AATSR Cloud retrieval and validation

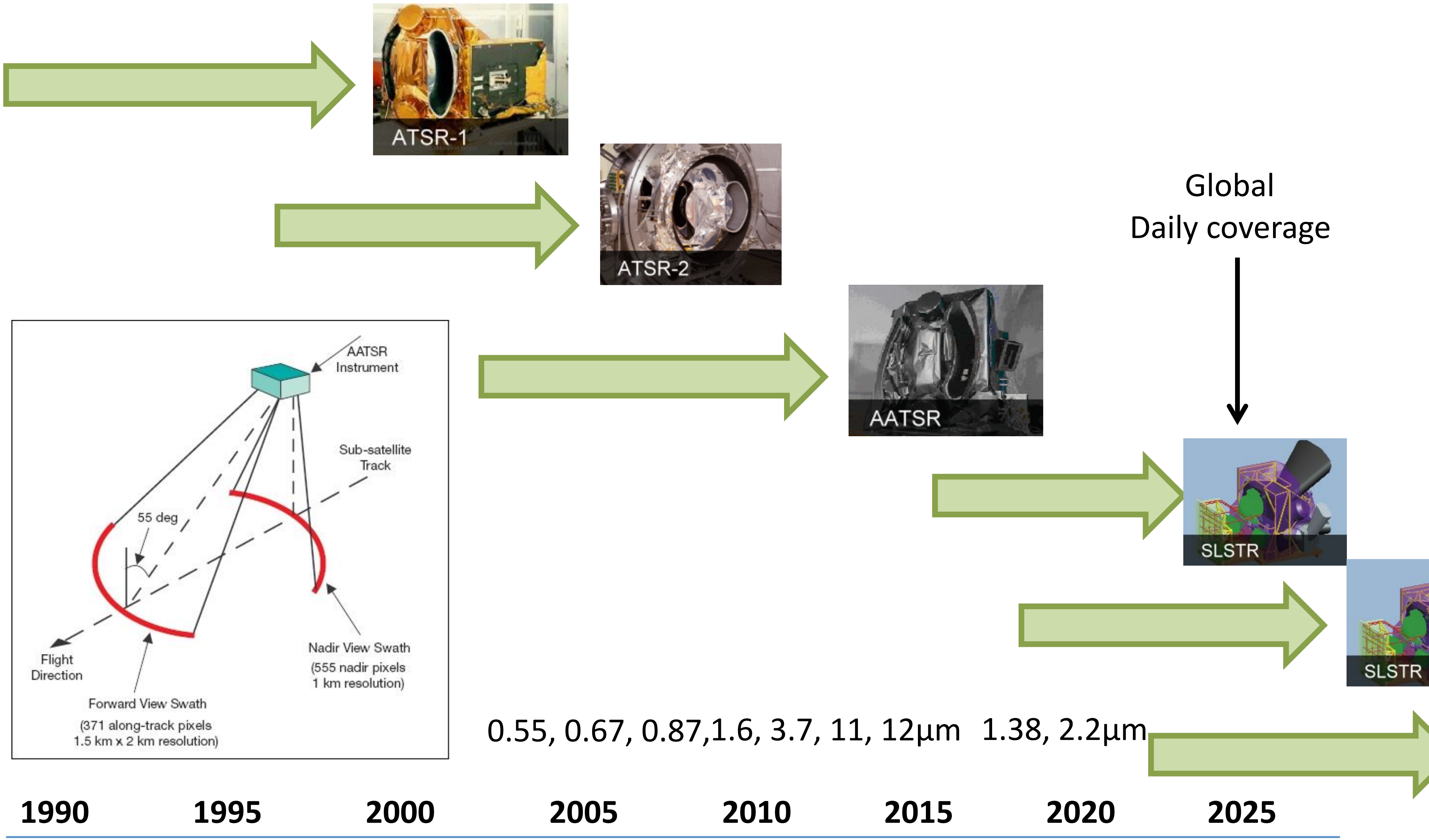
Caroline Poulsen, Gareth Thomas, Richard Siddans, Don Grainger,
Adam Povey and Greg McGarragh
RAL and University of Oxford
and thanks also to CCI team.

Outline

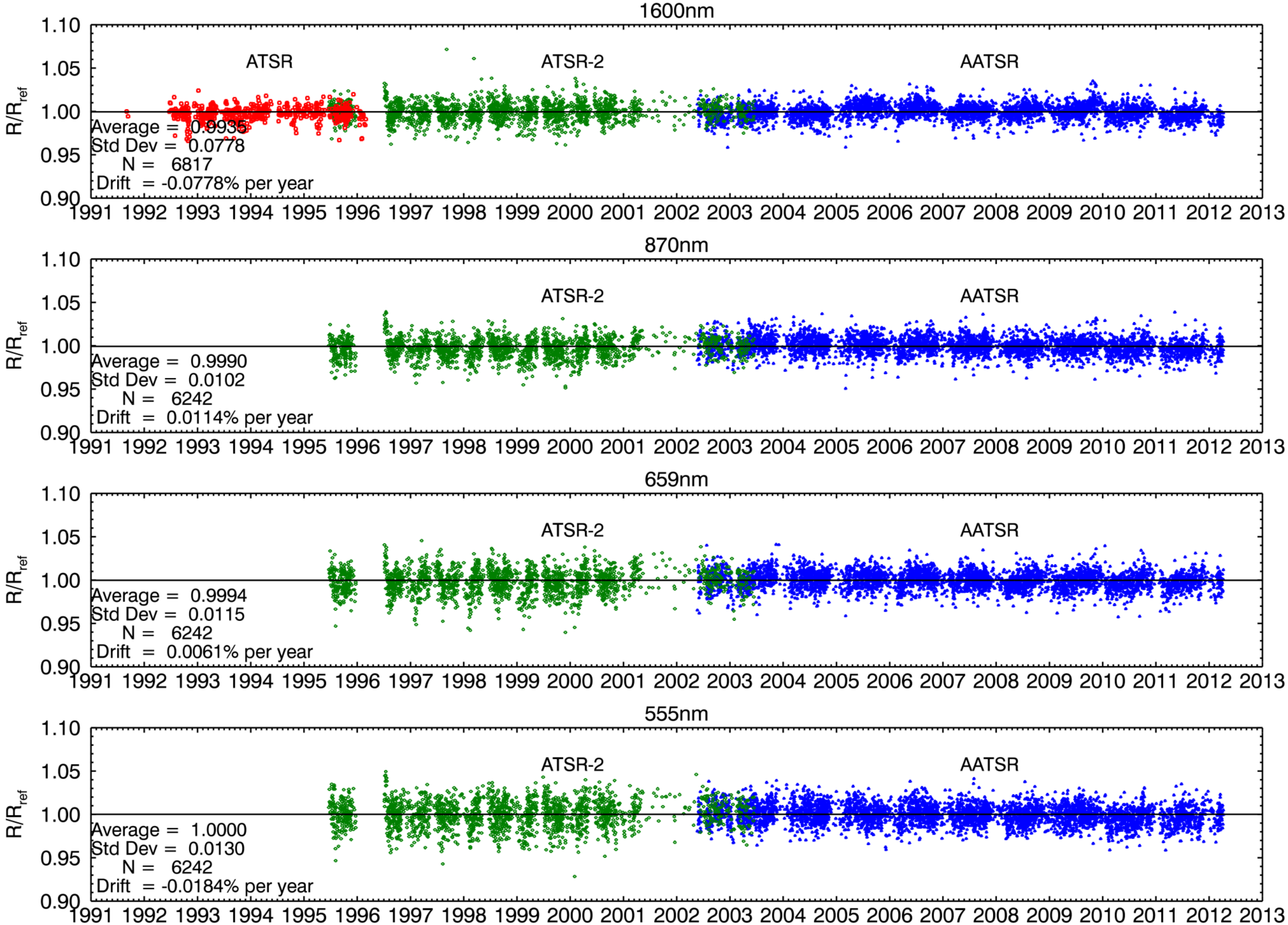
- AATSR instrument
- Algorithm
- Validation of properties and uncertainty
- Aerosol/cloud consistency
- Future

RAL Space

Oxford Physics



Time series of Along Track Scanning Radiometer Instruments



ATSR stability, slides courtesy Dave Smith

Climate friendly retrieval

- *Stable calibration, over a long time period*
- *Comprehensive uncertainty characterisation*
- *All surface-atmosphere properties determined from a satellite instrument are consistent with the TOA radiance field*

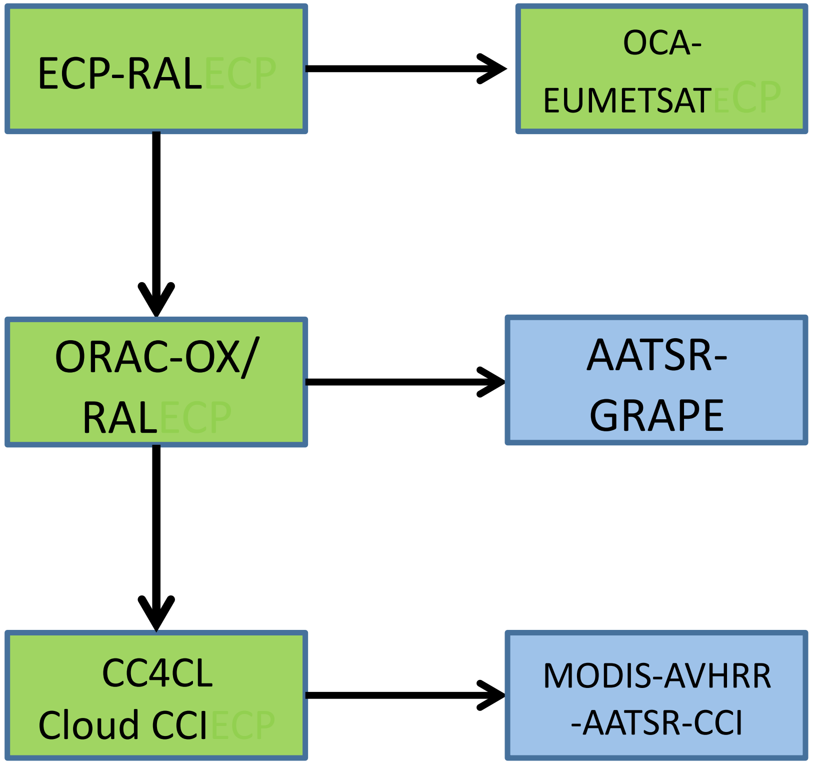
  – The retrieval of surface and atmospheric properties is such that TOA radiances simulated using the retrieved atmospheric and surface properties should not differ from the measured radiances.

  – The global TOA radiation field is generated from a mixture of clear and cloudy skies.
    - Aerosol and Cloud retrieved using similar algorithm
    - Aerosol and Cloud use a consistent cloud identification

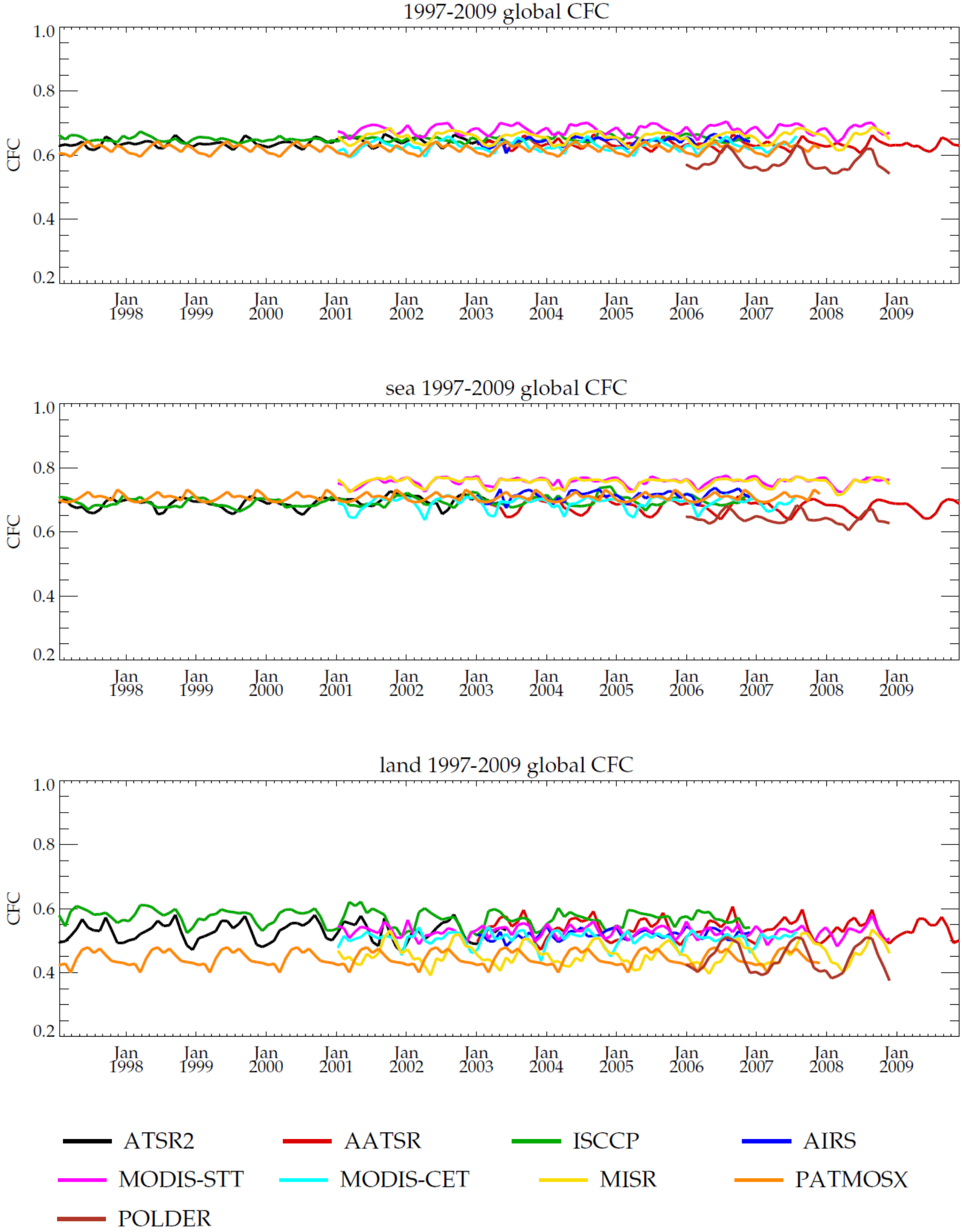
RAL Space

Oxford Physics

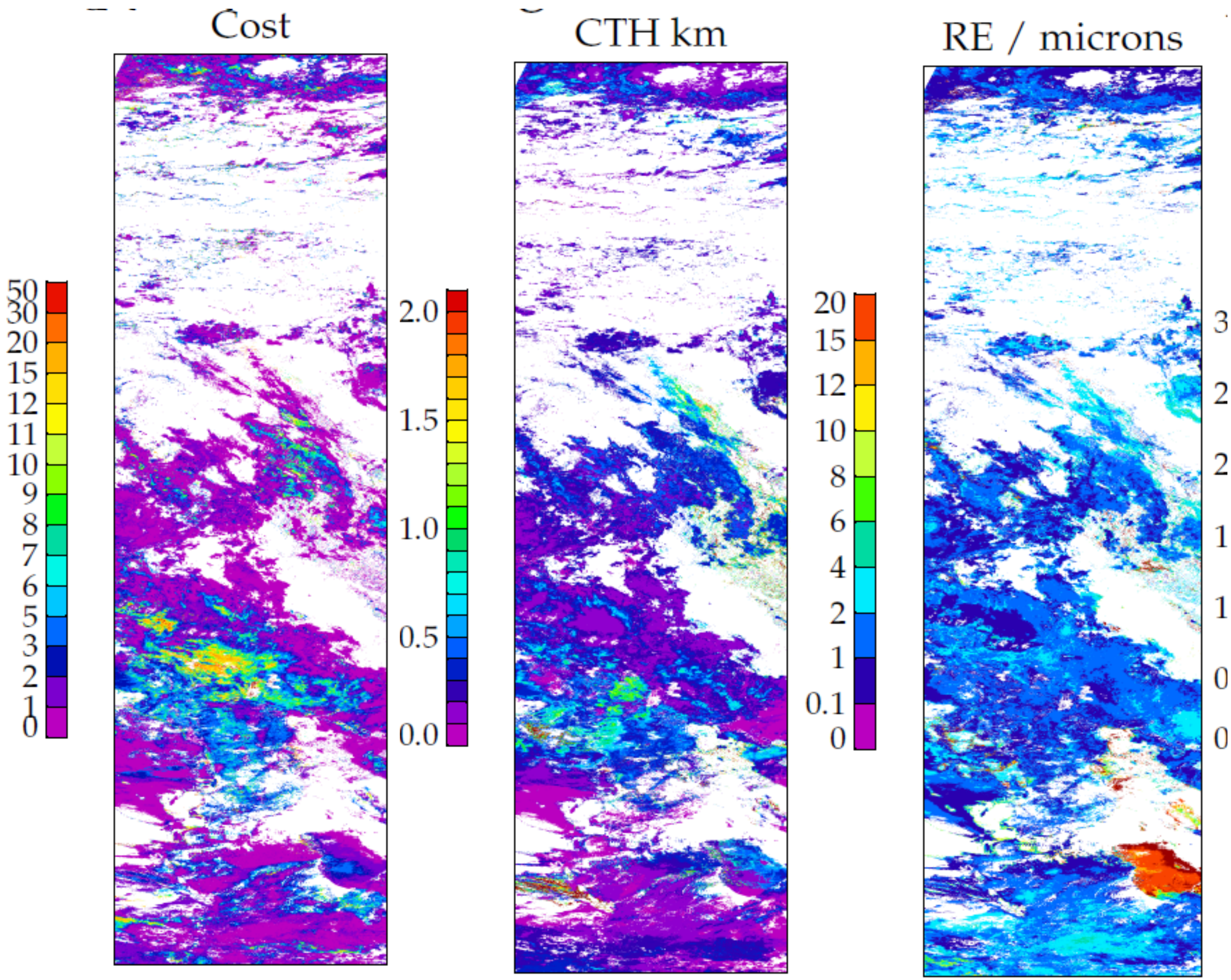
History of cloud Algorithm



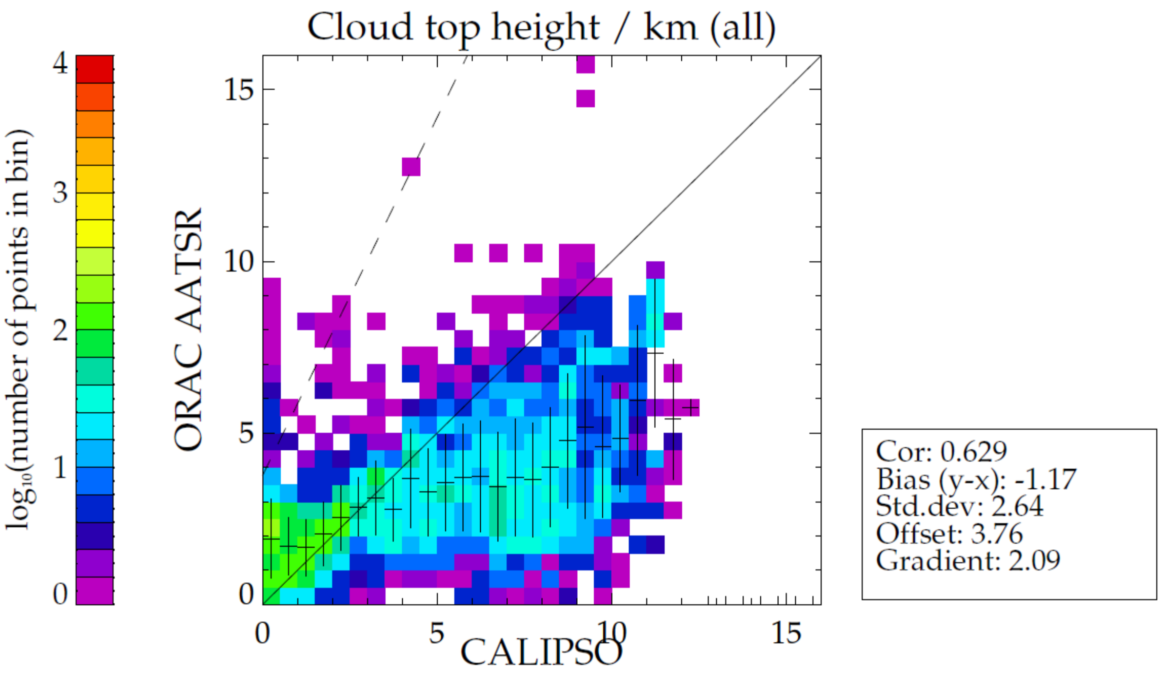
GEWEX comparison of Cloud fraction

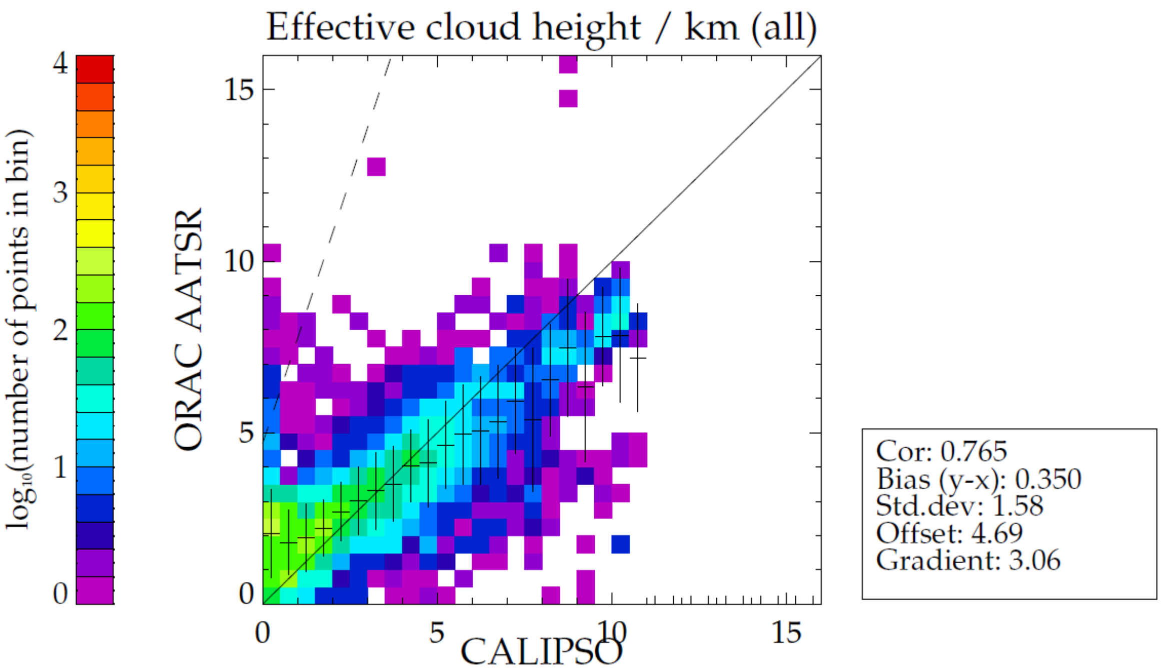


Retrieved cloud properties
Retrieval uncertainty information

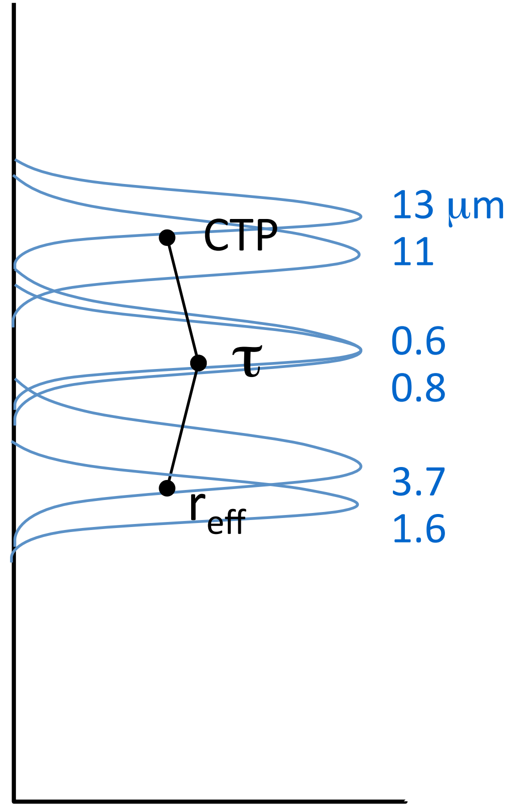


Pixel level uncertainty of cloud parameters from propagated forward model and measurement uncertainty

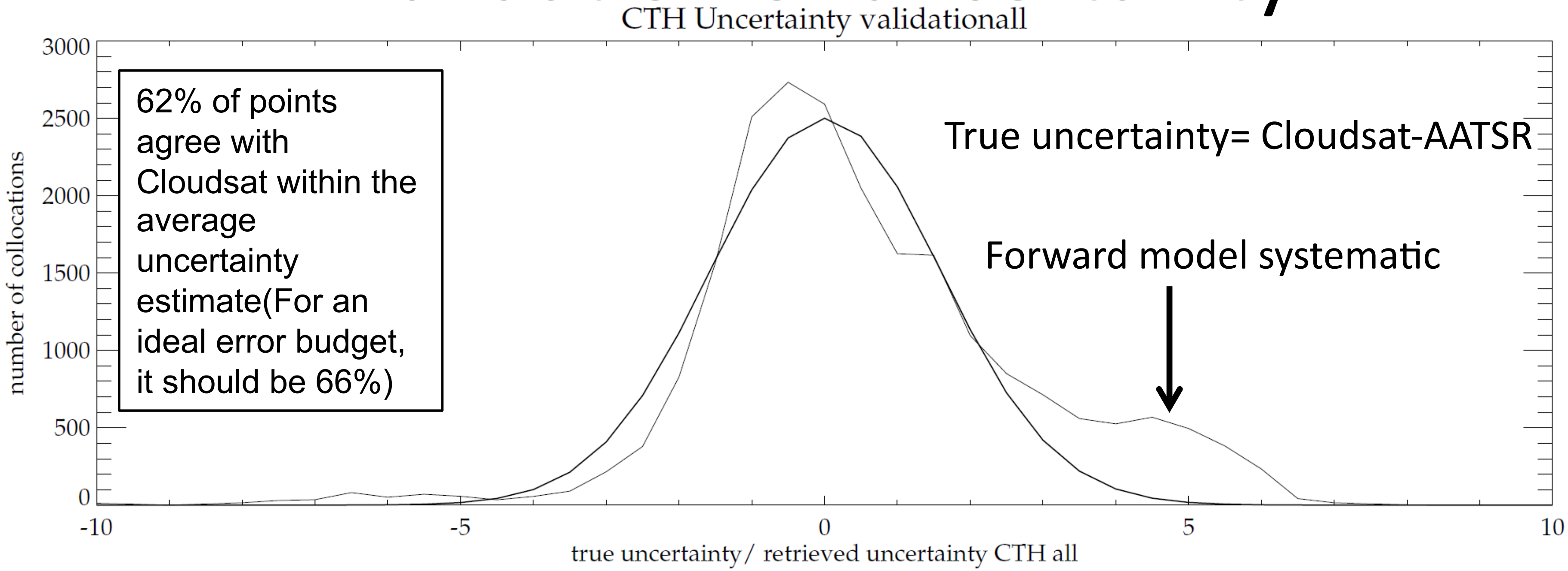




- Effective CTH accounts for vertical penetration of the IR clouds by using Calipso and Cloudsat optical depth to estimate the height (approx 1 optical depth) into the cloud.



Validation of uncertainty



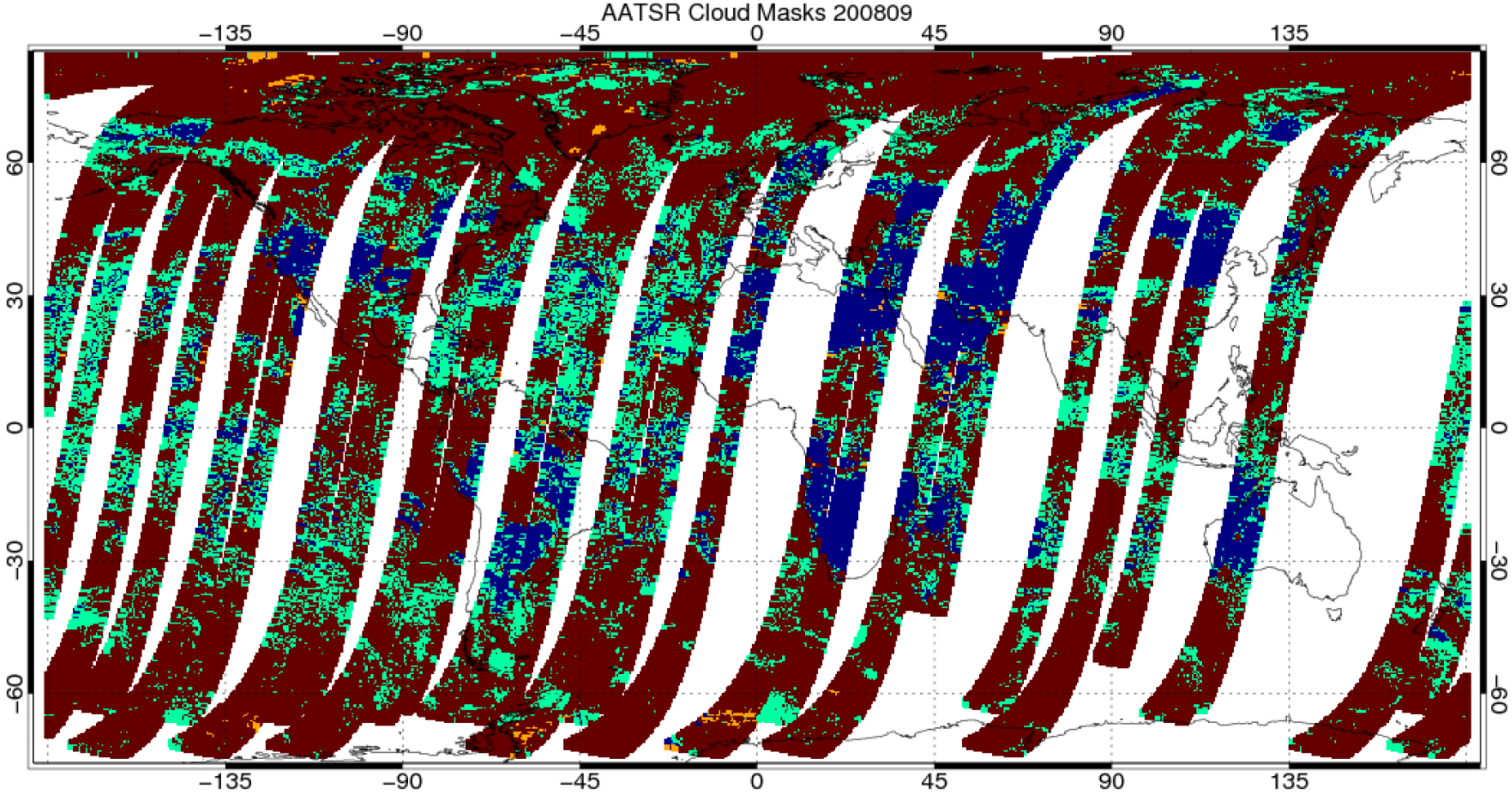
OE uncertainty is random

Currently: measurement, coregistration and homogeneity and surface uncertainty is propagated through the retrieval

Cost indicates good fit to the model- often identifies ML cloud

- >>1 OE uncertainty too low
- <<1 OE Uncertainty too high

Comparison of aerosol CCI and cloud CCI cloud masks



5 selected days Sep 2008 – safety zone included by Aerosol_cci

AEROSOL CCI/ CLOUD CCI

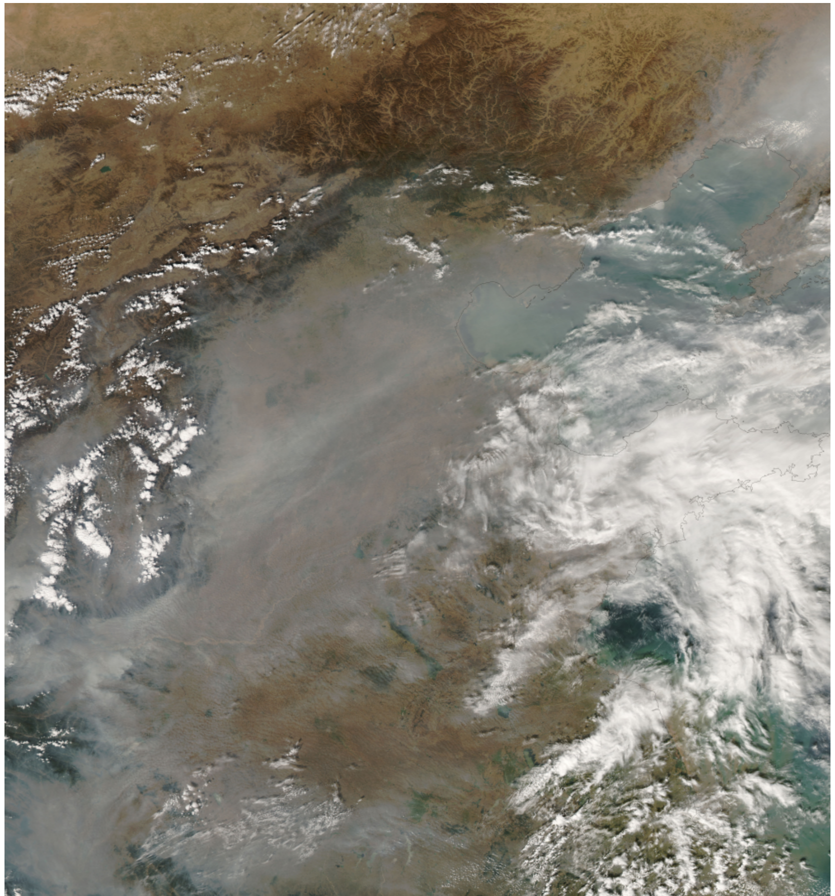
12,4 %	21,1 %	0,5 %	66,0 %
No Cloud / No Cloud	Cloud / No Cloud	No Cloud / Cloud	Cloud / Cloud

- Aerosol CCI applies a tight cloud flagging criteria.
- Cloud CCI misidentifies some thick aerosol as cloud
- Many observations are considered neither clear nor cloudy so that the global TOA radiance field simulated from the two products is not representative of the satellite measured field.

Bayesian cloud flagging

- Chinese haze event on 16-Oct-2008
- A good example of where traditional cloud flagging might struggle!

- AATSR processed:
  - Cloud_cci product
  - Aerosol_cci
  - "Bayesian" retrieval using cloud_cci processor



NASA Earth Observatory – from MODIS-Aqua
http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=35502&eocn=image&eoci=related_image

Theory

- OE retrieval provides statistics on the quality of the fit
  - In particular the retrieval cost is directly related to the conditional probability of the retrieved state given the measurement (for a particular set of assumptions):

$$J = -2 \ln P(\mathbf{x}|\mathbf{y})$$

- Can we use this information to distinguish between cloud and aerosol (and different cloud/aerosol types)?

χ^2 test

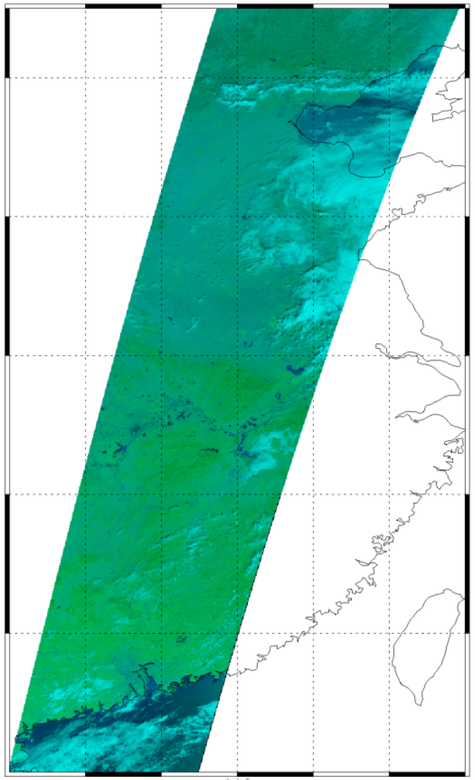
- Measurement cost function:

$$J_m = [\mathbf{y} - \mathbf{f}(\mathbf{x})]\ \mathbf{S}_y^{-1}\ [\mathbf{y} - \mathbf{f}(\mathbf{x})]$$

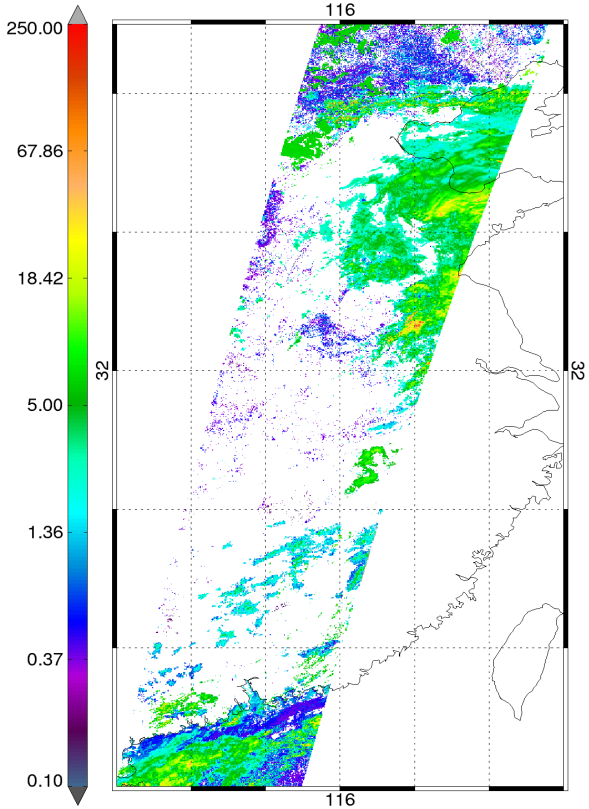
will be a random sample from a normal distribution with a standard deviation of 1, with degrees of freedom equal to the number of measurements, *m*.

- Thus, it should follow a χ^2 distribution with *m* degrees of freedom and each J_m value can thus provide a probability that the retrieval is consistent with the measurement
- *Assumes that the covariance matrix, $\mathbf{S}_y$, is an accurate representation of the uncertainty in the system and that the forward model, $\mathbf{f}(\mathbf{x})$, is a good representation of the physics of the measurement.*
- Similar argument can be applied to the a priori cost.

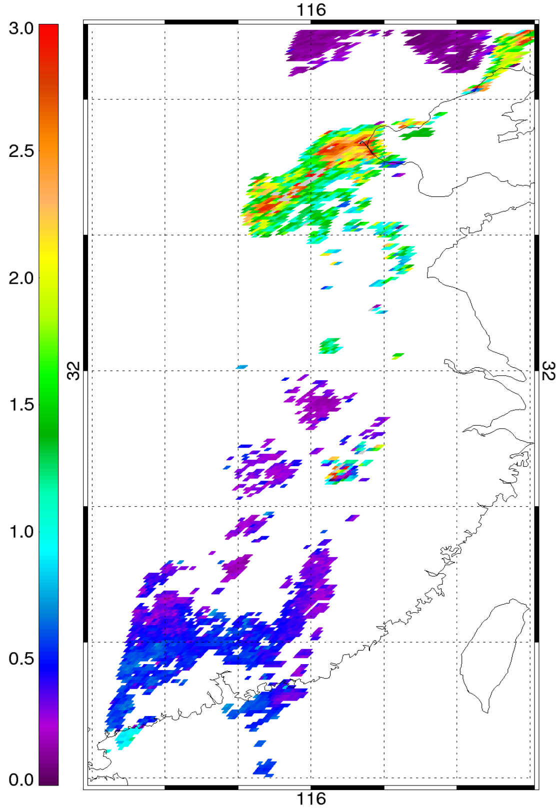
Cloud and Aerosol cci consistency



AATSR false colour

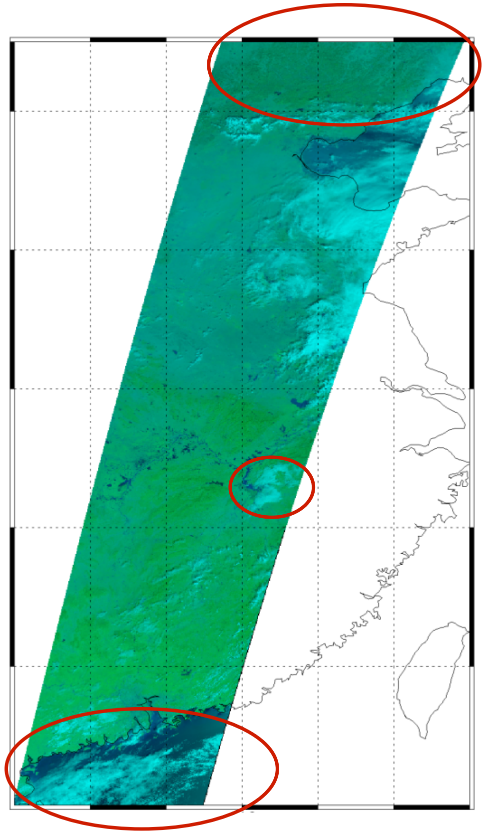


Cloud_cci L2 (CC4CL)
cloud optical depth



Aerosol_cci L2 (ORAC)
aerosol optical depth

Cloud and Aerosol cci consistency



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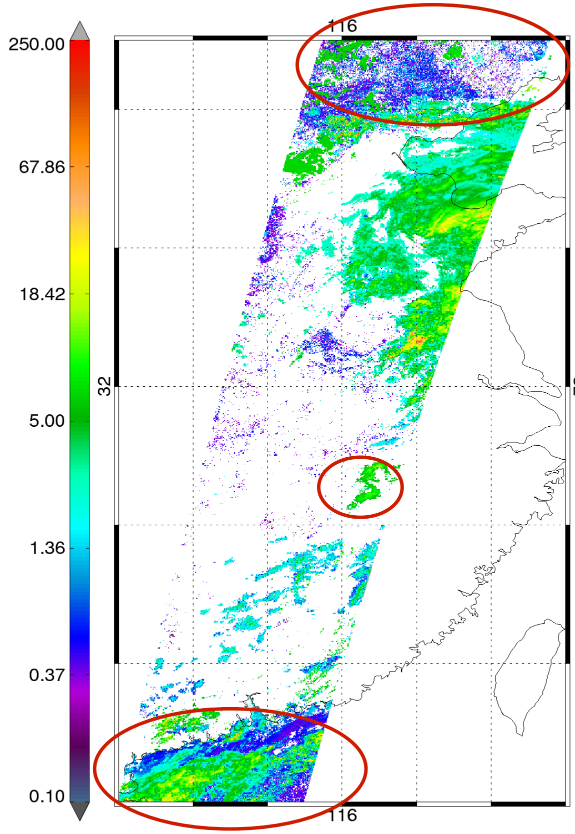
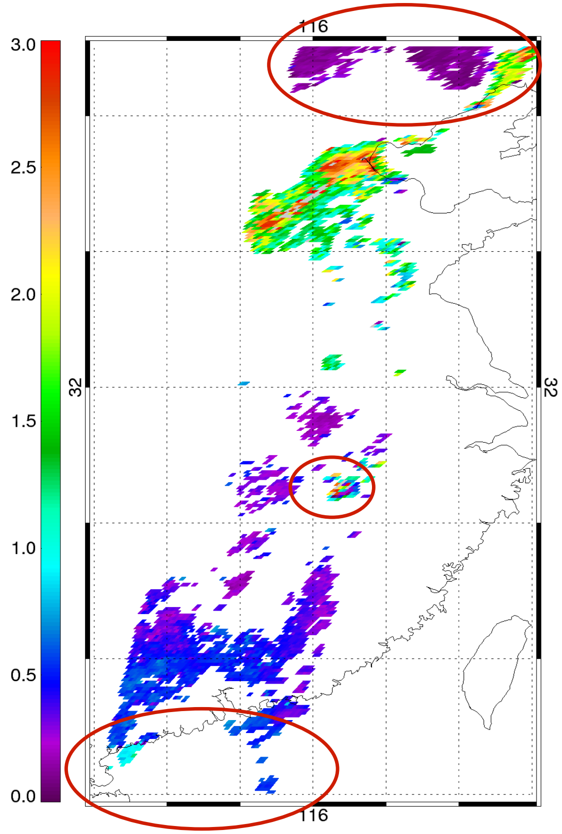
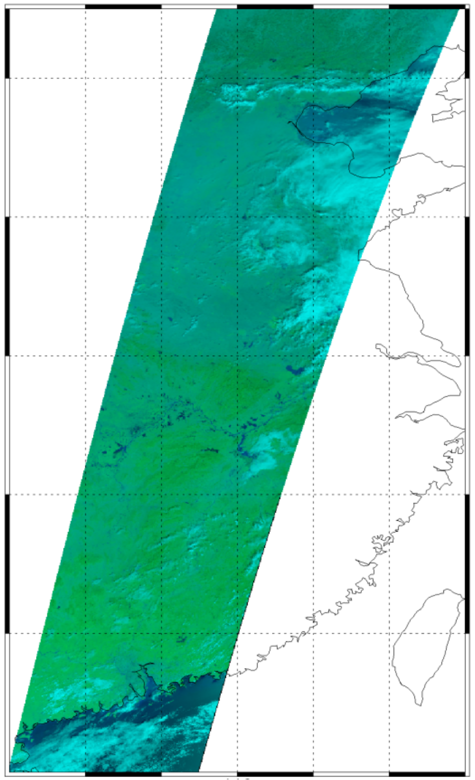


Cloud_cci L2 (CC4CL/ORAC)
cloud optical depth



Aerosol_cci L2 (ORAC)
aerosol optical depth

Bayesian approach…

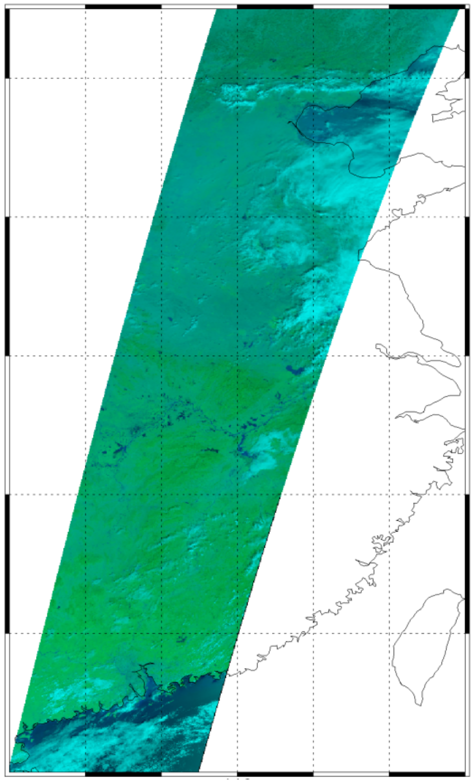


AATSR false colour

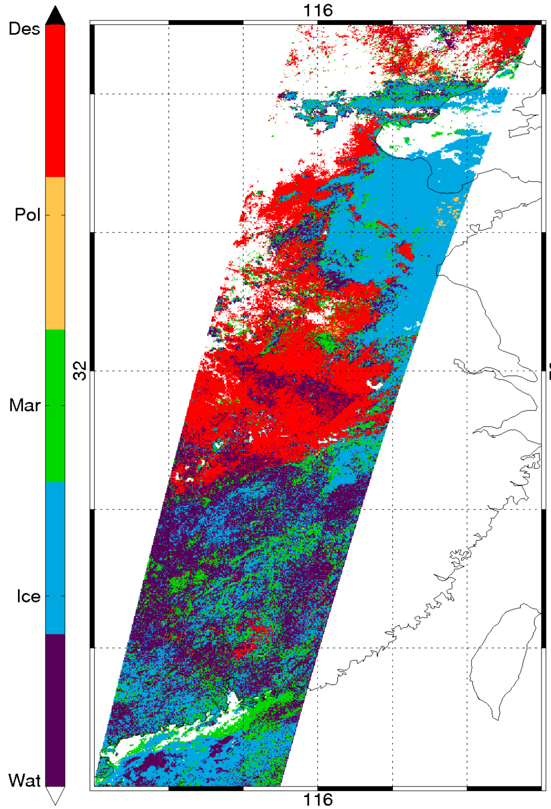
CC4CL cloud_cci processor re-run on the scene shown:

- Run with:
  - Water & ice cloud
  - Desert dust (OPAC with a non-spherical coarse mode)
  - Maritime class (OPAC at 80%RH)
  - Pollution (OPAC polluted continental)
- Used OPAC rather than aerosol_cci classes because the thermal IR properties needed

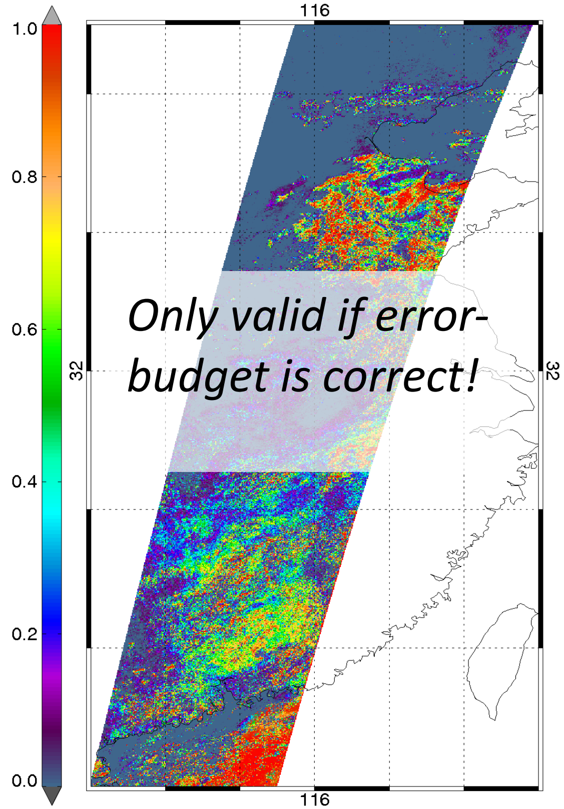
χ^2 results



AATSR false colour

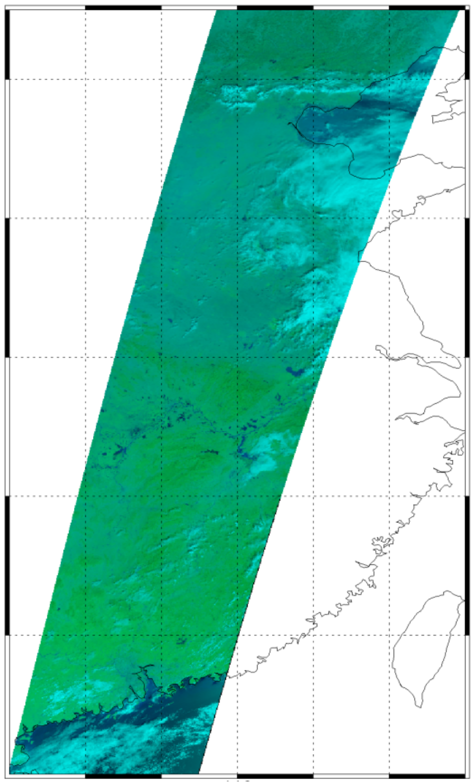


Best-type according to χ^2 test.



χ^2 probability of best-type.

Interpreting the results



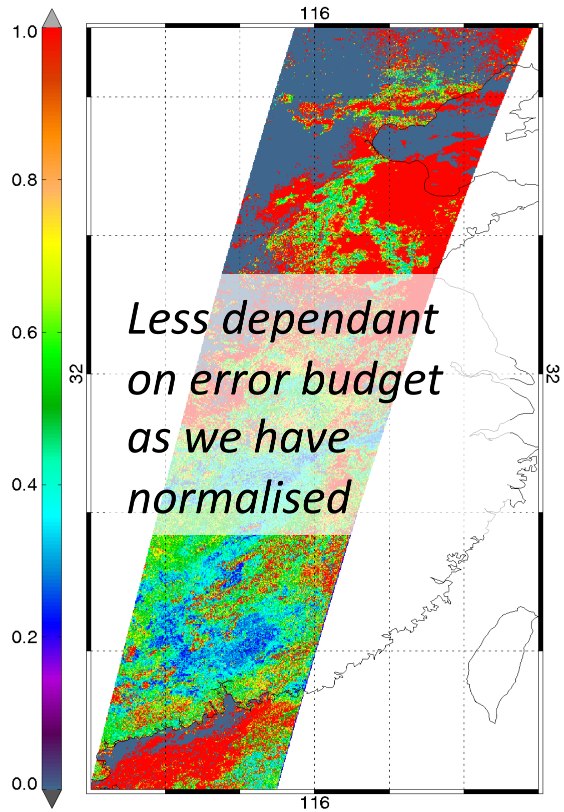
AATSR false colour

Of the available types, how certain are we of the best fitting?

- Normalise the probability:

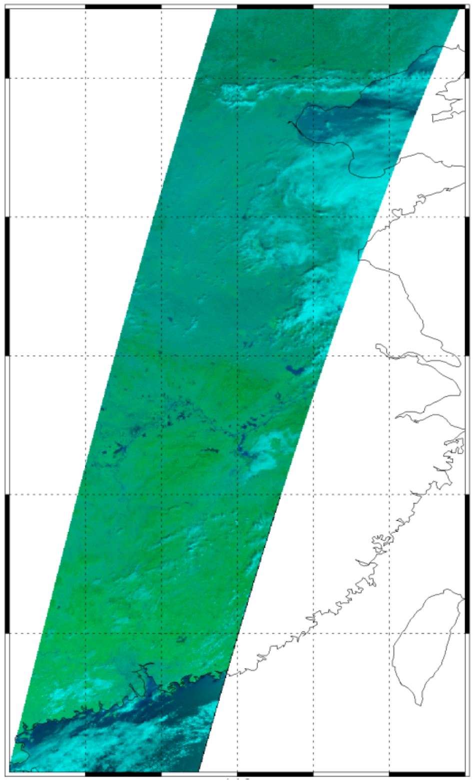
$$P_n = P_b \,/\, [\Sigma_i \, P_i]$$

- This can be used as a “cloud mask”



Normalised χ^2 probability of best-type.

Does it work?



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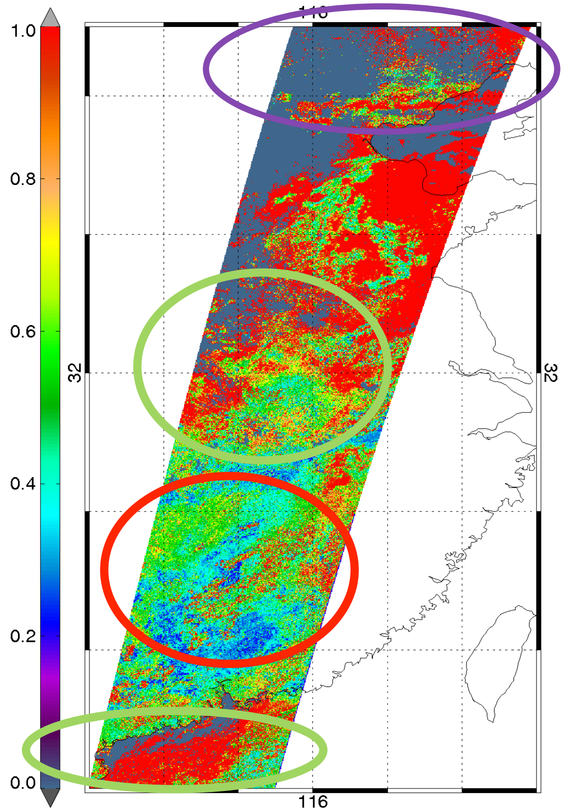
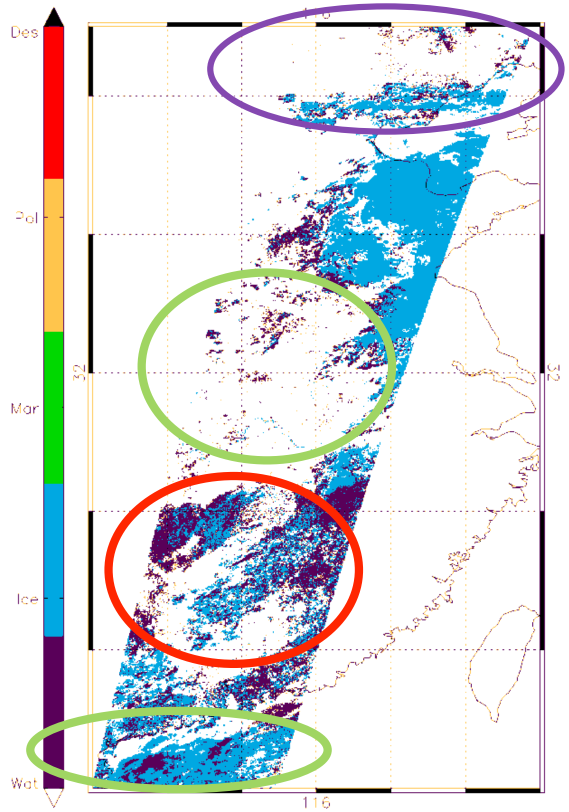


Cloud_cci cloud phase

Normalised probability



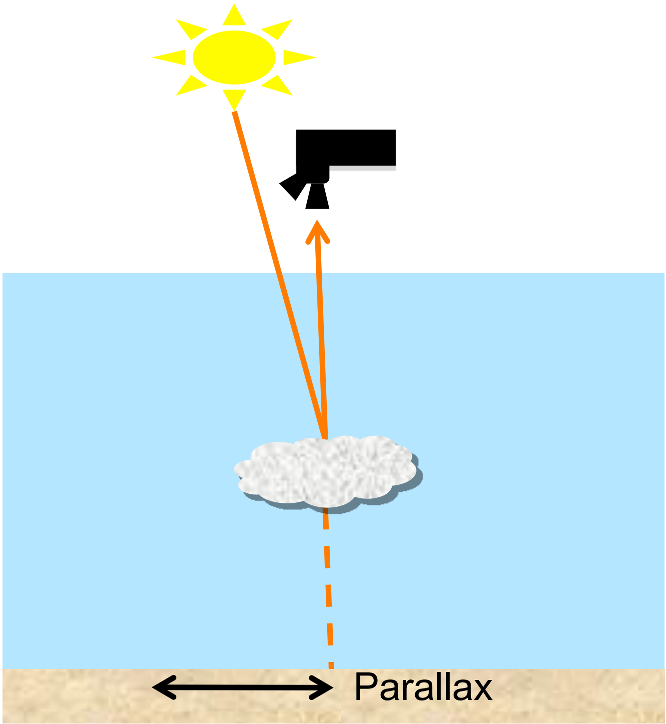
χ^2 cloud phase. Either:

- Pn > 0.75 of water or ice
- Sum of Pn > 0.85 for water and ice

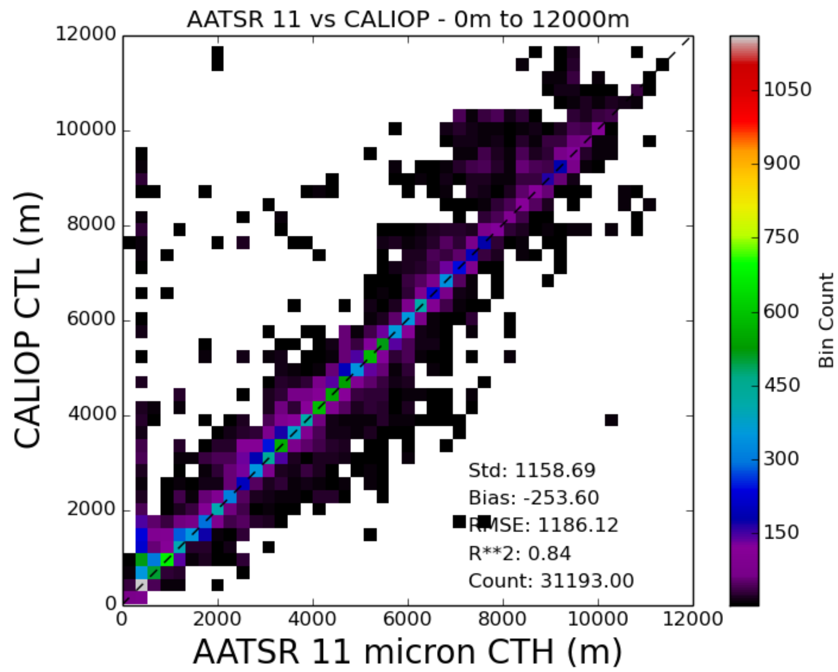
Success?

- The method shows both promise and potential problems. In this case:
  - Is not “tricked” by Chinese haze or sediment laden coastal waters.
    - The latter in particular seems to be a problem with the neural net mask.
    - Haze is a problem in Aerosol CCI
  - Both CCI and Bayesian scheme can fit very thin water cloud to (what appear to be) some clear sky pixels.
  - We don’t really get a cloud mask.
    - The question we are asking is “is our forward model consistent with observations”?
- Could be used in conjunction with NN and other techniques

Future: Stereo cloud top height



Comparison of retrievals over Greenland



- Stereo cloud top height will be used in OE retrieval as a priori information
- Dan Fisher/ JP Muller UCL- Census algorithm

Future work

- Some way to harmonising aerosol and cloud identification
- Improve treatment of uncertainty propagation
- Investigate ways of improving treatment of multi layer clouds and thin cirrus.

End

A test case

- Cumulative distribution of cost is very close to expected χ^2 distribution
- Note that the conditonal probability P(**x**|**y**) is pretty close to the χ^2 probabilty, but they are not the same