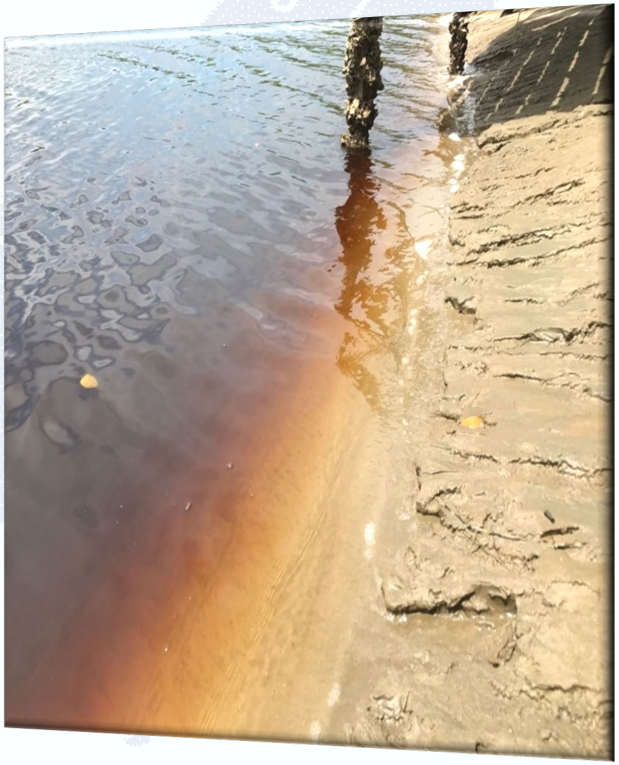
EGU General Assembly 2020

NANYANG TECHNOLOGICAL UNIVERSITY

Climatology and trends of Dissolved Organic Carbon in coastal waters off Sarawak, Borneo



Nivedita Sanwlani, Patrick Martin, Nagur Cherukuru, Moritz Müller, Chris Evans

NANYANG TECHNOLOGICAL UNIVERSITY
Asian School of the Environment

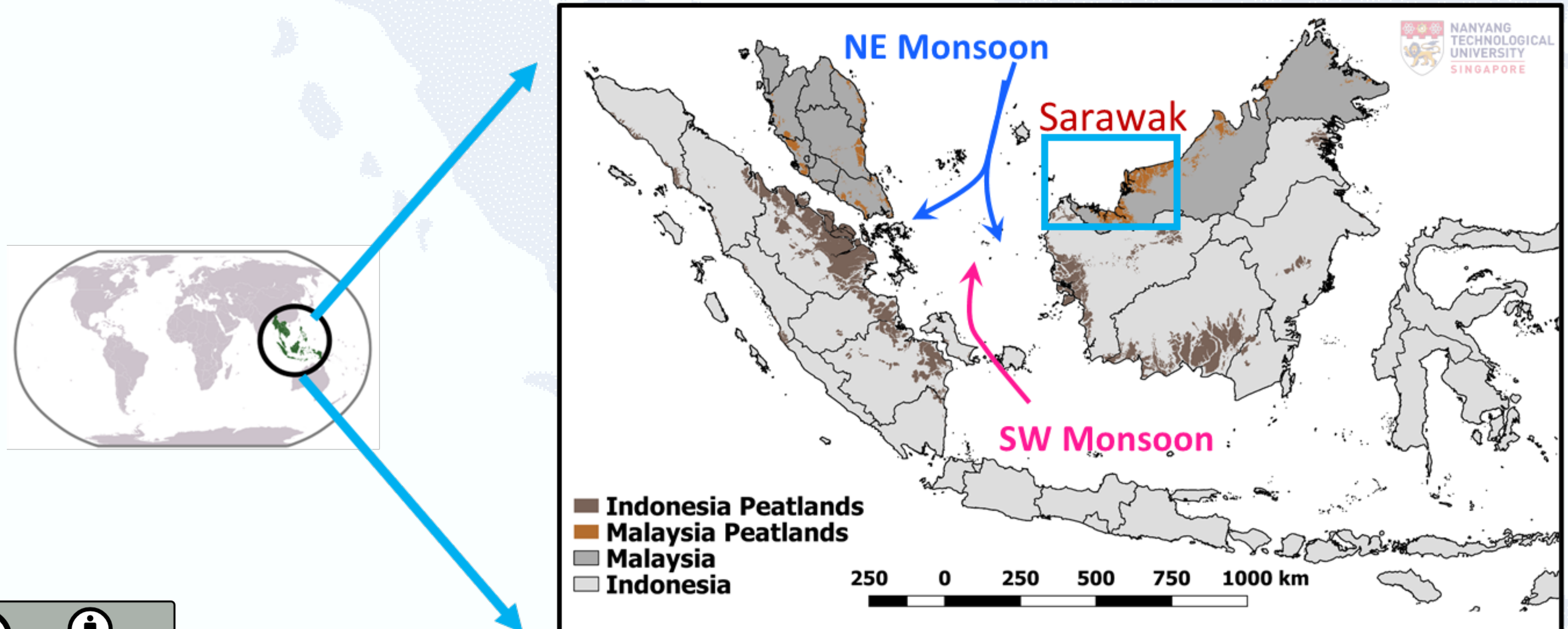
CSIRO

SWINBURNE UNIVERSITY OF TECHNOLOGY SARAWAK CAMPUS

UK Centre for Ecology & Hydrology

Sources of DOC in SE Asia

- Large land–sea fluxes: inorganic sediments (from mineral soils), and organic CDOM + DOC (from peatlands)
- Most peat-swamp forests in SE Asia have been deforested/drained & converted for industrial cultivations (Wetlands International, 2016)
- Small-scale field studies suggest that disturbed peatlands lose more DOC (Cook et al. 2018; Moore et al 2013)
- **No time-series or large-scale studies available to confirm that human disturbance has increased DOC fluxes**

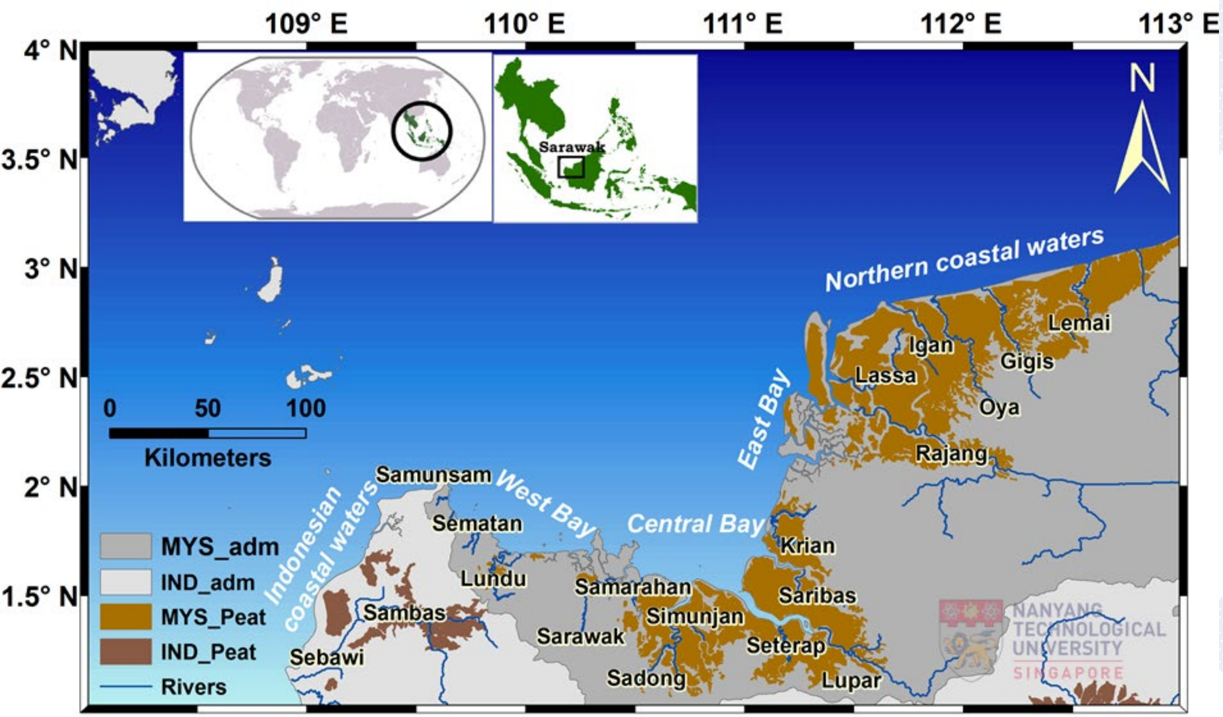


Sarawak - Region of Interest

- Bio-optical measurements were used to develop regionally-tailored MODIS remote sensing model to estimate CDOM and DOC from ocean colour

Objectives:

- Determine spatial and temporal distribution of CDOM and DOC
- Evaluate whether peatland disturbance since 2002 has caused long-term increases in CDOM and DOC in downstream coastal waters



Find out more: Results from several field programmes in the area are published as a special issue:

Biogeosciences

An interactive open-access journal of the European Geosciences Union

| EGU.eu | EGU Publications | EGU Highlight Articles | Contact | Imprint | Data protect

Special issue | Biogeochemical processes in highly dynamic peat-draining rivers and estuaries in Borneo

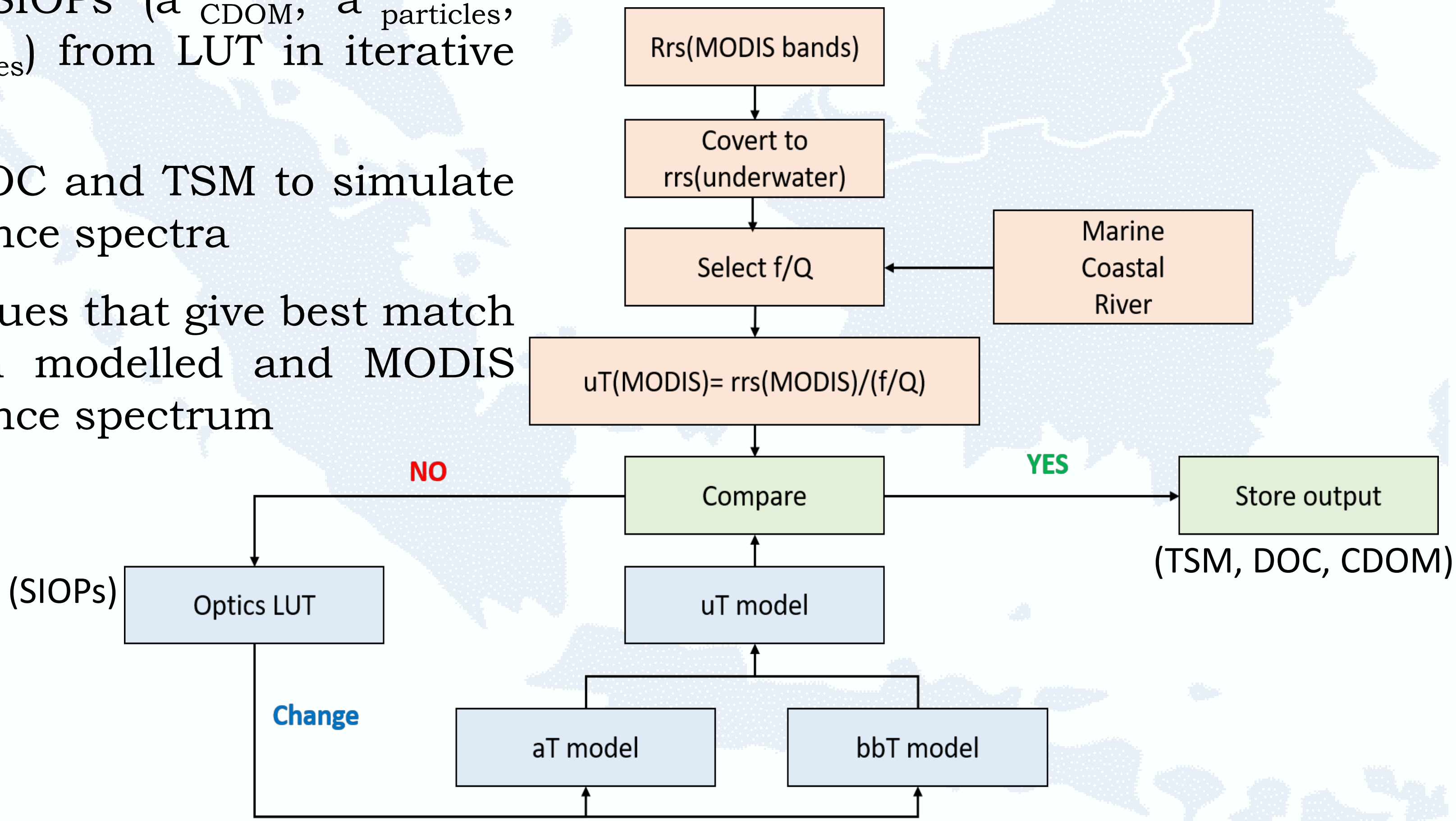
Editor(s): T. Jennerjahn, P. Shanmugam, P. Ford, and S. Bouillon

Methods – Remote Sensing Model

EGU General Assembly 2020

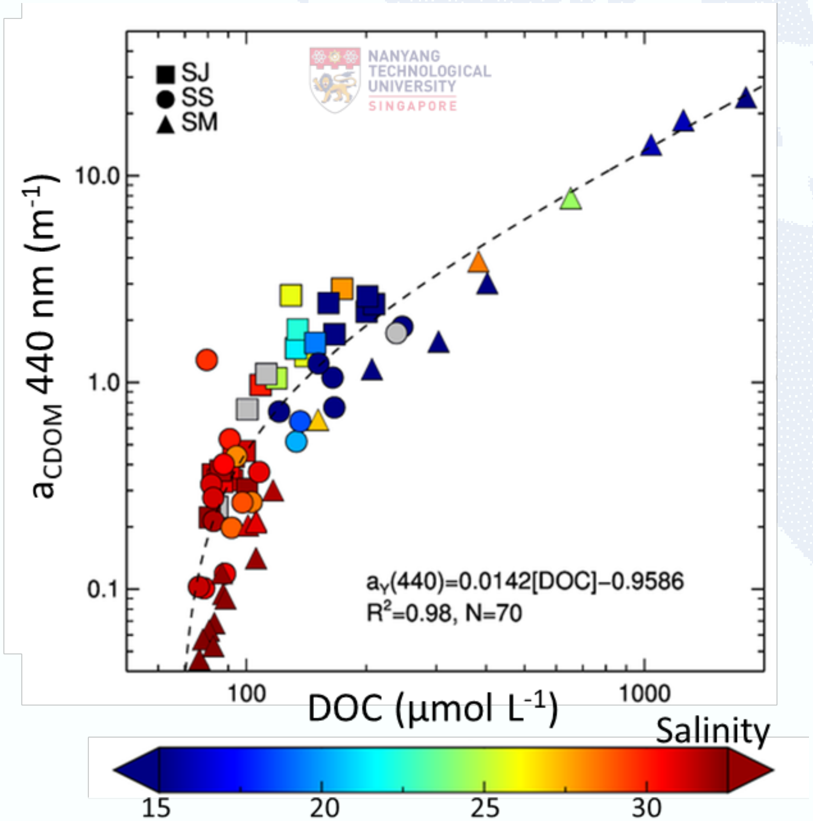
- Based on spectral matching of MODIS reflectance and reflectance modelled from specific inherent optical properties (SIOPs) in look-up table (from *in-situ* measurements)

1. Select SIOPs (a^*_{CDOM}, $a^*_{particles}$, $bb^*_{particles}$) from LUT in iterative fashion
2. Vary DOC and TSM to simulate reflectance spectra
3. Pick values that give best match between modelled and MODIS reflectance spectrum



CDOM as Proxy for DOC

- CDOM is the optically active component of the dissolved organic matter, absorbs strongly in UV and blue
- Terrestrially derived DOC is very rich in CDOM. Our *in-situ* data show a strong relationship between CDOM and DOC in Sarawak
- CDOM spectral characteristics reflect DOM origin, molecular weight, photo-oxidation



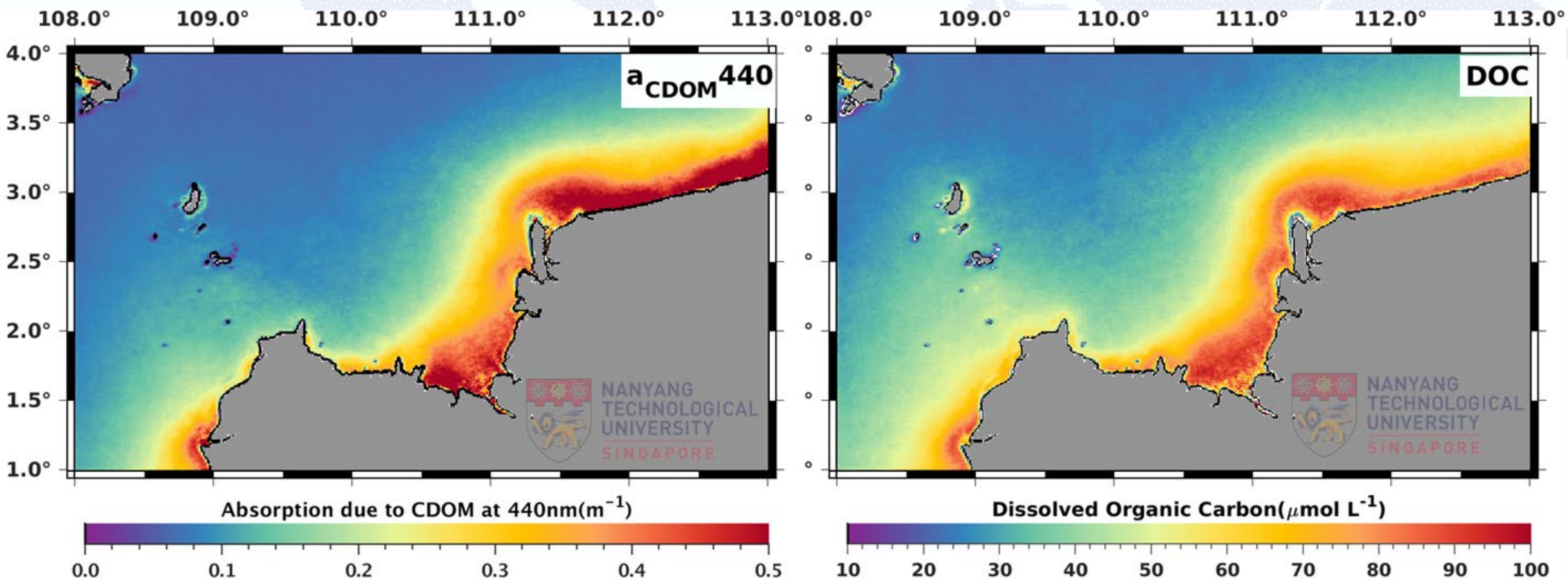
- A CDOM source index, γ_0, based on a_{cdom}(350nm) and hyperbolic slope (γ) distinguishes marine from terrestrial DOC (Shanmugam et al 2011)

$$a_{cdom}(\lambda) = a_{cdom}(350nm)\left(\frac{\lambda}{350}\right)^{\gamma}$$

$$\gamma_0 = \frac{a_{cdom}(350nm) - \left(\frac{1}{\gamma}\right)}{a_{cdom}(350nm) + \left(\frac{1}{\gamma}\right)}$$

Climatology (2002-2018)

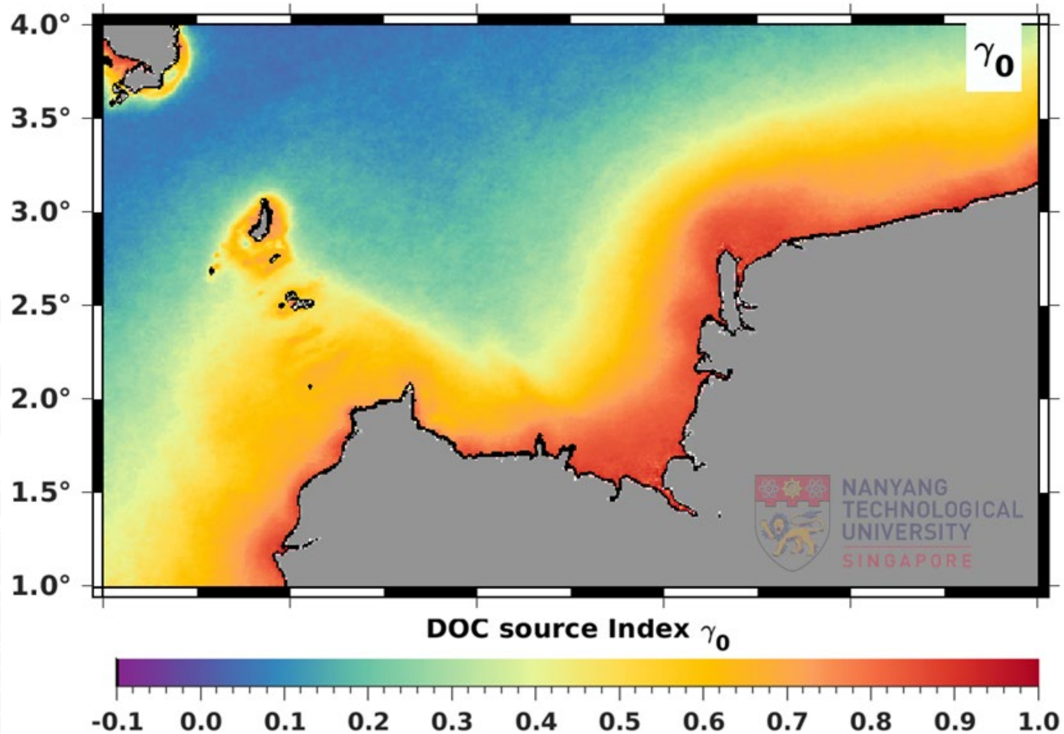
- High CDOM and DOC close to coast, esp. off-shore of peatlands (Northern coastal waters, Central Bay, part of Indonesian waters).
- Indicates that peatlands are the main source of CDOM and DOC
- Note: optical model is based on SIOPs from waters close to coast, so DOC will be underestimated in low-CDOM waters very far from shore



MODIS-Aqua- derived climatological (2002-2018) distribution of absorption coefficient of CDOM at 440nm (a_{CDOM}) and dissolved organic carbon (DOC)

Source Index of CDOM

- γ_0 > 0.7 close to coast indicates a terrigenous source of CDOM rather than merely freshwater planktons and macrophytes
- Progressively lower values of γ_0 further from shore reflect mixing between terrestrial CDOM with marine waters (with typical γ_0 of 0.2 to 0.7
- mixing between terrestrial CDOM and CDOM from aquatic primary production with typical γ_0 of -0.2 to 0.2

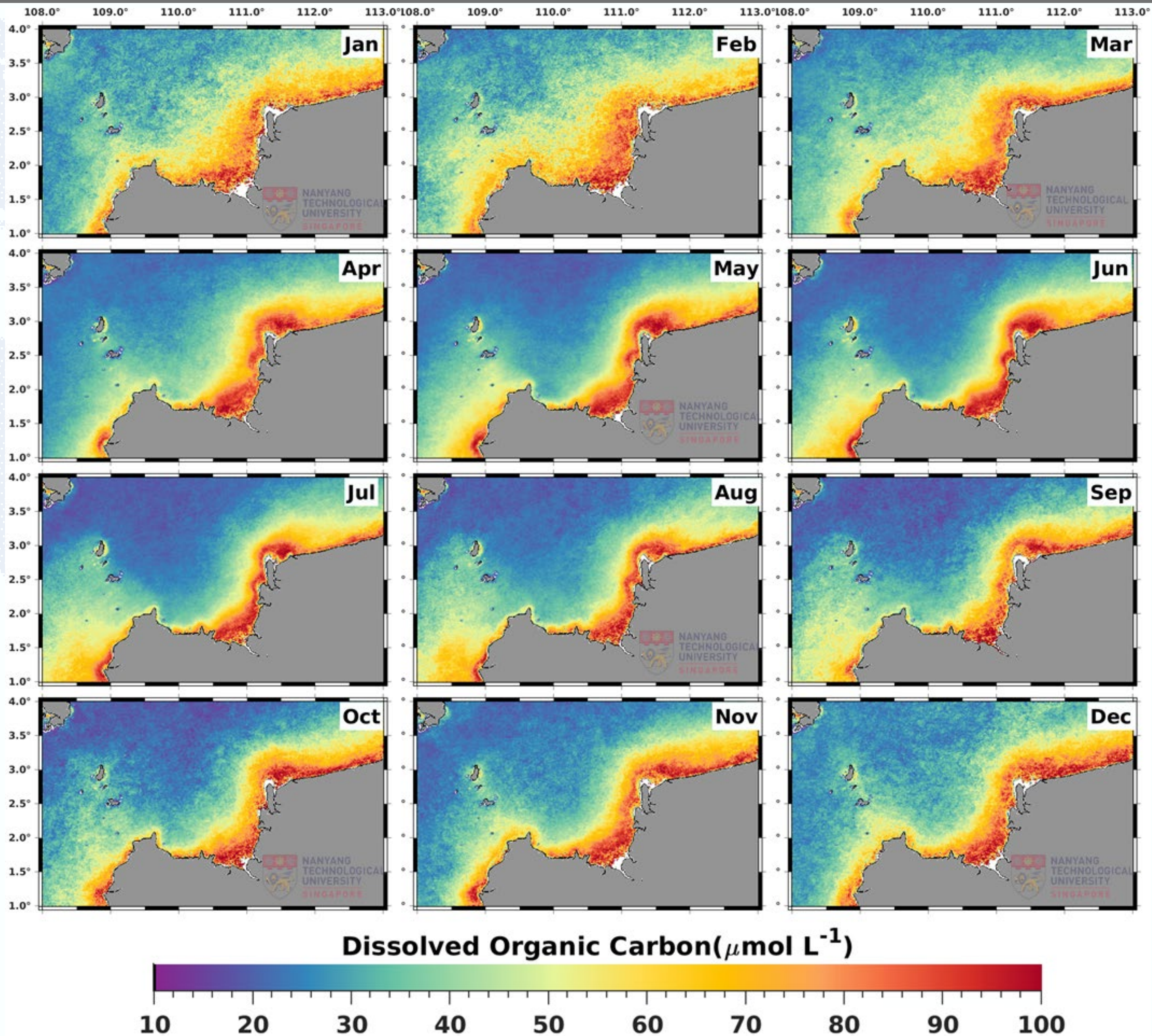


MODIS-Aqua-derived climatological (2002-2018) distribution of Source index (γ_0)

Monthly Climatology (2002-2018)

EGU General Assembly 2020

- DOC extends further off-shore during northeast monsoon (Nov-Feb), the season with highest rainfall
- During the drier southwest monsoon (Jun-Aug), DOC concentrations are higher close to shore but decrease more strongly with distance from the coast
- This pattern is expected, given the seasonal variation in rainfall



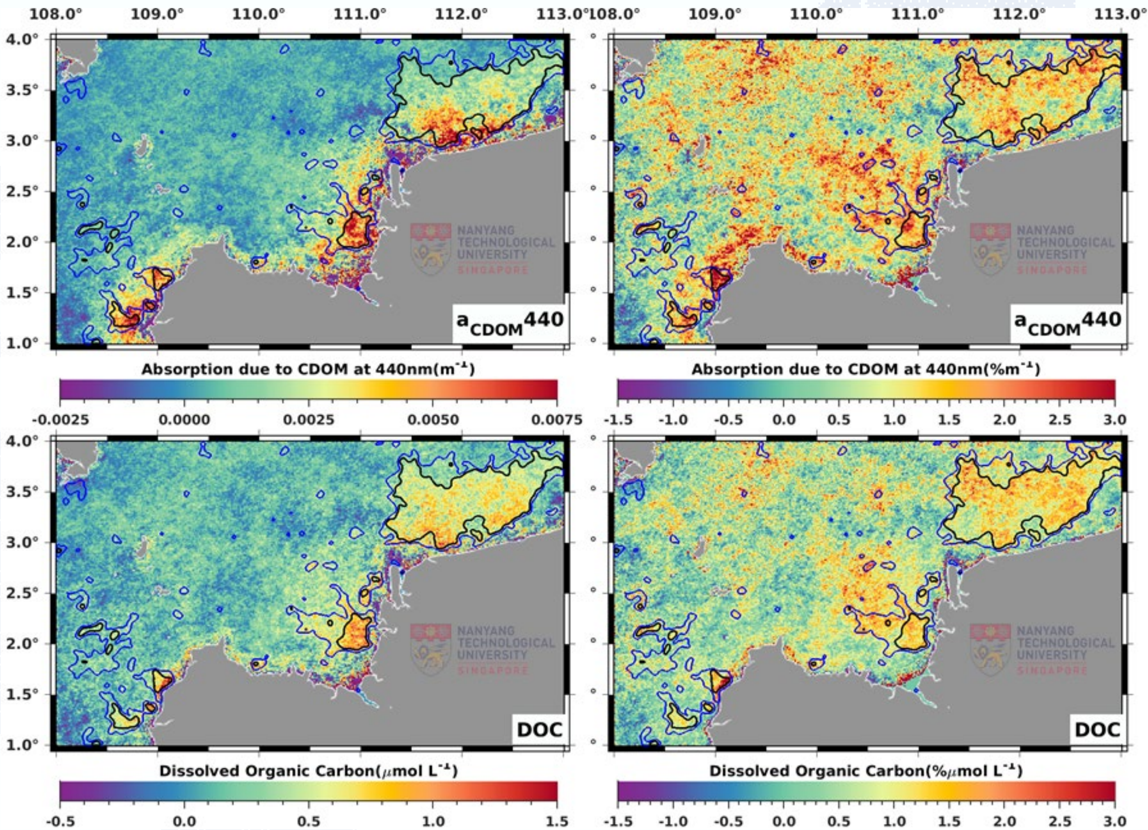
Long-term trends (2002-2018)

EGU General Assembly 2020

- CDOM & DOC concentrations increased significantly in three regions downstream of the main peatland areas

Average increase of 0.12 m^{-1} (~27.5%) in CDOM and 15.4 µmol L^{-1} (~17.6%) in DOC from 2002 to 2018

- Theil-Sen trend is statistically significant ($p<0.05$) in 1) Northern coastal waters, 2) Eastern Bay, and 3) Indonesian coastal waters



MODIS-Aqua derived spatial distribution of annual trend (2002-2018) and trend percentage of the absorption coefficient of CDOM at 440nm (a_{CDOM}) and dissolved organic carbon (DOC). Blue and black contours delineate areas where trends are significant with $p<0.1$ and $p<0.05$, respectively.

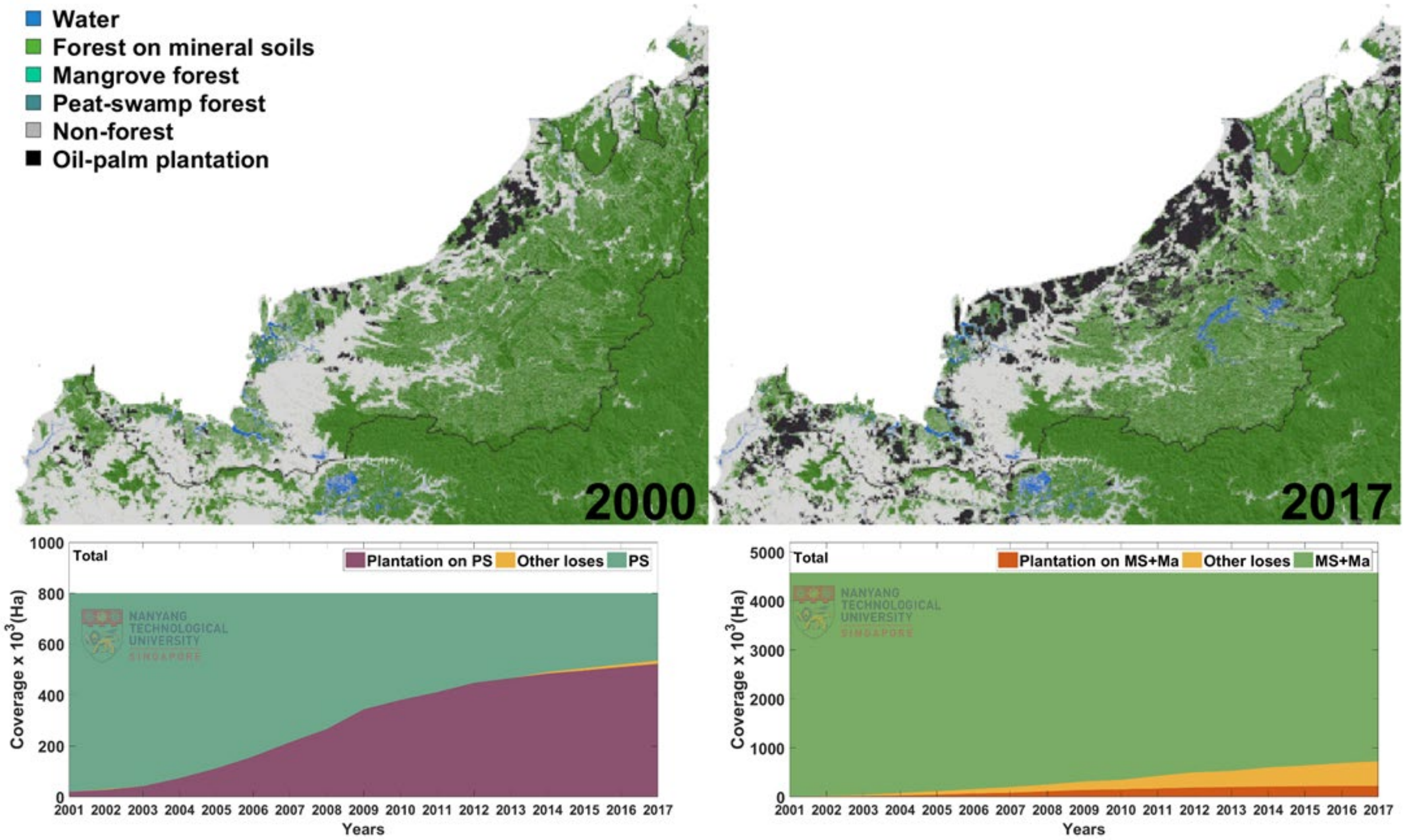
Trend - Land Transformations

EGU General Assembly 2020

- Compared trends in DOM with changes in land-cover reported by the Centre for International Forestry (CIFOR, Gaveau et al. 2016, https://atlas.cifor.org/)

Industrial plantations at the expense of :

- 2.5% to 66% peat-swamp forest loss from 2001-2018
- 1% to 17% of mangrove and mineral-soil forest loss between 2001 to 2018



Expansion of industrial plantation and associated deforestation on peatlands and mineral soil forests in the study-domain

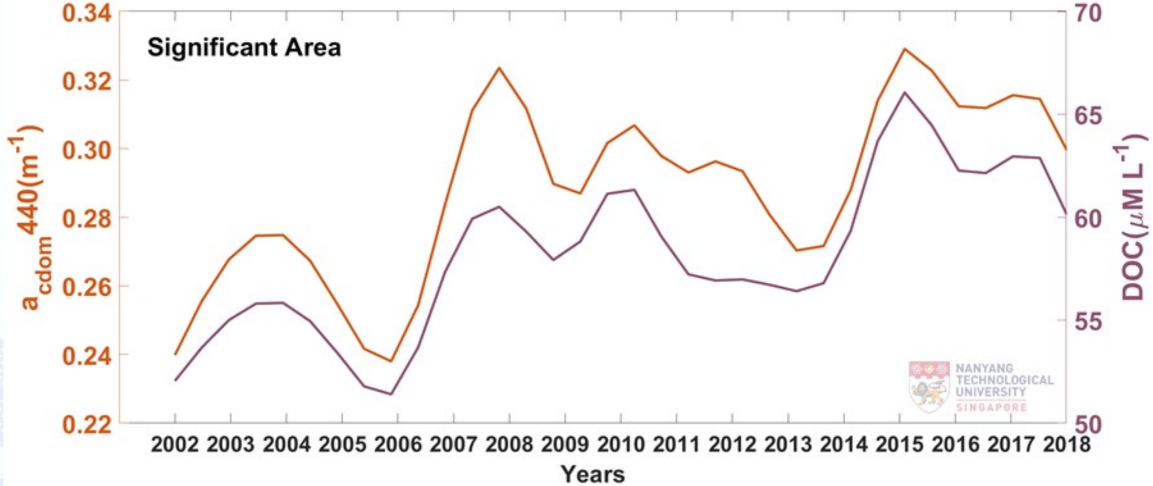
DOC Deforestation correlation

EGU General Assembly 2020

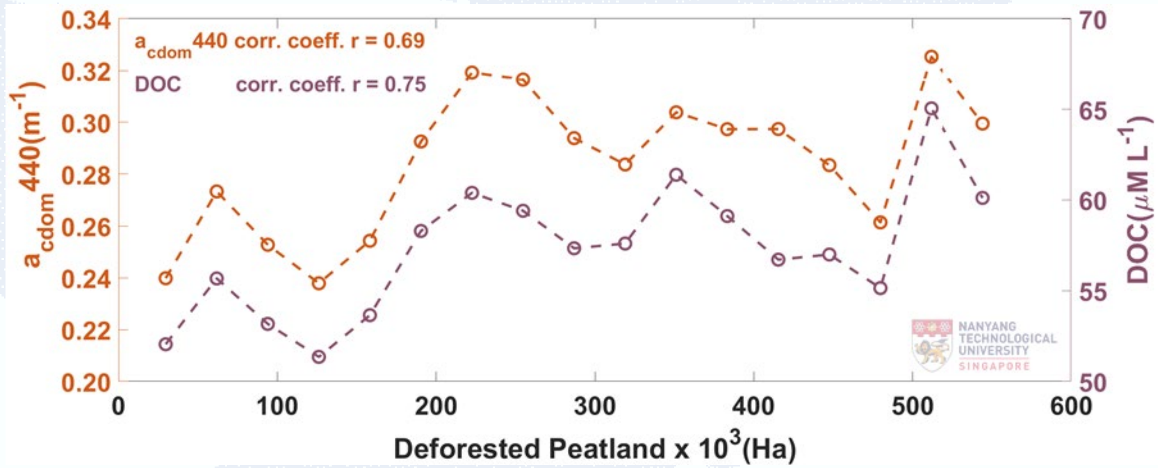
Time-series of mean DOC and CDOM in the three patches with significant trends show a clear increase over time

The annual mean DOC and CDOM are strongly correlated with the cumulative deforested peatland area

Our data provide the first large-scale confirmation that disturbance of tropical peatlands in SE Asia has increased fluxes of DOC through rivers to the coastal sea



Time-series (2002-2018) of MODIS-derived annually-averaged a_{CDOM} and DOC



MODIS-derived a_{CDOM} and DOC correlation with CIFOR-derived peatland deforestation (2002-2018)

Summary

- Extensive influence of peat-draining riverine discharges observed in spatial and seasonal distribution of CDOM and DOC in coastal waters of Sarawak Bay,
- Terrigenous source of CDOM is further confirmed by high values of the source index, γ_0 which is consistent with a predominantly peatland source of coastal DOM
- Trend analysis shows significant long-term increases in CDOM and DOC in coastal waters downstream of areas of peatland disturbance
- Overall average increases from 2002 to 2018 are $0.12 m^{-1}$, or ~27.5%, in CDOM and 15.4 µmol L^{-1}, or ~17.6%, in DOC; these increases are highly correlated with the cumulative deforestation of peatlands
- This study provides the first large-scale confirmation, using time-series observations, that peatland disturbance in SE Asia has increased the fluvial loss DOC to coastal waters

Thank you!

Acknowledgements

We are greatly indebted to the following people for assistance in the lab and the field:

- Aazani Mujahid
- Ashleen Tan Su Ying
- Joost Brandsma
- Claire Evans
- Faddrine Jang
- Edwin Sia
- Gonzalo Carrasco
- Jack Sim
- Akhmetzada Kargazhanov
- Florina Richard
- Faith Chaya
- Noor Iskandar Noor Azhar
- Fakharuddin Muhamad
- Kristy Chang
- Captain Juble
- Lukas Chin
- Minhad
- Pak Mat

Research permits were issued by the Sarawak Forestry Department and the Sarawak Biodiversity Centre