostly unchanged from the pre-industrial level.

Fitting natural gas and oil production data to the PRIMAP inventory is, however, not straight forward. Data quality is problematic for some regions/countries in both the emission as well as production/consumption data base. In addition, specific conditions in many countries/regions need to be taken into account in order to properly model emission trends: e.g. in the Middle East, flaring and venting of natural gas decreased as natural gas production started. In Europe not only production but also consumption needs to be considered.

There appears not to be a single, common regression formula that explains all regional emission data. However, generally the approach is promising to constrain emissions at the sector level and to improve a priori bottom-up emissions inventories.