Atmos. Chem. Phys. Discuss., 12, 1401–1418, 2012
www.atmos-chem-phys-discuss.net/12/1401/2012/
doi:10.5194/acpd-12-1401-2012

Atmospheric Chemistry and Physics Discussions

Introduction to special issue: the *TransBrom Sonne* expedition in the tropical West Pacific

K. Krüger and B. Quack

Helmholtz Centre for Ocean Research Kiel (GEOMAR), Kiel, Germany

Received: 3 November 2011 – Accepted: 24 December 2011 – Published: 13 January 2012

Correspondence to: K. Krüger (kkrueger@geomar.de),
B. Quack (bquack@geomar.de)

Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

This special issue provides an overview of scientific results from the TransBrom Sonne expedition in the tropical West Pacific, conducted during October 2009. The ship cruise was part of the national research project *TransBrom*, investigating very short lived *bromine* compounds in the ocean and their *transport* pathways into the stratosphere. For this purpose chemical and biological parameters were analysed in the ocean and the atmosphere, accompanied by intense meteorological measurements, to derive more insights in this multidisciplinary research field. This introduction paper presents the scientific goals and the meteorological and oceanographic background. The main research findings of the TransBrom Sonne expedition are highlighted.

1 Introduction

This special section of Atmospheric Chemistry and Physics gives a summary of results, collected during a West Pacific ship expedition with the German Research Vessel (RV) Sonne. The cruise focussed on chemical interactions between the ocean surface and the stratosphere above the tropical West Pacific and was planned within the national project TransBrom (www.ifm-geomar.de/~transbrom). TransBrom aims to particularly investigate very short lived bromine compounds in the ocean and their transport to the stratosphere.

The ship cruise comprised a transit through the tropical West Pacific covering an unique meridional cross-section from the northern mid-latitudes to the southern subtropics. The tropical West Pacific was chosen for the investigations because of the following scientific reasons: (1) The tropical West Pacific is thought to be an active source region for natural halocarbons (Yokouchi et al., 1999; Quack and Wallace, 2003; Butler et al., 2007); (2) However, only few marine halocarbon measurements exist in this ocean basin until now (https://halocat.ifm-geomar.de); (3) The atmosphere over the tropical West Pacific is convectively active throughout the year (Gettelman et al.,

Discussion Paper | Discussion Paper | Discussion Paper | Discussion Paper |

ACPD

12, 1401–1418, 2012

TransBrom Sonne expedition to the tropical West Pacific

K. Krüger and B. Quack

2002; Liu et al., 2007), enclosing the main gate (the "tropical tropopause layer", TTL) for trace gases entering the stratosphere (Bonazzola and Haynes, 2004; Fueglistaler et al., 2005; Krüger et al., 2008; Montzka et al., 2011). The meridional transect through the West Pacific allows to investigate halocarbon production, sea-air gas exchange and transport to the stratosphere on a coastal versus open ocean, tropical-extratropical, and with a hemispheric perspective.

The main goals were to measure the marine and atmospheric halocarbon concentrations, to investigate their sources and emissions and to quantify their contribution to the stratospheric bromine loading and ozone depletion potential (ODP). To reach these objectives the following studies were performed and are presented in this special issue and elsewhere (as indicated):

1. Regular sea water and air sampling to detect halocarbon abundances and to analyse their sources, including i.e. phytoplankton species. Quantification of halocarbon fluxes in particular for bromoform, dibromomethane and methyliodide (Quack et al., 2012; Bracher et al., 2012).

2. Analysis of the TTL and the marine boundary layer (MBL) across the West Pacific, using frequent radiosoundings. These measurements were delivered to the Global Telecommunication System (GTS) of the World Meteorological Organization (WMO) to improve global meteorological assimilations over the West Pacific (Krüger et al., 2012).

3. The bromocarbon transport to the stratosphere is calculated with a Lagrangian approach, taking the observed bromocarbon flux, the chemical degradation and the washout of the very short lived substances (VSLS) into account to estimate their stratospheric bromine loading and ODP (Tegtmeier et al., 2012a).

4. Investigating the iodine content in the atmosphere: (a) within the MBL by applying reactive halogen measurements in and above the ocean surface (Grossmann et al., 2012); (b) the stratospheric contribution of methyliodide based on the observed fluxes (Tegtmeier et al., 2012b).

5. Intercalibration of different instruments and methods to compare in-situ reactive halogens (BrO, IO) from MAX DOAS instruments and VSLS data from air canister samplings (Grossmann et al., 2012; Brinckmann et al., 2011).

6. Ozone, carbon monoxide, dimethyl sulfide (DMS) and more trace gases were measured throughout the entire troposphere to investigate its physical and chemical structure (Ridder at al. 2011; Rex et al., 2012; Zindler et al., 2012).

7. Validation of satellite retrievals of biological (phytoplankton) and chemical (formaldehyde, nitrogen dioxide) compounds by in-situ ship measurements over the West Pacific (Bracher et al., 2012 ; Peters et al., 2012).

2 Cruise overview

The ship expedition started in Tomakomai, Japan (42° N, 142° E) on 9 October 2009, arriving in Townsille, Australia (19° S, 147° E) on 24 October 2009. The cruise was designed as a transit through the tropical West Pacific, directly sailing from Japan to Australia performing regular underway measurements of sea water properties and atmospheric parameters. A detailed description of the measurements including a list of the instruments and operation times can be found in the cruise report by Quack and Krüger (IFM-GEOMAR Cruise Report No. 37, 2010). Figure 1 shows the meridional cross section through the West Pacific from the northern extratropics to the southern subtropics. Although the cruise took place towards the weakening phase of the typhoon season, three tropical storms hit the RV Sonne during the 16 day transit, influencing the trace gas content of the atmosphere by increasing their sea-to-air flux (Quack et al., 2012; Tegtmeier et al., 2012a).

The ship departure was delayed some hours due to the passage of the former supertyphoon Melor over Tomakomai on 8/9 October 2009, which turned into an extratropical storm while crossing Japan. Four days later, on 12 October 2009, the tropical storm Nepartak directly passed the ship route, leading to the wind maxima of the whole cruise

ACPD
12, 1401–1418, 2012

at 27° N (Sect. 2.3). However, Nepartak was only categorized as a tropical depression (http://www.usno.navy.mil/JTWC), since it weakened while propagating northeastward (Fig. 1). Again two days later, the tropical storm Lupit developed on 14 October 2009 at 12° N. In contrast to Nepartak, Lupit turned into a super typhoon of the category 4, while travelling towards the Philippines.

Next to this tropical storm activity affecting our trace gas measurements, we crossed the tropical West Pacific during the strengthening phase of an El Niño, which developed to a moderate-to-strong event during October 2009 (Climate Diagnostics Bulletin, 2009; 2010). In general, El Niño changes the oceanic and atmospheric circulations above the tropical Pacific, leading to an eastward shift of high sea surface temperature, enhanced convection and transport to the stratosphere, impacting the production, sea-to-air gas exchange and transport of trace gases to the stratosphere (i.e. Bonazzola and Haynes, 2004; Krüger et al., 2008, 2009).

2.1 Data

Meteorological data, including air temperature, pressure and wind, were measured every second by the ship instruments at 20 m altitude. Sea surface temperature (SST) was recorded from 5 m depth. The temperature, pressure and mean wind fields are displayed as 1-min respectively 10-min averages. Two different meteorological assimilations are analysed in more detail as they are used as data input for the transport studies, investigating the history of air parcels with trajectories (Sect. 3). On the one hand, the 4-D-Var assimilation of the operational European Centre for Medium Range Weather Forecast (opECMWF) model (cycle 35r3) is based on T799/L91 (~ 25 km) resolution (ECMWF Newsletter No. 121, 2009). If not specified, the opECMWF output is used with a 1° × 1° and 6-hourly resolution. On the other hand, the 3-D-Var analysis of the operational National Centre for Environmental Prediction – Global Data Assimilation System (NCEP-GDAS) is based on T382/L64 (~ 35 km) resolution (NCEP Technical Procedures Bulletin, 2005), used with an average grid of 1° × 1° and 6-hourly data output.

ACPD
12, 1401–1418, 2012

2.2 Oceanographic background

The water and air temperatures are displayed in Fig. 2 to characterize the existing oceanographic circulation and to show their potential impact on the sea-air gas exchange. In general, trace gas emissions depend on water temperature; at constant concentrations they increase with higher water temperatures (Wanninkhof, 1992; Nightingale et al., 2000).

At the beginning of the cruise, the ship passes the cold Oyashio current, when leaving Hokkaido Island southward. The SST steadily increases from 14 °C to 21 °C. At 38° N a pronounced jump to higher SST indicates the transition to the Kuroshio current with water temperatures around 25 °C. North Equatorial Current (NEC) waters are characterized by a slight increase of SST up to 28 °C, extending from 28° N to 10° N. The maximum SST of 31 °C, hence the "warm pool", is detected at 3° N within the region of the North Equatorial Counter Current (NECC) (10° N to 5° S), just before crossing the equator. Monthly mean October maps revealed warmest surface water (> 30 °C) shifted further eastward towards the tropical Central to East Pacific, exceeding a moderate deviation of 1 K above the equator (Climate Diagnostics Bulletin, 2009). Poleward of 6° S until the end harbor Townsville (19° S), the SST starts to decrease down to 25 °C, indicating the South Equatorial Current (SEC). Most of the time the air temperature stays below the water temperature ($\Delta T < 0$), except between 20° N to 15° N $\Delta T > 1$ due to the westward advection of warmer air from the Central Pacific (Sect. 3, Fig. 5). There is sharp drop in air temperature exceeding 7 K at the barrier between the Oyashio and the Kuroshio currents, when colder air masses from the North (Sect. 2.3) reach the warmer Kuroshio current.

2.3 Atmospheric background

During October 2009 the tropical convection and precipitation were enhanced over the central part of the tropical West-Pacific, which is typical for a strengthening El Niño (Climate Diagnostics Bulletin, 2009). Indeed, our meteorology observations on board

ACPD
12, 1401–1418, 2012

revealed recurring convective activity within the inner tropical regime (Krüger et al., 2012) accompanied by enhanced precipitation. Figure 2 displays the actual surface air temperature (SAT) along the ship cruise. The maximum SAT of 28 °C is reached between 20° N and 4° S, except at the equator, where the air cools to a relative minimum of 24 °C due to continuous rain fall.

Analysing sea level pressure (SLP) and wind measurements, the existing atmospheric circulation during the TransBrom Sonne cruise can be characterized (Fig. 3). The ship cruise started within the climatological westwind regime followed by the northern trade wind regime. The lowest air pressure of the whole transit is recorded at the departure reaching 1003 hPa, due to the passage of ex-Melor with strong northwesterly winds. Following, the air pressure steadily increases up to 1017 hPa at 34° N. With the development and the approach of the tropical depression Nepartak on 8 October 2009, the air pressure suddenly drops south of 30° N. The maximum storm intensity hit the ship cruise on 12 October 2009 with 1007 hPa and a mean wind speed of 19 m s^{-1} (in gusts reaching 21 m s^{-1}) from Northeast (Fig. 3). The ship passes Nepartak on the northern to northeastern flank (Fig. 4). However, higher wind speeds occur on the northwestern flank, expecting in general enhanced emissions in this quadrant of the tropical depression (Wanninkhof, 1992; Nightingale et al., 2000). Two days later, the next tropical storm Lupit is reached at 18° N (Fig. 3), who developed later into a super typhoon (http://www.usno.navy.mil/JTWC). As it passes the ship cruise with a distance of more than 500 km (Fig. 1), the influence of Lupit is weaker with strong easterly winds of 12 m s^{-1} and a SLP of 1010 hPa. Lupit strongly influenced the oceanic methyliodide emissions and their entrainment into the stratosphere (Tegtmeier et al., 2012 for GRL). After this storm event, air pressure and wind speed steadily decrease until crossing 10° N, when the wind speed starts to increase continuously (Fig. 3). We identify the inner tropical belt between 12° N and 6° S with a weak to moderate wind speed and a continuous left-hand rotation. South of 6° S intensifying southern trade winds begin to blow, exceeding 16 m s^{-1} at 12° S. These stormy winds lead to an increase of evaporation hence a cooling of the ocean surface within the SEC (Fig. 2). Simultaneously

ACPD
12, 1401–1418, 2012

with the SST decline, the SAT continuously decreases to 23 °C. The air pressure starts to increase up to the absolute maximum of the cruise with 1018 hPa, finally arriving the end harbor in Townsville under high pressure influence (Fig. 3). The influence of the atmospheric tides on SLP appears southward of 40° N, clearly visible as semi-diurnal pressure variations with maximum amplitudes up to 4 hPa.

Figure 3 compares also two different meteorological assimilations, which are used as input for the trajectory calculations (Sect. 3), with the ship measurements. Overall, the data intercomparison for pressure and wind fields shows a good agreement, influenced by the assimilation of the radiosonde measurements as they were delivered to the GTS data net from the WMO. For air pressure and wind speed, the NCEP-GDAS analysis is closer to the ship measurements than opECMWF almost throughout the NH. South of the equator the differences increase, revealing a bias towards lower wind speeds of $\sim$ 2–6 m s^{-1} for both assimilation systems in the data sparser hemisphere probably due to lower coverage of mainland observations.

3 Analyses of air mass origin

To analyse air mass origin and possible source regions of the trace gases, two different trajectory models are employed, which are commonly used for trace gas analyses (Quack et al., 2004; Immler et al., 2007; Brinckmann et al., 2011; Ridder at al., 2011). The online web version of the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model was applied (http://ready.arl.noaa.gov/HYSPLIT.php) using the NCEP-GDAS meteorological assimilation. The British Atmospheric Data Centre (BADC) trajectories were calculated online at the BADC trajectory service (http://badc.nerc.ac.uk) using the available opECMWF analyses with a 1.125° × 1.125° grid resolution. Both trajectory models are started daily at 12:00 UTC along the ship track within the MBL at 500 m altitude and 950 hPa for HYSPLIT respectively BADC, calculating 5-days backward. Trajectories started near the surface at 10 m height reveal qualitatively the same source areas (not shown here).

Discussion Paper | Discussion Paper | Discussion Paper | Discussion Paper |

ACPD

12, 1401–1418, 2012

TransBrom Sonne expedition to the tropical West Pacific

K. Krüger and B. Quack

Figure 5 displays a clear separation into three atmospheric regimes for both trajectory analyses, which is in good agreement with the ship measurements (Fig. 3). The first regime, including the stronger Northerly winds, reaches until ~20° N. The second regime with inner tropical characteristics, shows weaker winds (shorter trajectory length) and a rotation of the trajectories. At 6° S the air masses start to origin from the southeast distinguishing the third regime with the climatological moderate to strong trade winds. Based on meteorological factors and air mass sources together (Figs. 3 and 5), the atmospheric circulation during the TransBrom Sonne cruise can be classified into three regimes: (1) the "Northern Regime" from 42° N to 24° N; (2) the "Tropical Regime" from 24° N to 6° S; and (3) the "Southern Regime" from 6° S to 19° S.

Given the starting points from the 5-day trajectories (Fig. 5), we can identify a variety of halocarbon source regions for the atmosphere. In the first regime, the air masses origin from East Russian and Japanese mainland and coastal areas. This air crosses the open ocean during the following days, where high biological productivity at the coast and open sea east of Japan was determined from in-situ and via satellite measurements of chlorophyll-*a* (Bracher et al., 2012). Thus the atmosphere up to the NEC likely acquired anthropogenic, terrestrial and coastal properties, as well as an additional signature from oceanic phytoplankton. Within the Tropical Regime, the air masses origin from more nearby areas, indicating the direct influence of open ocean sources on the atmosphere and its content of trace gases. As the ship passed nearby small islands (< 20 nm distance) between 8° N and 4° S , marine bromoform concentrations increased (Quack et al., 2012). Within the Southern Regime the trajectories pass Southeast Australia, the Tasman, Coral and Solomon Seas as well as the Great Barrier Reef. These regions comprise islands, coasts and corals as possible sources for the oceanic and atmospheric trace gas content. In addition, Bracher et al. (2012) detected higher biological productivity especially towards the end of the ship cruise.

ACPD
12, 1401–1418, 2012

4 Conclusions

The TransBrom Sonne cruise through the tropical West Pacific took place in October 2009, during the typhoon season and a strengthening El Niño. Regular chemical, physical and biological measurements of air and sea water were successfully conducted. The marine and atmospheric trace gas concentrations varied within five oceanic and three atmospheric regimes, the "Northern", "Tropical" and "Southern" regimes. The northern part of the extratropical and the tropical West Pacific was influenced by tropical storm and typhoon activity. Over the central part of the tropical West Pacific higher convective activity was observed, being typical for a strengthening El Niño phase. The climatological wind regime of strong southern trade winds was encountered south of 6° S. Based on trajectory predictions, we identified populated and coastal source regions in the northern part of the extratropical West Pacific and remote and coastal regions including coral reefs in the southern part of the tropical West Pacific. Open ocean air from the northern and central tropical West Pacific dominated the air masses during the middle leg of the cruise. Anthropogenic and natural source areas were identified to play a role for the origin of the trace gases measured during the expedition.

Overall, the TransBrom Sonne cruise delivered an unique data set from the tropical West Pacific including both the surface ocean and the atmosphere. Radiative and chemical reactive trace gases from the tropical West Pacific impact the chemistry of the tropical troposphere and stratosphere, possibly influencing the atmosphere and the climate on a global scale.

ACPD
12, 1401–1418, 2012

Acknowledgements. We are grateful to all participants from TransBrom Sonne for their extensive work and help, who built the basis for the successful operation of the ship cruise. We thank Sebastian Wache and Steffen Fuhlbrügge for the preparation of the figures. Data were provided from RV Sonne for the ship measurements, from European Centre for Medium Range Weather Forecast for the operational ECMWF analysis and from National Centre for Environmental Prediction for the NCEP-GDAS analyses. The work of this study is funded by the national WGL project TransBrom; the ship campaign on RV SONNE was financed by the BMBF through grant 03G0731A. This work also contributes to the EU project SHIVA.

References

Bonazzola, M. and Haynes, P.: A trajectory-based study of the tropical tropopause region, J. Geophys. Res., 109, D20, 112, doi:10.10292003JD004356, 2004. 1403, 1405

Bracher, A., Dinter, T., Taylor, B., Altenburg Soppa, M., and Ribalta Torrecilla, E.: Temporal and spatial dynamics of phytoplankton composition in the Western Pacific from in-situ and satellite data, Atmos. Chem. Phys. Discuss., in preparation, 2012.

Brinckmann, S., Engel, A., Bönisch, H., Quack, B., and Atlas, E.: Short-lived brominated species – observations in the source regions and the tropical tropopause layer, Atmos. Chem. Phys. Discuss., 11, 22199–22245, doi:10.5194/acpd-11-22199-2011, 2011. 1404, 1408

Butler, J. H., King, D. B., Lobert, J. M., Montzka, S. A., Yvon-Lewis, S. A., Hall, B. D., Warwick, N. J., Mondeel, D. J., Aydin, M., and Elkins, J. W.: Oceanic distributions and emissions of short-lived halocarbons, Global Biogeochem. Cy., 21, GB1023, doi:10.1029/2006GB002732, 2007. 1402

Fueglistaler, S., Bonazzola, M., Haynes, P. H., and Peter, T.: Stratospheric water vapor predicted from the Lagrangian temperature history of air entering the stratosphere in the tropics, J. Geophys. Res., 110, D08107, doi:10.1029/2004JD005516, 2005. 1403

Gettelman, A., Salby, M. L., and Sassi, F.: The distribution and influence of convection in the tropical tropopause region, J. Geophys. Res., 107, 4080, doi:10.1029/2001JD001048, 2002. 1402

Großmann, K.,Frieß, U., Tschritter, J., Peters, E., Wittrock, F., Quack, B., Krüger, K.,Sommariva, R., von Glasow, R., Platt, U. and Pfeilsticker, K.: Iodine monoxide in the Western Pacific marine boundary layer, Atmos. Chem. Phys. Discuss., in preparation, 2012.

Immler, F., Krüger, K., Tegtmeier, S., Fujiwara, M., Fortuin, P., Verver, G., Schrems, O.: Cirrus clouds, humidity, and dehydration in the tropical tropopause layer observed at Paramaribo/Suriname (5.8° N, 55.2° W), J. Geophys. Res., 112, D03209, doi:10.10292006JD007440, 2007. 1408

Krüger, K., Tegtmeier, S., and Rex, M.: Long-term climatology of air mass transport through the Tropical Tropopause Layer (TTL) during NH winter, Atmos. Chem. Phys., 8, 813–823, doi:10.5194/acp-8-813-2008, 2008. 1403, 1405

Krüger, K., Tegtmeier, S., and Rex, M.: Variability of residence time in the Tropical Tropopause Layer during Northern Hemisphere winter, Atmos. Chem. Phys., 9, 6717–6725, doi:10.5194/acp-9-6717-2009, 2009. 1405

Krüger, K., Immler, F., Tegtmeier, S., Fuhlbrügge, S., Mohr, V., Wache, S., Rex, M., Quack, B.: High resolution meteorological data from radiosondes characterizing the atmosphere above the Western Pacific, Atmos. Chem. Phys. Discuss., in preparation, 2012.

Liu, C., Zipser, E. J., and Nesbitt, S. W.: Global distribution of tropical deep convection: different perspectives from TRMM infrared and radar data, J. Climate, 20, 489–503, 2007. 1403

Montzka, S., Reimann, S., O'Doherty, S., Engel, A., Krüger, K., and Sturges, W. T.: Chapter 1: Ozone-Depleting Substances (ODSs) and related chemicals, in: Scientific Assessment of Ozone Depletion: 2010, World Meteorological Organization, Geneva, Switzerland, 112 pp., 2011. 1403

Nightingale, P. D., Malin, G., Law, C. S., Watson, A. J., Liss, P. S., Liddicoat, M. I., Boutin, J., and Upstill-Goddard, R. C.: In situ evaluation of air-sea gas exchange parameterizations using novel conservative and volatile tracers, Global Biogeochem. Cy., 14(1), 373–387, 2000. 1406, 1407

Peters, E., Wittrock, F., Großmann, K., Richter, A., and Burrows, J. P.: Formaldehyde and NO_2 over the remote western Pacific Ocean: SCIAMACHY and GOME-2 validation, Atmos. Chem. Phys. Discuss., in preparation, 2012.

Quack, B. and Wallace, D. W. R.: Air-sea flux of bromoform: controls, rates, and implications, Global Biogeochem. Cy., 17(1), 1023, doi:10.1029/2002GB001890, 2003. 1402

Quack, B., Atlas, E., Petrick, G., Stroud, V., Schauffler, S., and Wallace, D. W. R.: Oceanic bromoform sources for the tropical atmosphere, Geophys. Res. Lett., 31, L23S05, doi:10.1029/2004GL020597, 2004. 1408

Quack B., Atlas, E., Krüger, K., Taylor, B., Dinter, T., Bracher, A., Petrick, G., Stange. K., Fuhlbrügge, S., Tegtmeier, S., Wache, S., and Wallace, D.: Distribution and air-sea fluxes of halocarbons through the Western Pacific, Atmos. Chem. Phys. Discuss., in preparation, 2012.

Rex, M., Immler, F., Lehmann, R., Krüger, K., Mohr, V., Tegtmeier, S., and Wache, S.: Is there a hole in the global OH shield over the tropical West Pacific Pool?, in preparation, 2012.

Ridder, T., Gerbig, C., Notholt, J., Rex, M., Schrems, O., Warneke, T., and Zhang, L.: Ship-borne FTIR measurements of CO and O_3 in the Western Pacific from 43° N to 35° S: an evaluation of the sources, Atmos. Chem. Phys. Discuss., 11, 22951–22985, doi:10.5194/acpd-11-22951-2011, 2011.

Tegtmeier, S., Krüger, K., Quack, B., Pisso, I., Stohl, A., and Yang, X.: Bridging the gap between halocarbon oceanic emissions and upper air concentrations, Atmos. Chem. Phys. Discuss., submitted, 2012a. 1404, 1408

Tegtmeier, S., Krüger, K., Quack, B., Pisso, I., and Wallace, D.: Oceanic methyliodide emissions contributing to the stratospheric ozone depletion?, in preparation, 2012b.

Wanninkhof, R.: Relationship between wind-speed and gas exchange over the ocean, J. Geophys. Res., 97, 7373–7382, 1992.

Yokouchi, Y., Li, H.-J., Machida, T., Aoki, S., and Akimoto, H.: Isoprene in the marine boundary layer (Southeast Asian Sea, eastern Indian Ocean, and Southern Ocean): comparison with dimethyl sulfide and bromoform, J. Geophys. Res., 104, D7, doi:10.1029/1998JD100013, 1999. 1406, 1407

Zindler, C., Marandino, C., Bange, H., and Atlas, E.: DMSP, DMSO, and DMS cycling and air-sea exchange in the Western Pacific, Atmos. Chem. Phys. Discuss., in preparation, 2012. 1402

ACPD

12, 1401–1418, 2012

TransBrom Sonne expedition to the tropical West Pacific

K. Krüger and B. Quack

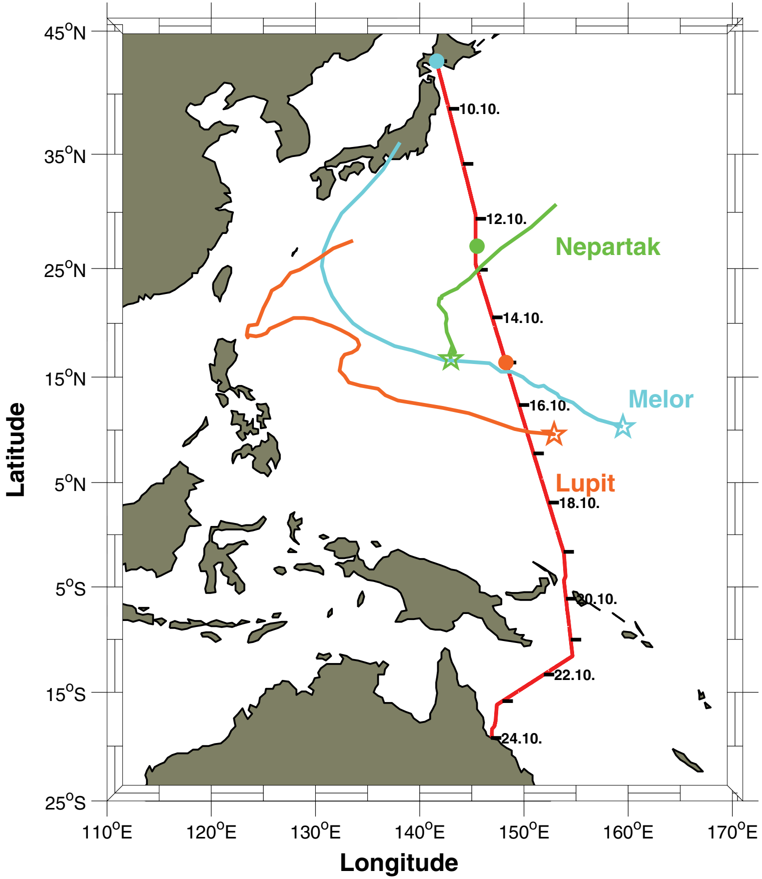

Fig. 1. TransBrom Sonne ship route in the West Pacific from 9 to 24 October 2009 (UTC time). The tracks from the tropical depression "Nepartak" and two typhoons "Melor and Lupit" are shown together with their localized influence on the ship measurements (filled circles). The data are taken from the Joint Typhoon Warning Center archive (http://www.usno.navy.mil/JTWC).

ACPD
12, 1401–1418, 2012

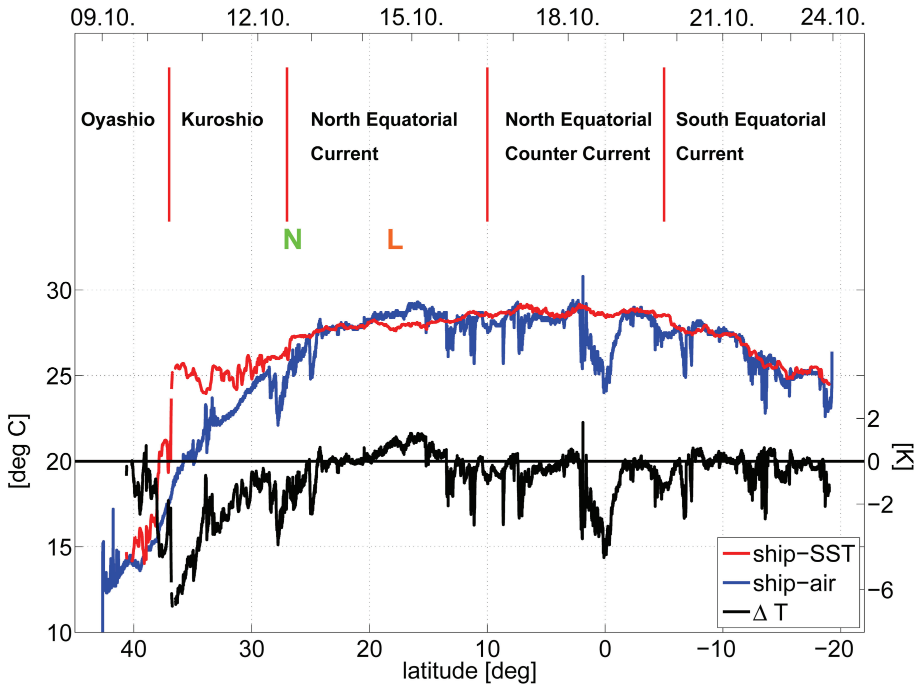

Fig. 2. Sea surface temperature (°C), surface air temperature (°C) and the difference between the two (ΔT, in K) measured on board of RV Sonne. The measurements are displayed as 1-min averages. The identified oceanic circulations are displayed, as well as the influence of the tropical storms Nepartak ("N") and Lupit ("L").

ACPD
12, 1401–1418, 2012

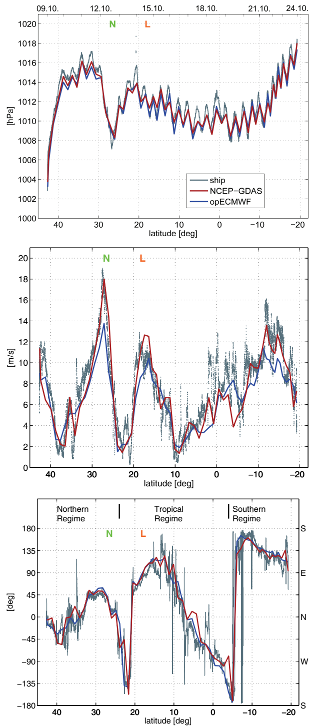

Fig. 3. Data intercomparison between ship measurements and two different data assimilations from: (top) sea level pressure (hPa), (middle) mean wind speed ($m\,s^{-1}$), and (bottom) mean wind direction (in $^\circ$ and compass direction) and atmospheric regimes. The ship measurements are displayed as 10-min averages; the NCEP-GDAS (red lines) and opECMWF (blue lines) data at 6 hourly intervals.

ACPD
12, 1401–1418, 2012

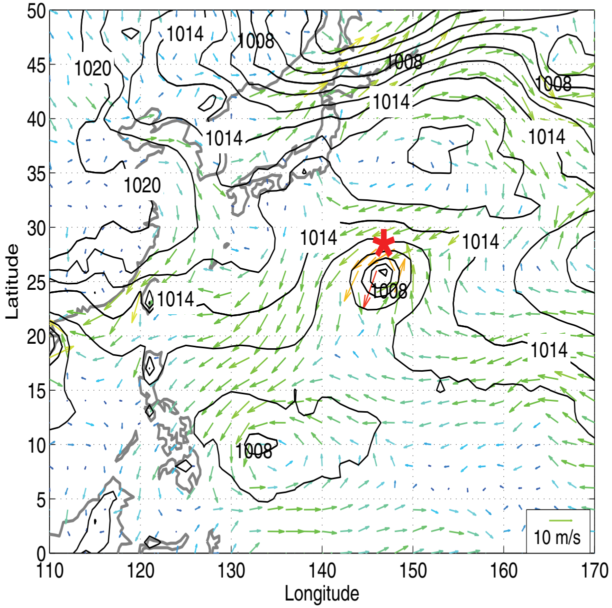

Fig. 4. SLP (hPa) and wind arrows ($m\,s^{-1}$) for the storm Nepartak on 12 October 2009 at 12:00 UTC, using opECMWF analysis. The location of RV Sonne is displayed by the red star. The contour intervals are 2 hPa.

ACPD
12, 1401–1418, 2012

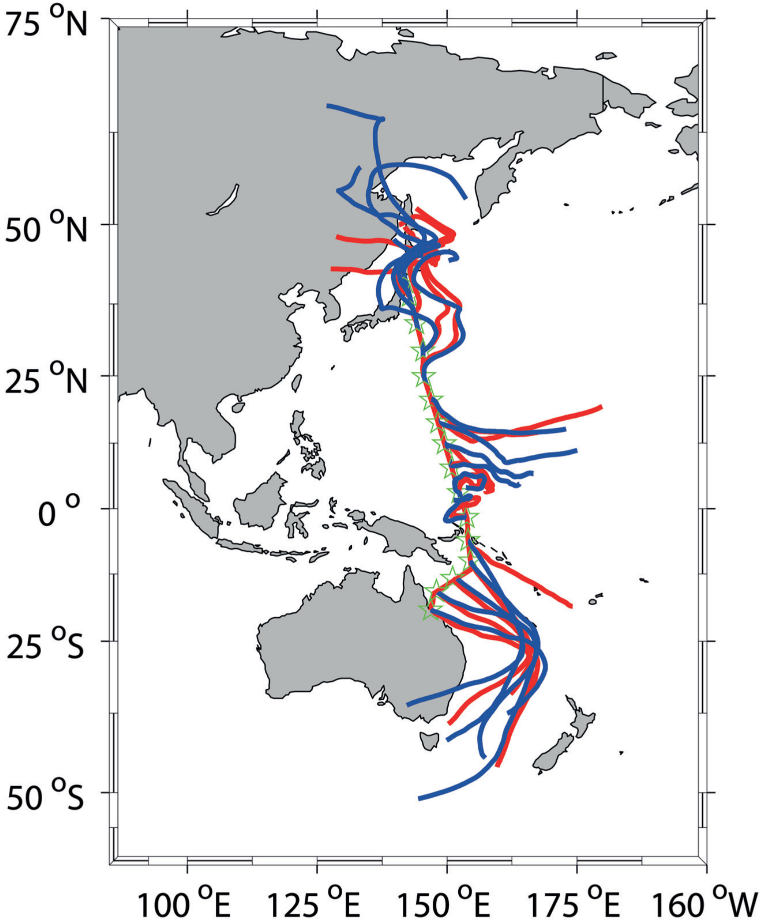

Fig. 5. 5-day backward trajectories calculated with the HYSPLIT (NCEP-GDAS data, red lines) and BADC (opECMWF 1.125° × 1.125° data, blue lines) models, started at 00:00 UTC and 500 m respectively 950 hPa height.

ACPD
12, 1401–1418, 2012

TransBrom Sonne expedition to the tropical West Pacific

K. Krüger and B. Quack