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ESA – Frascati, LPVE Conference

Lake Surface Water Temperature retrieval - a contribution for a LST data set

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Objectives to consider LSWT

- Lakes influence local and regional climate (water as heat sink – water as heat source)
  - Weather forecast
  - Land surface temperature near shoreline
  - Modifies precipitation (lake effect)
- **Lakes as sentinels for climate change** (R. Adrian, 2010)
- Limnology (mixing regimes, nutrients, etc.), of lakes changes with climate
- Lake surface temperature is defined as ECV by GCOS (2010)

Relevance for weather forecast and climatology

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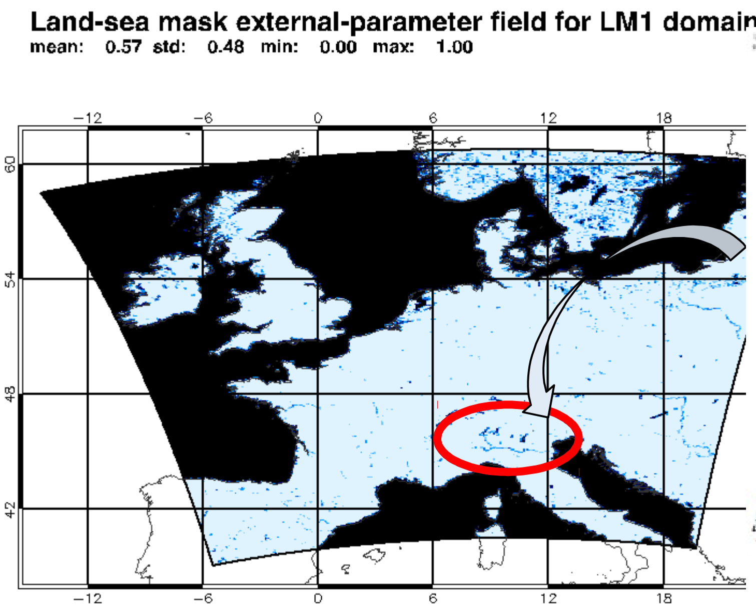
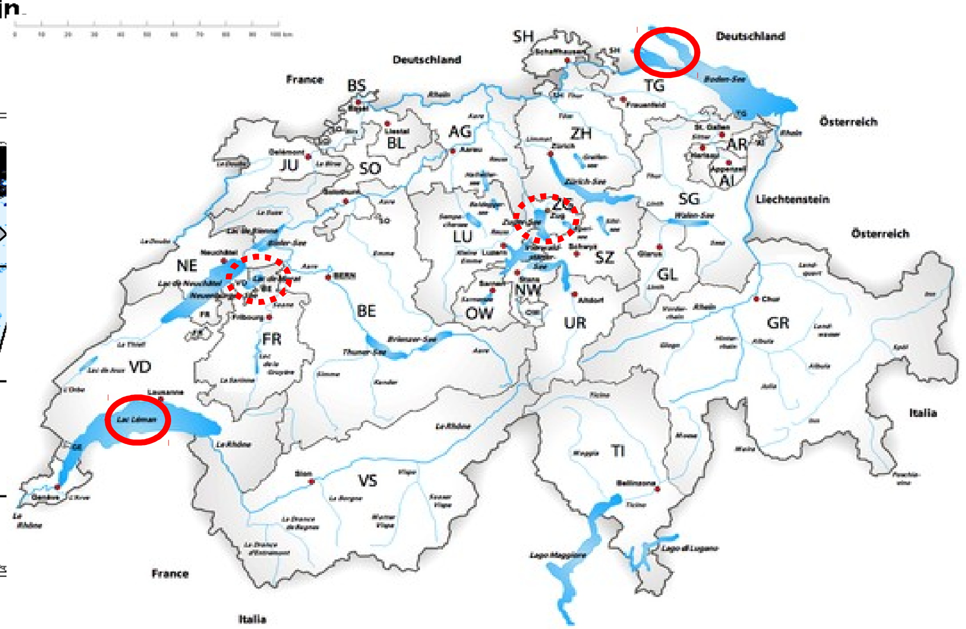
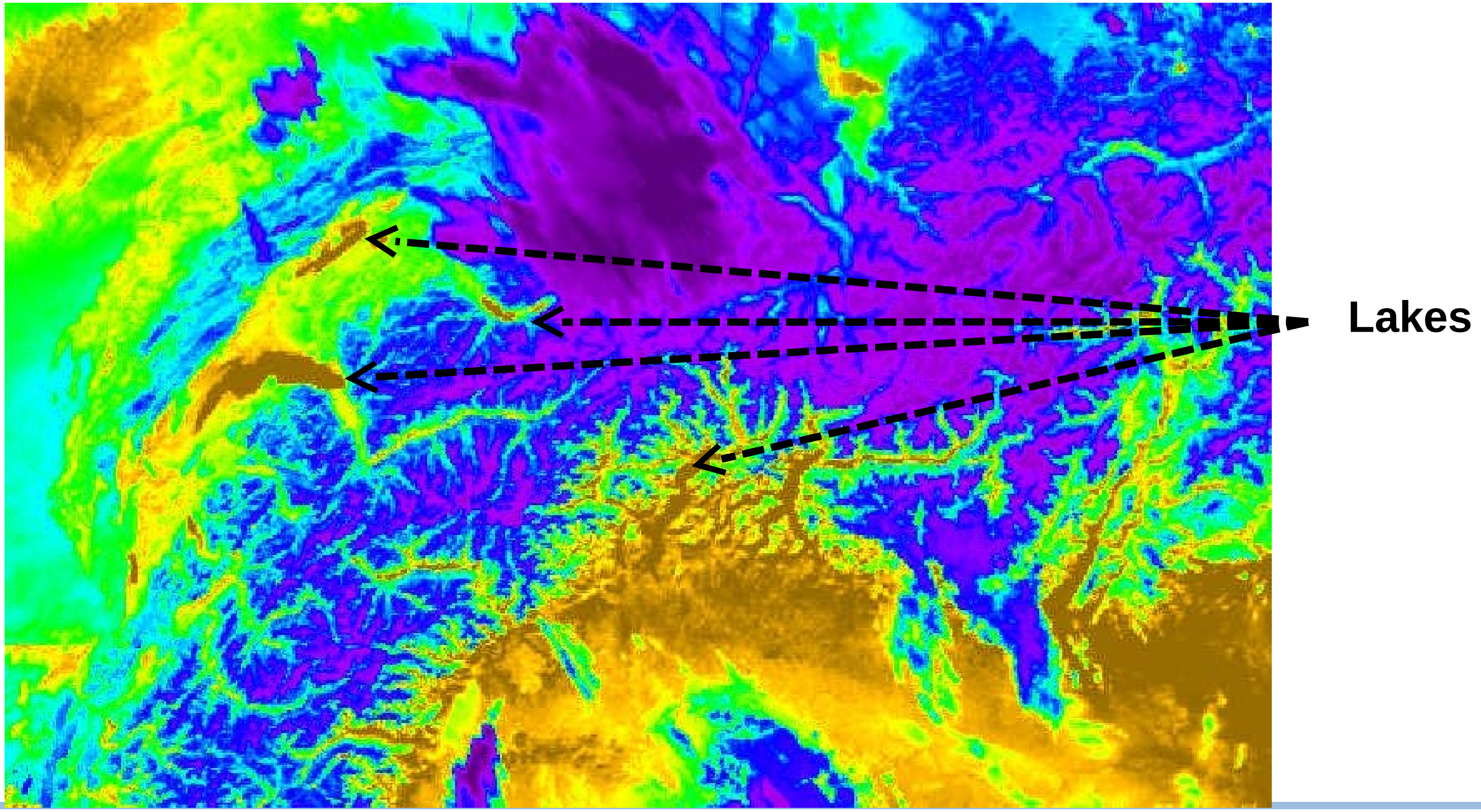
- There are more than 500 000 natural lakes larger than 0.01 km2 (1 ha) in Europe.
- Many are small, whereas around 16 000 have a surface area exceeding 1 km2. (European Environment Agency, EEA).
- **LSWT retrieval feasible for lakes > 15km2**



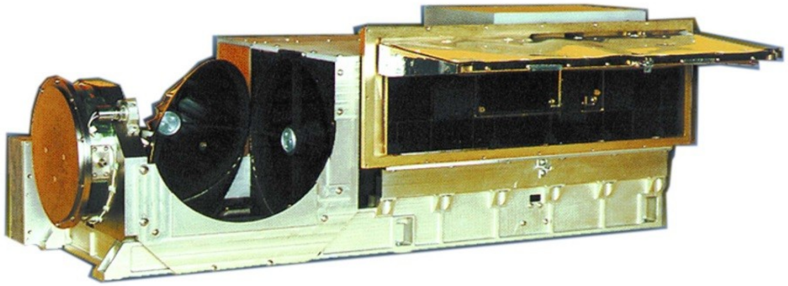


NOAA-AVHRR brightness temperature channel 4; January 2005

> Heat is released during cold season or during nights → significant influence of land surface



AVHRR – Advanced Very High Resolution Radiometer (1980 – ca. 2020)



> NOAA-satellites (1980 – ca. 2015)
> MetOp-satellites (2006 – ca. 2020)
> AVHRR: 30cm x 36cm x 80cm (32 kg)

AVHRR/3 Channel Characteristics (since 1998)

Channel Number	Resolution at Nadir	Wavelength (um)	Typical Use
1	1.09 km	0.58 - 0.68	Daytime cloud and surface mapping
2	1.09 km	0.725 - 1.00	Land-water boundaries
3A	1.09 km	1.58 - 1.64	Snow and ice detection
3B	1.09 km	3.55 - 3.93	Night cloud mapping, sea surface temperature
4	1.09 km	10.30 - 11.30	Night cloud mapping, sea surface temperature
5	1.09 km	11.50 - 12.50	Sea surface temperature

AVHRR reception, coverage and data considered for LSWT retrieval

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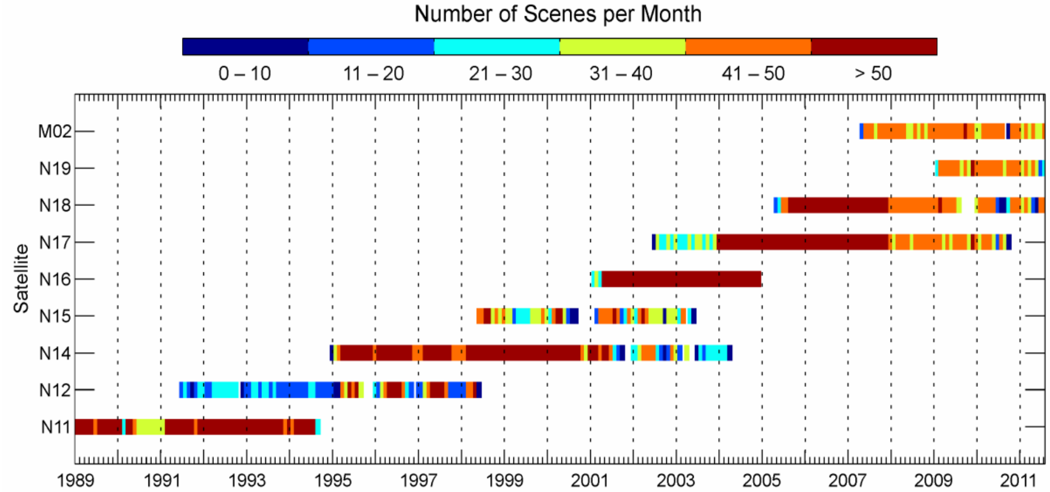
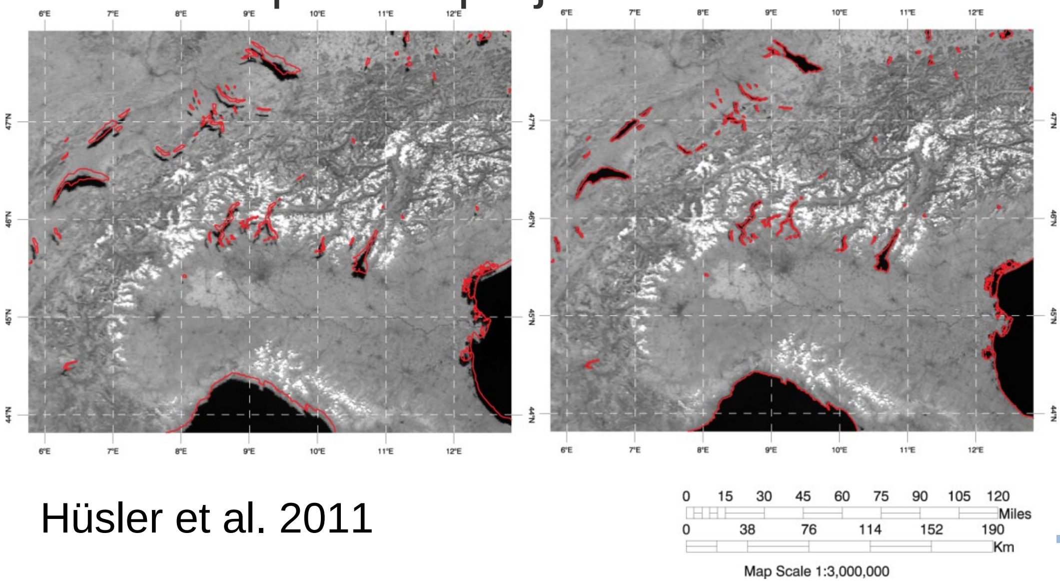


AVHRR data are archived at UniBe from 01/1985 – 01/2014

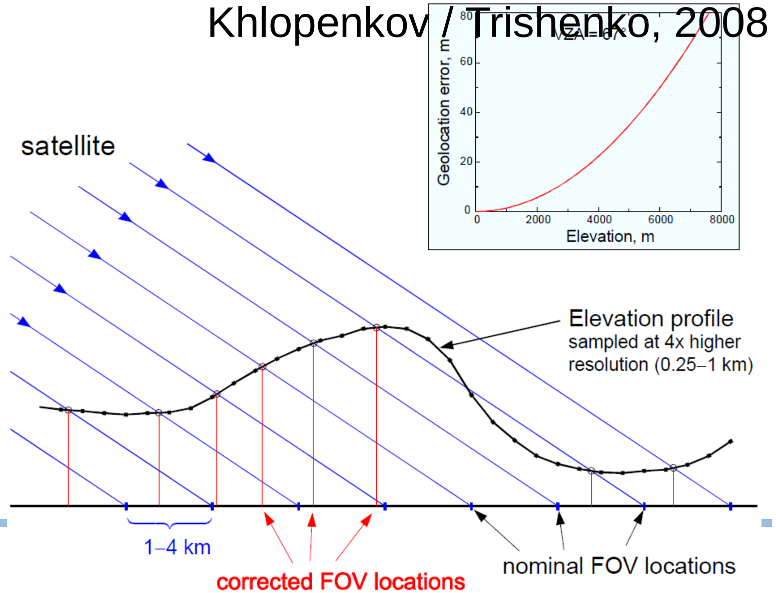
Geocoding - Orthorectification

- Objective: bring the pixel from satellite geometry to ground geometry
  - Orbit parameter → accuracy is approximately: 5km
  - Ground control points → accuracy is better than 1 pixel (=1km); aim → 0.3 pixel (GCOS requirement)
  - Ortho-correction: transformation of satellite projection into parallel projection and consider digital elevation model.



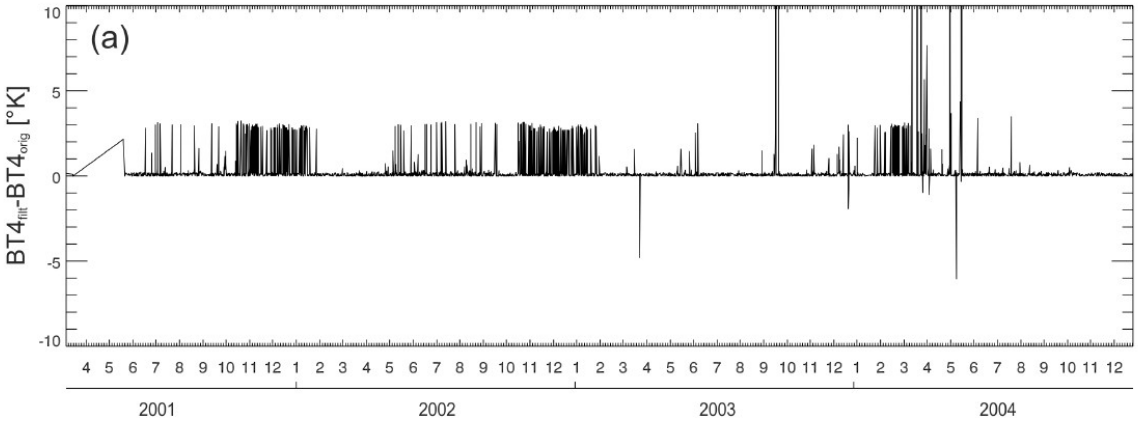
Hüsler et al. 2011

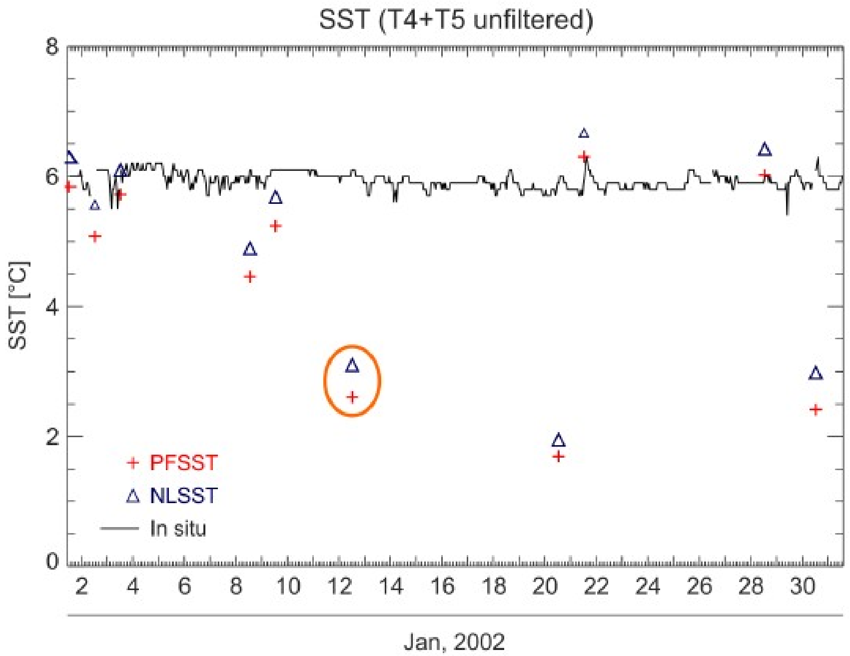
Khlopenkov / Trishenko, 2008

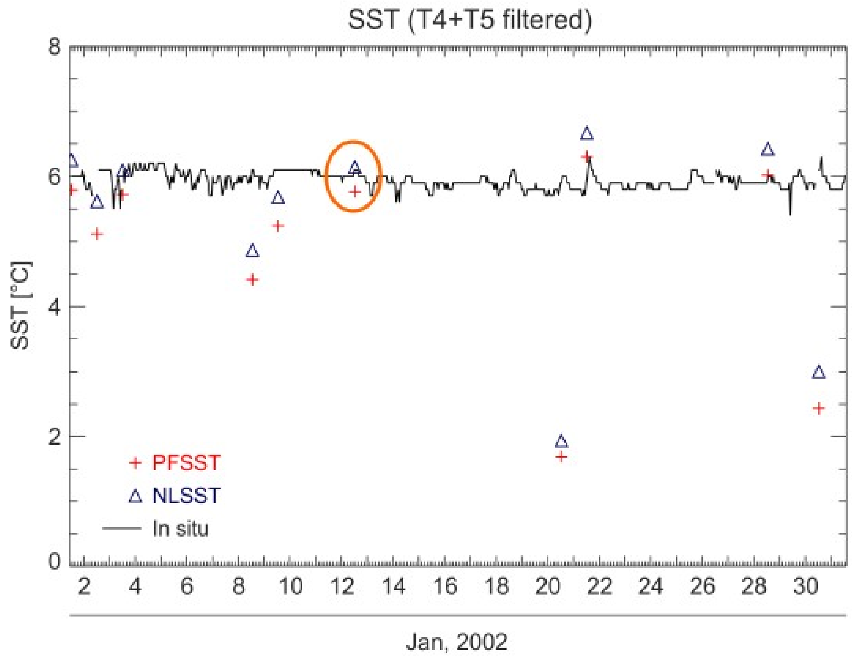


Improved thermal calibration of T4 and T5 (Trishchenko, A. 2002)

- NOAA-16
  - Left: ΔT4 (filt. – unfilt.); 2001 - 2004
  - Bottom: LSWT vs. in-situ, Jan. 2002







Calibration – mandatory for temporal consistency

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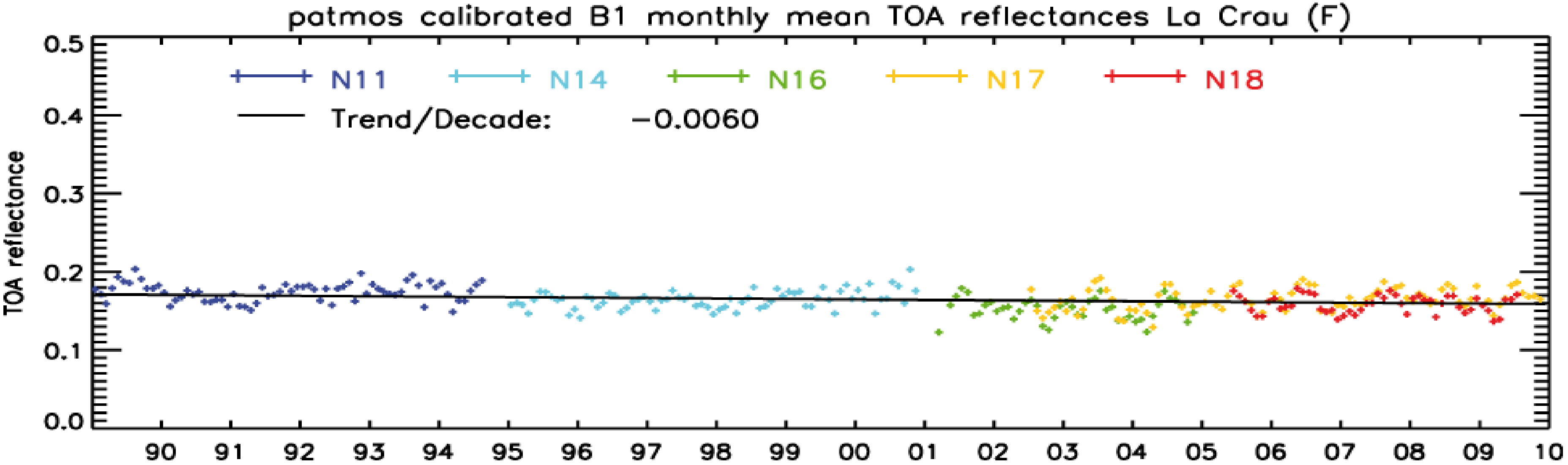

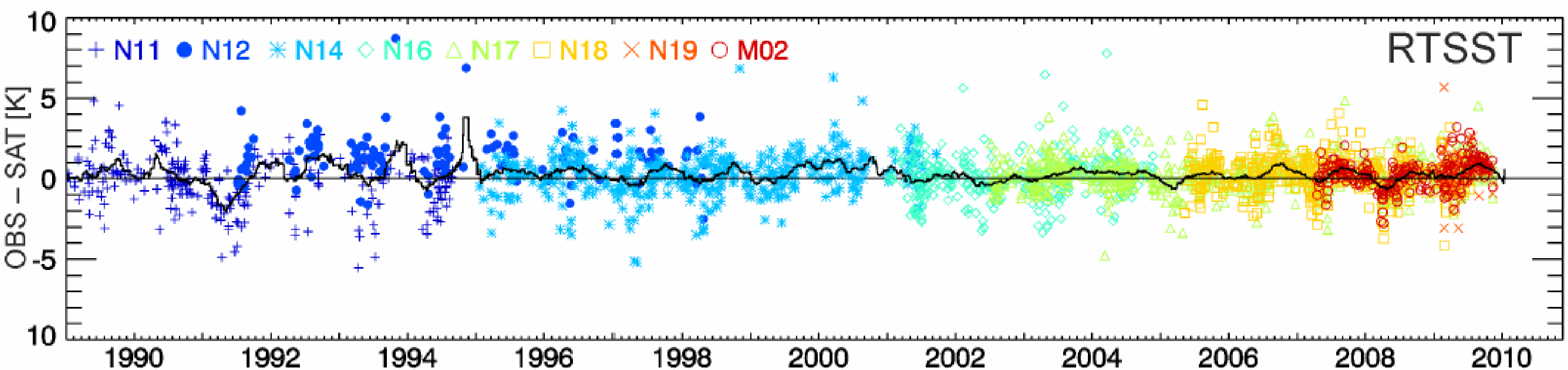

Hüsler et al. 2011, EARSeL eProc., Riffler, 2012 GCOS-report

Split-window approach (Hulley et al. 2011)

$$LSWT = a + bT_4 + c(T_4 - T_5) + d(T_4 - T_5)[1 - Sec(\Theta_v)],$$

- T4 and T5: brightness temperatures of AVHRR (11µm and 12µm)
- Sec (Θv) secant of viewing angle Θ
- a to d are the split-window coefficients.
  - Enhanced LakeST retrieval making use of radiative transfer modelling (RTTOVS-10) and ECMWF profiles (T, RH) to account for regional atmospheric variability
  - ECMWF profiles (21 p-Level) and parameter of the surface (T2m, Tskin, u, v, RH) daily 12:00 UTC

Method to retrieve SST/LakeST

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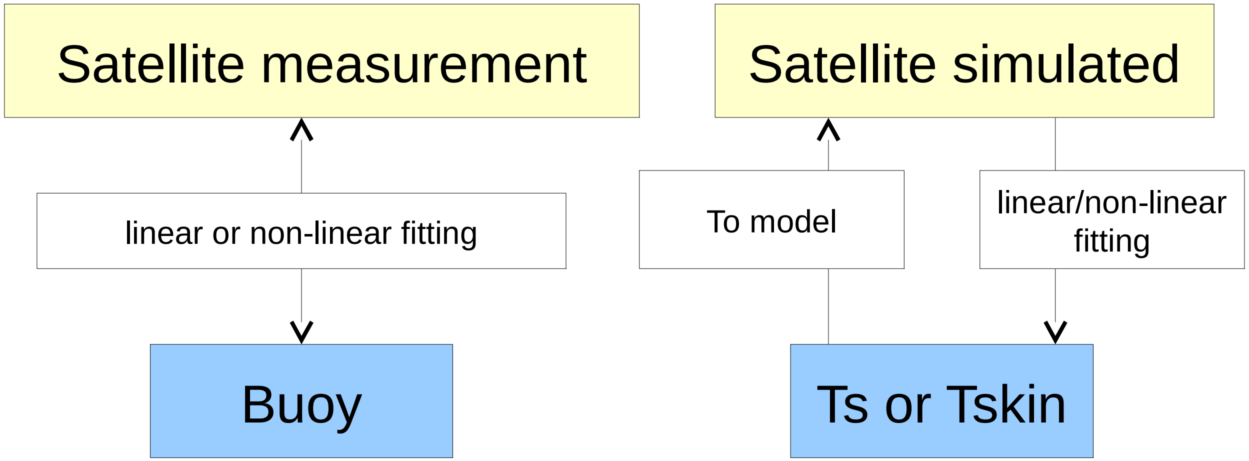
- Split-window NOAA NESDIS
- Split-window Pathfinder (climate project of NOAA)

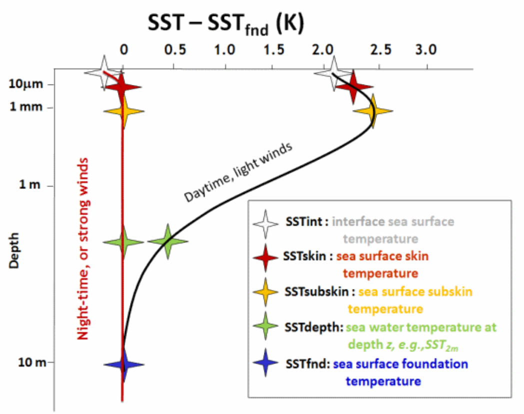
→ temporal homogenous retrieval (improvement to NOAA NESDIS)

- Independent from buoy measurements: use of radiative transfer code RTTOV-10



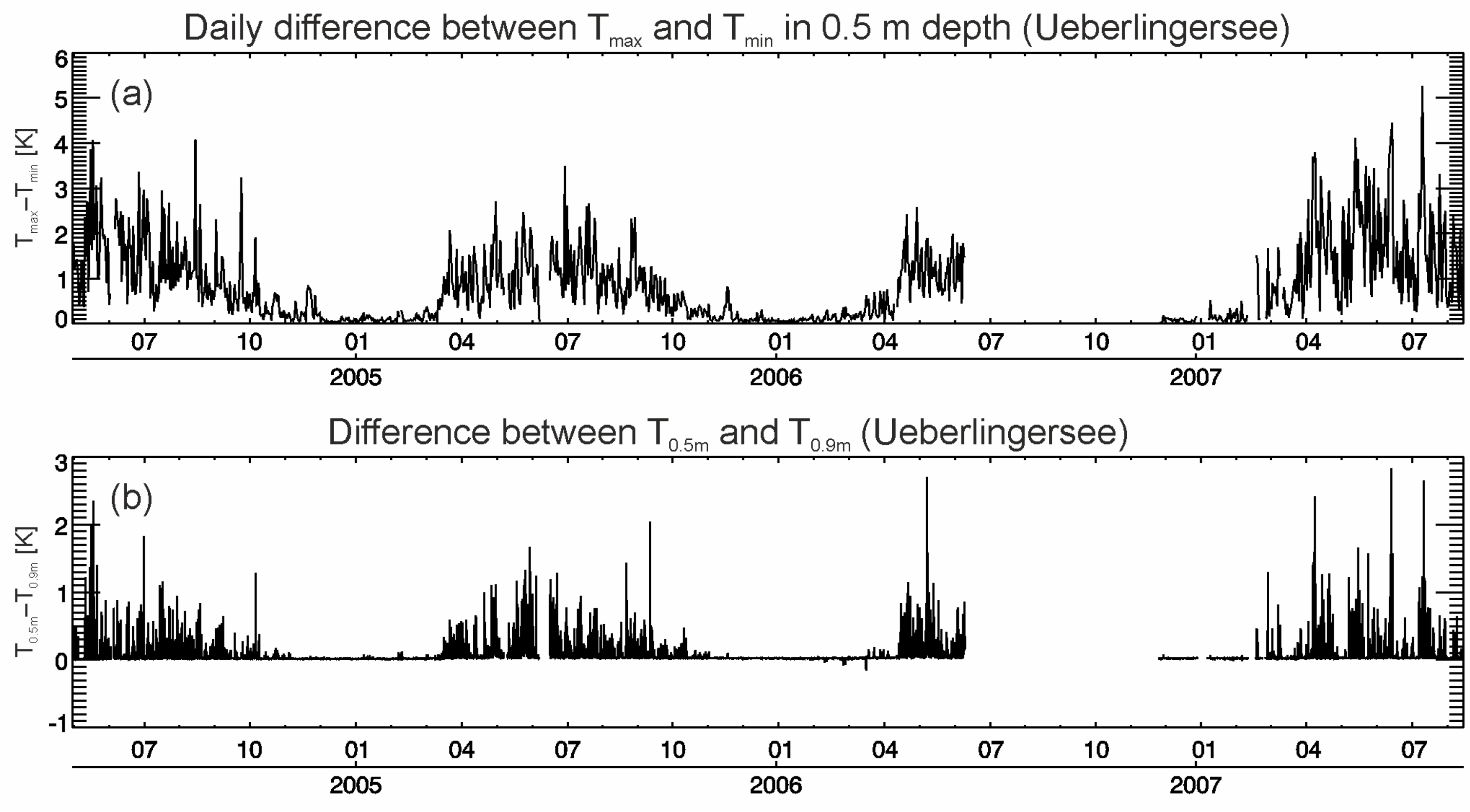
NOAA NESDIS, Pathfinder

Simulation

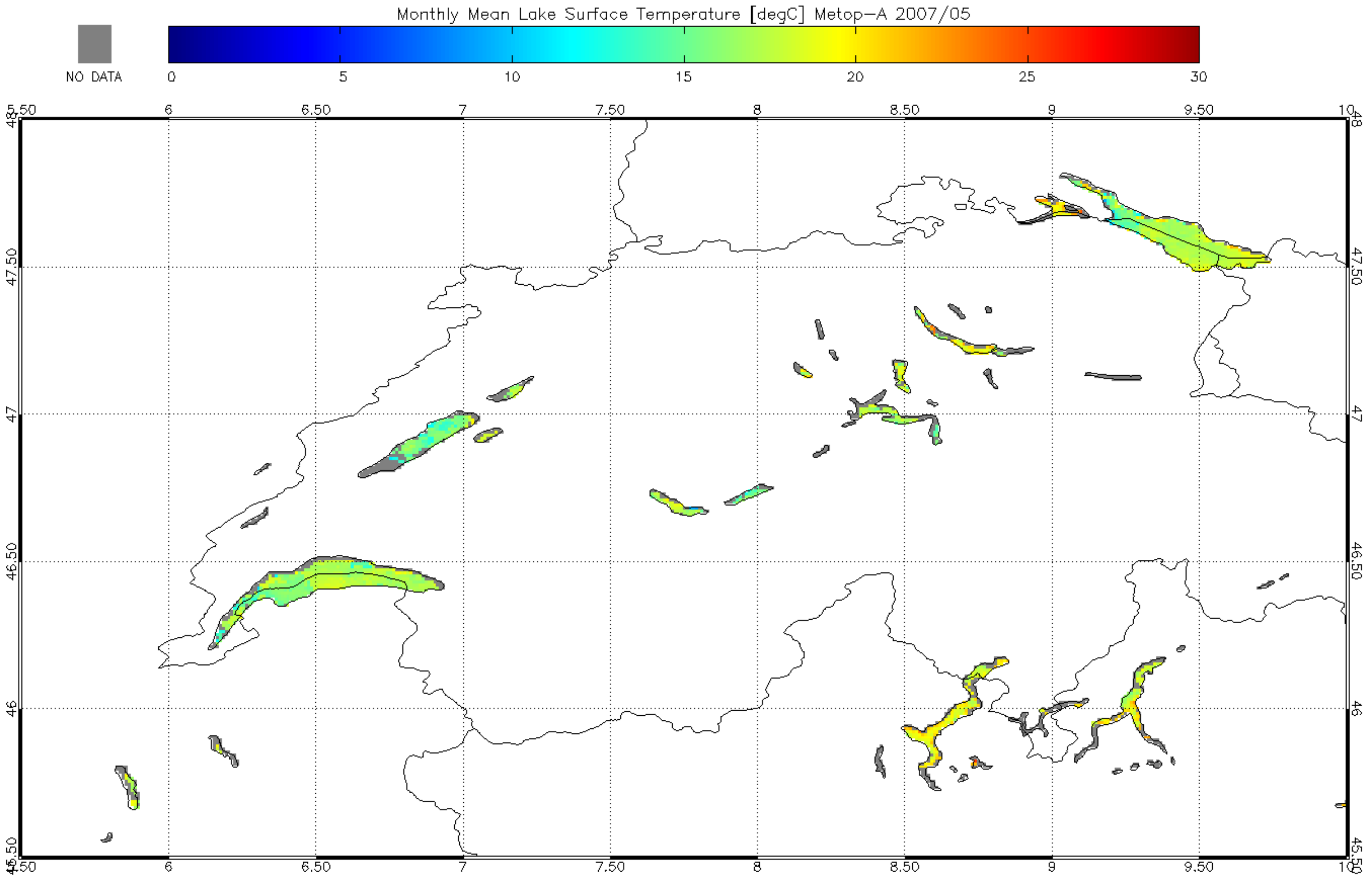


Correction of Tskin to Tbulk after Minnett et al., 2010

In situ station (Lake Constance) Überlingersee



Monthly mean lake surface temperature Metop-A (May 2007 – Dec. 2012)



Quality flags to improve the quality of a time series

- Initial tests
  - Cloud test
  - Water – land mask test
  - T4 > -10°C
  - LSWT should be in the range between -5°C and 35°C
  - Not only a single pixel (3x3 recommended)
  - Zenith angle < 55°
- Local std.dev: < 3°C
- Local std.dev. < 1.5°C and zenith angle < 45°
- Sun glint test

Validation of LSWT retrieval

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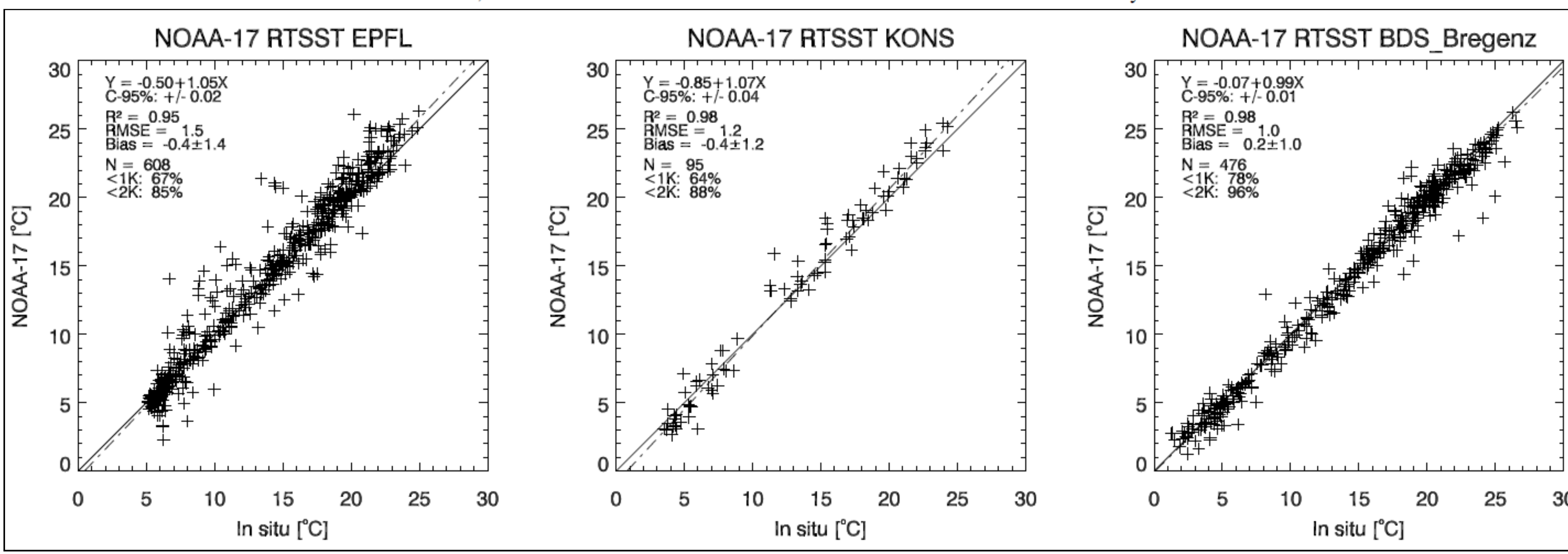
Lake	Lake size [km^2]	Location	Position	Time period	Sampling rate	Depth	Abbreviation
Geneva	580	46.46° N, 6.40° E	100 m offshore	2000–2011	hourly	1 m	EPFL
		46.37° N, 6.45° E	shoreline	1991–2011	T_{min}, T_{max}	1 m	INRA
Constance	536 (60)	47.76° N, 9.13° E, Lake Überlingen	1 km offshore	1987–2001	hourly	0.5 m	KONS
				2004–2007	hourly	0.5 m	KONS
		47.51° N, 9.75° E, Harbour of Bregenz	shoreline	1989–1996	daily mean	0.5 m	BDS1
				1997–2009	hourly	0.5 m	BDS2
Neuenburg	215	46.90° N, 6.84° E	mid-lake	2001–2012	monthly	surface	NBS
Zurich	88	47.30° N, 8.57° E	mid-lake	1989–2008	1–2 weeks	surface	ZUE1
		47.35° N, 8.53° E	shoreline	2008–2012	daily	0.5 m	ZUE2



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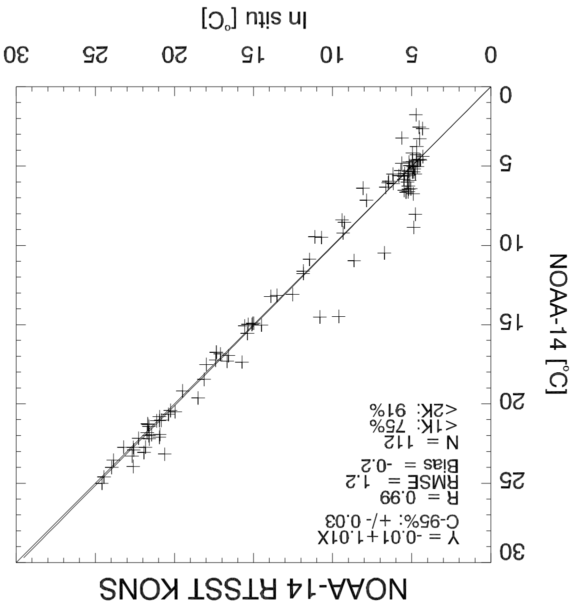
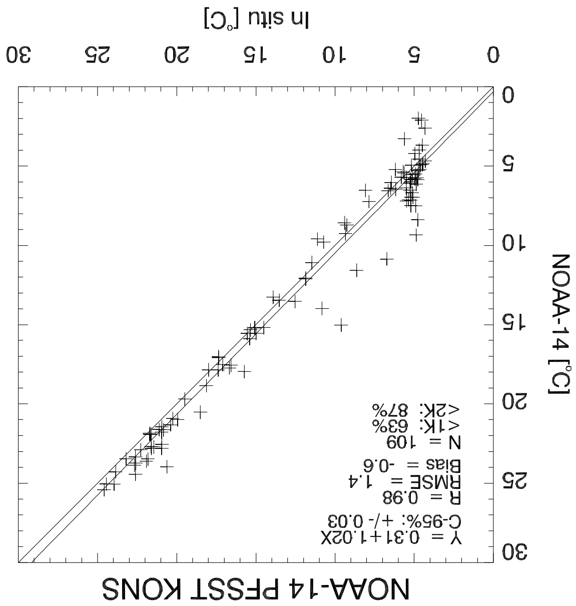
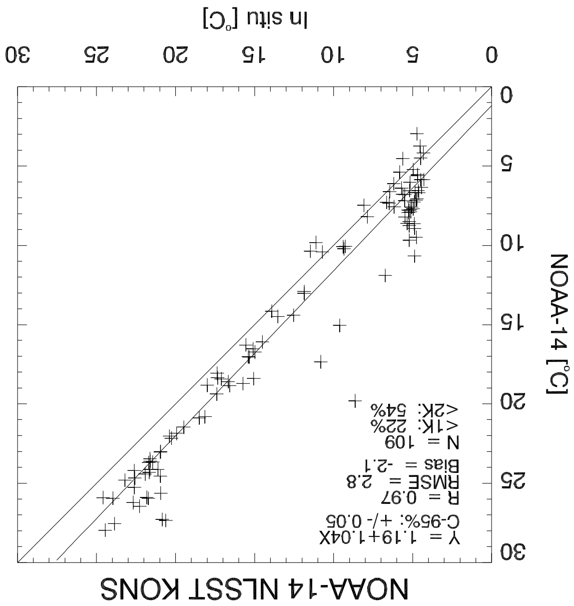
Validation for lake Constanze (part of it: 2-3km wide and 20km long)

> NOAA-14 compared with hourly data of Überlingersee



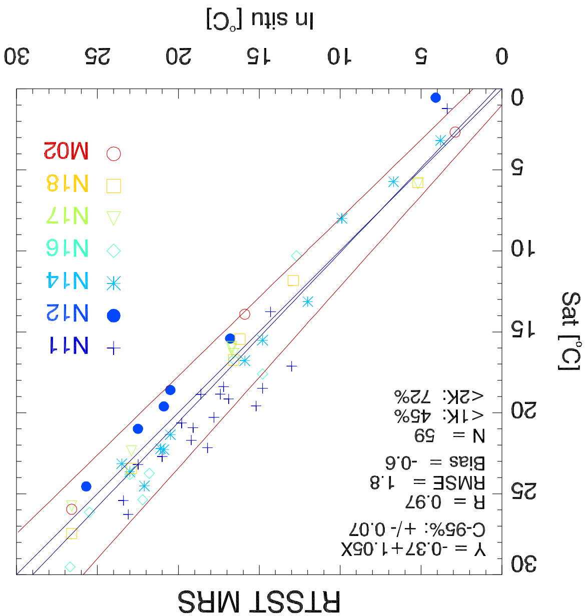




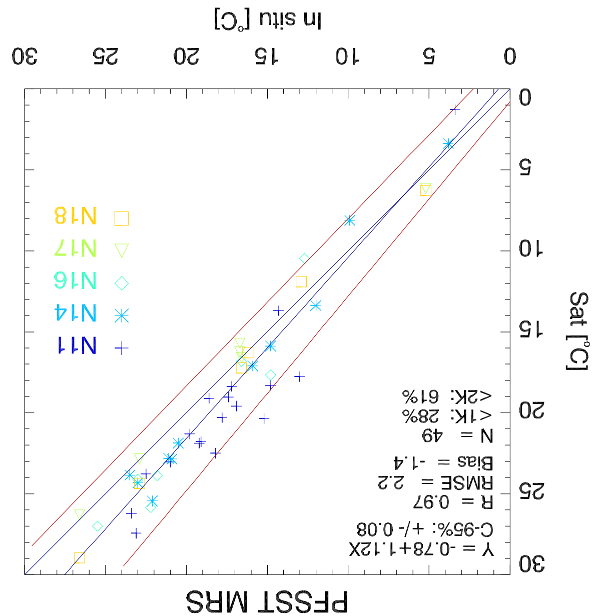
RTSST	PFSST	NLSST
RMSE = 2.8	RMSE = 1.4	RMSE = 1.2
Bias = -2.1	Bias = -0.6	Bias = -0.2

Validation for a small lake (N11 – MO2) - Murtensee (22km2)

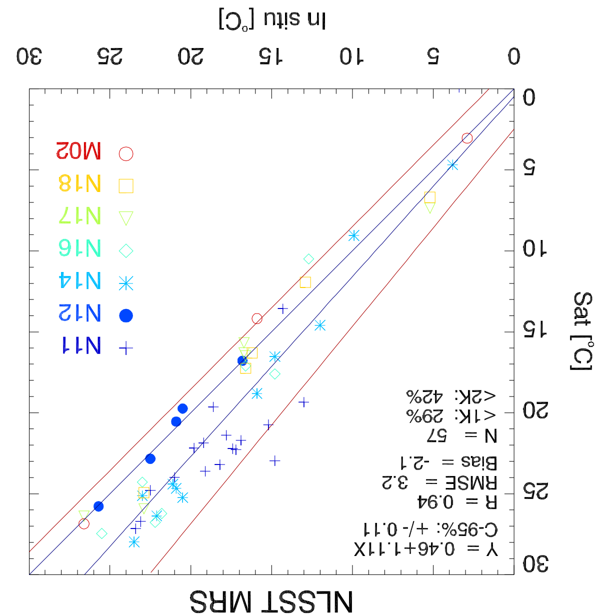
> In-situ data (monthly profiles of Murtensee) used for all NOAA/Metop satellites



RMSE = 3.2
Bias = -2.1



RMSE = 2.2
Bias = -1.4



RMSE = 1.8
Bias = -0.6

Validation for a small lake (N11 – MO2) - Lake Sempach (14km2)

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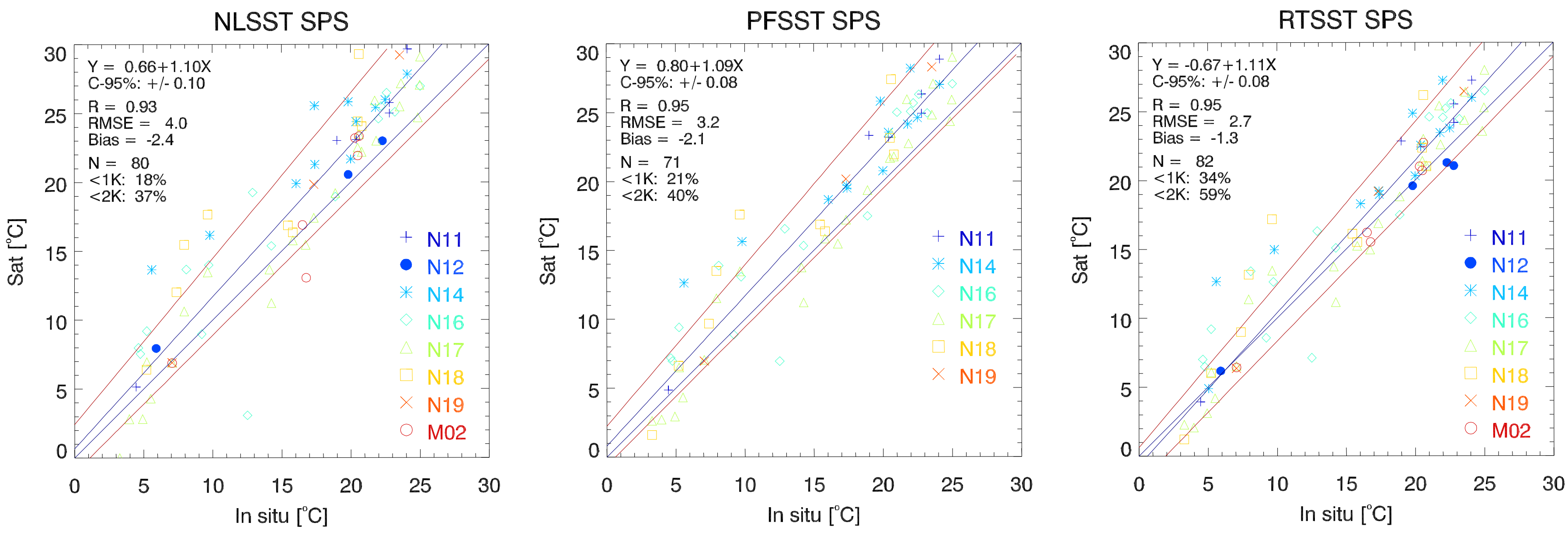

Next steps

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- Extend our data archive to the past (1981 – 1985); recently, data mining at ESA has started
- Include AVHRR night data into the processing
- Start of 3-year SNF-project “**Lake Water Surface Temperature of European lakes**”
  - 30 years time-series of LWST for lakes > 15km2
  - Develop and detect lake ice
  - Analysis of time series related to European climate
- Is there a climate signal in our time series? Analysis of ECV’s considering climate data (atmosphere and surface).

Summary and Conclusion

- Long AVHRR data archive (1985 – 2014) is stored and useable at University of Bern.
- We'll receive NOAA/Metop AVHRR data until the satellites lifetime (expected: 2020)
- The best possible pre-processing for AVHRR is implemented at RSGB.
- For the first time a spatial and temporal consistent data set of the ECV lake water surface temperature for the European Alps / Switzerland is processed (1985/1989 – 2011).
- We are ready for the retrieval of other ECV's and **any cooperation / ideas to use our data set are welcome**.

Thank you!

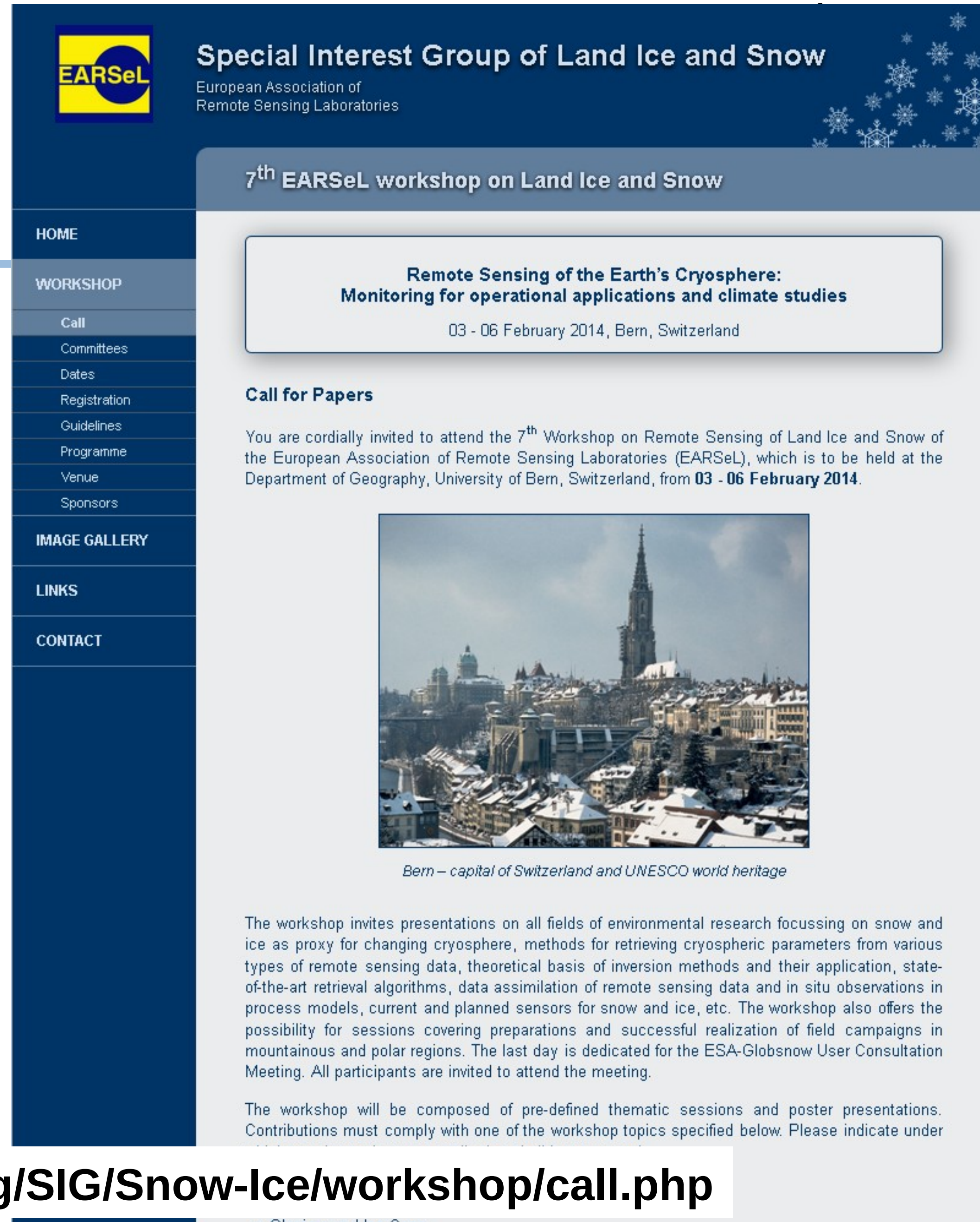
Acknowledgements:

- Konstantin Khlopenkov
- Andy Heidinger
- GCOS MeteoSwiss
- Swiss National Science Foundation
- ESA backfilling initiative for AVHRR

Lake at Swiss National Park

Snow and Ice WS
3 – 6. Feb. 2014

University of Bern



Special Interest Group of Land Ice and Snow

European Association of Remote Sensing Laboratories

7th EARSeL workshop on Land Ice and Snow

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The workshop invites presentations on all fields of environmental research focussing on snow and ice as proxy for changing cryosphere, methods for retrieving cryospheric parameters from various types of remote sensing data, theoretical basis of inversion methods and their application, state-of-the-art retrieval algorithms, data assimilation of remote sensing data and in situ observations in process models, current and planned sensors for snow and ice, etc. The workshop also offers the possibility for sessions covering preparations and successful realization of field campaigns in mountainous and polar regions. The last day is dedicated for the ESA-Globsnow User Consultation Meeting. All participants are invited to attend the meeting.

The workshop will be composed of pre-defined thematic sessions and poster presentations. Contributions must comply with one of the workshop topics specified below. Please indicate under

- Glaciers and Ice Caps

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