近海海洋环境科学国家重点实验室（厦门大学）
State Key Laboratory of Marine Environmental Science (Xiamen University)

Scaling Analysis of the Algal Blooms

Yongxiang Huang[1,2,3], Yang Gao[1,2], Qianguo Xing[4], Francois G Schmitt[2], Jianyu Hu[1,3]

yongxianghuang@xmu.edu.cn
qgxing@yic.ac.cn

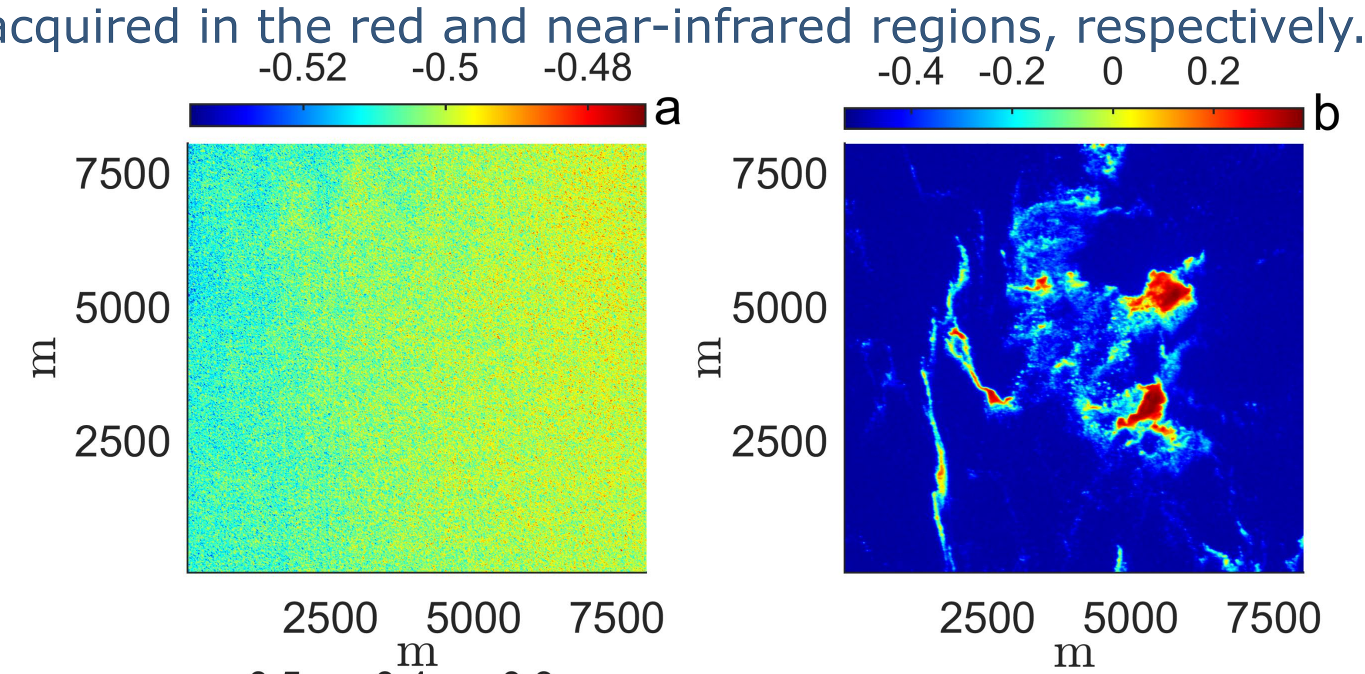
[1]State Key Laboratory of Marine Environmental Science & College of Ocean and Earth Sciences, Xiamen University, Xiamen 361102, China
[3]South Marine Science and Engineering Guangdong Laboratory (Zhuhai), Zhuhai 519000, China
[2]CNRS, Univ. Lille, Univ. Littoral Cote d'Opale, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, F 62930 Wimereux, France
[4]Yantai Institute of Coastal Zone Research Chinese Academy of Sciences, Yantai, Shandong 264003, China

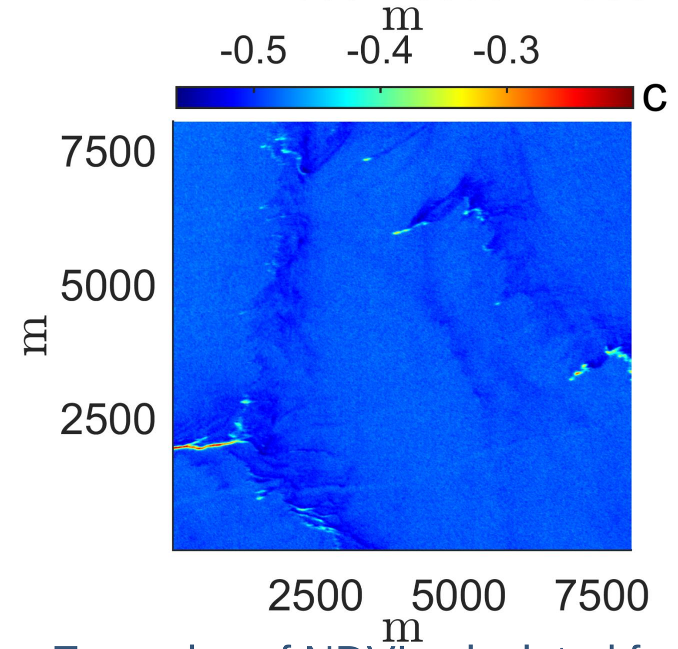
Abstract

Algal blooms are extremely harmful to the marine ecosystem. Satellite remote sensing is the most effective approach for monitoring these large scale algal blooms. Here we first derived a normalized difference vegetation index from the data provided by the Chinese satellite Gaofen 1 with spatial resolution 16m, and performed the classical structure-function analysis to study the structures of algal bloom at different scales. Our preliminary results confirm the existence of the power-law behavior on the spatial scale range from 100 to 400 m for the case of macro algae bloom (MAB). The corresponding scaling exponents are close to the ones of the classical passive scalar in three-dimension hydrodynamic turbulence. It suggests that the MAB could be treated as a passive scalar, which leads to not only a better understanding of the dynamics of algal bloom, but also a challenge of the modelling.

Data

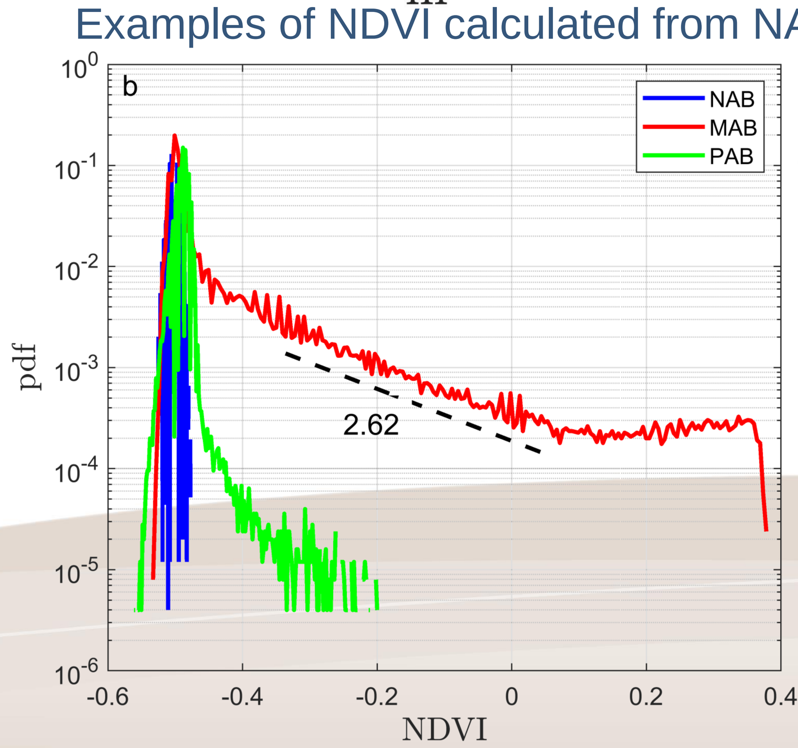
Normalized Difference Vegetation Index: $NDVI = \frac{NIR-RED}{NIR+RED}$,
RED and NIR stand for the spectral reflectance measurements acquired in the red and near-infrared regions, respectively.





- (a) NAB: No Algae Bloom
- (b) MAB: Macro Algae Bloom
- (c) PAB: Phytoplankton Algae Bloom
- The data are provided by Gaofen 1 satellite.

Examples of NDVI calculated from NAB (a), MAB (b), and PAB (c) images.



The probability density functions of NDVI derived from NAB, MAB and PAB. For MAB case, a power-law behavior of the distribution of NDVI can be observed, and the scaling exponent equals to 2.62.

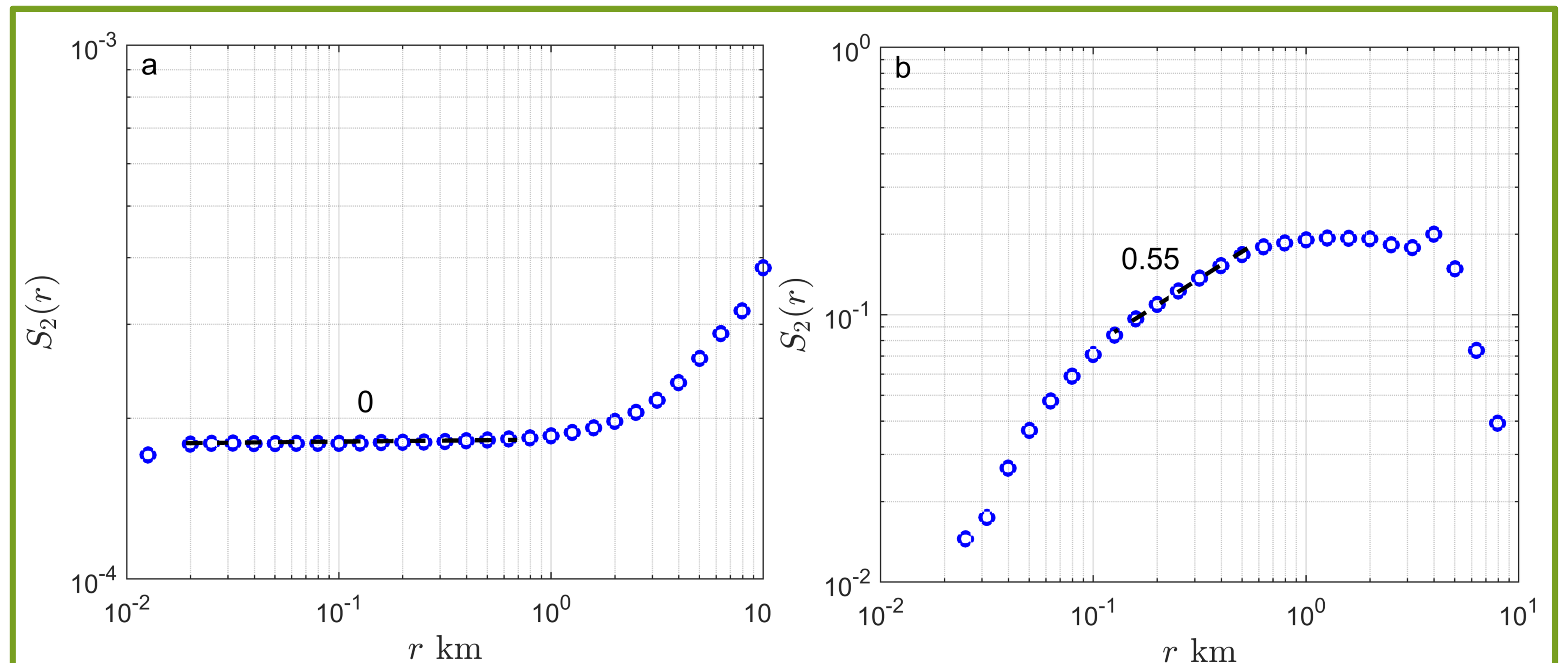
Method

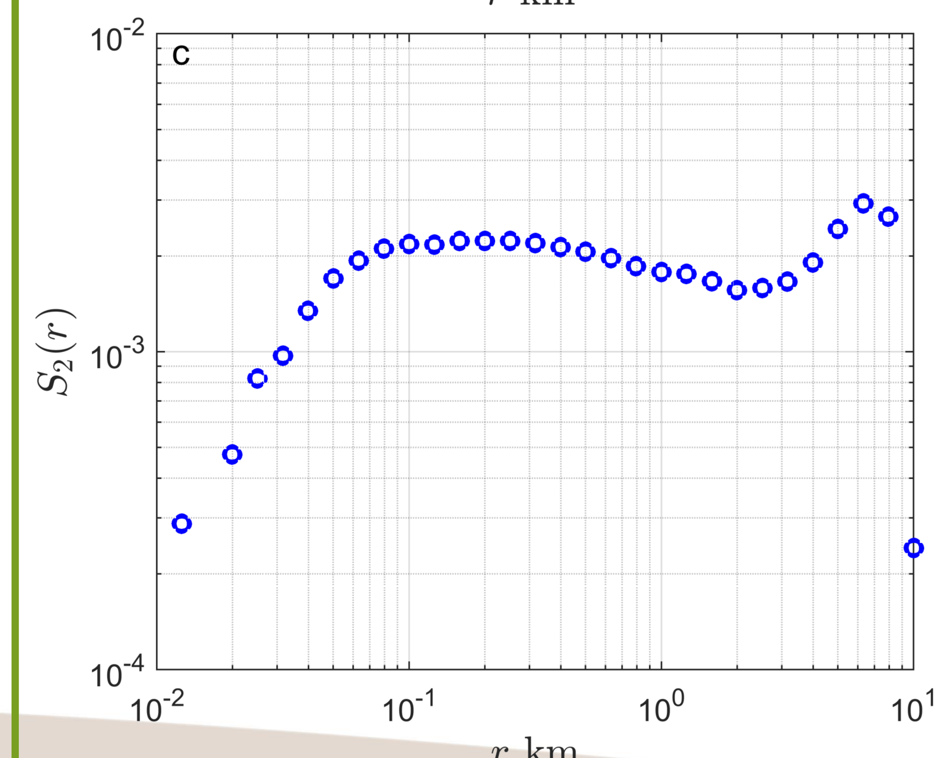
Structure function analysis

$S_q(r) = \langle |\Delta\theta_r|^q \rangle$ $\qquad S_q(r) \propto r^{\zeta(q)}$

$\Delta\theta_r = \{\theta_i - \theta_j\}|_{r_{ij}=r}$

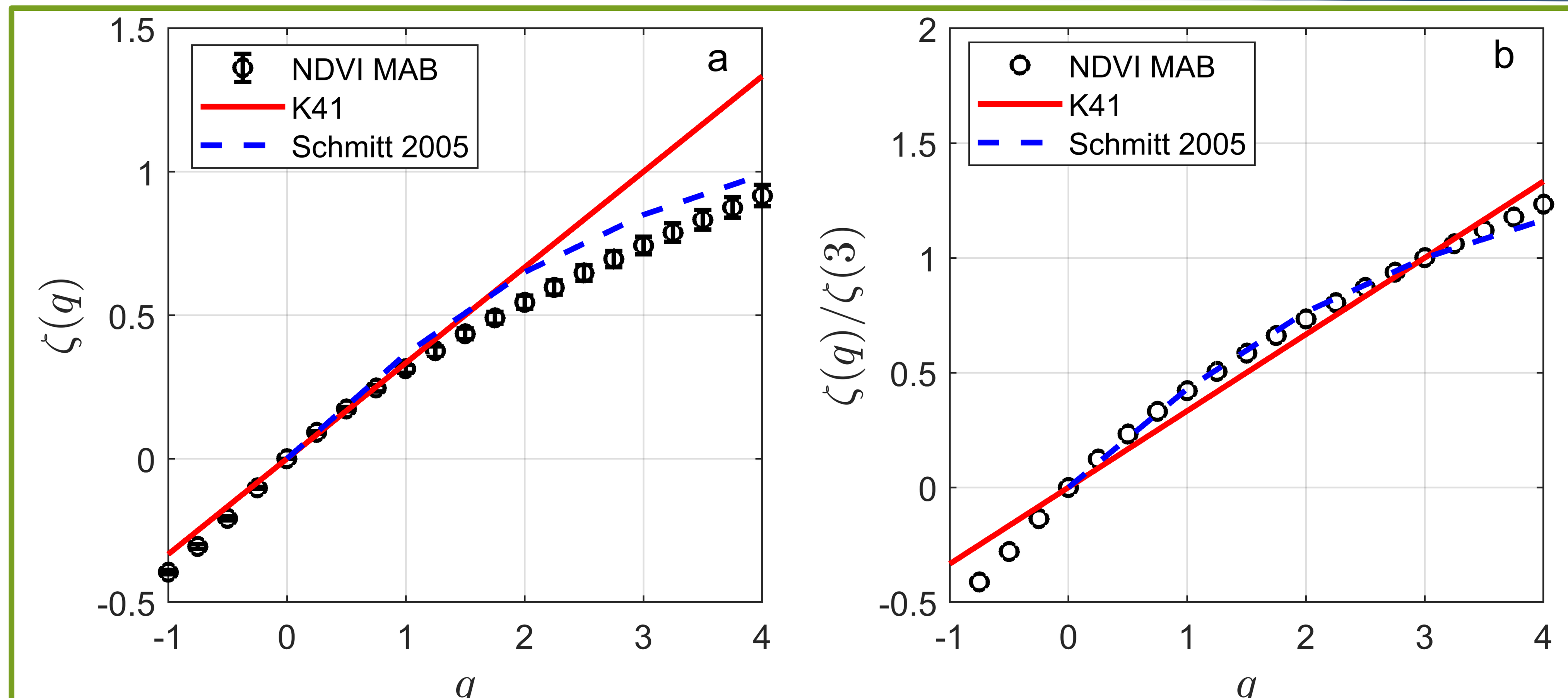
Results





The second-order structure functions measured from different categories of algae blooms show different forms, only the one corresponding to MAB illustrates a meaningful power-law feature in the spatial range of 100 to 400 m, and the scaling exponent $\zeta(2)$ equals to 0.55. $\zeta(2)$ measured from the NAB situation equals to 0, indicates the NAB can be treated as white noise.

Measured second-order structure function of NDVI derived from NAB (a), MAB (b), and PAB (c) images.



(a) The moment scaling functions of the NDVI derived from MAB image; (b) The corresponding extended self-similar (ESS). For comparison, the Kolmogorov value q/3 (red line) and the complied scaling exponents for the passive scalar (dashed line) are also shown.

The upward convex features of the moment scaling function and ESS indicate the intermittent characteristic of MAB. Furthermore, the measured ESS of NDVI and the passive scalar case are well overlapped.

Summary

(a) The probability density function of the NDVI data derived from MAB shows power-law features.

(b) Power-law features of the NDVI data derived from MAB image are observed by the structure function analysis.

(c) The scaling exponents calculated from the MAB case are close to the ones of the passive scalar in three-dimension hydrodynamic turbulence.

(d) $\zeta(2)$ measured from the NAB image equals to 0, indicates the NAB can be treated as white noise.

Fundings

CNRS-NSFC project 2019-2021 Nos. 41911530237 & 41676171 entitled TURBLOOMS (turbulence and marine algal blooms: use of satellite remote detection).

Reference

Kolmogorov, A. N., Dokl. Akad. Nauk, 30, 301 (1941).
Lovejoy, S., et al. Vadose Zone J, 7, 533-546 (2008).
Schmitt, F. G., EPJ B 48, 129-137 (2005).
Xing, Q. G., et al. IEEE Geosci. Remote. Sens. Lett, 14, 1815-1819 (2017).