A 7-year climatology of radiative fluxes and cloud radiative effect at the ENA: Uncertainties and preliminary results.

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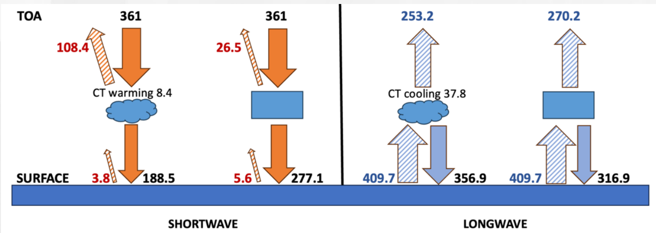
Summary figure: The SW (orange) and LW (blue) radiation budget at the ENA site for all sky (left) and clear sky (right) conditions. All quantities are W m^{-2}.



Introduction

The global Earth radiation balance is locally affected by temperature, water vapor, aerosols, and clouds. In this work we use *ground-based measurements and retrievals from ARM datasets* to calculate a climatology of the surface and Top Of Atmosphere (TOA) radiation budget at the ARM Eastern North Atlantic observatory during marine conditions. The site is representative of a broad range of cloud types over the Northeast Atlantic Ocean, and it is located at a transition point where the net (sum of shortwave and longwave) radiation at the TOA transitions from the net warming of the equatorial and tropical regions to the net cooling of the higher latitudes.

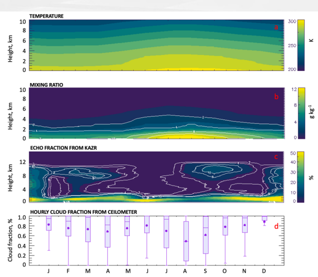


Fig. 1: Climatology of (a) temperature, (b) mixing ratio, (c) KAZR echo fraction, (d) hourly cloud fraction from ceilometer.

Dataset

The ENA merged dataset used in this work comprises **measurements and retrievals** between 2016 and 2022 at 1 minute resolution. It includes retrievals of total, cloud, and liquid water path (LWP), precipitable water vapor (PWV), vertical profiles of temperature and humidity (the latter scaled to microwave radiometer's PWV), cloud base and cloud top, vertical distribution of drizzle LWC and diameter below cloud base, and vertical velocity.

Methodology

The radiation calculations are carried out using the longwave and shortwave components of the line-by-line Rapid Radiative Transfer Model (RRTM). Inputs to the model are temperature, humidity, cloud liquid (ice) water content, as well as ocean albedo. It is noteworthy to mention that in this work we neglect aerosol because we don't have a reliable climatology to use. The shortwave and longwave components of the model are run every minute and the resulting fluxes are averaged over one hour.

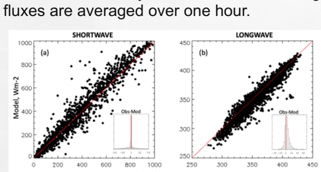


Fig. 2: Scatterplot of hourly averaged observations and corresponding model calculations for all marine cases.

Uncertainties

The following uncertainties are quantified:

- Underestimation of LWP in broken cloud scenes due to the large radiometer FOV leads to uncertainties in the surface fluxes.
- Undetected ice clouds by the KAZR cause uncertainties in calculation of the Outgoing Longwave Radiation (OLR).
- The uncertainty LWP retrieval affects surface LW fluxes calculations in clouds with LWP < 50 gm^{-2}.

> *"The Surface and Top Of the Atmosphere (TOA) radiation budgets are considered "Essential Climate Variables", or variables that critically contribute to our understanding of the Earth's climate."*

Surface radiation budget

Ground-based observations are particularly well suited to calculate the radiation arriving and leaving the Earth's surface with great accuracy because of our knowledge of the thermodynamic state of the boundary layer.

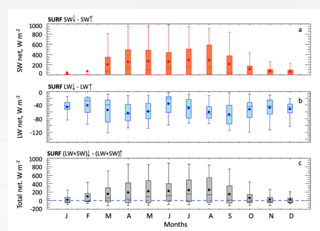


Fig 3: Surface radiation budget. (a) NET shortwave, (b) NET longwave, (c) NET total (SW+LW), and (d) cloud fraction for marine cases.

Net SW fluxes display a pronounced seasonal cycle with annual average of 184.7 W m^{-2} that represent a transition between the higher and lower fluxes reaching the subtropics and the higher latitudes. Increased cloud fraction in May-July reduces the shortwave net radiation reaching the surface. LW net fluxes under all sky conditions have little seasonal variability and annual average of -52.8 W m^{-2} (outgoing) but appears modulated by the cloud fraction (Fig. 3b, d) where higher cloud cover increases the LW downwelling radiation consequently reducing the net LW cooling.

TOA radiation budget

The top of the atmosphere (TOA) Earth radiation budget determines the exchange of energy between the Earth and the outer space and is of great importance to understand for example how changes in greenhouse gases affect radiation absorbed and released by the Earth. The average annual net SW is ~253 W m^{-2} indicating an upwelling SW flux of ~108 W m^{-2} due to reflection by clouds and atmosphere. The OLR displays an annual cycle with diminished outgoing radiation in winter correlated with lower tropospheric temperatures despite increased water vapor. However, a more important role in regulating the annual OLR is played by ice clouds.

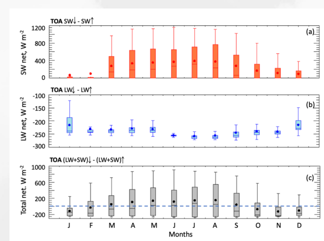


Fig. 4: TOA radiation budget: (a) NET shortwave, (b) NET longwave, (c) NET total (SW+LW) for marine cases.

The annual mean OLR is ~-241 W m^{-2}. The net total radiation at the TOA (SW+LW) shown in Fig. 4c displays a large interquartile range (~600 W m^{-2}) due to the diurnal cycle. The annual mean net total is negative Oct-Jan indicating a net loss of radiation by the Earth and becomes positive the rest of the year.

Summary and ongoing work

Accurate ground-based observations and retrievals at the ENA observatory can be used to estimate the surface, and TOA radiation budget. Future work includes using the data for process level studies, validation of E3SM and comparison with satellite data.

The radiation budgets estimated for the ENA are representative of the Atlantic Northeast region and provide the basis for further process studies and model evaluation.

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