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Adjacency effect considerations and simultaneous air/water constituent retrieval for Lake Constance

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Introduction

Recent work:

- Physically based algorithm for Daedalus (Heege & Fischer, 2004)
- Coupled atmosphere/water algorithm for MERIS (Miksa et al, 2006)
- Operational, physically based processor for MERIS (Odermatt et al, 2008)
- MERIS Lakes project validation April 2007 (Koponen et al, 2008)

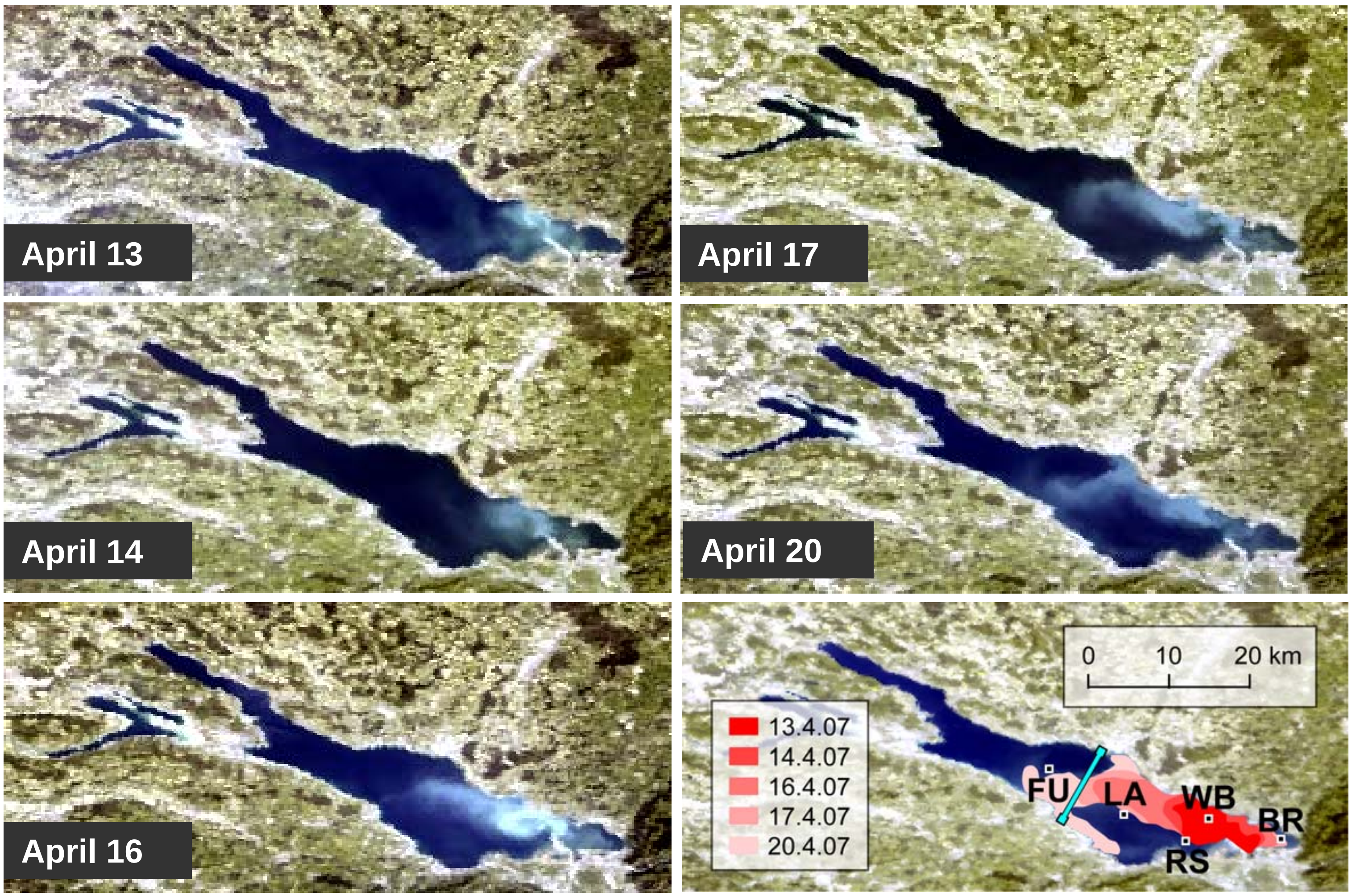
Challenges:

- Decoupling of AOT and water constituents
- Adjacency effects

Objective:

- Development of a flexible case II water constituent algorithm for use with several different sensors and case II water bodies

MERIS Lakes Validation FR Data April 2007



MERIS Lakes Validation Reference Data

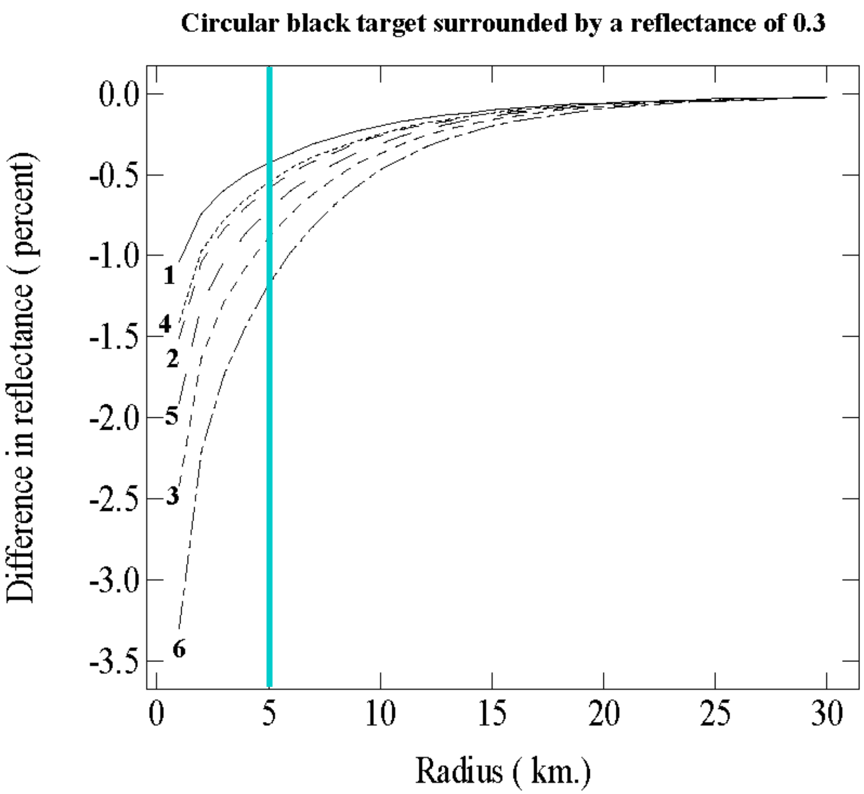
Subsurface irradiance reflectance data

- Acquired April 13 and 20
- 4 sites per day
- Measured with RAMSES by DLR

Water constituent reference samples

- Acquired April 13, 16 and 20
- Laboratory estimation of chl, tsm, y
- y estimates seem corrupt

Adjacency Effect Correction: ICOL (Santer & Schmechtig, 2000)



865 nm adjacency effect calculations for 3 visibilities (8-50 km) and 2 illumination zenit angles (30, 60°) over a round target of R=0 (Santer & Schmechtig, 2006). Lake Constance's main basin is about 30x10 km.

- Available as plug-in for BEAM 4.2
- Based on model calculations in 5s (Tanré et al, 1990)
- Calculates adjacency effect as a function of:

  - *atm. transmittance and albedo*
  - *illumination and viewing angles*
  - *ground reflectances*

  as output by the MERIS atm. correction over land (Santer, 2000)

Simultaneous Air/Water Constituent Retrieval

- Algorithm developed by Viacheslav Kiselev as part of EOMAP's MIP (Modular Inversion and Processing System)

- Based on 2 iterating minimization functions:

  1) τ : minimizing the difference of measured and modeled at-sensor radiance as a channel weighted sum

     with at-sensor radiance modeled for

  2) wc: minimizing the difference of atm. corrected and modeled irradiance reflectance as a channel weighted sum

- Optional regularization: Modifies the retrieved wc towards expected a priori concentrations in case of low variability.

Parameterization of Constituent Retrieval

- MIP-SIOP available from previous work (Odermatt et al, 2008)
- Yellow substance was regularized as 0.15 m^{-1} due to critical chl/y separation
- Aerosol modification n, similar to Angstrom exponent, for comparison of ICOL-corrected and uncorrected results of similar AOT (550 nm)
- C2R (Doerffer & Schiller, 2008) results are available from ESA Lakes
- Eutrophic lakes processor used due to more accurate y absorption
- 4 types of results:

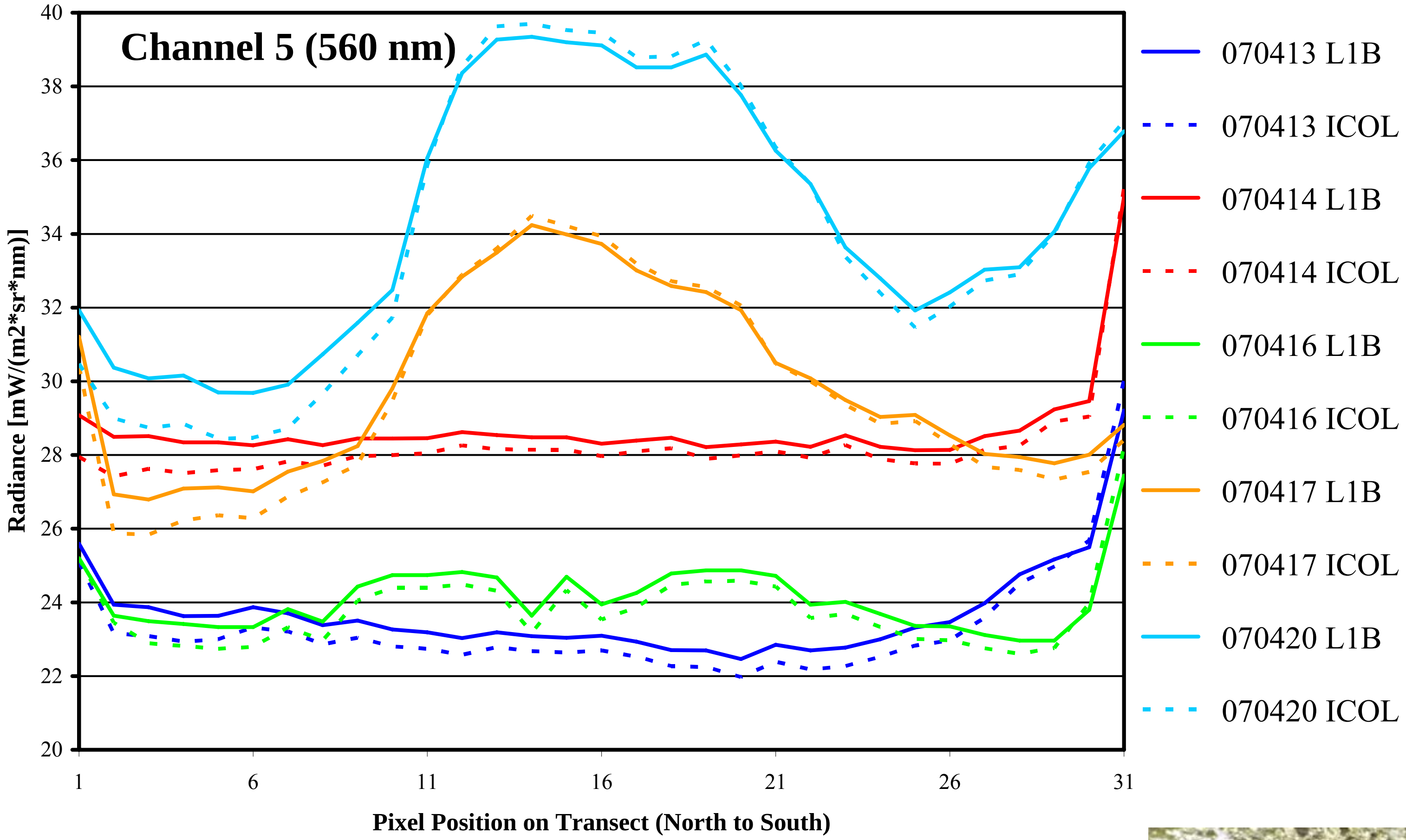
  L1B → eutrophic lakes

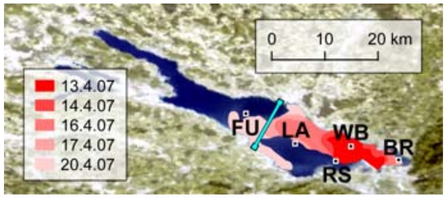
  L1B → MIP

  L1B → ICOL → MIP

  L1B → MIP(n)

ICOL-corrected Radiance Transects





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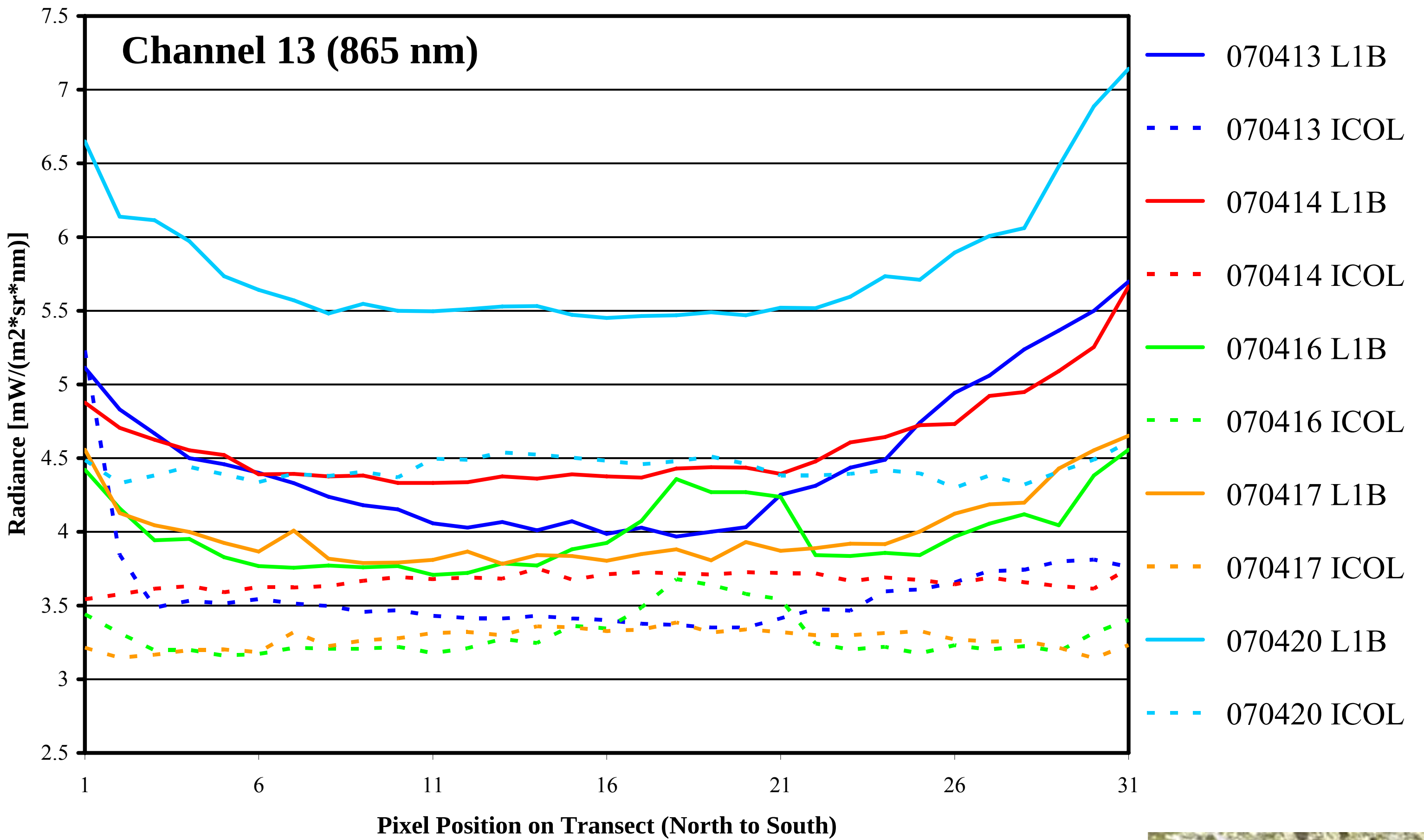
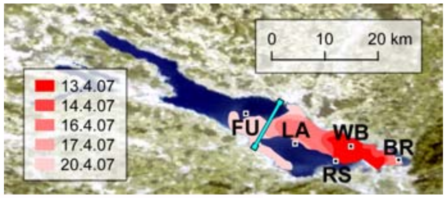
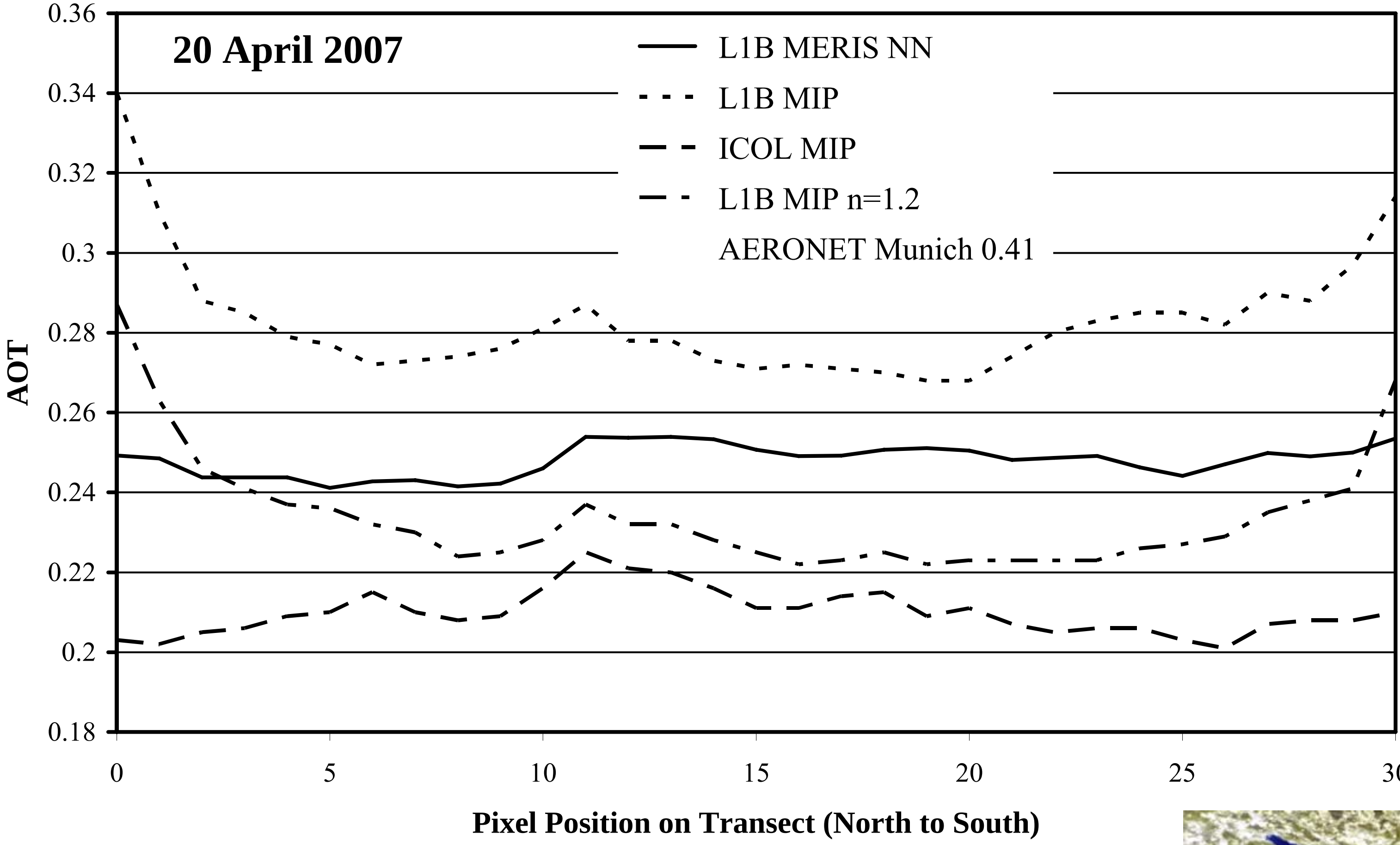
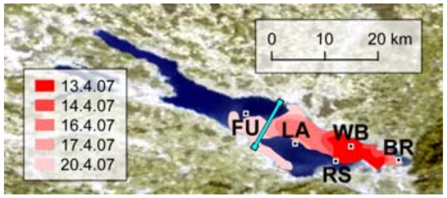
ICOL-corrected Radiance Transects





AOT Transects on 20 April 2007





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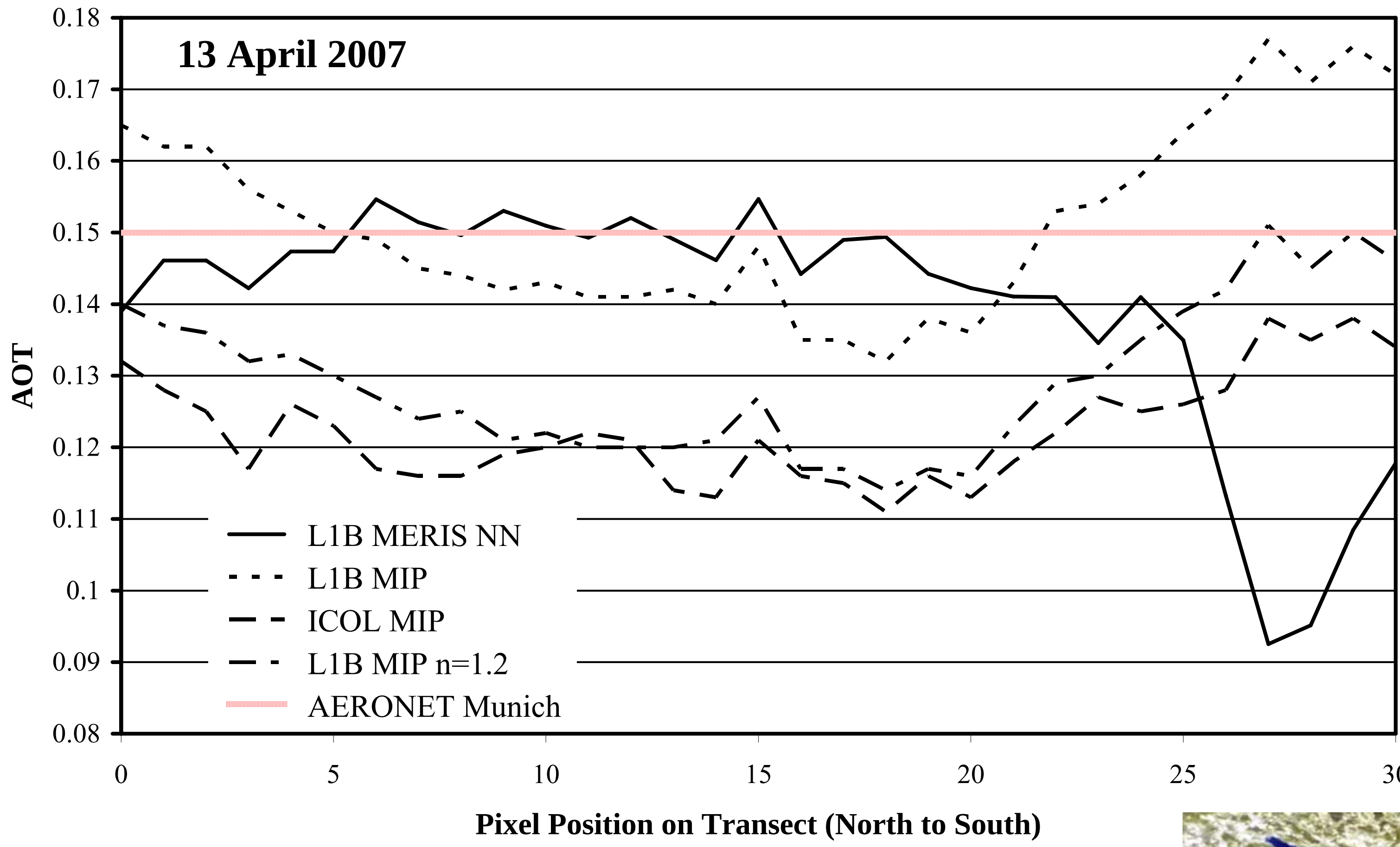
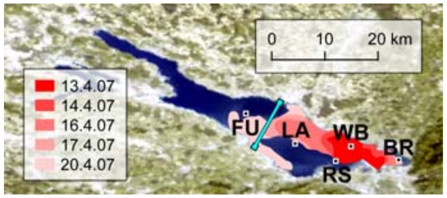
AOT Transects on 13 April 2007





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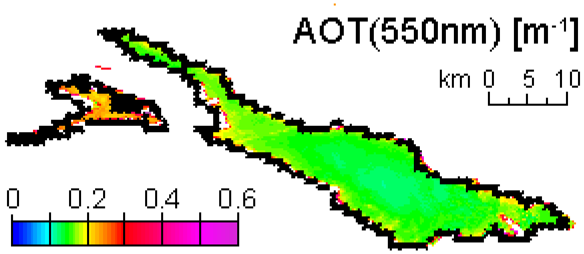
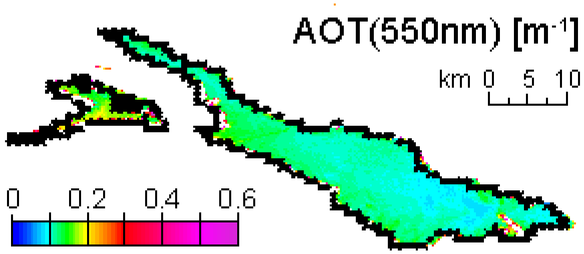
AOT Maps on 13 April 2007



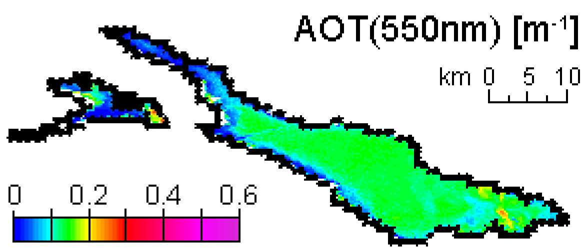
Uncorrected L1B MIP

- High AOT
- Increase towards shore



ICOL corrected MIP

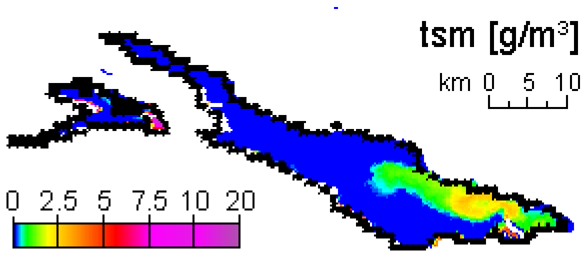
- Lowest AOT
- Spatially homogeneous



Uncorrected C2R

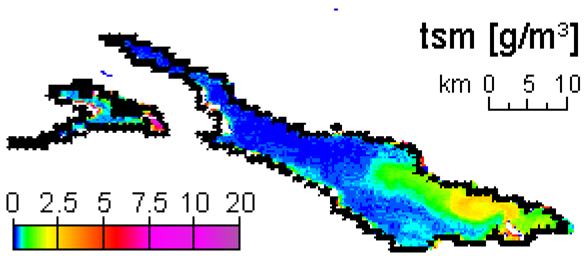
- Medium AOT
- Decrease towards shore

TSM Maps on 16 April 2007



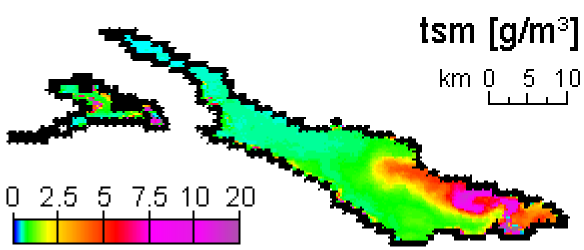
Uncorrected L1B MIP

- Concentrations generally underestimated
- 0 g/m^3 retrieved outside turbid area



ICOL corrected MIP

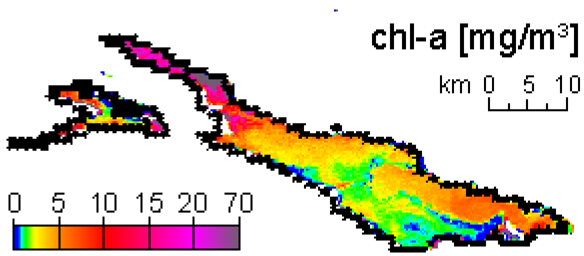
- Concentrations generally underestimated
- Improved representation of clear water



Uncorrected eutrophic lakes

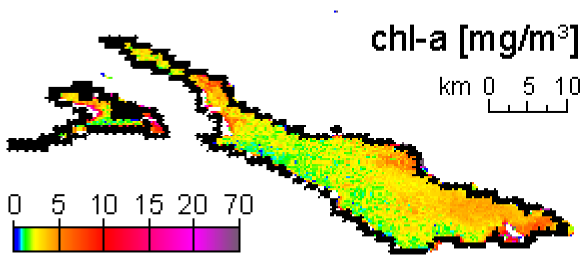
- Good estimate for clear water
- Strong overestimation in turbid water

CHL Maps on 16 April 2007



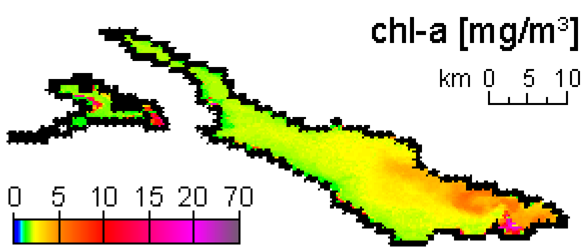
Uncorrected L1B MIP

- Pink indicates zero reflectances and adj. eff.
- Strong correlation with tsm patterns



ICOL corrected MIP

- Good concentration level
- Weak correlation with tsm



Uncorrected eutrophic lakes

- Good concentration level
- Weak correlation with tsm

Correlation Coefficients

	chl	tsm
MERIS C2R [11]	0.70	0.85
MERIS EUT	0.27	0.80
ICOL MIP	0.57	0.84
L1B MIP n=1.2	0.18	0.78
L1B MIP	0.32	0.78

Overall correlation of reference measurements in 4 sites on 13., 16. and 20. April 2007, and MERIS derived concentrations with 5 different processors.

Conclusions

- ICOL compensates littoral increase of NIR radiances and generally reduces radiance level by up to 30% (channel 13)
- Increase of MIP AOT towards shore is effectively accounted for by ICOL
- MIP atmospheric correction needs some improvement towards a physically sound representation of irradiance reflectance
- C2R is insensitive to littoral increase of NIR radiances, and was found more adequate without ICOL (Koponen et al, 2008)
- Eutrophic lakes algorithm calculates a_y more adequately, but C2R is better at chlorophyll.
- AERONET data of Lägern (80 km, 867 MASL) and Munich (175 km, 533 MASL) are inadequate for Lake Constance (495 MASL)

Thank you for your attention

Annex

Simultaneous Air/Water Constituent Retrieval 1

1) Minimizing the summed, channel weighted, squared differences of modelled and measured at-sensor radiance:

$$\min_{\tau} G(\tau) = \min_{\tau} \sum_{i=1}^{N_{ch}} w_i \left\{ L_s^{(0)} - L_s\left[\tau, \vec{c}(\tau)\right] \right\}^2$$

N_{ch}	number of channels
w_i	weighting factor for channel i
$L_s^{(0)}$	radiance measured at channel i
$L_s[\tau, c(\tau)]$	radiance modelled for channel i
τ	atmospheric optical width
$\vec{c}(\tau)$	vector of wc concentrations (chl, tsm, y) retrieved for τ

Simultaneous Air/Water Constituent Retrieval 2

2) Minimizing the summed, channel weighted differences of atmospherically corrected and modelled (Gordon Eq.) irradiance reflectances and a regularisation term:

$$\min_{\vec{c}} H\left(\vec{c},\tau\right) = \min_{\vec{c}} \sum_{i=1}^{N_{ch}} \tilde{w}_i \left\{\tilde{R}_i\left(L_s^{(0)},\tau\right) - R_i\left(\vec{c}\right)\right\}^2 + \sum_{j=1}^{3} \gamma_j \left(c_j - c_j^{(0)}\right)^2$$

N_{ch}	number of channels
w_i	weighting factor for channel i
$R_i(L_s^{(0)},\tau)$	irradiance reflectance atmospherically corrected with τ
$R_i(c)$	irradiance reflectance modelled with the wc concentrations c
τ	atmospheric optical width
$\vec{c}$	vector of wc concentrations (chl, tsm, y)
γ_i	regularisation factor for constituent j
c_j	concentration c of water constituent j
$c_j^{(0)}$	typical water constituent concentration for use with regularisation

Equations

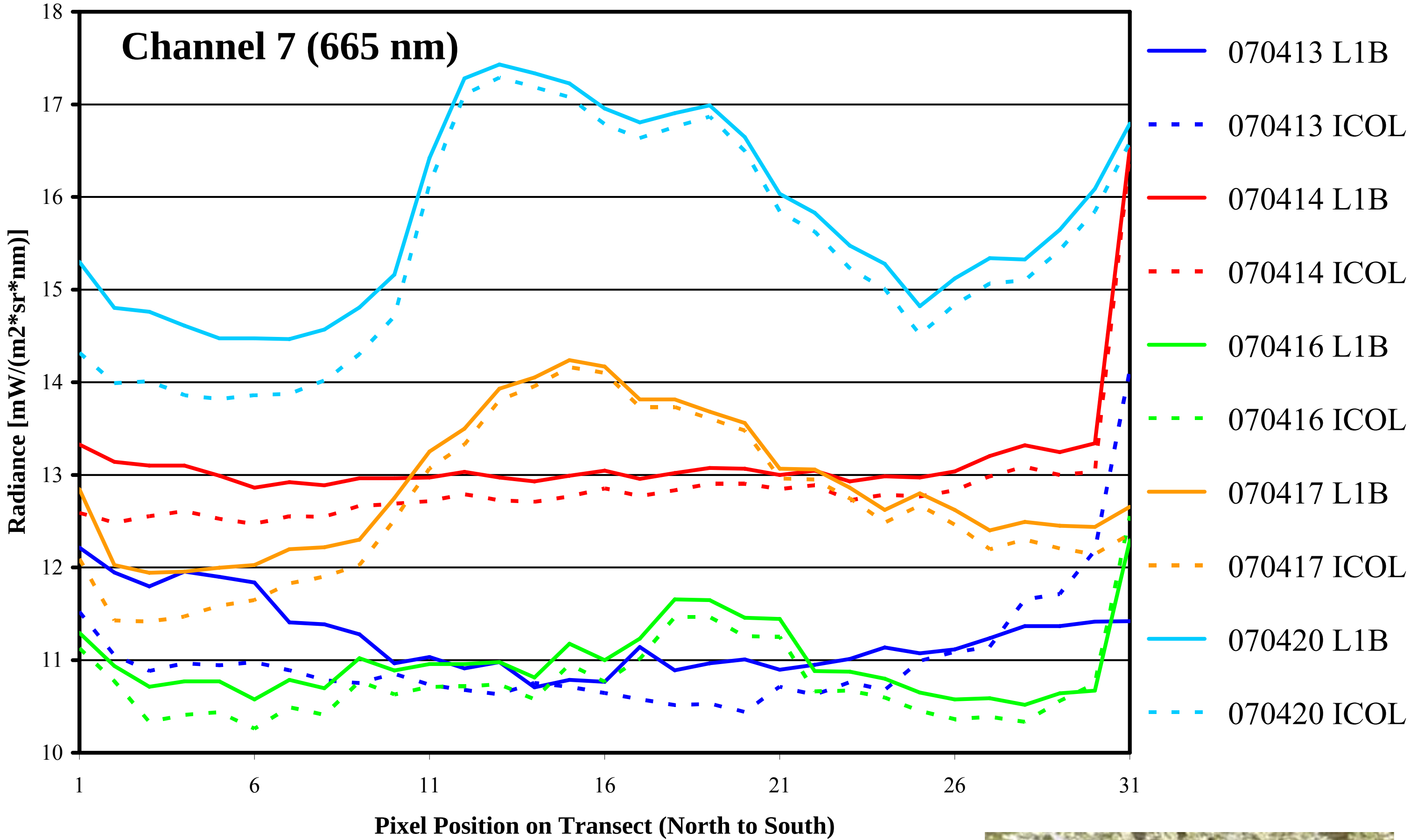
$$\Delta\rho^* = \frac{T(\theta_s)t_d(\theta_v)}{1-\rangle\rho\langle s}\left(\rangle\rho\langle - \rho_G\right)$$

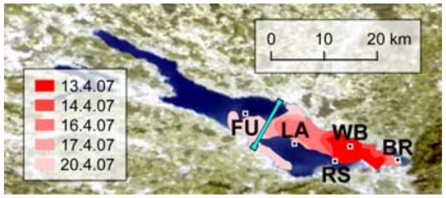
Adjacency Effect Correction: ICOL
(Santer & Schmechtig, 2000)

$$\tau^* = \tau\left(\frac{\lambda_i}{550}\right)^n$$

Aerosol spectral
dependence modification

Results: Radiance





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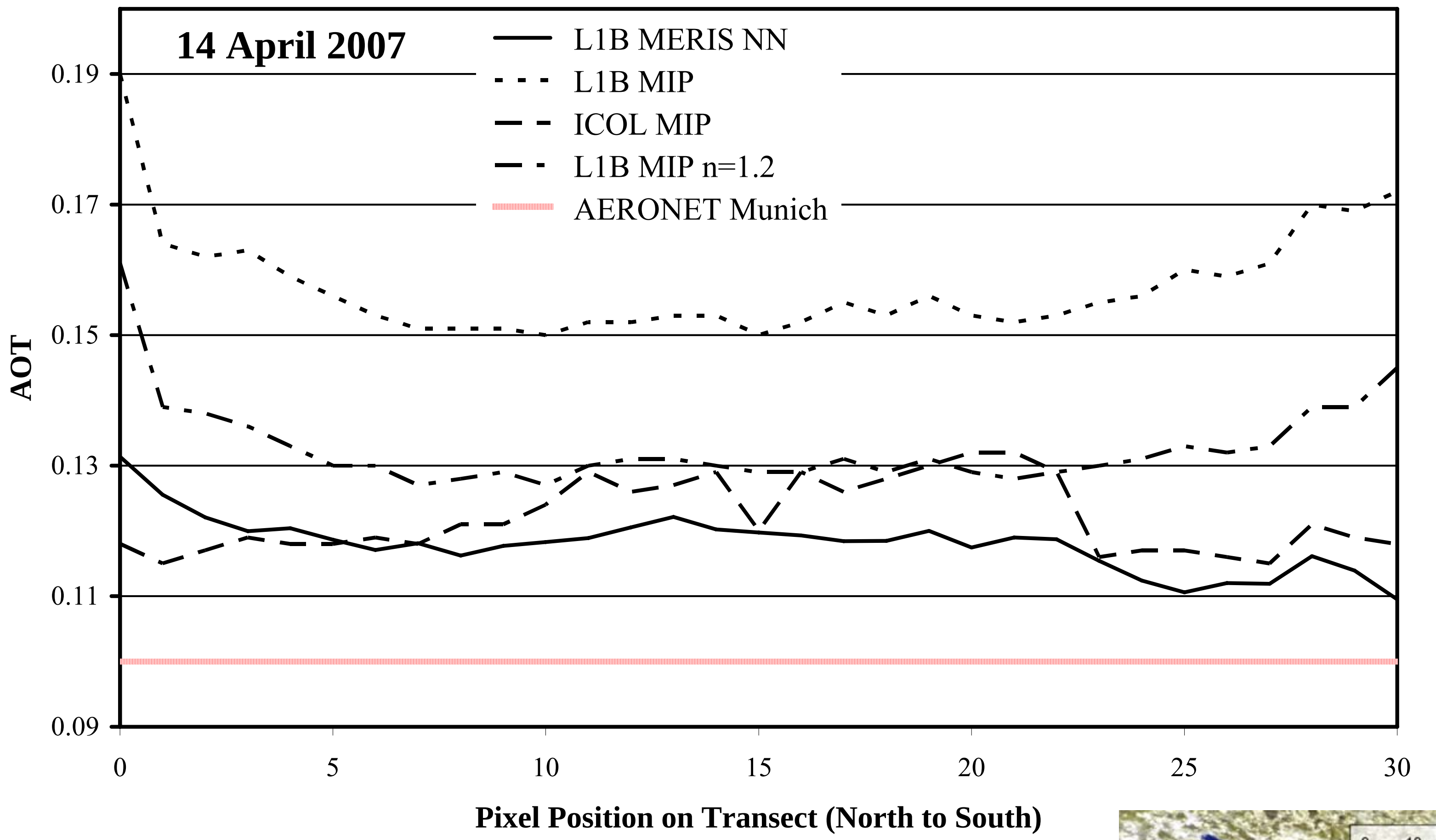
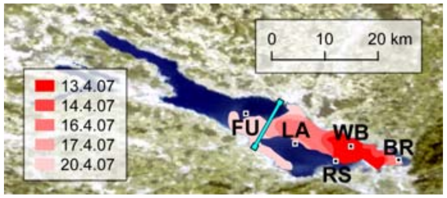
Results: AOT

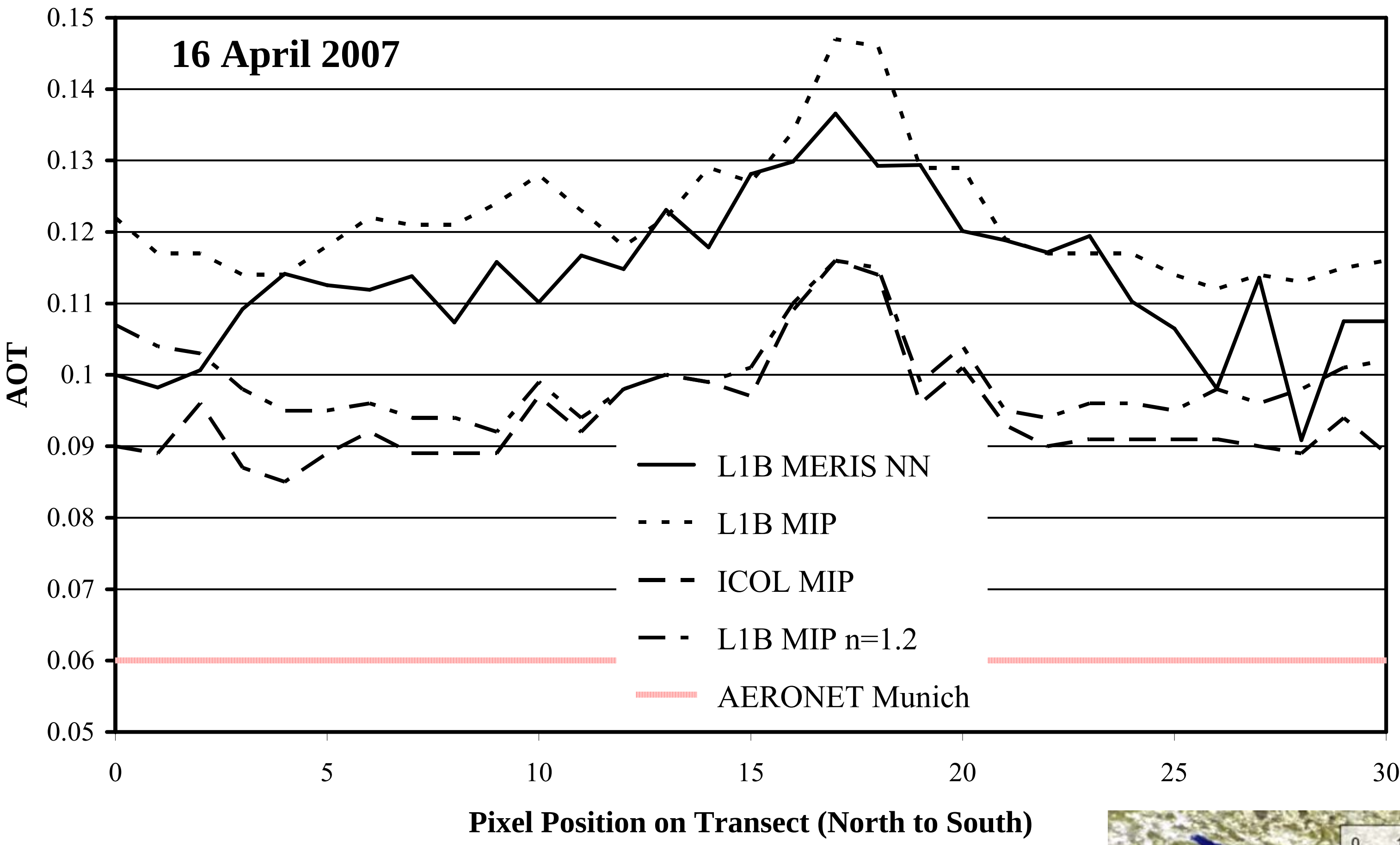


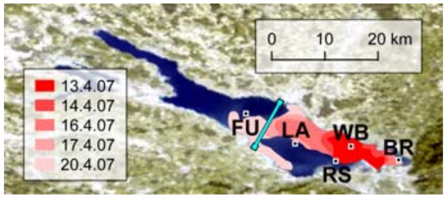
14 April 2007
L1B MERIS NN
L1B MIP
ICOL MIP
L1B MIP n=1.2
AERONET Munich
AOT
0.19
0.17
0.15
0.13
0.11
0.09
0
5
10
15
20
25
30
Pixel Position on Transect (North to South)



0 10 20 km
13.4.07
14.4.07
16.4.07
17.4.07
20.4.07
FU
LA
WB
BR
RS

Results: AOT





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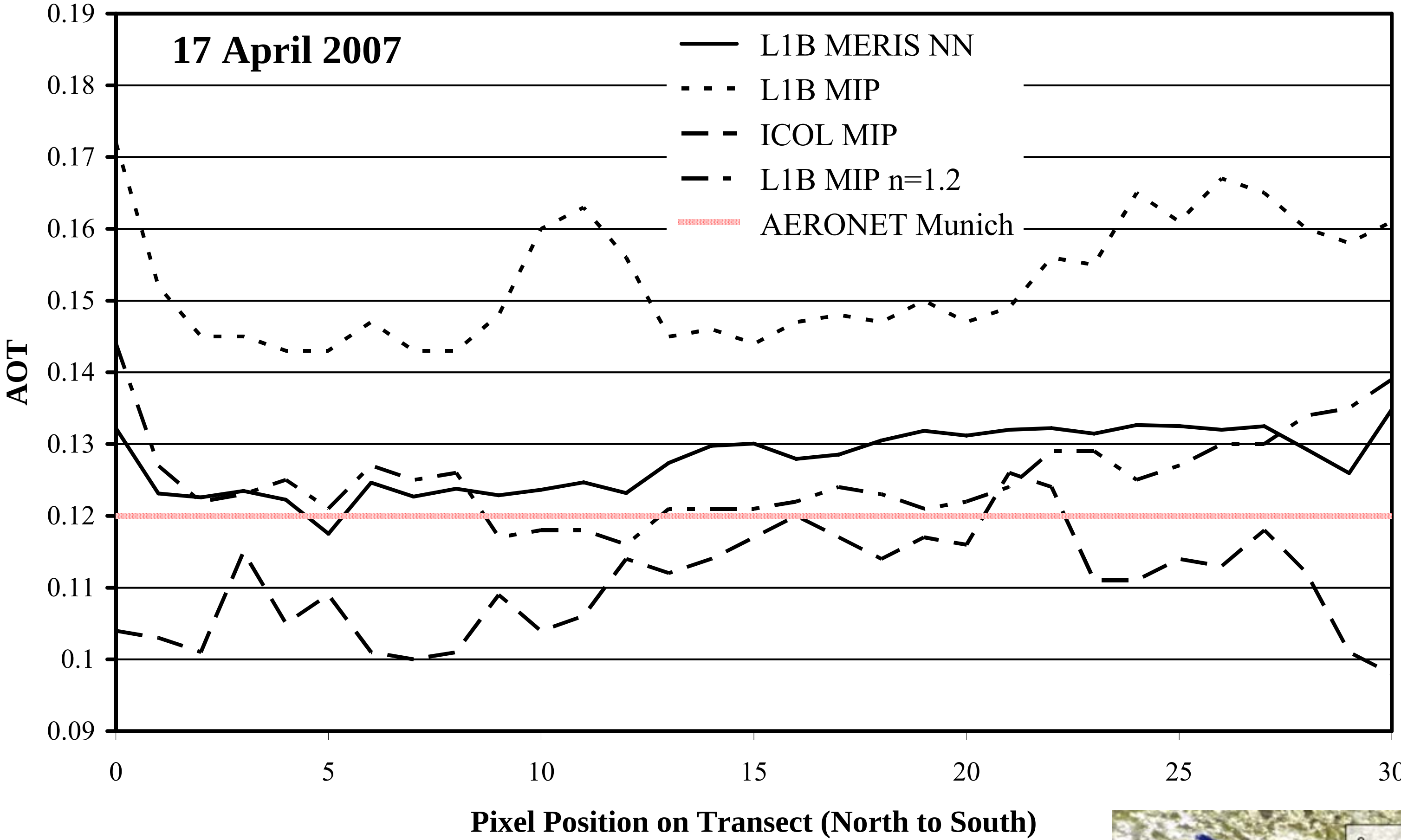
Results: AOT



17 April 2007
L1B MERIS NN
L1B MIP
ICOL MIP
L1B MIP n=1.2
AERONET Munich
AOT
0.19
0.18
0.17
0.16
0.15
0.14
0.13
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0.11
0.1
0.09
0
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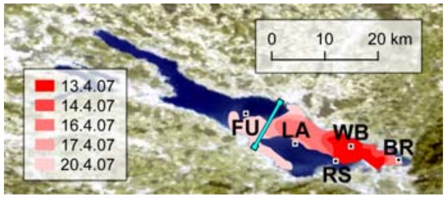

0 10 20 km
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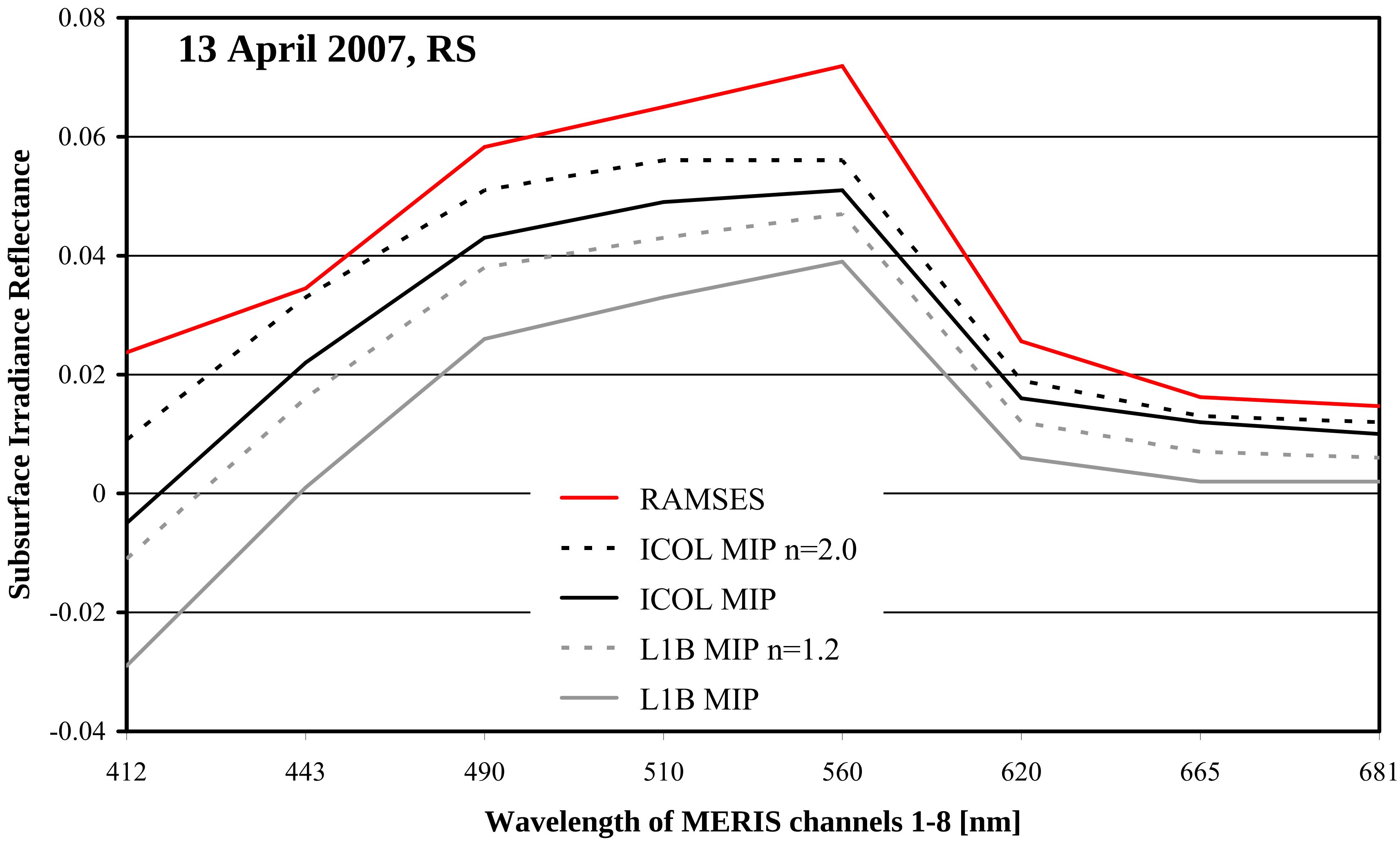
MIP Problems with Reflectance Level



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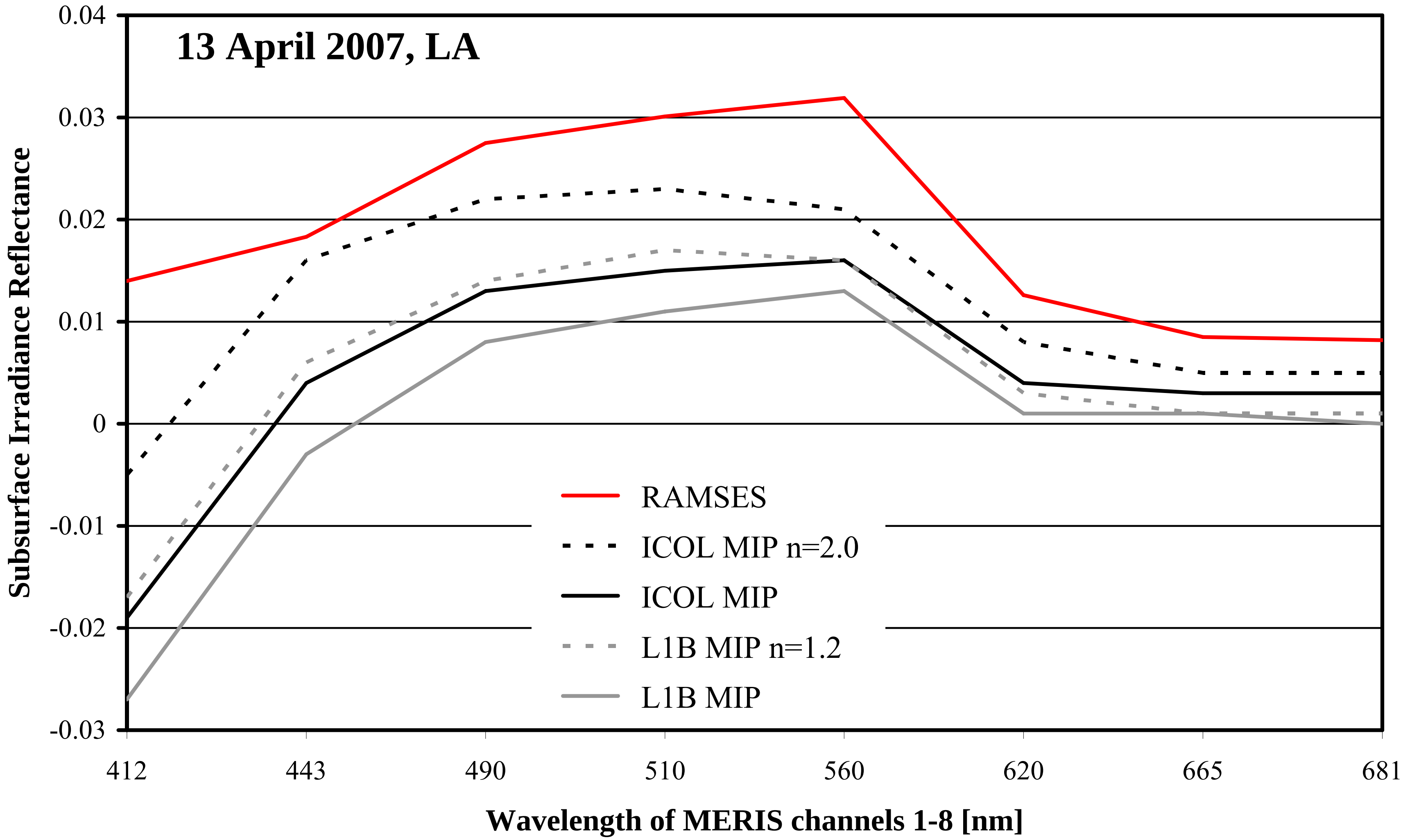
MIP Problems with Reflectance Level



MIP Problems with Reflectance Level