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NCEO and its Future Science

John Remedios

Future Director of NCEO

(1st October 2014)

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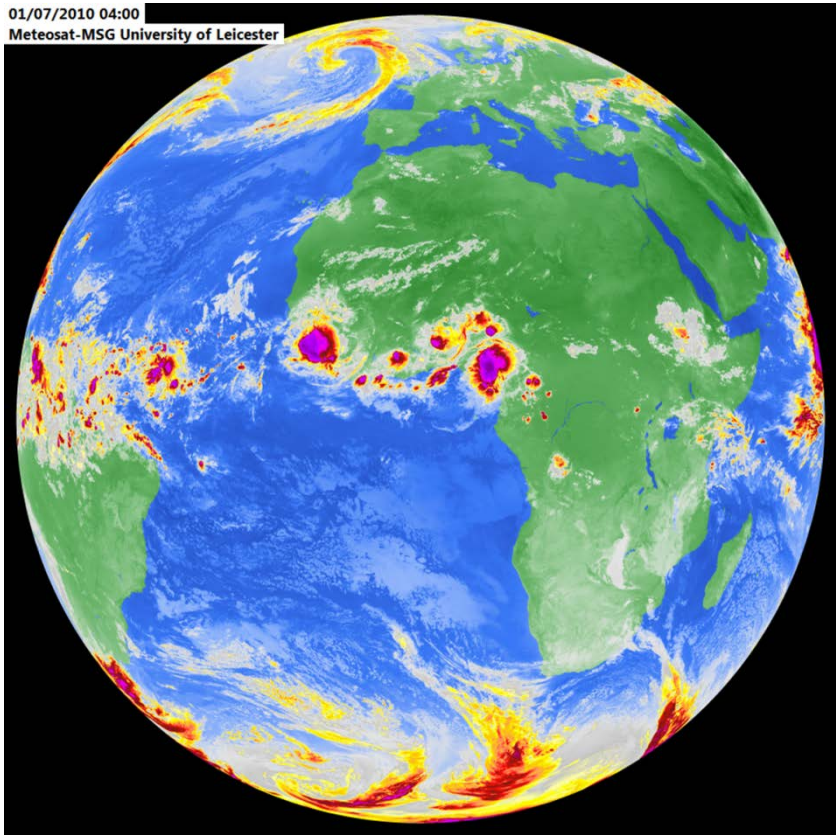
Next generation Earth System Observations

- NCEO Objectives
- EO data
- Direct model evaluation
- Data assimilation
- Instruments and facilities
- NCEO going forwards



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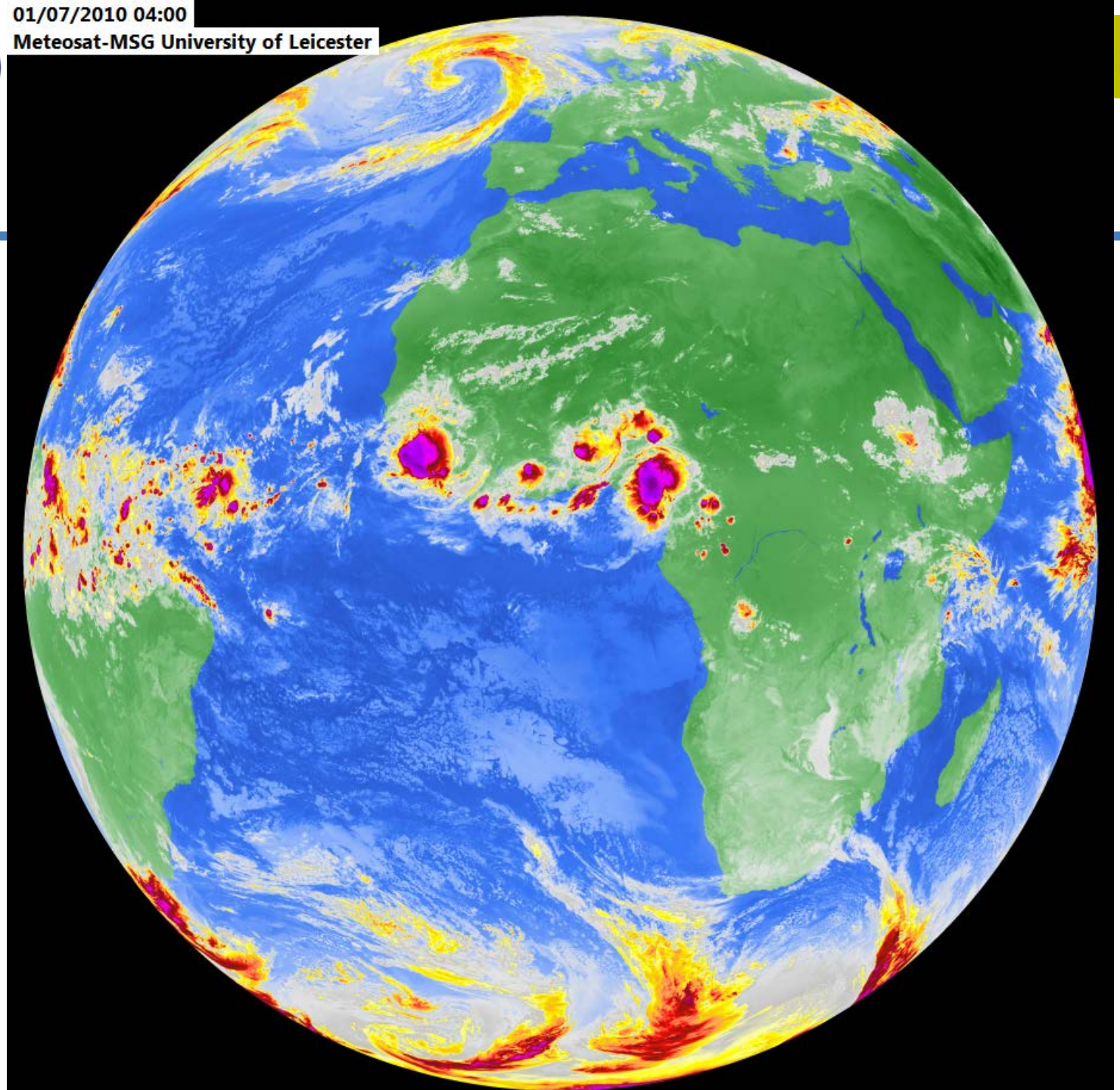
NCEO Objectives

"Transformational EO science capability to meet Earth System challenges":

- Innovative data assimilation (DA) for Earth state representation and interrogation with NWP impact.
- Critical historical and new observations of Earth System evolution with impact in operational /business services.
- Model-data evaluation for global ESM and component models with impact in policy
- Provision of instrument, data facilities and key tools for use by the wider NERC community



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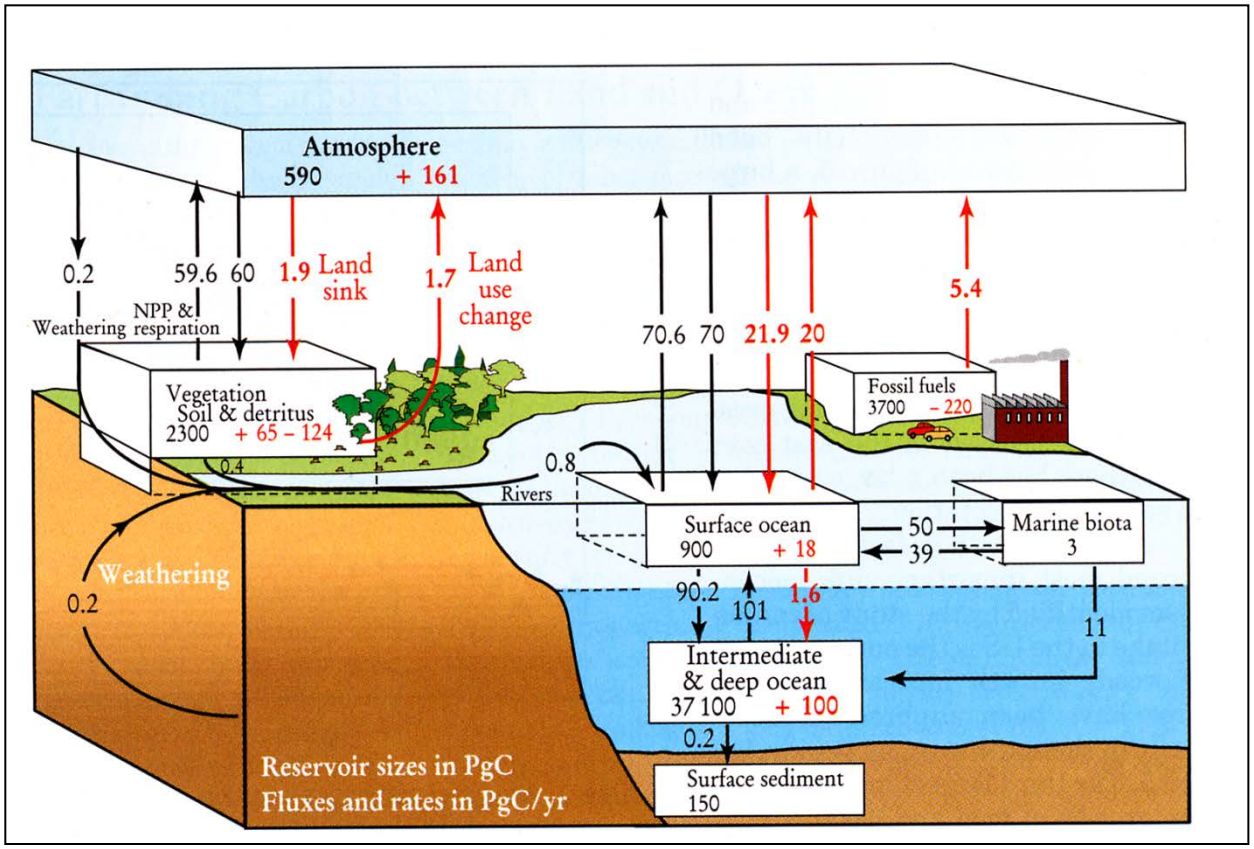
The Carbon Cycle

BOXES = RESERVOIRS
ARROWS = FLUXES
BLACK = NATURAL PROCESSES,
RED=ANTHROPOGENIC INFLUENCES



Sarmiento and Gruber, Physics Today, 2002

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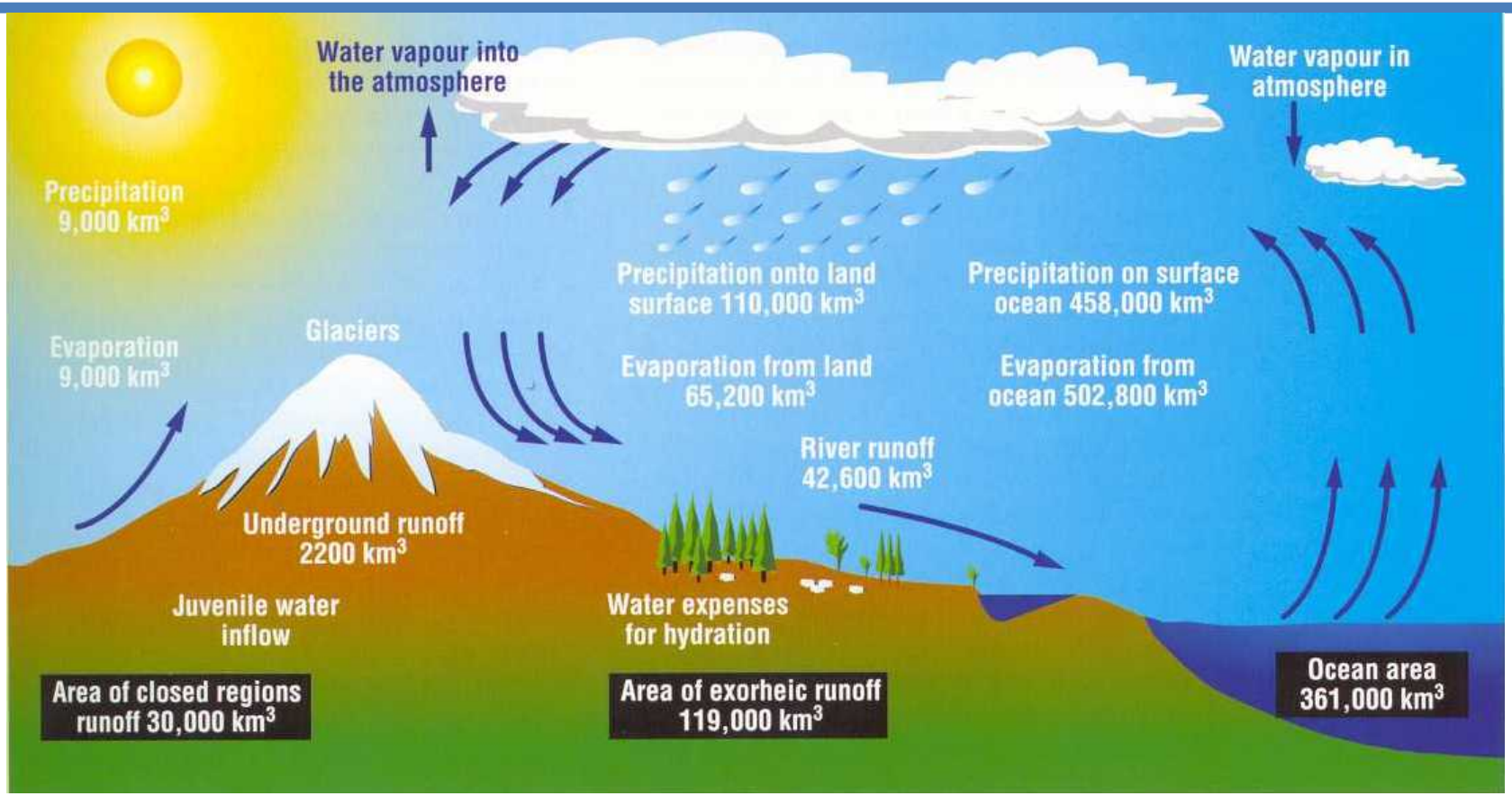
The Hydrological Cycle



Courtesy of Unesco

Physics: condensation, evaporation, latent heat, [electrification], heat capacity, fluid flow

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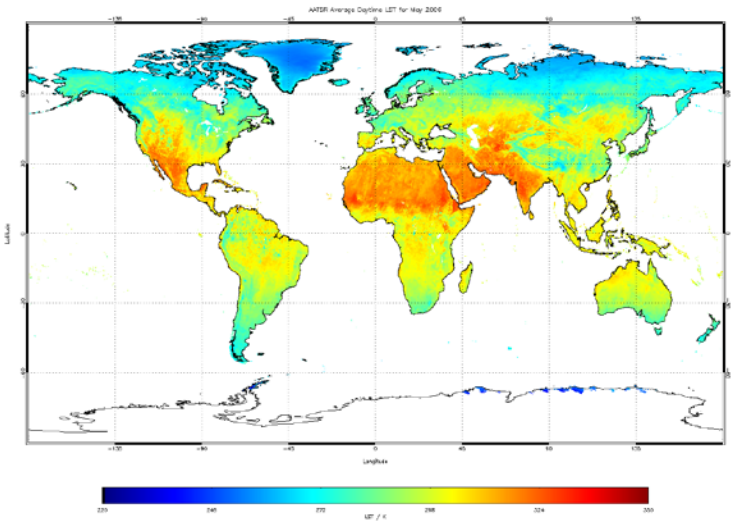
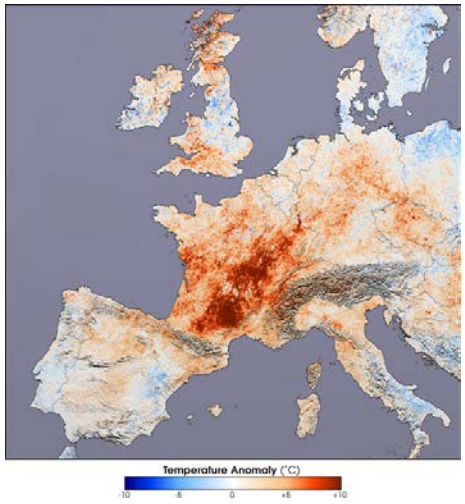
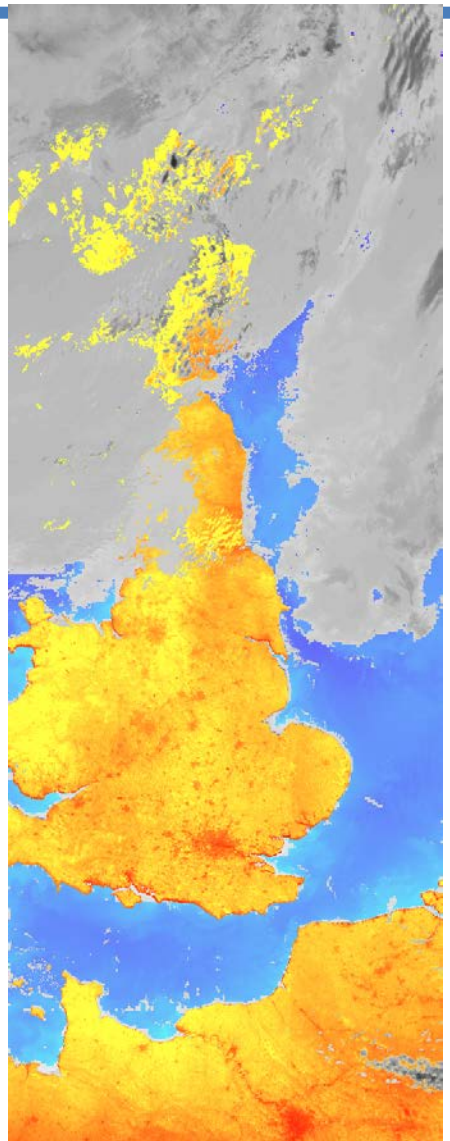
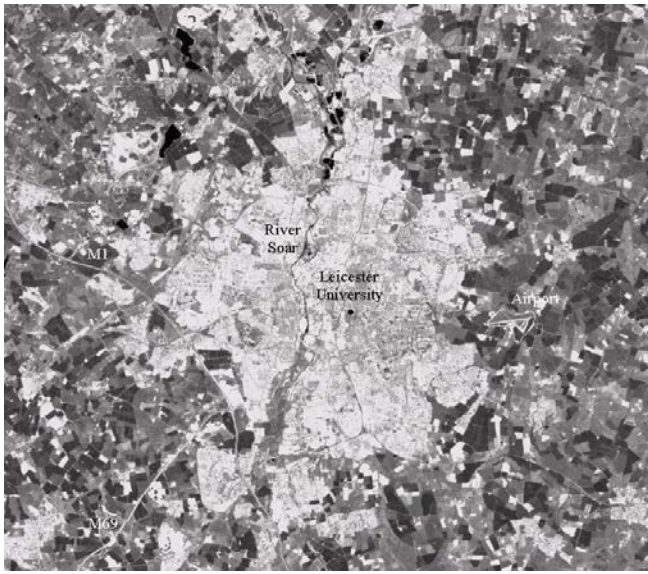
Global to local: interplay of the issues









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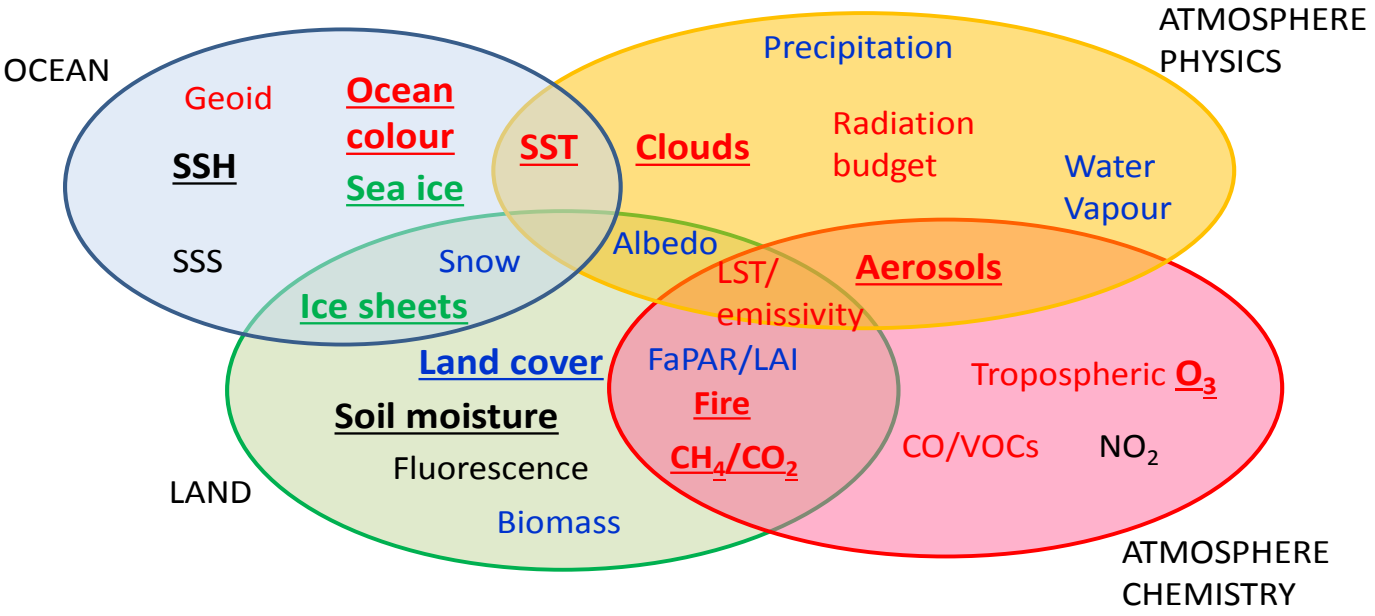
EO Parameters at the interfaces: a science revolution

Key data sets for NCEO organised by science area (ocean, land, atmosphere)
Red: "NCEO or NCEO supported data sets"
Blue: Data sets improved by NCEO activities
Green: Data sets required from other NERC centres
Bold and underlined: ESA CCI produced data sets



Key
SSH:Sea surface height
SSS: Sea surface salinity
SST: Sea surface temperature

LST: Land surface temperature
FaPAR: Fraction of absorbed photosynthetically active radiation
LAI: Leaf area index
VOCs: Volatile organic compounds

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EO data and models

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EO data for the long-term

- Long-term for climate
- Short-term for model emergent constraints and process studies
- Increased exploitation of data sets for multiple variables.
- Exciting new missions: Earthcare, Biomass, Sentinels, near-term missions

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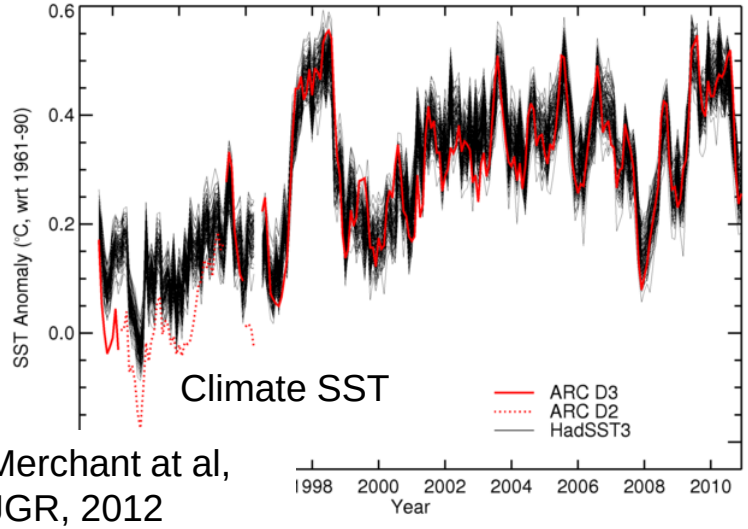
Climate T data sets

NERC, DECC and ESA-funded research



Merchant at al, JGR, 2012

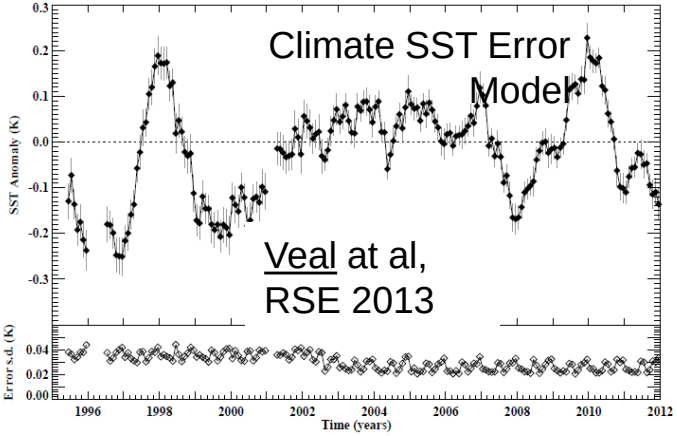
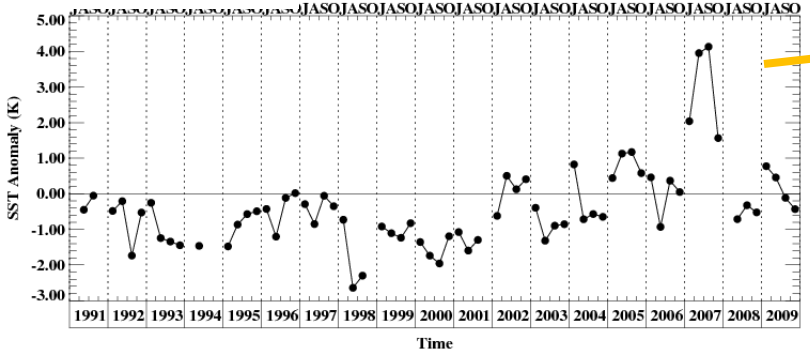
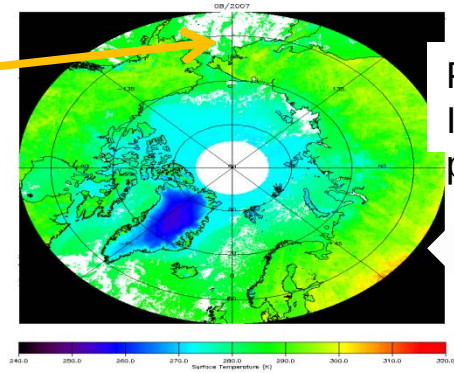
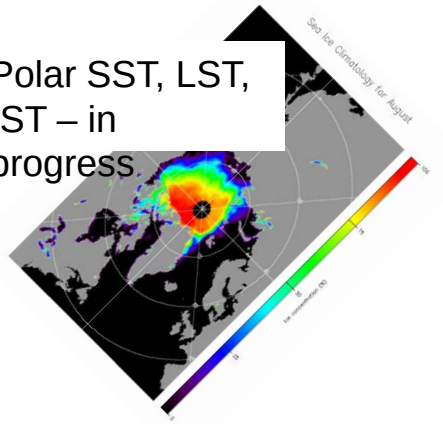


Figure 10: Night-time dual-view 3-channel monthly mean global SST anomaly (to climatology for the base period January 1997 to December 20[illegible] Error bars indicate the estimated 1 sigma uncertainty.





Polar SST, LST, IST – in progress



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King's College London GEO Fire Radiative Power Products

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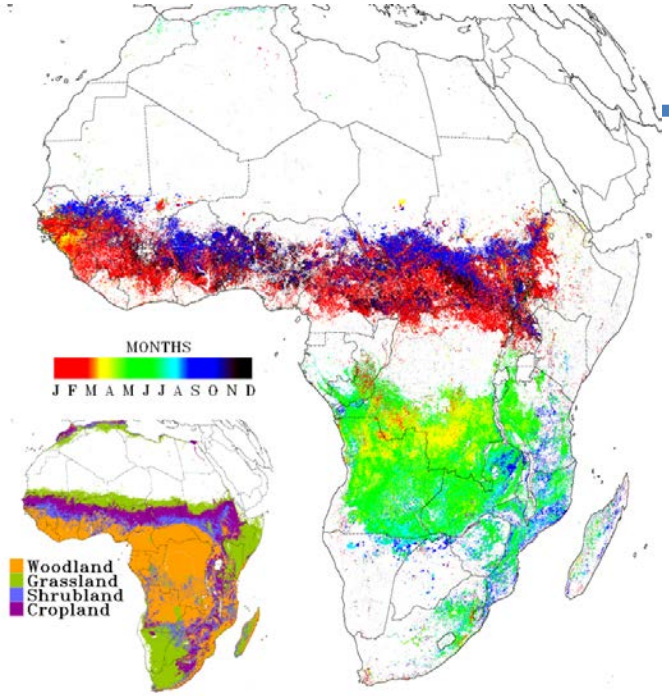
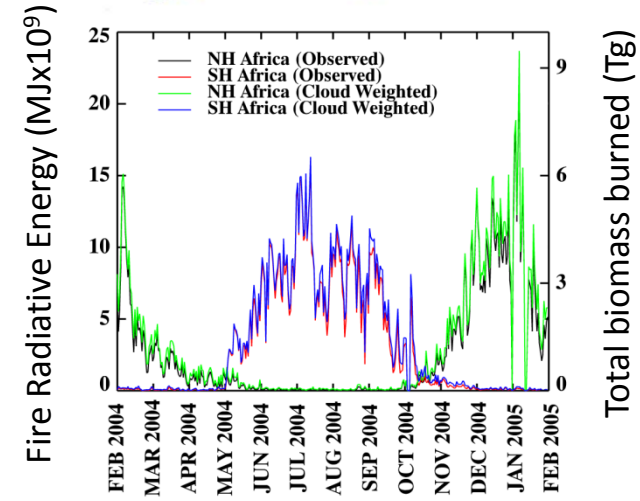
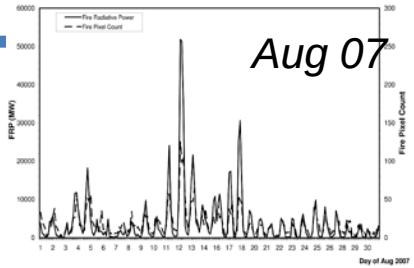
Meteosat SEVIRI FRP (Jan – Dec 04)

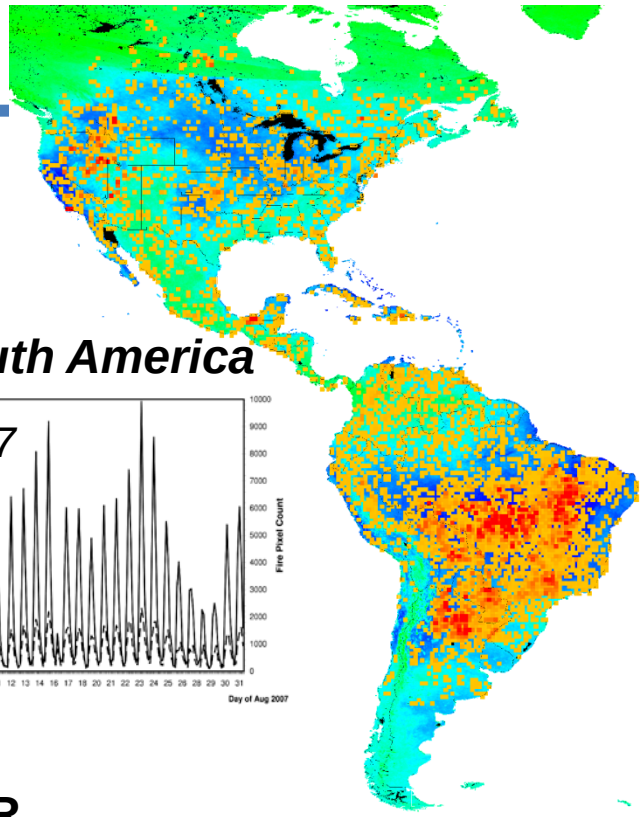




GOES East and West FRP (Jul 07)

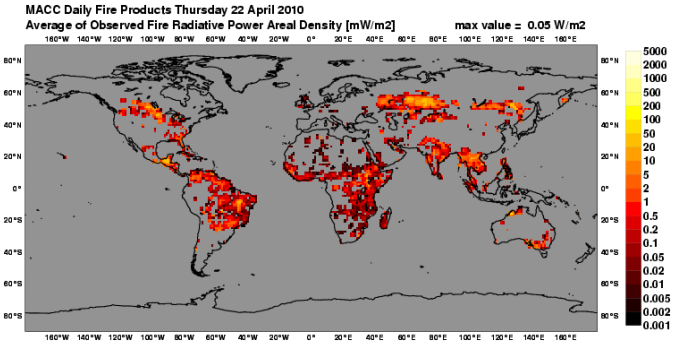
North America





South America

New Global Product from Sentinel-3 SLSTR



- Similar to MODIS FRP Product (13+ yr record)
- SLSTR 15+ yr record

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FRP-Derived Biomass Burning Emissions "Climatologies"

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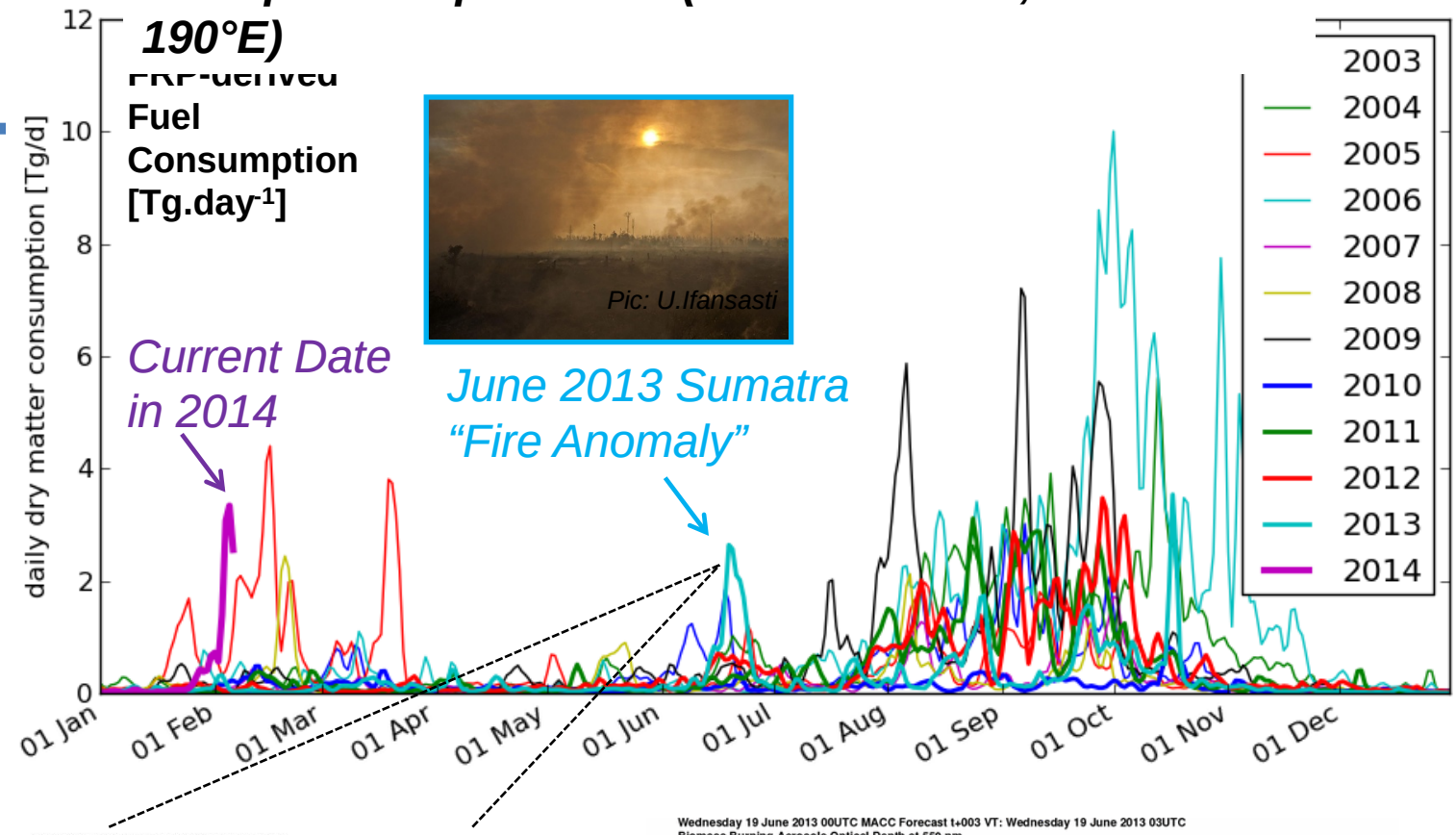
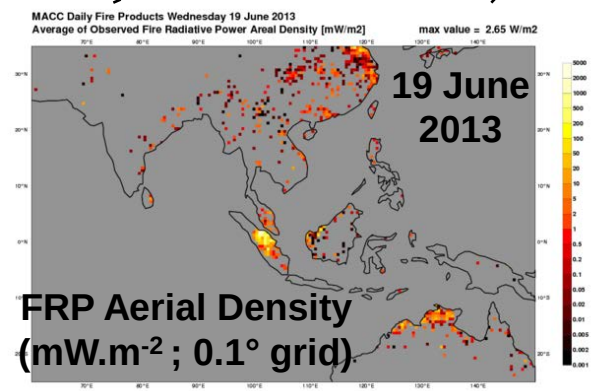
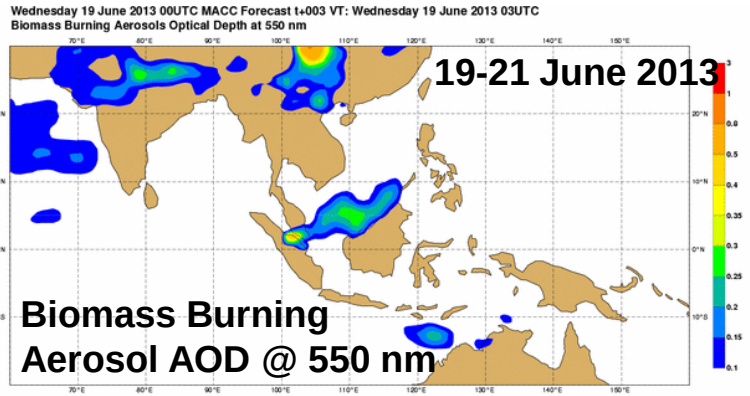
Copernicus Atmosphere Service

Example of Topical Asia (-10° to + 10° N, 60° to 190°E)







2003-2014 Data

- Two main fire seasons, Feb-Apr & Aug-Nov.
- Some anomalies departing from the norm, such as Oct 06 extreme and June 13 anomaly in Sumatra (below).

June 13 Sumatran peatland fires were responsible for worst air pollution ever measured in Singapore (PSI> 400)

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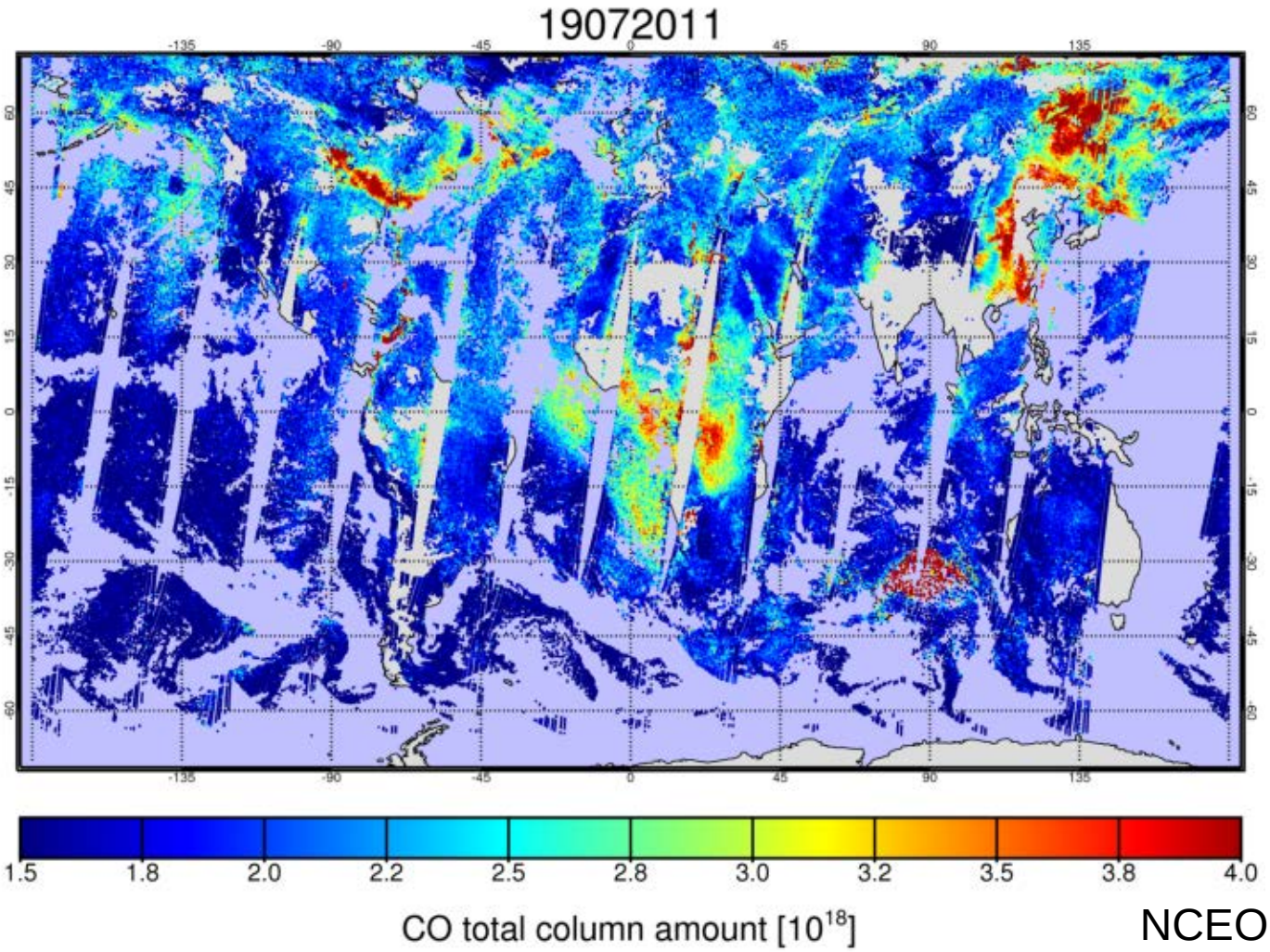
Tropospheric CO columns: with vertical information



NCEO-Leicester
IASI data

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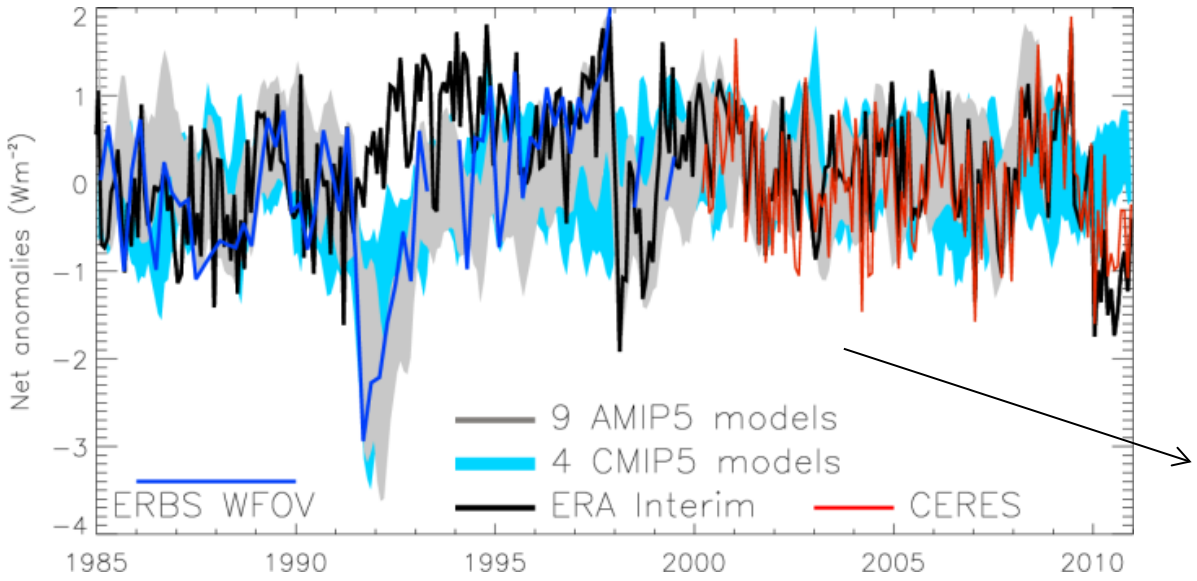
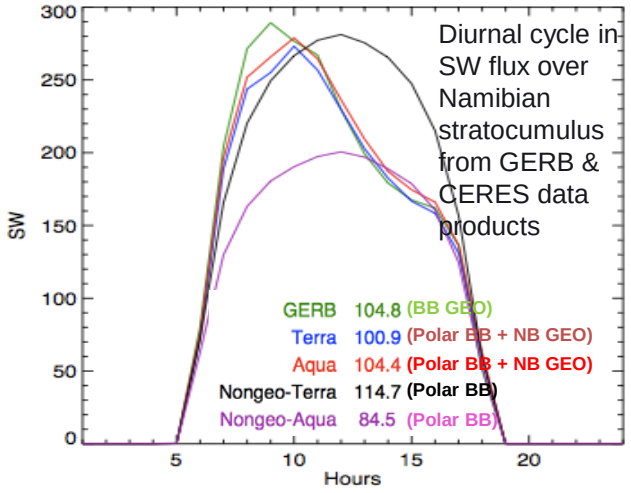
Monitoring the ERB with GERB

GERB: the world's only Earth Radiation Budget Instrument in Geostationary Orbit. Observations every fifteen minutes allow the impact of rapidly varying parameters on the Earth's energy balance to be assessed, accounted for and properly sampled longer term averages to be created

GERB data are: used in international efforts to quantify long-term variability in the global radiation budget





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EO data-model comparisons

- Direct EO data-model comparisons provide a (biased) insight into current model ability
- Particularly important at interfaces
  - UKESM models
  - Physical climate (atmosphere-ocean) coupled to ocean and land carbon, and climate-chemistry (with aerosols)
  - Multi-model comparisons ideal
- Comparisons can also provide constraints on model predictions.

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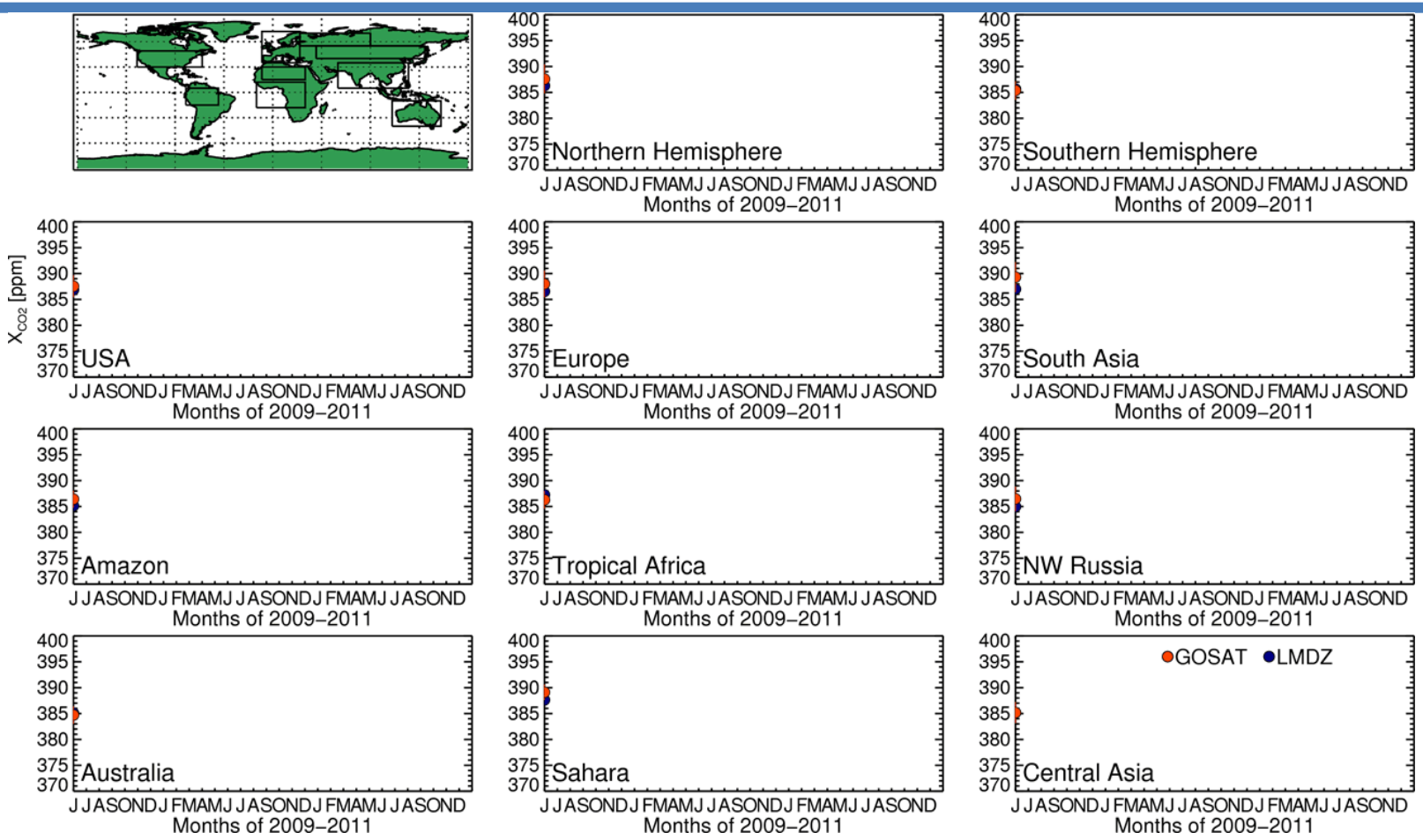
CO_2 Timeseries: Satellite vs Model



Regional Timeseries of X_{CO2} from the GOSAT Satellite (red) retrieved at the University of Leicester compared to a LMDZ model run (blue)

Testing Fast Chemistry: CCMVal Grading Matrix

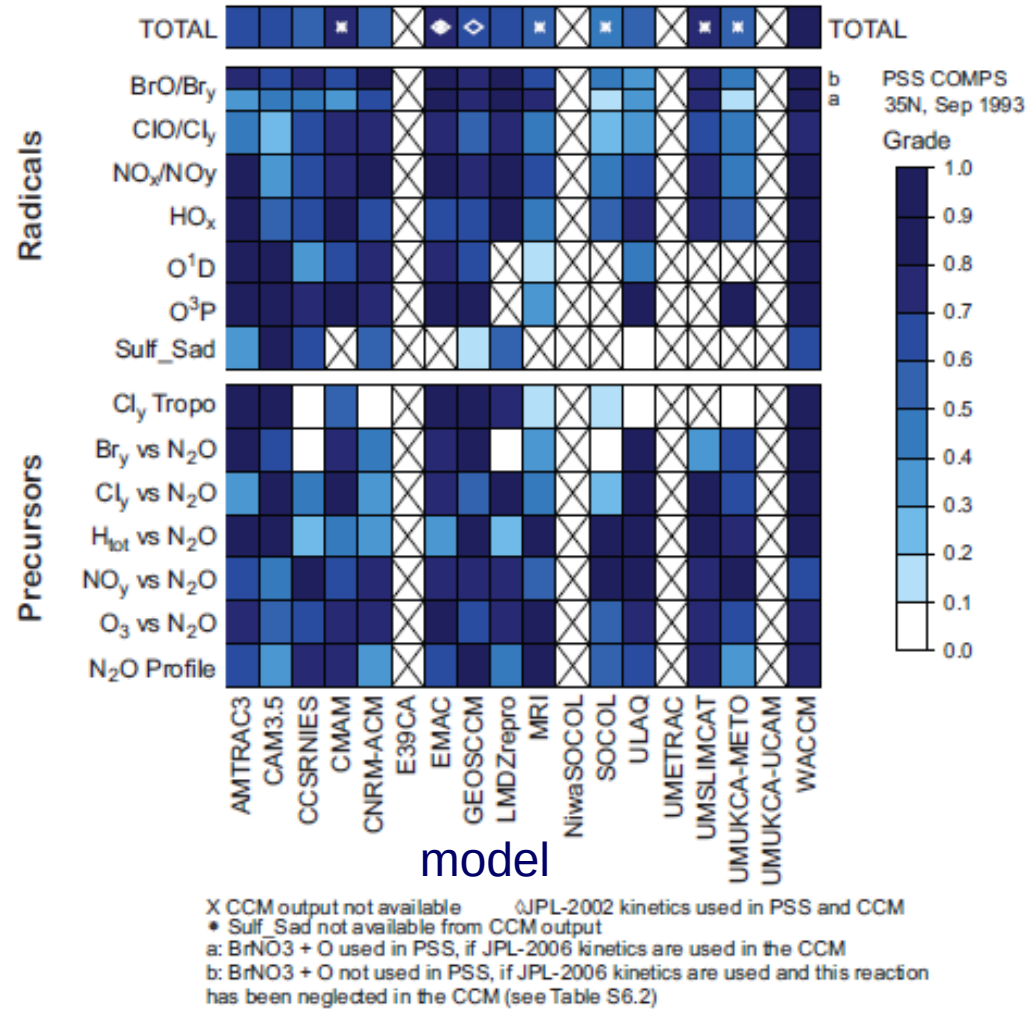


Figure 6.10: Metrics for (bottom) radical precursors and (top) sulfate surface area and radicals for a simulation carried out at 35°N, September 1993. The same dark shade of blue is used for $0.8 < g < 1.0$, reflecting that there is little significance in differences that fall within this range of values. The symbol X denotes CCM output not archived; ◊ denotes use of JPL-2002 kinetics, and * denotes sulfate SAD not archived (see text). For model that used JPL-2006 kinetics and neglected the $BrONO_2$+O reaction, two grades are given for the evaluation of BrO/Br_y (see text).

- Example of one of ~100 diagnostics.
- Wide range of grades, for different diagnostics and different models.
- Ability of CCMs to simulate processes varies between processes.

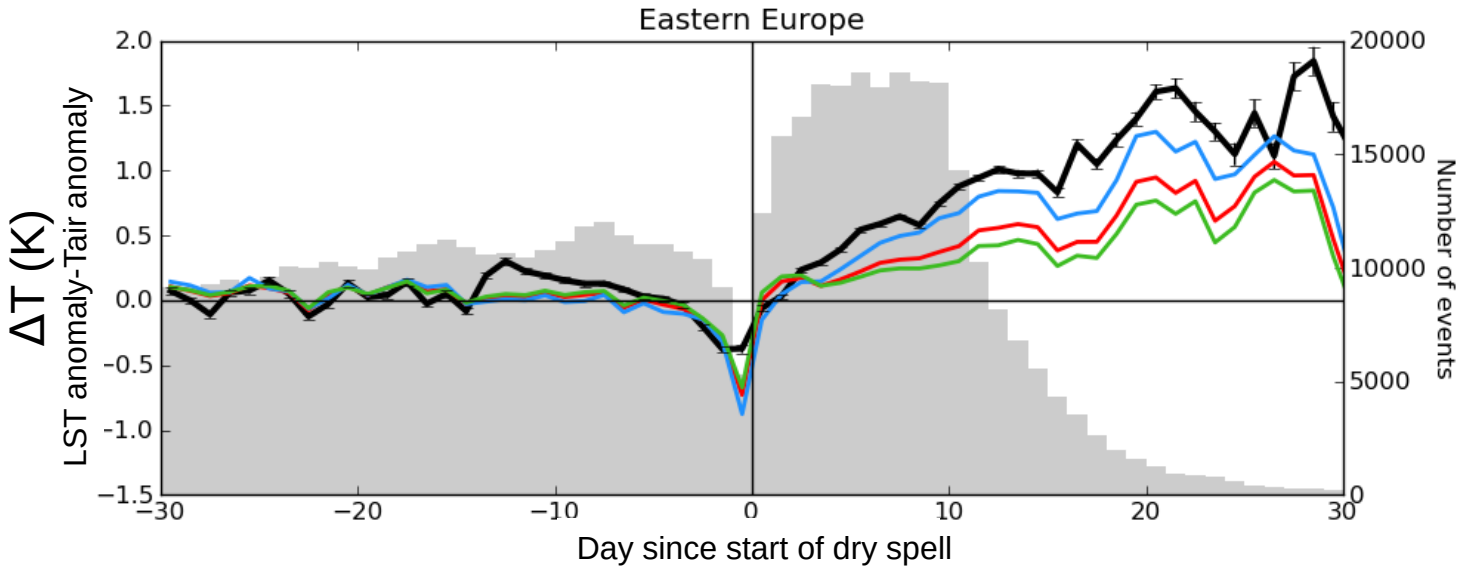
Chapter 6, SPARC CCMVal (2010)

UNIVERSITY OF LEEDS

LST evaluation of soil moisture control

Land models designed for a data-poor environment, but satellite data change the game

e.g. using Land Surface Temperature to evaluate soil hydrological control in JULES



MODIS observations
Standard JULES
JULES shallow roots
JULES deep roots

Harris et al in prep

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EO Data-Model Capability areas

- Terrestrial carbon and vegetation.
- Climate-composition interactions.
- Energy, flux and water cycle.
- Integrated climate data-model systems

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EO data-models Objectives

- World-class scientific capability for observing and evaluating environmental change globally and across domains
- Core capability with the expertise to generate leading EO data sets and derive the novel EO algorithms and missions of tomorrow.
- Tools [platform] for evaluating core models with high quality EO data.

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Data Assimilation

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EO data assimilation

- Direct assimilation of data into models can in principle inform the science.
- Needs very good data sets
- Needs “compatible” models
- Needs good understanding of increasingly complex mathematical theory.

CARDAMOM DALEC:
a terrestrial ecosystem carbon cycle analysis

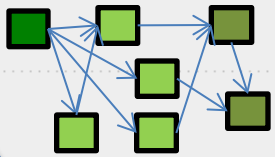
Posterior DALEC Parameter Probability
1° x 1° Pixel Scale Parameter, Flux & carbon pool estimates

C state likelihood function = observation likelihood & parameter priors
No spin-up
No PFTs
No Steady state

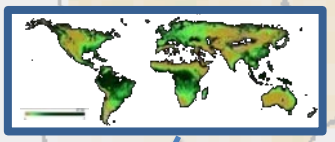
Biometric Data Constraints

Drivers:
ERA-interim 1° x 1° resolution 8-day time-step 2001-2010

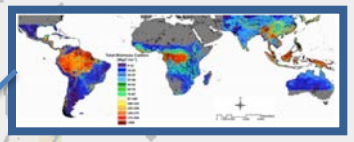
DALEC model



MODIS LAI time series



Pan-Tropical Biomass



Saatchi et al. 2011

HWSD Soil Organic C

Hiederer & Köchy, 2012

$$p(x|c) \propto p(c|x)\, p(x)$$

Parameter probability **p(x|c)** at each pixel derived using a Metropolis-Hastings MCMC algorithm

Dynamic & ecological data independent constraints.

Bloom et al., 2013, in prep.

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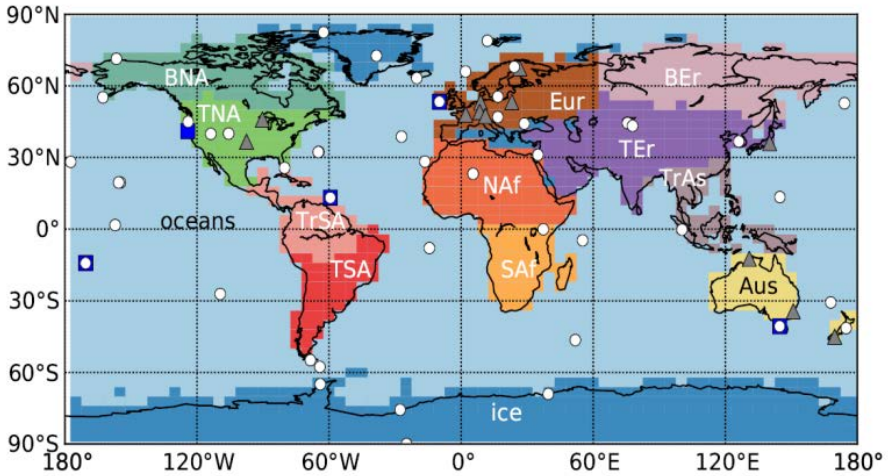
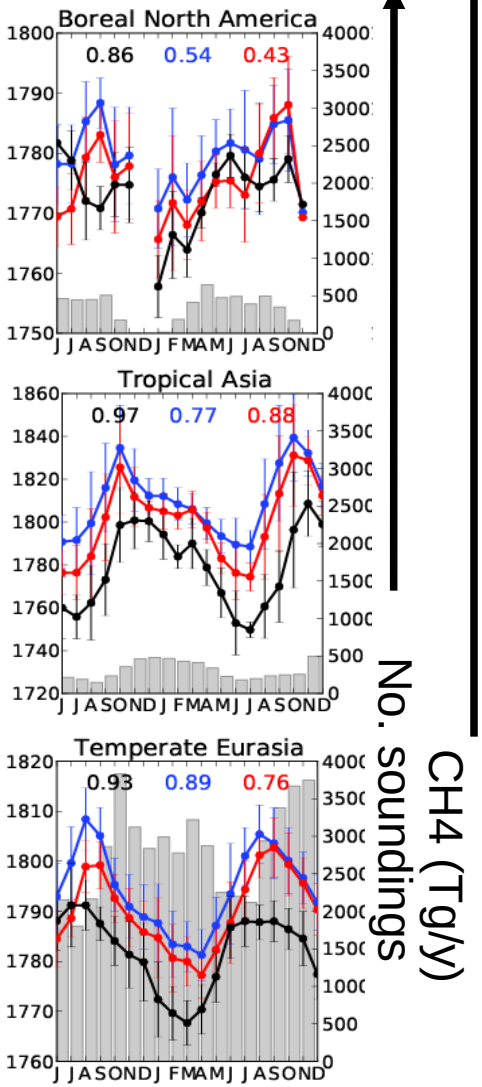
Estimating regional methane fluxes

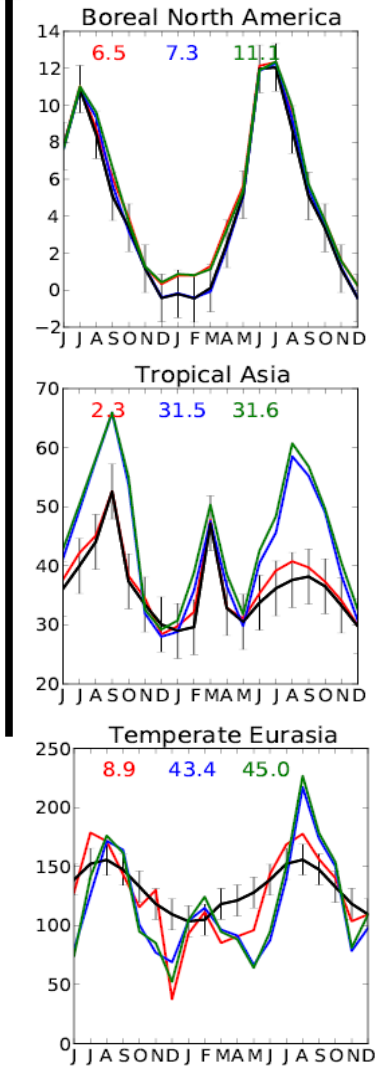
- ★ XCH_4 data from GOSAT (Jun'09 – Dec'11) and flask data from 57 sites
- ★ GEOS-Chem model with global emission inventories
- ★ EnKF flux inversion on monthly intervals for 13 regions
- ★ Fraser et al., ACP, 2013



GOSAT and model XCH4

CH4 fluxes: prior, surface, GOSAT, GOSAT + surface





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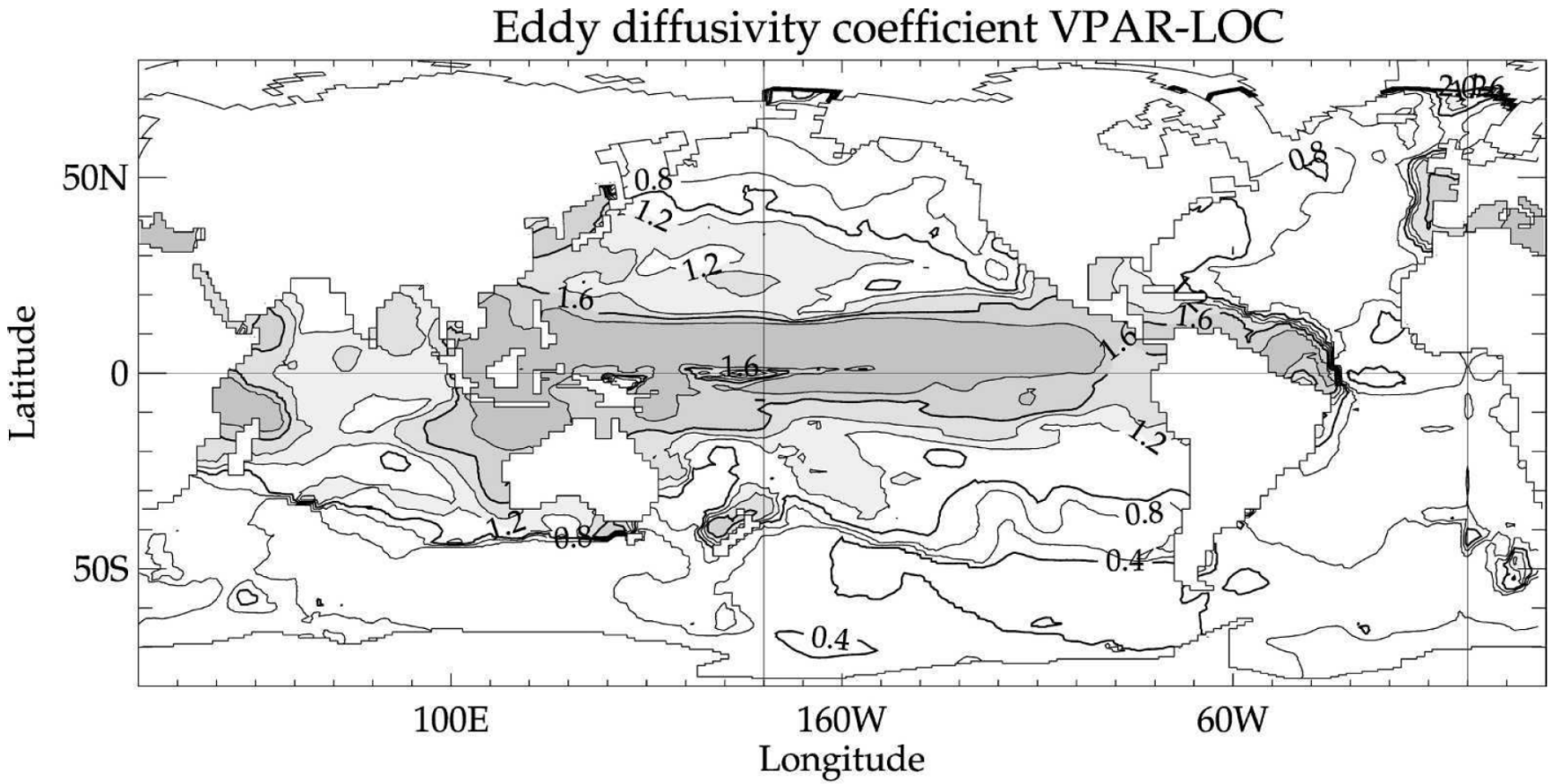
Parameter estimation using Standard Particle filter

Global ocean model 0.5M mixing parameters (state vector 3M)
Assimilating sea-surface heights



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DA Capability areas

- DA framework and theory
- Land-surface DA
- Ocean-atmosphere DA
- Atmosphere-surface DA and inverse modelling

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Data Assimilation objectives

- Accessible core models which can be used for assimilation experiments (and OSSEs)
- Common framework (sequential) for DA in core models; adjoint techniques. [platform]
- Data consistent state and parameter estimation for better representation, initialisation and driving of models
- New theoretical DA techniques for the challenges of tomorrow

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EO Instruments and Facilities

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EO Instruments and Facilities

- Essential for an NCEO able to be expert across scientific EO:
  - Instruments platform
  - Big data, NRT data platform
- Underpinning radiative transfer expertise
- UK Liaison with NERC Centres (aircraft, data); CEOI

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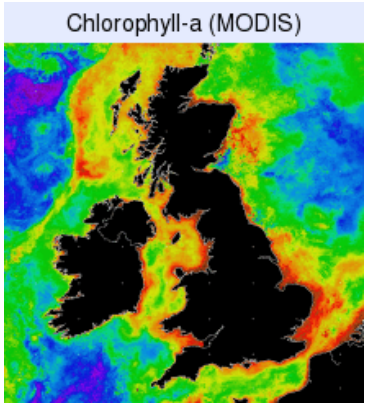
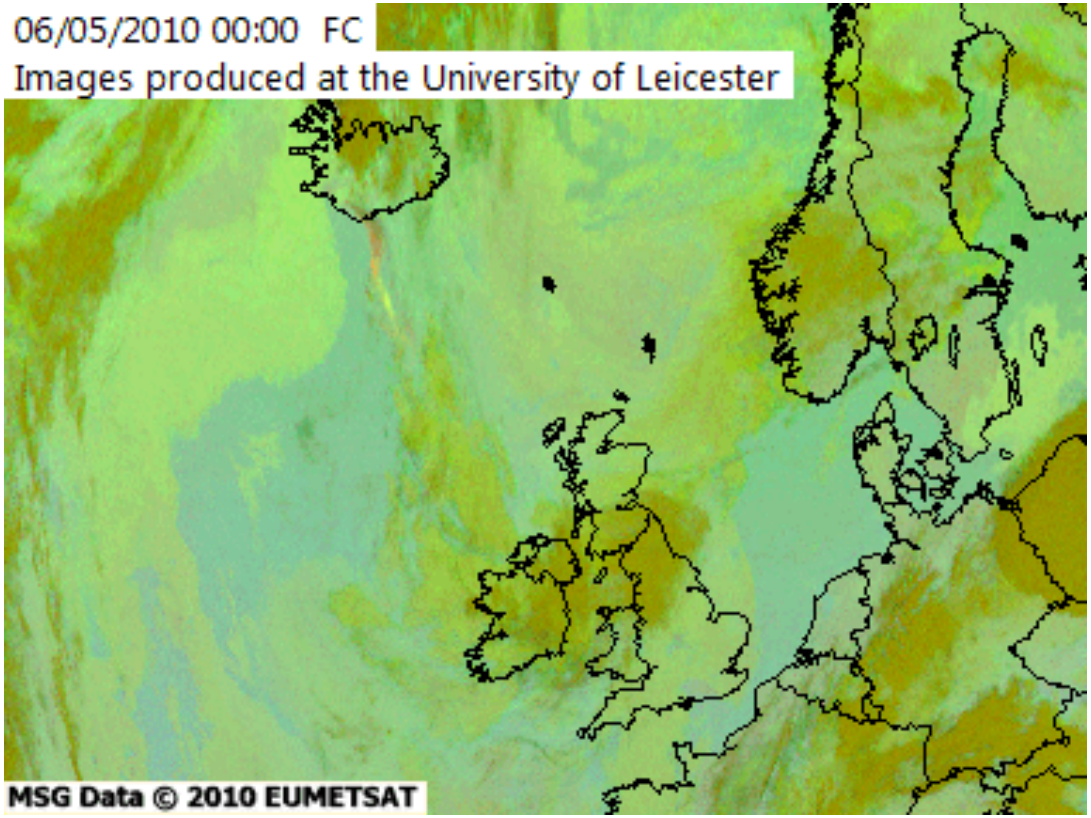
EO Instruments and Facilities

- Instruments: FSF (Edinburgh)+ NCEO instruments (space infrastructure)
- Data Facilities: NEODAAS (PML, Dundee), CEDA-EO and CEMS
- EO Radiative Transfer: Land and atmospheric models, surface and atmosphere spectroscopy



CEMS near-real time demonstrator – Detecting volcanic ash from space



- 2010 Iceland event
- Images available at up to 5 minute intervals from SEVIRI Rapid-Scan service
- Applications of NRT service:
  - Volcanic eruption monitoring
  - Storm events + other weather events
  - Educational outreach activities (schools)

Key
Volcanic ash
Thick Cloud
Warm surface

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EO Instruments/Facilities Capability areas

- Remote sensing field instrumentation and associated facilities
- Data facilities
- EO Rapid Response and NRT
- EO radiative transfer

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EO Instruments/Facilities Objectives

- To support the NCEO and wider NERC community with access to significant remote sensing instrumentation, facilities and measurement expertise
- To be an integral component of NERC's provision of EO data to its communities, and internationally, working with Big Data initiatives
- To deliver underpinning EO radiative transfer which is necessary for exploitation.

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NCEO going forwards

- Existing portfolio of NCEO science
- A high level sense of direction for long-term science
  - Major science challenges of today and tomorrow
  - Capability: national and NCEO
  - Capacity and facility
  - Serving the community
  - External partnerships
- New major NERC programmes, e.g. UK Earth System Model (UKESM), Big data initiatives, Instrumentation

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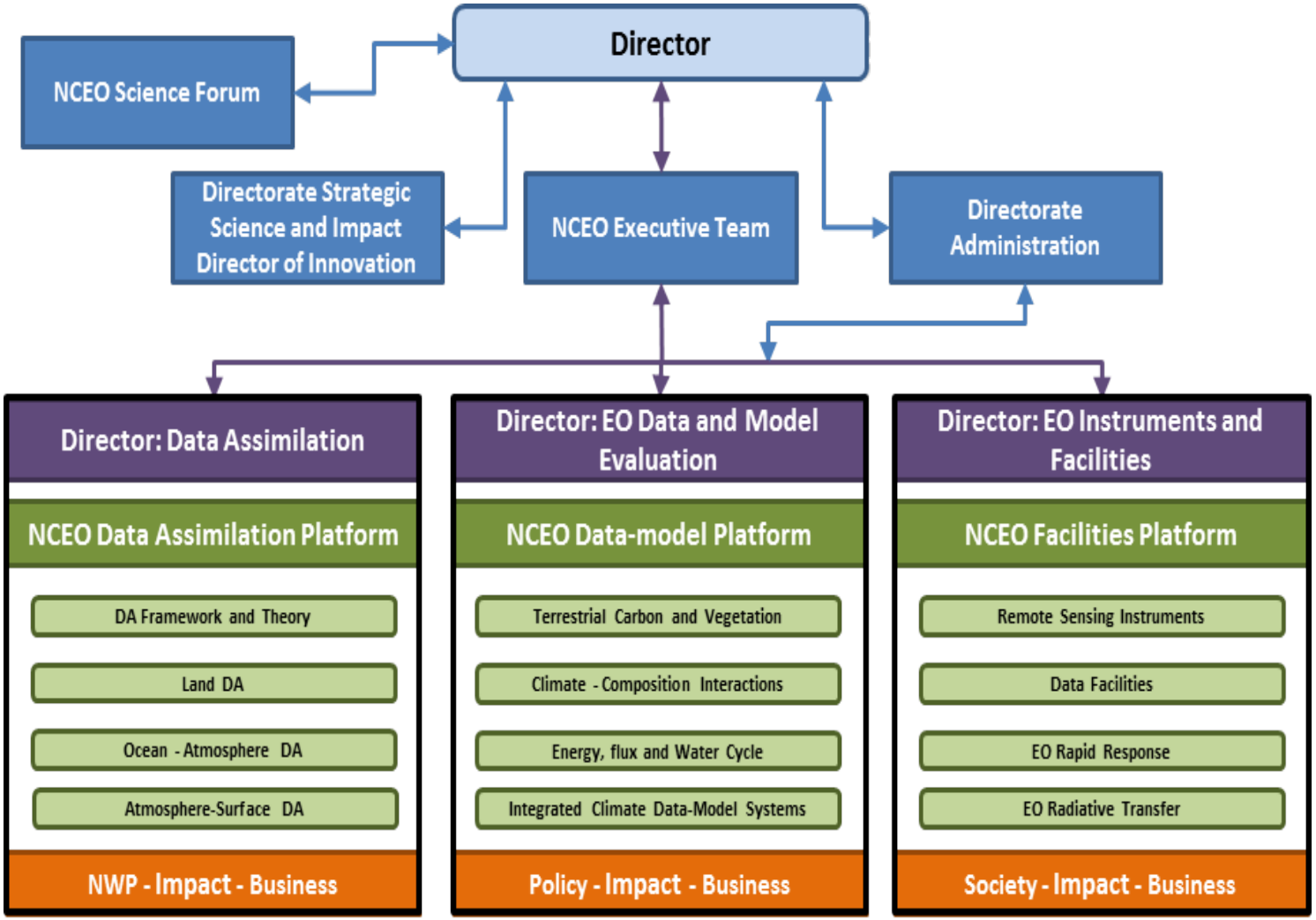
A Structure for NCEO



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NERC partnerships

- NERC Centres
  - Integrative NC
  - CEH, PML, NOC
  - EO Forum
- NERC community
  - EO data
  - NCEO facilities
  - EO data-model tools
  - Core DA
- Champion for NERC EO with external agencies

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External partnerships

- UK Space Agency
- Met Office
- Space Applications Catapult
- European Space Agency
- ECMWF

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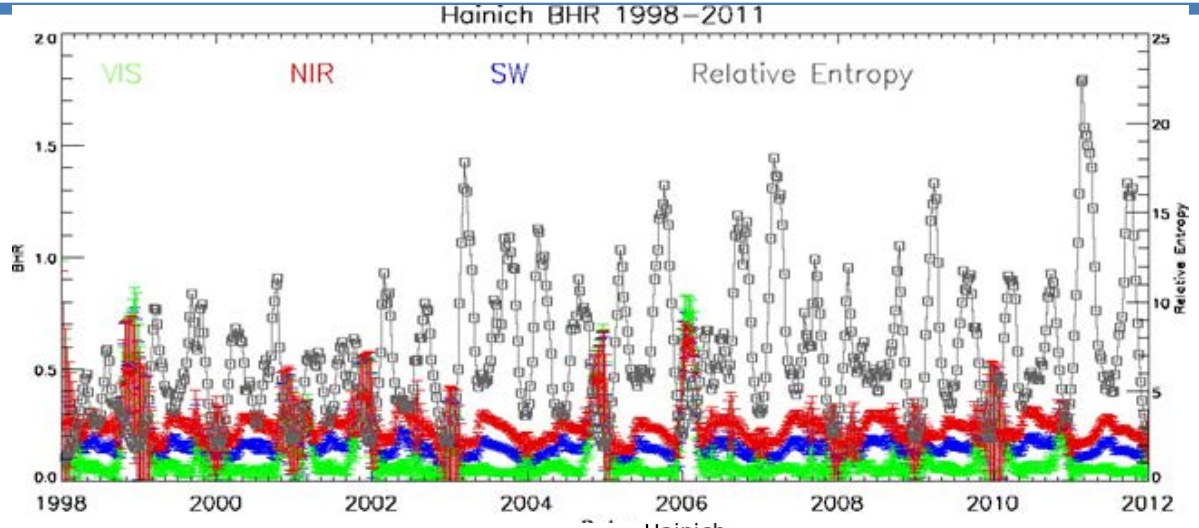
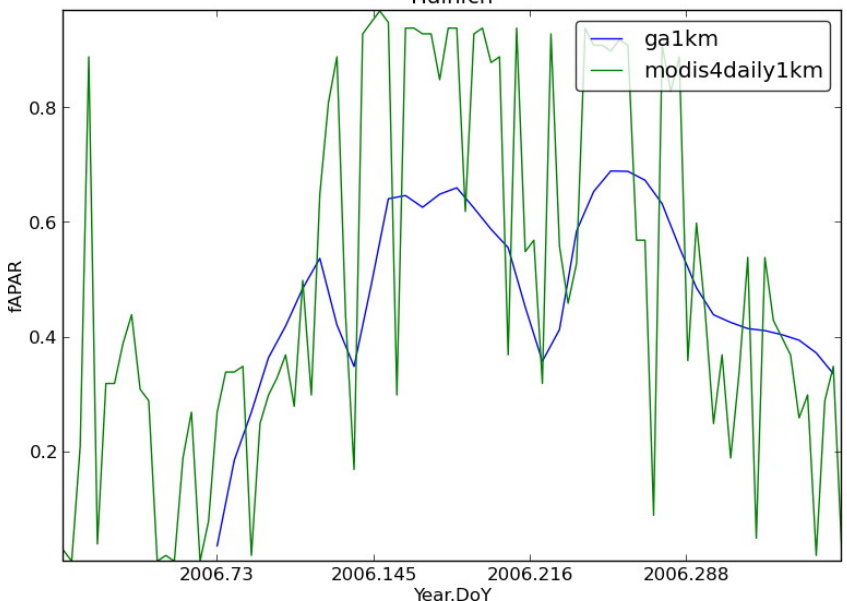
Albedo (ESA GlobAlbedo)



Bi-Hemispherical diffuse Reflectance [BHR]



Fraction of photosynthetically absorbed radiation [FAPAR]

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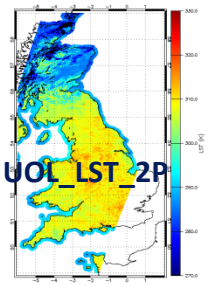
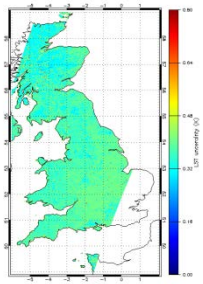
Land Surface Temperature

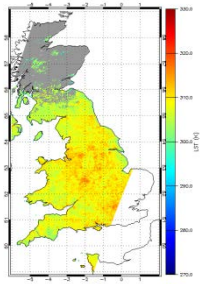
• Operational LST Data

- Release of new CEMS-processed state-of-the-art ESA operational Level-2 UOL_LST_2P dataset and NCEO Level-3 UOL_LST_3P at multiple resolutions on CEDA archive for science exploitation by NERC community





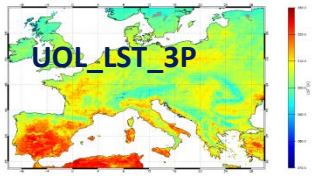
Full Uncertainty Budget for Data Assimilation



State-of-the-art Cloud Clearing

NetCDF-4 with CF-compliant metadata

Compatible with prototype SLSTR L2 LST data



GlobTemperature

NCEO-Leicester leading a large international consortium (including NCEO-Reading) to deliver the new GlobTemperature project under the Data User Element of ESA's 4th Earth Observation Envelope Programme

The project will deliver:

- **LST data from all major datasets in harmonised format with consistently generated uncertainty budgets**
- **The first global LST dataset which resolves the diurnal cycle**
- **The first long-term LST dataset of climate quality**
- **Increased engagement with the user community to promote the uptake of LST data**
- **A better understanding of the deficiencies in cloud clearing and improved masking**

- **Progress on deriving gridded level-2 LST data from MODIS instruments on Terra and Aqua satellites. Together with air temperature and soil moisture data this new dataset will be used to develop unique benchmark datasets for evaluating land surface models**
- **Two papers nearing submission on state-of-the-art AATSR LST retrieval scheme**

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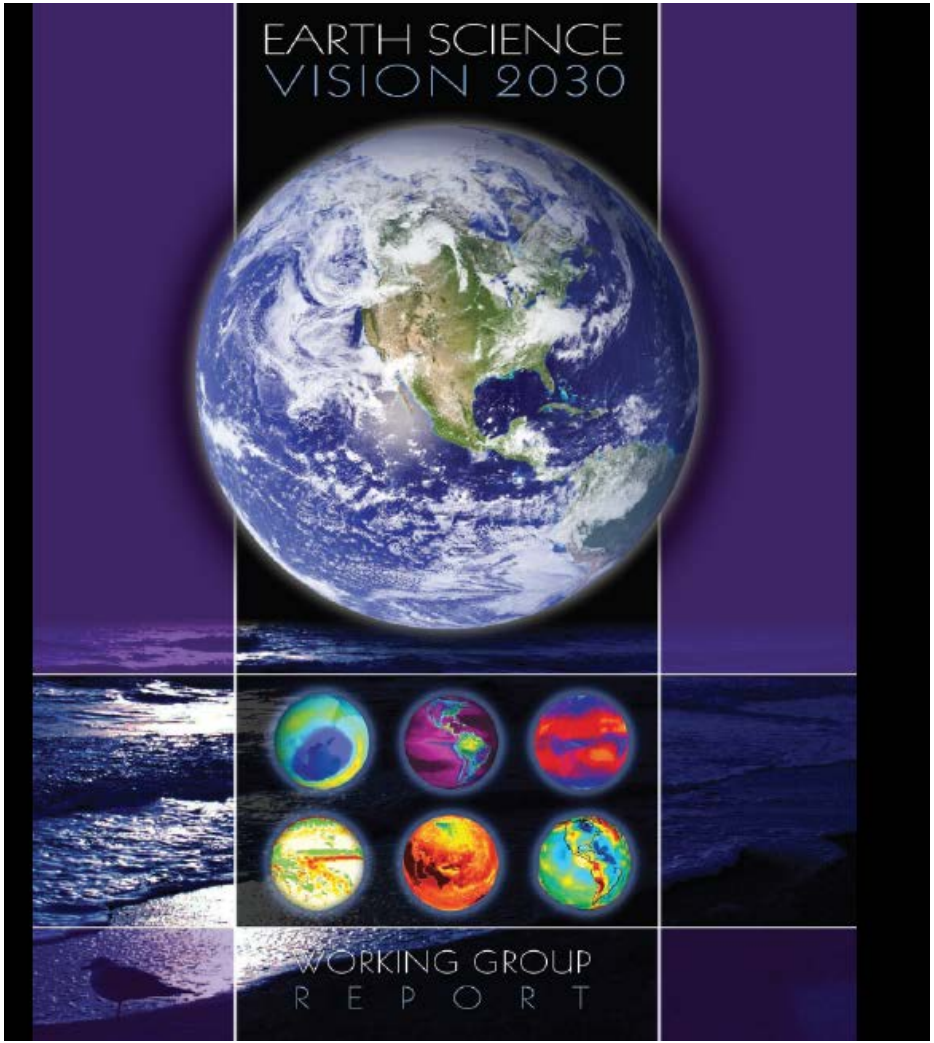
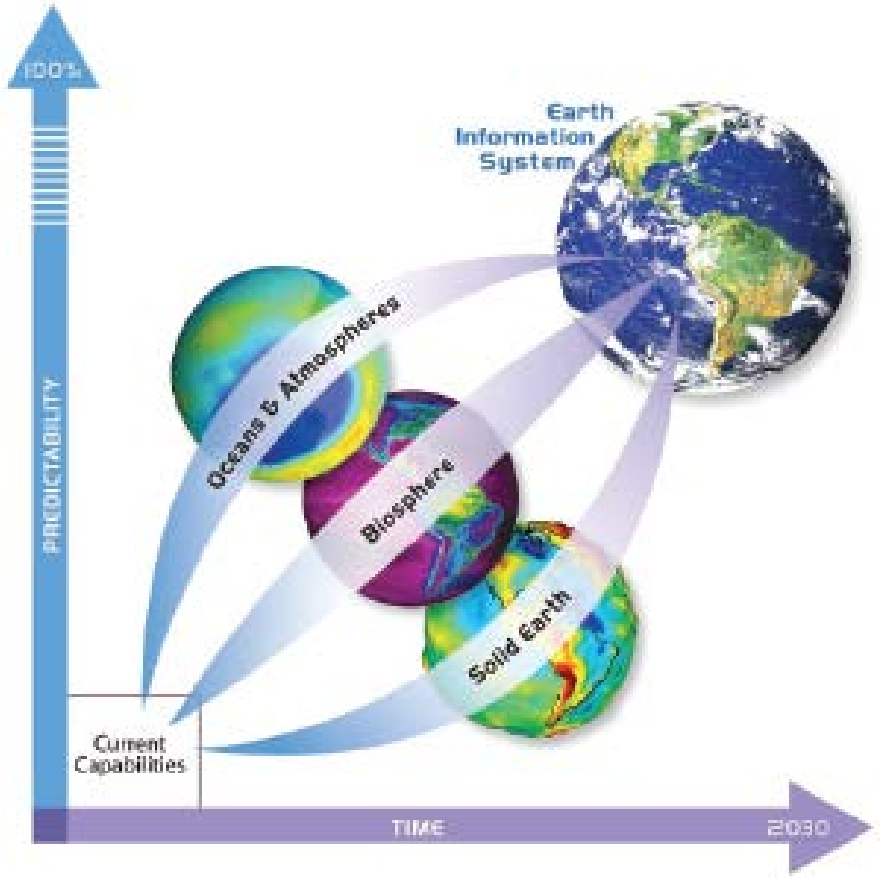
Science (and Society)





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(Science and) Society

Decadal Survey (NRC, 2007)

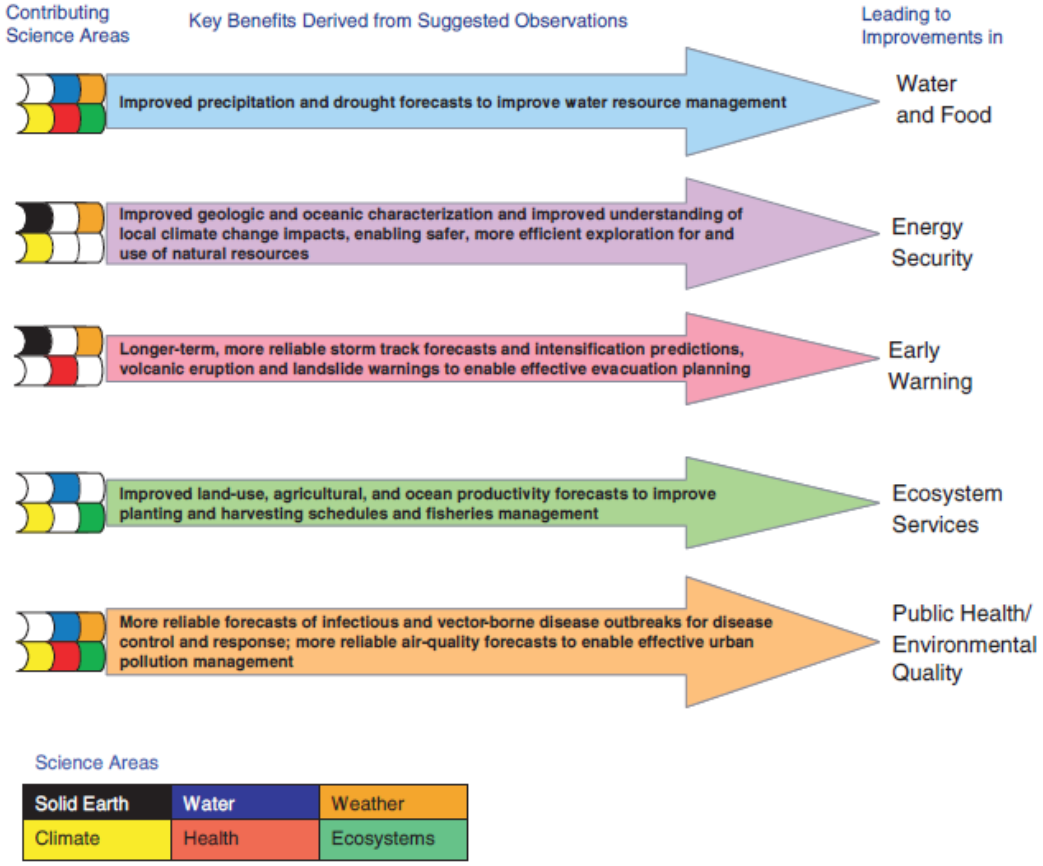

FIGURE 2.2 Addressing any given societal challenge requires scientific progress in many Earth system areas, as shown in these examples. Colored squares represent the scientific themes that contribute substantially to each of the selected benefit areas.

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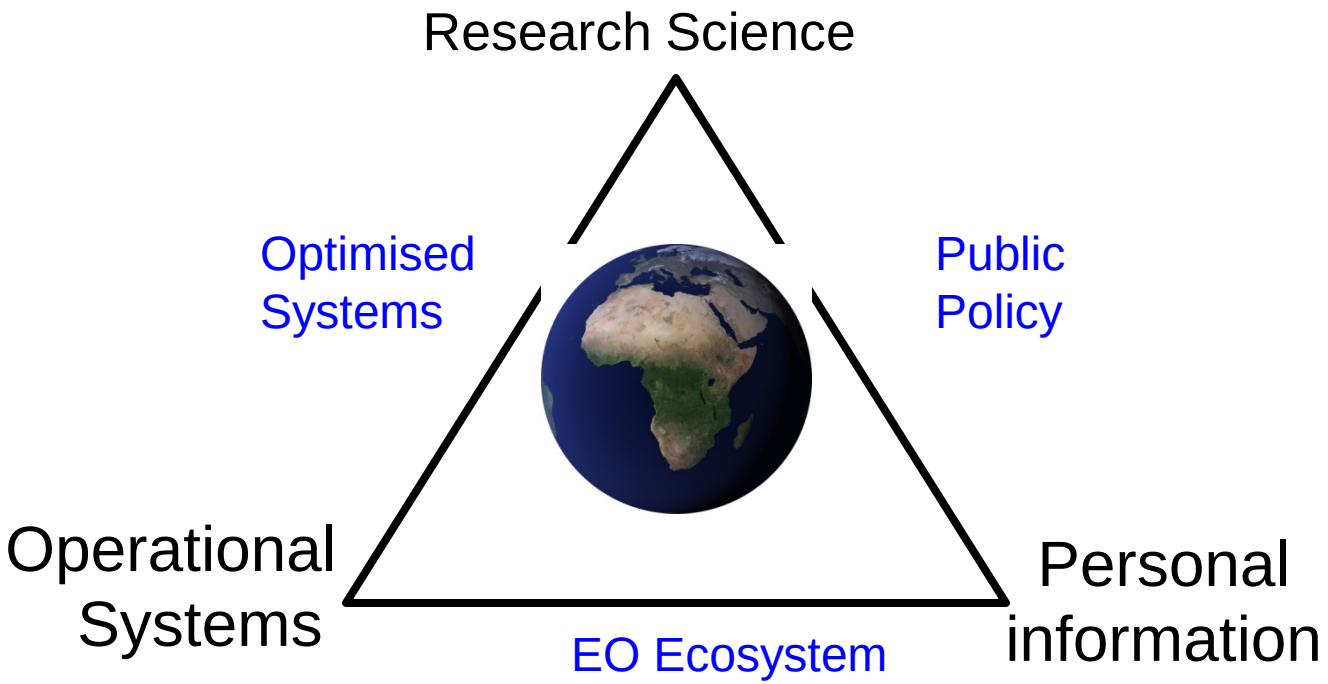
50 years forward

EO embedded in society



Impact of our work: the business of the environment

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A Business Plan for the National Centre for Earth Observation: NCEO 2014

NCEO 2014