Electronic Supplementary Material (ESI) for Environmental Science: Atmospheres.

Supporting information

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1. Glossary

Term/notation	Definition
Aircraft	Manned aircraft used in aerial surveys to measure emissions over facilities. Aircraft is equipped with technology capable of measuring methane concentration (cavity ring-down spectrometer, flask canisters, methane analysers) which is converted into methane flowrate through atmospheric inversion methods.
Bottom-up	Approach to emission estimations. Emissions are measured at the source and emissions extrapolated to facility/field/basin scale. Methods include point-source, enclosed chamber, micrometeorological, perimeter facility, external tracer, inverse dispersion modelling, drones and unmanned aerial vehicles (1)
Enclosed chamber	Chamber placed over emission source. Concentration/composition inside the chamber is analysed to derive the emission rate.
External tracer	A tracer gas released at (perceived) point source of emissions. Downwind concentration of tracer gas and methane is used to determine emission rate.
Flux	Net rate of exchange between ecosystems and the atmosphere. Has units of mass flow rate- kg CH_4/h, Mt CH_4/y etc.
Micrometeorological	Short towers located at or near a facility which measure methane concentration. Emission rate is derived through atmospheric inversion methods.
Mobile laboratory	A van equipped with equipment capable of measuring methane, such as cavity ring-down spectrometer, flask canisters, methane analysers. Methane concentration data is converted into flow rates through atmospheric inversion methods.
Perimeter facility	Onsite sensors (infrared or laser based) which measure methane concentration. Emission rates are derived through atmospheric inversion methods.
Point source	A technology which detects or measures emission rates at the source.
Remote observatory	An observation station which measures the atmospheric concentration of methane through infrared spectroscopy or other methods. Stations are not close to facilities and can be part of a network of observation towers. Emission rates are calculated through atmospheric inversion methods.
Satellite	Object which orbits the Earth which is equipped with technology capable of measuring atmospheric methane concentration- typically a spectrometer. Emission rates are derived through atmospheric inversion methods

Super-emitter	An emission source (component or facility) which is responsible for a disproportionate percentage of emissions. Numerous definitions have been used in past literature to define this, including 5% of components/facilities responsible for 50% of emissions (2) and top 10% of emission sources (3). Note, there is no emission threshold for a super emitter. A super emitter can have an emission rate of >100 kg CH_4/hr or $\ll$100 kg CH_4/h. An emission source is termed a super emitter provided it is a statistical outlier relative to other sources in the dataset.
Top-down	Approach to emission estimations where observations of atmospheric concentration are used in atmospheric chemistry transport models to allocate emissions to individual sources. Methods include remote observatory, towers, aircrafts (mass balance and sensing methods), drones and unmanned aerial vehicles and satellites (1).
Towers	Similar to an observatory but a tall tower instead of a dedicated observatory. Can also be part of a network.
Unmanned Aerial Vehicle	Light aircraft equipped with technology capable of measuring methane concentration. These are remote controlled and much smaller than aircrafts.

2. Overview of satellites for methane measurement

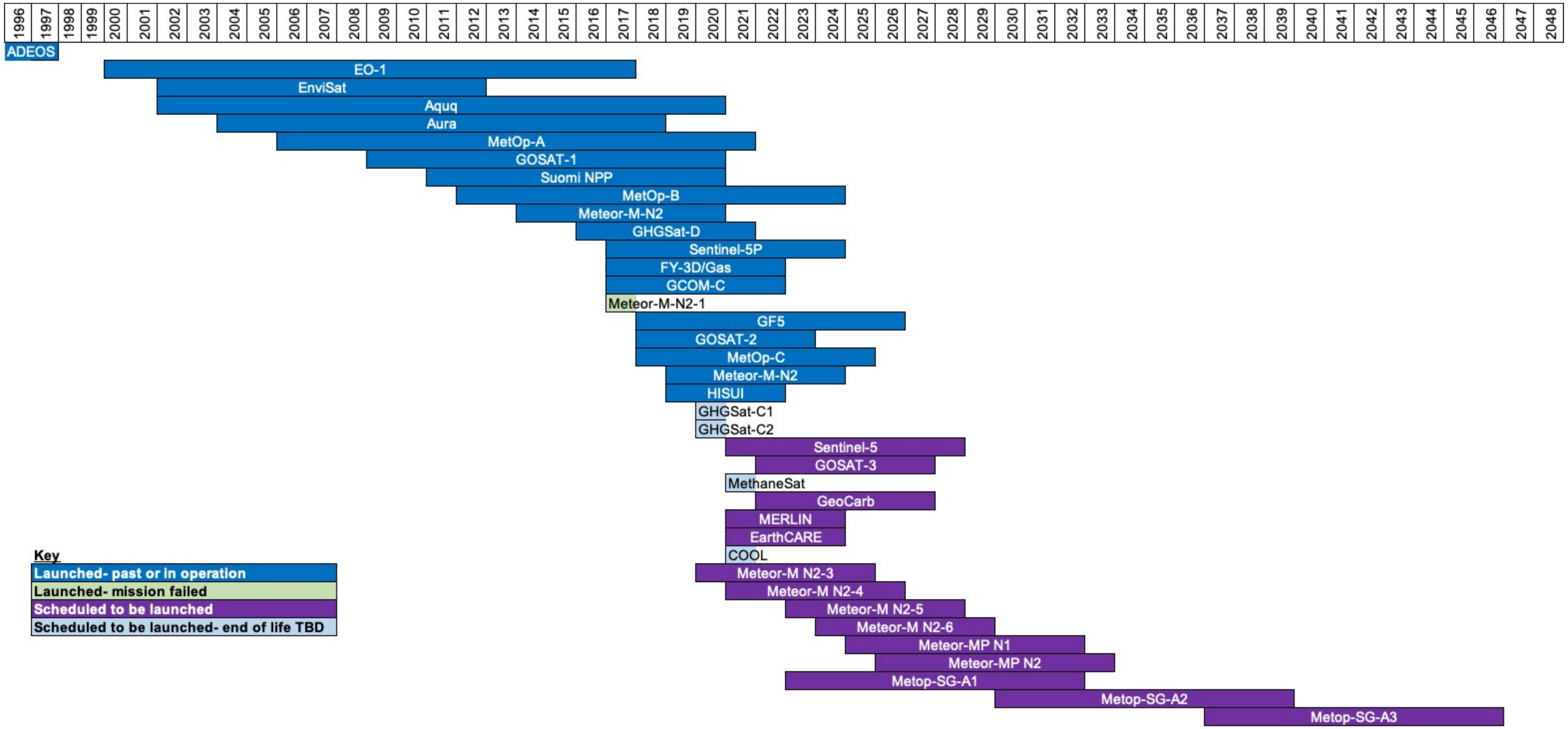


Figure S1: Timeline of satellites capable of detection and measuring methane. Please note that GHGSat-C1 was successfully launched on 2nd September 2020 but no expected end of life is specified.

Table S1: Overview of past and current satellites for methane monitoring (4-44).

Satellite[a]	Agency/enterprise[b]	Purpose	Launch date	Current status	End of life
ADEOS	JAXA, MITI	Earth environmental research	17/08/1996	Inactive	30/06/1997
Aqua	NASA	Study the water cycle	04/05/2002	In operation	>2020
Aura	NASA	Monitor the complex interactions of atmospheric constituents	15/07/2004	In operation	31/01/2018
EnviSat	ESA	Further the capacity to study and monitor the Earth and its environment	01/03/2002	Mission ended/inactive	08/04/2012
EO-1[c]	NASA	Explore new remote sensing technologies that advance and enhance climate monitoring capabilities	21/11/2000	Mission ended/inactive	30/03/2017
FY-3D/Gas	CNSA (CMA, NRSCC)	Scientific research on the Earth's atmosphere	14/11/2017	In operation	>2022
GCOM-C	JAXA	Global long-term observation of Earth's environment	23/12/2017	In operation	>2022
GF-5/GMI	CNSA	Provide global observations of the Earth's surface	08/05/2018	In operation	>2026
GHGSat-D (Claire)	GHGSat	High-resolution monitoring GHG emissions from industrial sites around the world	21/06/2016	In operation	>2021
GOSAT-1	JAXA	Estimate emissions of GHGs	23/01/2009	In operation	>2020
GOSAT-2	JAXA	Estimate emissions of GHGs	29/10/2018	In operation	>2023
ISS HISUI	NASA, CAS, ESA, JAXA, Roscosmos	Precursor to full-scale application of hyperspectral remote sensing for oil/gas/mineral resource exploration and other fields	05/12/2019	In operation	>2022
Meteor-M N2	RosHydroMet, Roscosmos	Global climate change monitoring	08/07/2014	In operation	>2020
Meteor-M N2-1[d]	RosHydroMet, Roscosmos	Global climate change monitoring	28/11/2017	Inactive	28/11/2017
Meteor-M N2-2	RosHydroMet, Roscosmos	Global climate change monitoring	05/07/2019	In operation	>2024
MetOp-A	CNES, EUMETSAT	Provide more detailed observations of the global atmosphere, oceans and continents	19/10/2006	In operation	>2021

MetOp-B	CNES, EUMETSAT	Provide more detailed observations of the global atmosphere, oceans and continents	17/09/2012	In operation	>2024
MetOp-C	CNES, EUMETSAT	Provide more detailed observations of the global atmosphere, oceans and continents	07/11/2018	In operation	>2025
Sentinel-5P	ESA	Perform atmospheric measurements with high spatial-temporal resolution	13/10/2017	In operation	>2024
Suomi NPP	NOAA, NASA	Provide data continuity for key data series observations initiated by NASA's EOS series missions	28/10/2011	In operation	>2020

a: ADEOS: Advanced Earth Observing Satellite; EnviSat: Environmental Satellite ; EO-1: Earth-Observing-1; FY-3D: Fengyun-3D; GF-5/GMI: Gaofen-5/Greenhouse gas monitoring instrument; GOSAT: Greenhouse gas observing satellite; ISS HISUI: International Space Station Hyperspectral Imager Suite; Suomi NPP: Suomi National Polar-orbiting Partnership.
b: China Meteorological Administration (CMA); Centre national d'études spatiales/French National Centre for Space Studies(CNES); China National Space Administration (CNSA); Canadian Space Agency (CSA); European Space Agency (ESA); European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT);Japan Aerospace Exploration Agency (JAXA); Japanese Ministry of International Trade and Industry (MITI); National Aeronautics and Space Administration (NASA); National Remote Sensing Centre of China (NRSCC).
c: 1.5 years/end of 2001 is design life, but mission was extended to 30/03/2017.
d: Satellite failed to separate from upper stage lost communication.

Table S2: Specifications and characteristics of past and current satellites for methane detection (4-44).

Satellite	Observation equipment	Earth coverage	Orbit height (km)	Orbit type	Spatial resolution	Period (minutes)	Repeat cycle

ADEOS	Interferometric Monitor for Greenhouse Gases (**IMG**)	Global	803	Sun-synchronised	10 to 60 km	100.8	41 days
Aqua	Atmospheric Infrared Sounder (**AIRS**)	Global	705	Sun-synchronised	2.3x2.3 km	98.8	16 days
Aura	Tropospheric Emission Spectrometer (**TES**)	Global	705	Sun-synchronised	0.53x0.53 km	100	16 days
EnviSat	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (**SCIAMACHY**)	Global	790	Sun-synchronised	120x30 km or 60x30 km	100	35 days
EO-1	Advanced Land Imager (**ALI**)/Hyperion	Global	705	sun-synchronised	30 m	99	16 days
FY-3D/Gas	Greenhouse Gases Absorption Spectrometer (**GAS**)	Global	836	Sun-synchronised	13 km	101.4	6 days
GCOM-C	Second-generation Global Imager	Global	798	sun-synchronised	0.25x1 km	100.9	3 days
GF-5/GMI	Spatial heterodyne spectroscopy technology for hyperspectral spectroscopy	Global	705	Sun-synchronised	10x10 km	98.8	
GHGSat-D (Claire)	Wide-Angle Fabry-Perot (**WAF-P**)	Location mapping	500	Sun-synchronised	12x12 km	90	14 days
GOSAT-1	Thermal And Near infrared Sensor for carbon Observation - Fourier Transform Spectrometer (**TANSO-FTS**) and Thermal And Near infrared Sensor for carbon Observation - Cloud and Aerosol Imager (**TANSO-CAI**)	Global	666	Sun-synchronised	10.5 km (diameter)	100	3 days
GOSAT-2	TANSO-FTS/2 and CAI/2	Global	613	Sun-synchronised	9.7 km (diameter)	97	6 days
ISS HISUI	Hyperspectral Imager Suite (**HISUI**)	Global	400	Low-Earth	20x30m	92	3 days
Meteor-M N2	Infrared Fourier Spectrometer-2	Global	825	Sun-synchronised	30 km	101.4	
Meteor-M N2-1	Infrared Fourier Spectrometer-2	Global	-	-	-	-	-
Meteor-M N2-2	Infrared Fourier Spectrometer-2	Global	832	Sun-synchronised	30 km	101.1	
MetOp-A	Infrared Atmospheric Sounding Interferometer (**IASI**)	Global	817	Sun-synchronised	12 km (diameter)	101.36	29 days
MetOp-B	IASI	Global	817	Sun-	13 km	101.36	29 days

				synchronised	(diameter)		
MetOp-C	IASI	Global	817	Sun-synchronised	14 km (diameter)	101.36	29 days
Sentinel-5P	TROPOspheric Monitoring Instrument (**TROPOMI**)	Global	824	Sun-synchronised	7x7 km or 5.5x7 km	100	16 days
Suomi NPP	Cross-track Infrared Sounder (**CrIS**)	Global	824	Sun-synchronised	14 km (diameter)	101	16 days

Table S3: Overview of future satellites for methane detection[a] (45-71).

Satellite[b]	**Space Agency/enterprise[c]**	**Current status**	**Launch date**	**EOL**	**Orbit height (km)**	**Spatial resolution**	**Earth coverage**
GHGSat-C1 (Iris)	GHGSat	Launch postponed/scheduled to be launched	2020	TBD	500	12x12 km	Location mapping
GHGSat-C2	GHGSat	Launch postponed/scheduled to be launched	2020	TBD	500	12x12 km	Location mapping
Sentinel-5	ESA	Scheduled to be launched/planned	2021	>2028	830	7.5x7.5 km	Global

GOSAT-3	JAXA	Scheduled to be launched/planned	2022	>2027	666	100x400 m	Global
MethaneSAT	EDF	Scheduled to be launched/planned	2021/22	TBD		1x1 km	Area mapping
GeoCarb	NASA	Scheduled to be launched/planned	>2022	>2027	35,786	5 to 10 km	The Americas
MERLIN	DLR/CNES	Scheduled to be launched/planned	2021	>2024	506	0.15x0.15 km	Global
EarthCARE	ESA, JAXA	Scheduled to be launched/planned	>2021	>2024	393		Global
COOL microsatellites	Bluefield	Scheduled to be launched/planned	>2020	TBD			
CarbonSat	ESA	Mission concept	TBD	TBD	594/794	2x3 km	Global
GEO-CAPE	NASA	Mission concept	TBD	TBD		4x4km	The Americas
G3E	European	Mission concept	TBD	TBD		2x3 km	Global
Meteor-M N2-3	RosHydroMet, Roscosmos	Scheduled to be launched/planned	>2020	>2025	832		Global
Meteor-M N2-4	RosHydroMet, Roscosmos	Scheduled to be launched/planned	>2021	>2026	832		Global
Meteor-M N2-5	RosHydroMet, Roscosmos	Mission concept	>2023	>2028	832		Global
Meteor-M N2-6	RosHydroMet, Roscosmos	Mission concept	>2024	>2029	832		Global
Meteor-MP N1	RosHydroMet, Roscosmos	Mission concept	>2025	>2032	830		Global
Meteor-MP N2	RosHydroMet, Roscosmos	Mission concept	>2026	>2033	836		Global
Metop-SG-A1	ESA/EUMETSAT	Scheduled to be launched/planned	>2023	>2032	823-848		Global
Metop-SG-A2	ESA/EUMETSAT	Scheduled to be launched/planned	>2030	>2039	823-848		Global
Metop-SG-A3	ESA/EUMETSAT	Scheduled to be launched/planned	>2037	>2046	823-848		Global

a: Other satellite mission concepts are Sentinel-7 and Cal-CEMS. These were not included in the table as no information on launch date, status and coverage were found.

b: GOSAT-3: Greenhouse gases Observing Satellite-3; GeoCarb: Geostationary Carbon Cycle Observatory; MERLIN: Methane Remote Sensing Mission; EarthCARE: Earth Clouds, Aerosol and Radiation Explorer; COOL: CH4 Observation of Lower troposphere; GEO-CAPE: Geostationary Coastal and Air Pollution Events; G3E: Geostationary Emission Explorer for Europe.
c: Environmental Defence Fund (EDF); German Space Administration (DLR); French Space Agency (CNES); European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT); for other acronyms see Table S1.

3. Atmospheric inversion

To convert the data measured by satellites into fluxes, statistical methods which combine top-down and bottom-up information are used. The most commonly used technique is Bayesian synthesis inversion but there are other techniques available e.g. geostatistical and data assimilation. Atmospheric inversion is required for data measured by all satellites, except GHGSat, which provides flux estimations. In general, atmospheric inversion tools consist of three stages:

Atmospheric observations data

Data collected from satellites or other top-down sources. It is important that uncertainties attached to these should be accounted for and both observational and representativeness is considered. The observation data can be raw or used as means (yearly, monthly, weekly etc.).

Prior fluxes/a prior knowledge of sources and sinks

This information is given by gridded inventories (e.g. Emission Database for Global Atmospheric Research (EDGAR)), models or other top-down emission sources (in-situ monitoring networks, e.g. Total Carbon Column Observing Network (TCCON), air sampling from aerial campaigns) (72). The information is optimised by the inversion procedure with a time resolution varying from one day to monthly.

Chemistry transport model (CTM)/ atmospheric transport model (ATM)

These are statistical models which solve the mass conservation equation to calculate the spatial-temporal distribution of an atmospheric trace gas (72). Surface sources and sinks are converted into atmospheric concentration in the model after being advected, convected and, for reactive species, chemically transformed. In addition to atmospheric and a priori data, the models need external forcing data (meteorological, surface conditions and climate). The models are used either in a forward mode (emissions give concentrations) or in a backward mode (concentrations give areas from which emissions originate). The model also requires the calibration of the response function; contribution of one specific region to a specific measurement.

Commercial CTM are available and are commonly used when using satellite data to detect/measure emissions from the oil and gas industry. The most commonly used CTM are GEOS-Chem (Goddard Earth Observing System-coupled with Chemistry) and WRF-Chem (Weather Research and Forecasting-coupled with Chemistry).

4. Factors affecting satellite capabilities

4.1. Clouds

Clouds are currently the most important limiting factor for satellites. Measurements can be taken over low coverage e.g. Cirrus. However, refraction may occur leading to inaccurate measurements. For thicker and denser clouds e.g. Nimbostratus, Stratus and Cumulonimbus, no detection can occur. For this assessment, cloud fraction data was collected from the Cloud, Albedo and Surface Radiation (CM SAF CLARA-A2) dataset from Advanced Very High Resolution Radiometer (AVHRR) data (73). Data from 2010 to 2015 were collected to assess the impact of cloud coverage. The resolution of the data is 0.25x0.25 degrees, meaning slight differences between pixels will occur for patchy cloud data. This will affect satellites with more precise resolutions. Only areas that contained more than 14 days of data per month were considered for analysis. Based on this, a handful of areas are well suited with current technology (Figure S2 and Figure S3). Other areas would require technology improvements due to cloud coverage. When daily measurements are not required, more areas become suitable for satellite detection (Figure S3).

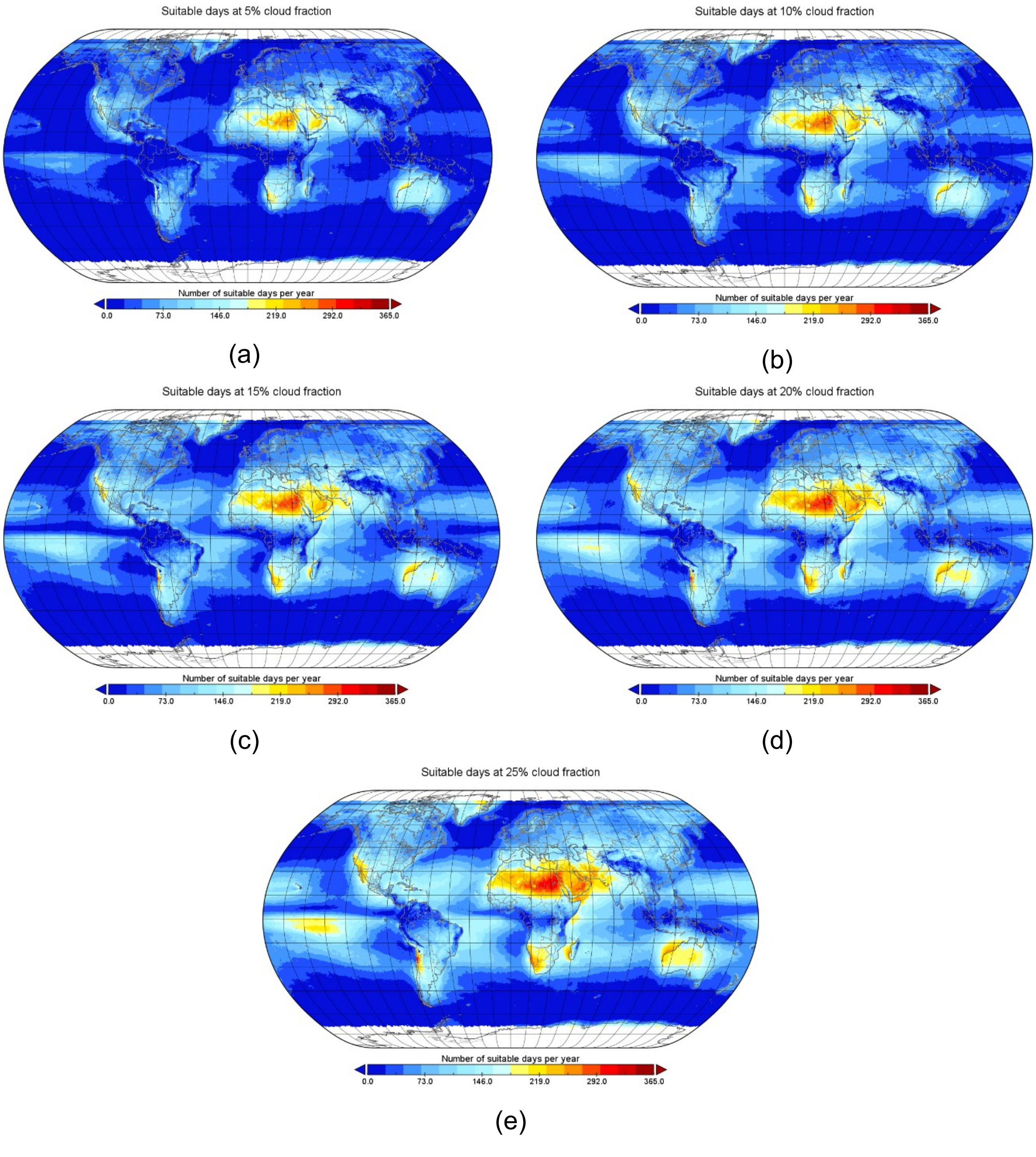
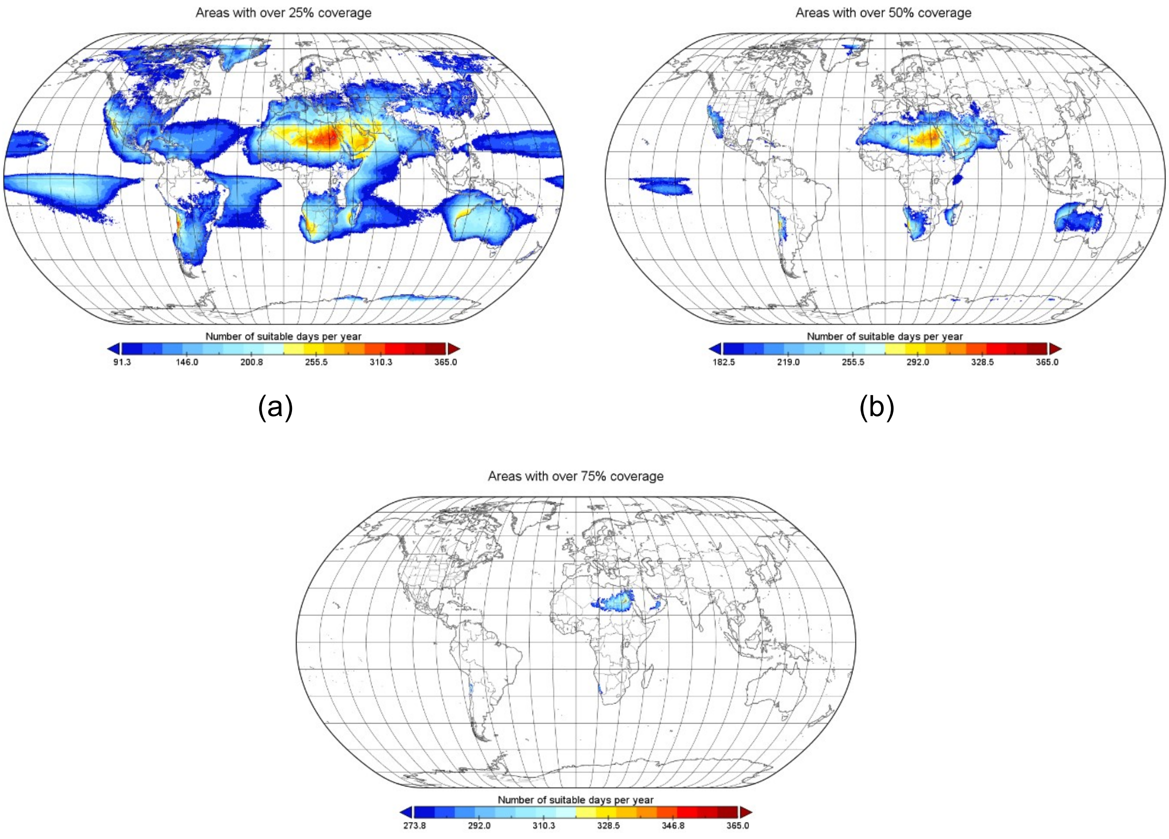


Figure S2: Impact of cloud coverage on suitability for measurement at daily monitoring. (a) At 5% cloud fraction; (b) at 10% cloud fraction; (c) at 15% cloud fraction; (d) at 20% cloud fraction; (e) at 25% cloud fraction. Map is based on data collected from multiple ESA and NASA satellites. Areas in white indicate no data available.

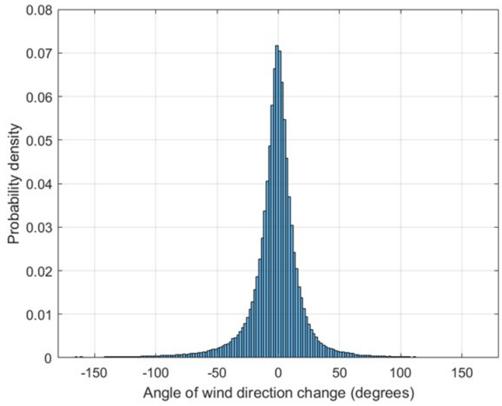


(c)

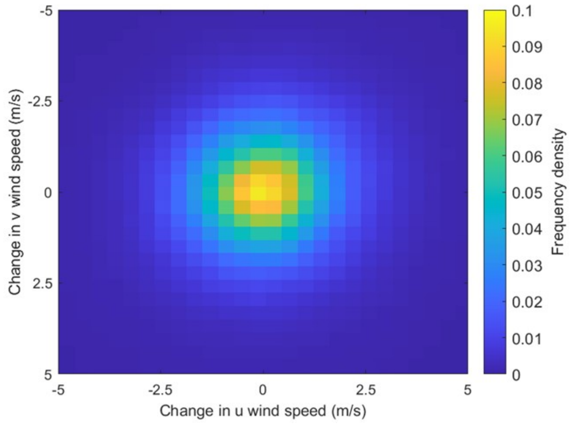
Figure S3: Impact of cloud coverage for non-daily monitoring. At 8% cloud fraction and shows areas where measurements are possible (a) once every four days (25%); (b) once every two days (50%); (c) three out of every four days (75%). Areas in white are those below the threshold e.g. in Figure S3 (a) the white areas are those where measurements are not possible once every four days.

4.2. Meteorological data

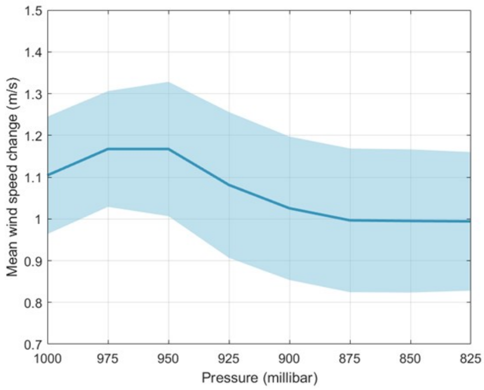
Based on North American Regional Reanalysis (NARR) (74) meteorological data, we examined uncertainties that could arise from the incomplete mapping of wind conditions (Figure S4). NARR provides data for 29 pressure levels every three hours across North America at approximately 0.3 degrees (32 km at lower latitudes) resolution. The main components examined were the variations in wind speed and direction between the 3-hour intervals and the variations in wind speed between the pressure levels and grids. Understanding the potential properties of this unattributed wind provides insight into the ways wind is not explicitly captured by inverse modelling. We examined the changes in wind speed across the u and v components between the hours of 15:00 and 18:00 UTC, (when Sentinel 5P would overpass in North America). To combine these uncertainties and calculate the effect of grid size and wind variability on the trajectory of methane, we examined the distance a particle in each grid would travel over three hours, using the NARR data. This was compared to using linear interpolation to account for the changes seen. The wind may have a different profile to the linear changes assumed, which would incur a different final distance uncertainty. However, it is a good approximation of the average wind change.



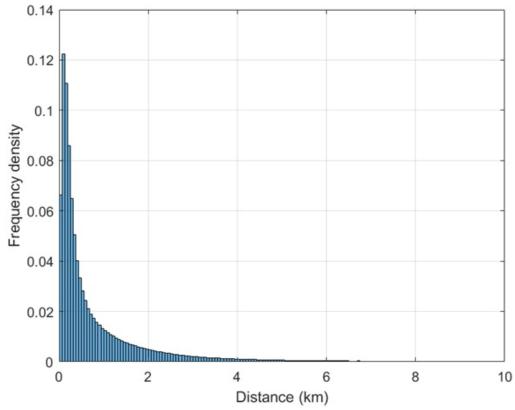
(a) Change in the wind direction from normalised angle between 12-3pm in NARR data



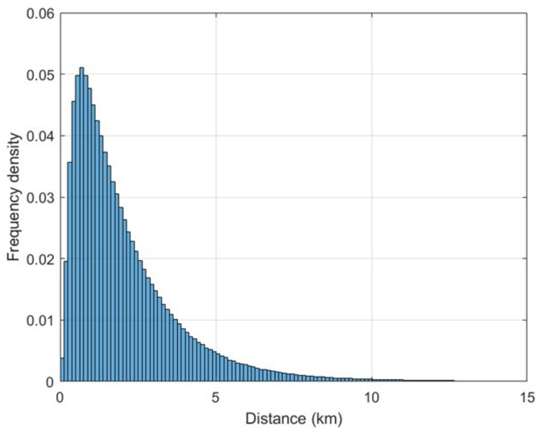
(b) Change in wind speed from 12-3pm in NARR data



(c) Change in wind speed across pressure levels in NARR data



(d) Uncertainty in particle location due to changes in wind speed over grid size, assuming linear change of wind speed



(e) Combination of all uncertainties for final particle location after 3 hours assuming linear changes in wind speed across domains

Figure S4: Uncertainties in NARR wind data.

4.3. Sunglint

Sunglint is the name given to a phenomenon which occurs when sunlight is reflected off of the surface of water (mainly the ocean). When sunlight is reflected at the same angle a satellite is viewing the ocean surface, the satellite can take measurements over water because the surface appears as a silver mirror rather than dark (75). Sunglint, while successfully used by Zhou*, et al.* (76), is a phenomenon which is inconsistent in its occurrence (77) and overall its use in methane retrieval is not well demonstrated in the literature. Therefore, although it offers some potential for offshore measurements, it should not be relied on for making consistent measurements over waterbodies.

4.4. Aerosols

The presence of aerosols and particle saltation (dust, smoke, pollution, sandstorms etc.) can impact detection and measurement through refracting or absorbing radiation. Aerosol optical depth (AOD) is a measure of solar radiation integrity when it passes through aerosols and is dependent on the wavelength of the scattered light. An AOD of zero indicates clear skies with maximum visibility while an AOD of one indicates extremely hazy conditions. Satellites can either directly measure AOD with suitable equipment or rely upon measurements taken by dedicated aerosol detecting satellites. At low AOD, the presence of aerosols poses no impact to satellite measurements. At medium AOD, aerosols will have an impact, but this can be accounted for through correction factors. A proxy method can also be used to account for aerosols at low levels. A prior estimate of a well-known gas, often carbon dioxide, is measured in the same wavelength as methane and the changes from the prior estimate can be used to calculate the correct methane concentration (78).

Once the AOD becomes too high, errors become too high for accurate measurements and the results are filtered out. The exact AOD this happens at is not clear and will vary. Butz*, et al.* (79) showed that for carbon dioxide, AOD >0.5 resulted in errors higher than 1%. We used this to examine the potential impact of no detection at 0.5 AOD. Using AOD measurements from the Sentinel-3 satellite between 2018/2019, we found that in certain months no detection is possible over the Middle East and North Africa because of high AOD, largely due to sandstorms during the summer months (Figure 5). However, for most of the world, AOD is not a primary limiting factor most of the year. Despite this, AOD alone does not tell the whole story, as retrievals are less likely to be successful when larger particles are located higher up in the atmosphere (79) and this is not demonstrated in Figure 3. Furthermore, the Figure shows the AOD at 1,600 nm, while most methane retrievals are done between 1,600 to 1700 nm or 2,300 nm (80), so while not a perfect match it offers a good representation of the effects of AOD.

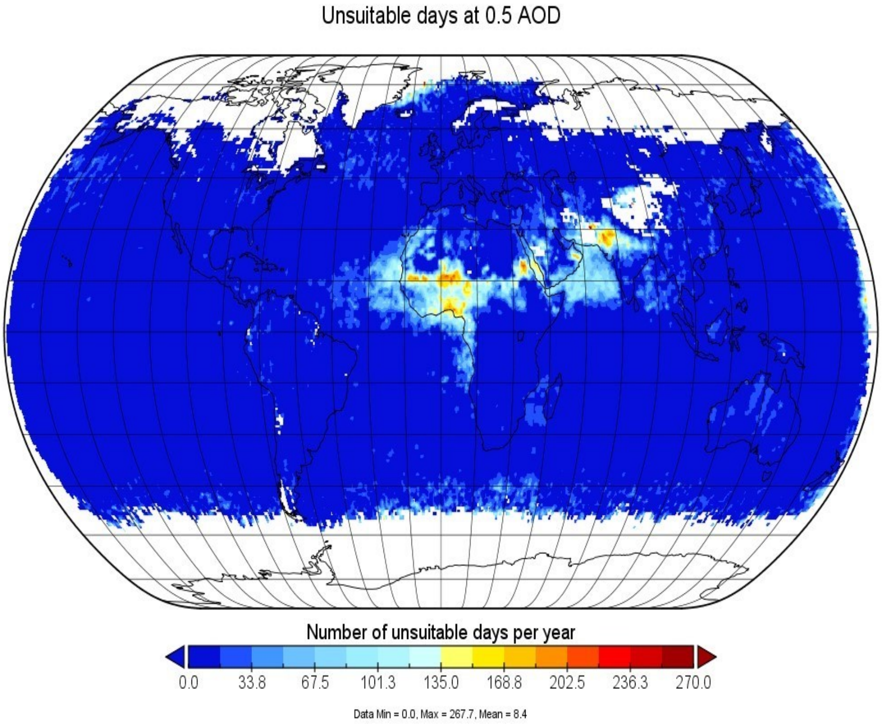


Figure 5: Map of inferred suitability for methane measurement based on AOD. Suitability identified based on AOD at 1,600 nm. Spectrometers can image methane in a range of wavelengths. Most satellites chose to image methane at 1600 to 1700 nm, the Sentinel 5P images at 2310 to 2390 nm. From the data availability 1600 nm was chosen as a suitable wavelength for analysis. Data taken from only one satellite (Sentinel-3). Please note that location suitability is inferred as the granularity of the data is poor. Daily data was not available, and the map is based on monthly average AOD.

4.5. Latitude

Satellites take images of the earth from numerous angles, which are dependent on longitude and latitude. Therefore, the solar zenith angle (angle between the vertical and the sun) is important in data reliability. At high solar zenith angle (approaching the Poles), data is unreliable due to the errors induced and low signal quality. Methane is also assumed to be a well-mixed gas in the Earth's upper atmosphere but there is an accumulation at high latitudes, which could skew emission estimates. The XCH4 differs between the tropics and mid to high latitudes, in particular the contribution from the stratosphere; 5% at the tropics and up to 25% at mid and high latitudes (81). However, well-known bias correction factors can be used to account for these. The oil and gas sector are mostly concerned with methane in the lower atmosphere where emissions occur. Therefore, background methane is first estimated and local enhancements from this are used to calculate emissions. Therefore, latitude has minimal effect on emissions estimates for the oil and gas sector.

4.6. Terrain

The physical features of an area can affect radiation backscattering and re-emittance. Uneven surfaces, such as mountainous regions, are impacted as well as regions at high or low altitude and consequentially, satellites are unable to take measurements in areas with highly uneven surfaces, such as hilly and mountainous regions. Satellites can filter terrain based on surface roughness, but overall, they are better suited for taking measurements over even surfaces. However, there is limited information available on this; GOSAT-1 and GOSAT-2 have cut-off surface roughness of 75 m (78) but similar data could not be located in the literature for other satellites.

5. Comparison to other technologies

Table S4: Overview of technology detection capabilities based on the peer reviewed literature. The MDL is dependent on both the technology and the conditions under which measurements are being taken, hence technologies used in multiple studies can yield multiple MDL. Where multiple MDL were collected, the range is given.

Method	**Technology[a]**	**Results reported[b]**	**Minimum detection limit**	**Uncertainty (%)**
Point source	Optical gas imaging (OGI) camera	12	2.0×10^{-6} to 3.0×10^{-2} kg CH_4/h	8
	High flow sampler (HFS)	16	5.8×10^{-3} kg CH_4/h	36
	Bagging	4	Not given	6
	Flame ionisation detector (FID)	2	2.0×10^{-6} kg CH_4/h	6
	Tunable diode laser	1	Not given	186
	Thermal mass flow meter	2	4.0×10^{-2} to 0.55 kg CH_4/h	56
	Fourier-transform infrared spectroscopy with tracer gas	2		41.5
	Handheld methane detector	2	5.0 ppm	-
Enclosed chamber	Static flux chamber	11	1.0×10^{-6} to 9.0×10^{-6} kg CH_4/h	236
	Dynamic flux chamber	1	1.5 ppb	7

Micrometeorological	Air sampling	2	50 ppb	23
Perimeter facility	FID	1	1 ppb	1
	Infra-red gas analyser	1	200 ppb	-
	Optical spectroscopic concentration measurement instruments (CMI) and sonic anemometer	1	Not given	-
	Passive Fourier transform infrared radiometer	1	92 ppm	-
	Los Gatos Research (LGR) Ultra-portable Methane Analyzer	1	Not given	38
Mobile laboratory (ML)[c]	Cavity ring-down spectrometer (CRDS) (Gaussian dispersion)	8	3.6×10^{-2} kg CH_4/h 3.6×10^{-2} kg CH_4/h	67
	Cavity ring-down spectrometer (CRDS) (OTM-33a)	7	3.6×10^{-2} kg CH_4/h	57
	Cavity ring-down spectrometer (CRDS) (Mobile plume integration)	1	3.6×10^{-2} kg CH_4/h	288
	Cavity ring-down spectrometer (CRDS) (Windtrax Lagrangian stochastic particle model)	1		38
	TILDAS (Gaussian dispersion)	6	6.0×10^{-3} kg CH_4/h	210

	Line Quantum Sensor (LI-COR) (Gaussian dispersion)	5	0.4 kg CH_4/h	42
	Los Gatos Research (LGR) Ultra-portable Methane Analyzer (Gaussian dispersion)	7	0.03 kg CH_4/h	34
	Bags filled with air (Windtrax Lagrangian stochastic particle model)	1	Not given	33
	FID (Gaussian dispersion)	1	Not given	23
	Open-path methane analyser	1	0.12 kg CH_4/h	54
	Cavity-enhanced absorption spectroscopy analyser	1	Not given	51
ML with external tracer	Cavity ring-down spectrometer (CRDS)	7	8.0×10^{-2} to 1.4 kg CH_4/h	23
	Tunable Infrared Laser Direct Absorption Spectroscopy (TILDAS) with tracer	11	1ppb	120
	ARI methane analyser	2	Not given	17
	LGR	1	Not given	3
Remote observatory	LGR Ultra-portable Methane Analyzer	2	Not given	27
	CRDS	2	Not given	24

	FID	2	1 ppb	66
	Fourier transform spectrometers	2	Not given	26
	Collaborative Carbon Column Observing Network (COCCON)	1	Not given	-
Towers	Gas chromatography FID	2	1 ppb	46
	Megacities Carbon Project (MCP)	1	Not given	37
	The University of Minnesota tall tower trace gas observatory	1	Not given	104
Helicopter	OGI camera	5	2.5 to 10.8 kg CH_4/h	280
Unmanned Aerial Vehicle	Feedback laser	1	1.1 kg CH_4/h	57
	OGI and TDLAS	1	2.5 kg CH_4/h	-
Manned Aerial Vehicle[c]	Airborne flux measurement	3	3.6×10^{-4} kg CH_4/m^2/h	27
	CRDS	59	4 to 5 kg CH_4/h	40

	Infrared imaging spectrometer	1	46 kg CH_4/h	-
	LGR methane analyser	4	10 kg CH_4/h/km^2	25
	NASA Langley Differential Absorption CO Measurement (DACOM) instrument	1	Not given	-
	Next Generation Airborne Visible/Infrared Imaging Spectrometer (AVIRIS-NG)	6	2 to 10 kg CH_4/h	16
	Quantum cascade laser spectrometer (QCLS)	1	Not given	-
Satellite	TROPOMI	10	4,200 kg CH_4/h	51
	SCIAMACHY	2	68,000 kg CH_4/h	64
	TANSO-FTS and TANSO-CAI	1	7,100 kg CH_4/h	21
	WAF-P	4	250 to 1000 kg CH_4/h	63
Isotopes	Mass spectrometer and gas chromatographer (FID)	7	Not given	450
	Headspace equilibration technique and gas chromatography (GC)	13	Not given	265

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