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Remote sensing of coccolithophore blooms within filaments of the Benguela upwelling system

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Introduction

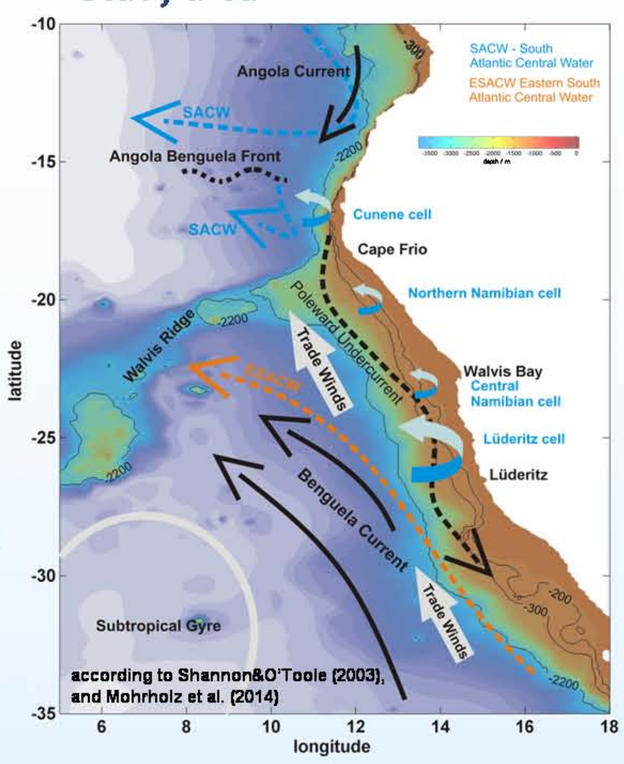
Benguela Upwelling System off Namibia

- One of the 4 major Eastern Boundary Upwelling Systems
- Benguela current → eastern edge of the Subtropical South Atlantic Gyre
- SE-trade winds induce upwelling along the coast, upwelled water is fed by SACW or ESACW, transported offshore via filaments
- High productive area

Coccolithophores off Namibia

- Omnipresent in water masses off Namibia (Siegel et al., 2007, Hansen et al., 2014)
- Blooms develop in aged upwelled water as final stage of a preceding phytoplankton succession (Siegel et al. , 2007, Hendriks et al., 2012) and survive in a shallow stable surface layer during moderate wind velocities (Siegel et al. , 2007)
- High P/N ratios are starting conditions (Siegel et al. , 2007, Hendriks et al.,2012)

Study area



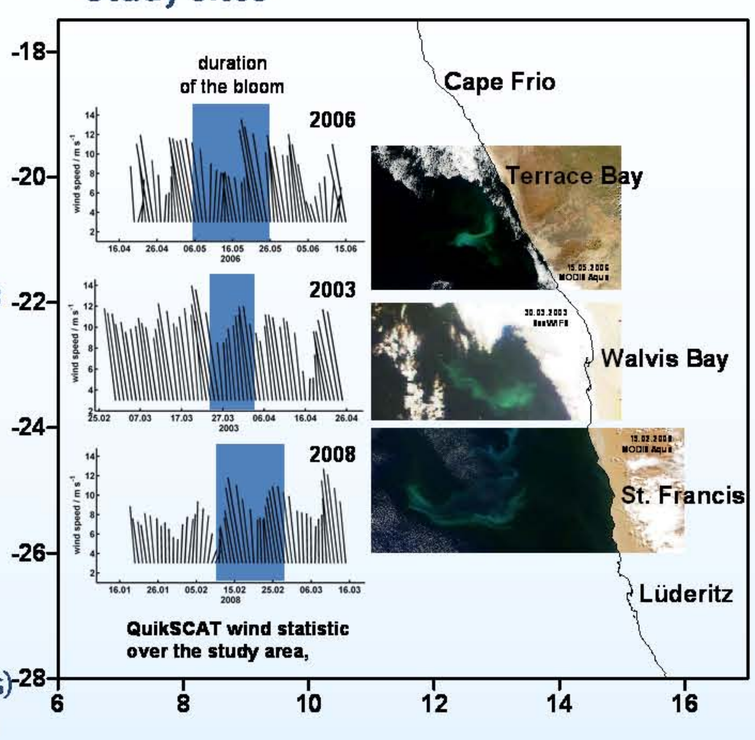
Methods

- Study area covers the region 9°-16°E and 17° -29°S,
- Time period: 2003-2008 and 2012
- Recognition of Coccolithophorid blooms and cloud coverage in RGBs
- Verifying blooms based on spectral reflectances
- Description of bloom development (3 examples are presented here, see study site)

Data basis

- Daily MODIS Terra and Aqua RGBs (2003-2008, 2012)
- MODIS Terra and Aqua L2 data (Chl-a, Rrs, SST)
- Monthly MODIS Terra L3 SST data
- Maps of Absolute Dynamic Topography (AVISO satellite products)
- QuikSCAT wind data, 3-day averages

Study sites



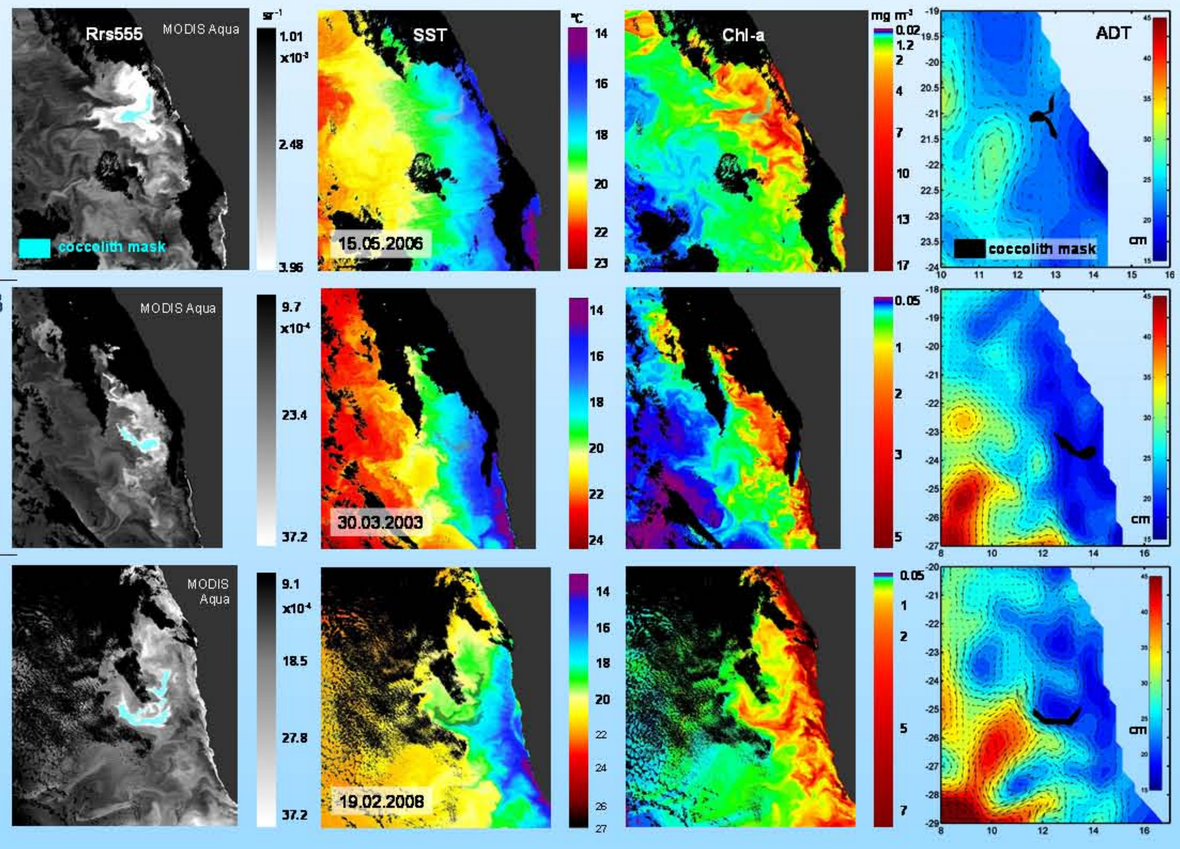
Results

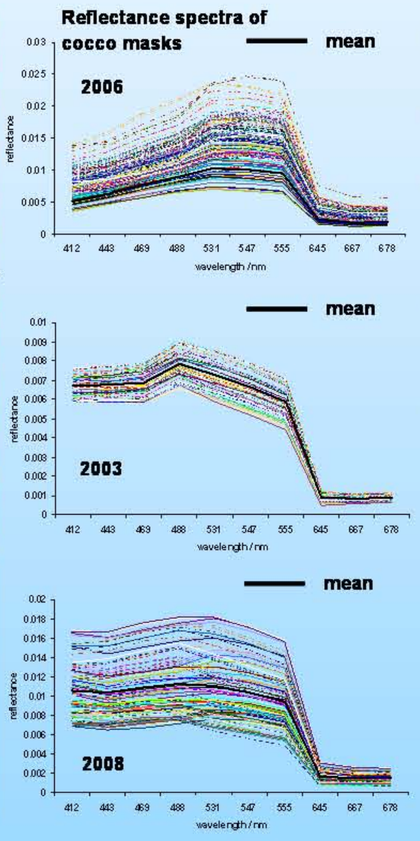
Remote sensing characteristics of coccolithophorid blooms

06 – 26 May 2006
Position: 11-13°E, 21-21.5°S
Duration: 20 d
Propagation: to W
Velocity: 1.5 cm/s

24 Mar – 03 Apr 2003
Position: 12-14°E, 23-24°S
Duration: 10 d
Propagation: quasi stable

12 – 29 Feb 2008
Position: 11-13°E, 24.8-25.2°S
Duration: 17 d
Propagation: to W
Velocity: 1.1 cm/s

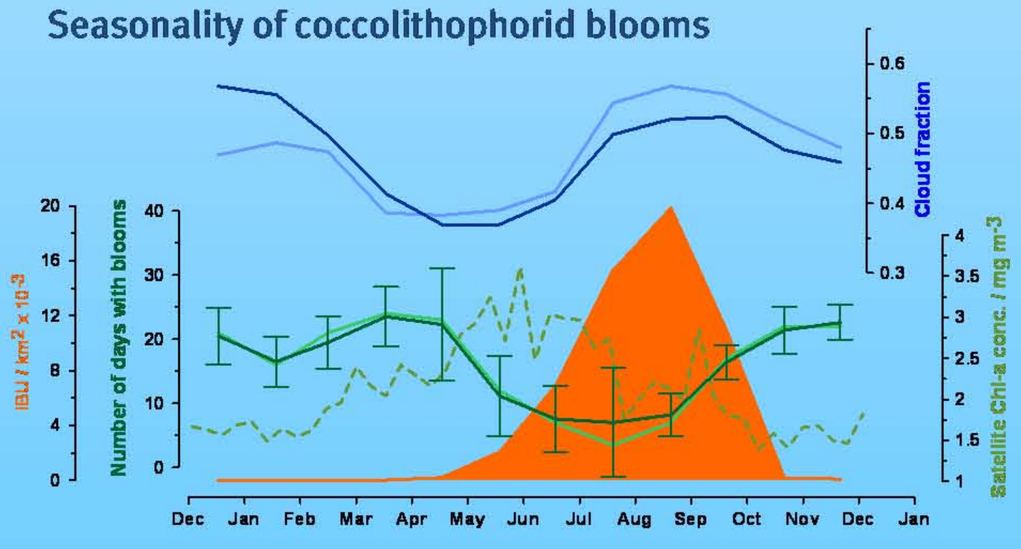




- Coccolithophorid blooms can be traced and identified by RGBs and Rrs555
- Reflectance spectra are highly variable due to optical background of water masses
- Blooms develop in water masses with intermediate SSTs with respect to upwelling and open ocean waters
- Bloom propagates along the geostrophic current fields (see time series below for the bloom event 2008)
- The blooms seem to be captured by eddies and therefore propagate very slowly with the main current in a westerly direction
- Propagation velocities of < 1.5 cm s^{-1} → slow compared to spreading of sulfur plumes along the Namibian coast (14 cm s^{-1}, Ohde et al., 2007)

Time series of absolute dynamic topography (ADT) – 2008

Seasonality of coccolithophorid blooms



- Coccolithophore blooms can be identified by turquoise water coloration in RGBs
- Satellite cloud fraction product and empirically determined cloud fraction (see diagram on the left) are in good agreement → confirms reliability of empirical data analysis
- Blooms occur 100 to 400 km offshore with variable spatial extend and last several days to weeks
- The bloom frequency decreases from S to N, with a maxima in area off Walvis Bay
- Bloom occurrence varies seasonally and inter-annually; main bloom season lies outside the main upwelling season (see diagram on the left) → Coccolithophorid blooms prefer hydrographic stable conditions
- The wind field over a bloom has no impact on bloom formation and termination (see also wind field vectors for the study sites, top right)

Outlook

- Long-term development of coccolithophore blooms in the entire area of investigation, in different regions, and in relation to upwelling intensity
- Detailed study of single blooms concerning the inducing physical processes
- Improvement of the MODIS and SeaWiFS coccolithophore bloom algorithms and comparison with the fuzzy optical water type (OWT) classification according to Moore et al. (2012)
- Validation of the occurrence of coccolithophorid blooms simulated with the GENUS ecosystem model

Acknowledgements

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Hagen et al. 2001, Oceanologica Acta 24: 1-12; Hansen et al. 2014, Journal of Marine Systems, in press.; Henderiks et al. 2012, Marine Ecology Progress Series, 448, 51-66; Mohrholz et al. 2014, ASLO, Honolulu, Hawaii, February 23-28, 2014.; Moore et. al 2012, Remote Sensing of Environment 117: 249-263; Ohde et al. 2007, Continental Shelf Research, 27(6), 744-756; Shannon & O'Toole 2003, In: Hempel & Sherman (Eds.), Elsevier, Amsterdam, 227-253; Siegel et al. 2007, Continental Shelf Research, 27(2), 258-274.