



Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Verkeer en Waterstaat

O₂ A-band cloud information from GOME and SCIAMACHY

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KNMI, The Netherlands

GEWEX Cloud Assessment workshop
Berlin, 22-25 June 2010

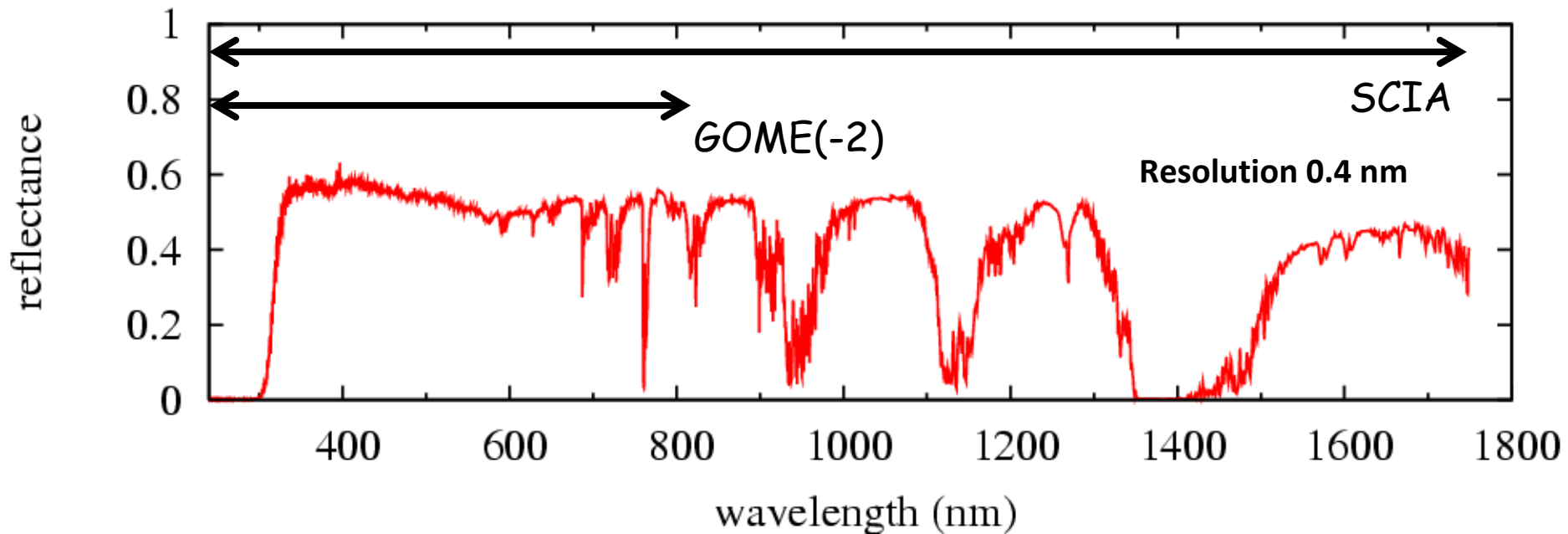
Overview

1. O₂ A-band satellite spectrometers
2. FRESCO algorithm
3. Effective cloud fraction and cloud pressure
4. Results: Seasonal cycles and trends

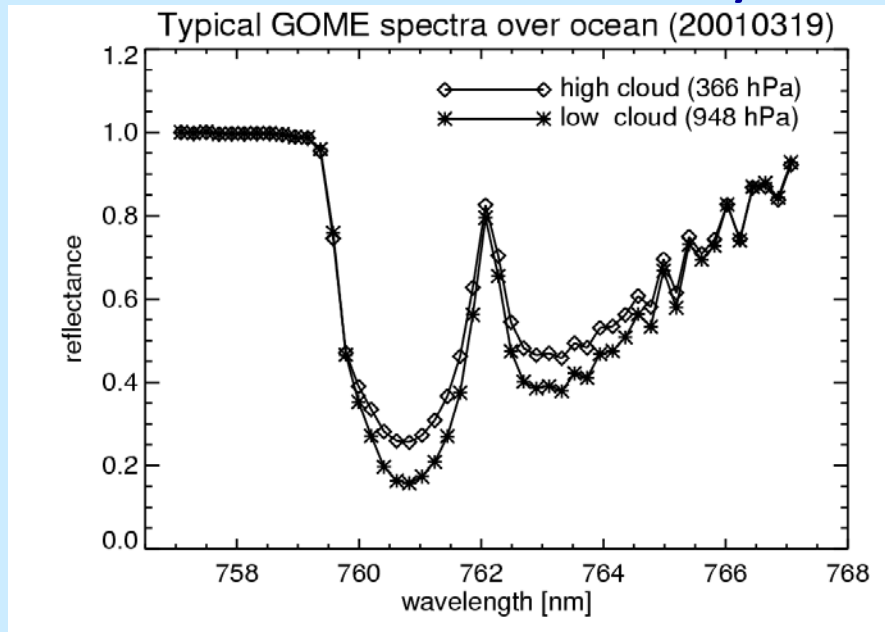
O2 A-band spectrometers

- GOME (1995 – 2003) ERS-2 240 – 800 nm 40x320 km²
- SCIAMACHY (2002-) Envisat 240 – 1750 nm 30x60 km²
- GOME-2 (2006-) Metop-A 240 – 800 nm 40x80 km²
- [OMI (2004 -) O₂-O₂ Aura 270 - 500 nm 13 x24 km²]

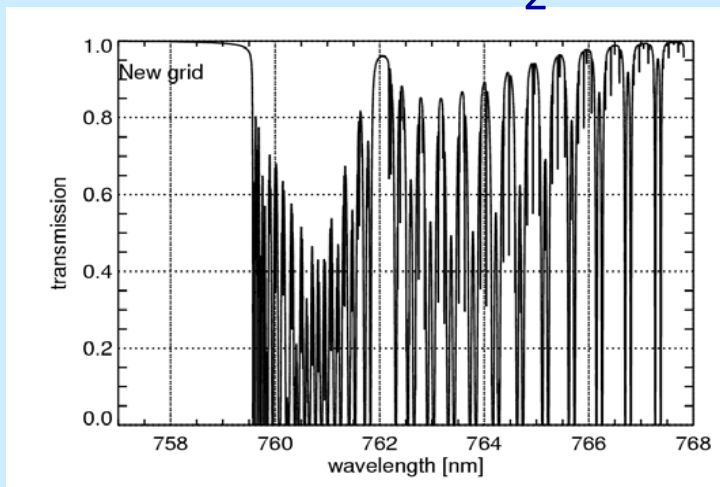
GOME/SCIAMACHY: *overpass at 10:30/10:00 LT *view angle range 0 - 30°
*On-board solar calibration



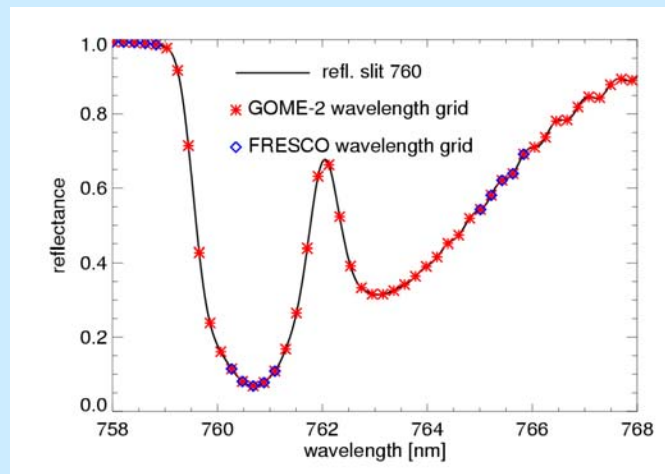
O₂ A-band measurement by GOME



O₂ A-band simulations



Spectral resolution: 1 pm



Spectral resolution: 0.4 nm

How to measure clouds?

& how to model clouds?

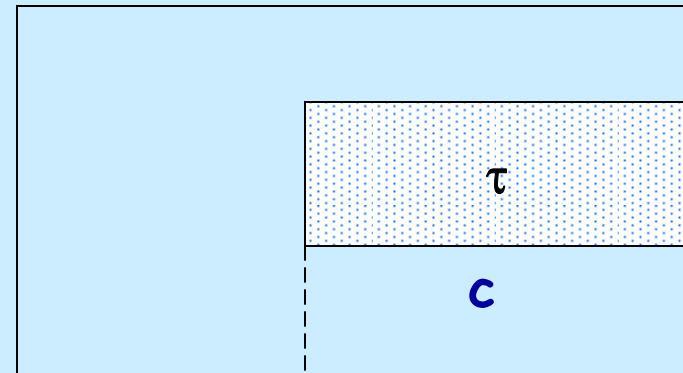


Jan Fabre, 1998

Approximating scattering clouds by Lambertian clouds

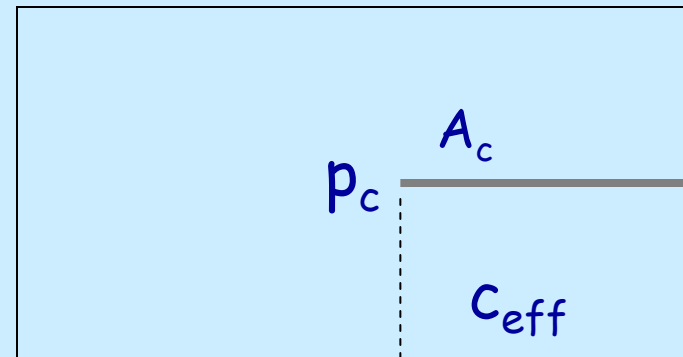
Scattering cloud (1D) parameters:

- Geometric cloud fraction: c
- Optical thickness: τ
- Cloud top height
- Cloud bottom height
- Cloud particle phase function
- Cloud extinction vertical profile



Lambertian cloud parameters:

- Effective cloud fraction: c_{eff}
- Effective cloud pressure: p_c
- Cloud albedo: A_c (*fixed*)



Retrieval of *two* Lambertian cloud parameters, c_{eff} and p_c ,
by fitting the O_2 A-band (in window of 758 – 768 nm).

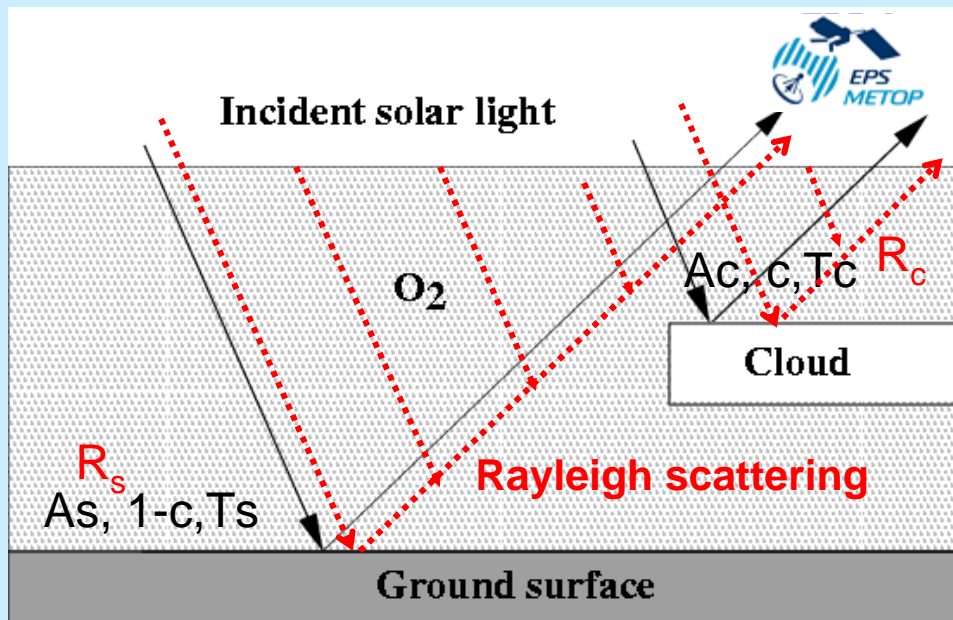
FRESCO atmospheric model

$$R_{sim} = \underbrace{cT_c A_c + (1-c)T_s A_s}_{\text{cloud + surface reflection}} + \underbrace{cR_c + (1-c)R_s}_{\text{Rayleigh scattering reflectance}}$$

cloud + surface
reflection

Rayleigh scattering reflectance

R_c , R_s are single Rayleigh scattering reflectances of cloudy and clear parts of pixel.



T_c , T_s are two-way transmissions including O_2 absorption and single Rayleigh scattering.

Koelemeijer et al., JGR, 2001

Wang et al., ACP, 2008

FRESCO effective cloud fraction

Effective cloud fraction =

$$c_{\text{eff}} = \frac{c_{\text{geom}} A(\tau)}{0.8}$$

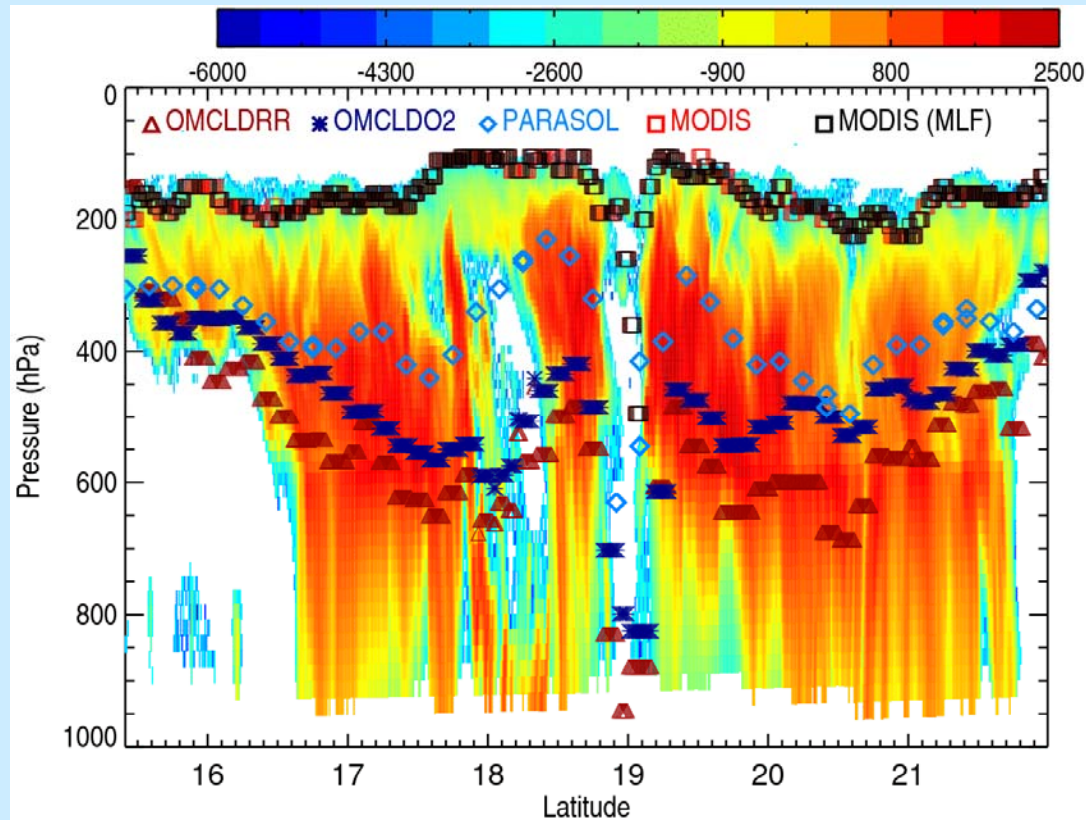
Concept is necessary for large, partly cloudy pixels, since it is not possible to separate cloud fraction and cloud albedo.

NOTE:

- *O2 A-band is mainly sensitive to optically thick clouds.*
- *O2 A-band is sensitive to clouds down to the surface.*

FRESCO effective cloud pressure

- Multiple scattering of light gives sensitivity to vertical extent of the cloud.
- O₂ A-band gives the *optical mid-level* of a cloud system.



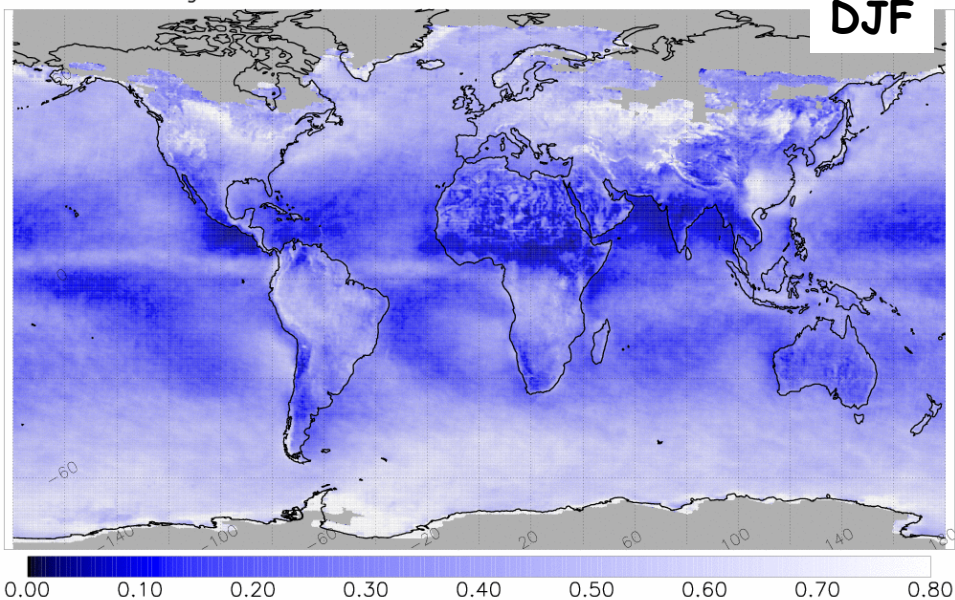
CloudSat

Sneep et al., JGR, 2008

Results for GOME & SCIAMACHY 1996 - 2009

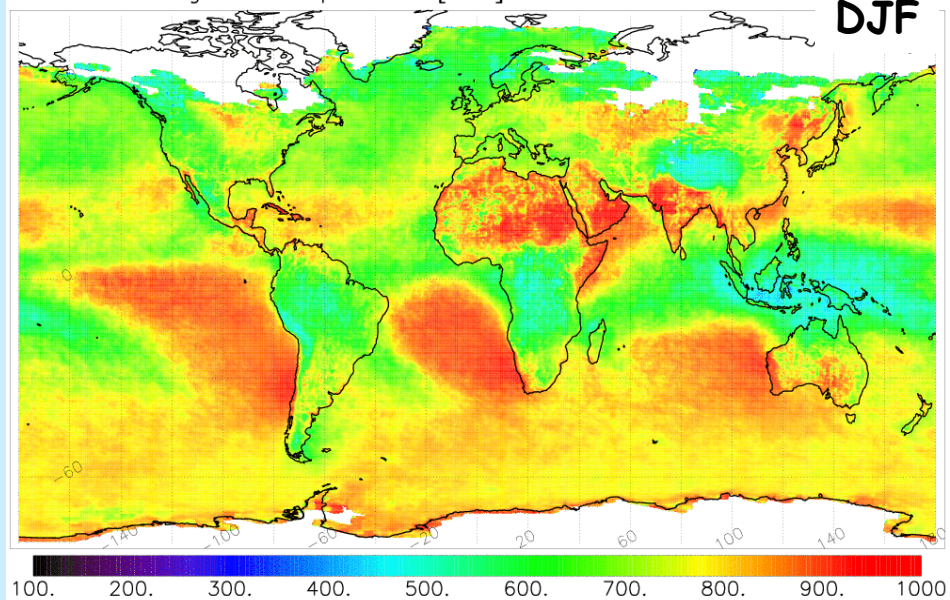
Cloud fraction

FRESCO averaged cloud fraction for 1996–2009 DJF

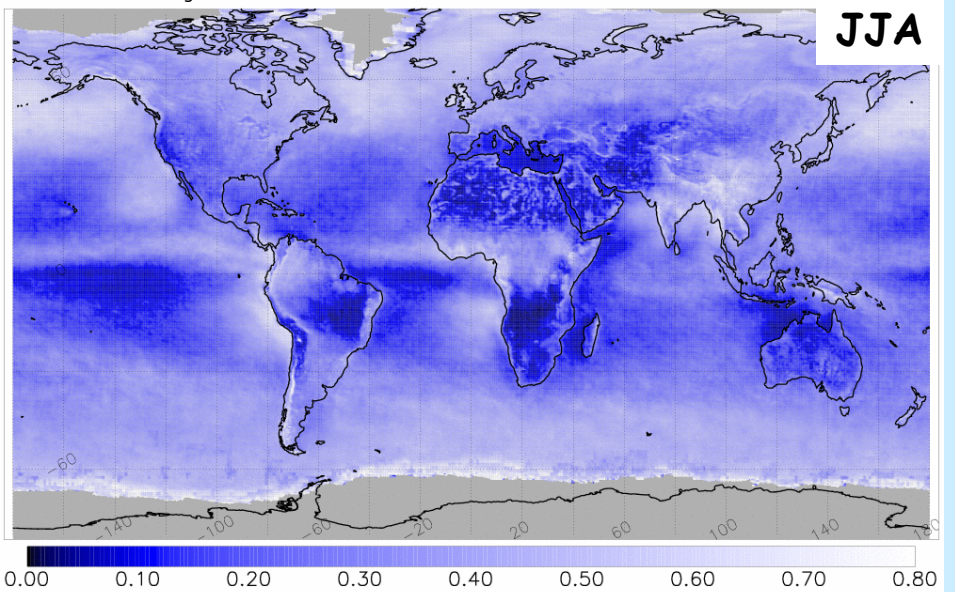


Cloud pressure

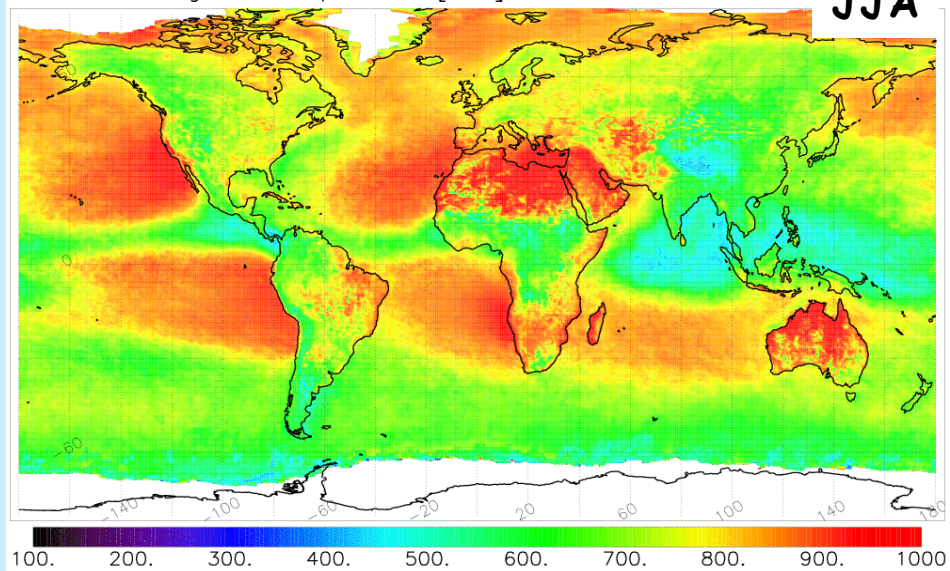
FRESCO averaged cloud pressure [hPa] for 1996–2009 DJF



FRESCO averaged cloud fraction for 1996–2009 JJA

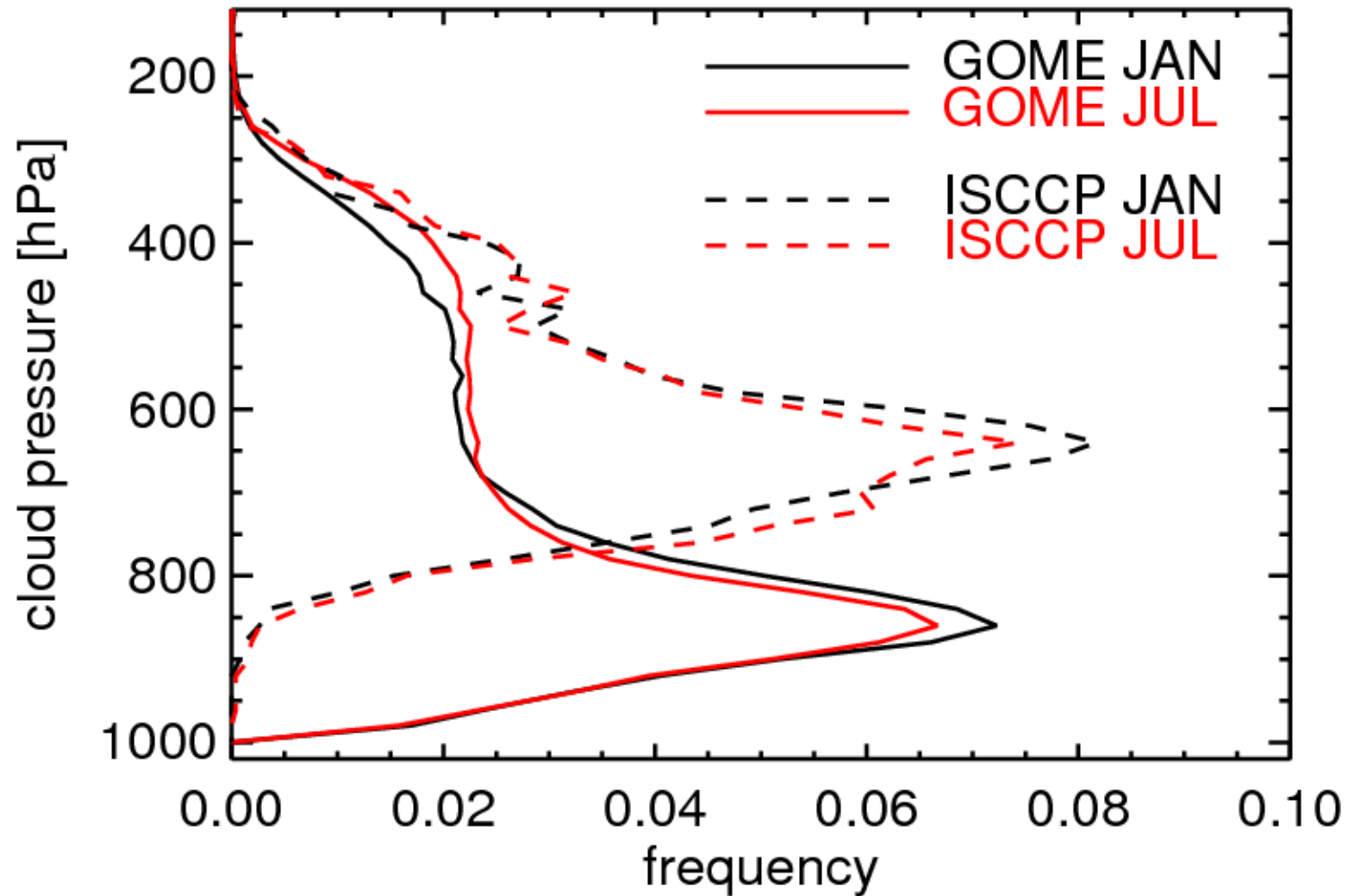


FRESCO averaged cloud pressure [hPa] for 1996–2009 JJA

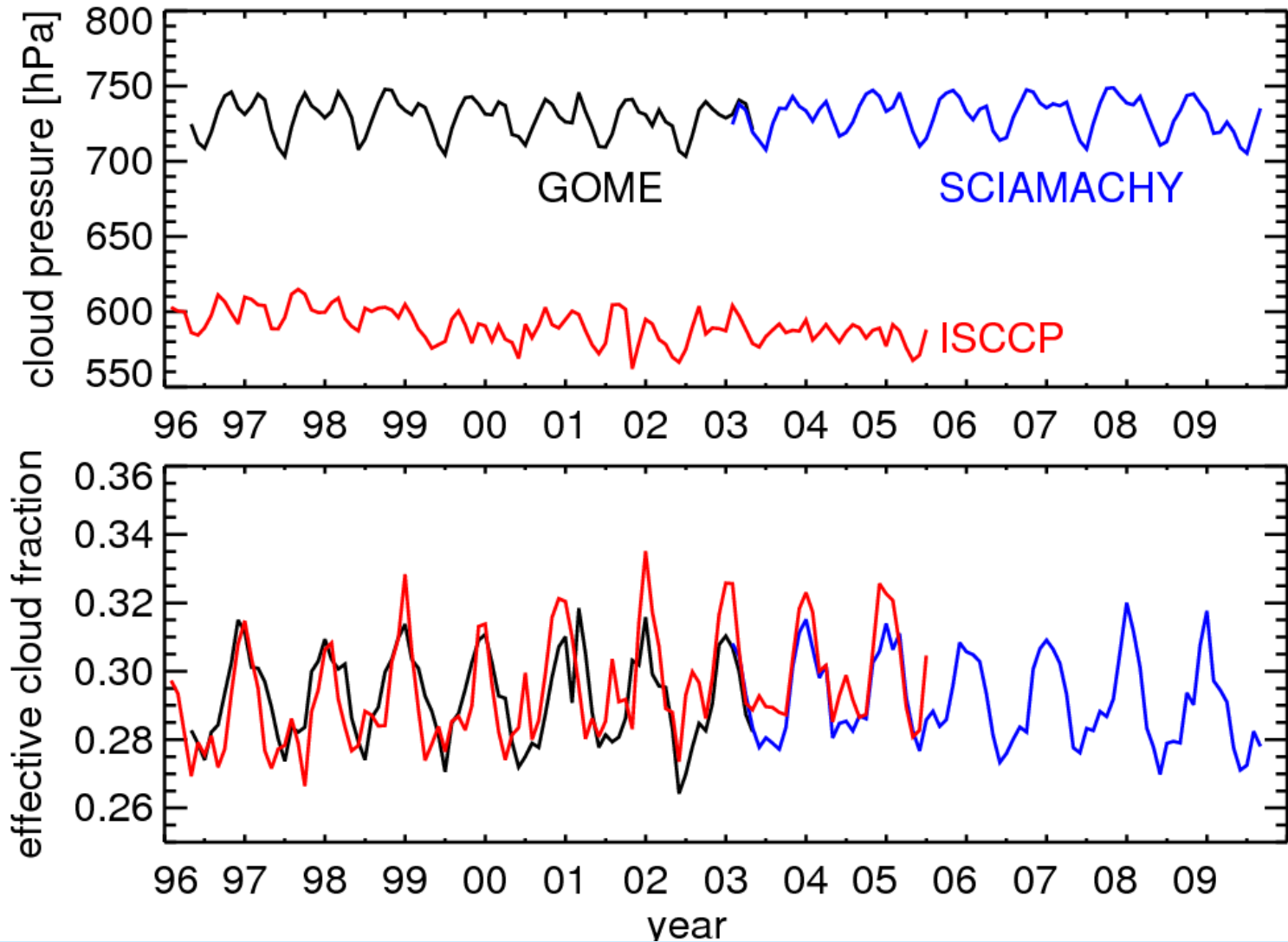


Global mean vertical distribution of clouds

1997



Global mean time series

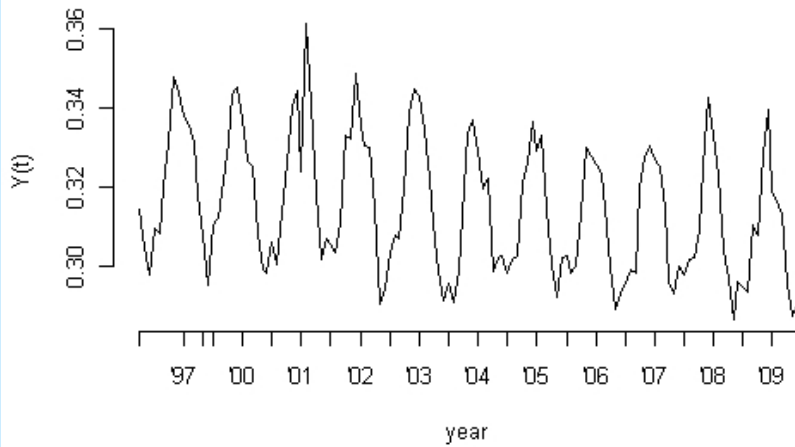


Data selection for seasonal cycles & trends

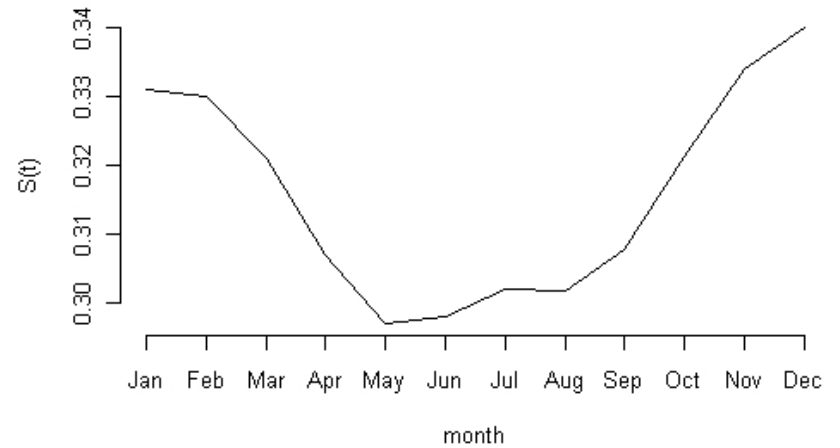
- 60 N – 60 S
- 1° x 1° monthly mean gridded data
- No snow/ice (from climatology)
- April 1996 – April 2009
- May 1997 – April 1999, with a strong El Nino, excluded
- GOME – SCIAMACHY time series have an overlap of 8 months. Small offset in global mean is corrected in GOME data.
- Statistical analysis provides:
 - Seasonal cycle
 - Deseasonalised signal
 - Trend
 - Residual
- Preliminary results!

Global mean effective cloud fraction

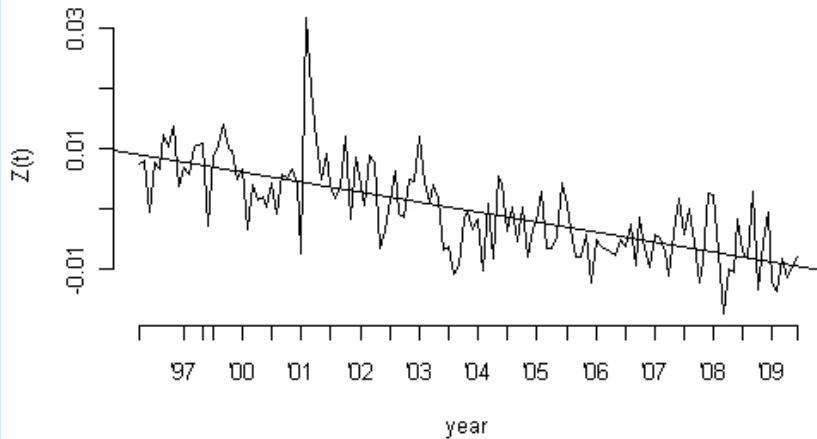
Cloud fraction at -60 ~ 59 Lat, -180 ~ 179 Long



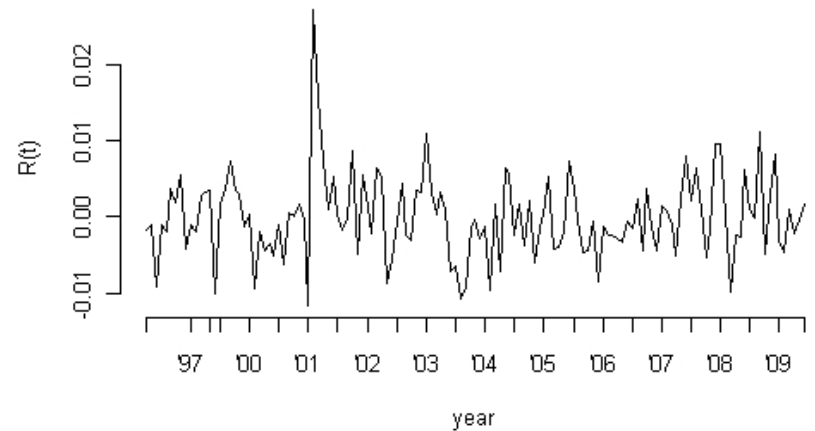
Seasonal component



Deseasonalised cloud fraction

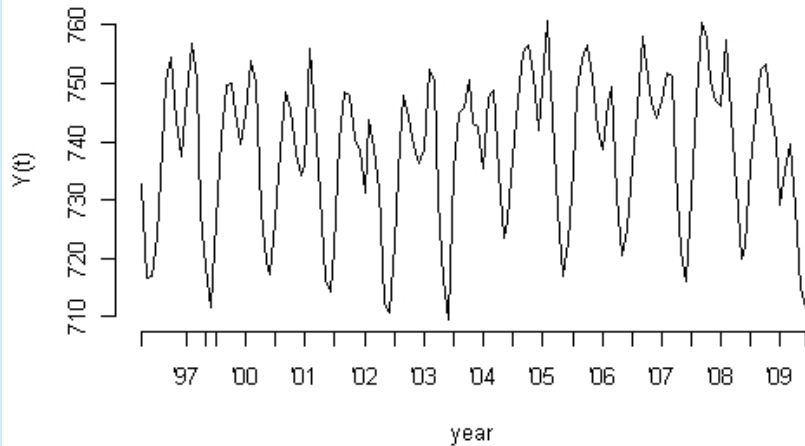


Residuals

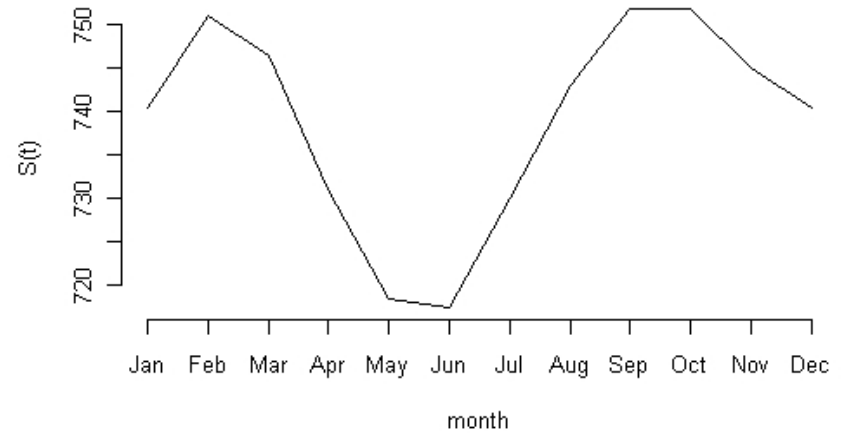


Global mean effective cloud pressure

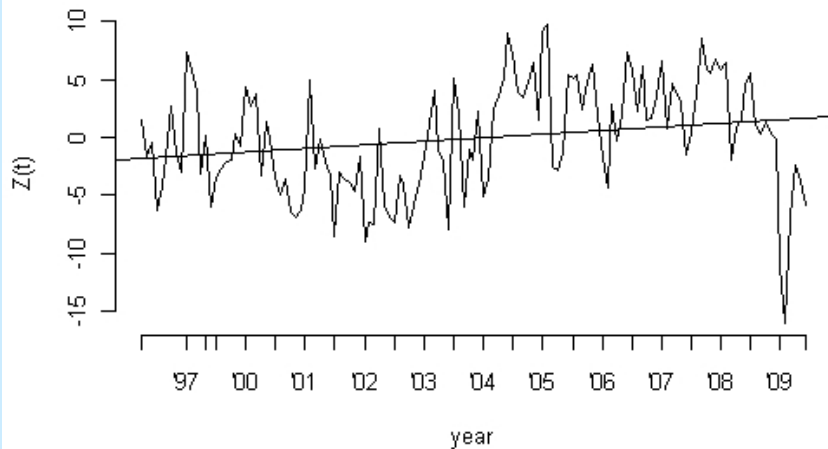
Cloud pressure at -60 ~ 59 Lat, -180 ~ 179 Long



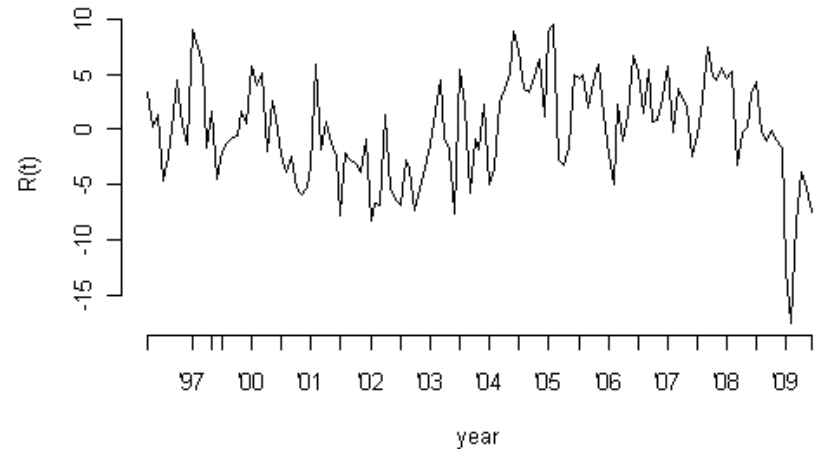
Seasonal component



Deseasonalised cloud pressure

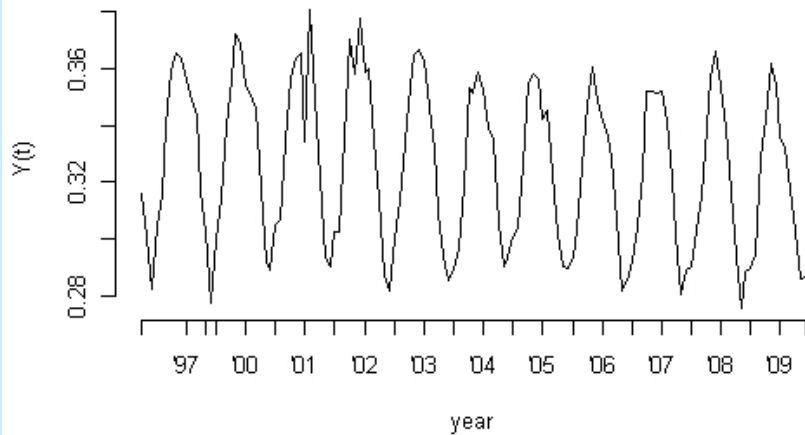


Residuals

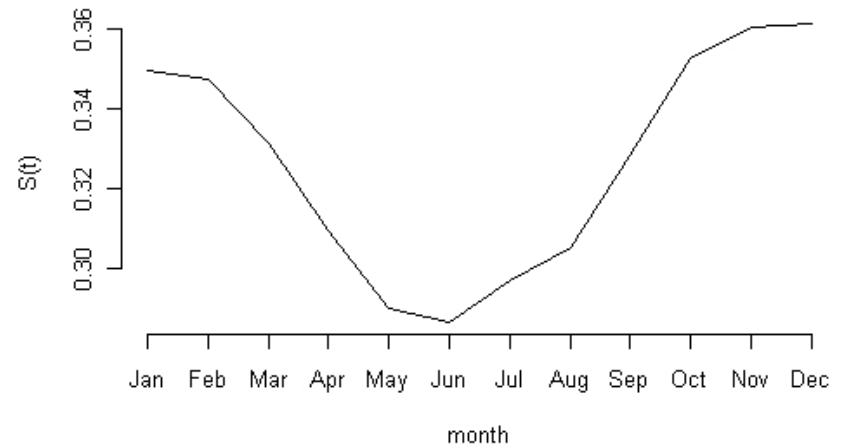


SH mean effective cloud fraction

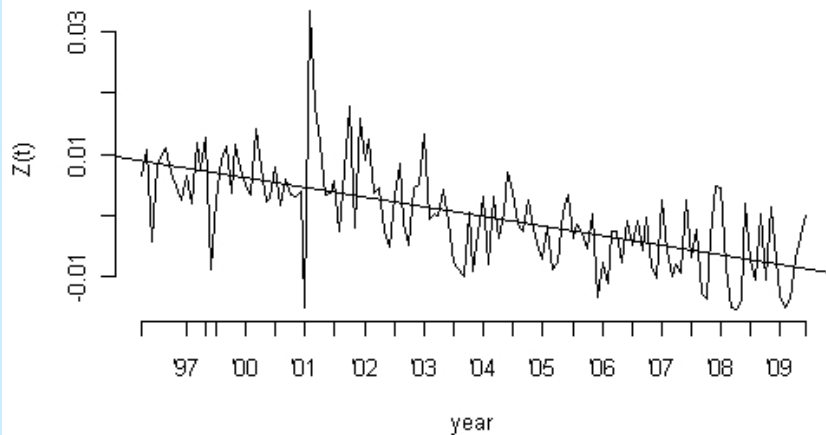
Cloud fraction at -60 ~ 0 Lat, -180 ~ 179 Long



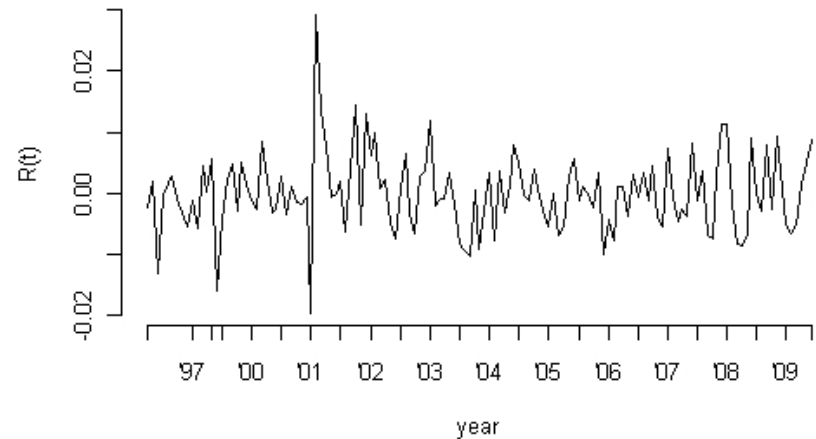
Seasonal component



Deseasonalised cloud fraction

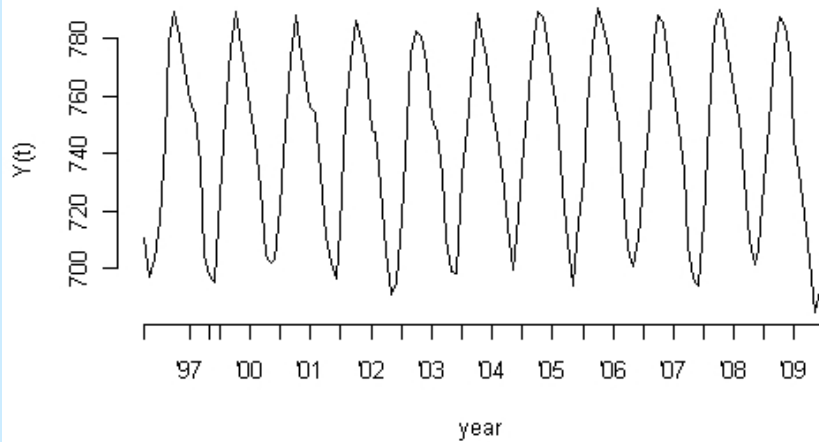


Residuals

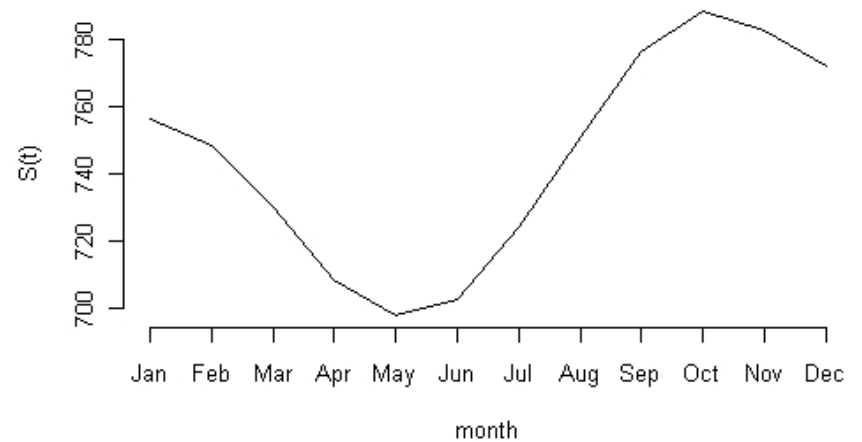


SH mean effective cloud pressure

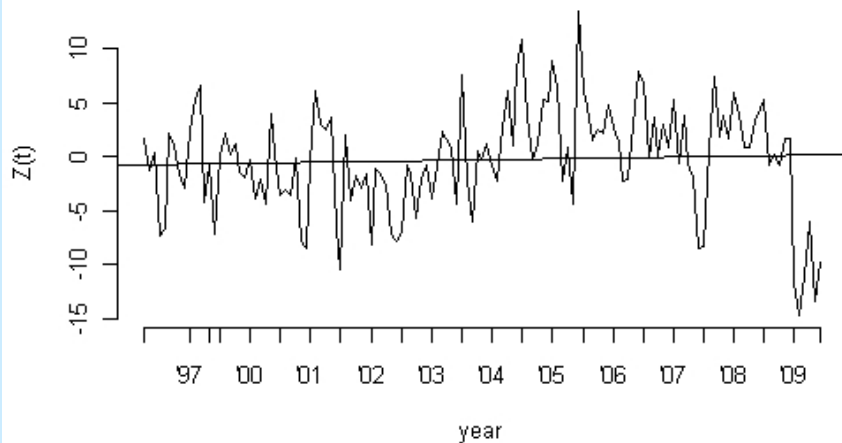
Cloud pressure at -60 ~ 0 Lat, -180 ~ 179 Long



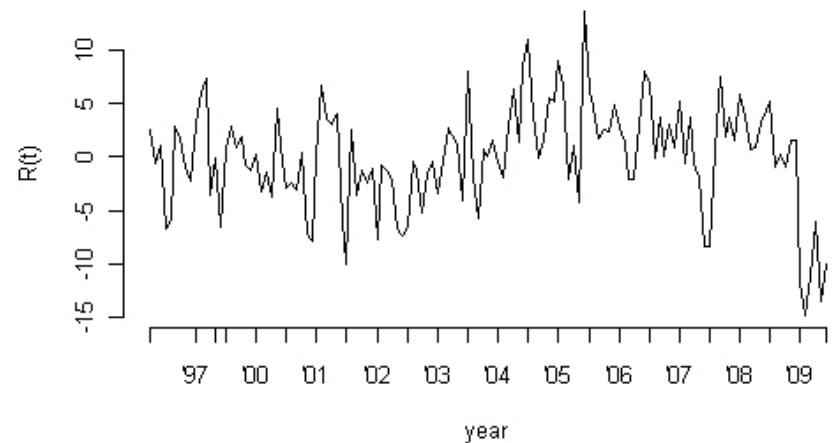
Seasonal component



Deseasonalised cloud pressure

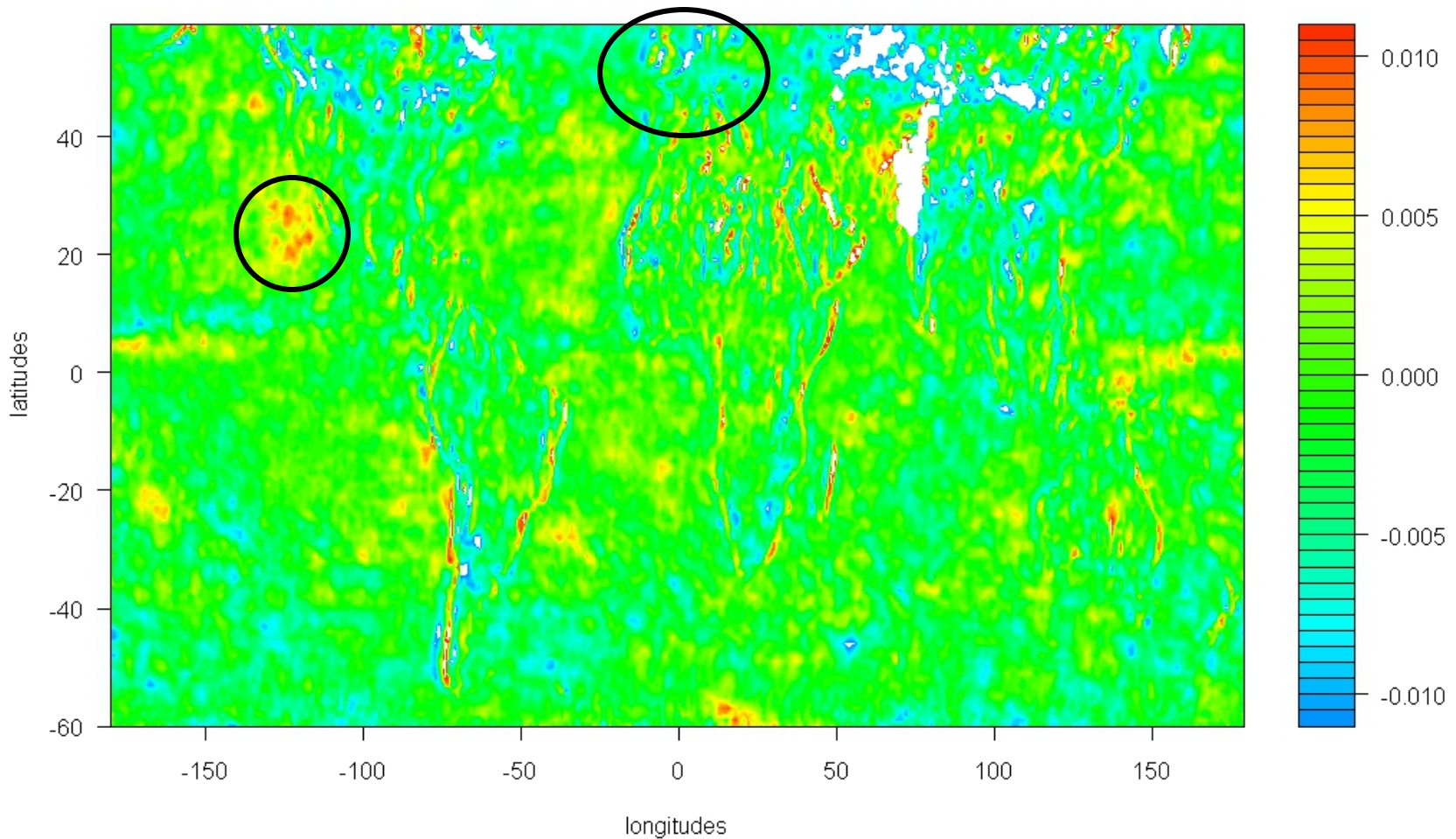


Residuals



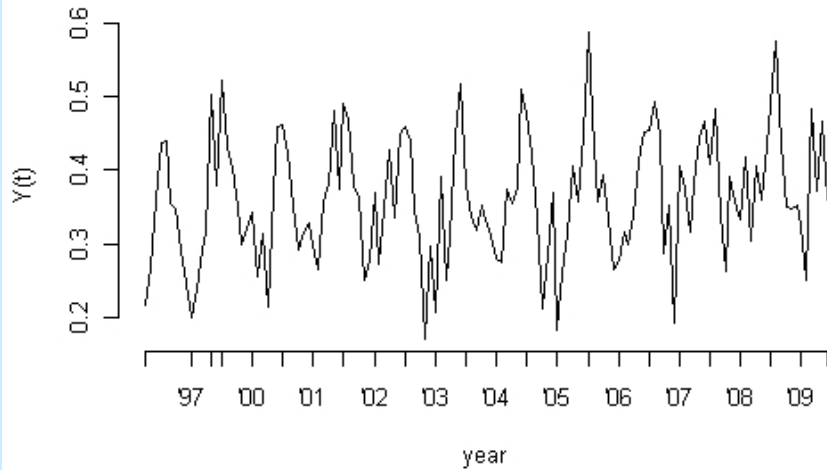
Global distribution of effective cloud fraction trends

Trend of cloud fraction per year

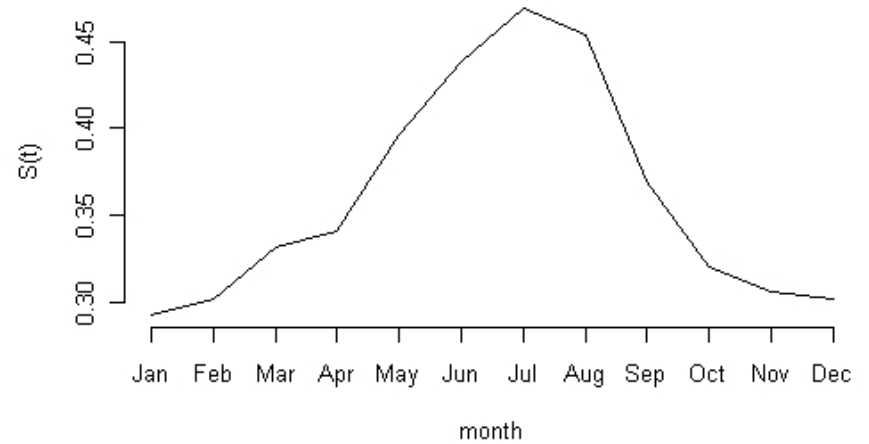


North-East Pacific

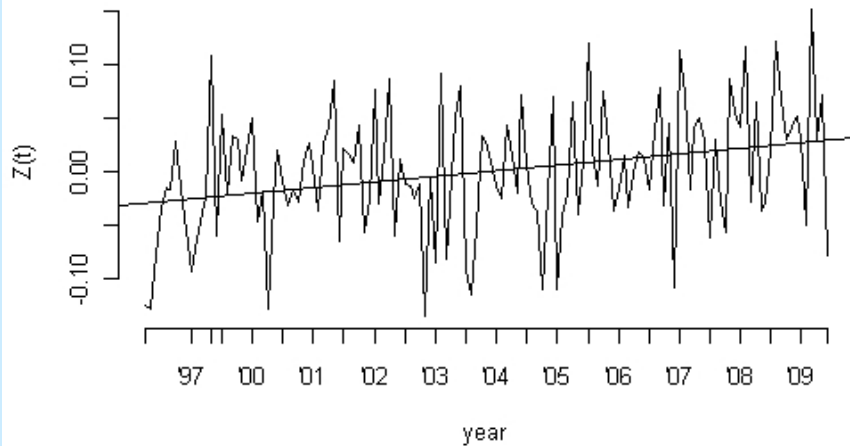
Cloud fraction at 20 ~ 30 Lat, -130 ~ -120 Long



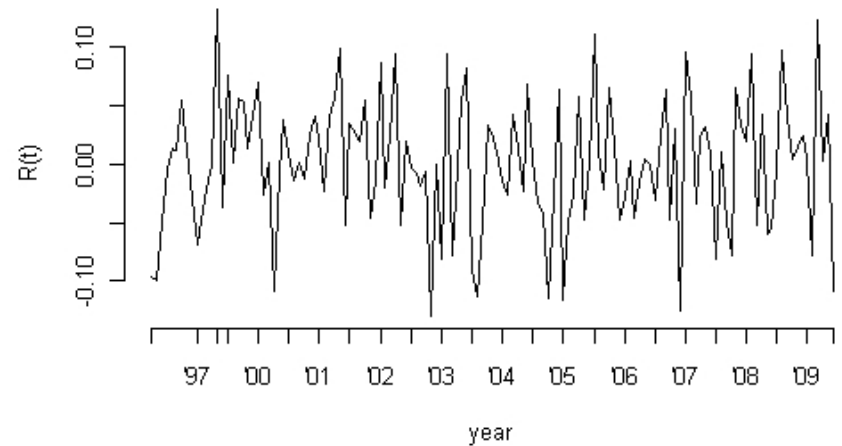
Seasonal component



Deseasonalised cloud fraction

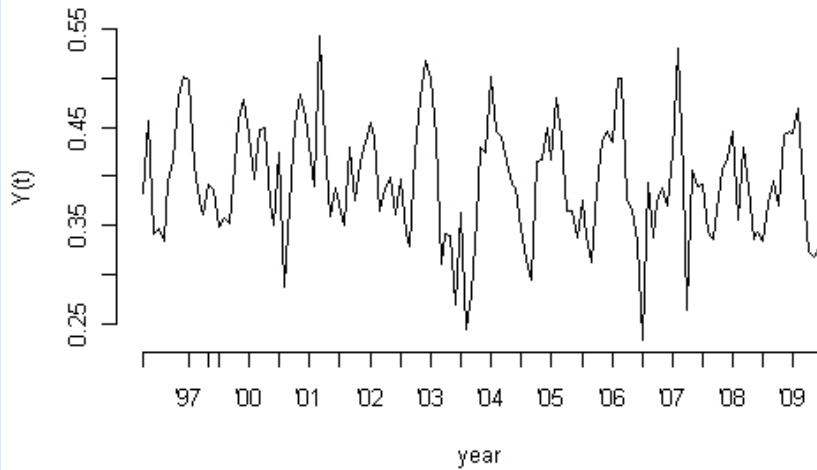


Residuals

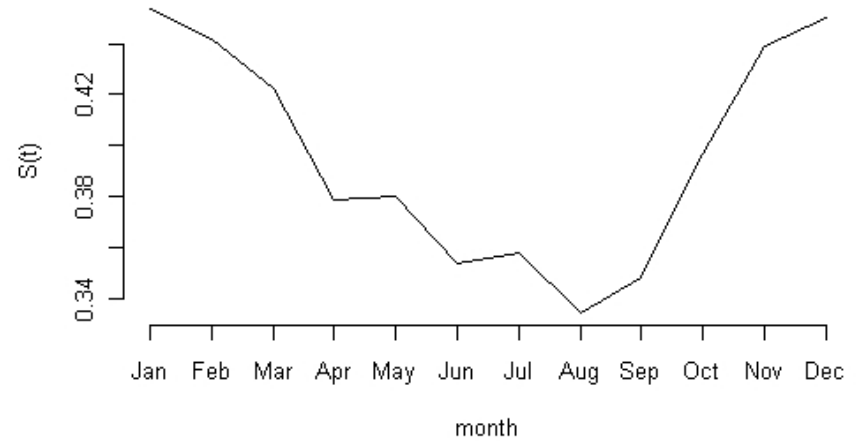


Europe

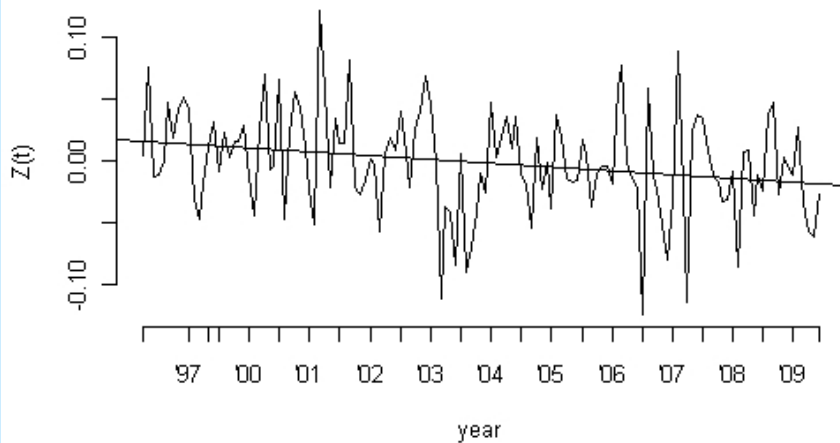
Cloud fraction at 40 ~ 60 Lat, -10 ~ 20 Long



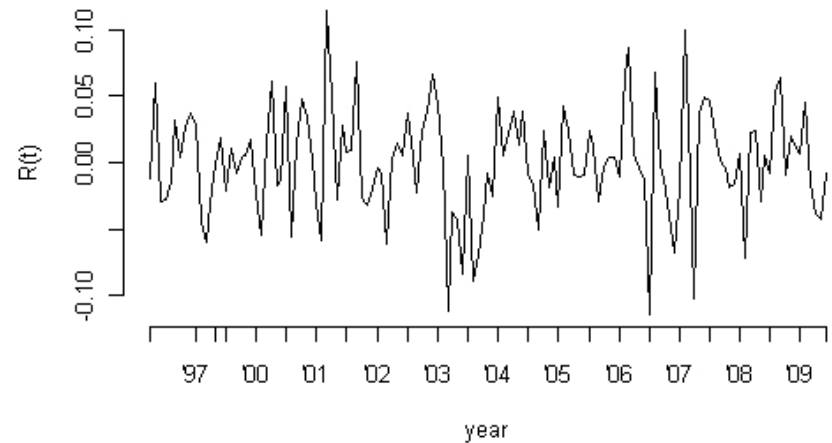
Seasonal component



Deseasonalised cloud fraction



Residuals



Conclusions (1/2)

- GOME and SCIAMACHY O₂ A-band data give a consistent time series of cloud fraction and cloud pressure since 1996.
- FRESCO O₂ A-band cloud pressures give the optical center of (single- and multilayer) clouds.
- FRESCO is biased towards optically thick, low clouds.
- A bimodal cloud height distribution is found from the O₂ A-band data.
- The seasonal cycle of clouds appears to be stronger in the O₂ A-band data than in ISCCP.
- A significant trend in effective cloud fraction (*decrease*) is found in the global mean for 1996 - 2009.
- Regional trends (up/down) in effective cloud fractions.

Conclusions (2/2)

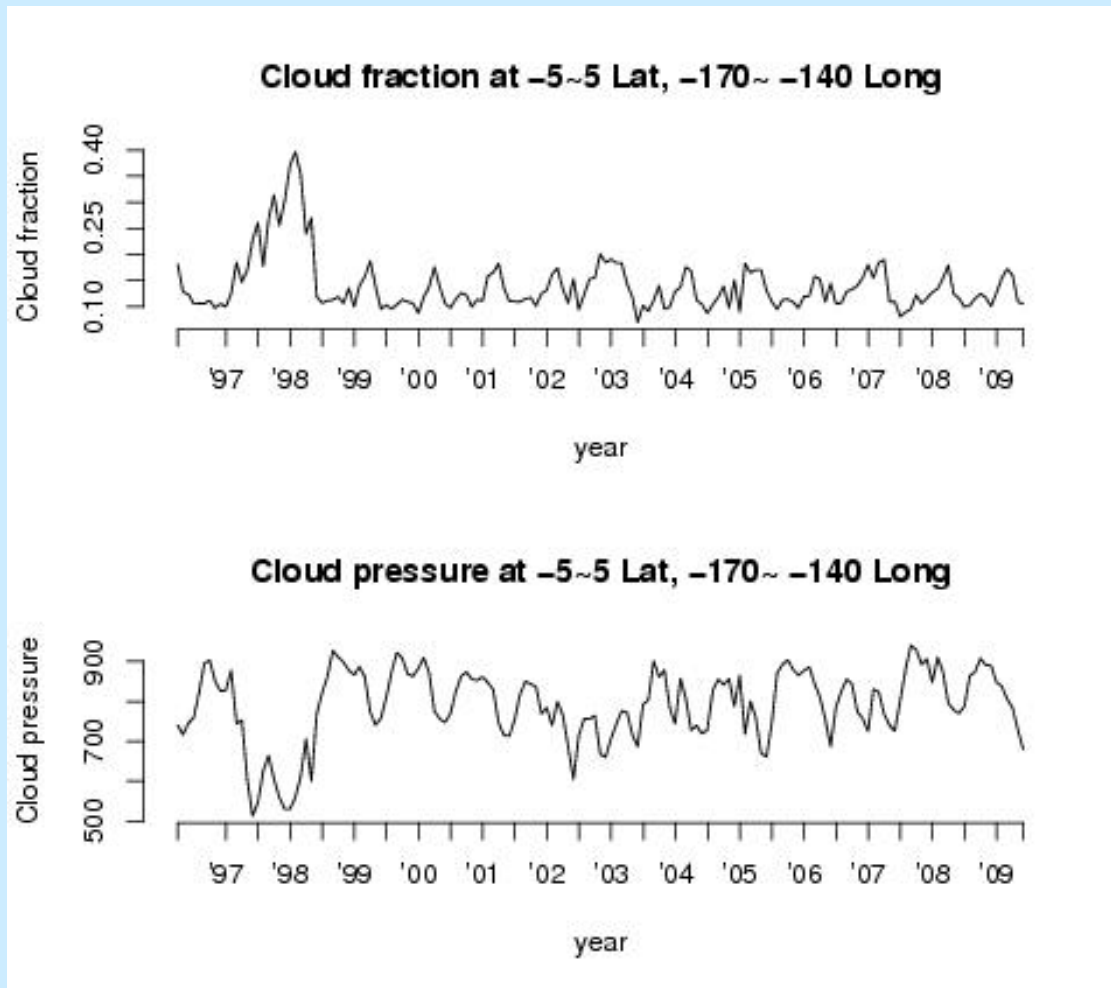
- The effective cloud fraction concept (=product of geometric cloud fraction and cloud albedo) is needed for partly cloudy pixels. It is a radiometric cloud quantity which can be transferred between different satellite instruments.
- FRESCO L2 and L3 data are available at TEMIS: www.temis.nl
- FRESCO L3 data are also available in the KNMI Climate Explorer: <http://climexp.knmi.nl>

Outlook

- FRESCO improvement: new land surface albedo database from MERIS
- ESA CCI project: Intercompare and improve various existing GOME O2 A-band cloud products: SACURA, ROCINN, FRESCO
- Add FRESCO data to GEWEX data base.

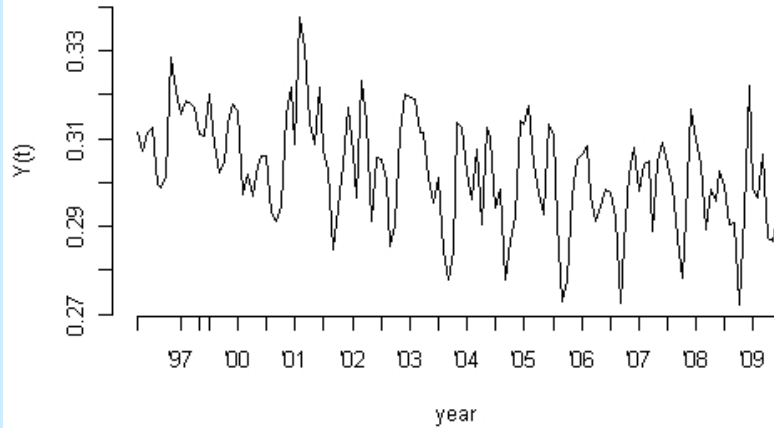
Back-up slides

El Nino effect on clouds

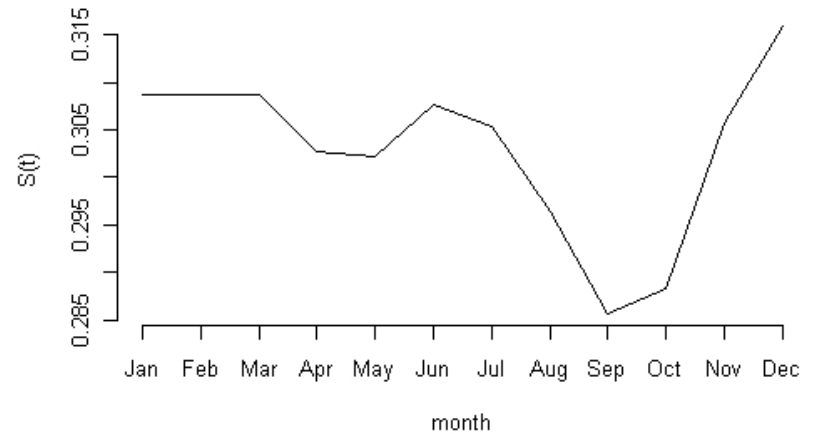


NH mean effective cloud fraction

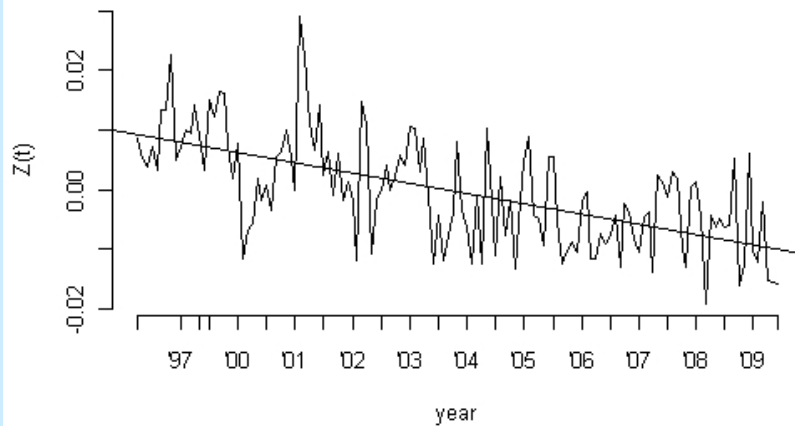
Cloud fraction at 0 ~ 59 Lat, -180 ~ 179 Long



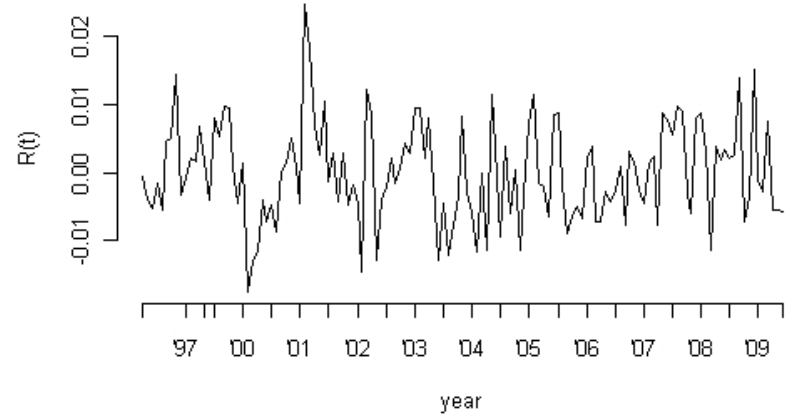
Seasonal component



Deseasonalised cloud fraction

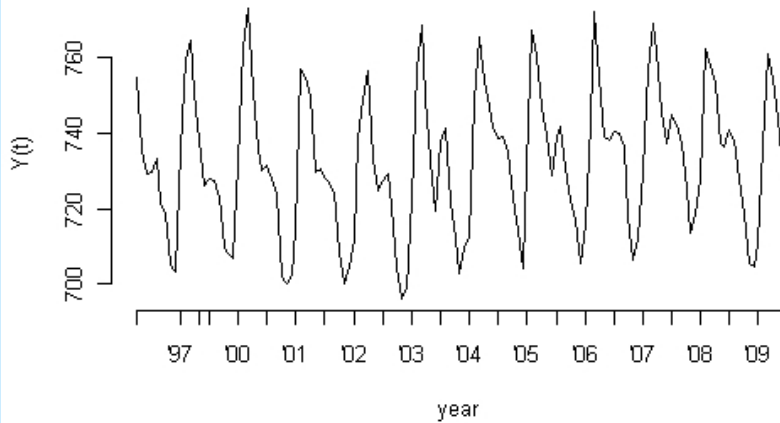


Residuals

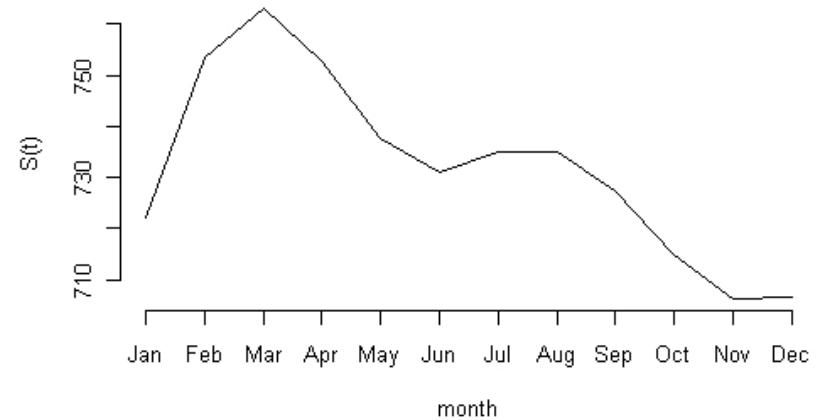


NH mean effective cloud pressure

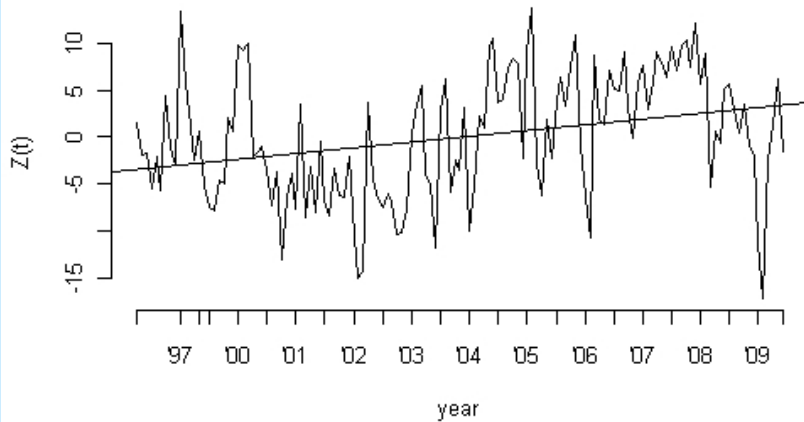
Cloud pressure at 0 ~ 59 Lat, -180 ~ 179 Long



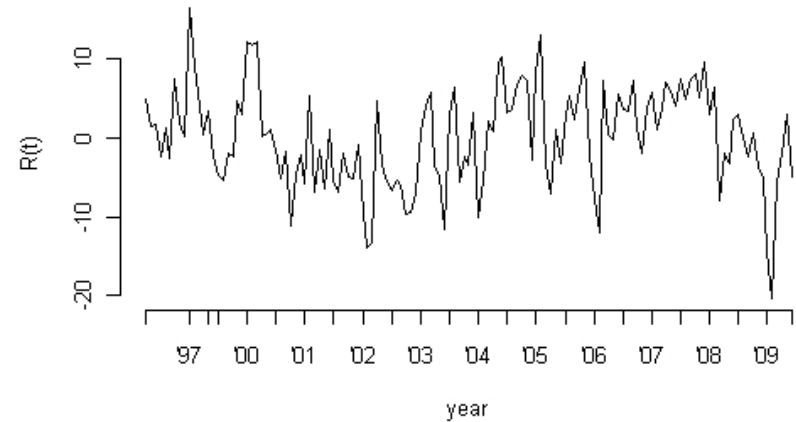
Seasonal component

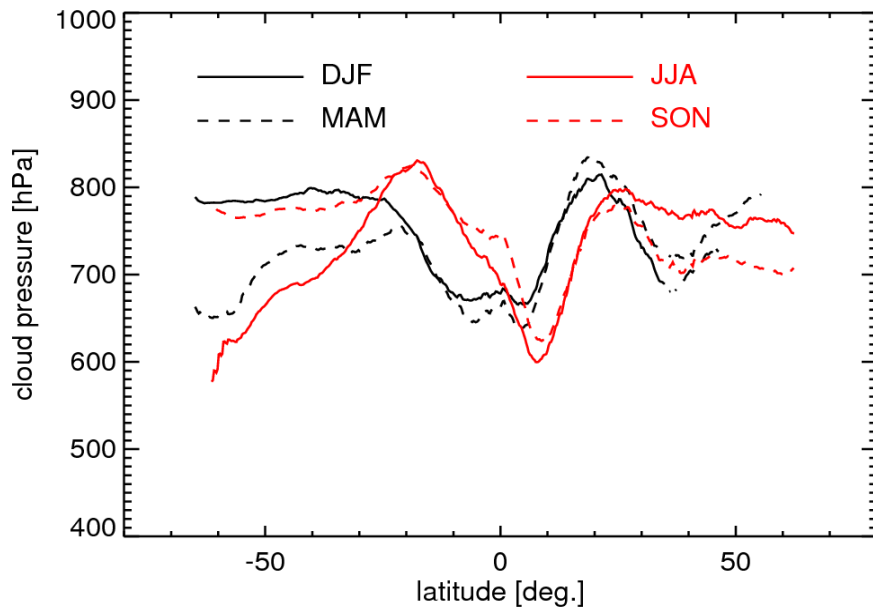
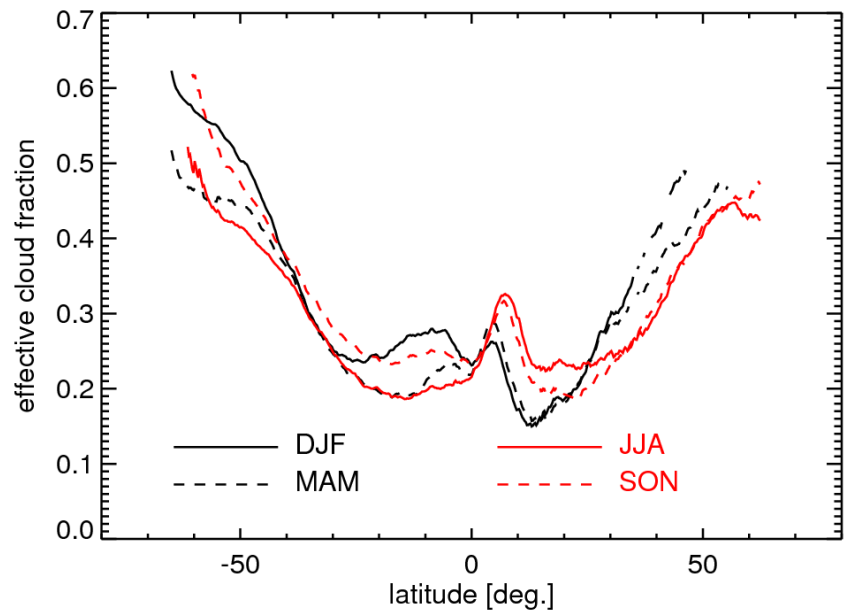


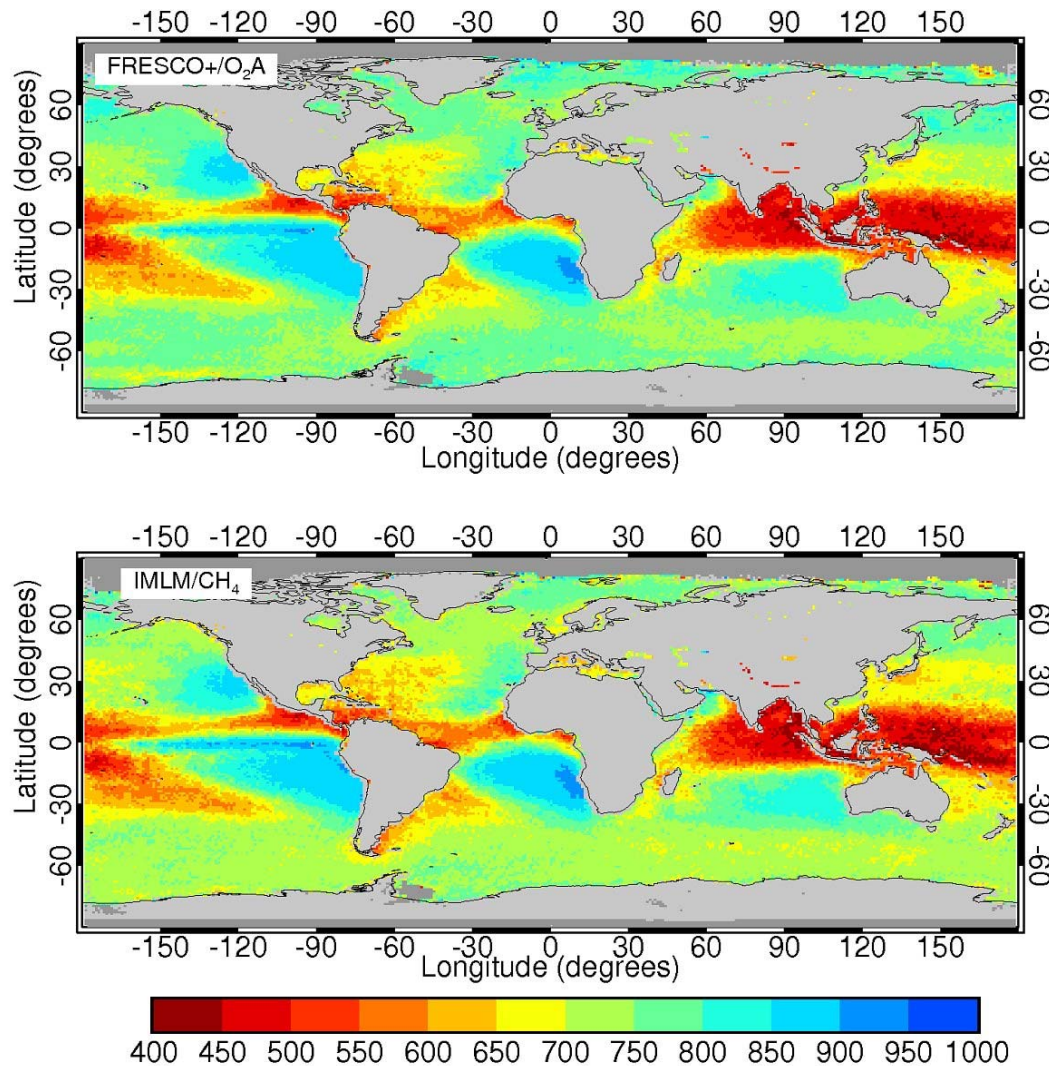
Deseasonalised cloud pressure



Residuals







From Gloudemans et al., ACPD, 2009:

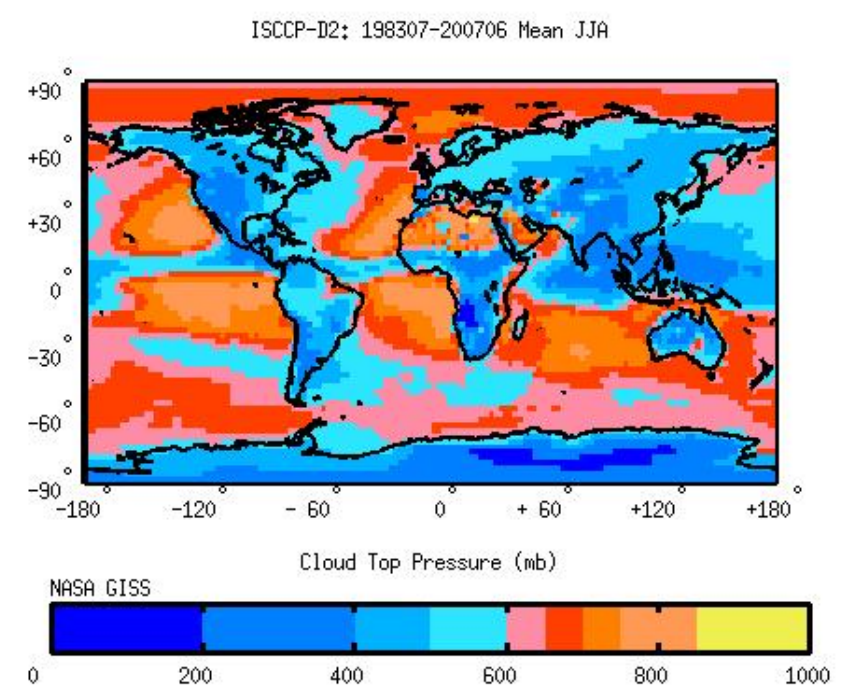
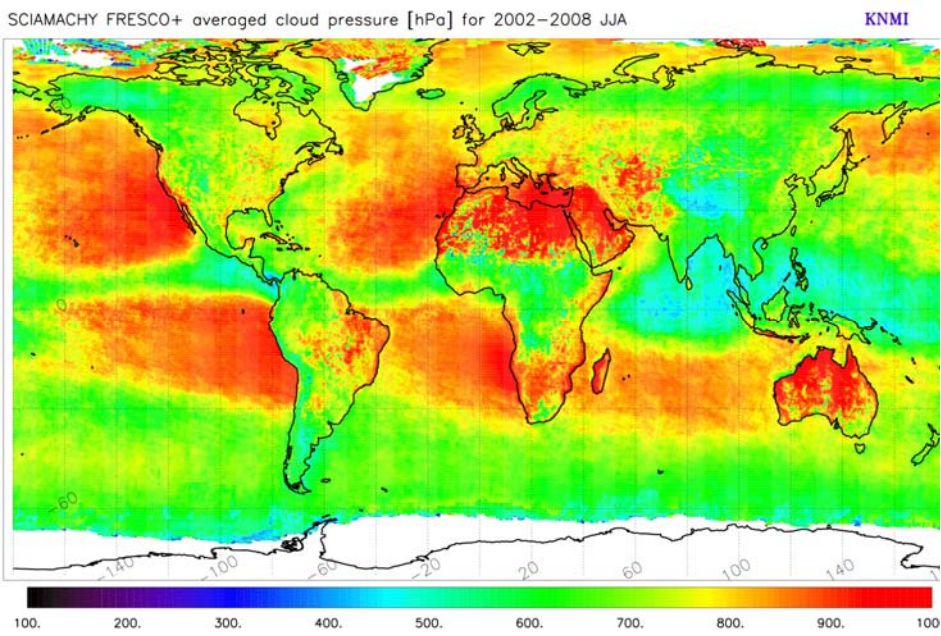
Global distribution of cloud top height in hPa based on daily gridded $1^\circ \times 1^\circ$ data for the period 2003–2007. Top panel: Cloud top height from the FRESCO+ algorithm using the SCIAMACHY O₂A band.

Bottom panel: average cloud top height based on the ratio between the SCIAMACHY IMLM $2.3 \mu\text{m}$ CH₄ column and TM4 CH₄ column over sea. Only data with a cloud fractions > 0.2 have been included in both panels.

Cloud pressures Jun-Jul-Aug

SCIAMACHY FRESCO+ 2002-2008

ISCCP 1983-2007

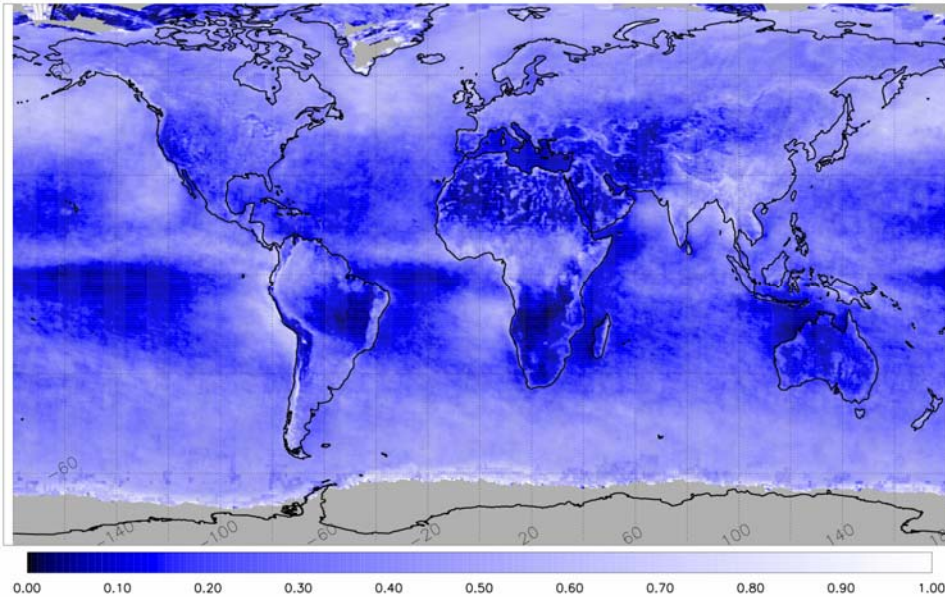


FRESCO cloud product from SCIAMACHY

Period: 2002-2008, Season: JJA

SCIAMACHY FRESCO+ averaged cloud fraction for 2002–2008 JJA

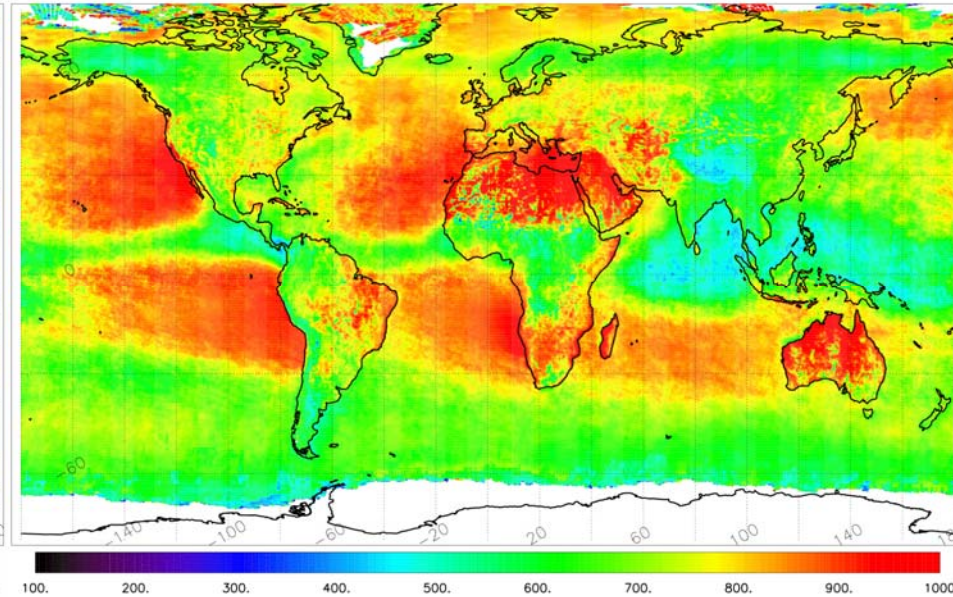
KNMI



Effective cloud fraction

SCIAMACHY FRESCO+ averaged cloud pressure [hPa] for 2002–2008 JJA

KNMI



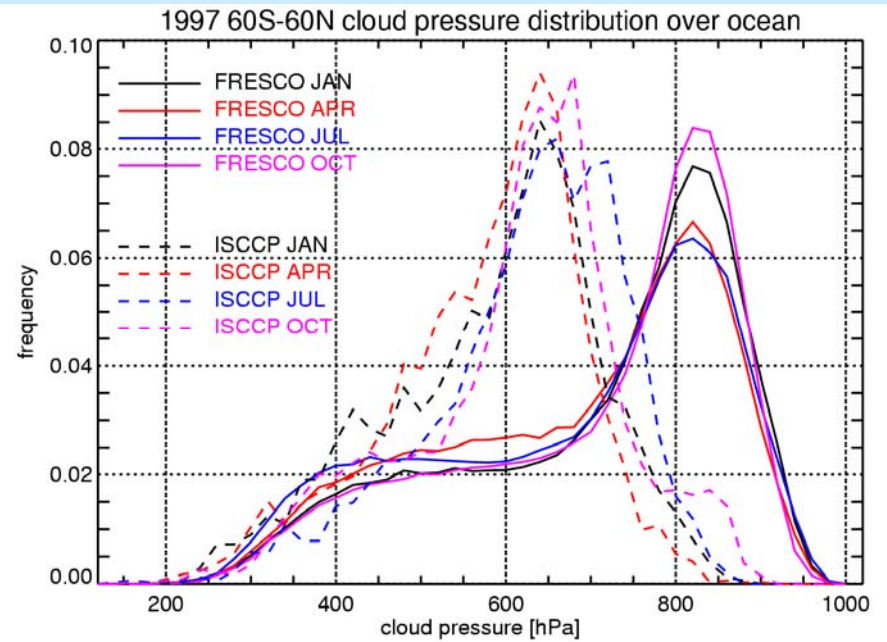
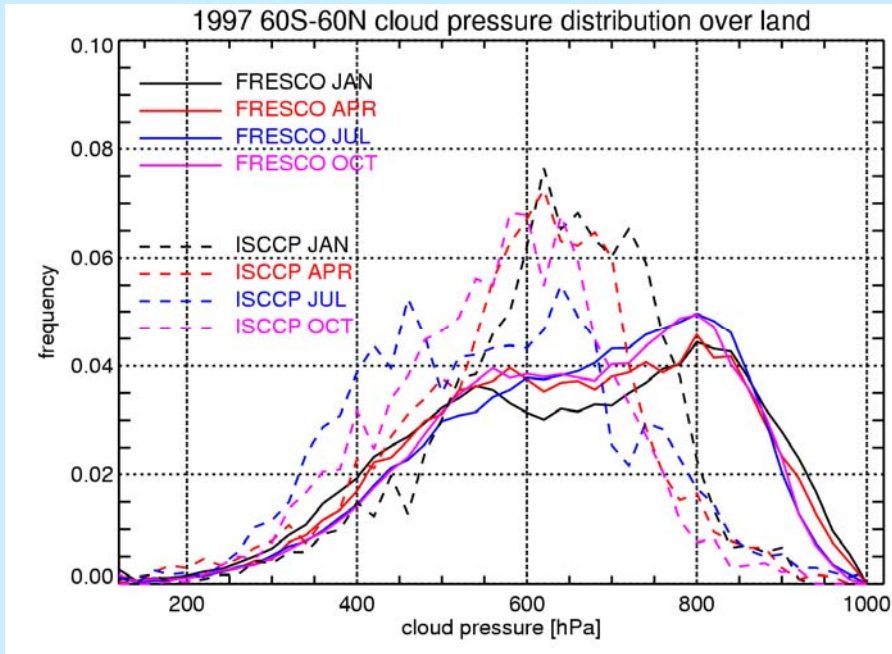
Cloud pressure

near-real-time product available: <http://www.temis.nl>

Comparison between GOME and ISCCP

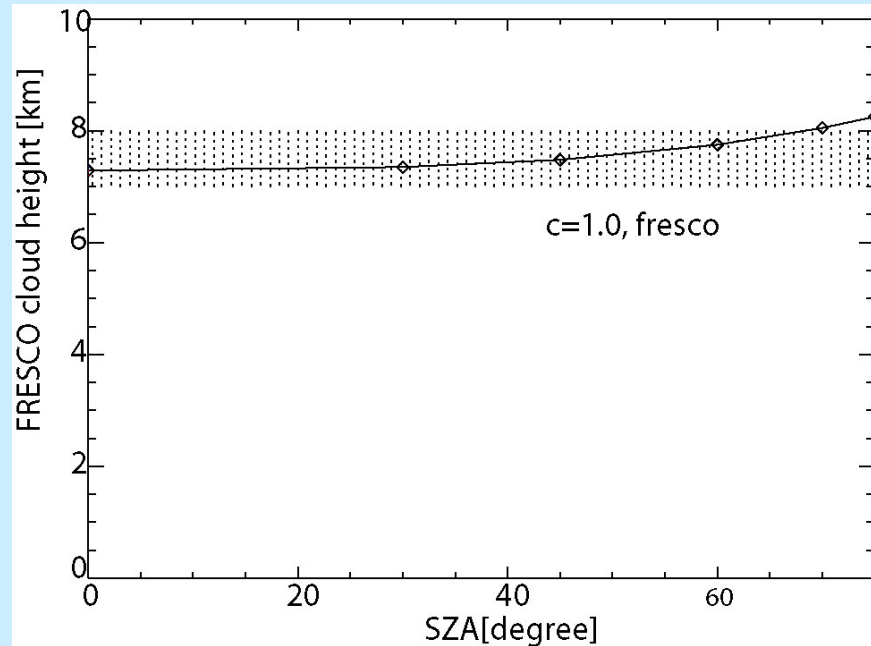
land

ocean

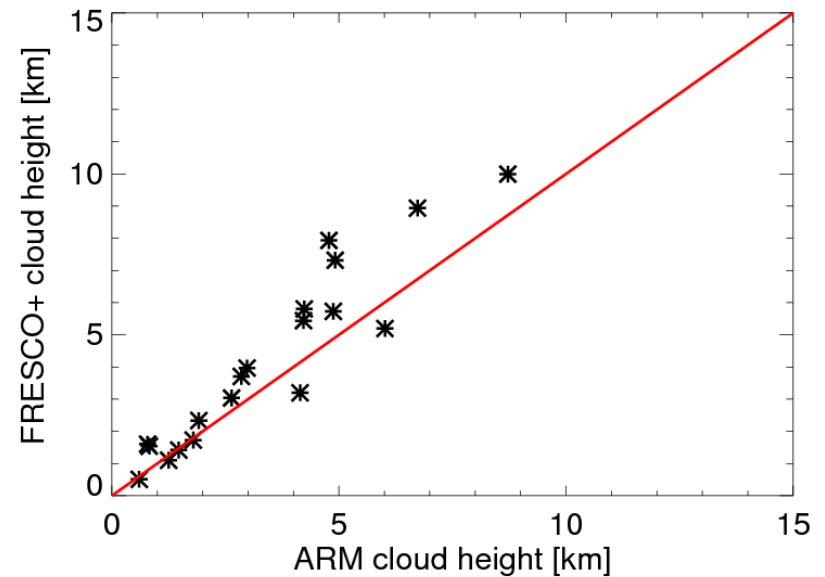


Global mean, 1997

Retrieval simulation



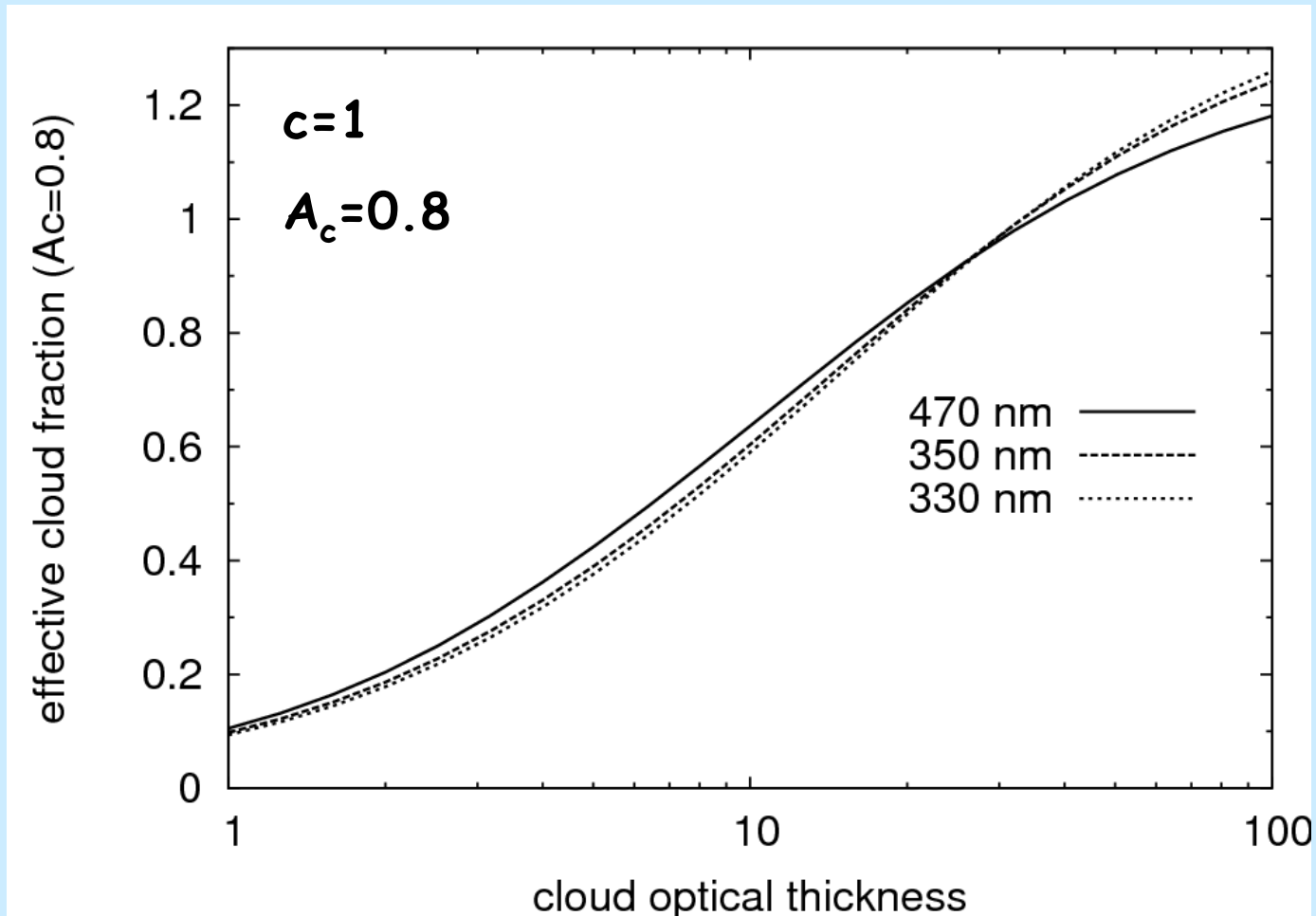
Validation with radar



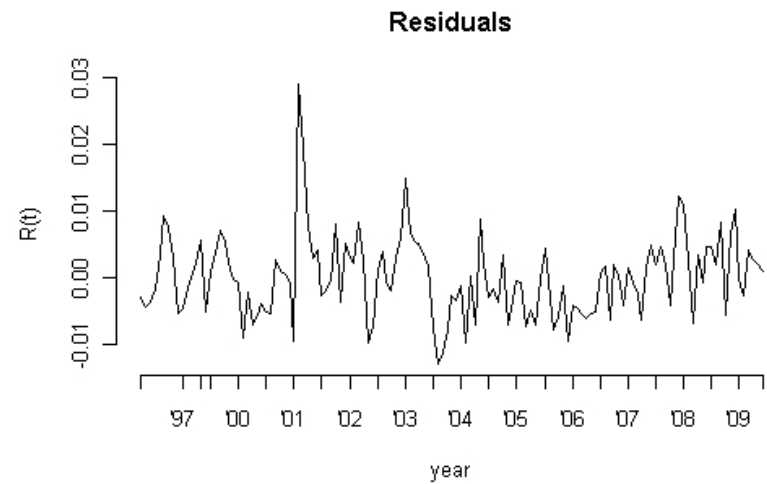
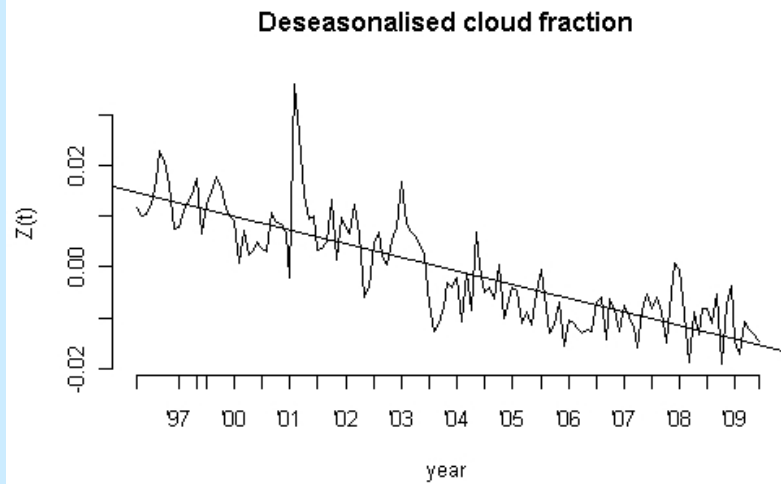
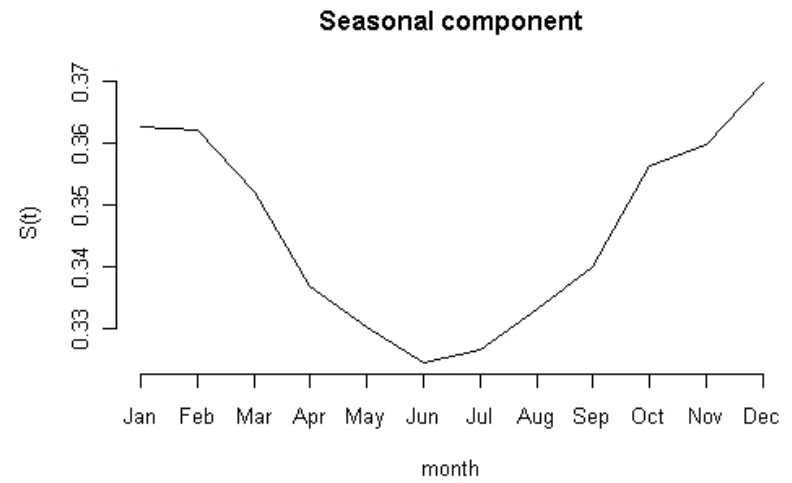
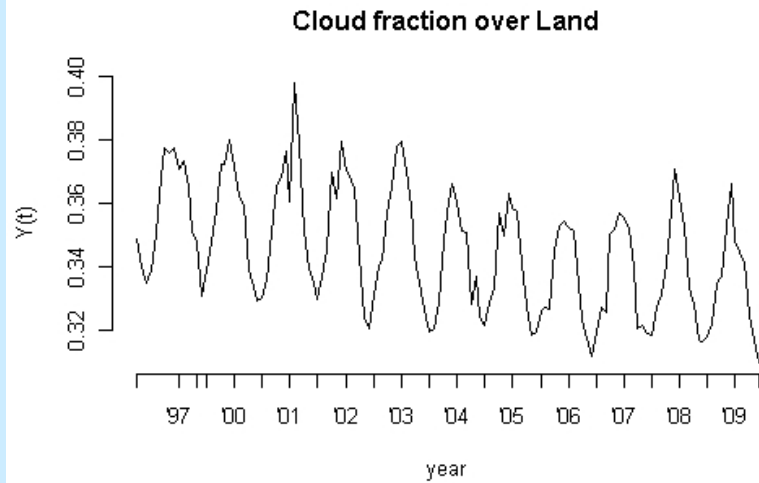
The retrieved cloud height from the O₂ A-band is about the optical middle of single-layer/multiple-layer clouds.

Effective cloud fraction

$$c_{\text{eff}} = c (R(\tau_c) - R_{\text{clear}}) / (R_{A_c} - R_{\text{clear}}) \cong c R(\tau_c) / A_c$$

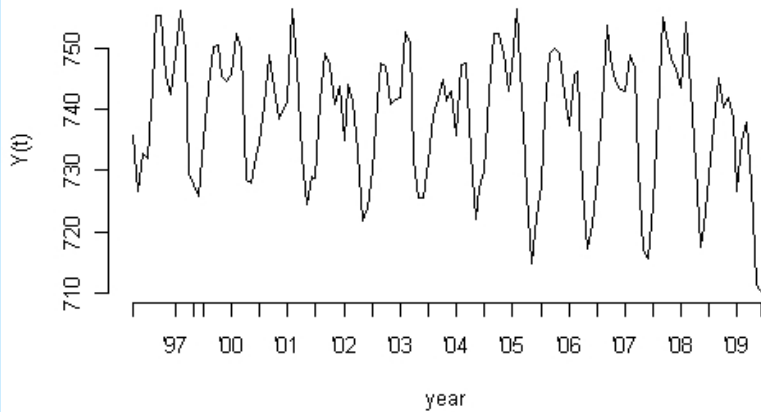


Land mean cloud fraction

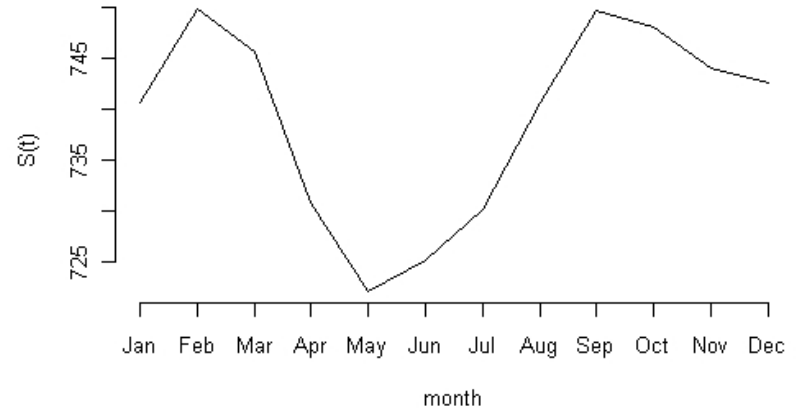


Land mean cloud pressure

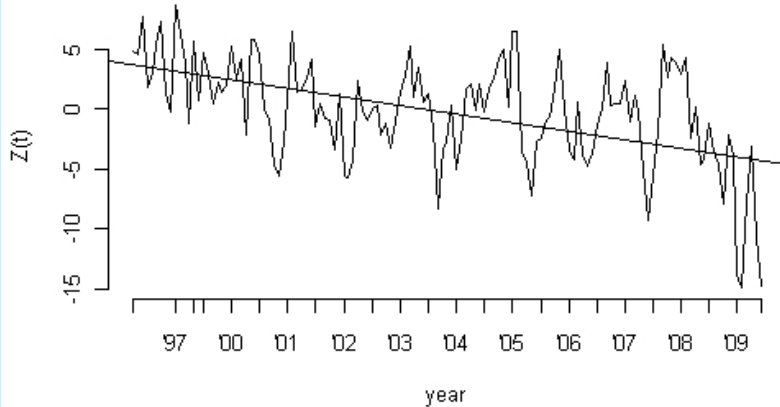
Cloud pressure over Land



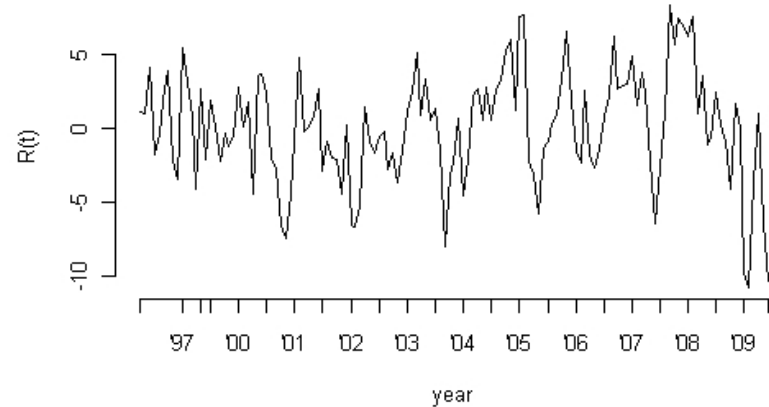
Seasonal component



Deseasonalised cloud pressure



Residuals



Global map of cloud pressure trends

Trend of cloud pressure per year

