Observation of the Changing Earth from Space

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European Geosciences Union – General Assembly

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Geoscience Information for Teachers (GIFT) Workshop
Austria Centre Vienna, 20 April 2009
Carbon cycle

Source: IPCC AR4-WGI, 2007
Earth Observation from Space Contributes to

- Detection and Exploitation of Windows of Predictability
- Warning of Geohazards and Mitigation of their Impacts
- Control of Compliance with International Law

Earth Observation from Space is the Backbone of Services

• established for weather forecasting
• in build-up phase for
  - oceanography
  - disaster prevention and mitigation
  - chemical weather forecast
Climate Data from Satellites (GCOS)

Source: GCOS IP 2004

<table>
<thead>
<tr>
<th>Domain</th>
<th>Essential Climate Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Atmospheric</strong></td>
<td><strong>Surface:</strong> Air temperature, Precipitation, Air pressure, Surface radiation budget, Wind speed and direction, Water vapour.</td>
</tr>
<tr>
<td></td>
<td><strong>Upper-air:</strong> Earth radiation budget (including solar irradiance), Upper-air temperature (including MSU radiances), Wind speed and direction, Water vapour, Cloud properties.</td>
</tr>
<tr>
<td></td>
<td><strong>Composition:</strong> Carbon dioxide, Methane, Ozone, Other long-lived greenhouse gases, Aerosol properties.</td>
</tr>
<tr>
<td><strong>Oceanic</strong></td>
<td><strong>Surface:</strong> Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Current, Ocean colour (for biological activity), Carbon dioxide partial pressure.</td>
</tr>
<tr>
<td></td>
<td><strong>Sub-surface:</strong> Temperature, Salinity, Current, Nutrients, Carbon, Ocean tracers, Phytoplankton.</td>
</tr>
<tr>
<td><strong>Terrestrial</strong></td>
<td>River discharge, Water use, Ground water, Lake levels, Snow cover, Glaciers and ice caps, Permafrost and seasonally-frozen ground, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (APAR), Leaf area index (LAI), Biomass, Fire disturbance.</td>
</tr>
</tbody>
</table>

- variable depends on satellite observations
Impact of Satellite Data on Forecast Skill

Source: The Changing Earth (SP-1304, ESA, 2006)

Increase in anomaly correlation of 500hPa height forecasts during recent decades is to a large extent due to the assimilation of satellite data.
HOAPS-G Freshwater Flux

HOAPS-G Freshwater-Flux JAN1988–DEC2005

www.hoaps.org  Freshwater-Flux [mm/d]  info@hoaps.org

Max-Planck-Institut für Meteorologie
## Trend Analyses with Satellites

<table>
<thead>
<tr>
<th>Variable</th>
<th>Start of Analysis</th>
<th>Observed Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level</td>
<td>1992</td>
<td>+ 3.2 ± 0.5 mm/a</td>
</tr>
<tr>
<td>SST</td>
<td>1991</td>
<td>+ 0.13 ± 0.03 °C/10a</td>
</tr>
<tr>
<td>ozone column</td>
<td>1978</td>
<td>intensification of ozone hole until 2006</td>
</tr>
<tr>
<td>nitrogen dioxide</td>
<td>1995</td>
<td>+ 50% over China</td>
</tr>
<tr>
<td>cloud albedo</td>
<td>1981</td>
<td>-2% over Europe due to pollution abatement policies and collapse of Soviet Union</td>
</tr>
<tr>
<td>solar output</td>
<td>1979</td>
<td>no trend</td>
</tr>
</tbody>
</table>
Observed Global Sea Level Rise

Source: The Changing Earth (SP-1304, ESA, 2006)

Sea level rise derived from several satellite altimeters
Decrease of cloud reflectance (unit: %) in thousandth from 1985-89 to 1996-99 for different mean reflectance classes as derived from AVHRR channel 2 satellite measurements over parts of Central Europe for winter (left) and summer (right) months. This is interpreted as a net reaction to less aerosol and soot emission after the breakdown of the eastern European industry production around 1990.
Cloud Reflectance and Ship Emissions

Source: A. Devasthale, 2006

Trend observed in monthly averaged cloud albedo (upper panel) and CTTs (lower panel) between May 97 and Aug. 02 for 3 harbour areas (R1, R3), the English Channel (R2) and a relatively remote ocean region (R4) clearly confirms the influence of increasing ship emissions.

In addition to an albedo increase the reduction of cloud top temperature hints at more intense convective activity in aerosol loaded clouds.
Understanding the Earth System

Schiffahrtsrouten

Courtesy of Steffen Beirle, Univ. Heidelberg, D

NO₂- column content observed by SCIAMACHY

10^{15} molecules/cm²

Increase in NO₂-concentration by 50%

Courtesy of John Burrows, Univ. Bremen, D

NO₂ above China, 110 - 125°E, 30 - 40°N

NO₂ column content observed by SCIAMACHY

Increase in NO₂-concentration by 50%

Copyright © 2006, Steffen Beirle

NO₂ column content observed by SCIAMACHY

Increase in NO₂-concentration by 50%

Copyright © 2006, John Burrows
Stability of the Solar Constant

Source: PMOD/WRC in Davos

Average minimum: 1365.561 ± 0.009 Wm⁻²
Difference between minima: -0.014 ± 0.007 Wm⁻²
Cycle amplitudes: 0.932 ± 0.019; 0.896 ± 0.020; 0.825 ± 0.017 Wm⁻²

0.1%
Challenges to be answered soon

- Source and sink distribution of CO, CH$_4$ and CO$_2$ by inverse modelling using data from ENVISAT, METOP

- Trends of cloudiness by better intercalibration of satellite series

- Phytoplankton time series through combination of CZCS, SeaWiFS, MODIS and MERIS
Did Earth Observation Influence International Law?

- yes, for the Montreal Protocol

- yes in parts, for EU climate policy if EU council decisions of March 2007 are implemented

- hopefully, for the follow-up to the Kyoto Protocol
Do we have a balanced European system of Earth Observation?

<table>
<thead>
<tr>
<th>Component</th>
<th>Institution</th>
<th>Purpose</th>
</tr>
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<tr>
<td>Earth Explorer Core and Opportunity Missions</td>
<td>ESA-EOEP</td>
<td>New observations with new technologies for understanding the Earth System</td>
</tr>
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</table>
| Operational Meteorological Satellites (built by ESA) | EUMETSAT                     | Improved weather forecasts  
Fundamental data for GMES services |
| Sentinel de la Terre (GMES operational satellite series) | European Commission + ESA   | New operational services within GMES as part of GEOSS                   |

Answer: Yes, soon
Thank you!