Searching for a 3D-cloud field with measured cloud properties

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Introduction

What. We want to generate 3D cloud fields (Liquid Water Content fields) based on measured data.

How. The clouds are made by searching for a 3D cloud field that has the same statistical properties as the measured cloud.

Why. These 3D clouds will be used for developing radiation parameterisations for climate and NWP models and for satellite retrievals.

4D CLOUDS
BMBF/AFO2000

The 4D-clouds project aims at capturing the radiative influence of inhomogeneous clouds and at implementing these influences in dynamical atmospheric models.

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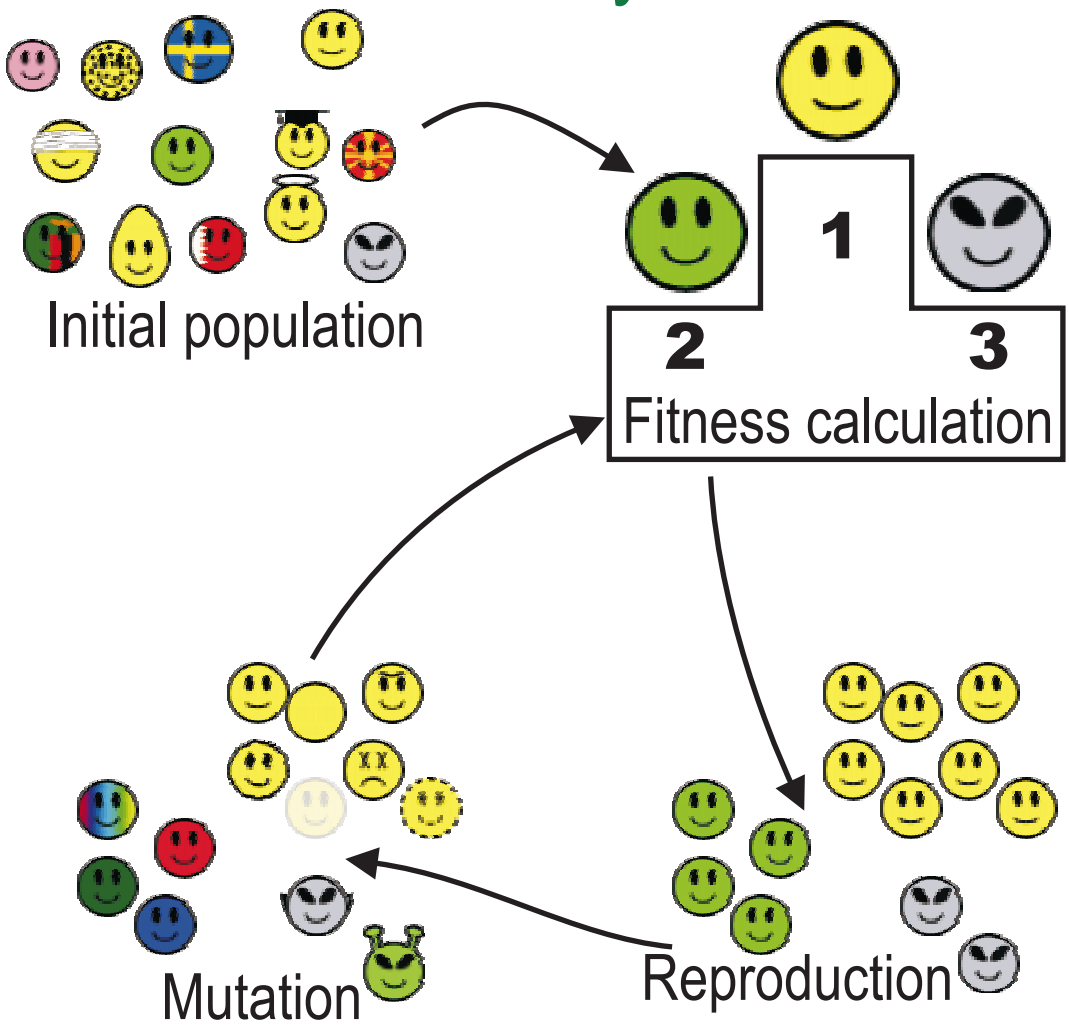
Search algorithm

The search is made using an evolutionary search algorithm, see plate 3. The fitness/cost of each cloud with respect to the statistical cloud properties (see plate 4) in a population (40 to 100 clouds) determines its reproductive success. Mutations/permutations are used to keep the population diverse. Other global search algorithms will probably also work (e.g. simulated annealing).

The search for large cloud fields is possible by utilising the scaling properties of clouds, see plate 5. The quality that can be achieved with a search algorithm is very high, see the plates q.

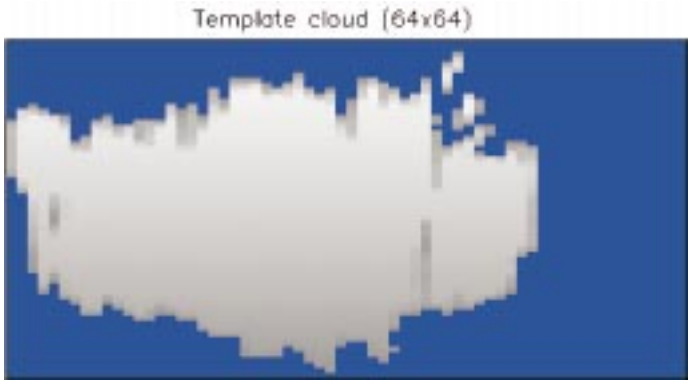
Evolutionary search



Statistical parameters

As a first test of the method the (artificial) cloud below is used to define the statistical parameters for the search (white means large LWC). The following parameters, which could have been measured, are used:

- Power spectrum and length
  - Cloud top height
  - Cloud base height
- Histogram, power spectrum and 'length'
  - Liquid Water Path (LWP)
  - Number of cloud layers
- Liquid Water Content (LWC) histogram
- Height profiles
  - Average LWC
  - Cloud bases
  - Cloud tops
  - Cloud cover



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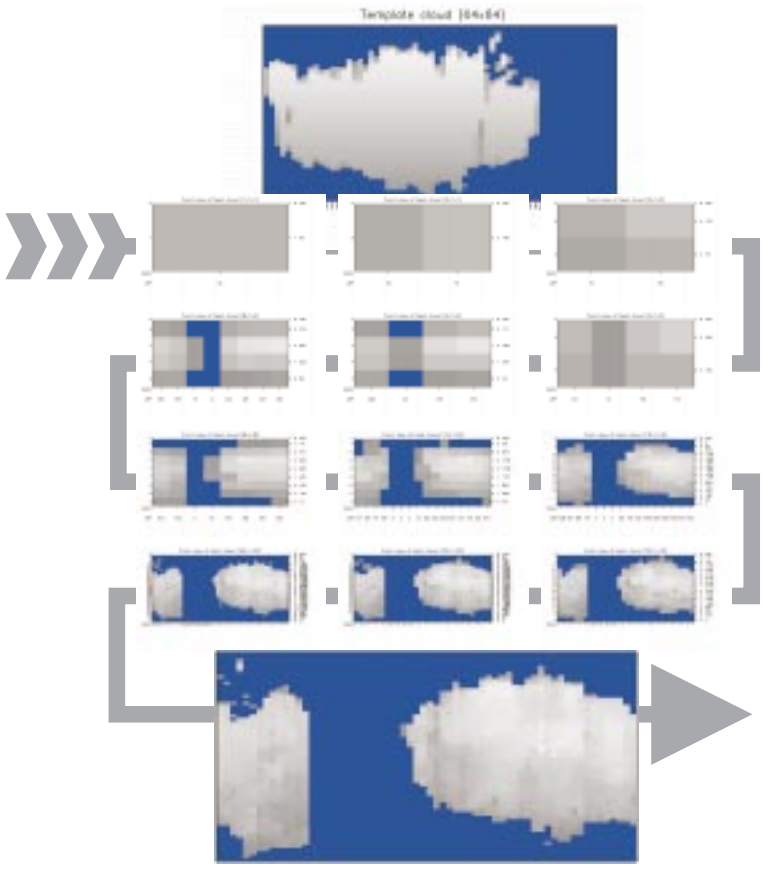
Scaling search

The search is started at low resolution and after (almost full) convergence it goes to higher resolutions, see the figure below. This uses the scaling property of cloud fields: The largest variations are at the large scales. Without this key idea the search would have been too large to be possible. For example the number of possible clouds with this resolution (64x64) and 256 LWC values is 256^{4096}, much more than the number of atoms in the universe (about 10^{78}).



6

Results

The clouds below are produced by the search; they have almost the same statistical properties as the cloud shown in plate 4 (with periodic boundary conditions. The quality of the statistical correspondence is shown in the plates marked with an q.

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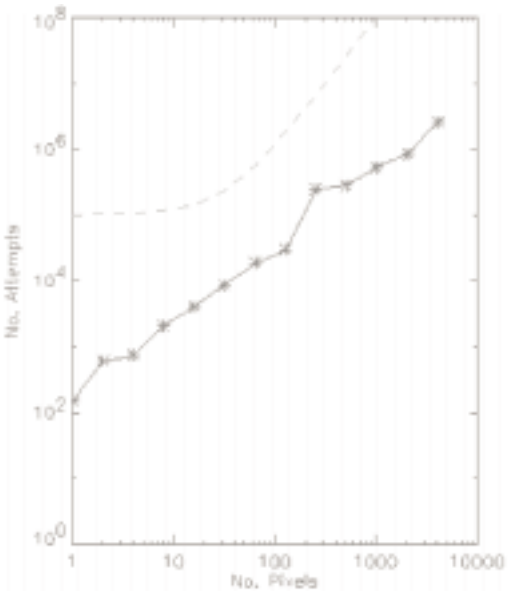
Convergence algorithm

The algorithm, which is written in IDL, needed 22 hours on a 700 MHz desktop PC to calculate one of the surrogate clouds (4096 pixels) shown here. It would not come as a surprise if we could still reduce the computation time by an order of magnitude, but the algorithm will remain a calculation intensive task. At the moment we are writing a C++ version that could also run on a parallel computer.



The calculation of the fitness of the clouds takes most computer resources. The number of clouds that are generated before convergence is an about linear function of the number of pixels, see left fig. That means that the calculation of large matrices is relatively easy. Given that the number of possibilities is a power law.

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Conclusions & Outlook

With a search algorithm one can make surrogate cloud fields whose properties correspond closely to measured clouds.

We want to test how suitable these clouds are for radiative transfer by making a set surrogate clouds using statistics from a set of LES clouds and intercomparing their radiative properties.

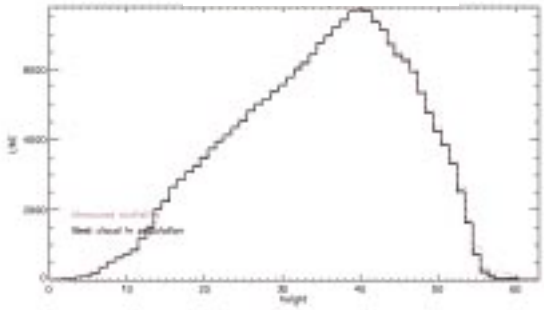
Finally we'll make clouds using measurements:

- Lidar + radar: cloud boundaries
- Microwave radiometer: LWP
- Infrared radiometer: cloud cover
- PVM-probe: LWC height profile, LWC difference

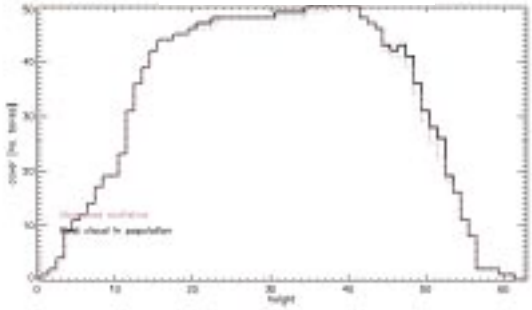
Quality of profiles

The quality of the LWC and 'cloud cover' height profile is close to perfect. Black: surrogate; Purple: original.

LWC profile

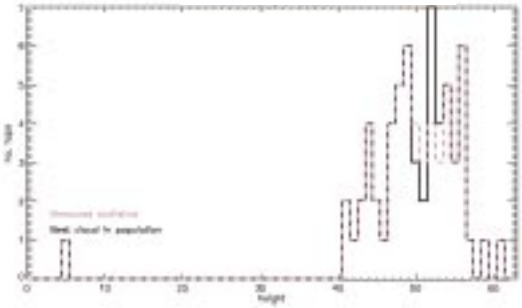


'Cloud cover' profile

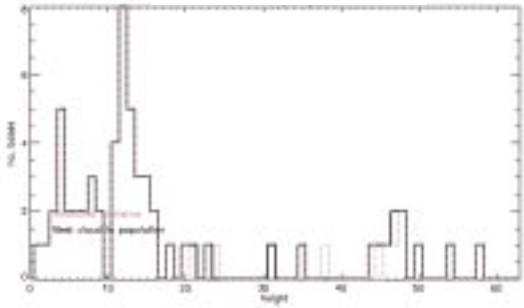


The quality cloud top and base height profiles are very good. The average cloud height is excellent.

Cloud top profile



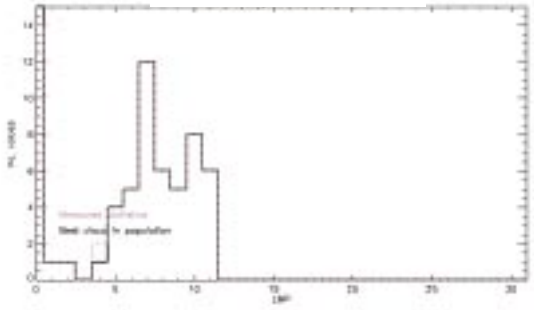
Cloud base profile



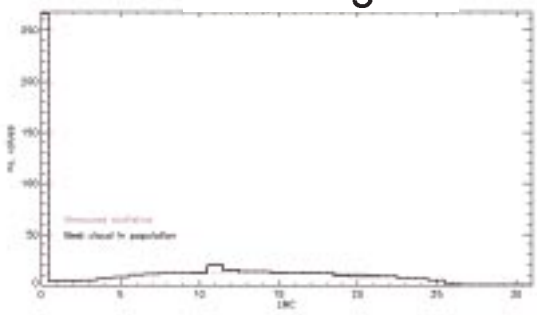
Quality of histograms

The quality of the LWC and LWP histogram is very good. The LWP histogram is important: it is the first order parameter for radiative transfer; cloud structure is only second order. Black: surrogate; Purple: original.

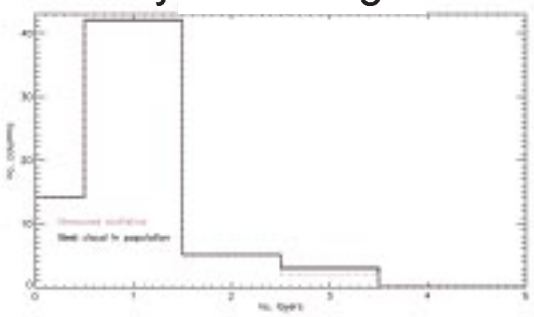
LWP histogram



LWC histogram



Layers histogram

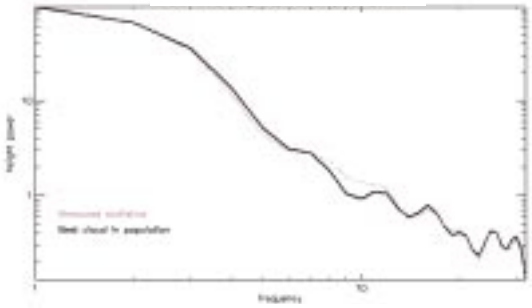


Zero cloud layers in the layers histogram indicates a clear column. A separate criterion assures that this value is correct within 1 %.

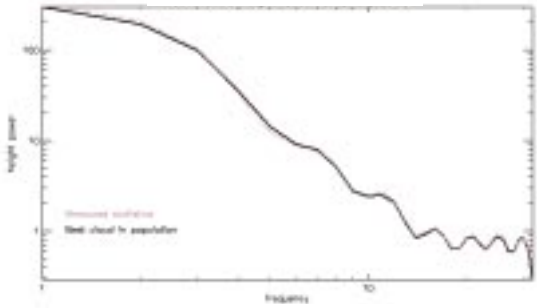
Quality of power spectra

Power spectra are noisy. Without smoothing, to remove this noise, the search does not converge. As smoothing can create artefacts, we want to use the autocorrelation function in future.

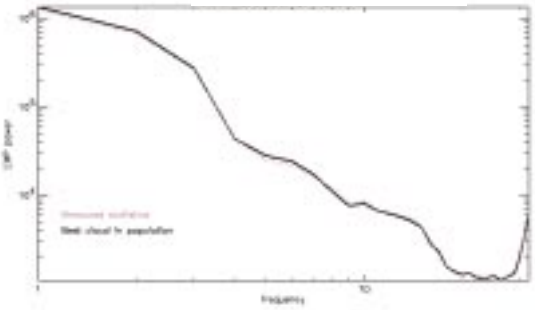
Cloud top spectrum



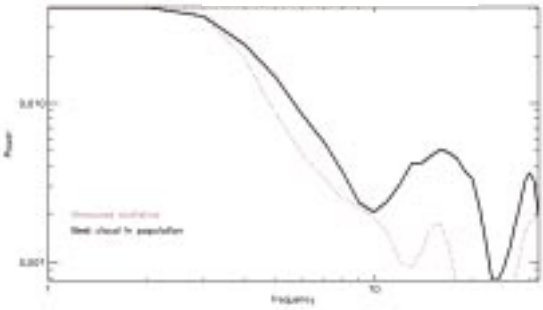
Cloud base spectrum



LWP spectrum



Layers spectrum



Quality of time series length

The length of the cloud top and base is used as a second cloud structure measure next to the power spectrum. The length is the cumulative absolute difference between two neighbouring values. This 'length' is also used for the time series of LWC, LWP and number-of-layers.

The length (and the power spectrum) of the number-of-layers does not converge very well. As it is not thought to be that important for radiative fluxes, its quality criterion was set relatively low.

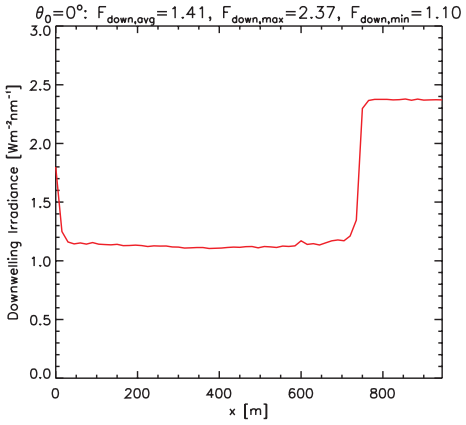
	model	measured	diff
LWC difference			
horizontal	38054	36380	1674 (4%)
vertical	24326	20344	3982 (20%)
Top height difference	200	200	0 (0%)
Base height difference	150	148	2 (1%)
LWP difference	26566	26566	0 (0%)
Number of layers difference	16	10	6 (60%)

Your contribution EAE03-A-06139 for the EGS - AGU - EUG Joint Assembly, Nice, France, April 2003 entitled: "Searching for a 3D-cloud field with measured cloud properties" by "Venema, V; Simmer, C" has been scheduled for a poster presentation in Session AS8, Poster Area Esplanade on Thursday, 10 April 2003, 8:30. Your poster board number is P0617 and your poster may be on display from Thursday, 10 April 2003, 8:00 to Thursday, 10 April 2003, 19:30. The clear dimension of your poster board is 90 cm width x 240 cm height.

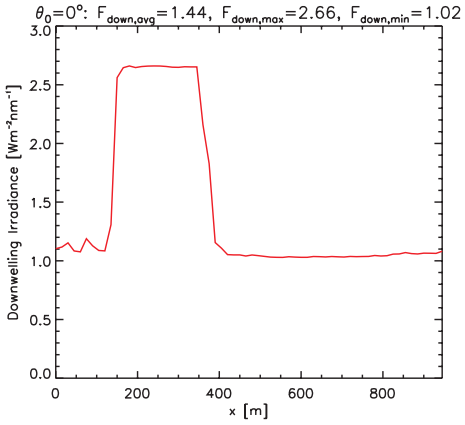
Last minute result

The radiative properties original test cloud and its surrogate have been calculated by Sebastián Gimeno García of the IfT Leipzig. This shows that the two clouds are very similar, with respect to their minimum, maximum and average downwelling irradiance (0° zenith; this plate), flux density (next plate) and flux density profile.

Original



Surrogate

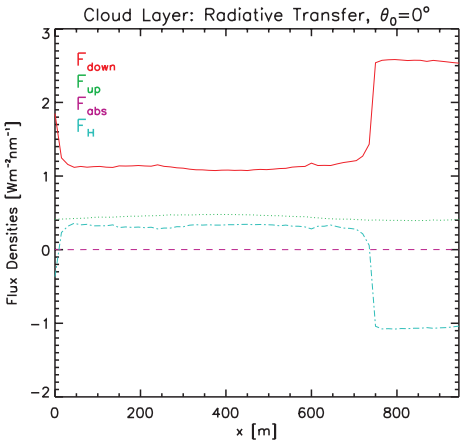


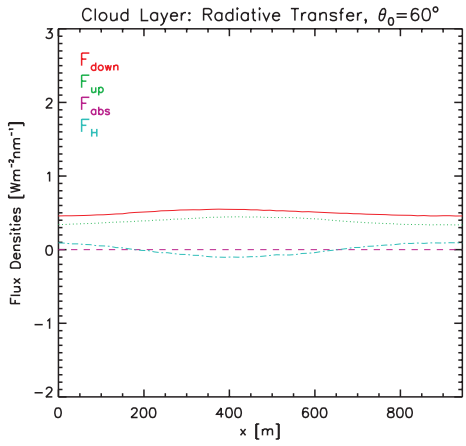
Last minute result

The flux density at 0 and 60 degree zenith angle.

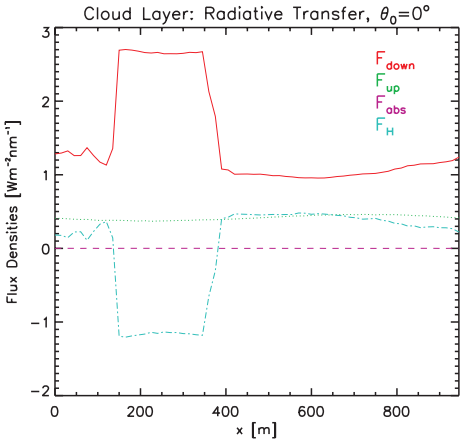
The cloud is at a different position in the surrogate.

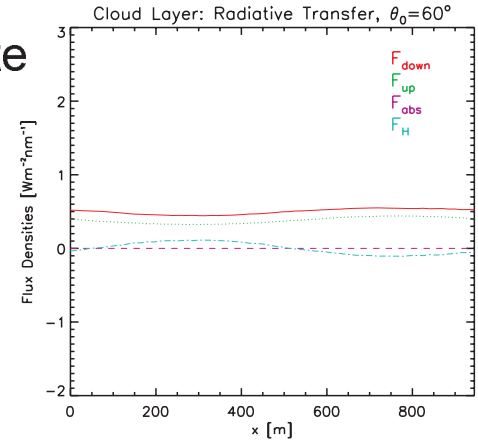
Original





Surrogate

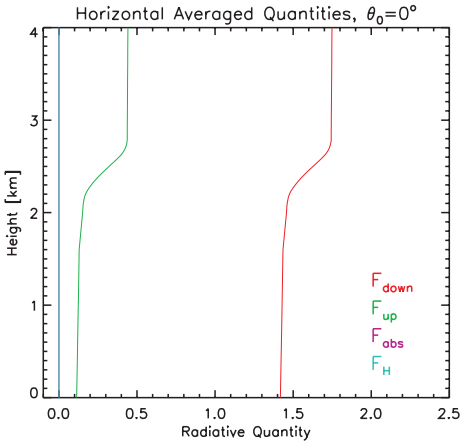


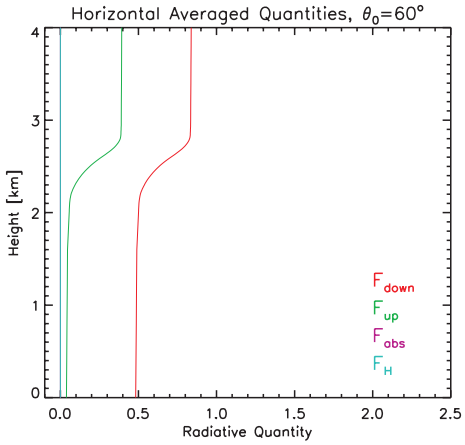


Last minute result

The flux density profiles at 0 and 60 degree.

Original





Surrogate