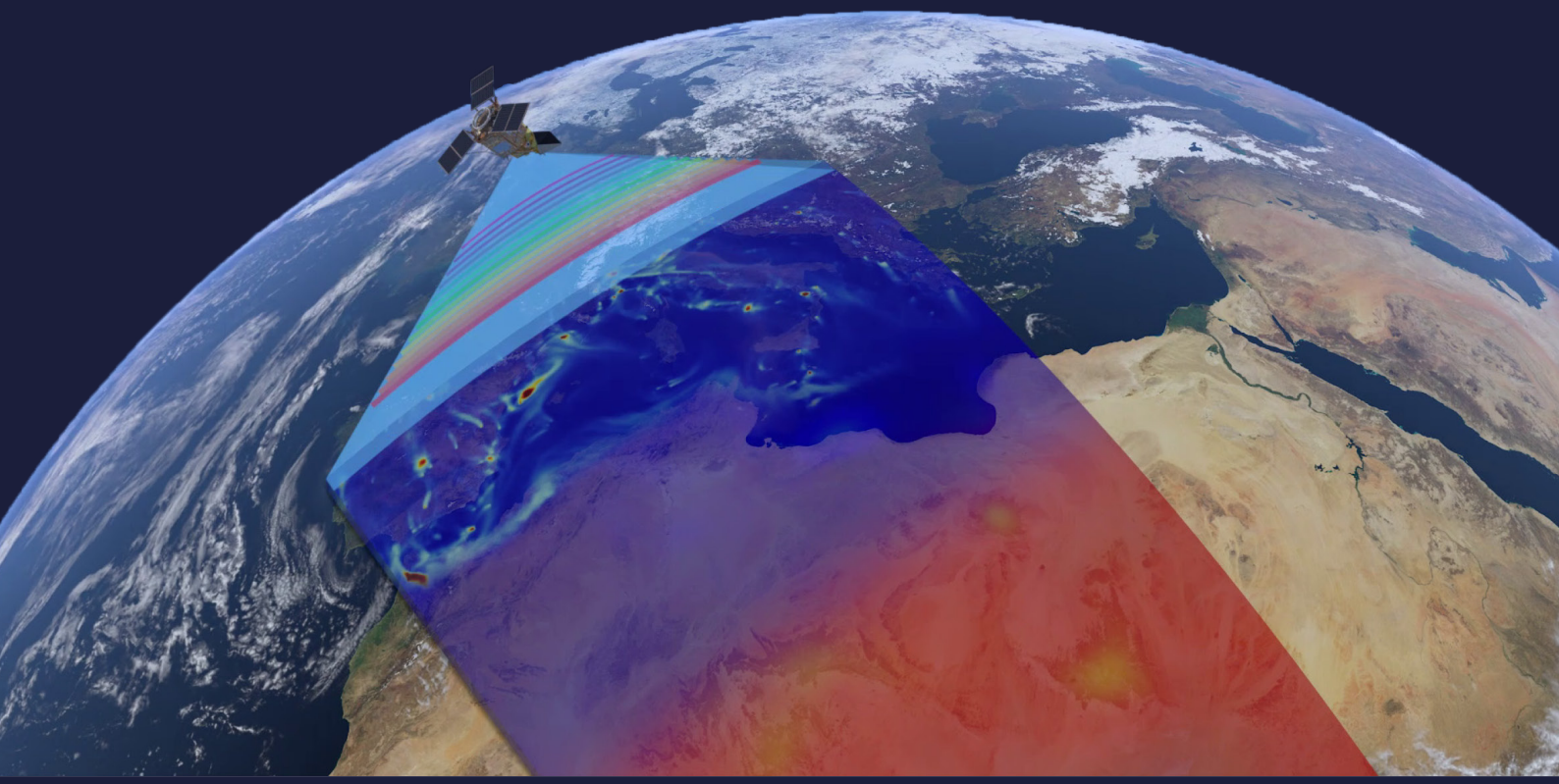
HOW TO ACT NOW AND EXPAND THE DUTCH LEADING POSITION IN CLIMATE SCIENCE AND AIR QUALITY



The Dutch Clear Air consortium aligns efforts to retain and extend the Dutch world-leading position in earth observation for climate and air quality.

October 2021

Authors:

KNMI	Pieternel Levelt, Rubert Konijn, Pepijn Veefkind, Frank Helmich
TNO	Kees Buijsrogge, Anton Leemhuis
SRON	Michael Wise, Aaldert van Amerongen
TU Delft	Henri Werij, Jérôme Loicq, Marte Bugel

October 2021

TU Delft Delft University of Technology

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

TNO

SRON Netherlands Institute for Space Research

HOW TO ACT NOW AND EXPAND THE DUTCH LEADING POSITION IN CLIMATE SCIENCE AND AIR QUALITY

The Dutch Clear Air consortium aligns efforts to retain and extend the Dutch world-leading position in earth observation for climate and air quality.

EXECUTIVE SUMMARY

Climate change and air pollution are the main global challenges of our time as recognised by the 195 countries that signed the 2015 Paris Agreement, and affirmed by the millions of deaths due to air pollution each year (WHO, 2018). In this White Paper KNMI, TNO, SRON and TU Delft show how **the Netherlands can play a key role** in providing global to local information needed to limit the impact of climate change and to improve air quality in order to meet national climate goals and achieve the emission reduction targets of the European Green deal.

The Netherlands is in a unique position to **take advantage of decades of Dutch excellence** in research and space-instrumentation for atmospheric chemistry (OMI, TROPOMI): our position in the small satellite industry and innovative artificial intelligence techniques. **Aligning this expertise will advance the forefront of atmospheric science with direct impact on our ability to predict and influence the atmospheric composition, which has societal benefit and will lead to economic growth.**

Knowledge leaders KNMI, TNO, SRON and TU Delft work, together with a broad array of involved parties, on a **R&D roadmap** for Earth observation for climate and air quality and bundle their expertise in **Clear Air.** This centre of excellence comprises world leading climate and air quality research, design and development of innovative spaceborne observing systems, a data centre based on advanced retrieval algorithms and artificial intelligence techniques, and yields actionable data for scientific, governmental and industrial communities.

Combining their capacities will **enable breakthroughs in science to tackle global challenges.** The centre will provide contributions to programmes of the EU and international space agencies such as ESA. At a national level Clear Air will focus on Earth Observation activities that are not covered in international programmes and **provide a direct value to the society and economy of the Netherlands.**

The societal and economic value of Clear Air will be to:

- Support the Netherlands, European countries and other international partners to provide **independent verification of greenhouse gas emission** in order to support future **Stock takes under the Paris Agreement**, by detection and identification of emission sources on different scales – from individual ships, farms and gas pipe leakages to the country level - realizing a global level playing field for emission reduction;
- Develop unique and innovative data products that **help constrain and monitor emissions that are central to Dutch environmental and public health policy,** for example ammonia and nitrogen dioxide emissions, which harm protected Natura2000 areas and have major economic implications;
- Stimulate the earning potential of the Dutch economy by strengthening the Dutch space and high-tech sector and establishing a value chain for data and satellite emission measurement capabilities - a **high-growth export product** - and serving as a **green accelerator for sustainable economic growth.**

This white paper serves as a joint **vision document** for the future; detailing several **concrete action** points to be carried out to make the Netherlands **leading the way to clear air.** As a first action the Clear Air consortium partners, together with Dutch stakeholders, will develop a R&D roadmap to realise our common climate mission.

LEADING THE WAY TO CLEAR AIR

>> Man-made emissions of air pollutants and greenhouse gases are the cause of some of the most pressing problems of our times.

Scientist have worked together under the umbrella of the United Nations to quantify the impact of anthropogenic emissions on climate. In their most recent assessment, the IPCC has clearly shown that the impact of climate change is global in scope and unprecedented in scale. Climate change causes shifting weather patterns that threaten food production and rising sea levels that increase the risk of major floods resulting in refugee and immigration flows. Today, air pollution causes over 4 million premature deaths annually (2018) and over 90% of the world population lives in areas where air pollution exceeds the WHO norms. Action is urgently needed because of the current huge number of years of life lost from air pollution and the rapidly increasing gap between actual greenhouse gas emissions and scenario's limiting global warming to 2 °C. Therefore, the United Nations have called on world leaders to act now: "As of now, we are still heading for at least a 3°C temperature rise this century – dangerously beyond the Paris Agreement goals of limiting global warming to well below 2°C and pursuing 1.5°C. To get back on track for a 2°C world, we will need to cut one-third off emissions by 2030. For 1.5°C, we need to halve them. Instead, the current projection of fossil fuel projections averages an annual increase of 2 percent every year. So, in view of these basic facts, the common thread is very clear. We are far, far behind."

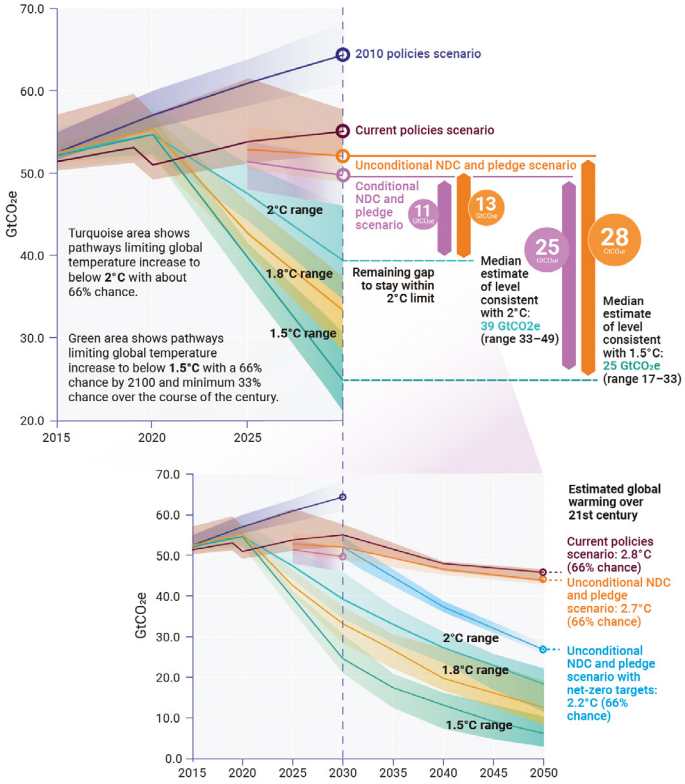
This year, the European Commission has reacted strongly by adopting a climate law and by proposing to transform the economy to reduce GHG emissions this decade by 55% compared to 1990 levels and towards climate-neutrality in 2050. Within this Green Deal transformation Europe also prioritises reduction of air pollution and protection of biodiversity. On the way to the COP26 Climate conference in Glasgow in November this year, following the work of the UN Environment programme (UNEP), US and EU leaders have taken concrete climate action by agreeing to reduce methane emission by 30% this decade. According to UNEP, this will prevent 200.000 premature deaths from methane related ozone pollution and reduce warming by at least 0.2 degrees Celsius by 2050. In order to address these challenges, the EU is now adopting the EU Methane Strategy, which explicitly points out the importance of satellite monitoring of methane emissions. This is a good illustration of how the science that has been developed for satellite remote sensing of the atmosphere can be deployed for the benefit of society and policy.

Now it is time for the Netherlands to join the effort and strengthen our leading position in climate science and air quality through the Clear Air consortium.

1 https://www.unep.org/news-and-stories/speech/european-union-can-level-climate-leadership
2 https://ec.europa.eu/commission/presscorner/detail/en/IP_21_4785

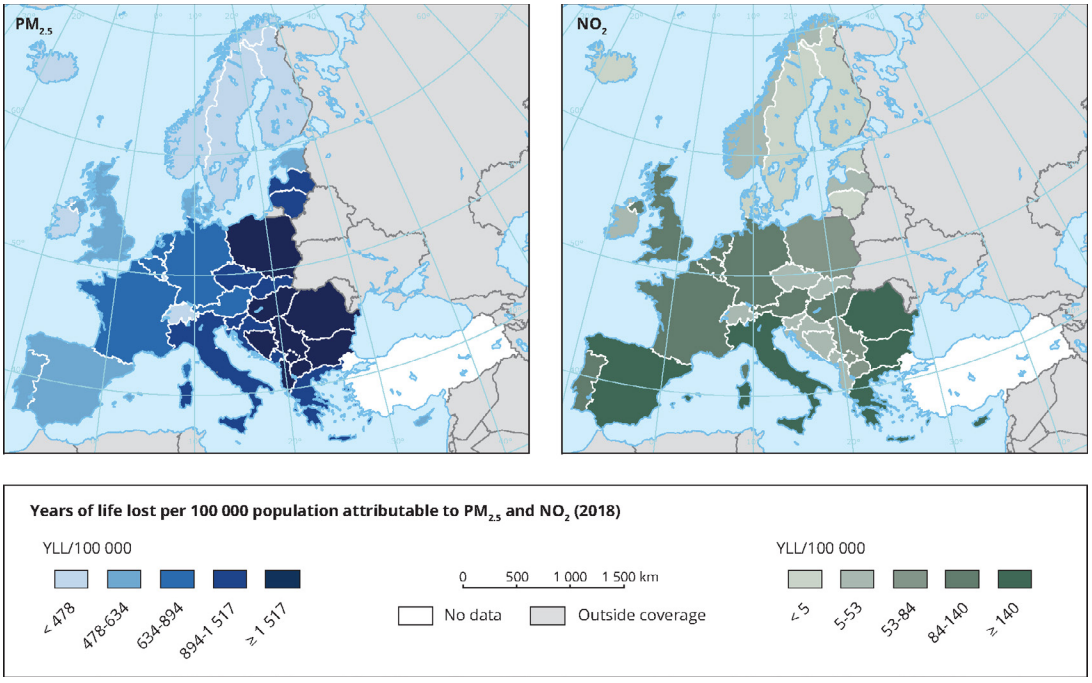
>> The impacts of both climate change and air pollution are global in scope and unprecedented in scale.

Global greenhouse gas emissions under different scenarios and the emissions gap in 2030



Source: UNEP Emissions Gap Report 2021, https://www.unep.org/resources/emissions-gap-report-2021

Air pollution deaths related to particulate matter and nitrogen dioxide



Source: European Environment Agency (EEA), https://www.eea.europa.eu/data-and-maps/figures/years-of-life-lost-per-3

>> Scientists, policy makers and industry have an urgent need for worldwide, comparable measurements and analysis to support the effectiveness of international policies and measures.

Climate change and air pollution are both consequences of man-made emissions. Unfortunately our knowledge of these emissions contains uncertainties. For example, the reporting of annual greenhouse gas inventories is generally based on bottom-up emission estimates, using statistical activity data and source- and country-specific emission factors. However, **for policies to be effective it is essential they are evidence-based**, and supported by observations that tell us the level of current emission, allow us to identify in which sectors and geographies emission reduction measures can be taken, and to monitor the impact of these measures.

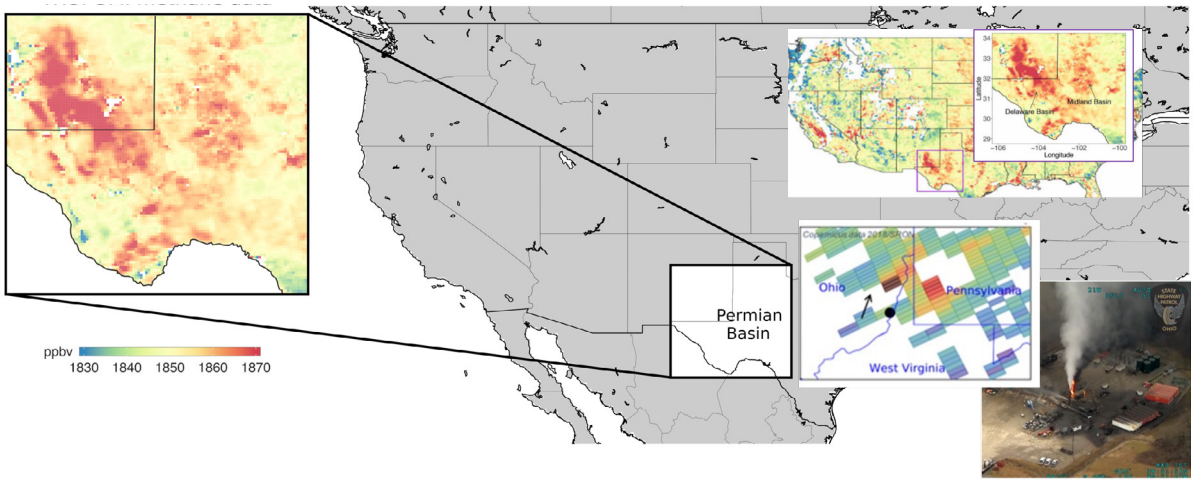
The availability of fine scale, global and independent emission monitoring data is therefore a major opportunity to support the realization of the Paris agreement and regional air quality policies as under the European Green Deal. The following scientific challenges present themselves:

- **Enable consistent and accurate emission observations** of greenhouse gases, short-lived climate gases and aerosols from space in support of policy measures;
- Based on those, **improve our understanding of the interplay between air quality and climate change**, including interpretation of methane emissions and the formation of tropospheric ozone and secondary aerosols;
- **Measure air pollution** from the global scale to sub-city scale;
- Based on those, **improve our understanding of the changes in chemical regimes** due to the impact of policy measures **as well as the understanding of chemical cycles in the atmosphere**, such as the carbon cycle and the nitrogen cycle.

Earth observation satellites are an essential tool to solve these challenges. Satellite instruments and satellite data provide **global, consistent, accurate and comparable observations.** Satellite data give unique information on the global atmosphere and the spatial variation of pollutants, which is essential to address the **cross-border nature** of air quality. Moreover, the global coverage of the satellite data can provide information about regions of the world for which no other observing infrastructure is available. An example is the detection with TROPOMI of methane emissions over the Permian basin in the USA were an international consortium of scientists found that measured methane emissions exceeded the numbers reported by the USA with a factor of two. This example shows how satellite data **enables us to know the scale of the problem**, what the **determinants** are and what **concrete and targeted measures** could be taken.

To limit the impact of climate change and improve air quality we need accurate measurements of the atmospheric composition for the whole globe with high temporal and spatial resolution. This information can only be provided by innovations in satellite hardware, new instruments, new observational strategies and innovations in data retrieval and data analysis.

>> Examples show how satellite data enables us to take concrete and targeted measures.



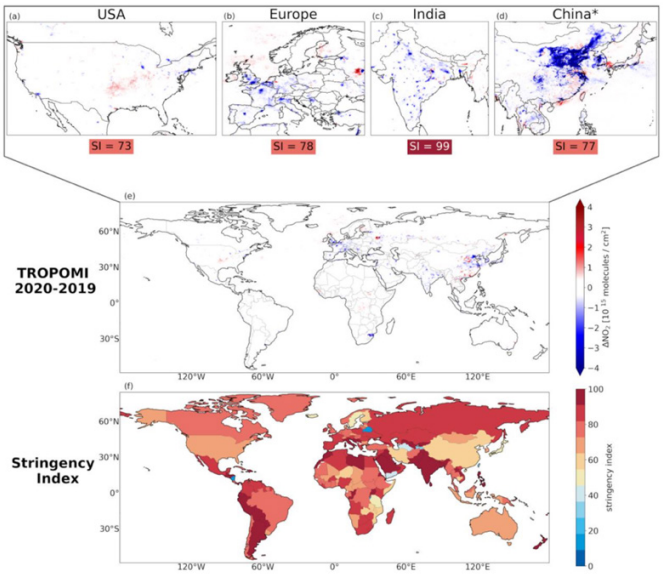
Greenhouse gas monitoring: estimation vs measurements

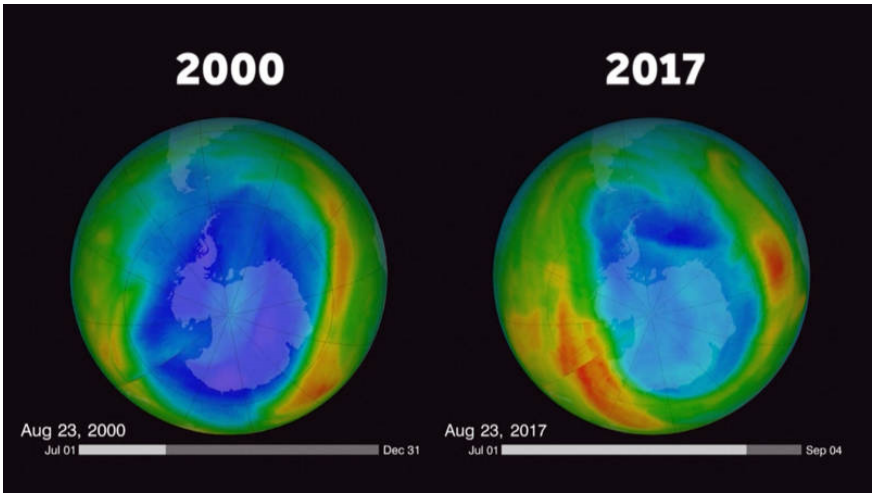
Methane is a greenhouse gas that is responsible for about 25% of the global warming. Major sources of emission are farming, the oil & gas industry, landfills and coal mines. The true extend of methane emissions is uncertain because they are estimated, not measured. Satellites are increasingly able to provide independent measurements of methane to support progress of emission reduction policies as part of the Paris Agreement. Based on new measurements from the Dutch space-based TROPOspheric Monitoring Instrument (TROPOMI) launched in 2017, an international consortium of scientists found that measured oil & gas field emissions over the Permian basin in the USA exceeded the numbers reported with a factor of two. Due to this kind of measurements, oil & gas companies are becoming increasingly active in methane leak mitigations, and governments who procure gas become increasingly aware of the carbon footprint of the resource they buy.

3 Dix et al, 2020, De Gouw et al., 2020, Zhang et al. 2020, Pandey et al, 2019.

Ozone and the Montreal Protocol: a success story for science & policy

Ozone depletion was the first human threat to the global atmosphere to be recognized. Since the 1970s scientists raised concerns about the potential threat to the ozone layer caused by increased emission of human-manufactured chlorofluorocarbons (CFC) and halons. A breakthrough in the public debate and in the negotiations was achieved when research provided additional hard evidence that ozone depletion was a threat to the environment and public health. In 1985, the scientific discovery of the so- called 'ozone hole' demonstrated that the loss of ozone was much larger than could be accounted for with existing scientific models. The resulting increase in global public attention to the problem of ozone depletion created a sense of urgency about the need for a robust global policy solution. The Montreal Protocol on Substances that Deplete the Ozone Layer, which celebrated its 30th anniversary last year, can claim to be one of the most successful international treaties ever. Since then, spatial ozone satellite measurements have been widely used to evaluate and quantify the spatial extension of the ozone hole and global ozone decreasing trends as a function of latitude and height. Validation and evaluation of satellite ozone data have been the subject of intense scientific activity, which has been reported in the various ozone assessments of the state of the ozone layer published after the signature of the Montreal protocol (https://csl.noaa.gov/assessments/ozone/). It has fulfilled its original objective by putting the stratospheric ozone layer on the road to recovery. But its effects have not stopped there: it has also done more than any other measure to date to combat climate change, due to the fact that the halogens that destroy ozone are extremely powerful climate gases. Monitoring the earth atmosphere with satellites has contributed greatly to the success of the Montreal Protocol. It is clear that with the current crisis on greenhouse gas emissions, more effective monitoring from satellites has a pivotal role to play to scientifically raise the sense of urgency, to monitor individual state commitments and, to identify large emitters and to show in undisputed measurement the step-by-step progress that will be made by reducing emissions.



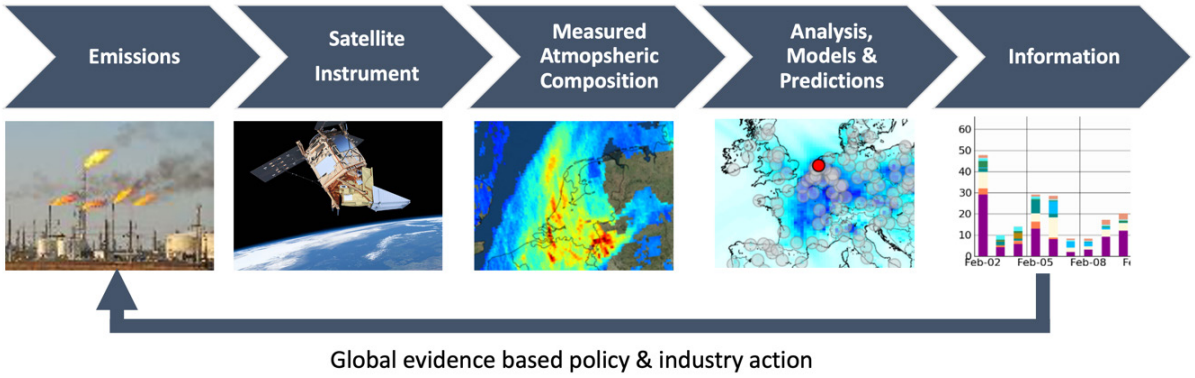


4 Farman, J., Gardiner, B. & Shanklin, J. Large losses of total ozone in Antarctica reveal seasonal ClOx/NOx interaction. Nature 315, 207–210 (1985). https://doi.org/10.1038/315207a0, Solomon, S., Garcia, R., Rowland, F. et al. On the depletion of Antarctic ozone. Nature 321, 755–758 (1986). https://doi.org/10.1038/321755a0

>> The Dutch economy benefits from a strong Dutch presence in Earth Observation: data and satellite emission measurement capability enable a level playing field for emission reduction.

In the Netherlands, in Europe and internationally, policies are being put in place to achieve net-zero greenhouse-gas emissions in the 2030-2050 timeframe using emission trading systems. As a result, **emissions have an economic value of a significant fraction of the carbon-based-economy itself.** With the first target date of 2030 nearing, we see the cost of emissions increase rapidly[5]. **Improvements in emission monitoring and quantification** will support this and help establishing a level playing field. Because of its global reach and orbital vantage point, satellite monitoring is key to reliable and globally calibrated measurements of emissions up to the top of our atmosphere and across all borders.

Through past government investments, the Netherlands have obtained a world-leading position in building and using advanced emission monitoring satellites such as OMI and TROPOMI. An **extensive ecosystem** emerged with universities, knowledge institutes, innovative satellite industry and value-adding companies that create actionable data using a diverse set of algorithms, including innovative AI-algorithms. Establishing a **strong value chain by connecting these players** to further develop innovations in satellite hardware, instruments, measurement possibilities, data retrieval and data analysis, will accelerate the Dutch green economy[6].



5 Cost of emission right of 1 ton of CO2 has risen from 20 Euro in early 2020, to 60 Euro in September 2021.
6 See also the value chain.

>> At this point in time and for the decade to come, The Netherlands is in a leading position to create the monitoring capability that is needed to address the challenges of climate change and air pollution through Earth observation. To utilise and retain this position we have to act.

There is currently no other country in the world as well equipped for this scientific and societal challenge as the Netherlands: providing science and technology for using Earth observation to tackle climate change and air pollution. The Netherlands is in the **unique position to play a major role, having world-class capabilities in the entire value chain** of atmospheric science: emissions, atmospheric chemistry modeling, satellite data processing and satellite instrument realisation.

- **Over the past decades, the Netherlands has played an internationally leading role in developing Earth observations for atmospheric science.** In nationally funded programmes state-of-the-art satellite systems have been designed, developed, built and used by scientists to study air pollution and greenhouse gases: Sciamachy on ESA's Envisat (2002), OMI on NASA's EOS/AURA (2004), TROPOMI on the Copernicus Sentinel 5p (2017) and SPEXone on NASA's PACE mission (2023);
- **The Netherlands is at the forefront in the field of atmospheric monitoring**, providing important contributions to the European air quality forecast as part of the Copernicus Atmospheric monitoring Service (EC/ ESA), the building of a prototype system for the global monitoring and verification of carbon dioxide (CO2) emissions by organisation from 14 EU countries (CoCO2), and the space-based detection and quantification of emissions of methane, the second most important greenhouse gas (GALES);
- **The Netherlands has an industry for small satellites and innovative artificial intelligence techniques**, which are at the frontier of allowing us to realise spaceborne observation quicker and more affordable.

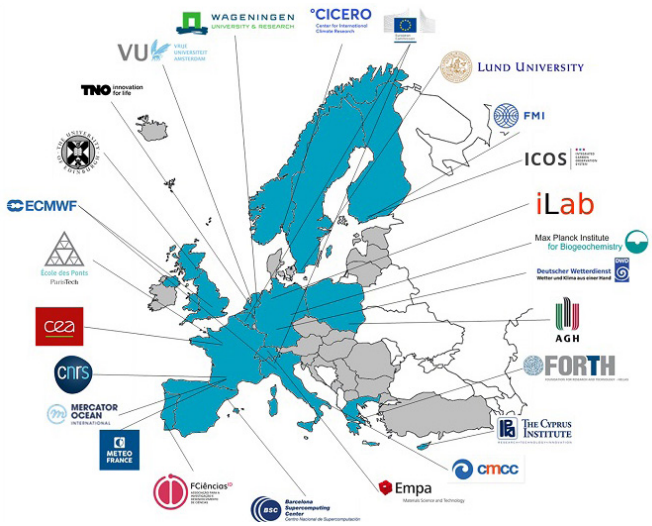
Aligning this expertise will further strengthen our ability to predict and influence some of the most pressing problems of our time. The Netherlands, a small country, **can play a major role in the international arena** by using satellite technology to support the effectiveness of international policies and measures. If we don't act and invest now, the Dutch frontrunner position will erode.

To this end, KNMI, TNO, SRON and TU Delft join forces.

>> Some great Dutch success stories: TROPOMI, Pan-European CoCO2 and Copernicus Atmospheric Monitoring Service (CAMS)

TROPOMI

The TROPOMI satellite instrument provides daily global information on concentrations of trace gases and aerosols important for air quality, climate, and the ozone layer. TROPOMI is a project in partnership between Airbus Defence and Space, KNMI, SRON and TNO, commissioned by NSO and ESA. In 2019 and 2020 TROPOMI was used to independently quantify large emission of greenhouse gases in the U.S. and Central Asia, as well as to measure the impact of the COVID pandemic on the sharp reduction in air pollution in Europe.

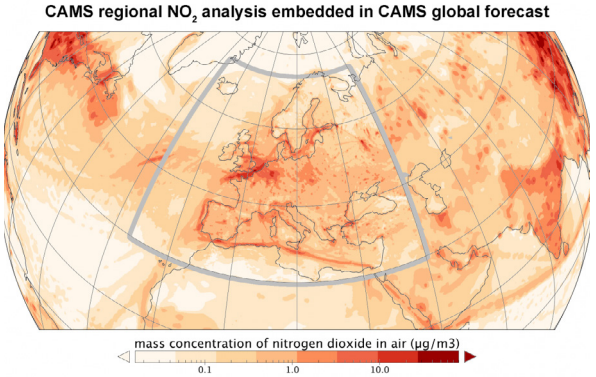


CoCO2 prototype system for monitoring and verification of CO_2 emissions

CoCO2 is the pan-European effort of 25 partners from 14 countries to build a prototype system for the global monitoring and verification of carbon dioxide (CO_2) emissions. A major innovation of CoCO2 will be the use of satellite observations. Three of the consortium partners are Dutch: TNO, Vrije Universiteit Amsterdam and Wageningen University & Research.

Copernicus Atmospheric Monitoring Service (CAMS)

CAMS provides consistent and quality-controlled information related to air pollution and health, solar energy, greenhouse gases and climate forcing, everywhere in the world. KNMI, SRON and TNO provide key contributios to the predictive modeling systems and satellite data utilisation capabilities of CAMS.



>> Knowledge leaders KNMI, TNO, SRON and TU Delft, together with a broad array of involved parties, bundle their expertise in Clear Air.

Clear Air comprises world leading climate and air quality research, design and development of innovative spaceborne observing systems, a data centre based on advanced retrieval algorithms and artificial intelligence techniques, to provide actionable data for scientific, governmental and industrial communities. The centre aims at being globally outstanding for the development and **use of satellite instrumentation and data products for the understanding and mitigation of climate change and air pollution**.

Its mission will be:

- To **align national expertise** and R&D efforts;
- To **stimulate collaboration** within the (inter)national Earth Observation community and across research domains;
- To **develop applications** that can be used in and beyond the air quality and climate domain that will benefit science
  and society;
- To **broaden the use and thus impact** of our knowledge and satellite data by policy makers and scientists alike;
- To cooperate with the growing commercial space sector and data service providers market to **allow spin-offs**;
- To develop a **national Earth observation strategy** and intensify the national space programme for Earth observation, including the development of new instruments.

At a national level, the Clear Air will focus on Earth observation activities that **provide a direct value to the society and economy of the Netherlands** and are not supported in international programmes of e.g. ESA, EUMETSAT and the EU. At an international level Clear Air is already working in and contributing to programs of **the EU, ESA, EUMETSAT and other agencies** and collaborates with atmospheric expert centres worldwide like NASA-GISS and NCAR in the USA.

>> Clear Air will enable the consortium partners to align their efforts, utilise synergies, work together on project level and share facilities and staff.

The Centre is a **distributed centre** and **will provide a cooperative effort** between universities and knowledge institutes working together closely with the private sector and the Dutch government. With a limited number of core partners, **the consortium covers all aspects of an internationally distinctive collaboration**: from instrument construction up to and including the generation of data products and exploitation of the data.

The core partners are:

- **The Royal Netherlands Meteorological Institute (KNMI)**, an agency of the Ministry of Infrastructure and Water Management and the national research and information centre for weather and climate. KNMI is Principal Investigator of both OMI that flies on NASA's Aura satellite (launched 2004), and TROPOMI: the satellite instrument on board of the Copernicus Sentinel-5 Precursor satellite (launched 2017) and expert in retrieval algorithm development for trace gases and aerosols and interpretation of satellite data for air quality and climate research;
- **The Netherlands Organisation for Applied Scientific Research (TNO),** a TO2 institute and 30+ year developer and supplier of optical satellite instruments and systems (hardware) for aerospace among which instruments that measure the composition of the atmosphere from space. The institute also has strong expertise in satellite data utilisation (assimilation), for example for analyzing and monitoring emissions and air quality;
- **SRON Netherlands Institute for Space Research (SRON)**, the Dutch national expertise institute for scientific space research, part of the Dutch Research Council NWO. The institute combines science, technology and engineering. Its scientific expertise is in atmospheric satellite remote sensing, in particular radiative transport and trace gas and aerosol retrieval algorithms and CO, methane, CO_2 emission quantification. SRON develops enabling technology and space-qualified instrumentation spanning the range from X-ray to far-infrared wavelengths;
- **Delft University of Technology (TU Delft)**, performing research, and engineering of end-to-end space systems. The university is ranked number 1 in Europe and top-5 worldwide on the subject of Aerospace Engineering. The university has also relevant expertise on atmospheric chemistry, data retrieval, supercomputing, and optical instrumentation. Its Climate Institute brings together the expertise of scientists across the university in the field of data-based climate knowledge for mitigation, adaptation and policy.

Their collaboration bundles excellence in science, technology and instrumentation and strengthens the partners leading positions in the atmospheric chemistry and Earth observation domain. Working cross-boundary between research fields and expertise will be a game changer for exploiting satellite observations in the climate and air quality domain to its full potential.

>> Clear Air stimulates collaboration within the (inter)national Earth Observation community and serves as a central hub for scientific, governmental and industrial communities to broaden the use and impact of its findings.

Clear Air is an **internationally distinctive consortium**, with collaboration as one of the key strengths. **Collaboration and alignment will be extended to the entire value chain**: from R&D to the development of components, system integration, system operation, data reduction, data dissemination, value adding and end users, creating a broad and sustainable knowledge infrastructure in the Netherlands.

Clear Air will be:

- Reaching out towards **industrial partners designing and building** instruments and data processing software (e.g. ISISPACE, Airbus DS Netherlands, S&T and other members of SpaceNed, trade organisation of the Dutch space sector);
- Reaching out towards **industrial partners using the data** for operational, commercial or related applications in the Earth Observation domain;
- Connecting and exchanging data with **knowledge institutes and expertise centres** all over the world in fields as diverse as climate, air quality, energy, agriculture and health;
- Serving as expert and advisor for **governmental organisations and ministries**, both national and international, advising on and supporting the effectiveness of policies and measures;
- Providing end users in various sectors with actionable data, among which insurance companies, energy companies, process industry, the oil & gas sector, transport sector, agriculture sector and financial sector.

>> Clear Air partners work on an R&D roadmap for Earth observation for climate and air quality, perform strategic studies for governmental organisations and contribute to commercial activities and broad outreach.

Based on a shared vision, Clear Air will put the importance of air pollution and greenhouse gas monitoring on the national and international climate and environment **agenda**. In close collaboration with the Netherlands Space Office (NSO), the partners will develop a **programme-based R&D Roadmap** to fulfill our climate mission and retain and expand Dutch excellence in research and space-instrumentation for atmospheric chemistry, the small satellite industry and innovative artificial intelligence techniques. The roadmap aims at **utilising synergies among universities and knowledge institutes**, increasing the impact of R&D efforts and speeding up development.

Each Clear Air partner is already involved in work that directly contributes to the centre's visions. Based on an R&D roadmap for the period up to 2030, Clear Air will focus its activities on the following themes:

> INSTRUMENTS AND PLATFORMS

To limit the impact of climate change and improve air quality we need information enabled by **innovations in satellite hardware, new instruments and new observational strategies**. Main pillar of Clear Air is to initiate technical innovations enabling new satellite remote sensing technology and satellite platforms and the development of new instruments. We will **enhance the capabilities of satellites** to quantify global greenhouse gas emissions and develop **scalable new monitoring solutions** answering the needs for **higher spatial and temporal resolution**, ranging from wide-field-of-view and multi-waveband solutions to distributed systems operating in a **constellation of targeted small satellites.** We will do so for national missions and initiatives where specific Dutch issues are at stake, and in international cooperation such as ESA programmes.

> ALGORITHMS AND DATA SERVICES

As a result of instrument innovations, data handling, downlinking as well as scientific treatment of the multi-dimensional data we will need **innovative processing strategies and technologies**, among which the development of data processing algorithms, innovations in data assimilation, inverse modelling, machine learning and artificial intelligence, and the development of platforms for **data science and dissemination** and valorisation with industry partners.

> CLIMATE, AIR QUALITY AND EMMISSIONS RESEARCH AND APPLICATIONS

Clear Air will perform a **great variety of research using the developed data products leading to scientific discoveries and pre-operational services** for society to tackle air pollution and climate challenges. Examples are: data and trends on **Nitrogen emissions** and the combination of NOx, aerosol and NH3 for **Nitrogen cycle** research – both extremely relevant for Nitrogen and Air Quality policy by Dutch ministries; the **detection and identification of Methane emission sources** on different scales and with an increasingly low detection threshold – from individual facilities, landfills and gas pipe leakages to the country - using a combination of satellite instruments; **greenhouse gas emission quantification** and independent emission data to support the **global stock take** of the Paris agreement in 2023 and 2028, and the assimilation of aerosol data in models to research the **radiative forcing of aerosols and air quality impacts** of aerosols.

> POLICY SUPPORT

Researchers connected to Clear Air will perform **supporting studies for policy and measures**, responding to **requests from governmental organisations:** for example the request to support cities as Amsterdam and Rotterdam in reducing GHG emissions.

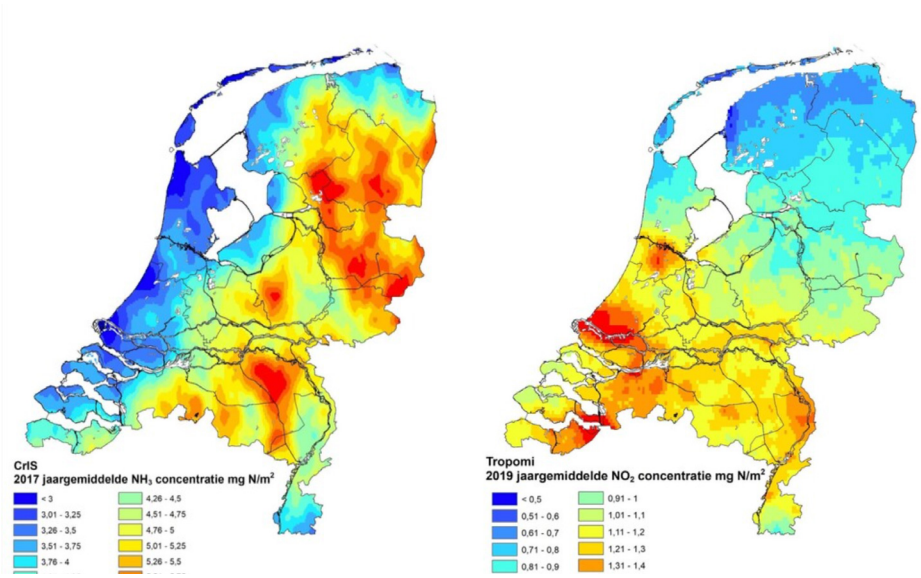
> VALORISATION

Clear Air aims to **bridge the gap between early phase technology demonstrations and commercial product offerings**, working with service providers and industry to realise Dutch entrepreneurship related to air pollution and climate monitoring: for example, supporting **Airbus Defense & Space Netherlands, ISISPACE and other industry represented in SpaceNed in setting up commercial air quality services** and support a growing ecosystem of **Dutch SME to develop commercial data products** of Dutch instruments such as TROPOMI and SPEXone.

> OUTREACH

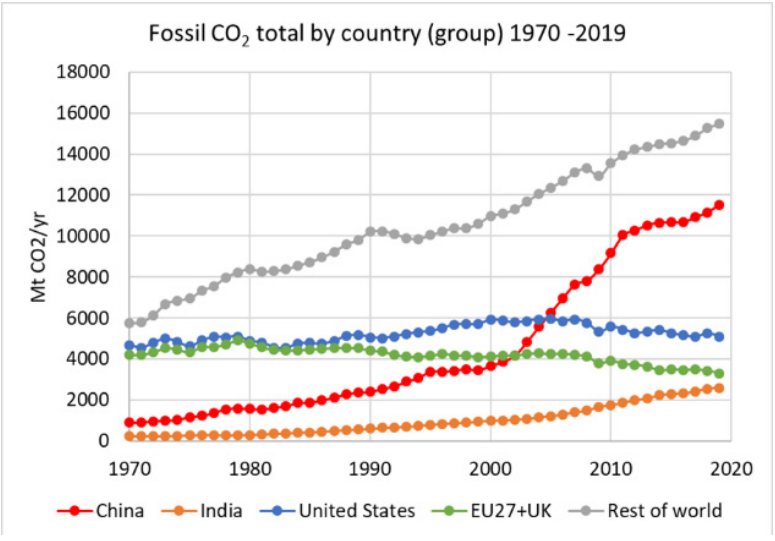
Clear Air will be established as the **Dutch knowledge centre** for atmospheric space research. It will communicate with stakeholders about activities and findings to broaden their use and impact. The outreach is co-facilitated by the development of an **Earth Observation web-portal** that provides policy makers, industry, scientists, journalists and the general public with up-to-date and high-quality information and visualizations on air pollution and greenhouse gases.

>> Nitrogen monitoring and global stocktake: examples where the Netherlands economy and society can greatly benefit from Earth observation innovations



Nitrogen monitoring – national challenge

Nitrogen emissions from industry and agriculture impact the biodiversity of Dutch Natura2000 areas. The Netherlands is implementing new policies to reduce such emission. However, a major challenge is that nitrogen emissions, dispersion and deposition are highly variable in space and time and very few ground measurements are available of this. An independent government committee (Committee Hordijk) sees an important role for satellite observations to overcome these data-issues. Currently the Dutch TROPOMI satellite instrument (ESA/NSO) provides measurements of nitrogen-dioxide at a spatial scale of roughly 7kmx3km and the CrIS satellite instrument (NASA/NOAA) provides measurement at a spatial scale of roughly 12kmx12km for ammonia. These measurements can help monitoring nitrogen at large spatial scales. However, Clear Air has the ambition to work on measuring emission directly at a sub 1km scale, allowing monitoring of individual farm areas. (Figure: Hordijk2019)



The road to realizing the Paris Agreement

As part of the Paris Agreement 196 countries, including the Netherlands, pledged to reduce greenhouse gas emissions to avoid dangerous climate change. Countries agreed on long-term goals backed by national plans, known as National Determined Contributions (NDCs). These plans are reviewed every five years in a process known as the global stocktake. A breakdown of the Global CO_2 emissions in the period 1970-2019 shows that CO_2 emissions are still rapidly rising. Due to this it will not be sufficient to focus efforts on Dutch or even European efforts to reduce emissions: all countries need to contribute. Affluent countries will have to support other countries to monitor progress, provide actionable information to reduce emissions and create a level playing field. This challenge is taken up by the European Committee through the CO2M satellite mission and the CoCO2 monitoring verification and support system, to which Clear Air members are making key contributions. In the coming years Clear Air will be able to put Netherlands in the position to support this even further with improved emission detection and quantification technologies (Figure: TNO/ EDGAR).

>> Retaining, extending and utilising the Dutch world-leading position in Earth observation for climate and air quality, will enable the Netherlands to lead the way towards clear air, serving science and society.

Combining the capacities of the core Clear Air partners will enable breakthroughs in multiple scientific fields. It will lead towards the best satellite instrumentation and data products in the climate and air quality domain and innovative ways to create and exploit these data, serving science and through it policy makers. The Netherlands is in a position to lead the way and make a real impact on the reduction of emissions under the EU Green Deal. Moreover, investing in retaining and extending the Dutch world-leading position in Earth observation for climate and air quality will lead to direct economic and societal benefit: a green accelerator for sustainable economic growth.

The work of Clear Air will:

> IMPACT CLIMATE AGREEMENTS AND CLIMATE ACTION

Support the Netherlands, European countries and other international partners setting and verifying greenhouse gas reduction measures that help realizing the goals of the Paris Agreement and the European Green Deal.

> IMPACT AIR QUALITY

Lead to high resolution emissions information and air quality forecasts, supporting air quality measures to reduce air pollution.

> IMPACT PUBLIC HEALTH

Improving people's health by reducing air pollution, responsible for the annual pre-mature death of over 4 million people per year globally. Insight into relation living environment and health and the relation between air quality and virus impact.

> SUPPORT POLICY MAKERS

The Centre will, Support Dutch and European governments with fact-based and science-checked information to make policy decisions that have major economic and societal impacts:

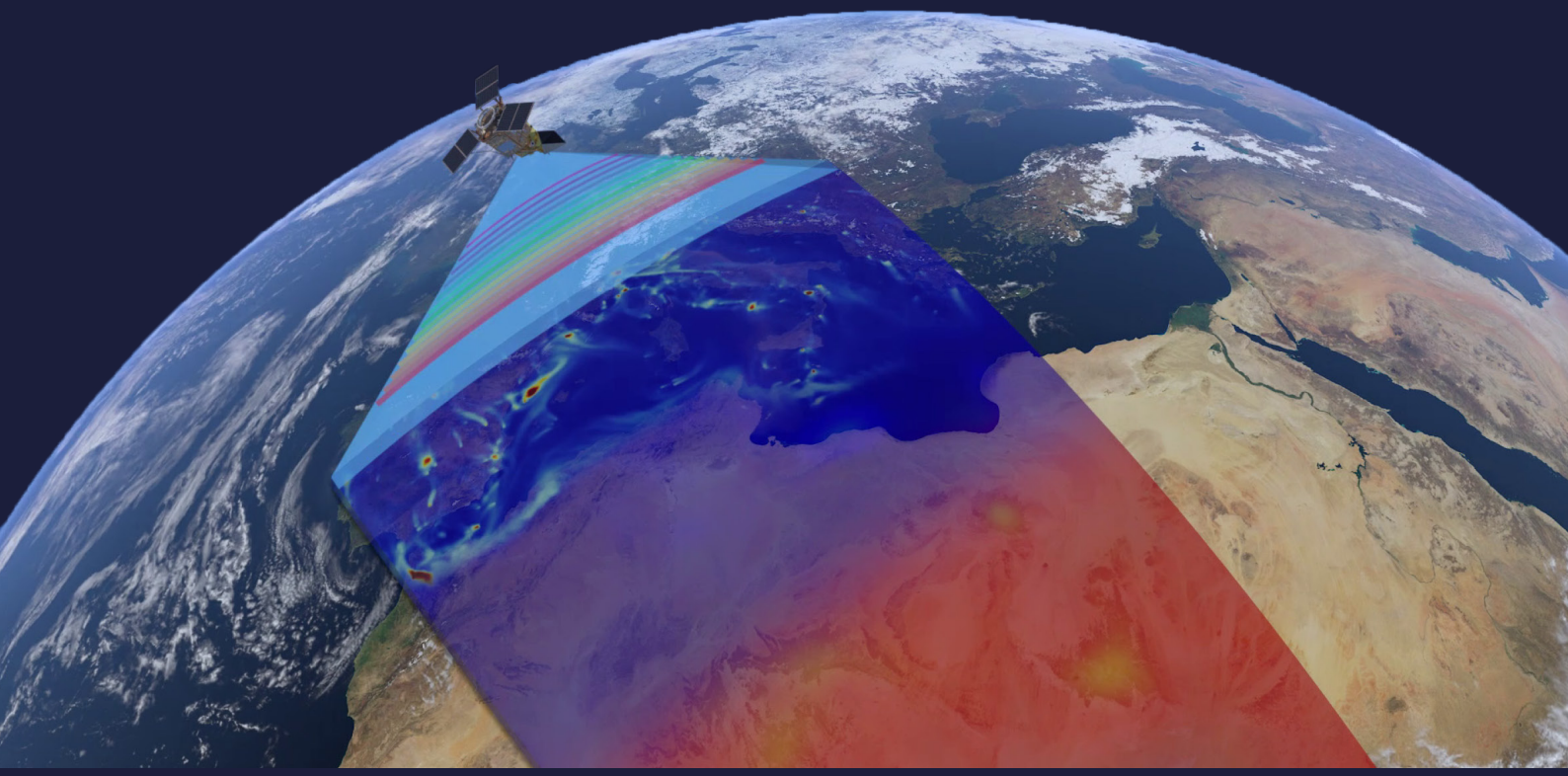
- Provide data to design and monitor emission reduction policies, thereby reducing harmful deposition of nitrogen in protected nature areas (Natura2000) and, as a result, increase biodiversity;
- Monitor the impact of industry, ports and infrastructure, growing towards a green economy;
- Validate greenhouse gas emissions of specific industries in the Netherlands (oil & gas exploration, landfills, power plants, waste, agriculture, transport), and increase transparency of carbon emission trading and cross border issues.

> SUPPORT INDUSTRY AND ECONOMY

Furthermore, the centre will stimulate the earning potential of the Dutch economy. It will establish a value chain starting from R&D, leading via upstream and downstream activities to valuable information for end users.

- **Strengthening the Dutch space sector** – both industry and knowledge institutions -, increasing ESA-ESTEC spin-off in the Netherlands.
- **Recurring business for the Netherlands high-tech sector** in manufacturing satellite instruments for constellations of small satellites and high-altitude pseudo satellite (HAPS) systems
- Supporting Dutch companies in gaining **a leading position in services that provide** accurate and reliable air quality and greenhouse **data on a commercial basis** in the international market. The growing market of end users consists of insurance companies, energy companies, process industry, oil & gas sector, transport sector, agriculture and financial sector.
- Supporting the **transition to a green economy** by providing determinants for green economic decisions.

Investing in the Clear Air agenda is an unique opportunity for The Netherlands; leading the way to effective climate and air quality policies and clear societal and economic impact. <<



TU Delft Delft University of Technology

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

TNO

SRON Netherlands Institute for Space Research