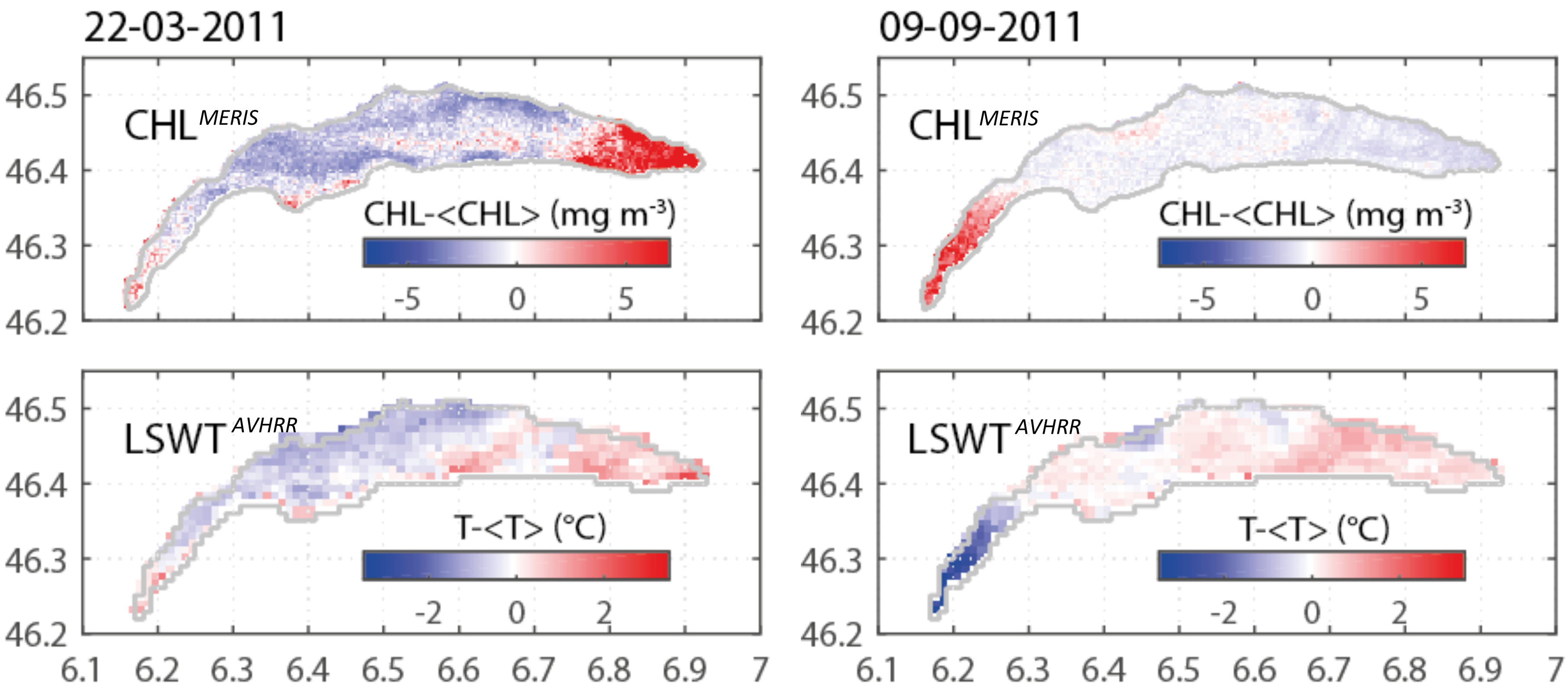
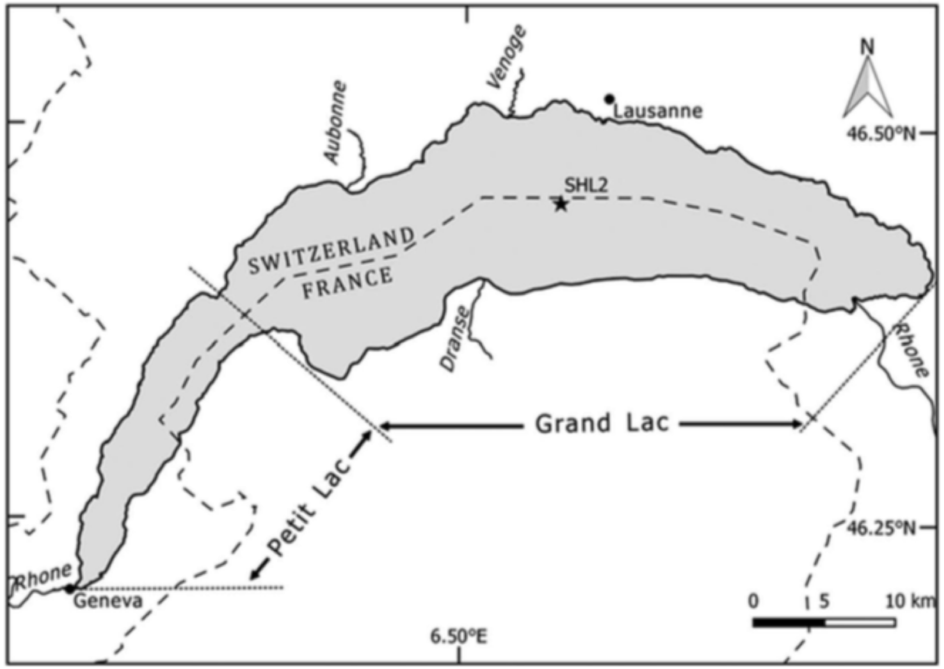
The Relevance of Thermal Forcing for Optical Remote Sensing of Stratified Lakes

Daniel Odermatt, Vincent Nouchi, Damien Bouffard

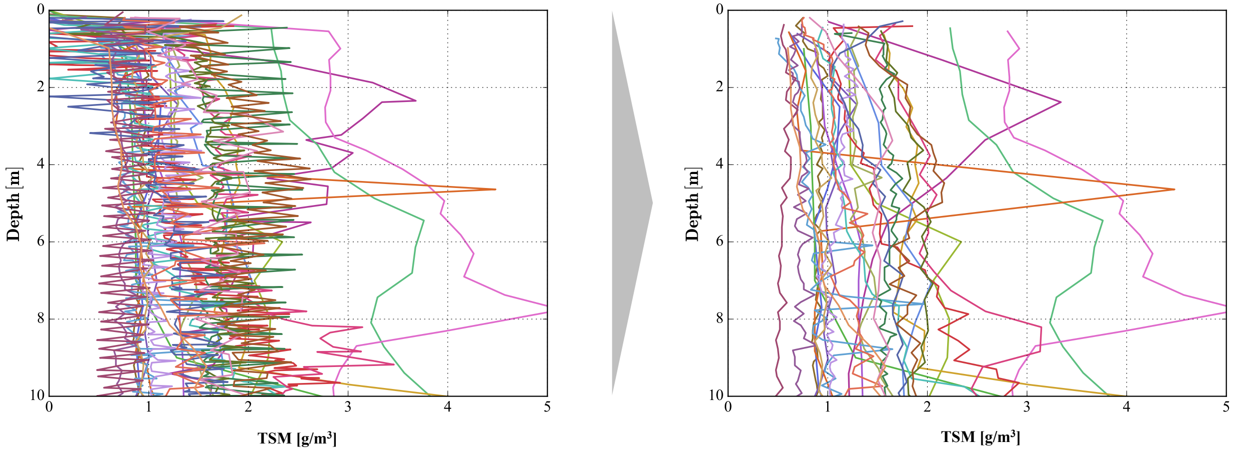


Bouffard, D., Kiefer, I., Wüest, A., Wunderle, S., and Odermatt, D. (2018). Are surface temperature and chlorophyll in a large deep lake related? An analysis based on satellite observations in synergy with hydrodynamic modelling and in-situ data. Remote Sens. Environ. 209, 510–523.

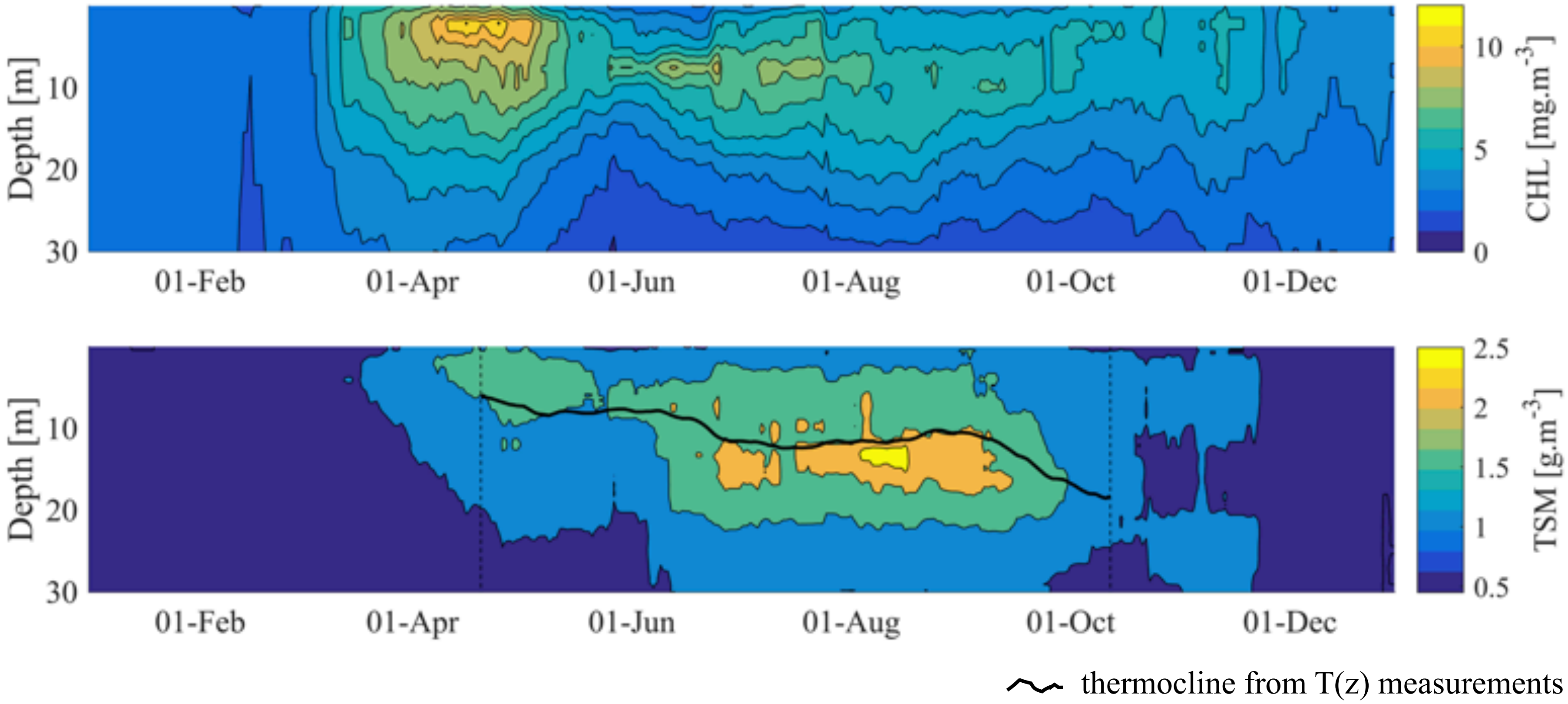
SHL2 Monitoring Data



- 2002-2015 verified data provided by INRA-Thonon
- Bi-weekly temperature, CHL and turbidity profiles
- TSM approximated using turbidity
- Quality control and filtering



Mean Thermocline Depth and Stratification



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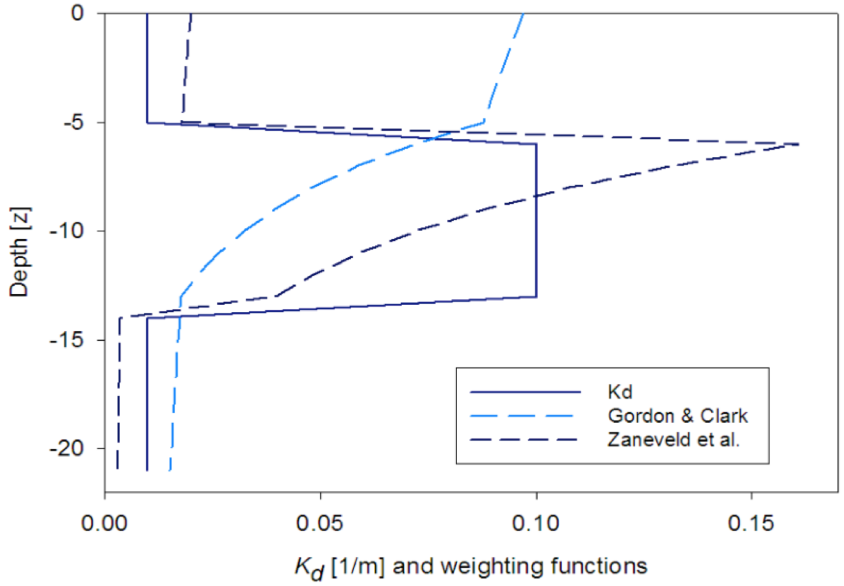
Nouchi, V., Odermatt, D., Wüest, A., and Bouffard, D. (2018). Effects of non-uniform vertical constituent profiles on remote sensing reflectance of oligo- to mesotrophic lakes. European Journal of Remote Sensing 51, 808–821.

Weighting Non-uniform Constituent Profiles

- *Journal rejection comment (2017)*: "It's well known that surface reflectance is a weighted mean of the entire water column with the weight decreasing exponentially with depth (Gordon et al., 1988)"
- But Zaneveld et al. (2005) recommends the derivative of the round-trip attenuation:



$$f(z) = \exp\left[-\int_0^z 2K(z')dz'\right]$$

The closer to surface, the stronger the weighting

$$f(z) = \frac{d}{dz}\exp\left[-\int_0^z 2K(z')dz'\right]$$

Maximum weighting at submerged layer surface

Piskozub, J., Neumann, T., and Wozniak, L. (2008). Ocean color remote sensing: Choosing the correct depth weighting function. Optics Express 16, 14683–14688.
Zaneveld, J.R.V., Barnard, A.H., and Boss, E. (2005). Theoretical derivation of the depth average of remotely sensed optical parameters. Optics Express 13, 9052–9061.

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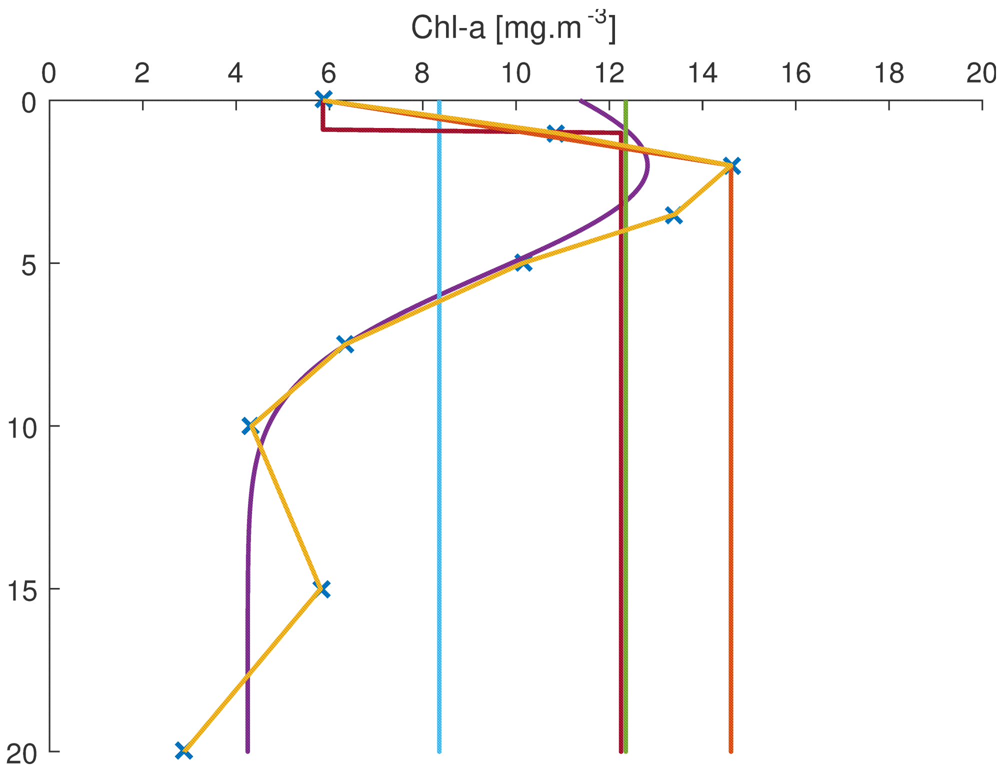
Hydrolight Reflectance Simulations

- Comparison for actual and approximated profiles at reflectance level
- For invariant SIOPs and CDOM(z)



INT are original profiles interpolated to 10 cm

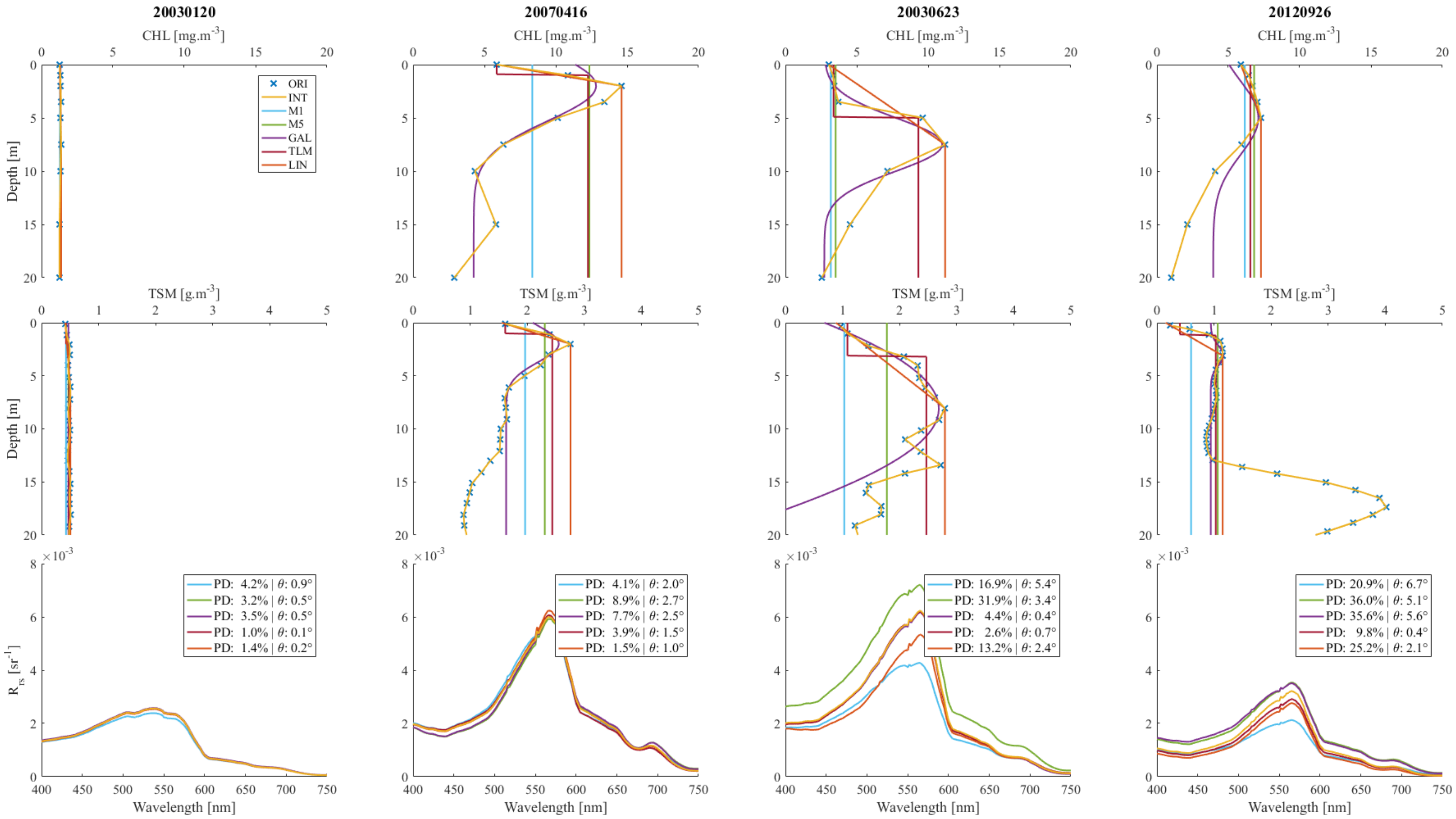
GAL: Gaussian Approximation according to Lewis et al. (1983)

TLM: Two-Layer Model using a binary k-means classification to obtain z_{l2}, and mean layer concentrations

LIN: Linear gradient between maximum concentration and concentration at $z=0$

'M1' and 'M5' are uniform averages of the top 1 and 5 m layer

Hydrolight Forward Simulations



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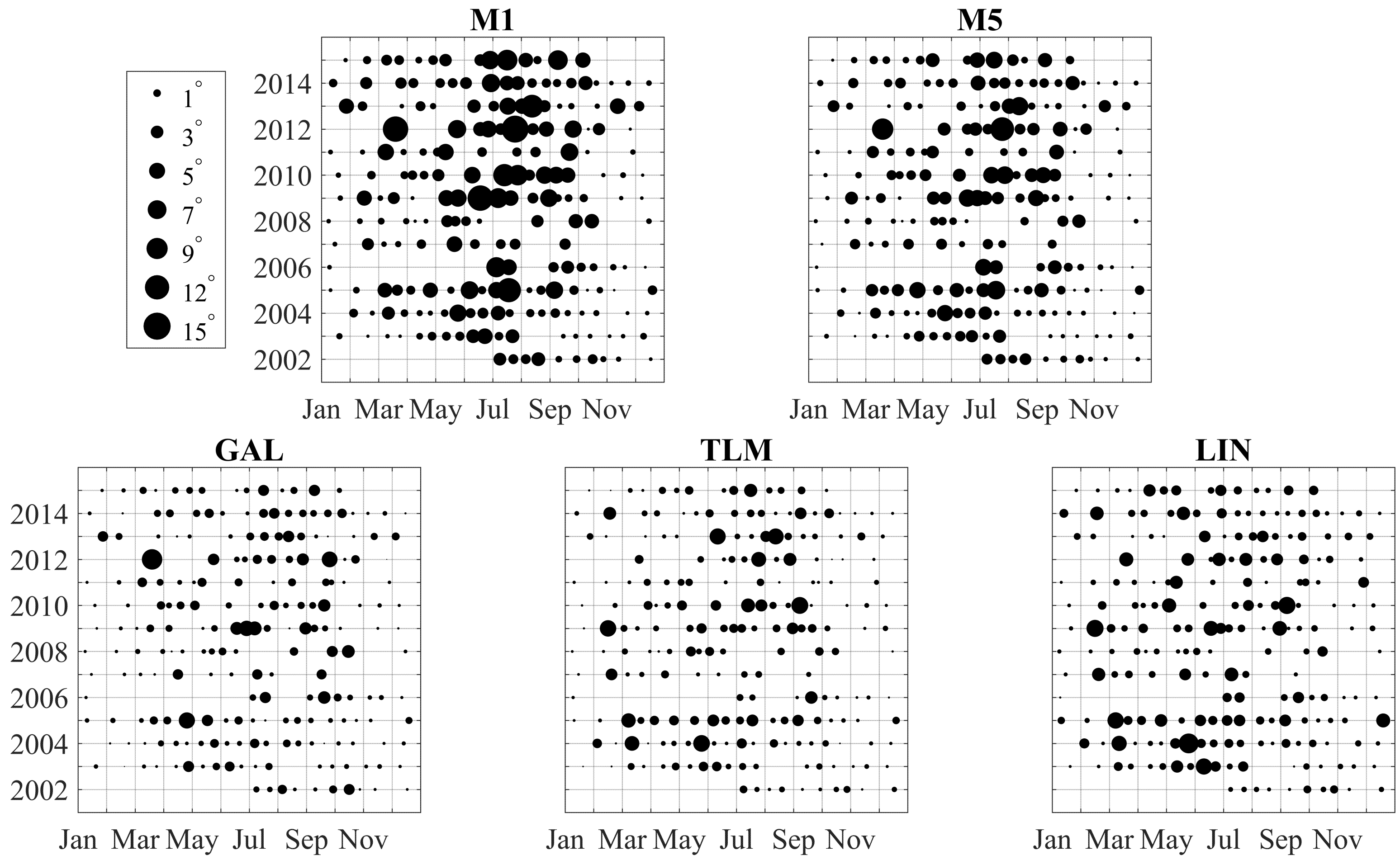
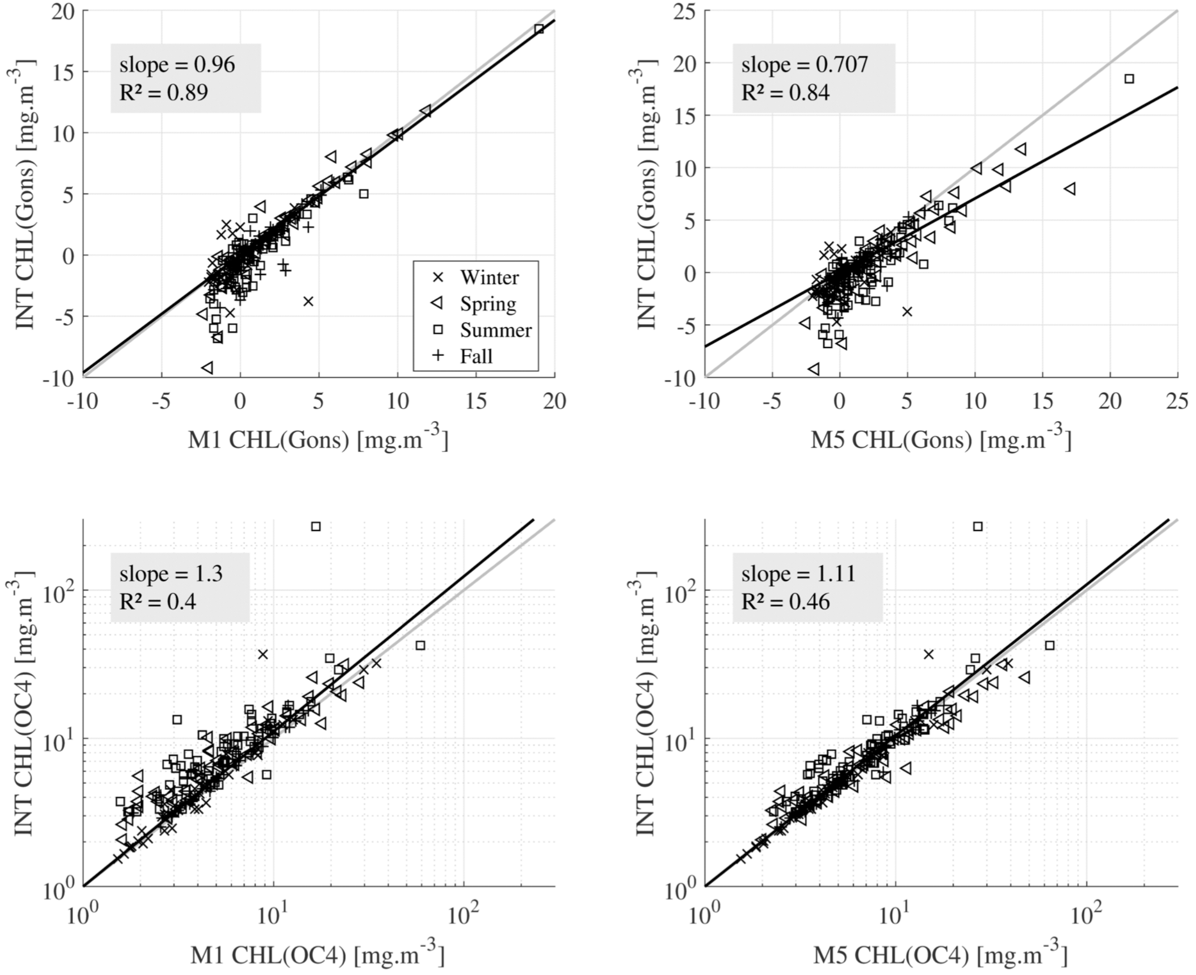
Reflectance of Measured vs. Approximated Profiles

- Spectral Angle (t):

$$\theta = \cos^{-1}\left(\frac{\sum_{\lambda=400}^{710} R_1(\lambda)R_2(\lambda)}{\sqrt{\sum_{\lambda=400}^{710} {R_1}^2(\lambda)}\sqrt{\sum_{\lambda=400}^{710} {R_2}^2(\lambda)}}\right)$$



Retrieval from Reflectances of Measured vs. Approximated Profiles



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Conclusions

- Vertical uniformity assumption impairs constituent retrieval especially in June to August
- TLM (3 shape parameters) and GAL (4) are the best non-uniformity approximations
- In order to invert with 7 instead of 3 unknown variables:
  - check how certain variables can be predicted e.g. based on modelled (1D/3D) thermocline depth
  - identify dependencies within target variables