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C2RCC Community Project

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[2] HEREON
[3] Brockmann Geomatics AB
[4] Ocean Obs AS

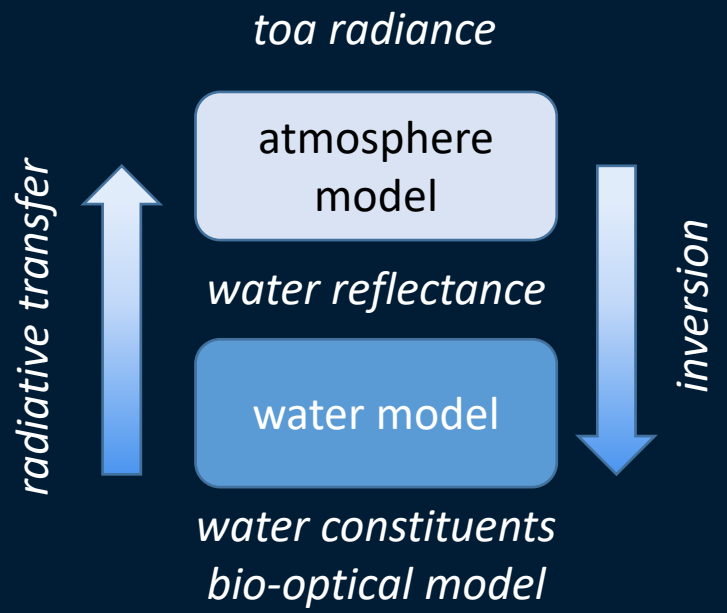
ESA Living Planet Symposium 2022, Bonn, Germany

C2RCC in a nutshell

- A method and related software to perform
  - Atmospheric correction
  - Retrieval of water optical properties (absorption, scattering)
  - Retrieval of concentrations of water constituents (Chl-a, TSM, YS, …)
  - Multi-sensor
- The method‘s core idea
  - Inversion of the radiative transfer in water and atmosphere with Machine Learning
  - Set of artificial neural nets, trained on simulated spectra
  - Schiller and Doerffer 1999
- The software
  - Open source
  - Plug-in to the SNAP toolbox
  - Processing of single images up to mass production in operational environments

Components to be addressed in Water Colour Remote Sensing

- Optical characterisation of the atmosphere
  - Aerosol type and concentration, gaseous absorption, surface pressure, …
  - Adjacency effect, shadows, …
- Optical characterisation of the water body
  - Bio-optical model
  - Type (specific optical properties) and concentration ranges of water constituents
  - Relationship between optical properties and concentration
  - Bottom reflection
- Mathematical model to invert the radiative transfer problem
  - Empirical, semi-empirical, analytical

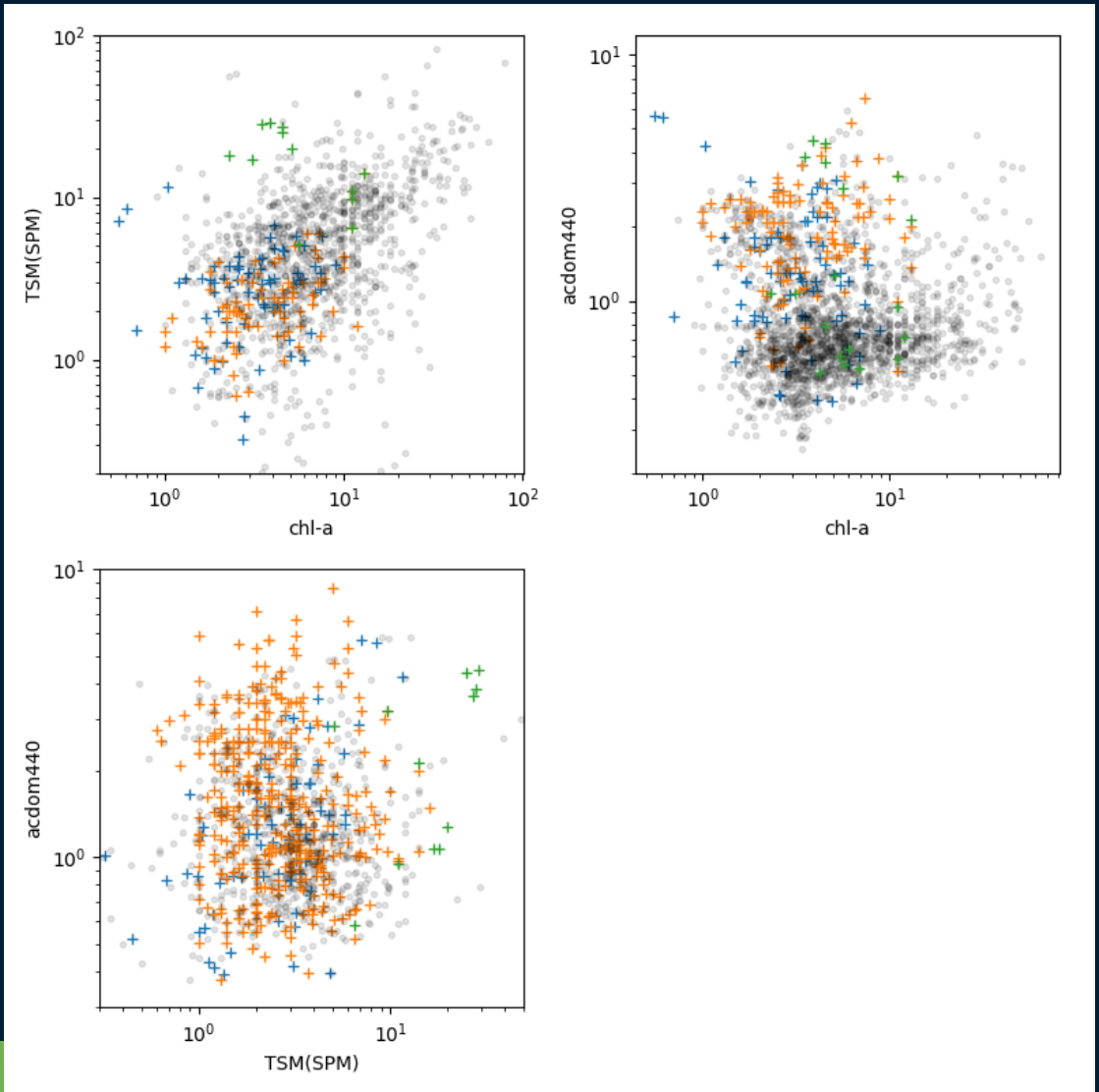


Definition of the bio-optical model and training dataset

- Analysis of in-situ measurements to understand the bio-geochemistry of the water body to be addressed
  - Global model?
  - Region specific model?
- Selection of phytoplankton assambledges = SIOPs
- Definition of concentration ranges
- Definition of co-variances
- Algorithm to populate the training dataset equally
- Investigating radiance vs IOP spaces – reducing ambiguities

- This is the most crucial step in the whole process of C2RCC development

Relationships of IOPs in in-situ measurements



Baltic Sea Example, Baltic+ SeaLaBio Project

In-situ data from **FIN** + **SWE** + **Estuaries**
+ estimates from secondary variables:

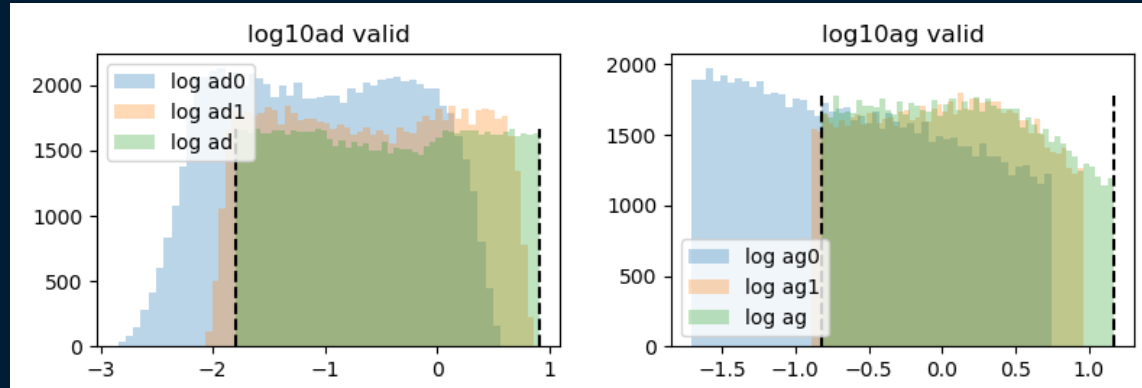
- TSM from turbidity,
- acdom440 converted from acdom400
- acdom440 estimates from PtColor and Salinity.

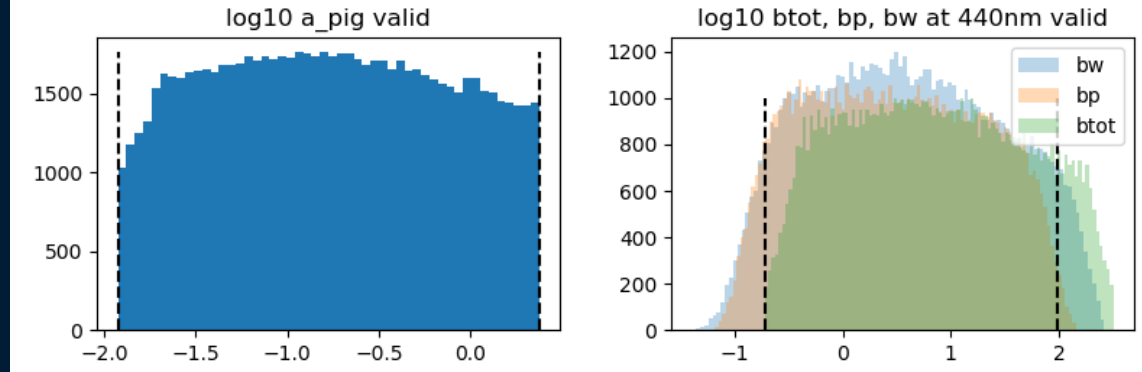
From the in-situ data the following dependencies are implemented:

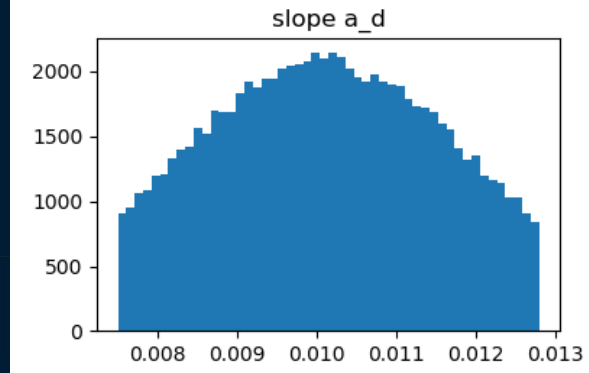
- Chl-a, TSM: linear with wide range of scatter.
- No special treatment of the estuary data.

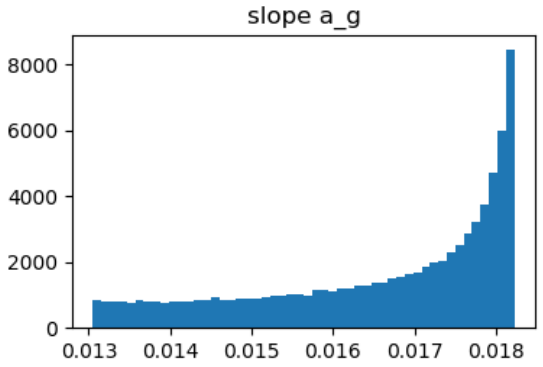
IOP combinations: Distributions

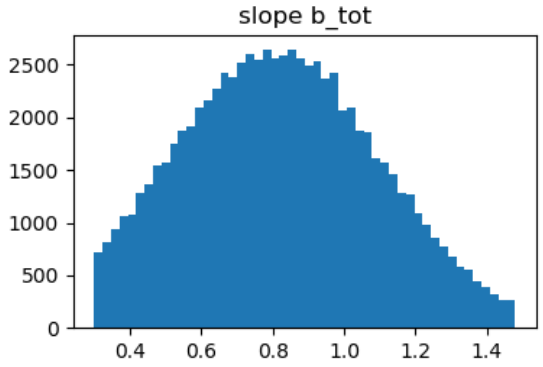
For the training of a NN, the variables should be uniformly distributed.
After the selection process, not all variables are uniformly distributed.

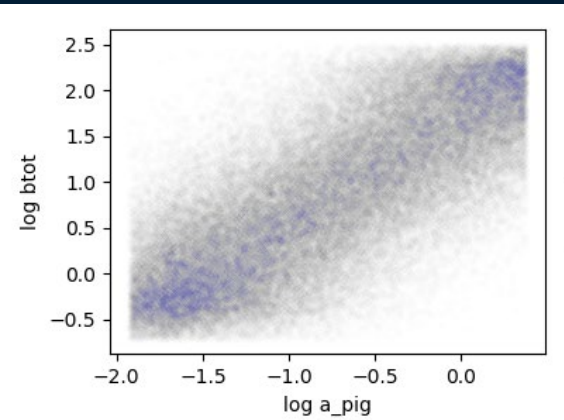


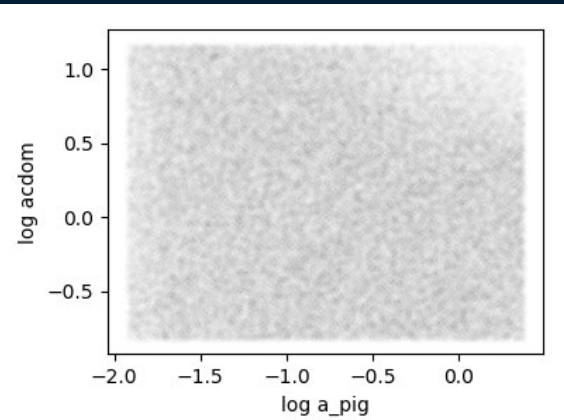


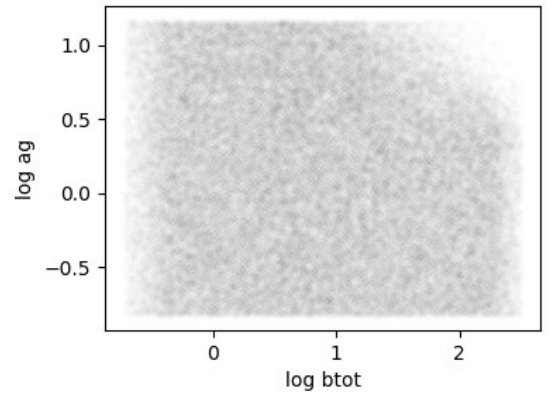


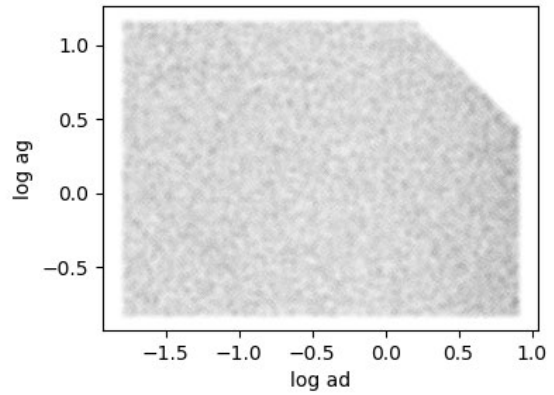












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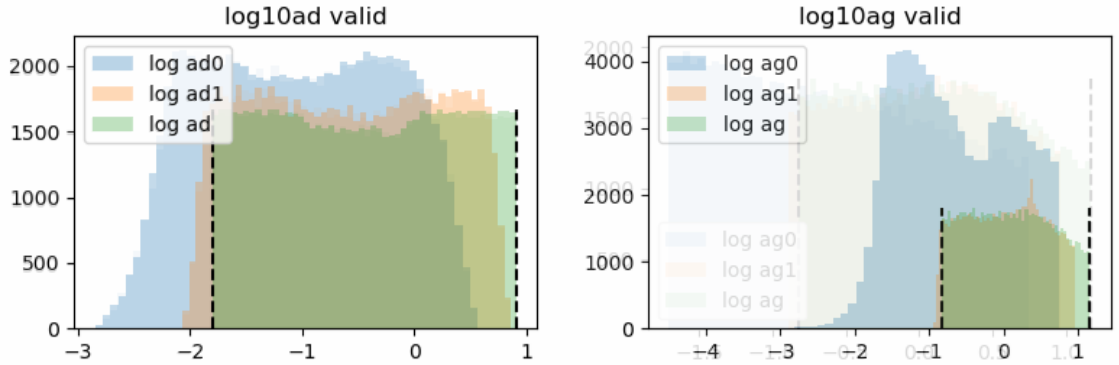
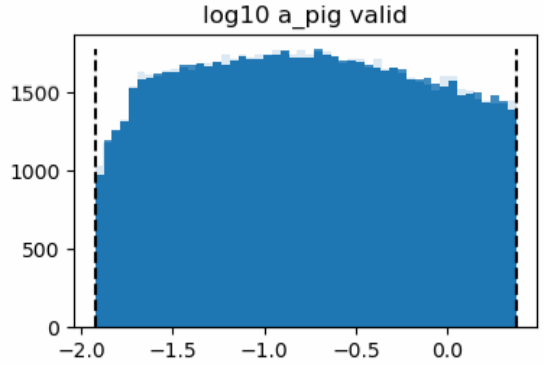
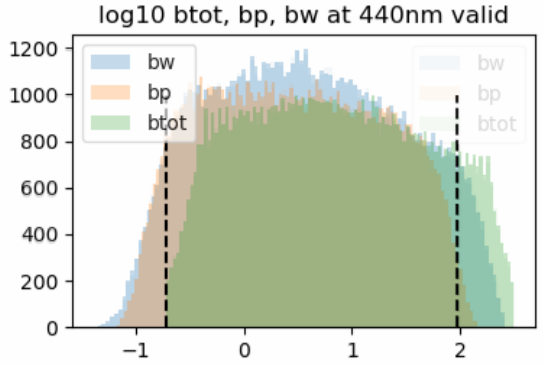
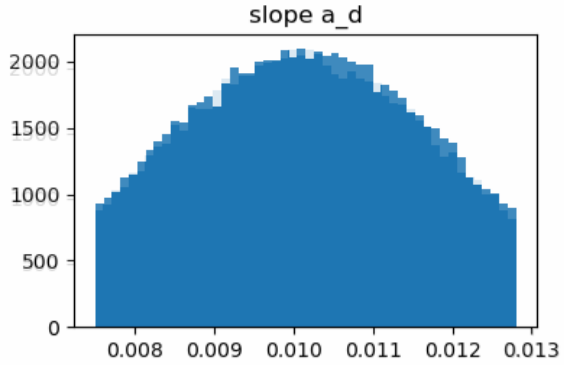
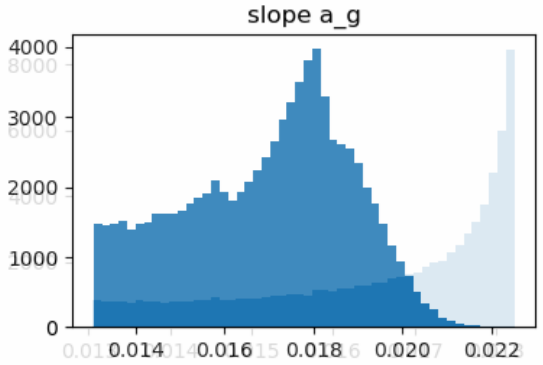
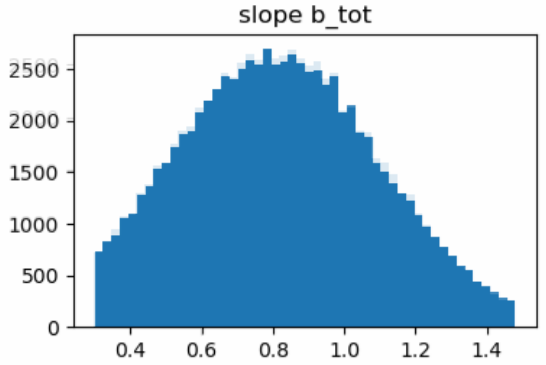


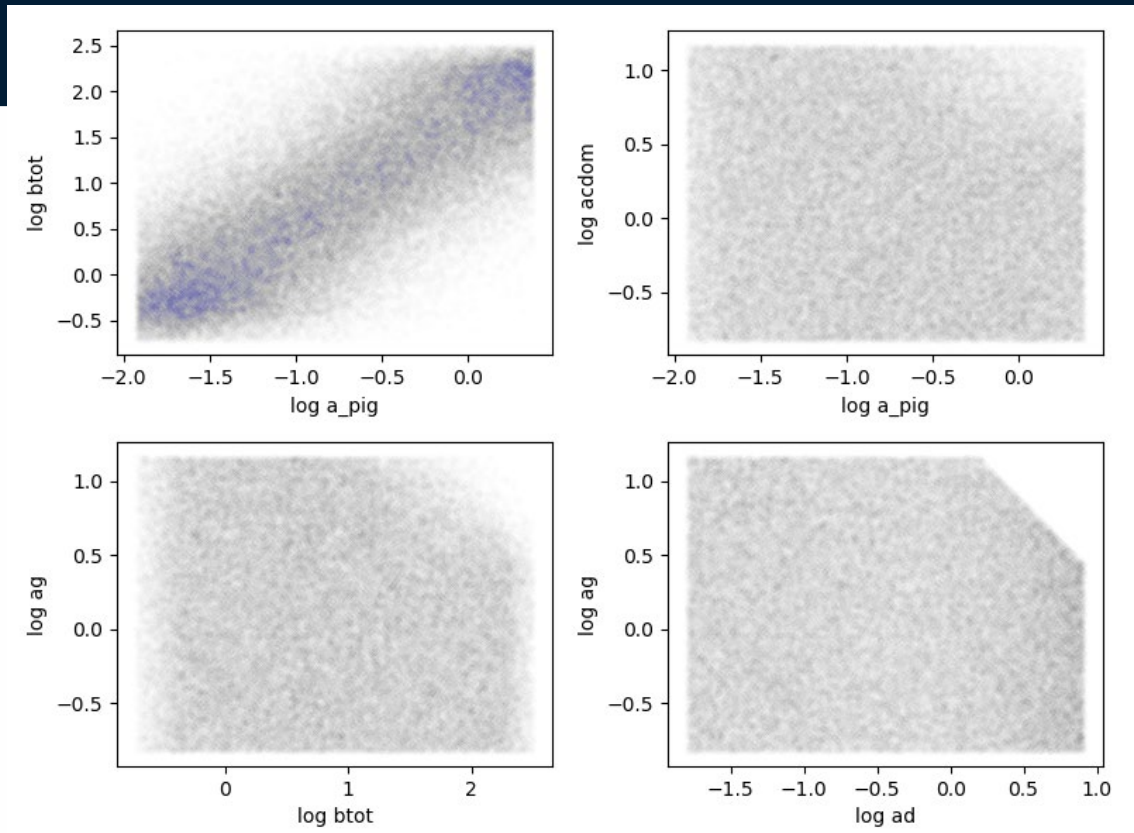




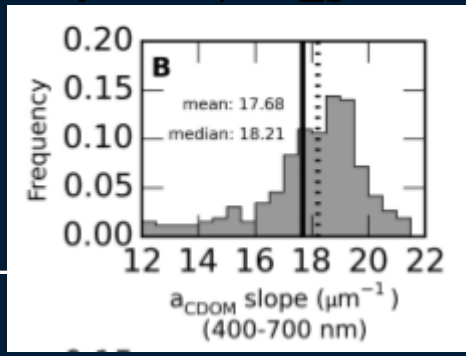








Adjust slope a_g !



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C2RCC Derivatives & Evolutions

- Baltic+ Approach by Mazeran, Müller & Steinmetz
  - Water model using C2RCC neural net with a dedicated Baltic bio-optical model
  - polynomial approach as in polymer to model atmosphere
  - Minimization approach for inversion

- ONNS and A4O by Hieronymi
  - ONNS - Swarm of neural nets for in-water processing
  - A4O – ensemble of AC neural nets for optical water types
    - See **poster 355** *Atmospheric correction for diverse optical water types (A4O)* during poster session on Tuesday

Validation of C2RCC CHL in Lakes

DASIF project

Indicators for Climate Change Mitigation Measures

Including phenology in lakes, using C2RCC on S2 MSI

Financed by German UBA

Conducted by Brockmann Consult & Uni Kiel EOM

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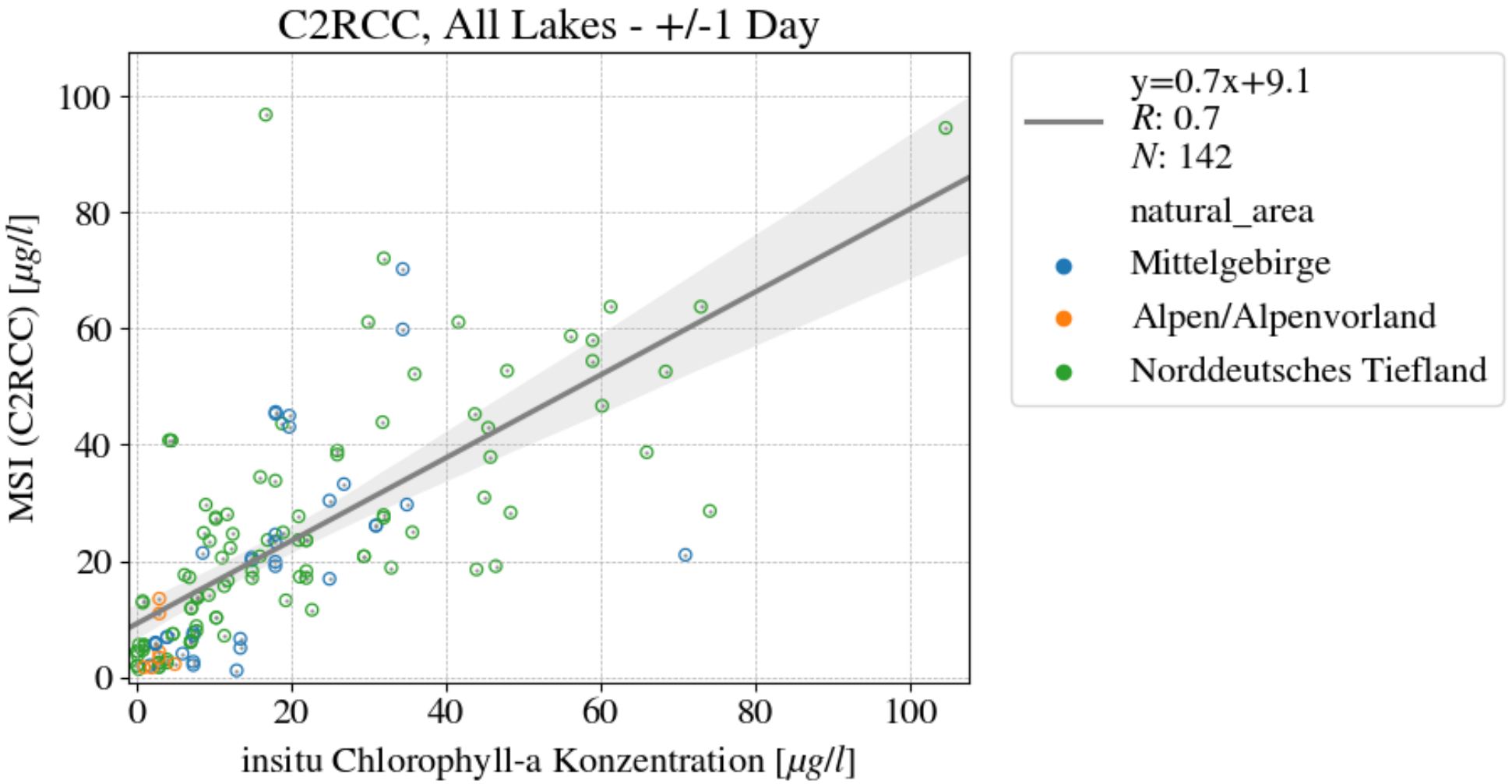

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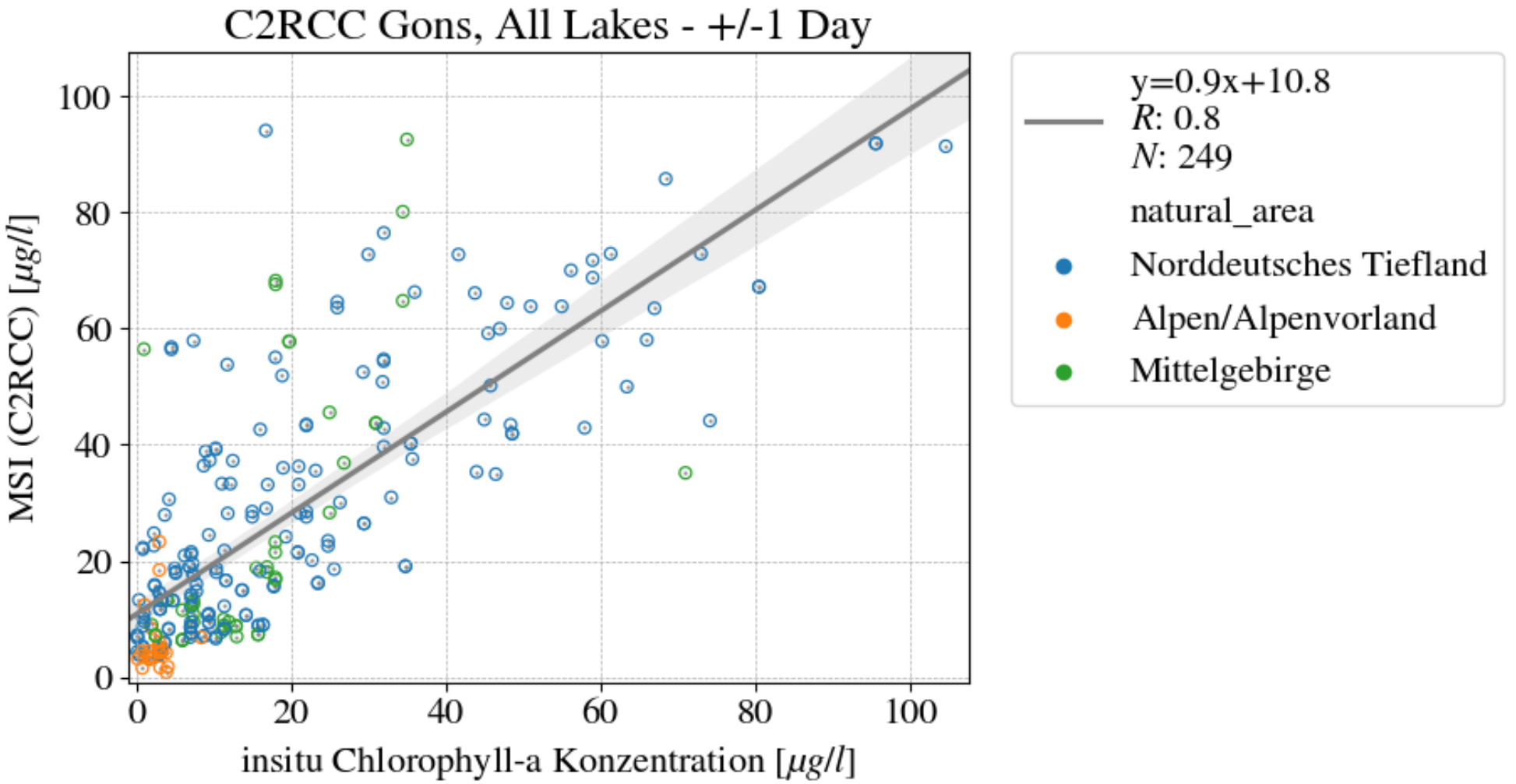

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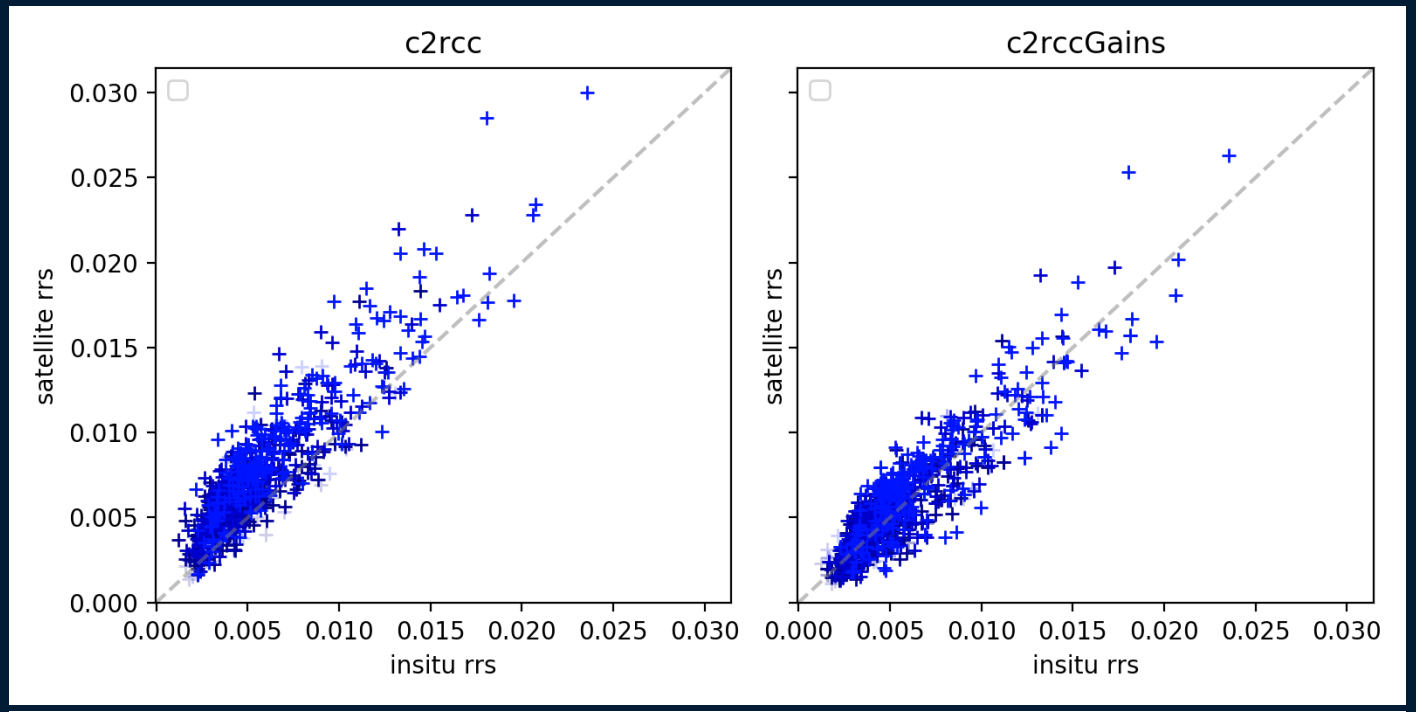
SVC for OLCI

- Deriving SVC gains for C2RCC is methodologically challenging

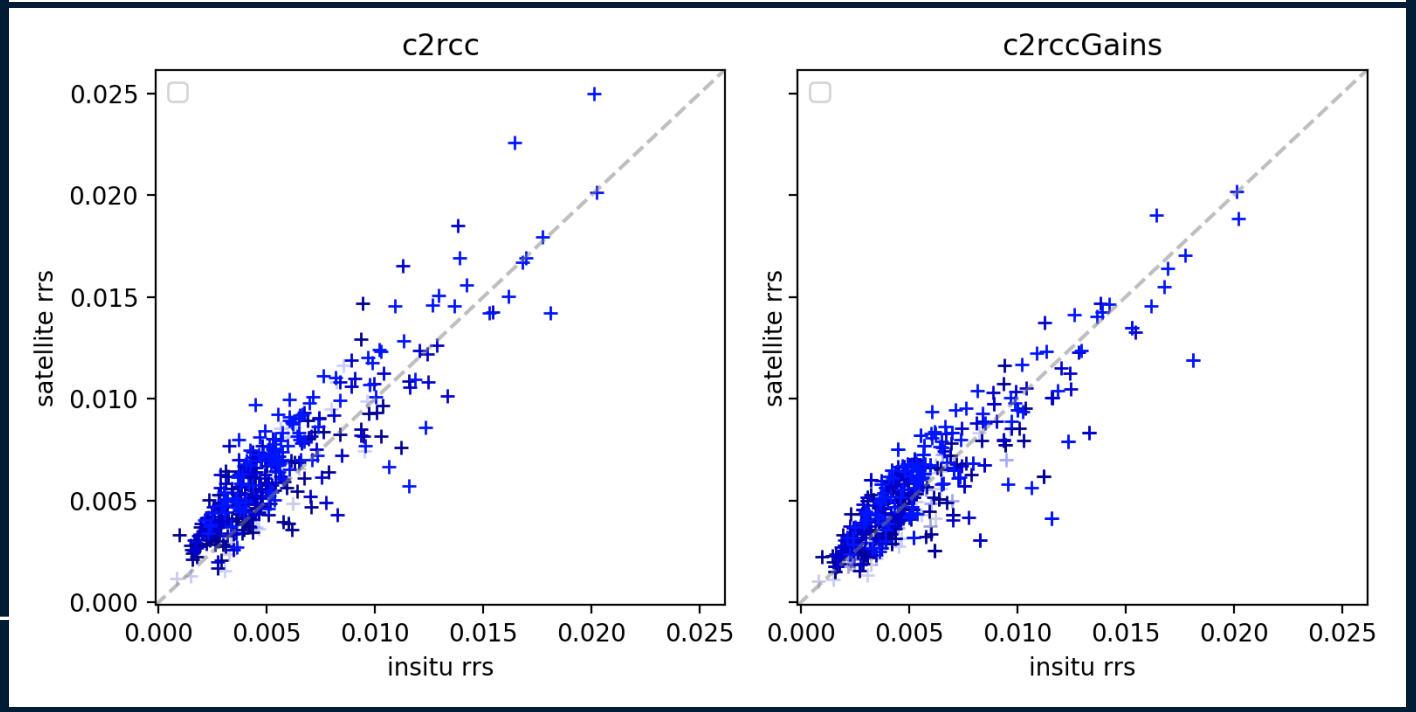
- Investigating effect of SVC gains from standard-AC as published by Eumetsat, on C2RCC at Aeronet stations

Venise

S3A



S3B



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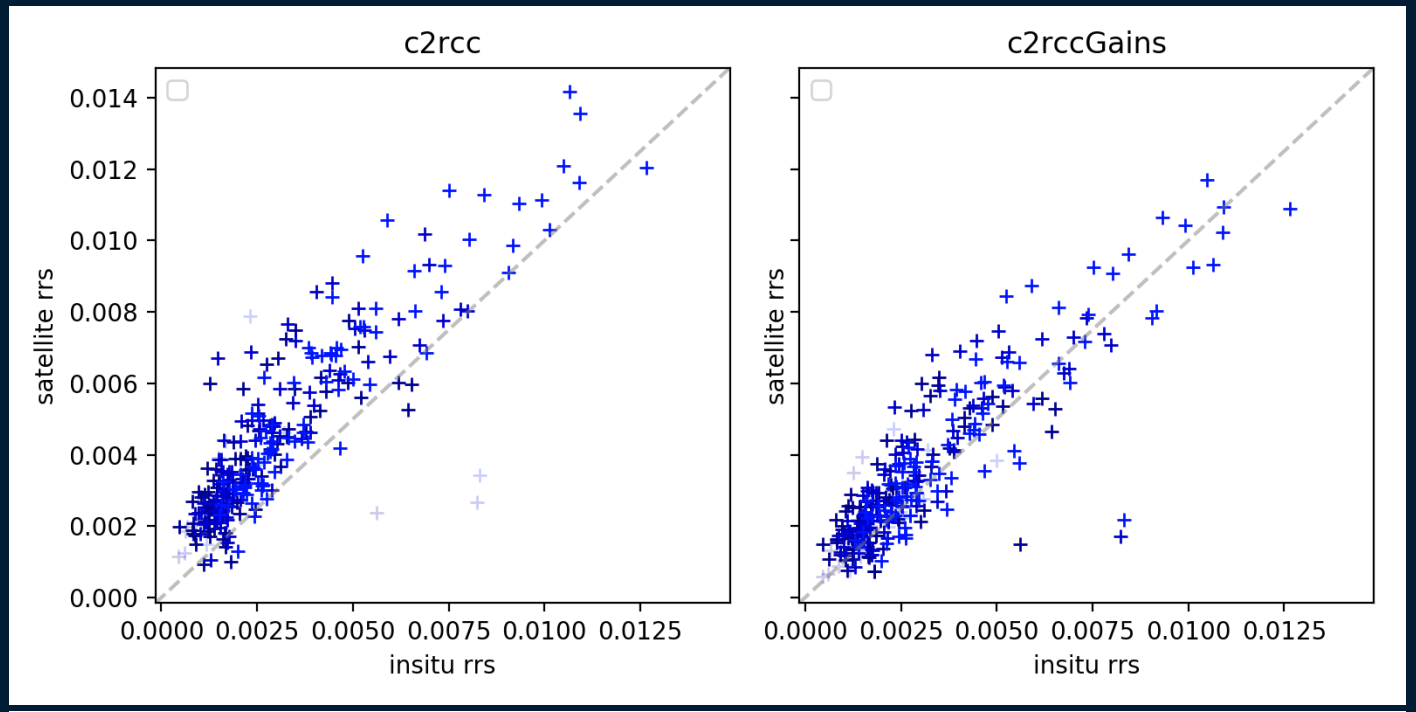
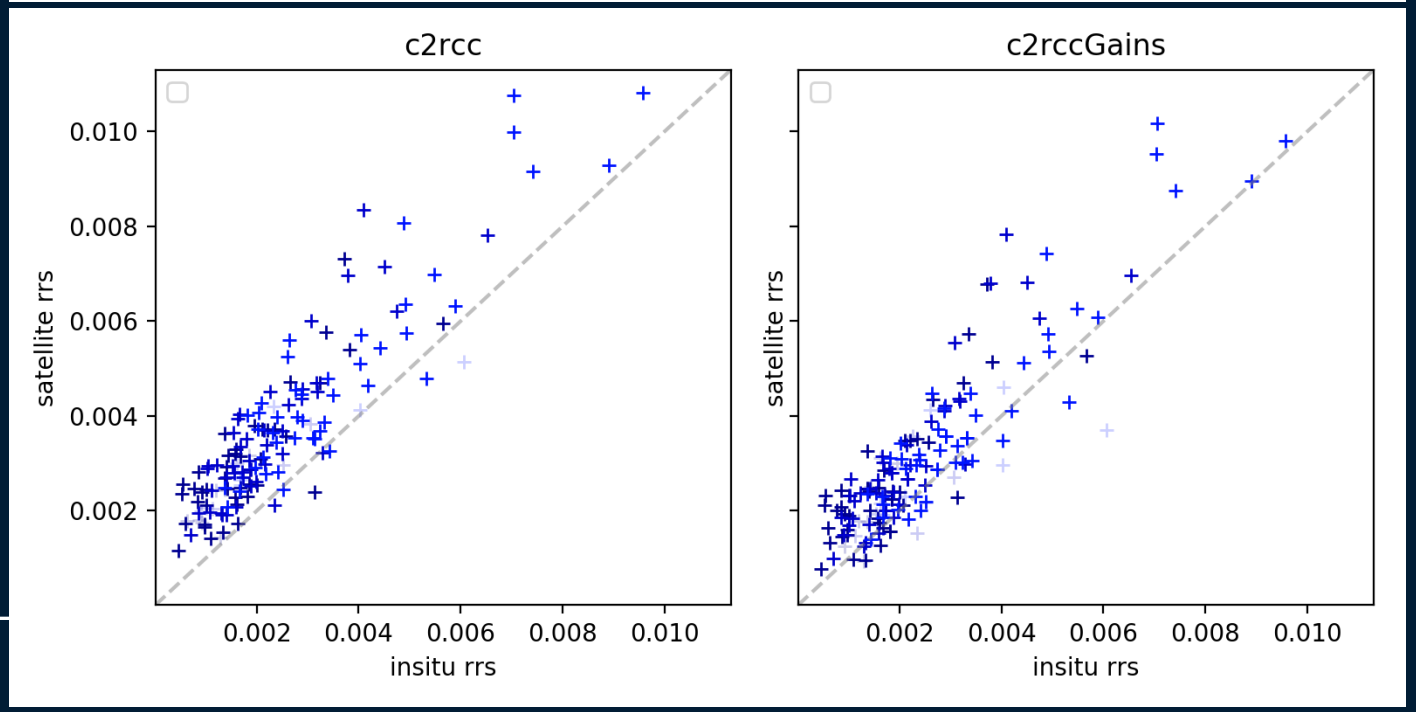
WaveCIS 6

S3A



S3B



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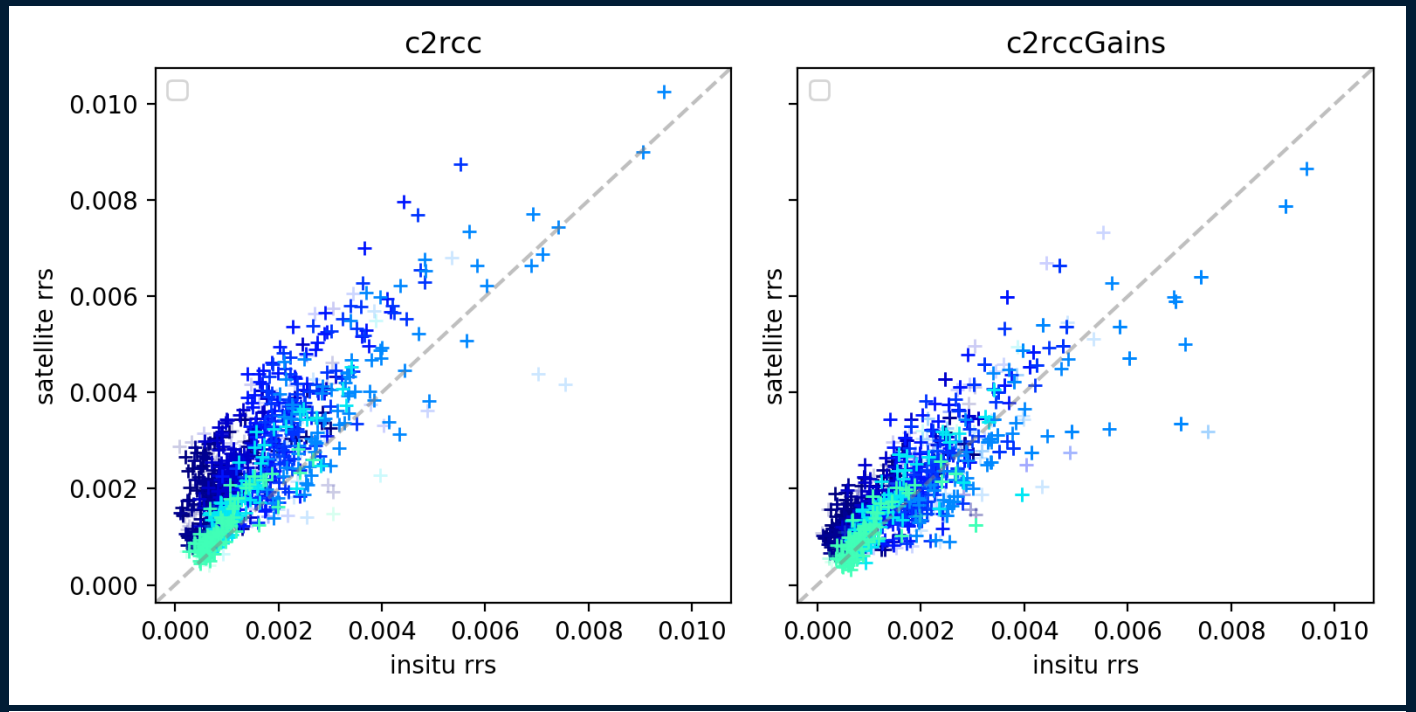
Gustav Dalen Tower

S3A



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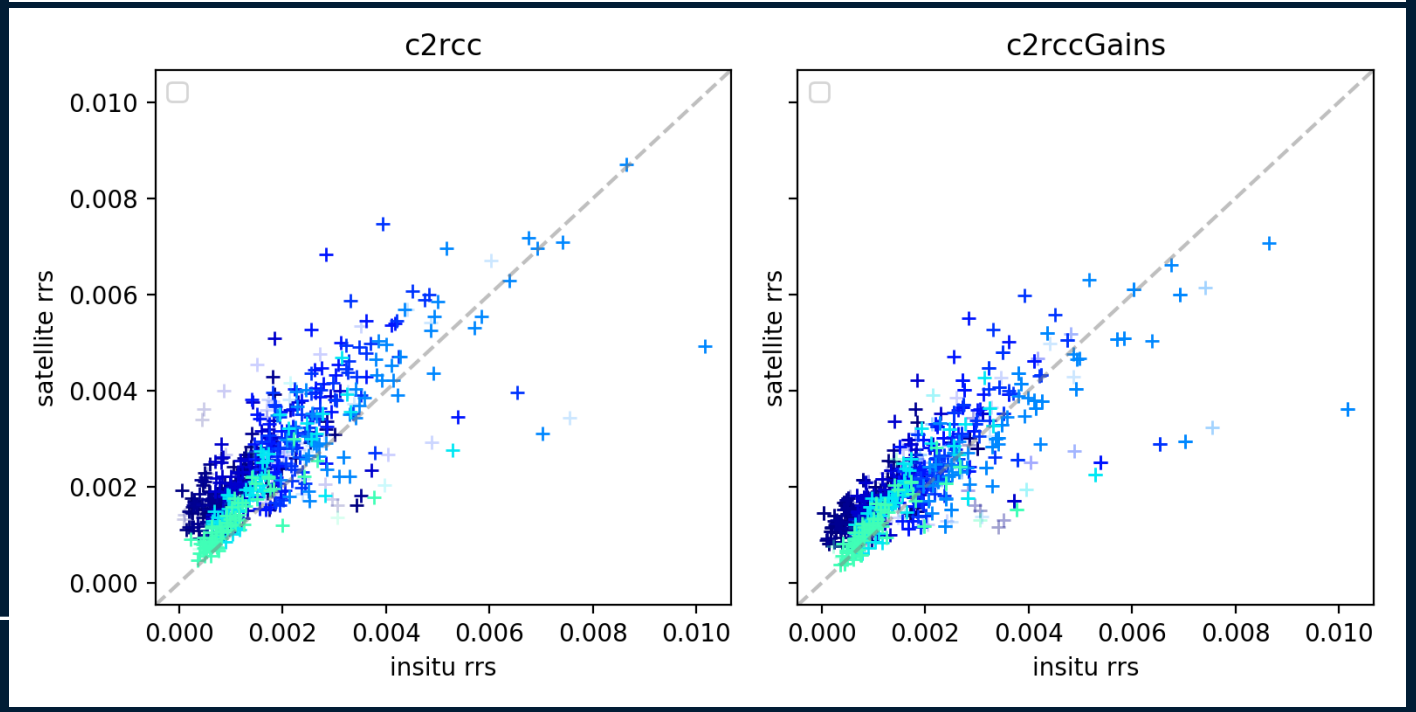

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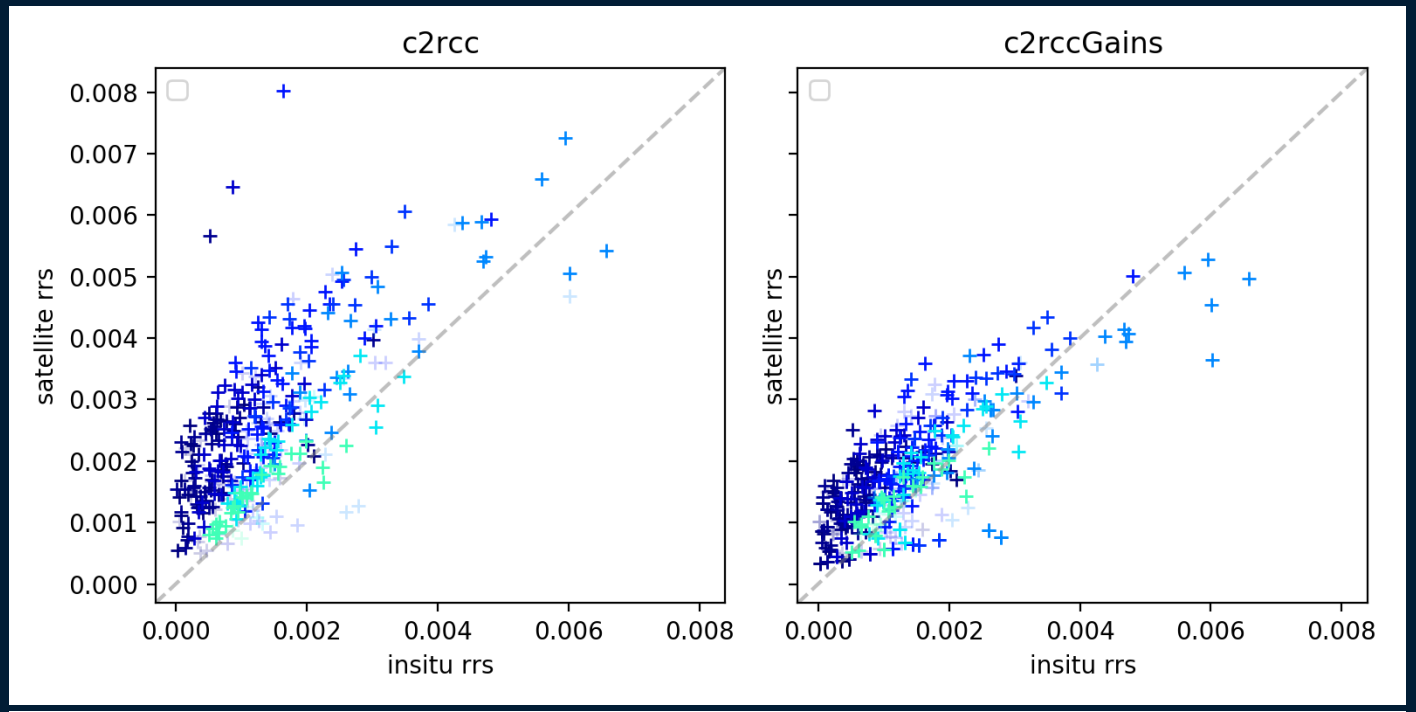
Helsinki Lighthouse

S3A



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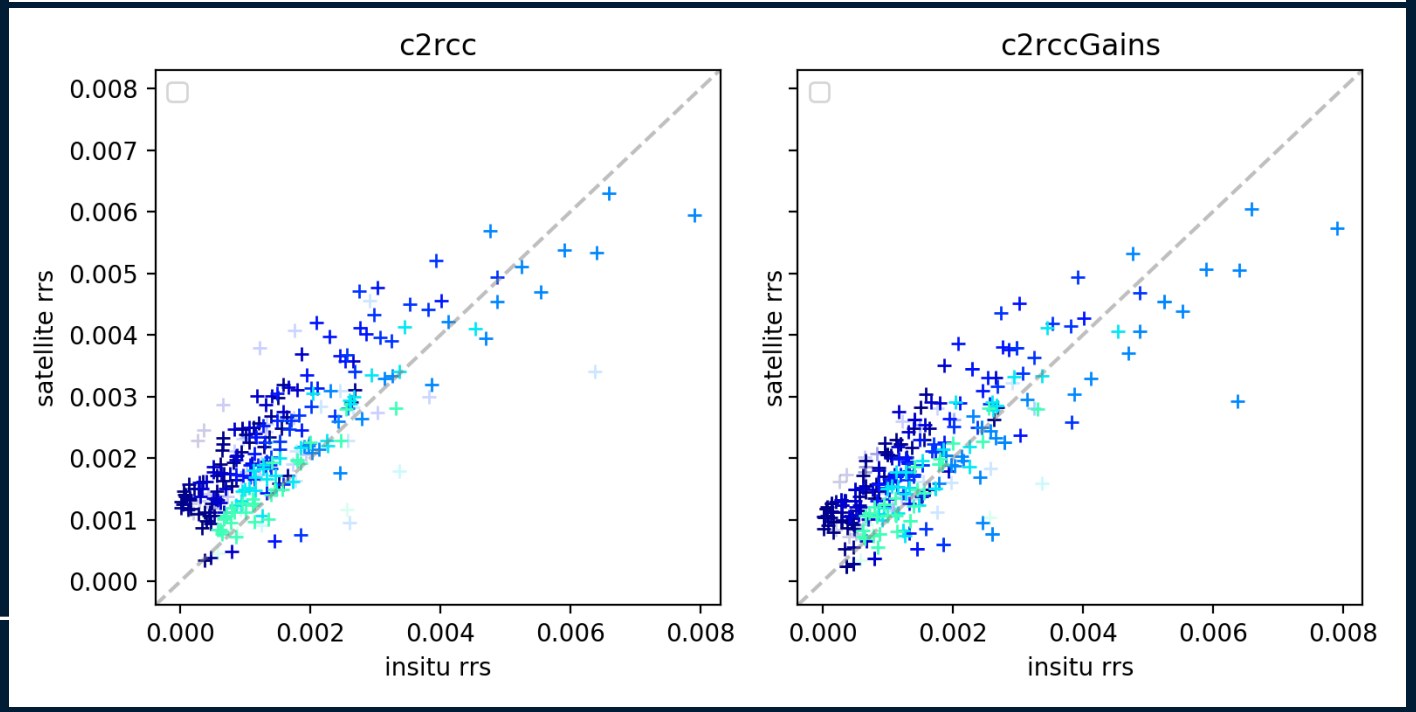

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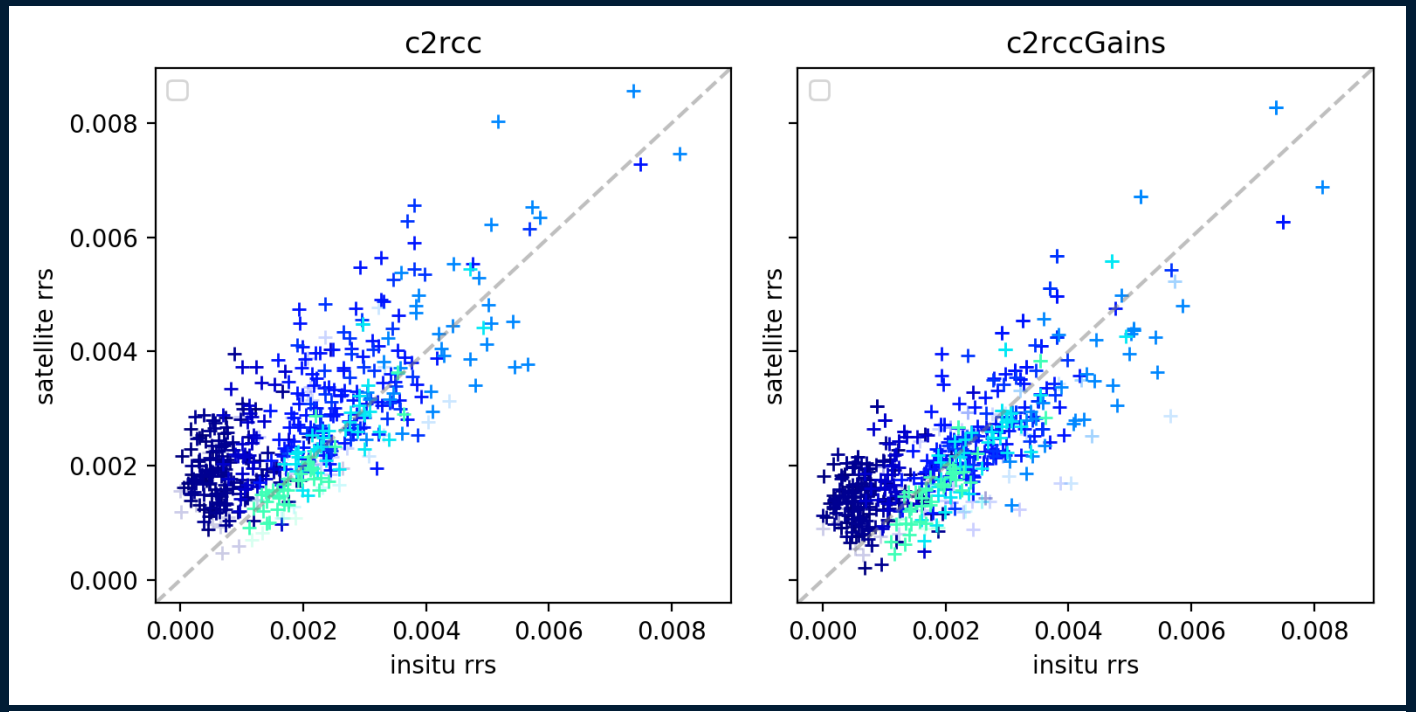
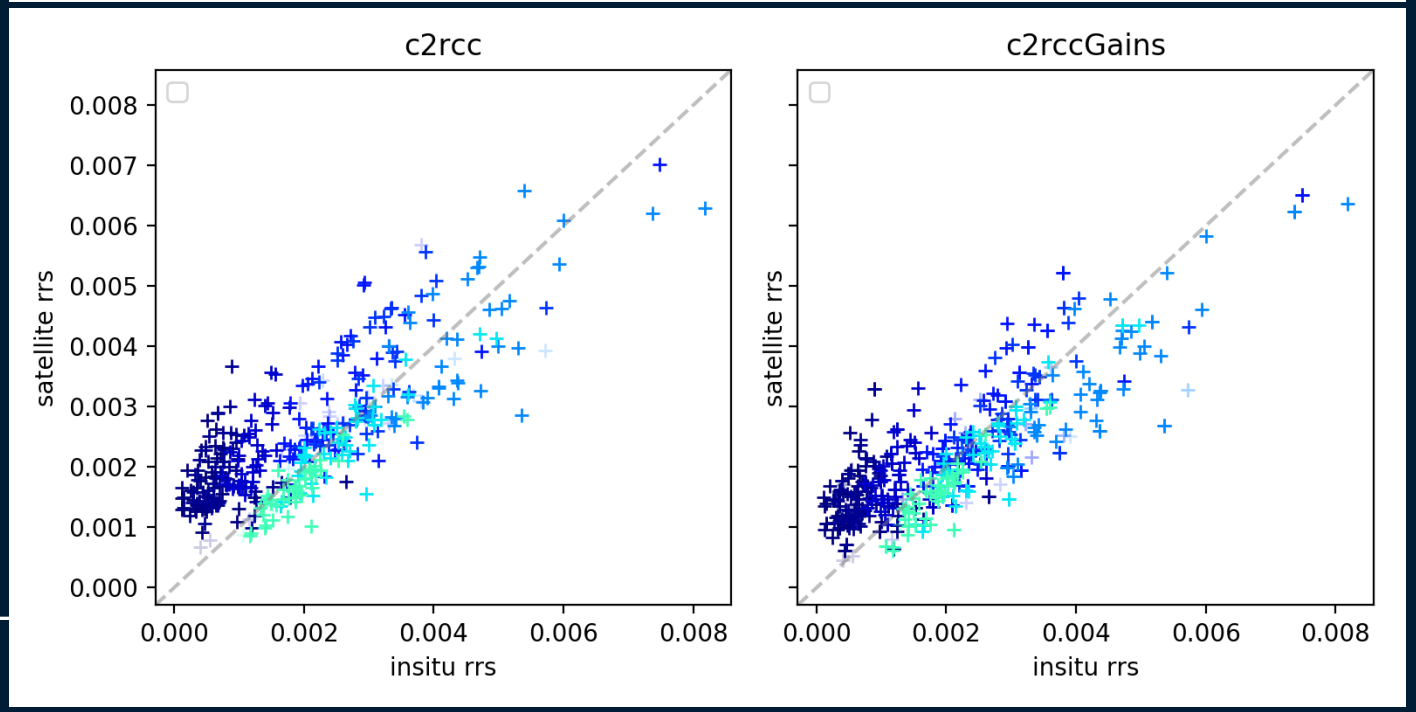
Palgrunden

S3A



S3B



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SVC gains for OLCI

- SVC gains from standard-AC improve the AC
- Significant positive effect on OLCI-A
- Less important but still noticeable effect on OLCI-B

C2RCC Community Project

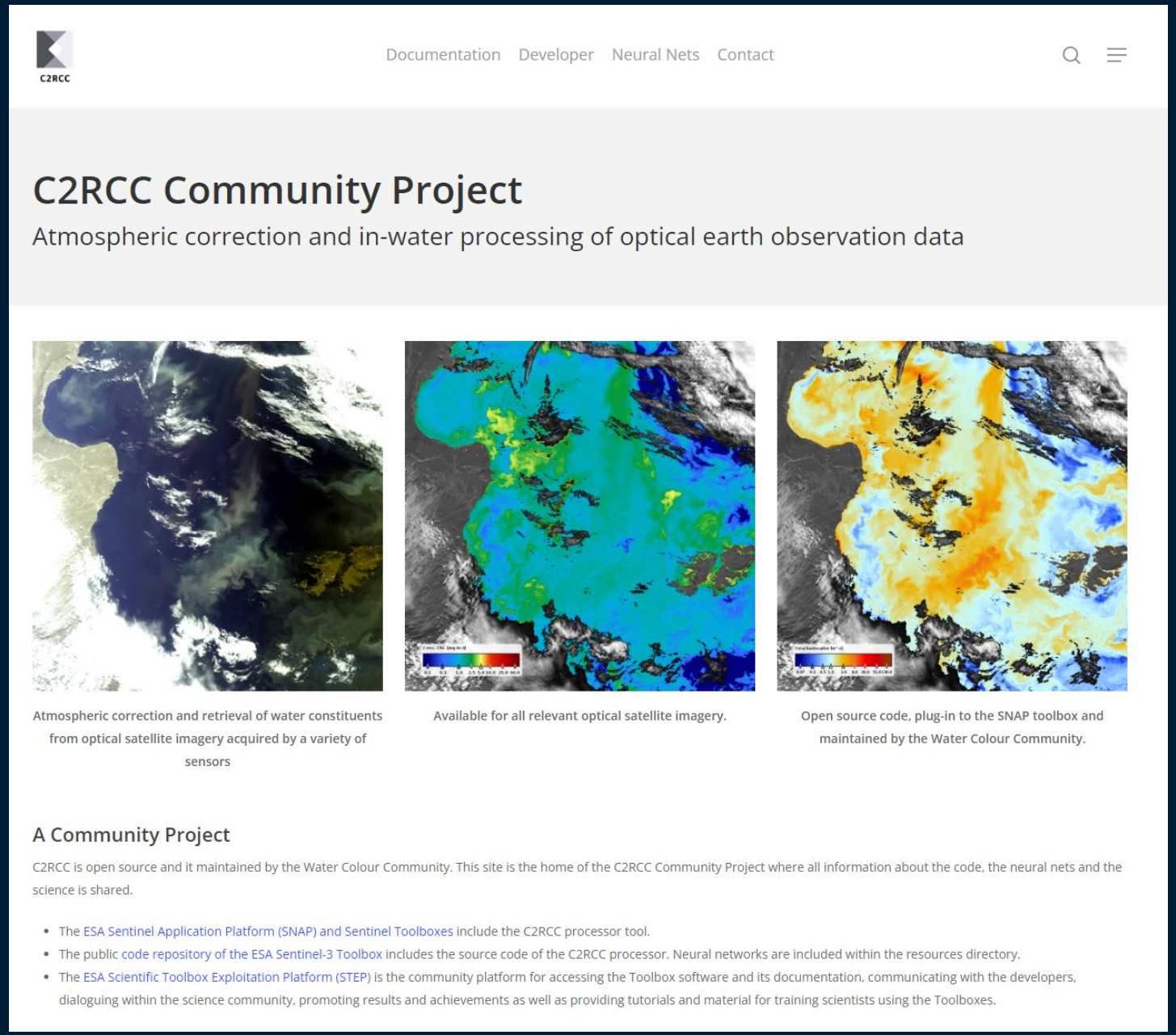
- Water Colour Remote Sensing requires broad range of know-how (see first slide) …
  - Optical characterisation of water including bottom substrate
  - Optical characterisation of the atmosphere
  - Radiative transfer modelling
  - Inversion methods
- … which available in the community
- … which is invited to contribute to the further development of the C2RCC processor

- C2RCC Community Project
  - Share detailed information about C2RCC (documentation, code, know-how)
  - Share findings, ideas and code-experiments
  - Release consolidated new versions

Subjects

- optical properties of aerosols and atmospheric gases
- specific inherent optical properties of water constituents (SIOP, ranges)
- models that link optical with biogeochemical parameters
- optical water type classification (OWT)
- phytoplankton diversity
- validation data (link to in-situ databases such as Limnades, EUM OCDB, NASA SeaBASS)
- training datasets derived by RT modelling (well referenced to above IOPs)
- trained neural nets for
  - atmosphere inversion (water leaving reflectance)
  - path reflectance
  - atmospheric transmittance
  - auto-associated nets for out-of-scope testing
  - water forward
  - water inversion (IOP retrieval)
  - kd spectral
  - uncertainties of IOPs
- applicability to new sensors

C2RCC.org



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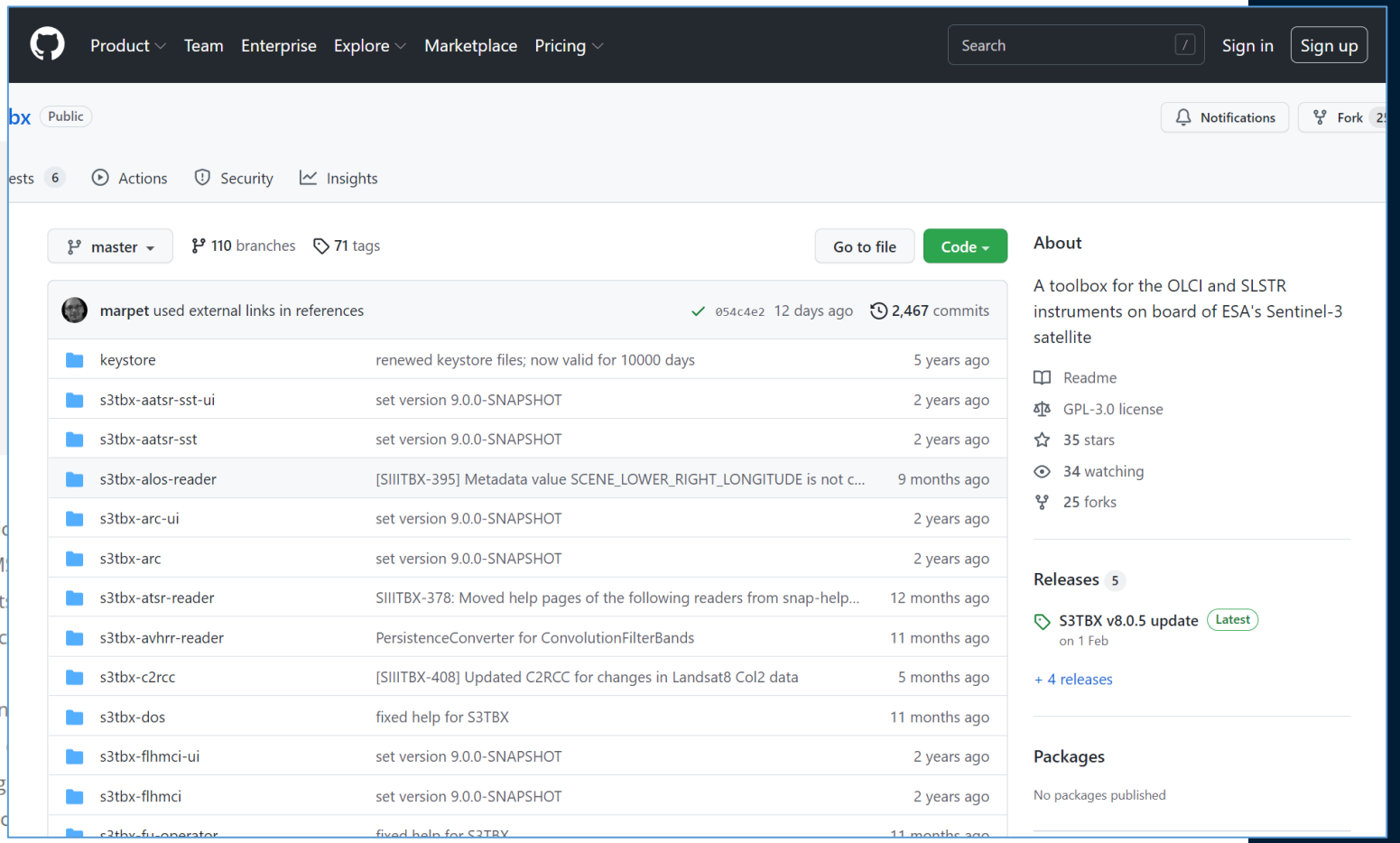
C2RCC

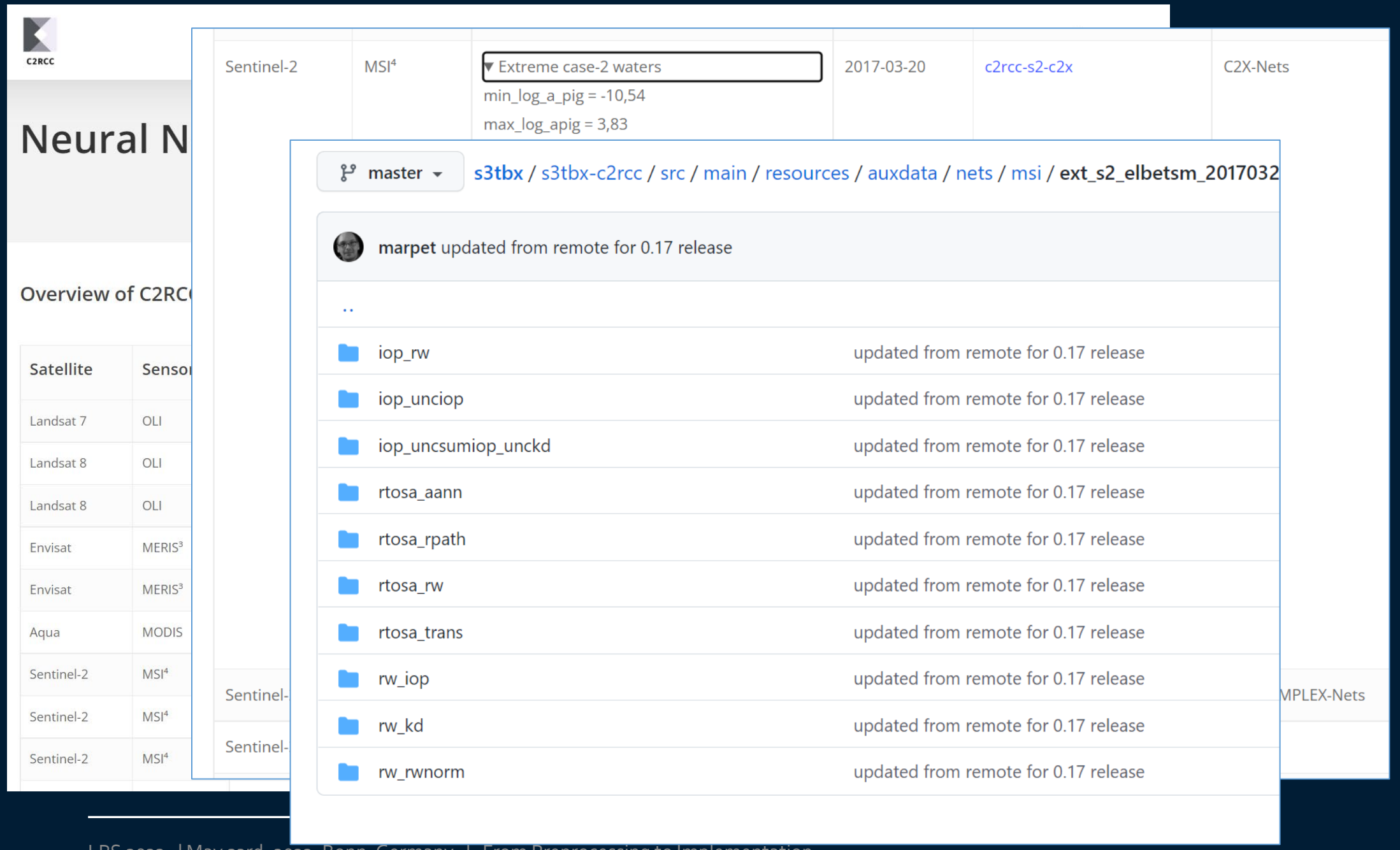
Developers

The C2RCC processor is an Open Source development, whic
Sentinel-3 OLCI, C2RCC can process data from Sentinel-2 M
community feedback and contributions by various scientist
C2RCC is an unfunded activity fully entrusted to the water c
Sweden, and Ocean Obs Norway.
The C2RCC developer and user community resources are in
for accessing the Toolbox software and its documentation,
providing tutorials and material for training scientists using
the public code repository of the ESA Sentinel-3 Toolbox inc



Software and associated community resources

- The ESA Sentinel Application Platform (SNAP) and Sentinel Toolboxes include the C2RCC processor.
- The public code repository of the ESA Sentinel-3 Toolbox includes the source code of the C2RCC processor. Neural networks are included within the resources directory.
- The ESA Scientific Toolbox Exploitation Platform (STEP) is the community platform for accessing the Toolbox software and its documentation, communicating with the developers, dialoguing within the science community, promoting results and achievements as well as providing tutorials and material for training scientists using the Toolboxes.


C2RCC
Neural N
Overview of C2RC
Satellite
Sensor
Landsat 7 OLI
Landsat 8 OLI
Landsat 8 OLI
Envisat MERIS³
Envisat MERIS³
Aqua MODIS
Sentinel-2 MSI⁴
Sentinel-2 MSI⁴
Sentinel-2 MSI⁴
Sentinel-2 MSI⁴ Extreme case-2 waters
min_log_a_pig = -10,54
max_log_apig = 3,83
2017-03-20
c2rcc-s2-c2x
C2X-Nets
Sentinel-
Sentinel-
MPLEX-Nets
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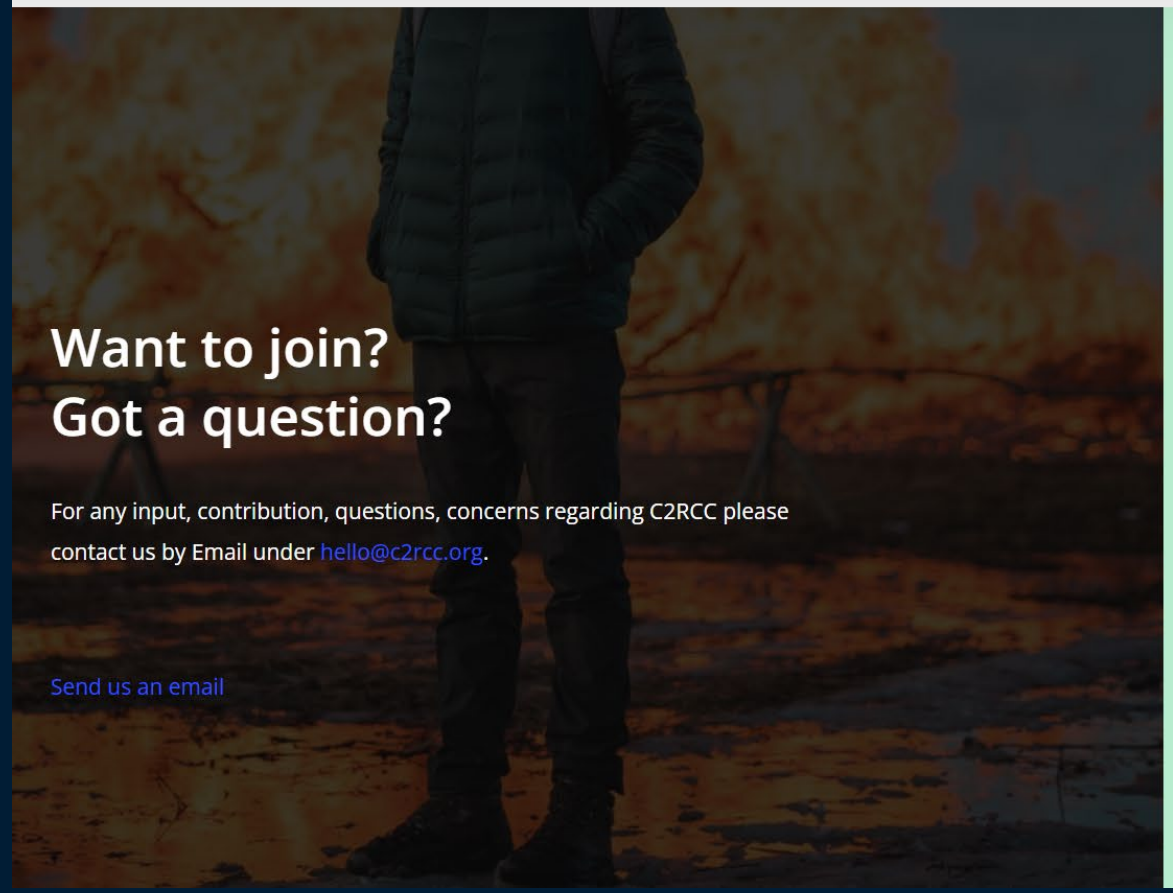
rw_iop updated from remote for 0.17 release
rw_kd updated from remote for 0.17 release
rw_rwnorm updated from remote for 0.17 release

C2RCC

Documentation Developers Neural Nets Contact



About C2RCC Community

C2RCC is an open source software and has a large community of users. Contributions to the software, new publications around C2RCC, validation results, training material, all this is welcome and will be published here.

The core team maintaining the code and the website consists of:

- Brockmann Consult GmbH, Germany
- HEREON, Germany
- Brockmann Geomatics AB, Sweden
- Ocean Obs, Norway

Summary

- C2RCC is a method and software processor for atmospheric correction and in-water processing applicable to multiple optical sensors

- Knowledge exchange and it‘s further development shall be carried out by the water colour community,sharing ideas, new developments and validation results, coordinated and supported by a core development group

C2RCC.ORG