Prescriptions to compare Modtran and LibRadTran

Dagoret-Campagne, Sylvie , LAL, *dagoret@lal.in2p3.fr*
Gilmore, David Kirk , SLAC, *dkg@slac.stanford.edu*
For PCWG team of DESC-LSST collaboration

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Overview

Motivation

- Want to use precise atmospheric models to correct LSST images from atmospheric attenuation,
- Target accuracy : 1% on flux or 10 mmag on Magnitude imply a 1% accuracy on air-transparency,
- From a few precise auxiliary measurements, can we infer the air transparency over the LSST full wavelength range ?
- It is difficult to compare simulation codes with well calibrated data (including with known air transparency).
- So the first stage of checking the simulation validity is to compare the prediction of Modtran-LibRadTran

Evaluation of air transparency simulation codes

- Modtran : Very popular code in the US, natural legacy, the reference.
- LibRadTran: More recent implementation, easy to use, open code, need to be evaluated wrt Modtran.

But Compare exactly what ?

We should first share the same input assumption for comparing the output results.

- What kind of "thermodynamical" atmosphere (gas) should we use as input ? $\rightarrow$ define the **atmospheric model**,
  - AltitudeTemperature profile,
  - AltitudePressure profiles,
  - Molecular species profiles (at least those that matter)
- Similar light-molecules interaction models: $\rightarrow$ define the **absorption models**,
- Check the air transparency for the same grid in (λ, z) points.

To agree with the parameters, we have to define the common parameters choice among hundreds of parameters to be tuned $\rightarrow$ define **prescriptions**.

Data points of the grid

Altitude

$h = 2.75$ km.

Wavelength range

$\lambda \in [250, 1200]$ nm, $\Delta\lambda = 1$ nm

Airmass range

z computed for 31 points in steps of 0.1 : $z \in [1, 3]$

The Atmospheric Profile

Compare predictions for 2 realistic atmospheric models.

- US standard atmosphere $\rightarrow$ probably good for LSST, but perhaps a little too wet
- Subarctic winter $\rightarrow$ very dry air, probably well suited for LSST site

The above atmospheric models are both available in Modtran(Data Card : Card1.MODEL) and LibRadTran (Data Card : atmosphere_file.)

The absorption models in LibRadTran

- **Spectrally resolved calculation**,
- **Line-by-line calculation**,
- **The correlated-k method**,(Kato and Kato2),
- **The correlated-k method**,(Fu and Liou),
- **Representative wavelengths parameterization (REPTRAN)**,
- **Pseudo-spectral calculation adapted from LOWTRAN**.
- **CRS: switching off spectral parameterization**.

Absorption models in LibRadTran :

1) REPTRAN, 2) LOWTRAN, 3) CRS, 4) Fu 5) KATO, 6) KATO2, 7) KATO2.96

The Data card for specifying the absorption model in LibRadTran is *mol_abs_param* . One should provides the values *reptran fine* or *reptran medium*, *reptran coarse* or *lowtran*,...

The absorption models in Modtran

- **Band models methods**, The Modtran or Lowtran models,
- **The correlated-k method**, The Modtran and Lowtran either in slow or medium modes.

Absorption models in LibRadTran :

1) MODTRAN band Model, 2) LOWTRAN Band Model , 3) MODTRAN correlated-k and slow speed, 4) MODTRAN correlated-k and slow speed, 5) MODTRAN correlated-k and medium speed

The Data card for specifying the absorption model in Modtran is *CARD1 MODTRN* . One should provides the values *T,M,C,K,F,L* and *CARD1 SPEED* is *S* or blank.

Comparison of light-atmospheric matter interaction processes

- Simulate with only molecular scattering (Rayleigh scattering).
- Simulate pure molecular absorption.

Variation of Precipitable Pressure Water *PWV*

absorption profiles for 31 points $pwv \in [0\ \mathrm{mm}, 15\ \mathrm{mm}]$ in steps of 0.5 mm

Variation of Ozone O_3

absorption profiles for 21 points $O_3 \in [200\ \mathrm{Dobson}, 600\ \mathrm{Dobson}]$.

- Simulate the combination of molecular scattering and molecular absorption.
  - perform similar variations in *PWV* and O_3

File naming : Part 1

filename

$P\_O\_\{rte\}\_\{atm\}\_\{proc\}\_\{mod\}\_zXX\_wvXX\_ozXX.extension$

P : **RT** or **MT** for LibRadtran or Modtran,

O : Observatory site **LS** or **HP** or **GM** or **MK** for LSST, OHP, Gemini South, Mauna Kea,...

{rte} : **pp** or **ps**,

{atm} : **us** or **sw**,

{proc} : **sc** for pure molecular scattering, **ab** for pure molecular absorption, **sa** for the combination of molecular scattering and absorption,

{mod} : in LibRadTran : **rt** for Reptran model, **lt** for Lowtran model, **cr** for CRS model, **fu** for the Fu and Liou model, **k2** for Kato2 model, and **kt** for Kato model.

{mod} : in ModTran : **mt** for Modtran band model), **mk** for Modtran correlated-k model, **lt** for Lowtran model.

zXX : Airmass z, where XX is the value of the airmass on 2 digit $XX = 2 \times z$,

wvXX : Precipitable water vapour pwv, where XX is the value of the pwv on 3 digit $XXX = 10 \times pwv$, pwv in mm unit,

ozXX : Ozone oz, where XX is the value of the oz on 2 digit $XX = oz/10$, oz is Dobson unit.

For example a filename for LibRadtran, for LSST could be :

$$RT\_LS\_pp\_us\_sa\_rt\_z15\_wv030\_oz30.txt$$

where $pwv = 3$ mm and $oz = 300$ Dobson unit and $z = 1.5$.

File naming : Part 2

Naming absorption models for Modtran

filename

P_O_{rte}_{atm}_{proc}_{mod}_zXX_wvXX_ozXX.extension

{mod} :

- **mt** for Modtran band model (CARD1.MODTRN='T'),
- **mm** for Modtran band model (CARD1.MODTRN='M'),,
- **lt** for Lowtran band model (CARD1.MODTRN='L' or 'F'),
- **mks** for Modtran correlate-k in slow mode (speed), (CARD1.MODTRN='K' or 'C and CARD1.SEED='S'),
- **mkm** for Modtran correlate-k in medium mode (speed), (CARD1.MODTRN='K' or 'C and CARD1.SEED='M'),

For example a filename for Modtran, for LSST could be :

$$MT\_LS\_pp\_us\_sa\_mt\_z15\_wv030\_oz30.txt$$

where $pwv = 3$ mm and $oz = 300$ Dobson unit.

Hierarchy of directories

rootdir	top directory
rootdir/RT/VXX/LS/pp/us/sc/	pure molecular scattering
rootdir/RT/VXX/LS/pp/us/ab/rt/wv/	pure molecular absorption for varying *pwv*
rootdir/RT/VXX/LS/pp/us/ab/rt/oz/	pure molecular absorption for varying *oz*
rootdir/RT/VXX/LS/pp/us/sa/rt/wv/	molecular absorption and scattering for varying *pwv*
rootdir/RT/VXX/LS/pp/us/sa/rt/oz/	molecular absorption scattering for varying *oz*
rootdir/RT/VXX/LS/pp/us/sc/ae/	pure molecular scattering and default aerosols scattering
rootdir/RT/VXX/LS/pp/us/sa/rt/ae/	molecular absorption scattering and default aerosols scattering
rootdir/RT/VXX/LS/pp/us/sc/as/	pure molecular scattering and special aerosols scattering
rootdir/RT/VXX/LS/pp/us/sa/rt/as/	molecular absorption scattering and special aerosols scattering

VXX is the version number of Radtrran or Modtran.

Status of the work

- GitHub Repository created by Nicolas at https://github.com/DarkEnergyScienceCollaboration/PC5AtmosphericExtinction
- Prescription note written to proceed with air transparency simulations and posted at https://github.com/DarkEnergyScienceCollaboration/PC5AtmosphericExtinction/tree/master/doc/Prescriptions
- Simulation with LibRadTran **done** and at posted at (see README) https://github.com/DarkEnergyScienceCollaboration/PC5AtmosphericExtinction/tree/master/LibRadTran/simulations
- Simulation with Modtran **soon performed** and at posted at (see README) https://github.com/DarkEnergyScienceCollaboration/PC5AtmosphericExtinction/tree/master/ModTran

- Ready for Atmospheric properties Analysis,
- Almost ready for comparison, at least comparing the different models inside LibRadTran.

The End