UV Ground-based imaging camera: EnviCam

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UV Camera systems

Development of an Ultra-Violet Digital Camera for Volcanic SO$_2$ Imaging


500 td $\sim$ 5800 g/s
UV Camera for volcanic SO$_2$

Toshiya Mori and Mike Burton
The SO$_2$ camera: A simple, fast and cheap method for ground-based imaging of SO$_2$ in volcanic plumes

# The NILU UVCam

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength range</td>
<td>200–600 nm</td>
</tr>
<tr>
<td>Pixels</td>
<td>1344 x 1024</td>
</tr>
<tr>
<td>UV lens</td>
<td>50 mm f/3.5</td>
</tr>
<tr>
<td>UV filter</td>
<td>307±5 nm</td>
</tr>
<tr>
<td>Quantum efficiency</td>
<td>25% @ 250 nm</td>
</tr>
<tr>
<td>Digitisation</td>
<td>10 bits</td>
</tr>
</tbody>
</table>

A portable UV imaging camera for industrial and anthropogenic gas emission monitoring and assessment.
Calibration Cells
Apogee UV camera
Filter wheel and lenses
Selecting the bands

Intensity ratio

Intensity ratio [AU]

SO2 concentration [10^18 mol/cm^2]

- 310 nm, FWHM: 10 nm, T = 0.65
- 320 nm, FWHM: 10 nm, T = 0.25
- 325 nm, FWHM: 10 nm, T = 0.12
- 326 nm, FWHM: 10 nm, T = 0.12
- 326 nm, FWHM: 3 nm, T = 0.15
EnviCam 1
Users

Mike Burton (INGV)
Fred Prata (NILU)
INOE – Romania (5 cameras – industrial pollution)
Nick Varley (U of Colima)
Simon Carn (MTU)
Matt Watson (Bristol U.)
Users - Envicam 2

SERNAGEOMIN - VHP/Chile
- 3 cameras - volcanoes

Matthias Hort -
- 1 camera - volcanoes

JRC/European Commission
- 1 camera - ship emissions

NILU
- 2 cameras - volcanoes/ship emissions

South Africa
- 1 camera - industrial emissions
SUVEX: Svalbard UV EXperiment
Cruise ship visits to Ny Ålesund
Summer 2009

Passenger numbers

Week number

Passenger numbers

SUVEX
The Costa Majica at anchor in Kongsfjorden, 03.08.2009 (approx. 3,500 passengers)
Visible and UV camera comparison
Costa Majica entering Kongsfjorden

Costa Majica arriving at Ny Alesund 02.08.2009 Start time: 16:34:18 UTC

Mean (3-min) = 13.9 ± 3.2 gs⁻¹
Mean (3-min) = 3.8 ± 1.0 g s⁻¹

Visible camera image

UV camera image

Mona Lisa at anchor at anchor, Ny Alesund 30.07.2009 Start time: 18:57:00 UTC

Mona Lisa at anchor (in fog)
## Summary

Results are preliminary and should not be reproduced without permission from NILU

<table>
<thead>
<tr>
<th>Ship</th>
<th>GRT§</th>
<th>(\text{SO}_2) Emission rate (gs(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS Expedition</td>
<td>6,336</td>
<td>11–14 (7.8*)</td>
</tr>
<tr>
<td>Sergei Vavilov</td>
<td>6,450</td>
<td>8.5</td>
</tr>
<tr>
<td>Mona Lisa</td>
<td>26,678</td>
<td>3.8*</td>
</tr>
<tr>
<td>Costa Majica</td>
<td>102,587</td>
<td>10–18</td>
</tr>
<tr>
<td>Ny Ålesund power plant</td>
<td></td>
<td>&lt;0.5 gs(^{-1})</td>
</tr>
</tbody>
</table>

*At anchor

§Gross Registered Tonnage
Rotterdam Ship Emissions Campaign 14–29 September, 2009

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UV Camera at Hoek van Holland

Calibration cell
UV Camera on Stena Ferry

Camera pointing at one funnel
UV Camera at Hoek van Holland

Emissions from power plant potentially cause much higher background levels
NILU UV camera in operation

Port of Rotterdam
Emissions from power plant

- Emission rate: 670.4 gs⁻¹
- Emission range: 670.0 — 670.9 gs⁻¹
- Peak path conc: 4.700 gm⁻²
- Mean path conc: 3.068 gm⁻²
- Std. dev: 1.550 gm⁻²
- Plume thickness: 19.9 m
- Date: 18.09.200
- Time: 1515LT
- Distance: 400 m
- Frame: 130 Pixel: 350
Summary of some measurements

Ship emissions, Hoek van Holland. 16.09.2009

SO$_2$ emission rate (gs$^{-2}$)

Relative time (mins)

Stena

Planet V

Norfolk

NILU
Some ships ...
Power plant in Australia
Instrument set-up
SO$_2$ emissions
The Genova Ship Emissions Campaign

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Motivation

Ship emissions considered an important contributor to climate change and environmental pollution ($SO_2 \sim 7\%$ of global emissions; $-0.11\text{ Wm}^{-2}$ forcing)

Virtually no incentive for ships to reduce emissions

Current estimates of ship emissions are based on global bunker fuel sales

New EU regulations (July 2010, Annex VI MARPOL) need enforcement (traditional estimates based on inventories)

JRC are leading a project to investigate possible technologies for measuring ship emissions ($SO_2$, NOx, CO$_2$)
Logistics

Participants:
• JRC (Lead)
• NILU (Fred Prata)
• OctoCopter pilot (Wolfgang)

Where:
Genova harbour area

Platform:
Guardia Costea vessel
3 days hire; 6 hr per day

Measurements:
Gas sniffers (NOx, SO₂, CO₂)
UV imager (SO₂/particles)
OctoCopter (SO₂)
Ship speed, position, direction.
EnviCam (nearly 2)
Example

\[ A = -\ln \left( \frac{I}{I_0} \right) = \alpha \rho L \]
EnviCam
Measurements
OctoCopter

UAV
8 propellers
Battery powered
Maximum load 1 kg
Endurance (under load) ~7 minutes
OctoCopter SO₂ canister

Jacob (JRC-?)

Wolfgang (?-Austrian)

Fritz (JRC-Austrian)

Balint (JRC-Hungarian)

Canister with SO₂ cells
Canister
CE Merapi

Seattle Bridge

Alessandro F

San Francisco Express
Results (very preliminary)

0.1 ppm*m, 2 m thick plume gives concentration ~50 ppb
... how not to fly an OctoCopter
Ferry measurements at Punta Arenas - 13 January, 2011