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An update on CAMS and C3S: opportunities for the agriculture and forestry sectors

Recent climate and air pollution impacts on Indian agriculture

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Recent research on the agricultural impacts of climate change has primarily focused on the roles of temperature and precipitation. These studies show that India has already been negatively affected by recent climate trends. However, anthropogenic climate changes are a result of both global emissions of long-lived greenhouse gases (LLGHGs) and other short-lived climate pollutants (SLCPs). Two potent SLCPs, tropospheric ozone and black carbon, have direct effects on crop yields beyond their indirect effects through climatic emissions of black carbon and ozone precursors have risen dramatically in India over the past three decades. Here, to our knowledge for the first time, we present results of the combined effects of climate change and the direct effects of SLCPs on wheat and rice yields in India from 1980 to 2010. Our statistical model suggests that, averaged over India, yields in 2010 were up to 36% lower for wheat than they otherwise would have been, absent climate and pollutant emissions trends, with some densely populated states experiencing 50% relative yield losses. Our point estimates for rice (~20%) are similarly large, but not statistically significant. Upper-bound estimates suggest that an overwhelming fraction (90%) of these losses is due to the direct effects of SLCPs. Gains from addressing regional air pollution could thus counter expected future yield losses resulting from direct climate change effects of LLGHGs.

climate impacts | ozone | aerosols | agriculture | India

Ever since the Green Revolution first staved off famines in the 1960s, Indian rice and wheat systems have grown over the past half century to play critical roles in the world food economy: India's 1.2 billion people depend primarily on food produced within the country, and other Asian and African nations rely heavily on imports of Indian rice. During the 2007–2008 world food price crisis, with wheat harvests falling elsewhere in the world, India banned rice exports out of concern for domestic food security, setting off a worldwide cascade of export bans and food riots. Global food security is thus tightly linked with India's rice and wheat production. In 2008, India produced 148.8 million tons of rice (paddy) and 78.6 million tons of wheat (Fig. S1). In 2006, before the food price spike crisis, India imported over 6 million tons of wheat (~\$1.3 billion) and exported over 4 million tons of milled rice (~\$0.6 million tons of paddy equivalent, ~\$1.5 billion) (1).

Yields for wheat and rice in India have recently begun to level off or even drop in some states (Figs. S2 and S3). This trend, particularly for wheat, counters decades of increasing yields driven by technological innovation (2). At the same time, growing season temperature trends have been positive for major wheat- and rice-producing Indian states (Fig. S4; precipitation trends are mixed). Studies have shown that these climate trends have had a negative impact on Indian agriculture, reducing relative yields by several percent (3, 4). However, although temperature and precipitation changes have and will continue to (5) impact future yields, these two variables alone do not tell the entire story of India's changing crop yields.

Research in the past decade has underscored the importance of short-lived climate pollutants (SLCPs)—nonlong-lived greenhouse gases (non-LLGHGs) climate warming pollutants—on

Significance

Rising temperatures because of increased emissions of long-lived greenhouse gases (LLGHGs) have had and will continue to have significant negative impacts on crop yields. However, other climate changes caused by short-lived climate pollutants (SLCPs) are also significant for agricultural productivity. The SLCPs black carbon and ozone impact temperature, precipitation, radiation, and—in the case of ozone—are directly toxic to plants. To our knowledge, this study provides the first integrated historical examination of the roles of both SLCPs and LLGHGs on wheat and rice yields in India, and finds that the majority of losses are attributable to SLCPs. Agricultural consequences from SLCP mitigation are expected to be large, and because SLCPs have short atmospheric lifetimes, almost immediate.

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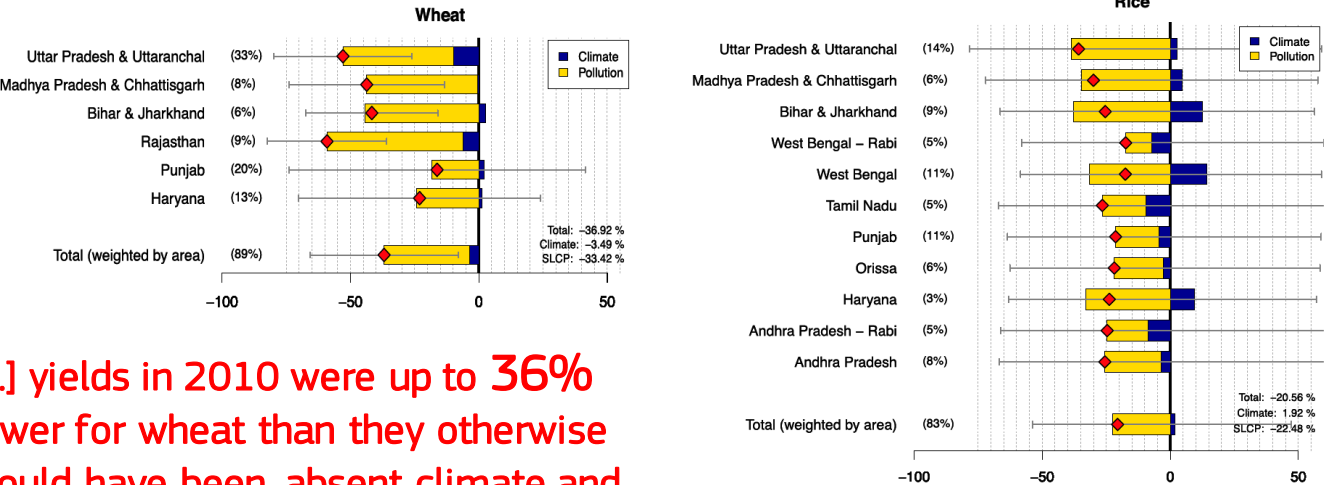
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The authors have nothing to disclose. Email: jburney@ucsd.edu. This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1317275111/-DCSupplemental.

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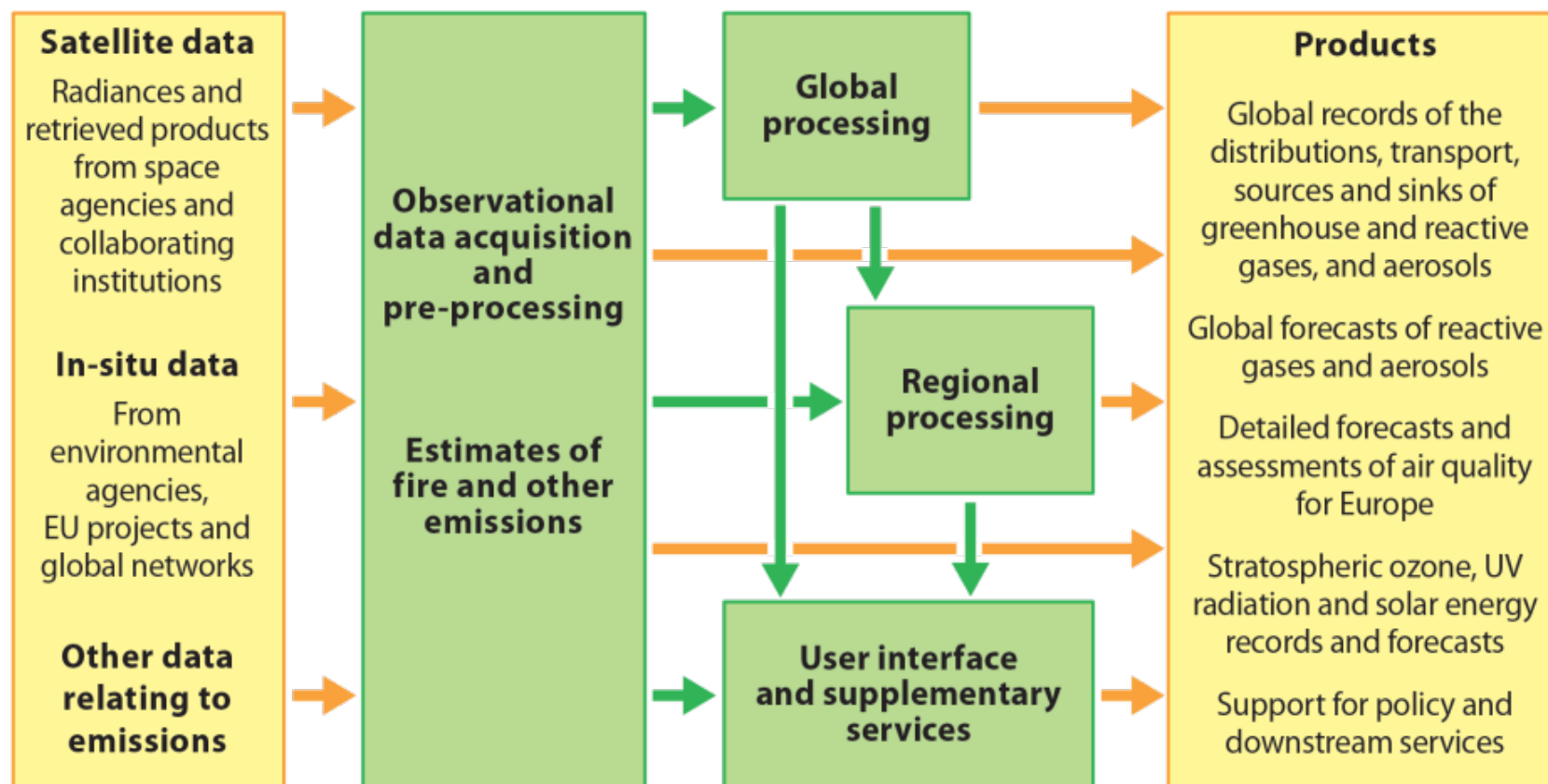
Relative Yield Change (%) for different Indian States between 1980 and 2010 due to air pollution and climate changes



[...] yields in 2010 were up to 36% lower for wheat than they otherwise would have been, absent climate and pollutant emissions trends.

Climate change and air pollution have significant impacts on crops and ecosystems...

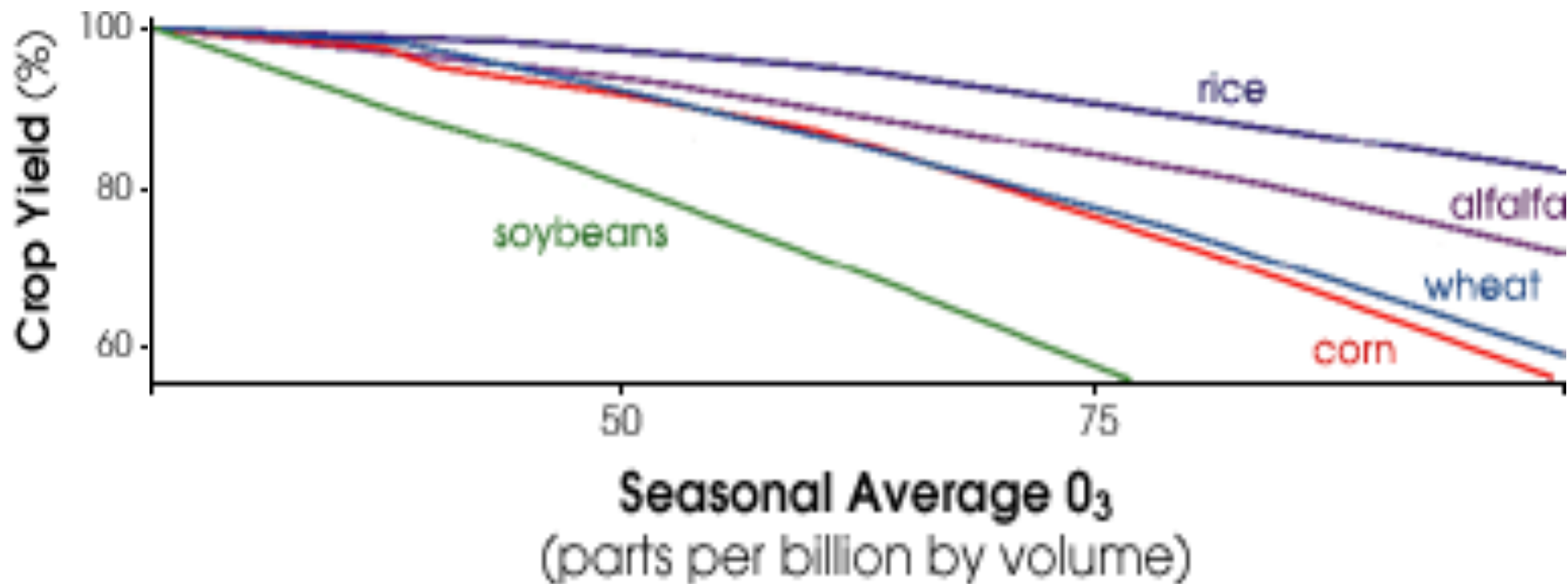
... what is (and will be) available in the portfolio of CAMS and C3S that could be of interest for the agriculture and forestry sectors?





Effects of high ozone
on soybean foliage

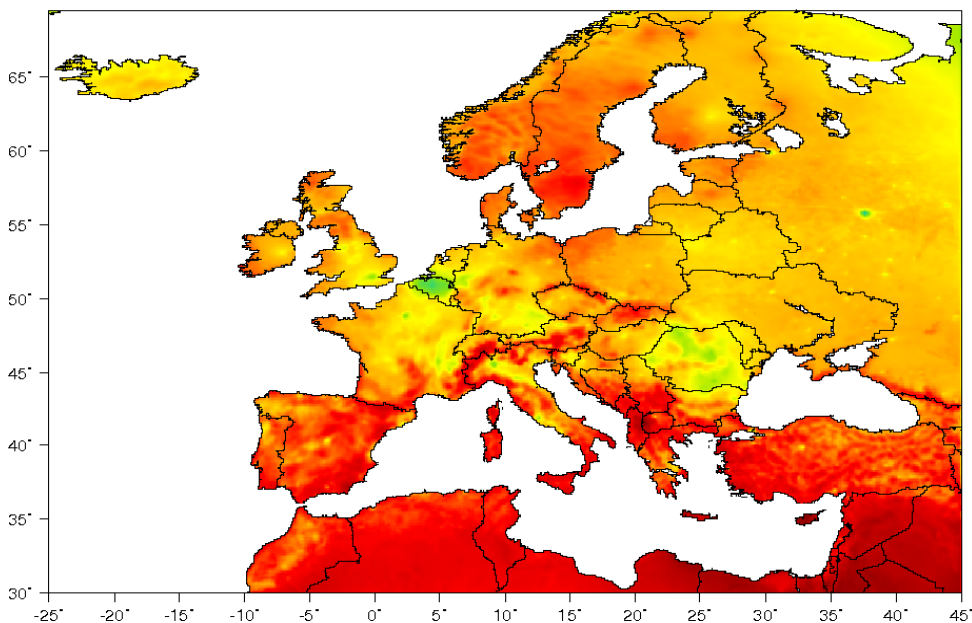
Effects of high ozone
on potato leaves



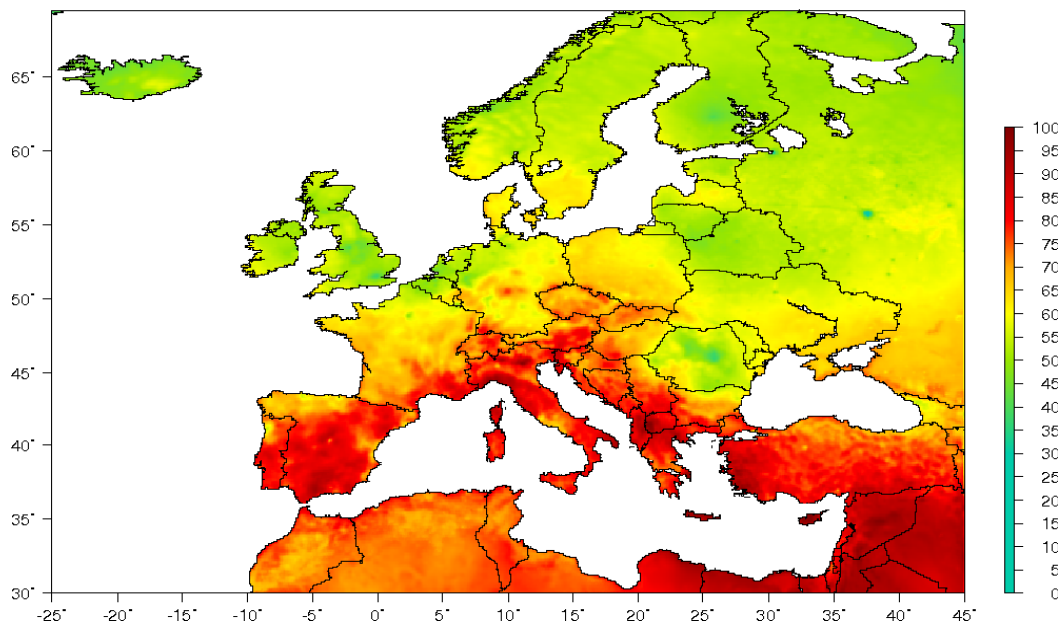
Graph by Adams et al., 1989, adapted by Chameides et al., 1999

Regional atmospheric composition re-analyses

Ozone 2013 reanalysis
avgspring indicator in $\mu\text{g}/\text{m}^3$



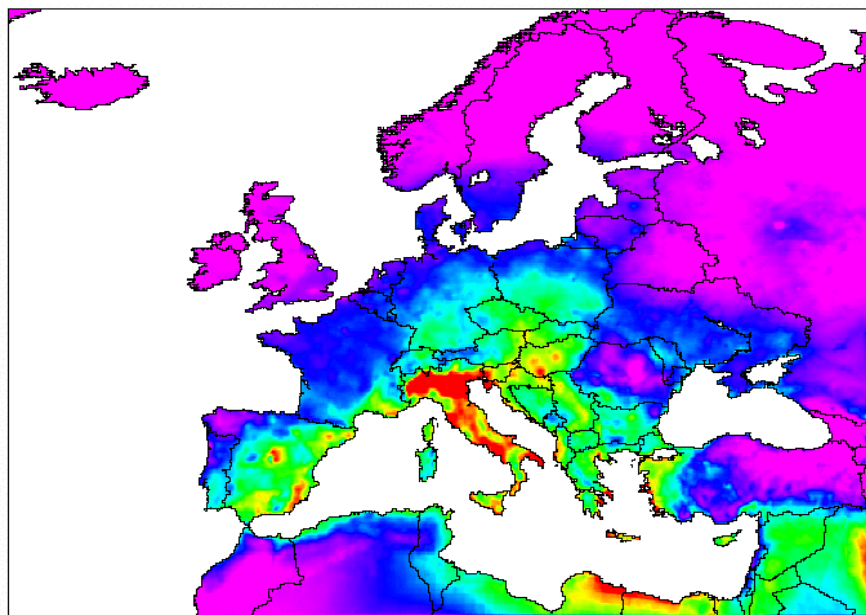
Ozone 2013 reanalysis
avgsummer indicator in $\mu\text{g}/\text{m}^3$



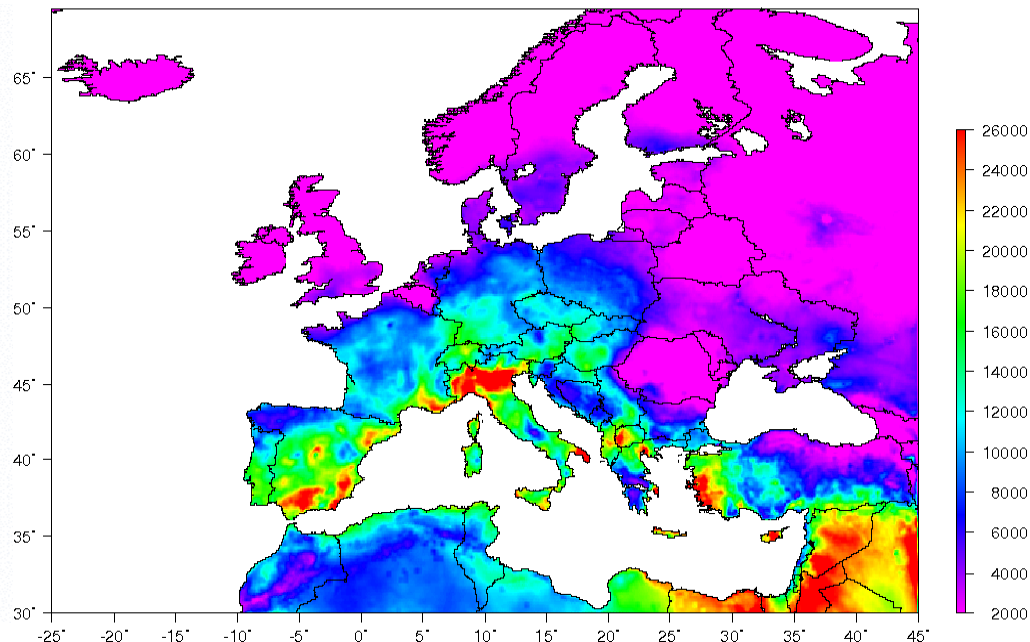
- Combines satellite and validated surface observations as well as model
- Maps with no gaps (including outside of cities)
- Available 2010 to 2013; horizontal resolution is 0.1 degree

AOT40 indicator ($\mu\text{g}/\text{m}^3\cdot\text{hours}$)

2012

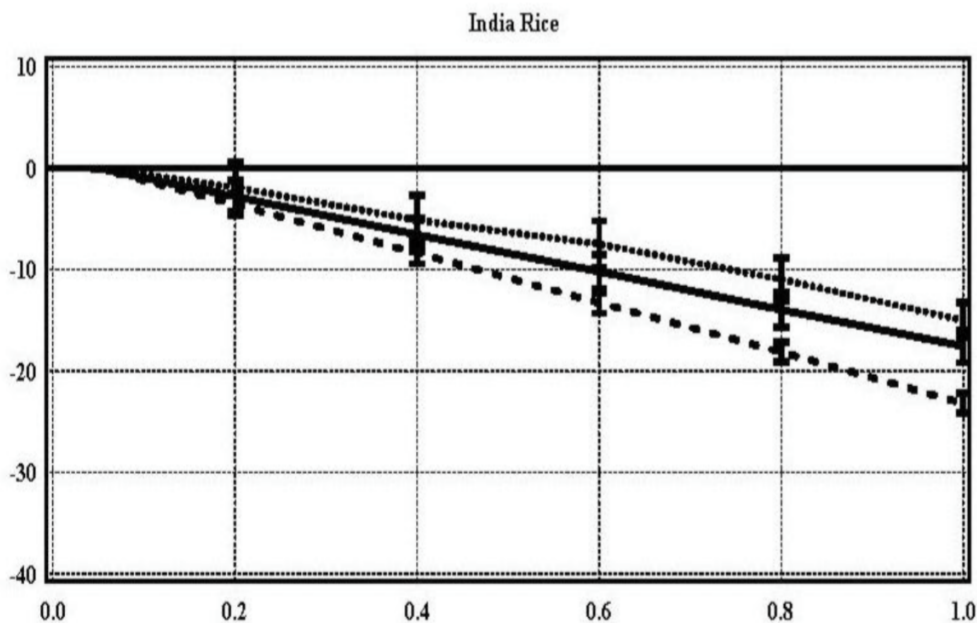


2013



- In the Air Quality Directive, the target value of AOT40 calculated from May to July is $18.000 \mu\text{g}/\text{m}^3\cdot\text{hours}$, with a long term objective of $6.000 \mu\text{g}/\text{m}^3\cdot\text{hours}$.
- Data for other pollutants are also available (SO_2 , PM...).
- Deposition fluxes under evaluation.

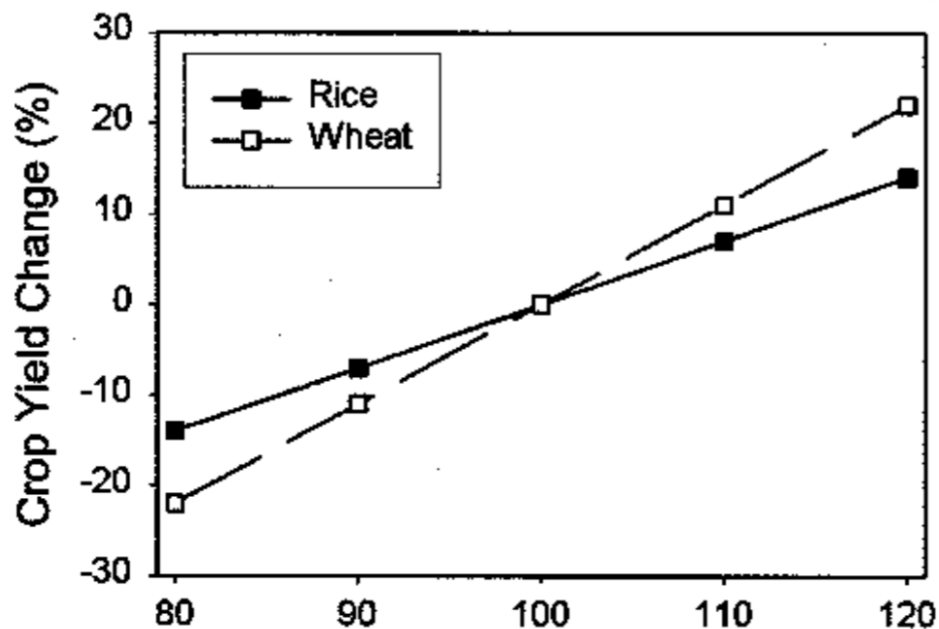
Greenwald et al., 2002



Aerosol Optical Depth

Available
in CAMS!

Chameides et al., 1999



Total surface solar irradiance
(% of observed irradiance)

- Aerosol deposition on leaves under evaluation. Results suggest as much as a 30% reduction in PAR available to plants over a growing season due to extinction of photons by deposited aerosol particles (Bergin, 2002).

MCCLEAR

Max Extent | Back | Next | Search Address:

coord: x = 517, y = 299 | lat = 12.8975, lon = 22.1250

Latitude (deg):	44.0876	Start Date (from 2004-01-01):	2004-01-01	Time Reference:	Universal Time
Longitude (deg):	2.0859	End Date (up to 2 days ago):	2015-06-24	Include detailed info on atmosphere (1 min UT .csv):	True (for experts only)
Altitude (m, Automatic if empty):	Automatic	Time Step:	1 min 15 min Hour Day Month	Output Format:	Comma Separated Val

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Post-production of clear-sky (global) and all-sky surface (MSG disk currently) radiation products taking into account CAMS aerosol information. Provider is DLR (Germany).

HOW TO ACCESS PRODUCTS?

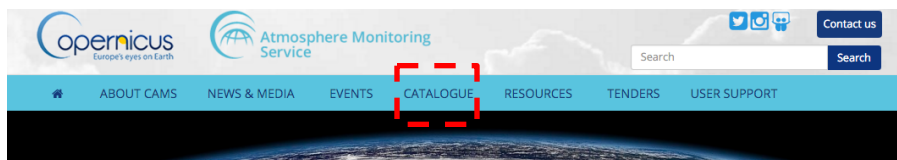


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1. Search the on-line interactive catalogue



Portfolio	Product groups
A. Regional products	European AQ NRT analyses
	European AQ NRT forecasts
	European AQ interim reanalyses
	European AQ reanalyses
B. Global products (troposphere and stratosphere)	Global atmospheric composition NRT analyses
	Global atmospheric composition NRT forecasts
	Global atmospheric composition reanalyses
C. Supplementary products	Policy support products
	Solar radiation
	Greenhouse gas fluxes
	Climate forcings
D. Emissions products	Anthropogenic emissions
	Fire emissions

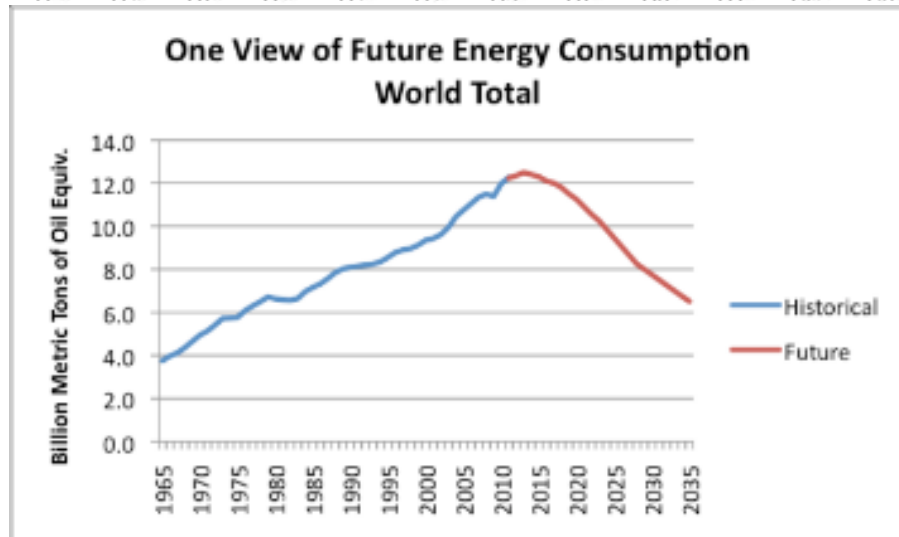
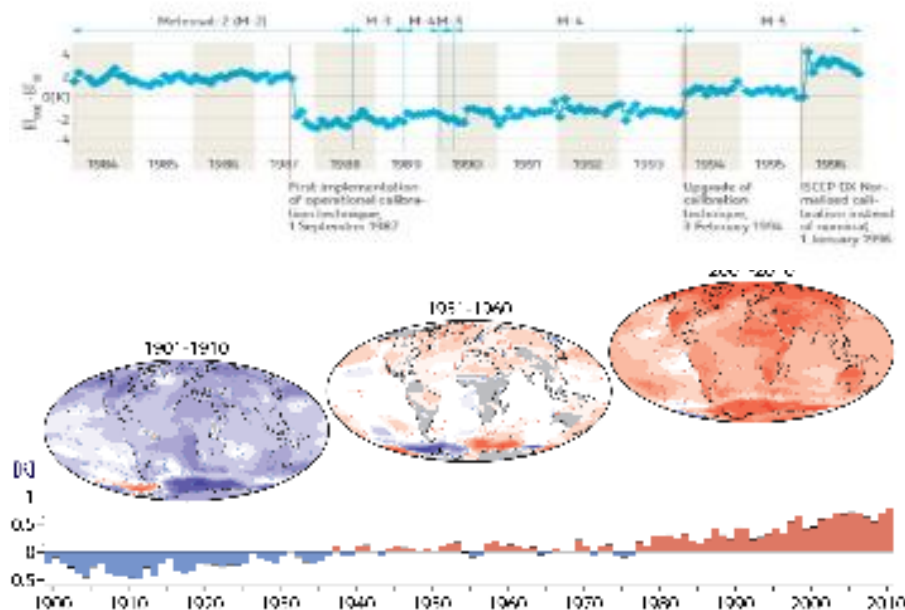
2. Or download the Service Products Portfolio (including detailed products data sheets) at: <http://atmosphere.copernicus.eu/reports>. Edition available is dated 24/03/2016.



To be an **authoritative source** of climate information for Europe

To **build upon national** investments and **complement** national climate service providers

To **support the market** for climate services in Europe



How is climate changing?

- Earth observations
- Reanalyses

Will climate change continue or accelerate?

- Predictions
- Projections

What are the societal impacts?

- Climate indicators
- Sectoral information

Climate Data Store

- ECVs past, present and future
- Observed, reanalysed and simulated
- Derived climate indicators
- Tools to support adaptation and mitigation at global and European level
- **Open and free access**

Sectoral Information System



Proof-of-concept
developments

Evaluation and Quality Control

- **Monitors quality of C3S products and services**
- Ensures C3S delivers state-of-the-art climate information to users
- Identifies gaps in service provision
- Bridges Copernicus with the research agenda in Europe (e.g. H2020, national research projects)

Outreach and Dissemination

- Web content
- Public outreach
- Coordination with national outreach
- Liaison with public authorities
- Conferences, seminars
- Training and education



Seven proof of concept SIS contracts have been awarded

SIS water management

- SWICCA (Service for Water Indicators in Climate Change adaptation) – lead SMHI (Sweden)
- EDgE (End-to-End demonstrator for improved decision making in the water sector in Europe) – Lead CEH (UK)

SIS energy

- CLIM4ENERGY (Climate for Energy) – Lead CEA (France)
- ECEM (European Climatic Energy Mixes) – Lead UEA (UK)

SIS others

- AgriCLASS (Agriculture Climate Advisory Services) – Lead Telespazio – Vega (UK)
- WISC (Windstorm Information Service) – Lead CGI (UK)
- URBAN-SIS (touching health, infrastructure, water) – Lead SMHI (Sweden)



AgriCLASS: Agricultural CLimate Advisory ServiceS

To Build: C3S Agricultural Information System

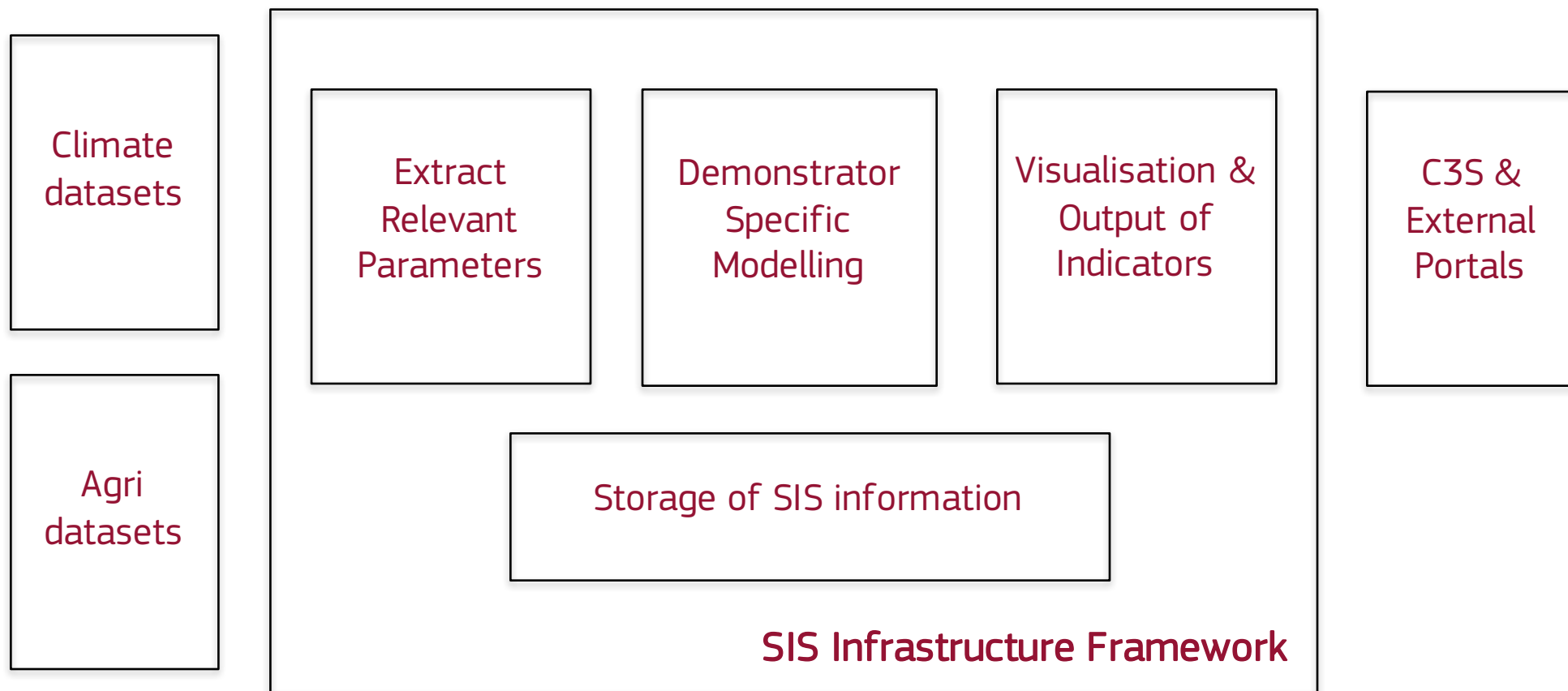
Using: High Quality Climate & Agricultural data & models

Demonstrated Through: Producing Impact Indicators for woody perennial Crops - that are high investment, multi-year yield, responsive to cumulative change – i.e. climate affected.

Achieved By: Productivity impacts are multi-factoral: water, light, temperature, day length, phenology, local conditions, past history, future trends

Derek GREER
Chief Operating Officer
Telespazio VEGA UK Ltd

- Combine know-how of climate data experts, system implementation experts, local meteorological data
- Agricultural experts apply crop response models
- Make available proof-of-concept system and published indicators



Hosted at Agrimetrics - Centre for Agri-Informatics and Sustainability



Forestry

Southern forests die-back due to drought, reduced productivity/ biodiversity



Drought Stress Indicator

Olives

40% loss of crop due to pest, increasing scarcity of virgin olive oil – quality drop



Pest Impact Indicator

Viticulture

3-4 weeks shift in harvest date, reduced sugar content, change in typicality



Phenological Indicator

Thanks for your attention!

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