The ICOS France Science day 2021.

Understanding the greenhouse gases cycle in a warming Earth.

Université de Reims, France, 12th - 14th Oct. 2021.

https://www.icos-france.fr/

https://colloque.inrae.fr/ast-icos-reims2021

The ICOS France Science day 2021.

Forewords

The winter heat wave in February 2020, followed by the reduction in greenhouse gas emissions due to COVID 19 lock-down, a new drought and several hot days during last summer, and a new period of near-universal lock-down during the winter of 2021 are unpredictable and historically unprecedented events that affect the atmospheric greenhouse gas budget. They highlight the critical importance of accurate, distributed, real-time measurements of the surface carbon cycle. The ICOS France research infrastructure, its laboratories and data processing centres, and the network of stations it deploys in the atmosphere, ocean surface waters, and on major types of continental ecosystems, responds well to this challenge today. The ICOS France Open Science Days, organized in **Reims from October 12th to 14th, 2021**, present the latest research and data on the carbon cycle and on the impacts of rare events.

Four speakers will inaugurate the open presentation sessions. The latest report of the G.I.E.C. Working Group I (**Valérie Masson**, WGI co-chair), carbon in surface waters from source to ocean (**Richard Sanders**, head of the Ocean thematic centre), the coupling of carbon and nitrogen cycles (**Mark Sutton**, Centre for Ecology and Hydrology) and inversion approaches for determining surface fluxes (**Frédéric Chevallier**, L.S.C.E.) will be presented.

These days will be organized to minimize its fossil carbon emissions with the involvement of the hotel school of Reims.

Venue

October 12th , 13th and 14th until Lunch:

Hôtel de la Paix, 9 Rue Buirette 51100 Reims, (tel +33 (0)3 26 40 04 08).

October 14th afternoon:

Atmospheric Station Inauguration :

GPS : 49.243442187164106, 4.060832353290433

(arrival along the « *chemins des rouliers*” and *Conservatoire National des Arts et Métiers*).

Organising committee :

Marie-Odette Victor, URCA.
Lilian Joly, GSMA, CNRS,
Patricia Braconnier, UMR ISPA, INRAE,
Gregory Lambert, SDAR, INRAE,
Denis Loustau, UMR ISPA, INRAE.
Christelle Aluome, UMR ISPA, INRAE

Scientific committee :

PhIlippe Ciais, LSCE, CEA.
Léonard Rivier, LSCE, CNRS.
Michel Ramonet, LSCE, CNRS.
Lilian Joly, GSMA, CNRS.
Nathalie Lefèvre, LOCEAN, IRD.
Jean-Marc Limousin, CEFE, CNRS.
Benjamin Loubet, ECOSYS, INRAE.
Denis Loustau, ISPA, INRAE.

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The ICOS France Science day 2021.

Tuesday Oct. 12.

Hôtel de la Paix, Salle Athènes

Accueil 09h00-09h30

Bienvenue 09h30-09h45 : Accueil par **Guillaume Gelé**, Président d'Université Reims-Champagne et mot de bienvenue

09h45-10h30 : **Richard Sanders (visio)**,
Director of the ICOS Ocean Thematic Centre.
The Oceans role in the global C cycle: Future priorities for research.

10h30-10h50 : **Margaux Brandon**, Catherine Goyet, Franck Touratier, Nathalie Lefèvre : Spatial and temporal evolution of surface biogeochemistry in the southern ocean

10h50-11h10 : Laurent Coppola, Marine Fourrier, Dominique Lefevre, Caroline Ulses, **Thibaut Wagener** : Integrated observations of oceanic CO_2 in the North-Western Mediterranean Sea. A synthesis of the last ten years and perspectives.

11h10-11h25 Coffee Break

11h25-11h45 : **Leseurre Coraline**, Lo Monaco Claire, Reverdin Gilles, Metzl Nicolas, Fin Jonathan, Mignon Claude : Trends and drivers of sea surface fCO_2 and pH observed in the Southern Incian Ocean over the last two decades (1998-2019)

11h45-12h05 : **Léa Olivier**, Sabrina Speich, Jacqueline Boutin , Johannes Karstensen : Impact of North Brazil Current rings on air-sea CO_2 fluxes variability in winter 2020 in the north-western tropical Atlantic

12h05-12h25 : Fengjiao Shen, Jingjing Wang, Gaoxuan Wang, Tu Tan, Zhensong Cao, Xiaoming Gao, Pascal Jeseck, Yao-Veng Te, **Weidong Chen** : Remote sensing of greenhouse gases in the atmospheric column using ground-based laser heterodyne radiometers (LHR)

12h25-12:45: **Carole Deniel**, Programmes spatiaux en Atmosphère, CNES-Paris : Quelle place pour les observations spatiales de GHG dans l'étude du cycle du carbone ?

12h45:14:00 Lunch - Salle Berlin

14:00-14h20 : **Jean-Daniel Paris**, Mia Schumacher, Roberto Grilli, Mathis Lozano, Marc Delmotte, Thomas Giunta, Dominique Birot, Camille Blouzon, Jean Pierre Donval, Vivien Guyader, Helene Leau, Vlad Radulescu, Sorin Balan, Jens Greinert, Livio Ruffine : Toward direct evidence of methane transfer from the sediment to the atmosphere using a suite of systematic observations

14h20-15:05 : **Mark Sutton (visio)**

Why nitrogen and climate change? Emerging science-policy needs

15h05-15h25 : **Maryam Gebleh-Goydaragh**, Pauline Buysse, Nicolas Saby, Sébastien Lafont, Claudy Jolivet, Céline Ratie, Jean-Philippe Chenu, Nicolas Proix, Brigitte Durand, Benjamin Loubet : ICOS ETC soil carbon and nitrogen stocks uncertainties evaluations. Application to soil stock changes at an agricultural site (FR-GRI).

15h25-15:45 : **Gwenaëlle Lashermes**, Sylvie Recous, Gonzague Alavoine, Baldur Janz, Klaus Butterbach-Bahl, Maria Ernfors, Patricia Lavilled : N_2O emissions from decomposing crop residues in soils

15h45-16h05 : **Pauline Buysse**, B. Loubet, F. Lafouge, R. Ciuraru, L. Gonzaga-Gomez, B. Durand, O. Zurfluh, C. Decuq, O. Fanucci, J.-C. Gueudet, S. Bsaibes, F. Truong, C. Boissard, Dominique B., R. Sarda-Estève, V. Gros. : VOC fluxes measured by eddy-covariance with a PTR-Qi-TOF-MS over a rapeseed field near Paris

16h05-16:25 : **Sauveur Belviso**, David Montagne, Dalila Hadjar, Didier Tropée, Laurence Vialettes, Victor Kazan, Marc Delmotte, Camille Abadie, Fabienne Maignan, Michel Ramonet, Morgan Lopez, Camille Yver-Kwok, Philippe Ciais : Carbonyl sulfide dynamics in agricultural ecosystems: comparative study of emissions from wheat and rapeseed crops

16h25-16h45 Coffee Break

16h45:18h45 **POSTER SESSION**

- Eddy-covariance methane flux estimation in a western France landfill site. **Mathis Lozano.**
- Two numerical tools for an easier generation of level 3 products: flexpart-toolbox and the CIF. **Isabelle Pison.**
- Développement et mise à jour du réseau ICOS France atmosphère. **Morgan Lopez.**
- AirCore : Couplage des Picarro G24 et G53 pour mesure in situ des concentrations atmosphériques de CO2, CH4, N2O et CO. **Julien Moyé.**
- The Moulin De la Housse launching site. **Nicolas Dumelie.**
- Ground-based FTIR measurements. An efficient way to the GHG-satellites monitoring validation? **Bruno Grouiez.**
- Development of a Tunable Diode Laser based fluxmeter for eddy covariance of H2O and CO2 co-localized with 3D wind measurements. **Julien Cousin.**
- Soil sampling protocol and analysis by the ICOS ecosystem thematic center (ETC). **Benjamin Loubet.**

Exhibitors list

- **LI-COR Biosciences GmbH** : Mme Katia Bonne; M. Graham Leggett
- **Picarro Inc** : M. Ruthger van Zwieten
- **ENVITEC** : M. Adrien Danner

- **MIRO Analytical AG** : M. Morten Hundt

18h45 : End of the session.

The ICOS France Science day 2021.

Wednesday 13th Oct. 2021.

Hôtel de la Paix Salle Athènes

8h30-9h15: **Valérie Masson-Delmotte (visio)**

LSCE, IPCC WGI vice chair

Changement climatique, points clés du rapport du GIEC de 2021

9h15-9h35 : **Herig Coimbra**, P., Buysse, P., Loubet, B., Simioni, G., Lafont, S., Berveiller, D., Ruffault, J., Fléchard, C. R., Martin-St-Paul, N., Bornet, F., Brut, A., Calvet, J-F., Chipeaux, C., Cuntz, M., Darsonville, O., Dufrêne, E., Galy, C., Gogo, S., Jacotot, A., Klumpp, K., Léonard, J., Lily, J-B., Limousin, J-M., Loustau, D., Marloie, O., Ourcival, J-M, Tallec, T., Voisin, D., Zawilski, B. : Impact of heat wave episode in summer 2019 on the carbon flux of the French ICOS sites

9h35-9h55 : Renaud Decarsin, Nicolas Martin - Saint Paul, Julien Ruffault, Olivier Marloie, **Guillaume Simioni** : Déterminants et variations de la respiration du sol dans une forêt mélangée méditerranéenne

9h55-10h15 : **Nicolas Delpierre**, Jean Maysonnave, Daniel Berveiller, Christophe François, Eric Dufrêne, Kamel Soudani, Ivan Cornut, Gaëlle Vincent, Alexandre Morfin : Keeping cool during drought: access to subsoil water relaxes water stress in a temperate deciduous forest

10h15-10h35 : **Angela Che Ing Tang**, Denis Loustau, Matthias Cuntz, Silvano Fares, Paul C. Stoy, Christophe Flechard, Guillaume Simioni, Katja Klumpp, Emilie Joetzjer, Ladislav Šigut, Matthias Peichl, Ivan Mammarella, Daniel Berveiller, Nina Buchmann, Corinna Rebmann, John Douros, Renske Timmermans, Alexander Knohl, Bernard Heinesch, Nicola Arriga, Mats Nilsson, Jiří Dušek, Ivan Janssens, Damiano Gianelle, Natalia Kowalska, Marilyn Roland, Eeva-Stiina Tuittila, Andrej Varlagin : The impact of COVID-19 lockdown on ecosystem gross primary productivity

10h35-10h55 Coffee Break

10h55-11h15 : **Nicolas Brodu**, Yao Liu : Data-based inference of ecosystem dynamics

11h15-11h35 : **Michel Ramonet**, Jérôme Tarniewicz, Bavo Langerock, Thorsten Warneke, Nicolas Gourgue, N.C.O. Diaby, Tanguy Martinez, Léonard Rivier, Anna Agustí-Panareda and Henk Eskes : Evaluation of the the CAMS greenhouse gas global reanalysis and high resolution forecasts using ICOS, TCCON, NDACC, Aircraft and Aircore measurements

11-35-11h55 : **Cyril Crevoisier**, Jérôme Pernin, Axel Guedj, Lilian Joly, Delphine Combaz, Nicolas Dumelie, Michel Ramonet, Julien Moyé, Morgan Lopez, Jean-Luc Baray, Aurélie Colomb, Jean-Claude Rubio, Frédéric Thoumieux and Caroline Bès : What is brought by

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measuring vertical profile of concentrations of greenhouse gases?

11h55-12h15 : **Jean-Louis Bonne**, Jérémie Burgalat, Nicolas Chauvin, Delphine Combaz, Gregory Albora, Julien Cousin, Thomas Decarpenterie, Ludovic Donnat, Catherine Juery, Abel Mauroury, Nicolas Galas, Olivier Ventre et Lilian Joly : Industrial site emissions quantification from simultaneous CH_4/CO_2 in-situ concentration measurements on-board unmanned aircraft vehicles

12h15-12h30: **Yver-Kwok Camille**, Fuente-Lastra Martha : Trace radon: a project to develop metrology to determine emission reduction strategies of GHG and improve radiation protection of the general public

12h30:14:00 Lunch - Salle Berlin

14:00-14:45 :

Frédéric Chevallier

LSCE, IPSL

Atmospheric inversion : : where is the beauty contest between surface measurements and space observations?

Conference Closure

ICOS France general Assembly (private)

14h50:15h20 : ICOS France activity report: stations networks, ATC, ETC, (ICOS France ex com)

15h20-15h40 : ICOS-RI report: evaluation, new members, (D. Loustau). Administrative and financial report (Contract renewals, labelling, Fench RI roadmap , Publimetric project, Good practice project) (D. Loustau)

15h40-15h50 : Ongoing and future projects: OBS4CCLIM, PAUL, ATMO-ACCESS, ENVRI-CLIM (L. Rivier, M. Ramonet)

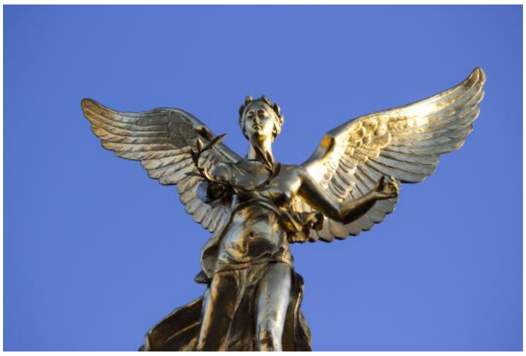
15h50-16h00 : Retour du COPIL ICOS France et mot du MESR

End of the ICOS-France General Assembly.

Social events

16h15 : Visit of Champagne wine cellars, duration about 1h15

20h00 : Gala Dinner sponsored by University of Reims-Champagne . Hôtel de Ville de Reims (10 Place de l'Hôtel de Ville, 51100 Reims)



The ICOS France Science day 2021.

Thursday 14th Oct. 2021.

Hôtel de la Paix, Salles Lisbonne, Rome, Athènes

8h30 : Scientific and technical workshops (private) : parallel sessions: Ecosystem, Ocean, Atmosphere

10h30-11h00 Coffee Break

11h00 : Scientific and technical workshops (private) : parallel sessions Ecosystem, Ocean, Atmosphere ; Transverse session: "ICOS France trans domain projects"

12h30:14:00 Lunch - Salle Berlin

14h00-15h00 : Transfer to the University Campus (special bus to be confirmed)

Reims-Champagne-Ardenne University Campus

15h00 Inauguration of the ICOS Atmospheric station (followed by a cocktail).

15h30 -16h30 :

- Demonstration of Aircore and Amulse under balloon for atmospheric sounding 0-30km.
- Spatio-temporal mapping of surface CO2 CH4 exchanges in real time by drone.

16h30 : Departures (special bus, to be confirmed)

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Abstracts

Oral presentations

Remote sensing of greenhouse gases in the atmospheric column using ground-based laser heterodyne radiometers (LHR)

Author Speaker : Weidong Chen

Information about other authors :

Fengjiao Shen[1], Jingjing Wang[1,2], Gaoxuan Wang[1], Tu Tan[2], Zhensong Cao[2], Xiaoming Gao[2], Pascal Jeseck[3], Yao-Veng Te[3], Weidong Chen[1*]

1. Laboratoire de Physicochimie de l'Atmosphère, Université du Littoral Côte d'Opale, 59140 Dunkerque, France
2. Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, 230031 Hefei, China
3. LERMA, Université Pierre et Marie Curie, 75252 Paris, France

Abstract :

Monitoring of vertical concentration profiles of key atmospheric trace gases, in particular greenhouse gases (GHGs), is essential for our understanding of regional air quality and global climate change trends. In this context, infrared (IR) laser heterodyne radiometers (LHR) have been developed for ground-based remote measurements of GHGs in the atmospheric column [1-6]. The sunlight traverses the Earth's atmosphere and undergoes absorption by atmospheric species (molecules and aerosols). The shape of the ground-based measured absorption spectrum of the molecular absorber contains information on its vertical concentration distribution. By de-convoluting this spectral signal (absorption line shape and depth) through a retrieval algorithm, the target gas abundance at different altitudes can be retrieved.

In the present work, near-IR (~1.5 µm) and mid-IR (~8 µm) LHRs have been recently developed and deployed to field campaigns. The developed LHR instruments as well as the preliminary results of their applications to the measurements of CH_4, N_2O, CO_2 (including $^{13}CO_2/^{12}CO_2$), H_2O vapor (and its isotopologue HDO) in the atmospheric column will be presented and discussed.

Acknowledgments The authors thank the financial supports from the LABEX CaPPA project (ANR-10-LABX005), the MABCaM (ANR-16-CE04-0009) and the MULTIPAS (ANR-16-CE04-0012) contracts, as well as the CPER CLIMIBIO program.

References :

[1] R. T. Menzies, and R. K. Seals, Science 197 (1977) 1275-1277
[2] D. Weidmann, T. Tsai, N. A. Macleod, and G. Wysocki, Opt. Lett. 36 (2011) 1951-1953
[3] E. L. Wilson, M. L. McLinden, and J. H. Miller, Appl. Phys. B 114 (2014) 385-393
[4] A. Rodin, A. Klimchuk, A. Nadezhdinskiy, D. Churbanov, and M. Spiridonov, Opt. Express 22 (2014) 13825-13834
[5] J. Wang, G. Wang, T. Tan, G. Zhu, C. Sun, Z. Cao, W. Chen, and X. Gao, Opt. Express 27 (2019) 9600-9619

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GRAND REIMS COMMUNAUTÉ URBAINE

[6] F. Shen, G. Wang, J. Wang, T. Tan, G. Wang, P. Jeseck, Y.-V. Te, X. Gao, W. Chen, Opt. Lett. (June 2021)
Keywords : Greenhouse gases, trace gas concentration in the atmospheric column, laser heterodyne radiometer, ground-based remote sensing

UNIVERSITÉ DE REIMS CHAMPAGNE-ARDENNE

GRAND REIMS COMMUNAUTÉ URBAINE

Carbonyl sulfide dynamics in agricultural ecosystems: comparative study of emissions from wheat and rapeseed crops

Auteur Orateur : Sauveur BELVISO

Liste complète des auteurs - Affiliations :

Sauveur Belviso[a], David Montagne[b], Dalila Hadjar[b], Didier Tropée[c], Laurence Viallettes[a], Victor Kazan[a], Marc Delmotte[a], Camille Abadie[a], Fabienne Maignan[a], Michel Ramonet[a], Morgan Lopez[a], Camille Yver-Kwok[a], Philippe Ciais[a]

[a] UMR LSCE, CNRS-CEA-UVSQ, IPSL, Université Paris-Saclay, 91 191 Gif sur Yvette, France

[b] UMR ECOSYS, INRA, AgroParisTech, Université Paris-Saclay, 78 850 Thiverval-Grignon, France

[c] UMR GQE, INRA, UPS, CNRS, AgroParisTech, Université Paris-Saclay, 91 190 Gif sur Yvette, France

Résumé :

The importance of non-photosynthetic fluxes in carbonyl sulfide (OCS) dynamics in agricultural ecosystems was investigated in the context of three independent and complementary approaches. Firstly, during the growing seasons of 2019 and 2020, monthly variations in the nighttime ratio of measured vertical mole fraction gradients of OCS and CO_2 were monitored in central France at a rural site near Orléans (i.e., a “profile based” approach). Then, field observations of OCS nocturnal fluxes, obtained by Radon Tracer Method (RTM) at a sub-urban site near Paris, were used to examine the dynamics of a biogenic process yet unaccounted for by the recently updated vegetation and soil modules of ORCHIDEE land surface model (i.e., a “model and RTM” joint approach). Finally, during the growing seasons of 2019, 2020 and 2021, horizontal mole fraction gradients of OCS, calculated from downwind-upwind surveys of wheat and rapeseed crops, highlighted new aspects in OCS dynamics in agricultural ecosystems (i.e., a “crop based” comparative approach). The “profile based” approach suggests that the nocturnal net OCS uptake gradually weakens during the peak growing season and recovers from August on. The “model and RTM” joint approach provides evidence of the existence of compensation fluxes (i.e., a source of OCS) the intensity of which culminates in late June early July. Our “crop based” comparative approach demonstrates that both crops shift from OCS uptake to emissions when they reach the ripening stage. However, rapeseed appears to be a much more important source of OCS than wheat at the local scale. A first assessment of the significance at the country scale of rapeseed emissions is presented.

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Trends and drivers of sea surface fCO2 and pH observed in the Southern Incian Ocean over the last two decades (1998-2019)

Auteur Orateur : Leseurre Coraline

Liste complète des auteurs - Affiliations :

Leseurre Coraline[1], Lo Monaco Claire[1], Reverdin Gilles[1], Metzl Nicolas[1], Fin Jonathan[1], Mignon Claude[1]

[1] Laboratoire d'Océanographie et du Climat: Expérimentation et Approches Numériques (LOCEAN-IPSL), Sorbonne Université-CNRS-IRD-MNHN, Paris, 75005, France

Résumé :

The Southern Ocean is recognized as a major player in the sequestration of anthropogenic CO_2. As pH is naturally low at high latitudes, the increase in oceanic CO_2 raises particular concerns in this region where surface waters could become rapidly under-saturated with respect to carbonate. To investigate the changes and drivers of the carbonate system in the Southern Indian Ocean (45°S-57°S) we used repeated observations, including fugacity of CO_2 (fCO_2), total alkalinity (A_T) and carbon (C_T) collected by the French monitoring program OISO (Océan Indien Service d'Observations) in the surface ocean and the water column over the last two decades (1998-2019), conducted on board the Marion Dufresne (IPEV/IFREMER). South of the polar front around 50°S, in the High Nutrients Low Chlorophyll (HNLC) region, our results show an increase in the fCO_2 during summer, close to the increase in the atmosphere (on the order of +2 µatm yr_{-1}) associated with a decrease in pH in the range of the mean global ocean trend (on the order of -0.0020 yr^{-1}). However much larger changes are found in the phytoplankton fertilized blooms in the vicinity of Crozet and Kerguelen Islands for both fCO_2 (between +3.1 and +5.1 µatm yr^{-1}) and pH (ranging from -0.0033 to -0.0060 yr^{-1}). In HNLC region, the trends observed during summer are mainly driven by an increase in C_T that is consistent with the accumulation of anthropogenic carbon evaluated below the summer mixed layer. In the bloom regions the fCO_2 and pH trends in summer are also modulated by natural processes, probably linked to variations of productivity.

Mots clés : CO2, Southern Ocean, Observation, Acidification

Impact of North Brazil Current rings on air-sea CO2 fluxes variability in winter 2020 in the north-western tropical Atlantic

Auteur Orateur : Léa Olivier

Liste complète des auteurs - Affiliations :

Léa Olivier - LOCEAN-IPSL, Sorbonne Université-CNRS-IRD-MNHN, Paris, France

Jacqueline Boutin - LOCEAN-IPSL, Sorbonne Université-CNRS-IRD-MNHN, Paris, France

Nathalie Lefèvre - LOCEAN-IPSL, Sorbonne Université-CNRS-IRD-MNHN, Paris, France

Gilles Reverdin - LOCEAN-IPSL, Sorbonne Université-CNRS-IRD-MNHN, Paris, France

Peter Landschützer - Max Planck Institute for Meteorology, Hamburg, Germany

Sabrina Speich - Laboratoire de Météorologie Dynamique, ENS-Ecole Polytechnique-CNRS-Sorbonne Université, Paris, France

Johannes Karstensen - GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany

Markus Ritschel - Max Planck Institute for Meteorology, Hamburg, Germany

Rik Wanninkhof -

Atlantic Oceanographic and Meteorological Laboratory (AOML) of NOAA, 4301 Rickenbacker Causeway, Miami, FL 33149

Résumé :

In the western tropical Atlantic, the North Brazil Current (NBC) flows northward across the Equator and passes the mouth of the Amazon River, entraining fresh and nutrient-rich water along its nearshore edge. Close to 8°N, the NBC is unstable and forms the world's largest oceanic eddies, propagating westward toward the Caribbean. We identify and characterize the large-scale, mesoscale and sub-mesoscale processes driving the variability of salinity and air-sea CO_2 fluxes in February 2020 based on in situ measurements made by three research vessels during the EUREC^{4}A-OA/ATOMIC campaign in the region [50°W-62°W – 5°N-16°N] (Stevens et al., 2021). In-situ surface measurements of the fugacity of CO_2 (fCO_2), salinity and temperature combined with maps of satellite salinity, chlorophyll and temperature highlight the different regimes in the region. In February 2020, the area globally behaves as a CO_2 sink (-1.7 TgC/month). The NBC rings transport saline and high fCO_2 water indicative of their equatorial origins. They also stir filaments and generate a high variability of salinity (Reverdin et al., 2021) and biogeochemical parameters. During the campaign, a freshwater plume from the Amazon River is stirred up to 12°N associated with a biological bloom leading to a significant carbon drawdown (~20 % of the total sink). On the other hand, filaments of shelf water rich in detrital material act as a strong local source

of CO_2. Ocean dynamics are therefore responsible for most of the salinity and fCO_2 variability south of 12°N. The less variable North Atlantic subtropical water extends from Barbados northward. They act as the main CO_2sink (~60 % of the total sink) in the region due to their lower temperature associated with winter cooling and strong winds.

Références bibliographiques :

Reverdin, G., Olivier, L., Foltz, G. R., Speich, S., Karstensen, J., Horstmann, J., ... & Boutin, J. (2021). Formation and evolution of a freshwater plume in the northwestern tropical Atlantic in February 2020. Journal of Geophysical Research: Oceans, 126(4), e2020JC016981.

Stevens, B., Sandrine, B., David, F., Felix, A., Alan, B., Christopher, F., et al. (2021). EUREC4A. Accepted in Earth System science data. Retrieved from https://essd.copernicus.org/preprints/essd-2021-18/

Mots clés : NBC Rings, Tropical Atlantic, CO2 air-sea fluxes

Keeping cool during drought: access to subsoil water relaxes water stress in a temperate deciduous forest

Auteur Orateur : Nicolas Delpierre

Liste complète des auteurs - Affiliations :

Nicolas Delpierre (a,b), Jean Maysonnave (a), Daniel Berveiller (a), Christophe François (a), Eric Dufrêne (a), Kamel Soudani (a), Ivan Cornut (a,c), Gaëlle Vincent (a), Alexandre Morfin (a)

(a) Université Paris-Saclay, CNRS, AgroParisTech, Ecologie Systématique et Evolution, 91405, Orsay, France.
(b) Institut Universitaire de France (IUF)
(c) CIRAD, UMR Eco\&Sols, F-34398 Montpellier, France

Résumé :

Climate change is imposing drier atmospheric (vapor pressure deficit) and edaphic (soil water content) conditions on temperate forests. In this contribution, we investigate how subsoil (down to 300 cm) water extraction contributed to the provision of water in the Barbeau (FR-Fon) oak forest over two dry years, including the 2018 record drought. Deep water provision was key to sustain tree transpiration during drought, with layers below 150 cm contributing up to 60\% of the transpired water in August 2018, despite their very low density of fine roots. We further show that soil databases used to parameterize ecosystem models clearly underestimate the available water holding capacity (AWHC), with an average of 207 mm when our estimate based on SWC measurements is 390+/-17 mm. Running the CASTANEA forest model with the database-derived AWHC yields a 350 $gC/m^2/yr$ error on annual GPP, reaching up to 700 $gC/m^2/yr$ under climate change scenarios (RCP8.5, Hadgem and MPI climate models). Correctly estimating AWHC is a challenge for accurate simulations of the carbon cycle in a changing climate. We show that subsoil SWC measurements are needed for this, and advocate the generalization of deep SWC measurement in the context of the ICOS network, well below the 100 cm depth currently recommended.

Mots clés : drought, GPP, evapotranspiration, soil water content, canopy conductance, CASTANEA model

TraceRadon: a project to develop metrology to determine emission reduction strategies of GHG and improve radiation protection of the general public

Auteur Orateur : Camille Yver-Kwok

Liste complète des auteurs - Affiliations :

Camille Yver-Kwok, Laboratoire des Sciences du Climat et de l’Environnement (LSCE-IPSL), CEA-CNRS-UVSQ, Université Paris-Saclay, 91191 Gif-sur-Yvette, France

Martha Fuente-Lastra, Laboratoire des Sciences du Climat et de l’Environnement (LSCE-IPSL), CEA-CNRS-UVSQ, Université Paris-Saclay, 91191 Gif-sur-Yvette, France

Résumé :

An overlapping need exists between the climate research and radiation protection communities for improved traceable low-level outdoor radon measurements, combining the challenges of collating and modelling large datasets, with setting up new radiation protection services.In the climate community, the radon data produced from networks such as ICOS can be used to improve transport modelling and the estimation of GHG emissions based on the Radon Tracer Method (RTM), which uses the correlation between GHG and radon concentrations.

The overall aim of the EMPIR TraceRadon project is the development of metrological capacity (reference monitors, transfer standards and robust methodology) to measure low levels of radon in the environment, which can be used to determine emission reduction strategies of GHG and improve radiation protection of the general public.

We present here the different work packages with a focus on those concerning the climate community and show first results after one year of the project.

Mots clés : radon, greenhouse gas flux, metrology

Impact of heat wave episodes in summer 2019 on the carbon flux of the french icos sites inferred through modelling from ICOS Ecosystem stations in France

Auteur Orateur : Pedro Henrique Herig Coimbra

Liste complète des auteurs - Affiliations :

Pauline Buysse, INRAE, ECOSYS, Université Paris Saclay, FRANCE
Benjamin Loubet, INRAE, ECOSYS, Université Paris Saclay, FRANCE
Guillaume Simioni, INRAE, URFM, FRANCE
Sébastien Lafont, INRAE, ISPA, FRANCE
Daniel Berveiller, CNRS, ESE, FRANCE
Julien Ruffault, INRAE, URFM, FRANCE
Chris R. Fléchard, INRAE, SAS, FRANCE
Nicolas Martin-StPaul, INRAE, URFM, FRANCE
Frédéric Bornet, INRAE, AgroImpact, FRANCE
Aurore Brut, Université Paul Sabatier, CESBIO, FRANCE
Jean-Christophe Calvet, Meteo-France, CNRM, FRANCE
Christophe Chipeaux, INRAE, ISPA, FRANCE
Matthias Cuntz, INRAE, SILVA, FRANCE
Olivier Darsonville, INRAE, UREP, FRANCE
Eric Dufrêne, CNRS, ESE, FRANCE
Catherine Galy, ANDRA, FRANCE
Sébastien Gogo, Université d'Orléans, ISTO, FRANCE
Adrien Jacotot, Université d'Orléans, ISTO, FRANCE
Katja Klumpp, INRAE, UREP, FRANCE
Joël Léonard, INRAE, AgroImpact, FRANCE
Jean-Baptiste Lily, INRAE, SILVA, FRANCE
Jean-Marc Limousin, CNRS, CEFE, FRANCE
Denis Loustau, INRAE, ISPA, FRANCE
Olivier Marloie, INRAE, URFM, FRANCE
Virginie Moreaux, INRAE, ISPA, FRANCE
Jean-Marc Ourcival, CNRS, CEFE, FRANCE
Tiphaine Tallec, Université Paul Sabatier, CESBIO, FRANCE
Didier Voisin, Université Grenoble-Alpes, IGE, FRANCE
Bartosz Zawilski, CNRS, CESBIO, FRANCE

Résumé :

Under increasing frequency and intensity of climate extremes, there is an urgent need to better understand their effects on ecosystems, particularly on carbon and water cycles. The 2019 European summer heat waves were particularly strong in France, both national and local temperature records were broken. France is equipped with 18 sites connected to the European ICOS network (Integrated Carbon Observation System), which allows us to have real-time and high-frequency monitoring of

CO_2 and water vapor fluxes. This study uses part of this powerful database to reveal the impacts of 2019 heat waves in France by analyzing the evolution of meteorological and carbon/water fluxes at the different sites and trying to unveil the role of water stress and elevated temperature on the net ecosystem exchange.

To this end, after identifying heat wave episodes from 2003 onward, 2019 indeed appears as a significant intense event in France. The study operated three models, two of which using environmental variables and a third one purely statistical based on synthetic control method. All three models aimed at building a typical 2019 carbon flux at each site to compare with the measured 2019 fluxes. These three models were then used to investigate the carbon flux on a daily and annual basis. The models allowed to question the normality of carbon fluxes in 2019 even outside the heat wave events and evaluate their possible links with water stress and temperature.

For forests, sites were found sequestering from 16 to 315 $g.C.m^{-2}$ less than what was predicted as a normal 2019 depending on the model and site, and with an uncertainty varying from 34 to 157 $g.C.m^{-2}$. For agricultural sites during the main cropping season, there were two negatively impacted and a third one, Lamasquère, which was the only irrigated site and the only one with higher carbon flux than predicted. The ones negatively impacted had values from 47 to 218 $g.C.m^{-2}$ less than predicted (uncertainty varying from 14 to 136 $g.C.m^{-2}$) while Lamasquère sequestered from 7 (±37) to 229 (±62) $g.C.m^{-2}$ more than predicted.

Sites under water stress showed a larger decrease in carbon sequestration with increasing temperature, notably through a decline in photosynthesis rather than any change in respiration. However, the difference between predicted and observed carbon budget varied between models and sites. Our results suggest, nonetheless, that irrigation can maintain good levels of primary production in agricultural sites. This may lead to higher water demand in the future and hence further tensions on water availability.

Models were useful in identifying periods with atypical behavior. The study allowed a better understanding of the conditions in which heat waves affect the most ecosystems, giving keys for seeking strategies to avoid such impact.

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Mots clés : heat wave, carbon flux, eddy covariance, model

Quelle place pour les observations spatiales de GHG dans l'étude du cycle du carbone ?

Auteur Orateur : Carole DENIEL

Liste complète des auteurs - Affiliations :

Carole DENIEL, Programmes spatiaux en Atmosphère, CNES-Paris

Résumé :

Depuis près de 10 ans, les données spatiales de concentrations des gaz à effets l'atmosphère sont utilisées pour accéder au flux de surface par la communauté scientifique. Avec le développement de nouvelles missions, notamment dans le cadre Copernicus, on assiste à une attente forte des pouvoirs publics de pourvoir contribuer également à l'estimation des émissions de surfaces et à la surveillance opérationnelle et globale des efforts des états pour répondre à l'accord de paris sur al réduction des émissions.   Pour cela, les agences spatiales se sont organisées au niveau international, notamment dans le cadre du CEOS, pour proposer un schéma global où les observations spatiales, sol mais également les données socio-économiques sont combinées dans les modèles pour proposer des informations pertinentes pour les utilisateurs finaux non spécialistes de la données.

La présentation proposera un panorama des projets et des actions entreprises par l'agence spatiale Francaise en concertation avec ses partenaires scientifiques nationaux, et ses homologues au niveaux internationaux afin de promouvoir l'expertise technologique et scientifique française et les liens entre les observations sol et spatiales.

Références bibliographiques :

Mots clés : satellites, validation, GHG, complémentarité, collaborations

Déterminants et variations de la respiration du sol dans une forêt mélangée méditerranéenne

Auteur Orateur : Guillaume Simioni

Liste complète des auteurs - Affiliations :

Renaud Decarsin, Nicolas Martin - Saint Paul, Julien Ruffault, Olivier Marloie, Guillaume Simioni

Ecologie des Forêts Méditerranéennes (URFM), INRAE, Avignon, France

Résumé :

La respiration du sol (Rsol), qui comprend les émissions de CO2 par les organismes décomposeurs et les racines, est une composante majeure des flux de carbone des écosystèmes terrestres. Elle dépend typiquement de facteurs abiotiques (température et humidité) et biotiques (chutes de litière, exsudats racinaires...), mais les mécanismes sont complexes et suivent des rythmes journaliers, saisonniers, et pluriannuels, dont sa caractérisation peut être encore rendue plus difficile par la variabilité spatiale. L'objectif de cette étude était d'améliorer notre compréhension de la dynamique de Rsol sur le site ICOS de Font-Blanche, une forêt méditerranéenne dominée par le chêne vert et le pin d'Alep, et de confronter les estimations de Rsol avec celles de la respiration totale de l'écosystème (Reco) obtenues par eddy covariance. Pour cela nous disposions de plusieurs années de mesures continues semi-horaires de Rsol issues de 3 chambres automatiques, ainsi que de données mensuelles issues de mesures faites à l'aide d'une chambre portative sur 30 points répartis dans le dispositif. Nous avons cherché à (i) modéliser et analyser les variations temporelles de Rsol avec une approche de "machine learning" sur les données issues des chambres automatiques, (ii) corriger le meilleur modèle en introduisant la variabilité spatiale obtenue à partir des mesures à la chambre portative, et (iii) comparer Rsol et Reco.

Nos résultats confirment l'importance la température et de l'humidité du sol, mais montrent aussi une influence du déficit de pression de vapeur d'eau, qui est rarement pris en compte. Cependant, il a fallu introduire des "effets correcteurs" ("jour Julien", "année") pour obtenir un bon niveau de précision ($R^2>0.8$), probablement pour compenser la non prise en compte explicite des facteurs biotiques. Certains, tels que les chutes de litière, pourraient être incorporés dans de futures versions. Enfin, la Rsol dérivée du modèle le plus fiable était la plupart du temps 1.5 à 2 fois supérieure à Reco. Cela tend à confirmer que la séquestration de carbone établie à Font-Blanche par eddy covariance est surestimée.

Mots clés : respiration, modélisation, boosted regression tree, forêt, cycle du carbone

Data-based inference of ecosystem dynamics

Auteur Orateur : Nicolas Brodu

Liste complète des auteurs - Affiliations :

Nicolas Brodu - Inria
Yao Liu - Northumbria University

Résumé :

This work presents a new method for extracting global state variables and identifying the internal states of a natural process, solely from observations. These state variables should also correspond to some combination of ecological factors driving the ecosystem. Trajectories in state space define a global dynamic, possibly lying on a chaotic attractor which is then reconstructed. Predictions can be made by encoding the evolution operator of these trajectories. We apply this method to publicly available ecological and meteorological data in order to build predictive models, in particular models involving carbon and water fluxes in terrestrial ecosystems.

Références bibliographiques :

Project web site: https://team.inria.fr/comcausa/terrestrial-carbon-water-fluxes/
Main method article: https://arxiv.org/abs/2011.14821

Mots clés : causal states, ecosystem dynamics, modeling, global state variables

UNIVERSITÉ DE REIMS CHAMPAGNE-ARDENNE

GRAND REIMS COMMUNAUTÉ URBAINE

Spatial and temporal evolution of surface biogeochemistry in the southern ocean

Auteur Orateur : Margaux Brandon

Liste complète des auteurs - Affiliations :

Margaux Brandon[1*], Catherine Goyet[2], Franck Touratier[2], Nathalie Lefèvre[1]

[1] Institut de Recherche Pour le Développement, Laboratoire d'Océanographie et du Climat Expérimentations et Approches Numériques (LOCEAN), Sorbonne Université, Centre National de la Recherche Scientifique, Muséum National d'Histoire Naturel, 4 Place Jussieu, 75005 Paris, France *margaux.brandon@locean.ipsl.fr

[2] ESPACE-DEV, Univ Montpellier, IRD, Univ Antilles, Univ Guyane, Univ Réunion, Montpellier France, Laboratoire IMAGES-ESPACE-DEV, Univ

Résumé :

The quantification of interannual to decadal evolution of anthropogenic carbon concentration (C_{ant}) in the ocean is key to better understand the impact of the ocean to mitigate the increase in anthropogenic carbon in the atmosphere and the consequences of this uptake on the biogeochemistry of the ocean. Of the different regions of the ocean, the Southern Ocean plays a major role in the uptake and storage of C_{ant}. However, in situ data in this part of the ocean are sparse in space and time, in particular Total Carbon measurements, that are valuable to quantify the C_{ant}. Here we present spatial and temporal evolution of austral summer SST, SSS, A_T, C_T and pCO_2 in the Southern Ocean, South of Tasmania for the period 2005-2019, as part of the MINERVE programme. Our results show strong latitudinal variability in the measured parameters, allowing to study the relations between them in two delimited regions: the Subantarctic and the Antarctic Regions. Based on the regions determined previously, we formulate new simple equations to calculate A_T and C_T as a function of SSS and SST. Decadal trends in SST, SSS, A_T and C_T are then determined for both regions in order to discuss the long-term changes at the surface ocean in the Southern Ocean. Using the long-term trend in C_T, a new method to estimate decadal variation in surface C_{ant} is proposed.

Mots clés : Biogeochemistry, Southern Ocean, Spatial changes, Decadal changes, Anthropogenic Carbon

Observations intégrées du CO2 océanique en Méditerranée nord-occidentale

Synthèses des travaux réalisés au cours des 10 dernières années et perspectives

Auteur Orateur : Thibaut Wagener

Liste complète des auteurs - Affiliations :

Laurent Coppola , LOV, Villefranche sur Mer, France

Marine Fourrier, LOV, Villefranche sur Mer, France

Dominique Lefevre, MIO, Marseille, France

Caroline Ulses, LEGOS, Toulous, France

Thibaut Wagener, MIO, Marseille, France

Cathy Wimart-Rousseau, MIO, Marseille, France

Résumé :

La mer Méditerranée présente une circulation thermohaline rapide et des processus océaniques similaires à l'océan global. Elle est considérée comme un « point chaud » du changement climatique où les effets sont plus rapides qu'à l'échelle de l'océan global [*Durieu de Madron et al. 2011*]. Le bassin nord-occidental concentre, dans une zone géographique restreinte, plusieurs mécanismes océaniques clefs, avec (1) une zone de convection où a lieu une ventilation des eaux intermédiaires et profondes en hiver [*Testor et al., 2018*], (2) une variabilité saisonnière de la production phytoplanctonique marquée en raison du mélange vertical et des apports d'éléments nutritifs associés au mélange hivernal [*D'Ortenzio et Ribera d'Alcalà, 2009*] et (3) des interactions côtes-larges. Ce bassin fait l'objet, depuis plus de trente ans, d'observations de ses propriétés physico-chimiques. Ces observations se sont largement étoffées au cours des dix dernières années dans le cadre des activités des Services Nationaux d'Observations (SNO) MOOSE et SOMLIT (IR ILICO), faisant de ce bassin une des zones océaniques les plus observées du globe.

Le suivi des paramètres du CO_2 océanique doit permettre d'étudier l'évolution à long terme du flux air-mer de CO_2, mais aussi du contenu océanique en carbone et de l'acidification océanique. L'observation du CO_2 océanique est basée sur des observations de variables essentielles (EOV) dans l'ensemble de la colonne d'eau (alcalinité totale, A_T, et carbone total, C_T) mesurées avec les méthodes éprouvées et reconnues (« best practices »). Ces mesures discrètes collectées au cours de campagnes océanographiques (mensuelles au large et bi-mensuelles en zone côtière) sont complétées une fois par an par une couverture large du bassin (campagne annuelle MOOSE-GE) [*Coppola et al., 2021*]. Des mesures à haute résolution temporelle, essentiellement basées sur des capteurs autonomes de pH et de pCO_2, sont réalisées à partir des plateformes fixes et mobiles (lignes de mouillage DYFAMED et ANTARES, flotteurs profileurs Argo et drones de surface) viennent compléter ces observations discrètes. Ces observations in-situ sont aussi complétées par des mesures « virtuelles » déduites à partir de réseaux de neurones (CANYON-MED) [*Fourrier et*

al., 2020] et des sorties de modèles régionaux couplés physique-biogéochimie (SYMPHONIE ECO3M-S) [*Ulses et al., 2021*].

Dans cette présentation, nous discuterons des principaux résultats obtenus grâce à ce système d'observations intégré en nous intéressant en particulier à la compréhension de la variabilité saisonnière des flux air-mer de CO_2 mais également aux mécanismes saisonniers de transfert de CO_2 océanique entre la surface et les eaux intermédiaires et profondes. Les tendances à long terme (à l'échelle décennale) enregistrées au cours des 20 dernières années en termes de contenu en CO_2 océanique mais également en terme d'acidification seront également discutées. Nous montrerons comment ces observations soutenues de la Méditerranée nord-occidentale peuvent constituer une plateforme pour la validation de nouvelles méthodes de mesure ou de prédiction. Enfin, l'amélioration de l'intégration des activités CO_2 océanique en Méditerranée réalisées dans le cadre des SNO aux sein des activités de l'infrastructure de recherche européenne ICOS sera discutée.

Références bibliographiques :

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Ulses, C., Estournel, C., Fourrier, M., Coppola, L., Kessouri, F., Lefèvre, D., and Marsaleix, P. (2021). Oxygen budget of the north-western Mediterranean deep- convection region, Biogeosciences, 18, 937–960, https://doi.org/10.5194/bg-18-937-2021.

Mots clés : CO2 océanique, Méditerranée, observations

Evaluation of the the CAMS greenhouse gas global reanalysis and high resolution forecasts using ICOS, TCCON, NDACC, Aircraft and Aircore measurements

Auteur Orateur : Michel Ramonet

Liste complète des auteurs - Affiliations :

Michel Ramonet[1], Jérôme Tarniewicz[1], Bavo Langerock[2], Thorsten Warneke[3], Nicolas Gourgue[1], N.C.O. Diaby[1], Tanguy Martinez[1], Léonard Rivier[1], Anna Agustí-Panareda[4] and Henk Eskes[4]

[1] Université Paris-Saclay, CEA, CNRS, UVSQ, Laboratoire des Sciences du Climat et de l'Environnement (LSCE/IPSL), Gif-sur-Yvette, France

[2] Royal Belgian Institute for Space Aeronomy, Avenue Circulaire 3, 1180 Uccle, Belgium

[3] Institute of Environmental Physics, Bremen University, Otto-Hahn- Allee 1, 28359, Germany

[4] European Centre for Medium Range Weather Forecasts, Shenfield Park, Reading RG2 9AX, United Kingdom

[5] Royal Netherlands Meteorological Institute, Utrechtseweg 297, NL-3731 GA De Bilt, Netherlands

Résumé :

As one of the service products, CAMS is producing global-scale reanalyses, one for the greenhouse gases (GHG), and one for the reactive gases and aerosol concentrations. This study presents the validation results for the greenhouse gases (CO2, CH4), covering 18 years of the re-analysis run from 2003-2020.The reanalysis has been made publicly available in May 2021, after an in-depth evaluation process. The GHG reanalysis has been evaluated using the existing the long term time series available for surface observations from the OBSPACK and ICOS databases. The total columns measured at TCCON sites for CO2 and CH4, and the partial CH4 columns at some NDACC sites have also been used to characterize the CAMS experiments. In order to make the link between the surface concentrations and the total/partial columns we have also used the vertical structures of CO2 and CH4 measured by the CONTRAIL program based on commercial aircrafts, and the Aircore measurements performed at the Trainou tall tower. The presentation will show the comparison with those dataset, in order to characterize the biases of the reanalysis, and will also show the performance of the high resolution forecasts as a support to the understanding of synoptic scale variations.

Références bibliographiques :

Ramonet, M., B. Langerock, T. Warneke, H. J. Eskes, Validation report of the CAMS greenhouse gas global re-analysis, years 2003-2020, Copernicus Atmosphere Monitoring Service (CAMS) report CAMS84_2018SC3_D5.1.2-2020_v0.1.pdf, April 2021, doi: 10.24380/438c-4597.

Mots clés : CO2, CH4, CAMS, ICOS, TCCON, NDACC, Aircore, Trainou

Industrial site emissions quantification from simultaneous ch4 and co2 in-situ concentration measurements on-board unmanned aircraft vehicles

Auteur Orateur : Bonne Jean-Louis

Liste complète des auteurs - Affiliations :

Gregory Albora[1], Jean-Louis Bonne[1], Jérémie Burgalat[1], Nicolas Chauvin[1], Delphine Combaz[1], Julien Cousin[1], Thomas Decarpenterie[1], Ludovic Donnat[2], Olivier Duclaux[2], Nicolas Dumelié[1], Nicolas Galas[2], Lilian Joly[1], Catherine Juery[2], Abel Maunoury[2], Olivier Ventre[2]

[1]Université de Reims Champagne Ardenne, CNRS, GSMA UMR 7331, 51100 Reims, France

[2]TotalEnergies, R&D, Air Quality Laboratory, Solaize, France

Résumé :

We developed a light-weight open path laser absorption spectrometer operable on-board Unmanned Aircraft Vehicles (UAVs) for high frequency (24 Hz, up to 180 Hz) simultaneous in situ CO_2 and CH_4 concentration measurements, with respective 0.4 ppm and 5 ppb precisions at 1 s. The large range of measurable concentrations (up to 1000 ppm for CO_2 and 200 ppm for CH_4) allows industrial sites applications at a short distance from the emission sources, thus avoiding many logistical and legal limits associated with most long-range airborne observations .

To achieve a precise emissions quantification, this analyzer is employed to measure atmospheric concentrations throughout a plume cross-section, downwind of a source. The emission estimate is derived from these measurements using a box model approach, with additional information on the wind speed and direction at the altitude of the UAV recorded in parallel by a wind LIDAR. The high precision of our method compared to current alternative airborne quantification techniques benefits from the fine spatial resolution of our records and the actual wind profile measurements.

The high reliability of our method has been demonstrated during inter-comparison field validation campaigns on the TADI test platform at Lacq, south-west France, to which several institutes participated with various measurement systems (gas lidar, hyperspectral and multi spectral camera, acoustic sensors, ground mobile and fixed CRDS analysers): for 21 controlled CO_2 and CH_4 leak experiments analyzed, 27% of our quantification estimates were within the +/-20% precision compared to the true emissions and 91% were between -50% and +100% of the true values.

Several field campaigns have been conducted to quantify the instantaneous greenhouse gases emissions of multiple sources in the oil and gas sector, such as offshore platforms and land

processing facilities. Recent applications focused on agricultural facilities, with the quantification of CO_2 and CH_4 emissions of biogas plants and animal farming buildings: in addition to this emissions quantification method, a horizontal mapping of the agricultural site highlighted emission hotspots, revealing it potential as a source tracking tool.

Future developments of our sensor, among the scopes of the ATMOSFERE industrial chair (**AT**mospheric **MO**nitoring to **S**upport greenhouse gases **F**lux**E**s **RE**porting), will include its integration into a VTOL (Vertical Take Off and Landing) UAV, gaining substantial spatial coverages increases for applications to larger natural or industrial sites. Upcoming on-board wind measurements will also improve our quantifications and simplify applications on the field.

INDUSTRIAL SITE EMISSIONS QUANTIFICATION FROM SIMULTANEOUS CH4 AND CO2 IN-SITU CONCENTRATION MEASUREMENTS ON-BOARD UNMANNED AIRCRAFT VEHICLES

Mots clés : drone, UAV, CO2, CH4, industrial, biogas

The impact of covid-19 lockdown on ecosystem gross primary productivity

Auteur Orateur : TANG, Angela Che Ing

Liste complète des auteurs - Affiliations :

Angela Che Ing Tang[1*], Denis Loustau[1], Matthias Cuntz[2], Silvano Fares[3], Paul C. Stoy[4], Christophe Flechard[5], Guillaume Simioni[6], Katja Klumpp[7], Emilie Joetzjer[2], Ladislav Šigut[8], Matthias Peichl[9], Ivan Mammarella[10], Daniel Berveiller[11], Nina Buchmann[12], Corinna Rebmann[13], John Douros[14], Renske Timmermans[15], Alexander Knohl[16], Bernard Heinesch[17], Nicola Arriga[18], Mats Nilsson[19], Jiří Dušek[8], Ivan Janssens[20], Damiano Gianelle[21], Natalia Kowalska[8], Marilyn Roland[22], Eeva-Stiina Tuittila[23], Andrej Varlagin[24]

[1]UMR ISPA, INRAE, Villenave d'Ornon, France

[2]Université de Lorraine, AgroParisTech, INRAE, UMR Silva, Nancy, France

[3]CNR-National Research Council, Rome, Italy

[4]Department of Biological Systems Engineering, University of Wisconsin-Madison, Madison, WI, USA

[5]UMR SAS, INRAE, Rennes, France

[6]URFM, INRAE, Avignon, France

[7]UMR UREP, VetAgro Sup, INRAE, Clermont-Ferrand, France

[8]Department of Matter and Energy Fluxes, Global Change Research Institute of the Czech Academy of Sciences, Brno, Czech Republic

[9]Department of Forest Ecology and Management, Swedish University of Agricultural Sciences, Umeå, Sweden

[10]Institute for Atmospheric and Earth System Research/Physics, University of Helsinki, Helsinki, Finland

[11]Université Paris-Saclay, CNRS, AgroParisTech, Ecologie Systématique et Evolution, Orsay, France

[12]Department of Environmental Systems Science, ETH Zurich, Zurich, Switzerland

[13]Department of Computational Hydrosystems, Helmholtz Centre for Environmental Research – UFZ, Leipzig, Germany

[14]Royal Netherlands Meteorological Institute (KNMI), De Bilt, the Netherlands

[15]Climate Air and Sustainability Unit, Netherlands Organisation for Applied Scientific Research (TNO), Utrecht, the Netherlands

[16]Bioclimatology, Faculty of Forest Sciences, University of Göttingen, Göttingen, Germany

[17]TERRA Teaching and Research Centre, University of Liege, Gembloux, Belgium

[18]Joint Research Centre, European Commission, Ispra, Italy

[19]Department of Forest Ecology & Management, Swedish University of Agricultural Sciences, Umeå, Sweden

[20]Department of Biology, University of Antwerp, Wilrijk, Belgium

[21]Department of Sustainable Agro-Ecosystems and Bioresources, Research and Innovation Centre, Fondazione Edmund Mach, San Michele all'Adige, Italy

[22]Plants and Ecosystems, University of Antwerp, Wilrijk, Belgium

[23]School of Forest Sciences, University of Eastern Finland, Joensuu, Finland

[24]A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, Russia

Résumé :

During the spring of 2020, many countries around the world imposed lockdown measures involving economic activity and movement restrictions to contain the outbreak of the novel coronavirus disease (COVID-19), thereby leading to reproducible changes in air pollutant concentrations. The unprecedented reductions in primary pollutant emissions created a unique opportunity to assess the response of photosynthetic activity of terrestrial ecosystems to changes in air quality. The working hypothesis was that concentration decrease in particulate matter (and their impact on light scattering) may have affected photosynthesis via changes in direct and diffuse radiation as well as a reduction of ozone precursors may have impacted on the formation of ozone and its phytotoxic effects. Thus, we analysed CO_2 fluxes from eddy covariance measurements and meteorological data collected at the Integrated Carbon Observation System (ICOS) ecosystem stations. Using observations from 44 sites in Europe spanning eleven countries and nine vegetation types, we calculated a 4-month (March-April-May-June) anomaly of gross primary productivity (GPP) as the cumulative difference of GPP between 2020 and the reference period from 2015 to 2019. We also examined possible mechanisms that might underlie the GPP anomaly across the study sites with respect to meteorology, air pollution and maximum photosynthetic rate.

Références bibliographiques :

Mots clés : COVID-19, gross primary productivity, lockdown, eddy covariance

VOC fluxes measured by eddy-covariance with a PTR-Qi-TOF-MS over a rapeseed field near Paris

Auteur Orateur : Pauline Buysse

Liste complète des auteurs - Affiliations :

P. Buysse[1], B. Loubet[1], F. Lafouge[1], R. Ciuraru[1], L. Gonzaga-Gomez[1], B. Durand[1], O. Zurfluh[1], C. Decuq[1], O. Fanucci[1], J.-C. Gueudet[1], S. Bsaibes[1,2], F. Truong[2], C. Boissard[2,3], Dominique B.[2], R. Sarda-Estève[2], V. Gros[2].

[1] UMR ECOSYS, Université Paris-Saclay, INRAE- AgroParisTech, Route de la Ferme, 78850 Thiverval-Grignon, France

[2] Laboratoire des Sciences du Climat et de l'Environnement, LSCE, UMR CNRS-CEA-UVSQ, IPSL, Gif-sur-Yvette, Île-de-France, 91191, France

[3] Université de Paris and Univ Paris Est Creteil, CNRS, LISA, F-75013 Paris, France

Corresponding author : pauline.buysse@inrae.fr

Résumé :

Volatile organic compounds (VOCs) play a key role in atmospheric chemistry. VOC emissions can be either anthropogenic or biogenic (BVOCs), this latter source being predominant largely by about 90 % at the global scale. While exchanges of VOC compounds in forests have been largely studied, showing that such ecosystems represent the main source of biogenic monoterpenes and isoprene, the identity and quantity of VOC compounds exchanged in croplands are less known, and particularly in rapeseed crops for which France appears, together with Germany, as the main producer in Europe. Thanks to the use of a high-precision PTR-Qi-TOF-MS (National instrument within the ANAEE-France framework) coupled to a sonic anemometer to measure eddy-covariance fluxes, this work aimed at quantifying BVOC flux exchanges over a rapeseed crop located close to Paris in France.

The experimental campaign took place at the Grignon ICOS site, between 7th April and 25th August 2017, during which the BVOC fluxes were measured continuously by the eddy-covariance method. The present study focuses more specifically on four distinct weeks corresponding to contrasted vegetation development and soil cover periods. During each of these periods, BVOCs were identified and emission/deposition fluxes were quantified.

Seventy-one BVOCs were emitted or deposited over the four periods of focus. Most compounds showed net cumulated emissions, and only 24 exhibited net deposition. Not all compounds could be identified. All detected compounds exhibited a similar diel emission or deposition pattern (in absolute terms) during all four periods of interest: BVOC fluxes increased until mid-day then decreased back to lower nocturnal emission rates, following radiation and temperature variations. Among the emitted compounds, methanol was by far the most important one, representing between 60 and 85% of total emissions (on a molar basis), followed by acetone (4 to 5% of emissions) and

monoterpenes (0.4 to 3% of emissions), at least when the crop was present as these latter ones were not detected on bare soil, contrarily to methanol. Formic and acetic acids were the most deposited compounds, with about 40 and 30% of total depositions respectively during the end of the senescence phase.

The magnitude of methanol emissions was larger during senescence (maximum 2-3 nmol $m^{-2}s^{-1}$ during the day) than at the end of the flowering and bare soil phases (maximum 0.3 to 1 nmol $m^{-2}s^{-1}$ during the day). Those values were in the same range as previous observations made at the same site when winter wheat was cropped, except that no deposition fluxes of methanol were observed at night in the rapeseed crop. These values were also in good agreement with those found at a few other sites cropped with maize or winter wheat where eddy-covariance fluxes were also measured during the crop development season. As a result, this study provides first values of BVOC fluxes in a rapeseed crop.

Références bibliographiques :

Mots clés : Volatile organic compounds, cropland, rapeseed, eddy-covariance fluxes

N2o emissions from decomposing crop residues in soils

The IPCC N2O emission factor of residues from nonsenescent crops is underestimated.

Auteur Orateur : Lashermes Gwenaëlle

Liste complète des auteurs - Affiliations :

Gwenaëlle Lashermes[a,*], Sylvie Recous[a], Gonzague Alavoine[a], Baldur Janz[b], Klaus Butterbach-Bahl[b], Maria Ernfors[c], Patricia Laville[d]

[a]Université de Reims Champagne Ardenne, INRAE, FARE, UMR A 614, 51097 Reims, France

[b]Karlsruhe Institute of Technology, Institute of Meteorology and Climate Research–Atmospheric Environmental Research, Garmisch-Partenkirchen, Germany

[c]Swedish University of Agricultural Sciences, Department of Biosystems and Technology, P.O. Box 103, SE-230 53 Alnarp, Sweden

[d]Paris-Saclay, INRAE, AgroParisTech, UMR ECOSYS, 78850, Thiverval-Grignon, France

*Corresponding author: gwenaelle.lashermes@inrae.fr

Résumé :

The emission of nitrous oxide (N_2O) during crop residue decomposition in the soil can offset the benefits of residue recycling. The IPCC inventory considers agricultural N_2O emissions proportional to the amount of nitrogen (N) added by residues to soils. However, N_2O involves several emission pathways driven directly by the amount and form of N returned and indirectly by changes in the soil induced by decomposition. This study investigated gaseous emissions during decomposition of crop residues under controlled conditions to clarify the effects of the residue chemical characteristics. Residues of nine crops, varying by maturity at the time of collection, were incubated in two soils during 60 days, at 15°C, with a water-filled pore space of 60%. Their chemical composition was characterized via the different chemical criteria that influence their degradability. The dynamics of N_2O[1] and carbon dioxide (CO_2) fluxes, and the soil contents in ammonium and nitrate were measured.

The residue initial composition drastically influenced the dynamics of C mineralization and soil ammonium and nitrate during their decomposition, and was correlated with N_2O flux dynamics. N_2O emissions occurred mainly in the very first days of decomposition and were related to the consumption of soluble compounds. The net cumulative N_2O emitted ranked as Mustard (4828 ± 892 g N-N_2O ha^{-1}) > Sugar beet (2818 ± 314 g N-N_2O ha^{-1}) > Red Clover (2567 ± 1245 g N-N_2O ha^{-1}); the other residue treatments had much lower emissions (<200 g N-N_2O ha^{-1}) (Figure 1). Therefore residues with a high soluble content (>25% DM) promoted high N_2O emissions (representing 1–5% of applied N), likely directly by nitrification and indirectly by denitrification in

microbial hotspots. The soluble contents of plants decrease with increasing plant maturity. The N_2O emissions were thus higher for residues that were physiologically non-senescent, i.e., mature or still green at the time of recycling. The results showed for the first time that N_2O emissions from crop residues can be explained by a single chemical characteristic, their soluble matter content. Other characteristics were less explanatory.

The current recommended values for residue EF-N_2O in national inventories have been revised to 0.6% and 0.5% of residue N for wet and dry climates, respectively[2]. The median EF-N_2O calculated in this study under controlled conditions (0.78% of the residue N) was close to the revised value proposed. In contrast, for residues that were physiologically non-senescent, the EF-N_2O strongly underestimated the measured emissions.

Acknowledgement: This work was supported by the FACCE ERA-GAS ResidueGas project. French funding grant number ANR-17-EGAS-0003.

Références bibliographiques :

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[2] IPCC, 2019. Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/

Mots clés : Greenhouse gas (GHG), Nitrous oxide (N2O), Litter, Nitrogen, Soil, Decomposition

ICOS ETC soil carbon and nitrogen stocks uncertainties evaluations. Application to soil stock changes at an agricultural site (FR-GRI).

Auteur Orateur : Maryam Gebleh-Goydaragh

Liste complète des auteurs - Affiliations :

Maryam Gebleh-Goydaragh[1,2], Pauline Buysse[1], Nicolas Saby[2], Sébastien Lafont[3], Claudy Jolivet[2], Céline Ratie[2], Jean-Philippe Chenu[2], Nicolas Proix[4], Brigitte Durand[1], Benjamin Loubet[1].

[1] UMR ECOSYS, Université Paris-Saclay, INRAE- AgroParisTech, Route de la Ferme, 78850 Thiverval-Grignon, France

[2] US Infosol, US1106, INRAE, CS 40001 Ardon, 45075 Orléans cedex 2, France

[3] UMR ISPA, INRAE, 71 Avenue Edouard Bourlaux, 33882 Villenave d'Ornon cedex, France

[4] Laboratoire d'analyse des sols, INRAE, 273 rue de Cambrai, 62000 ARRAS, France

Corresponding author: Benjamin.loubet@inrae.fr

Résumé :

The soil is a major component of the terrestrial carbon cycle and monitoring the temporal changes in the Soil Organic Carbon (SOC) and Nitrogen (SON) stocks is required in order to close the ecosystem mass balance of these elements and to assess the role of terrestrial ecosystems in the global carbon cycle. A key challenge of ICOS soil measurement is to determine soil stock changes over several years and compare it to the carbon balance approach based on EC, incoming and outgoing carbon fluxes.

The SOC and SON stocks determination by the ETC is based on 20 randomly chosen locations, complying with the stratified simple random sampling method. At each location, 3 to 5 samples are taken at 5 depths spanning one meter depth. The SOC and SON stocks are computed according the design-based theory, using 10 equally sized compact in space strata, containing two sampling locations. This method allow an optimized determination of the means, sums as well as sampling and spatial variances. The methodology is detailed in the ICOS soil sampling and preparation protocol[1].

In this presentation, we detail the methodology used to evaluate the SOC and SON stocks by ETC and discuss their uncertainties, and how these can cope with long term carbon stock change evaluations. We exemplify the methodology with the dataset obtained on a crop rotation in Grignon (FR-Gri), and propose a preliminary comparison with previous evaluations of the carbon balance by eddy covariance.

Références bibliographiques :

[1] http://archive.sciendo.com/INTAG/intag.2017.32.issue-4/intag-2017-0047/intag-2017-0047.pdf

Mots clés : soil carbon and nitrogen stocks, crop rotation, carbon balance, ICOS, measurements

What is brought by measuring vertical profile of concentrations of greenhouse gases?

Auteur Orateur : Cyril Crevoisier

Liste complète des auteurs - Affiliations :

Cyril Crevoisier[1], Jérôme Pernin[1], Axel Guedj[1], Lilian Joly[2], Delphine Combaz[2], Nicolas Dumelie[2], Michel Ramonet[3], Julien Moyé[3], Morgan Lopez[3], Jean-Luc Baray[4], Aurélie Colomb[4], Jean-Claude Rubio[5], Frédéric Thoumieux[6] and Caroline Bès[6]

[1]Laboratoire de Météorologie Dynamique, LMD-IPSL, CNRS, Ecole polytechnique

[2]Groupe de Spectrométrie Moléculaire et Atmosphérique, GSMA, UMR CNRS 7331, Université de Reims Champagne Ardenne, 51100 Reims, France

[3]Laboratoire des Sciences du Climat et de l'Environnement, LSCE-IPSL, CEA-CNRS-UVSQ, Université Paris Saclay, 91191 Gif sur Yvette

[4]OPGC/Laboratoire de Météorologie Physique (LaMP), Université Clermont Auvergne, CNRS, Clermont-Ferrand, 63100 France

[5]Centre National d'Etudes Spatiales, 40800 Aire-sur-l'Adour, France

[6]Centre National d'Etudes Spatiales, 31100 Toulouse, France

Résumé :

Understanding the global atmospheric budget of the two major anthropogenic greenhouse gases emitted by human activities, carbon dioxide (CO_2) and methane (CH_4), is essential for predicting their future concentration levels. A global atmospheric CO_2 and CH_4 monitoring network of surface-based stations has been established to provide continuous information on their atmospheric concentrations. Although essential to infer surface fluxes, these surface measurements lack information pertaining to the vertical structure of the atmospheric CO_2 and CH_4 which is needed to understand carbon exchanges along the atmospheric column. Moreover, the validation of total columns made by existing or planned satellite missions, at the level of precision needed for carbon cycle studies, requires having a good knowledge of the vertical distribution of gas concentration, in particular in the upper troposphere and the stratosphere.

To answer this need, instruments flying under weather balloons flying up to 40 km have been designed. In particular, the atmospheric sampler AirCore allows the measurement of the vertical profiles (from the surface up to 30 km of altitude) of atmospheric concentration of greenhouse gases. Its concept, initially proposed by NOAA, is extremely simple: it consists of a long tube of stainless steel placed under a meteorological balloon which, in the ascending phase, empties its air by its open end, to fill with air during its downward phase. The captured air column is then interpreted in terms of the vertical gas concentration profile using a laser diode analyzer.

Since 2013, several AirCores designed at LMD have be developed and are now regularly launched at several sites or during specific campaigns by GSMA, CNES, LSCE and OPGC, as part the French AirCore program (https://aircore.aeris-data.fr) and the MAGIC field campaigns (https://magic.aeris-data.fr). In particular, specific validations performed with co-located flights of research aircrafts and balloon-borne Amulse have been performed and will be presented.

Building on the analysis of this dataset, stemming from more than 120 flights, we will highlight how measurements of vertical gas profiles contribute to the above-mentioned objectives. We will particularly focus on the validation of total or partial columns of gas measured from space ('level 2 products'), with examples taken from the validation of OCO-2 XCO2 total column and IASI mid-tropospheric CH_4 columns, as well as on the evaluation of atmospheric transport models, such as CAMS reanalyses, which in particularly highlights the over-estimation of methane in the stratosphere. We will finally describe lessons learned concerning the operation of such instruments and way forwards.

Références bibliographiques :

Mots clés : vertical profiles, greenhouse gases, aircore, transport errors, satellite validation

Documents :

Toward direct evidence of methane transfer from the sediment to the atmosphere using a suite of systematic observations

Auteur Orateur : Jean-Daniel Paris

Liste complète des auteurs - Affiliations :

Jean-Daniel Paris[1], Mia Schumacher[2], Roberto Grilli[3], Mathis Lozano[1], Marc Delmotte[1], Thomas Giunta[4], Dominique Birot[4], Camille Blouzon[3], Jean Pierre Donval[4], Vivien Guyader[4], Helene Leau[4], Vlad Radulescu[5], Sorin Balan[5], Jens Greinert[2], Livio Ruffine[4]

[1] Laboratoire des Sciences du Climat et de l'Environnement, LSCE/IPSL, CEA-CNRS-UVSQ

[2] GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany

[3] CNRS, Univ. Grenoble Alpes, IRD, Grenoble INP, IGE, 38000 Grenoble, France

[4] IFREMER, Unité des Géosciences Marines, Technopole Brest-Iroise, 29200 Plouzané, France

[5] National Institute of Marine Geology and Geoecology – GeoEcoMar, Bucharest, Romania

Résumé :

L'océan mondial est une source nette de CH_4 dans l'atmosphère. Parmi les processus naturels, les émissions marines représentent une contribution notable affectée par de grandes incertitudes. Les émissions océaniques de CH_4 peuvent être soit du CH_4 transporté depuis le fond marin, soit une production in situ dans les eaux de surface. Les émissions du plancher océanique comprennent à la fois le CH_4 émanant de la dégradation des hydrates de CH_4 et le gaz libre dans les sédiments. En fin de compte, le CH_4 pénètre dans l'atmosphère à travers l'interface mer-air, soit par des bulles remontant du fond marin, soit par diffusion à partir de gaz dissous.

De grandes quantités de méthane biogénique sont produites dans les sédiments sur le plateau continental et les marges continentales où elles sont soit stockées sous forme d'hydrates de gaz naturel, soit rapidement dégradées dans les sédiments supérieurs, soit transférées dans la colonne d'eau. Là, le méthane est soit dissous, soit oxydé, ou encore une petite fraction peut finalement atteindre l'atmosphère. Il existe une grande incertitude quant à la contribution marine au bilan atmosphérique. Les facteurs qui gouvernent l'ampleur du transfert du méthane à travers la colonne d'eau vers l'atmosphère (profondeur d'eau, stratification, pression atmosphérique, communautés microbiennes, ...) restent mal connus.

Notre étude vise à comprendre et à quantifier les flux de méthane aux interfaces sédiment-eau et eau-air dans une zone peu profonde du secteur roumain de la Mer Noire où des suintements de méthane ont été identifiés. La mer Noire se caractérise par des émissions généralisées de méthane sur ses plateaux et ses pentes, une fraction de ce méthane pouvant atteindre l'atmosphère. Elle abrite également des hydrates de gaz dans ses sédiments anoxiques à la limite desquels des milliers de sites d'émission de gaz ont été cartographiés, et représente donc un bon laboratoire naturel pour étudier le devenir du méthane dans des scénarios potentiels de déstabilisation des hydrates dans un climat changeant.

Nous avons développé une expérience pilote conjointe pour mesurer le transfert du méthane du fond marin vers l'atmosphère. A bord du navire de recherche (R/V) Mare Nigrum en 2019, nous avons étudié deux sites différents à 60m et 100m de profondeur. Un échosondeur a été utilisé pour identifier les zones d'émission par la détection de panaches de bulles massives. 8 carottes gravitaires ont été prélevées à la base des panaches de bulles afin d'estimer la concentration en méthane du fluide près de l'interface sédiment/eau et d'identifier l'emplacement de la zone de transition méthanogénèse/méthanotrophie dans les sédiments. Nous avons estimé le débit de gaz au fond de la mer en utilisant le signal de rétrodiffusion du sondeur pour évaluer la distribution de la taille des bulles et la vitesse d'ascension des bulles. Des mesures in situ, à haute résolution et en temps réel du CH4 dissous ont été effectuées à l'aide d'un spectromètre laser à entrée par membrane (MILS). Les flux atmosphériques de surface sont estimés à l'aide des modèles d'échange gazeux mer-air, des mesures de méthane dissous du capteur MILS à faible profondeur et des mesures atmosphériques recueillies par un analyseur Picarro G2401. La sensibilité des flux estimés au choix du modèle et aux différents traitements des concentrations de CH4 fournit une estimation de l'incertitude des flux.

Les concentrations de méthane vont de près de 0,001 mmol/L près de l'interface sédiment/colonne d'eau, jusqu'à > 4 mmol/L. En accord avec les études précédentes sur les sédiments peu profonds de la mer Noire, les profils de concentration de méthane, de sulfate et de DIC définissent une SMTZ peu profonde (70-120cm), reflétant la transition entre une activité de méthanogenèse à une certaine profondeur dans le sédiment (probablement au-delà de la profondeur maximale de nos carottes gravimétriques), et la méthanotrophie. Les profils verticaux de méthane dissous ont montré un maximum de 925 nM de CH4 à 96 m de profondeur, et, à un site moins profond, un maximum de 60 nM. Pour les emplacements des suintements détectés, les débits massiques de CH4 variaient entre environ 1,5 et 63gCH4/s. Les emplacements de groupes de suintements (pockmark et pente) ont montré des taux de flux plus élevés que les emplacements de torches simples. Nous fournissons une estimation des flux à l'interface air-mer en utilisant le gradient de pression partielle de CH4. Le site le plus profond a montré une libération négligeable de CH4. Dans l'atmosphère sus-jacente, des excès allant jusqu'à 30 ppb ont été trouvés à proximité du site moins profond, et en accord avec les rehaussements de la colonne d'eau et la distribution des panaches.

Notre approche, intégrant désormais une mesure de type eddy covariance, vise une mesure intégrée des transferts de méthane au fond de la mer et à l'interface air-mer à travers la colonne d'eau. Notre approche peut être utilisée pour acquérir des séries temporelles, et peut être couplée avec les observatoires du fond marin. Cette expérience jette les bases d'un concept de capacité de surveillance systématique pour détecter les changements à grande échelle des flux de méthane marin.

Mots clés : méthane, océan, interface air-mer, mesures in situ

Posters

Eddy-covariance methane flux estimation in a western france landfill site

Auteur Orateur : Lozano Mathis

Liste complète des auteurs - Affiliations :

Mathis Lozano, LSCE – Laboratoire des Sciences du Climat et de l’Environnement

Jean-Daniel PARIS, LSCE – Laboratoire des Sciences du Climat et de l’Environnement

Olivier LAURENT, LSCE – Laboratoire des Sciences du Climat et de l’Environnement

Adil SHAH, LSCE – Laboratoire des Sciences du Climat et de l’Environnement

Luc LIENHARDT, LSCE – Laboratoire des Sciences du Climat et de l’Environnement

Philippe CIAIS, LSCE – Laboratoire des Sciences du Climat et de l’Environnement

Résumé :

In a climate change and an increase of the global temperature context, it is crucial to identify the greenhouse gas sources. Understanding the process of these emissions will allow us to build better strategies for greenhouse gas emission mitigation. It has been established that the waste management sector and more particularly landfill sites, have emitted between 2008 and 2017 over 67 Tg/y of CH_4 (Saunois et al. 2020). This number is sometimes underestimated because of the difficulty in quantifying these types of emissions. This is why, in collaboration with SUEZ, the landfill of Amailloux allowed us to estimate the CH_4 emissions with different bottom up and top down methods like inversion models or Eddy-Covariance flux estimation. These methods will help us to better understand the emission drivers on site.

Références bibliographiques :

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Mots clés : Eddy-Covariance - Landfill - Methane flux calculation - LSCE - CEA - SUEZ

Two numerical tools for an easier generation of level 3 products: flexpart-toolbox and the cif

Auteur Orateur : Isabelle Pison

Liste complète des auteurs - Affiliations :

Antoine Berchet [a] , Isabelle Pison [a], the CIF development team and the LSCE users' community of FLEXPART-Toolbox.

[a] Laboratoire des Sciences du Climat et de l'Environnement, LSCE-IPSL (CEA-CNRS-UVSQ), Université Paris-Saclay, 91191 Gif-sur-Yvette, France

Résumé :

To facilitate the elaboration of level 3 products from observations, two numerical tools have been developed in the last few years: FLEXPART-Toolbox and the Community Inversion Framework (CIF).

FLEXPART-Toolbox is a toolbox [1] including a graphical user's interface (GUI) for the well-know Lagrangian model FLEXPART (FLEXible PARTicle dispersion) model[2].
From a text file containing the measurements, back-trajectories are computed and can be convolved with emissions e.g. to obtain the contributions of various areas to the concentrations. The results are provided as NetCDF files for the various products: footprints, total columns, etc.
Limited numerical skills are required: the measurements must be pre-processed so that the text file fits the right format, then launching the GUI to run FLEXPART and finally, dealing with the NetCDF files to plot figures.
So far, the production of figures (.png files for example) is not included and the FLEXPART-Toolbox has not been ported outside LSCE.

The Community Inversion Framework (CIF)[3,4] is a python-based system designed for data assimilation with various methodologies. It makes it easy to run various (chemistry-)transport models (CTMs) with embedded comparisons to numerous types of observations: satellite (partial) columns, surface concentrations, isotopic ratios, air-cores. The direct comparison mode is simple to change to data assimilation modes of the same observations to produce emission fluxes.
From NetCDF files containing the measurements, associated to the usual inputs for the CTM used, NetCDF files are provided for the measurement to model comparison (same format as the input measurement file with the addition of the equivalent of each data as computed by the model) and, if required, for the emission fluxes.
The required numerical skills are to be able to format the NetCDF input files, to run the CIF python code and to provide the required environment for running the targeted CTM and finally, to post-process the NetCDF output files.
So far, there is no GUI for the CIF and, even though its portability is ensured, it may require the support of an IT team to first install its environment.

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[4] http://www.community-inversion.eu/ for code documentation and tutorials.

Mots clés : level 3 products, numerical tools, FLEXPART, CIF

Développement et mise à jour du réseau ICOS France atmosphère

Auteur Orateur : Morgan Lopez

Liste complète des auteurs - Affiliations :

M. Lopez et al.

Laboratoire des Sciences du Climat et de l'Environnement, Unité mixte CEA-CNRS-UVSQ, 91191 Gif-sur-Yvette, France.

Résumé :

Le LSCE a la charge de coordonner le réseau de mesure atmosphérique de gaz à effet de serre ICOS-France, qui comprend une vingtaine de station réparties sur le globe. Ce réseau harmonisé, vise à acquérir des données de haute qualité et à haute fréquence pour mieux comprendre les cycles biogéochimique du CO2, CH4, CO et N2O ainsi que de caractériser leurs sources et leurs puits.

Ces dernières années, plusieurs outils ont été développés ou sont en cours de développement au LSCE pour 1/ automatiser les différents tests de biais liés aux mesures, 2/ mesurer les paramètres nécessaire au bon fonctionnement des stations et du réseau dans son ensemble et 3/ rendre les stations plus autonomes. Le but de ces développements est d'obtenir un réseau robuste et de pouvoir diagnostiquer rapidement les éventuelles biais de mesure afin de limiter la perte de données. Certains de ces développements ont aussi pour vocation d'être déployés dans les stations européennes d'ICOS.

Le poster visera à présenter ces dernières avancées et à ouvrir la discussion avec les différents acteurs des réseaux de mesure ICOS-France.

Mots clés : capteurs, développement, automatisation

AirCore : Couplage des Picarro G24 et G53 pour mesure in situ des concentrations atmosphériques de CO2, CH4, N2O et CO

Auteur Orateur : Julien Moyé

Liste complète des auteurs - Affiliations :

Julien MOYÉ, Michel RAMONET, Thomas LAEMMEL, LSCE

Résumé :

Depuis 2016, des lancers réguliers de AirCore sont effectués par le LSCE depuis Trainou (Loiret). Les échantillons récoltés permettent de mesurer les concentrations de certains gaz à effet de serre jusqu'à plus de trente kilomètres d'altitude. Initialement, les analyses s'effectuaient à l'aide d'un spectromètre (Picarro G24) permettant de mesurer les concentrations de CO_2, CH_4, CO et H_2O.

Depuis novembre 2020, les échantillons atmosphériques provenant des AirCore sont analysés dans deux instruments installés en parallèle (Picarros G24 et G53). Cette installation permet d'obtenir, en plus des espèces déjà mesurées, la concentration en N_2O. L'ajout de ce nouvel instrument, permet également d'obtenir des mesures de CO plus précises.

Depuis la mise en place de cette installation, deux AirCore sont systématiquement lancés en parallèle. Un échantillon est mesuré par le Picarro G24 et l'autre échantillon est mesuré par la combinaison des deux Picarros G24 et G53. La comparaison des deux profils permet de montrer que les résultats obtenus sont cohérents et que l'installation n'affecte pas les données CO_2 et CH_4.

Ce poster présentera l'installation ainsi que les résultats des premiers vols.

Mots clés : AirCore, Picarro, CO2, CH4, N2O

Moulin De la Housse launching site

Auteur Orateur : Nicolas DUMELIE

Liste complète des auteurs - Affiliations :

N.Dumelié(1), D.Combaz(1), N.Chauvin(1), G.Albora(1), J.Burgalat(1), F.Parent(1), M.Angot(1), J.Cousin(1), T.Decarpenterie(1), Caroline Bès(2), Cyril Crevoisier(3) and L.Joly(1)

[1]GSMA, UMR CNRS 7331, U.F.R. Sciences Exactes et Naturelles, Université de Reims, Reims, France

[2]Centre National d'Etudes Spatiales, 31100 Toulouse, France

[3]Laboratoire de Météorologie Dynamique, LMD-IPSL, CNRS, Ecole polytechnique

Résumé :

This poster presents the scientific balloon launch site on the Moulin de la House (MDH) campus in Reims, France. This site has been active since 2014 with about 120 successful launches and has been since 2018, part of the MAGIC initiative (Monitoring Atmospheric composition and Greenhouse gases through multi-Instrument Campaigns - https://magic.aeris-data.fr/). Its objective is to provide a facility for the regular launches of light instruments (<3kg) for atmospheric studies such as Aircores and Amulses spectrometers for vertical profiles of CO2, CH4, CO, as well as O3 probes and aerosol counter such as LOAC. These obtained vertical greenhouse gases (GHG) measurement profiles aim to validate atmospheric transport model and to collect data for comparative studies of satellite measurements (Metop A &B, Sentinel 5-P, OCO2) and meteorological models.

It is the only site making regular atmospheric profiles between 0 and 30km in the northern part of France. It complements the measurements of LSCE and CNES facilities respectively located in centre (Trainou) and south (Aire-sur-l'Adour) of France. It also has an interesting geographical localization both in terms of road infrastructure and topography, which greatly facilitates the rapid recovery of instruments. Since its creation, it has regularly hosted several French laboratories including the CNRM, the LSCE, the LMD or the LPC2E.

To ensures maximum safety for both people and instruments, we have developed a set of procedures, instrumental tools (automatic inflators, communicating separators) and software (I.R.M.A). This allows us to have real time instrument tracking with trajectory prediction and realtime landing zone updates from the recovery teams. Over the last three year, we have carried out 47 flights with a 100% recovery rate with monthly as well as intensive flight campaign. Since 2021, we have been able to carry out so-called "medium" flights with two instruments weighing less than 3 kg each, thus enabling inter-comparison campaigns between instruments or to complete the measurements made by a single instrument during a flight.

We are also working in collaboration with the CNES on the development of a new carrier allowing the control of the buoyancy altitude of standard weather balloons. This type of carrier will allow so-

called quasi-Lagrangian observations by following air masses at fine scales (urban plumes), regional scales (GHG gradients between agricultural and forest areas), and large scales to characterize key ecosystems of the carbon cycle in regions that are difficult to access or heavily regulated.

Mots clés : high alttitude balloon, green house gases vertical profiles, satellite validation

Ground-based FTIR measurements. An efficient way to the GHG-satellites monitoring validation?

Auteur Orateur : Bruno GROUIEZ

Liste complète des auteurs - Affiliations :

1. Bruno GROUIEZ, bruno.grouiez@univ-reims.fr, Groupe de Spectrométrie Moléculaire et Atmosphérique, GSMA, UMR CNRS 7331, Université de Reims Champagne Ardenne, 51100 Reims, France
2. Abdelhamid HAMDOUNI, abdelhamid.hamdouni@univ-reims.fr, Groupe de Spectrométrie Moléculaire et Atmosphérique, GSMA, UMR CNRS 7331, Université de Reims Champagne Ardenne, 51100 Reims, France
3. Lilian JOLY, lilian.joly@univ-reims.fr, Groupe de Spectrométrie Moléculaire et Atmosphérique, GSMA, GSMA, UMR CNRS 7331, Université de Reims Champagne Ardenne, 51100 Reims, France
4. Yao TE, yao-veng.te@sorbonne-universite.fr, Laboratoire d'Etudes du rayonnement et de la Matière en Astrophysique et Atmosphères, LERMA-IPSL, Sorbonne Université, Observatoire de Paris, Université PSL, CNRS, 75005 Paris, France
5. Pascal JESECK, pascal.jeseck@sorbonne-universite.fr, Laboratoire d'Etudes du rayonnement et de la Matière
6. en Astrophysique et Atmosphères, LERMA-IPSL, Sorbonne Université, Observatoire de Paris, Université PSL, CNRS, 75005 Paris, France
7. Caroline BES, caroline.bes@cnes.fr, Centre National d'Etudes Spatiales, 31401 Toulouse, France
8. Denis JOUGLET, denis.jouglet@cnes.fr, Centre National d'Etudes Spatiales, 31401 Toulouse, France
9. Cyril CREVOISIER, cyril.crevoisier@lmd.ipsl.fr, Laboratoire de Météorologie Dynamique, LMD-IPSL, CNRS, Ecole polytechnique, 91128 Palaiseau, France
10. Hervé HERBIN, herve.herbin@univ-lille.fr, Laboratoire d'Optique Atmosphérique, LOA, UMR CNRS 8518, Université de Lille, 59655 Villeneuve d'Ascq Cedex, France
11. Marie-therese EL KATTAR, marie-therese.el-kattar@univ-lille.fr, Laboratoire d'Optique Atmosphérique, LOA, UMR CNRS 8518, Université de Lille, 59655 Villeneuve d'Ascq Cedex, France
12. Morgan LOPEZ, morgan.lopez@lsce.ipsl.fr, Laboratoire des Sciences du Climat et de l'Environnement, LSCE-IPSL, CEA-CNRS-UVSQ, Université Paris Saclay, 91191 Gif sur Yvette, France
13. Michel RAMONET, michel.ramonet@lsce.ipsl.fr, Laboratoire des Sciences du Climat et de l'Environnement, LSCE-IPSL, CEA-CNRS-UVSQ, Université Paris Saclay, 91191 Gif sur Yvette, France
14. Christof JANSSEN, christof.janssen@sorbonne-universite.fr, Laboratoire d'Etudes du rayonnement et de la Matière en Astrophysique et Atmosphères, LERMA-IPSL, Sorbonne Université, Observatoire de Paris, Université PSL, CNRS, 75005 Paris, France

15. Marc DELMOTTE, marc.delmotte@lsce.ipsl.fr, Laboratoire des Sciences du Climat et de l'Environnement, LSCE-IPSL, CEA-CNRS-UVSQ, Université Paris Saclay, 91191 Gif sur Yvette, France
16. Deniel CAROLE, carole.deniel@cnes.fr, 75039 Paris, France
17. Corinne BOURSIER, corinne.boursier@sorbonne-universite.fr, Laboratoire d'Etudes du rayonnement et de la Matière en Astrophysique et Atmosphères, LERMA-IPSL, Sorbonne Université, Observatoire de Paris, Université PSL, CNRS, 75005 Paris, France
18. Nicole MONTENEGRO VARELA, Nicole.MontenegroVarela@cnes.fr

Résumé :

The precise assessment of the greenhouse gases (GHG) concentrations has become one of the main challenges of our modern society [Paris agreement]. Satellites are very effective for GHG measurements and already provide tangible evidence of CO_2 and CH_4 concentration rising [Buchwitz2018]. However, an expert study funded by the European Commission [Ciais2015] pointed out that a fully effective monitoring of anthropogenic carbon emissions requires a satellite constellation, observing column averaged Dry air Mole Fractions (DMF) XCO_2 at high precision (< 0.7ppm) and low systematic bias (< 0.5 ppm).

It therefore seems necessary to be able to compare these satellite-based data with other set-ups to precisely determine the accuracy of their measurements. The MAGIC initiative (Monitoring of Atmospheric composition and Greenhouse gases through multi-Instruments Campaigns) has been initiated for this purpose (https://magic.aeris-data.fr). Since 2018, it has been coordinating at the national level, the validation activities of satellite instruments measuring greenhouse gases by bringing together several partners with complementary specialities in instrumentation (ground, airplane, balloon) and measurement techniques (in situ, remote sensing).

Ground-based FTIR (Fourier Transform InfraRed spectrometer) measurements are one of these validation techniques. The Total Carbon Column Observing Network (TCCON) networks already use this kind of instruments providing high resolution spectra from the total atmospheric gas column. A derivated network has been created a few years ago, known as the Collaborative Carbon Column Observing Network (COCCON) initiated by Karlsruhe Institute of Technologie (KIT), which uses low resolution portable FTIR (EM27/SUN) instead [Frey2019]. 6 FTIR have been used during the MAGIC campaigns, five EM/27 SUN operated by the LERMA, LMD, LSCE, GSMA laboratories and by the CNES and one CHRIS by the LOA laboratory. These instruments have the advantage of being easily deployed on identified sites of interest and along satellite tracks during measurement campaigns.

With the aim to centralize the FTIR measurements analysis of MAGIC campaign, a French working group has been created. Concerning the EM27/SUN's DMF calculation, the PROFFAST software (developed by KIT in the COCON context) is mainly used. In this poster, the authors present an overview of the conducted studies to better master the full data processing chain in order to be able to perfectly characterize the performance, sensitivity and accuracy of our extracted values. Intercomparisons with satellites and in situ measurements will also be considered.

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Building the COllaborative Carbon Column Observing Network (COCCON): longterm stability and ensemble performance of the EM27/SUN Fourier transform spectrometer

Atmospheric Measurement Techniques, 2019, 12, 1513-1530

Mots clés : Greenhouse gases, GHG-Satellites, XCH_4, XCO_2, column averaged Dry air Mole Fractions, Fourier transform spectrometer

Development of a tdlas based fluxmeter for eddy covariance of h2o and co2 co-localized with 3d wind measurements

Auteur Orateur : Julien Cousin

Liste complète des auteurs - Affiliations :

Julien Cousin[1], Jérémie Burgalat[1], Thomas Decarpenterie[1], Gregory Albora[1], Lilian Joly[1], Benjamin Loubet[2], Denis Loustau[3]

[1] Université de Reims Champagne Ardenne, CNRS, GSMA UMR 7331, 51100 Reims, France

[2] INRAE UMR EcoSys, AgroParisTech, Université Paris-Saclay, 78850 Thiverval-Grignon, France

[3] INRAE Centre de Bordeaux Aquitaine 71 avenue E. Bourlaux, 33882 Villenave d'Ornon

Résumé :

We developed a new prototype of a scientific instrument dedicated to 3D wind measurements simultaneously with carbon dioxide and water vapor concentrations at high frequency (up to 50 Hz), synchronously, and spatially co-localized. This sensor combines a commercial sonic wind 3D anemometer (Gill HS 50) with a specifically developed Tunable Diode Laser Spectrometer (TDLAS).

Overview

For more than 25 years' flux measurements are widely used to estimate the exchange of heat, water, and carbon dioxide, as well as methane and other trace gases (crops, forests, meadows …). The eddy covariance method is one of the most direct and defensible ways to measure such fluxes. This method works by measuring vertical turbulent transport of gas to and from the surface. It consists in simultaneously measuring the vertical air speeds (wind) and its instantaneous gas concentration (CO_2, H_2O, CH_4, etc.) and its temperature and calculating the time covariance of the variables over a time interval of 30 to 60 min. If we can measure the gas concentration, temperature, humidity and the speed of the vertical air movement, we will know the vertical upward or downward fluxes of gas and water vapor concentrations, temperature, and humidity.

The measurement systems currently used for these measurements consist of two separate sets: a sonic anemometer and a gas analyzer (H_2O, CO_2, CH_4, N_2O ...). They do not allow these two measurements to be co-located, which imposes a whole series of more or less well-established corrections and a cumbersome and complex raw data processing procedure. Recent systems offered on the market (LiCOR analyzer model 72001) give only very marginal technical improvements and their configuration (plumbing) has not yet stabilized. Several hundred or even thousands of measurement sites are currently operating all over the globe; more than 6000 publications cite this measurement technique.

The purpose of the project is to develop a prototype instrument collocating measurements in the measuring sphere of a sonic anemometer and to carry out test campaigns of this instrument in real conditions.

Spectrometer setup

The spectrometer is equipped with two lasers (purchased from Nanoplus GmbH, Germany). Both laser are interband cascade laser (ICL) DFB diode, one emitting at 2.6 µm and the second at 4.2 µm. The lasers' driving current is ramped at 100 Hz. After collimation, the laser beams then pass into an open-path cell achieving an optical path length of 21 cm on both channels (CO_2 and H_2O). This open-path cell is integrated on the sonic head, and several positions were tested in order to compare with actual systems, Licor 7200 and 7500. At the output of the cell, both laser beams are focalized onto the two photodetectors. The central processing unit (National Instruments real-time module) records all data (spectra, pressure, temperature and humidity (PTU), GPS and sonic 3D wind synchronization).

Results

First prototype of our fluxmeter for field measurements will be presented (Figure 1.a, 1.b) as the first intercomparisons results with commercials instruments of reference for ICOS site: Licor 7200, Licor 7500, Picarro. The first in situ campaign on the Grignon ICOS site, during September 2021, will be presented as well.

Evolution and perspectives

A more compact and fully integrated optical fiber based version is in the way (Figure 1.c). This optimized version will have a perfect co-localization of the lasers optical paths and the sonic transducers paths. Furthermore, a third optical path will be added in order to measure the methane (CH_4) gas concentrations.

Mots clés : Flux measurement, Eddy covariance, TDLAS, laser diode spectrometer

Soil sampling protocol and analysis by the ICOS ecosystem thematic center (ETC)

Auteur Orateur : Benjamin Loubet

Liste complète des auteurs - Affiliations :

Benjamin Loubet[1], Nicolas Saby[2], Sébastien Lafont3, Maryam Gebleh[1,2], Claudy Jolivet[2], Céline Ratie[2], Jean-Philippe Chenu[2], Nicolas Proix[4].

[1] UMR ECOSYS, Université Paris-Saclay, INRAE- AgroParisTech, Route de la Ferme, 78850 Thiverval-Grignon, France

[2] US Infosol, INRAE, CS 40001 Ardon, 45075 Orléans cedex 2, France

[3] UMR ISPA, INRAE, 71 Avenue Edouard Bourlaux, 33882 Villenave d'Ornon cedex, France

[4] Laboratoire d'analyse des sols, INRAE, 273 rue de Cambrai, 62000 ARRAS, France

Corresponding author: Benjamin.loubet@inrae.fr

Résumé :

The soil is a major component of the terrestrial carbon cycle and monitoring the temporal changes in the soil organic carbon (SOC) and soil organic nitrogen (SON) stocks is required in order to close the ecosystem mass balance of these elements and to assess the role of terrestrial ecosystems in the global carbon cycle.

In ICOS ecosystem sites, the SOC and SON stocks are computed within the target area of the eddy covariance (EC) flux tower, based on 20 randomly chosen locations, complying with the stratified simple random sampling method. At each location, 3 to 5 samples are taken at 5 depths spanning one meter depth. Samples at each depths are mixed together to produce composite samples, which are dried and send to the ETC central laboratory (LAS, INRAE) for SOC and SON content analysis following the ISO 14235 and ISO 13878 norms. The SOC and SON stocks are then determined from carbon and nitrogen contents, as well as bulk density, rock and roots fractions reported by the station team that also prepares composite samples. Remaining soil samples are stored in the INRAE long term soil storage facility.

The SOC and SON stocks are computed according the design-based theory. Ten strata are determined over each site. The strata are designed to be of equal size and compact in space. In each stratum, two sampling locations, selected randomly, are used. This method allow an optimized determination of the means, sums as well as sampling and spatial variances. The methodology is detailed in the ICOS soil sampling and preparation protocol[1].

The SOC and SON stocks will be determined by ETC over around 60 ICOS ecosystem sites in the coming years, as a required measurement for site labeling. A remaining challenge will be to determine the stock change over 10 to 20 years and compare it the carbon balance approach based on EC, incoming and outgoing carbon fluxes.

In this poster, we present the ETC methodology to evaluate the SOC and SON stocks, the way ETC is organized to provide these evaluations, and we present some carbon and nitrogen stocks and their uncertainties over a few sites.

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Mots clés : soil organic carbon stock, measurement, ICOS, ecosystem thematic center

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