Atmospheric Correction matters!

A case study with Sentinel 2 data over the UK

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Analysis Ready Data

- **Common pre-processing** tasks:
  - Conversion to magnitude (e.g. **calibration**).
  - Common **corrections/normalisations**
    - **Atmospheric** effects
    - **Topographic** effects
    - **Angular** (BRDF) effects
  - **Cloud/cloud** shadow clearing
  - "Quack!" (=**QA**+**UQ**)

Analysis Ready Data

- This requires
  - Specialist knowledge
  - Specialist resources
- Many potential **users** are very **disadvantaged**
- Common pre-processing can be **centralised**
  - **Expert assessment**
  - Operational/Online QA **"continuous improvement"**

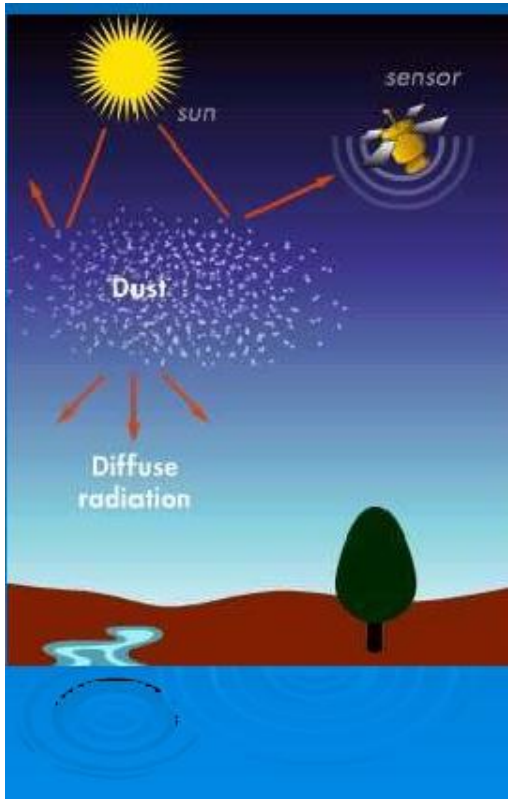
Centralised ARD

- **Partially** addressed via
  - Data Hubs
  - DIAS
- However, most take a data producer perspective
  - Whatever the data producer thinks is "good enough"
  - Only a few simplistic use cases required
- But *quality* of the data matters!

Atmospheric correction

Dealing with the atmosphere in a nutshell

- **Compensate** scattering and absorption of photons due to
  - **Gases** (e.g. water vapour, O3, …)
  - Particles (**aerosols,** AOT)
- Usual **recipe**
  1. **Estimate** atmospheric **composition** (e.g. AOT, WV, O3)
  2. **Calculate effect** of atmosphere in optical signal
     - Mostly using physical model (e.g. radiative transfer)
  3. **Remove** the atmospheric effect
- Easy!



AtCorr issues

- Infer atmosphere -> **Requires surface reflectance**
- Approaches:
  - **Known targets** in the scene with known reflectance:
    - Static targets -> *atmospheric normalisation*
    - **Dark dense vegetation** or water
  - Exploit **empirical relationships** to infer AOT
  - Reliant on **abundant** and **ubiquitous targets**
- ***OR*** Use **coarse resolution** products to predict surface reflectance
  - **Globally** available
  - Lots of pixels in *any* scene
  - Automatic reference to coarse res radiometric standard

S2 atmospheric correction

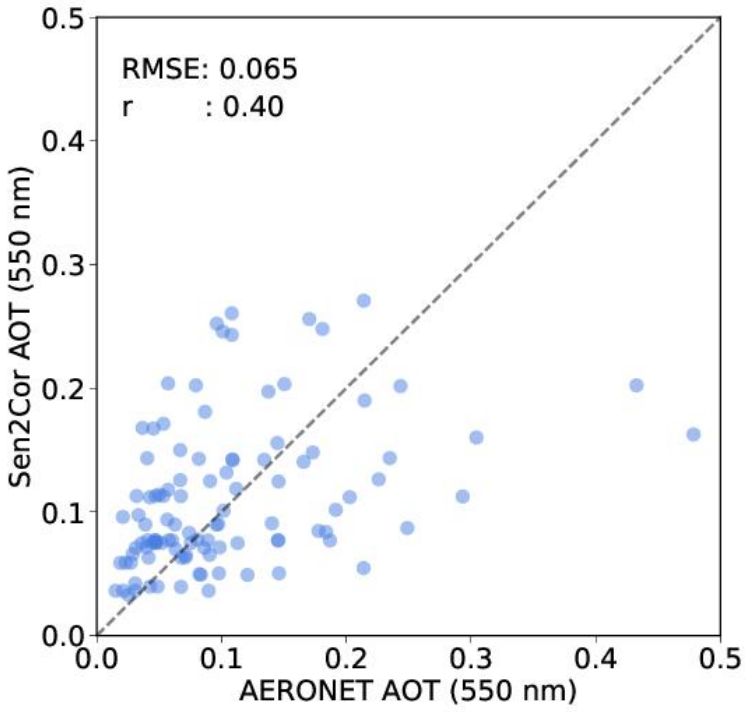
- AtCorr for S2 **not very mature**
  - **Lots of processors** from lots of groups
  - Ongoing **intercomparison efforts**
- How can we **assess quality** processors?
  - Most apply **same recipe** for AtCorr, but **differ on parameterisation**
  - Assess **quality of atmospheric composition**
    - … But **not necessarily uniqsufficient** (you may do an OK correction with the wrong parameters-> "the right solution for the wrong reasons")
  - Absolute surface reflectance relies on in situ radiometers -> Few & far between
    - And usually in deserts!

Benchmarking effort

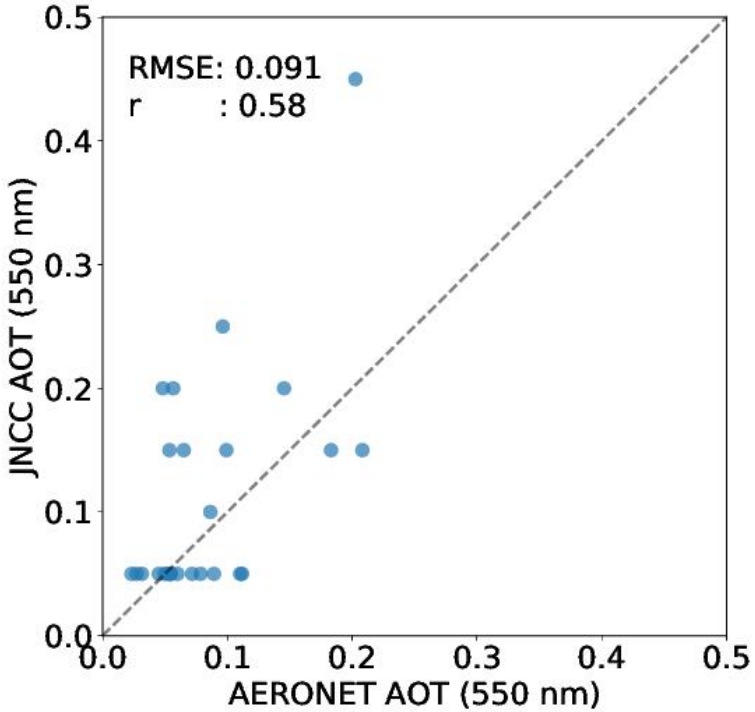
- Compare AtCorr **AOT** versus *in situ*
- User AERONET sites over the UK for 2018
- We selected three products
  - ARCSI/JNCC
  - Sen2Cor/"ESA"
  - SIAC/UCL/NCEO
- Match-up criterion:
  - Less than 30 minutes
- In total, ~200-250 data points per product
- No RadCalNet site in the UK
- Haven't bothered with TCWV, as most methods can use same approach

Results

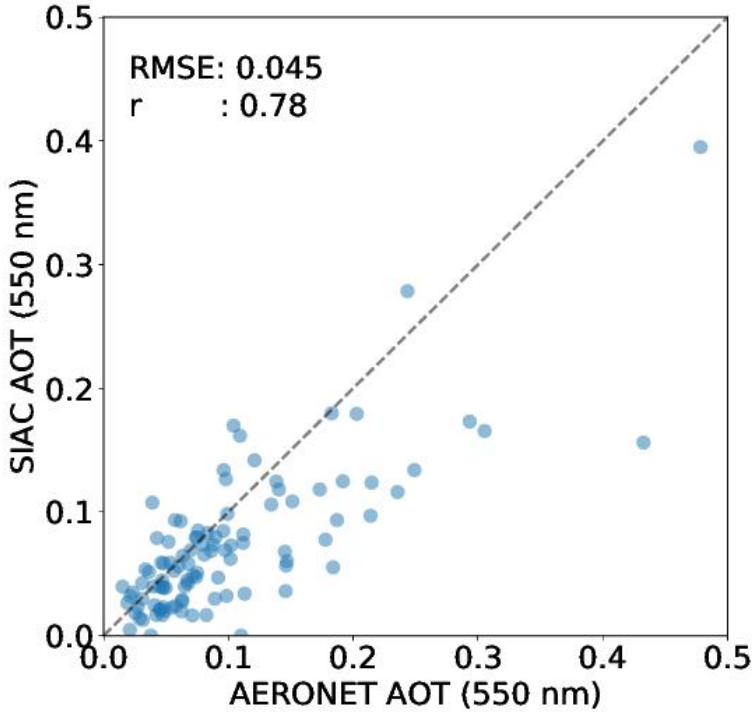
Sen2Cor



JNCC/ARCSI

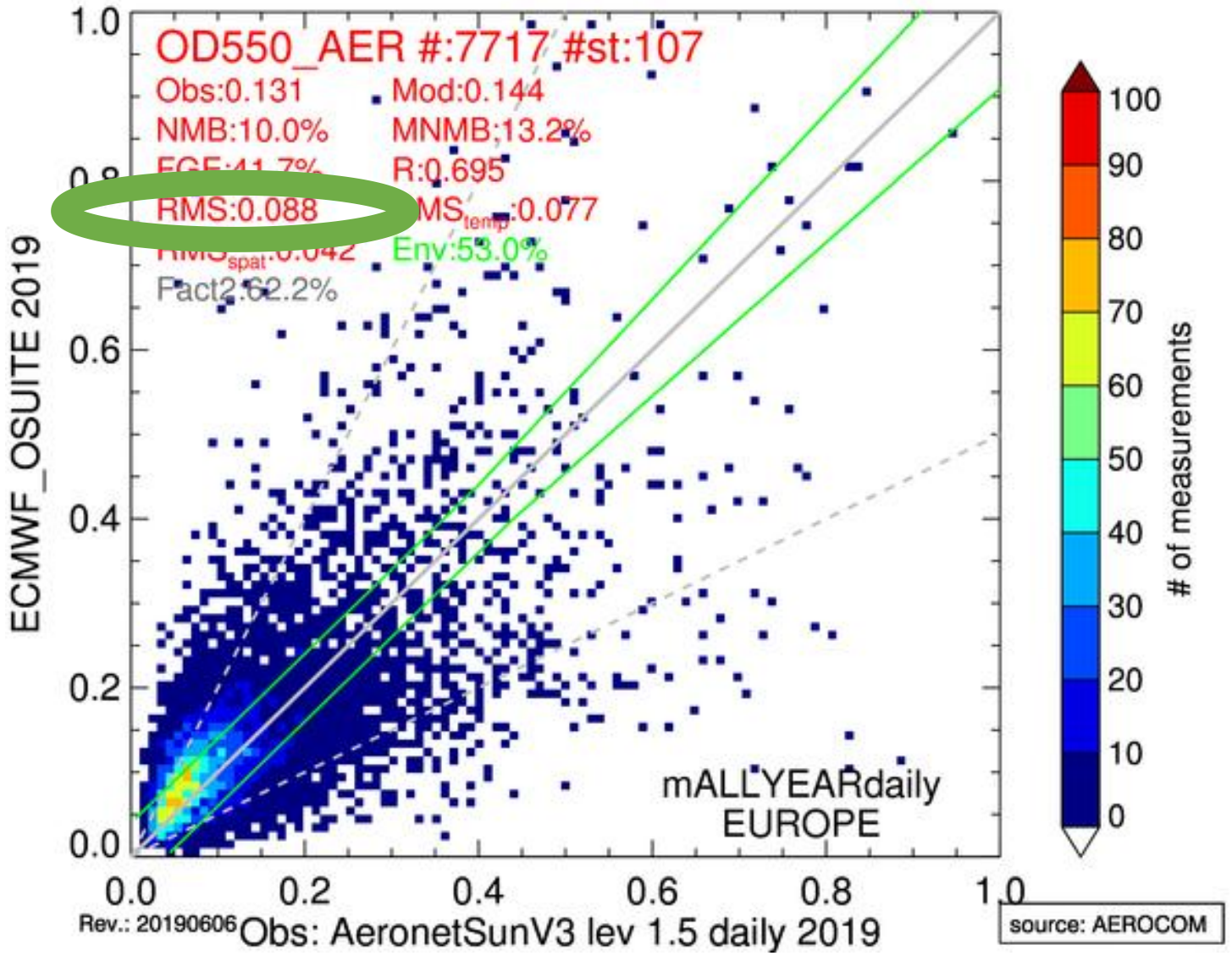


SIAC

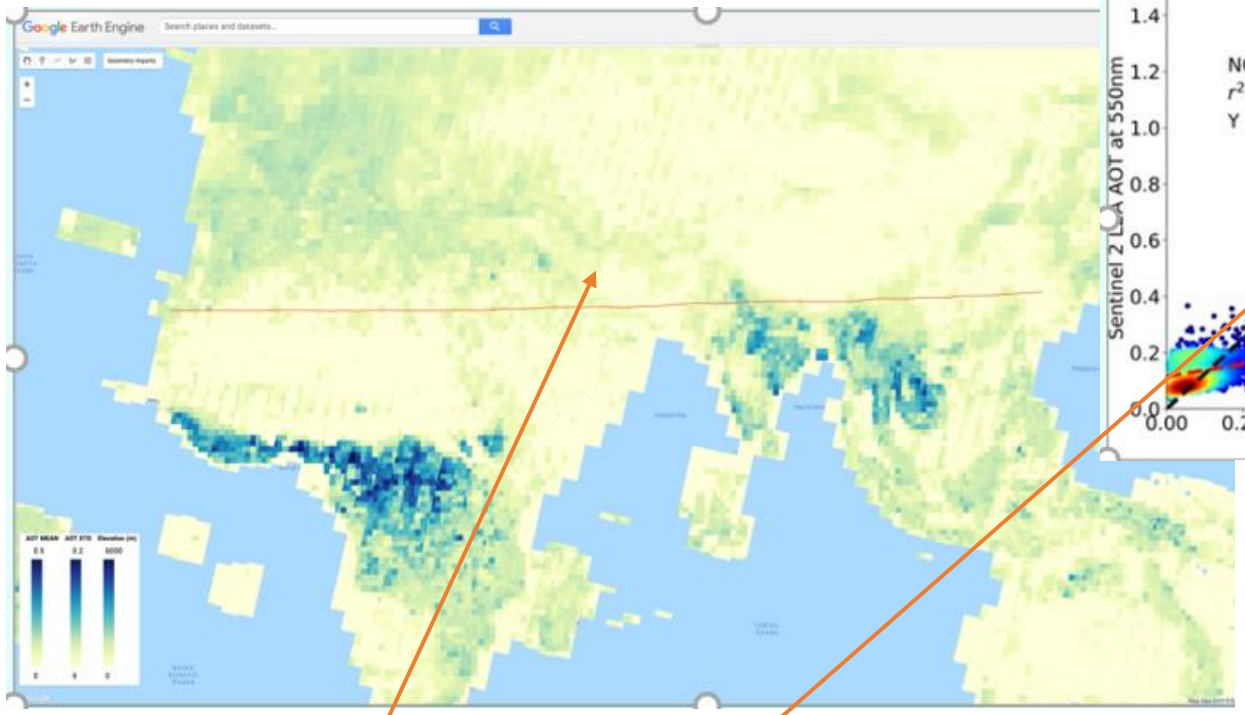


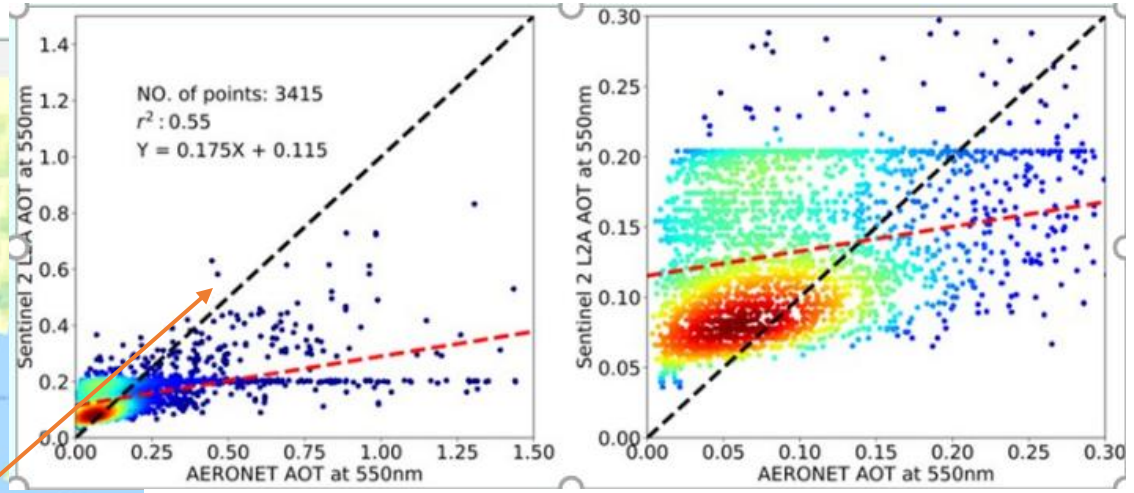
What do we know before AtCorr?

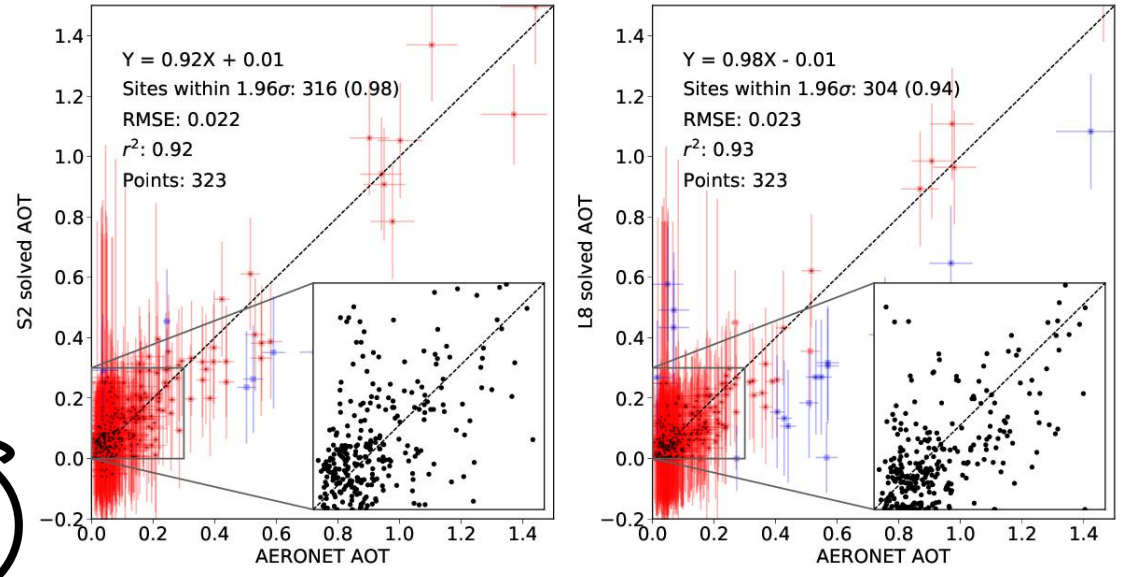
- The *Copernicus Atmosphere Monitoring Service* (CAMS) **predictions** of AOT over Europe **as good as Sen2Cor and JNCC**
- Clearly, we need improvements



Some interesting findings: global analysis







Sen2Cor *doesn't correct* over arid regions!!!

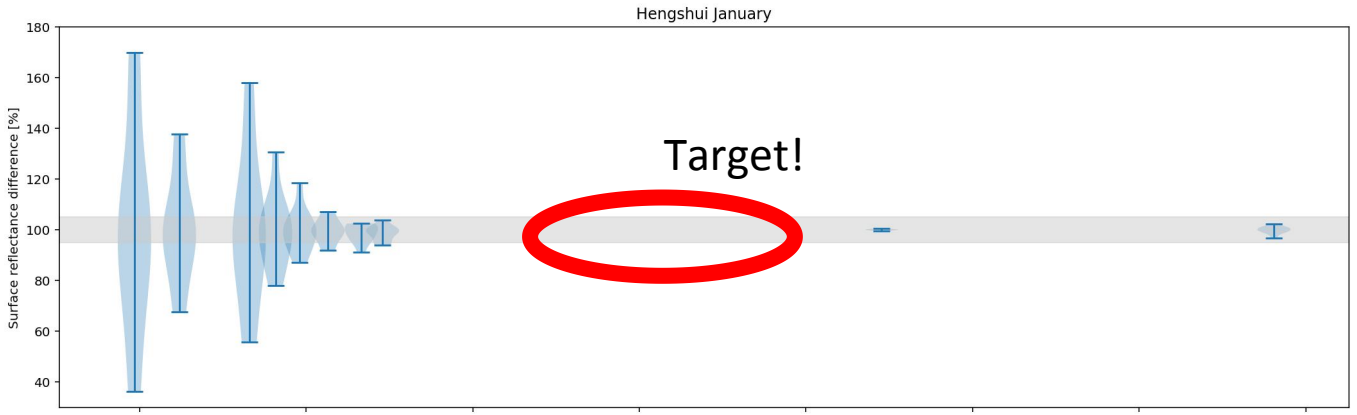
SIAC does! DOI

Effect of AtCorr on parameter retrieval

- Propagate BOA reflectance to TOA
- Retrieve BOA from simulated TOA with usual AOT/TCWV error
- **Map** surface **reflectance** to **biophysical parameters**
- Using a neural net on individual pixels
  - Concentrate on S2
  - Trained on PROSPECT+SAIL RT model
  - Main parameter of interest: LAI
  - Leaf pigments
  - Concentrate on crops (wheat, barley)
- Synthetic experiment -> Only concerned with AtCorr effect
  - Not the only source of uncertainty!!!

ARCSI: Hengshui (Jan & June)

% True - Retrieved reflectance



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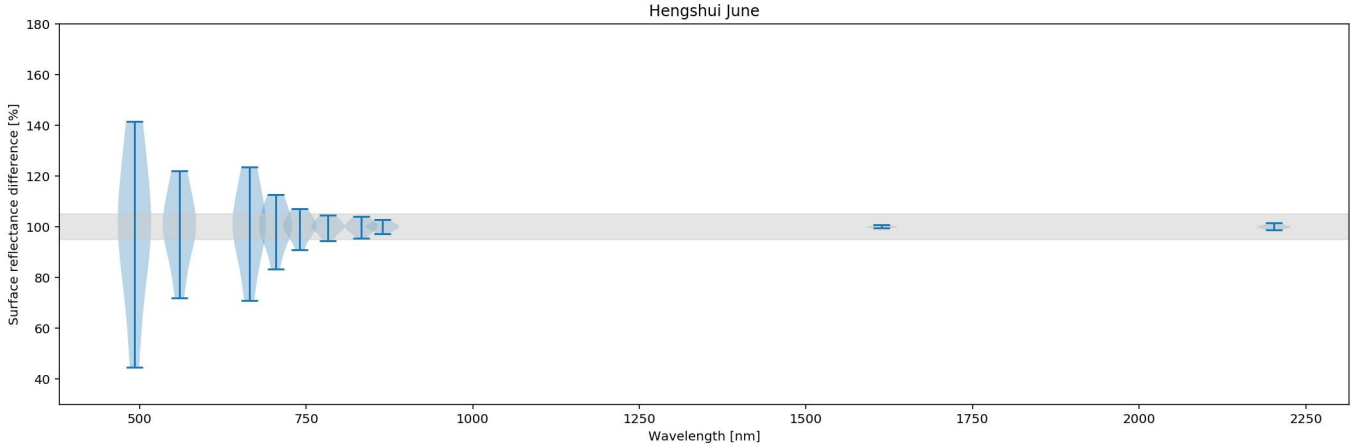

Sen2Cor: Hengshui (Jan & June)

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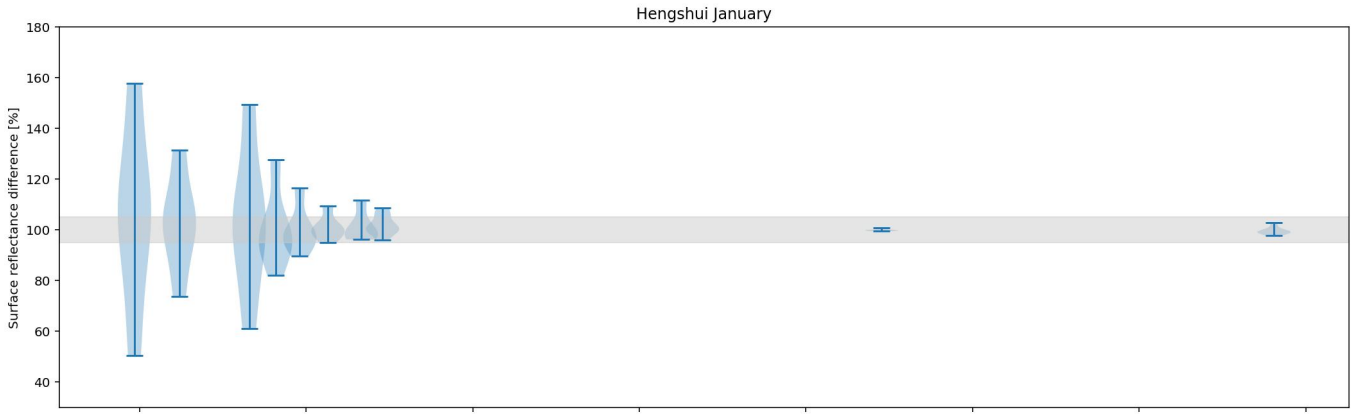

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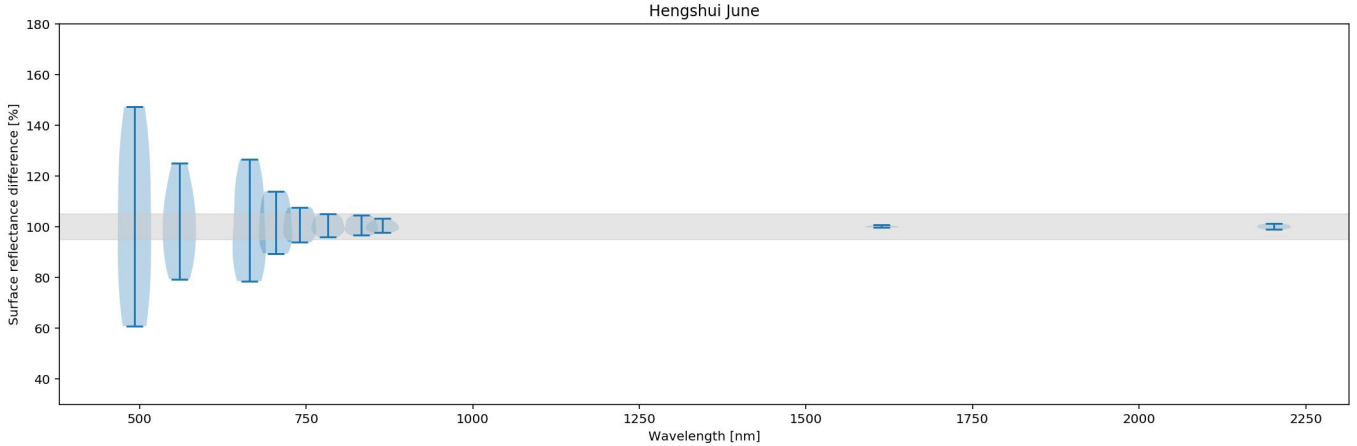

SIAC: Hengshui (Jan & June)

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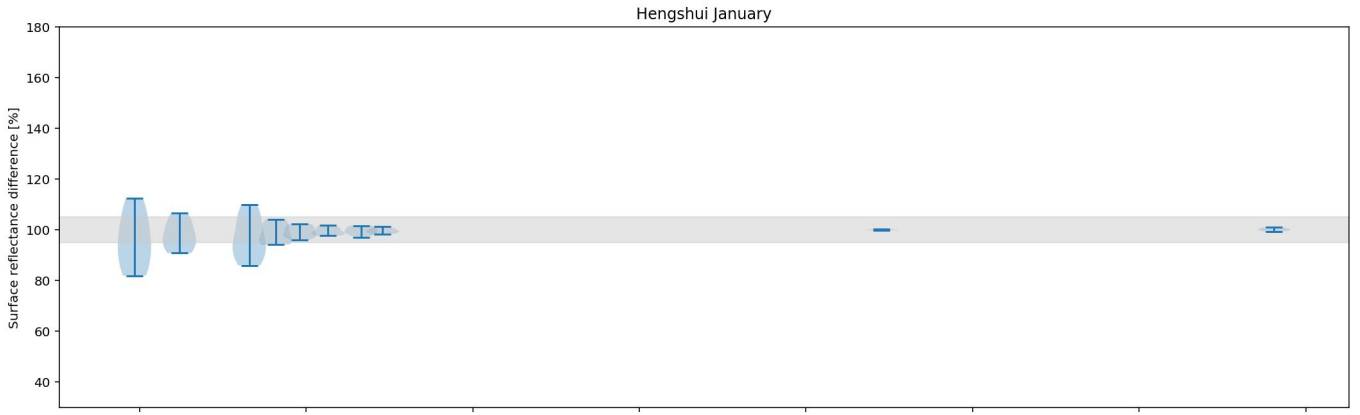

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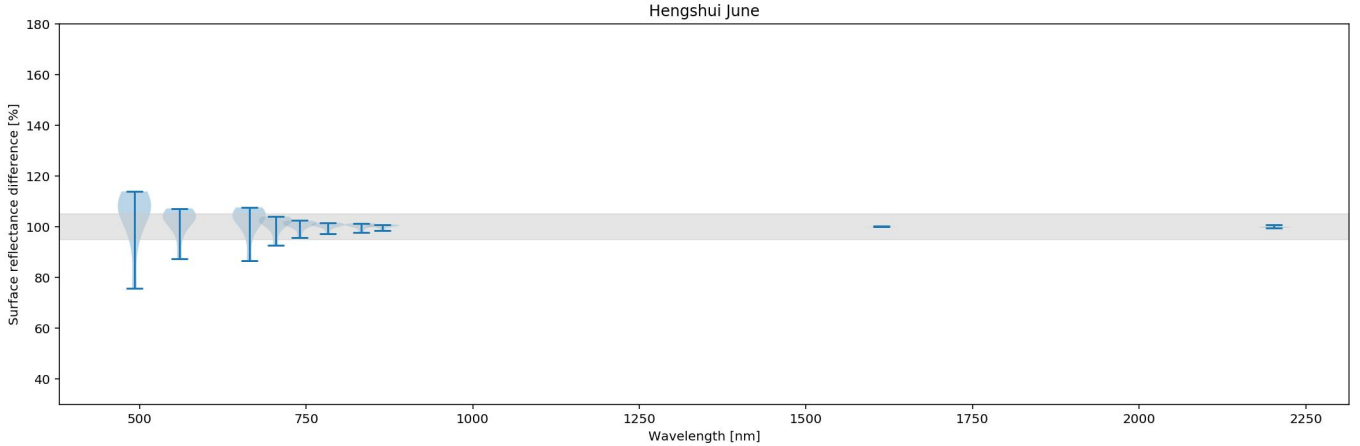

Impact of AtCorr error in parameter retrieval

AtCorr\Parameter	LAI	Leaf chlorophyll	Leaf senescence
ARCSI	40%	6%	17%
Sen2Cor	48%	10%	36%
SIAC	**31%**	**5%**	**14%**

Final remarks

- Atmospheric correction of S2 is maturing
- Novel methods that exploit coarse resolution BRDF descriptors have an edge
- Even in the UK, DarkDenseVegetation based methods perform poorly
- Issues affecting AOT retrieval affect surface reflectance
  - Which affects final parameter retrievals, particularly using very non-linear mappings such as NNets
- Remember that there are other additional forms of uncertainty available!
  - Uncertainty in the L1C product
  - Suitability of the RT model used to train the NNet, ...

Resources

- The pre-print of the SIAC method:
  - **https://eartharxiv.org/ps957/**
- The SIAC code (GPLv3)
  - **https://github.com/MarcYin/SIAC/**