Neural Network Approach to the Retrieval of Cloud Parameters of Inhomogeneous Clouds

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Results of work (before 2001) :

Feasibility of the cloud parameter retrieval of inhomogeneous clouds

- **Cloud parameters retrieval to retrieve**

  1 - mean optical thickness (τ)

  2 - effective radius (ref)

  3 - cloud inhomogeneity at sub-GLI pixel (standard deviation of τ)

  4 - fractional cloud cover at sub-GLI pixel

- **Input data (prepared with SHDOM without atmosphere)**

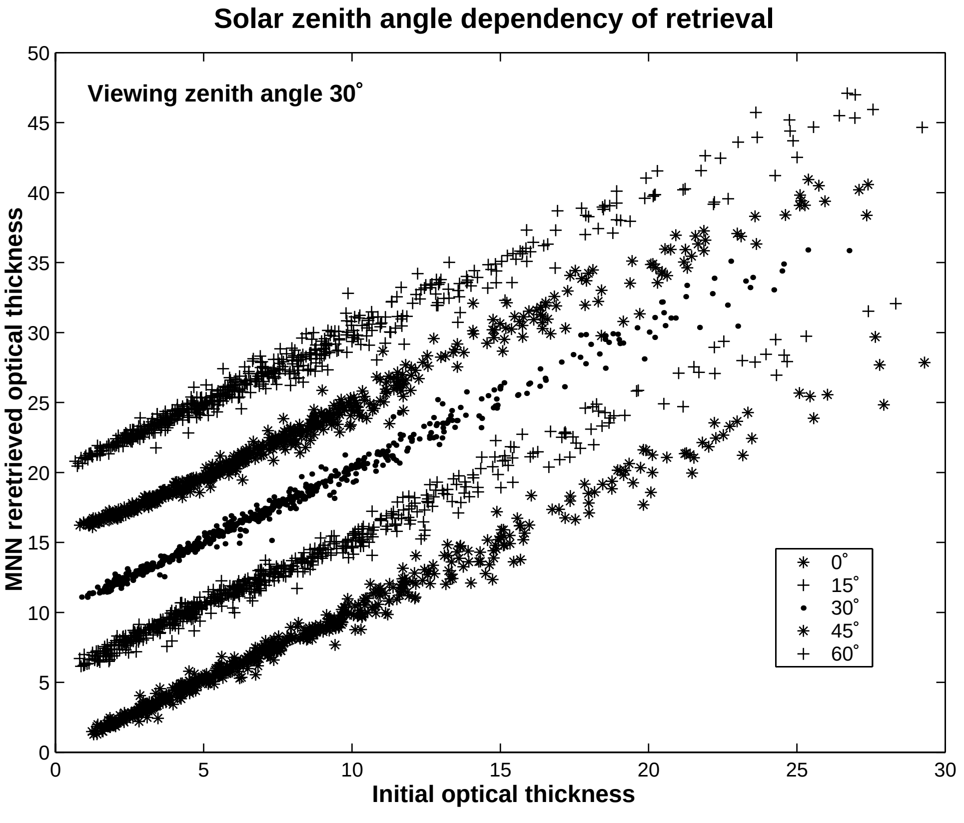
  - ch08, ch28, ch30, and ch35 radiance data of target pixel (1km pixel)

  - standard deviations of radiance (ch08, ch28, ch30) estimated from 0.25km pixel radiance at 1km pixel

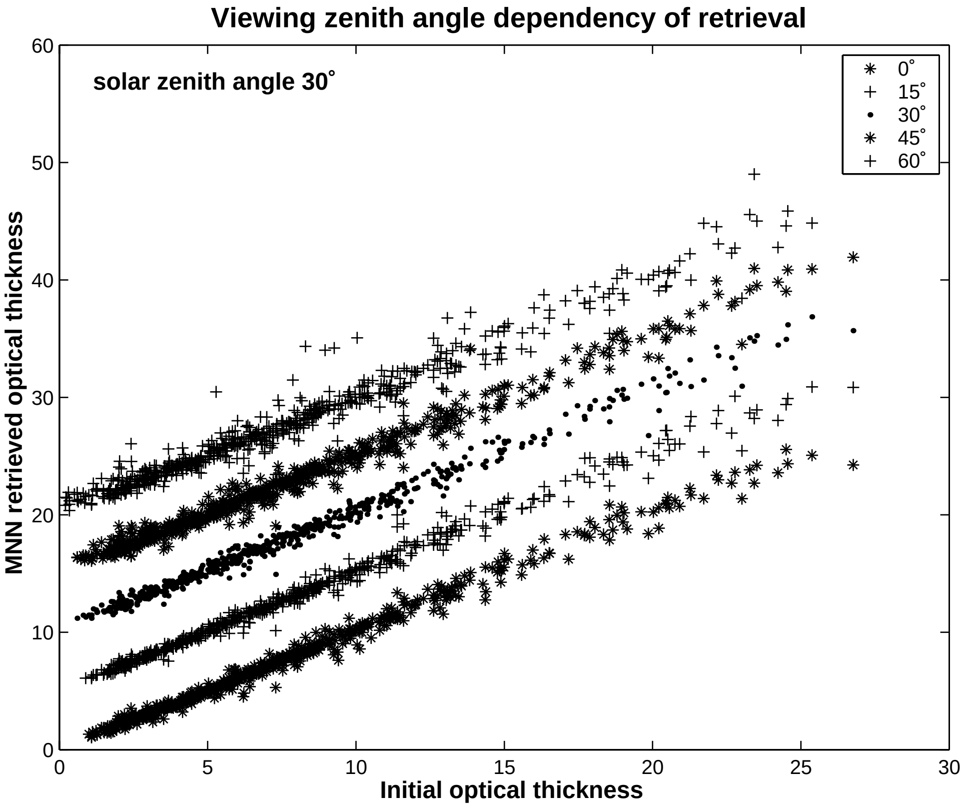
  - the same data from neighbor pixels (if necessary)

  * assumed that all necessary corrections are already done to radiance data.

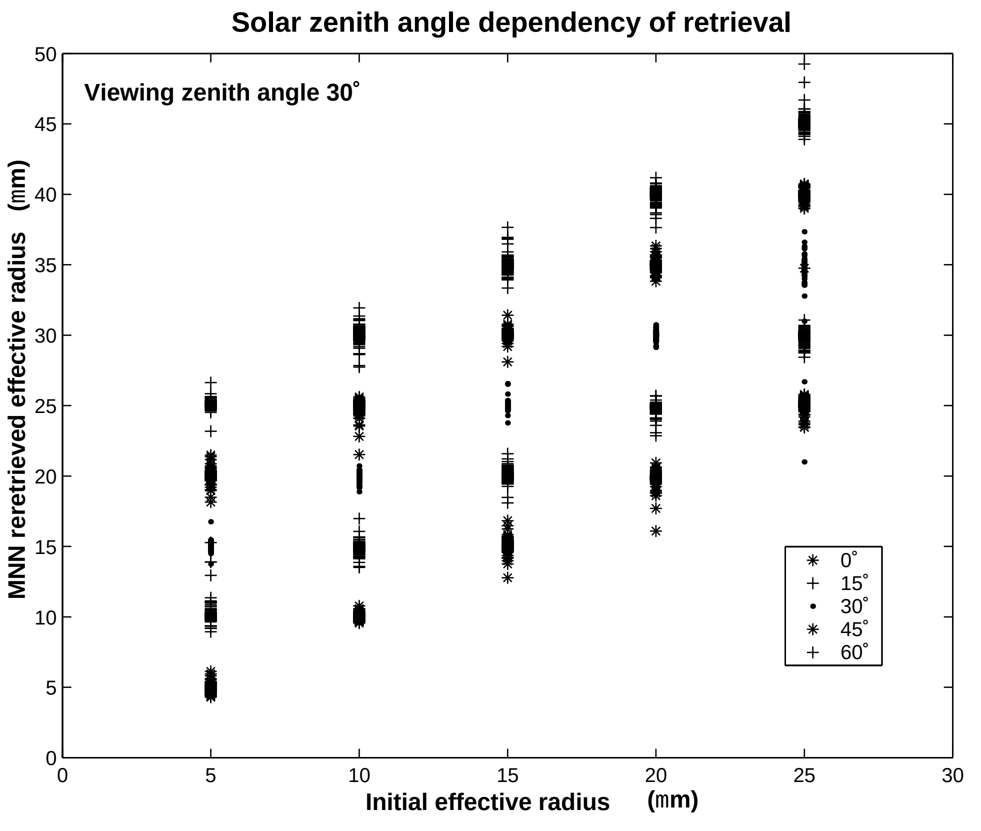
Neural network retrieval (bounded cascade clouds) : mean optical thickness (1)



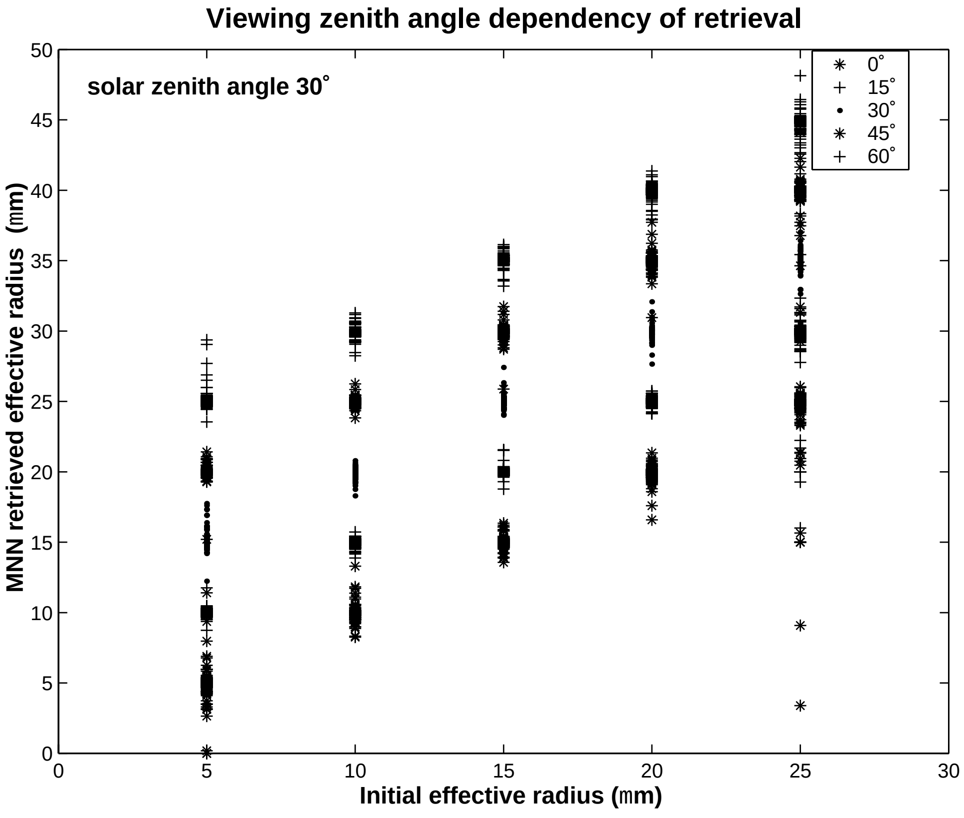
Neural network retrieval (bounded cascade clouds) : mean optical thickness (2)



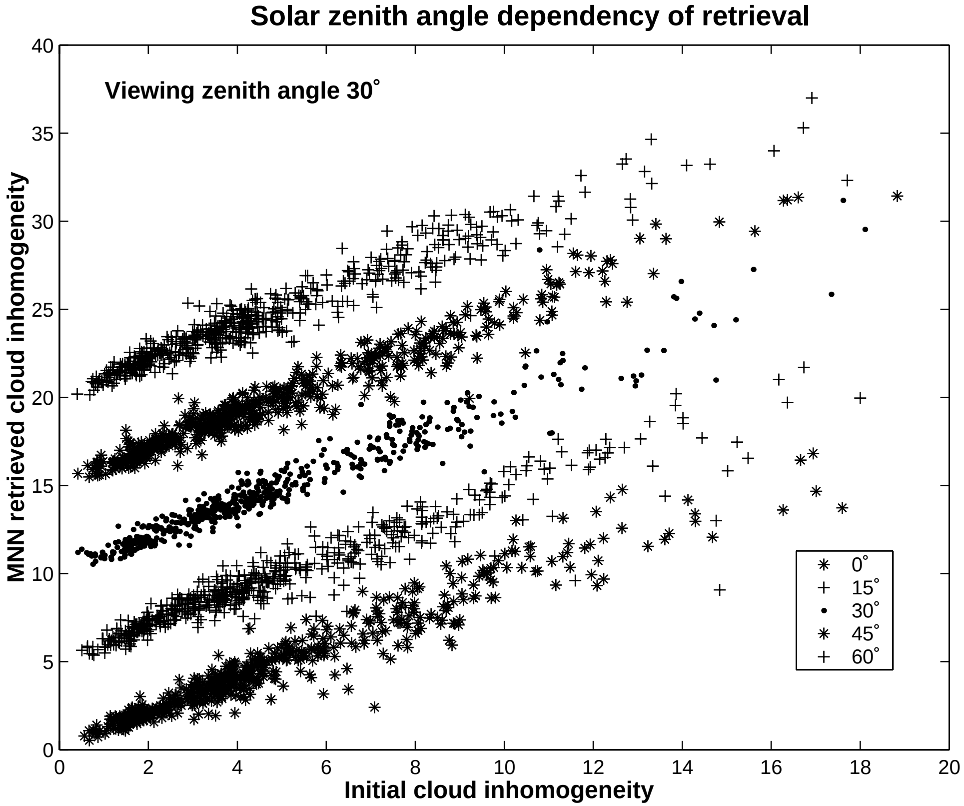
Neural network retrieval (bounded cascade clouds) : (mean) effective radius (1)



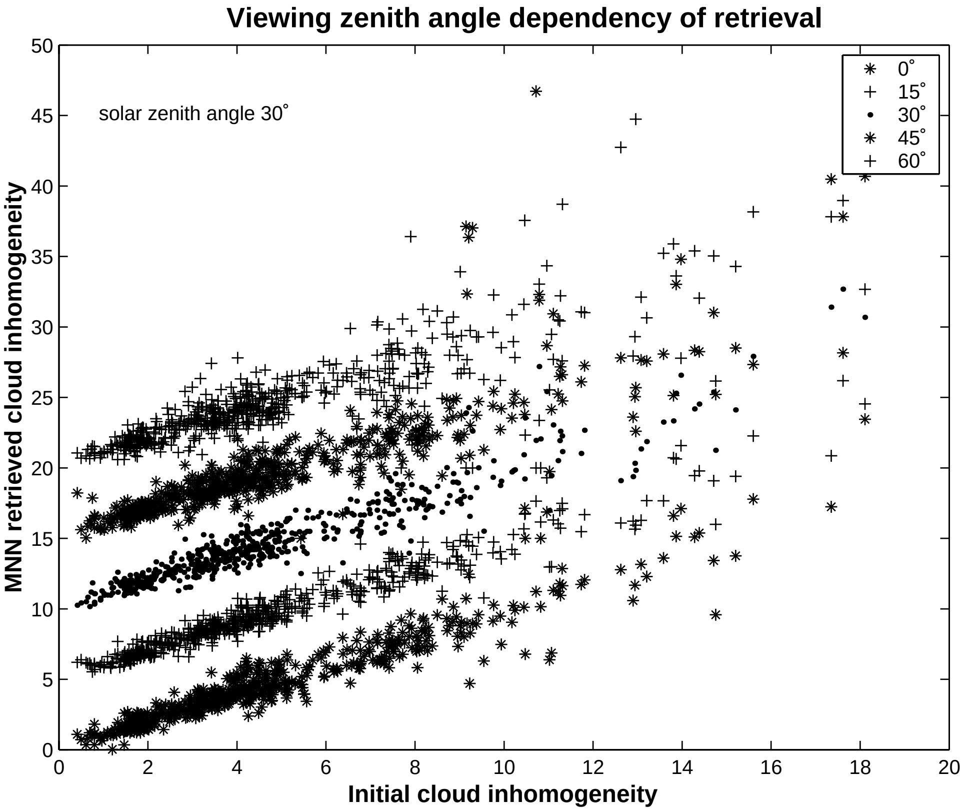
Neural network retrieval (bounded cascade clouds) : (mean) effective radius (2)



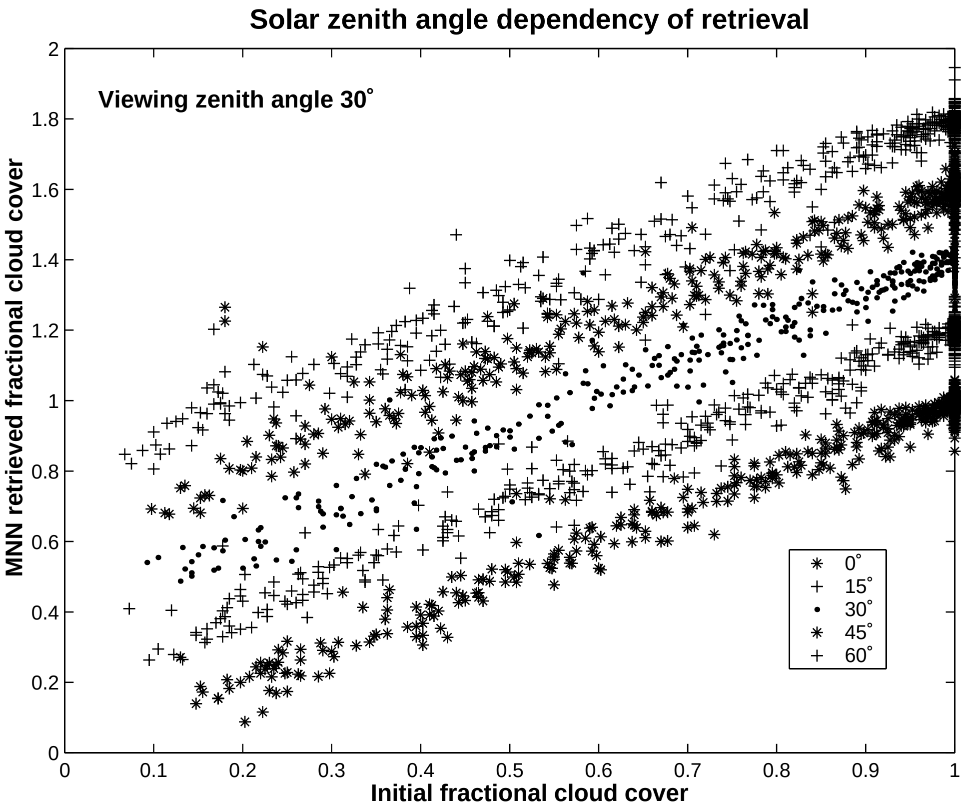
Neural network retrieval (bounded cascade clouds) : cloud inhomogeneity (1)



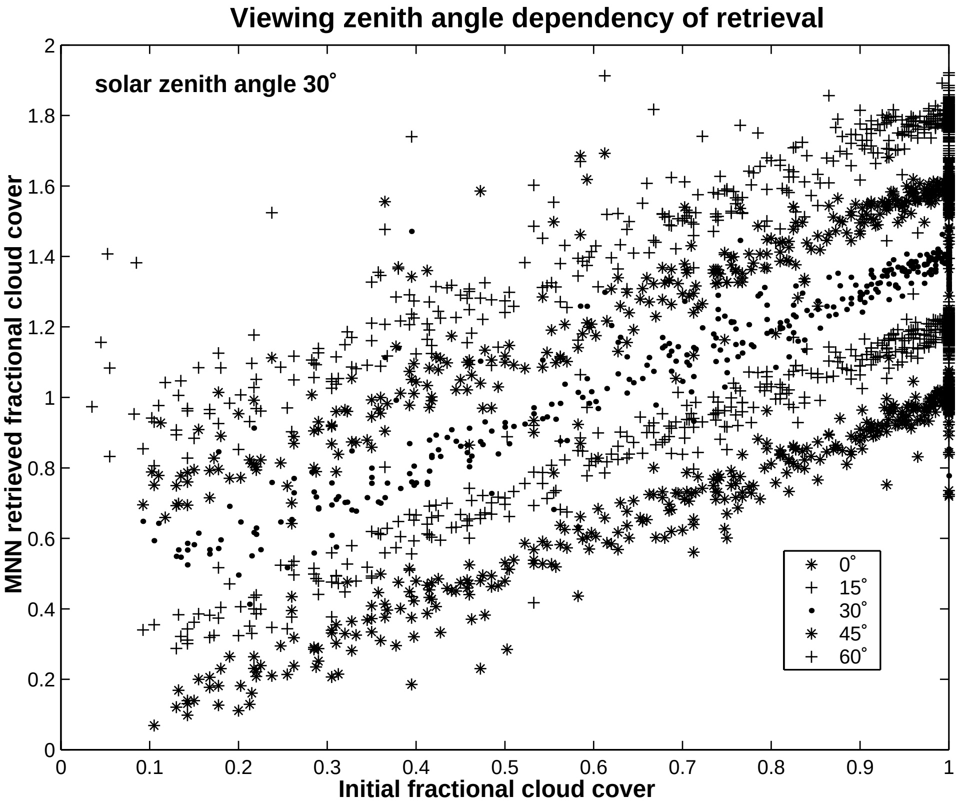
Neural network retrieval (bounded cascade clouds) : cloud inhomogeneity (2)



Neural network retrieval (bounded cascade clouds) : fractional cloud cover (1)



Neural network retrieval (bounded cascade clouds) : fractional cloud cover (2)



Necessary corrections to radiance data

- **Interpolation of observed radiance values**
  - **GLI sun-obs configuration .NE. NN sun-obs configuration**
  - **Interpolation to the nearest NN sun-observation configuration**

- **Correction of albedo-effect in radiance**
  - **NNs are trained with radiance data computed for totally absorbing underlying earth surface**
- **Correction of emission-effect in 3.7 μm radiance**
  - **NNs are trained with 3.7 μm radiance data computed without emission (earth surface, cloud, atmosphere)**
- **Correction of atmospheric-effect in radiance (eventually)**
  - **The need of this correction is not yet studied.**

Plane-parallel clouds

- radiance simulated with shdom (without atm.) and rstar 5b

- **Characteristics of simulation**

- SHDOM: (step=7.5°)

cloud types: 1. constant effective radius; 2. linearly variable effective radius

cloud base height: 0.5 km; cloud geometrical depth: 0.3 km;

cloud optical thickness: 0.1, 0.5, 1, 2, 5, 7, 10, 15, 20, 25, 30, 40, 50, 70

effective radius: 1, 3, 5, 7, 10, 12, 15, 17, 20, 25, 30, 40μm

- rstar5b (step=7.5° and 15°)

cloud types: 1. constant effective radius; 2. linearly variable effective radius

cloud base height: <u>0.5</u>, 0.8, <u>1.2</u>, 1.8, 2.5 km;

cloud geometrical depth: <u>0.3</u>, 0.5, <u>0.8</u>, 1.2, 1.8km;

cloud optical thickness: 2, 4, 7, 10, 14, 19, 25, 32, 42, 55

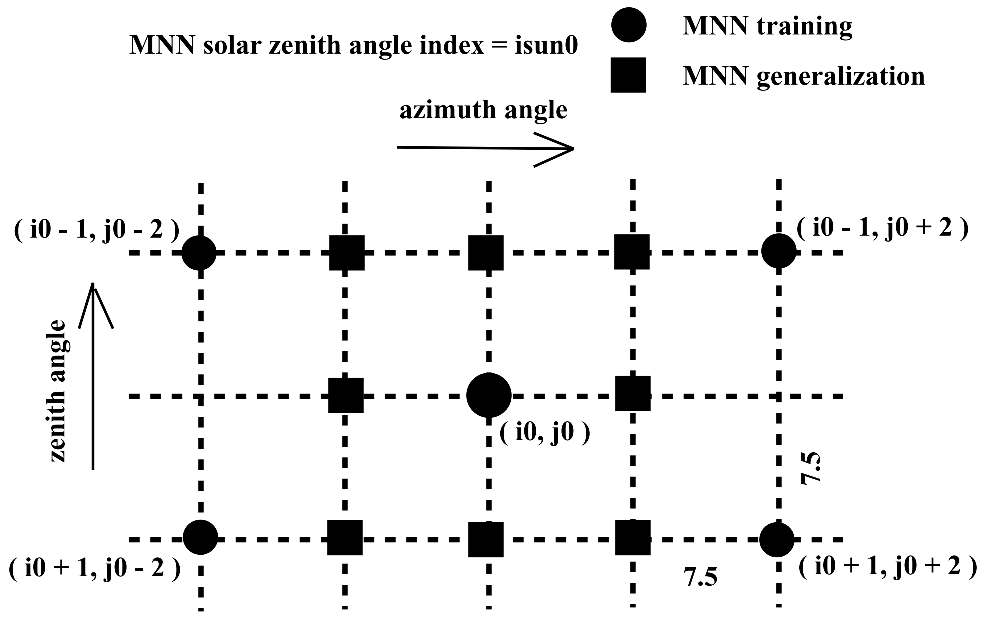
effective radius: 2, 4, 7, 10, 14, 18, 23, 28, 35, 42μm

surface albedo (Lambertian): <u>0.05</u>, <u>0.10</u>, 0.15, <u>0.20</u>, 0.25, <u>0.30</u>

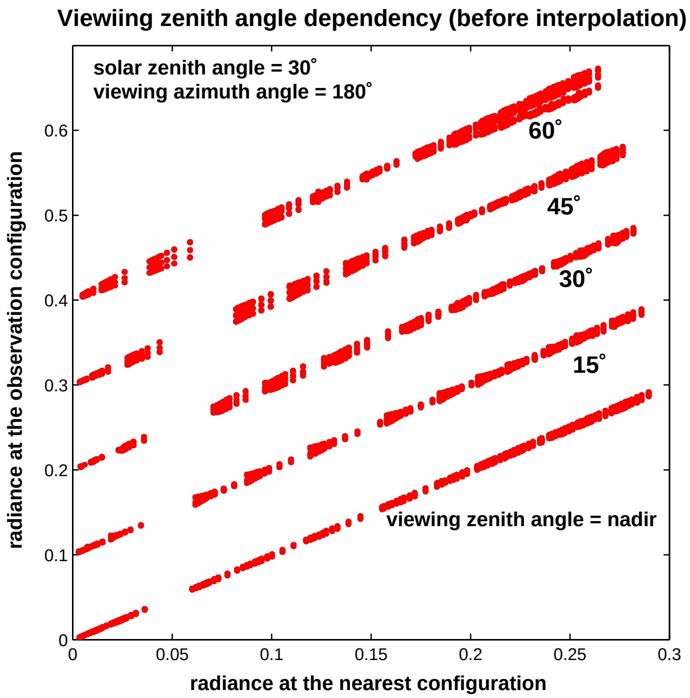
surface temperature: <u>8</u>, 13, <u>18</u>, 23, <u>28</u>, 33, <u>38</u>°C

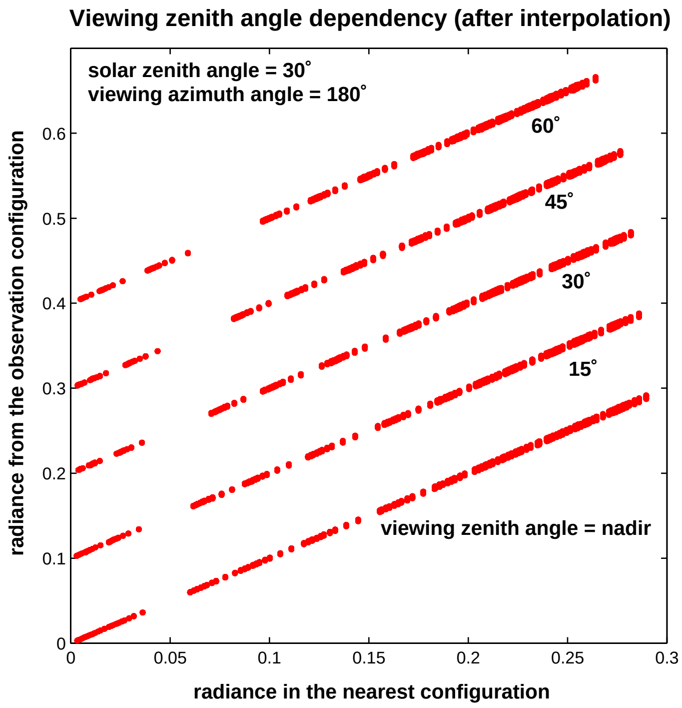
Interpolation of radiance values (SHDOM):
from $R_{ch.i}(\theta_{s.obs}, \theta_{v.obs}, \varphi_{v.obs})$ to $R_{ch.i}(\theta_{s.MNN}, \theta_{v.MNN}, \varphi_{v.MNN})$

- **Target parameter:**
  - Radiance of a given wavelength at the nearest MNN config.
- **Input parameters:**
  - 3 Angular distances to the MNN configuration
  - radiances (0.67, 1.6, 2.2, 3.7 μm)
- **Training data patterns**
  - 3 solar zenith angles
  - 5 neighbor configurations
- **Generalization patterns**
  - 3 solar zenith angles
  - 9 neighbor configurations with all pairs of τ and ref

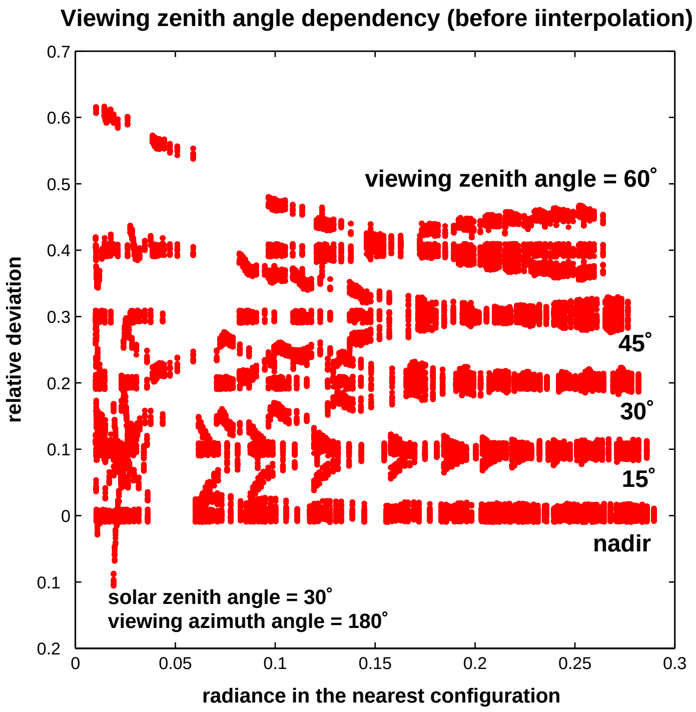


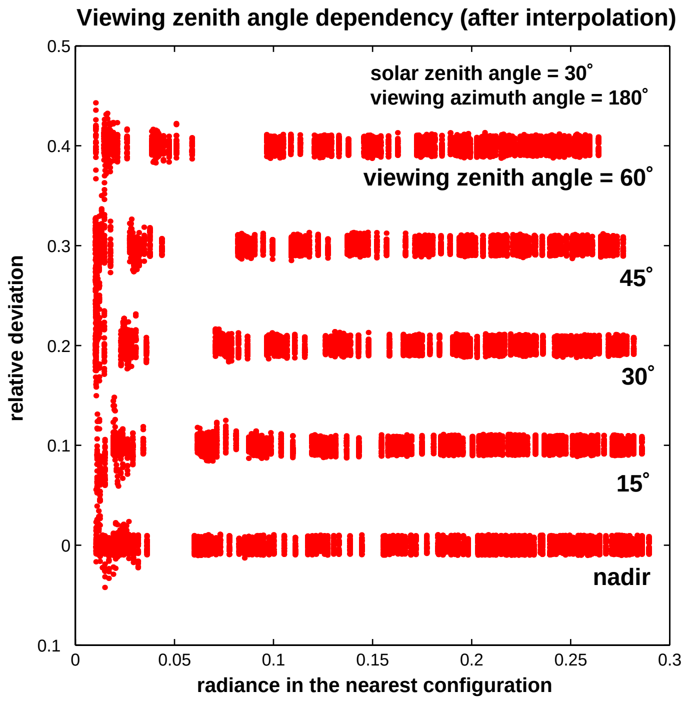
Interpolation of radiance values (SHDOM): Generalization (0.67 μm)



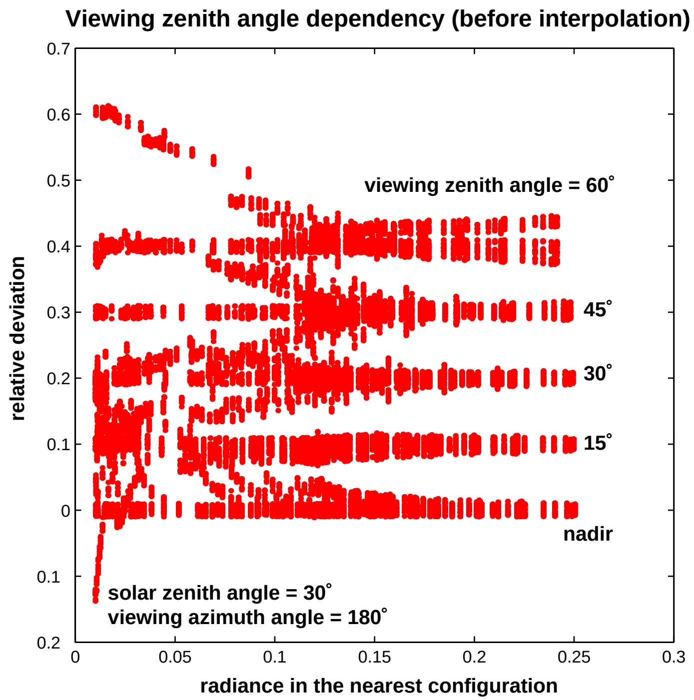


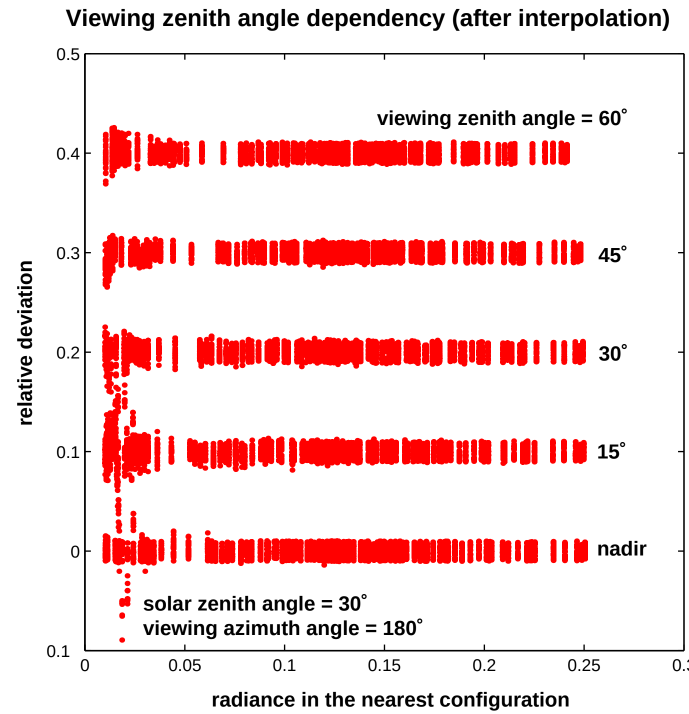
Interpolation of radiance values (SHDOM): Generalization (0.67 μm)



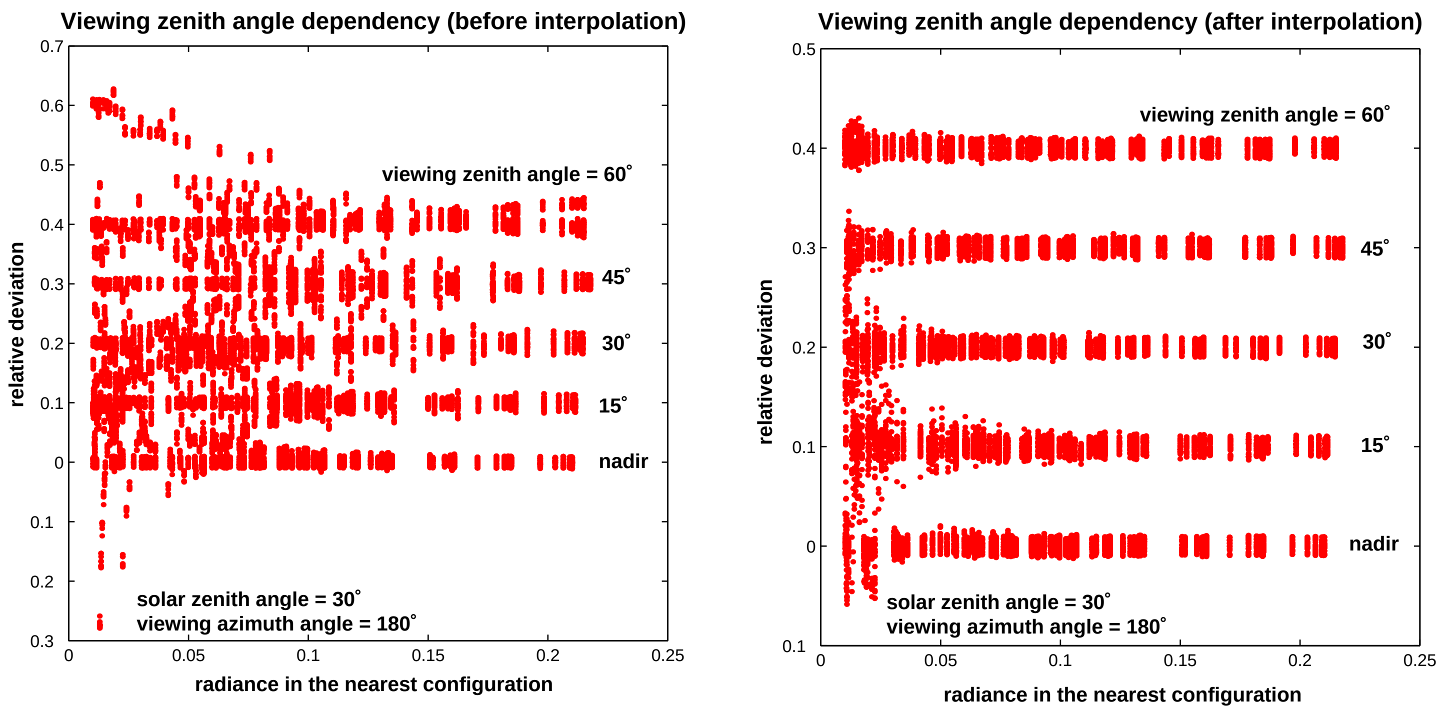


Interpolation of radiance values (SHDOM): Generalization (1.6 μm)

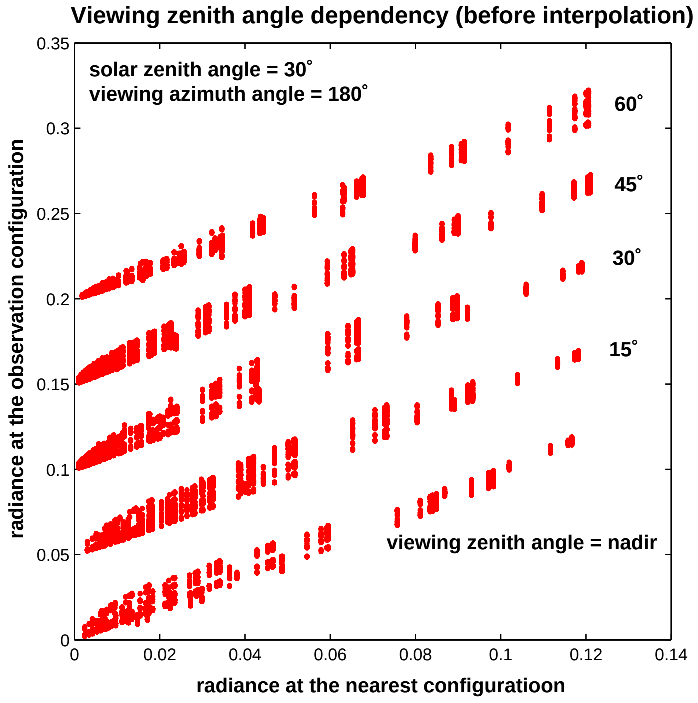


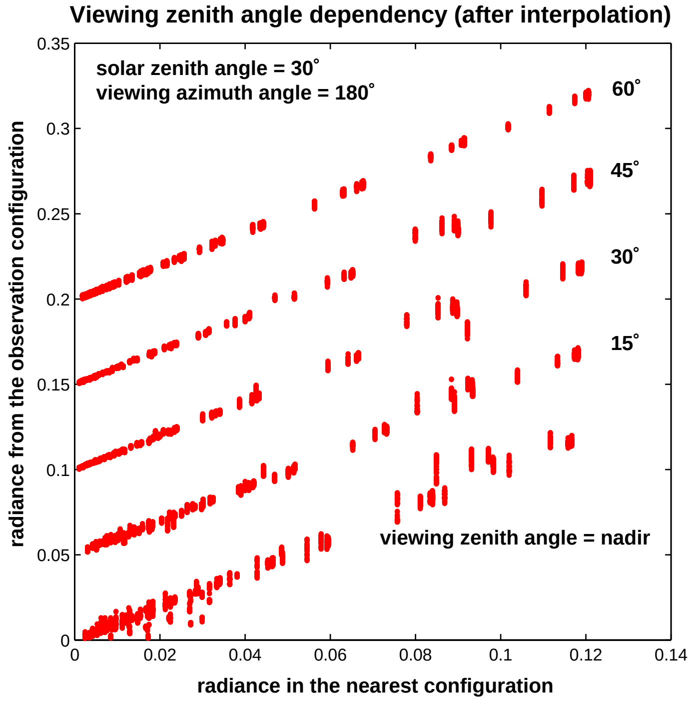


Interpolation of radiance values (SHDOM): Generalization (2.2 μm)



Interpolation of radiance values (SHDOM): Generalization (3.7 μm)

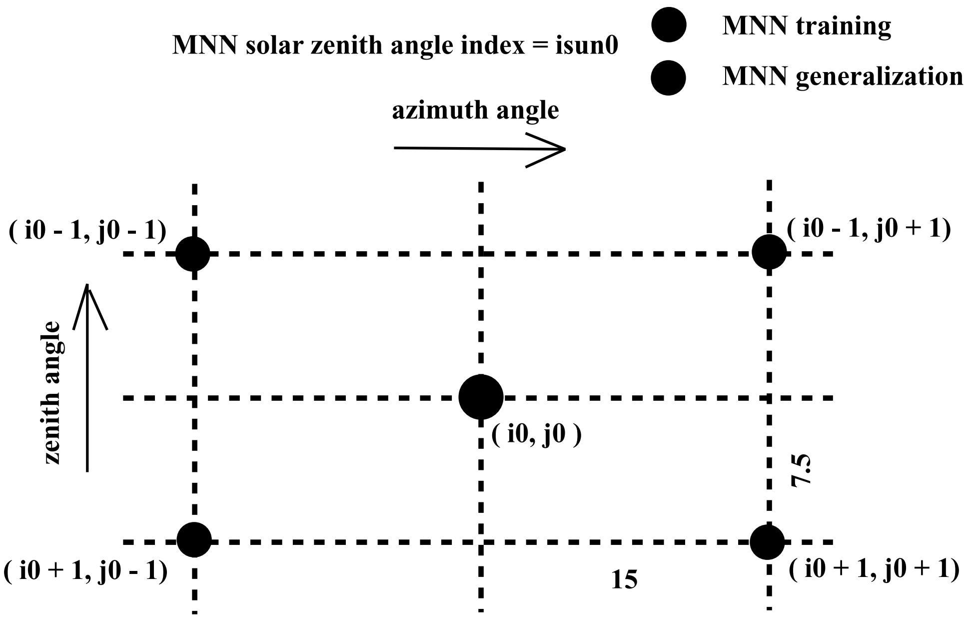




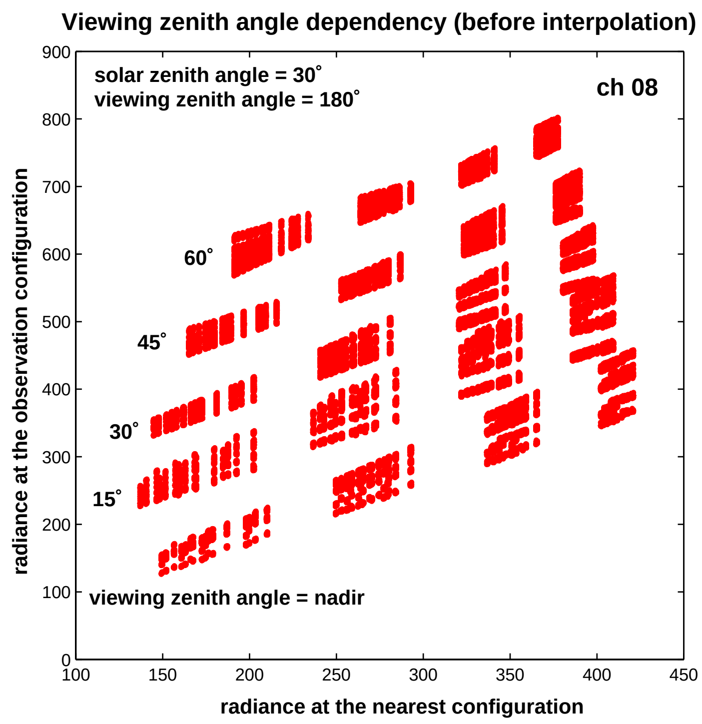
Interpolation of radiance values (rstar5b):

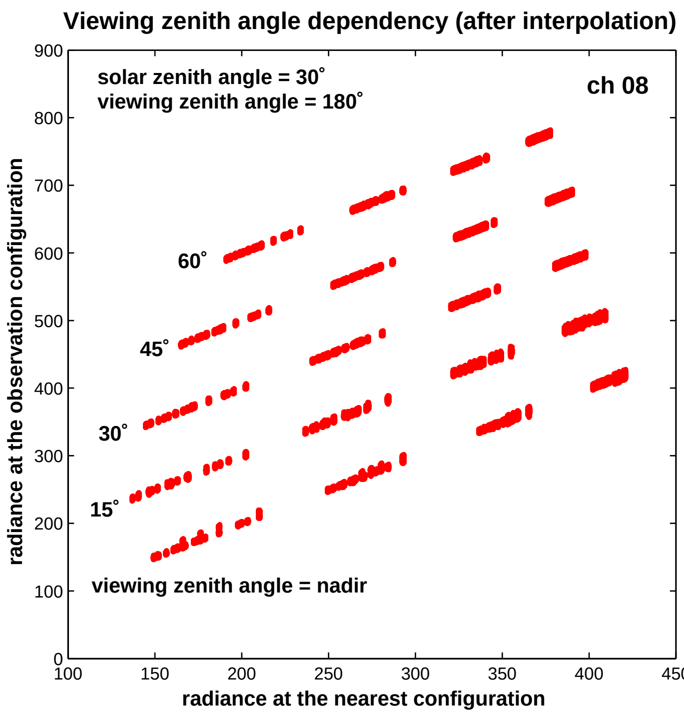
from $R_{ch.i}(\theta_{s.obs}, \theta_{v.obs}, \varphi_{v.obs})$ to $R_{ch.i}(\theta_{s.MNN}, \theta_{v.MNN}, \varphi_{v.MNN})$

- **Target parameter:**
  - Radiance of a given wavelength at the nearest MNN config.
- **Input parameters:**
  - 3 Angular distances to the MNN configuration
  - radiances (7 wavelengths)
- **Training data patterns**
  - 3 solar zenith angles
  - 5 neighbor configurations
- **Generalization patterns**
  - 3 solar zenith angles
  - 5 neighbor configurations with different τ and ref

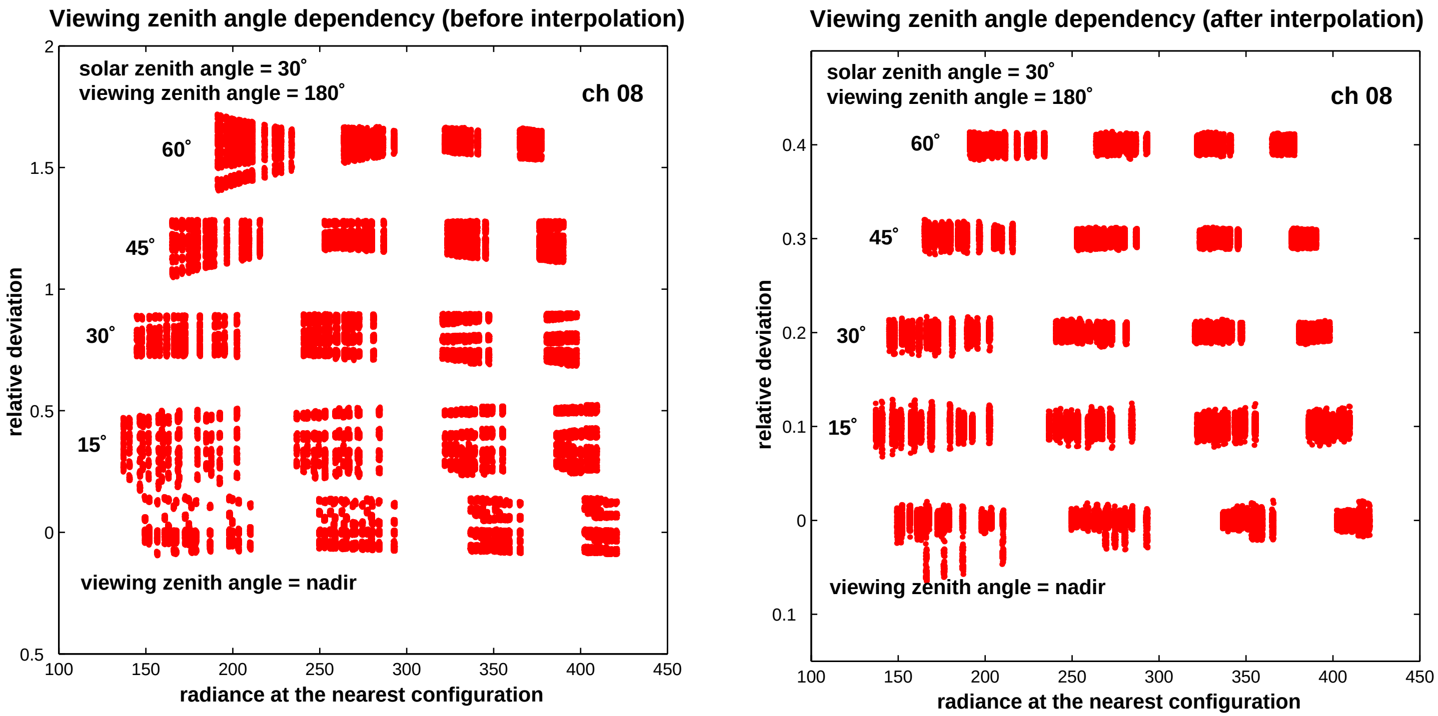


Interpolation of radiance values (rstar5b): Generalization (ch 08)

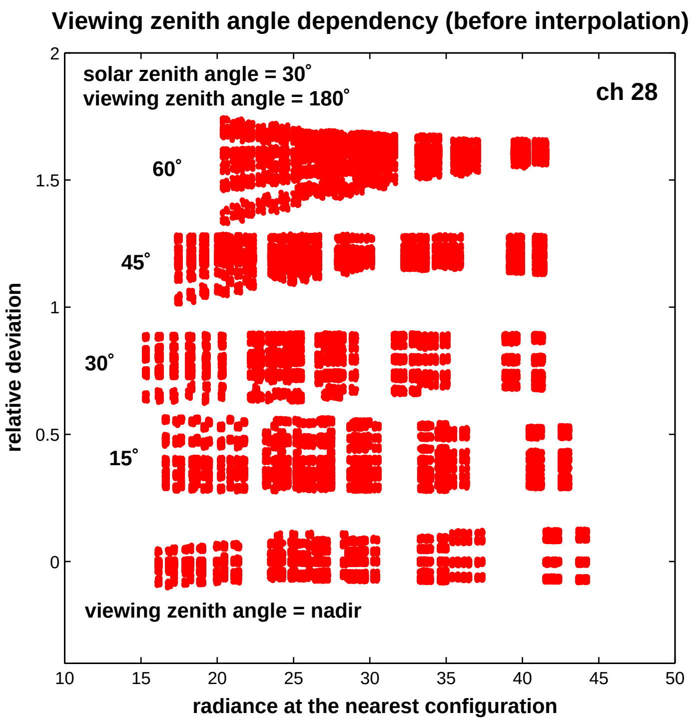


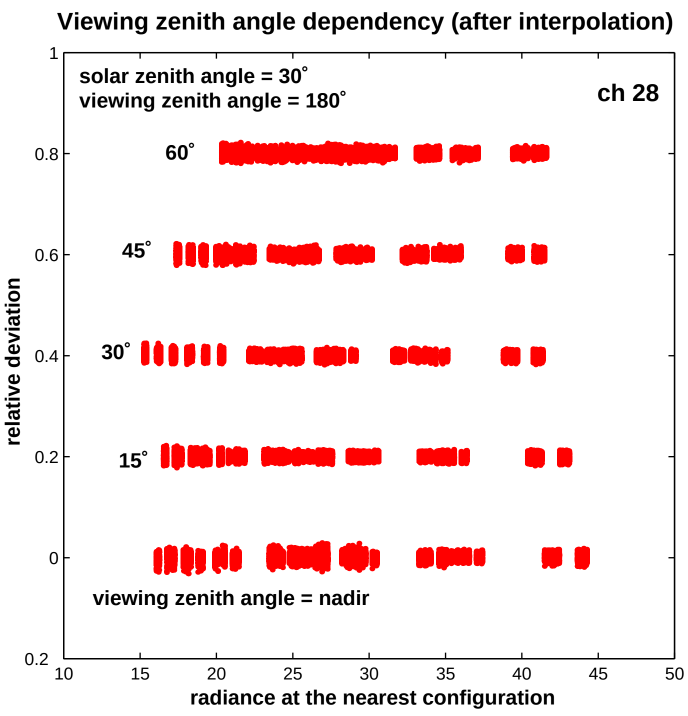


Interpolation of radiance values (rstar5b): Generalization (ch 08)

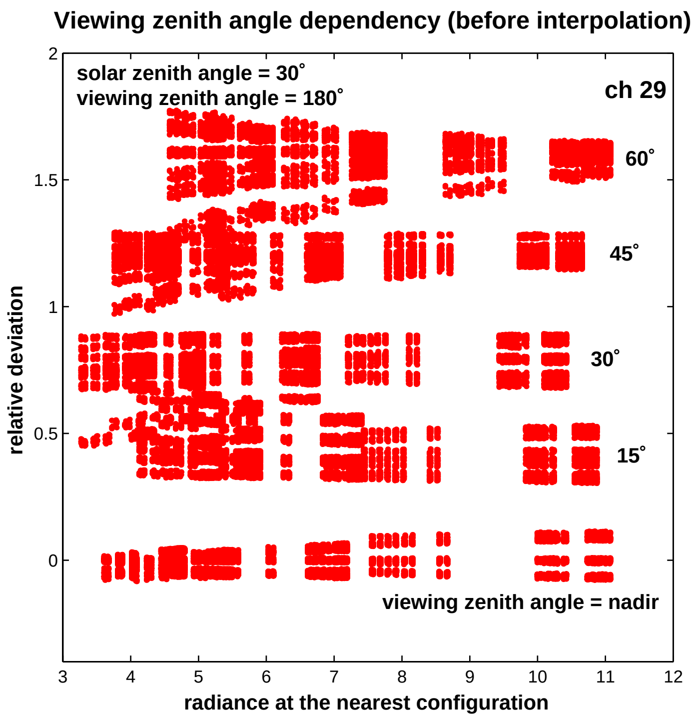


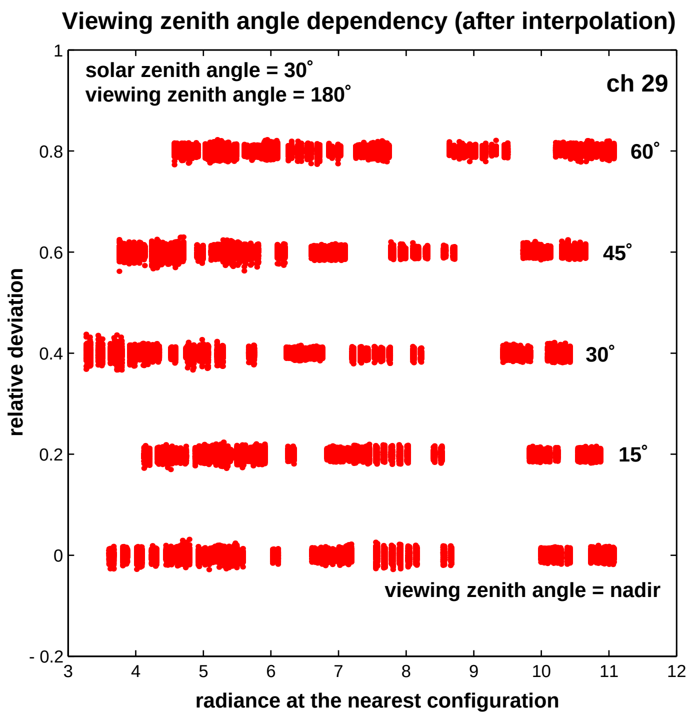
Interpolation of radiance values (rstar5b): Generalization (ch 28)



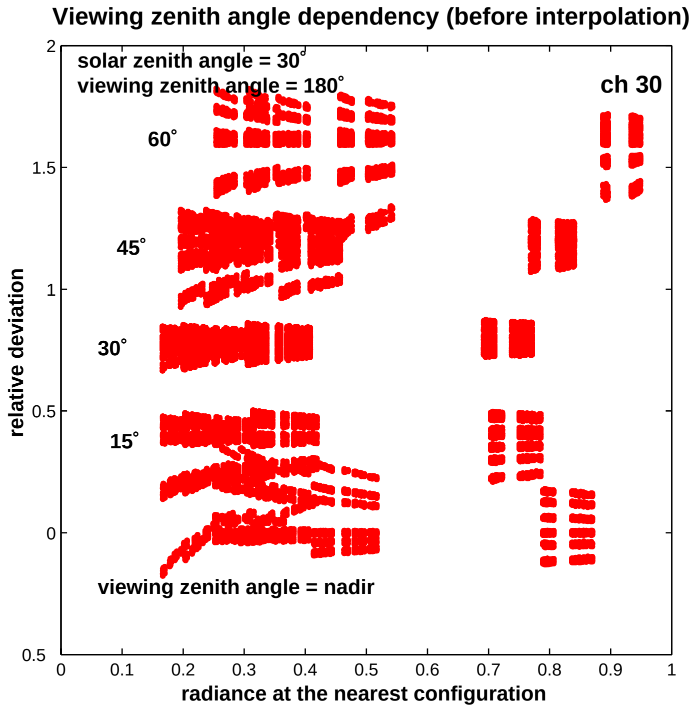


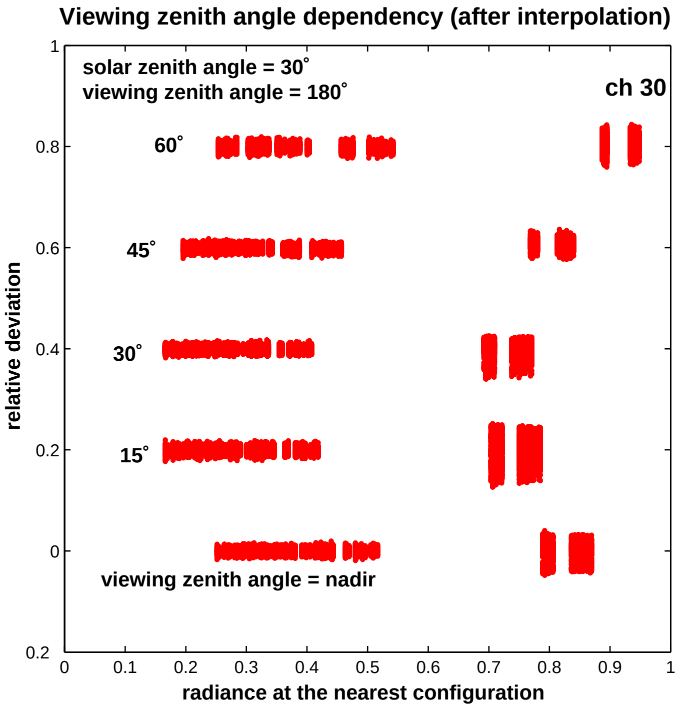
Interpolation of radiance values (rstar5b): Generalization (ch 29)





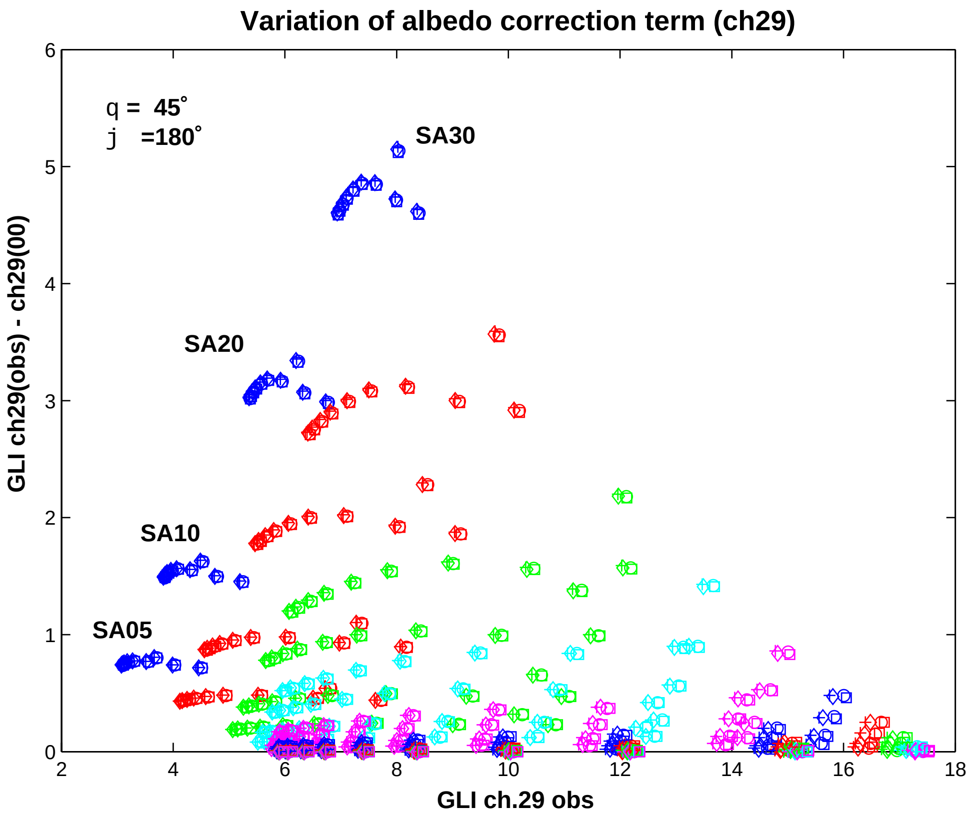
Interpolation of radiance values (rstar5b): Generalization (ch 30)





Variation of ch29 albedo correction as a function of ch29 radiance (nadir)

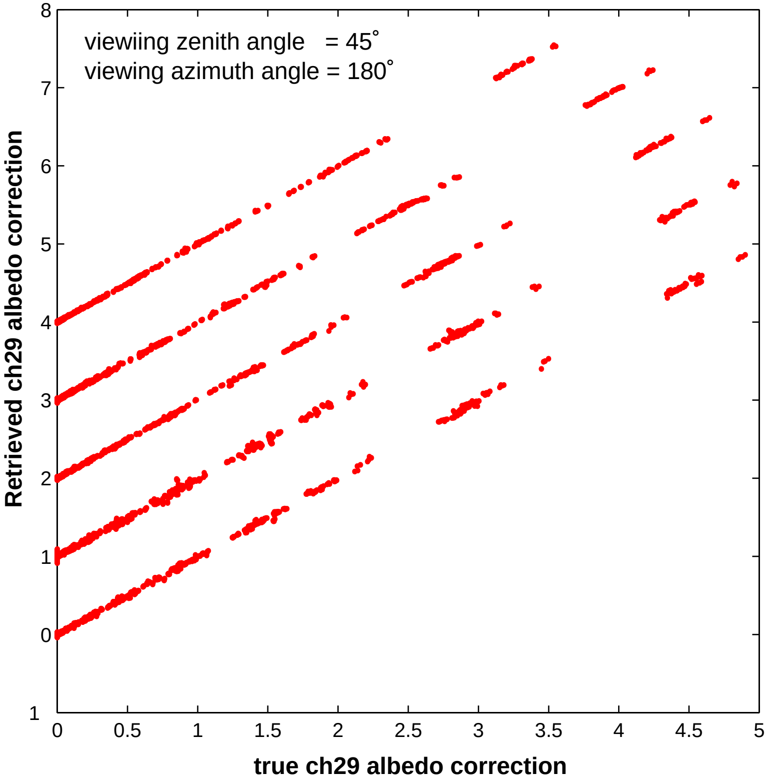
variable parameters: optical thickness, effective radius, cloud geometry, surface albedo



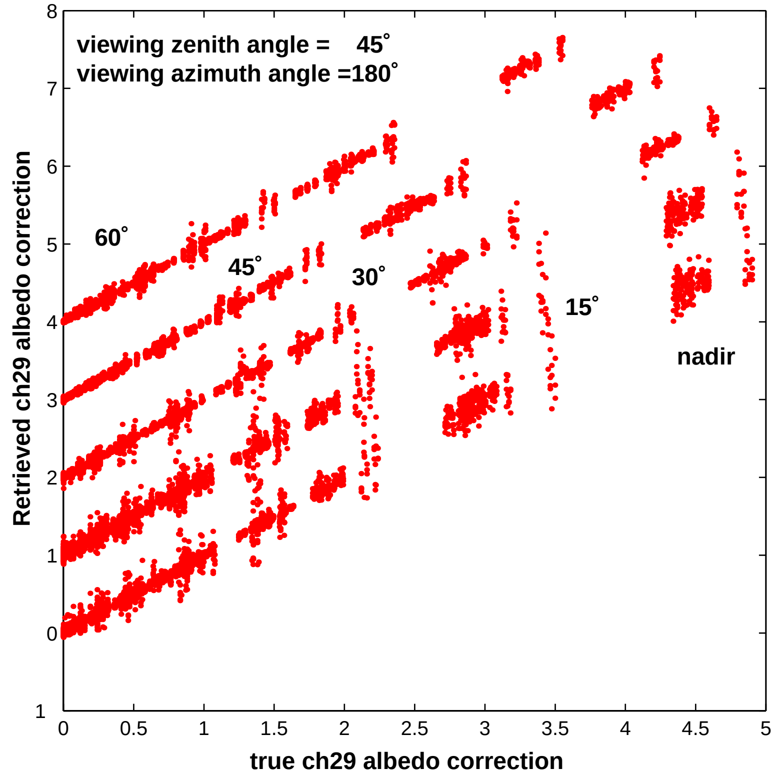
Albedo correction of ch29 radiance:

- Performance of NN for the estimation of albedo correction
- input vector components: ch08, ch013, ch28, ch29 radiance + surface albedo

solar zenith angle dependency of albedo correction (training)

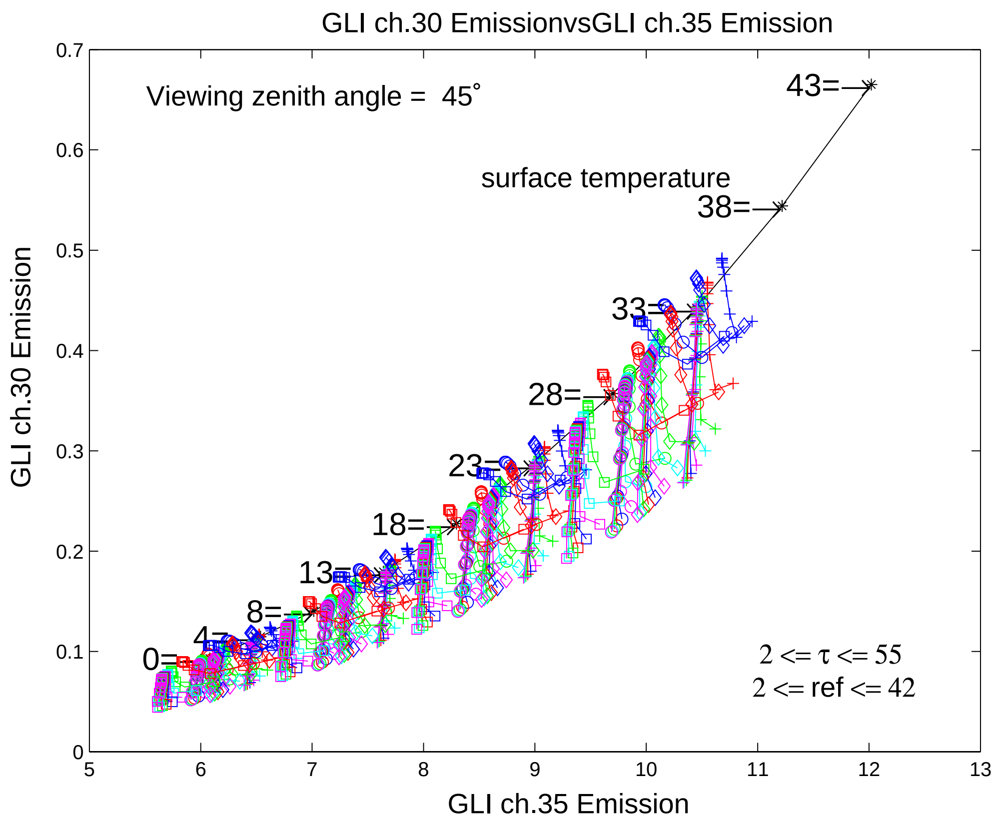


solar zenith angle dependency of albedo correction (gnrl 1%)



Variation of ch30 emission as a function of ch35 emission

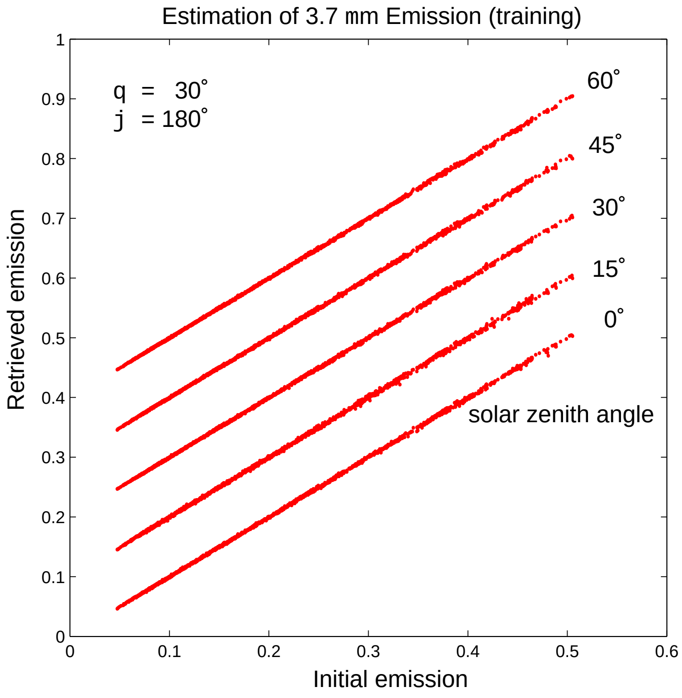
variable parameters: optical thickness, effective radius, cloud geometry, surface temperature

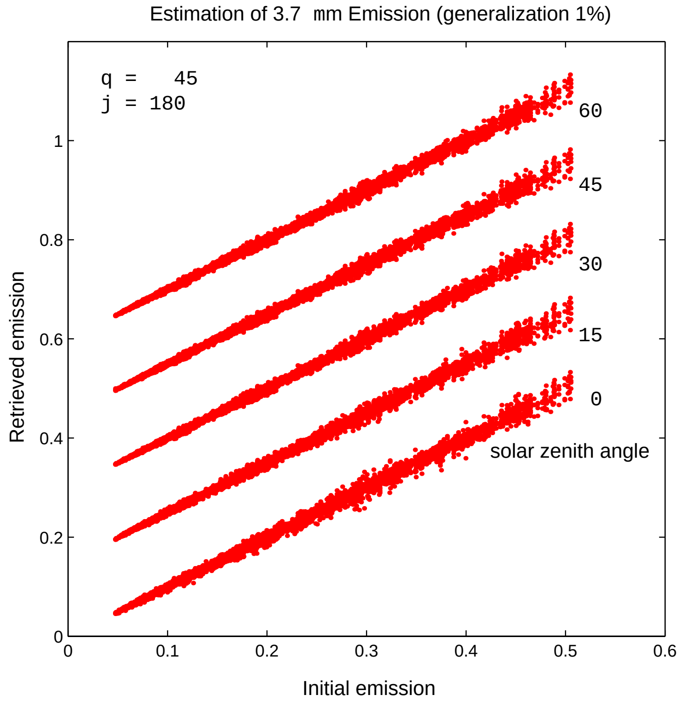


Correction of 3.7 µm emission:

- Performance of NN for the estimation of ch30 emission

- input vector components: ch08, ch013, ch28, ch29, ch35 radiance + surface temperature





Bounded cascade clouds with fractional cloud cover

- radiance simulated with Evan's shdom code

- **Characteristics of simulation**

- Clouds without atmosphere (ch13, ch28, ch29, ch30; step=7.5°)

256x256 pixels of 50x50m cloud column

cloud types: constant effective radius

cloud base height: 0.5 km; cloud geometrical depth: 0.3 km;

domain mean cloud optical thickness: 5, 10

effective radius: <u>5</u>, <u>10</u>, <u>15</u>, <u>20</u>, <u>25</u>, 30, 40μm

fractional cloud cover: 0.5, 0.7, 1.0

- Clouds with atmosphere (tested for ch30 and ch 35; step=7.5°)

test simulation (64x64 pixels of 50x50m cloud column) for variable cloud geometrical characteristics

systematic simulation not started

Adaptation of SHDOM code

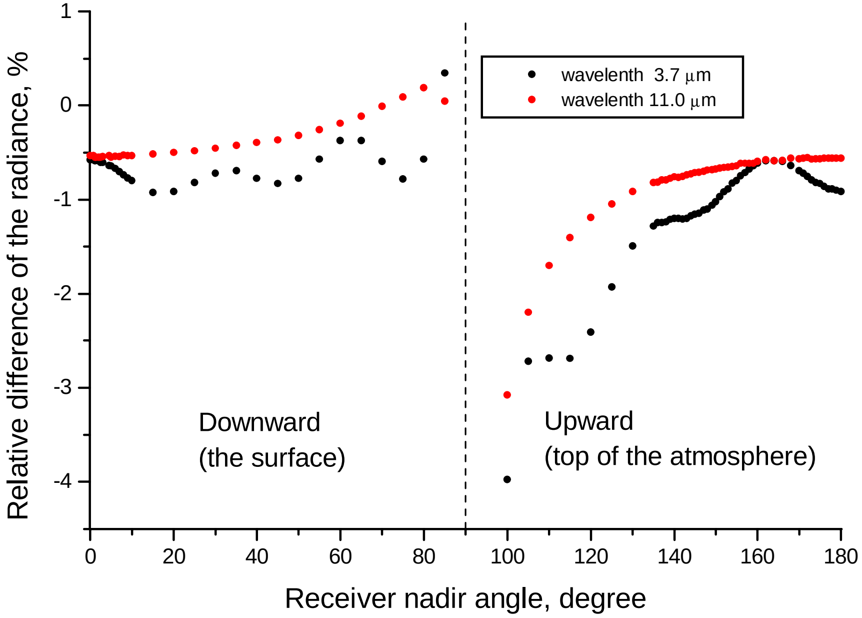
- Integration of rstar5b atmosphere into SHDOM code to make rstar5b and SHDOM compatible in near and thermal infrared
- Compared with rstar5b for plane-parallel cloud case
- Comparing with Mayer's Monte Carlo code for inhomogeneous cloud case

3.7 μm	SHDOM	rstar5b (250m)		rstar5b (25m)	
Upward flux at Top of atmosph.	0.1246 W/m2	0.1434 W/m2	-13.1 %	0.1263 W/m2	-1.36 %
Downward flux Surface	0.2882 W/m2	0.3166 W/m2	-8.97 %	0.2873 W/m2	0.31 %
11.0 μm					
Upward flux Top of atmosph.	13.03 W/m2	13.66 W/m2	-4.63 %	13.12 W/m2	-0.70 %
Downward flux Surface	15.32 W/m2	16.69 W/m2	- 8.18 %	15.26 W/m2	0.42 %

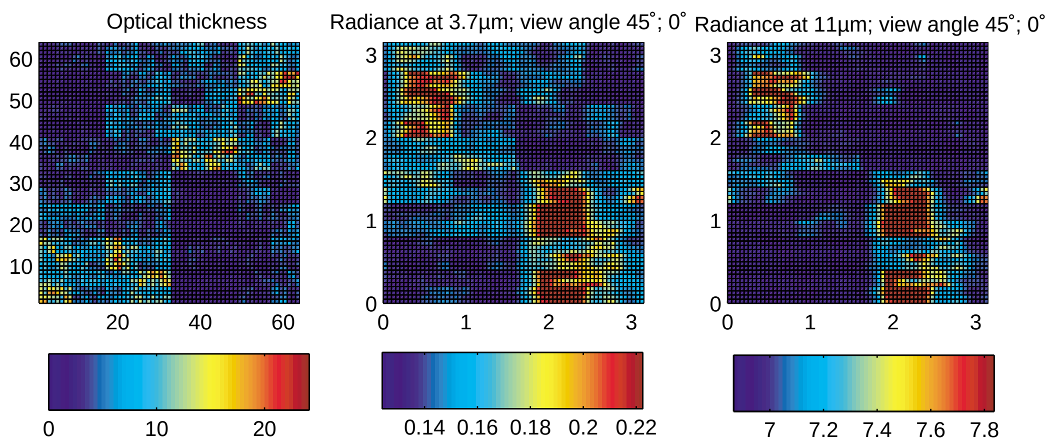
Relative differance of SHDOM and rstar5b radiances (25 m resolution):

$$\delta R(\theta)=[(R_{SHDOM}(\theta)- R_{Nakajima}(\theta))/ R_{Nakajima}(\theta)]*100\ \%$$

US standard atmosphere; Cloud from 5 km up to 5.5 km altitude; Surface albedo = 0.0
Optical thickness 10 at the corresponding wavelength
Effective radius 10 μm with a lognormal size distribution $\sigma = 0.35$



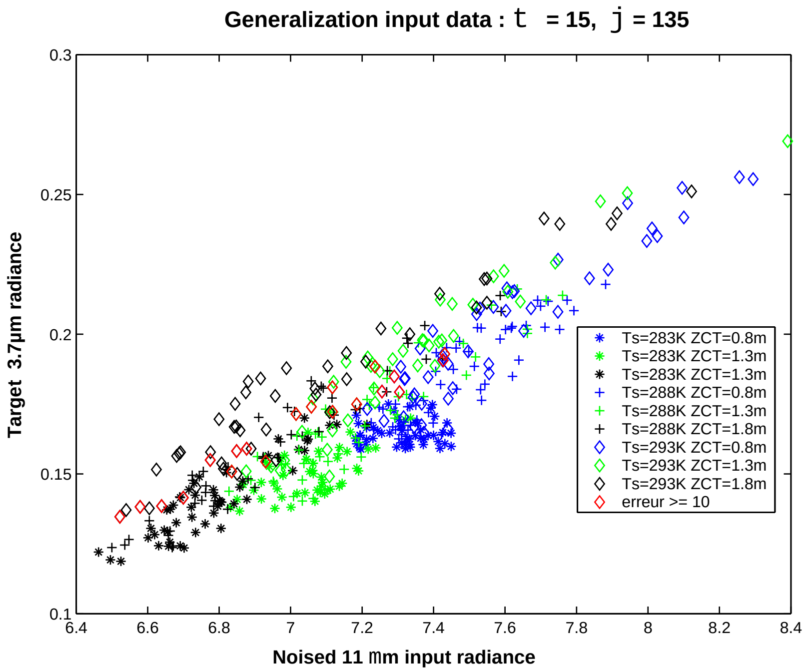
Night time 3.7 µm and 11 µm radiance (bounded cascde clouds) (64 x 64 pixels)

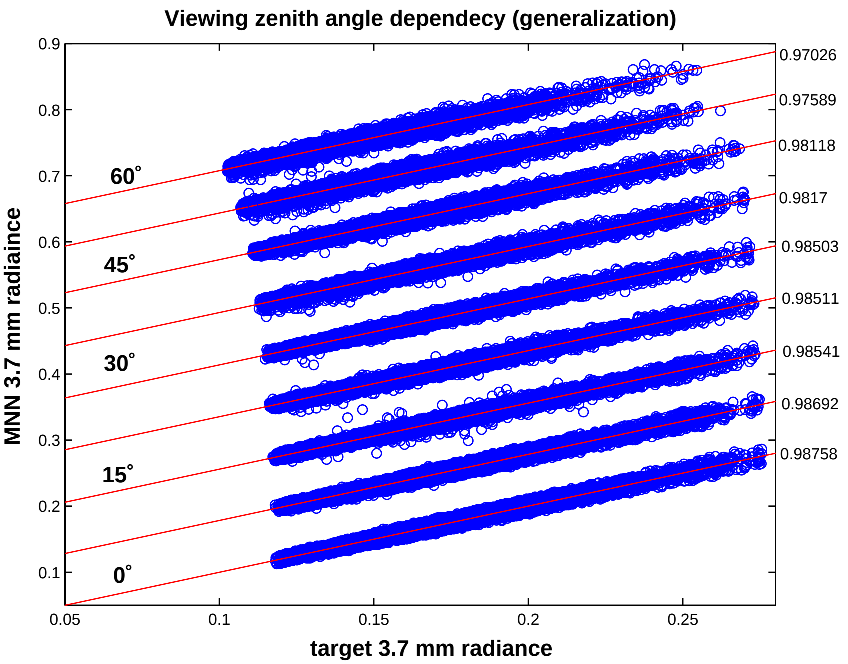


mean optical thickness:5; fractionnal coverage: 0.2; effective radius: 10µm
surface temperature: 288 K; cloud top1.30 km; cloud thickness 0.3 km

Neural network estimation of 3.7 µm emission correction

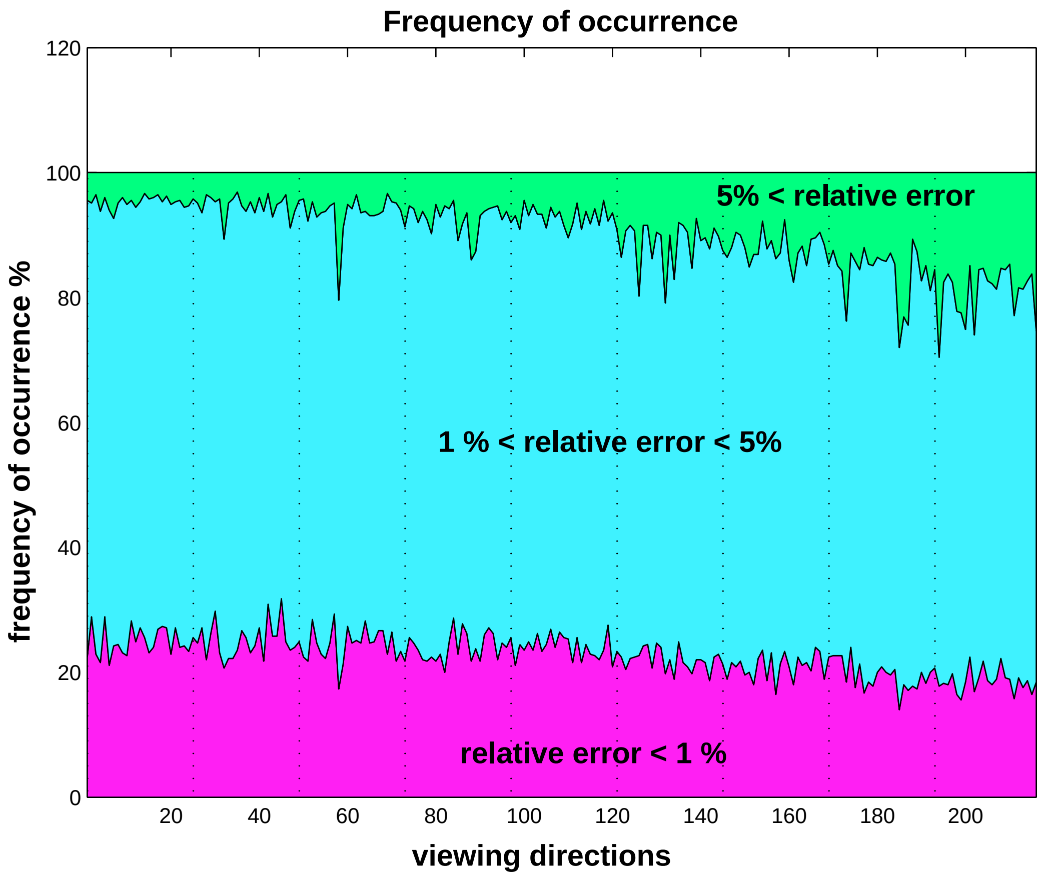
- Input parameters: 11 µm radiance, surface temperature, std of τ, and fractional cloud cover





Relative error distribution of MNN 3.7 μm emission correction

- Input parameters: 11 μm radiance, surface temperature, std of τ, and fractional cloud cover



Actual State of Development

MNN cloud parameter retrieval

plane-parallel clouds	inhomogenous clouds
data base (not completed)	data base (not completed)
interpolation : tested	interpolation : not tested
albedo correction : tested	albedo correction : not tested
ch30 emission correction tested	ch30 emission correction tested
MNN retrieval possible 2 and 3 comp. tested need new training	MNN retrieval possible tested need new training

Work to be done (plane-parallel cloud case)

- **Complete radiance data base (rstar5b simulation)**
- **Refinement of neural networks (change statistical representativity)**
  - **- radiance interpolation**
  - **- albedo-effect correction**
  - **- 3.7μm emission correction**
- **Training of neural networks**
  - **- cloud parameter retrieval of plane-parallel clouds (rstar5b radiance data)**
- **Definition of cloud model selection criteria**
- **Organization of neural network retrieval of cloud parameters for plane-parallel coud case**
- **Evaluation of neural network retrieval with real data**

Work to be done (bounded cascade cloud case)

- **Complete radiance data base (shdom and modified shdom)**

  - The situation will be slightly improved with the arrival of a new DEC alpha work station (8 Gbytes RAMs and 4 processors)

- **Test of neural networks**

  - radiance interpolation (not tested, but seems possible)

  - albedo-effect correction (not tested, but seem possible)

  - 3.7μm emission correction (possible)

- **Training of neural networks (change statistical representativity)**

  - cloud parameter retrieval of imhomogeneous clouds

- **Integration of neural network retrieval code for the neural network retrieval of cloud parameters for plane-parallel couds and inhomogeneous clouds**