Exam NS-M0442M, Physics of Remote Sensing
Date: 27-06-2012, 14:00-17:00

The exam consists of 4 problems, which receive equal weight. This holds also for each individual question, with the exception of problem 3 where the weights are indicated per question.

Problem 1: Atmospheric science.

Measurements of the O_2A band in Sciamachy's channel 4 are used for cloud detection. Figure 1 shows theoretical simulations of the O_2A band, which SCIAMACHY used to measure (before the recent loss of the satellite platform EnviSat) at a spectral resolution of 0.48nm.

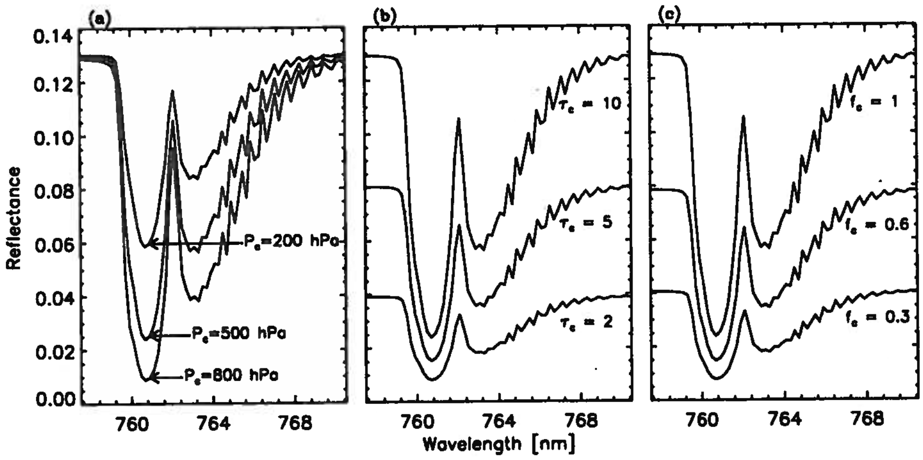

Fig 1: Simulations of satellite observed reflectances in the O_2A band, varying cloud top pressure (P_c), cloud optical depth (τ_c), and cloud fraction (f_c).

a) Besides the O_2A band, SCIAMACHY measures many other gases. Give 2 reasons why the O_2A band is important for the retrieval of those gases.

Figure 1 shows simulated spectra obtained by varying 3 important characteristics of cloud cover.

b) Explain the simulated sensitivity of reflectance to these 3 parameters.
c) How many parameters can be retrieved independently? Explain your answer.

To improve the resolution of the SCIAMACHY cloud retrieval additional measurements from Channel 2 are used (see Figure 2).

d) Make a qualitative drawing of how the reflectance due to cloud and Rayleigh scattering vary between channel 4 and channel 2.
e) Explain why the use of channel 2 improves the resolution of cloud parameters (hint: use your answer to the previous question).

f) Would the use of polarization measurements allow further improvement? Explain your answer.

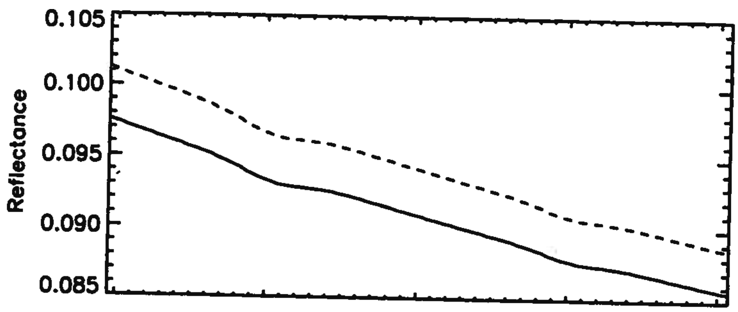

Fig 2: Simulated reflectances in the 350-390 nm spectral window for 2 combinations of cloud parameters (solid and dashed lines), which yield the same reflectance in the O_2A band.

Problem 2: Glaciology.

a) Name three remote sensing methods currently used to determine ice sheet mass balance, and provide a short (~5 lines) explanation how they work and their main advantages/disadvantages.

b) Name two advantages and two disadvantages of laser over radar altimetry applications over snow-covered surfaces.

c) Name the five vertical velocity components of a snow surface on top of a glacier.

d) The figure below shows time series of (A) accumulation (snowfall minus sublimation minus melt) and (B) the associated firn depth anomaly. Explain how, for similar temporal variability in accumulation, the firn depth can either decrease (green lines) or increase (blue lines).

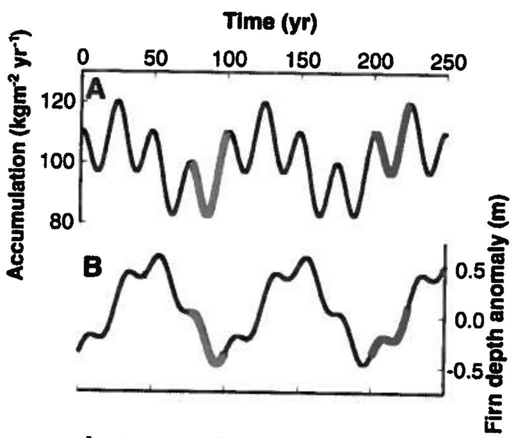

Fig 3: Accumulation and associated firn depth anomaly.

Problem 3: Oceanography.

Altimeter data are an essential component of ocean observation. Consider a spherical wave front which is emitted by a nadir looking altimeter antenna with a pulse time τ. Let t_0 be the time that the beam hits the surface at nadir. A typical signal, which is received by the antenna, is shown in Figure 4.

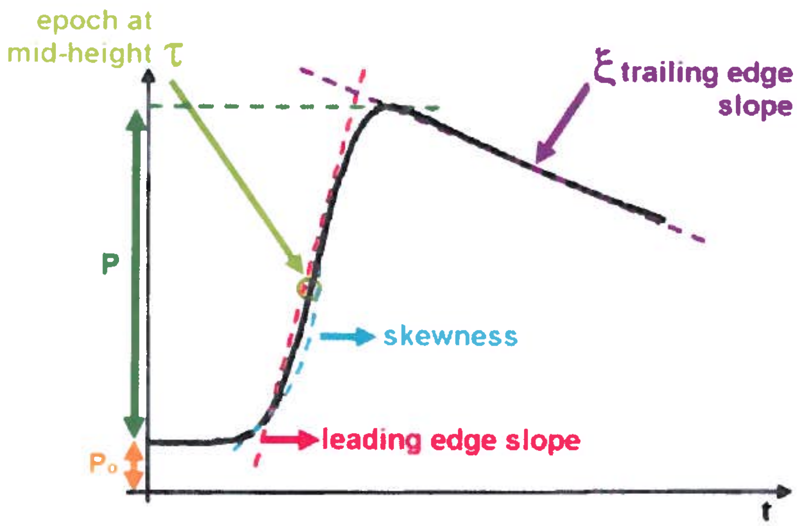

Fig. 4: Typical signal of the intensity P of the reflected signal, which is received by the altimeter versus time t.

a. (25%) Explain the shape of this curve using a description of the different stages of the reflection of the altimeter pulse. Indicate where the time t_0 is located in this figure.
b. (15%) Sketch (and explain briefly) the differences in the return (backscattered) signal between an ocean with swell present and a flat ocean surface.

A student wants to determine the mean surface geostrophic velocity field of the Gulf Stream from available altimeter data. He/she first determines a best estimate of the mean dynamic topography (Fig. 5).

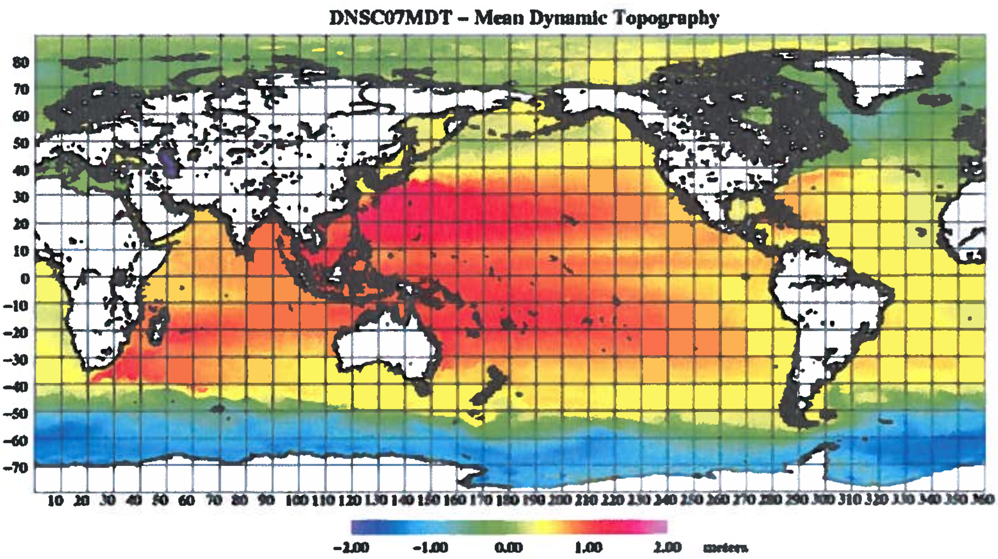

Fig. 5: Mean dynamic topography as determined by the Danish National Space Center. Units of the colour bar are in meters.

c (25%) Provide a derivation how geostrophic velocities are calculated from the mean dynamic topography. Make an estimate of the maximum mean Gulf Stream velocity from Fig. 5; use an ocean density $\rho = 10^3$ kg/m³.
d. (20%) Describe why it is (still) not possible to determine the mean velocity field of the Gulf Stream accurately, say with an error of 1 cm/s.
e. (15%) Which type of phenomena in the ocean circulation can be observed with a high accuracy using altimeter data? Provide several examples of these phenomena.

Problem 4: Atmospheric science.

The Tropospheric emission spectrometer (TES) is used to measure several gases in the atmosphere including methane.

a) The observed tropical radiance (see Figure 6) between 1250 and 1320 cm^{-1} cannot be explained by the contribution of CH_4 and N_2O only. Which other gas plays a role?
b) TES is a Fourier Transform Spectrometer. Biefly explain the concept of this technique.
c) The performance of TES is superior to that of, for example, the grating spectrometer AIRS. How could this be explained? Why is the difference between AIRS and TES critical in this wavelength range?

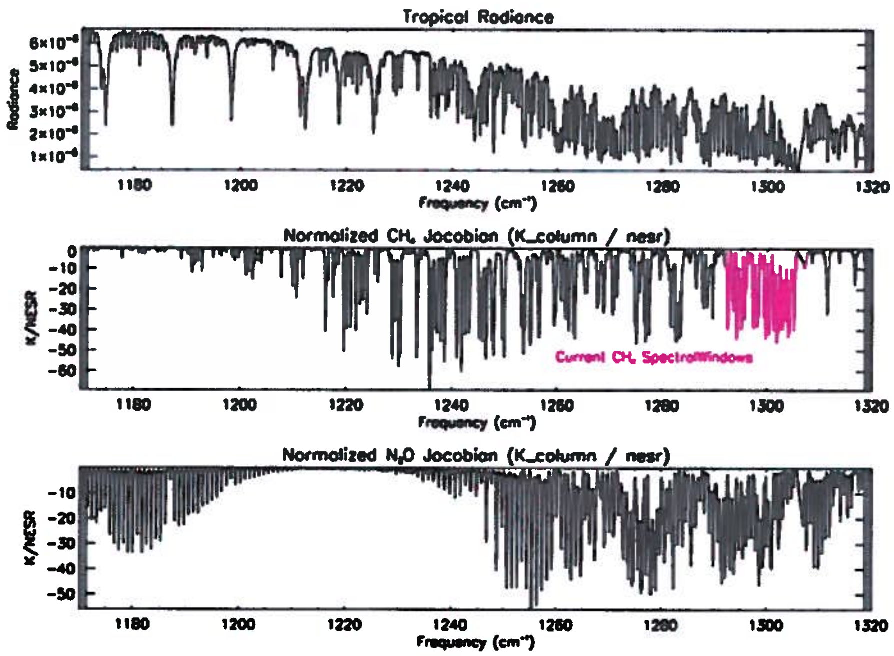

Fig 6: TES observed spectral radiance over a tropical scene. The spectral window of the 'old' retrieval is indicated in red. The spectral window of the 'new' retrieval covers the entire band (black+red).

d) Recently a new retrieval method was introduced (see Figure 6 and 7). Did it improve the results? Explain your answer. Can you explain the meaning of the 'degree of freedom of signal' (DOFS) in Figure 7?

e) Since then attempts have been made to infer CH_4 in the planetary boundary layer using a combination of TES and GOSAT measurements. Explain how.

f) Suppose that GOSAT measures a CH_4 column number density over the ocean of $3.65x10^{19}$molec/cm^2. Calculate the corresponding column mean mixing ratio in ppb CH_4 (N_{avo}=6.022e23; M_{air}=29 g/mol)

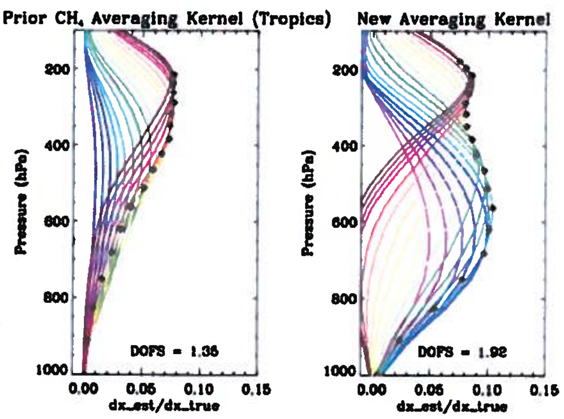

Fig 7: Comparison of the averaging kernels of the old (left) and new (right) TES CH_4 retrieval