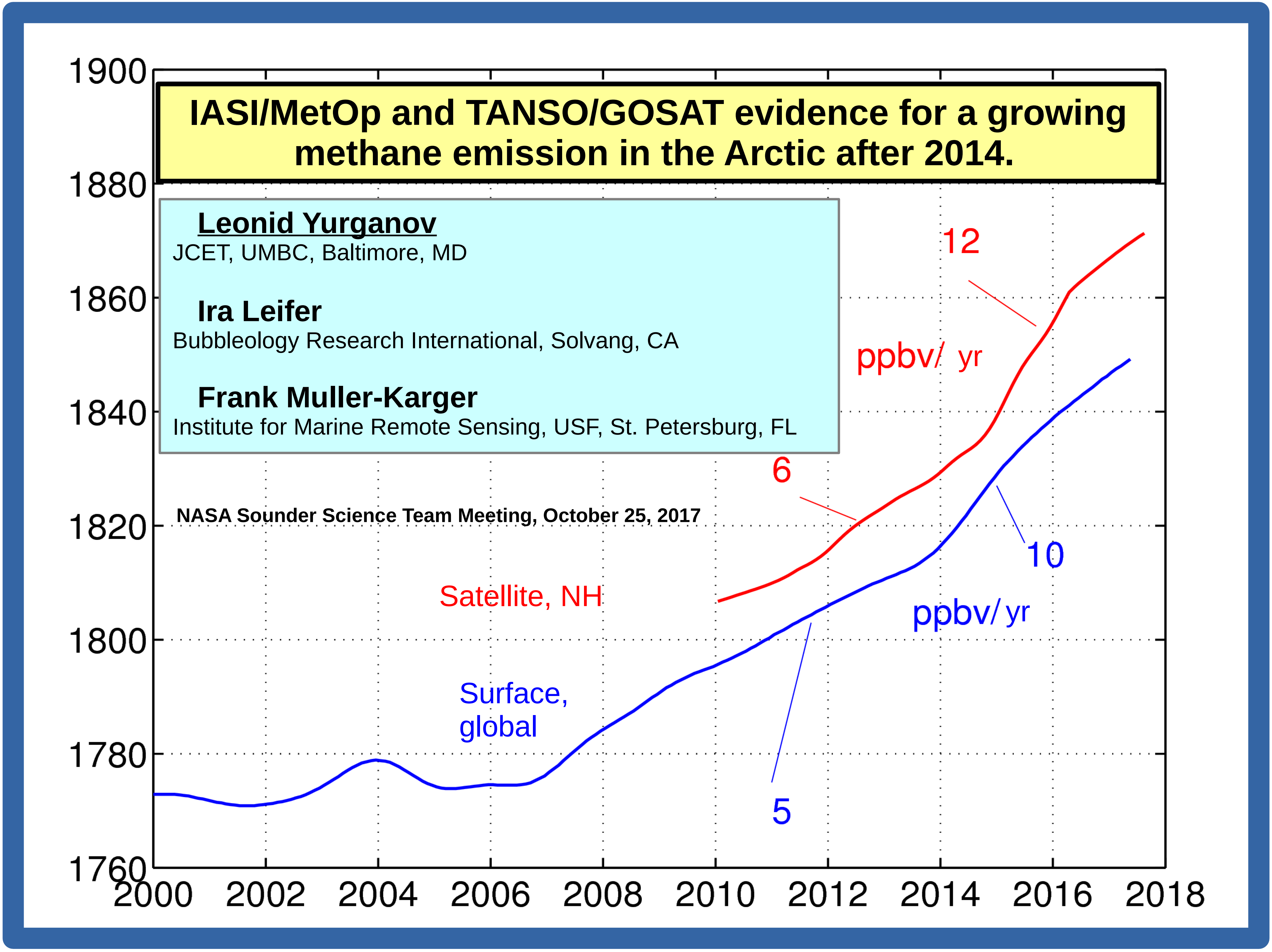

IASI/MetOp and TANSO/GOSAT evidence for a growing methane emission in the Arctic after 2014.
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Ira Leifer
Bubbleology Research International, Solvang, CA
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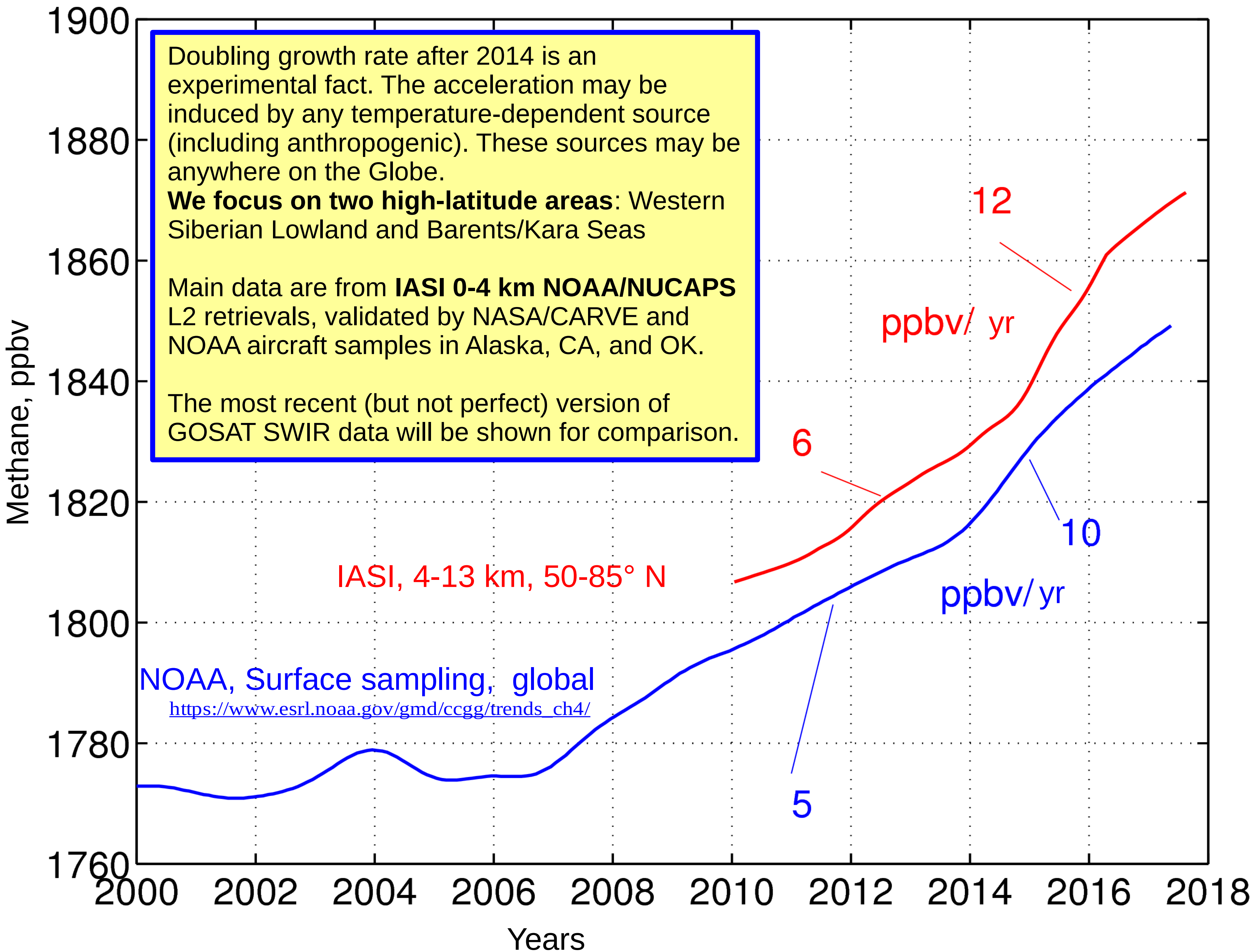
Institute for Marine Remote Sensing, USF, St. Petersburg, FL
NASA Sounder Science Team Meeting, October 25, 2017
Satellite, NH
Surface, global
12
ppbv/ yr
6
10
ppbv/ yr
5
1900
1880
1860
1840
1820
1800
1780
1760
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018

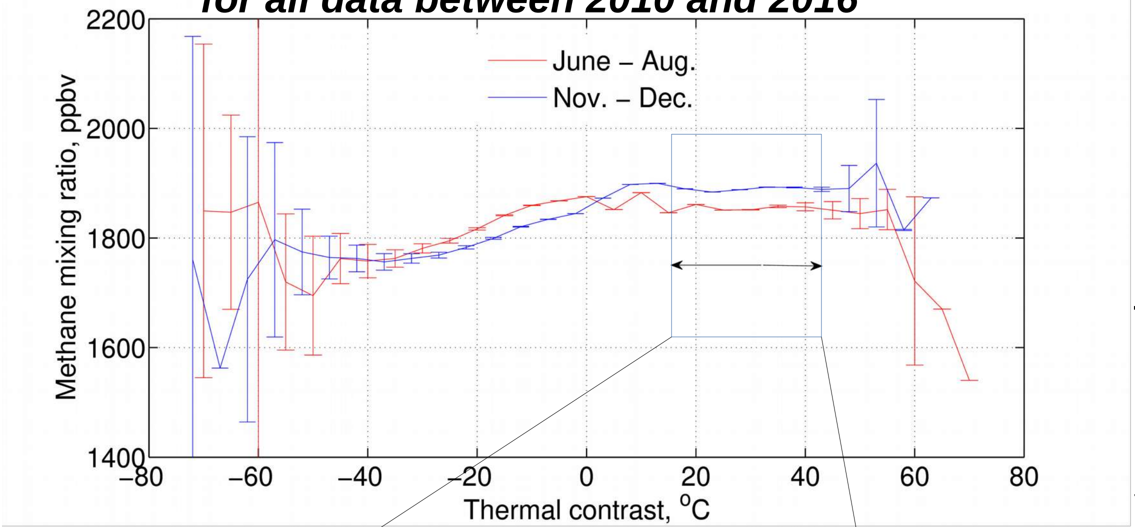


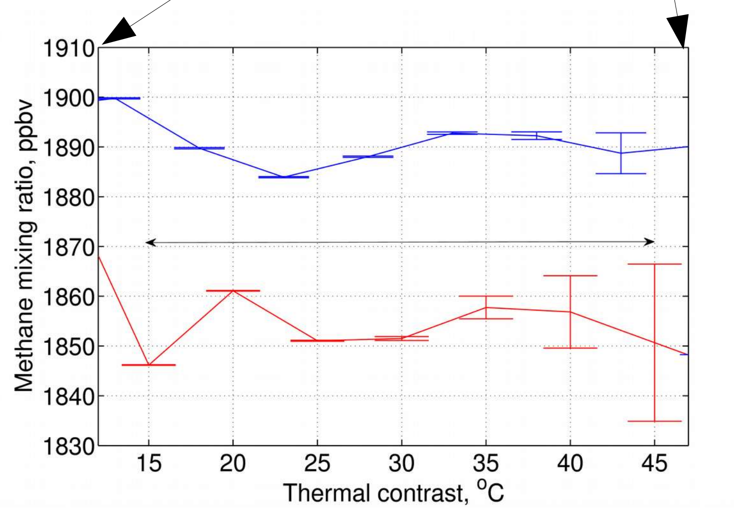
Doubling growth rate after 2014 is an experimental fact. The acceleration may be induced by any temperature-dependent source (including anthropogenic). These sources may be anywhere on the Globe.
We focus on two high-latitude areas: Western Siberian Lowland and Barents/Kara Seas
Main data are from **IASI 0-4 km NOAA/NUCAPS** L2 retrievals, validated by NASA/CARVE and NOAA aircraft samples in Alaska, CA, and OK.
The most recent (but not perfect) version of GOSAT SWIR data will be shown for comparison.
12
ppbv/ yr
6
IASI, 4-13 km, 50-85° N
10
ppbv/ yr
5
NOAA, Surface sampling, global
https://www.esrl.noaa.gov/gmd/ccgg/trends_ch4/
Methane, ppbv
1900
1880
1860
1840
1820
1800
1780
1760
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Years

The lower tropospheric methane is expected to be perturbed by local sources more than upper tropospheric methane. Though the profiles of cloud-cleared data were averaged between 0 and 4 km for areas with elevations asl < 1000 m (avoiding mountines).

ADDITIONAL FILTERING FOR THE ARCTIC IS NECESSARY!

Empirical dependence of mean 0-4 km methane on ThC for all data between 2010 and 2016



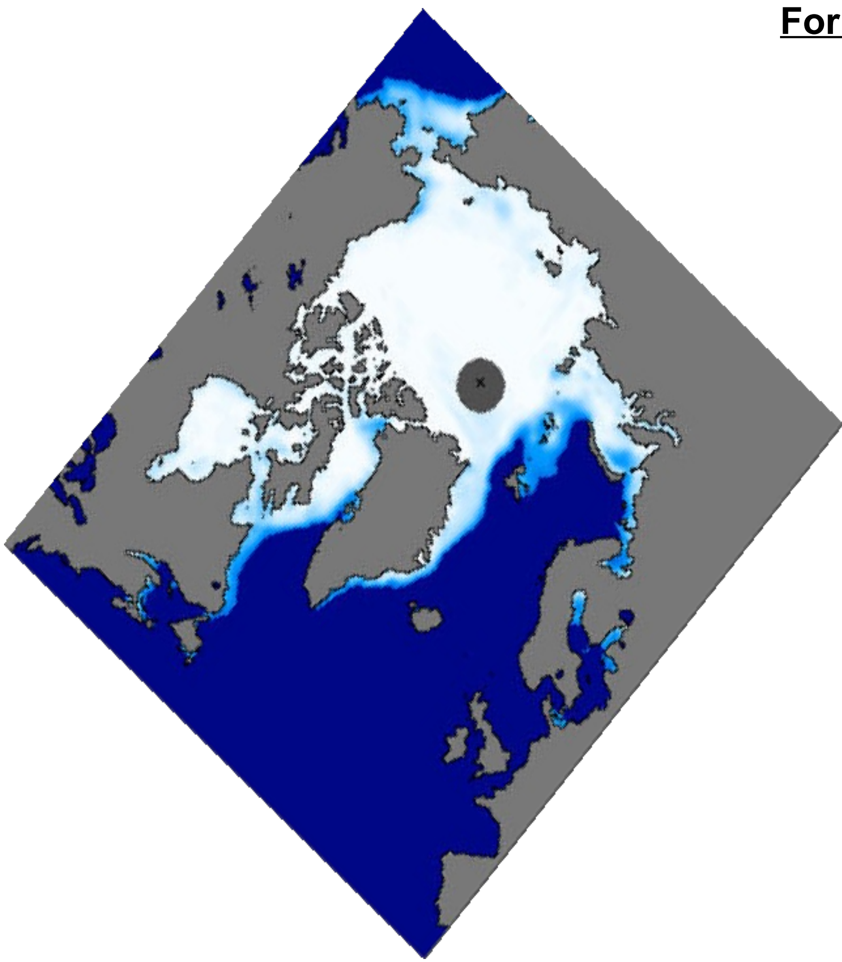


The higher vertical **thermal contrast between the surface and air near 4 km of altitude (ThC)**, the higher sensitivity to the lower troposphere. **We selected data only for the ThC range 15-45 °C**, all other retrievals have been screened out.

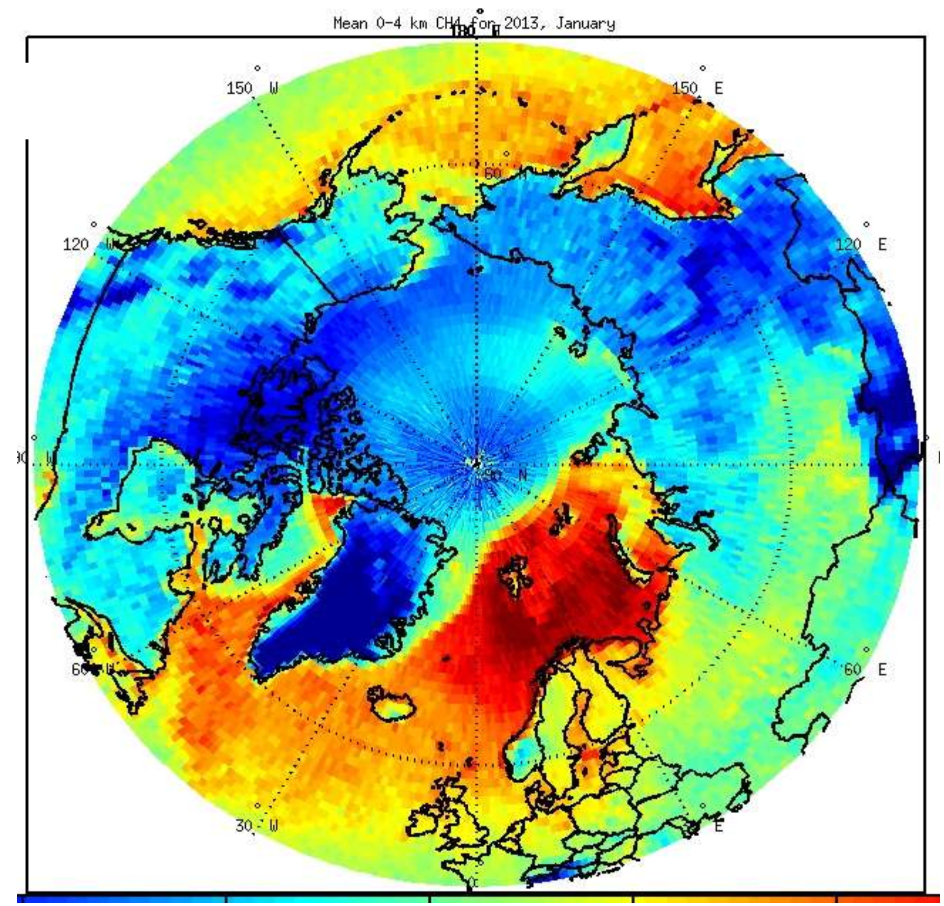
Error bars are 2 x STD divided by sqrt(N-1)

January 2013 monthly IASI L3 methane (0-4 km) with standard quality control

Ice map (NASA)

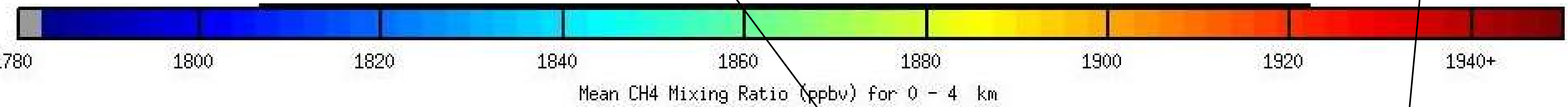


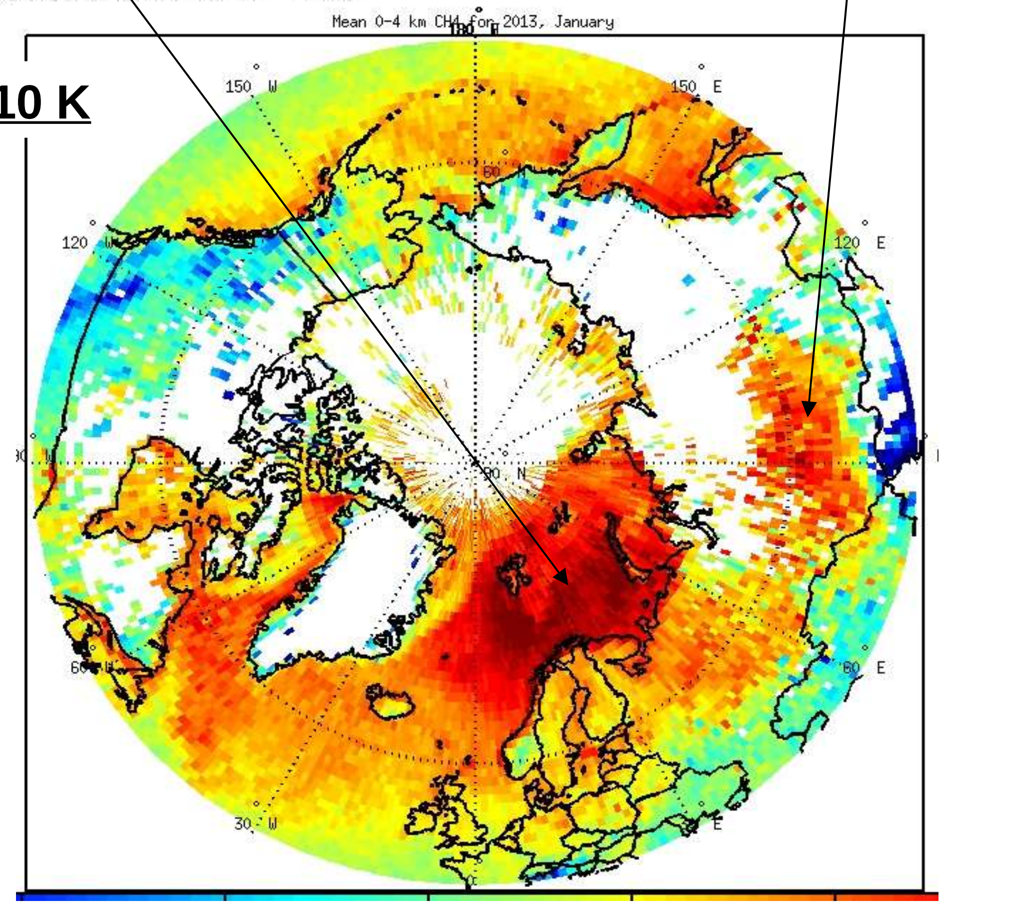
For all data



After removing points for insufficient thermal contrast some areas change the color for white (no reliable data at all),
for some areas CH4 do not change, for some areas values increase.

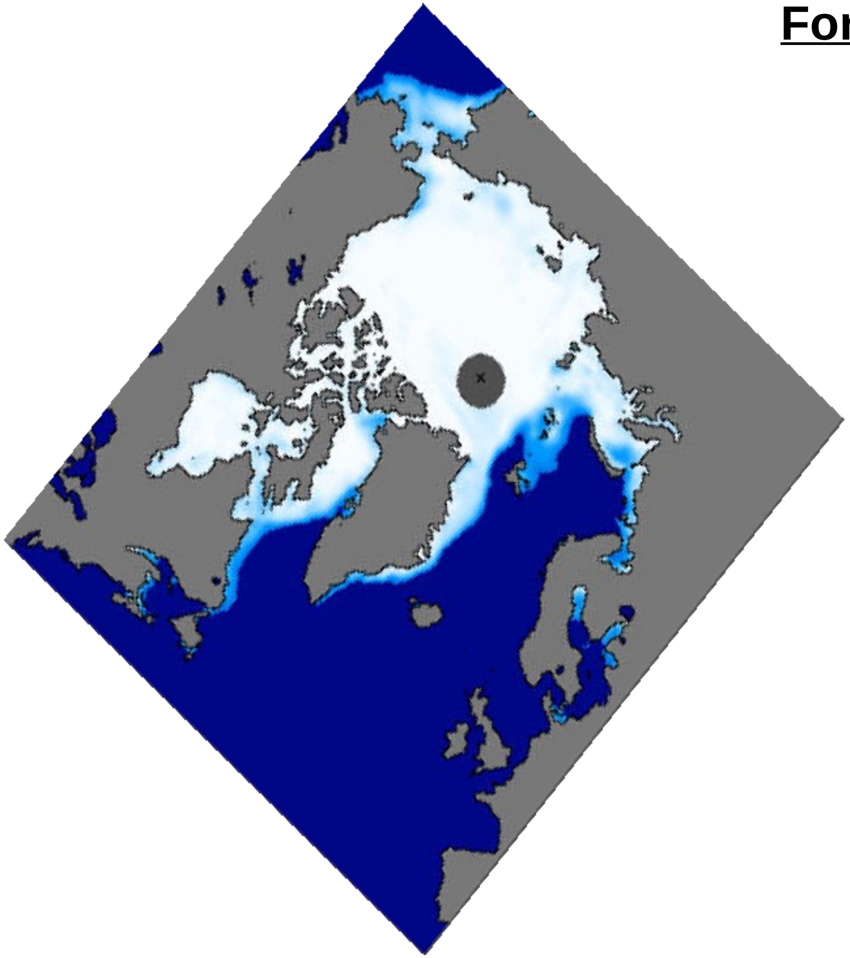
January 2013 monthly IASI L3 methane (0-4 km)





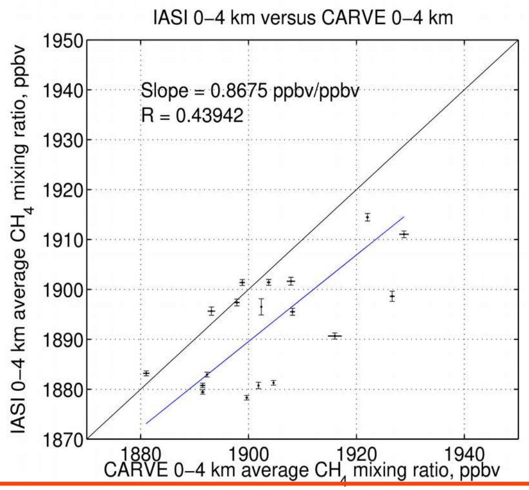
For ThC>10 K

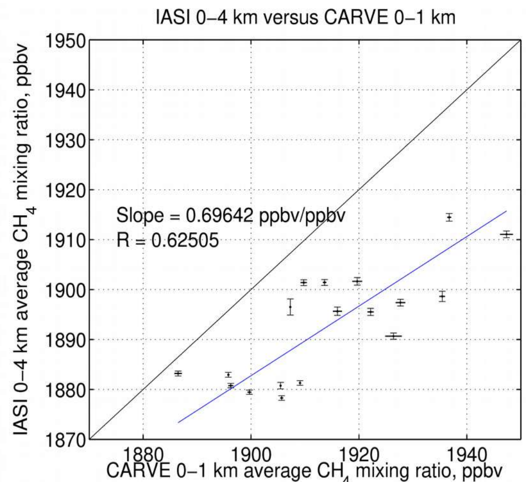
Ice map (NASA)

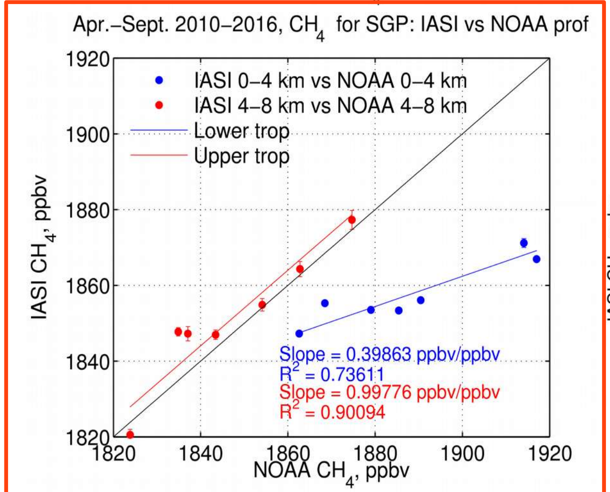


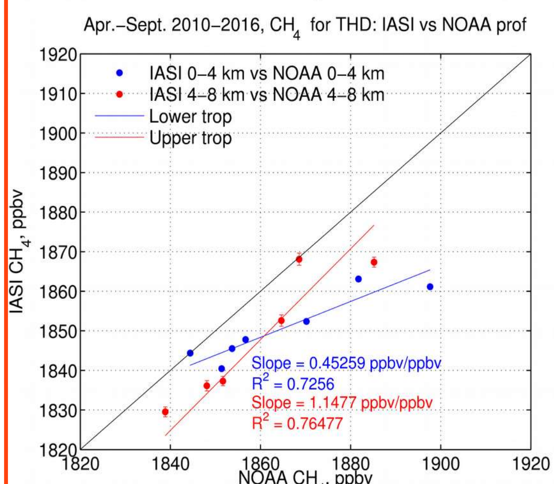
Validation

Concentration

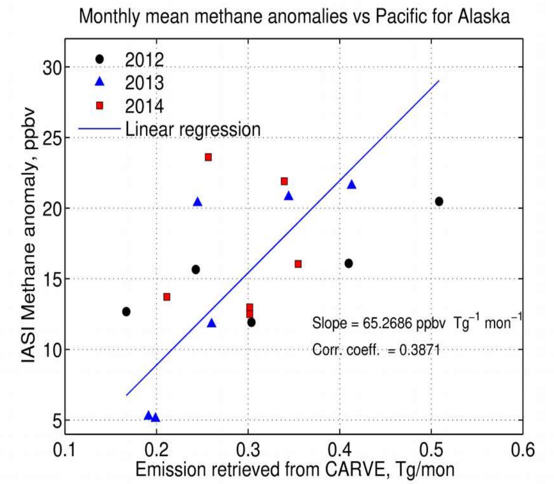


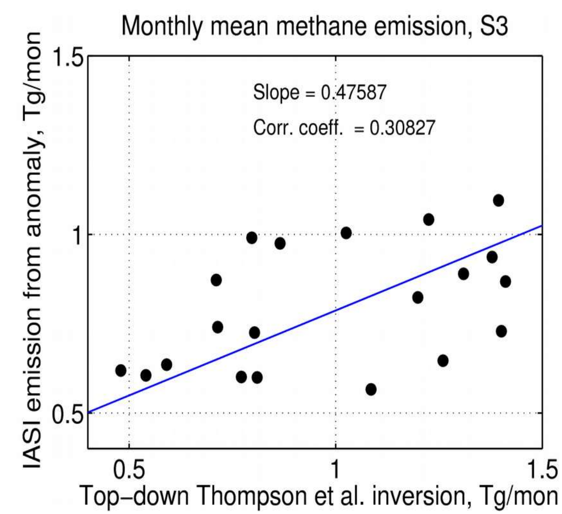






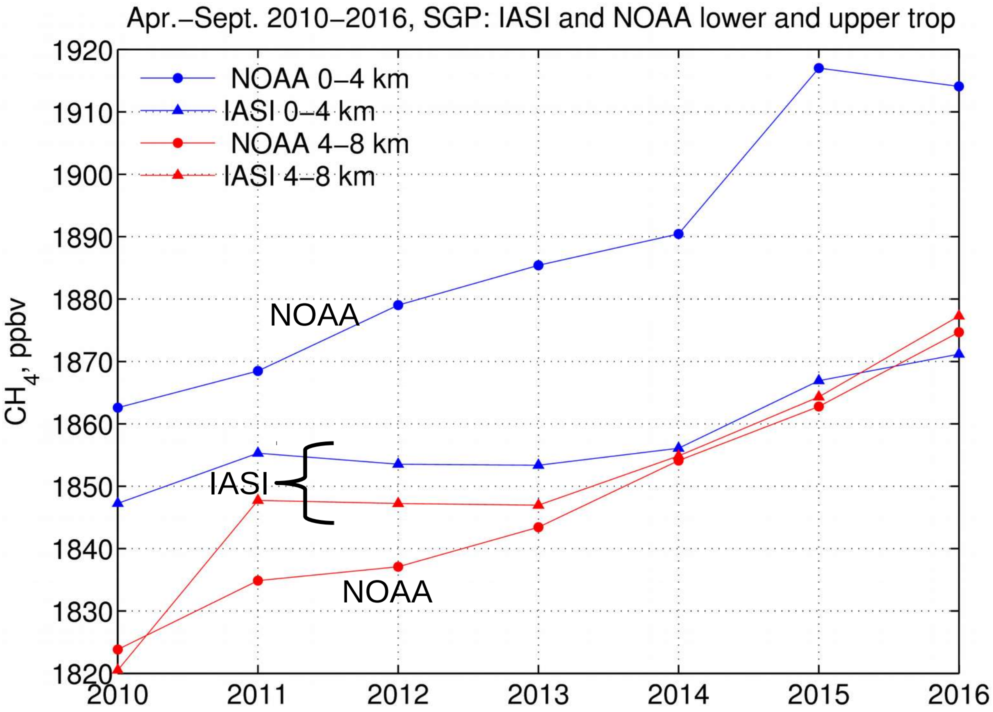
Anomalies and emissions

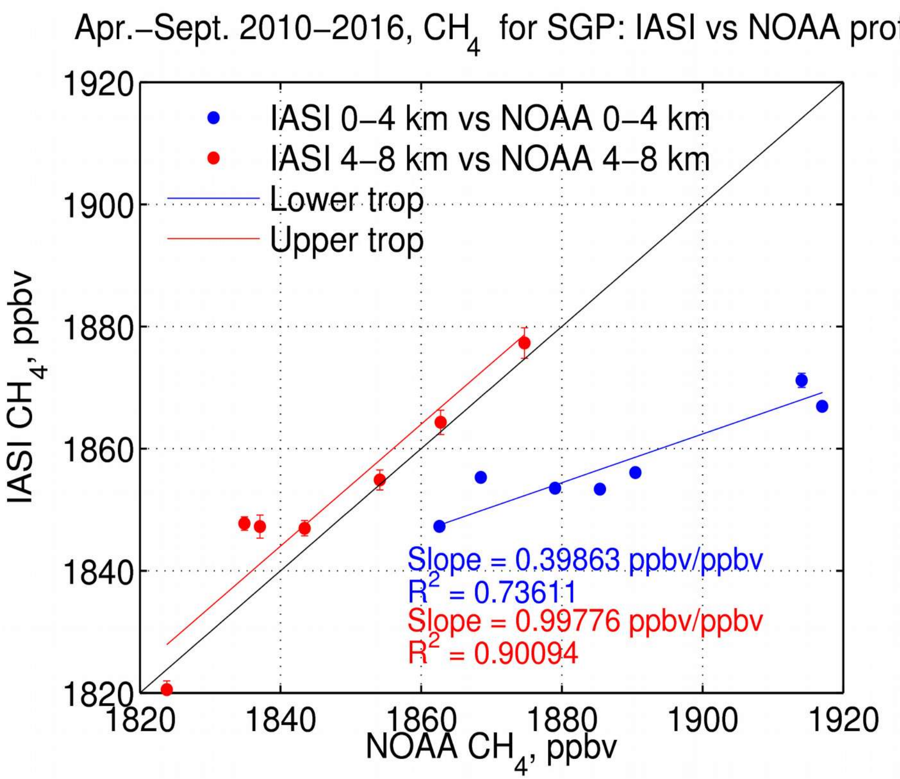




An example of validation. Comparison of IASI with aircraft samplings over Oklahoma during warmer periods of 2010-2016 provided by NOAA

Blue: lower troposphere, red: upper troposphere



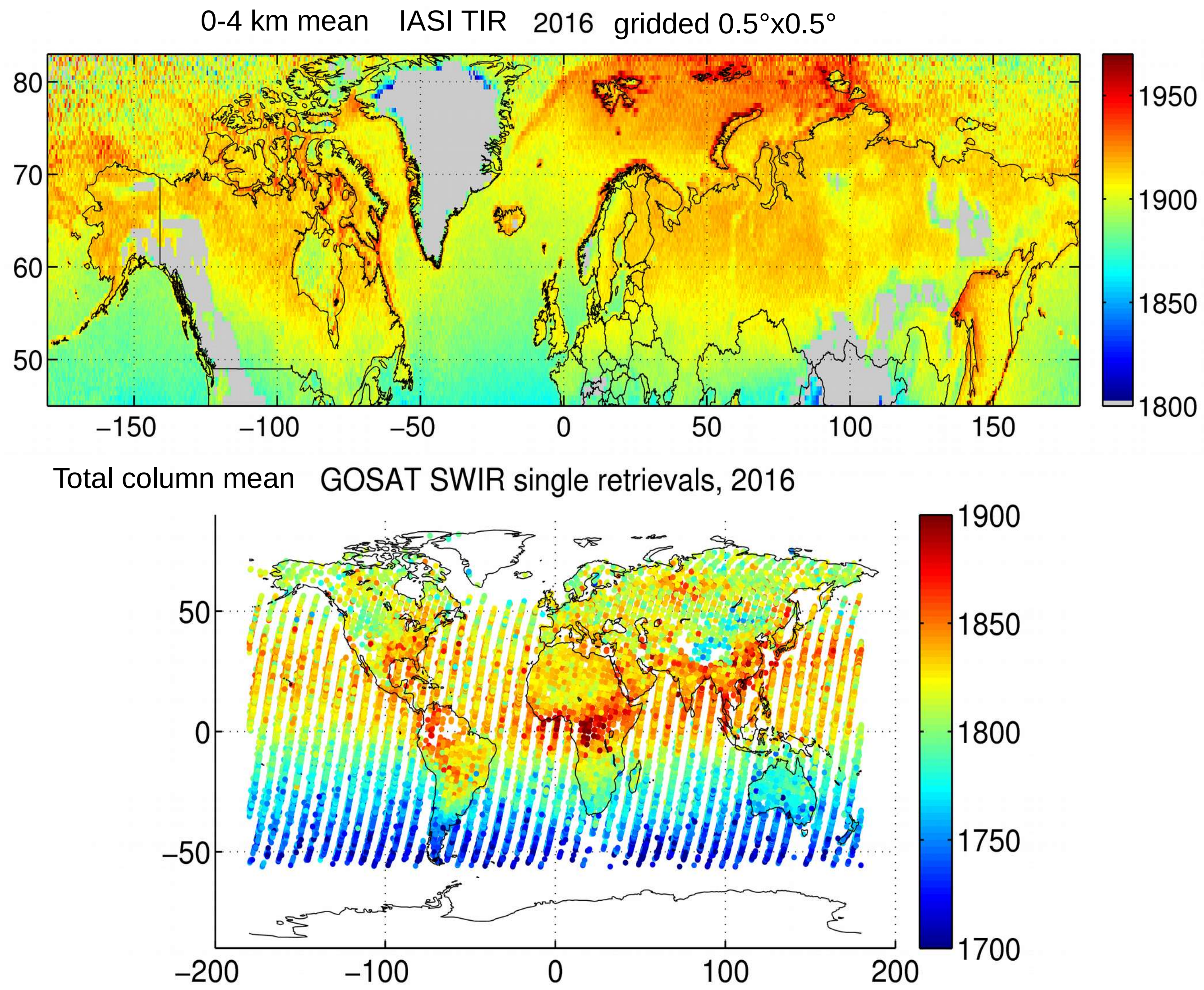


The slope, or $S=\Delta C_{IASI} / \Delta C_{in\ situ}$, where ΔC_{IASI} and $\Delta C_{in\ situ}$ are changes in methane VMRs retrieved and directly measured, respectively.

The S-value is an empirical analog of the Averaging Kernel. For this example S ~= 0.4. This means ~ 60% **underestimation** of real anomalies. For other validation efforts values of S were estimated in a range 0.4 – 0.7, so IASI results for LT are rather underestimated, than overestimated.

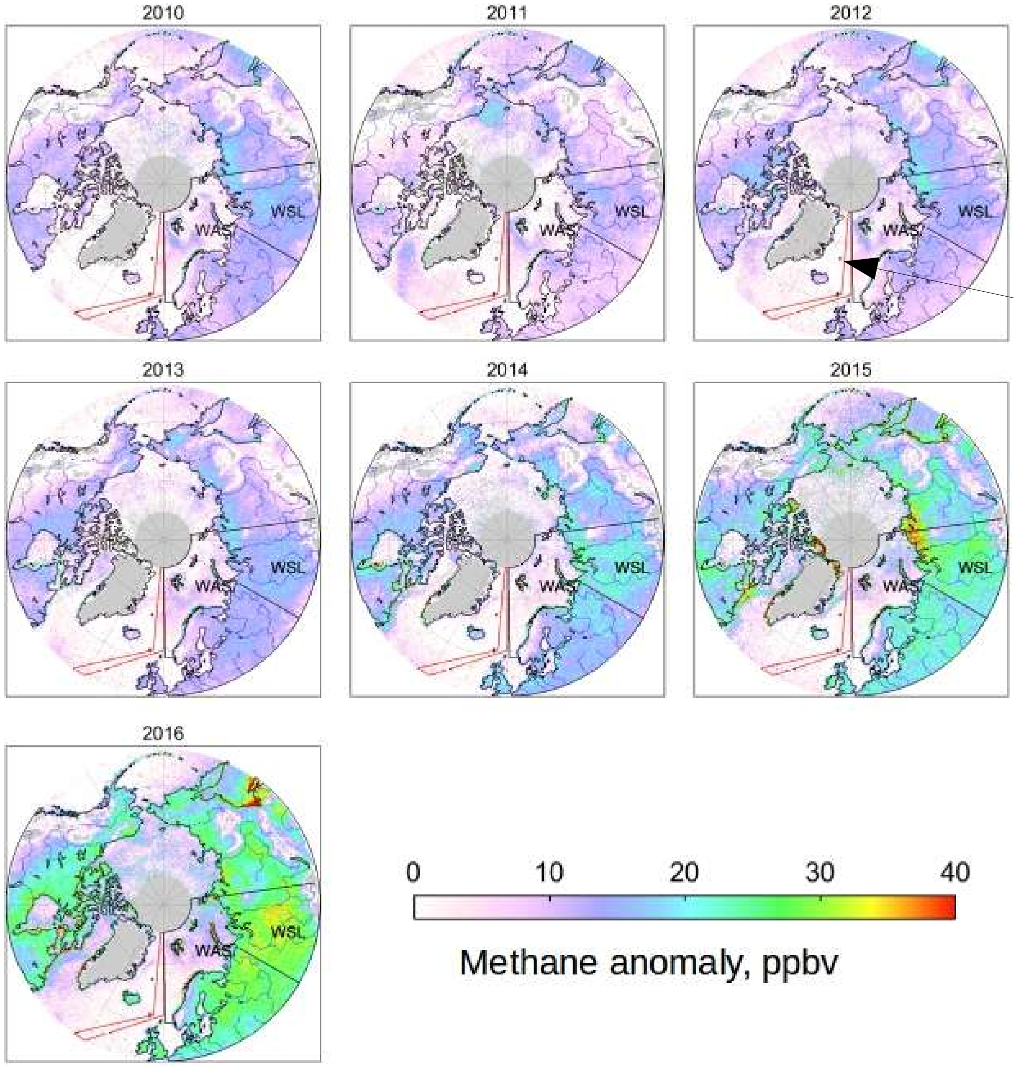
TIR satellite low tropospheric data is a matter to study, but not a trash to ignore

TIR versus SWIR satellite data for entire 2016: focus on the Arctic seas



Polar sea areas are missing in GOSAT data, in West Siberia the numbers of measurements after filtering relate as 1/100 in favor of IASI. So, GOSAT may be compared with IASI only over land or between 50°S and 50°N over sea.

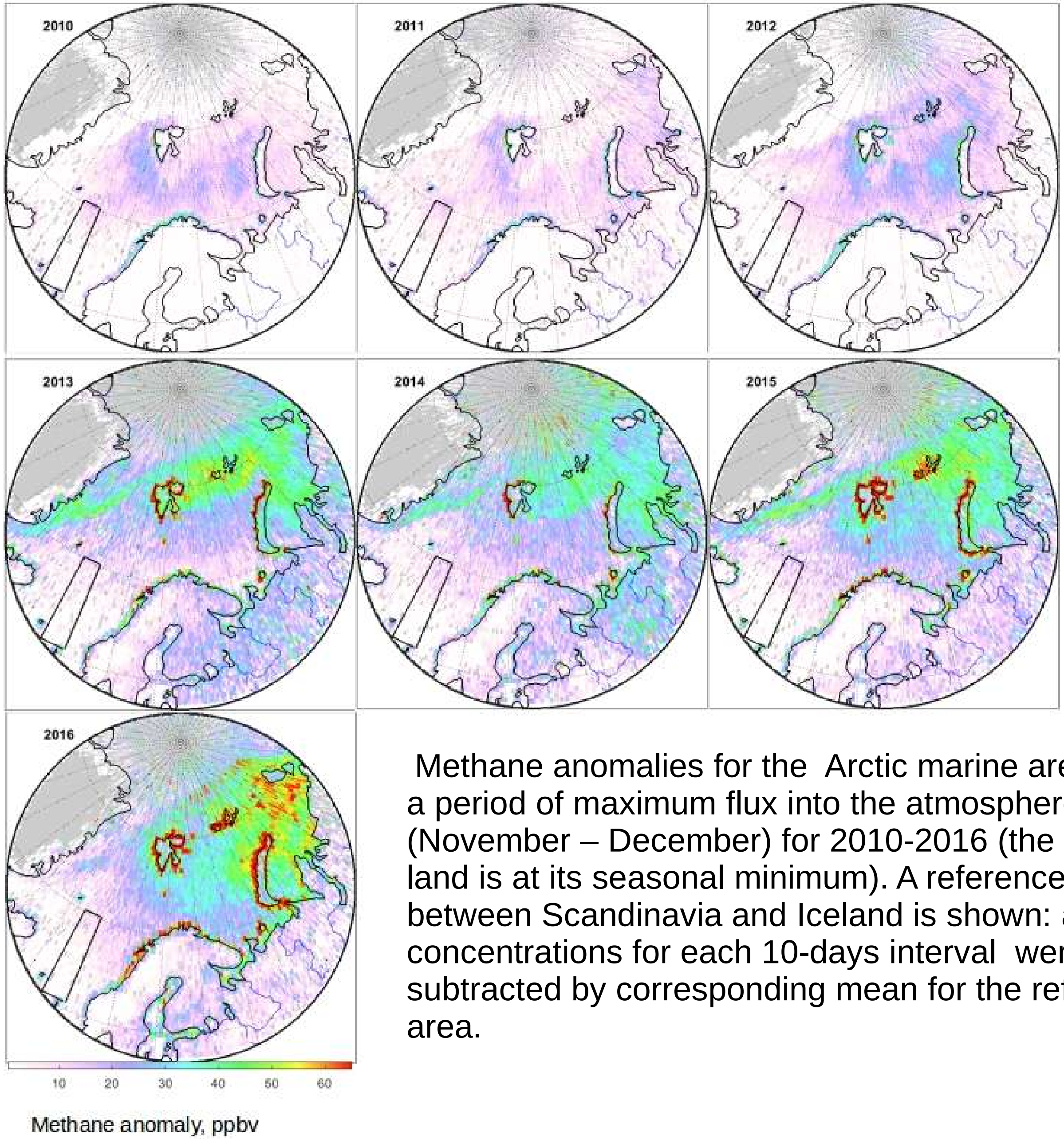
Annual IASI methane anomalies in the North high latitudes referenced to the N. Atlantic quasi-latitudinal band (red).



Concentration anomalies may be preliminary used as a.k.a. for the flux. The most “clean” area in respect of methane is North Atlantic. A quasi-meridional band bounded in red is used as a reference for each 1 degree span of latitude between 50°N and 85°N . Reference VMRs were subtracted from all data.

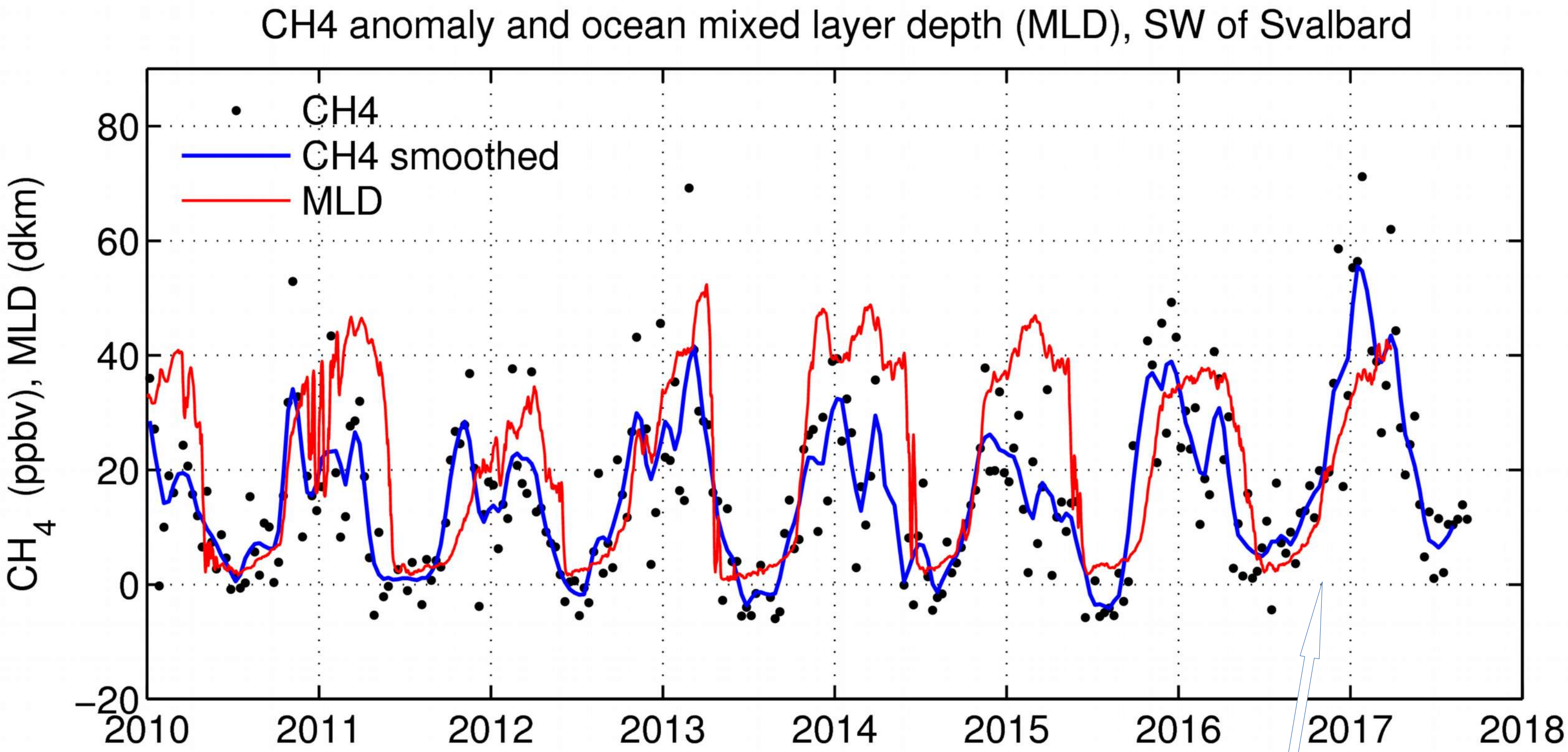
A growth of annually averaged methane anomaly over the Arctic land is obvious, anomalies over seas in winter grew as well but mostly clearly in winter (next slide).

November-December is a period of maximal emission from the Arctic seas

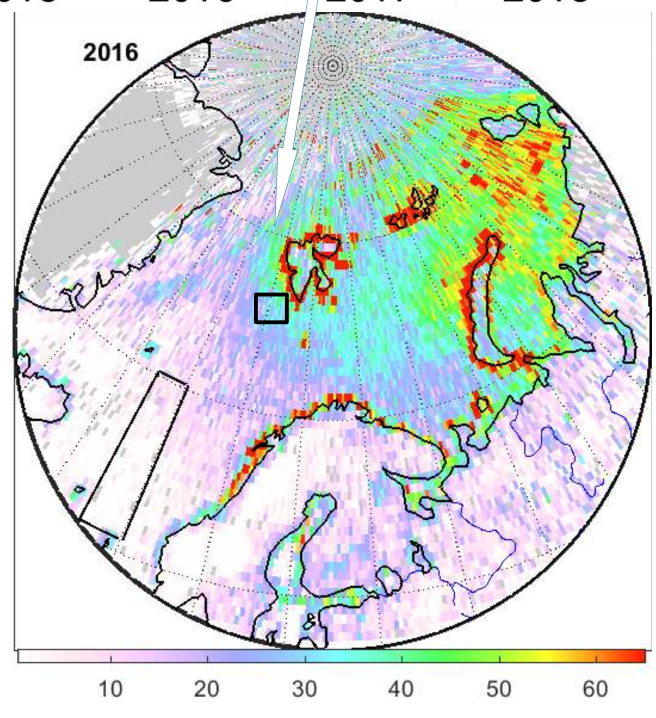


Methane anomalies for the Arctic marine areas during a period of maximum flux into the atmosphere (November – December) for 2010-2016 (the flux from land is at its seasonal minimum). A reference area between Scandinavia and Iceland is shown: all concentrations for each 10-days interval were subtracted by corresponding mean for the reference area.

Explanation of methane seasonal variation over sea

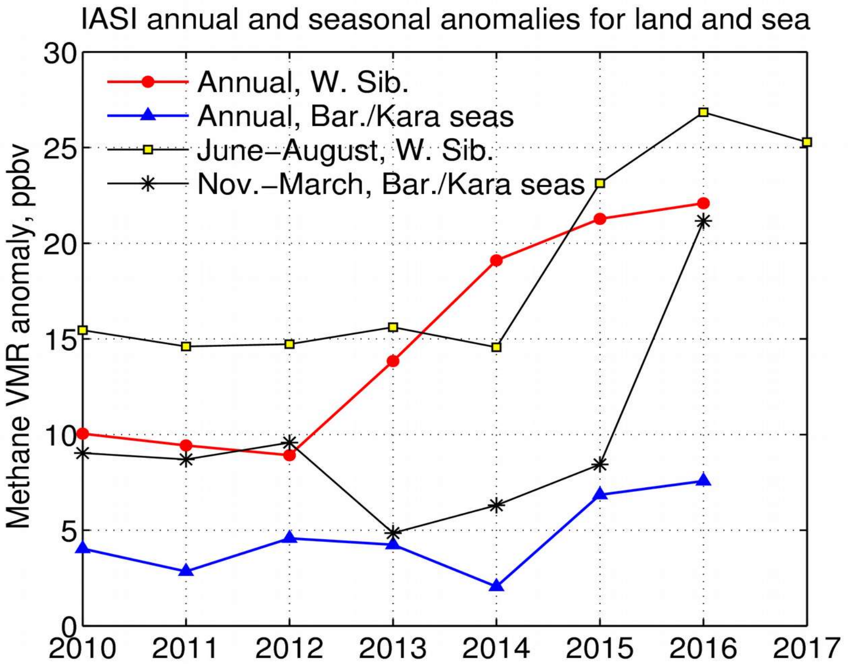


Ocean mixed layer depth (shown in the plot as a red line in dkm) characterizes a degree of ocean mixing; in summer it is less than 20 m, in winter it amounts to 400 – 500 m, i.e, to the total sea depth. A good mixing facilitates transfer of methane from the sea bed to the sea surface and methane anomaly in the atmosphere increases.



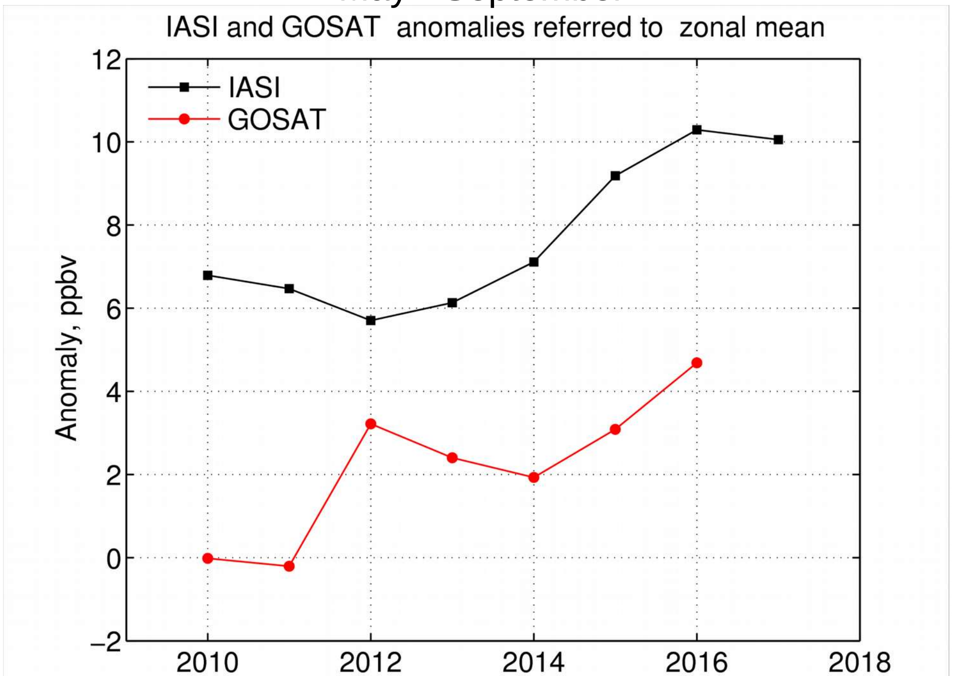
Methane anomalies over sea and land

Anomaly vs time



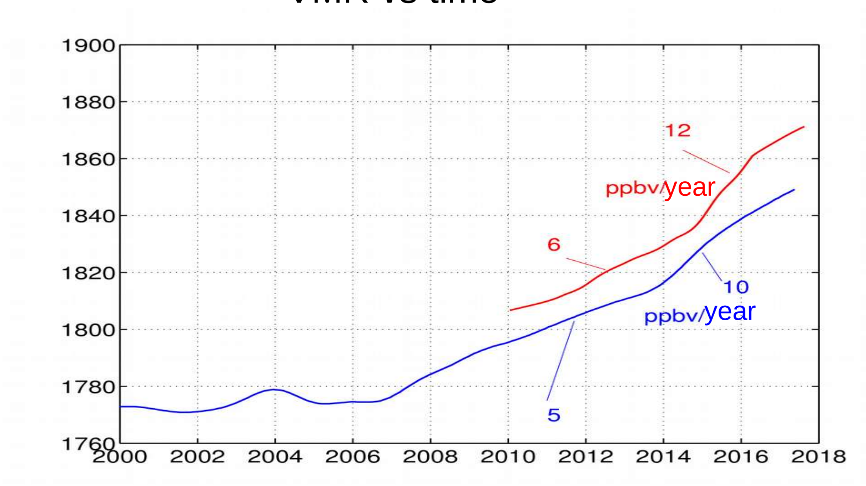
Anomaly is referenced to quasi-meridional band over the North Atlantic

Anomaly over W. Siberia vs time
May - September



Anomaly is referenced to zonal mean

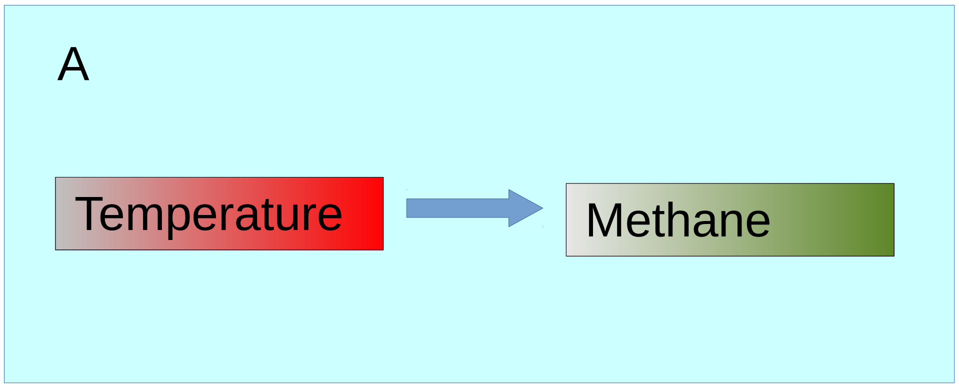
VMR vs time

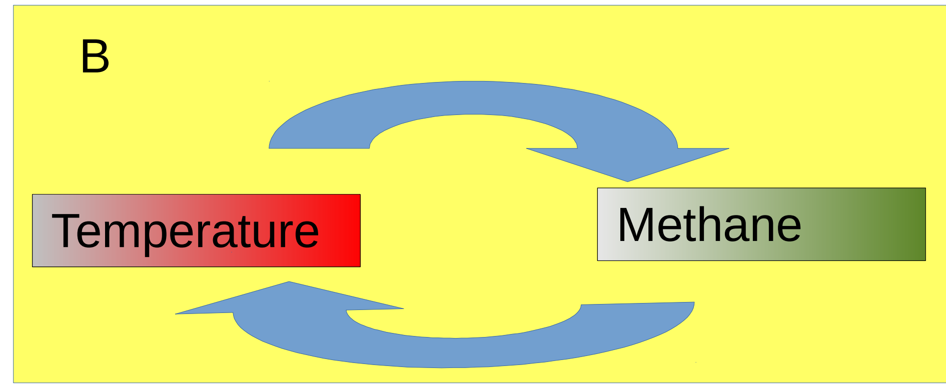


Anomalies doubled in 3 years after stabillity of 2010-2013. VMR growth rate also doubled at the same time. The Arctic (esp. terrestrial) sources contributed into this acceleration. Other sources on the Globe may increase as well.

Conclusions

During three years in a row methane concentrations were growing with a double rate. Anomalies of methane also grew, and by now they are twice as large compared with 2010-2013. Growing temperature is the most likely reason of growing methane (including some anthropogenic). There are two options of the current and future methane trend (among many others):





Option A may be a case of the El-Nino explanation for growing temperature. Option B is a positive feed back loop. Next 2-3 years of measurements may clarify the picture.

Mean anomalies over Barents/Kara seas are just ~ 1/3 of anomalies over Siberia, but marine emissions are growing too and the area of enhanced methane expands eastward. The "***Methane Gun***" hypothesis is still not proven, but can not be ruled out.

Marine methane flux seems to have a seasonal maximum in winter. A winter-time intensification of vertical transport of gases from the sea bed to the sea surface evidently plays a decisive role in methane emission.

The IASI TIR interferometer of relatively high spectral resolution demonstrates a significant sensitivity to methane in the lower 4-km layer of the troposphere. The NASA CrIS instrument of a similar design and resolution promises to supply reliable Arctic CH4 data too. CO2 concentrations over the Arctic, especially in winter time, where and when OCO-2 is inefficient, also need to be retrieved and analyzed.

Most of the results presented are from a paper submitted to the GBC:

L. Yurganov, F. Muller-Karger , and I. Leifer, 2017, Methane Variation Over Terrestrial And Marine Arctic Areas (2010 – 2016): IASI Satellite Data., *Global Biogeochemical Cycles,* submitted.

Also from published papers:

Yurganov L.N., Leifer I., Lund Myhre C., Seasonal and interannual variability of atmospheric methane over Arctic Ocean from satellite data, *Current problems in remote sensing of the Earth from space,* 2016, Vol. 13, No 2, pp. 107-119;

Yurganov L.N., Leifer I., Estimates of methane emission rates from some Arctic and sub-Arctic areas, based on orbital interferometer IASI data, *Current problems in remote sensing of the Earth from space,* 2016, Vol. 13, No 3, pp. 173–183.

Yurganov L.N., Leifer I., Abnormal concentrations of atmospheric methane over the Sea of Okhotsk during 2015/2016 winter, *Current problems in remote sensing of the Earth from space,* 2016, Vol. 13, No 3, pp 231-234.

Yurganov L.N., Leifer I. S., & Vadakkepuliyambatta, S. , Evidences of accelerating the increase in the concentration of methane in the atmosphere after 2014: satellite data for the Arctic, *Current problems in remote sensing of the Earth from space*, 2017,14(5), in press.

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Or available on request from yurganov@umbc.edu

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