Fjernmåling. Jordobservasjoner - Envisat

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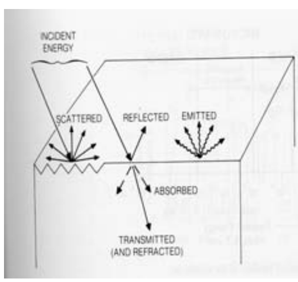
Fjernmåling av atmosfæren

Kan foregå fra bakken eller rommet (ballong, fly, satellitt, romferge)

- 3 prinsipper
- Målemetoder (delvis dekket av Stette i kap. 7)
- Anvendelser (miljøovervåkning, meteorologi)

3 teknikker

- Passiv måling: benytter sol lys som strålingskilde, kamera eller spektrofotometer som detektor.
- Passiv måling: benytter varmestråling fra jorda som strålingskilde, kamera eller spektrofotometer som detektor av re-emitert stråling fra atmosfæren
- Aktiv fjern måling (bruker strålingskilde (laser, radar, mikrobølgegenerator) og detekterer refleksjoner og spredt lys.



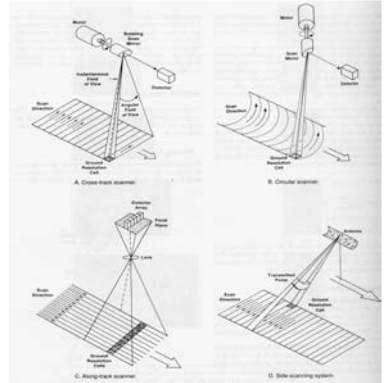
Detektorteknologi

- Solar radiation detectors
  - detector
    - CCD cameras (diodes)
    - photomultiplicators (Spectroradiometers)
  - filters
    - bandwidth narrow <10 nm
    - broad band 20-100 nm
  - field of view and direction (nadir)
  - different scanning modes (limb)
  - solar radiation (0.2 – 3 m)

- Radar
  - microwave transmitter and receiver
  - wavelength 100 – 1 cm
  - active (transmitter on the satelitte)
- Lidar
  - light transmitter (laser) and receiver
  - active sensing, only
- Thermal detector
  - ”temperatur sensors” from –20 Celsius to several hundred degree Celsius
  - wavelength 1000 – 7 m

Tracking

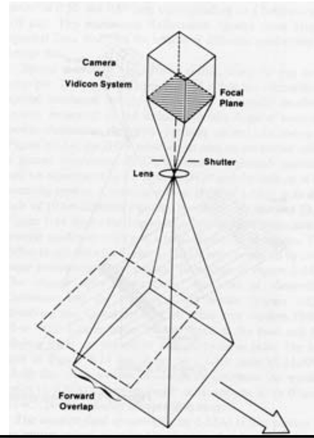
techniques



Billedbehandling

- Preprocessing
  - radiometric (wavelength bands, brightness, remove ”background” signal)
  - image matching (geometric correction by resampling)
  - image classification (meaning of each pixel different correlation procedures – neural network)
- Validation
  - field data (from ground)
  - other satelittes

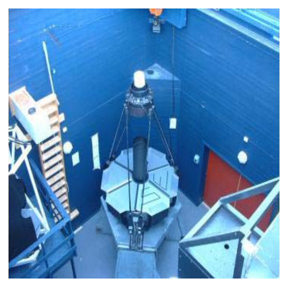
Overlapping



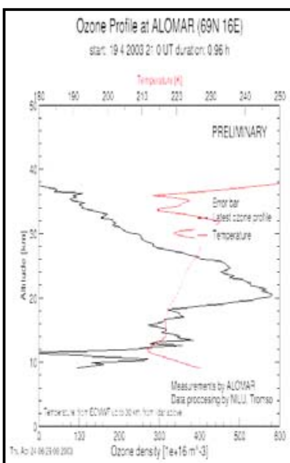
Aktiv fjernmåling

LIDAR
Fra bakken og fra rommet

Lidar
LIght Detection And Ranging
(similar to RADAR)

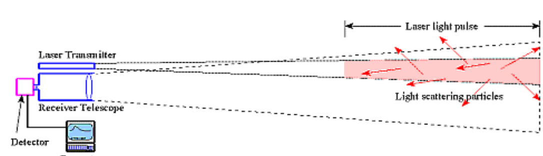


Bilde fra Alomar ved Andøay rakettstasjon, Lidar

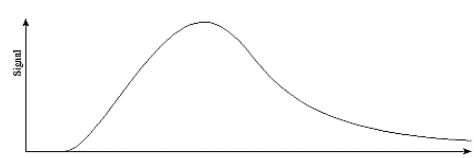


Profiles in the atmosphere

- temperature
- ozone
- aerosols
- OClO
- Na
- ....



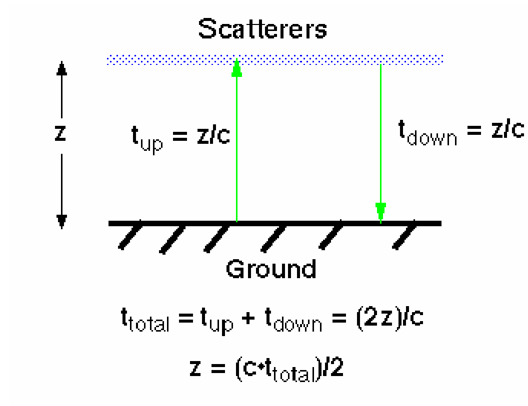
(a) Basic components of lidar



(b) Typical lidar signal as a function of range

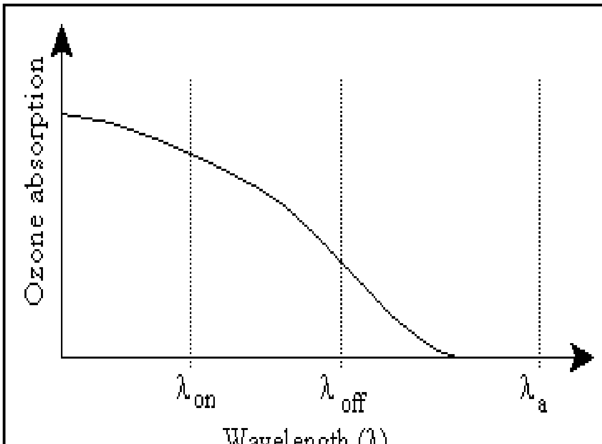
A lidar transmits short pulses of laser light into the atmosphere. The laser beam loses light to scattering as it travels. At each range, some of the light is backscattered into a detector. [Fig. 1a]

Because the light takes longer to return from the more distant ranges, the time delay of the return pulses can be converted to the corresponding distance between the atmospheric scatterer and the lidar. The end result is a profile of atmospheric scattering versus distance. [Fig. 1b] Analysis of this signal can yield information about the distribution of aerosols in the atmosphere. The amount of backscatter indicates the density of the scatters.



- A frequency shift in the light because of the Doppler effect permits measurement of wind speeds.
- By detecting the amount of depolarization, one can discriminate between liquid droplets and nonspherical ice particles.
- Differential Absorption Lidar (DIAL) uses absorption, as evidenced by reduced backscatter from greater distances, to measure the concentration of atmospheric gases.
- A Raman lidar detects particular atmospheric components (such as water vapor) by measuring the wavelength-shifted return from selected molecules.

- DIAL measurements of ozone require less precise laser frequency because ozone has a broad (~200 nm) absorption band instead of narrow lines lines like water vapor. This requires that the on- and off- wavelengths be chosen with sufficient wavelength separation to ensure a significant difference in their absorption.
- However, uncertainty in the changes of aerosol scattering and patterning between the wavelengths can introduce error. The difference in aerosol scattering at $_{on}$ and $_{off}$ can be extrapolated from a third measurement taken at a longer wavelength, $_{a}$.
- Therefore, DIAL measurements with three wavelengths can be used to determine ozone concentration profiles to good accuracy.

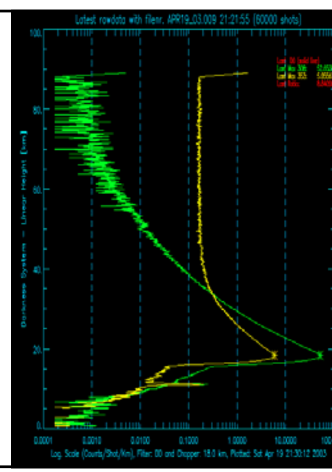


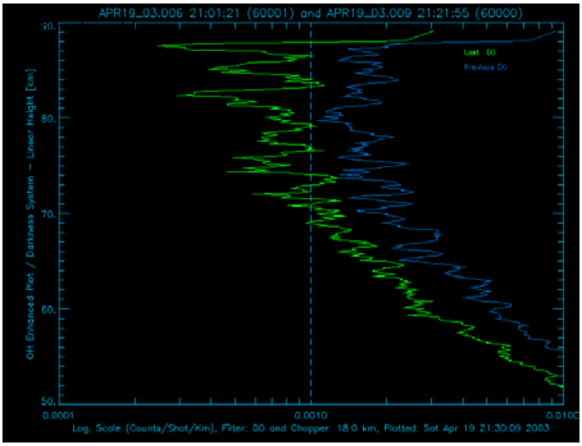
Reference:

http://alomar.rocketrange.no/ozon-latest-rawdata.html

Profiles of 308 nm and 353 nm laser light

Algorithms give ozone profiles





Passiv fjernmåling

Reflektert solstråling fra jorden og atmosfæren målt med instrumenter på satelitt

Satellitt: miljø overvåkning

1960 - Første værsatellitt kun til meteorologi (Tiros1)

1970 - Første miljøovervåkningsinstrument (ozon, BUV) Nimbus 4

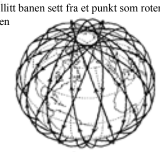
1972 – Landsat (jord observasjoner) NASA

1984 - Første rene klimaovervåknings satellitt. ERBS (Earth Radiation Budget Satellite, ERS 1 og 2)

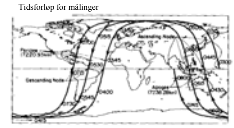
2002 – Envisat

Bane for miljøovervåknings-satellitter

Satellitt banen sett fra et punkt som roterer med jorden



Tidsforløp for målinger



- Meteo - satelittene - GEO
- Klima - satellittene - POLAR
- Høy ”inclination angle” - 96°-99° eller Low Earth orbit
- Dekker nesten hele kloden på et døgn.
- Deler av ekvator blir ikke dekket.
- Stort sett for man en observasjon pr. døgn pr. sted

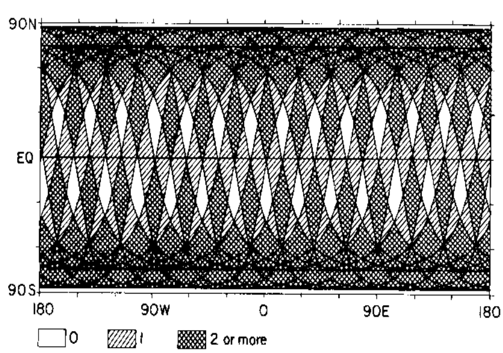
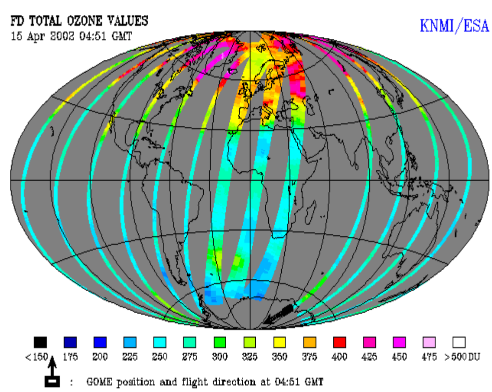
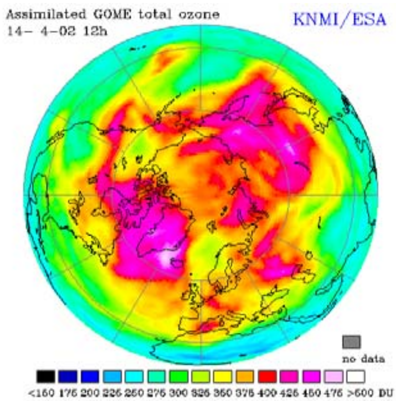


FIGURE 2.18. One day's coverage by a hypothetical instrument on a sunsynchronous satellite. The coverage at the equator is 50%. The orbit is circular with a semimajor axis of 7228 km and an inclination angle of 98.8°. Note that slightly different orbit parameters can result in quite different patterns.



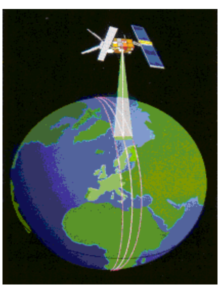
Averaged

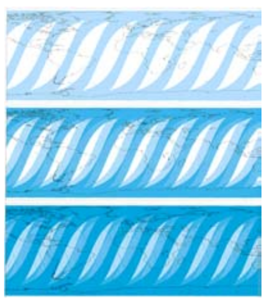


ERS 2 - ESA environmental satelite

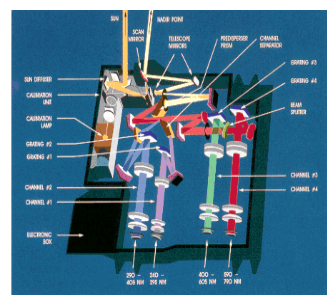
- ERS-2 flies in a sun-synchronous polar orbit with an inclination of 98 °, a mean altitude of 780 km, and a local time of 10.30 h of the equator crossing at the descending node. This results in an orbital period of approximately 100 minutes and a speed of the subsatellite point of 7 km/s.
- The instrument instantaneous field of views has been chosen to be 40 x 2 km, or 2.8° x 0.14 °.
- By movement of the scan mirror, this instantaneous field of view can be scanned across track. With a +/- 31 ° scan, a global coverage can be obtained within 3 days, except for a gap of approximately 4 ° around both poles. To overcome this limitation a special pole view mode has been included.

ERS 2 - covers the earth in 3 days

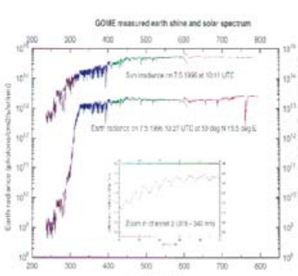




ERS2 - Gome
UV and visible spectroradiometer



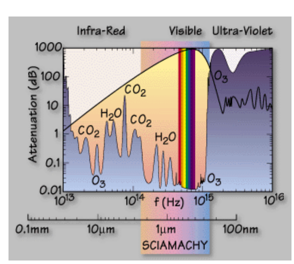
Instrumentering - optiske instrumenter



- Spektral instrumenter likt med bakkeinstrumenter
- Inngangsoptikk
- Monokromator (med gitter)
- Detektor

- Måler spekteret fra solen (øverste kurve)
- Måler spekter tilbakereflektert fra atmosfæren (nederste spekter)

Fjernmålingsalgoritme: fra strålingsmåling til mengde gass i atmosfæren.



- Stråling i atmosfæren
  - absorpsjon
  - spredning
  - refleksjon
- Algoritmer som omdanner solstrålingsmålingene til mengde gass.
- Mest benyttet: måling av absorpsjon ved to nærliggende bølgelengder.
- Forskjell i intensitet angir mengde absorberende stoff

Beer Lambert's law; Absorption

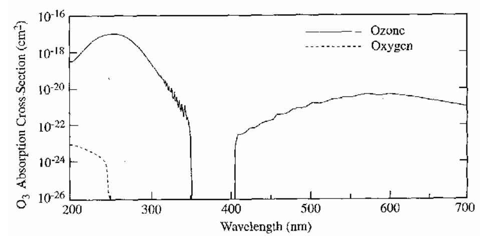
The ***optical depth*** of a medium   at a given distance z from 0 is defined by:

$$\tau = \int_0^z \sigma_n(\lambda) n(z) dz$$

where $_n(\ )$ is the ***cross section*** for the absorption process we are looking at, *n(z)* is the density of absorbing molecules per volume in the pathway. Note that this is wavelength dependent!

Example: ***absorption cross sections*** of ozone

Ex.: Absorption cross section, ozone



Scattering, Rayleigh

Rayleigh scattering is the process of scattering on air molecules. The scattering cross section of air molecules is given by:

$$\sigma_{Ray}(\lambda) = \frac{8\pi}{3}\left(\frac{2\pi}{\lambda}\right)^4 \alpha_p^2$$

What is important here is that this cross section ***increase with decreasing wavelength***.

The scattering cross section of air is larger for blue and ultraviolet than for visible radiation.

Extinction = absoption + scattering

When light is absorbed by a medium of optical thickness   the total optical thickness is a sum of all attenuation processes. For absorption and scattering processes:

$$\tau_t = \tau_{abs} + \tau_{scatt}$$

in general:

$$\tau_t = \sum \tau_i$$

In the atmosphere there are several absorption and scattering processes:

Ozone absorption (uv).

Scattering by clouds, by air and by aerosols.

The spectrum F(λ,z) is modified by the absorption of all atmospheric constituents integrated over the line-of-sight from the satellite to the star, according to the Beer-Lambert law. When only ozone absorption is considered (for simplicity) the spectru m can be written as:

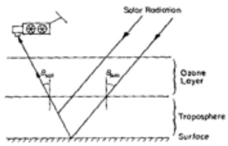
$$F(\lambda, z) = F_o(\lambda) e^{-\sigma_\lambda N(z)}$$

λ is the wavelength, z is the altitude of the line-of-sight above the horizon, N(z) (molecules/cm2) is the integrated quantity of ozone along the line-of-sight and σ the absorption cross section of ozone.

$$N(z) = -\frac{1}{\sigma_\lambda} \log\left(\frac{F(\lambda, z)}{F_o(\lambda)}\right)$$

Bestemmelse av mengde ozon.

- F( )=F_{sun}( ) $_{ozone}$· $_{rest}$ ($_{sun}$, $_{sat}$, $_{sfc}$, $_{air}$) radiance measured by the sat
- F_{sun}( ) = solar irradiance at the top of the atmosphere
- combined reflectance
- $_{ozone}$ must be solved
- $_{ozone}$ = exp[-σ_a( )U_{ozone}]
- U_{ozone} (mass of ozone per unit area) = density N_{ozone} • pathlength.
- N prop. $\log_{10}$[F($_1$)/F_{sun}($_1$)]
- Select two wavelengths $_1$ and $_2$ close to each other to remove $_{rest}$



Ozone measurements

If we now combine measurements from the two pairs 1 and 2:

$$\left(\frac{I}{I'}\right)_1\left(\frac{I}{I'}\right)_2=\left(\frac{I_0}{I_0'}\right)_1\left(\frac{I_0}{I_0'}\right)_2\left(\frac{\exp(-\tau_t m)}{\exp(-\tau_t' m)}\right)_1\left(\frac{\exp(-\tau_t\ m)}{\exp(-\tau_t' m)}\right)_1$$

If we rearrange and solve this for X as we did just for one pair we get

$$X_{12}=\frac{N_1-N_2-[(\tau_R-\tau_R')_1-(\tau_R-\tau_R')_2]m_R\frac{p}{p_0}-[(\tau_a-\tau_a')_1-(\tau_a-\tau_a')_2]m_a)}{\mu[(\alpha_{O3}-\alpha_{O3}')_1-(\alpha_{O3}-\alpha_{O3}')_2}$$

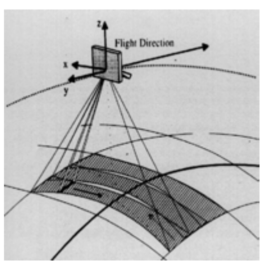
and now if we chose the second in a right manner we can remove the aerosol dependence $[(\tau_a-\tau_a')_1-(\tau_a-\tau_a')_2]m_a)$ and say that this cancel out. This leaves us with

$$X_{12}=\frac{N_1-N_2-[(\tau_R-\tau_R')_1-(\tau_R-\tau_R')_2]m_R\frac{p}{p_0}}{\mu[(\alpha_{O3}-\alpha_{O3}')_1-(\alpha_{O3}-\alpha_{O3}')_2]}$$

Since the airmass of rayleigh scattering and the airmass for rayleigh scattering is well known we only have to concern with the ozone absorption coefficients and ozone airmass μ. But these values has been calculated and exist in tables and hence we can get an estimate of the total ozone X_{12} in the atmosphere above the dobson instrument.

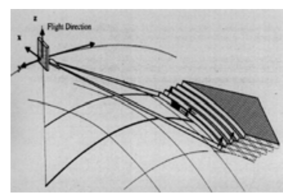
Ulike måleinstillinger - Nadir

- PRINCIPLE
- The instrument is scanning across-track with a selectable swath width of up to +/- 500 km with respect to the subsatellite track. This maximum swath ensure a global coverage with a maximum of three days at the equator.
- APPLICATIONS
- Determination of total column amounts of trace gazes
- Stratospheric and troposheric profiles of certain species at limited height resolution
- Cloud detection
- Aerosols
- Surface reflectance



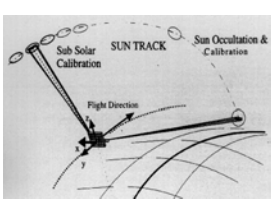
Ulike måleinstillinger - Limb

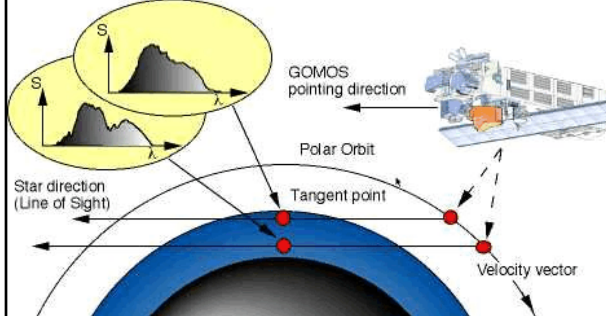
- PRINCIPLE
- Looking forward and starting at the Earth horizon the atmosphere is scanned tangentially over a 1000km swath.
- At the end of each azimuth scan, the elevation is increased by a step which correspond of a increase in altitude at the tangent point of 3 km. This basic scan pattern is reproduced until the maximum altitude of 100 km is reached.
- APPLICATIONS
- Determination of trace gas stratospheric profiles with a improved resolution (compared to nadir)
- Aerosol profiles

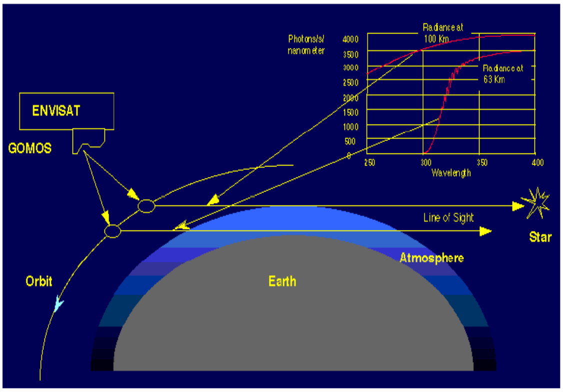


Ulike måleinnstillinger - Occultation

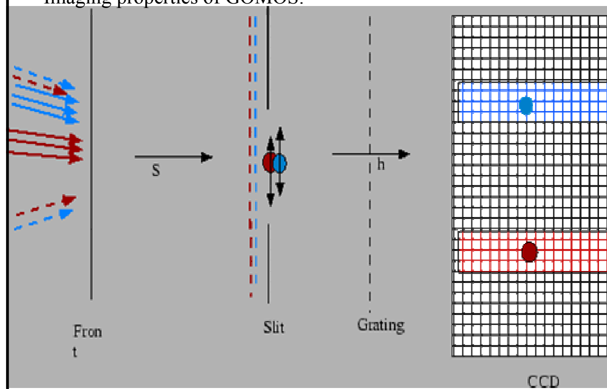
- Special for Gomos, on the new ENVISAT
- Selects a target , the sun or the moon and tracks it as soon as it comes above the horizon and until the line of sight reaches a maximum tangent height of 100 km.
- Spectra of the source radiation transmitted through the atmosphere are recorded during the complete sequence.
- APPLICATIONS
- Possible uses of occultations measurements are quite similar to limb measurements i.e. there are well suited to determine distribution profiles of trace gazes and aerosols.





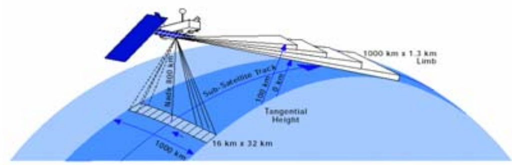


Imaging properties of GOMOS:



Ref: http://envisat.esa.int/dataproducts/gomos/CNTR1-1-1.htm

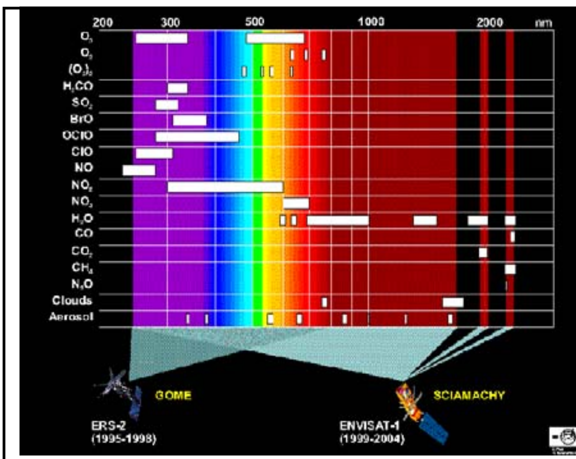
Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY)

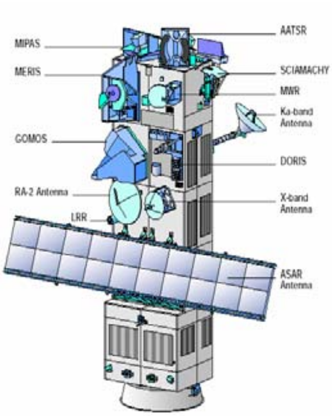


Envisat homepage:

http://envisat.esa.int/

esa





Platform:

ESA Developed Instruments (EDI's)

MERIS **(Medium Resolution Imaging Spectrometer)**

MIPAS **(Michelson Interferometric Passive Atmospheric Sounder)**

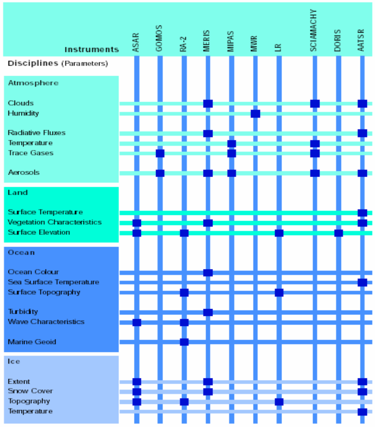
ASAR **(Advanced Synthetic Aperture Radar)**

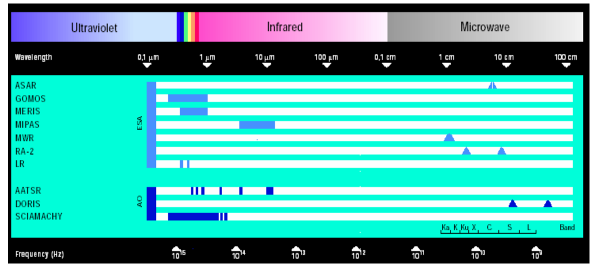
GOMOS **(Global Ozone Monitoring by Occultation of Stars)**

RA2 **(Radar Altimeter 2)**

MWR **(Microwave Radiometer)**

LRR **(Laser Retro Reflector)**





Observasjon av havet, produktspekteret til MERIS

ESA’s nye instrument på ENVISAT.
http://envisat.estec.esa.nl/index.html

- MERIS is designed to acquire 15 spectral bands in the 390 - 1040 nm.
- 15 spectral bands has been derived for oceanographic and interdisciplinary applications. Mulige anvendelser er angitt.

	Band centre (nm)	Bandwidth (nm)	Potential Applications
1	412.5	10	Yellow substance, turbidity
2	442.5	10	Chlorophyll absorption maximum
3	490	10	Chlorophyll, other pigments
4	510	10	Turbidity, suspended sediment, red tides

	Band centre (nm)	Bandwidth (nm)	Potential Applications
5	560	10	Chlorophyll reference, suspended sediment
6	620	10	Suspended sediment
7	665	10	Chlorophyll absorption
8	681.25	7.5	Chlorophyll fluorescence
9	705	10	Atmospheric correction, red edge
10	753.75	7.5	Oxygen absorption reference
11	760	2.5	Oxygen absorption R-branch
12	775	15	Aerosols, vegetation
13	865	20	Aerosols corrections over ocean
14	890	10	Water vapour absorption reference
15	900	10	Water vapour absorption, vegetation

Produksjon av instrumentering

- Høykvalitets instrumenter, samme prinsipp som brukt ellers.
- Krever utprøving, kalibrering og holdbarhetstester før oppsending
- Kalibreringsrutiner underveis
- Validering via bakkemålinger og fly, ballong ekspedisjoner
- Sammenligning av ulike satellitter

Different levels of dataproducts

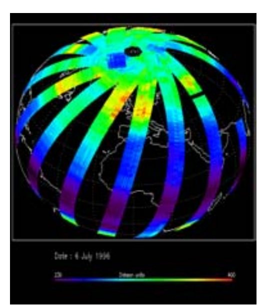
•Raw data: level 1 a

•Data retrieved from calibrated spectral irradiance measurements: level 1b.

•”Non” quality controlled daily images: level 2

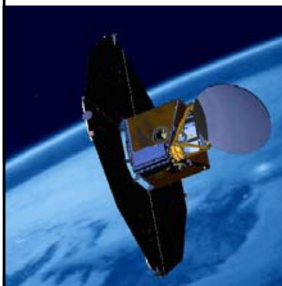
• Scientifical quality control: level 3 data,

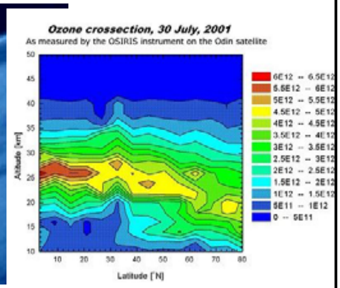
•(usually not official on web).



Svensk miljøsatelitt: Odin, skutt opp mars 2001

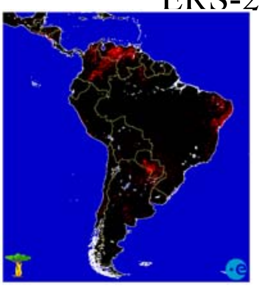
Webside: http://www.ssc.se/ssd/frameodinresults.html



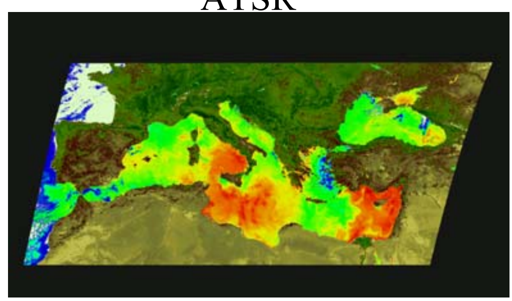


Jordobservasjon - miljøfysikk

Fire detection - 1993 January - February ERS-2 ATSR

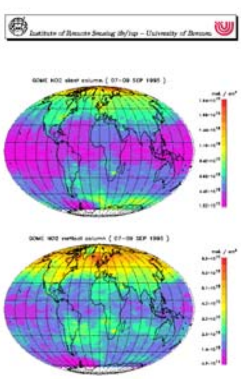


Sea surface temperatures - ERS-2 ATSR



ERS dataproducts

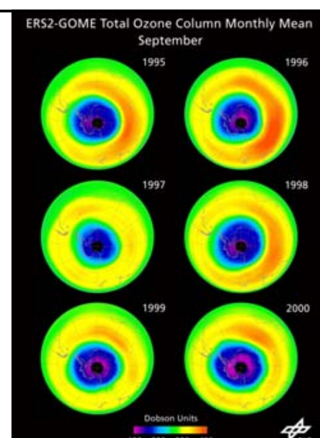
- Total coloumn Ozone
- Ozone profiles
- Nitrogen dioxide, NO2
- BrO, OClO, SO2
- aerosols (small particles >0.5   m)
- clouds
- albedo (reflection from ground and clouds)
- photochemistry studies



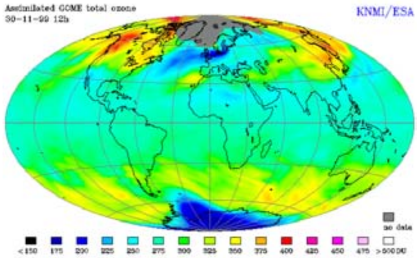
ESR2 GOME dataproducts

September Mean O3 coloumn for southern Hemisphere

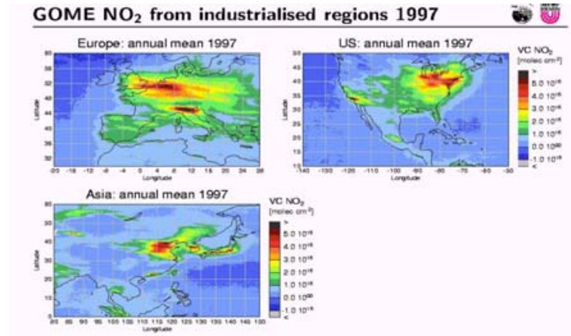
Product delivered by DLR Germany



ESR2 Gome Low O3 in Europe

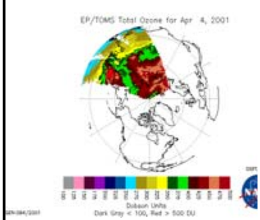


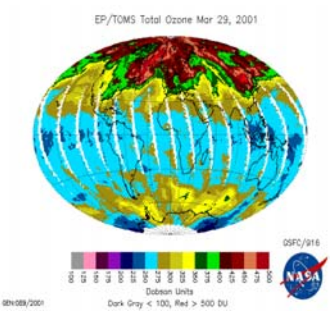
Annual means



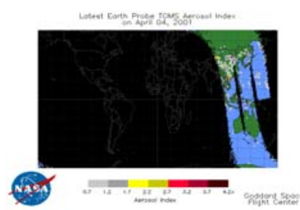
NASA - TOMS daily ozone - online

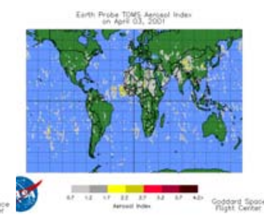
http://jwocky.gsfc.nasa.gov/TOMSmain.html



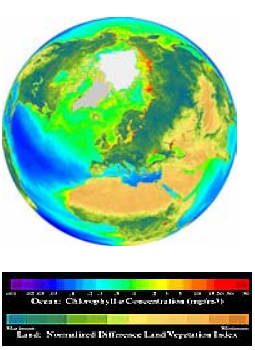


NASA - TOMS daily aerosols- online
http://jwocky.gsfc.nasa.gov/TOMSmain.html





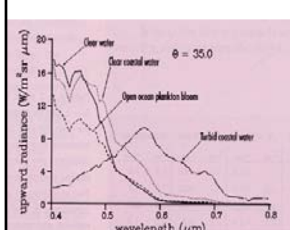
NASA - Observasjoner av havet.



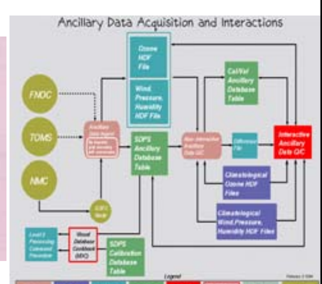
- NASA SeaWifs, fra september 1997
- Algoritmer for å omgjøre spektrale målinger til vannkvalitet
- Atmosfære transmisjon må korrigeres for

Nadirmålinger - algoritmer - havtilstand

Spektrale målinger rett over havoverflaten



Korrigering for atmosfæren



SeaWifts dekning

seawifs_daily_coverage[1].mpeg

Interessante lenker:

Satelitter

http://envisat.esa.int (envisat, homepage)

http://eopi.esa.int (ESA earth observation , principle investigator portal)

http://www.ssc.se/ssd/ (odin, miljøovervåkning

http://eos-chem.gsfc.nasa.gov/ (troposfære kjemi)

http://jwocky.gsfc.nasa.gov/TOMSmain.html (ozon)

http://seawifs.gsfc.nasa.gov/SEAWIFS/SEASTAR/SPACECRAFT.htm (hav målinger)

http://neonet.knmi.nl/ (ozon)

Litteratur

Introduction to Remote Sensing, 3rd Edition, James B. Campbell, The Guilford press, NewYork London, 2002, 620 pages.