SWIR Carbon Observation Retrieval Model Intercomparison Project (SCORE-MIP):
Task 1a - Comparison of scalar and vector radiative transfer codes

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Objective: Radiative transfer intercomparisons of scalar and vector RT codes for synchronized layer properties for the SWIR spectral range.

Brief description of the experiment:
For a range of different geophysical scenarios with given optical layer properties (optical depth, single scattering albedo and scattering matrix) the top-of-atmosphere radiances will be calculated for three narrow spectral ranges in the oxygen A Band, the 1.6 micron CO2 band and the 2.03 micron CO2 band. The geophysical scenarios considered for this experiment will contain different aerosol and cirrus loadings and solar zenith angles. We will consider only nadir observations for Lambertian surfaces and sunglint observations (viewing zenith angle = solar zenith angle) for ocean surfaces. For each scenario, we will then compare the calculated intensities I (scalar) and I-Q (vector) obtained with different RT codes. It is planned to carry out the calculations with a RT code with standardized setup with parameters chosen for high accuracy and with an 'operational' version that will allow faster RT calculations. We will also keep track of clock time since we are interested in RT codes that can be run on large number of retrievals.

Geophysical Scenarios:

- for 5 different aerosol scenarios:
  a) Low aerosol loading (AOD ~ 0.05); no cirrus cloud: use gas + Rayleigh + aerosol (low_aod)
  b) Low aerosol loading (AOD ~ 0.05) with cirrus cloud: use gas + Rayleigh + aerosol (low_aod) +cirrus
  c) High aerosol loading (AOD ~ 0.3) no cirrus cloud: use gas + Rayleigh + aerosol (high_aod)
  d) High aerosol loading (AOD ~ 0.3) with cirrus cloud: use gas + Rayleigh + aerosol (high_aod) + cirrus
  e) No aerosol (pure Rayleigh): use gas + Rayleigh

- Geometry
  a) Solar zenith angle: SZA = 10, 45, 70
  b) Viewing angle: nadir and sunglint

- Surface
  a) Lambert albedo (same in each band): 0.05, 0.1, 0.3
  b) Ocean sunglint: windspeed 5 m/s with viewing zenith angle = solar zenith angle

Setup of input layer data

- For each layer of a 60 layer atmosphere:
    a) Optical depth of gaseous absorption, aerosol, cirrus and Rayleigh extinction
    b) Single scattering albedo of aerosols and cirrus
    c) Scattering matrix for aerosols, cirrus and Rayleigh (layer independent)

- Spectral range:
    a) Band 1: O2 A-band:
       Window w1: 13080 – 13090 cm-1 (1000 spectral points)
       Window w2: 12976 – 12980 cm-1 (400 spectral points)

    b) Band 2: 1.61 micron CO2:
       Window w1: 6202 – 6206 cm-1 (400 spectral points)

    c) Band 3: 2.04 micron CO2:
       Window w1: 4841-4845 cm-1 (400 spectral points)
       Window w2: 4815–4819 cm-1 (400 spectral points)

RT Setup:

- The RT calculations for each scenario will be carried out for 4 setups of the RT code:
    - 'scalar accurate': scalar RT with standardized setups
    - 'scalar fast': fast version of scalar RT code
    - 'vector accurate': vector RT with standardized setups
    - 'vector fast': fast version of vector RT code
- Parameters for ‘accurate’ setup: 32 full streams, delta-M on, single scattering correction on, plane parallel, 60 vertical layers
- ‘Fast’ setup: here the code should be run in a configuration so that the RT calculations are sufficiently fast for the retrieval of a large number of spectra
- Groups can also provide the RT calculations only for some of the 4 setups.

Organization and Convention for input data

- The data directory contains subdirectories for aerosol, cirrus, gas and Rayleigh that contain files with the optical depth, single scattering abedo and scatteringmatrix

- Optical depth for is given for each spectral point and each vertical layer. The first column is the wavenumber, the second column is the optical depth of the uppermost layer and the last column is the optical depth of the bottom layer.

- Single scattering albedo (ssa) for aerosol and cirrus is given for each spectral point

- The input files are given for each spectral band separately. They will be identified with b1, b2, b3 for the O2 A Band, the 1.6 micron Band and the 2.03 micron band followed by the window number (w1 or w2).

- We assume that the scattering matrix is constant across each band, ie. only one scattering matrix is given per band. The scatteringmatrix file contains all 3 bands

- Scattering matrix is given as alpha1-4,beta1-2 according to following representation (Note that alpha1 is the scalar phase function):

$$S^{\ell} = \begin{pmatrix} \alpha_1^{\ell} & \beta_1^{\ell} & 0 & 0 \\ \beta_1^{\ell} & \alpha_2^{\ell} & 0 & 0 \\ 0 & 0 & \alpha_3^{\ell} & \beta_2^{\ell} \\ 0 & 0 & -\beta_2^{\ell} & \alpha_4^{\ell} \end{pmatrix}.$$

- Elements of scattering matrix for Rayleigh scattering:

  alpha1(m=0) = 1.d0
  alpha1(m=2) = (1.d0-depolf)/(2.d0+depolf)
  alpha2(m=2) = 6.d0*(1.d0-depolf)/(2.d0+depolf)
  alpha4(m=1) = 3.d0*(1.d0-2.d0*depolf)/(2.d0+depolf)
  beta1(m=2) = dsqrt(6.d0)*(1.d0-depolf)/(2.d0+depolf)

  with depolf =0.0279. m is the moment. All other moments are zero.

- Please note that the forward peak of cirrus phase function has been truncated and the other optical properties of cirrus (single scattering albedo) had modified accordingly.

Organization of output data:

- Give output as 2 column ASCII files with wavenumber and I or I-Q
- Generate separate file for each geophysical scenario
- Include header that provides information about the run (RT setup, code version etc). Start header lines with #
- Provide the computation time for each scenario together with the computation time for the test programme (tespol.f90)

Benchmark Vector RT results:

- We recommend that groups also contribute to the vector RT comparison that has been set-up by Alexander Kokhanovsky from University of Bremen.
- Inputs for this RT test can be obtained at: http://www.iup.uni-bremen.de/~alexk/
- Please submit results directly to Alexander Kokhanovsky (alexk@iup.physik.uni-bremen.de)

Some Considerations:

- Total optical depth:

$$\tau = \tau_{gas} + \tau_{aero} + \tau_{cirrus} + \tau_{Rayleigh}$$

- Total single scattering albedo:

$$\varpi = \frac{\varpi_{aero} \times \tau_{aero} + \varpi_{cirrus} \times \tau_{cirrus} + \tau_{Rayleigh}}{\tau}$$

- Total phase function:

$$ph = \frac{\varpi_{aero} \times \tau_{aero} \times ph_{aero} + \varpi_{cirrus} \times \tau_{cirrus} \times ph_{cirrus} + \tau_{Rayleigh} \times ph_{Rayleigh}}{\varpi_{aero} \times \tau_{aero} + \varpi_{cirrus} \times \tau_{cirrus} + \tau_{Rayleigh}}$$

- Calculation of Phasefunction from Phasefunctionmoment a_l

$$ph(\cos\theta) = \sum_l a_l \times P_l(\cos\theta)$$