You can manage what you measure:
International Photonics Advocacy Coalition (IPAC) for Future Environmental Sensing

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IPAC is a global initiative supported by The Optical Society (OSA), that seeks to bring together the global optics and photonics sector to:

**EDUCATE** policymakers and staff in target regions & countries about photonics

**ADVOCATE** for funding for optics and photonics initiatives

**COLLABORATE** and coordinate among industry, government and academia to advance knowledge of photonics technologies
IPAC approach is analogous to translational medicine

• **Translational Medicine** is a rapidly growing discipline in biomedical research and aims to expedite the discovery of new diagnostic tools and treatments by using a multi-disciplinary, highly collaborative, "bench-to-bedside" approach.

• The **IPAC** concept is similar: “**Translational Technology**” approach that educates, advocates and coordinates among industry, government, academia and in order to engage and connect with resource management user needs.

• The **IPAC objective** is to deliver advanced optics and photonics technologies to fill information gaps and be part of the end-to-end environmental solutions.
IPAC advanced environmental monitoring: some climate change examples

Why do we have a Paris Agreement?
Measurements were the cause for concern about global warming and climate change.

The bedrock of the **UNFCCC process** and the **Paris Agreement** is the high-precision, long-term, science-based (or evidence-based) information from data records like the “Keeling curve” and the global average temperature records.
Paris Agreement and GHG Monitoring: Evolving policy and technology solutions. Scientific measurements are needed for evidence-based solutions.

As nations make pledges to reduce their greenhouse gas (GHG) emissions, concentration measurements of GHGs will unequivocally determine whether the policies and actions taken are having the desired effect.

Then (2009)

**Binding Multi-national Treaty Commitments**

“we will *verify* your reported emissions”

Now (2017)

**Nationally Determined Contributions**

“we will *help* you *improve* your data”
The Integrated Global Greenhouse Gas Information System (IG$^3$IS): An example of good practice in cooperation and coordination

- IG$^3$IS is a joint initiative of the World Meteorological Organization (WMO) and the UN Environment Programme (UNEP). Its aim is to combine atmospheric measurements with socioeconomic activity data to better quantify and attribute greenhouse gas emissions.

- IG$^3$IS will serve as an international coordinating mechanism and establish and propagate consistent methods and standards in the gathering of this data.

- Stakeholders and users are entrained from the beginning to ensure that information products meet user priorities and deliver on the foreseen value proposition.

- Success-criteria are that the information guides additional and valuable emission-reduction actions.

- IG$^3$IS, and INSPIRE, must mature in concert with evolution of policy and technology.
The Integrated Global Greenhouse Gas Information System (IG³IS): An example of good practice in cooperation and coordination

Objectives of IG³IS:

Support of Paris Agreement

• Improved national inventory reporting by making use of atmospheric measurements for developed and developing countries
• Timely and quantified trend assessment in support of countries’ NDC tracking and “Global Stocktaking”

Key sub-national efforts and industrial mitigation opportunities:

• GHG monitoring in large urban source areas (megacities)
• Detection and quantifying large unknown CH4 emissions
New network of advanced GHG photonics-based sensors

The inclusion of atmospheric measurements with statistical activity data confirms national emission total but with about 50% reduced uncertainty on the reported value.

However the difference between the a posteriori (with measurements) and the a priori emissions and suggests increased methane emissions for northeastern Switzerland.

Henne, S., D Brunner et al., 2016: Validation of the Swiss methane emission inventory by atmospheric observations and inverse modelling, Atmos. Chem. Phys., 16, 3683–3710, www.atmos-chem-phys.net/16/3683/2016/
A tiered strategy for monitoring methane leaks in the US

**Tier 1:** Satellite detects hotspot region

**Tier 2 (Blue boxes):** Aircraft spectrometers estimates local fluxes & attributes source sectors

**Tier 3:** Plume Imaging aircraft map point sources

**Tier 4 (not shown):** Surface observations

Enhanced Activity Data

50 km

500 m

500 km

Pixel size 1.5m

Turner et al 2015

Taft dairies

Kern River oil field

Elk Hills oil field
Advanced photonics sensors to separate biological from fossil fuel CO$_2$ emissions

$^{14}$CO$_2$ concentration in biologically active organic matter approximately 1 part-per-trillion, but CO$_2$ originating from the burning of fossil fuels is devoid of the radioactive C-14 isotope. So, the mole fraction of C-14 therefore acts as a proxy for fossil fuel CO$_2$ emissions.

A large-scale network of radiocarbon sensors would vastly improve knowledge of CO$_2$ emissions inventories, but current methods are too costly and not widely available (needs a particle accelerator mass spectrometry facility)

Advanced photonics techniques have shown feasibility of C-14 cost effective optical detection with needed sensitivity and deployability.

Miller et al, 2012

\[ \Delta^{14}\text{C} \]

\[ \text{CO}_2\text{-ff} \]

Mostly fossil fuel, but small effects from ecosystems, oceans, nuclear power, cosmic rays

Includes only fossil fuel
Photonics-based sensing can meet many future environmental monitoring needs

- Optics and Photonics provide technologies which are able to measure the environment both in situ as well as remotely, providing accurate environmental monitoring data. They therefore provide a key part of the necessary environmental monitoring toolkit.
- Sensors can be deployed on a wide variety of platforms, including orbiting satellites, unmanned aerial vehicles, balloons, ocean floats, city street lights and even underground oil and gas wells.
- A wide range of applications including accurate measurement of the emissions of greenhouse gases, giving detailed overviews of land use, and tracking the presence of substances, such as pollutants, in the atmosphere and the marine environment.
Recent Innovations in Optical Technology

(a) \[ f \]  

Absorption feature

**Diagram:**
- **Trigger:** D1, D2
- **PPLN crystal**
- **PPLN waveguide**

**Graph:**
- \( \Delta f_r \)
- rf frequency
Figure 3 / Phase A model of a 2U-CubeSat used for preliminary tests of basic system properties.
Conclusion: IPAC and INSPIRE: How will the future look?

- Photonics-based sensing has invaluable applications for environmental monitoring, including in the area of climate change policy.
- However, this produces a number of challenges of compatibility with the INSPIRE framework, and the key question that must be addressed is how such challenges can be overcome.
- We invite EU policymakers to reflect on these issues, and stand ready to advise and provide scientific support.
Thanks for listening. Are there any questions?

For more information on IPAC, please click on the link below:
http://www.osa.org/en-us/ipac/about/
Photonics-based Environmental Monitoring and INSPIRE

- Photonics-based sensing: innovative technology that will revolutionize the nature of environmental monitoring data
- The INSPIRE Framework: a major success in facilitating the interoperability of European geospatial data, but not ideally adapted to capitalize on the photonics revolution
- Reflected in the fact that the data from the Copernicus project, the EU’s flagship Earth Observation initiative, is itself not fully INSPIRE compliant.
- This is particularly important given the recent Commission Roadmap on Environmental Reporting, which emphasized the need to use Copernicus data better
  - Several key questions must be addressed in terms of how INSPIRE will interact with photonics-based environmental monitoring data:
    1. How will the proliferation of data available as technologies become more widespread interact with the requirements of INSPIRE?
    2. How will citizen science data, gathered, for example, from smartphone based sensors, be incorporated?