Processing and Use of Direct Broadcast Data at the Met Office

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CSPP/IMAPP Users Group meeting – 21st May 2013

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- Met Office capabilities for direct readout processing
- Satellites and software packages
- Developments in VIIRS imagery
- Processing of NPP sounder data
- Example of the use of CSPP for anomaly investigation in ATMS
- Summary

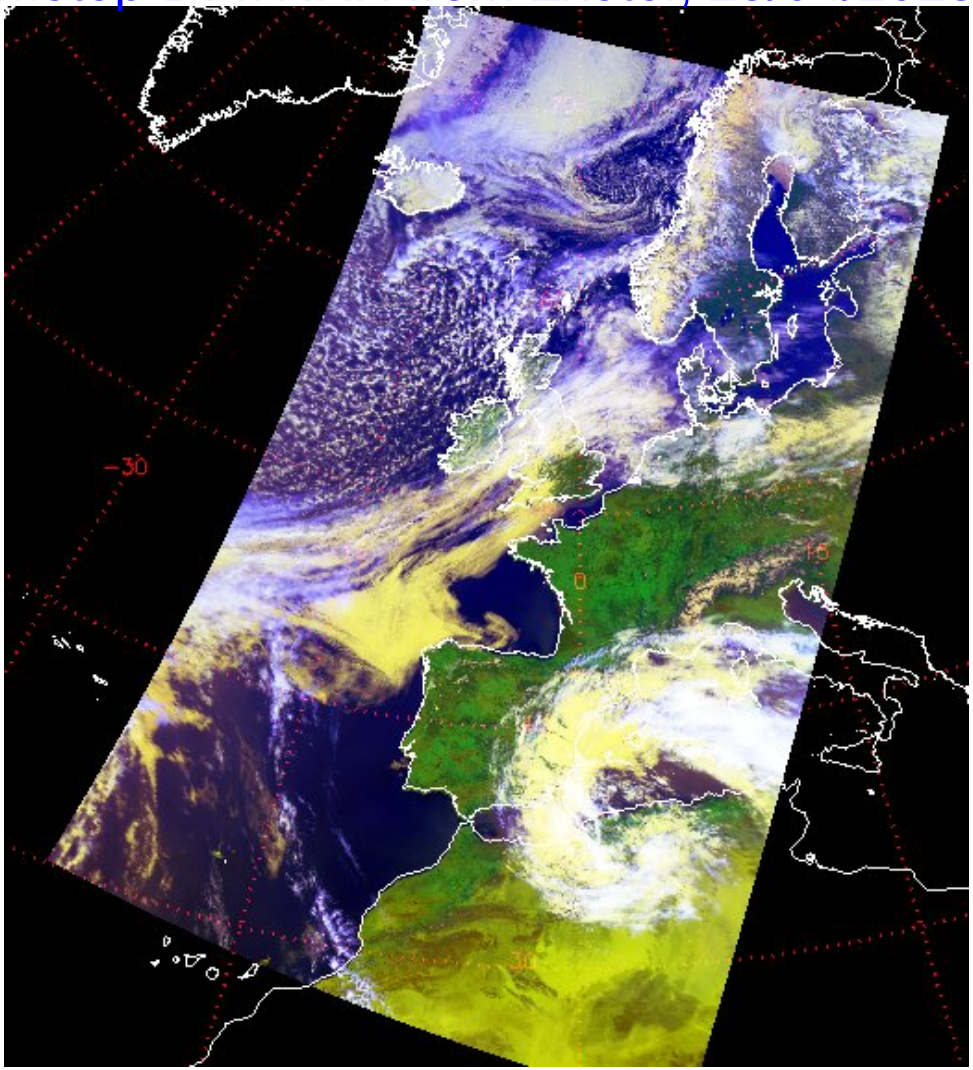
Why direct readout?

- Timeliness – satellite broadcasts what it sees
- No reliance on external comms links – suitable for remote locations

Direct broadcast = what the satellite transmits

Direct readout = what the user receives

Metop-B AVHRR from Exeter, 25/04/2013



Satellites and instruments of interest

Satellite	Frequency	Data rate	Instruments
NOAA POES	L-band (HRPT), 1.7 GHz VHF (APT), 137 MHz	0.67 Mbps 0.04 Mbps	AVHRR, AMSU, MHS, HIRS AVHRR (2 channels)
Metop-A/B/C (EPS)	L-band (AHRPT), 1.7 GHz	3.5 Mbps	AVHRR, AMSU, MHS, HIRS, IASI
Terra/Aqua	X-band, 8.2 GHz	13.1 / 15 Mbps	Terra: MODIS Aqua: MODIS, AIRS, AMSU, AMSR-E
Suomi NPP (JPSS 2017+)	X-band, 7.8 GHz	15 Mbps	VIIRS, ATMS, CrIS
FY-3A/3B (FY-3C soon?)	L-band, 1.7 GHz X-band, 7.8 GHz	4.2 Mbps 18.7 Mbps	VIRR, MWTS, MWHS, IRAS MERSI
EPS-SG (2020+)	X-band		Imagers, sounders, etc., on 2 satellites

Direct Readout Reception

3m dish at Met Office, Exeter

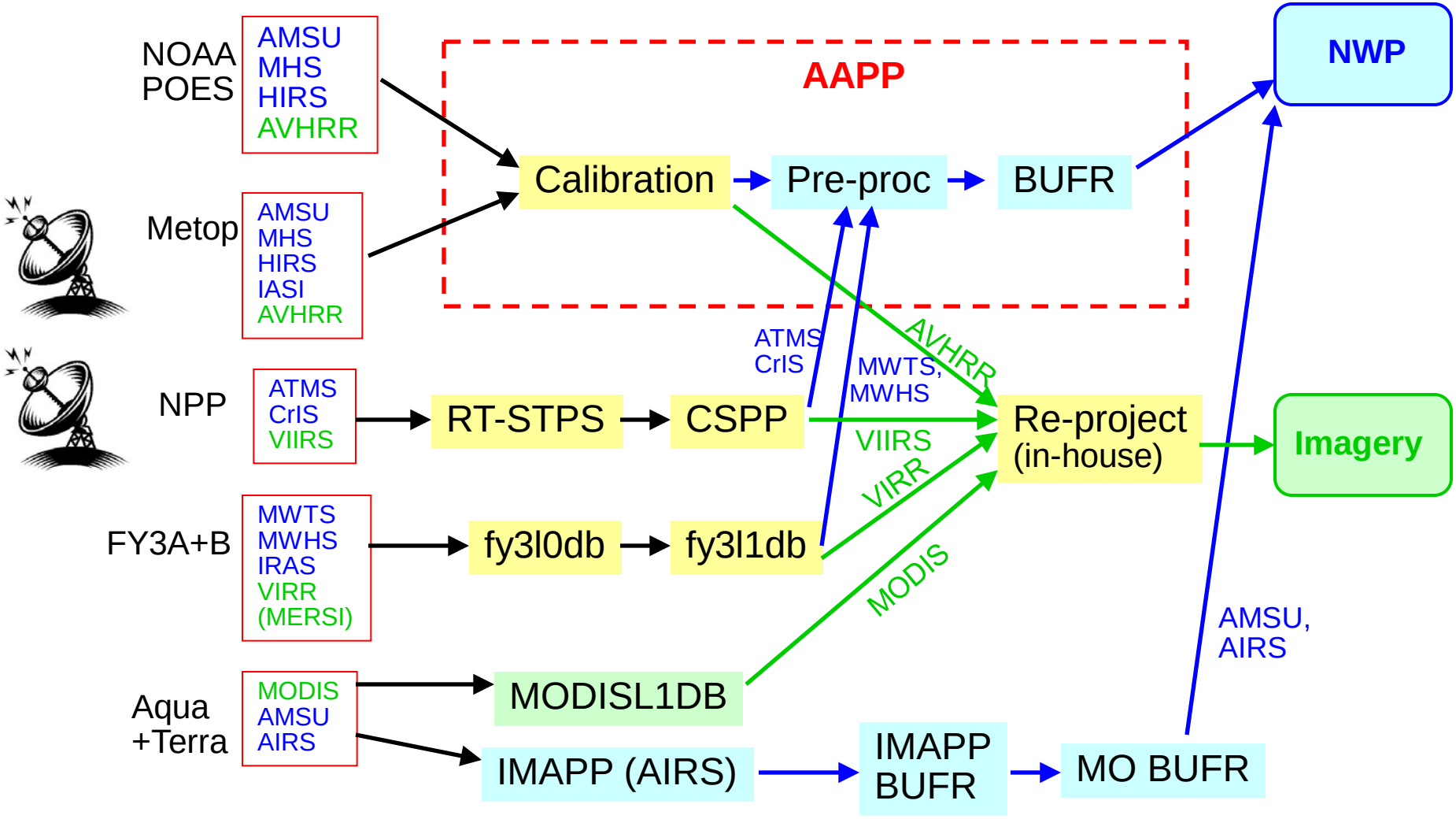
Installed 2003

Direct Readout Reception (2)

Installation of new 2.4m system, March 2012

Direct Readout Reception (3)

DB processing chain at the Met Office



Processing packages

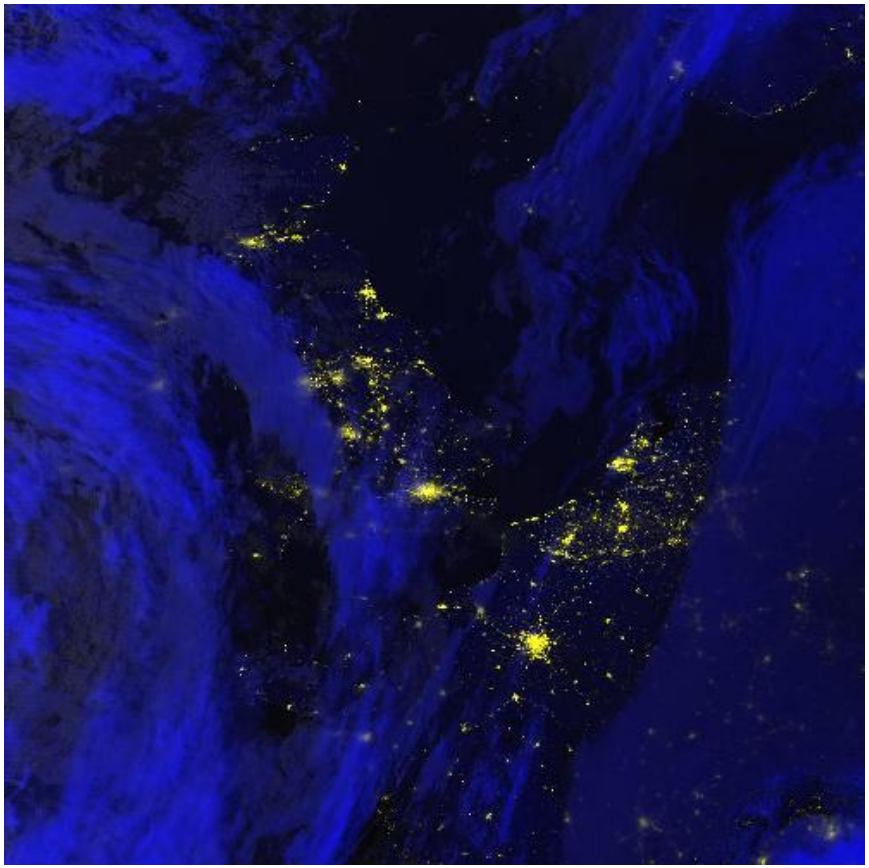
Satellite	Software	Available from	Output format
Aqua/Terra	MODISL1DB (SeaDAS) IMAPP MODIS level 2 AIRS level 1 & 2 AMSR-E level 1 & 2	http://seadas.gsfc.nasa.gov/ http://cimss.ssec.wisc.edu/imapp/	HDF-EOS BUFR
NPP	RT-STPS (raw → RDR) and CSPP (RDR → SDR)	http://cimss.ssec.wisc.edu/cspp/	HDF5
	IPOPP (NASA Direct Readout Lab)	http://directreadout.sci.gsfc.nasa.gov	
NOAA POES and Metop	AAPP	NWP SAF http://www.nwpsaf.org	AAPP native BUFR
FY-3A and FY-3B	FY3L0pp and FY3L1pp	http://www.nsmc.cma.gov.cn/NewSite/NSMC_EN Training → FAQs	HDF5
DMSP (U.S. military)	No	-	-
Meteor-3M (Russia)	No	-	-

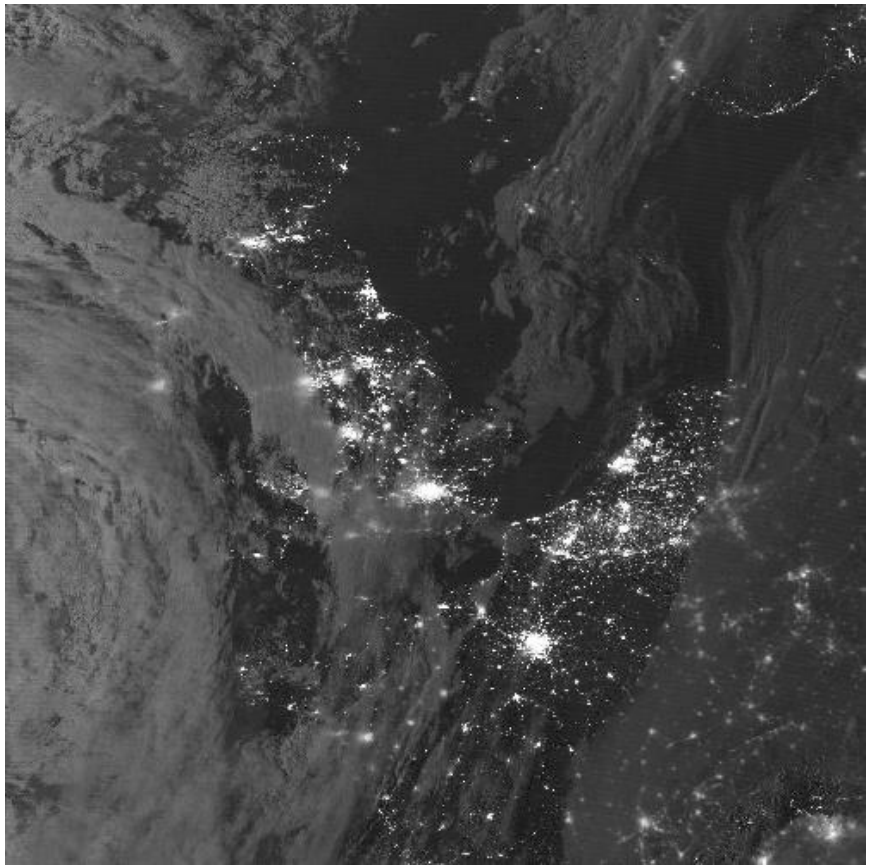
Processing server for DB data (and global data)

- Procured in 2012
- 2 production systems and 1 test system
- Redhat Enterprise Linux 6
- 2 x Hexa-core Intel Xeon X5675 Processors - 3.06GHz. 24 virtual cores
- 64 GB RAM
- 6 x 600 GB disks (2 RAID 1, 3 RAID 5, 1 spare)

We look forward to a multi-threaded version of CSPP VIIRS SDR!

VIIRS Day-night band

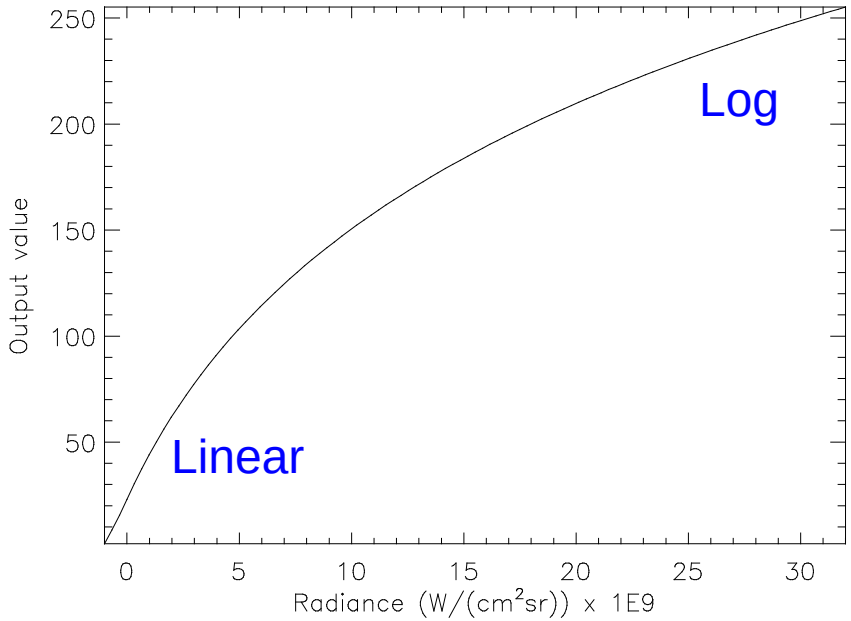




Colour:
blue = M15 infrared
red+green = DNB

DNB only:
- lunar illumination
- enhance low intensities
- useful for low cloud / fog detection

Enhancement of low intensities



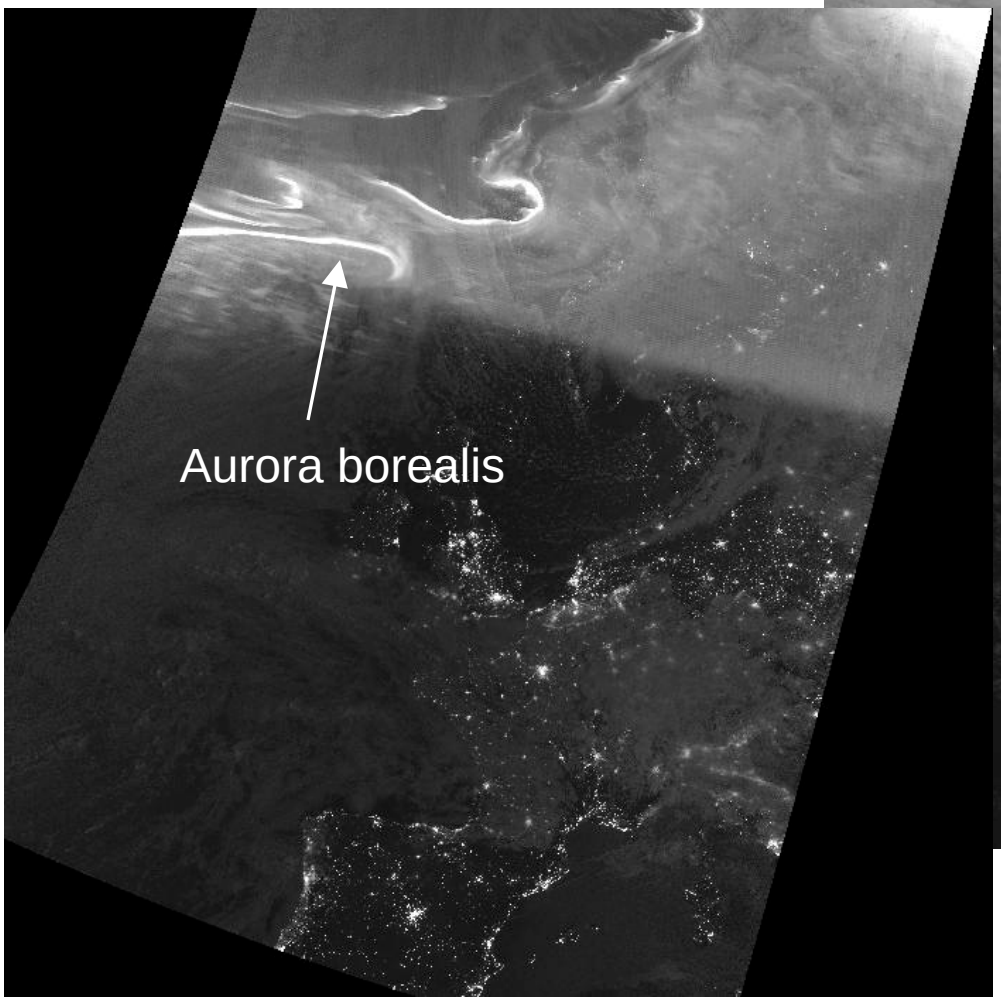
$$r' = A \ln\left(1 + r / A\right)$$

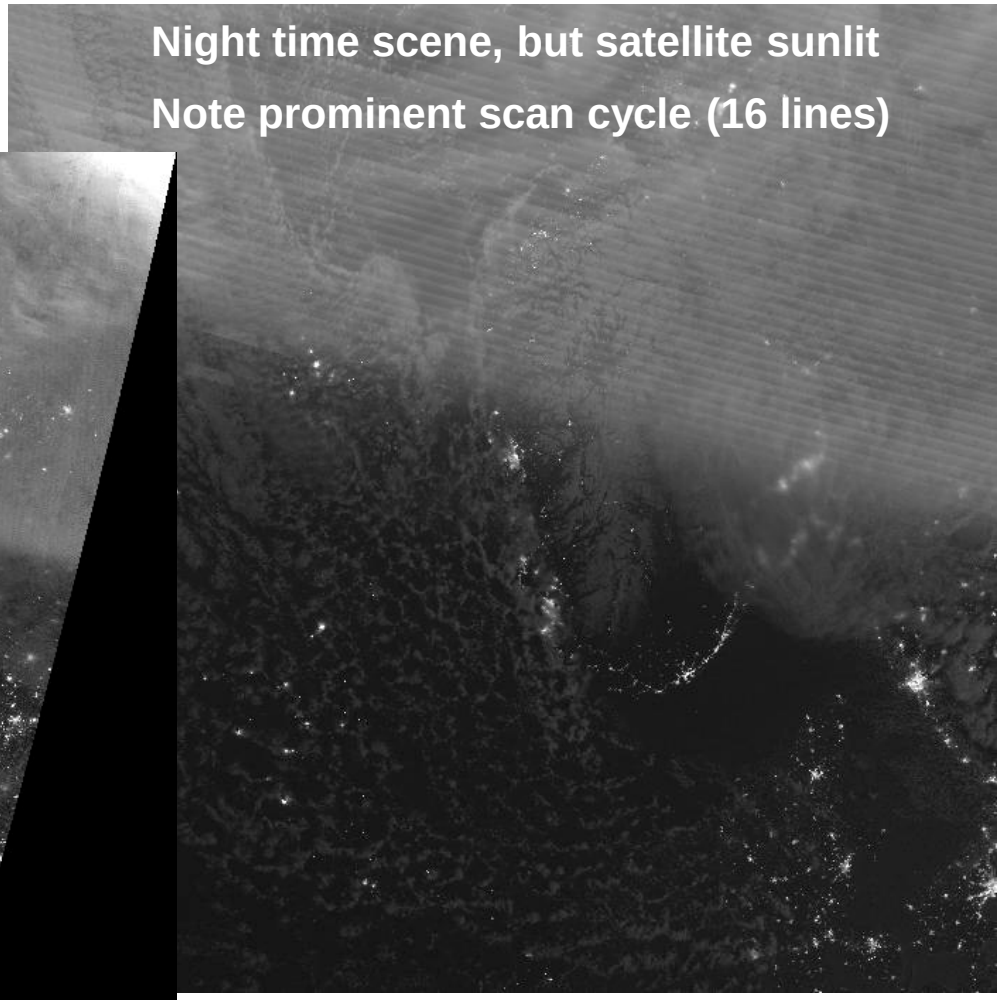
$A = 5\text{x}10^{-9}$ W/(cm² sr)

Scale r' such that $-1\text{x}10^{-9}$ to $1\text{x}10^{-8}$ fills 0-255

Suitable throughout the lunar cycle

DNB stray light problem





9th Oct 2012

Our solution

1. Estimate a radiance correction for each of the 16 detectors in a scan (use a reference dark scene)
2. Use SCSolarZenithAngle to roughly locate the day/night transition (look at 70°-82°)
3. For each line in the test scene, compute the 25th percentile of the radiance
4. For each scan (16 lines), compute the product of the radiance, *r*, and the reference correction, *R*

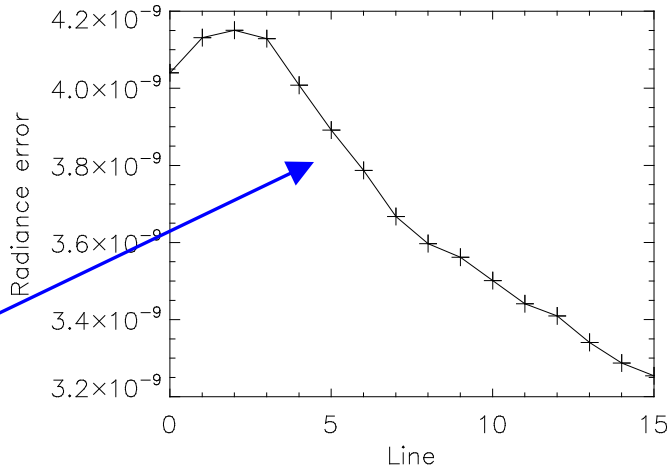
$$\frac{\sum (r-\bar{r})(R-\bar{R})}{\left(\sum (R-\bar{R})\right)^2}$$

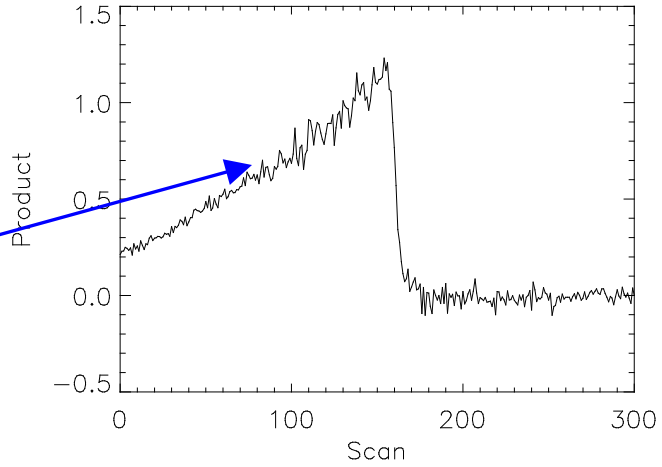
5. Take a fixed reference function and shift it until the best match is obtained

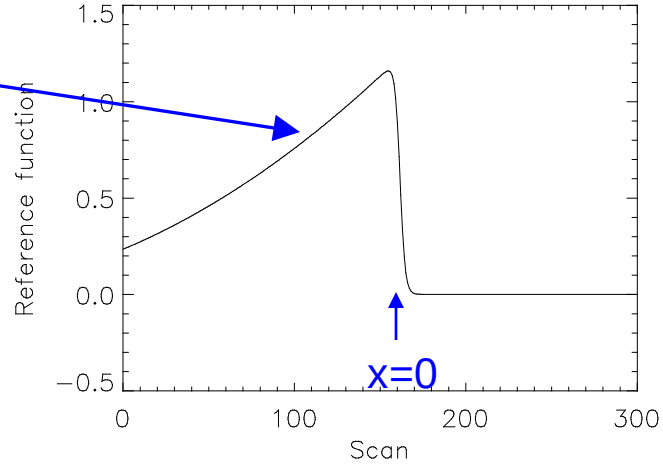
$$y = A + Bx + Cx^2 + 0.5\left(1-\tanh\left(x/w\right)\right)$$

A, B, C, w are constants; vary the *x* origin

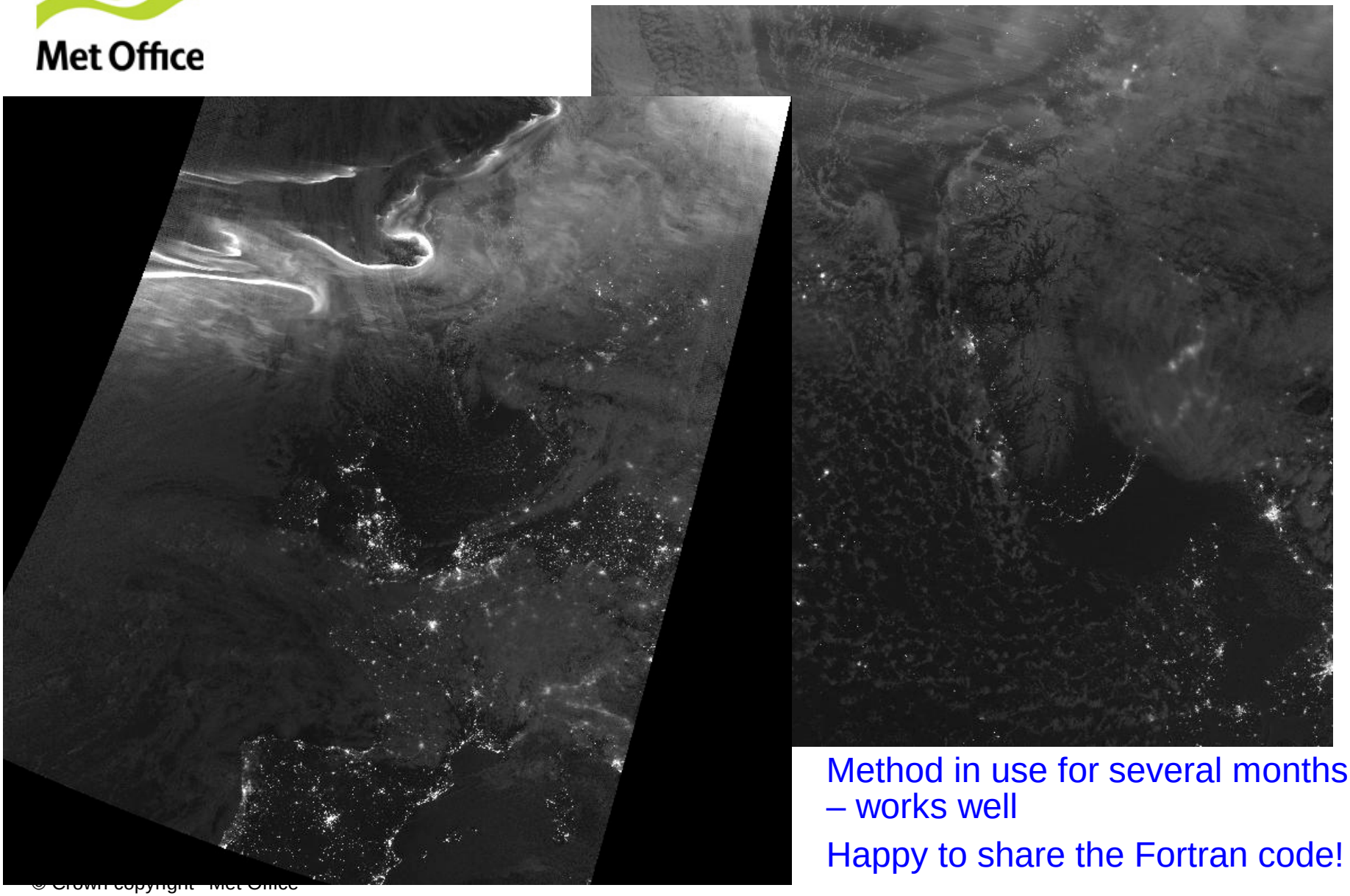
5. Fit the amplitude
6. For each scan, multiply the radiance correction (step 1) by the optimised reference function (step 5), hence correct each line







Corrected DNB imagery

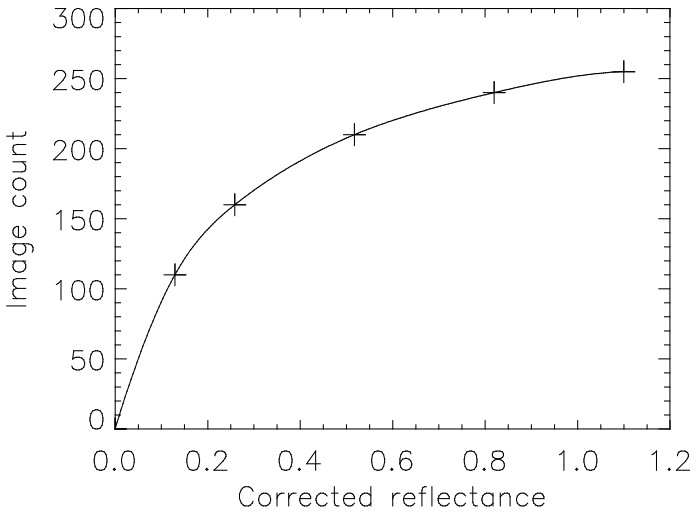


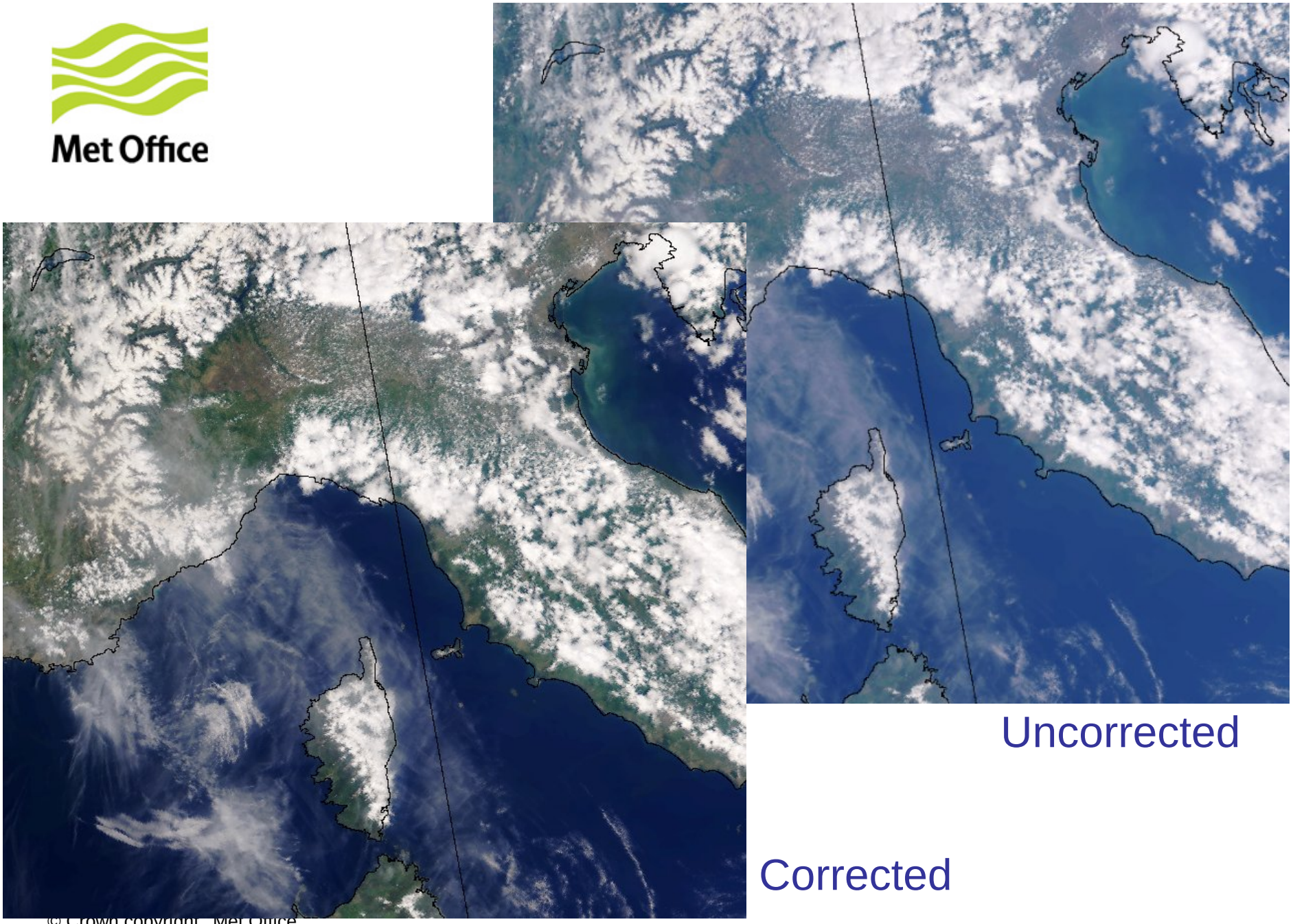
Method in use for several months – works well

Happy to share the Fortran code!

VIIRS true colour

- Using the new version of UW's "crefl" software (version 1.7.1)
  - supports MODIS and VIIRS
- Channels M2, M4, M5 or I1
- Same radiance to grey-scale mapping as MODIS (see *Creating Reprojected True Color MODIS Images: A Tutorial* by Gumley et al.)





Uncorrected

Corrected

High resolution VIIRS and MODIS

- MODIS:
  - Band 1 (250m & 500m), Band 4 (500m), Band 3 (500m)
- VIIRS:
  - I1 (370m), M4 (740m), M2 (740m)
  - Create a low res version of I1 (average 2x2)
- As per Liam's tutorial, define

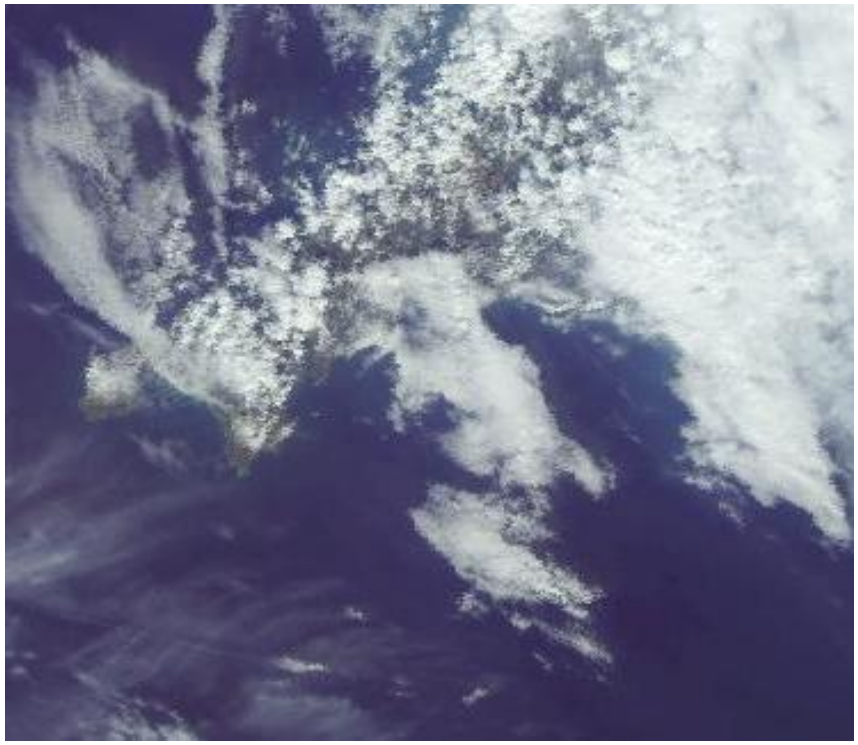
$f = \text{Red}_{\text{High res}} / \text{Red}_{\text{low res}}$

$\text{Green}_{\text{High res}} = \text{Green}_{\text{Low res}} \times f$

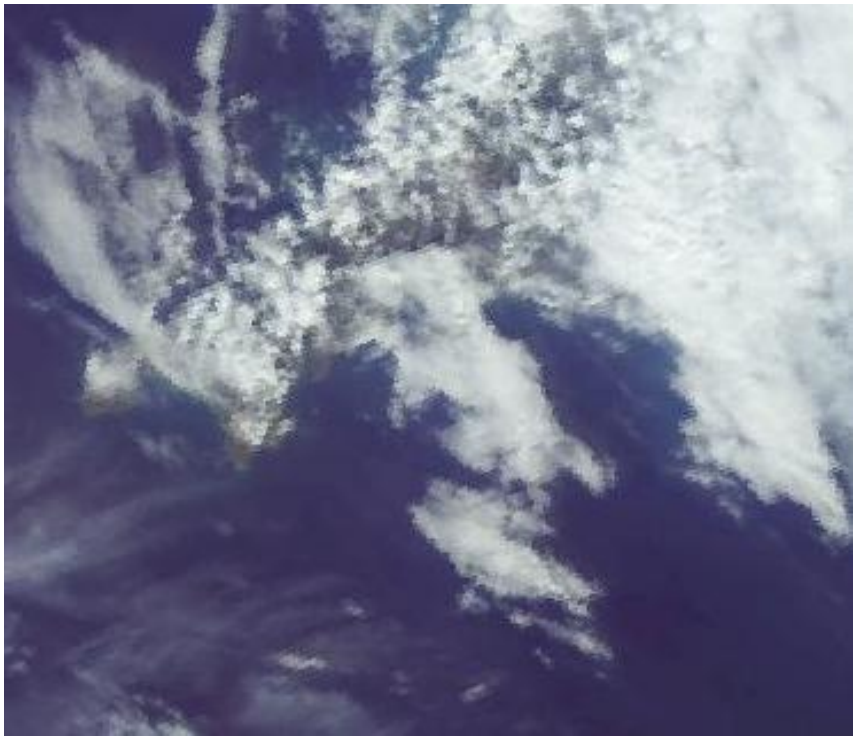
$\text{Blue}_{\text{High res}} = \text{Blue}_{\text{Low res}} \times f$

} We do this *after reprojection*

VIIRS over Cornwall



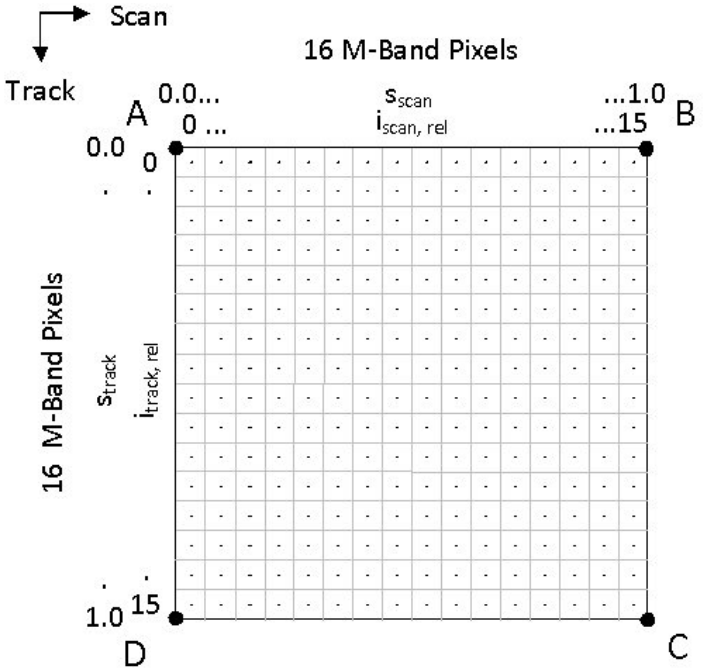
Sharpened (370m)



Original (740m)

Aside: VIIRS SDR format

- The VIIRS SDR format (hdf5) is not well suited to dissemination
- Geolocation is bulky
- Some channel radiances are floating point numbers



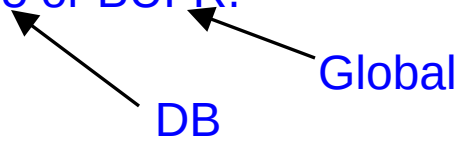
- We strongly support EUMETSAT's initiative to devise a new format for EARS-VIIRS service (see Anders Soerensen's talk)
  - Tie points (1 in 256 reduction)
  - 16 bit integer radiances
  - Software to convert to standard SDR
- Could the new format be use more widely (e.g. NOAA CLASS)?

AAPP support for Suomi NPP

from AAPP v7.1 (Feb 2012)

AAPP ingests the SDR files – hdf5 or BUFR.

Stores in “AAPP-format level 1c”



ATMS

- Spatial filtering (noise reduction and channel matching)
- Spatial thinning
- Map to CrIS
- BUFR encoding

CrIS

- Channel selection
- Spatial thinning
- BUFR encoding

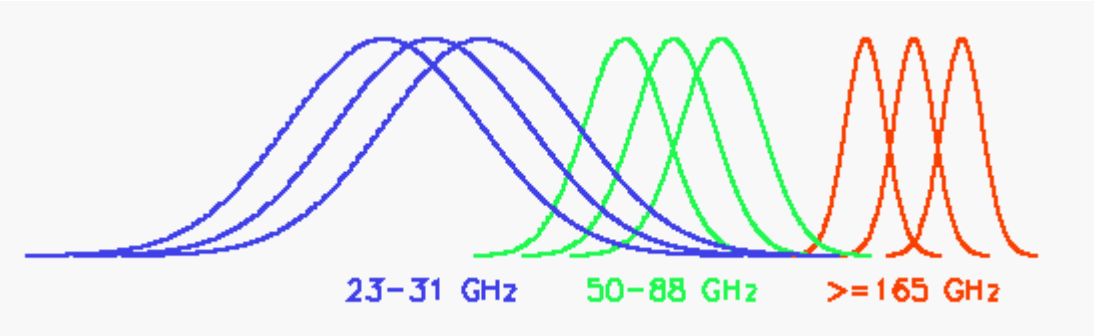
VIIRS

- Cloud mask coming soon

ATMS spatial filtering

Two issues for NWP:

1. For many channels, raw NEΔT is larger than model background error (and larger than AMSU NEΔT)
2. Difficult to use channels 1&2 due to beamwidth mismatch with channels 3-15 (5.2° vs 2.2°)



These issues are handled by AAPP:

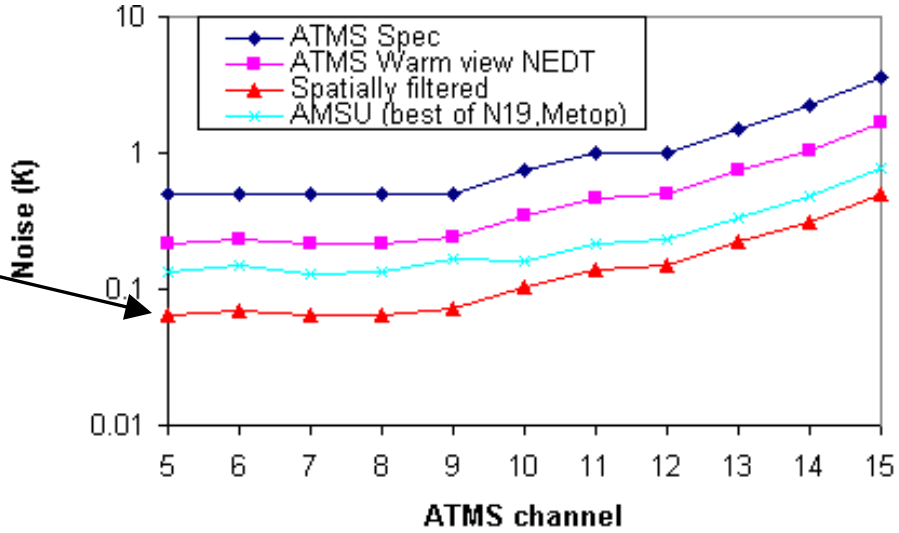
- Broaden ch 3-15 beam width to that of AMSU-A
- Narrow ch 1-2 (as far as possible without increasing noise)

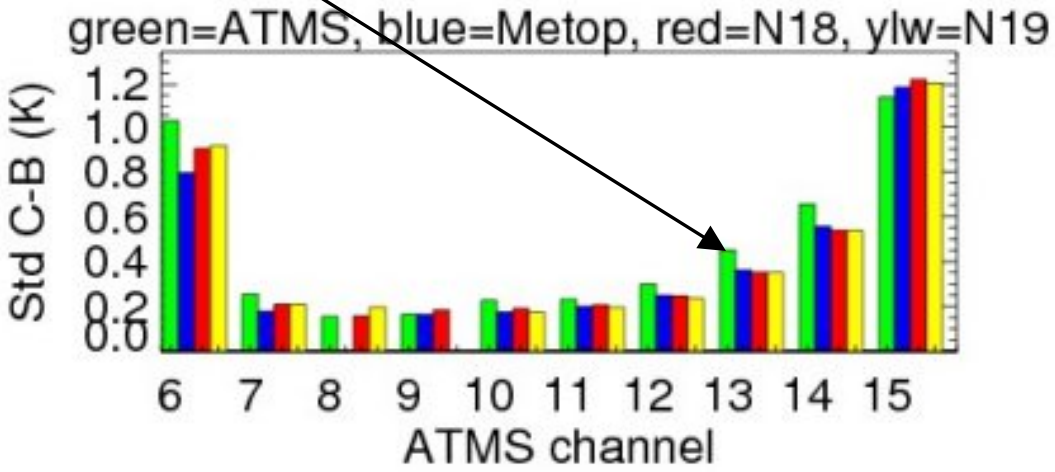
see AAPP document on ATMS processing at http://www.nwpsaf.org

- ➢ Technique now used operationally at several centres

ATMS noise performance

- Expect NEΔT to be well below AMSU values
- However, noise wrt *NWP* is slightly inferior to AMSU – Why?

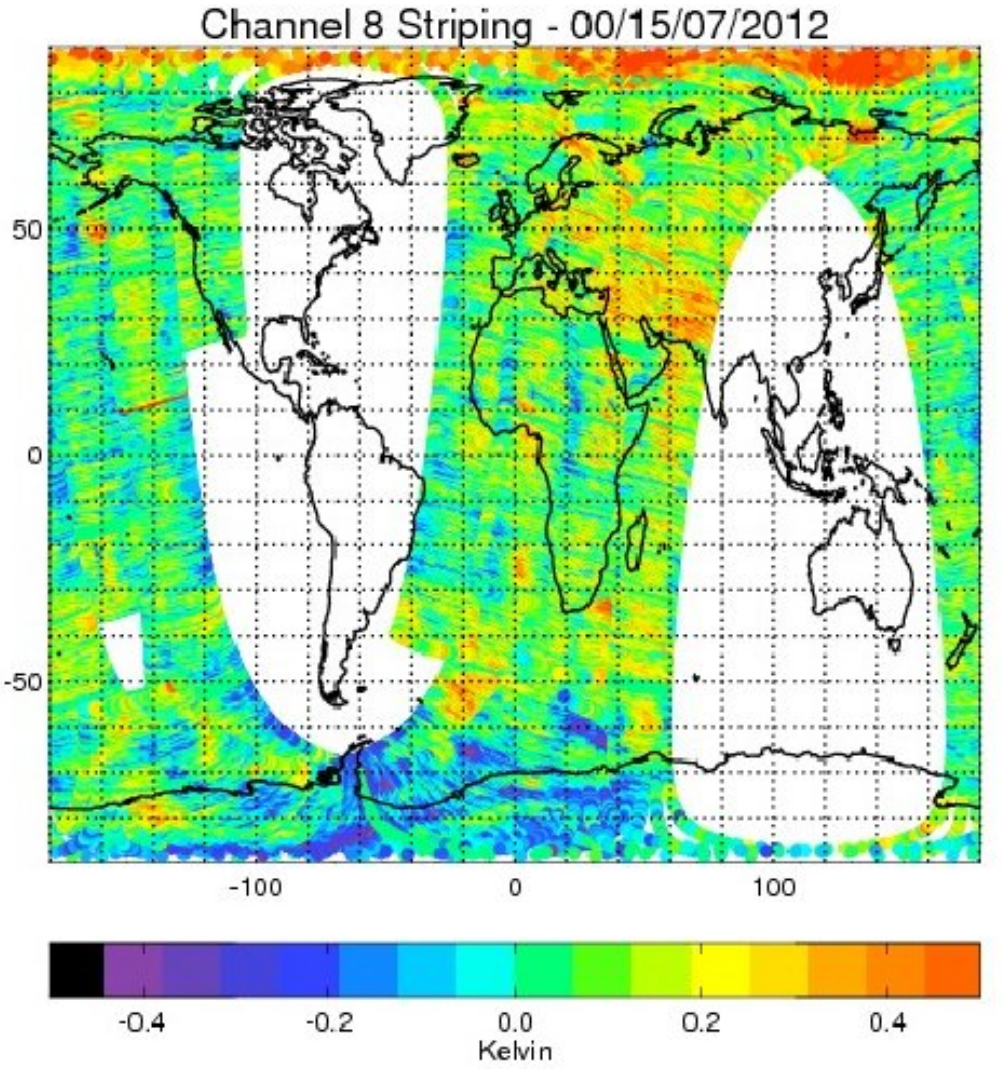




Doherty et al., 2012

Striping noise

- Reported at ITSC-18 (March 2012)
- At that time we were speculating that this was calibration noise
- Difficult to investigate due to lack of access to raw counts for calibration views (not in the SDR)



Extract from ITSC-18 Products Working Group report

- Recommendation: ATMS, VIIRS, and CrIS SDR calibration traceability must be improved to allow users to investigate detailed instrument performance.
  - Action 6.1: Investigate ways to expose or save calibration information from the RDR files. RayG, NigelA
  - Action 6.2: In order to maintain a record of product provenance, create a set of guidelines for metadata to be associated with satellite products. GeoffC

Recipe for extracting raw counts for ATMS

1. Configure CSPP to generate a “Verified RDR” file:

   Edit ADL/cfg/ProSdrAtmsVerifiedRDR_CFG.xml

```
<group name="ATMS_VERIFIED_RDR">
    <config>
       <name>DataEndianType</name>
       <configValue>Both</configValue>
    </config>
    <config>
       <name>OutputType</name>
       <!--                                                    -->
       <!-- Note changing this from heap will output       -->
       <!-- it with a dataset type tag which is not        -->
       <!-- supported in the DPIS                          -->
       <!--                                                    -->
       <configValue>DMS</configValue>
    </config>
    <config>
       <name>OfficialShortName</name>
       <configValue>ATMS-Verified-RDR-IP</configValue>
    </config>
 </group>
```

Changed from HEAP

Thanks to Ray Garcia

2. Deduce the contents of the Verified RDR – using ADL source code ADL/algorithms/ADL/SDR/ATMS/src/atms_struct.f

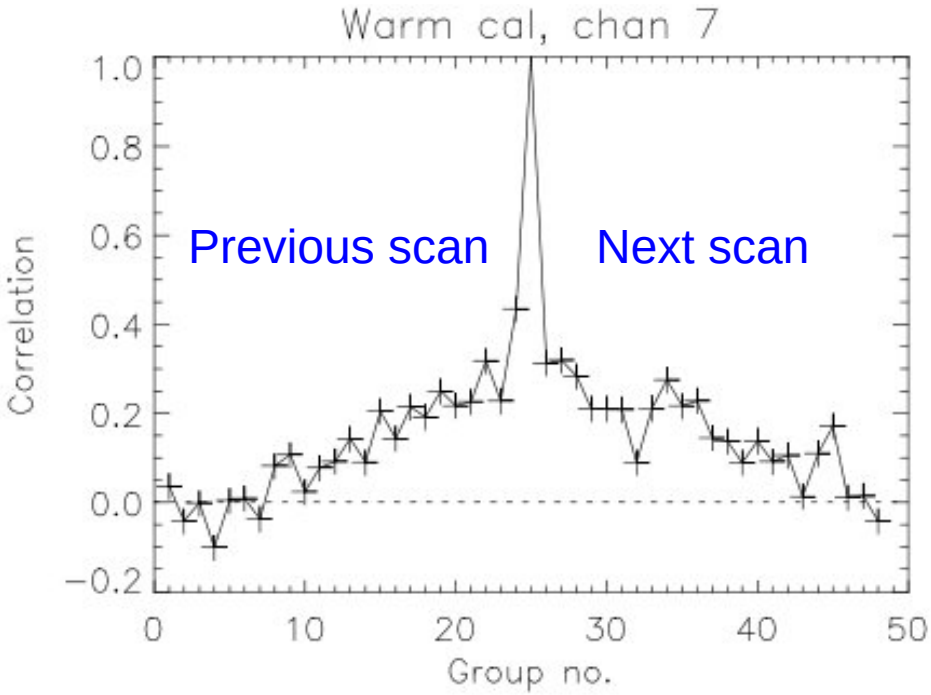
3. Wrote an IDL reader

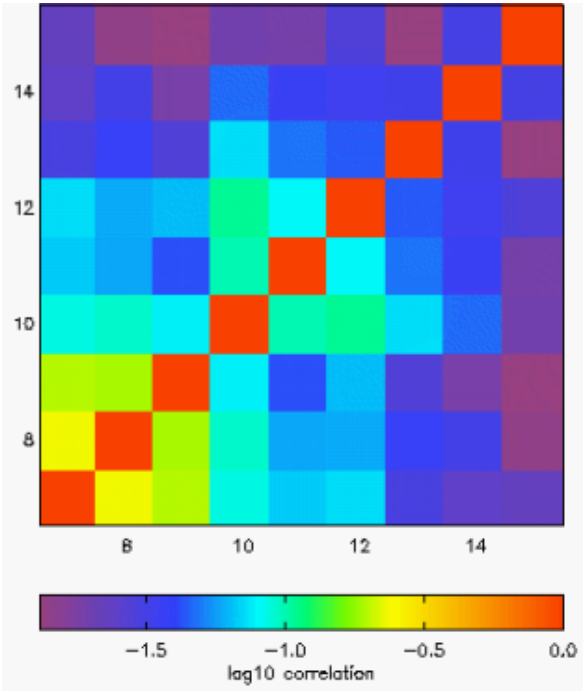
   - Gives earth counts, space counts and warm counts, as well as other instrument health data.
   - IDL code available on request!

- This procedure is far from obvious!
  - compare the AMSU 1b format in which raw counts are fundamental
- Consider ways to document for ATMS?
- Can we improve visibility for future instruments and missions?

What did we find?

Results derived from DB data





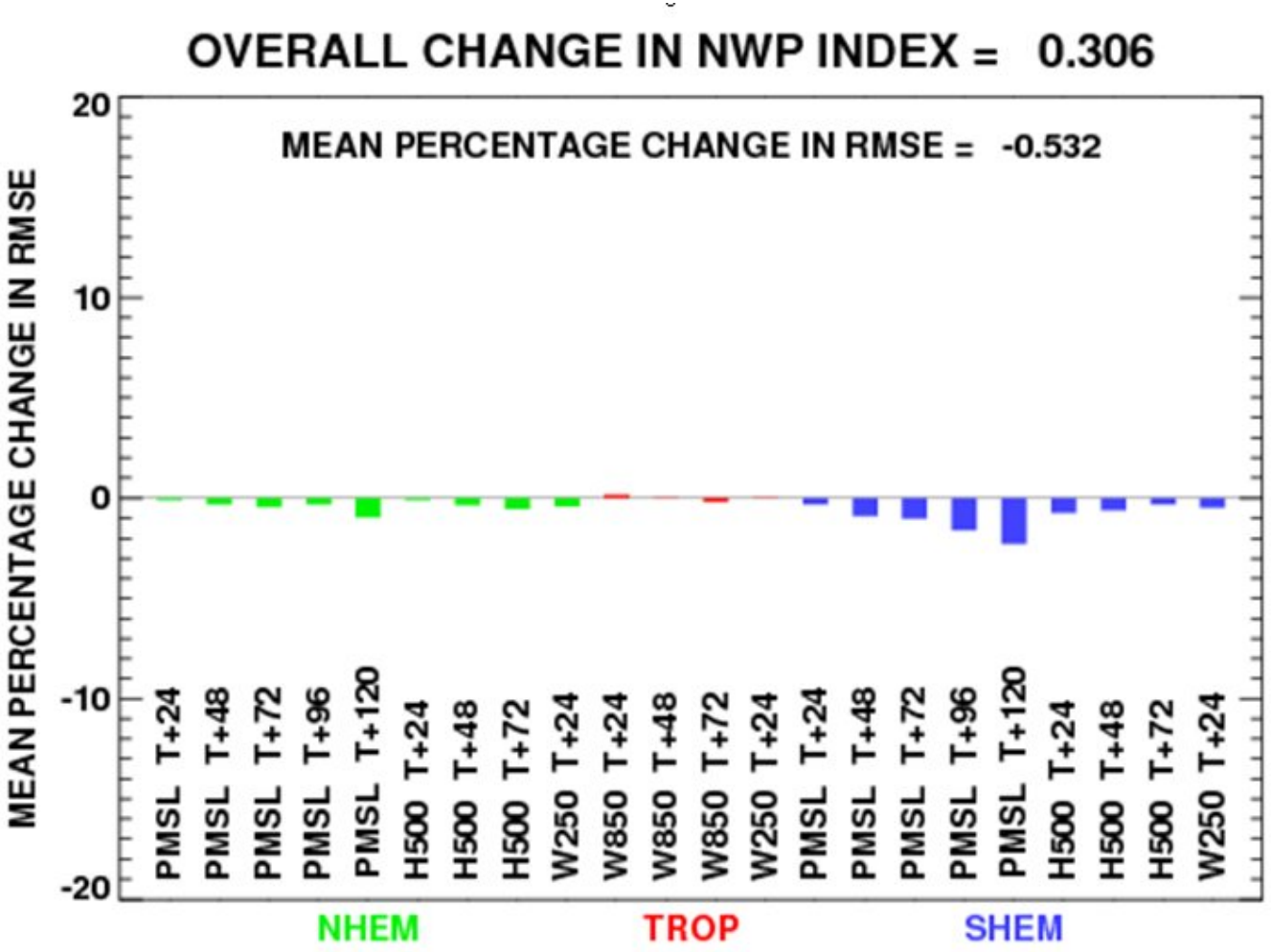
- Warm counts (and cold counts) are correlated with neighbouring earth view counts
- Correlation extends over approx 1 scan
- Also some inter-channel correlations in the BT fields
- Extending the calibration view averaging does *not* help to reduce noise
- Manufacturer (NGES) confirmed that this “1/f noise” is a known “feature” of ATMS (the pre-amp)

ATMS striping - conclusions

- Striping (1/f noise) is a characteristic of the instrument
- The NEΔT values in the SDR do not take account of 1/f noise – so are optimistic
- Spatial averaging of the BT fields does not beat down the noise as much as originally expected
- Performance is within the official spec
  - Importance of specifying future instruments correctly
- Nevertheless, impact of ATMS in NWP is positive!

Use of NPP data in NWP

- ATMS and CrIS data assimilated operationally in Met Office global model from April 2013

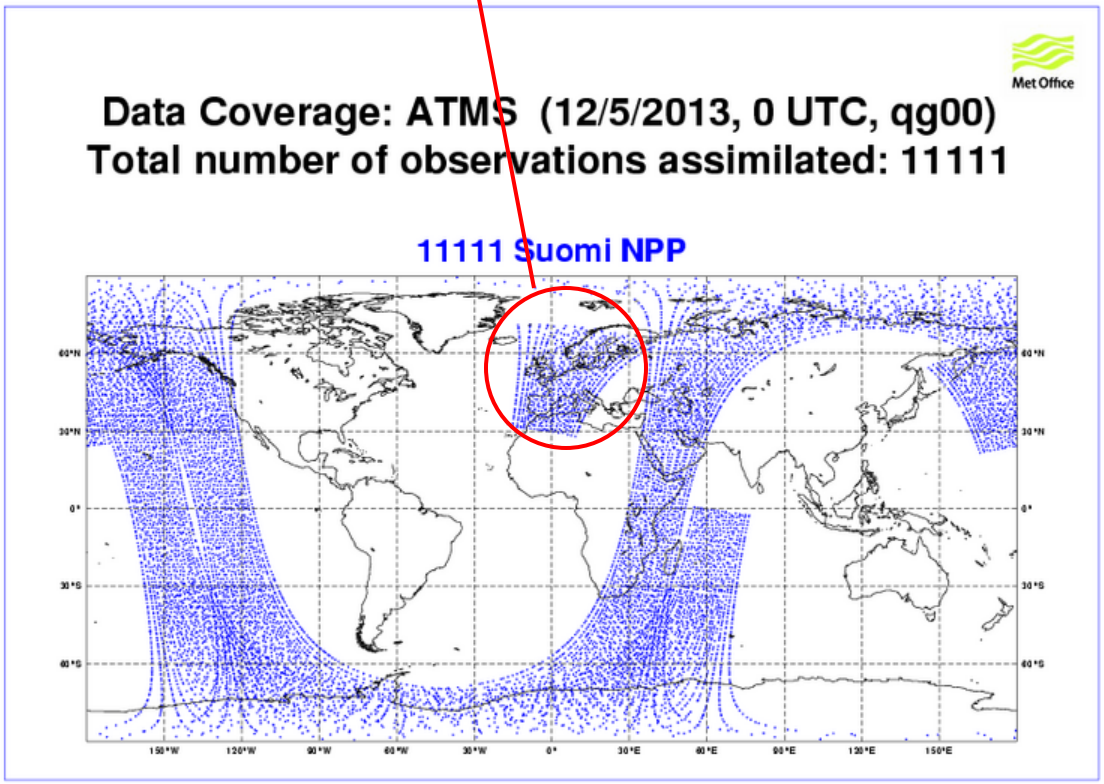


Lower errors

From package trials

Use of NPP data in NWP (cont.)

- Direct readout ATMS and CrIS data (50km) supplement the global data



- Also store at full spatial resolution, for future use in regional models
- Plan to make use of EARS-ATMS and EARS-CrIS

Summary

- Met Office DB systems receive POES, Metop, NPP, EOS and FY-3
- The data are used for imagery and NWP
- The level 1 processing uses several freely-available processing packages, and runs OK on a Linux server
- Techniques developed for displaying VIIRS
  - e.g. true-color and DNB images
- CSPP can be used for in-depth investigations, as in the ATMS striping anomaly
- ATMS and CrIS deliver positive impact in NWP at the Met Office

Thank you for listening!

For more information:
http://www.metoffice.gov.uk
http://www.nwpsaf.org

Questions?

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