**Using a fish-eye camera for radiometry and assessment of light environments with ELF (Environmental Light Field)**

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The camera’s CCD is a very linear light meter, and it can be calibrated to conveniently take absolute intensity readings as a function of vertical angle. We use the calibration unit: photons per m2, steradian, s and nm wavelength (q/m2·sr·s·nm). The values are given for RGB and white, where B is the average for 400-500 nm, G is 500-600 nm and R is 600-700 nm. White is the average over 400-700 nm. In combination with a fish-eye lens, a modern SLR camera can thus be used to measure the intensity distribution of scenes and habitats. Apart from averages of absolute photon flux values in different vertical angles, the same photos can also be used to extract information on image structure statistics.

Camera and lens requirements

Use an SLR camera fitted with a fish-eye lens producing 180° circular images. For Sigma fish eye lenses, take care to remove the entire lens cap (including the sliding part – not just the snap on part), or else the photos will only cover 140°. A good idea is to joint the two lens caps with electrical tape. We recommend Nikon 810 with a Sigma 8 mm F3.5 fisheye lens.

It is important that the camera can store images in RAW format, with a fixed white balance for direct sunlight, and that all picture enhancement functions can be turned off. The camera must be calibrated in the laboratory with exactly the same settings as those used for habitat measurements.

Procedure

Take photos of at least 15, ideally 40 scenes within the habitat (type of environment) that you want to evaluate. All 15-40 scenes should be photographed in as rapid succession as possible, such that time of day and weather remains roughly the same. Try to choose scenes randomly in different horizontal directions, and such that the set of scenes makes a representative random sample of the habitat. Avoid adjusting the camera position to make nice-looking photos. On open sunlit areas your own shadow should be visible at random positions in about half of the scenes.

Note for each series the location, time, weather and other circumastances of possible importance. Make sure the camera’s clock is adjusted for the correct place and time of year (take a note about daylight savings such that astronomic time can be reconstructed).

Always confirm that the camera is exactly horizontal in both tip and tilt angles. The most important end result is the relation between luminance and vertical angle. It is thus essential that the midpoint as well as the straight line connecting the extreme right and left edges of each image are in the horizontal plane. Do not be fooled by sloping terrain. A bubble level mounted on the camera is an ideal solution, which also makes it unnecessary to look through the finder.

Free hand photography works fine in daylight and early dusk intensities. Under darker conditions a tripod is necessary.

Because the dynamic range of a single photo is often not large enough to capture the entire range of luminances within a scene, it is necessary to use “bracketing” (a series of different exposures instead of a single photo of each scene). This can be done automatically by most cameras.

Camera settings

Because we use Nikon D810 with a Sigma 8 mm/3.5 fisheye lens, the descriptions below are aimed specifically at this equipment. Other models or makes may have different names or symbols for the same settings, or offer additional settings not mentioned here. It is also necessary to have an intensity calibration of the camera, which is a complicated and advance procedure, but since Nikon D810 and the Sigma 8 mm/3.5 fisheye vary so little, it is possible to use our calibration for that particular camera and lens combination.

For the photos to be usable for VEPS, it is essential that images are stored in RAW format, the white-balance is fixed for daylight, and no automatic image enhancement functions are turned on. The images must also be taken with a fixed aperture, and without flash. It is essential that the bracketing series of exposures cover the full dynamic range of the scene.

**Exposure**

Use automatic exposure with fixed aperture (A) for intensities where the exposure meter works.

For darker conditions (less than moonlight), use fully manual exposure (M), and make test exposures to find the correct exposure time. A tripod and a cable release or wireless remote is recommended for long exposures. At a clear starry night with no moon a good exposure is given by three exposers: 8 min, 1 min, 8 s.

Use the only the calibrated apertures, F3.5, F8, or F22 depending on the luminance. Avoid 22 unless you intend to bracket so much as to measure the luminance of the sun or a bright light source (aperture 22 generates some hexagonal flare which may affect the measurements).

Set ISO to Manual or Auto. Because of the fixed aperture, the ISO value effectively determines the shutter speed that the camera will use. The ISO setting should be in the range 64-1600). Avoid extended ranges because it boosts noise as much as the image. High ISO values generate noise, which pollutes the measurements. The aperture setting (F3.5, F8, F22) and ISO setting (64-1600) should be used to make sure shutter speeds are not hitting the roof of 1/8000 s or longer that about 1/8 s for a handheld camera. Typical settings for daylight is ISO 200 and F8.

Set bracketing to 3 exposures differing by 3 EV between each. If possible, set bracketing order to go from – to + (rather than starting with the middle exposure).

Make test exposure to confirm that exposure is not too dark or washed out. In the brightest photo of the bracketing series there should be no completely black pixels, and in the darkest exposure in the series there should be no fully white pixels. If necessary, make a general exposure correction + or – to avoid parts of the picture being completely black or completely white through the entire bracketing series. It is of course also possible to extend the bracketing range for scenes with unusually large dynamic range. For Nikon D810, a correction of –1 EV is good for most scenes.

At late dusk, early dawn or dimmer conditions, the exposure meter will under-expose significantly. Manual exposure and trials are recommended in these conditions.

If the brightness of a light source in view (sun or lamp) is important to know, then the exposure considerations above must include also the light source. This may call for very long bracketing series (the sun’s disc is about 5 log units, or 16.5 EV binary units brighter than the scene it illuminates. Auto ISO may help here.

It is necessary to ensure that the automatic exposure time gives enough headroom for the shutter to manage the shortest exposure in the bracketing series. If the camera’s fastest shutter speed is 1/8000 s, then the ISO has to be set such that the normal exposure is no shorter than 1/2000 for 5 exposures with 1 EV difference, and 1/1000 for 3 exposures with 3 EV difference. It is good with some extra margin also because the shutter time accuracy drops for the fastest speeds. A sound rule is to set ISO such that the shutter speed does not exceed 1/2000 s. Alternatively, use auto ISO but use the menu to restrict the ISO to minimum 64 and maximum 1600.

If possible, set the camera to take the entire bracketing series with one push on the release button, and then stop (CH on Nikon).

Set exposure meter area to centre integration (), Centre area 20 mm (in tools menu)

Use exposure lock with release button pressed halfway (not continuous sports exposure setting)

**Lens**

Autofocus: off (on camera body)

Set aperture to fully open (3.5; on camera upper display) for dim conditions, twilight, night or indoor use. In bright daylight use an aperture setting of 8. If the sun or other bright light source is to be correctly assessed, aperture 22 is necessary. Aperture 22 can also be used to obtain maximum depth of focus of objects are close. Do not use any other than these three settings because the others are not calibrated.

Set focus on the lens to ∞ at R (on Sigma 8 mm Fish Eye), unless important objects are closer than 0.5 m. For scenes with close objects, set aperture to 22, and ∞ to 22 setting, which makes sharp from infinity to 13.5 cm).

To avoid unintentionally changing the focus, use a piece of tape on the focusing ring.

If the camera refuses to take exposure it is likely that the autofocus has been accidentally turned on and it fails to focus because of the tape locking the focus ring. Just turn autofocus off to solve the problem.

**Picture storage format**

Image quality RAW (NEF).

Store RAW image: RAW L (large), NEF compression OFF, Bit depth 14-bit

Image area: 5:4 (30x24) or FX (36x24). The smaller format will have less unused space, with smaller files as a result.

There is no point in using double storage formats (such as RAW + JPEG). It will only slow down the camera and fill up the data storage cards.

**Other camera settings**

Set White balance to daylight (direct sunlight). Do not use automatic white balance. This is very important!!

Nikon: Picture control: Flat or Neutral (although this does not change RAW files)

Colour space: use sRGB (although this does not change RAW files)

Active D-Lighting: off (very important)

HDR: off (very important)

Vinjetting control off

Noise reduction for long exposures: On

Noise reduction for high ISO: High

Flash: off

Finder grid: on (if it exists, will help orient the camera horizontally)

Virtual horizon in the tools menu is good but it has to be turned on for each new photo. It shows the horizontal plane on the back screen.

Nikon: Show ISO on (if it exists, will make ISO selection easier to see)

If the camera has automatic image enhancement functions other than those mentioned here, those must also be turned off.

Because the astronomic time of day may be important information, it is advised that the camera clock and time-zone is correctly set, preferably without using daylight savings correction.

**Night shooting with Nikon D810**

Use tripod and shutter release cable or wireless

Use SETTINGS MENU (the spanner): Virtual Horizon, to level the camera

Change ISO from Auto to 1600 for starlight or 800 for moonlight.

Change Mode from A to M

Alt 1 (moonlight or brighter):Use normal bracketing (3 x ±3EV), Set exposure time to 4s (F3.5, 4”)

Alt 2 (less than full moonlight): Turn off bracketing, set time to BULB, and use remote to expose a manual series with the long, and make three separate exposures 8s, 1min, and 8 min. Please note that with such long exposures the camera automatically makes a dark noise expose of equal length after each shot. So for the 8 min shot, the camera will be busy for another 8 minute after completing the real 8 min exposure (in effect requiring 16 min for the longest exposure in starligt).