Arctic River Delta Change Analysis with RapidEye Data – Concepts & Challenges

(RESA 473)

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Intro

- **ESA DUE PF = Data User Element Permafrost**, Juni 2009 - 2012
- **Goal**: define, demonstrate and validate a permafrost monitoring information service (local to large scale), mainly towards climate change studies (pan-boreal/arctic zone).

  1. Define EO based services for permafrost monitoring based on user requirements,
  2. Integrate the latest EO technology,
  3. Validate the services with the user organizations,
  4. Develop mid to long term scenarios for boreal permafrost monitoring.

- **Erdbeobachtungsprodukte**: Landcover (local, regional, pan-arctic), Water Bodies, Land Surface Temperature, Soil Moisture, Snow, Methane, Terrain Height/Subsidence

- [http://www.ipf.tuwien.ac.at/permafrost](http://www.ipf.tuwien.ac.at/permafrost)

- **Konsortium:**

  ![TU Wien](image1)
  ![University of Waterloo](image2)
  ![AWI](image3)
  ![Gamma Remote Sensing](image4)
Arctic River Delta Change Analysis

Arctic Delta Change (a spin-off of ESAs DUE PF):

Motivation:

- Arctic coastal interface: sensitive zone of interaction between land and sea, infrastructure investments, area in which climate warming is expected to trigger landscape instability, rapid responses to change

- Understanding trends and underlying causes of delta changes:
  - eastern Canadian Archipelago & Greenland are uplifting (1cm/year),
  - Some Siberian Coasts are retreating (no ice sheet cover in ice ages),
  - wave/wind directions, storm duration, currents, amount of sediment transported, strong dependence on open-water season (3-4 months) and its change (Leont’yev 2004),

- PF Degradation Add-On /Feedback with Climate Change
Circum Arctic map of coastal erosion rates

Overduin et al. 2014:
The arctic environment is changing: air temperatures, major river discharges and open water season length have increased, and storm intensities and tracks are changing.

(a) Wave action has undercut ice-rich deposits along the Yukon coast (image credit: N. Couture, August 2008).

(b) Aerial view of block failure along the Yukon coastline (image credit: N. Couture, August 2008).
Study Sites

Arctic Delta Change Study Sites (RESA274/344/473)

- Lena Delta (Siberia) (1967 vers. 2011), Lena Delta Reservat 60k sqkm, Lena riverbasin 2.49 mio sqkm
- Yana Delta (Siberia) (1966 vers. 2013), Yana riverbasin: 238k sqkm
- Mackenzie Delta (Canada)(1966 vers 2013) (Alexander Mackenzie 1789, schottisch-kanadischer Entdecker), riverbasin 1,7mio sqkm
RapidEye Preprocessing

1. **Data conversion**, e.g. NITF to PCIDSK (OrthoEngine)
2. **Georeferencing** (provided using RPC Rapideye information)
3. **Reprojection** to UTM (8) WGS84 6.5m
4. **Atmospheric Correction (ATCOR)** to scaled reflectance
5. **Co-registration** of Corona KH4 data (from 1966) Lake Center Point Correction (LCPC)
6. **Radiometric balancing and multi image mosaicing**
Data & Preprocessing (Corona 1966-67)

1. Flight Row Film Stitching
2. Local variance sensitive noise reduction (Adobe LR)
3. Geotiff –to- PCIDSK Pix File conversion
4. LCPC based manual 3rd order Polynom, Georeferencing (Rapideye as reference information) Reprojection to UTM 8 WGS84 6.5m
5. Radiometric balancing (overlap) and hot spot removal
Data & Preprocessing

Lena Delta Mosaic:
1. 8 RapidEye (from 39) data sets (2009-2011) and 35 Corona sub-scenes (1965)
2. Cloud mask generation for histogram matching
3. Cutlines definition in overlapping areas
4. Radiometric normalization to one reference dataset) (KH-4A data: trend removal)
5. 3rd order Polynomial mosaicing based on LCPC (Lake Center Point Correction) GCPs

Single images (A, C) and data mosaic (B, D) of Corona and RapidEye data for the Lena delta study area
RapidEye Data Coverage Yana Delta

5x L1b Streifen 4.7.-11.8.2011

Corona Datenmosaik
1967

3x L1b Streifen 14.7.-25.8.2013
RapidEye Data Coverage Mackenzie Delta

L1b: 15.6.-23.6.2011

L1b: 12.9.2011

L1b: 14.7.-8.8.2013

Corona 22.9.1967
Mackenzie Delta Region

Largest arctic delta in North America (North West Territories/Beaufort Sea), 250x70 km Holocene sediments, continuous permafrost, off-shore sea ice (9 months),

- Mackenzie Delta: retreat rates between 2-6 m yr⁻¹ and up to 20 m yr⁻¹ (Solomon 2005)
- Sea level rise: 1-2 mm yr⁻¹ but higher in the past (Hill et al. 1985; Jenner & Hill 98).
- No traditional accretional landform, morphology is dominated by erosional landforms
- Short term high energy storm events responsible for coastal sediment transport – long shore transport instead of on-off-shore.
- Annual sediment input is at 150 x 10⁶ t

(Mackenzie Delta extent after Rampton ‘88 and modified by Jenner & Hill 1998)
Mackenzie Delta Region – Olivier Islands

Corona Mosaic Subset (22.9.1966) spatial resolution 2m, Greylevel threshold classification: land vers. Water; Olivier Islands, North West Territories/Canada

RapidEye RGB 532 (August 2013), spatial resolution 6.5m, multispectral land/water-classification,
Mackenzie Delta Region – Olivier Islands

Coastline Retreat – intensity mapping using zonal statistics
Mackenzie Delta
Mackenzie Delta - Coastal Change

2. Calculating Euclidean Distance from 1966 Coastline status
3. Classification of coastline losses based on overlay analysis with Euclidean distance from 1966 status
4. Reclassification of 1966 coastline with overlay to land cover classification (water+land) in 2013
5. Reclassification (based on existence of) to different coastal “Gain” classes for 2013 -> transfer to large areas:
Mackenzie Delta - Coastal Change

Change Statistics Outer Limit Mackenzie Delta:

Mackenzie Outer Delta (West)
6441 Data Points: 101km with Degradation 1967-2013 (46 years):
• Mean: 131 m (2.8 m/year)
• Max: 571 m (12.4 m/year)

Mackenzie Outer Delta (West)
1836 Data Points: 28km with Aggregation 1967-2013:
• Mean: 143 m (3 m/year)
• Max: 745 m (16 m/year)
Coastal Change Rate MD (Salomon 2005):

Comparison with published results

**Change 1972 vers 2000:**
Lena Delta


Verlust und Zugewinn über Grid Model Analysen
Coastal Change – other Concepts

Zonal Change Mapping within the inner delta structure – distance from “Point of Separation”:
- Hotspot Change
- Delta Genesis
Summary

• Technical Challenges
  – Radiometric balancing of large Corona KH-4A mosaics: Multi year/season data mosaicing - missing NIR information for shallow water to land differentiation
  – Missing reference data with satisfying spatial distribution for the 60s (seasonal variability!) ACD Arctic Coastal Dynamics Database, CALM (Circumpolar Active Layer Monitoring) and GTN-P (Global Terrestrial Network for Permafrost)?
  – What is a change? (Arc/Node/Vertex/Pixel/ImageObject Comparison)

• Outlook
  – Full Mackenzie Delta processing (internal structure) full zonal change analysis – volume regression
  – Concept adaption to Lena/Yana Delta areas
  – Sub setting to coastal classification regimes (shoreline types)
Thank You!

Questions

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Coastal Change Rate MD (Salomon 2005):

Fig. 5. Summary of coastal stability measurements (retreat and progradation rates). a. Stability summarized by 25-km averages. b. Stability summarized by subregion.