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→ TOWARDS UNRAVELLING COMPLEX LAND-ATMOSPHERE PROCESSES IN BOREAL EURASIA

Mattia Marconcini – ESA-ESRIN
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Anni Reissell – iLEAPS IPO
Garry Hayman – NERC-CEH
Jerome Helbert – NOVELTIS
Gerrit de Leeuw – University of Helsinki

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motivation

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- ALANIS (Atmosphere-LANd Interaction Study) is one of the Strategic Actions of the ESA Support to Science Element (STSE) aimed at establishing an International Science Partnership with iLEAPS;

- iLEAPS (Integrated Land Ecosystem-Atmosphere Processes Study) was established in March 2004 as the land-atmosphere core project of the International Geosphere-Biosphere Programme (IGBP).

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motivation

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- Land-atmosphere interactions include a variety of critical feedbacks among radiative, hydrological, and biogeochemical processes (→ complex exchanges of energy and matter that influence the overall Earth system and its climate).

- EO data have demonstrated the potential to become a major tool for observing key variables and characterizing main processes governing land-atmosphere interactions (globally to locally).

- In the next future the capabilities of monitoring land surface and atmosphere will further improve by the increasing number of EO missions to be launched by space agencies.

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motivation

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- In the next future the capabilities of monitoring land surface and atmosphere will further improve by the increasing number of EO missions to be launched by space agencies.

- The full exploitation of such increasing multi-mission observational capacity requires harmonized research efforts involving both EO researchers and Earth system modellers to develop robust biophysical products to be effectively integrated with in situ data and within appropriate coupled models.

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objectives

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- The main objectives of the ALANIS activity are:
  - Enhance the coordination and collaboration between EO researchers and Earth system scientists and modelers (complementary knowledge transfer and compelling collaboration);

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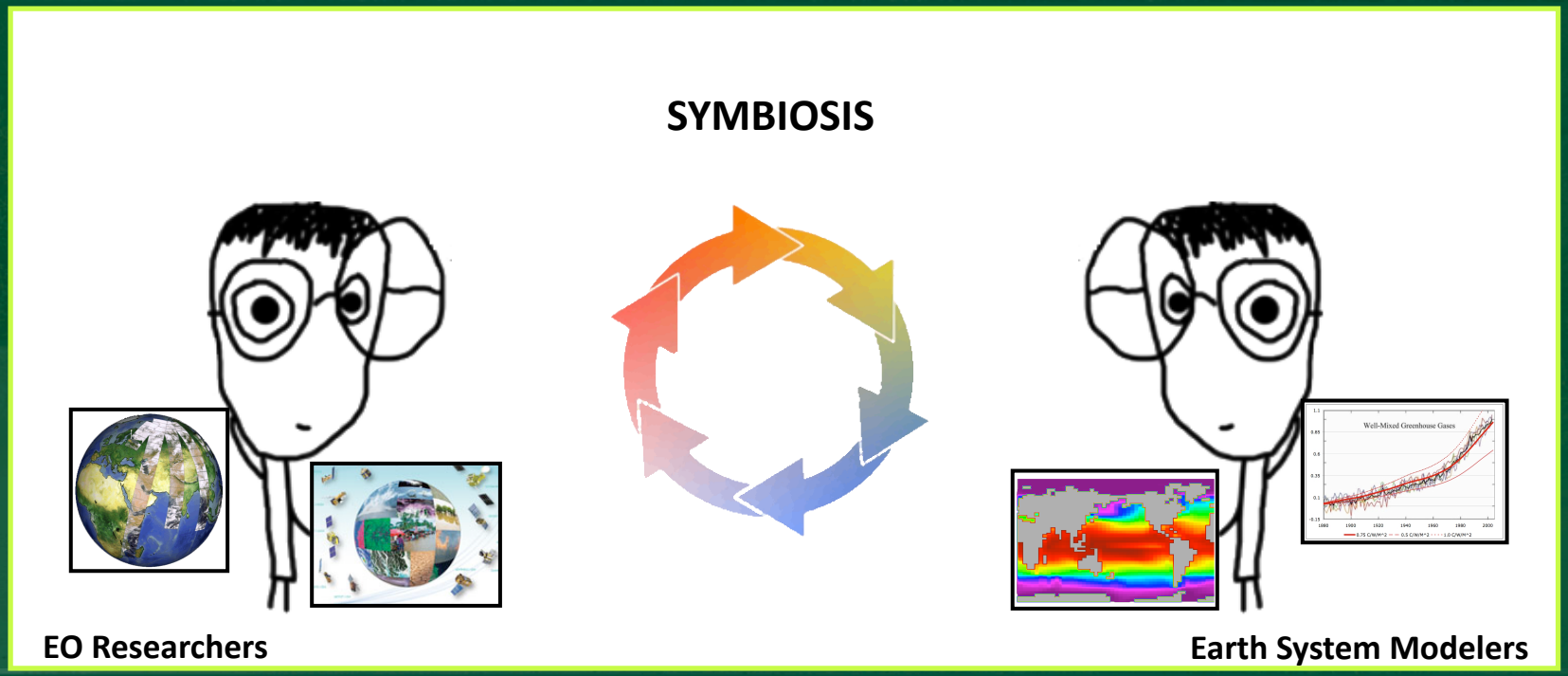

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objectives

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- The main objectives of the ALANIS activity are:
  - Enhance the coordination and collaboration between EO researchers and Earth system scientists and modelers (complementary knowledge transfer and compelling collaboration);
  - Advance towards the development and validation of novel EO-based multi-mission products and their integration into suitable land-atmosphere coupled models;
  - Set up a solid scientific basis for the development of a robust consistent long-term data set of EO-based land and atmospheric geo-information products over the boreal area in support of the iLEAPS scientific efforts.

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investigated area

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- Attention will be focused on Boreal Eurasia since:
  - it represents the largest terrestrial ecosystem on the planet;
  - human activities and climate changes occurred in the last few years have altered the natural equilibrium in the region;
  - such extremely vast and remote region can most benefit from the use of satellite EO data.

3 thematic projects

- A scientific consultation workshop was held on 20th April 2009 at the Austrian Academy of Sciences in Vienna for defining main research needs of the scientific communities investigating land and atmosphere dynamics in northern Eurasia (both modellers and EO scientists);

- Finally, three main thematic areas have been identified as more suitable to be investigated. For each of them, a specific project has been issued, namely:

  – ALANIS – methane — www.alanis-methane.info
  – ALANIS – smoke plumes — www.alanis-smokeplumes.info
  – ALANIS – aerosols (feasibility study) — www.alanis-aerosols.info

- Kicked-off between March and April 2010, they last 20 months.

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- Boreal Eurasian wetlands play an important dual role in the global carbon cycle: they represent both the largest natural methane source and one of the major carbon sinks;
- The combination of elevated water tables, high productivity and low decomposition has created a significant carbon storage, favoured by low temperatures and slow diffusion of oxygen into the soil;
- Under such anoxic conditions, *methanogens* produce methane, most of which is subsequently oxidised by *methanotrophic* bacteria. The remainder is transported to the atmosphere via bubbling and diffusion or by escaping through vascular plants.



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- The high spatial and temporal variability of CH_4 emissions combined with the patchy information on their geographical dispersion makes obtaining reliable estimates difficult;
- The estimates of global CH_4 emissions from lakes/wetlands still have larger uncertainty than those of any other natural (such as ocean, termites, hydrates) or anthropogenic (such as rice agriculture, ruminants, energy, landfills) source.



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- The main goal of *ALANIS methane* is to investigate the potential of EO data to reduce current uncertainties in methane emissions from boreal lakes and wetlands through the synergic use of land and atmosphere EO-based products in a coupled land-atmosphere model (study interval: 2007-2008).

- The *ALANIS methane* project is run by a Consortium including:
  - the Centre of Ecology and Hydrology of the Natural Environment Research Council (UK, Prime Contractor);
  - the Technical University of Vienna (Austria);
  - the Institute of Environmental Physics of the University of Bremen (Germany);
  - ESTELLUS (France);
  - the UK Met-Office (UK, Collaborator).

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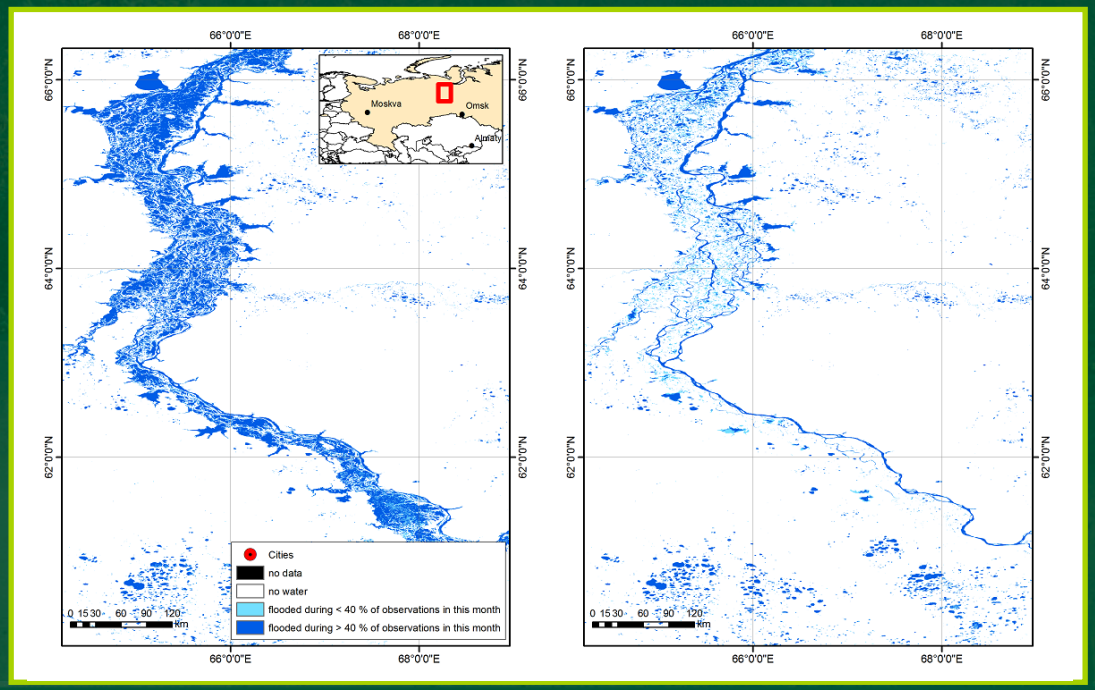
- **Novel advanced EO-based target products:**

local wetland extent dynamics (ASAR) → spatial changes of lake and wetland surface at medium spatial resolution (10 days frequency)

June 2007



September 2007

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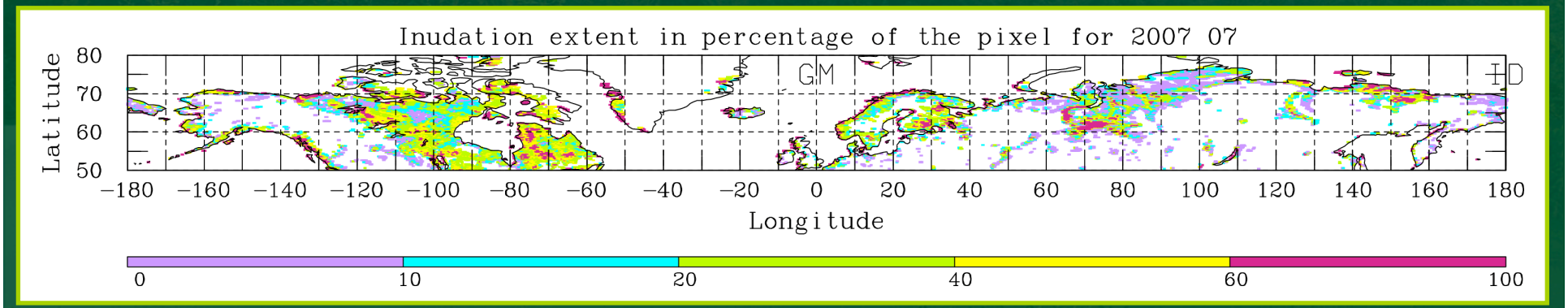
- **Novel advanced EO-based target products:**

local wetland extent dynamics (ASAR) → spatial changes of lake and wetland surface at medium spatial resolution (10 days frequency)

regional wetland extent dynamics (SSM/I, AVHRR, ASCAT) → spatial changes of inundated areas at low spatial resolution (10 days frequency)



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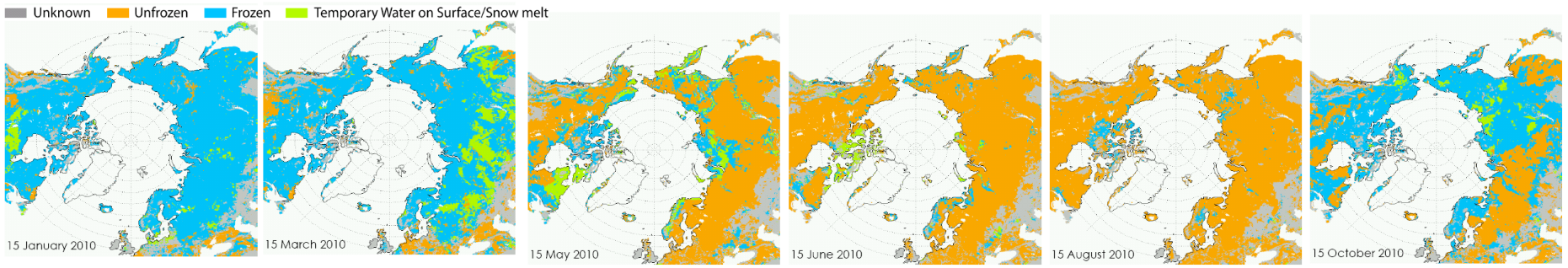
- **Novel advanced EO-based target products:**

local wetland extent dynamics (ASAR)	→	spatial changes of lake and wetland surface at medium spatial resolution (10 days frequency)
regional wetland extent dynamics (SSM/I, AVHRR, ASCAT)	→	spatial changes of inundated areas at low spatial resolution (10 days frequency)
snow-melt onset/end (ASCAT)	→	suitable for determining when methane emissions from wetland restart after the winter season



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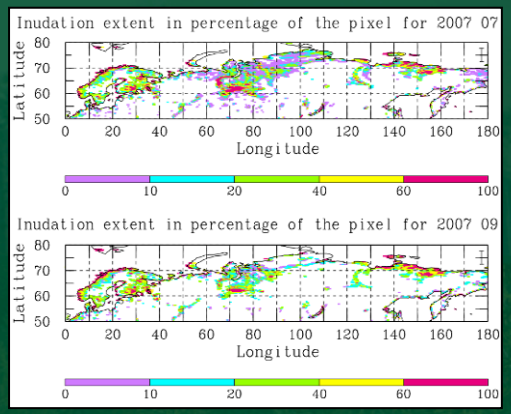
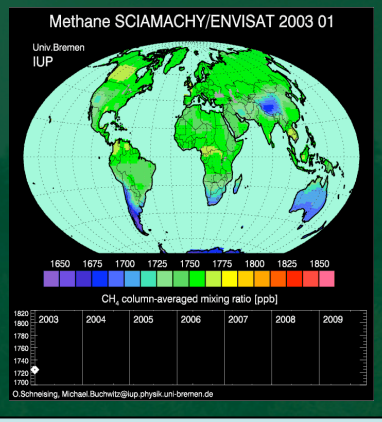
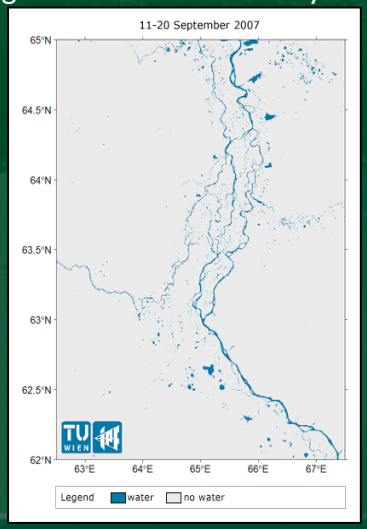
- **Improved state-of-the-science land-atmosphere model:**



regional wetland extent dynamics



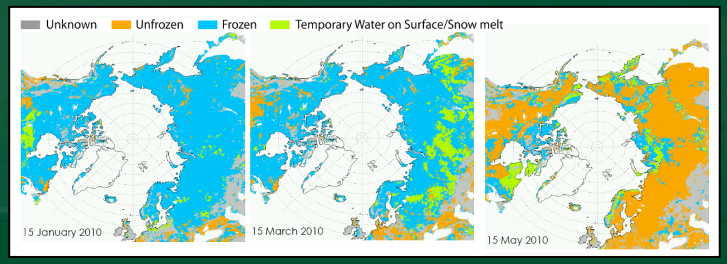
CH_4 concentration (SCIAMACHY)

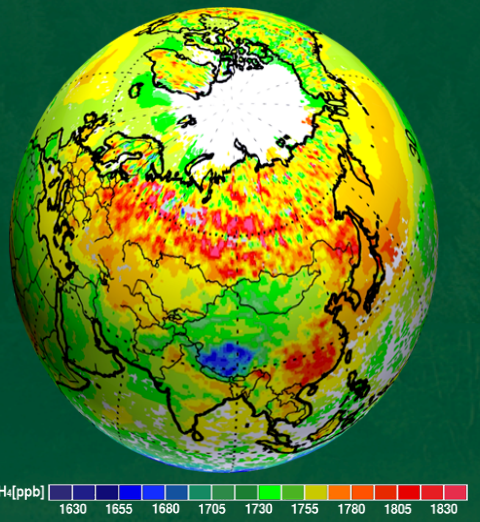


local wetland extent dynamics

JULES (Joint UK Land Environment Simulator) + **HadGEM3** (Hadley Centre Global Environmental Model)

snow-melt onset/end





CH_4 emissions from boreal Eurasian wetlands

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- STARTING POINT
  → Standard version of JULES

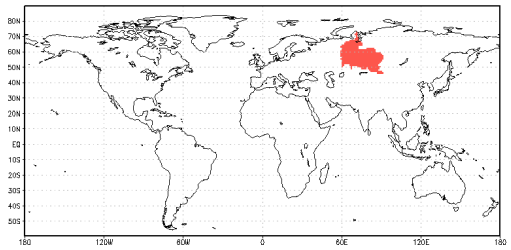
- OB RIVER AREA
  → Time series at point of high inundation (66.5°E, 66.5°N)

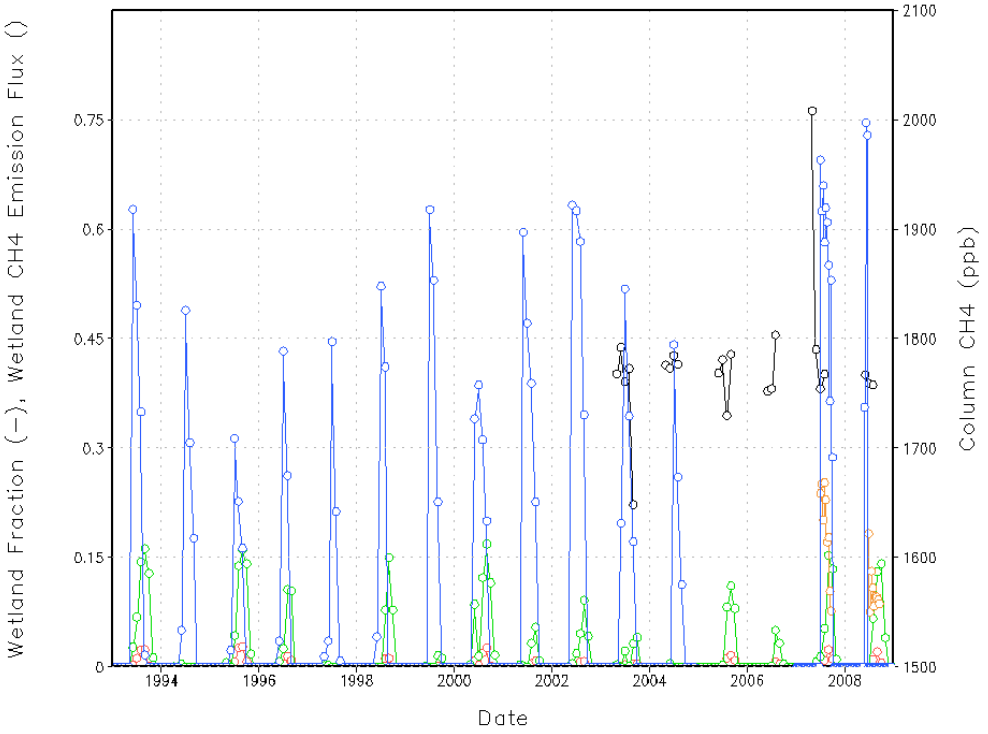
— EO 'wetland' fraction

— JULES 'wetland' fraction

— JULES CH_4 emission flux

— SCIMACHY CH_4 column





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- Biomass burning events in boreal Eurasia have a significant influence on atmospheric chemistry.

- Under high atmospheric instability and high energy release (typical at high northern latitudes), fire emissions can be injected even into the upper troposphere or the lower stratosphere, where the atmospheric lifetime of most trace gases and aerosols is longer, hence affecting greater regions.



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- Understanding the influence of fires on climate requires the use of transport models to be initialised with reliable estimations of smoke-plume injection height.
- As auxiliary data is scarce, the model often needs to be initialised with rather arbitrary assumptions, such as fixed vertical injection levels.
- Satellite remote sensing may provide useful information on variable and widespread boreal fires and may be used to monitor regional to global dispersion of fire-related aerosols and trace gases.



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- The main objective of the *ALANIS smoke plumes* project is to exploit the complementary capabilities offered by multi-mission EO data for improving the estimation of plume injection height of biomass burning events occurred in boreal Eurasia and reducing current uncertainties in related greenhouse-gas and aerosol dispersion forecast (study interval: 2008-2011).

- The *ALANIS smoke plume* project is run by a Consortium including:
  - NOVELTIS (France, Prime Contractor);
  - the Wageningen University Research Centre (Netherlands);
  - the Institute for Environment and Sustainability of the European Joint Research Centre;
  - the University College of London (UK);
  - LATMOS (France).

Noveltis WAGENINGEN UNIVERSITY WAGENINGEN UR JRC EUROPEAN COMMISSION LATMOS UCL

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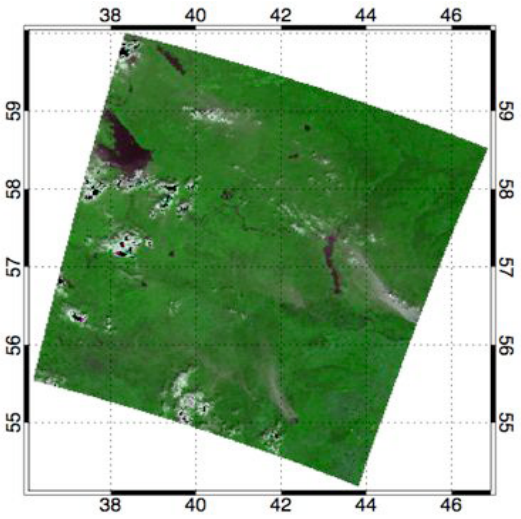
- **Novel advanced EO-based target products:**

smoke-plume injection height
(AATSR)

→ Smoke plume-height information extracted from AATSR stereo retrievals



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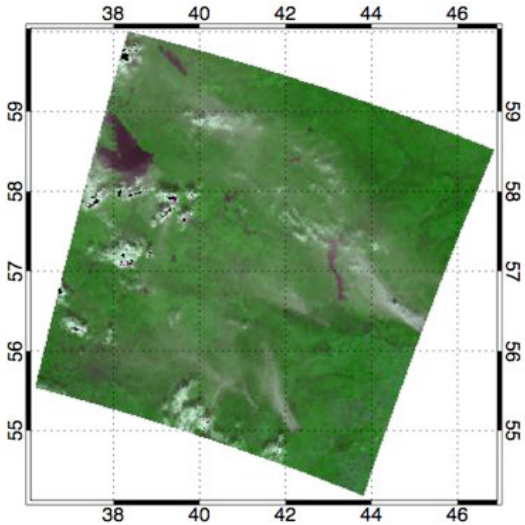
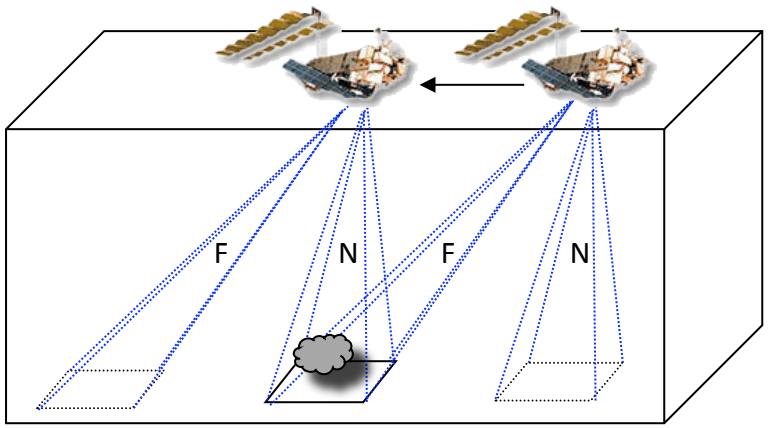


Forward (55°)



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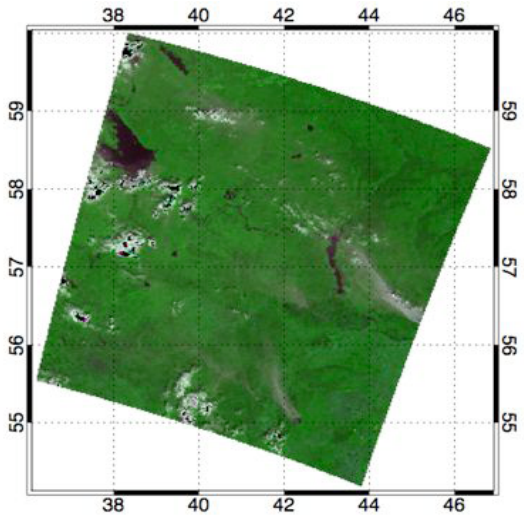
smoke-plume injection height (AATSR) → Smoke plume-height information extracted from AATSR stereo retrievals



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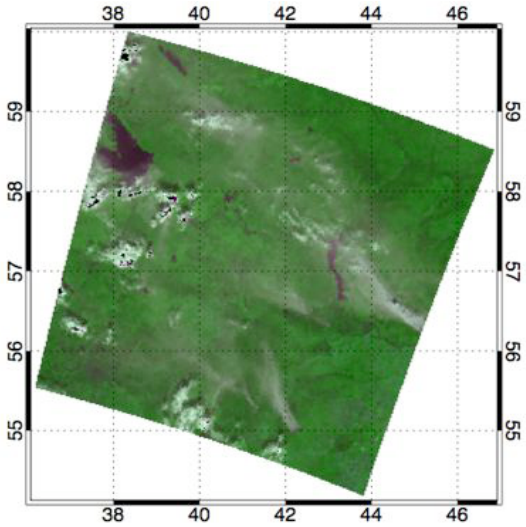

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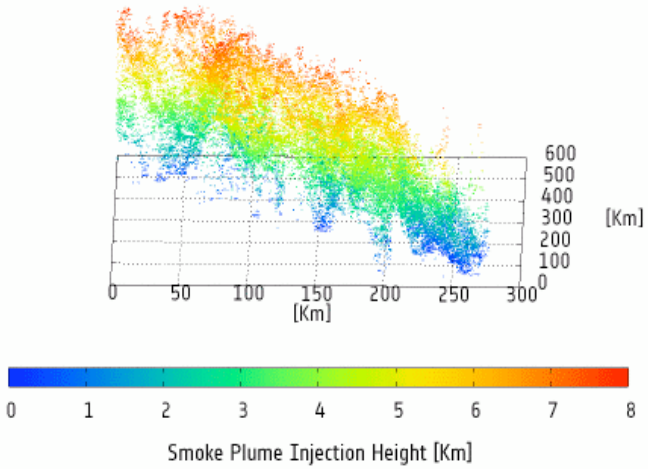

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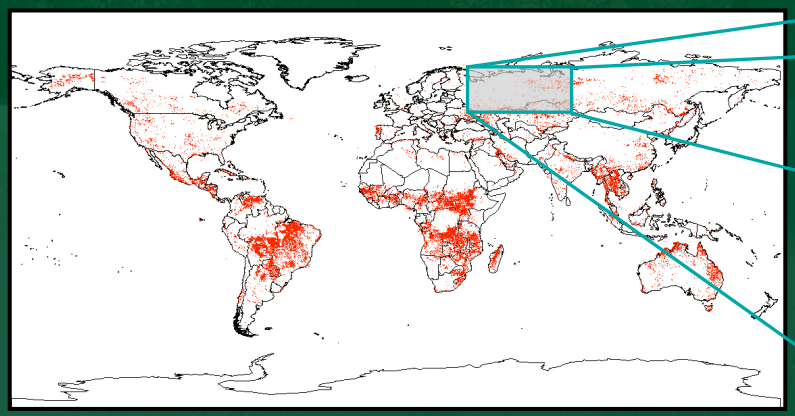
- **Novel advanced EO-based target products:**

smoke-plume injection height (AATSR)	→	Smoke plume-height information extracted from AATSR stereo retrievals
burned areas extent and CO emission (MERIS + AATSR World Fire Atlas)	→	Use of multi-temporal MERIS data and WFA to assess the extent of burned areas + estimated amount of emitted CO



AATSR World Fire Atlas

2009 Burned Areas derived from MERIS data

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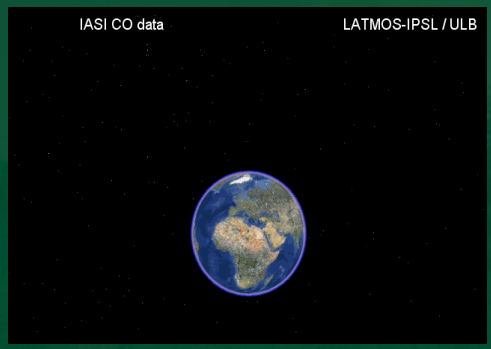
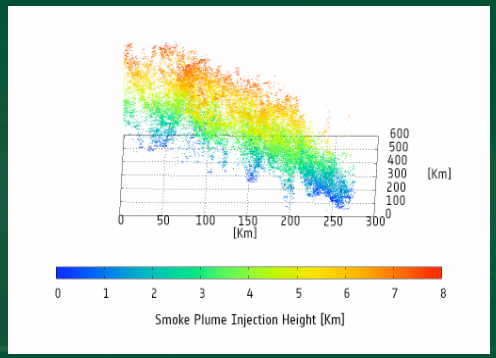
- **Improved state-of-the-science land-atmosphere model:**

burned area
(MERIS + WFA)
+
estimated CO
emitted

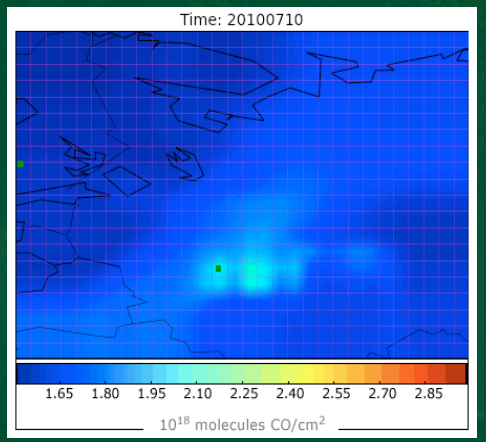
CO concentration
(IASI)



Injection-height modelling → Plume dispersion modelling (TM5) → GHG dispersion forecast



smoke-plume
injection height
target product
(AATSR)



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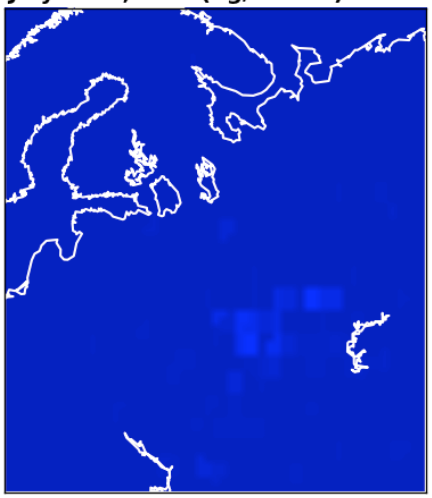
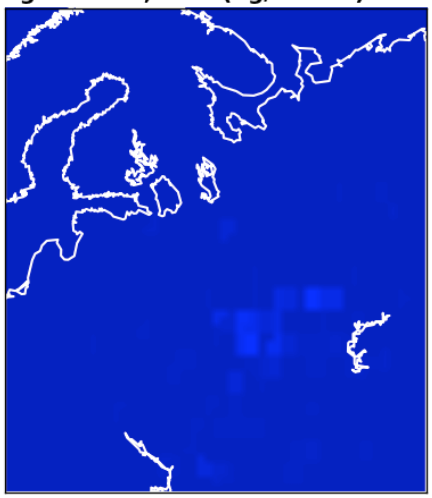
WITHOUT USING EO DATA

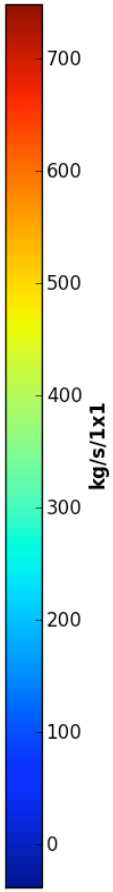
July Prior, sum (Tg/month) 2.39



August Prior, sum (Tg/month) 2.39

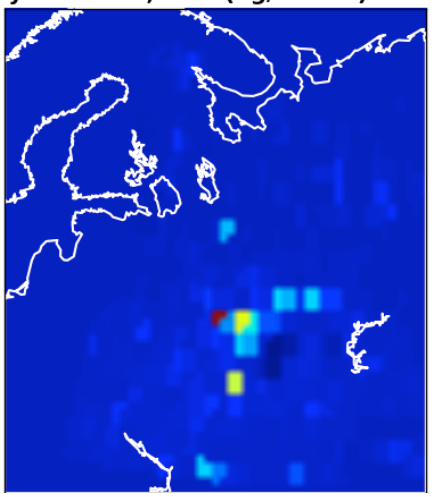


WITHOUT USING EO DATA

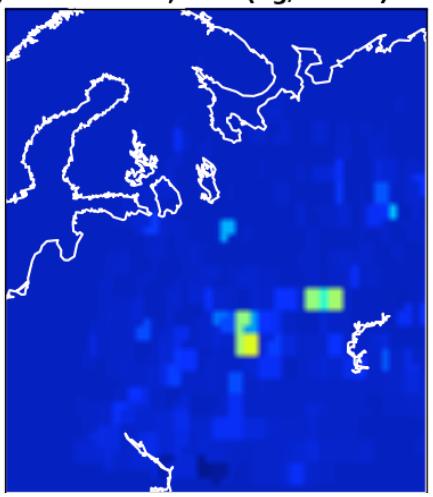


USING EO DATA

July Posterior, sum (Tg/month) 20.95



August Posterior, sum (Tg/month) 19.34



USING EO DATA

2010 MOSCOW FIRES

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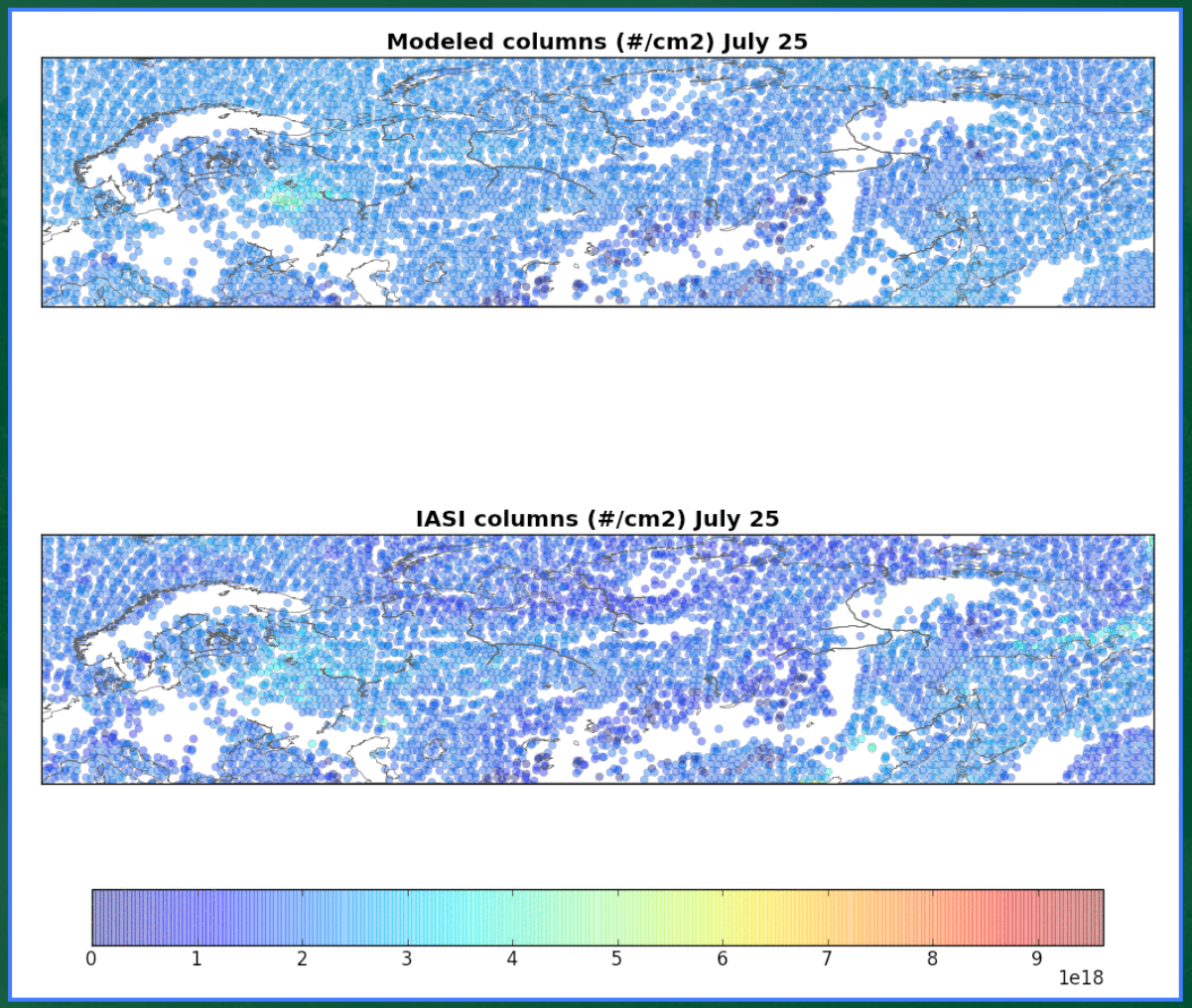

Posterior fit to IASI data

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- Aerosols in the atmosphere are composed by particles of different nature:
  - natural (e.g., emitted by forests)
    → contribute to Earth's natural evolution;
  - anthropogenic (e.g., pollutants by energy production, traffic and industrial activities)
    → represent an external cause of climate change;

- Accordingly, separating the contribution of anthropogenic from that of natural aerosols is essential for assessing the human influence.

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- There is a great interest in investigating the boreal Eurasian region for two main reasons:
  - new particle formation events generating secondary organic aerosols regularly occur in boreal Eurasian forests;
  - due to particular wind circulation conditions, boreal Eurasia is influenced periodically by long-range-transported anthropogenic aerosol.

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- The aim of the *ALANIS aerosols* project is to study how existing multi-mission EO-based products could help in discriminating long-range transported anthropogenic aerosols from natural aerosols in boreal Eurasian forests.

- The *ALANIS aerosols* project is run by a Consortium including:
  - the University of Helsinki (Finland, Prime Contractor);
  - the Finnish Meteorological Institute (Finland);
  - the Lund University (Sweden).

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HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

FINNISH METEOROLOGICAL INSTITUTE

LUND UNIVERSITY

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- Natural aerosols: newly formed particles are initially too small to be directly observed by EO satellite sensors → use of proxies [GLOMAP model + AATSR Aerosol Optical Depth (AOD) data]

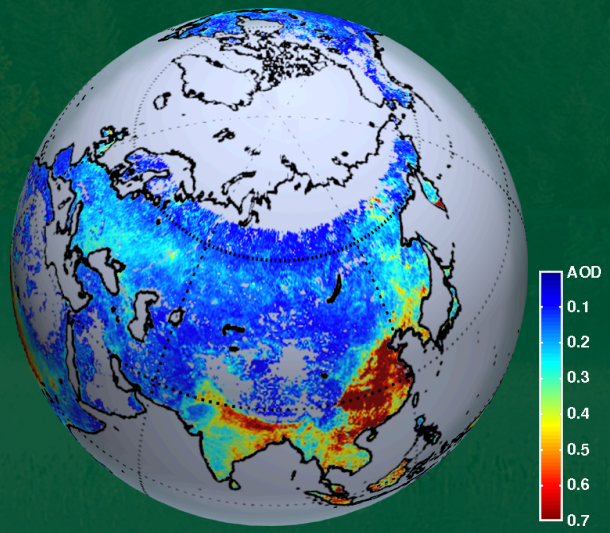
nucleation mode particle number concentration

$$N = \frac{UV\left[SO_2\right]}{CS^2}$$

UV → Ultraviolet radiation intensity

SO_2 → Sulphur dioxide concentration

CS^2 → Condensation sink [AOD]



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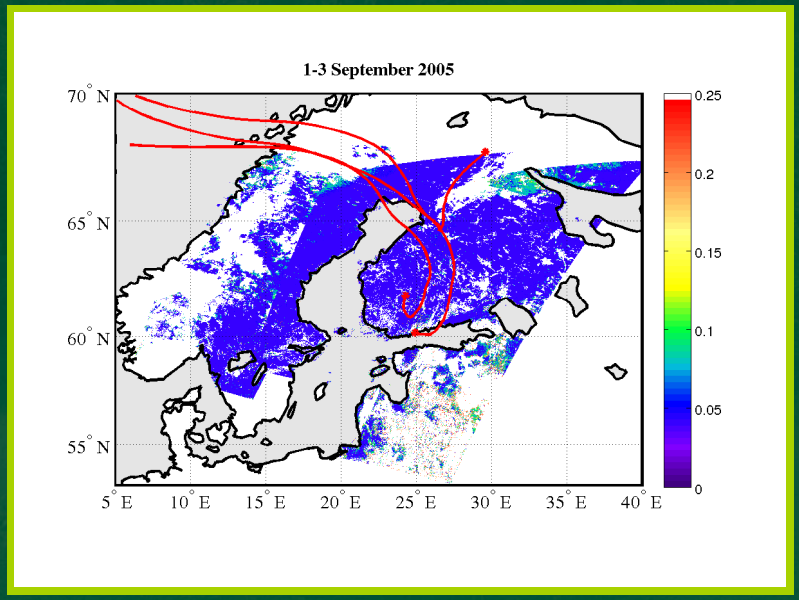
- Anthropogenic aerosols: diameter larger than 50-100 nm
  - AATSR AOD;
  - Ground-based in-situ data;
  - Air masses back trajectories;
  - GLOMAP model.



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… so far …

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- ALANIS has raised a lot of interest in the land-atmosphere community:
  - Several talks and posters presented in a number of scientific international conferences;
  - Papers published/submitted to international peer-reviewed journals;

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  - ESA-iLEAPS-EGU joint Conference Earth Observation for Land-Atmosphere Interaction Science, Frascati (Rome, Italy), 3-5 November 2010 (~200 participants);

    → Dedicated Special Issue in the EGU Biogeosciences Journal (IF 3.587)

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… so far …

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    → Dedicated Special Issue in the EGU Biogeosciences Journal (IF 3.587)
  - Session dedicated to "Earth Observation for Land-Atmosphere Interaction Science" @ EGU2011 General Assembly, Vienna (Austria), 3-8 April 2011;
  - Proposal for a Session dedicated to "Earth Observation for Land-Atmosphere Interaction Science" @ EGU2012 General Assembly, Vienna (Austria), 22-27 April 2012;

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… so far …

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- ALANIS has raised a lot of interest in the land-atmosphere community:
  - Several talks and posters presented in a number of scientific international conferences;
  - Papers published/submitted to international peer-reviewed journals;
  - ESA-iLEAPS-EGU joint Conference Earth Observation for Land-Atmosphere Interaction Science, Frascati (Rome, Italy), 3-5 November 2010 (~200 participants);

    → Dedicated Special Issue in the EGU Biogeosciences Journal (IF 3.587)
  - Session dedicated to "Earth Observation for Land-Atmosphere Interaction Science" @ EGU2011 General Assembly, Vienna (Austria), 3-8 April 2011;
  - Proposal for a Session dedicated to "Earth Observation for Land-Atmosphere Interaction Science" @ EGU2012 General Assembly, Vienna (Austria), 22-27 April 2012;
  - **ALANIS Final Workshop**, Frascati (Rome, Italy), 21 February 2012.

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… what's next? …

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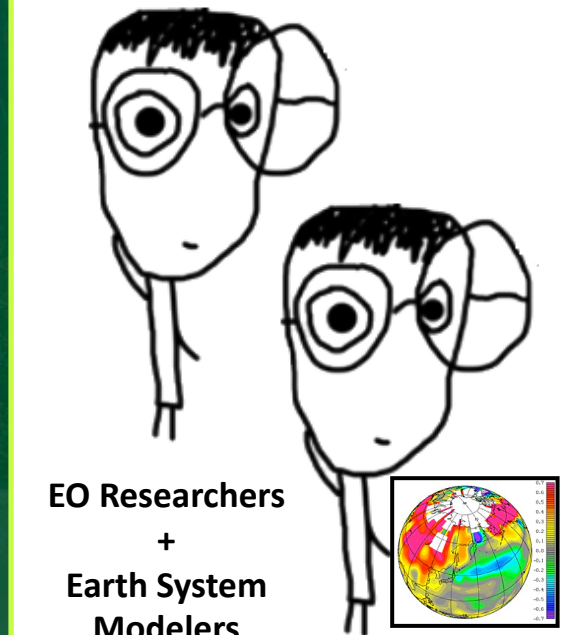
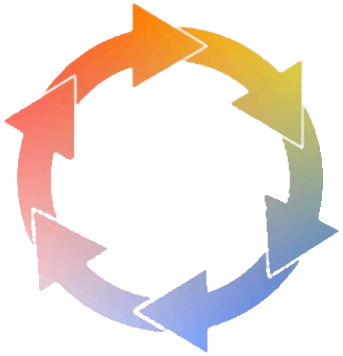
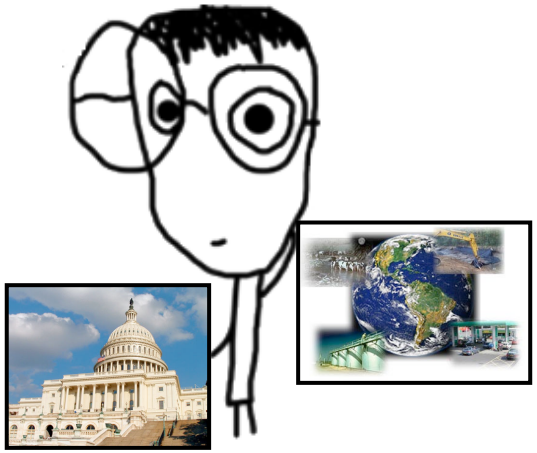


EO Researchers
+
Earth System
Modelers

ACTIONABLE SCIENCE





Decision Makers

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Thank you