Reducing Canada's vulnerability to climate change - ESS

J28 Earth Science for National Action on Climate Change

Generating Comprehensive Earth Observation (EO) database for assessing the Canadian landmass response to climate change

Rasim Latifovic,

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Workshop on Inter-Comparison of Large Scale Optical and Infrared Sensors
12-14 October 2004 ESA/ESTEC
Noordwijk, The Netherlands

The objective of NRCan/ESS Program “Reducing Canada’s Vulnerability to Climate Change” (RCVCC) is to contribute to the understanding of climate variability and change in order to enhance society’s ability to plan and respond.

Earth Science for National Action on Climate Change

What is our objective ?

Project is focused on the synthesis products used by national process (Joint Ministers) & Intergovernmental Panel on Climate Change

Project activities

1) Radiation, albedo, clouds	- A. Trishchenko
2) **Satellite records for CC**	- R. Latifovic
3) Ecosystem modeling	- S. Wang
4) Water resources and vegetation dynamics	- R. Fernandes
5) Cryosphere	- M.Demuth, L.Gray: Glaciers
	- S.Smith: Permafrost
6) Coastal zone	- B. Taylor and S. Solomon
	- Landscape hazards A.Blais-Stevens and T. Kulkarni
	- Coastal zone B.Taylor and K.Parlee

Long-term observations sustained over decades are a critical first-step in providing the climate data necessary for scientists, decision makers and stakeholders to make adaptive choices that could improve resilience to climate change and vulnerability, as well as maintain economic vitality.

CDRs – Climate data records

Time series of measurements of sufficient length, consistency and continuity to determine climate variability and change.

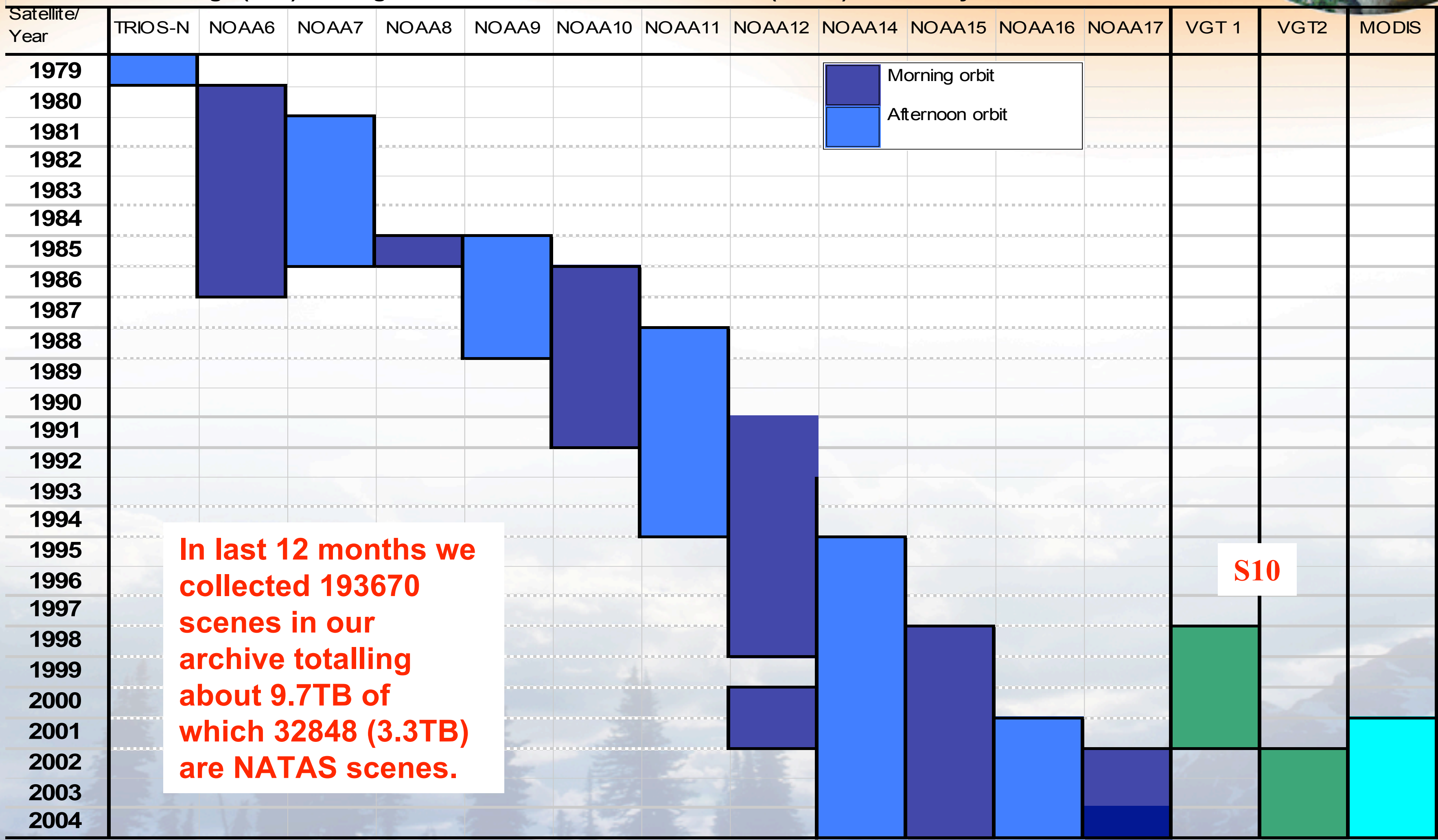
FCDRs – Fundamental climate data record	**TCDRs** – Thematic climate data record
Calibrated and quality-controlled sensor data that have been improved over time	Geophysical variable derived from the FCDRs such as surface temperature and cloud fraction

Satellite CDRs unique characteristic

- Long term commitment to data collection and analysis.
- The need for continual calibration, validation and algorithm refinement i.e. monitoring performance of multiple observing platforms for long-term applications.
- Periodic reprocessing and reanalysis to improve error identification and reduce uncertainties.
- Archiving and timely access to data and metadata.
- The need to manage extremely large volume of data.
- The need of significant computational resources for processing and archiving.

What satellite data do we have ?

Local Area Coverage (LAC) and High Resolution Picture Transmission (HRPT) Availability Based on Satellite Active Archive



In last 12 months we collected 193670 scenes in our archive totalling about 9.7TB of which 32848 (3.3TB) are NATAS scenes.

What do we want to generate ?

Directory

YYYYMMDD

Sub-directory

NOAA09
NOAA10
NOAA11
…
NOAA17

Orbits

BO1_RETO
BO2_RETO
BT3_RETO
BT4_RETO
BT5_RETO
NDVI
Solar_Zenith
Solar_Azimuth
View_Zenith
View_Azimuth
Time_Acquisition

1-day composite

BO1_RETO
BO2_RETO
BT3_RETO
BT4_RETO
BT5_RETO
NDVI
Solar_Zenith
Solar_Azimuth
View_Zenith
View_Azimuth
Time_Acquisition
Num_Measurements
Map_Index
Cloud_Mask
Daily_Air_Temp
Water_Vapour
Ozone
Pressure

10-day composite

BO1_RETO
BO2_RETO
BT3_RETO
BT4_RETO
BT5_RETO
NDVI
LAI
Solar_Zenith
Solar_Azimuth
View_Zenith
View_Azimuth
Time_Acquisition
Num_Measurements
Map_Index
Water_Vapour
Ozone
Pressure
Aver_Air_Temp
Cloud_%
Snow_Days
Diurnal_C
Radiation

30-day

Aver_BO1_RETO
Aver_BO2_RETO
Aver_BT3_RETO
Aver_BT4_RETO
Aver_BT5_RETO
Aver_NDVI
Aver_LAI
Num_Measurements
Aver_Water_Vapour
Aver_Ozone
Aver_Pressure
Aver_Air_Temp
Cloud_%
Snow_Days
Aver_Radiation

Season

Integrated_NDVI
Integrated_LAI
Num_Measurements
Aver_Water_Vapour
Aver_Ozone
Aver_Pressure
Aver_Air_Temp
Cloud_%
Snow_Days
Aver_Radiation
Length_Growing

Satellite CDR 1980-2005

What methodology and tools do we have ?

APS (AVHRR Processing System)

Data ingest:

HRTP Data Record created before September 8,1992
HRTP Data Record between October 21,1992 and November 15,1994
HRTP Data Record created after November 15,1994
HRTP KLM (NOAA 15,16,17) DATA RECORD
NATAS all years

Georeferencing

Winter, summer day and night time orbit georeferencing and resampling
Brower orbit model, TBUS archive 1983-2004, chip image data base winter and summer
Orbit calibration data analysis

VPS (VGT Processing System)

Compositing

Include radiometric, acquisition geometry and georeferencing accuracy criteria

Data correction

Calibration and recalibration
Atmospheric correction using time dependent atmospheric conditions
BRDF normalization
Cloud screening
…..

Data analysis

Seasonal profile analysis
Time series

Why do we need CDRs ?

TIME SERIES 1980 – 2005

Changes in vegetation phenology
- Minimal, Maximal, Mean NDVI
- Amplitude in NDVI
- Total length of the growing season
- Fraction of growing season in green up
- Rate of green up
- Rate of senescence
- Integrated NDVI, green up, senescence, growing season

Changes in surface characteristic
- Winter summer albedo
- Minimal, maximal surface temperature
- Diurnal surface temperature cycle
- Duration of snow cover
- Land cover and land cover change
- Leaf Area Index

Changes in water characteristic
- Lake surface temperature
- Diurnal lake surface temperature cycle
- Ice brake-up

Radiation

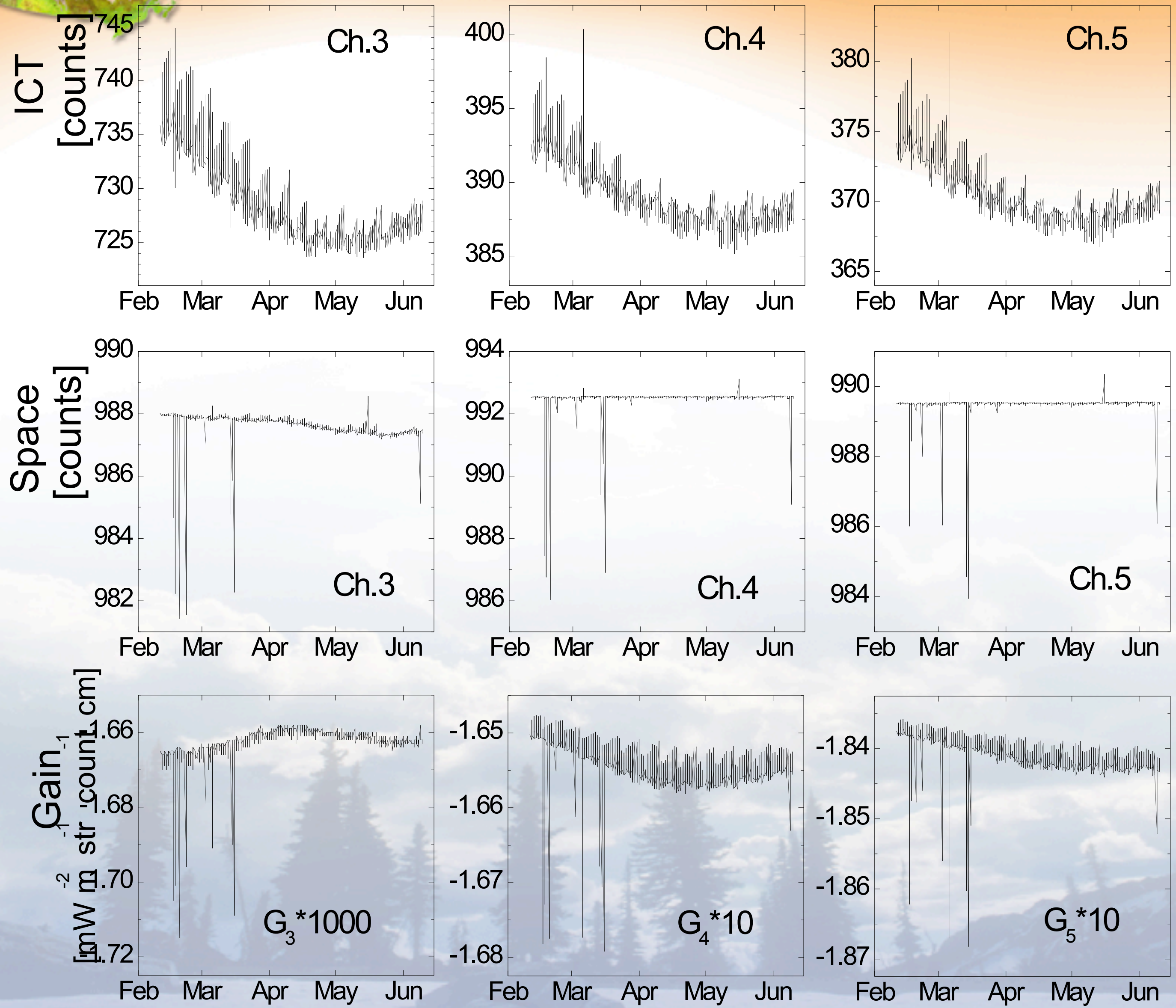
Statistics on cloud cover

Trend
NDVI
LAI
Air_Temperature
Radiation
Precipitation
Snow
Lake temperature
Forest fire

Pattern
Forest fire – NDVI-Air_Temp-Radiation-Precipitation-Snow-Cloud
Drought – NDVI-Air_Temp-Radiation-Precipitation-Snow-Cloud
#Traffic Accidents- Air_Temp-Precipitation-Snow-Cloud
Household -Energy Consumption
Sever weather events

Models

AVHRR thermal calibration



☞ **There are variuos unwanted fluctuations in thermal calibration data that can not be removed by standard quality control procedures and require robust techniques to be used**

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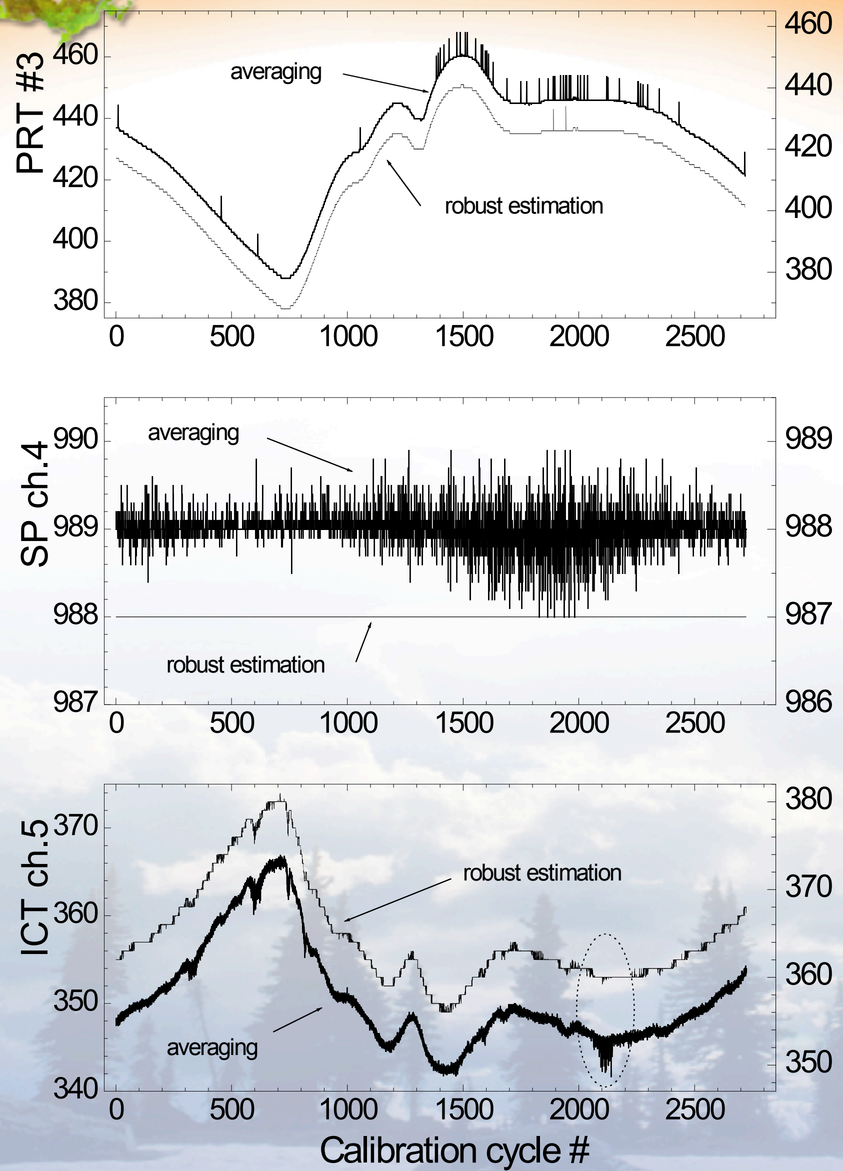
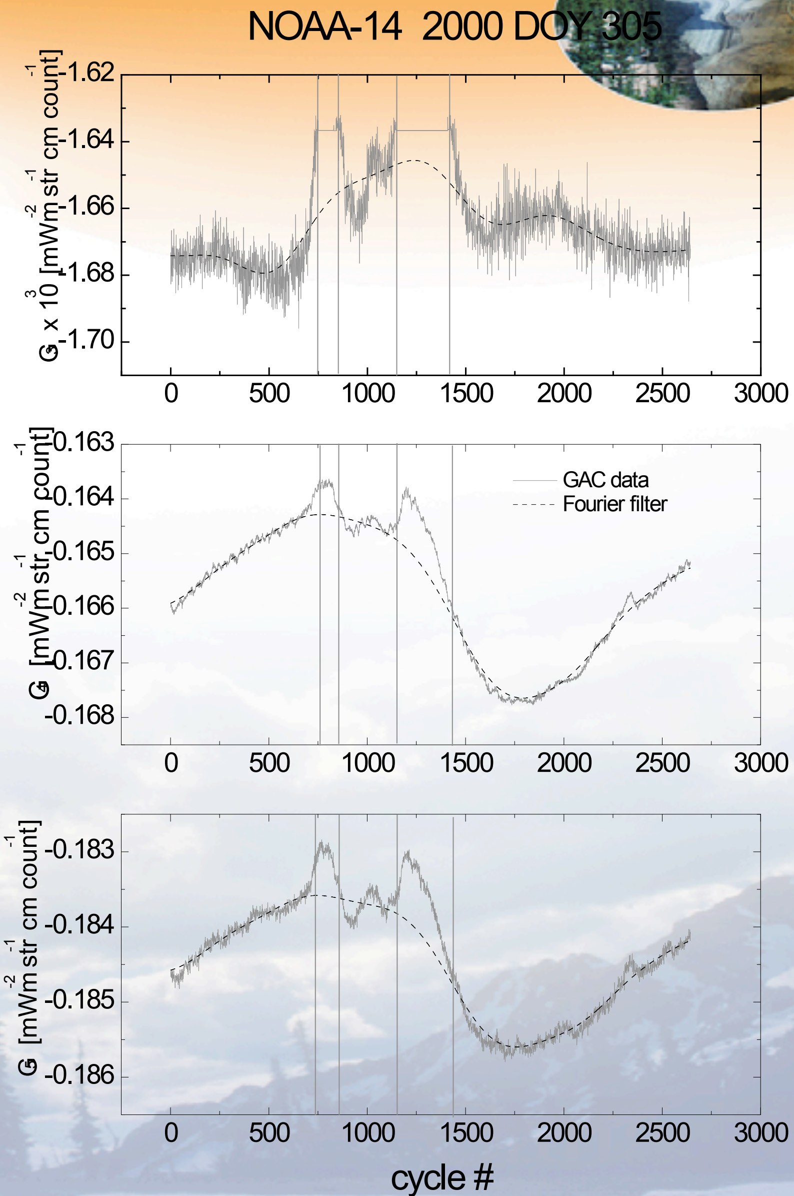
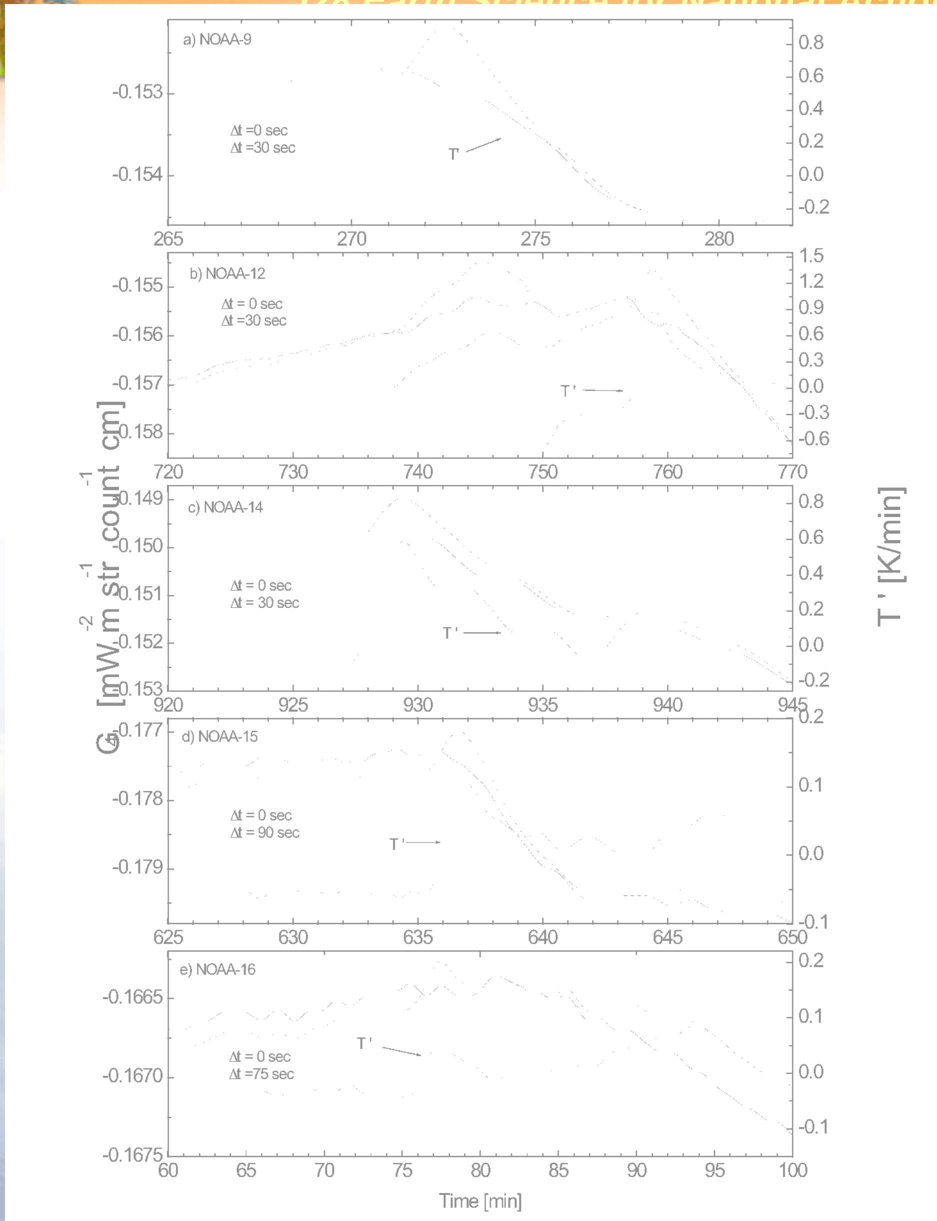




Removing solar radiative contamination

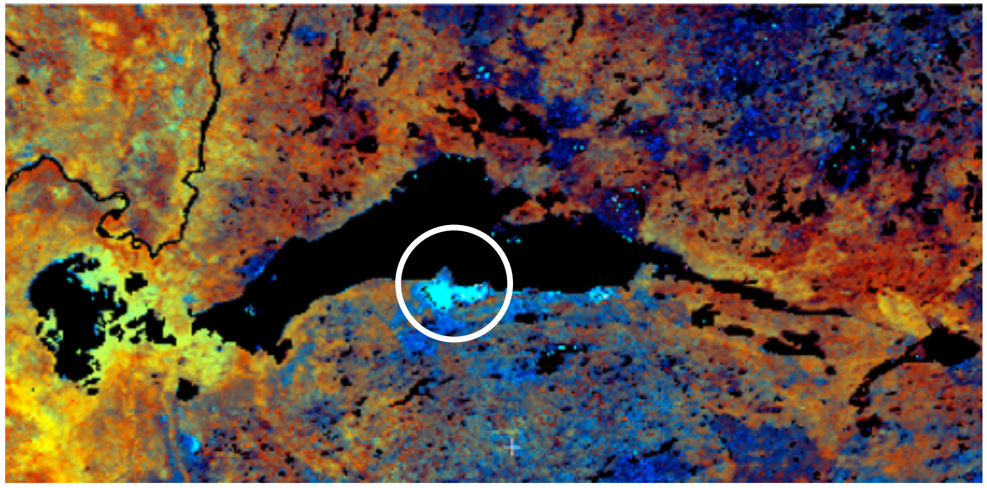
Natural Resources Canada | Ressources naturelles Canada

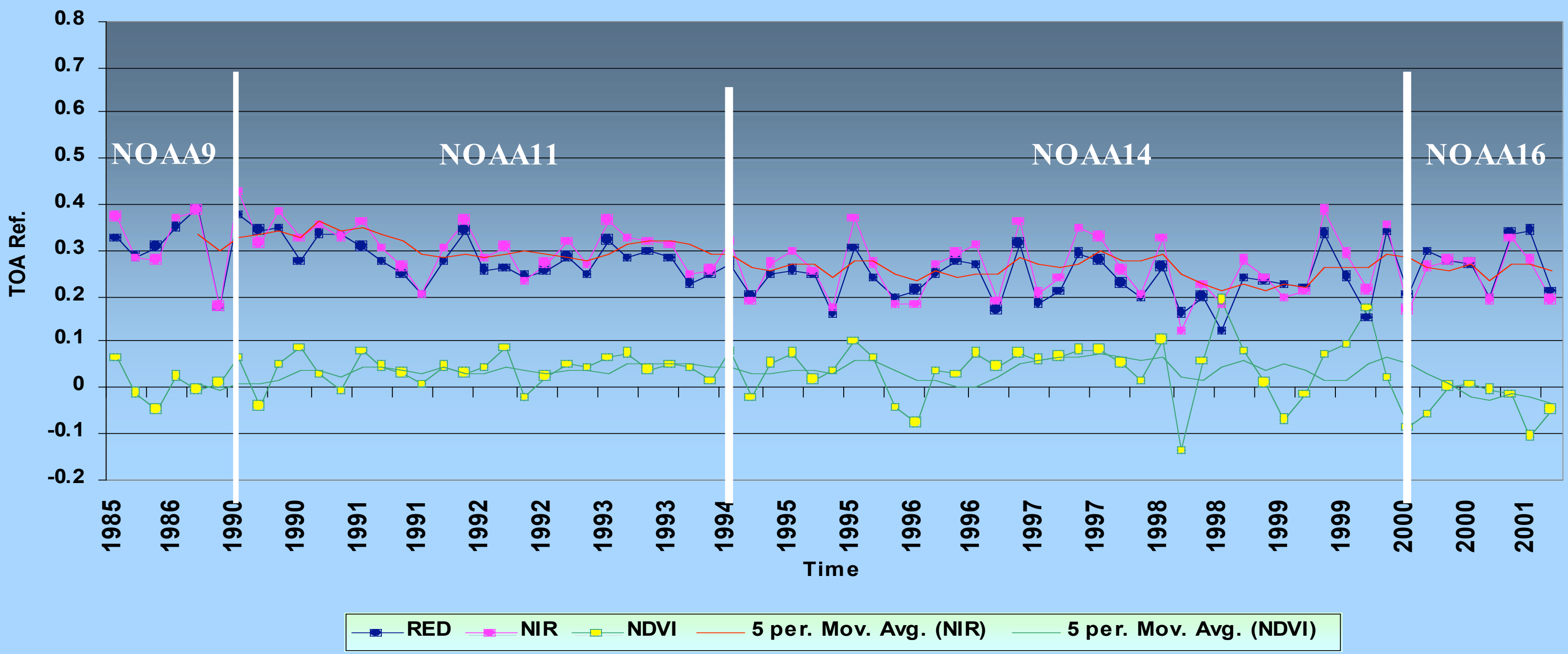
Canada



☞ **Thermal inertia effect leads to biases in observed pixel brightness temperature**

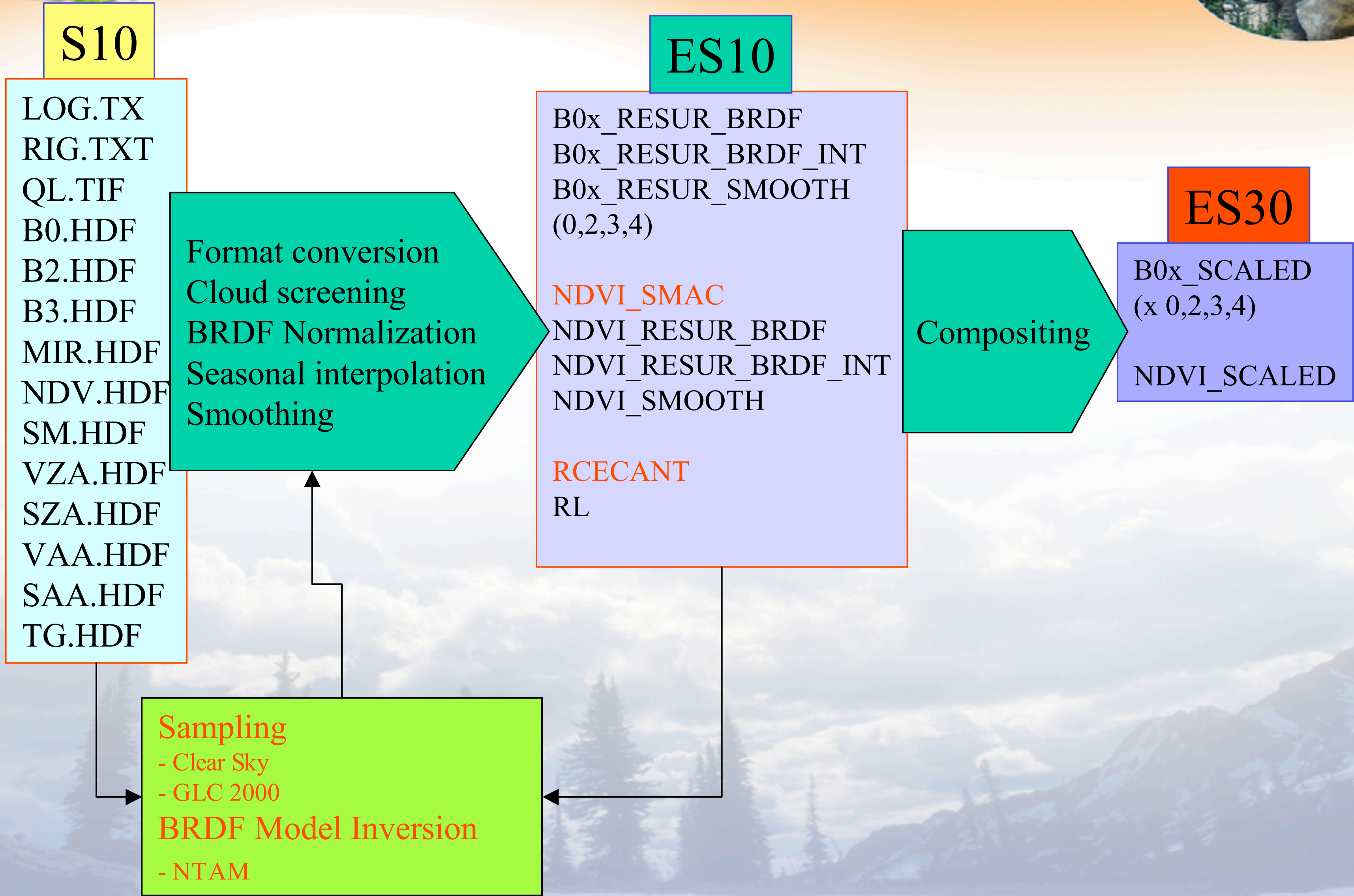
VIS and NIR calibration

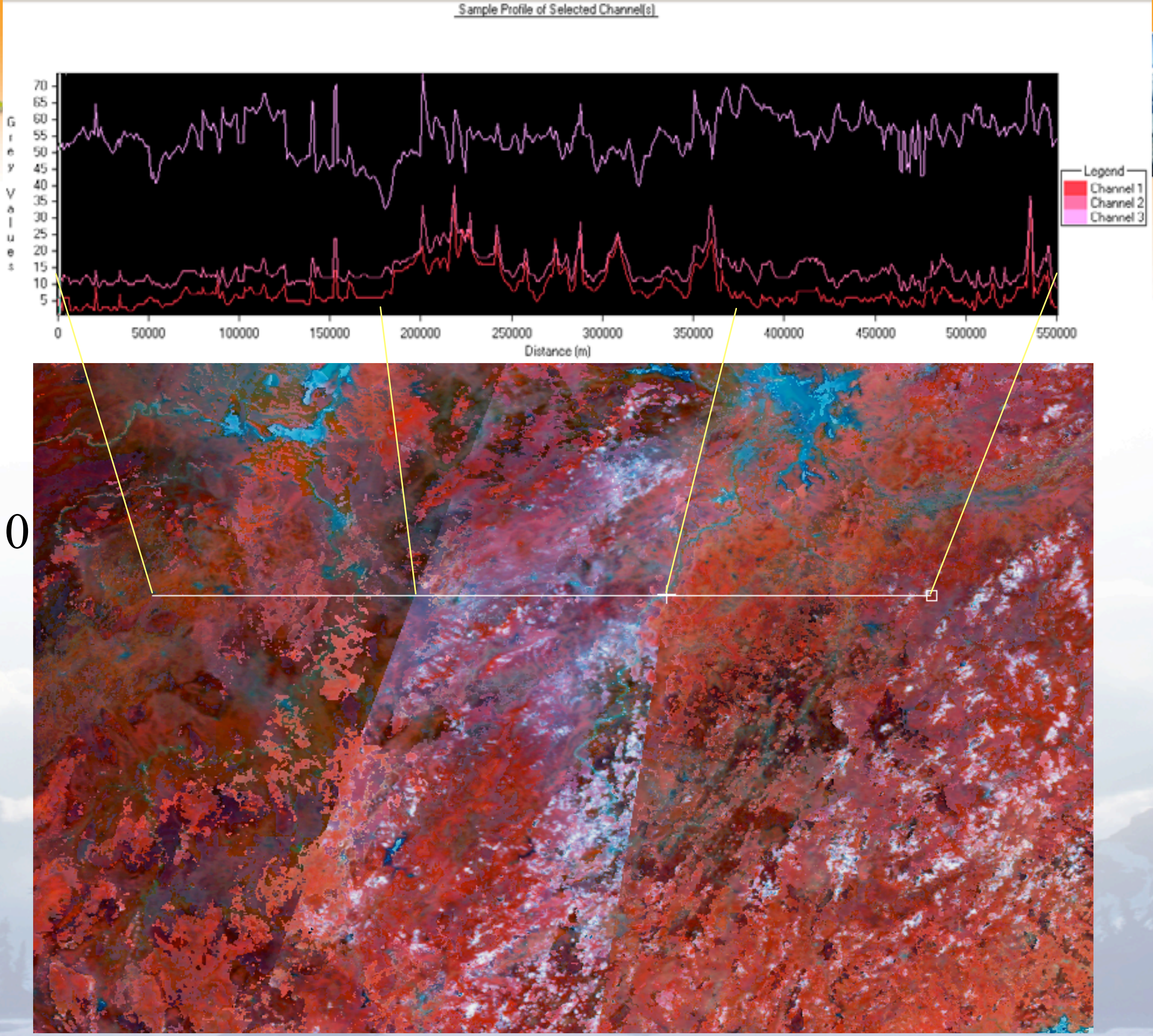




CCRS Calibration Coefficients Teillet, P & Fedosejev, G.

VPS processing scheme

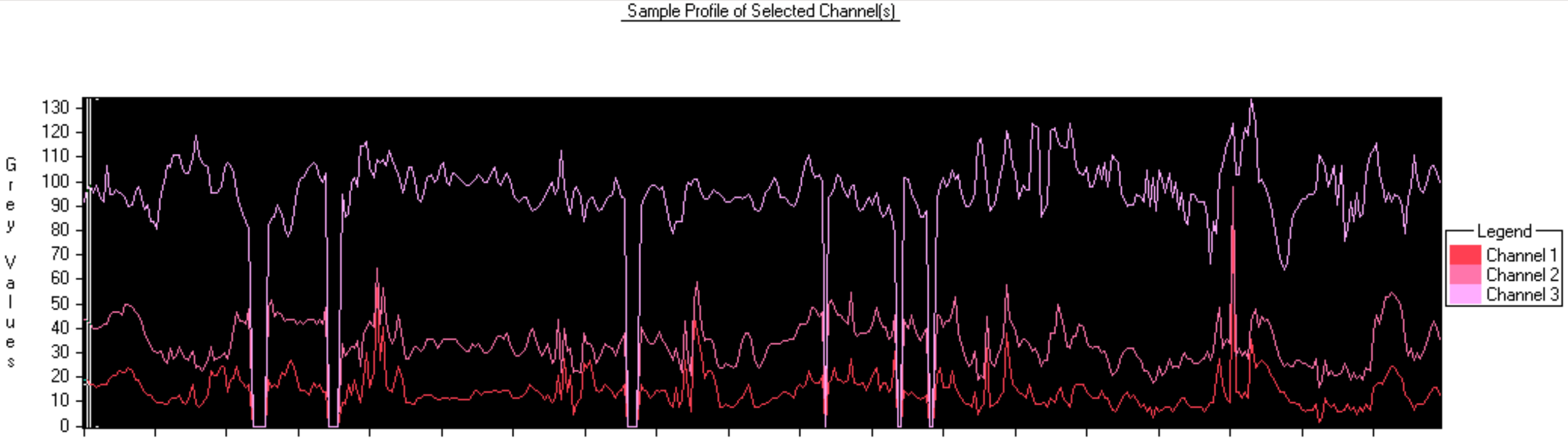




Sample Profile of Selected Channel(s)
Grey Values
Distance (m)
Legend
Channel 1
Channel 2
Channel 3

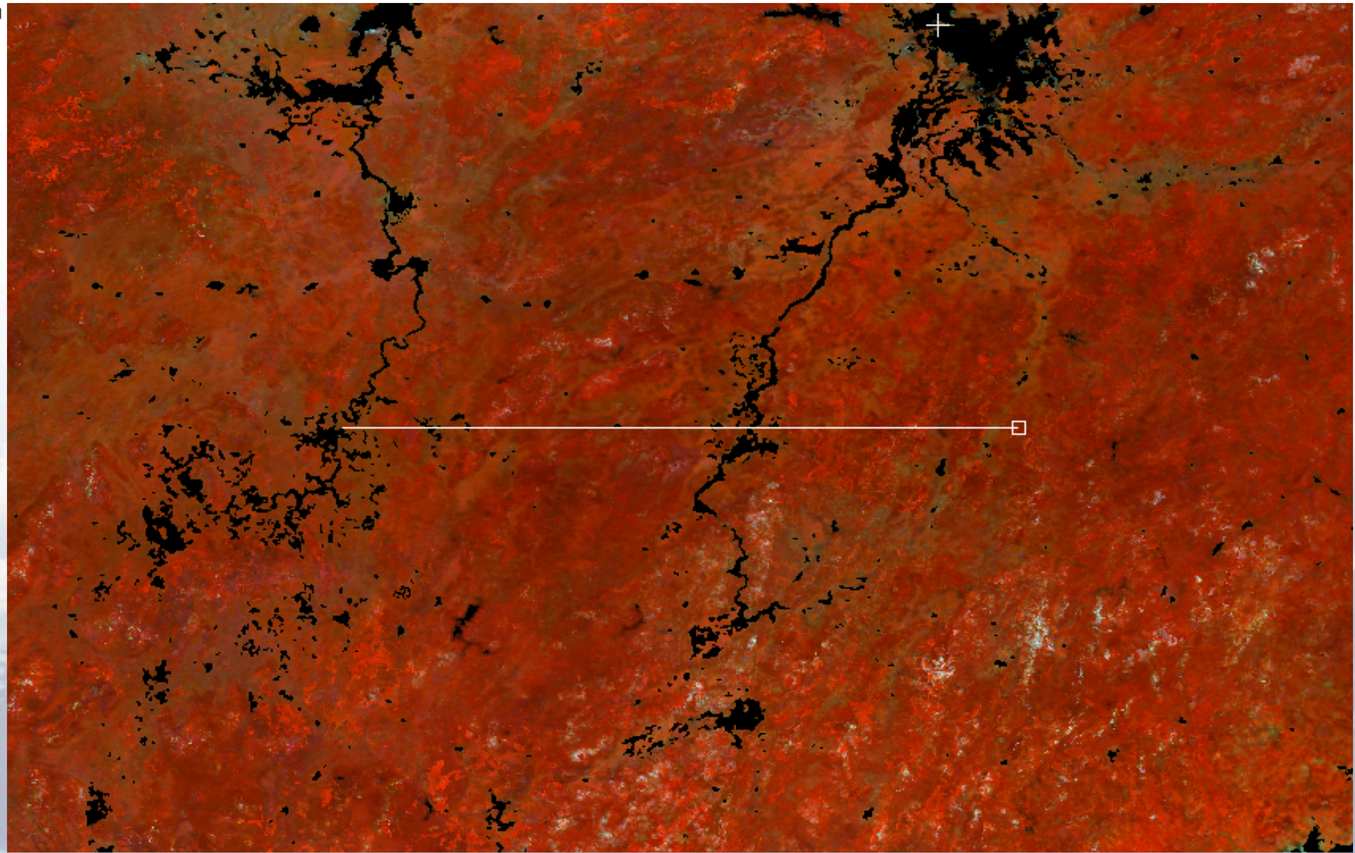
VGT S10

☹

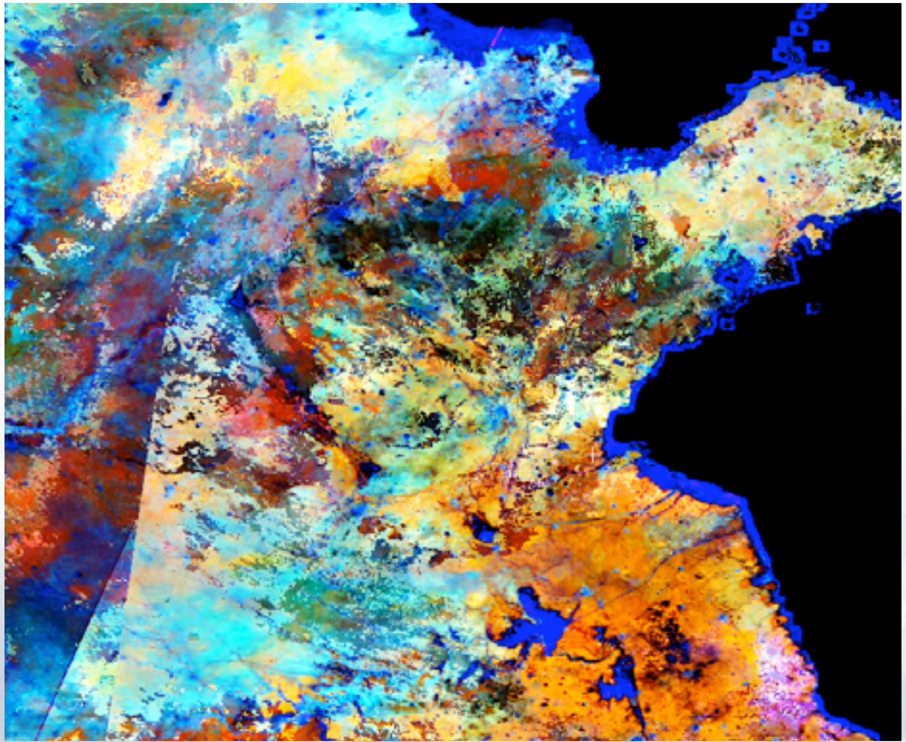


Corrected VGT ES10

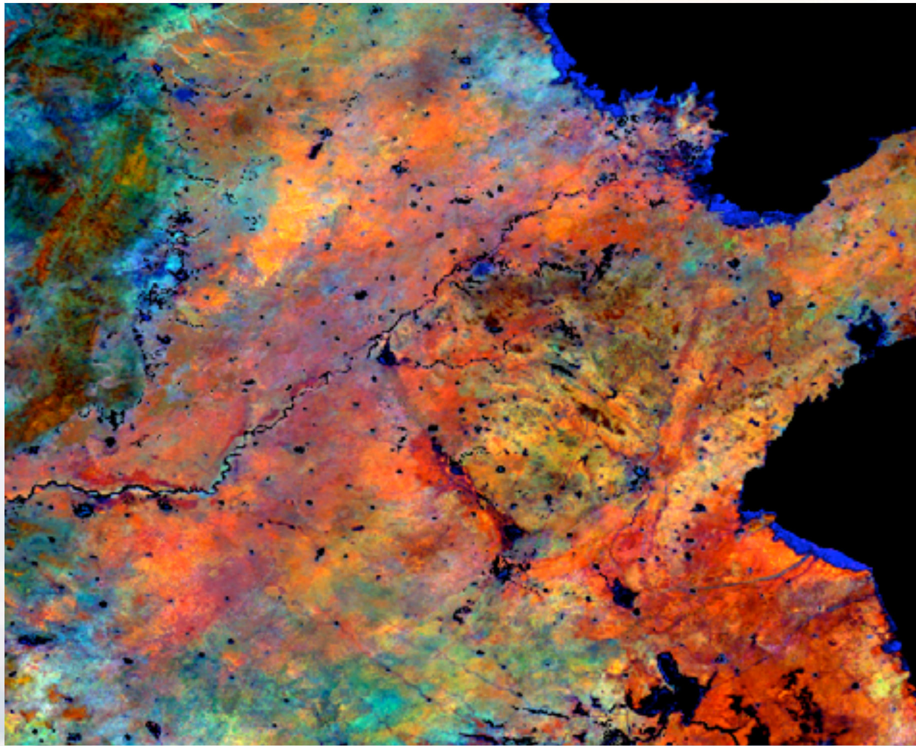
☺



S10



ES10



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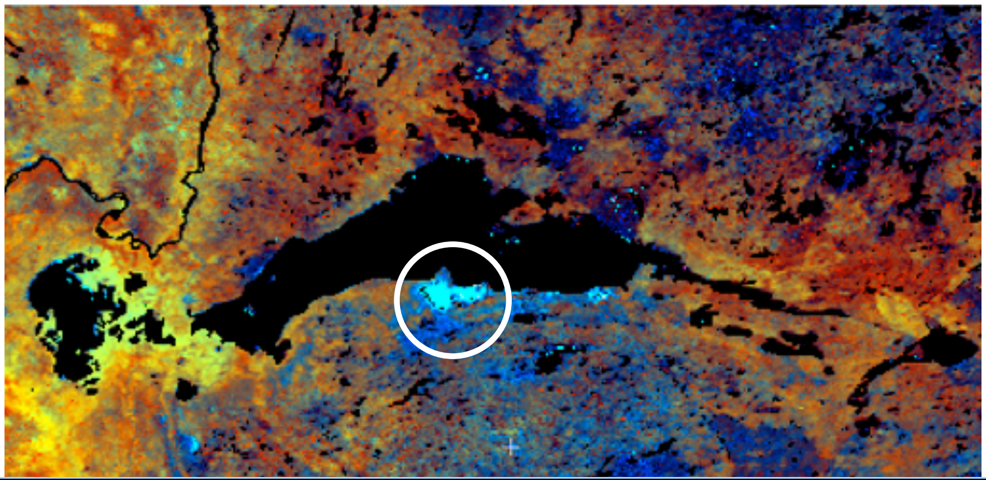
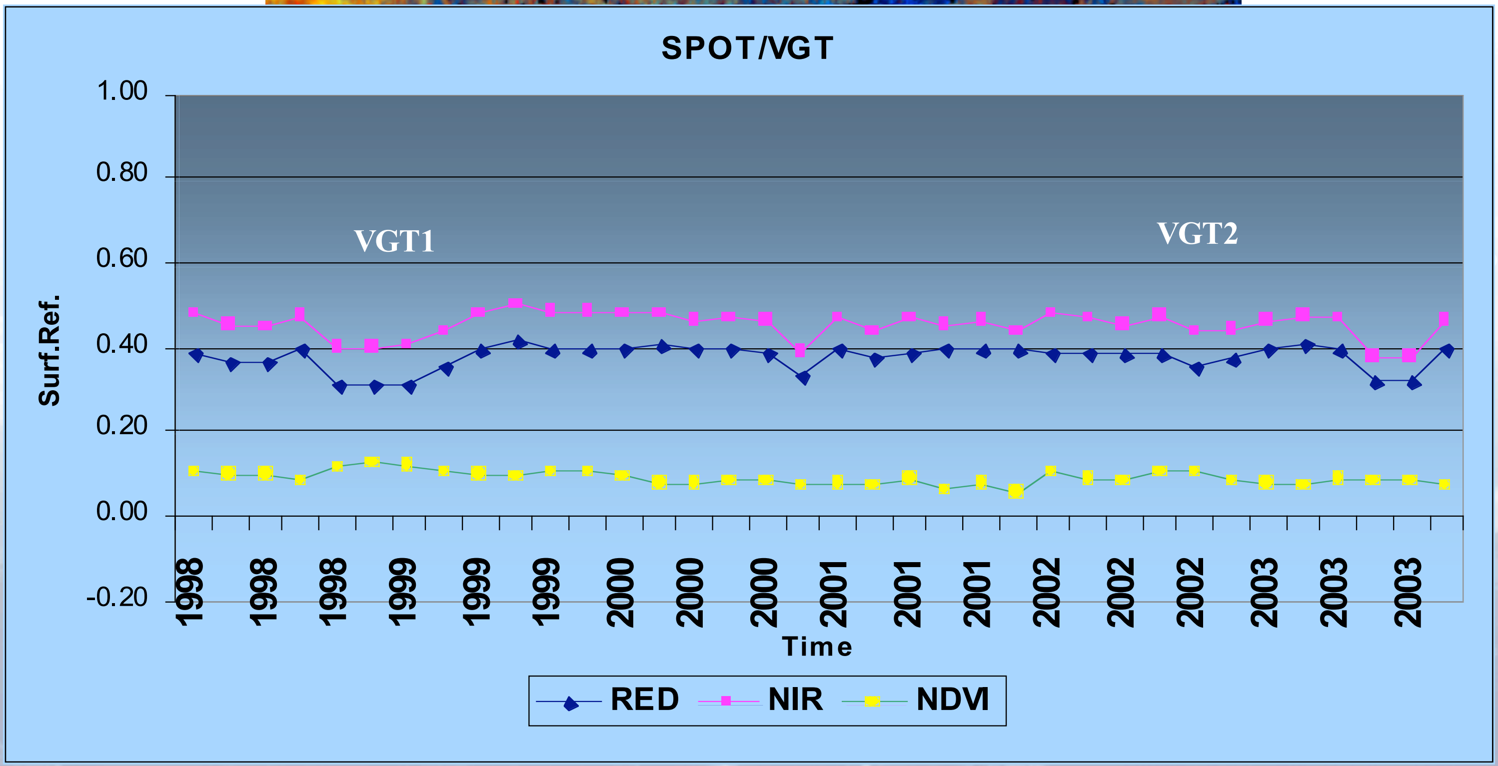




Inter-Comparison of Large Scale Optical Sensors

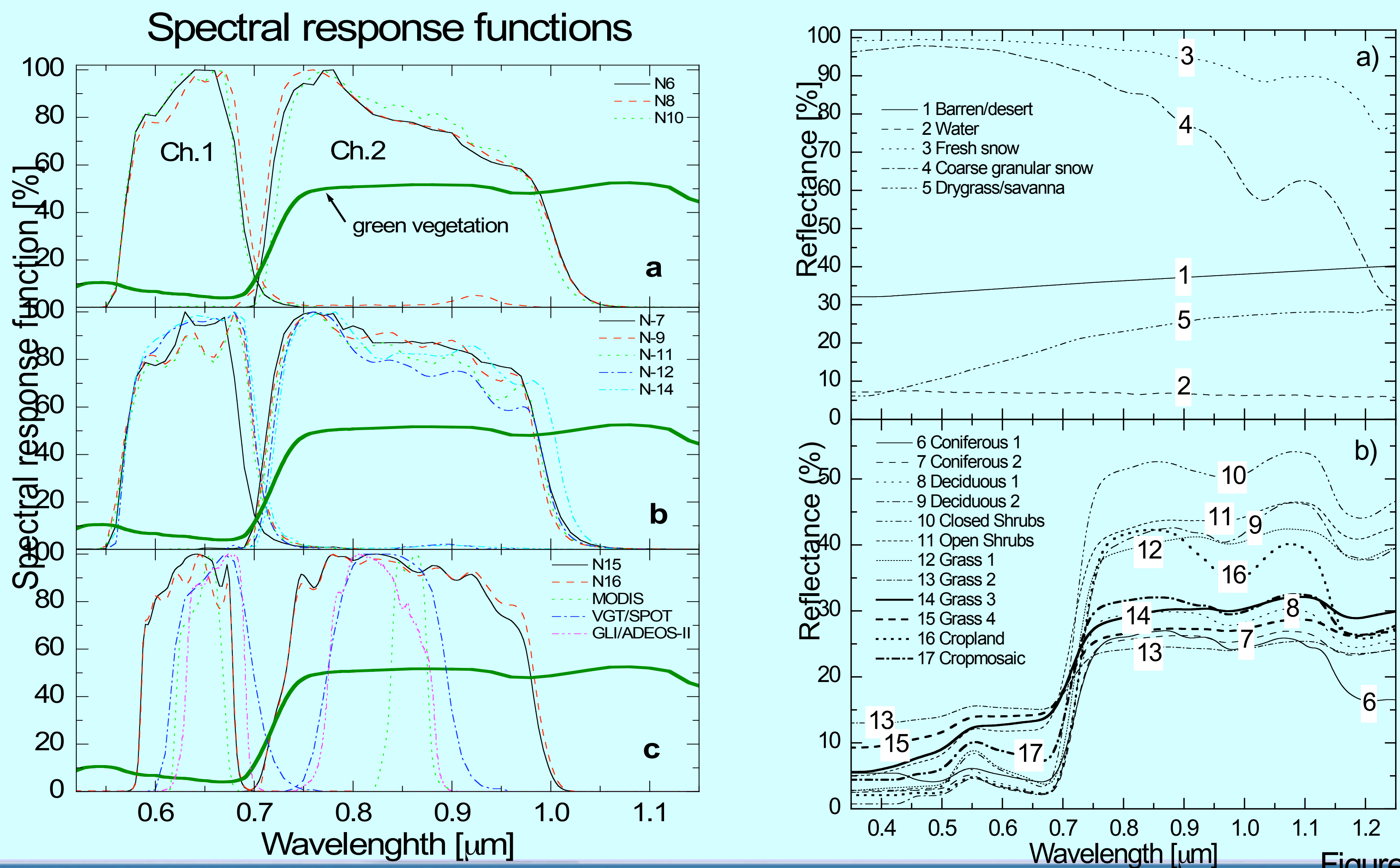


Figure 2

Difference in surface reflectance for visible (red) channel relative to AVHRR/NOAA-9

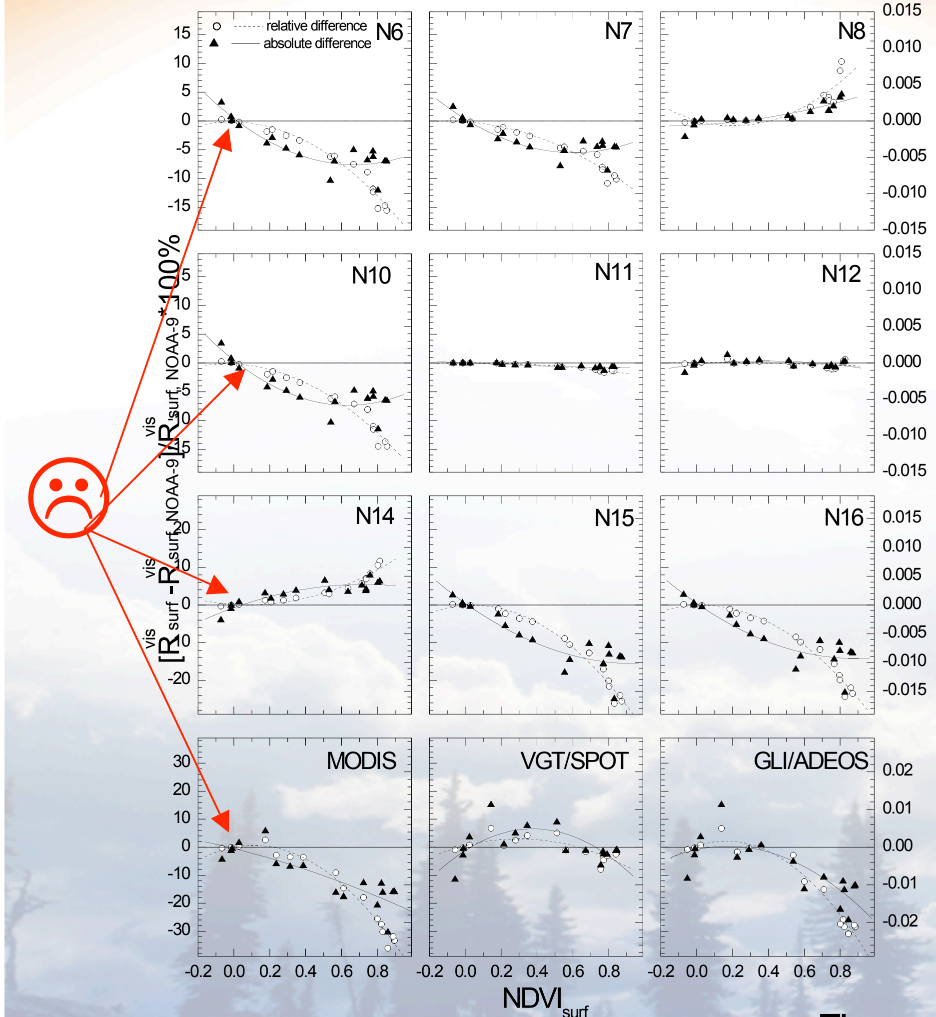


Figure 4

Difference in surface reflectance for NIR channel relative to AVHRR/NOAA-9

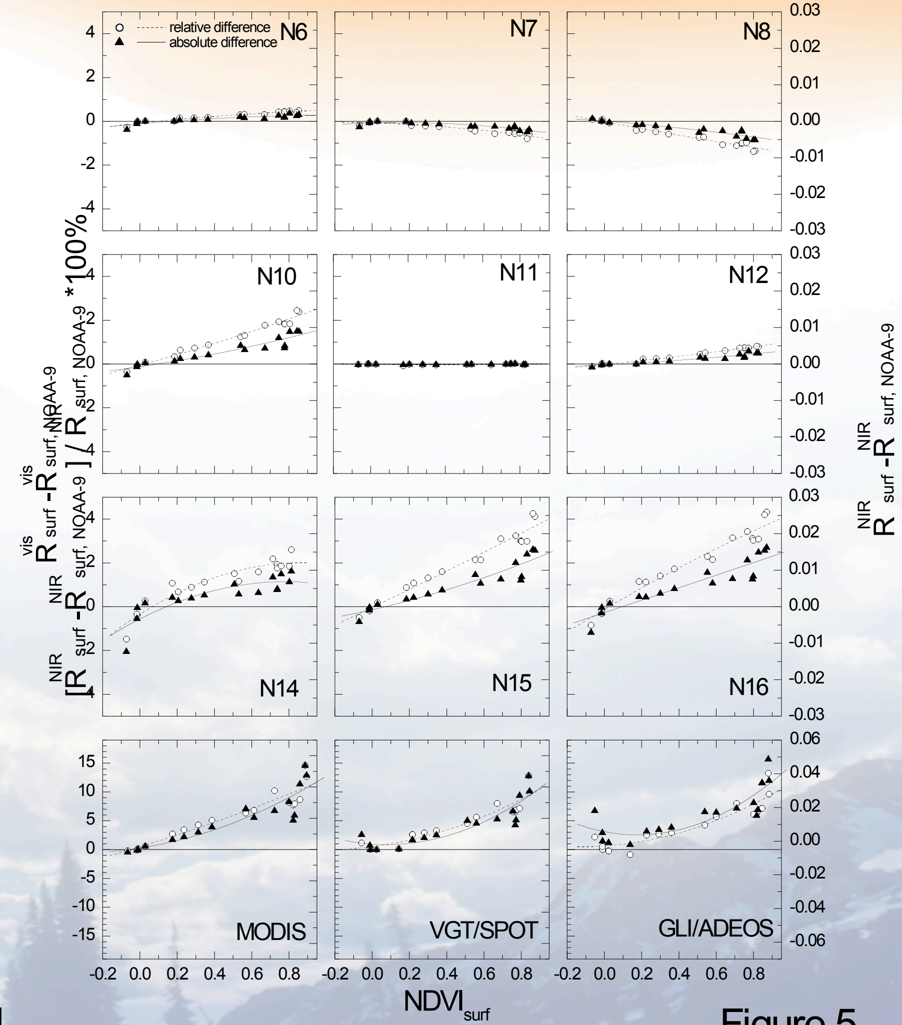
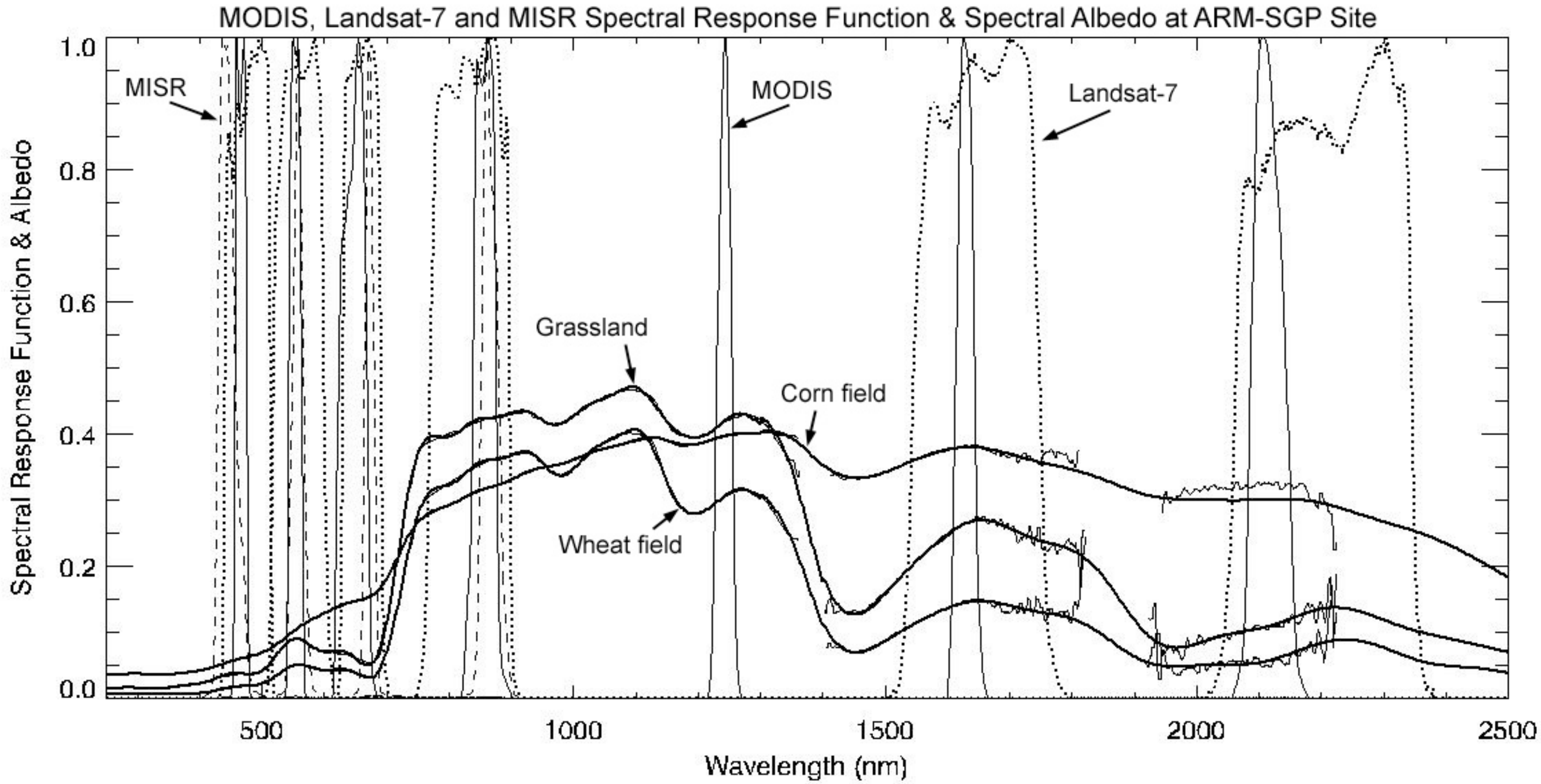
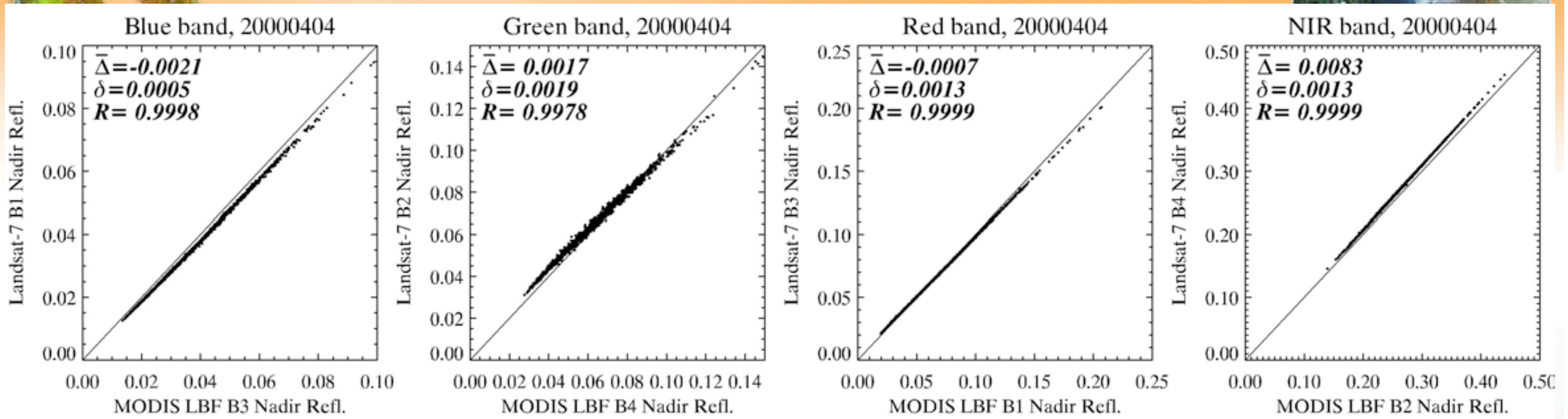


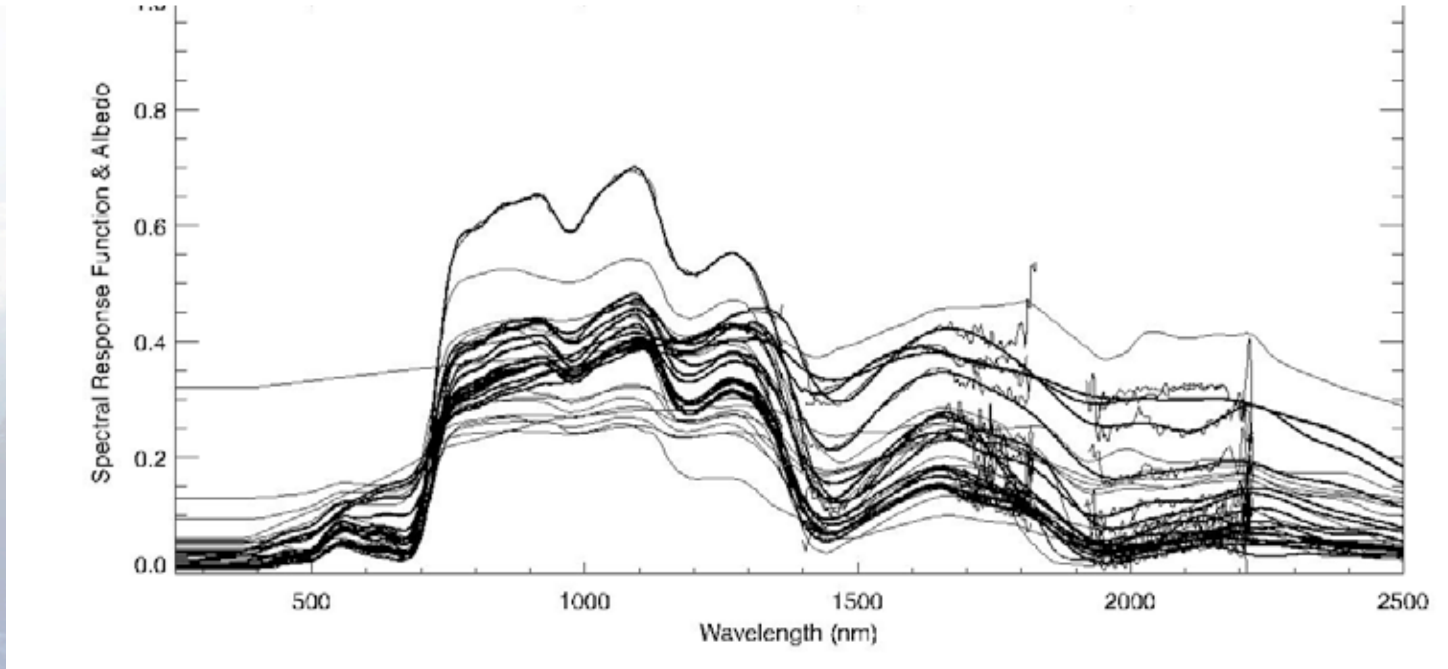
Figure 5

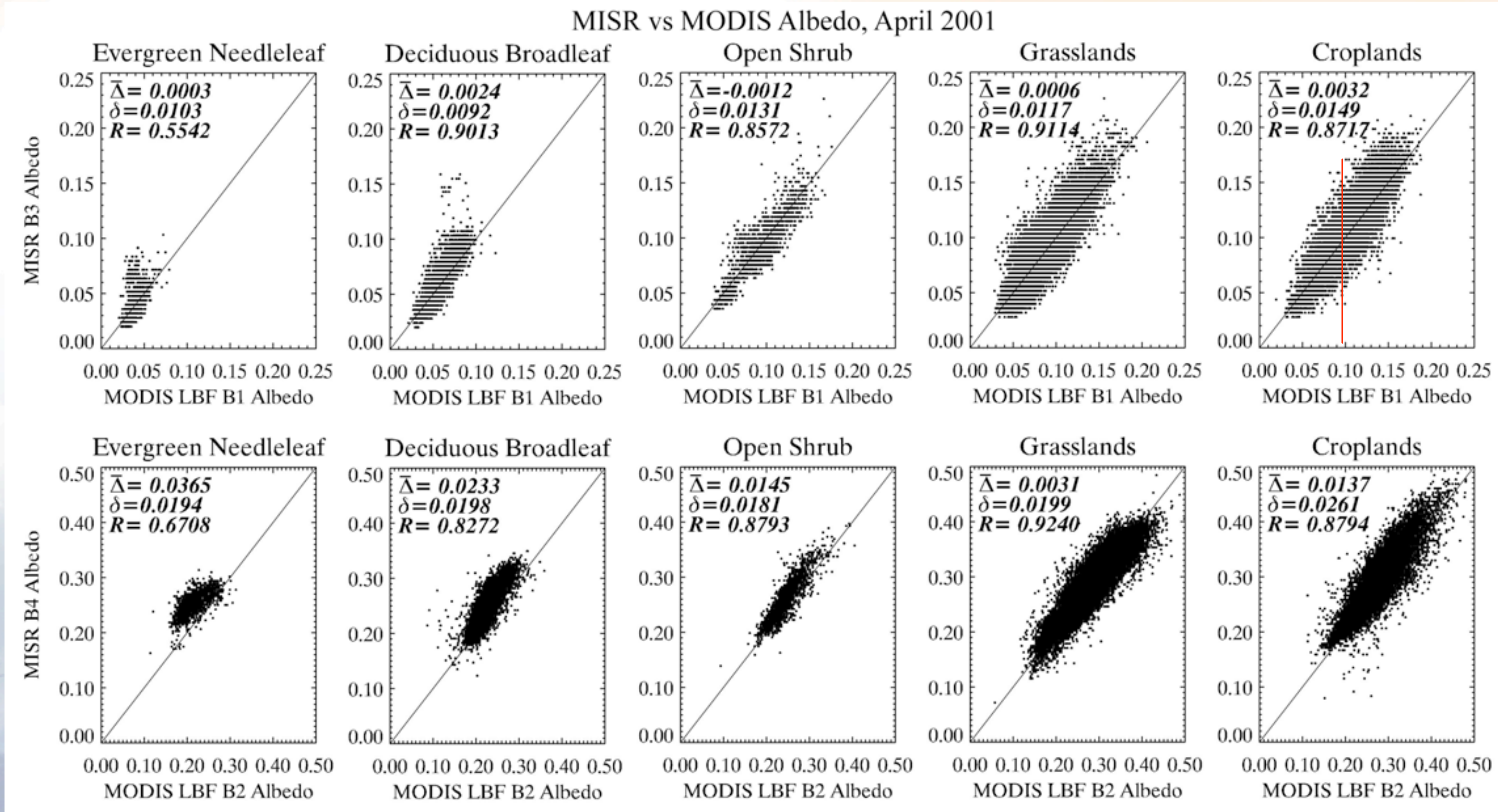
Validation

Albedo




Blue band, 20000404
$\overline{\Delta}$=-0.0021
δ=0.0005
R= 0.9998
Landsat-7 B1 Nadir Refl.
MODIS LBF B3 Nadir Refl.
Green band, 20000404
$\overline{\Delta}$= 0.0017
δ=0.0019
R= 0.9978
Landsat-7 B2 Nadir Refl.
MODIS LBF B4 Nadir Refl.
Red band, 20000404
$\overline{\Delta}$=-0.0007
δ=0.0013
R= 0.9999
Landsat-7 B3 Nadir Refl.
MODIS LBF B1 Nadir Refl.
NIR band, 20000404
$\overline{\Delta}$= 0.0083
δ=0.0013
R= 0.9999
Landsat-7 B4 Nadir Refl.
MODIS LBF B2 Nadir Refl.


Spectral Response Function & Albedo
Wavelength (nm)


MISR vs MODIS Albedo, April 2001
Evergreen Needleleaf
Δ̄= 0.0003
δ=0.0103
R= 0.5542
Deciduous Broadleaf
Δ̄= 0.0024
δ=0.0092
R= 0.9013
Open Shrub
Δ̄=-0.0012
δ=0.0131
R= 0.8572
Grasslands
Δ̄= 0.0006
δ=0.0117
R= 0.9114
Croplands
Δ̄= 0.0032
δ=0.0149
R= 0.8717
MISR B3 Albedo
MODIS LBF B1 Albedo
0.00 0.05 0.10 0.15 0.20 0.25
Evergreen Needleleaf
Δ̄= 0.0365
δ=0.0194
R= 0.6708
Deciduous Broadleaf
Δ̄= 0.0233
δ=0.0198
R= 0.8272
Open Shrub
Δ̄= 0.0145
δ=0.0181
R= 0.8793
Grasslands
Δ̄= 0.0031
δ=0.0199
R= 0.9240
Croplands
Δ̄= 0.0137
δ=0.0261
R= 0.8794
MISR B4 Albedo
MODIS LBF B2 Albedo
0.00 0.10 0.20 0.30 0.40 0.50

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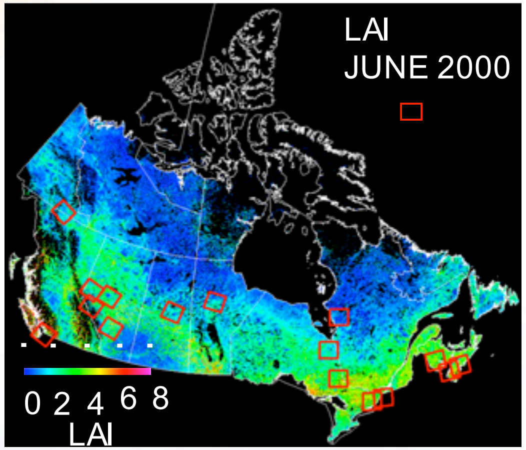
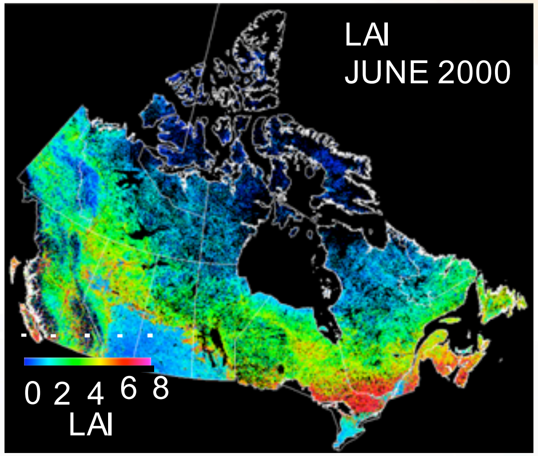
LAI

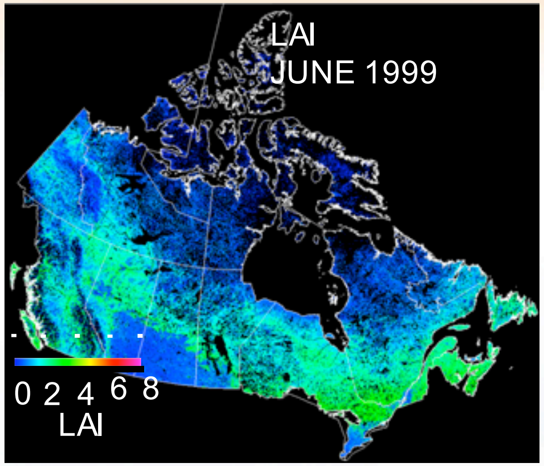
SPOT-Vegetation 10-day 1km

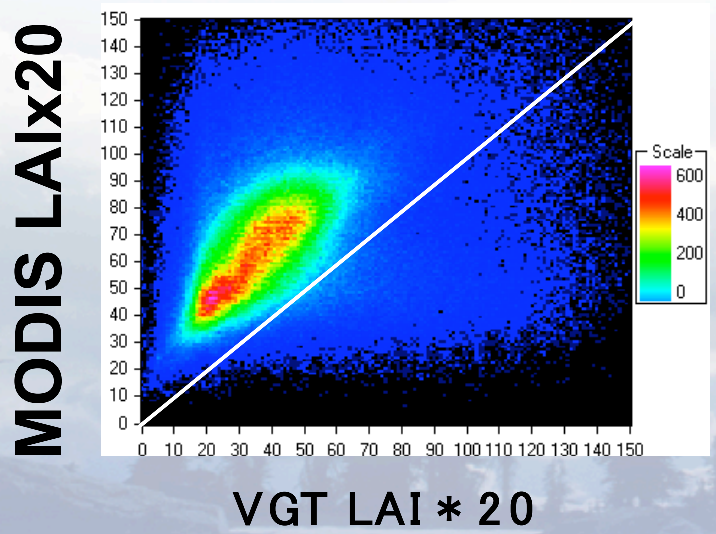


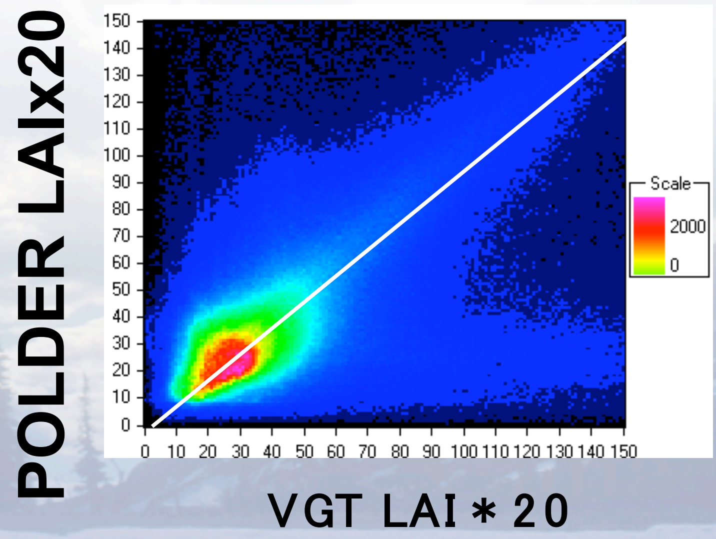
MODIS Monthly 1km



POLDER 10-day (1/18 deg)

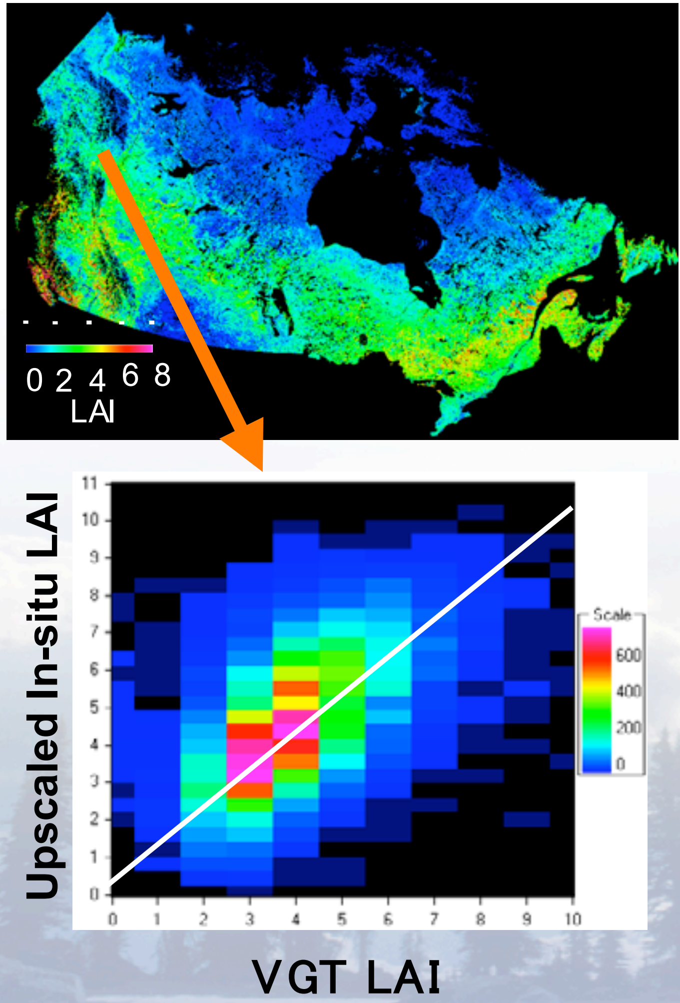




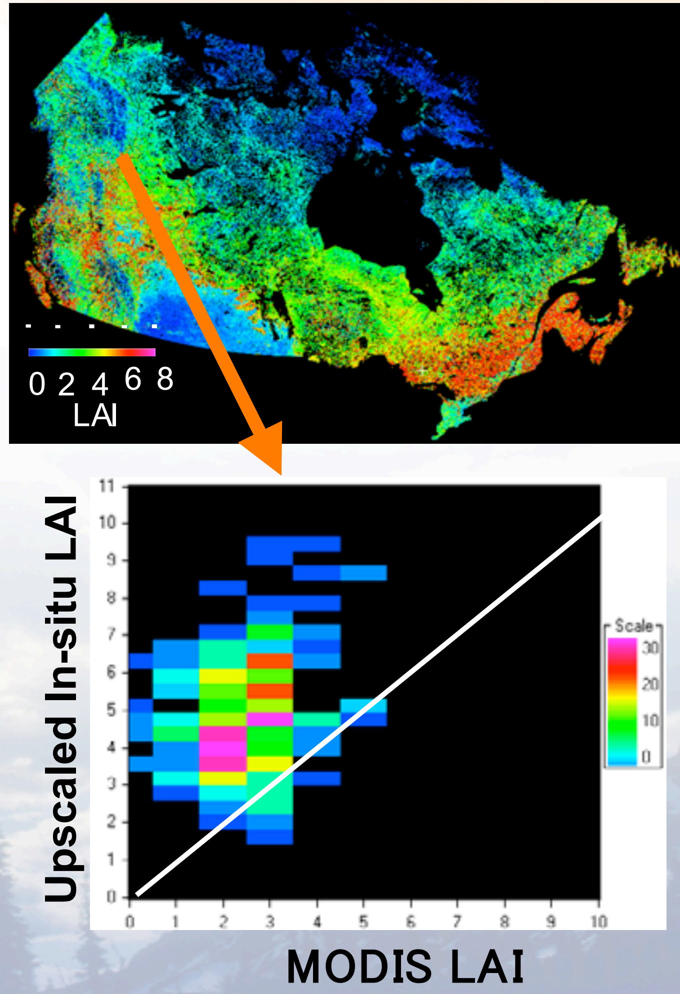


LAI Validation over Canada
Canadian VGT vs US MODIS

SPOT-Vegetation 10-day 1km



MODIS Monthly 1km



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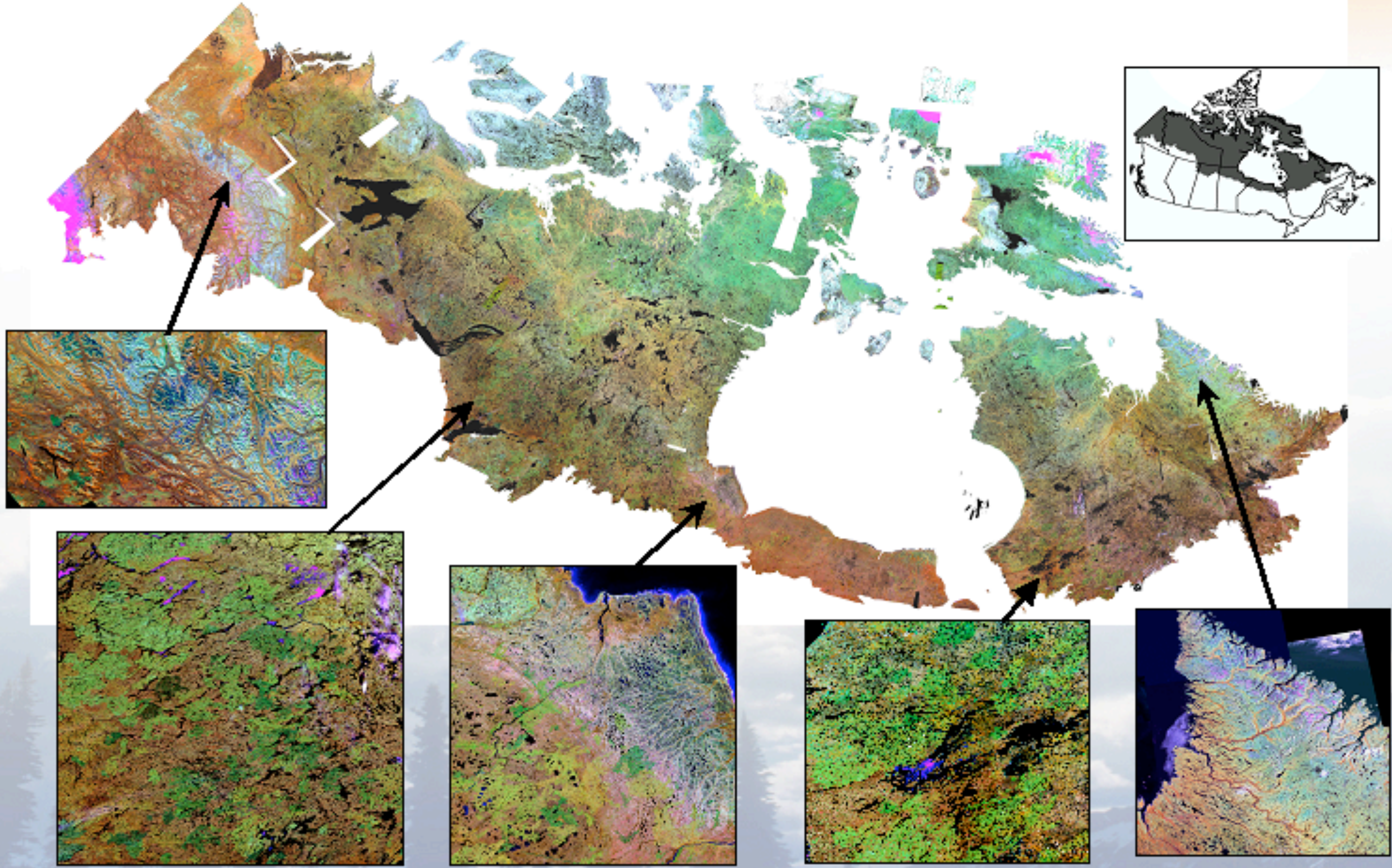
Multi-sensor data fusion for northern landcover mapping

Landsat ETM+ mosaic of northern Canada – 353 scenes



Olthof, I., Butson, C., Fernandes, R., Fraser, R., Latifovic, R. and Orazietti, J. (2004). Landsat ETM+ mosaic of northern Canada. *Canadian Journal of Remote Sensing*, submitted 06/04.

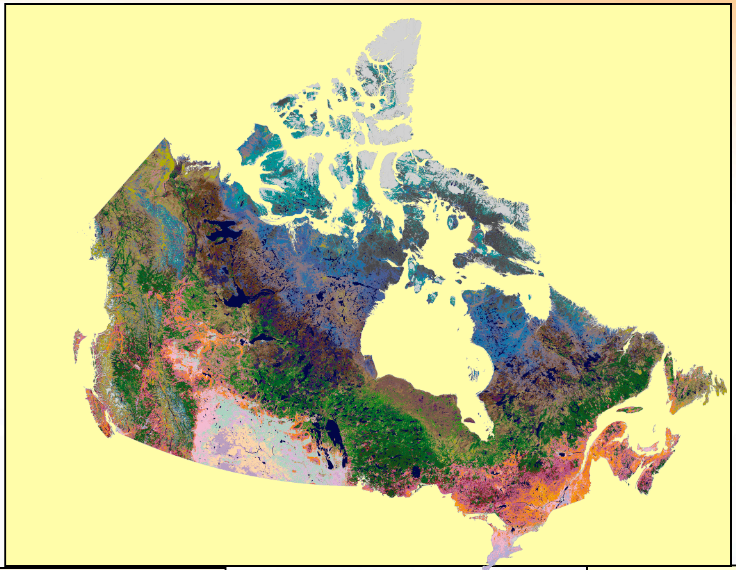
Multi-sensor data fusion for northern landcover mapping

- Simulate SPOT/VGT data with ETM+ by resampling using VGT Point Spread Function
- Use robust regression (Thiel-Sen) that is insensitive to ~ 29% outliers with ETM+ as independent and VGT as dependent variable to derive ETM+ normalization coefficients
- Apply coefficients and mosaic in two directions
- Use MVC to select clearest data in overlap areas

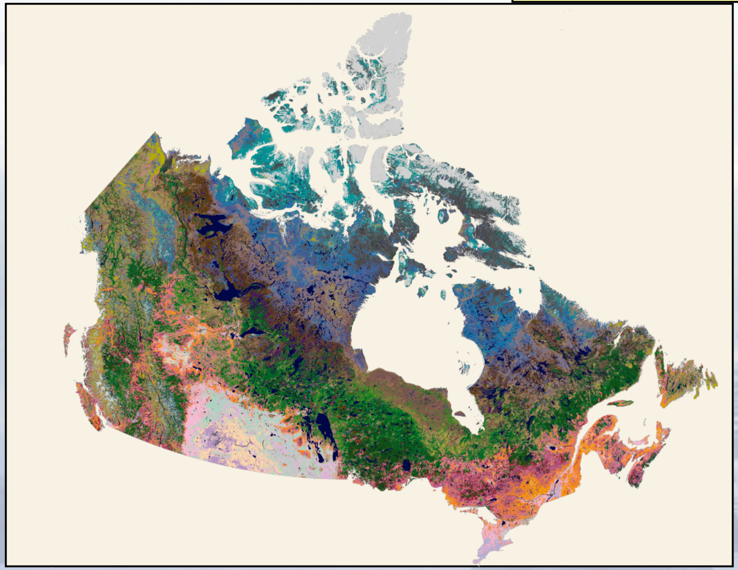
Olthof, I, Pouliot, D., Fernandes, R., and Latifovic, R. (2004). Landsat ETM+ radiometric normalization comparison for northern mapping applications. *Remote Sensing of Environment*, accepted 05/04.

Multi-temporal land cover mapping 1990, 1995 and 2000 using data from NOAA11 and NOA14

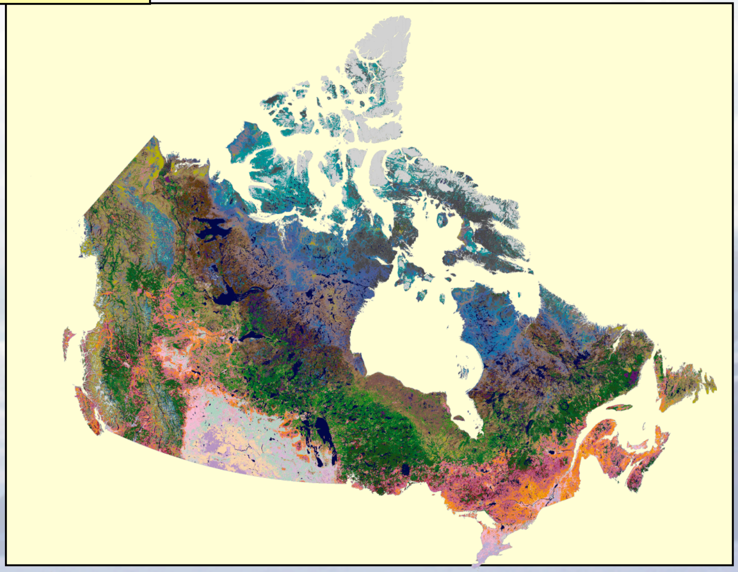
1995 Land cover



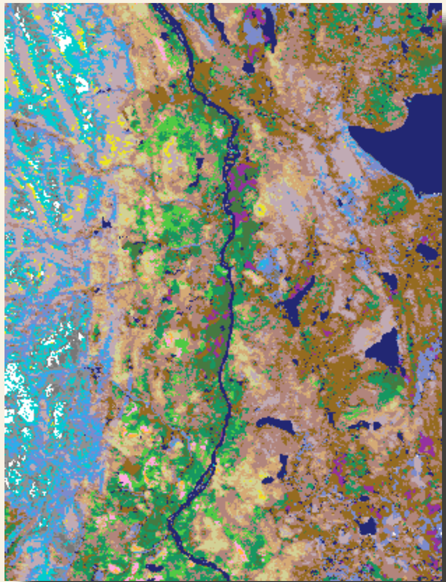
1990 Land cover



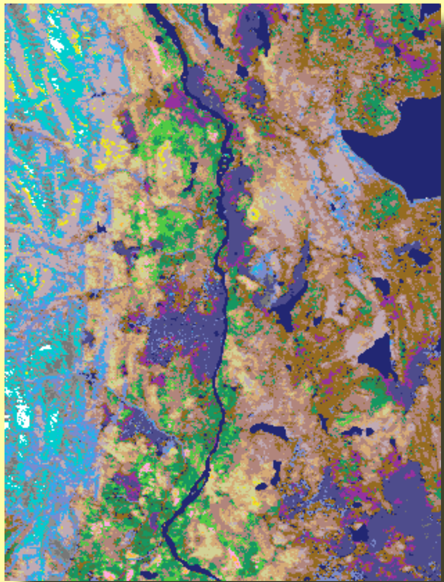
2000 Land cover



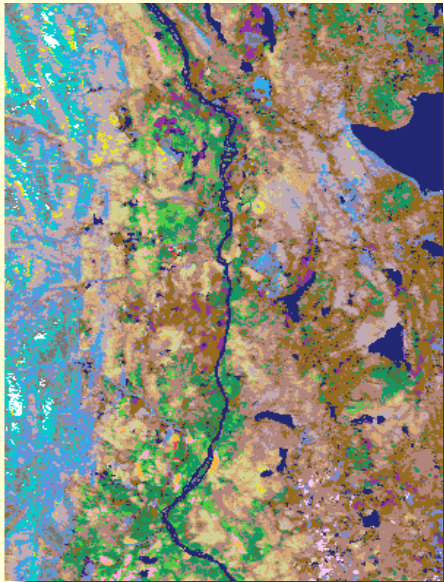
1990



1995



2000



Summary

•Long-term observations sustained over decades are a critical first-step in providing the climate data necessary for scientists, decision makers and stakeholders to make adaptive choices that could improve resilience to climate change and vulnerability, as well as maintain economic vitality.

•CDR’s generated from long-term satellite observations have unique characteristics including periodical reprocessing and reanalysis. Thus, processing system need to be constantly improved as the new data correction methodology become available.

•Significant initial steps in generating satellite CDR’s over Canada have been accomplished under the ESS Program RCVCC and CSA GRIP project CCEI.

-AVHRR database that include 9.7 TB is established

-Core part of AVHRR and VGT processing system is developed

•Today and near feature satellite sensors as ENVISAT–MERIS, NPOESS –VIIRS need to be assimilate in to CDRs.

Reference:

Cihlar, J., R. Latifovic, J. M. Chen, A. Trishchenko, Y. Du, G. Fedosejevs, and B. Guindon, 2004. Systematic corrections of AVHRR image composites for temporal studies. *Remote Sensing of Environment*, **89**, 217-233

Fernandes, R., Butson, C., Leblanc, S., & Larifovic, R. (2003), Landsat-5 TM and Landsat 7 ETM+ based accuracy assessment of leaf area index product for Canada derived from SPOT-4 VEGETATION data. Canadian Journal of Remote Sensing, 29, pp241-258

Latifovic, R., Cihlar, J., & Chen, J. M. (2003). A comparison of BRDF models for the normalisation of satellite optical data to a standard sun-target-sensor geometry. IEEE Transactions on Geoscience and Remote Sensing, 41, No.7

Latifovic, R. Zhu, Z., Cihlar J., Giri, C. and Olthof, I. (2004). Land cover mapping of North and Central America – Global Land Cover 2000. Remotes Sensing of Environment N.89. pp116-127

Teillet, P.M., & Holben, N.B. (1994). Towards operational radiometric calibration of NOAA AVHRR imagery in the visible and near infrared channels. Canadian Journal of Remote Sensing 20:1-10.

Trishchenko, A.P, (2002). Removing Unwanted Fluctuations in the AVHRR Thermal Calibration Data Using Robust Techniques. Journal Of Atmospheric and Oceanic Techniques Vol.19 No.12

Trishchenko, A.P., Cihlar, J. & Li, Z. (2001). Effects of spectral response function on surface reflectance and NDVI measured with moderate resolution satellite sensors. Remote Sensing Of Environment 81:1-18.