Arctic Ocean as a significant source of atmospheric methane: year-round satellite data

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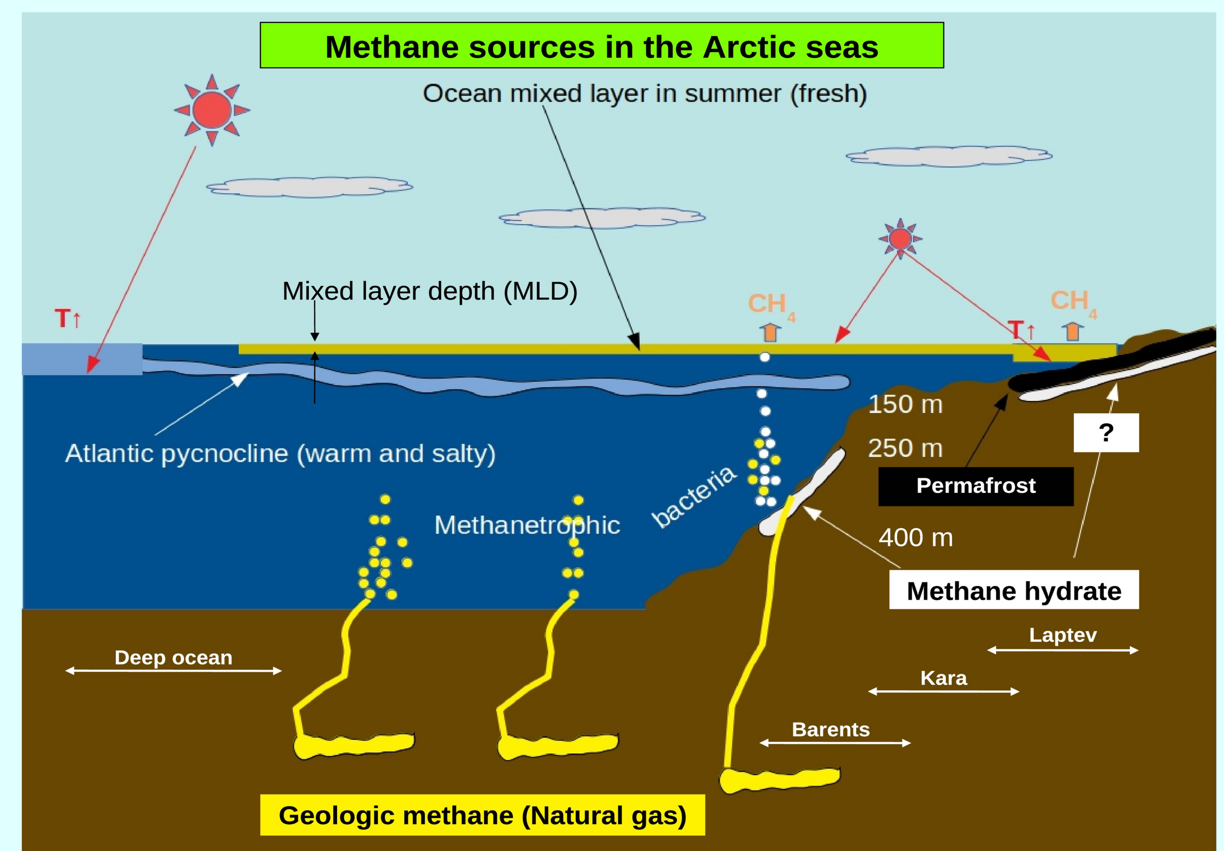
Methane is a greenhouse gas, most of its sources are temperature-dependent. The Arctic is rapidly warming, methane hydrates buried in the seabed may be destabilized and liberated methane may amplify the warming further as a positive feed-back.

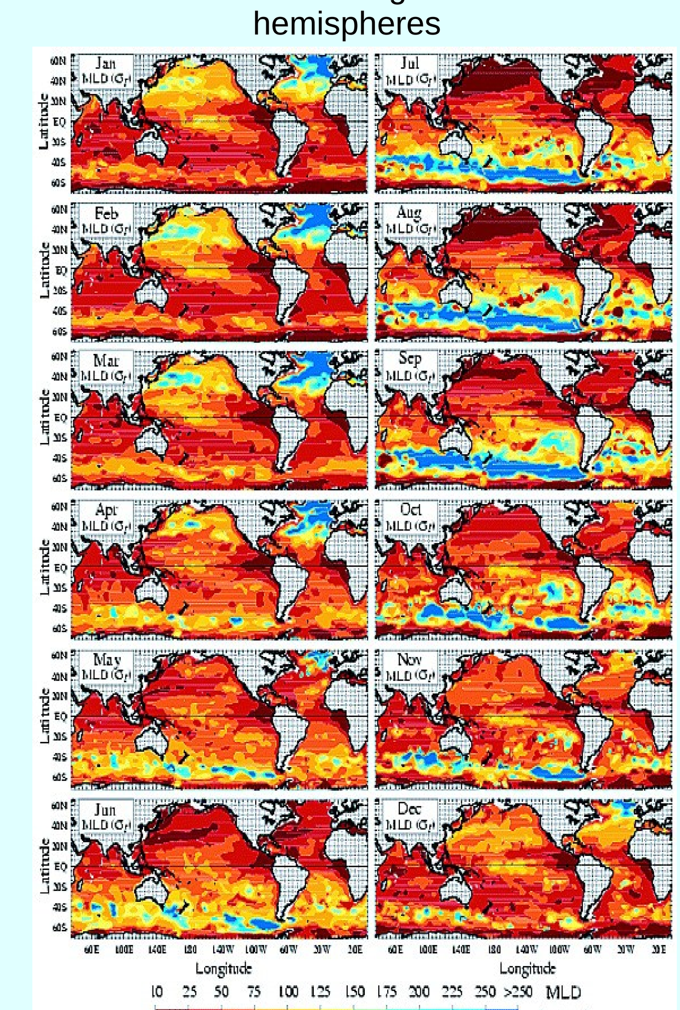
The question is: «ARE THE ARCTIC MARINE SOURCES IMPORTANT FOR REGIONAL AND GLOBAL METHANE BUDGETS?» Thermal IR (TIR) sonders may help to answer this question. They are capable to supply data day-and-night, year-round in contrast to Short-Wave IR (SWIR) that require Sun light.

METHANE IN SEAWATER AND ITS TRANSPORT TO THE TROPOSPHERE

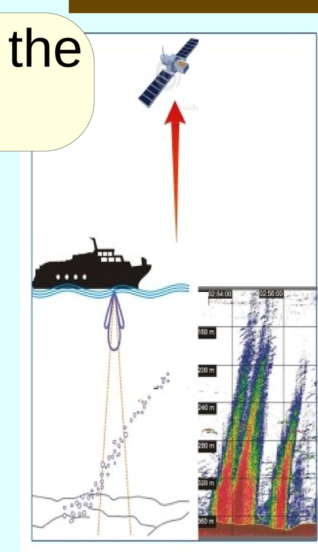
A diagram to the right illustrates location of CH_4 sources and density stratification of the ocean **in summer.** Methane bubbles ascend from the seafloor and dissolve in the seawater en route ***(a bottom-left diagram)***. Finally, methane is consumed by bacteria in seawater. Deep layers of the Arctic seas (***right-bottom graph***) are strongly enhanced with methane but the flux to the amosphere in summer is negligible due to a blocking effect of the pycnocline with a typical mixed layer depth ~50 m. **The situation changes dramatically in late autumn.** The surface layer cools, convection starts, wind mixing grows and the water column becomes well-mixed down to the seafloor. This lets methane reach the atmosphere.



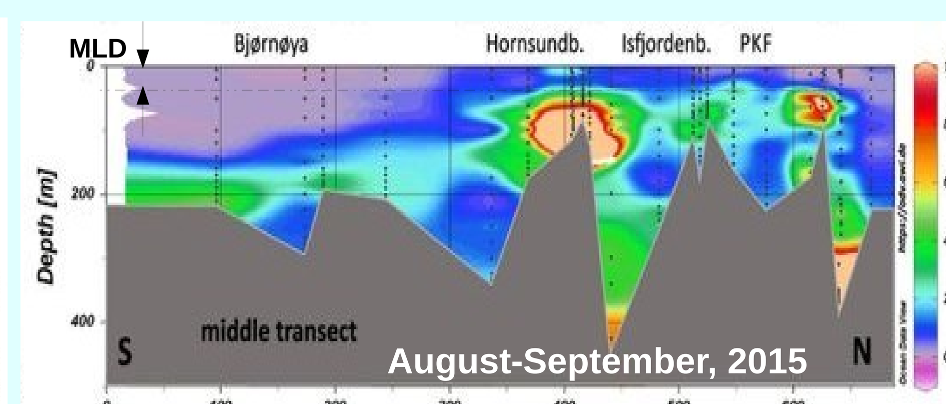
Mixed Layer Depth (MLD)
By Kara et al. (2003)
Note enhanced MLD in high latitudes of both hemispheres



Sonars observe diminishing bubble concentration as the plume approaches the surface. By Veloso et al.(2015)



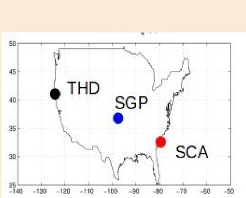
The mixed layer (see a ***top diagram***) is shallow in summer and deepens starting in October-November. Kara et al. (2003) calculated its depth (MLD) globally (below), but in the Arctic only to 65° N. MLD>250 m is estimated for high latitudes of both hemispheres. We calculated it specifically for the box #8 (***map to the right***) using the same global circulation model and compared with methane concentration measured by IASI and AIRS (below).



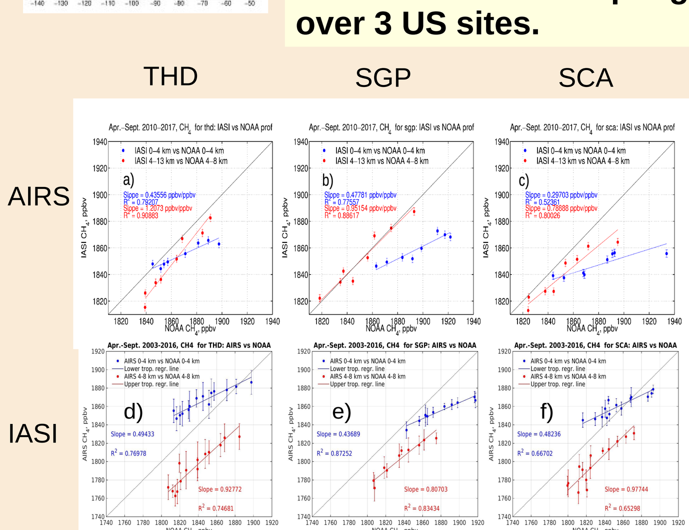
"Widespread methane seepage along continental margin off Svalbard - from Bjørnøya to Kongsfjorden" by Mau et al. (2016)

DO SATELLITES SEE INCREASED METHANE AS THE PYCNOCLINE BREAKS DOWN?

TIR sounders are sensitive to the lower troposphere



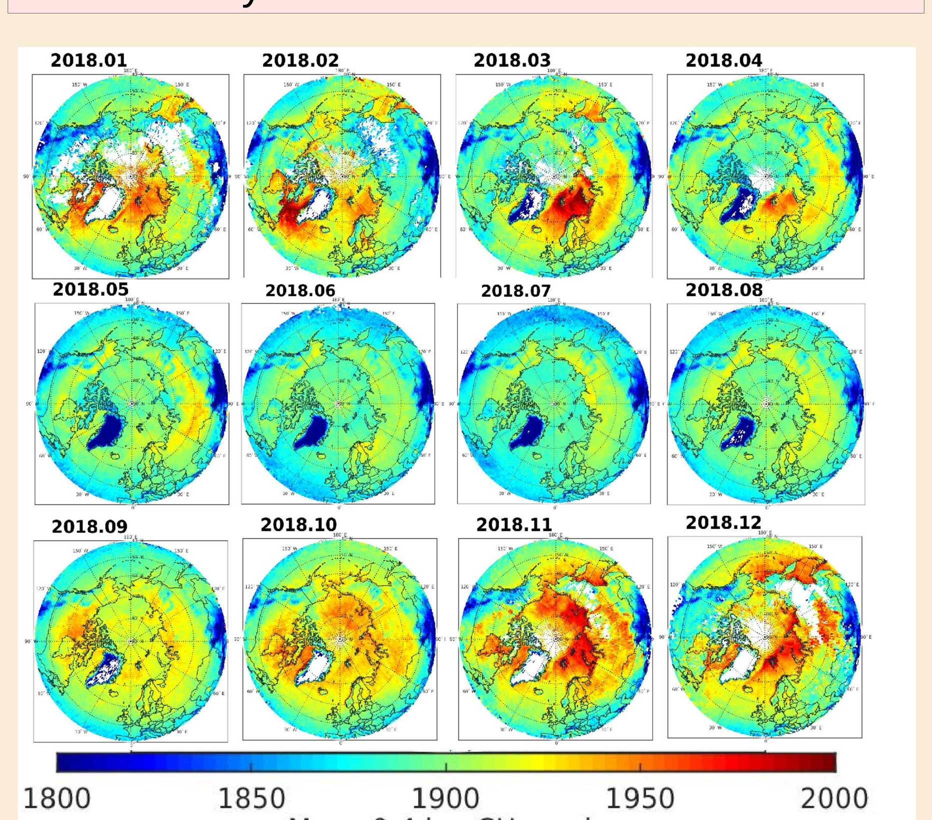
Validation of methane measured by IASI and AIRS satellite sounders versus aircraft sampling over 3 US sites.



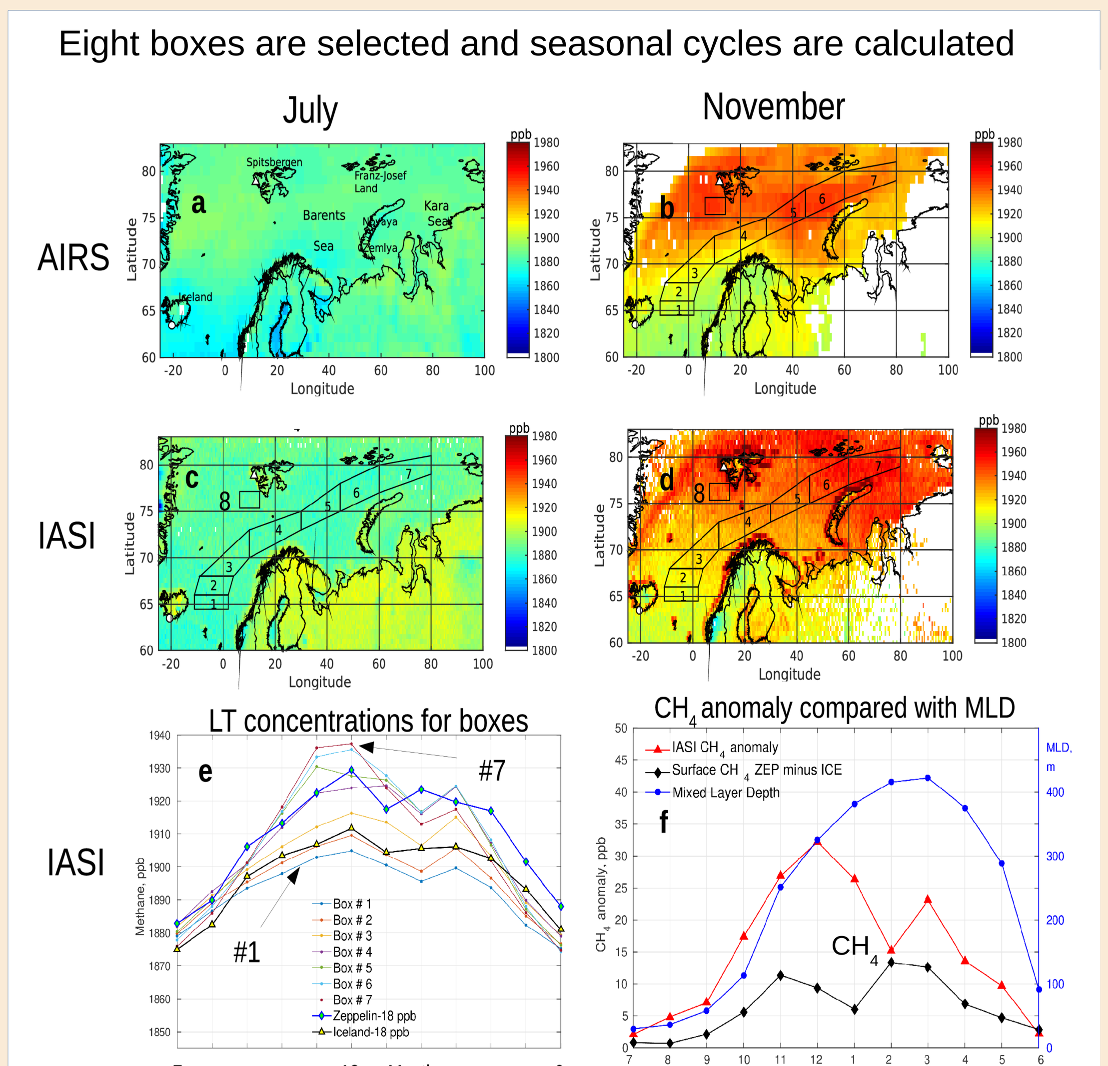
Sensitivity to 0-4 km layer is ~ 0.5. That means underestimation of real methane variations.

Monthly mean IASI methane concentrations in 2018

1. No variations over seas between May and August.
2. Spots of increased methane during autumn-winter mostly in Western Arctic.



Eight boxes are selected and seasonal cycles are calculated



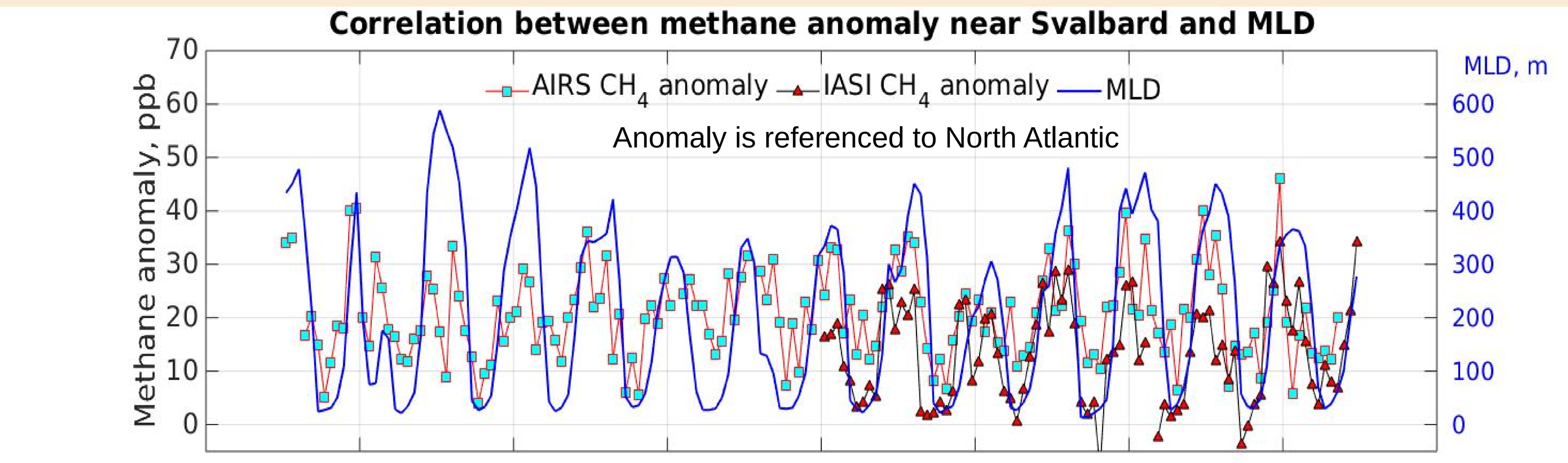
Thick lines for Iceland and Svalbard surface samplings
IASI monthly LT concentrations averaged over 2014-2018

Red: IASI. Black: surface. Blue: MLD
All three lines are 2014-2016 averages for Box #8

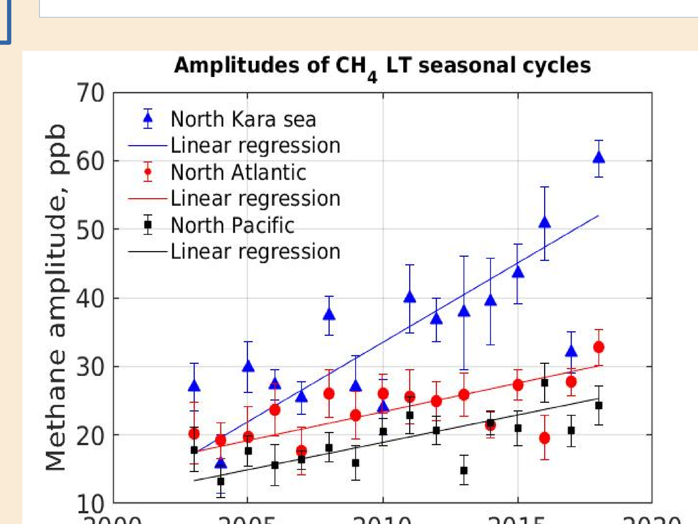
DISCUSSION AND CONCLUSIONS

Various studies have shown Arctic methane seabed emission from west Svalbard and elsewhere. However, current atmospheric methane budgets count the Arctic marine contribution as negligible; a priori it assumed as zero in reverse modeling simulations. TIR sounders AIRS and IASI clearly indicate non-negligible marine methane emissions in late autumn and winter. Yurganov et al. (2016) preliminary estimated its annual magnitude as ~2/3 of terrestrial methane emission to the North of 60° N. Existing estimates of terrestrial emission are in a range between 20 and 30 Tg/yr. Thus the current marine contribution may be in the range 15-20 Tg/yr, i.e., 3-4% of the global emissions. The amplitude of atmospheric CH_4 seasonal cycle is growing at many areas. This may be interpreted as a growing methane emission from the Arctic ocean. Much more work is necessary to investigate trends and inter-annual variability of this methane source.

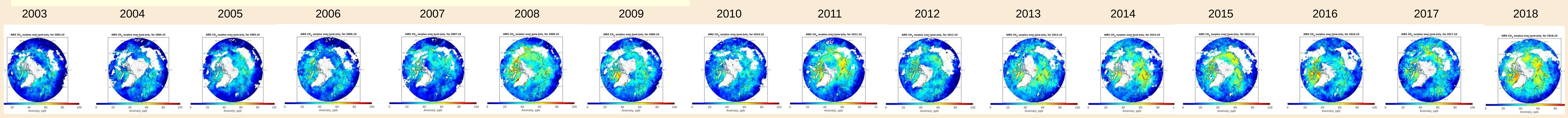
Correlation between methane anomaly near Svalbard and MLD



Methane anomaly referenced to the N. Atlantic background increases since October. This is explained by seawater mixing intensification and/or a breakdown of the summer pycnocline



Seasonal maximum (Nov.-Dec.-Jan.) subtracted by seasonal minimum (May-June-July)



October AIRS methane concentration subtracted by the summer background for the same locations

1) University of Maryland Baltimore County,MD; 2) University of South Florida, St. Petersburg, FL.; 3) Bubbleology Research Int., Solvang, CA