The PGGM measurements of atmospheric carbon dioxide concentrations over the Asia-Pacific and the Asia-Europe commercial shipping routes: The 2009-2017 results

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The Pacific Greenhouse Gases Measurement (PGGM) project has conducted measurements of global greenhouse gases for climate research: started from June 2009 for the ship-based CO2 measurements; and started from June 2011 for the air-based H2O, O3, CO, and cloud particle measurements. The main EU partner for the PGGM air-based measurements is the IAGOS project; while the main partner for the PGGM ship-based measurements is the Cambridge University in the UK. The main industrial partners for the PGGM project are Evergreen Marine Corporation (EMC) for the ship-based measurements and China Airlines (CAL) for the air-based measurements. The ship-based measurements have collected data over the the Pacific Ocean, Indian Ocean, Persian Gulf, Red Sea, Mediterranean Sea, northwestern and northeastern Atlantic Ocean. As a result, we are able to understand CO2 concentrations downwind of the main industrial countries in the world, including East Asia, Japan, Korea, North America (Canada and USA), South America (Peru and Chile), Southeast Asia countries, India, Arabian countries, Mediterranean countries (Italy and countries from north Africa), and European countries (UK, Germany, France, the Netherland, Spain, Portugal, Belgium). The air-based measurements collect data cover regions of East Asia, Japan, Korea, North Pacific upper troposphere, Southeast Asian countries (the Philippine, Vietnam, Indonesia, Malaysia, Singapore), European countries (Germany, the Netherland, Austria), north America (Canada), and upper troposphere over the Euro-Asian continent. The ship-based measurements use 9 biggest and newest global commercial cargo ships (L-type, S-type, and D-type ships) from EMC. We have collected a total of more than 300 cruises of measurements since June 2009. The ship-based measurements are still on going. The ship-based CO2 data shows that CO2 levels close to the industrial regions have surpassed 430 ppmv, while the CO2 levels in the middle of Pacific have also passed 400 ppmv. The CO2 trends are higher than 1.5 ppmv per year from over both industrial regions and remote regions. As a bonus of the industrial collaboration with the EMC, we have also collected data of atmospheric dose rates over the Tokyo Port and the North Pacific Regions from March 2011 (right after the Fukushima nuclear power plant accident) to end of 2015. Our ship-based data and land-based data clearly indicated the immediate impact of nuclear radioactive materials over the Tokyo and the North Pacific regions. These data indicate the importance and add-on values of data collected from routine and scheduled global container cargo ships. The flexibility and agility of a commercial container cargo ship moving around global waters enable us to collect data that are normally difficult to collect by conventional methods.