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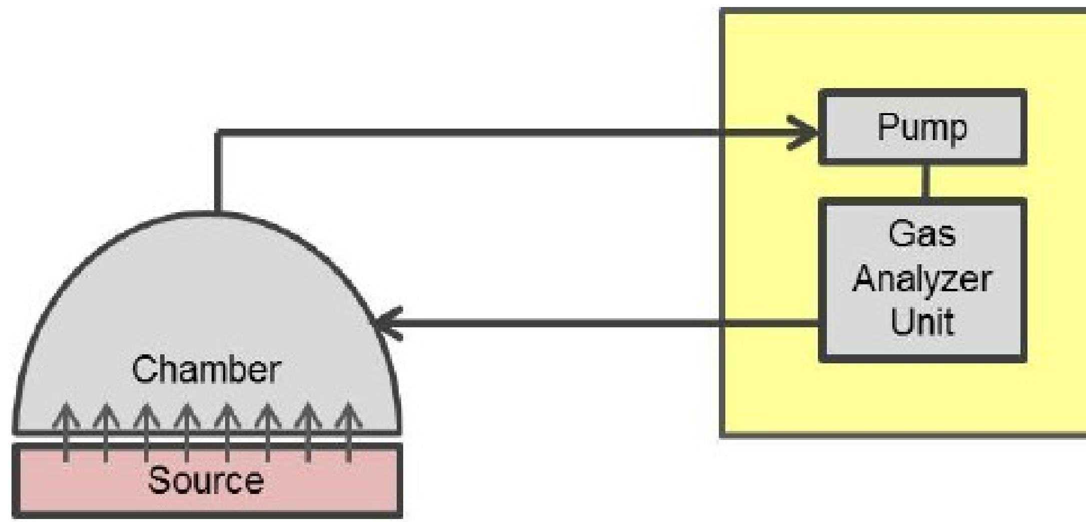
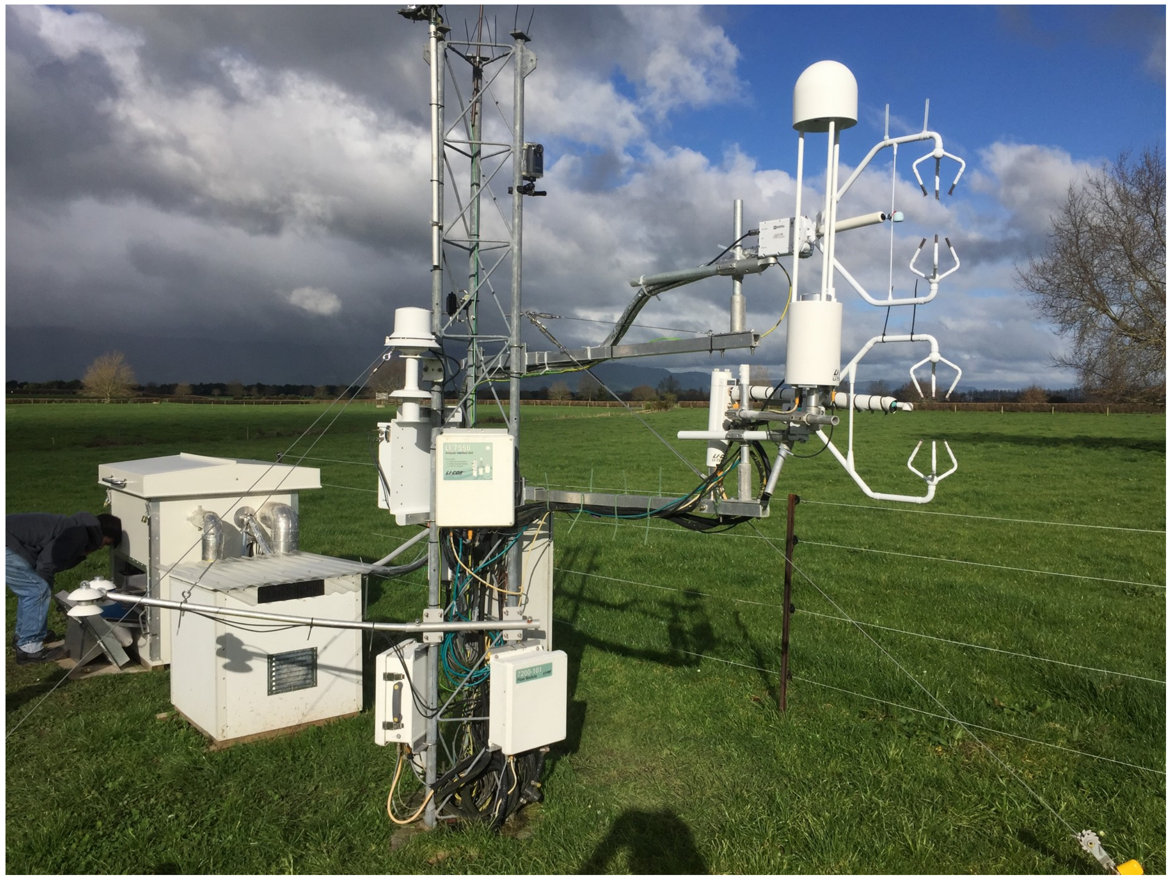
Дополнение к докладу А.В.Елисеева “Глобальный цикл метана”

Измерение потоков метана: камерный метод



- Измеряется поток “в точке”
- Нарушается естественный турбулентный режим приповерхностного слоя воздуха

Измерение потока метана: метод вихревых пульсаций



- Измеряет поток w’C’, эквивалентный осреднённому по некоторой поверхности (footprint area) потоку
- Обладает множеством неопределённостей технического и методического характера

Пресноводные объекты в углеродном цикле

(Tranvik et al. 2009)

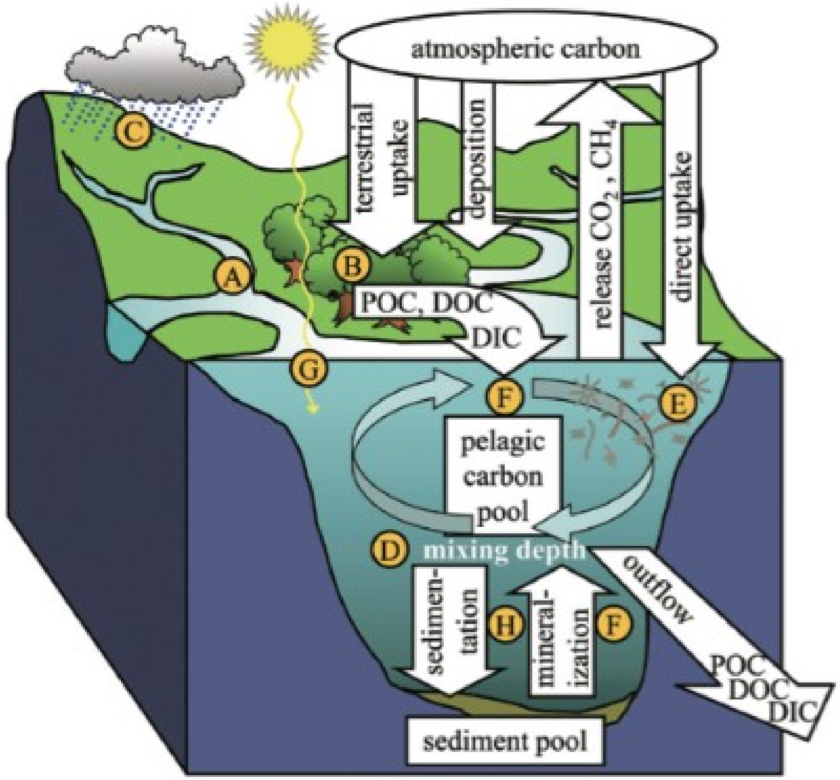


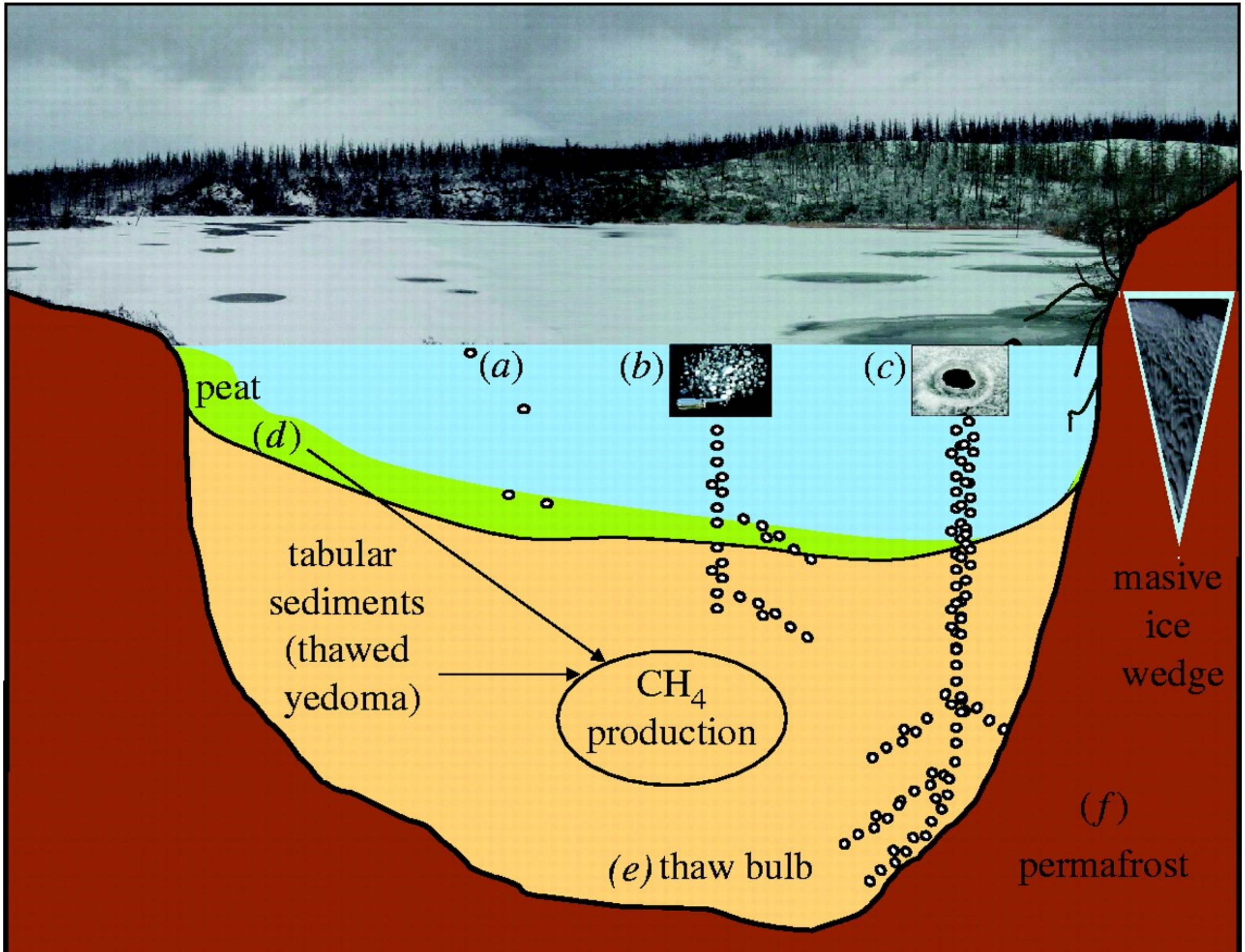
Fig. 2. Schematic diagram showing pathways of carbon cycling mediated by lakes and other continental waters. The letters correspond to rows in Table 1.

(Bastviken et al. 2011)

Latitude	Fluxes: Total open water Emiss.	n	CV	Ebullition Emiss.	n	CV	Diffusive Emiss.	n	CV	Stored Emiss.	n	CV	Area (km^2)
Lakes													
>66°	6.8	17	72	6.4	17	74	0.7	60	37				288,318
>54°–66°	6.6	5	155	9.1	9	60	1.1	271	185	0.1	217	2649	1,533,084
25°–54°	31.6	15	127	15.8	15	177	4.8	33	277	3.7	36	125	1,330,264
<24°	26.6	29	51	22.2	28	54	3.1	29	97	21.3	1		585,536
Reservoirs													
>66°	0.2†												35,289
>54°–66°	1.0	24	176	1.8	2	140	0.2	4	93				161,352
25°–54°	0.7‡												116,922
<24°	18.1	11	87										186,437
Rivers													
>66°	0.1	1											38,895
>54°–66°	0.2†												80,009
25°–54°	0.3	20	302										61,867
<24°	0.9‡												176,856
Sum open water	93.1	116		55.3	71		9.9	397		25.1	254		
Plant flux	10.2												
Sum all	103.3												

- Total freshwater methane emission is 104 Tg yr^{-1}, i.e. 50% of global wetland emission (177-284 Tg yr^{-1}, IPCC, 2013)
- greenhouse warming potentials from freshwater-originating CO_2 and CH_4 are roughly equal

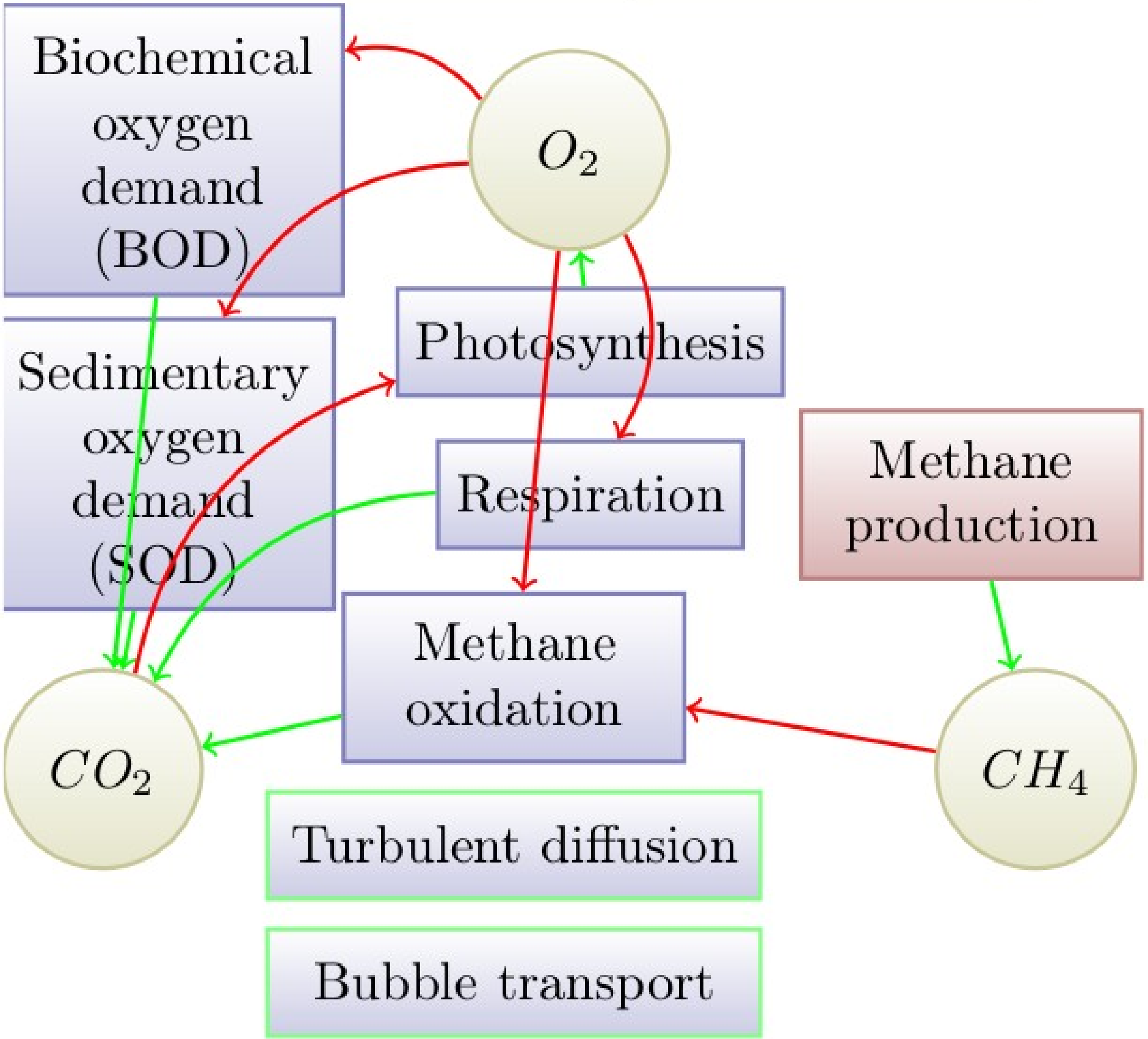
Генерация метана в талике термокарстового озера *(Walter et al., 2007)*



Биогеохимические процессы

- Photosynthesis, respiration and BOD are empirical functions of temperature and Chl-a (Stefan and Fang, 1994)
- Oxygen uptake by sediments (SOD) is controlled by O_2 concentration and temperature (Walker and Snodrgass, 1986)
- Methane production $\propto P_0 q_{10}^{T-T_0}$, P_0 is calibrated (Stepanenko et al., 2011)
- Methane oxidation follows Michaelis-Menthen equation

Sinks and sources of gases in a lake



Результаты моделирования эмиссии метана водоёмами Арктики *(Tan et al., 2015, ERL)*

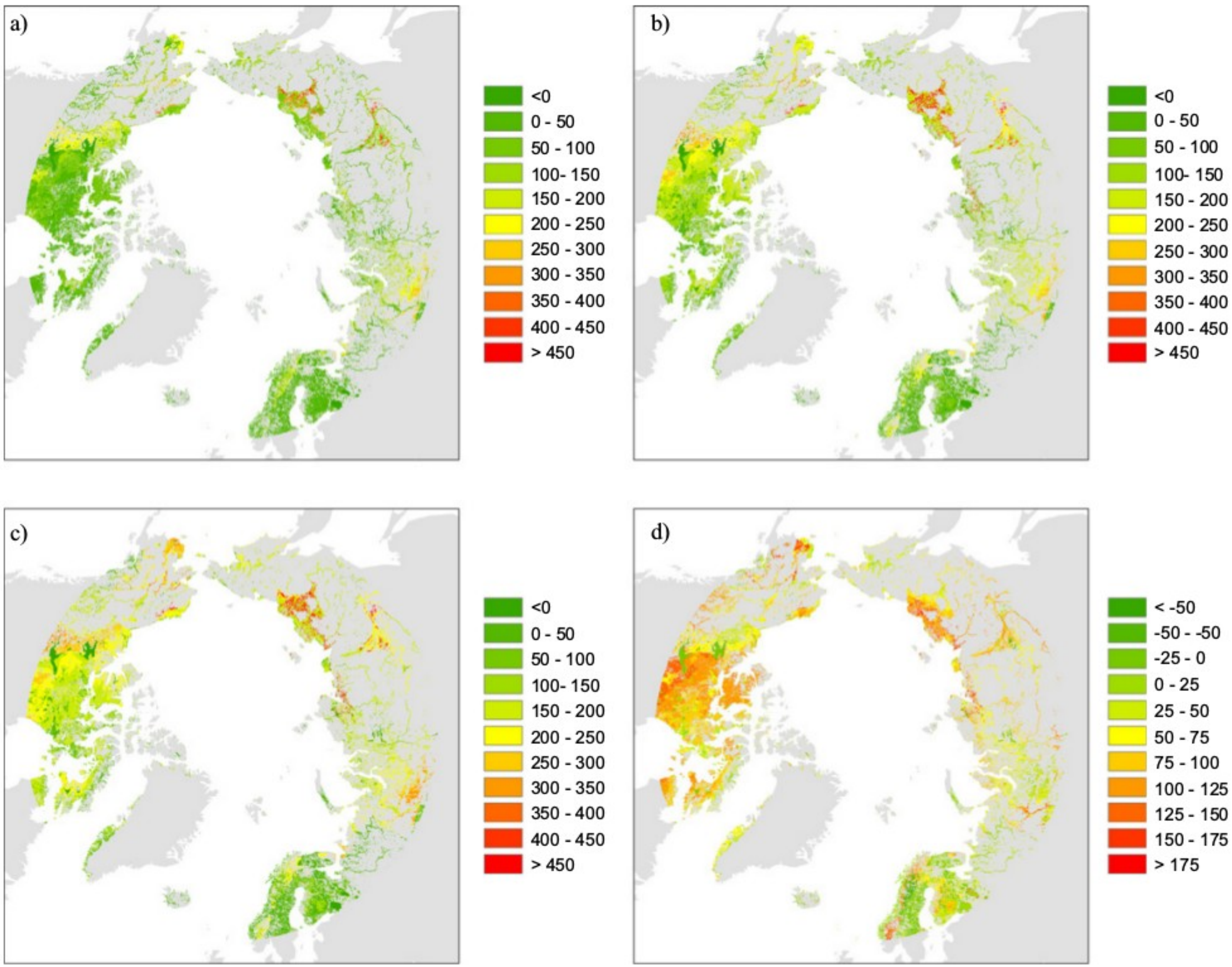


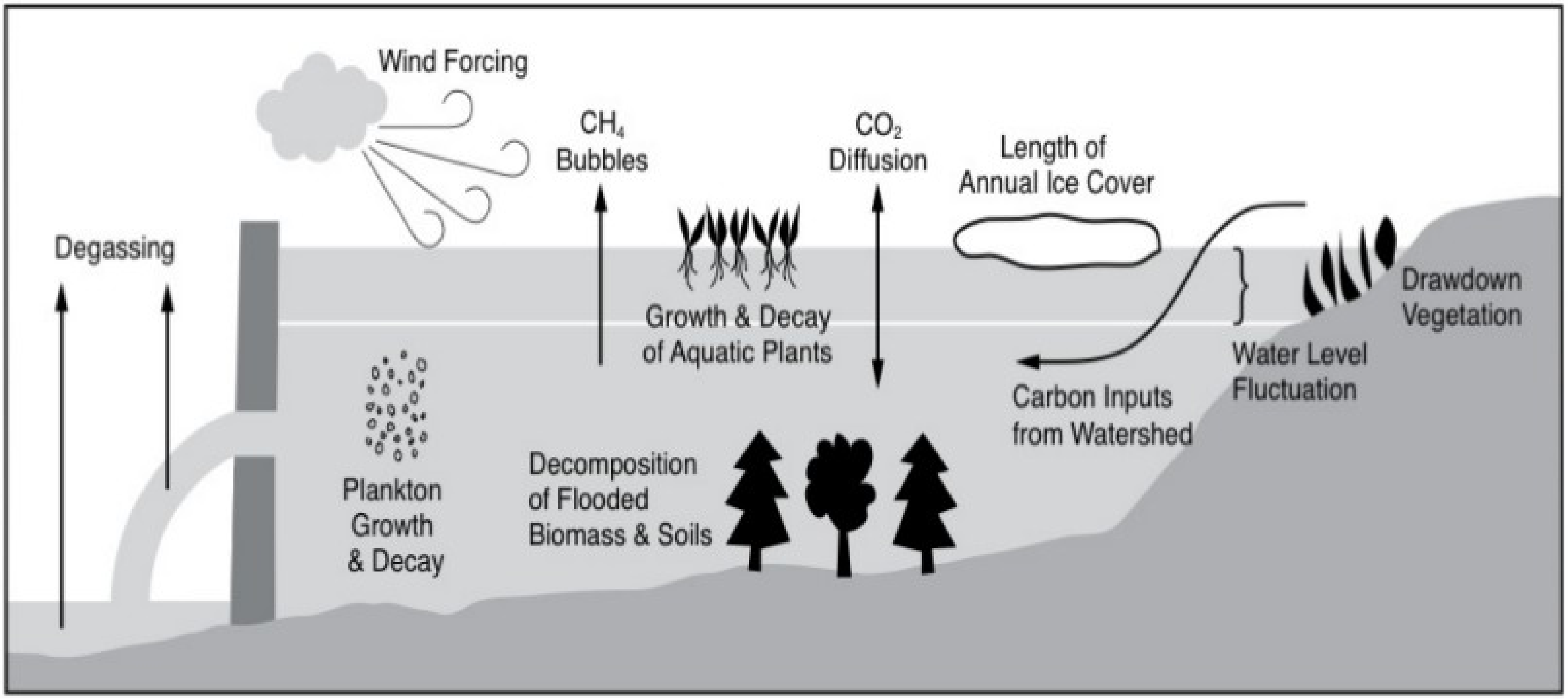
Figure 2. Distribution of CH_4 emissions from arctic lakes (units: mg CH_4 m^{-2} day^{-1}). (a) CH_4 emissions averaged from 2005 to 2008, (b) CH_4 emissions averaged from 2096 to 2099 (RCP 2.6), (c) CH_4 emissions averaged from 2096 to 2099 (RCP 8.5), and (d) the difference of future and present CH_4 emissions.

Сумарная эмиссия Арктическими озёрами за 2005–2008 гг.
11.86 Tg CH_4 yr^{-1}

24.2 +- 10.5 Tg CH_4 yr^{-1}
(Walter et al., 2007)

Средние погоки за 2096 – 2099:
RCP2.6
22.19 Tg CH_4 yr^{-1}
RCP8.5
28.06 Tg CH_4 yr^{-1}

Эмиссия парниковых газов из водохранилищ



- Затопленные экосистемы подвергаются длительному разложению в преимущественно анаэробных условиях
- В отличие от естественных водоемов, имеется дополнительный путь для эмиссии метана в атмосферу – через турбины

Потоки парниковых газов
с водных экосистем суши
(Deemer et al., 2016)

Table 1. The global surface area and GHG flux estimates from reservoirs compared with those of other freshwater ecosystems and other anthropogenic activities.

System Type	**Surface Area (x 10^6 km^2)**	**Annual teragrams (Tg) C or N (Tg per year)**			**Areal Rates (milligrams per square meter per day)**			**Annual CO_2 Equivalents (Tg CO_2 Eq per year)**			
		CH_4-C	**CO_2-C**	**N_2O-N**	**CH_4-C**	**CO_2-C**	**N_2O-N**	**CH_4**	**CO_2**	**N_2O**	**Total**
All Reservoirs (This Study)	0.31[a]	13.3	36.8	0.03	120	330	0.30	606.5	134.9	31.7	773.1
All Reservoirs (Other Work)	0.51–1.5[b,c]	15—52.5[b,d]	272.7[b]	–	82–96	498	–	680–2380	1000	–	
Hydroelectric Reservoirs	0.34[e]	3–14[e,f]	48—82[e,f]	–	24–112	386–660	–	136–635	176–301	–	
Lakes	3.7–4.5[c,g,h]	53.7[d]	292[g]	–	40	216	–	2434	1071	–	
Ponds	0.15– 0.86[i]	12[i]	571[i]	–	27[i]	422[i]	–	544	2094	–	
Rivers	0.36–0.65[d,g]	1.1–20.1[d,j]	1800[g]	–	6–98[j]	7954	–	50–911	6600	–	
Wetlands	8.6–26.9[k]	106—198[k]	–	0.97[l]	15—63[k]	–	0.1–0.31	4805–8976		908	
Other Anthropogenic Emissions (2000s)	N.A.	248[m]	9200[m]	6.9[m]	–	–	–	11243	33733	6462	51438

Note: The values presented are mean estimates; the ranges of mean values are reported when there are multiple relevant models. In cases in which the areal rates are not referenced, they were derived from dividing annual teragrams (Tg) of C or N by the global surface-area estimate. The annual CO_2 equivalents were calculated by multiplying the mass-based flux (in units of Tg CH_4, CO_2 or N_2O per year) by the 100-year global warming potential of each gas (1 for CO_2, 34 for CH_4 and 298 for N_2O). [a] (Lehner et al. 2011). [b] (St. Louis et al. 2000). [c] (Downing and Duarte 2009). [d] (Bastviken et al. 2011) . [e] (Barros et al. 2011). [f] (Li and Zhang 2014). [g] (Raymond et al. 2013). [h] (Verpoorter et al. 2014). [i] (Holgerson and Raymond 2016). [j] (Stanley et al. 2016). [k] (Melton et al. 2013). [l] (Tian et al. 2015). [m] (Ciais et al. 2013).