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Research excellence supporting a sustainable ocean

Low-cost water radiometry

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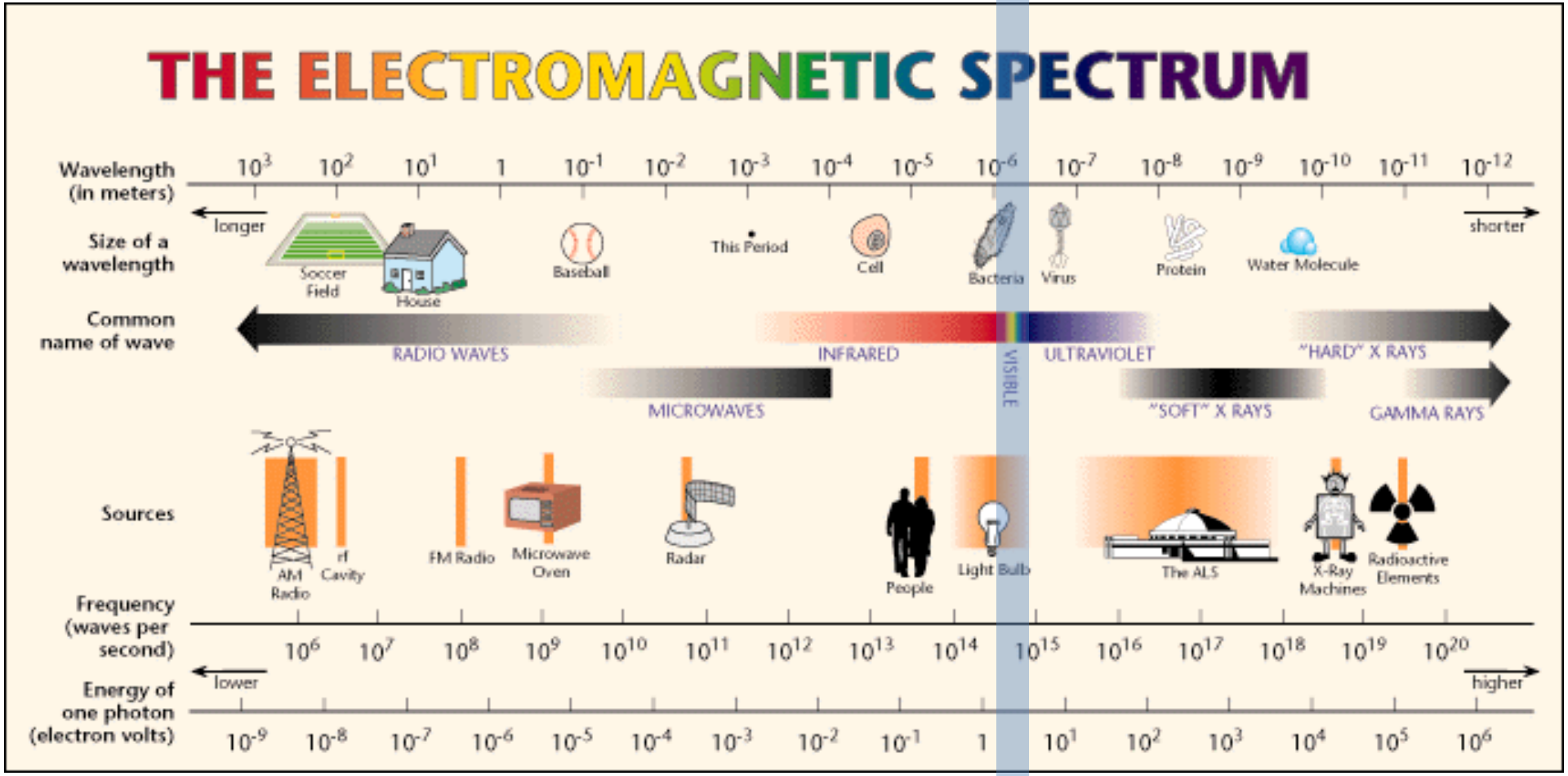
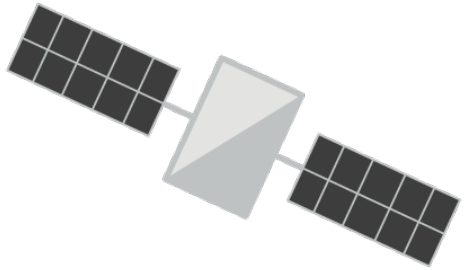
Radiometry = measuring electromagnetic radiation

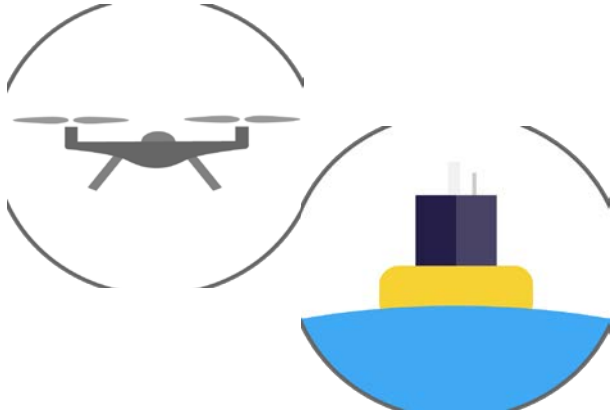
Optical =
Visible +
near infra-red

~400-900 nm



Radiometric water colour measurements across spatial scales





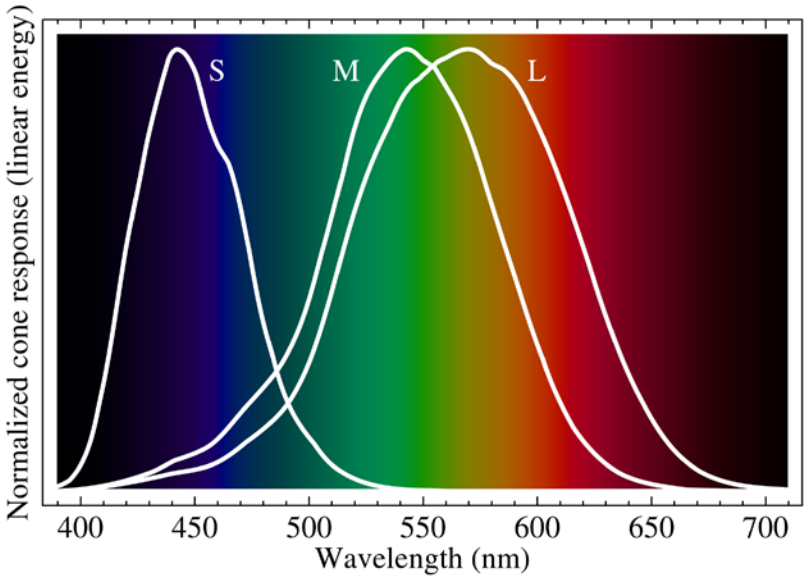
Global
Multispectral
Few platforms
Atmospheric correction

Micro-scale
Hyperspectral
Many observers
Inter-sensor variability

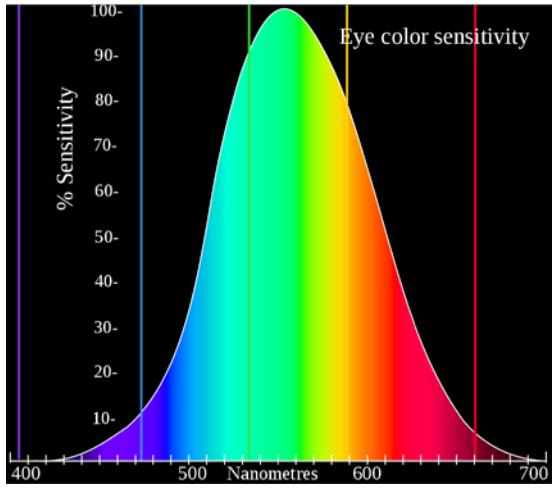
Which light sensor is ‘best’?
Which offers ‘best value’?
Is there a sensor you already carry with you every day?

Example of a great sensor

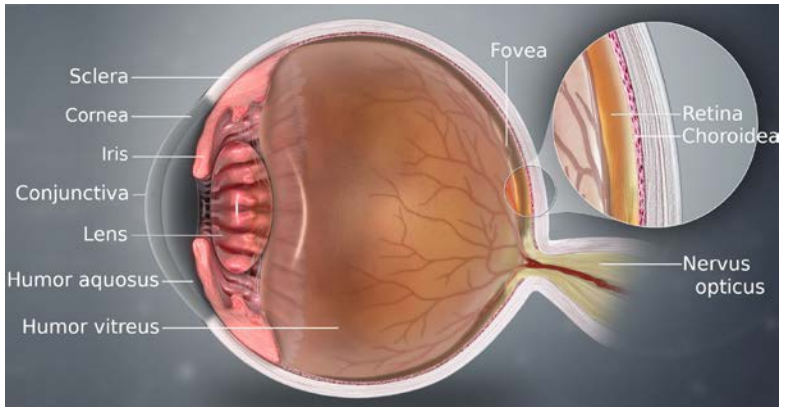
Dynamic range of 10^{14}
3 wavebands.
1 million colour hues through high-end data processing.



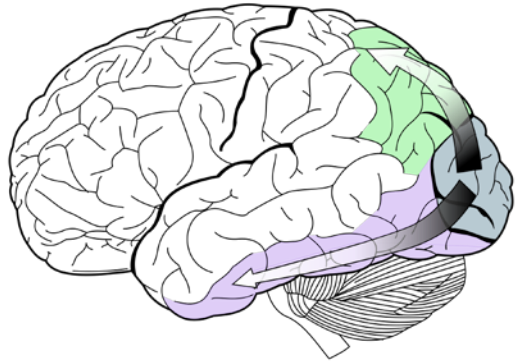
What range can it detect? Spectral response of the Short, Medium and Long cones in the human eye. We can differentiate 100 shades with each receptor → 1 million colours .



Sensitivity: Relative spectral sensitivity of the human eye (most sensitive to green light)

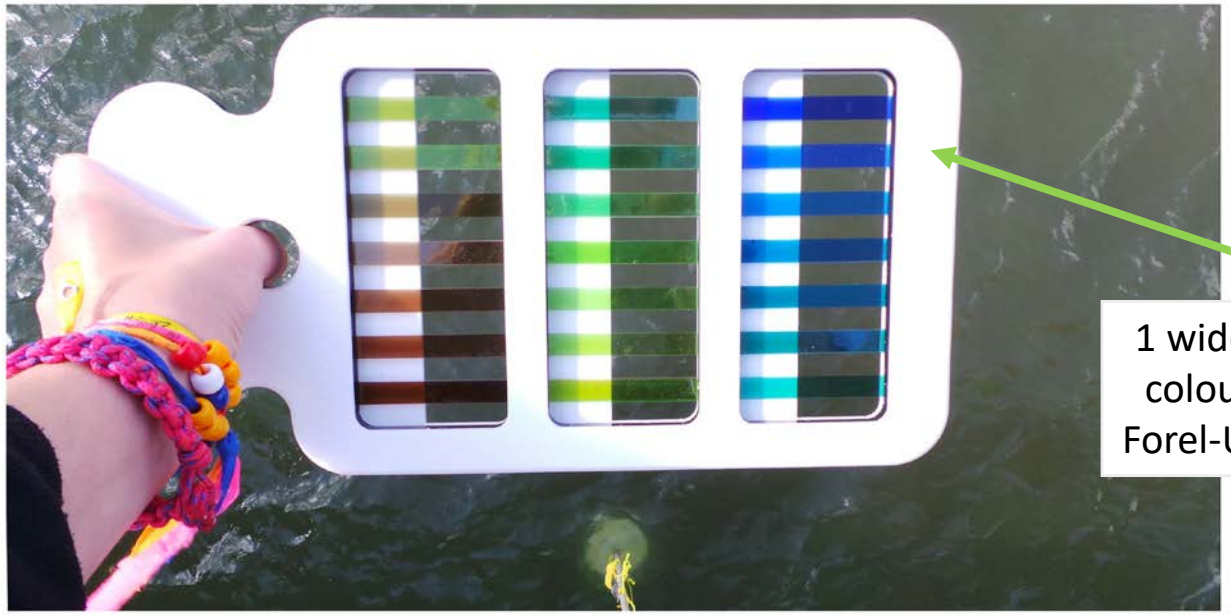


Design: anatomy of the human eye and the visual cortex



Using human-eye radiometry to describe water colour

- Comparative colour scales remove most observer bias
- Kits and smartphone apps available – mobility, standardisation, context



1 widely used colour scale: Forel-Ule index

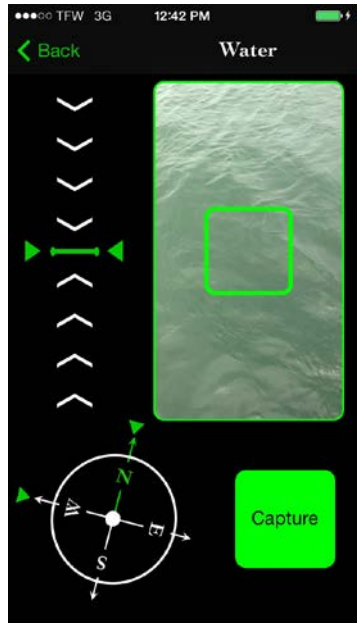
A mini-Secchi disk with FU scale

Smartphone cameras are an accessible way to measure water reflectance

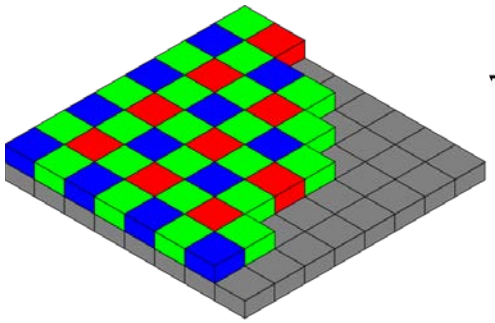
HydroColor (Leeuw and Boss 2018) and *EyeOnWater* (Busch et al. 2016) estimate water reflectance using smartphones.

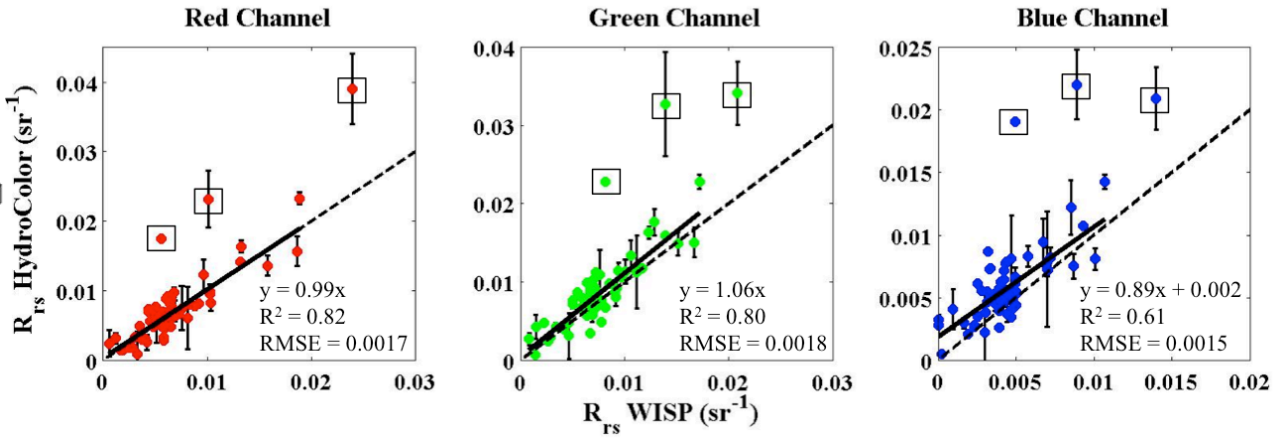
Clear benefits for citizen science, low-cost monitoring and science education.
> 5k HydroColor downloads, >15k EyeOnWater photos.

Limitations for stricter applications of water radiometry
(accuracy ~ 30%, reproducibility between phones, limited to 3 RGB channels).



Above: HydroColor app

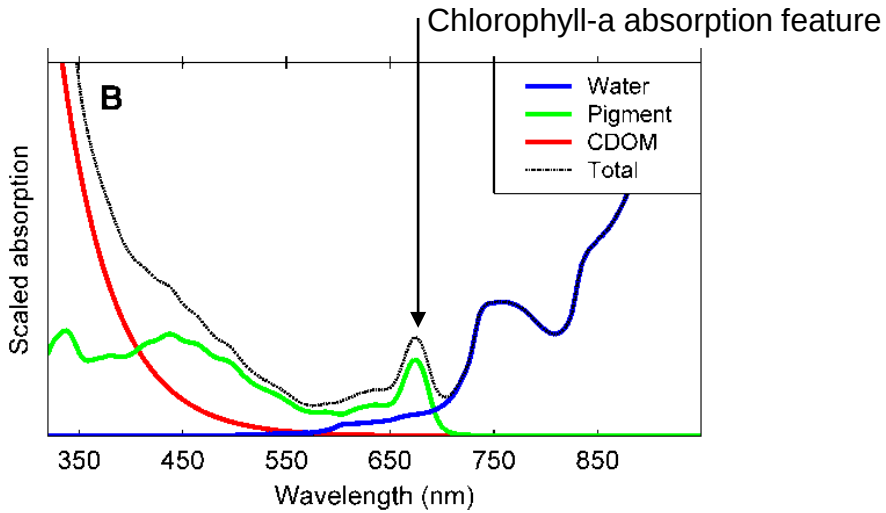


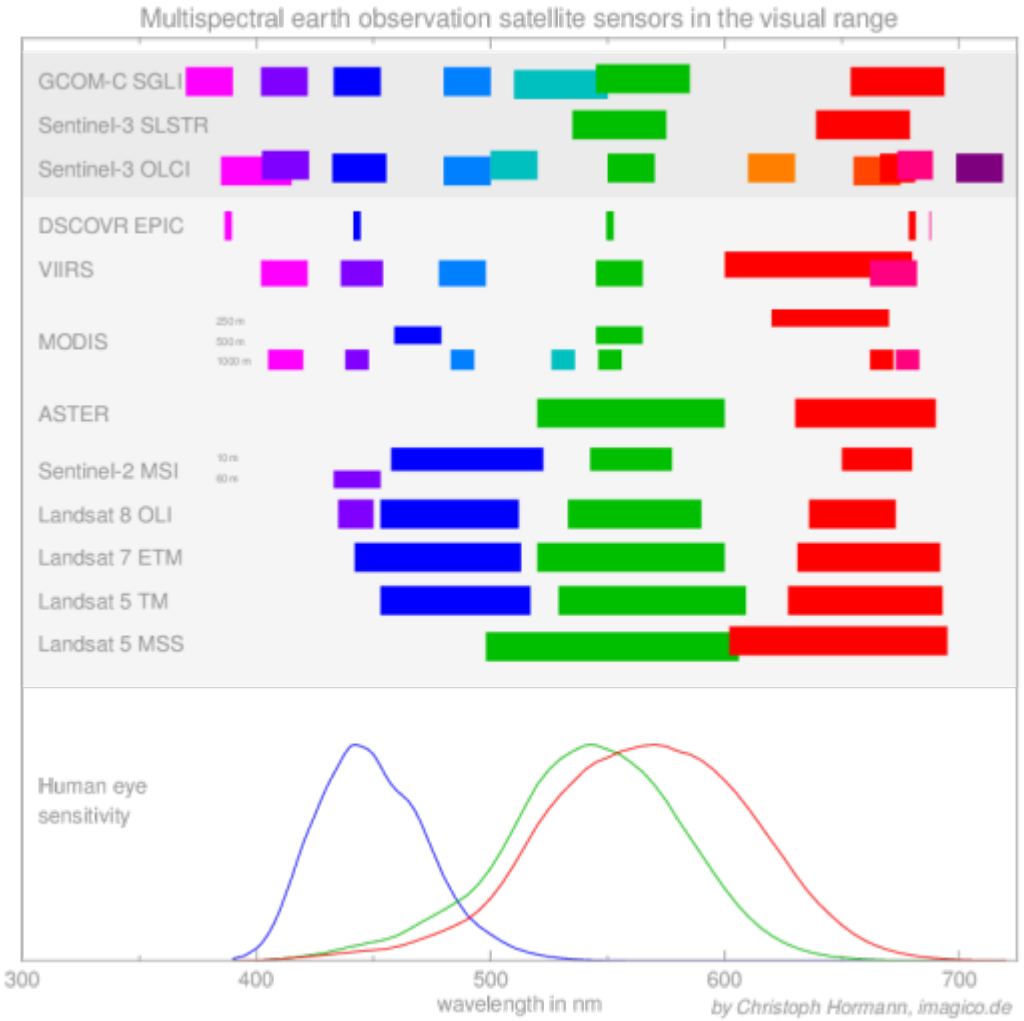


Left: RGB detector array in smartphone camera, radiometric validation of HydroColor in RGB channels

Hyperspectral is better..

Sensor wavebands are either aligned with human eye response or with specific optical features such as chlorophyll-*a*

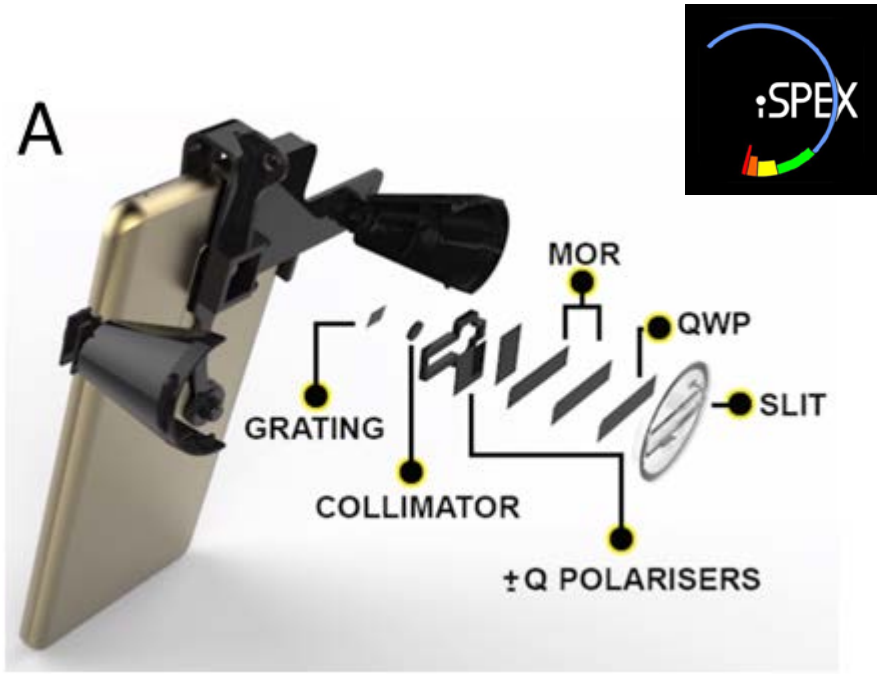




Specific bands to look at atmospheric and water components

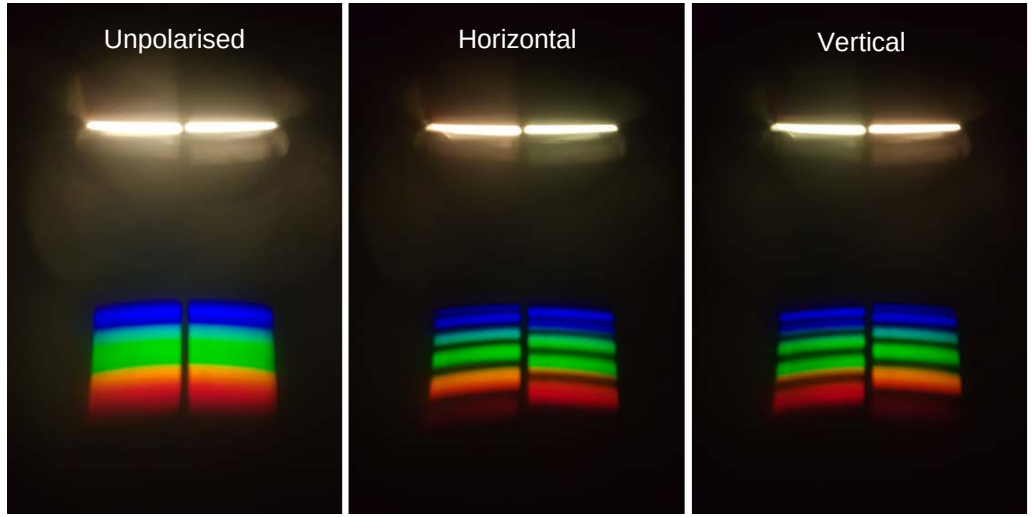
Similar to human eye: these sensors take ‘true colour images’

iSPEX 2: universal smartphone spectropolarimetry



iSPEX 2 optical elements (Burggraaff et al. 2020)
QWP – Quarter Waveplate
MOR – Multi-Order Retarder

Physical smartphone add-on based on `polarisation modulation optics'.



Direct light

Projected from grating

Component cost approx. €25.

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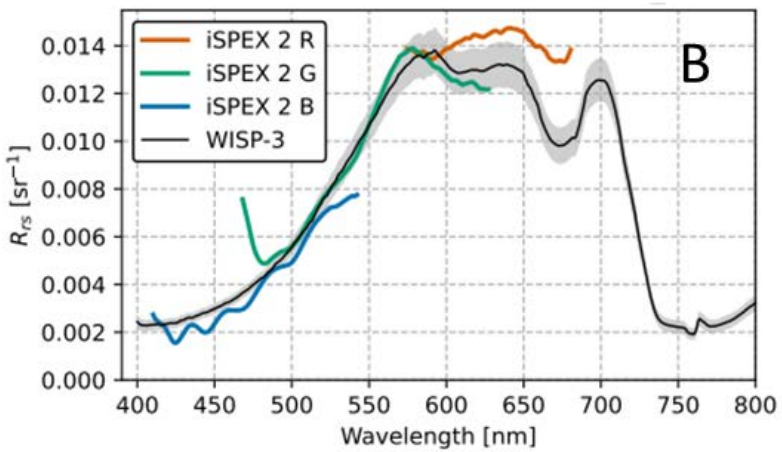
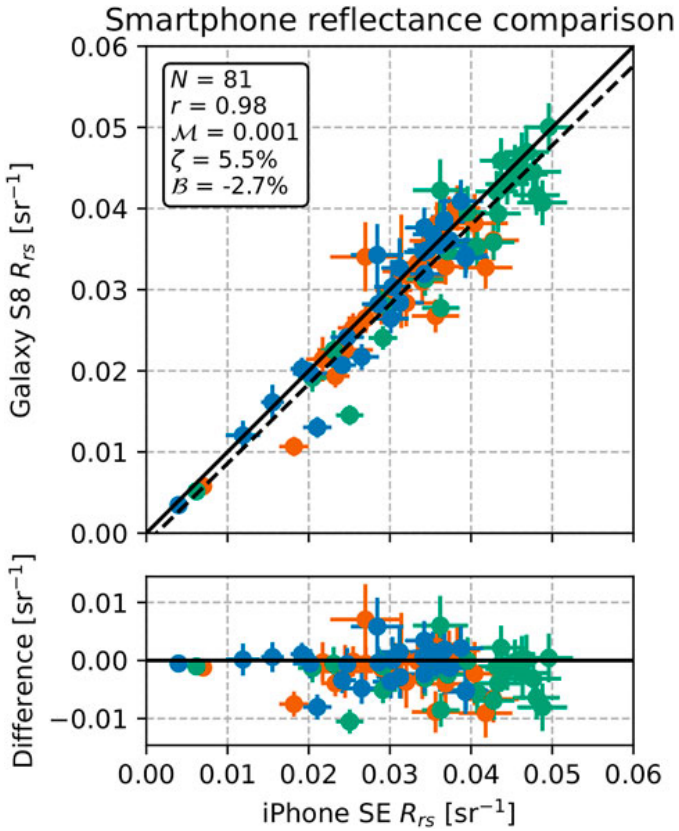
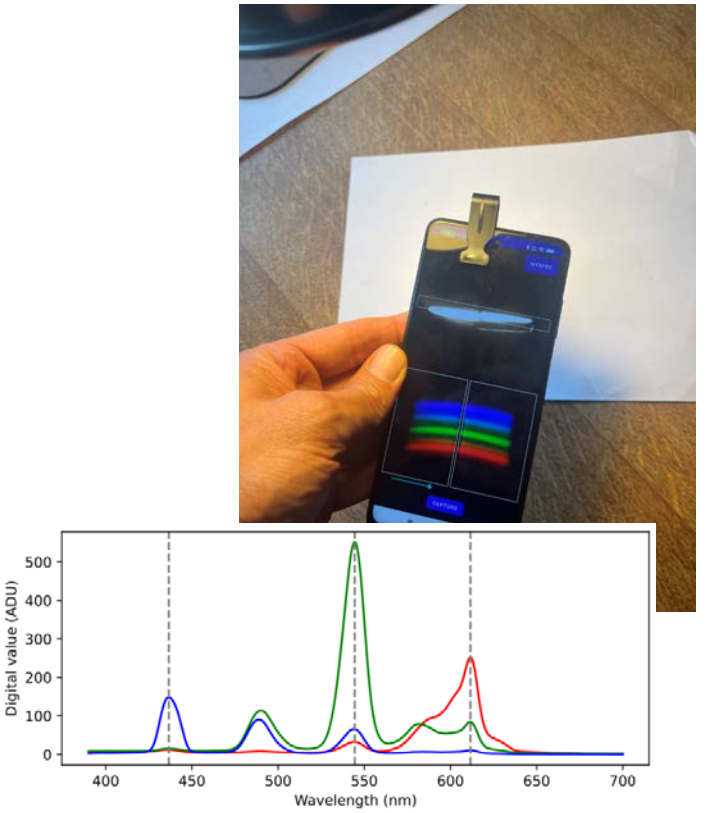
iSPEX 2 calibration, reproducibility



Water reflectance from iSPEX 2 and WISP-3. Data after calibration, without demodulation / quality control. (Burggraaf 2022: PhD thesis).



Reproducibility between phones, using RAW data and image corrections. (Burggraaf 2022: Frontiers in RS)



Wavelength calibration (per camera model)

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Hardware design, data processing, lab-based testing, calibration database

Protocols, Validation, Data flows

LOT LAND SEA

Spectral inversion algorithms, concentration estimates in water and air

“Citizen science”

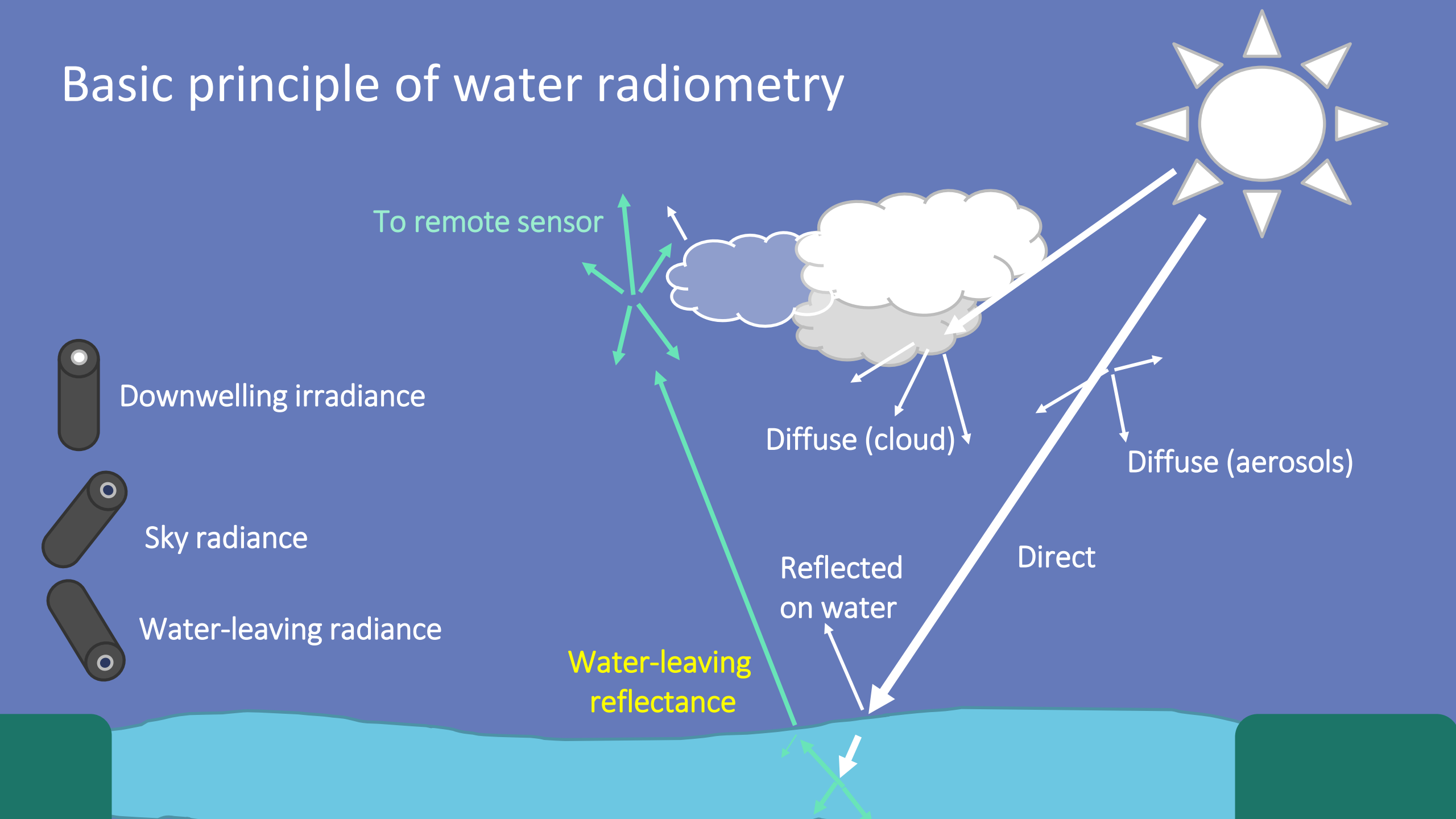
Technological development

Demonstrate use case

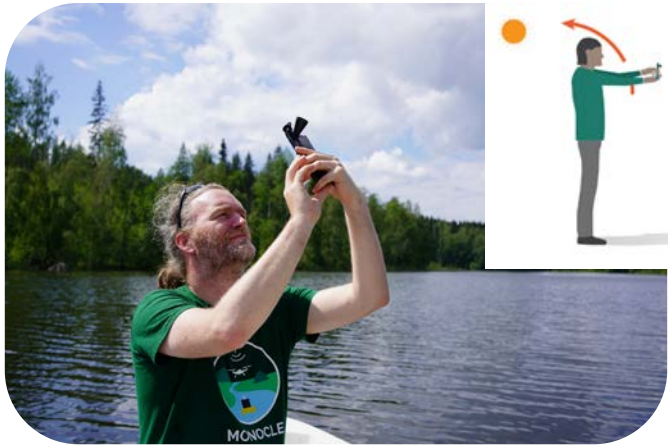
Specific applications

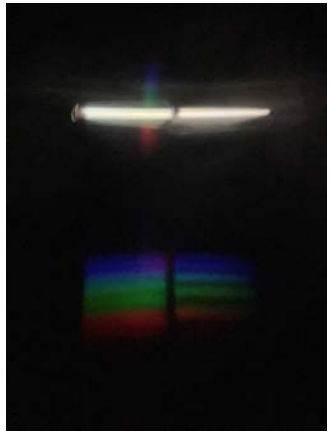
Upscaling, engagement

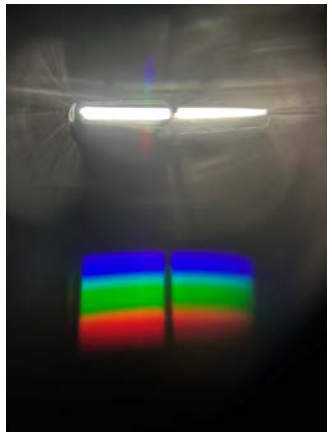
Basic principle of water radiometry

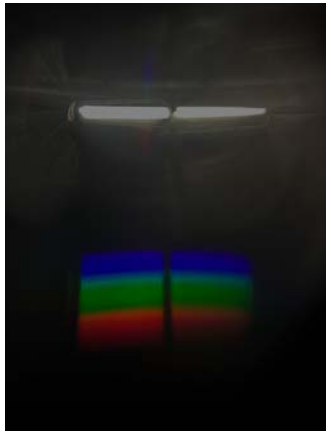


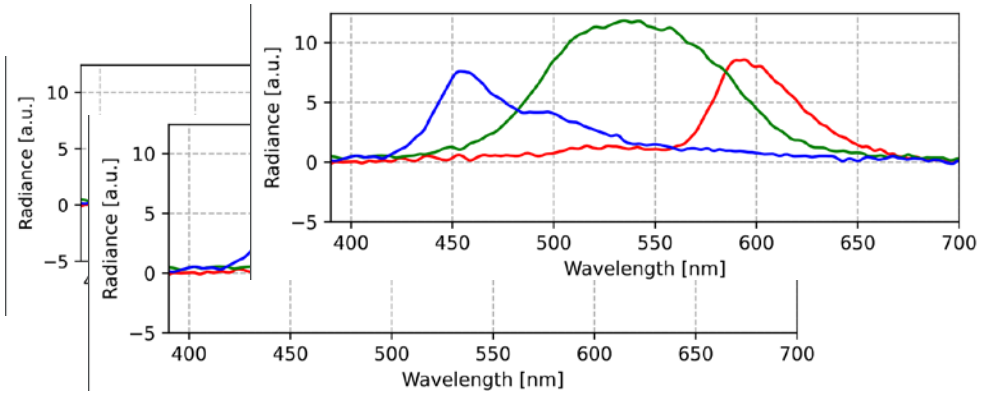
iSPEX 2 data collection



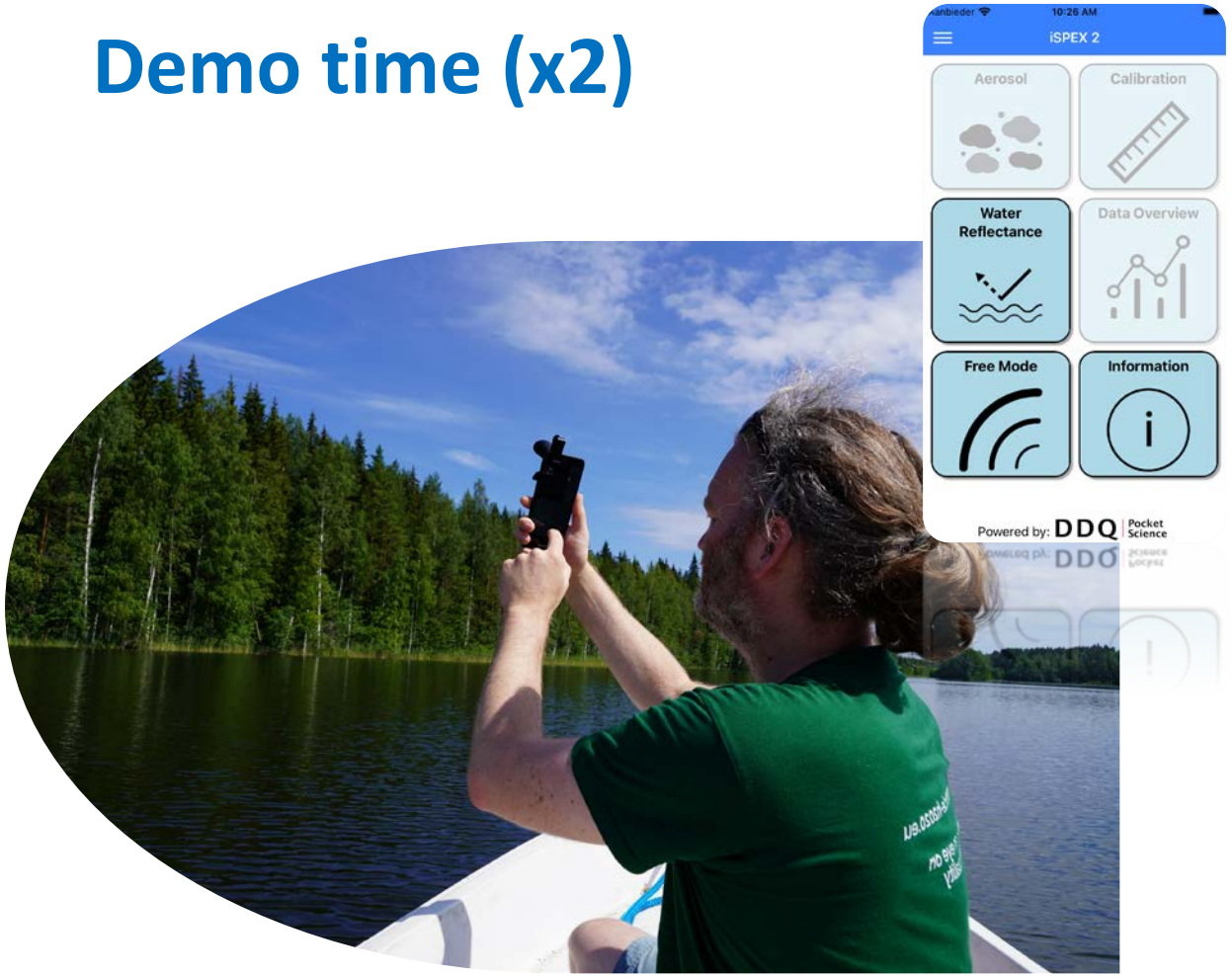




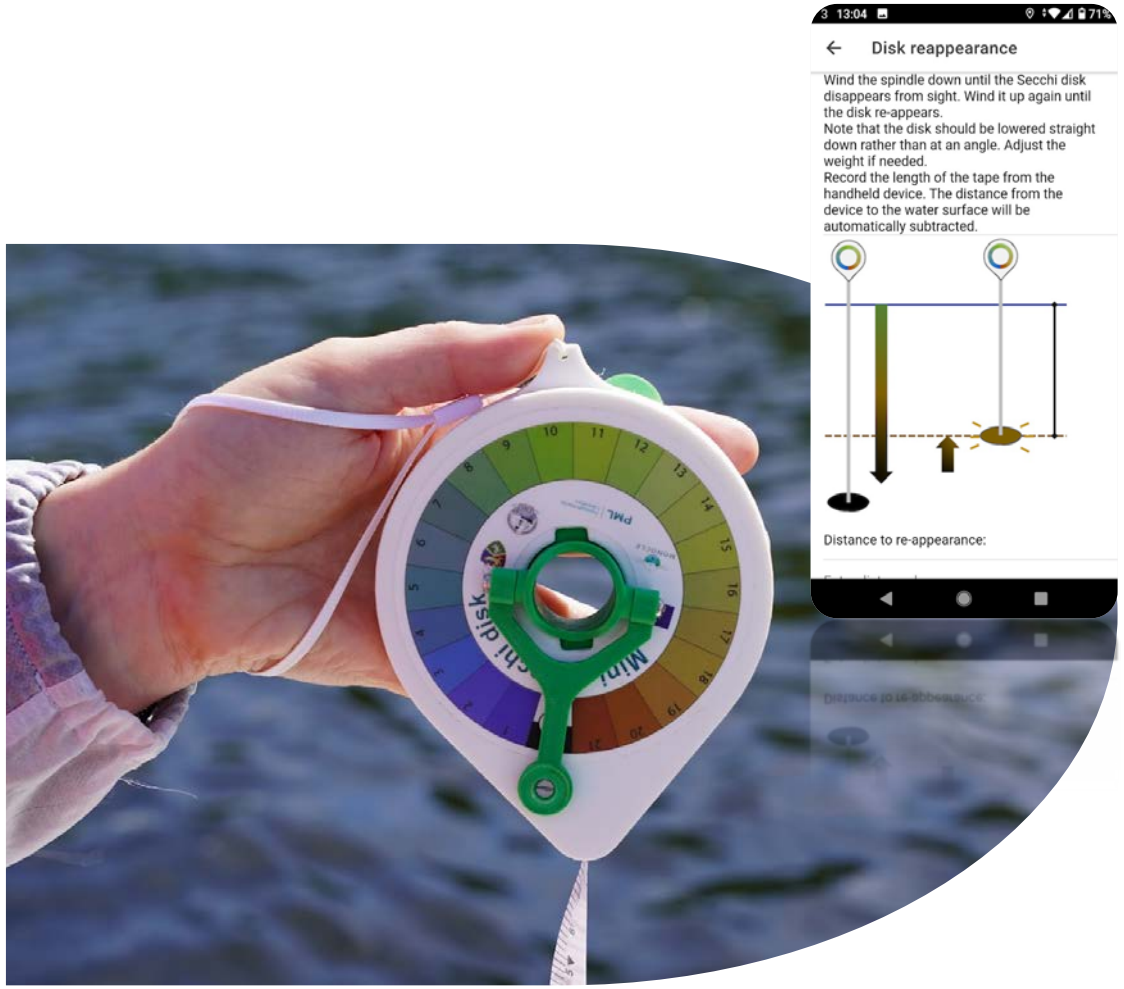




Demo time (x2)



iSPEX 2: water colour/reflectance



Mini-Secchi disk: transparency, colour-by-eye, pH
'mini Secchi' in app stores
https://www.brewtek.online to build or purchase