

User Manual

CMS FCT-22 DB (Findclouds Trinity DB)

Cloud Analysis Software

Release 2024-11-08

Cloudiness & Cloud Base Height & Cloud Motion Vector & SQL Database

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1 Introduction

CMS FCT-22 (FindClouds Trinity) Cloud Analysis Software allows to calculate cloudiness and other cloud parameters based on raw JPG images delivered by CMS "ASI-16 "All Sky Imagers". CMS FCT-22 comes with new multi-user features and with significant improvements in stability, fast multi-camera support (up to 5-8 imagers), and short shooting-interval real-time analysis.

CMS FCT-22 stores all evaluation and BMP data in an SQL Database, in parallel to traditional CSV and TXT file based storage. Such allows real-time access to evaluation results via SQL queries using a database client application and/or a user-developed software (e.g., "Nowcasting Software"). NOTICE: Working with SQL DB requires knowledge of SQL and/or some database client software.

Please also refer to and check "FCT22_setup-config_yymmdd.pdf". - !!! !!!

The above document describes all pre-requirements and setup procedures for the FCT-22_DB.

2 System Requirements - ASI-16 Imagers

Operating System: Microsoft Windows (MS Windows 10 pro, [or MS Windows 11 pro])
Ad-On Software: Java RT, PDF reader, Doc/XLS software, IP/Port scanner, Web Browser.
 ZIP/RAR software, FTP client, AnyDesk/RustDesk, CMS ASI tools, xxx.

RAM: ≥ 32 GB recommended; 16 GB minimum;

CPU: ≥ 8 cores recommended; 4 cores minimum;
 ≥ 4 GHz recommended; 3.5 GHz minimum;

GPU: not used, not relevant;

HDD: Disc 1 (OS, SW): ≥ 500 GB; ≥ 100 GB available memory, (2 partitions).
 (Partitions: We recommend to split esp. Disc 1 into min. two partitions.)

When using this PC also as (Postgres) SQL DB and data server:

BEST: RAID-1, total useable space ≥ 2 TB (consisting of 2 HDD @ ≥ 2 TB).
 The RAID-1 array should be split into three logical partitions/drives.
 1x 500 GB: OS, SW; 1x 500 GB: Backup; Rem. about 1 TB: Data.

OR: Disc 2 (DB, data): ≥ 1 TB; ≥ 500 GB available space, (1/2 partition).

ASI-16 Imager(s): One (or more) CMS ASI-16 Imager(s) [cams] to deliver raw JPG image data.

(S/) FTP Server: FTP Server to receive raw JPG image data from one (or more) ASI-16 cams.

3 FCT License - ASI Imager bound "License Keys"

Use of CMS "FCT-22 Cloud Analysis Software" is subject to purchase of a valid FCT License (one or more License Key/s). Please refer to CMS EULA (End User License Agreement), as enclosed. FCT-22 requires one (1) individual "License Key" for each CMS ASI-16 imager to be evaluated.

4 Cloud Analysis Algorithms -

Depending on payable and optional licenses, the software evaluates sky images and calculates the cloudiness, cloud base height, and cloud motion vector. It was designed for the CMS ASI-16 All Sky Imager using a fisheye lens to generate all-sky images.

The evaluations of all-sky images can be performed automatically in real-time or later for campaign-based data sets. The software classifies the sky by recognizing cloud contours (objects) and assigning ratio values to these contours. All analysis results can be stored as ASCII files, image files, or in a database for further inspection. The database entries are also used to read back the results of earlier evaluations for the table view in the main window. In addition, a list of "blue values" and their amount of sky coverage can be stored, estimating the distribution of cloud densities in the image. The position of the sun disk is detected automatically. The horizon can be defined manually, to avoid incorrect results in areas where the sky is not visible (e.g. mountains, buildings, or other structures in the image).

The **cloudiness** indicates how much of the sky is covered with clouds. It ranges from 0.00 for a cloudless sky to 1.00 for a sky completely covered with clouds. For cloudiness evaluation, only one image is necessary. A hierarchy of cloud objects is generated, where each object consists of an outer contour, hole contours, a "blue value", and a barycentre. The exported results are much simpler.

The **cloud motion** evaluation estimates the movement of the clouds from two consecutive images. The *clouds' speed* [Pixel/s] and *direction* [°] in the image space are calculated by analysing the movement of the cloud contours. To retrieve the speed in absolute units [m/s], it is necessary to know the height of the clouds. -

The **cloud height** evaluation estimates the height of clouds from two images that provide a stereoscopic view of the clouds. It looks for clouds detected on both images and calculates their height using the stereoscopic displacement. The evaluation uses the cloud objects of the cloudiness evaluation. Objects, that can be identified in both images are assigned a height.

Note 1: The cloudiness evaluation is based on the "BRBG ratio" of the RGB colour channels. We tested different ratio algorithms like

$$RATIO = \frac{B}{R} + \frac{B}{G} \quad \frac{R}{B}; \quad \frac{B}{G}; \quad R - B; \quad \frac{(B - R)}{B + R}; \quad Y - (L - D); \quad \frac{\max(R, G, B) - \min(R, G, B)}{\max(R, G, B)}$$

The "BRBG ratio" outclasses them all by the most detailed result and best evaluation of cloudiness. Especially this ratio proved to be widely independent from light exposure and shows nearly the same result for normal and underexposed pictures without change of thresholds. The difference only shows up for regions near the sun, where the sun outshines details in low dynamic exposed pictures.

Note 2: The quality of the evaluation depends on the colour contrast of the image. With a high colour contrast the "BRBG ratio" shows a lot more details, like thin clouds or haze. Only one parameter, which depends on the colour contrast of the camera must be adjusted manually for desired range of evaluation. The range starts with white areas, like thick clouds or the overexposed sun, and then looks "into the blue" – the deeper the range goes, the more thin clouds and haze will be detected.

Note 3: Depending on the type and structure of clouds and the overall cloud scenario (morning, evening, >80% cloudiness), the evaluation sometimes may deliver wrong results. - Especially for CBH and CSV evaluation in most scenarios only a small part of raw images (< 10% of all raw images) might be qualified to deliver respective numeric analysis data results. - Client's post-processing software must be prepared to deal with such "non-continuous" data sequences.

5 Main Window

The main window shows the existing images and offers the possibility to evaluate them. Also, it shows the results of the evaluations in a table of values. It can be used for manual evaluations and analysis, but also in automatic mode, which automatically recognizes new pictures and Eval Data.

| Name | Cloud | Dir [°] | Motion [px] | T [°] | RH [%] | GHI [W/m ²] |
|--------------------|-------|---------|-------------|-------|--------|-------------------------|
| 20200401 072900 11 | 0.11 | 56 NE | 19.5 | 10 | 93 | 76 |
| 20200401 072915 11 | 0.11 | 56 NE | 21.6 | 10 | 93 | 78 |
| 20200401 072930 11 | 0.12 | 64 NE | 19.8 | 10 | 93 | 81 |
| 20200401 072945 11 | 0.12 | -1 | -1 | 10 | 93 | 83 |
| 20200401 073000 11 | 0.12 | -1 | -1 | 10 | 93 | 86 |
| 20200401 073015 11 | 0.13 | 64 NE | 22.3 | 10 | 93 | 90 |
| 20200401 073030 11 | 0.12 | 57 NE | 18.4 | 10 | 93 | 93 |
| 20200401 073045 11 | 0.12 | 60 NE | 20.4 | 10 | 93 | 97 |
| 20200401 073100 11 | 0.13 | 69 ENE | 19.9 | 10 | 93 | 100 |
| 20200401 073115 11 | 0.13 | 62 NE | 18.2 | 10 | 93 | 104 |
| 20200401 073130 11 | 0.14 | 58 NE | 20.1 | 10 | 93 | 107 |
| 20200401 073145 11 | 0.14 | -1 | -1 | 10 | 93 | 110 |
| 20200401 073200 11 | 0.13 | 62 NE | 21.4 | 10 | 93 | 113 |
| 20200401 073215 11 | 0.15 | -1 | -1 | 10 | 93 | 122 |
| 20200401 073230 11 | 0.16 | 62 NE | 20.5 | 10 | 93 | 120 |
| 20200401 073245 11 | 0.13 | 57 NE | 21.6 | 10 | 93 | 122 |
| 20200401 073300 11 | 0.16 | 54 NE | 21.2 | 10 | 93 | 124 |

| Key | Value |
|------------------|-------------------|
| Angular_Area | -1.00 |
| Angular_Distance | -1.00 |
| Cam | asi_16124 |
| Cloudiness | 0.13 |
| Date | 20200401 |
| Direction | 62.03 |
| Error | |
| Exact_Time | 073115 |
| Heights | |
| Humidity | 93 |
| Irradiance | 104 |
| Is_Asi | 1 |
| Local_Date | 20200401 |
| Local_Time | 073114 |
| Motion_Diameter | 1536 |
| Motion_Image | 20200401073100_11 |

[Evaluate All]: Starts the evaluation of all (!) loaded images. May take hours or even days if your archive contains a lot of images. *Example: If your ASIs are set to a 15-second shooting interval, necessary for CMV (cloud motion vector analysis), you will generate on average 2800 images per day and camera!*

[Evaluate Selected]: Evaluate the selected images/days only.

[Automatic mode]: Temporarily activate or stop continuous real-time evaluation. Whenever a new image arrives in a camera image directory – usually by receiving this image via an FPT server – it will be evaluated within 1-2 seconds after arrival. - For permanent 24/7 live evaluation "Automatic Mode" MUST be activated in "Program Settings".

Inside the "**Days**" browser, it is possible to select one or more days. The software will then read out these directories and display all the camera images matching the selected date and camera in the browser "**Images**". You can select one date by clicking on its entry or multiple ones by holding the "Ctrl" key while clicking on them. It is possible to add a block of directories by clicking on the first entry, holding the "Shift" key and clicking on the last entry. To add several different blocks, you must click on the first entry, hold the "Shift" key and click on the last entry of first block, then

release "Shift" key, hold "Ctrl" key and click on the first entry of the second block, release the "Ctrl" key and hold the "Shift" key to click on the last entry of second block, and so on.

On the top centre of the main window are the tabulator items "**Cloudcams**", "**Pairs**" and "**Messages**" described below.

The bottom left contains elements to filter which results of the evaluations should be shown.

[Threads] The number of active evaluation threads. When there is an evaluation running, an additional progress bar visualizes the current progress of the evaluation.

[Days Back] How many days back shall be loaded and displayed. A large archive with many days and/or many (fast shooting) images will dramatically slow down startup and some operations. We recommend testing in your environment and to set this parameter to a value for which the startup time is acceptable.

[Hold Evaluations] When activated, all results of the evaluation/s will be retained in memory. Entries of images with retained evaluations are highlighted with a gray background. Please be aware, that this can cause the memory to overflow, when there are many evaluation results. When deactivated, the results of the evaluations are removed from memory right after they have been written to the database and output files.

[Show Evaluations] When activated, the resulting picture of the current evaluation will be shown at the bottom of the main window next to the preview of the raw image. This is helpful to monitor ongoing evaluations. For automatic evaluation it can be deactivated to save memory and CPU time.

The next setting configures which images should be loaded at startup or when the "Load Images" button is pressed:

[Ignore Results] Load all images but not the existing evaluation results.

[Load Results] Load all images and the existing results. (*Default*)

[Skip evaluated] Load only images that have not yet been evaluated. Can be used to complete missing results.

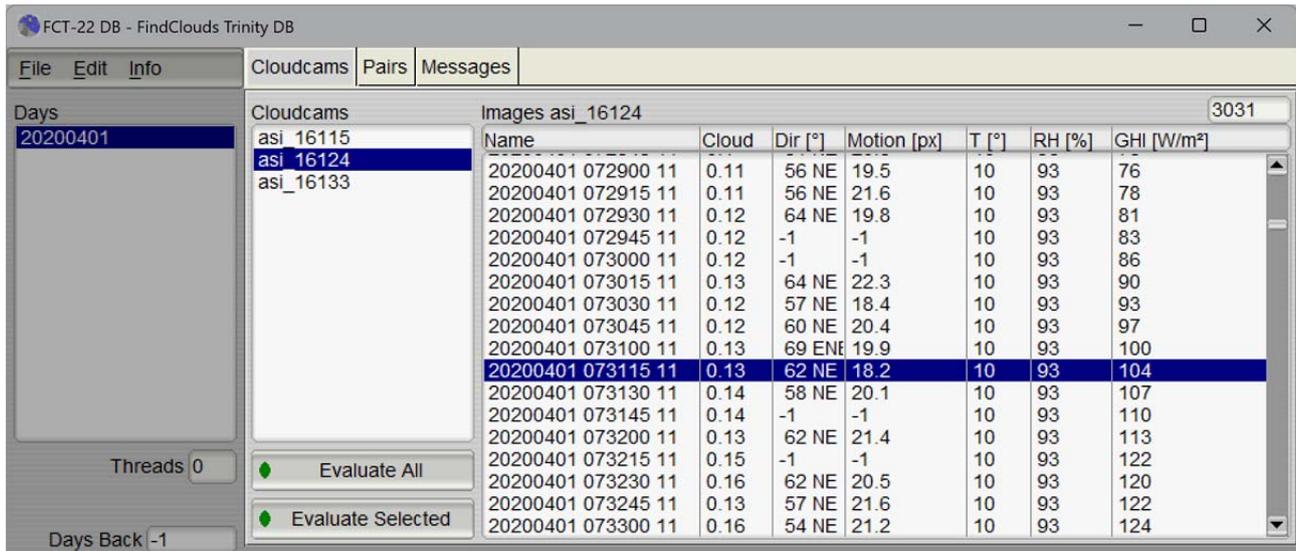
[Active Configuration] Active set of FCT- and Camera-Configuration. - NEW! - See 6.5.1

[Active DB Client ID / Active DB Config ID] User-definable IDs that are saved with each evaluation result in the database. This allows for the separation of evaluation data sets in the database, and filtering/extracting of data in SQL queries. Shall be used if multiple users (on multiple workstations) want to use the same database with a variety of evaluation settings, and later want to compare results. Click "Change" to select or add a (new) Config or Client ID.

[Postfix] Can be used to restrict evaluation to images with a certain postfix. The image names consist of a date part, followed by the time and a postfix, that encodes the light exposure. E.g. an image "20150911095000_11.jpg" is an image taken in 2015/09/11 at 09:50:00 with the postfix "11".

[Load Images] Pressing this button loads the images for the previous days specified in the [Days Back] setting. It can be used to reload images after changing the [Days Back] setting, the results setting, or the postfix setting.

5.1.1 Main Window "Cloudcams" View



The "**Cloudcams**" view can be opened by clicking the tabulator in the top left of the main window. The browser "Cloudcams" shows all registered All Sky Imagers (ASI). It can be used to select a specific CMS ASI-16 imager.

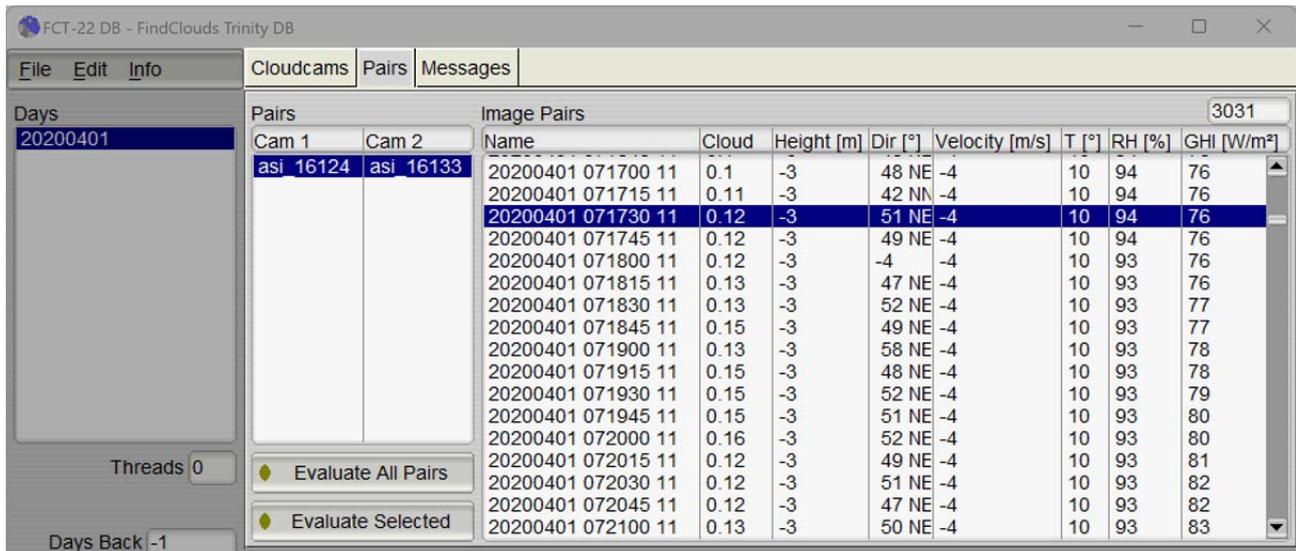
When an ASI-16 is selected, the browser "**Images**" on the right-hand side shows all images that were loaded for this ASI. When an image in the Images browser is selected, the evaluation result will be shown in the list below the Images browser.

- "Name": the date, time, and postfix of the picture.
- "Cloud": the computed cloudiness i.e. how much of the entire sky is covered by clouds.
- "Dir [°]": the wind/cloud movement direction in degrees followed by the cardinal direction.
- "Motion [px]": how many pixels the clouds have moved compared to the previous image.
- "T [°]": the measured temperature in degrees Celsius at the time that the image was taken.
- "RH [%]": the measured relative humidity at the time that the image was taken.
- "GHI [W/m²]": the measured global horizontal irradiance at the time that the image was taken.

[Evaluate All] Starts an evaluation of all images of all imagers of all days displayed. Depending on the number of days and images per day such evaluation may take very long time, many hours! - To reduce the "number of days" set the parameter "**Days Back**" from "-1" (means "all days found") to a more reasonable number of days, the number of days since the last evaluation run.

[Evaluate Selected] Starts an evaluation of some select images. You can either select one or multiple images, or one or multiple days. This is useful for manual evaluation of interesting images.

5.1.2 Main Window Pairs View (CBH - Cloud Base Height)



The CBH Pairs view can be opened by clicking the tabulator in the top left of the main window.

"Pairs" This browser shows all defined pairs of All Sky Imagers (ASI). When a pair of imagers is selected, the software shows all images of that pair in the **"Image Pairs"** browser:

"Image Pairs" shows all images found for the day selected in "Days". The file names of the images are split into date, time, and postfix. Only valid pairs of images with the same time are displayed.

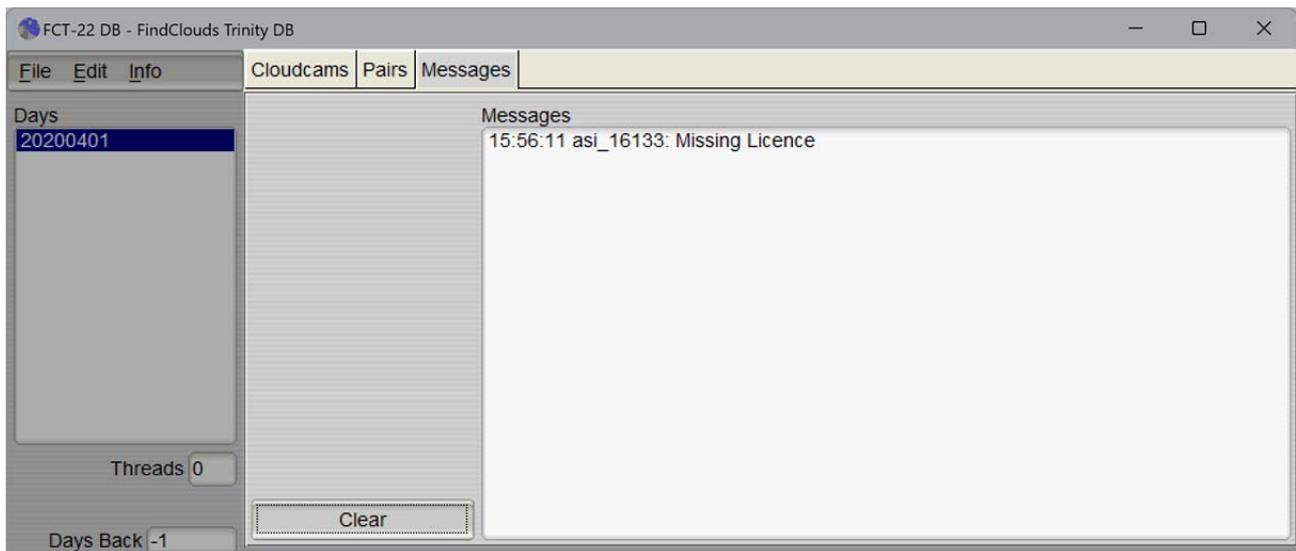
- **"Name"**: the date, time, and postfix of the picture.
- **"Cloud"**: the computed cloudiness i.e. how much of the entire sky is covered by clouds.
- **"Height [m]"**: the cloud height in [m] above sea level. When more than one height was determined, the minimum and maximum height will be written in this column.
- **"Dir [°]"**: the wind/cloud movement direction in degrees followed by the cardinal direction.
- **"Velocity [m/s]"**: the cloud velocity in [m/s]. When more than one cloud height was detected, multiple values corresponding to the different heights will be calculated for the cloud velocity as well.
- **"T [°]"**: the measured temperature in degrees Celsius at the time that the image was taken.
- **"RH [%]"**: the measured relative humidity at the time that the image was taken.
- **"GHI [W/m²]"**: the measured global horizontal irradiance at the time that the image was taken.

When a line of the browser is selected, the details of both pictures and evaluations will be shown in the list beneath the image browser. There will be a column for each picture.

[Evaluate All Pairs] Starts an evaluation of all pairs defined and all pictures found.

[Evaluate Selected] Starts the evaluation of all selected images of the current chosen camera pair. The results will appear in the "Image Pairs" browser. The evaluation can be stopped at any time by pushing the evaluate button a second time. For evaluation purposes, the image can be selected the same way described above. It is possible to deselect by a click to the current camera pair in "Pairs" browser.

5.1.3 Main Window Messages View



When an error occurs during an evaluation, the Messages tabulator will change its color to yellow and the error message will be printed to the Messages browser. This does not interrupt or stop the ongoing evaluations.

[Clear]: Can be used to clear the messages list. The start of a new evaluation also clears this list.

6 Menu - Configurations

| Name | Cloud | Dir [°] | Motion [px] | T [°] | RH [%] | GHI [W/m ²] |
|--------------------|-------|---------|-------------|-------|--------|-------------------------|
| 20210330 092415 11 | 0.36 | -6 | -6 | 12 | 43 | 705 |
| 20210330 092430 11 | 0.36 | -6 | -6 | 12 | 44 | 705 |
| 20210330 092445 11 | 0.36 | -6 | -6 | 12 | 44 | 723 |
| 20210330 092500 11 | 0.36 | -6 | -6 | 12 | 44 | 744 |
| 20210330 092515 11 | 0.35 | -6 | -6 | 13 | 44 | 745 |
| 20210330 092530 11 | 0.35 | -6 | -6 | 13 | 42 | 741 |
| 20210330 092545 11 | 0.36 | -6 | -6 | 13 | 43 | 749 |
| 20210330 092500 11 | 0.35 | -6 | -6 | 13 | 43 | 741 |

There are three menus in the top menu bar:

- "File" includes menu items, that will be used in normal operation.
- "Edit" includes menu items to configure the software, the cameras, and the evaluation algorithms. Most of these settings must be adapted once before the first evaluation.
- "Info" provides the information about the program and can be used to access the manual.

The menus contain the following items:

"File"

- "*Overview*" opens a dialog to view details of the evaluation. There is no restriction to the number of dialogs that can be opened, so every choice of this menu item will open an additional dialog.
- "*Show Curves*" opens a graphical visualization of evaluation values for selected imager.
- "*Hide Curves*" closes all curves dialogs.
- "*Setup Curves*" opens a dialog to configure the curves dialog.
- "*Export Evaluations*" opens a dialog to set up and perform the export of evaluations into a table. This dialog also defines the format of the exported table lines.
- "*Memo Directory*" opens a directory chooser to select a destination directory for "memo" files. This belongs to the "Memo" button of the overview dialog, which allows to note the name of interesting cloud photos.
- "*Quit*" closes all open software windows, saves their positions and quits the software.

"Edit"

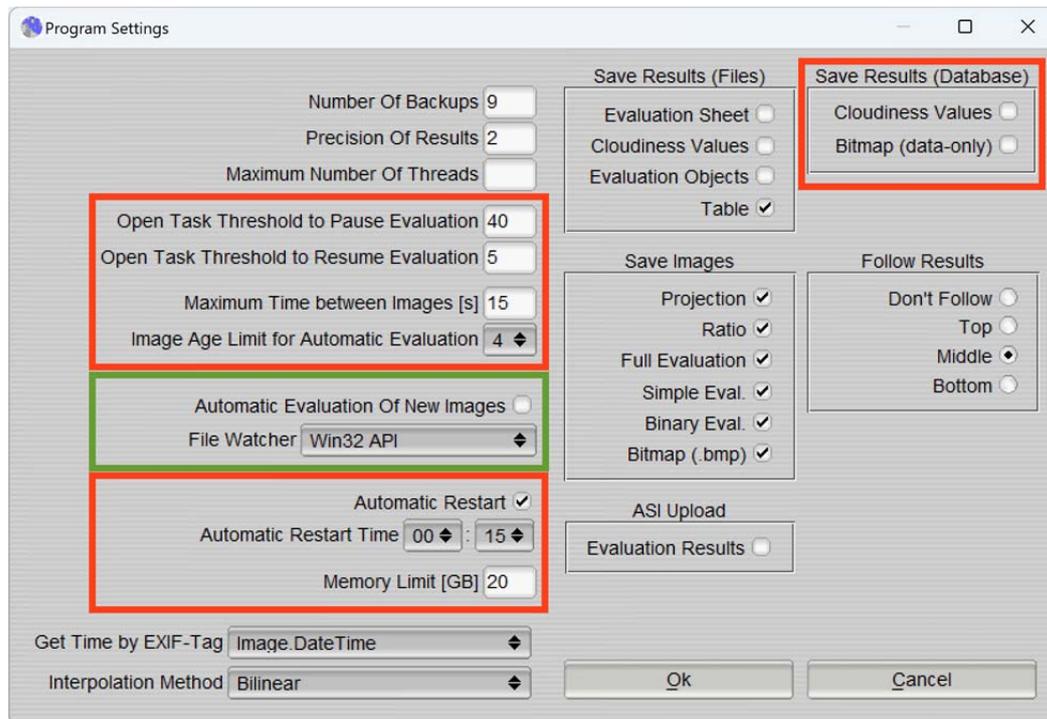
- "*Folder For All Configurations*" sets the basic directory, where all configurations will be stored.
- "*Camera And Directory Definitions*" opens a dialog to set up all the imagers and the paths where their images are located, as well as the directories for storing the evaluation results. There is no dependency between the basic configuration folder and these paths.
- "*Program Settings*" opens a dialog containing miscellaneous settings. These are settings that do not belong to the other configuration dialogs. An example is the number of threads that should be used for evaluations or the files that should be generated during an evaluation.
- "*Configuration Camera*" opens a dialog to change basic settings for the selected imager. These settings must be defined for each imager before the first evaluation.

- *"Configuration Cloudiness"* opens a dialog to set up and control the cloudiness evaluation. The dialog shows the camera that is selected in Cloudcam View of the main window, e.g. to set up the evaluation range regarding to the colour contrast of this camera.
- *"Pair Definitions"* opens a dialog to configure pairs of cameras for height evaluation.
- *"Configuration Cloudheight"* belongs to the "Pair Definitions". It allows an exact adjustment of the pair evaluation settings. This dialog shows the configuration of height evaluation and offers a method to control and adjust them.
- *"Configuration Cloudmotion"* opens a dialog that offers some parameters to configure the Cloudmotion evaluation.

"Info"

- *"About"* shows information about the software.
- *"User Manual"/ "Quick Install Guide"* opens this manual or the quick install guide.
- *"Log Files"* opens the directory containing the log files.

6.1 Program Settings:



This dialog provides basic settings of the system. Ranges and recommendations of the settings are provided by tool tips and will be shown, when placing mouse arrow over the input field. The text file "config_misc.sys", that belongs to this dialog, also contains hidden options, like the position and size of windows or the options of the main window.

"Number Of Backups" When a configuration file was changed, this configures, that up to "Number Of Backups" preceding versions of this file will be stored. For every number larger than zero, saving a configuration will not overwrite the latest version, but rename it for backup. The file "config_misc.sys" so will cause backups like "config_misc.001", "config_misc.002" and so on. This makes it possible to restore settings, that were overwritten by accident.

"Precision Of Results" Allows to adjust all the values of the ASCII result files to a number of decimal places. The default value of "2" should not be reduced, because there are many values that don't make sense without decimal places (like "Cloudiness" with values from 0.00 to 1.00).

"Maximum Number Of Threads" Limits the number of threads the software opens for evaluation. If this value is not set, the software uses the number of hardware threads supported by the system. This can cause problems if other software besides the FCT is running at the same time, as it will consume a lot of CPU resources. Reducing the number of threads will limit the FCT's use of system resource but also slow down the evaluation.

"Automatic Evaluation" When activated the software will observe the picture folders and evaluate new pictures automatically. Other than the automatic evaluation button on the main dialog, this setting remains active even after restarting the software.

"Get Exact Time By Tag" For motion evaluation the software works better when the exact time is known when the picture was made. Usually there is an entry inside of the exif tag, that shows this exact time, but the name of the entry can differ. This option gives the choice to set up the exif tag, that is used by the cameras.

"Interpolation Method" For rotation and resize of images. The default method is the fastest and it is possible to select a slower, but more accurate method for rotation and resize.

[Follow Results] Sets the mode for update of the main windows browsers. If an evaluation exceeds the shown lines, it is possible to activate a placement of the current lines. Otherwise, the evaluated lines will run out of the visible area. In fact, this is no problem, but it looks better to see the current lines.

[Save Images] Activates the export of evaluation images. The "Projection" is the projected cut out of the original image from which the evaluation starts. The other images are different representations of the final evaluation, more details can be found in the "Configuration Cloudiness" chapter. - Select only those evaluation image types which are really needed!

[Save Results (Files)] This configures which files should be written during evaluation:

Evaluation Sheet: Text-file, Key/Value comparable to the displays at the main screen.

Cloudiness Values: Additional table of "blue values" and the size of their image area in percent for every evaluated picture.

Evaluation Objects: The whole cloud evaluation with all contour vectors.
(Very large, and no practical use for typical end-user clients.)

Table: Evaluations as lines of a CSV table. The export dialog must be used to configure the format of the table, e.g. values to save ("Keys") and character of delimiter.

[Save Results (Database)] Configures which information will be written to the database. For further information, please refer to the document "*FCT22_setup-config_240529.pdf*".

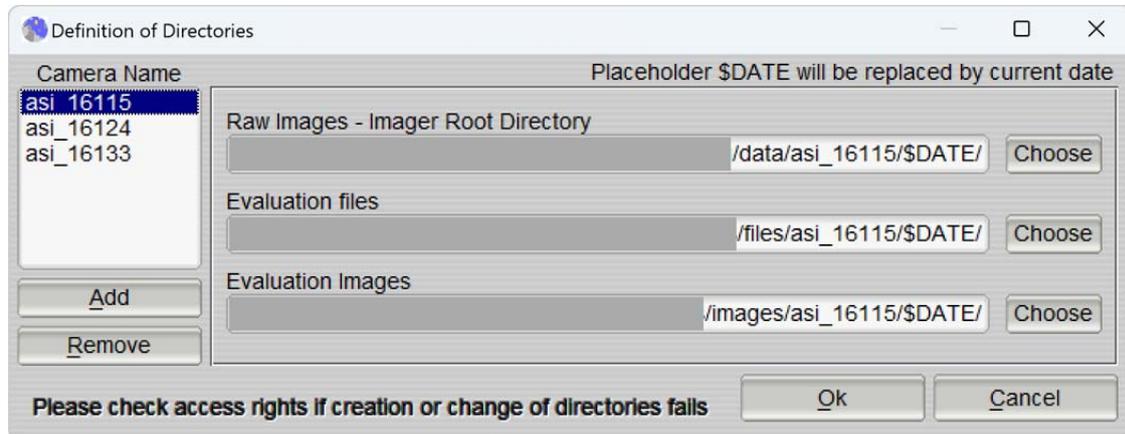
[ASI Upload] Activates upload of current evaluation results of an ongoing automatic evaluation to the ASI Web Interface for live display. If "Evaluation Results" is checked, a small file containing the most recent evaluation results will be stored in the camera data directory. This file is read and displayed by the ASI Web Interface. **Works only if the file is accessible by the camera i.e. the camera folder is synchronized both ways!** Please refer to "*FCT22_setup-config_240529.pdf*" for further information.

[Ok]: Applies all the changes.

[Cancel]: Exits without changes.

6.2 Camera And Directory Definitions

This dialog defines the cameras and directories for all other functions of the software. It must be used to define at least one camera the software can work with.



All paths can be free defined for each individual camera. Especially the paths are independent from the configuration directory. Add, Remove or Rename will always be applied to directories inside of the basic folder. This configuration defines all the paths the software uses to find pictures and to store results.

[Add]: Add a new camera. - After "ADD" you must "configure" any new added imager!

[Remove]: Remove a camera.

[Ok]: Will apply all inputs and changes.

[Cancel]: Discards all changes and closes the dialog.

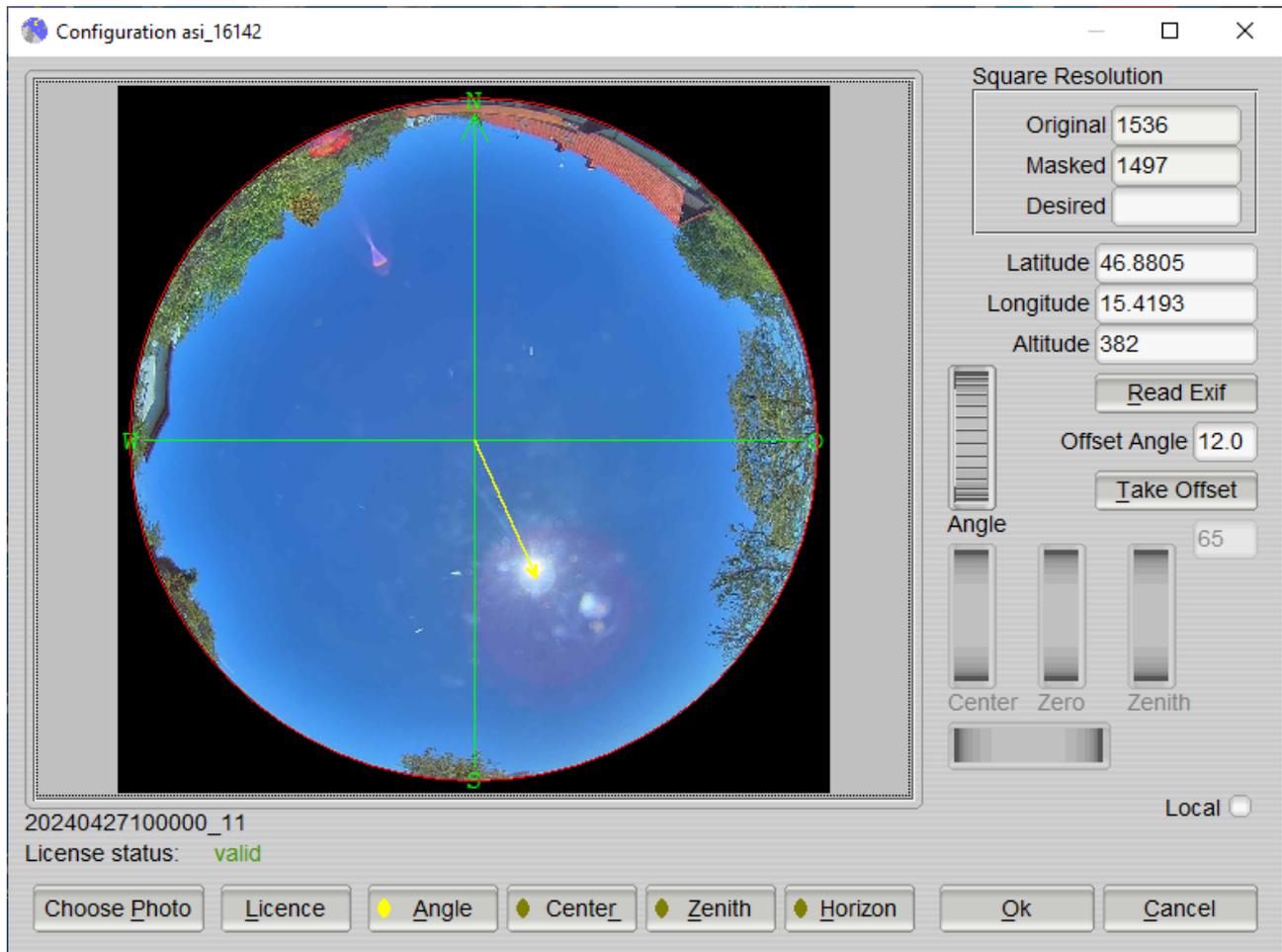
[Raw images]: The root directory where images of an ASI-16 are stored. The ASI root directory MUST follow ASI-Name rules (e.g. "asi_16124"). After selecting the root folder, the FCT automatically generates the camera name. The placeholder "\$DATE", will be replaced by the date folder names, e.g. "20150918", to automatically parse or generate multiple days of the ASI. This directory is monitored by the FCT to detect new images if the automatic evaluation is active.

[Evaluation files]: Root ./files/ Directory where evaluation data files are stored.
Evaluation Data Files: TXT and/or CSV, as defined in "Program Settings".
NOTE: Not necessary if you are accessing data via SQL DB access!

[Evaluation Images]: Root ./images/ Directory where processed eval images are stored.
Evaluation Images: PNG and/or BMP, as defined in "Program Settings".
NOTE: Not required for daily use, only for special research purpose!

[Choose]: Button beside the path inputs.
It allows to choose the related path by file browser.

6.3 Configuration Camera



This is the start window of Cloudcam configuration dialog. For each Cloudcam in use there must be a configuration file for definition of the Cloudcam characteristics. There are some basic options, that can be changed at once by filling in values. Some options, that belong to the images made, are deactivated and for better control these options can only be changed, when a Cloudcam image was load. This way provides a direct verification of specified values, because they are applied to a real example.

[Square Resolution]

The Cloudcam uses a fisheye lens ("whole-sky lens") which takes a circular image near the middle of the rectangular photo. Because of that, both sides of the image are unused black areas, which can be cut off, resulting in a square image with same width as height. But also this image contains a lot of unused black areas. So configuration allows to define a "zero circle" that covers just the fisheye area and allows software to cut image into best detail.

"Original", "Masked" When there was an example image loaded, the "Original" resolution (original height) and the "Masked" resolution (the image is cut to) is shown.

"Desired" To speed up evaluation it is possible to reduce resolution one time more by setting a "Desired" resolution. When the masked resolution exceeds the desired resolution, the software will scale the image down to desired resolution. Also when there are images with different

resolutions this can be useful to get normalised images with the same size. When there is no desired size given (by empty input) the masked size will be used.

"Latitude", "Longitude", "Altitude", these values specify the position of the All Sky Imager. They are necessary to calculate the position of the sun, when evaluating the "near sun area" by underexposed images. When the position is not known, e.g. "Google Maps" could be used to find out, where the Cloudcam is placed.

[Read Exif] reads in the GPS infos from the selected ASI-16 JPG image to "Latitude", "Longitude" and "Altitude".

Adjustment rollers: There are five rollers for adjustment of picture position and orientation. The "angle" roller rotates the picture around the center, the two "Center" rollers move the picture in horizontal or vertical direction, the "Zero" roller defines the picture borders and "Zenith" defines final circular cut-out of the image made by evaluation. These rollers will be activated by buttons [Angle], [Center], [Zenith] and [Horizon].

[Local] if selected, the time stamp of the files (defined by file name) is not UTC, but local time.

[Choose Photo] loads an image made by the current Cloudcam. This image must be used for further adjustments and will activate buttons [Center] and [Zenith] when it was loaded successful.

[Licence] shows the current licence conditions of this Cloudcam and offers a possibility to enter a licence key.

[Angle] will switch to adjustment of the ASI-16 all sky imager offset angle. XXX

[Center] will switch back to adjustment of centring and calibration of fisheye area and deactivate accentuated contrast. It allows to centre up the image and adjust size of fisheye area.

[Zenith] will switch back to adjustment of offset angle and show not equalised image without field of view circle.

[Horizon] window for input of horizon.

[OK] saves changes and closes the window.

[Cancel] closes the window without saving changes, but asks for saving, when there are unsaved changes.

6.3.1 Centring and calibration of fisheye area

This screenshot shows mode for centring and adjusting size of fisheye area.

The image is shown with accentuated contrast, because normally the border of the fisheye area is dark and not easy to differentiate from unused black area. This way it is easy to see, where the real photo ends and a corona begins, which doesn't belong to the image.

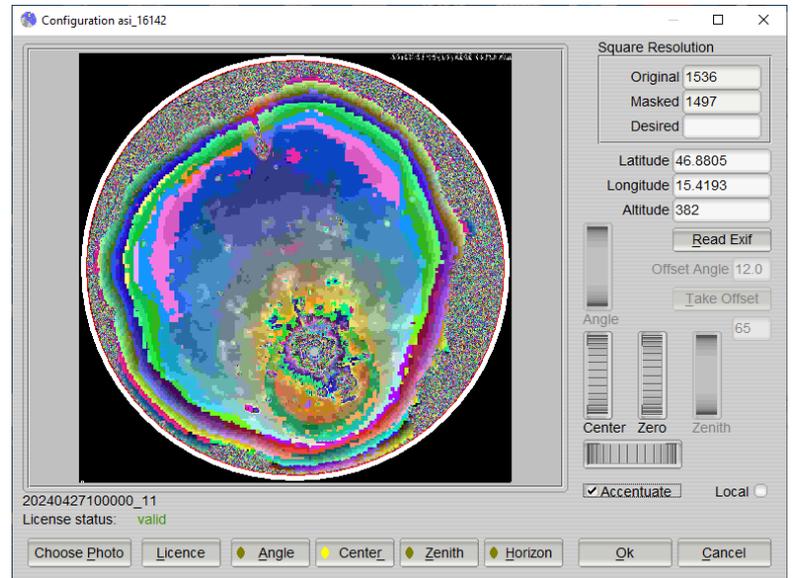
Roller "Center": The fisheye area sometimes is not fully centred. Using the vertical and horizontal "Center" roller, the image can be moved until exactly fitting to the center.

Roller "Zero": The roller "Zero" allows adjustment of the border by changing size of white and red "zero circle". The white area of the circle is only meant to make it better visible. The inner red circle shows position of the border finally being used.

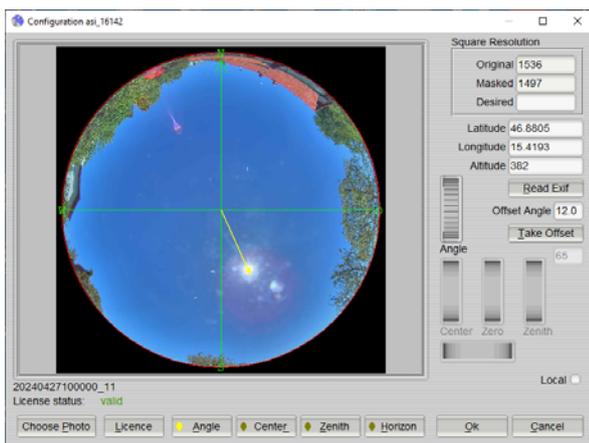
[Accentuate] makes image more colourful, when selected.

[Center] will switch back to adjustment of offset angle and deactivate accentuated contrast. It allows to centre up the image and adjust size of fisheye area.

[Zenith] equalises the image and allows to adjust field of view.



6.3.2 Calibration of angle offset



This is the configuration window, when an image was loaded, and only the basic values had been changed. It is possible to change the offset angle of the Cloudcam. Buttons for further adjustments are activated now.

The screenshot shows current orientation of the image by a green wind rose and current size of fisheye area by a red circle. A little yellow arrow points to direction of the calculated sun position. For calculating the sun's position the software uses the longitude/latitude and the date and time of the filename (shown bottom left under the photo).

The images should be oriented like a map, with direction to north on upper side (green arrow points to north) and west and east side directed like a map. Because the photos are taken from the sky, but a map is orientated to the earth, the software swaps the sides of the image, when loading it. After that a cloud that is shown in the west in fact comes from the west and also the sun moves to the right direction.

Looking at the screenshot above, it is easy to see by the sun pointer, if the Cloudcam is not placed in the right direction and an angle offset must be rectified. Also, there might be another problem to see - the fisheye area is not placed right to the middle, but there is an offset. - So before rotating the image, it must be centred by using button [Center], because an eccentric rotation will move the whole image to the wrong place.

Using the angle roller (the only one activated) the wind rose was rotated to the position it should have, if the photo would be a map. In the input field the value of rotation is shown as -2° , so the photo must be rotated -2° in (mathematical) positive direction. By pushing button [Take Offset] or selecting input field "Offset Angle" and pushing enter key, this will be completed and the image will rotate. The arrowhead of the sun pointer is not meant to point exact to the middle of the sun and also a little difference in angle won't be a problem, because area of sunmask is a good deal bigger than area of the sun.

6.3.3 Calibration of zenith angle

This is the configuration window for adjusting the field of view by zenith angle. It shows a image after being centred, north orientated and fitted into the window by borders of fisheye area.

The **zenith angle** starts with 0° at center and goes to 90° at red borderline, so a zenith angle of 90° would evaluate the whole image. But the zenith angle is restricted to 85° , because the plane projection of the image works with the mathematical tangent, so larger angles will approach infinity and prevent the image from being evaluable.

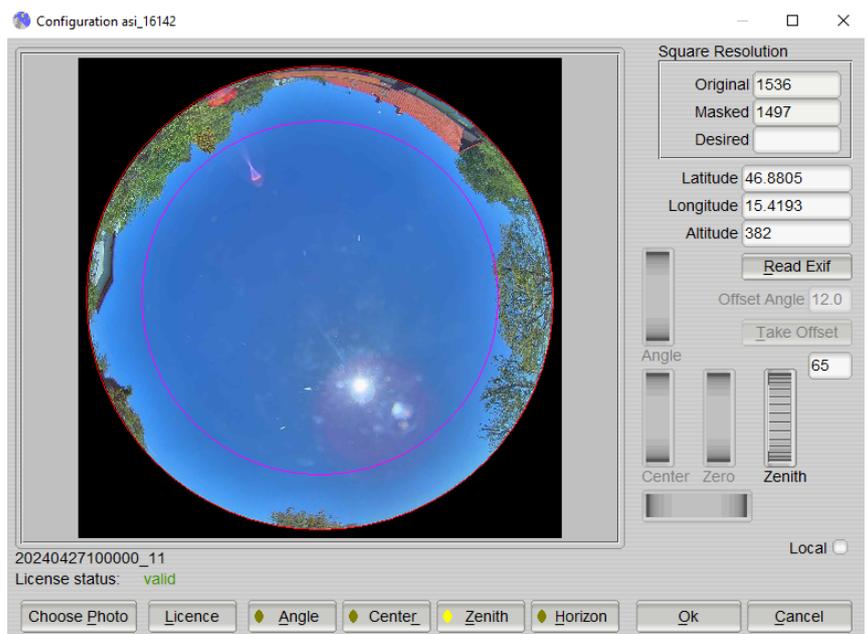
"Zenith": The roller "Zenith" or the input field can be used to define a reduced zenith angle, shown by the pink circle. In the final calculation of cloudiness software will only

evaluate cloudiness inside of this circle. - We recommend to **keep the pre-defined value of 65°** , as this is a value used and recommended by many international institutes. Values above about 75° make no practical sense and may lead to confusing results, as detection of clouds close to the horizon is highly instable and may vary depending on minor changes in atmospheric conditions.

At this point all necessary adjustments are done and the dialog should be left by using [Ok] button for saving.

[Choose Photo] can be used to load another photo for comparison, e.g. to control match of sun position.

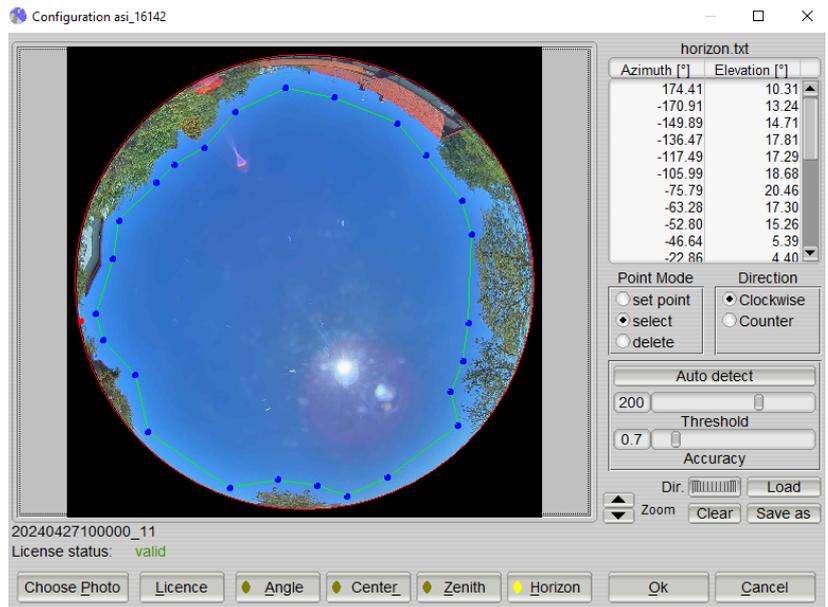
[Zenith] will switch back to adjustment of offset angle and show not equalised photo without field of view circle.



6.3.4 Input of Horizon

This is the configuration window for input of horizon, shown by the green line with supporting points. This view uses the projected image, to get a better match of input to real values of horizon line. This way the final mask used for evaluation will fit exactly to the projection of images. The listed values of elevation may differ from outdoor measured values, because graphical centring and equalisation are not high precision.

We recommend to do horizon input, after all other calibrations had been done, because changing these basic values will shift position of horizon to a wrong place.



The points of horizon line can be entered and edited by use of mouse and to be more exactly it is possible to zoom the window.

"Point Mode"

There are three operation modes, which can be switched circular by right mouse key:

- "set point" sets a point on left mouse click.
- "select" selects the point closest to left mouse click and allows to drag it by holding the left mouse button.
- "delete" deletes the point closest to left mouse click.

"Direction"

The "Direction" clockwise/counter (-clockwise) sets direction of "down the list". When there is "clockwise" activated, it is necessary to set consecutive horizon points in clockwise direction. Going into the wrong direction would switch inside and outside of the mask and would mask the inside of the horizon area and not the outside. It is possible to insert points by choosing a position inside of the list and go on with "set point".

[Load]: Loads a horizon file from inside the current Cloudcam configuration directory.

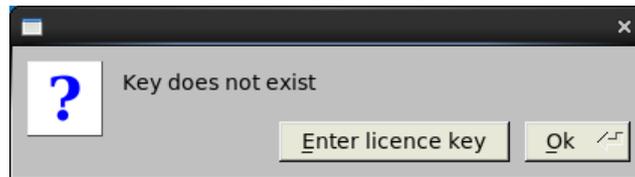
[Save as]: The horizon points are stored as "horizon_*.txt" inside of the current Cloudcams configuration directory, or the current chosen custom directory

[Clear] removes all points. This might be helpful, when centring of camera was changed and the horizon line doesn't fit any more.

6.3.5 Camera licence

The software evaluates images provided by CMS All Sky Imagers. For every camera to use, a licence key is needed and must be entered to the configuration of the camera. The name of the camera configuration is independent from the ASI name and can e.g. be name of the camera location. The licence key assigns an ASI product number to a special configuration and does not create a camera configuration.

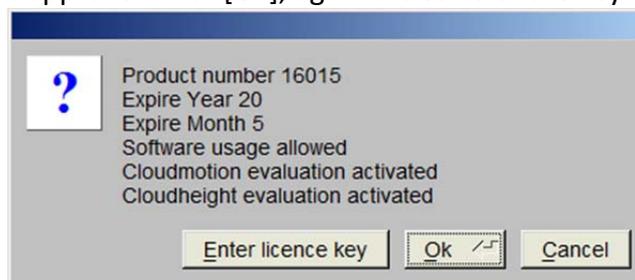
When the key [**L**icence] was pressed at first the current licence state will be shown:



The current state can be approved with [O]k or a licence key can be entered:



When the licence key was approved with [O]k, again the state of the key will be shown:



Now it is possible to accept the new key with [O]k, [C]ancel without change of key, or enter the licence key again. **Please be aware that the whole camera configuration dialog must be closed with [O]k to save the new configuration.** The entries are in detail:

- "*Product number*" tells the product number of the ASI hardware, that was assigned to this configuration.
- "*Expire Year*" and "*Expire Month*" restricts the evaluation of images to the period before this month of year.
- "*Software usage allowed*" summarises the restrictions to a special software version and the enabling of cloudiness evaluation.
- "*Cloudmotion evaluation activated*" enables the cloudmotion evaluation for this camera.
- "*Cloudheight evaluation activated*" enables the cloudheight evaluation for this camera. Please be aware that for height evaluation both involved cameras must be enabled for height evaluation.

When an evaluation was not possible by wrong licence, it will result in error number "-6".

6.4 Other Menu Items – File

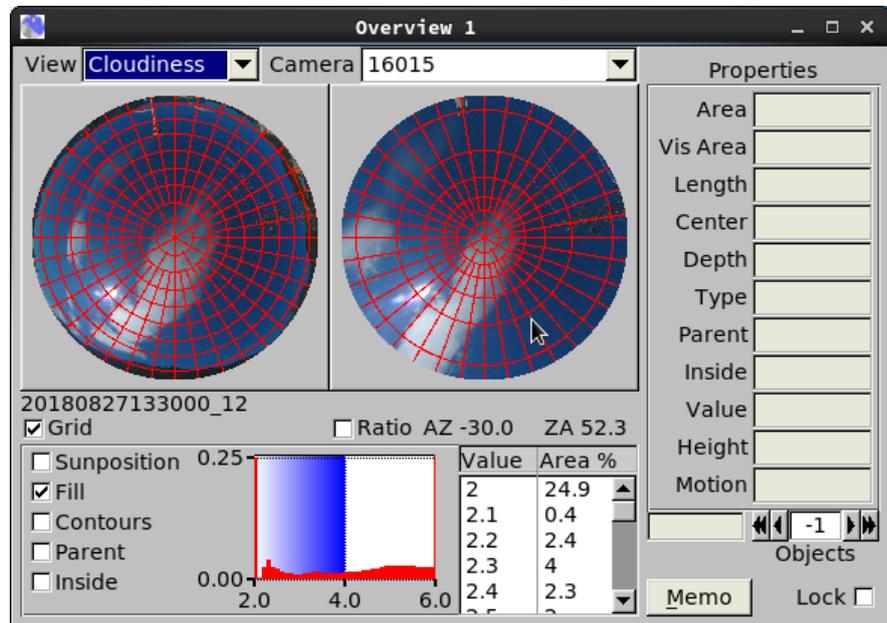
The "File" menu items provide standard operations of normal software use, like display of graphs or closing the software. Below there comes a detailed description of the items:

6.4.1 Overview

The *Overview* window offers a possibility to view images before evaluating them and to examine details of the evaluation.

When there are evaluation results that seem to be wrong, the *Overview* can be used to understand where the results came from.

There are three modes of the *Overview* window to examine the three types of evaluation - cloudiness, cloudheight and cloudmotion. It is possible to switch one *Overview* window between the modes. It is also possible to open several *Overview* windows with different modes and views to different objects. There is no internal restriction to the number of *Overview* windows.



When in "cloudiness" mode and there is no evaluation, the *Overview* shows on the left-hand side the original image of the current browser line. The projection of the original image is shown on the right-hand side. By activating the checkbox "**Ratio**" it is possible to show the BRBG ratio of the projection, without a previous evaluation.

When in "cloudiness" mode and there is an evaluation, the *Overview* shows the projected image on the left-hand side and the resulting evaluation on the right-hand side. There are several ways to get an evaluation displayed:

When one or more lines are in evaluation, the output of the *Overview* depends on the main windows option "Show Evaluation" :

[Show Evaluation] activated → the output will show all ongoing evaluations, that match the *Overview* output, e. g. the displayed camera.

[Show Evaluation] not activated → the output will show the last result of the evaluation. When only one line is evaluated, the result of this line will be displayed. When more than one line is evaluated, only the last result will remain.

[Hold Evaluations] activated → this window option holds evaluations in memory. That makes it possible, that the *Overview* window can display the full evaluation of every existing evaluation (greyed background of lines shows existing evaluations for this line).

[View] sets the viewing mode of the dialog, there are three modes:

- Cloudiness: shows the source and the result of a single evaluation.
- CBH - Cloudbase Height: shows the two images of a "pair evaluation" and makes it possible to manually determine the height of objects.
- CMV - Cloudmotion Vector: shows the two images of a "motion evaluation". At the moment there are no evaluation details, that can be displayed.

[Camera] sets the camera (mode Cloudiness or Cloudmotion) or camera pair that is desired to be displayed. The display of evaluations is restricted to one source. It is possible to open an overview window for each camera that should be displayed.

[Grid] activates a grid that shows azimuth and zenith angle in steps of ten degrees. Anyway when the mouse pointer is inside the image, under the images there will appear an output of "AZ" (Azimuth) and "ZA" (Zenith Angle) to show the current position.

[Ratio] switches from projected image to its BRBG ratio.

[Properties] is common to all modes of the *Overview* dialog. It shows the properties of a single evaluation object. Because this mainly refers to image details the most often used unit is 'pixel', e.g. the "Area" consists of a number of pixels and also the "Length" is a number of pixels. (Remark: Calculation of the Area is done with the Contour Area method from Open CV).

"Area" is the complete area [pixel] inside of the objects' borderline.

"Vis Area" is the visible part of the area [pixel], which is not covered by other objects.

"Length" is the length of the borderline in [pixel].

"Center" is the position of the centre of mass of the objects inside of the image.

"Depth" is the number of contours that were merged to get this object.

"Type" regards to individual properties of the object. The following are in use:

- Sun: the object includes the sun position. It is smaller than $\frac{1}{4}$ of the image's area.
- Horizon: the object is defined by the horizon mask. It is not an object retrieved from the image.
- Border: the object is clipped by the image border or by a horizon object. Clipped objects cannot be used for height or movement evaluations.

"Parent" is the number of the object, that includes the current selected object.

"Inside" displays the numbers of objects, that are included by the current selected object.

"Value" is the average BRBG ratio of the "Vis Area".

"Height" is the result from a successful evaluation of the objects' height [m].

"Motion" is the result from a successful evaluation of the objects' motion.

[Objects] this counter provides the possibility to select a single object from the evaluation. When an object was chosen, its borderline will be shown inside of the image and its properties will be displayed. Beside this counter there is the number of all evaluation objects.

[Lock] activated → protects the current view from changes by new selection or new evaluations.

[L] and **[R]** are not common to all modes. When there are different images displayed at the both image outputs (in contrast to different views of the same image) this chooses the image to use for "Objects" counter choice.

[Memo] this button is only visible in cloudiness mode.

6.4.2 Overview Cloudiness

The "Cloudiness" mode shows the source and the result of a single evaluation. It makes it very easy to compare the evaluation with the original image. The basic option of displaying single objects by counter choice is enlarged by mouse query - the example above shows that the mouse can be used to select an object inside of the images and view its properties.

Furthermore, it shows a bar chart and a table of the evaluated "blue values".

When the original image is shown, the bar chart shows the values of the ratio up to the maximum bar chart range. When the evaluation

is shown, the bar chart shows the values up to the "sky range". In both modes the bars on left-hand and right-hand side contain all values, that exceed the ranges. E.g. when there is a large bar on right-hand side, this means, there are a lot of "blue values" on right-hand side outside of the chart, but these values are summarised in this right limit bar.

The difference between ratio bar chart and evaluation bar chart comes from summarised areas by the evaluation. E.g. the original ratio shows a distribution inside of sky range, but the evaluation summarises all these values to "blue sky".

Properties to configure the view:

[Sunposition] inserts the sun position to the images. This can be useful, when there is a total cloud cover, that hides the sun completely.

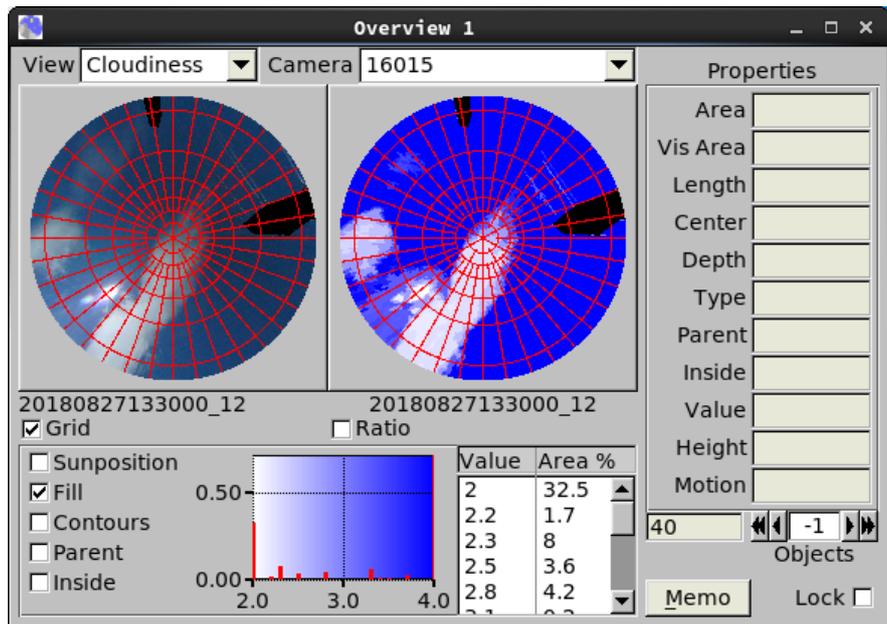
[Fill] is activated by default. It reduces the evaluation to the contour lines, when deactivated.

[Contours] inserts the contours (borderlines) of the objects to both images.

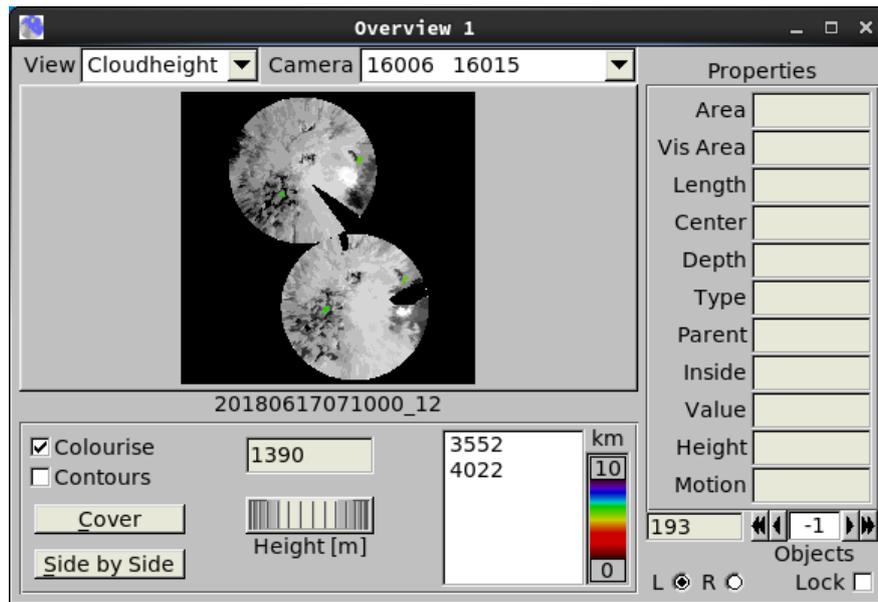
[Parent] shows also the parent, when an object is selected.

[Inside] colourises all included objects when an object is selected.

[Memo] this button is only visible in cloudiness mode. When pressed it will create or open a text file with camera name (e.g. "Memo_asi_16015.txt") in the memo directory (declared by "File -> Memo Directory") and append the name and path of the current photo.



6.4.3 Overview Cloudbase Height - CBH



The "Cloudheight" mode shows the two images of the current pair. It allows to move them to each other to determine the height of special objects or to control the objects found by the evaluation. In contrast to the height configuration dialog the images are shown in original north orientation, they are not rotated to optical axis. The evaluated heights are shown inside of a browser at the bottom of the dialog. Selecting an evaluated height inside the browser also selects the associated objects inside of the images.

"Colourize" when activated, the objects which were used for height calculation are coloured. The colour bar "km" on right-hand side defines the corresponding height.

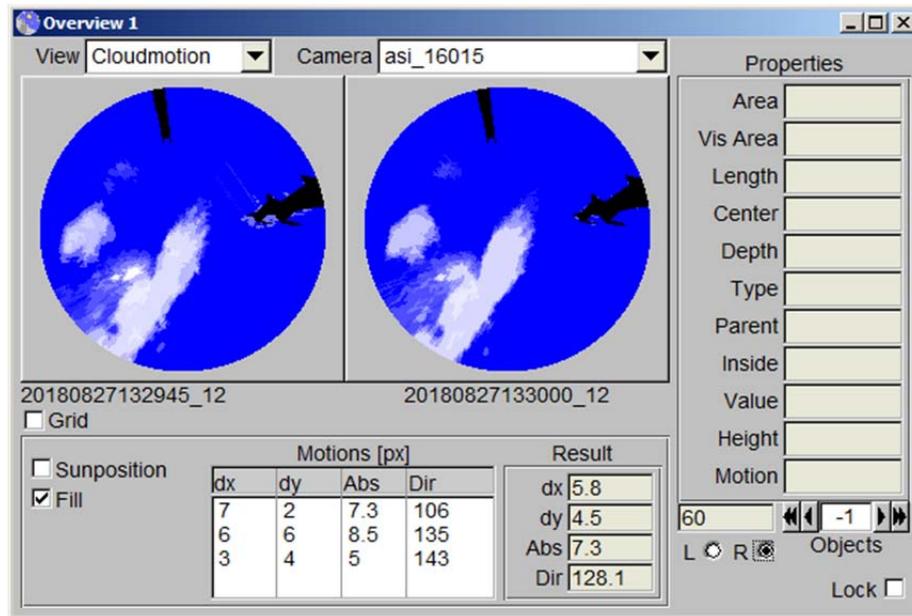
"Contours" inserts the contours (borderlines) of the objects to both images.

"Cover" moves the two images one upon the other. This is equal to height "infinite" and should move the sun object of both images to the same place.

"Side by Side" moves the two images to a position, where their borders touch. This is the height starting to see an object on both images.

"Height" this roller moves the images to each other to determine the height of objects. The current height of objects that cover each other will be shown in the output above.

6.4.4 Overview Cloudmotion Vector - CMV



The "Cloudmotion" mode shows the two consecutive images of a cloudmotion evaluation. The cloudmotion evaluation looks for the same objects in both images and determines the difference of their positions. The table "Motions [px]" shows all the determined displacements. With a mouse click to a table line, also the related objects will be shown by inserting their contours to the images. Also the properties of one object will be shown in "Properties" section, depending on the "Left-"/"Right-"choice.

The columns of the table are:

- dx* the displacement in x direction.
- dy* the displacement in y direction.
- Abs* the absolute value of the displacement.
- Dir* the direction of the displacement in degree [°].

"Result" shows the final result of the cloudmotion evaluation.

"**Sunposition**" inserts the position of the sun to the images, when activated.

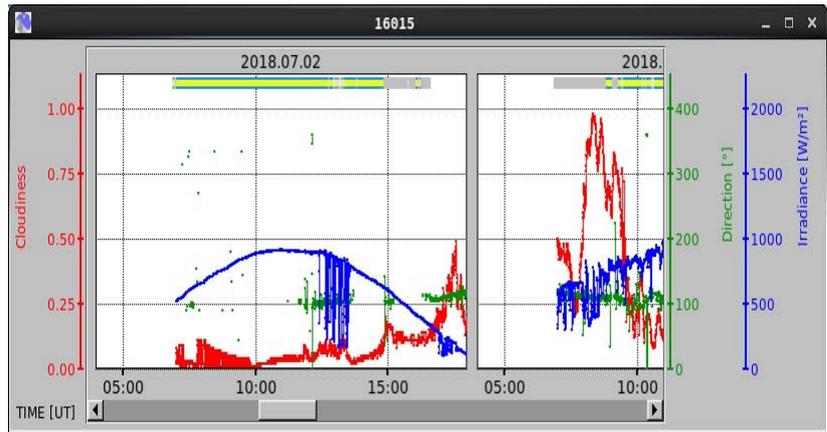
"**Fill**" is activated by default. It reduces the evaluation to the contour lines, when deactivated.

Note:

This dialog catches ongoing evaluations and assigns them by the information of the previous motion image (Result key "Motion_Image") to the image displays. Because of multi-threading, it is possible, that the evaluations don't appear in chronological order and this dialog doesn't show the consecutive motion of the images. When it is desired to see the consecutive motion of the images, it is recommended to activate "Hold Evaluations" and browse the completed evaluations using the main windows image browser.

6.4.5 Show, Hide, and Setup Curves

The graph dialogs show the evaluations as graphical line plot, to provide a better overview of the evaluations. It consist of one common configuration dialog and one or several dialogs to display the evaluations of the cameras. So when there are two cameras, a maximum amount of three dialogs can be opened - the configuration dialog and two graph dialogs, one for each camera. The configuration dialog sets up common settings for the graph dialogs, like the colour of the graphs.



The display shows only selected days. When at least one display is opened ("File/ShowCurves"), -an additional display will be opened, when days of another camera is selected. Because this can cause a lot of open displays, in the menu of the main window there is an option to close them all together ("Hide Curves"). As shown above each day gets an own drawing area. It is possible to scroll to the left or to the right for viewing single days. Every display can be resized and positioned to match better to the available screen area and will store its position and size.

The setup dialog sets up common options of all graph windows.

On the top the dialog shows the keys that are activated to be displayed. These keys are the "name" of the evaluated values and appear in the evaluation sheet. They are also in use to define the table columns of evaluation export.

[Add] provides a list of keys to choose from. The values of the key will be displayed, and the corresponding scaling will be shown beside the graph.

[Remove] removes the selected key from the browser, the corresponding graph from the graph views and the scaling of the graph.

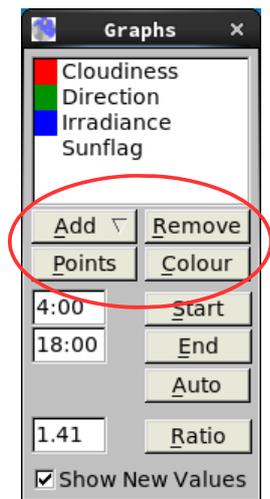
[Points] offers an input to define the number of pixels that will be used to mark a data point. A value of zero causes "flat" line graphs, a value of two or more (pixels) will draw a thick point at the position of the value.

[Colour] offers a browser to choose a graph colour. The selected colour also will be shown on left-handed side of the browser by coloured squares.

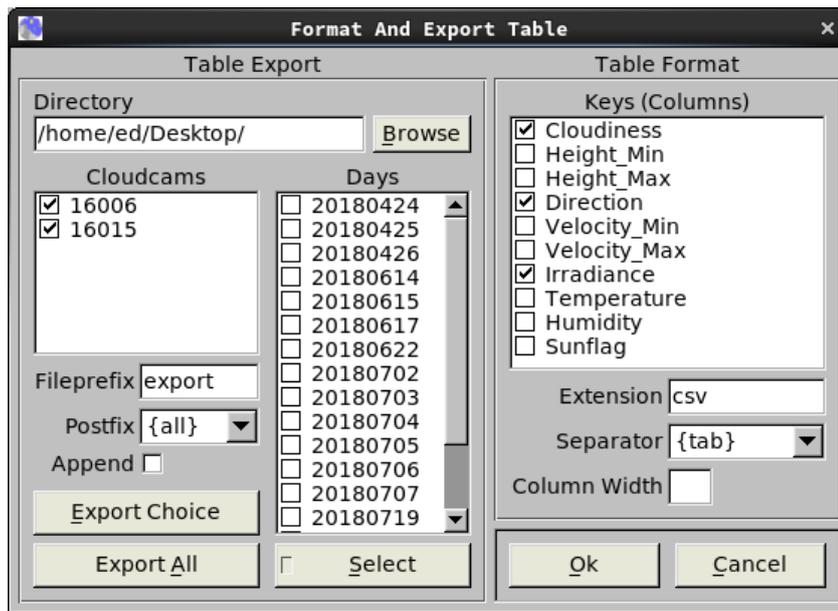
[Start] and **[End]** are buttons that belong to the corresponding inputs. They define the daily time range to show. It is possible to input times in format "HH:MM" (press [enter] to take them over). When there is no time given, the software will take the time range out of the evaluation data, this can be forced by button **[Auto]** to overwrite existing times. It is possible to enter only begin or end and the software will calculate the missing value of time range.

[Ratio] corresponds belongs to the input and sets the aspect ratio of the drawing area (the way, that width will be ratio * height). The example value of "1.414" is the DIN ratio of paper. Larger values will stretch the drawing area, e.g. to show lots of values more detailed.

[Show New Values] inserts a line at time of current selection and makes the plot follow an ongoing evaluation, when activated.



6.4.6 Export Evaluations



This is a dual use dialog to set up the format of CSV table output and export an amount of evaluations with the current table format.

6.4.6.1 Table Format

The right-hand part of the dialog is for configuration of the table format. This format will be used to write the table of evaluations, that can be set up by [Configuration Miscellaneous] -> [Save Results] -> [Table]. Please be aware that table export is not activated by default.

"Keys" is a list of defined export items and allows to choose the columns to export. The keys refer to the identifier of a single evaluation sheet and will copy these values from the sheets.

"Extension" sets up the extension of the tables file name. The default "csv" (character separated values) extension is a format, that will be recognised by other programs, like LibreOffice.

"Separator" defines the character that will be used to separate the values.

"Column Width" defines a common column width and will fill up the columns with space characters, until this width is equal to the desired column width. This bloats the size of the exported table but makes it better readable for humans or some programming languages like FORTRAN. When the content of a column exceeds this width, it will not be cut, so this option will only enlarge the columns, not restrict their width.

[Ok] this button saves the current format, activates it for evaluation table writing and closes the dialog. Also, the settings of the "Table Export" will be saved.

[Cancel] this button discards the current changes and closes the dialog. This is useful, when the "Table Export" was used with special options, but a change of standard table writing is not desired.

6.4.6.2 Table Export

This part of the dialog can be used to export a special subset of the evaluations. This is not a configuration, but a tool.

"**Directory**" is the target directory the exported files will be written to. It can be entered directly, or the button [**Browse**] can be used to find the target by a file chooser. This entry will be saved when leaving with the [Ok] button.

"**Cloudcams**" offers the choice to restrict export of evaluations to special cameras.

"**Days**" offers the choice of days to be exported.

[**Select**] this button can be used to select or deselect all days entries.

"**Fileprefix**" offers the possibility to enter a prefix for the exported files, e.g. "20150911.csv" can be changed to "export_20150911.csv".

"**Postfix**" is the same postfix used in the software to identify the light exposure, e.g. "11", "12". It can be used to restrict the list to a single type of pictures.

"**Append**": When activated the export will be appended, when a file with the defined name already exists. This can be used to append new data to older evaluations. Otherwise, the export will overwrite the existing file.

[**Export Choice**] this button performs the export of the selected Cloudcams and Days.

[**Export All**] this button exports all evaluations without need to make a choice.

This dialog is designed to perform an export, but nevertheless it makes a difference to leave the window by [Ok] or [Cancel], because [Ok] saves changed export settings, while [Cancel] discards them.

6.4.7 Quit

This file menu option saves the size and position of all visible windows, additional parameters of the windows (e.g. overview settings), finishes ongoing operations and finally closes all windows. As a result, the software will restore the last arrangement of windows at next start.

6.5 Menu Items – Edit

The "Edit" menu items provide dialogs to configure the software, like the basic setup of directories and cameras, but also fine-tuning of the evaluation.

6.5.1 Configuration Selection

The FCT offers a simple multi-configuration workflow to change between different configurations easily. Here, "configuration" means all settings, including program settings, database configuration, cloudiness configuration, camera/pair configuration, etc. Each configuration has its own configuration directory. The configuration directory contains all configurations of the software and must be writeable by the software. The following files will be stored in the directory:

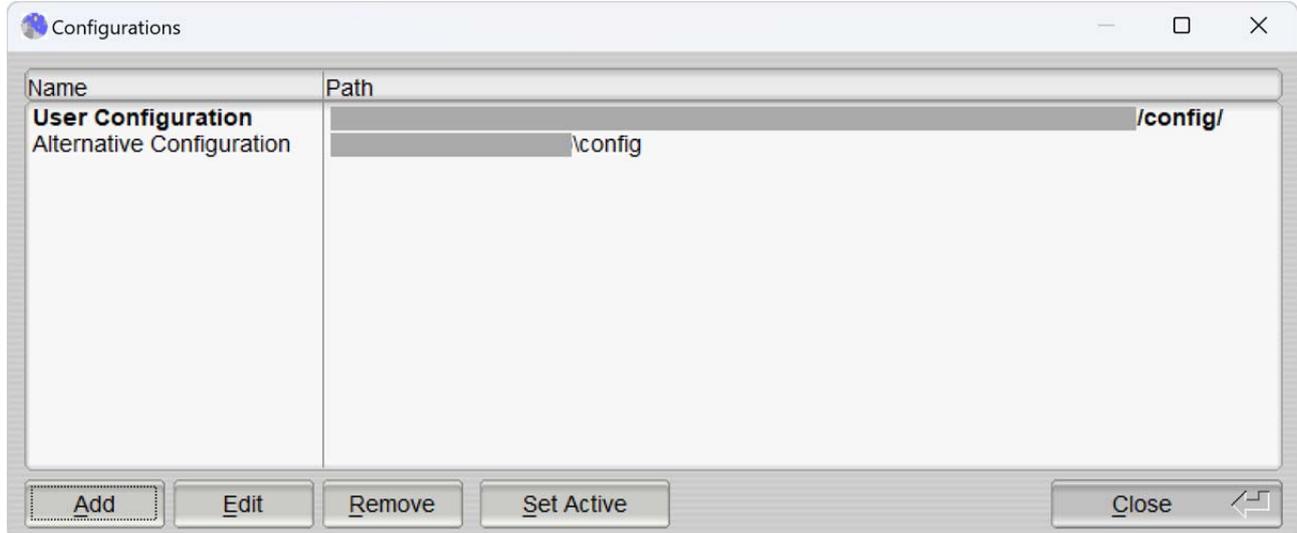
- config_misc.sys:** General settings.
- config_pairs.sys:** Camera pair definitions including the distance between them and the direction of the optical axis.

Inside camera-specific subfolders:

- config_cam.sys:** Contains camera-specific settings like latitude, longitude, directories, etc.
- horizon.txt:** Contains a list of points, that define the horizon of camera images.

Switching between configurations is the same as switching between these configuration directories. Additionally, a configuration can specify a validity period. If specified, only images within that period will be loaded and displayed in the FCT if the configuration is active.

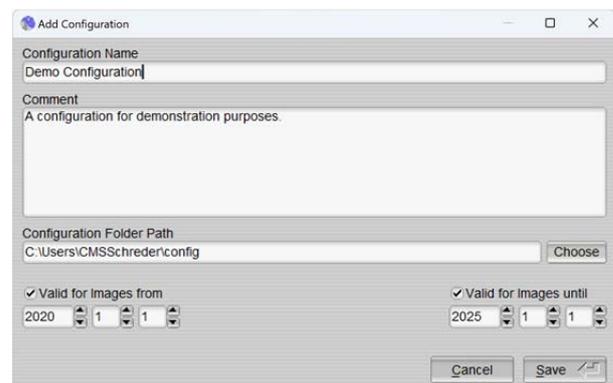
Open the **Configurations** dialog in **Edit** → **Configuration Selection**. This dialog shows all available configurations. The currently active configuration is displayed in boldface.



Click **Add** to add a new configuration. The Add Configuration dialog allows specifying all relevant information of the new configuration:

[Configuration Name] Name of the configuration. This is used only to help the user easily distinguish between different configurations.

[Comment] Optional user comment.



[Configuration Folder Path] Directory in which the configuration will be stored. Should be an empty folder.

[Valid for images from/until] If set, images outside of this period will be ignored by the FCT when the configuration is active.

Click **Save** to save the new configuration. A message will appear asking if settings from an already existing configuration should be copied to the newly created one. Click **Skip** to create a completely new and empty configuration or **Copy Settings** to copy settings.

Note: If no settings are copied, the new configuration will be completely empty. This is the same as starting the FCT on a new system for the first time. No database settings or camera definitions will be available in the new configuration.

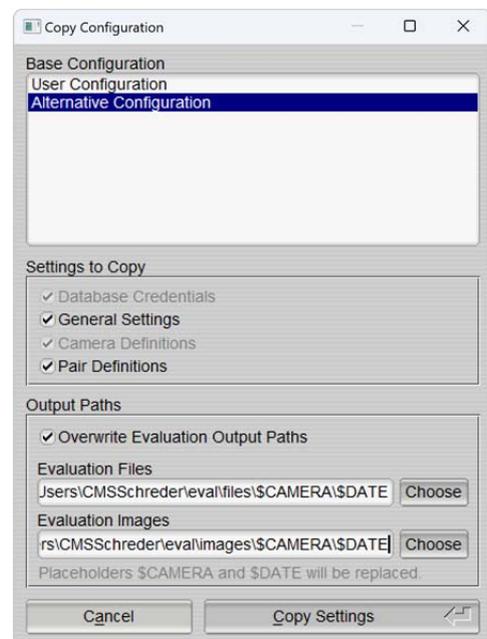
If Copy Settings has been selected, a new dialog will open, allowing the user to specify the settings that should be copied to the new configuration:

[Base Configuration] The existing configuration from which the settings should be copied.

[Settings to Copy] Settings that should be copied. Some combinations are impossible, for example copying the *General Settings* always includes the *Database Credentials*. Similarly, copying the *Pair Definitions* also requires copying the *Camera Definitions*.

[Output Paths] If the *Camera Definitions* are copied, a user might want to change the output path of evaluation results (images and text files) to avoid mixing up results generated by different configurations. To automate this process, the user can specify new directories for the output files and images. The output paths of all cameras in the new configuration will then be rewritten with the specified directories.

The placeholders \$CAMERA and \$DATE will be replaced automatically with the camera's name and the image date/s.

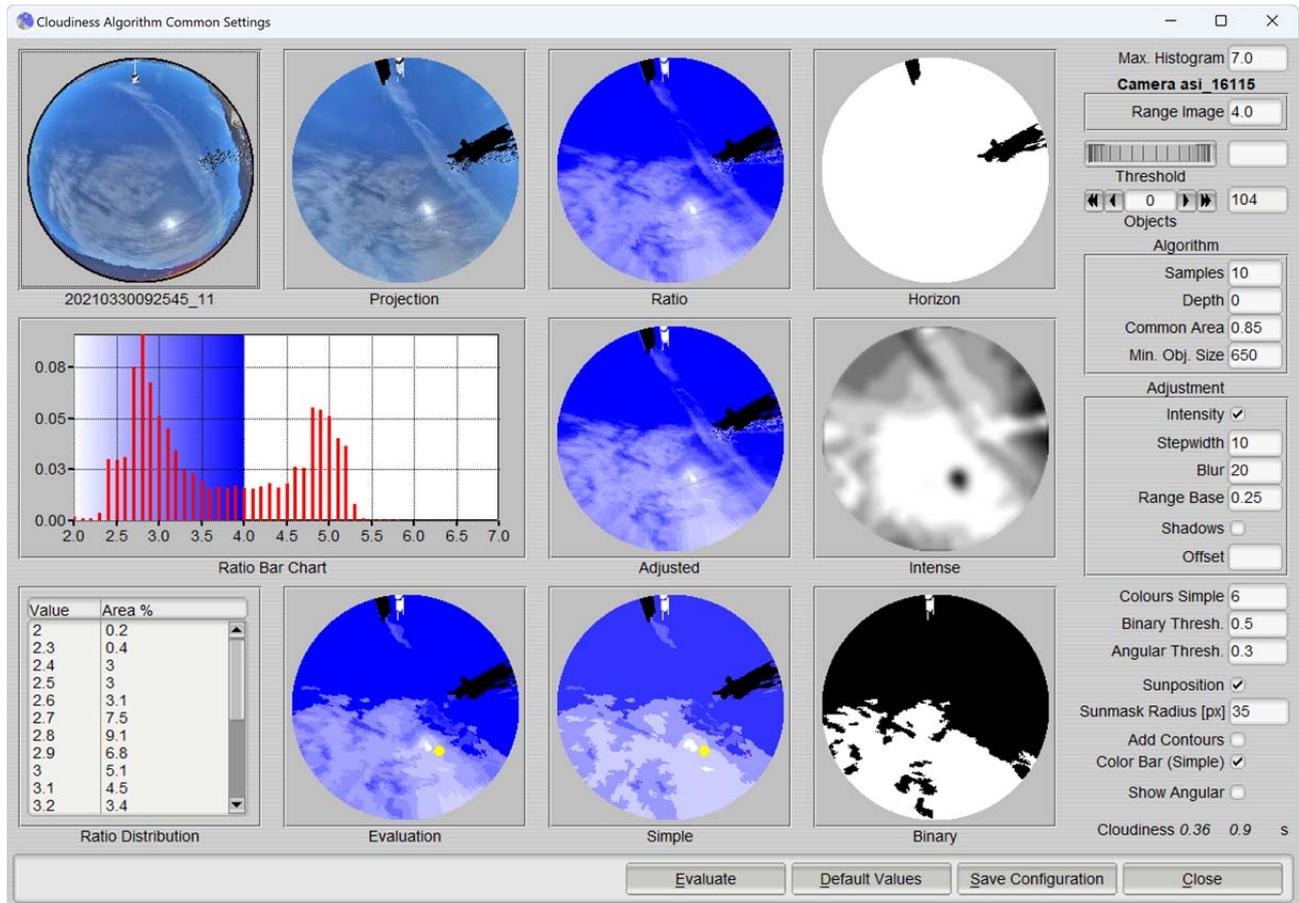


Click **Copy Settings** to copy the settings and complete the creation of the new configuration. The new configuration will then be shown in the Configuration dialog.

To activate a configuration, select it and click **Set Active**. The FCT must be restarted for the change to become effective.

Configurations can be removed or edited by selecting them and clicking **Remove** or **Edit** respectively.

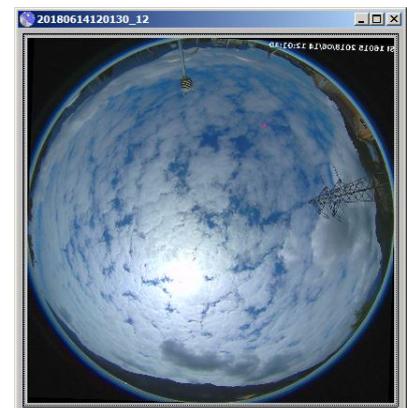
6.5.2 Configuration Cloudiness



This allows to configure the parameters and details of the evaluation and all steps of evaluation. So, the evaluation can be controlled in detail and adjusted. This is a configuration dialog and for normal evaluation it is recommended to close this dialog. The **"Range Image"** option is specific for the colour saturation of the camera, so before opening this dialog, it is necessary to choose a camera from the main window. After that, an image from the list of images can be selected and will be shown and evaluated in this dialog. The "Range Image" should be set up for all existing cameras.

As a feature a more detailed image will be shown by clicking on one of the images. This is a copy and will stay when doing a new evaluation, so it can be used for comparison to evaluate parameter changes.

The evaluation starts on top left, showing the original image '20180707120700_12.jpg' and its name. This image provides an impression of the whole weather situation.



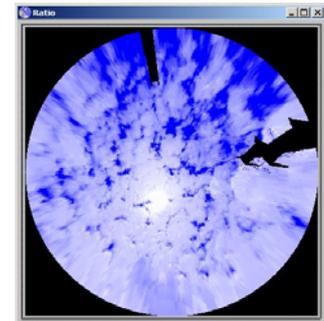
"Projection":

The first step of evaluation is equivalent map projection of the fisheye image to a plain image, which shows the area of zenith angle (The details of fisheye projection are explained in appendix). Now each pixel of the image covers the same size of sky area, so the cloudiness can be determined by counting of pixels (Remark: it shows the clouds in original sizes).



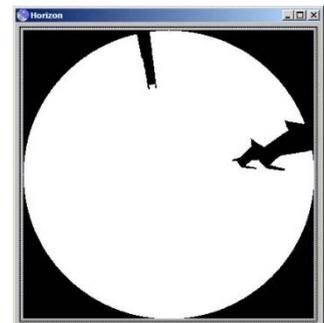
"Ratio":

Next step is the application of the BRBG algorithm. The algorithm calculates the Ratio = Blue/Red + Blue/Green as a single value of each pixel of the projected RGB image. The result is something like a greyscale image. For better visualisation, the result "Ratio" is presented as coloured image with a white to blue colour gradient. This coloured image will be nearly the same when images of different light exposures are used. There are some areas of haze, that are not shown in the ratio. In fact, they are present, but not coloured. To understand this, it is necessary to look to the histogram "Value Distribution".



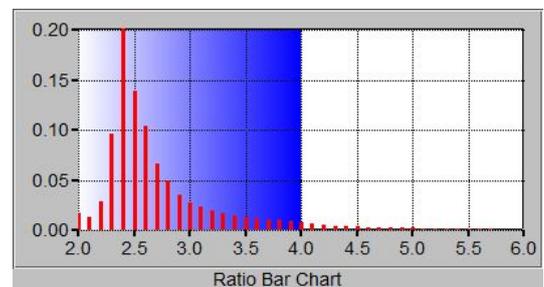
"Horizon":

Another step is the generation of a horizon mask. The horizon mask excludes parts of the image from evaluation, e.g. a tree. Anyway, a circular mask will be used, to exclude the parts outside of the circular image.



"Ratio Bar Chart":

It shows the distribution of the "Ratio" values. The histogram shows how many pixels of the image are inside the slots. The width of each slot is 0.1. The table shows the same "Ratio" values as a percentage. In addition, in the histogram the colour gradient is presented, which colourise the "Ratio" image and the final evaluation. The colour gradient starts at the value 2.0 and ends at value "Range Max" (example: 4.0).



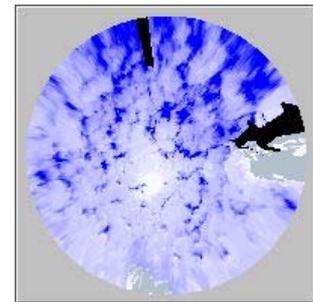
Cloudy Sky: The white part at the left limit of the "Ratio Bar Chart" comes from the fact, that a white RGB pixel has the value [255,255,255]. Therefore, the $RATIO = B/R + B/G = 2$. That means, the lower limit of the ratio is 2. Ratios less than 2 are ignored, because they only appear for "not sky colours". If the blue part gets dominant in correlation to the red and green part, the ratio is rising. $RATIO = [2 \dots RangeMax] \rightarrow CloudySky$

| Value | Area % |
|-------|--------|
| 1.5 | 0.1 |
| 1.6 | 0.2 |
| 1.7 | 0.5 |
| 1.8 | 1.4 |
| 1.9 | 1.3 |
| 2 | 1.7 |
| 2.1 | 1.3 |
| 2.2 | 2.9 |
| 2.3 | 9.6 |
| 2.4 | 20.2 |

Blue Sky: "Ratio" values larger than "Range Max" are defined as blue sky in the coloured 'Ratio' picture. These values also contain the haze, which is ignored for the actual evaluation. The haze is inside the 'Projection' picture but not coloured inside the 'Ratio' picture. So the limit "Range Max" determines, how deep the "Ratio" value is looking into the haze. It could be used to restrict the evaluation to thick clouds.

"Adjusted":

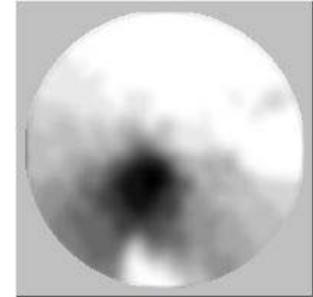
This shows the "Ratio" values after the "intensity" and / or "shadow" adjustment was applied. These adjustments will be made before evaluation of the image details.



Adjusted

"Intense":

This is the blurred intensity distribution created from the 'Projection' and is needed for adjustments.

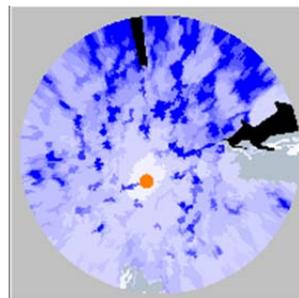


Intense

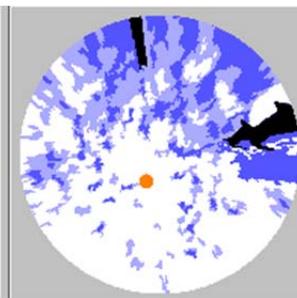
"Evaluation", "Simple" and "Binary":

These 3 pictures are the results of the evaluation.

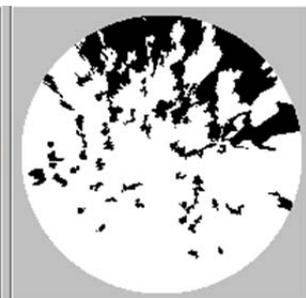
The "Evaluation" is the detailed evaluation and looks nearly the same as the original "Ratio", but it consists of single



Evaluation



Simple



Binary

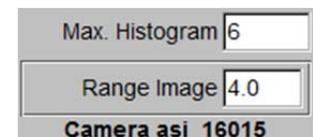
objects that are coloured by the mean value of the covered ratio area. Also the relations between the contours are determined, e.g. which contour is inside of another one and how deep it is nested.

The "Simple" image shows a reduced colouration somewhere between "Evaluation" and "Binary".

The "Binary" is a reduced image that only differentiates between clouds and sky. The final value of cloudiness will be determined from this image (and the horizon mask).

"Max. Histogram":

This option sets up the full range of the histogram for all cameras. In the example above ("Ratio Distribution") this will be the value "6.0" on right-hand side of the histogram.

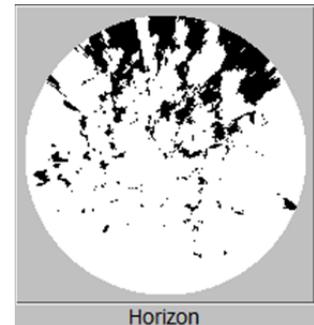


"Range Image":

The value "Range Image" is **the only camera-specific option of this dialog**. It depends on the camera's colour saturation and should be set up for each camera. The name of the current camera is shown below this input field and must be chosen in main window before opening this dialog. This value defines the range of cloudiness and defines the upper limit of cloudiness. When there is a low saturation, this value is smaller (e.g. 2.7) for high saturation this value must be bigger (e.g. 4.0), to show the details of cloudiness. Below this limit there is the range of cloudiness. Above this limit everything is estimated as blue sky.

"Threshold":

The "Threshold" roller allows to examine the "Ratio" value in relation to the histogram bars. It shows the regions, that belong to the left-hand side of the selected value. This example was set to threshold 3.1 and shows the regions with clouds (or haze) in white and the sky region in black. Changing the threshold to 2.0 would only show the parts, that are illuminated by the sun and so on. The output of "Threshold" and "Objects" (next item) will be shown inside of the double used "Horizon" image field.

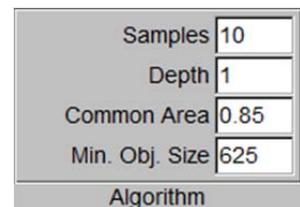
**"Objects":**

The "Objects" counter belongs to the evaluation. It switches between the detected objects and shows only one of them. It shows the current object as white contour and the parent of the object as a grey contour to examine the details of the evaluation. This is not a configuration; it is a feature to show more details of the evaluation.

The **Algorithm** items are for configuration of the evaluation algorithm.

"Samples":

The algorithm cuts the range of "Ratio" values from 2.0 to "Range Image" into several "Samples" and changes these slices to contours. The number of 10 Samples is the recommended number of slices. It is a good compromise between evaluation speed and evaluation details. More samples result in more details, but also longer evaluation time.

**"Depth":**

The "Depth" defines the number of contours that must be found in different slices to define an object. There are contours generated by light effects (e. g. brightness gradients near the sun) - the "Depth" can filter them out, because these contours only appear once, but "real clouds" repeat their contours in consecutive slices. To make zero a valid entry ("no restriction"), the number of contours must be larger than the depth; so a number of '0' means, that all contours will be used, a number of '1' means, that at least more than one contour must be found to define an object. The "Depth" relates to the "Samples" and when there are more samples, also the depth can rise.

"Common Area":

This defines, how much the area of contours on the same place must match to be merged to one object. This also differentiates brightness gradients from real objects.

"Min. Obj. Size":

The "Minimal Object Size" excludes small details to be changed into an object. Sometimes the clouds look like a "cloud of points" and without restriction the algorithm will find several hundreds of objects. The recommendation of 650 pixel is equal to a square of about 25x25 pixel and refers to an image of 1500x1500 pixel. When the resolution of the image changes, this value should be adjusted. Please be aware that a value of zero results in very long evaluation times.

Adjustment: *The next items are for configuration of the ratio adjustments. Please be aware that the adjustments are independent, it is possible to activate only one of them.*

[Intensity]

This option can be activated to raise BRBG ratio values that are at darker regions of the image. Clouds near the sun are very bright and look "thick" in the BRBG ratio. The same clouds far away from the sun look "thinner" in the BRBG ratio. The "Intensity" image is used to determine the regions that should be raised. Raising the BRBG ratio at darker regions results in more details and the BRBG ratio values match better to the real thickness of the clouds (or haze).

It is possible to setup the adjustment by the following parameters:

"Stepwidth" sets up, how detailed the image will be adjusted.

"Blur" sets up the blurring of the "Intense" image. Please be aware, that rising values will cause less blurring.

"Range Base" sets up the range of BRBG values that will be used to determine the correction factors. This is similar to the "Binary Threshold" or "Angular Threshold" and refers to the "Range Image".

[Shadows]

This option can be activated to look for shadow parts of clouds. This means the "dark side of the cloud", that is on the far side of the sun. The problem is, that these parts of the clouds are illuminated by the blue atmospheric scattering, so the BRBG ratio shows these parts of the clouds like a hole, that shows the sky. The problem becomes worse because of the fact, that the intensity distribution of the whole image is larger, than the intensity reduction by the shadow: There is no direct way to determine whether a BRBG value is less intense sky or a shadowed part of a cloud. So the algorithm tries to find shadow parts by nested contours, but does not work perfectly. It makes things better, but normally doesn't find all "holes in the clouds". Actually we classify this option as "Experimental".

"Offset" this value can be raised to find more shadows in dark parts of the images.

The next items are some more general options to configure the evaluation results:

"Colours Simple":

The resulting image "Evaluation" looks almost the same as the original "Ratio". The "Simple" image integrates similar values of this fine evaluation to a predefined number of colours. This makes it easier to differ between "thick clouds", "haze" and "sky".

"Binary Threshold":

This is a very important value. It adjusts the final result of cloudiness.

The binary image changes the coloured evaluation image to a black/white image by use of the "Binary Threshold" inside of the evaluation range ("Range Image"). The "Binary Threshold" value ranges from "0.0" to "0.99". Value "0.0" is the minimal binary threshold "Range Min" and would only show sun position or white clouds. Value "0.99" is maximal binary threshold "Range Max" and would show all clouds and haze. The recommended value of "0.5" results in the normally

anticipated "cloud image" showing the thick clouds. When there are wrong results of cloudiness, the "Range Image" and "Binary Threshold" are the values, that should be checked.

"Angular Threshold":

This is similar to "Binary Threshold", but it is in use to create a binary image for an angular distance evaluation. Normally this value will be less than the binary threshold, to exclude haze from angular distance evaluation.

[Show Angular]:

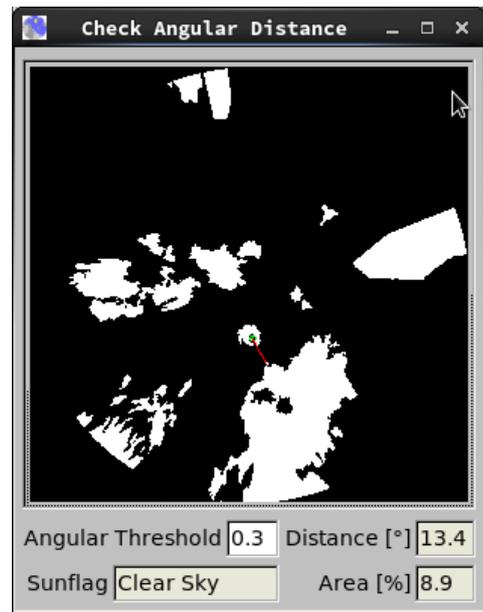
The "Show Angular" tries to detect the object (cloud) that is nearest to the sun. It determines the distance in degrees and the area of the object (cloud) in percent in relation to the whole image circle.

If activated, an individual window "Check Angular Distance" will be opened. It allows to check the angular distance evaluation and adjust the angular threshold.

Normally the evaluation will only be done, when the sunflag shows a "clear sky", but for this dialog the evaluation will be always made without considering the sunflag. This way the user can always see a resulting image and is prevented from thinking this does not work at all, in case of a not matching sunflag.

Please be aware that the angular distance can provide unexpected results, e.g. when it shows distance to next horizon mask or image border.

In the right-hand example the sun position is shown by green circles and the distance by a red line to the next cloud. It is possible to change the value "Angular Threshold" and press the <enter> key, to get an updated image. Please be aware, that a changed threshold must be taken over to the "Angular Threshold" of the settings by the user. This "Check Angular Distance" is a dialog to check out things, not to set up the configuration value.



"Sunposition":

If activated, the position of the sun will be inserted to all resulting images as a filled circle. This concerns not only the example images of this dialog, but all exported images written to disk. The colour of the sun position can be set by button [Colour sun].

"Sunmask Radius [px]":

Specifies the radius of the sun disk mask in pixels. The sun disk mask is added to evaluation images to hide the area around the calculated sun position where clouds cannot be segmented accurately due to the overexposure caused by the sun.

"Add Contours":

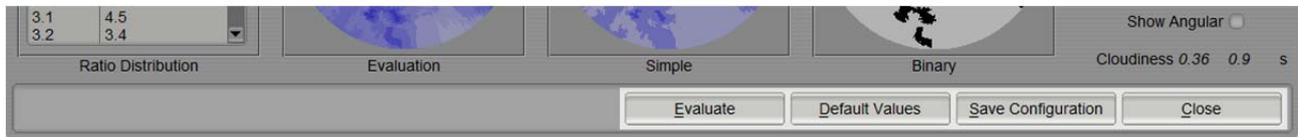
This feature allows to insert the cloud contours to the examined images.

"Colour Bar (Simple)":

If active, a colour bar will be added to the bottom of the Simple evaluation image visualizing the ratio colour mapping for easier visual inspection of images.

"Cloudiness":

The output "Cloudiness" is calculated from the "Binary" image by counting the not masked black and white pixel and calculating their ratio. This is the final result of the cloudiness evaluation. On the right-hand the calculation time in seconds is displayed the whole evaluation lasted.

Buttons:**[Evaluate]**

This button repeats the evaluation using the current settings of the dialog. This can be used to check the effect of changed options.

[Colour Sun]

This button opens a colour chooser to set up the colour of the inserted sun position. The default colour is yellow, but this colour often is not very good to see.

[Default Values]

This button restores the original default values that are known to make a valid evaluation. Please be aware this will not restore the last settings made by the user.

[Save Configuration]

This button saves the current settings of this dialog, without closing the dialog.

[Close]

This button closes the dialog without saving the current settings.

Note:

The [Save]/[Close] is similar to the commonly used [Ok]/[Cancel], but allows to save "in between" without closing the dialog, while approximating to best settings.

6.5.3 Cloudbase Height - Pair Definitions (CBH)

| Cam1 | Cam2 | Dist [m] | Dir [°] | Alt1 [m] | Alt2 [m] | H-Max [m] |
|-----------|-----------|----------|---------|----------|----------|-----------|
| asi_16006 | asi_16015 | 1649.1 | -67.1 | 526 | 526 | 9895 |

This is a part of the Cloudbase Height (CBH) evaluation and defines the basic parameters of camera positions. Two cameras are necessary to get a stereoscopic displacement of objects between two images and calculate the height of the objects from this displacement. This dialog provides a table to define camera pairs and their options. The current row is selected by dark blue colour and the buttons [Del Row] and [Get Values] will handle this selected row.

In general, a mouse click on a cell will open an input to edit the value, only the column "Cam1" cannot be changed after the creation of the row. In addition, the button [Get Values] provides an automatic determination of the cameras distance and direction.

The columns of this table are:

"Cam1" is the first camera of the pair. This also is the row header and can not be changed, it is only possible to delete the whole row and insert a new row with another leading camera.

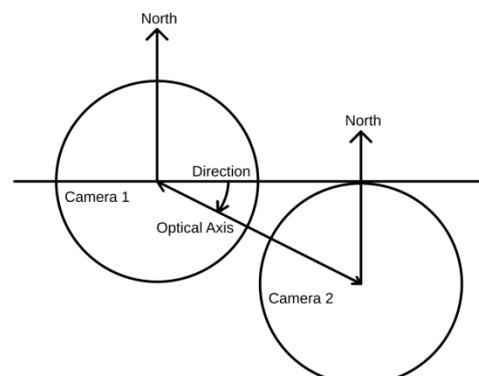
"Cam2" is the second camera of the pair. This one can be chosen by a mouse click to the cell.

"Dist" is the distance between the two cameras with unit "meter".

"Dir [°]" is the angle of the direction from one camera to the other. This value is important, because there is a problem of the optical axis: The images are aligned to north direction on top of the image, but the cameras are not aligned to the east - west orientation, there is a random direction between them. This direction must be known, because the height dependent displacement works along the optical axis.

The figure at the right side shows the arrangement which is assumed for the parameters of the height evaluation:

Camera 1 is on left side and camera 2 on right side. Their position is shown by two circles. The line between the center points of the circles is the optical axis. It also defines the distance between the cameras. The images are aligned to north, but the direction of the optical axis differs from the cardinal directions. Here the direction



angle is about -67° . This direction must be inserted into the "Dir" column of the 'Cloudcam Pairs' setup. Because the arrangement of the cameras is specified to "Camera 1 at left or west side" and "Camera 2 at right or east side", this direction is restricted to a range from $+90^\circ$ to -90° .

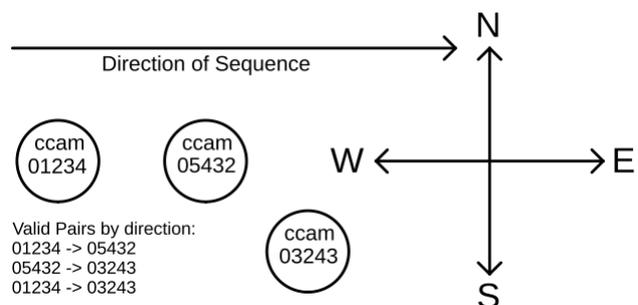
[Alt1], [Alt2]: These entries are the altitudes in [m] of the cameras above sea level. This offset must be added to the height, that is measured by the cameras, to get the absolute altitude. For the moment the software doesn't care about differences between the camera altitudes and simply adds the average of Alt1 and Alt2 to the measured height. So it should be avoided to place the cameras at considerably different altitudes.

[H-Max]: Limits the evaluation range. It should be smaller than six times of the distance between the cameras. It is used to exclude results that are too high to make sense. This value also is in use to scale the graphs. When there are pairs with different distances, this entry can be changed to a common height to get a common scaling for the graphs of height.

Dialog buttons are:

[Add Cloudcam] provides a choice that shows every All-Sky-Imager found inside of the basic image folder. As soon as an All-Sky-Imager is selected, it appears as header of a new line inside of the table. Now it is possible to select the second All Sky Imager by clicking to the second column. This will open a choice, where the second camera can be selected.

Please be aware, that the valid sequence of camera pairs depends on the location. The pairs must be arranged the way, that the first camera is on west side and the second camera is on east side of the sequence. So the second camera must be in a direction of -90° to $+90^\circ$ east from the first one.



[Get Values] When there are valid values inside of the Cloudcam configuration (Longitude, Latitude and Altitude), the software can use these values to determine the values of distance and direction and insert them to the selected row.

Please be aware, that the accuracy of the determined heights depends on the accuracy of the distance. The next chapter shows a method to calibrate the direction, but there is no way to control the distance from "inside" of the software.

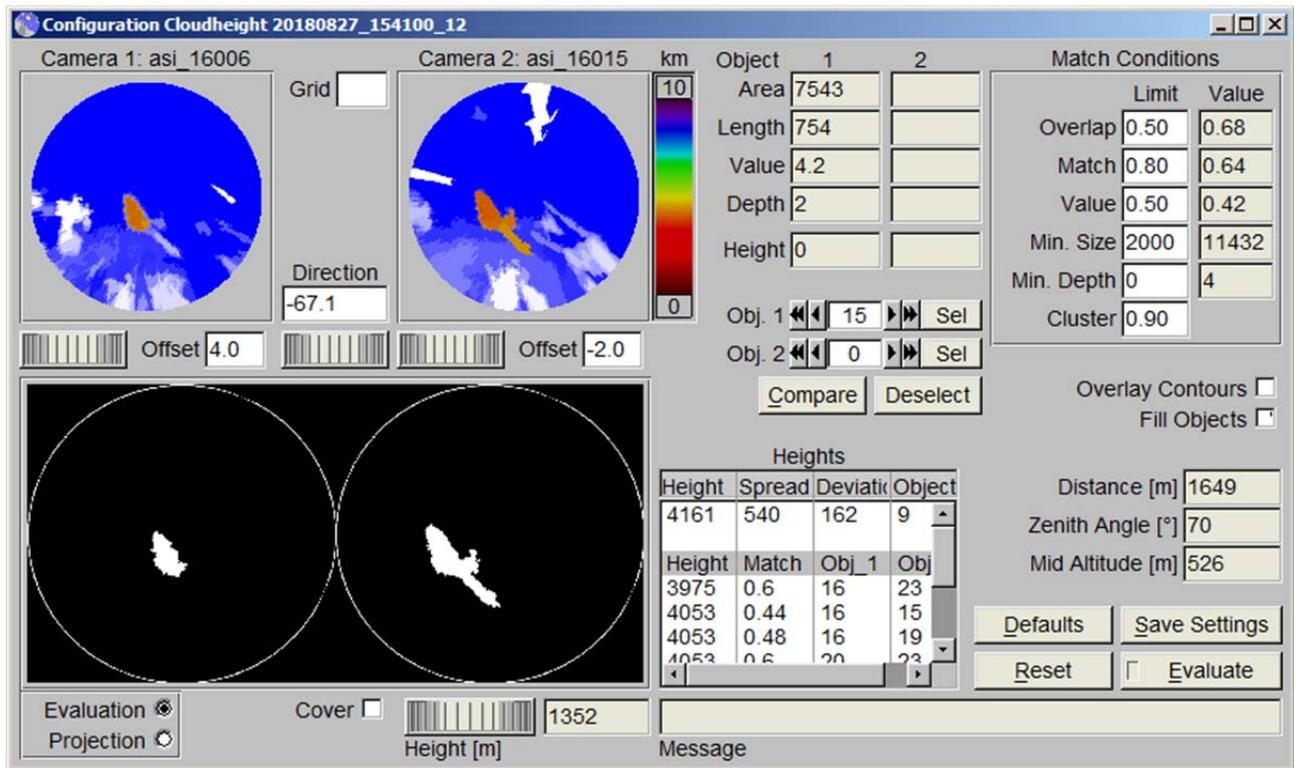
[Del Row]: Removes the selected row from the table.

[Del Invalid]: Deletes lines with a cloudcam that can't be found in the basic image directory.

[Ok] saves the new configuration to disk and closes the window.

[Cancel] closes the window and discards changes.

6.5.4 Configuration Cloud Base Height (CBH)



Beside the "Definition of Pairs" this is the second dialog, that belongs to the cloud height evaluation. It can be used to adjust the angles and the direction of the optical axis. Furthermore, it provides methods to adjust the match conditions of the height evaluation. The orientation of the images is different to all other dialogs, because they are not aligned to north, but to the horizontal optical axis of the camera pair, providing a better impression of stereoscopic displaced objects.

On left-hand side of the dialog there are the tools to adjust the orientation of the cameras:

"Camera1" and **"Camera 2"** show the view from camera 1 and camera 2. The images they show must be chosen before in "Pairs view" of the main dialog. So please be aware, that the images of this dialog must be committed from outside. The image presentation can be switched between **"Evaluation"** and **"Projection"**. "Evaluation" creates an image from the evaluation, "Projection" shows the original projected picture.

By default, the objects of the evaluation are shown filled, but it is possible to show only their contours by deactivating **"Fill Objects"**. Also, it is possible to add the contours to the images by activating **"Overlay Contours"**.

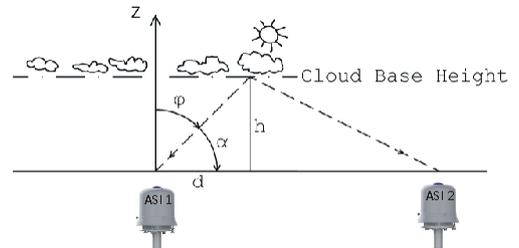
The **"Offset"** rollers and inputs can be used, to adjust the offset angle of a single camera. This is the same offset provided by "Camera Configuration" and a changed value will be transferred to this configuration. In contrast the **"Direction"** roller and input will rotate both images and the value belong to the "Pair Definitions". It also will be transferred when saving changed settings.

"Cover": To calibrate the common justification, especially the offset, this option puts one image upon the other for alignment of the sun position. Because the sun is located at 'infinity' it must be at the same place on both images. Activating "Cover" deactivates the height roller because it also overwrites a chosen height.

The **"Grid"** provides lines that help to align objects inside of the two images. The distance of the lines must be entered to this input (e.g. 10 pixel) and after these lines were drawn to the images, it is plain to see, when they are at the same vertical position.

The black area below these controls is a **"drawing pad"**, where these images, or selected objects, can be shifted together by a height roller. This allows the manual determination of an objects height and provides another method to check, whether objects belong together.

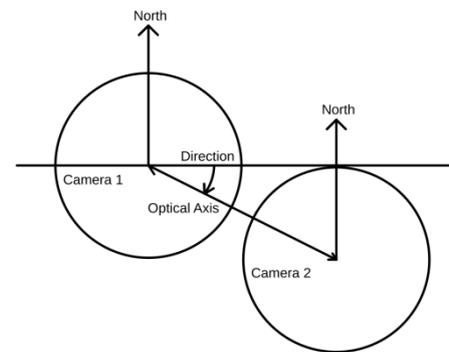
Inside of the "Camera" images it is possible to select individual objects by manual input (mouse or counter). These selected objects may be individually compared to control their match. The resulting match values are listed inside the "Match Conditions" under "Values" beside the defined "Limits".



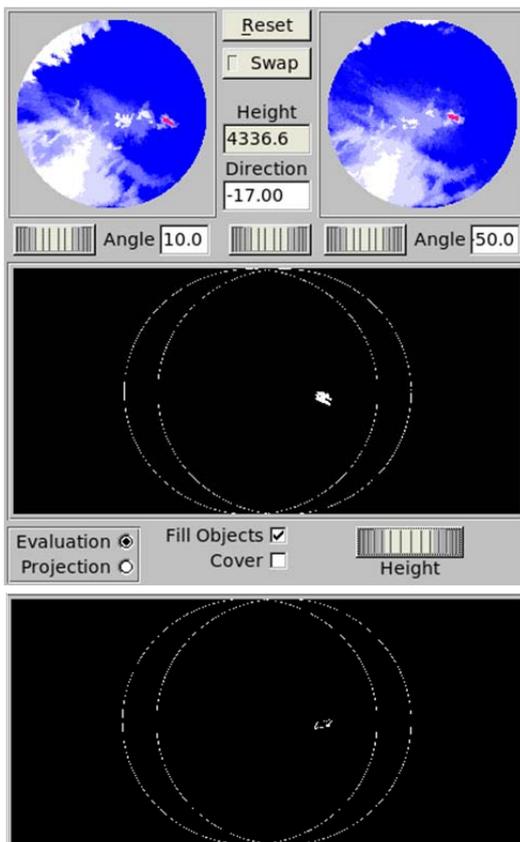
The cloud height evaluation works by searching for similar objects in stereoscopic image pairs with contour matching. If similar objects are detected, their position is used to calculate their height directly from the displacement. So, the matching of contours is the primary method to find out the height.

Fine tuning of the optical axis:

To simplify the determination of stereoscopic displacement, the optical axis must be rotated to the horizontal position. The amount of the rotation in degree [°] is shown in the **"Direction"** input.



As soon as the optical axis is horizontally, the evaluation of an object height is reduced to the evaluation of the displacement in the x-position of the object in the stereoscopic image. In addition, only objects on the same y-position must be compared.



Inside the dialog 'Pair Definition' the direction can be determined automatically from the geographical coordinates (latitude, longitude) of the camera position. But in case they are given with insufficient accuracy, the direction is inaccurate and therefore the height evaluation will fail, because it cannot match objects. To correct a possible misalignment, the software offers the possibility to control and adjust the alignment: Select a correspondent object pair of the stereoscopic images. Use the **"Height"** roller to move them one upon the other. It is plain to see if it is possible to cover them. When there is a displacement, it can be adjusted by the **"Direction"** roller.

The example shows the misplaced objects (top image), that were adjusted until they overlap (bottom image).

The following conditions are defined:

Overlap: First the overlap calculation determines the extent in vertical direction of both objects (max extent). Second the common extent in vertical direction is determined. Finally divides common by max. So when the objects are equal and at the same vertical position, this will result in value 1.0 and fall to zero the more of the objects is not on at the same vertical position. **A valid overlap must be > than the limit.**

Match: The match of contours deals with the areas of the contours and their overlap. The match is calculated by the ratio "not common" divide by "common" area. This match falls to zero the better the areas overlap. **A valid match must be < than the limit.**

$$Match = \frac{(Area_{ONLY1} + Area_{ONLY2})}{Area_{COMMON}}$$

Value: The value corresponds to the objects value from the "BRBG ratio". The value limit is similar to the threshold, that changes an evaluation to the binary image. It defines how much a matched object is a cloud, haze, or blue sky.

A "Value" of 0.0 means, that the object is at the beginning of the evaluation range (BRBG ratio=2) and equal to the sun or white clouds.

A "Value" of 1.0 means, that the object is at the end of the defined "Range Image" (e.g. 4.0) and equal to clear sky.

The default Value of 0.5 results in a comparison of clouds and ignores the blue parts of the image. Otherwise, it would calculate the height of holes in the cloud cover.

To be valid in comparison, the value of both objects must be smaller than the value.

$$RangeImage_{MIN} + Limit \leq (RangeImage_{MAX} - RangeImage_{MIN})$$

The value of the match conditions doesn't show the original "BRBG ratio". **The value of the match condition shows the equivalent limit inside of the defined range.** It can make sense to deactivate this condition, because for dense blanket of clouds the "holes" may provide a valid cloud base height.

Min. Size: This is the minimal number of pixel an object must have to be valid for comparison. This refers to the fact, that objects look more similar, the smaller they are. The area of an object must be larger than the minimal size to make this object valid for comparison.

Min Depth: This can be used to restrict the compared objects to significant objects (similar to "value"). A "Min. Depth" of zero is equal to "no restriction", rising values will restrict to objects that are found in more than one samples. So this value at least is restricted by the number of samples, but in fact values larger than two normally will exclude all matches.

Cluster: This does not belong to the match conditions, but to the final selection of "significant heights" and "possible wrong matches". The heights from the matching were merged to groups and the cluster value tells how similar the heights must be, to be merged into one group. The cluster value "0.0" would merge all heights, the cluster value "1.0" would only merge heights, that are the same.

Furthermore there is the hidden condition, that objects only will be compared, when they don't hit the border of the image or of a horizon mask. It only works to compare whole objects. When parts of them are cut away, it is not possible to find areas that can be compared meaningful.

"Heights"

The heights browser shows the results of the height evaluation and is divided in two parts. At the top it shows the results of clustered heights with 4 columns:

- Height: The final result of height evaluation in [m].
- Spread: Is the difference from lowest to largest height in [m].
- Deviation: The standard deviation of the clustered heights in [m].
- Objects: The number of objects that were used to determine the height.

| Heights | | | |
|---------|--------|-----------|--------|
| Height | Spread | Deviation | Object |
| 4161 | 540 | 162 | 9 |
| Height | Match | Obj_1 | Obj_2 |
| 3975 | 0.6 | 16 | 23 |
| 4053 | 0.44 | 16 | 15 |
| 4053 | 0.48 | 16 | 19 |
| 4053 | 0.6 | 20 | 23 |

The second part starts with new column headers and shows the single objects that were found:

- Height: The height determined in [m] for this object.
- Match: The match value of the compared objects.
- Obj_1: The number of the object inside of the first evaluation.
- Obj_2: The number of the object inside of the second evaluation.

Selecting a single calculated height inside of the browser shows the corresponding objects highlighted inside the pictures and the drawing pad. Also, the positions and the resulting height will be shown in "Message" output.

"Message": A message output with additional information. This dialog has its own evaluation and needs a possibility to display errors or results.

"Distance", **"Zenith Angle"**, **"Mid Altitude"** show parameters of the height evaluation. The distance between the current displayed cameras, the zenith angle of the current image projection and the mid altitude that was added to get the height above sea level. Please be aware that all results include the mid altitude offset.

[Defaults] restores the default values, that will work for most of the images.

[Save Settings]: takes over the changes of limits and settings and saves the configuration to disk.

[Reset]: discards the changes and resets to the original configuration.

[Evaluate]: can be used to check the result with new match conditions. This will evaluate the current images again, using the last changes.

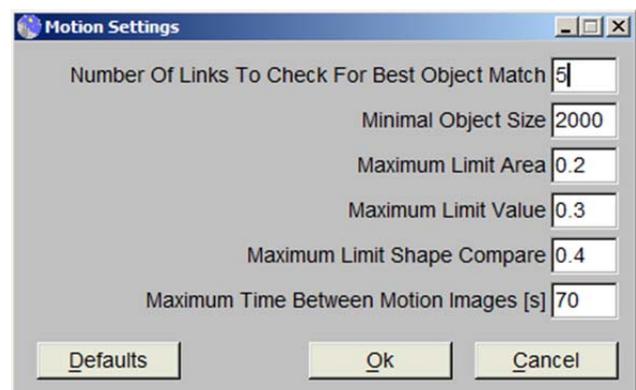
6.5.5 Configuration Cloud Motion Vector (CMV)

This dialog handles parameters of the cloud motion evaluation. It compares two images which are measured in a relative short time interval and tries to find matching objects. The motion displacement within a short time interval is small and relative homogenous.

The comparison of values uses the:

$$standard\ difference = \frac{(C_1 - C_2)}{\max(C_1, C_2)}$$

The more similar the comparison values 'C' are, the smaller the result will be and equal comparison values will result in zero.



"Number Of Links To Check For Best Object Match": To compare one object in image 1 (at time t_1), the software looks for objects at the same position in the second image (at time $t_2=t_1+\Delta t$). When there is no movement, the compared object will be found at the same place. When there is fast movement, around this place there are some more objects, that would have been there at this place before.

This is the number of the objects near the starting position, the program compares with the original object. A low number will fail for fast movements, a high number might find objects, that are far away from real movement, but look like a better match.

"Minimal Object Size": One single pixel looks like another pixel - also small objects do so. There must be an amount of pixel to get an individual shape that can be compared. The recommended value is "2000" equal to a square of about 45x45 pixel.

"Maximum Limit Area": "standard difference" of object pairs area .
A valid match must be < than the limit.

"Maximum Limit Value": "standard difference" of object pairs value.
A valid match must be < than the limit.

"Maximum Limit Shape Compare": This is equal to the height match in the clought height. It deals with the areas of the contours and their overlap. It is calculated by the ratio "not common" divide by "common" area. This match falls to zero the better the areas overlap.

$$\text{Maximum Limit Shape Compare} = \frac{(\text{Area}_{\text{ONLY1}} + \text{Area}_{\text{ONLY2}})}{\text{Area}_{\text{COMMON}}}$$

A valid match must be < than the limit.

"Maximum Seconds Between Motion Images" : Defines a maximum time limit Δt in [seconds] for motion evaluations. The cloud motion evaluation is based on optical flow and can only evaluate small movements, so it does not work to compare images with a big time distance.

[Defaults]: This button inserts the default values that are known to find valid results.

[Ok]: This button saves the current settings and closes the dialog.

[Cancel]: This button discards the current settings and closes the dialog.

6.6 Menu Items – Info and Help

The menu **"Info -> Info"** shows the standard about dialog with basic software infos like version, name and copyright.

The menu **"Info -> Help"** calls this manual. Please be aware this will only work, when there is a pdf reader installed and associated with the extension ".pdf".

7 Appendix

The appendix contains several addendums to the software, like error message tables or other details.

7.1 Format of ASCII TXT evaluation files

The result of an evaluation will be written to an ASCII file and will use the image name for the name of the text file. For example, the evaluation of an image "20150918075000_02.jpg" will result in a text file "20150918075000_02.txt".

In the text file for every result there is a line, which is formatted "Key=Value". The number of lines can differ between evaluations, so the keys should be used to retrieve a value. Because this is a text file, of course all values are text, but some of these texts represent a data type, e.g. "1234" is not only a text, but represents an *unsigned* number without decimal places. A *signed* number also can get negative, and a *double* value is a number with decimal places. Finally, *bool* is a number that can only have the values '0' or '1'.

The following keys are defined:

| Key | Data type | Value |
|------------------|-----------|---|
| Angular_Area | double | Arey in [px] of the object with minimal angular distance |
| Angular_Distance | double | Minimal angular distance of clouds (objects) from the sun in [°] |
| Cam | text | Name of the camera the image was made with |
| Is_Asi | bool | '1' when the camera is an "ASI" |
| Name | text | Name of the image consisting of date and time |
| Postfix | text | The postfix of the image. Normally this names an exposure level |
| Date | text | The date the image was made |
| Time | text | The time slot the image was made |
| Exact_Time | text | From exif data the exact point in time the image was made |
| Sunflag | unsigned | A number that tells state of the sun, more details please see below |
| Error | text | Tells last error of evaluation or is empty |
| Cloudiness | double | Number from 0.0 to 1.0 of cloudiness |
| Product | text | Serial number of the camera |
| Sun_Elevation | double | The elevation of sun when image was made in [°] |
| Sun_Azimuth | double | The azimuth of sun when image was made in [°] |

| | | |
|-----------------|----------|---|
| Sun_Inside | unsigned | '0' / '1' ... sun outside view / sun inside view |
| Sunflag | Unsigned | Flag if sun is visible |
| Temperature | signed | Temperature in [°C] measured with external Sensor |
| Zenith_Angle | double | The area inside this angle in [°] is used for evaluation |
| Humidity | Unsigned | Rel. Humidity [%] measured with external Sensor |
| Irradiance | Unsigned | Irradiance in [W/m ²] measured with external Sensor |
| Heights | int | Negative error number or at least one height in [m] |
| Motion_X | double | Motion X of optical flow from previous picture in [pixel] |
| Motion_Y | double | Motion Y of optical flow from previous picture in [pixel] |
| Motion_Diameter | unsigned | The whole diameter of the evaluated area in [pixel] |
| Motion_Image | text | Name of previous image to calculation Motion |
| Motion_Seconds | unsigned | Time difference to previous picture |
| Direction | double | Direction in degree calculated from Motion_X and Motion_Y |
| Velocity | double | Wind speed in [m/s] calculated from height information |

*Azimuth defined in the Range of +/- 180° and zero degree is direction to south

7.2 Sunflag numbers

There is an evaluation of the sun position beside of the cloudiness evaluation, to tell the exact state of suns visibility by a "sunflag". These numbers are defined:

| | |
|---|--|
| 0 | Sun not visible, because completely hidden by clouds or horizon object |
| 1 | Sun completely visible on clear sky or opening in the cloud cover |
| 3 | Sun partially covered by clouds - <i>number not in use, remained from previous version</i> |
| 5 | Sun behind clouds or haze |
| 8 | Sun outside field of view |
| 9 | Sunflag is not evaluated |

7.3 Error codes

There are some negative error codes to show basic state of evaluation. Normally these codes are completed by an error message, that describes the cause of the error.

| | |
|----|---|
| -1 | There is no result, because no evaluation was performed or no result loaded |
| -2 | The cloudiness evaluation failed |
| -3 | The CBH (cloud base height evaluation failed |
| -4 | The CMV (cloud motion vector) evaluation failed |
| -5 | The CMV (cloud motion vector) evaluation results in no motion |
| -6 | The evaluation was not possible because of missing or wrong FCT licence ke< |

7.4 Error Messages

The software writes a lot of detailed error messages to prevent the problem "It does not work!". On every step that failed to complete the evaluation, the software writes a specific error message to the evaluation itself and to the "Message" browser of the software. When an error occurred, the software doesn't stop or wait for user action, but goes on with the next task. This is no problem because it is possible to repeat evaluations after changing the settings. There are also errors, that can be ignored. Furthermore, there are "internal errors", which are defined, but only can occur by an unexpected malfunction of the software.

Errors from main program

Most of the main program errors are caused by the file system, when there are invalid paths, invalid access rights or other problems to load or save files.

There are a lot of error messages like *"Error when reading ..."*, *"Failed to save ..."*, *"Image folder missing ..."*, *"Configuration not found ..."* and so on, all followed by the name of the path, file or configuration. When such an error appears, the user must check for existing paths, missing access rights, or other problems, like names containing invalid characters.

These are not errors of the software itself, but the errors came from file system or users definitions, e.g. a directory name containing invalid characters. Beside this, there are messages regarding to errors, that the software can solve itself. For height evaluation the both images must have the same size and field of view (zenith angle) and when an evaluation failed because of these settings, the software automatically applies working settings to make *the next* evaluations work:

- *"Height evaluation adjusts existing common size to ..."* changes an existing common size.
- *"Height evaluation sets new common size ..."* sets a new common size.
- *"Height evaluation adjusts common zenith angle to ..."* sets a common angle, using the smallest defined angle.
- The message *"Start Evaluation: No images found, please check the default postfix"* tells, that no images for evaluation are defined and the user should check the postfix or the image names, e.g. when there is an image extension ".JPEG" where ".jpg" is expected. There are a lot more error messages regarding to load of images and save of results, they all require a check of the names by the user:
- *"Load Images: Directory Configuration Not Found <CAMERA>"* wrong or missing directory definitions of <CAMERA>.
- *"Load Images <CAMERA> Invalid Date/Time Format: <FILENAME>"* the name of the image doesn't meet the required format of "YYYYMMDDhhmmss_postfix.jpg".
- *"Load results ..."* these messages tell, that the software can not find or load evaluation sheets to restore the table of the main window.
- *"Save result ..."* also some messages will appear regarding to different problems that can appear when saving the resulting evaluation sheet.

Further messages are possible from these subsystems:

Errors from cloudiness evaluation

- *"Eval_Cloudiness: Invalid length of time or date ..."* the name of the image file does not match the default format.

- *"Eval_Cloudiness: Invalid binary level changed to 0.5"* this is an information, that the software applies a better setting by itself (needed to create "Binary Cloudiness").
- *"Eval_Cloudiness: No Cloudiness calculated because of invalid horizon mask"* this is an internal error that probably never will occur. It means, that not even an empty background can be created.
- *"Eval_Cloudiness: Failed to load exif data or read exact_time tag ..."* probably the image is damaged or doesn't contain exif data. In the latter case "Load Exif" in misc configuration should be unchecked.
- *"Eval_Cloudiness: No image for evaluation"* this is an internal error and appears, when an evaluation was called, after the setup of the image failed.

Errors from CBH (cloudbase height) evaluation

- *"Evaluation Height: Unexpected error when committing evaluation, different sizes"* internal error, the evaluation was changed before the result was delivered.
- *"Evaluation Height: At least one cloudiness evaluation is empty"*. In fact this will be caused by an empty evaluation, e.g. evaluation of "blue hour" early in the morning.
- *"Evaluation Height: Images are from different Zenith-Angles"* this is a problem, the software can resolve automatically for further evaluations, but this one must be repeated. When this message appears several times, common zenith angle should be set by the user.
- *"Evaluation Height: Images with different or zero sizes"* this can be caused by a damaged image, or different "Square sizes" of the camera configuration. The latter case can be resolved by the software for following images.
- *"Evaluation Height: Missing configuration for pair ..."* please check the pair configuration definitions.

Errors from CMV (cloud motion vector) evaluation

- *"Evaluation motion: Missing image, two images are necessary"* internal error, motion evaluation called without committing images.
- *"Evaluation motion: Previous image newer than current image"* probably the exact shooting time from exif differs from file name time.
- *"Evaluation motion: Previous image too old by misc config"* the time difference of the images exceeds the default maximum time difference.
- *"Evaluation motion: Images of different cameras"* internal error, motion evaluation called with wrong files.
- *"Evaluation motion: At least one motion image missing"* at least one of the images misses the previous cloudiness evaluation, maybe the evaluation failed because of blue hour or darkness.
- *"Evaluation motion: Cloudiness too low by misc config"* the minimum cloudiness required to start motion evaluation is not given.

Errors from FCT licence key

- *"Double licence removed"* one licence was entered to two camera configurations and the software deleted both of them. The licence must be entered again to just one camera.

- *"Old licence removed"* also a licence of one "ASI" was entered to two camera configurations and the software deleted the older one of them.
- *"Missing Licence"* a cloudiness evaluation was tried without licence.
- *"Invalid Licence"* the checksum of the licence key is wrong.
- *"Licence invalid product number"* the new image was not generated by the ASI camera, that was assigned to the current license key configuration.
- *"Image date exceeds licence"* the date of the image exceeds the expiration date of the licence key.
-

Unexpected errors

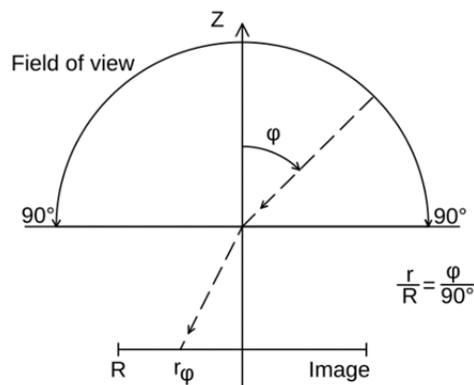
All the previous errors are well defined and will be processed by the software without crashing it. But it is also possible, that an error happens, that is not anticipated and will crash the software. This will be caught by an "exception" and will cause a message that tells details about the problem. In case of repeated crashes this will help the developer to find the problem, but it is important to tell all details of the message.

8 Discussion of Fisheye Projection

8.1 Fisheye Projection Geometry

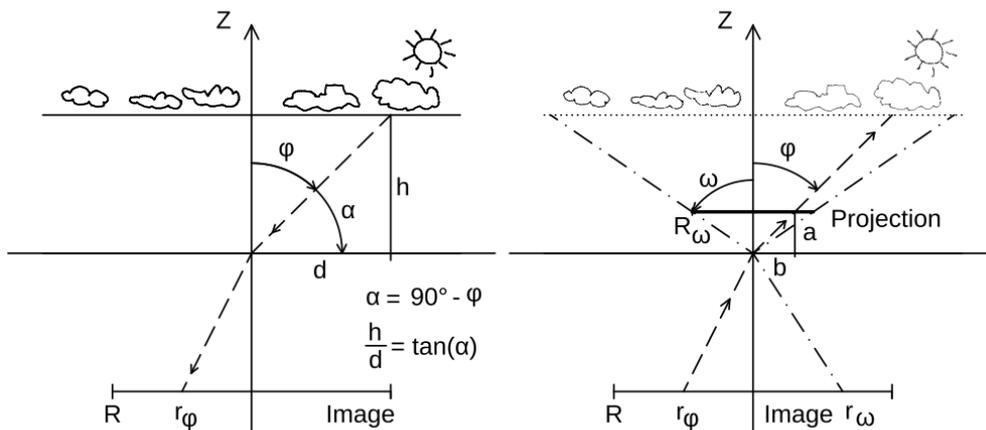
This text focuses on a fisheye lens, which maps a hemispherical view field conformal to an image plane and produces a circular image. The radius of the image relates to the opening angle (zenith angle). The following image shows the path of rays inside of a fisheye lens.

For an ideal fisheye lens the image radius relates linear to the view angle and the whole field of view will be mapped to concentric circles. A real fisheye lens will produce some distortions, especially for larger angles. There will be aberrations from linear ratio of view angle and image radius. But for the moment we assume a linear, not distorted mapping.



A cloud cover can be seen like a two-dimensional plane at a specific height in the sky, but when using a fisheye lens for cloud monitoring, it maps a hemispherical view field to the image and not the original plane.

The first part of the chart shows that for mapping of a plane in constant height h to an angular dependent fisheye lens image, the distance d depends on the tangent of the viewing angle. For zenith angles approaching 90° this distance will approach infinity. So the angular dependent concentric circles of the fisheye lens image for small angles φ maps the correspondent circle of the sky plane almost 1:1. For larger angles, the mapped area will rise fast until it even corresponds to infinity when approaching 90° .



The second part of the chart shows, how an existing fisheye lens image can be used to create a reproduction of the original sky plane by rear projection. Now the path of rays starts from the fisheye lens image and crosses an image plane in height a. The image plane covers the viewing angle ω . Dependent on ω and a, an image radius of R_ω results. - The crossing point of image plane and angle φ results in height a and distance b and fulfills equations $h / d = a / b = \tan(\alpha)$. It is obvious to see, that the path of rays produces a projected image ("Projection") that shows original sky plane true to scale.

In practice, a constant viewing angle will be assigned to a constant image radius R_ω , whereby a constant distance a will result for all angles φ :

$$a / b = \tan(\alpha); \alpha = 90^\circ - \varphi \rightarrow a = b * \tan(90^\circ - \varphi)$$

By use of the specified values for ω and R_ω the constant a can be calculated:

$$a = R_\omega * \tan(90^\circ - \omega)$$

Using this it can be calculated, which distance b results out of a projection angle φ . So every radius of the fisheye lens image results in a radius of the plane image. R_ω sets the unit of measurement and it is most simple to use the unit "pixel". This way a pixel of the fisheye lens image can be moved to correspondent position on sky plane:

$$b = a / \tan(90^\circ - \varphi) = a / \tan(90^\circ - 90^\circ * r/R)$$

with r equal to current radius and R equal to whole radius of fisheye lens image.

By using $\tan(\alpha) = \cot(90^\circ - \alpha)$, $\cot(\alpha) = 1/\tan(\alpha)$ and keeping periodicity of tangent in mind it is possible to simplify the equation:

$$f(r) = a * \tan(90^\circ * r/R)$$

("forward calculation": Fisheye lens pixel to image plane)

This "forward calculation" doesn't include, that size of pixel raises in dependency from the angle, so projecting pixel one to one causes rising gaps between the pixel. A simple solution to avoid this problem is to calculate the pixel of the image plane backward to fisheye lens image and taking over one pixel for several times, when necessary:

$$f(r)^{-1} = R / 90^\circ * \text{atan}(b / a)$$

("backward calculation": plane image pixel with distance b to fisheye lens pixel with radius r)

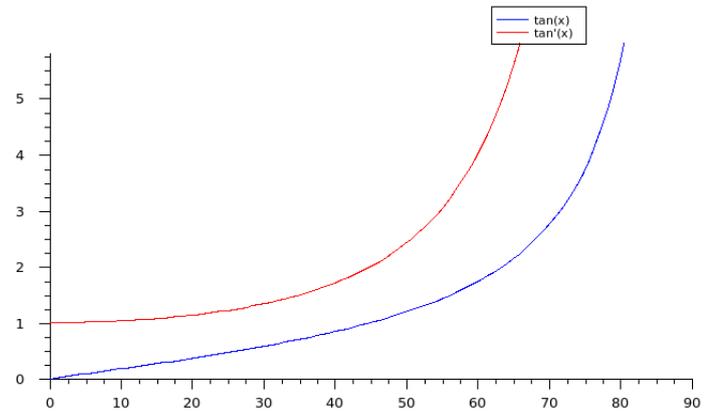
This way a complete image will be created, but because of aliasing for large zenith angles there will result an aberration from the original sky plane. The pixel not only were enlarged, also a jitter appears, because the fisheye lens pixel won't match to an even number of plane image pixel. For plane pixel located on borderline of two fisheye lens pixel an interpolation should be used to reduce aberration.

8.2 Limits of Useful Graphical Representation

To appraise the effect of rising zenith angle and size of aberration it makes sense to look at the underlying tangent function. Especially the derivation of the tangent shows directly the difference between original fisheye lens pixel and resulting plane image pixel.

$f(r) = a * \tan(90^\circ * r/R)$ results in an angle range from 0° to 90° , because the ratio r/R covers the range from 0 to 1.

This plot shows the dependency of the plane image radius (y-axis) on zenith angle in degrees (x-axis). For angles less than 50° it is plain to see, that the radius rises almost linear with the angle, so the middle part of the image will project the original sky plane almost unaltered. In range from 50° to about 80° the projection will get more and more stretched until for angles larger than 80° the radius steeply rises to infinity. Also the derivation shows



accordant factor of projection for range from 0° to 50° by 1:1 or 1:2 and fast rising for larger angles.

The following example shows some "forward projections" containing gaps to demonstrate effect of rising angles and loss of image content. To make the images more demonstrative not a sky image was used, but an image of laboratory window.



First image is original fisheye lens image, second is projection of 60° , third of 80° and fourth of 85° .

These images demonstrate how the image content evolves with zenith angle. For 60° projection there are only small gaps that need to be filled. For 80° it is clear to see that from half the image radius on, large areas must be interpolated from small pixel information. For 85° angle the image content is restricted to a small region in the middle and most of the image must be interpolated.

Practically, the zenith angle should be restricted to values $<80^\circ$. For opacity classification (CDOC algorithm) scientists recommended not to exceed 70° of zenith angle (Field Of View $< 140^\circ$).

8.3 Distortion and Correction for "Real Fisheye Lenses".

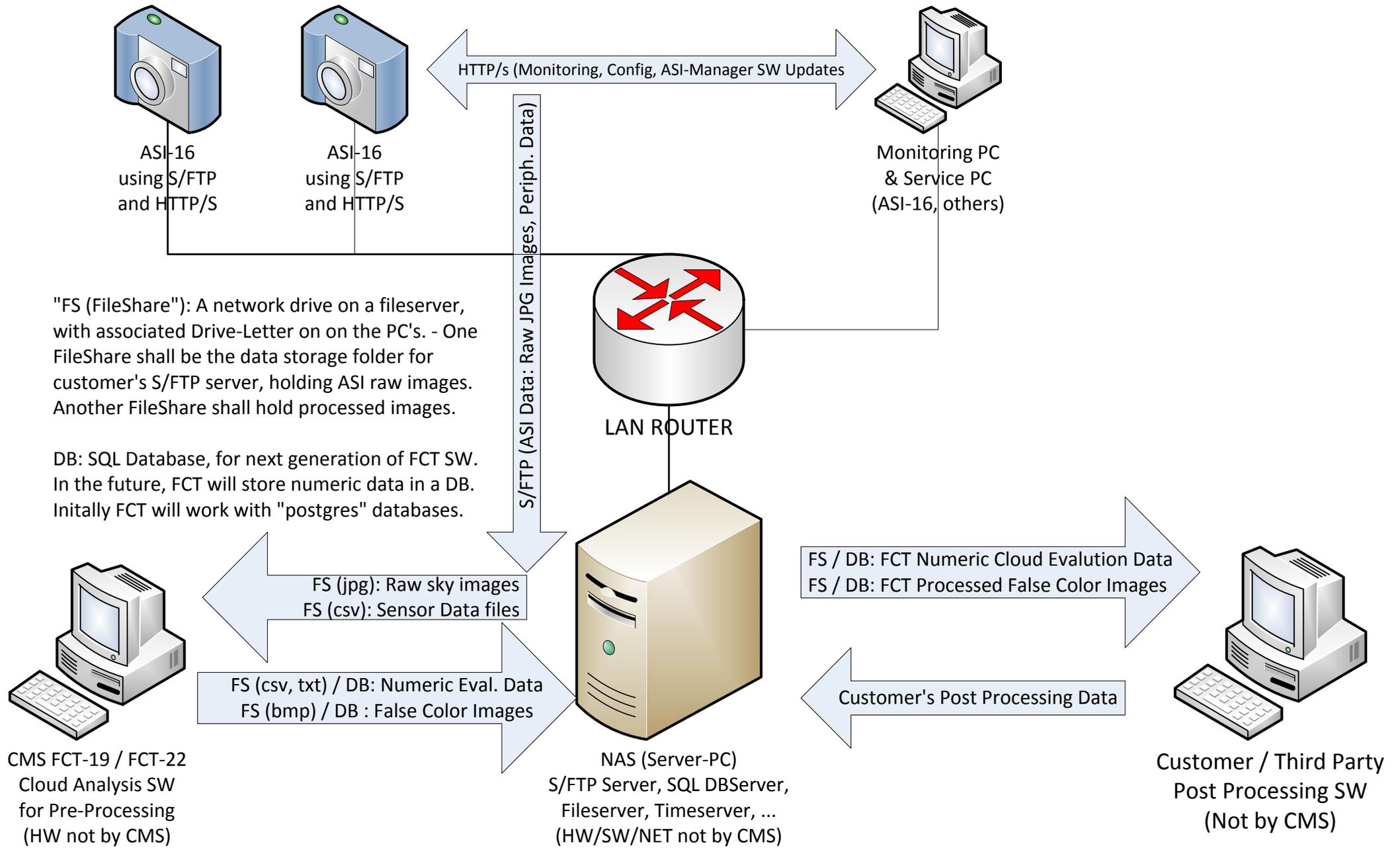
Because of lens distortions in actually used "Real Fisheye Lenses" there will be deviations to an the theoretically-only "Ideal Fisheye Lens", as higher the zenith angle as higher the distortion.

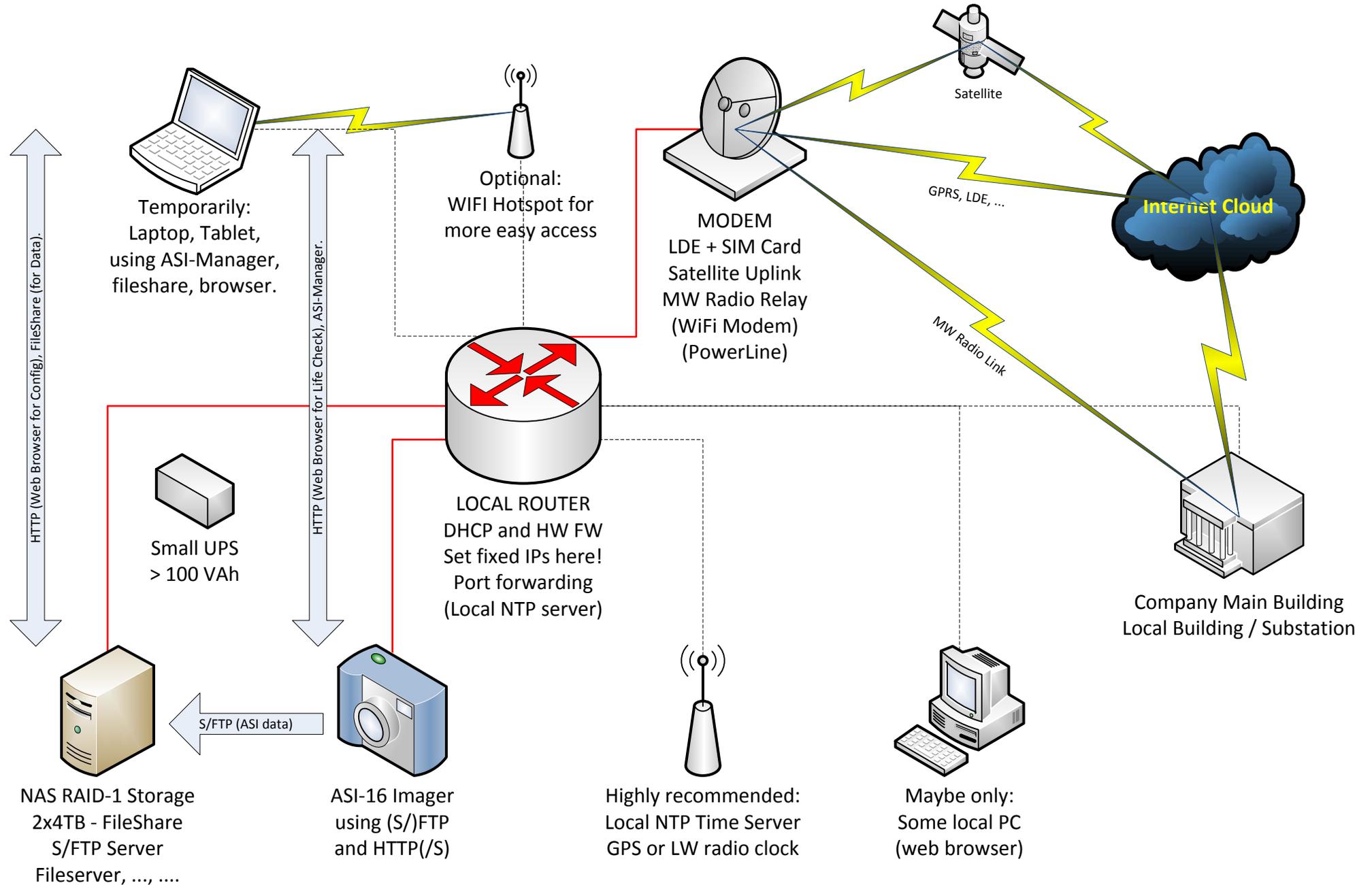
Upon request CMS Schreder can provide a "Correction Table" matching the specific lens used.

ASI-16/50 & ASI-16/10 : "FE8174_lens distortion table.xls" .

ASI-16/51, ./52, ./12, ... : "FE9381_lens distortion table.xls" .

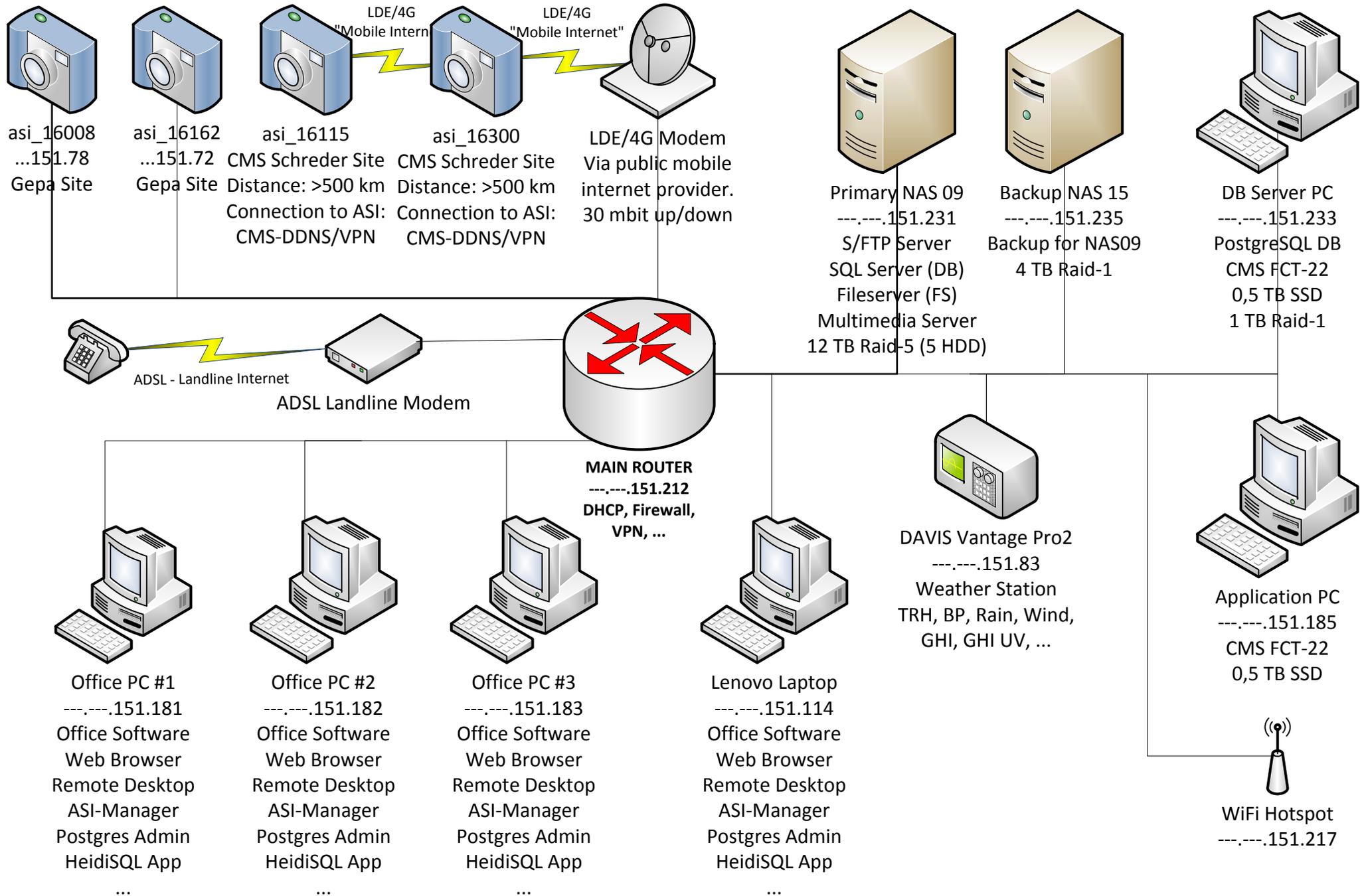
ASI-16/55, ./15, ..., ..., . : "FE9382_lens distortion table.xls" .





Red line connections: Minimum requirements; Black dashed line connections: Optional, temporarily;

Operative example: LAN/NAS/PC/ASI setup at GEPA CONSULTING (Gerhard Papst) site in Styria/Austria, >500km distance to CMS Schreder office site.



Not shown: Scanner/Printer (.215), PLC (.191), 8P Switch (.217); 16P PoE Switch (.219); 8P Switch (.124); APC UPS; two small NAS, multimedia devices, ...

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Version V03, 2024-05-02 (gepa)

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