

RTIASI-4: An improved version of the  
ECMWF fast radiative transfer model for the  
Infrared Atmospheric Sounding  
Interferometer

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RTIASI-4 is the most recent and significantly improved version of the ECMWF fast radiative transfer model for IASI (Matricardi and Saunders 1999).

RTIASI is a regression based (on fixed pressure levels) fast radiative transfer model.

Layer optical depths  $\tau_j$  are modelled as functions of profile dependent predictors  $X_{k,j}$ :

$$\tau_j = \sum_{k=1}^M a_{k,j} X_{k,j}$$

The expansion coefficients  $a_{k,j}$  are obtained by multiple linear regression: accurate optical depths are computed for a diverse set of atmospheric profiles and then the values of  $\tau_j$  are regressed against the corresponding values of  $X_{k,j}$ .

The database of accurate optical depths used to produce the fast transmittance model is generated using the GENLN-2 (Edwards 1992) line-by-line radiative transfer algorithm.

The database of molecular line parameters and gas cross-sections adopted for the GENLN2 computations is the year 2000 version of HITRAN (Rothman et al. 2003).

GENLN2 computations were performed selecting 14 gaseous species: H<sub>2</sub>O, CO<sub>2</sub>, O<sub>3</sub>, N<sub>2</sub>O, CO, CH<sub>4</sub>, N<sub>2</sub>, O<sub>2</sub>, OCS, CCl<sub>4</sub>, CF<sub>4</sub>, CCl<sub>3</sub>F, CCl<sub>2</sub>F<sub>2</sub> and HNO<sub>3</sub>.

Among the 14 gaseous species used in the GENLN2 computations,  $\text{HNO}_3$ ,  $\text{OCS}$ ,  $\text{CCl}_4$  and  $\text{CF}_4$  were not featured in the previous versions of RTIASI.

In RTIASI-4, fixed amounts are used for  $\text{N}_2$ ,  $\text{O}_2$ ,  $\text{OCS}$ ,  $\text{CCl}_4$ ,  $\text{CF}_4$ ,  $\text{CCl}_3\text{F}$ ,  $\text{CCl}_2\text{F}_2$  and  $\text{HNO}_3$  whereas  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ ,  $\text{O}_3$ ,  $\text{N}_2\text{O}$ ,  $\text{CO}$ ,  $\text{CH}_4$  are allowed to vary and are profile variables in the fast model.

The diverse profiles used to derive the regression coefficients for H<sub>2</sub>O, O<sub>3</sub> and fixed gases are described in Matricardi and Saunders (1999).

The training profiles for CO<sub>2</sub>, N<sub>2</sub>O, CO and CH<sub>4</sub> are a blend of profiles from in-situ measurements and chemistry model generated ones (Matricardi 2003).

Stratospheric profiles for CH<sub>4</sub> and N<sub>2</sub>O are from the Cryogenic Limb Array Etalon Spectrometer (CLAES) dataset.

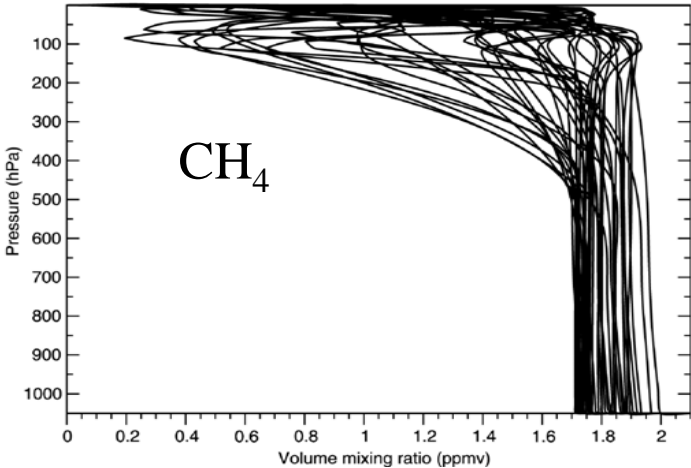
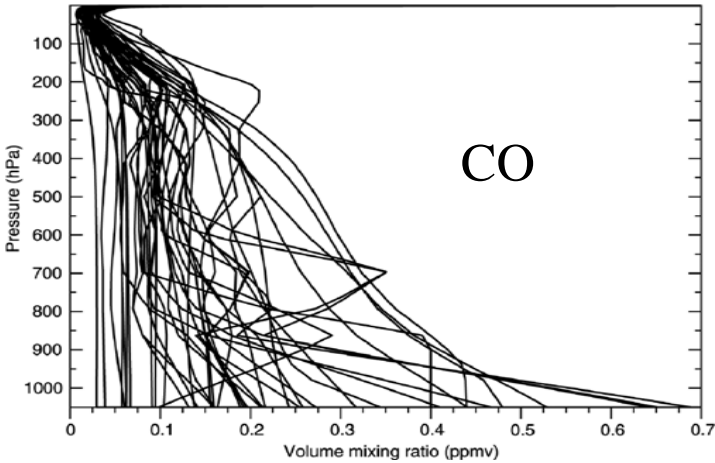
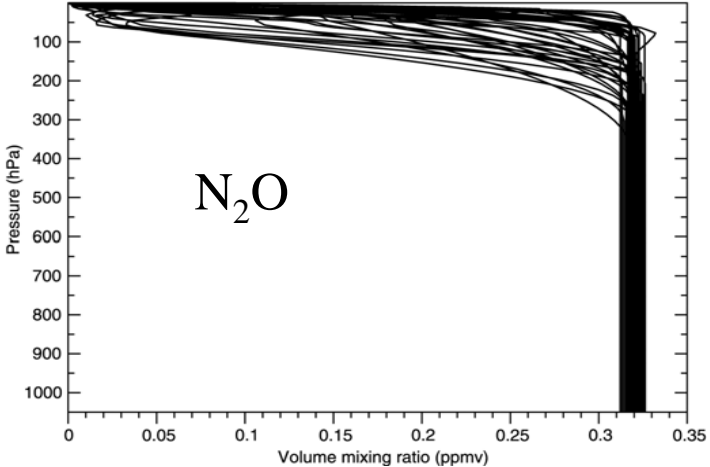
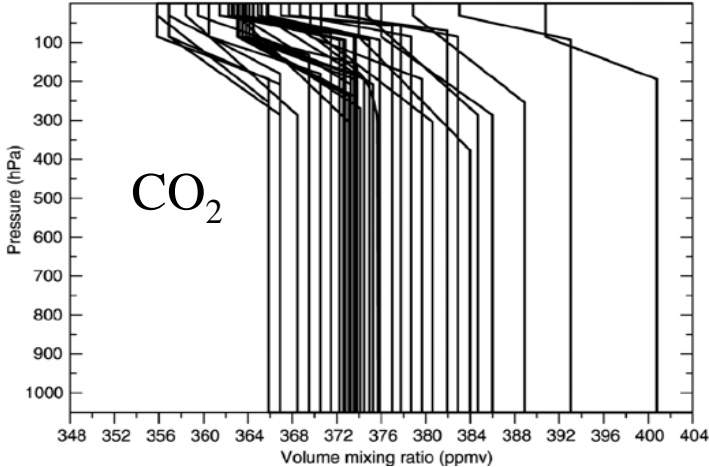
N<sub>2</sub>O is assumed to be well mixed in the troposphere whereas tropospheric profiles for CH<sub>4</sub> are based on the IMAGES model calculations (Muller and Brasseur 1995; Clerbaux et al. 1998).

CO<sub>2</sub> profiles are based on the assumption that the vertical distribution of this gas is constant in the troposphere and decreases by 5 to 10 ppmv between the tropopause and about 22 km altitude (Bischof et al. 1985).

Tropospheric profiles for CO are based on MOZART 3D model calculations (Brasseur et al. 1998; Cunnold, 2001) and measurements taken during the STRATOZ III and TROPOZ campaign (Marenco et al. 1995). Mixing ratios in the troposphere are extrapolated to the stratosphere assuming a lapse rate equal to the one from the corresponding seasonal USAFGL CO profile.



# The training profiles for CO<sub>2</sub>, N<sub>2</sub>O, CO and CH<sub>4</sub>.



To model the layer optical depths, RTIASI-4 uses predictors that are functions of the layer temperature, absorber amount and viewing angle .

Since the layer optical depths are obtained from ratios of layer-to-space transmittances, predictors that take into account the dependence of the layer optical depth on the layers above are introduced.

To compute the local mean path angle in each atmospheric layer, a ray tracing in the earth's atmosphere is performed in RTIASI.

The height of the pressure levels is obtained by integration of the hydrostatic equation using virtual temperatures to account for the presence of water vapour.

The variation of gravity with latitude is introduced using the international gravity formula (Woollard 1979).

The refractive index of air is computed using an updated version of Edlen's equation (Birch and Downs 1993).

The RTIASI-4 fast transmittance algorithm uses:

Ten predictors for fixed gases

Up to 14 predictors for water vapour  
(line absorption).

Eleven predictors for ozone, CH<sub>4</sub> and CO

Up to 11 predictors for CO<sub>2</sub>

Up to 12 predictors for N<sub>2</sub>O.

In RTIASI-4, water vapour continuum type absorption is handled separately from line absorption so that any change in the continuum can be addressed without the need of generating a new line-by-line database.

A fast transmittance model for the water continuum has been developed based on a database of accurate transmittances generated using the CKD 2.4 water continuum model (Clough et al. 1989).

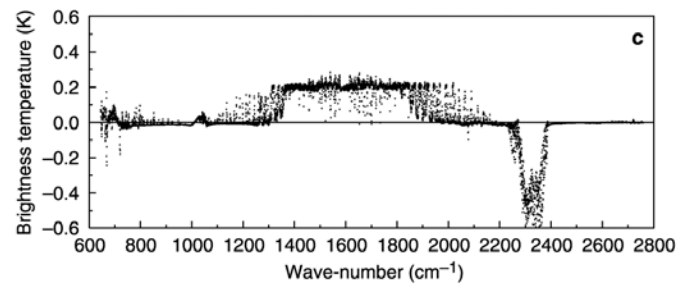
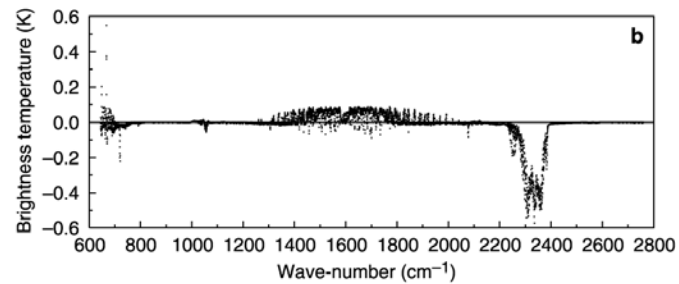
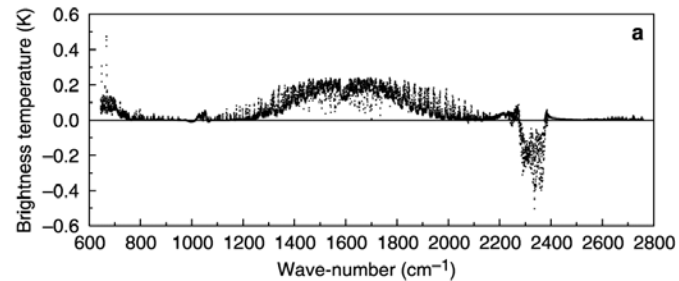
The fast transmittance model for the water vapour continuum uses 4 predictors.

Radiance calculations in RTIASI-4 are performed assuming that the atmosphere is divided into 89 layers of fixed pressure levels. The pressure grid extends from 1050 hPa to 0.005 hPa.

This is a significant improvement to the 43 layers pressure grid used in the previous versions of the model.

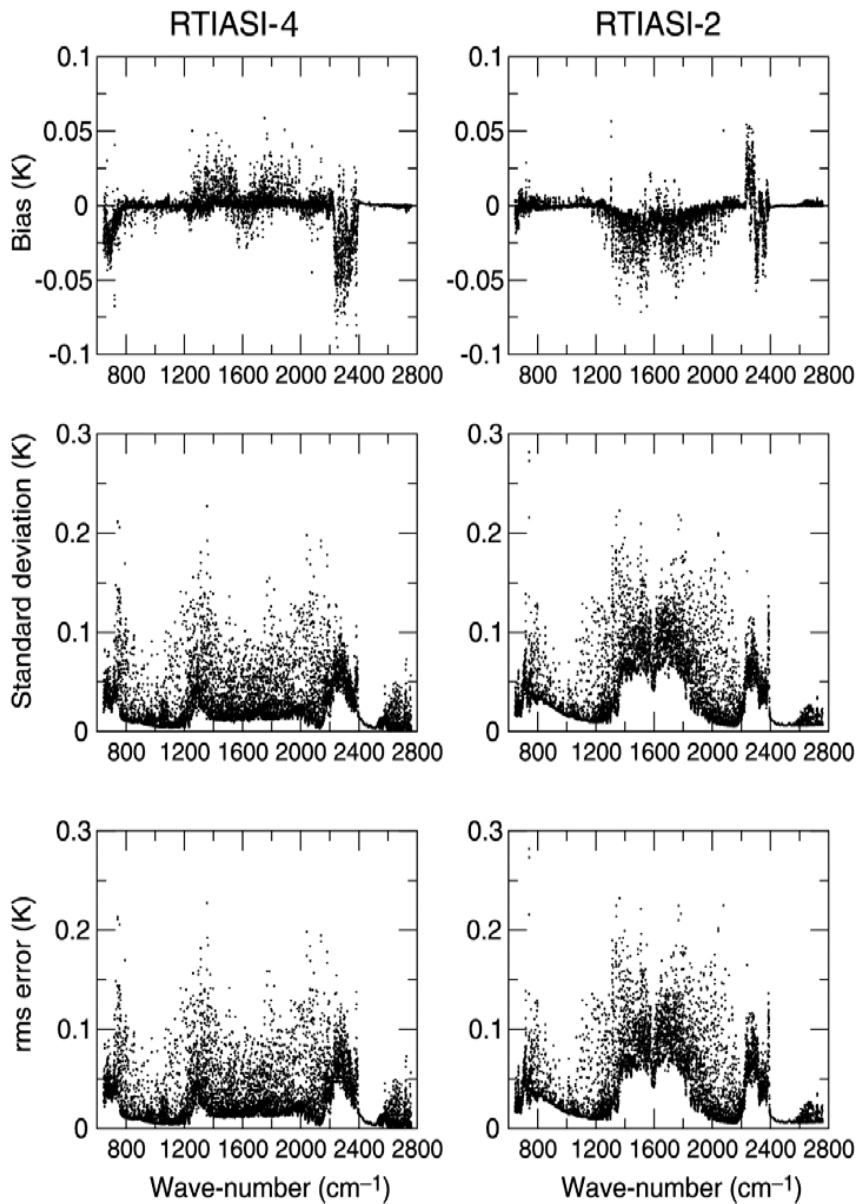
The 89 layers grid is considered to be optimal since any refinement of the grid results in radiance increments well below the noise of the IASI instrument.

Difference between IASI level 1C spectra obtained using the layering definition adopted in RTIASI-2 and RTIASI-4. Results are shown for (a) Mid-latitude spectrum; (b) Arctic spectrum; (c) Tropical spectrum.

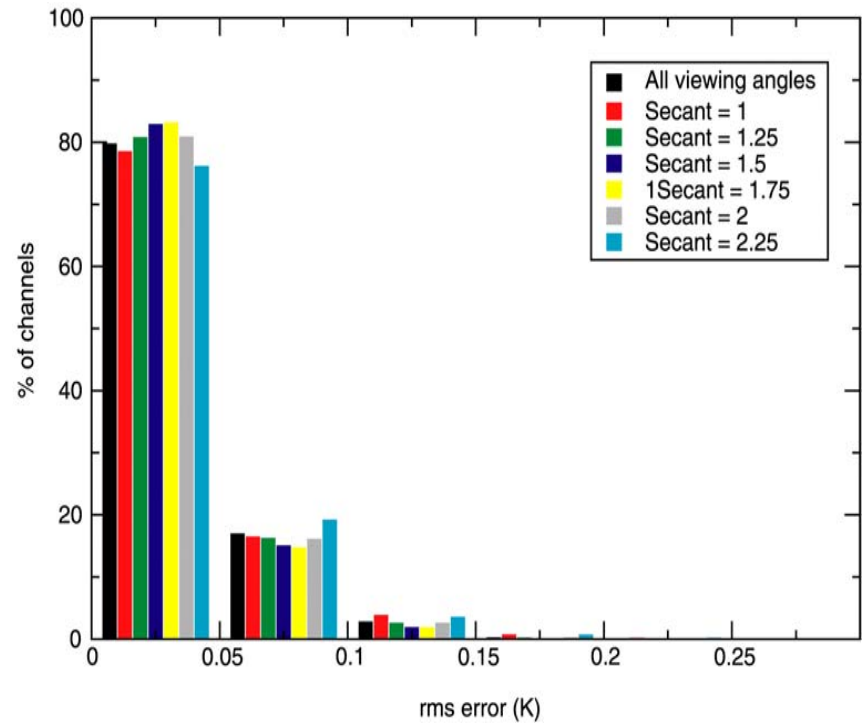


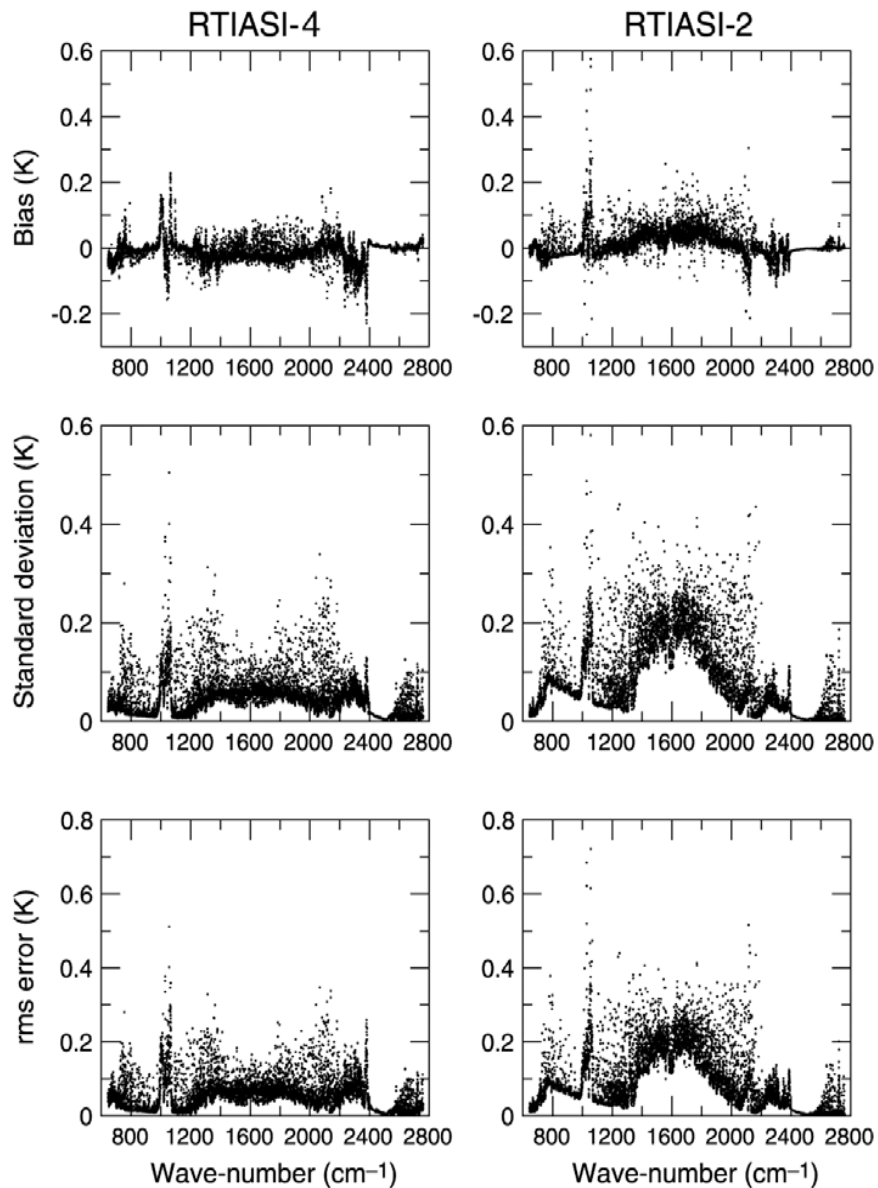
The ability of RTIASI-4 to reproduce GENLN2 computed radiances can be assessed by comparing fast model and line-by-line radiances for the dependent set of profiles used to train the fast model and for a set of profiles independent to the regression coefficients.



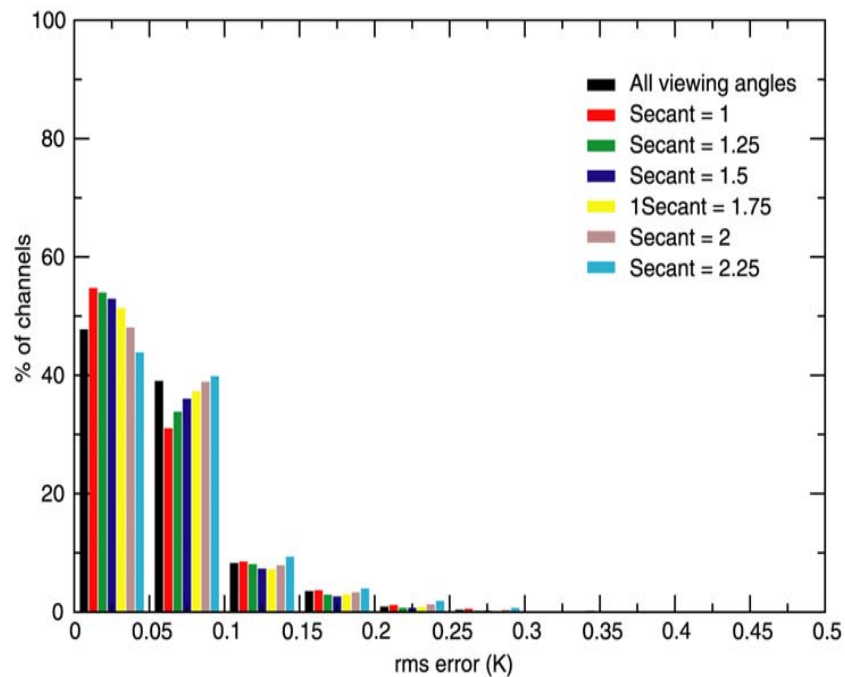


Mean value, standard deviation and rms of the difference between fast model and GENLN2 computed radiances for 43 diverse profiles and 6 viewing angles.



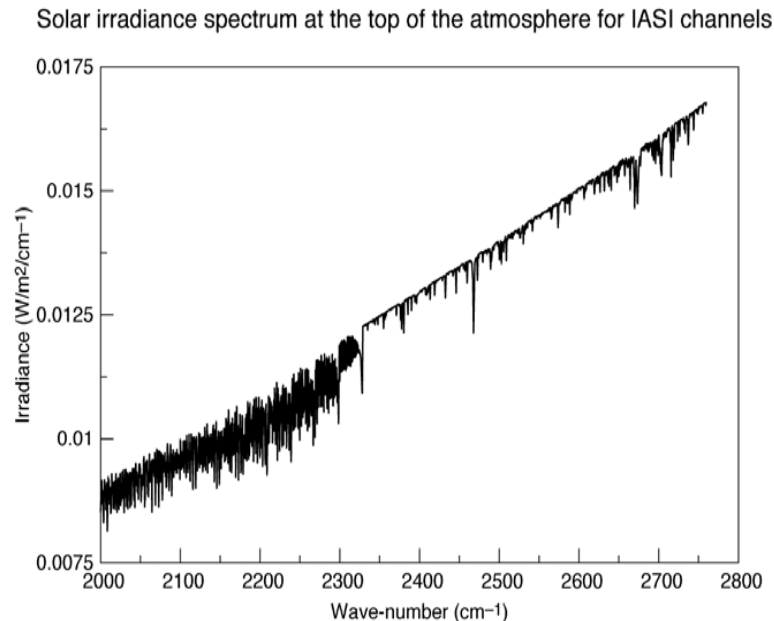


Mean value, standard deviation and rms of the difference between fast model and GENLN2 computed radiances for 117 independent profiles and 6 viewing angles.



The radiative transfer equation used in RTIASI-4 includes the effect of solar radiance reflected from the surface in clear sky conditions and in absence of scattering.

The solar irradiance spectrum at the top of the atmosphere is from theoretical radiative transfer calculations made by Kurucz (1992) based on measurements made by the ATMOS instrument on the space shuttle.



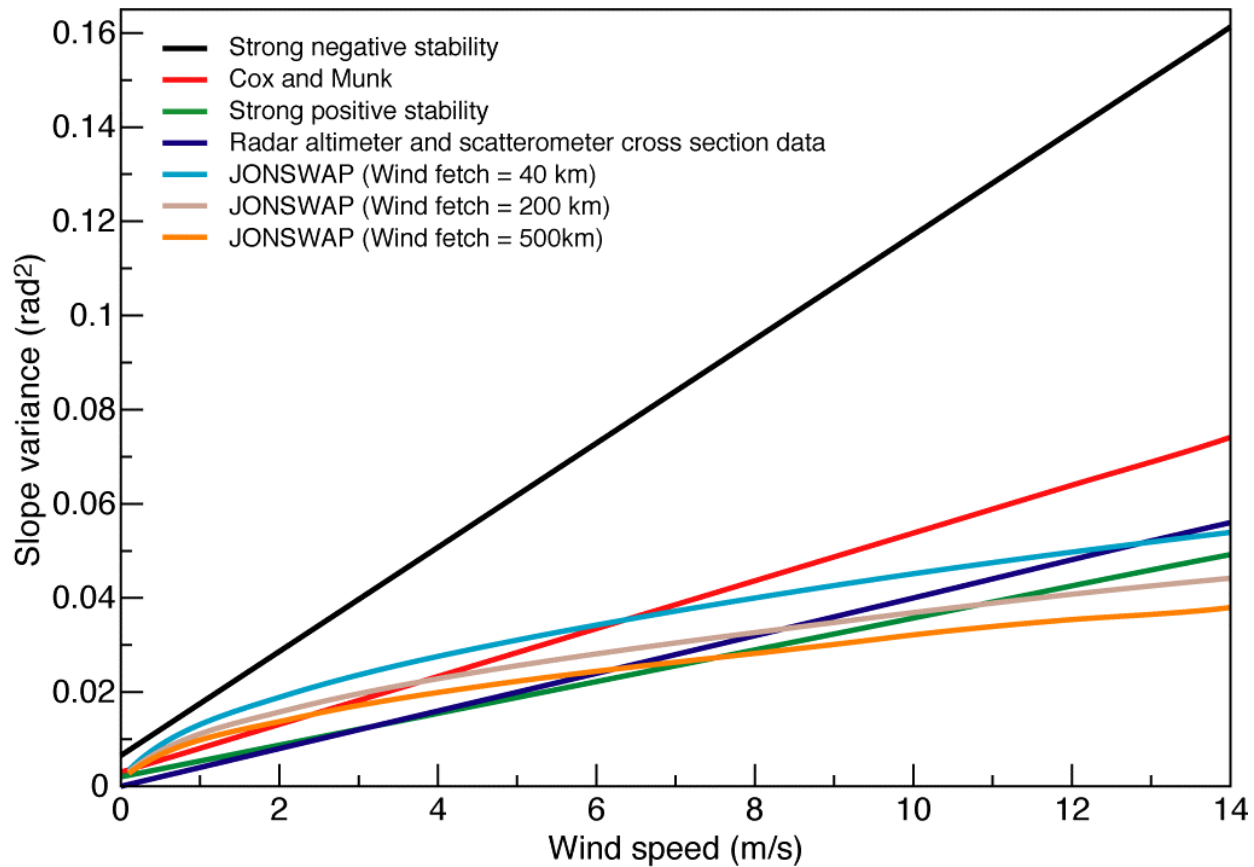
For the case of solar radiance reflected by a land surface, the reflecting surface is treated as a perfect diffuser following the Lambert law.

For the case of solar radiance reflected by a wind roughened water surface, the bistatic reflectivity is computed using the scheme by Yoshimori et al. (1995).

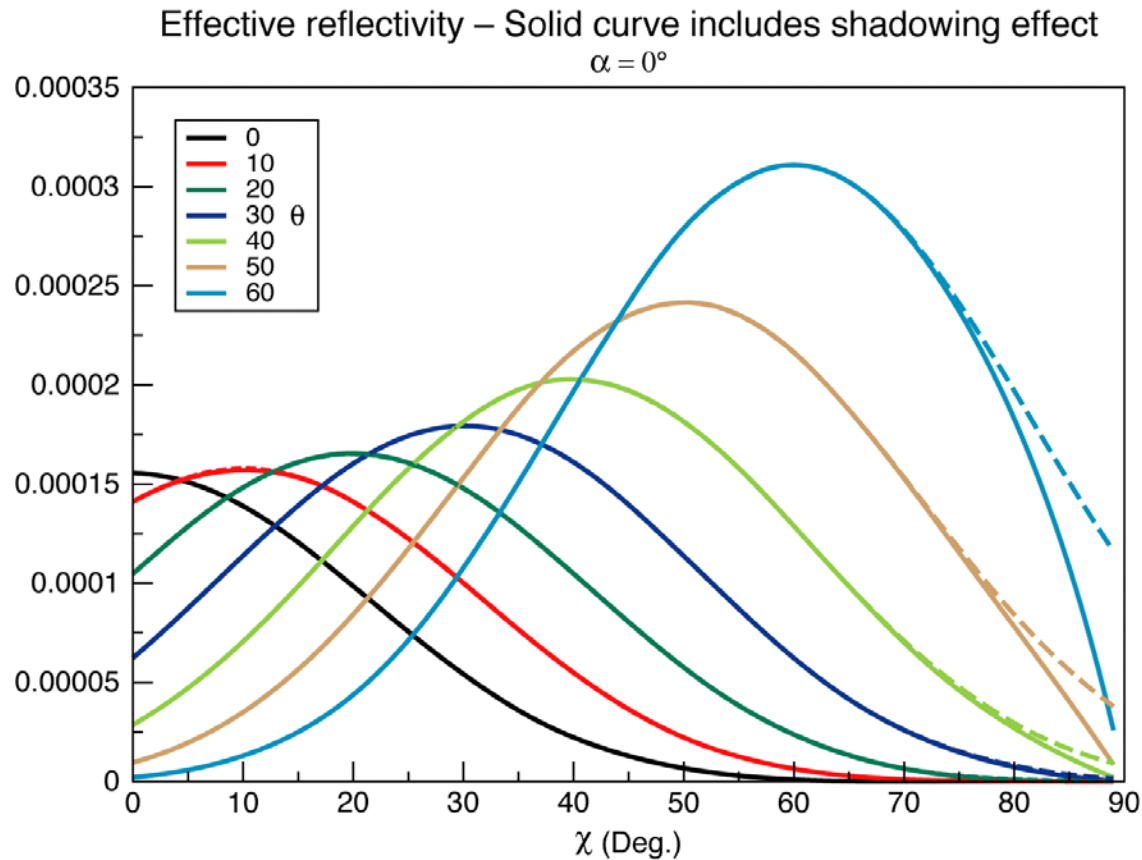
The wave slope probability density obeys a Gaussian distribution and the total variance of the slope is determined from the spectrum of the wave slope as specified in the Joint North Sea Wave Project (JONSWAP) wave-spectral model.

Shadowing (the fact that slopes on the back sides of the waves and deep in the troughs between waves are hidden from view) is fully accounted for.

The dependence on the wind speed of the total variance of the slope.



The bistatic reflectivity of a wind roughened water surface for a wind speed of 7 m/s and a wind fetch of 40 km.



The computation of the solar term requires the evaluation of transmittances at very large zenith angles. This increases the difficulty of fitting the line-by-line optical depths and consequently a dedicated fast transmittance model for the shortwave has been developed that uses a set of revised predictors.

The fast transmittance model in the shortwave can accurately reproduce line-by-line transmittances for solar zenith angles as large as  $85^\circ$ .



The root mean square of the difference between fast model and GENLN2 radiances for the 43 dependent profiles. The solar term is included. Results in the top panel are for the direct and reflected solar beam in the same vertical plane. Results in the bottom panel are obtained by tilting by  $30^\circ$  the vertical plane that contains the reflected solar beam.

