Snow products for assimilation and verification

Debbie Clifford

NCEO

Ross Brown ::: Chris Derksen ::: Mike Durand ::: Jim Foster ::: Robert Gurney ::: Richard Kelly ::: Alex Langlois ::: Nick Rutter ::: Marco Tedesco

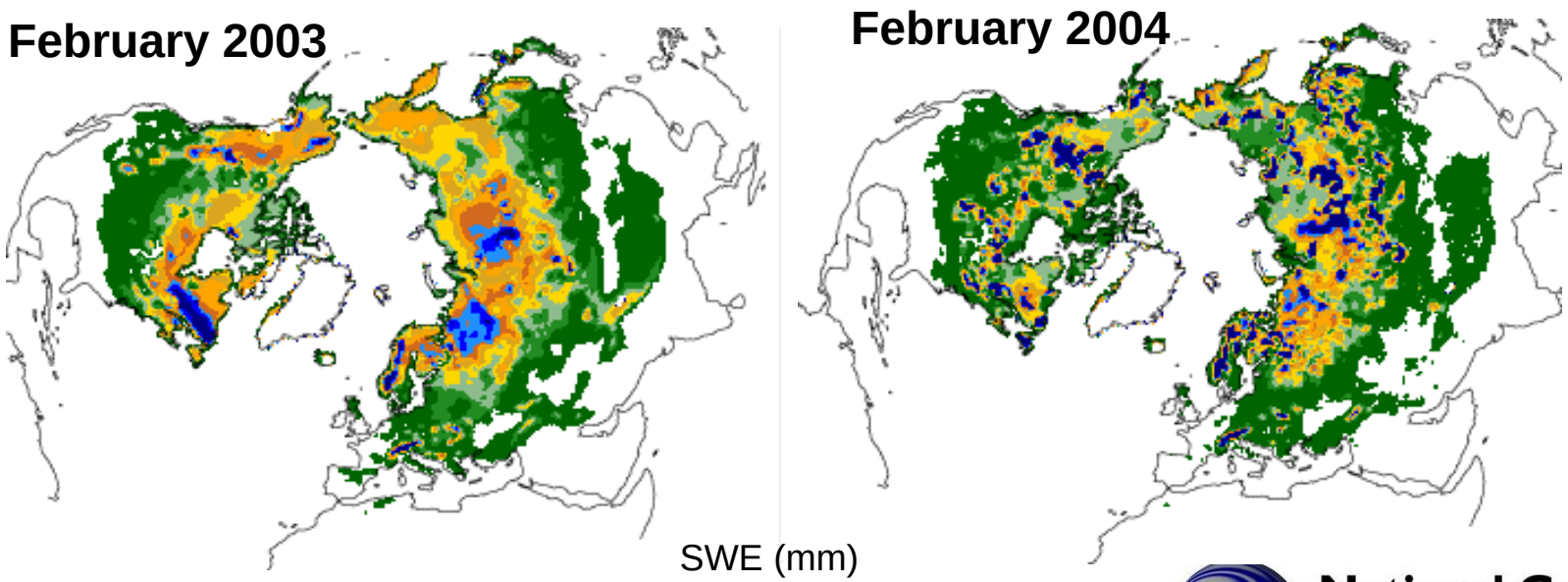
d.j.clifford@reading.ac.uk

National Centre for Earth Observation

NATURAL ENVIRONMENT RESEARCH COUNCIL

Importance of background climatology

- ERA-Interim SWE field very different before and after recent changes to operational snow scheme
- Pre-2003: relaxed to Foster and Davy climatology (looks like ERA40), only station snow data assimilated
- Post-2003: snow extent data from remote sensing assimilated



National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Ground data

- WMO SYNOP observations – already used
- ERA40 uses Canadian and Russian snow surveys
  - Atmospheric Environment Service, Canada, Canadian snow depths, 1946-1995
  - NCAR, Snow dataset from former USSR, 1966-1990
- Snotel - SWE, precipitation, temperature, snow depth and soil moisture/temperature data at sites in the western US in near real time
- CEOP stations – several are in cold regions
- GPS in future? (Larson et al, GRL, 2009)

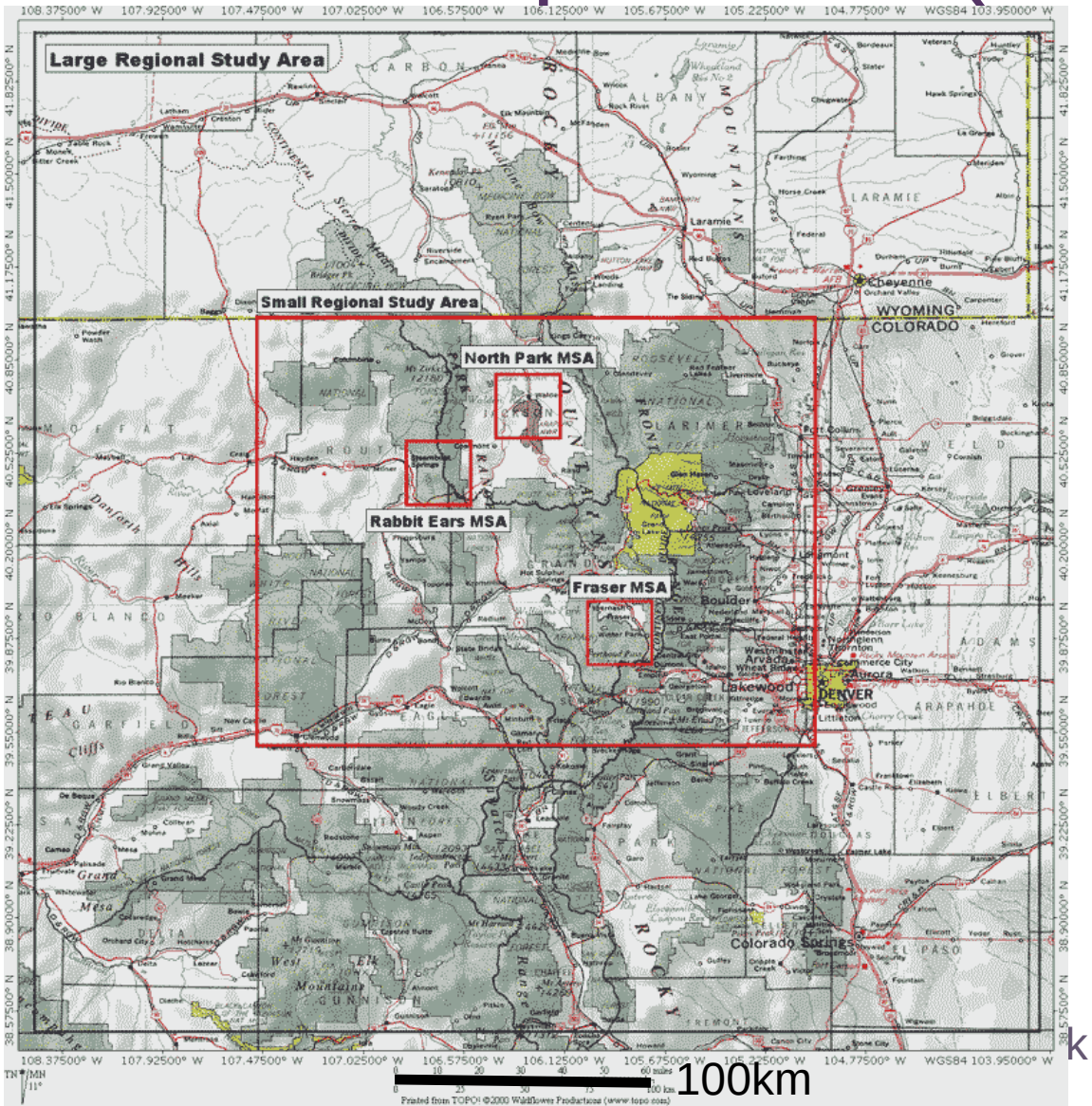
But....

- To map snow depth with an error of less than 5cm in a 1 degree by 1 degree grid cell, at least ten measurements are required (Chang et al, J. Hydromet., 2005)

d.j.clifford@reading.ac.uk

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

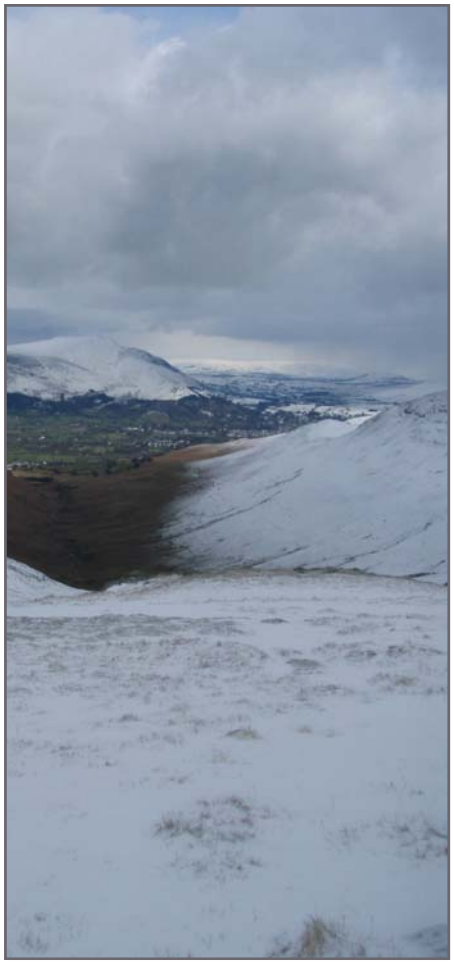
NASA Cold Land Processes Field Experiment (CLPX)



- A multi-sensor, multi-scale field program of nested study areas in Colorado and Wyoming, USA
- Intensive Observation Period (IOP) 1 was carried out in February 2002, IOP2 in March 2002, IOP3 in February 2003, and IOP4 in March 2003.
- CLPX special issue in JHM: 2008, vol 9, iss 5.

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Snow extent/duration/albedo from space



- Visible sensors can see reflectance, scatterometers can detect changes in backscatter due to melt, multiple datasets available...
- NESDIS IMS – already used
  - 4km/24km, daily/weekly
  - Manual interpretation of multi-satellite data
- MODIS
  - From daily 500m to monthly 0.05deg
  - Automated algorithm
- Passive microwave can see through clouds but can't see thin snow
- Grain size/albedo products have also been derived from MODIS measurements Painter et al, Rem Sens of Environment, 2009
- Extent and snow-off dates have been compiled by the Canadian Centre for Remote Sensing using AVHRR Zhao, H. & Fernandes, R. JGR, 2009
- Quikscat: part of NASA's Scatterometer Climate Record Pathfinder has been flying since 1999

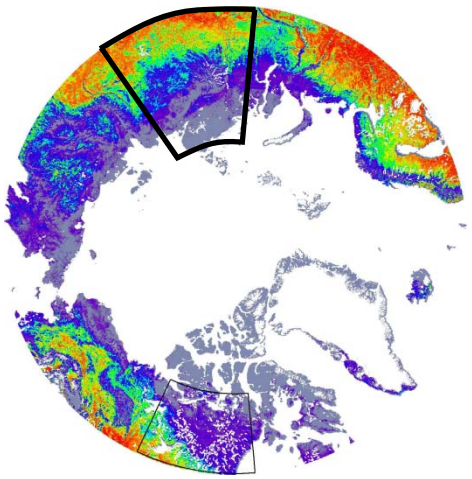
d.j.clifford@reading.ac.uk

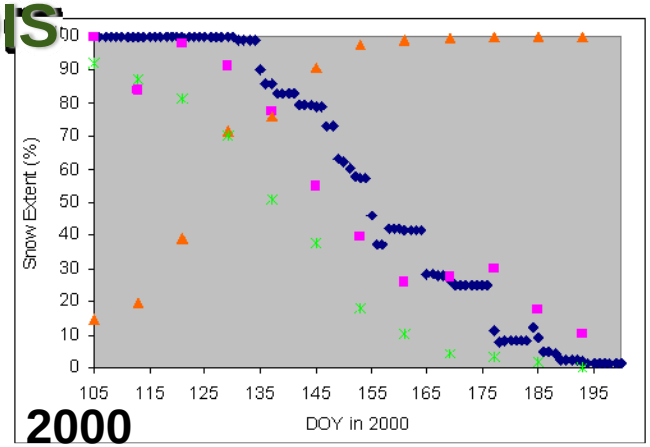
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

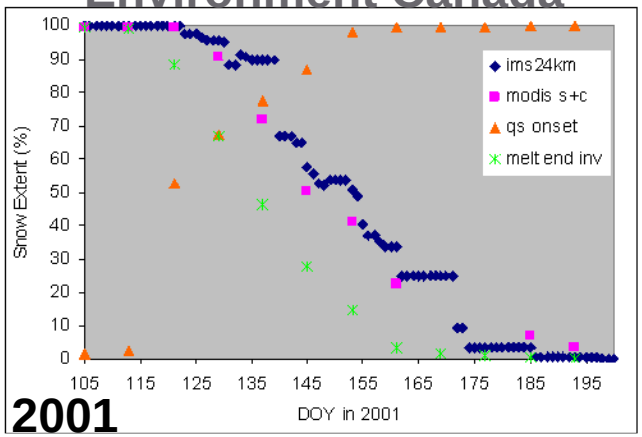
Comparison of weekly snow extent: IMS vs. MODIS vs. QSCAT

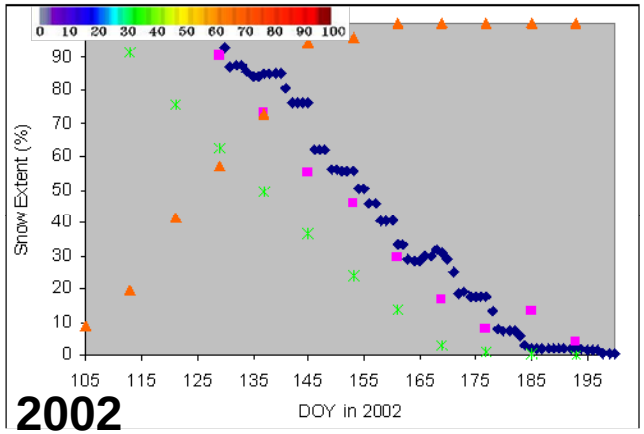
Chris Derksen, Environment Canada

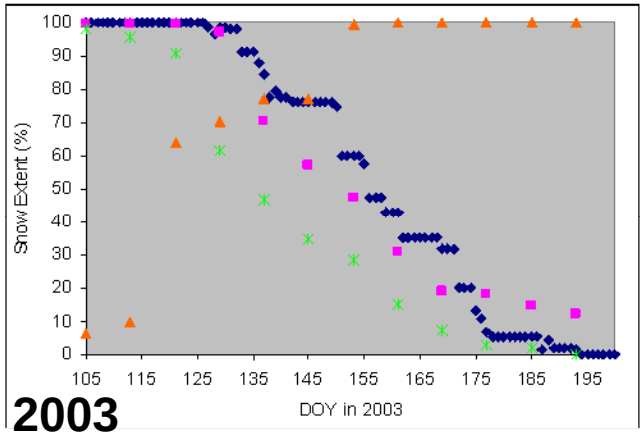
Central Siberia
60º – 77ºN
80º – 120ºE

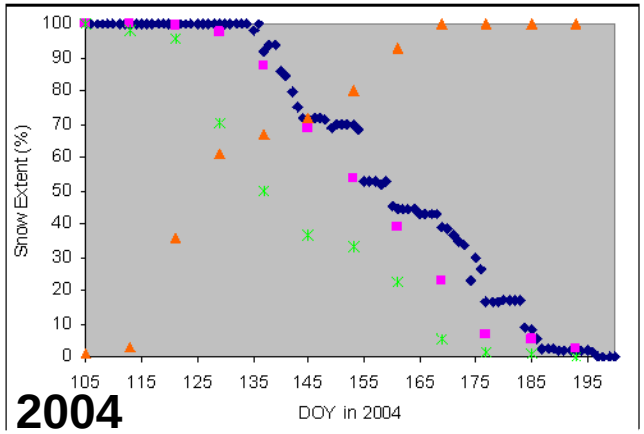


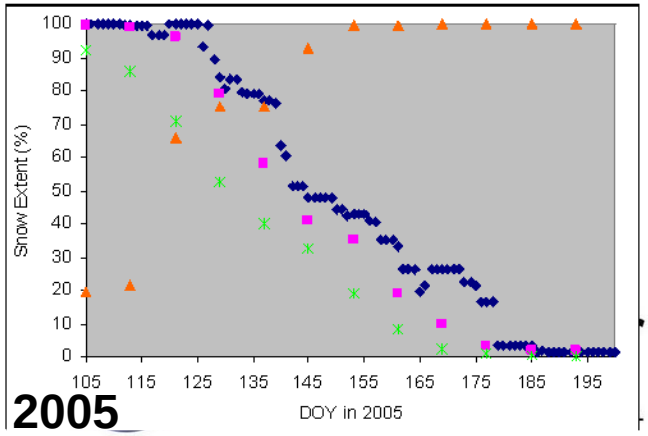












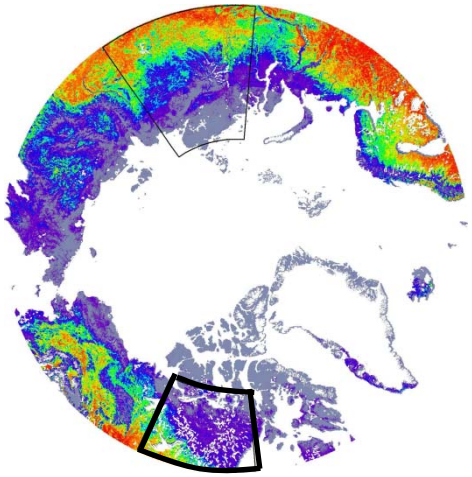
Comparison of weekly snow extent: IMS vs. MODIS vs. QSCAT

Chris Derksen,
Environment Canada

Canadian Tundra

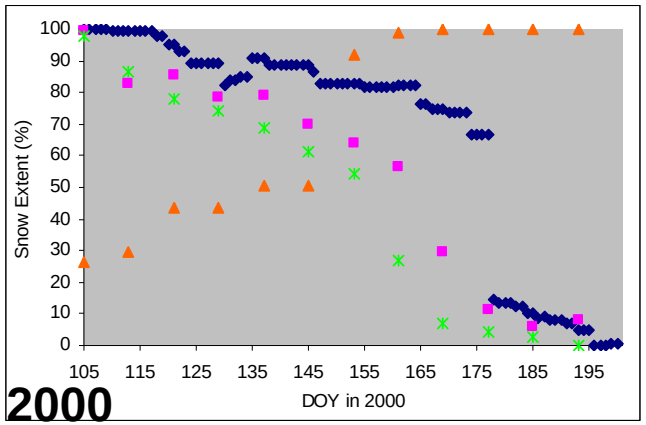
60º – 70ºN

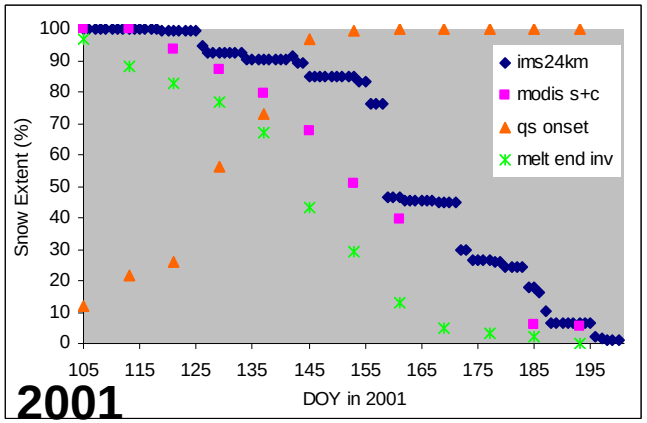
90º – 120ºW

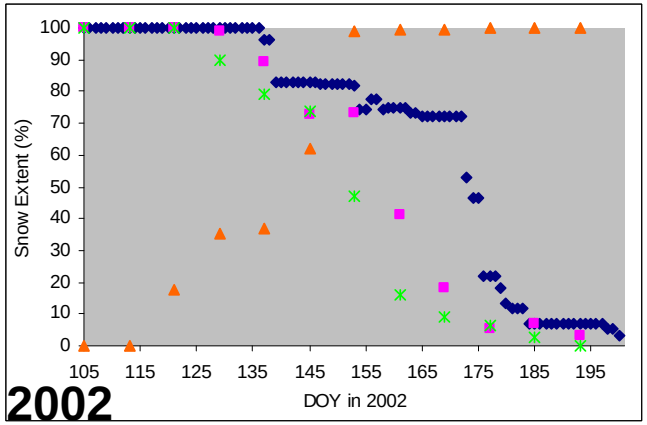


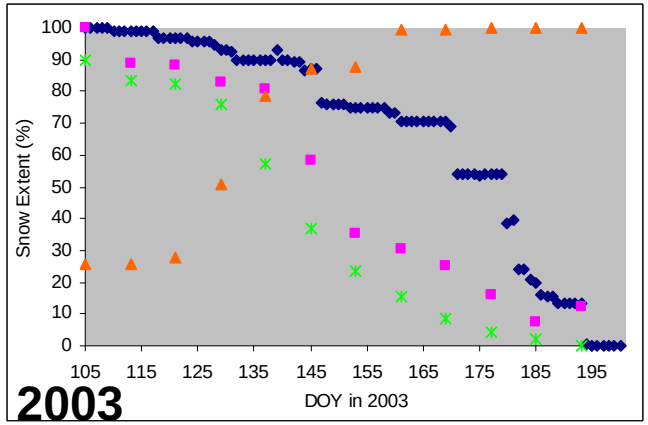
IMS over extends the snow cover season.

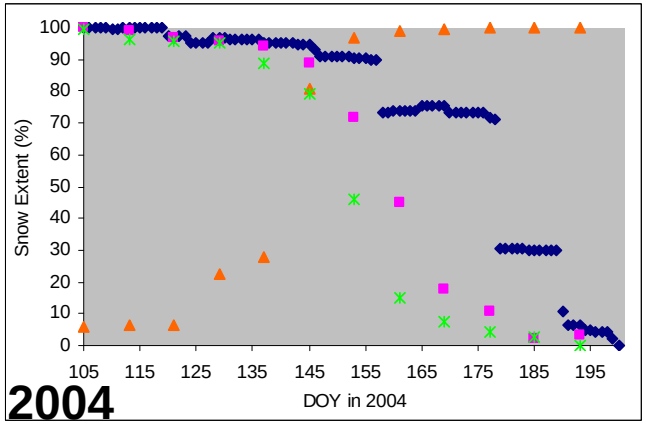
Explanation: high lake fraction with late season ice cover confuses IMS analysts.

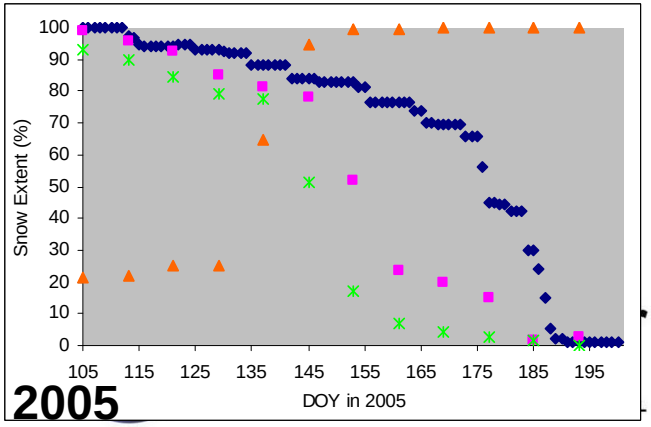






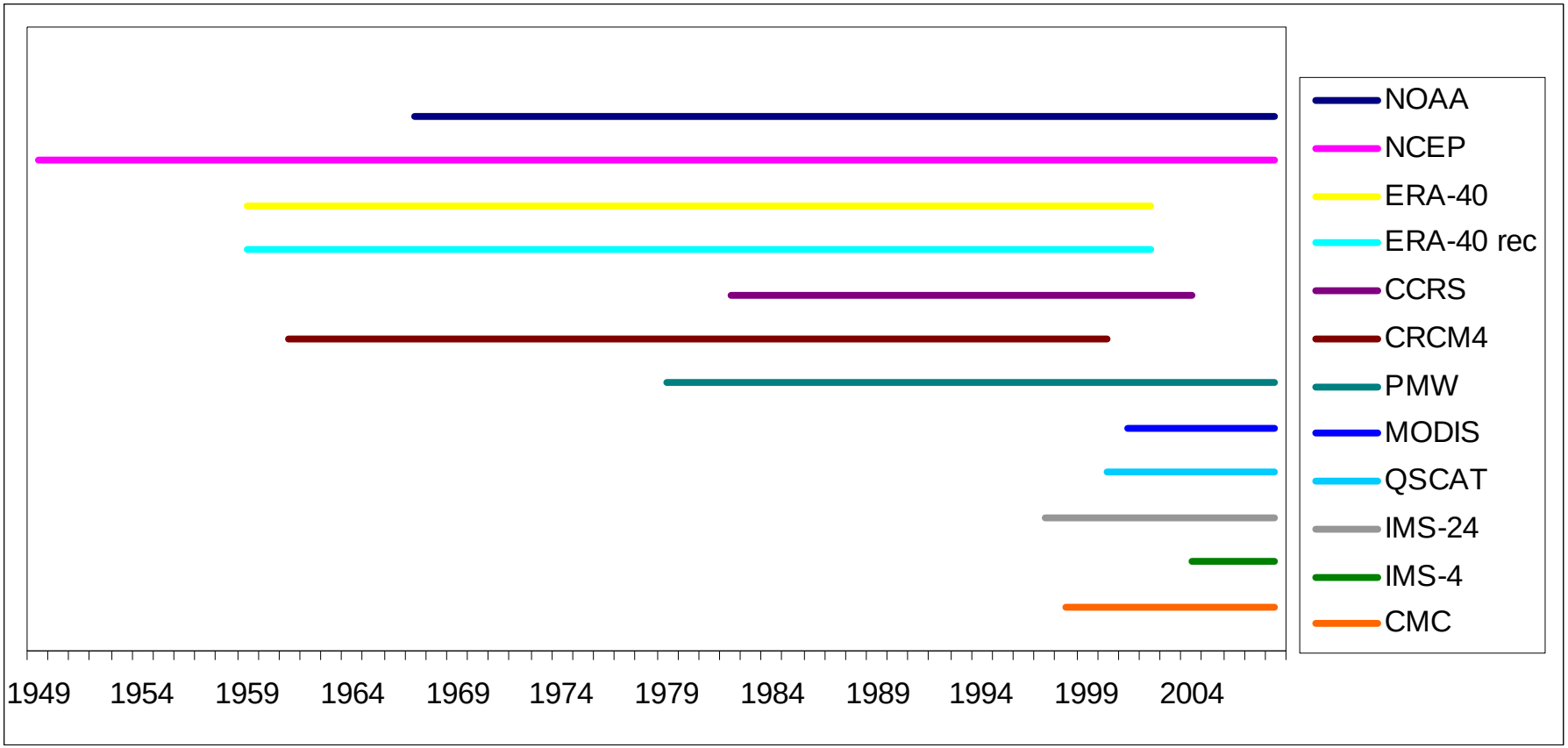






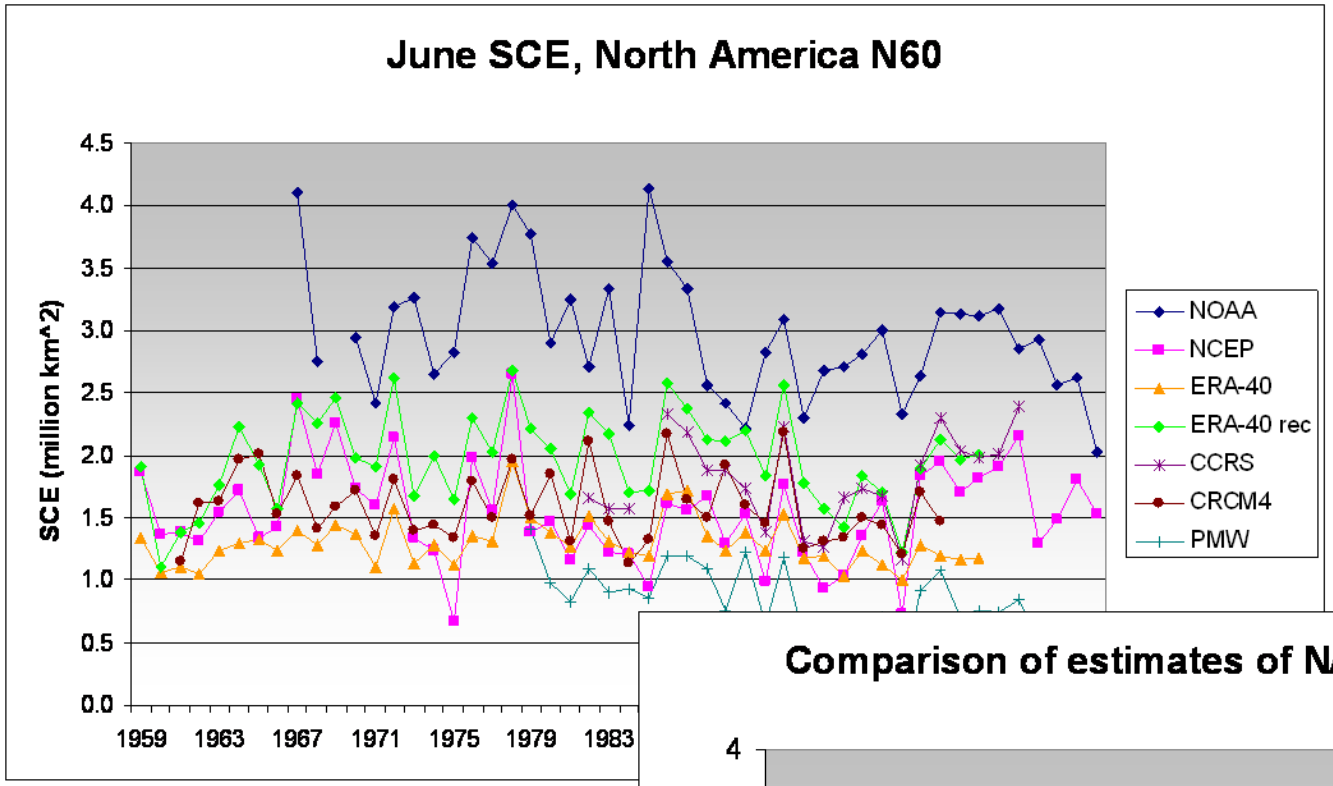
Ross Brown,
Environment Canada

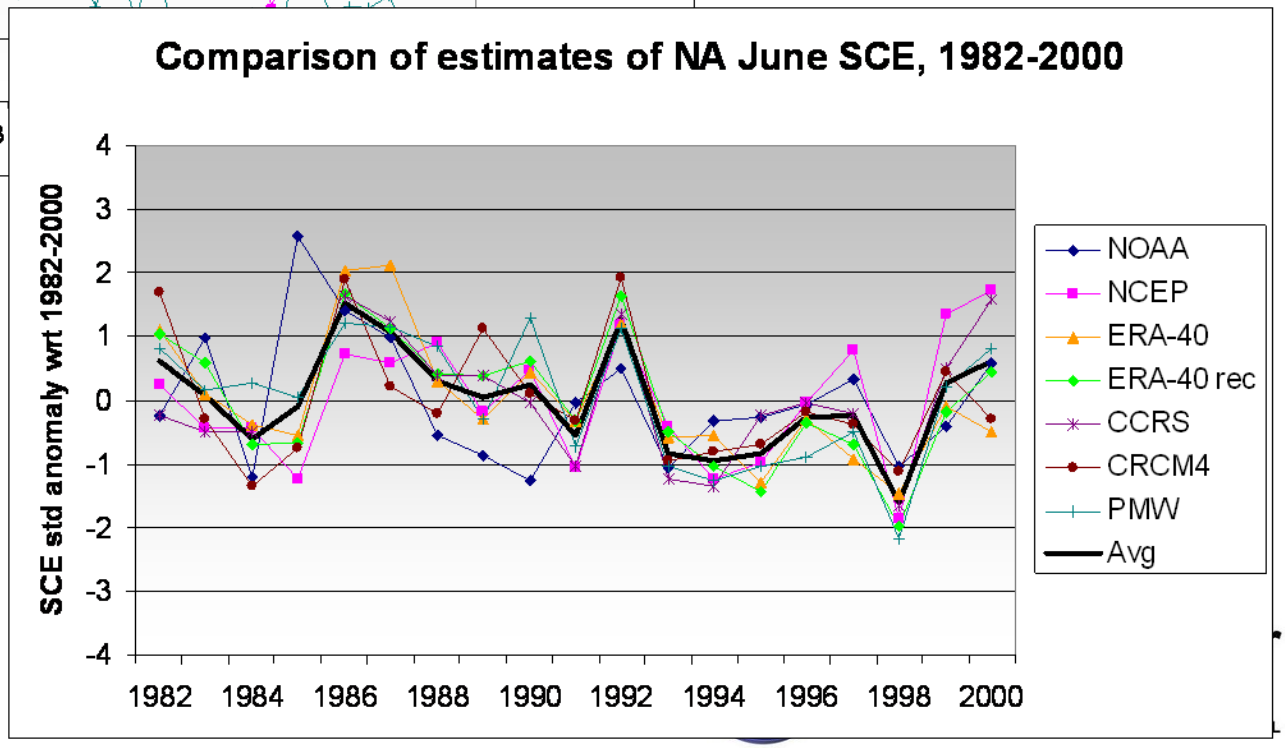
Problem that dataset temporal coverage is quite variable…



Temporal distribution of NH snow cover data sets (CRCM4 only available for North America)

Ross Brown,
Environment Canada





Snow mass from space

- NSIDC snow water equivalent (SWE) datasets from passive microwave:
  - ‘Global SWE Climatology’ 25km, monthly, from SMMR and SSM/I, 1978 onwards
  - AMSR-E 25km, daily/5-day/monthly, 2002 onwards
- ‘Static’ retrieval most common – linear fit to two frequency channels: simple approach but not physically-based and has problems dealing with grain size and vegetation
- Some success in forward modelling brightness temperatures
  Durand et al, GRL, 2008
- New dynamic retrieval methods being tried which update the retrieval parameters or forward models based on ancillary data eg snow depth measurements, temperature history

d.j.clifford@reading.ac.uk
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

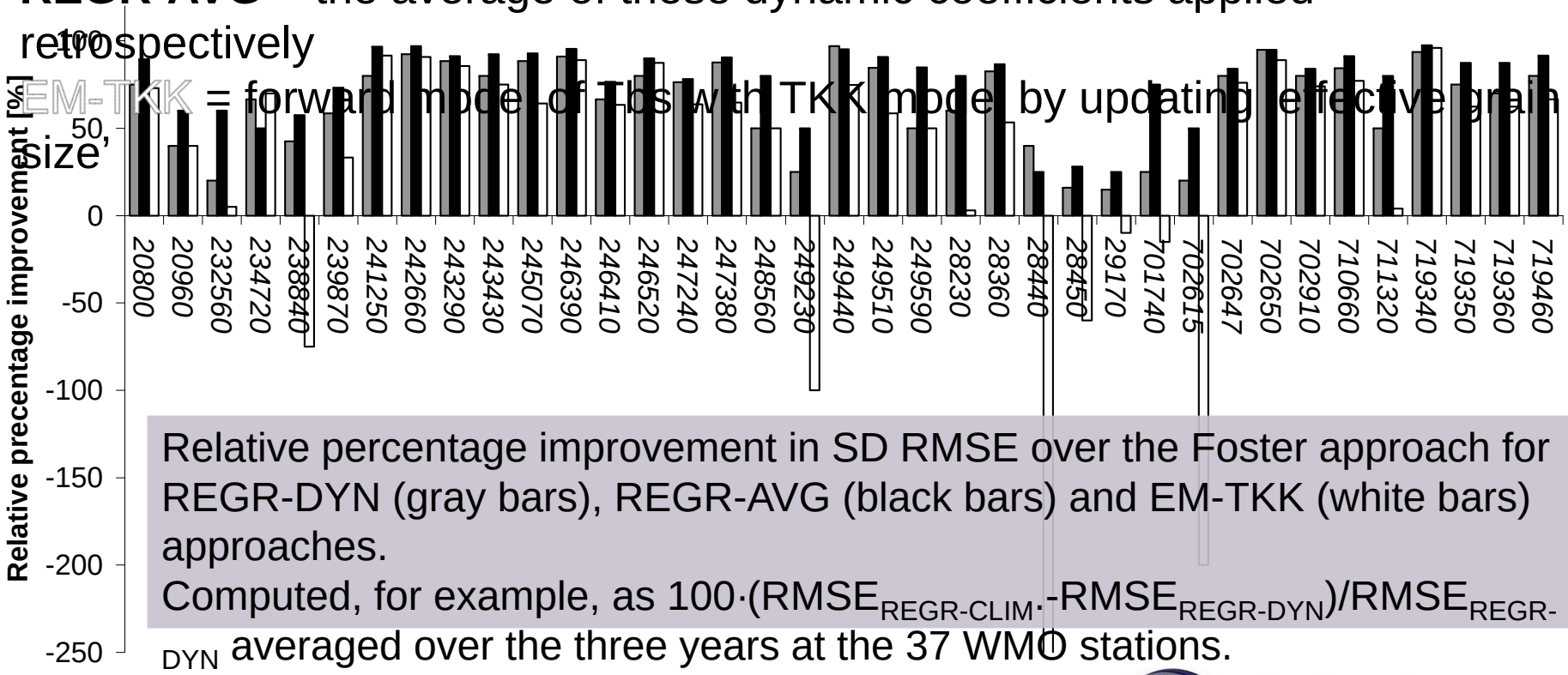
Comparison of new SWE algorithms

Benchmark = Climatological retrieval coefficients (Foster et al 2005, J Clim)

REGR-DYN = dynamic retrieval coefficients updated with ancillary snow depths

REGR-AVG = the average of these dynamic coefficients applied retrospectively

EM-TKK = forward mode of Tbs with TKK model by updating effective grain size



Relative percentage improvement in SD RMSE over the Foster approach for REGR-DYN (gray bars), REGR-AVG (black bars) and EM-TKK (white bars) approaches.

Computed, for example, as $100 \cdot (RMSE_{REGR\text{-}CLIM} - RMSE_{REGR\text{-}DYN}) / RMSE_{REGR\text{-}DYN}$ averaged over the three years at the 37 WMO stations.

d.j.clifford@reading.ac.uk

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

SWE from LSMs

- RMSE for LSM similar to the retrieved SWE, but the model has a higher average correlation

"It must also be noted that the novel retrieval approaches, when driven with (weekly) ancillary SD estimates from CLSM, do not outperform SD estimates from the land surface model alone (CLSM)."

Tedesco et al, manuscript in press, TGARS, 2009

Multi-sensor and assimilation-based products

- ANSA product (Jim Foster, NASA, manuscript in prep)
  - Extent, SWE, fractional snow cover, snowpack ripening, onset of snowmelt and actively melting areas in all weathers.
  - MODIS for snow cover data and as a quality check on SWE retrievals from AMSR-E, which use Kelly's dynamic retrieval
  - QSCAT diurnal difference (relative backscatter between morning and afternoon passes) is used to identify active snowmelt.
  - ANSA product was found to be better for snow cover than AMSR-E or MODIS alone
- SNODAS – NOHRSC
  - US, 1km daily
- GLDAS – GEWEX/NASA
  - Global, 0.25-1deg, 3hrly to monthly

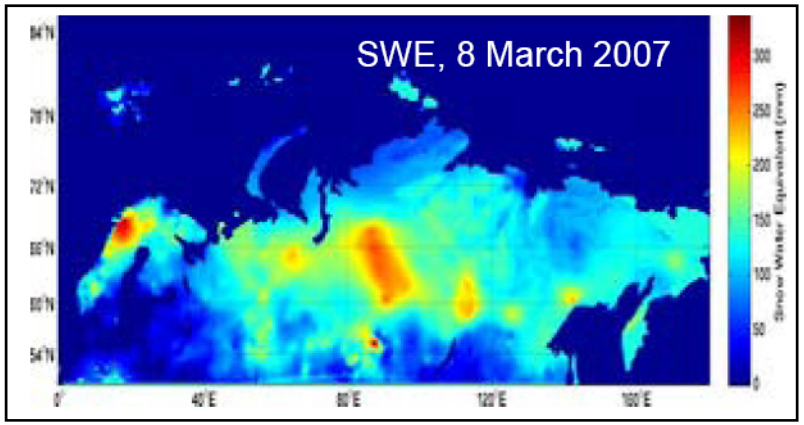
d.j.clifford@reading.ac.uk
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

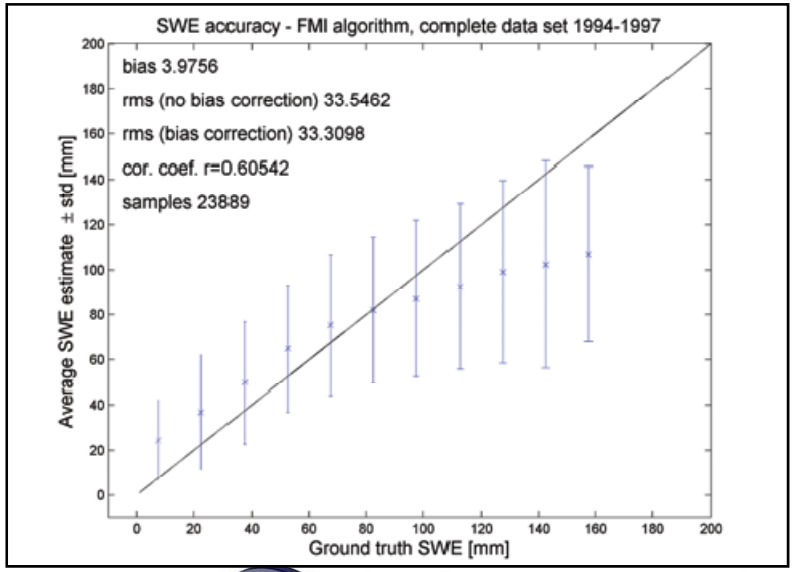
FINNISH METEOROLOGICAL INSTITUTE

Chris Derksen,
Environment Canada

GlobSnow SWE Dataset

- Following an intercomparison of algorithms from Environment Canada, NASA, and FMI over Eurasia and Canada, the GlobSnow SWE product will be derived using the method described in Pulliainen (2006) and currently employed operationally over Eurasia by FMI.
- Assimilation of satellite data with *in situ* observations (snow depth/temperature from weather stations).
- Kriged daily effective grain size background field (determined by adjusting HUT model to weather station SD).
- Statistical uncertainty produced for each grid cell.
- SWE retrievals will not be produced for alpine regions.
- e ro[illegible]



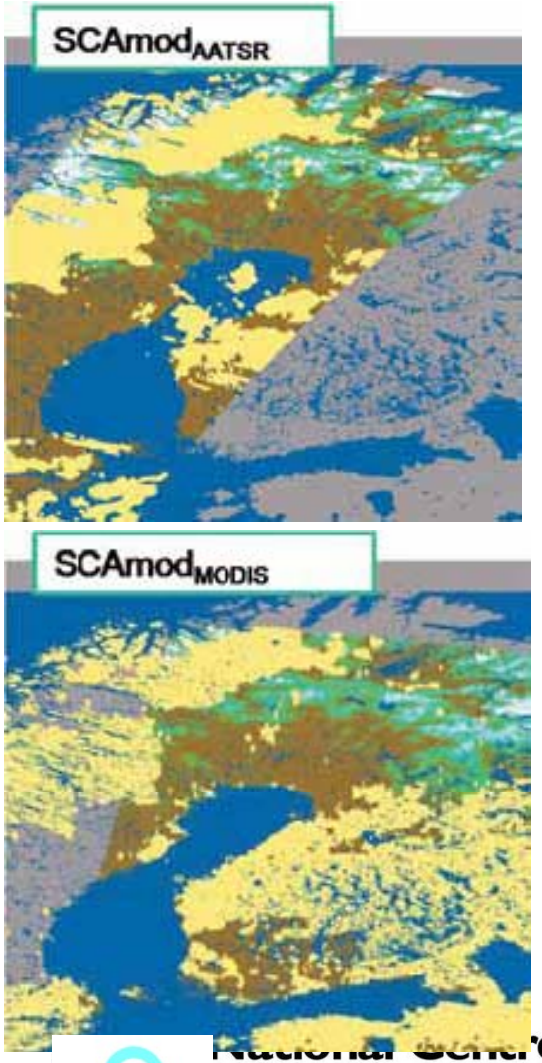


FINNISH METEOROLOGICAL INSTITUTE

Chris Derksen,
Environment Canada

GlobSnow SE Dataset

- SE retrieval techniques were evaluated using AATSR and MODIS imagery.
- GlobSnow SE product will combine the Finnish Environment Institute's SCAmod algorithm for non-alpine areas, and the Norwegian Linear Reflectance (NLR) fractional snow cover (FSC) algorithm for mountainous regions.
- A continuous time series of AATSR data will be processed with the above algorithms for a three-year period (2003-2005) for comprehensive analysis and final algorithm selection.
- Final data record will be produced using optical imagery from ATSR (1995-) and AATSR (2002-).



Final remarks

- Lots of new datasets appearing, some now with error estimates attached
- More emphasis on trying to develop global datasets – but how well will we do where ground truth is lacking?
- Longest remote sensing time series go back decades
- Snow extent from space is intercomparable
- Snow mass – still many doubts and problems

d.j.clifford@reading.ac.uk
National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL