ATOMIC 2020 Cruise Report for NOAA ESRL Physical Science Division (PSD) effort
Updated 3/12/20

Boundary Layer Observations and Processes Team
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(please acknowledge all of the above for data collection, processing, and quality control)

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i. Data Availability

Data were processed and posted to shared cruise folder daily. Our data will be kept up to date on the NOAA ESRL PSD FTP site maintained by the Boundary Layer Observations and Processes Team:

ftp://ftp1.esrl.noaa.gov/psd3/cruises/ATOMIC_2020/RHB/

Instructions:
Type address into web browser.
Login as Guest - no username or password needed.
File structure will mount in Finder from Safari, or will appear in the web browser for Chrome.

Please contact elizabeth.thompson@noaa.gov and chris.fairall@noaa.gov for more information.

We also successfully tested an Iridium-based file transfer system using a Rasberry Pi wireless router.

ii. Goal

Collect and analyze data between BCO and NTAS buoy that enables deeper understanding and quantification of cloud processes, the environments in which they either grow or dissipate, and how the ocean and atmosphere interact. Emphasis was also placed on better understanding the spatial variability of these processes. Clouds appear organized in about 4 regular patterns in the Caribbean. Beneath the cloud field, ocean eddies, fronts, and filaments produced rich surface variability in T, S, currents, and ocean color.

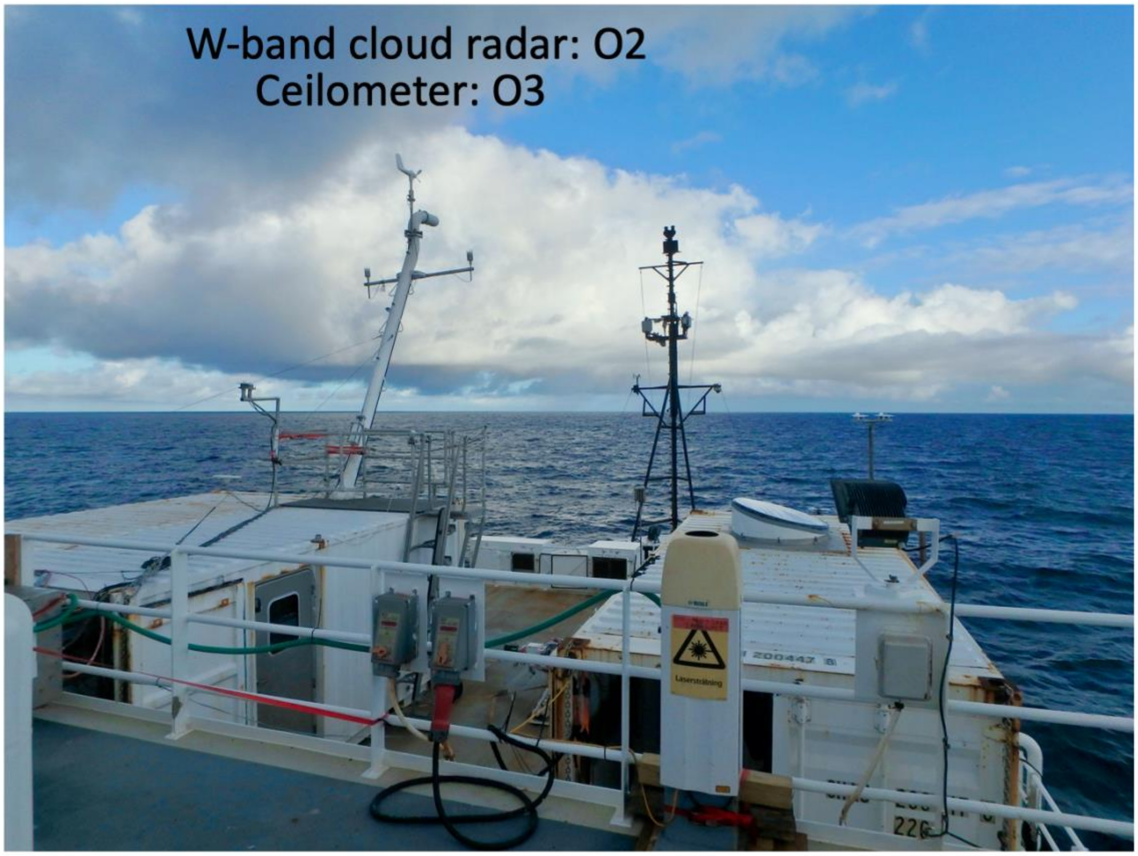
iii. Coordinated Measurements between Ship and Other Platforms

- For about 2 days during leg 2 on 8-9 Feb 2020, ship data was collected when Saildrone #1064 was within 0.5-1 nm away. The goal of this exercise is to compare fluxes, meteorological, and seawater data from each platform.
- During deployments, recoveries, and one day following first deployment, data was collected from the ship when 2 Wave Gliders and 6 SWIFT buoys were nearby. The goal of this exercise is to compare measurements of the same fields from different heights, the

autonomous assets provided high quality wave data for the ship, and the ship provided high quality data for checking and correcting near-surface data on the autonomous assets.

- Each time the 6 SWIFTs were deployed, the ship transited across the intended gradients meant to be sampled by SWIFTS, such as in SSS, SST, and surface currents. SST gradients during these deployments were on the order of 0.75 deg C in SST and 0.2-0.5 kt in current magnitude, with additional variability in current direction. The SST and SSS fronts were identified in real time with underway TSG data from the ship and the ship's ADCP.
- After SWIFTs and Wave Gliders were recovered at the end of leg 2 on local evening of 11 Feb, or early on 12 Feb in UTC time, the ship transited for several hours across an SST front in the upwind direction in order to study air-sea interaction, atmospheric, and ocean mixed layer variability. uCTDs were deployed continuously.
- The NOAA P3 visited the ship, SWIFT arrays, and Wave Gliders regularly to complete dropsonde circles, cloud modules, isotope measurements, and AXBT grids within 10-20 km around these assets. Meanwhile, remote sensing data being collected along these grids of surface ocean waves, clouds, and surface wind. Cloud microphysical characteristics and flight level meteorological properties were also collected in flight around the Brown, including upwelling infrared radiation. The goal of this exercise was to assess air-sea interaction, ocean-atmosphere coevolution, atmospheric vertical velocity, and the spatial variability of all these processes except for vertical velocity.

iv. Instrumentation Deployed



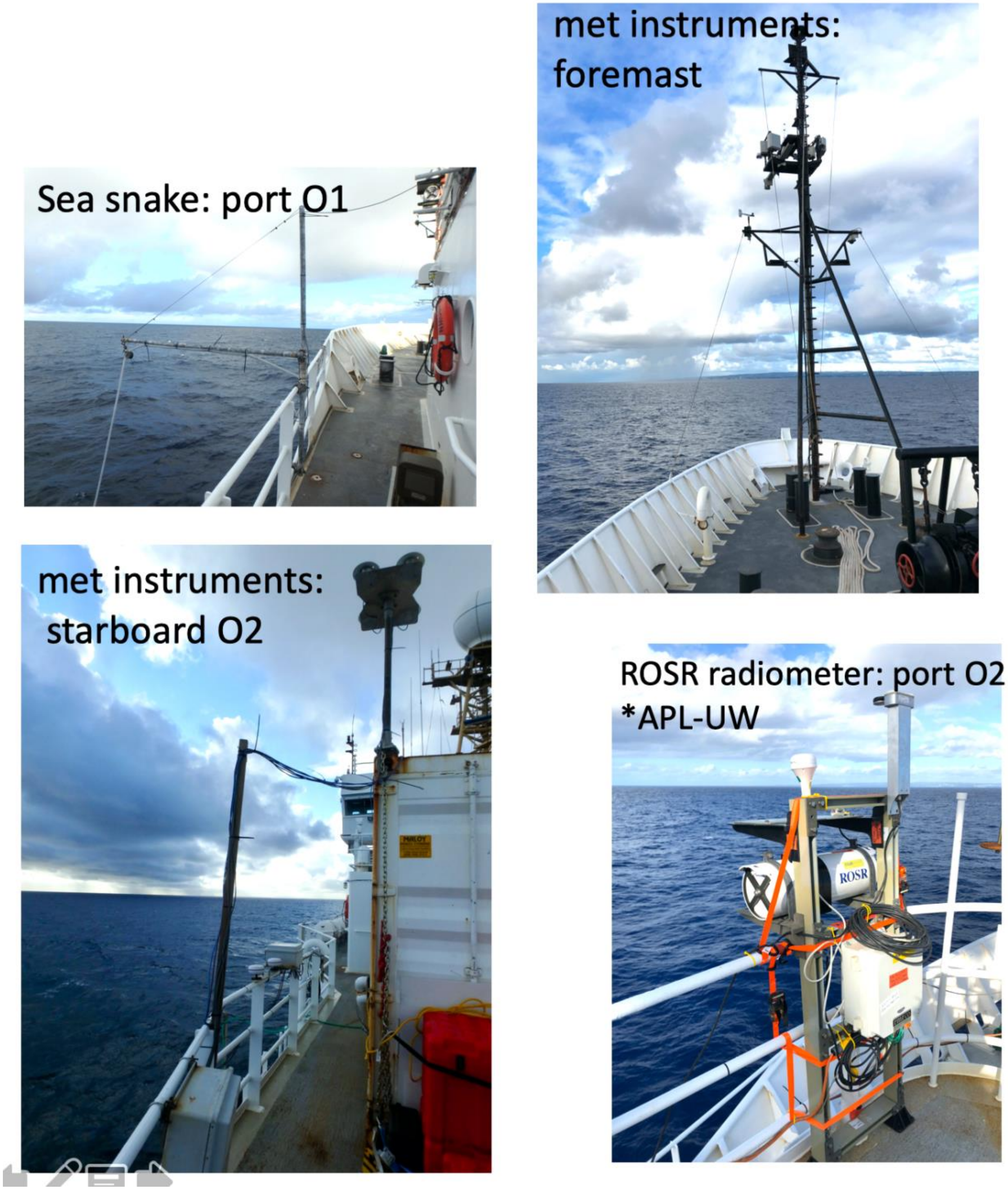


Fig. PSD9. Photo of instrumentation by NOAA ESRL PSD –except for ROSR radiometer (APL-UW).

University of Miami W-band Doppler vertically-pointing cloud radar:

- Measured vetical profiles of the non-precipitating and lightly-precipitating cloud population between 0-4.2 km height with 30 m vertical resolution and temporal update intervals on the order of minutes after averaging is completed in post-processing.
- The cloud radar worked on the 2nd cruise. Some test data was collected on leg 1, but it doesn't appear to be useful because it was only sensitive enough to see rain. We turned the transmitter and receiver off for the remainder of Leg 1, but kept the motion stabilization system running. The radar was fixed in between the 2 legs, Jan 26-28. The fix involved replacement of the low noise amplifier (LNA) and software fixes to ensure that the transmitted signal didn't leak as much into the received channel. A protocol was developed to ensure that the radar could be run without endandering the receiver.
- The radar had a 10 dB attenuator that prevented radar from resolving the full extent of non-precipitating cloud field. It appears that the radar is sensitive enough to resolve a portion of non-precipitation clouds with larger drops and most likely all clouds with rain drops. A more thorough comparison is needed between W-band, lidar, and ship rain gauges.
- The motion stabilization system had to be reset twice. This reset was done using software provided by Sergio Pezoa and Ken Moran. It is unclear how long it was off or under-functioning each time. During these two time periods, the radar data will appear to have coarser vertical and temporal resolution because the radar wasn't pointing to true vertical.
- The radar was turned off when we went back into port during Leg 2: 2-4 through 2-6.

Ceilometer:

- Measured vertical profiles of backscatter from refractive index gradients, such as differences between dry air above the trade wind inversion vs. the atmospheric boundary layer that is laden with aerosol, sea spray, and water vapor. Strong returns are produced across the cloud base, then the signal is attenuated above that level. The ceilometer will also detec a strong scattering return from the horizontally-sheared lateral edges of clouds. For example, during situations when the cloud top becomes sheared laterally away from cloud base, the ceilometer return will no longer correspond to cloud base and should be interpreted differently. Detrained, leftover cloud debris from mature, disspating clouds can also produce a detectable signal from the ceilometer when the original cloud base has already evaporated. Only the lowest altitude signals from the ceilometer should be interpreted as cloud base. A more thorough check should be conducted between ceilometer, lidar, and LCL height calculated from mixed layer air parcels (not surface parcels).
- The ceilometer worked at all times except for a 9-hour outage between 03:30 UTC Jan 30 to 00:30 UTC Jan 31. This issue appears to be due to incorrect or faulty file paths. We specified a new path to save files and this fixed the issue for the rest of the cruise. A screen shot of the GUI collecting the data was taken from an iphone to visually describe the missing data time period.

Laser altimeter:

- A downward-looking 1-D Reigel laser altimeter was deployed on the foremast. This measures statistics and properties of ocean surface gravity waves. The data have not been investigated yet.

Meteorological and seawater characteristics, and air-sea fluxes:

- Data were collected continuously throughout the cruise from a variety of oceanic and atmospheric instruments. The data are most trustworthy when the ship was pointed into the wind. When wind blew from stern to bow, or in other words when the ship was transiting or pointed downwind, flow distortion and deck heating corrupted the data quality. Thankfully, the ATOMIC cruise plan allowed for the wind to blow onto the bow most of the time.
- The seawater measurements are slightly less trustworthy when ship speed was nearly zero knots. During these times, the ship's propulsion system mechanically stirred the water at the ship.
- After the first few days of Leg 1, a few additional parameters of ship-based (equipment from Ronald H. Brown) data were added to the files processed and produced by NOAA PSD.
- The readme of these met, seawater, and flux data describes known issues with the data quality of some ship variables (IR radiometer was off, foremast wind wasn't good, RH, T, and P were slightly off) and NOAA ESRL PSD variables (one of the solar radiometers was inconsistent and so wasn't used). The NOAA-supported COARE 3.5 algorithm as used to compute estimates of bulk, eddy covariance, and inertial dissipation fluxes at 10-min resolution. These include evaporation (latent heat flux), sensible heat flux, and wind stress (momentum flux).
- An infrared radiometer system, ROSR, from APL-UW was deployed to measure skin-level sea surface temperature. ROSR = Remote Ocean Surface Radiometer. A KT-15 infrared radiometer is contained in a system built by RMR, Co. in Seattle, WA. The data might not be completely well calibrated. Corrections are needed. An unknown software and/or connection error occurred between leg 1 and leg 2 that prevented measurements from being collected during leg 2. However, the same infrared T_{skin} measurements are being made by the MAERI system and will be incorporated into the cruise dataset when ready (collaboration with Peter Minnet and U Miami).

v. Work to be Completed during 2020

- Add the zonal and meridional components of near-surface ocean current from ship ADCP measurements. Kyla Drushka (APL-UW) provided these from the ship's ADCP data.
- Add zonal and meridional components of wind and wind stress.
- Calibrate the ROSR measurement of skin T. Compare to MAERI measurement of same thing from U Miami.
- Add MAERI measurement of skin T to cruise dataset
- Develop a better understanding of the measurement capability of the U Miami W-band radar deployed on the ship given its lower sensitivity compared to the NOAA PSD W-band radar.

vi. File Information and Formats

Data fields and their order are subject to change during post-processing.

Readme for file of flux, met, seawater data at 10-min resolution:
readme_ATOMIC_2020_10min_flux_met_sea_data.txt

Readme file for met, seawater data collected at 1-min resolution:
readme_ATOMIC_2020_1min_met_sea_data.txt

Readme file for ceilometer cloud statistics:
_ceilometer_readme.txt

vii. Examples of Data Collected

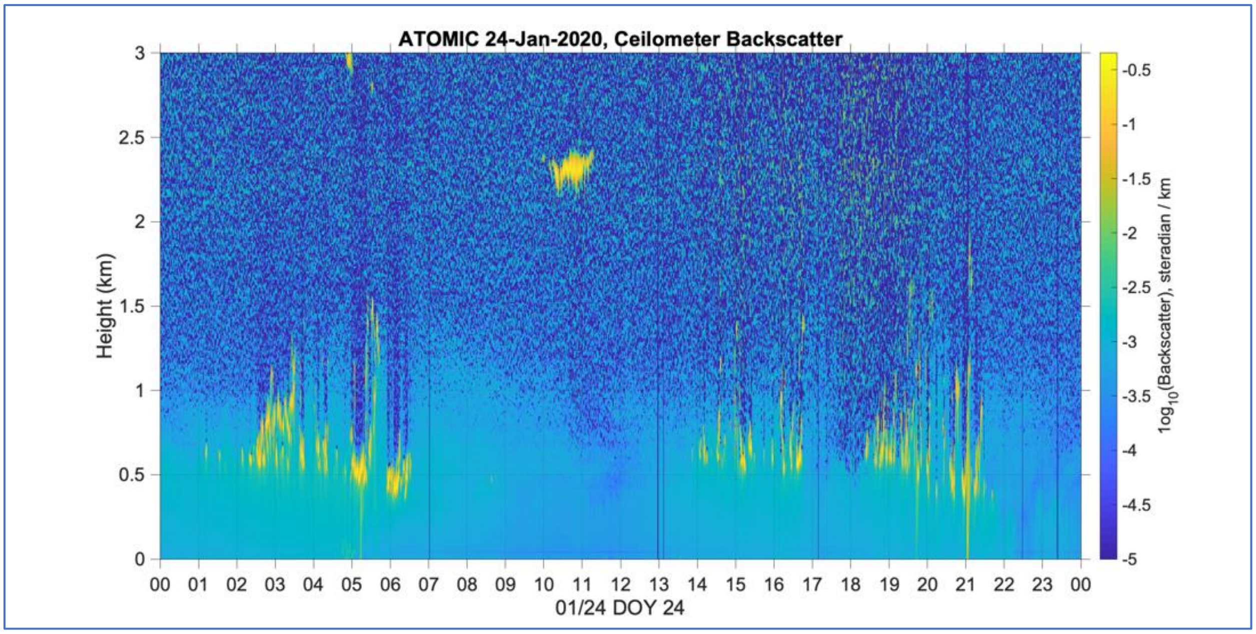


Fig. PSD1. Ceilometer daily plot in time vs. height format of scattered signal from aerosols, water vapor, and clouds.

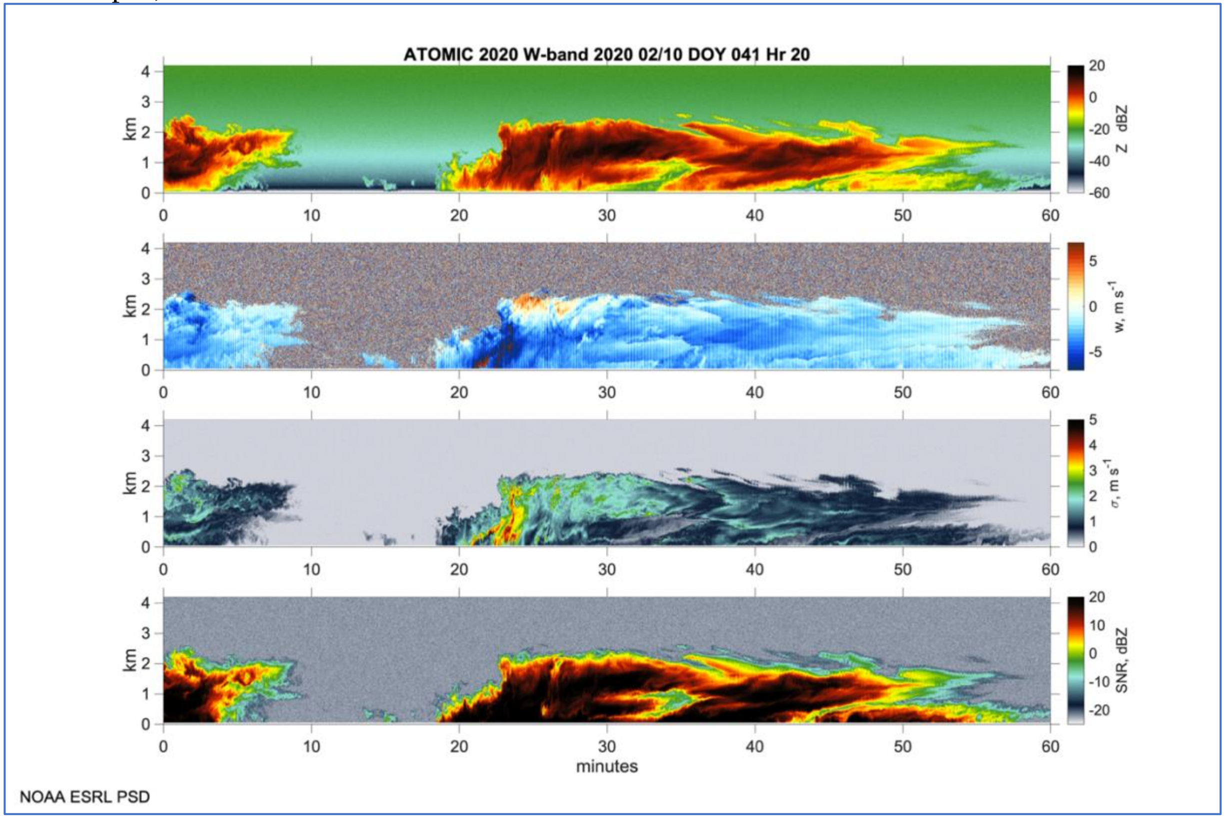


Fig. PSD2. W-band vertically-pointing radar data from one hour: Z: reflectivity (dBZ), w: vertical velocity (m s^{-1}, blue toward radar, red away from radar), spectral width (m s^{-1}), σ: spectral width (m s^{-1}), SNR: signal to noise ratio (dB).

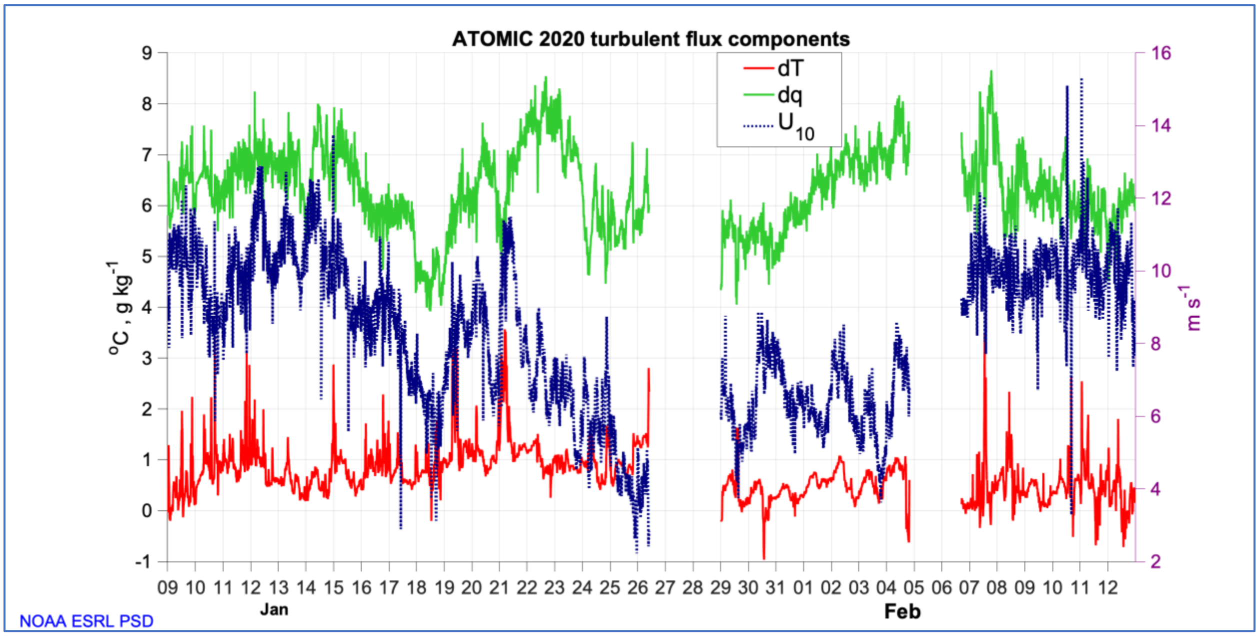


Fig. PSD3. Measurements of the air-sea humidity and temperature gradients, as well as wind speed adjusted to 10 m height.

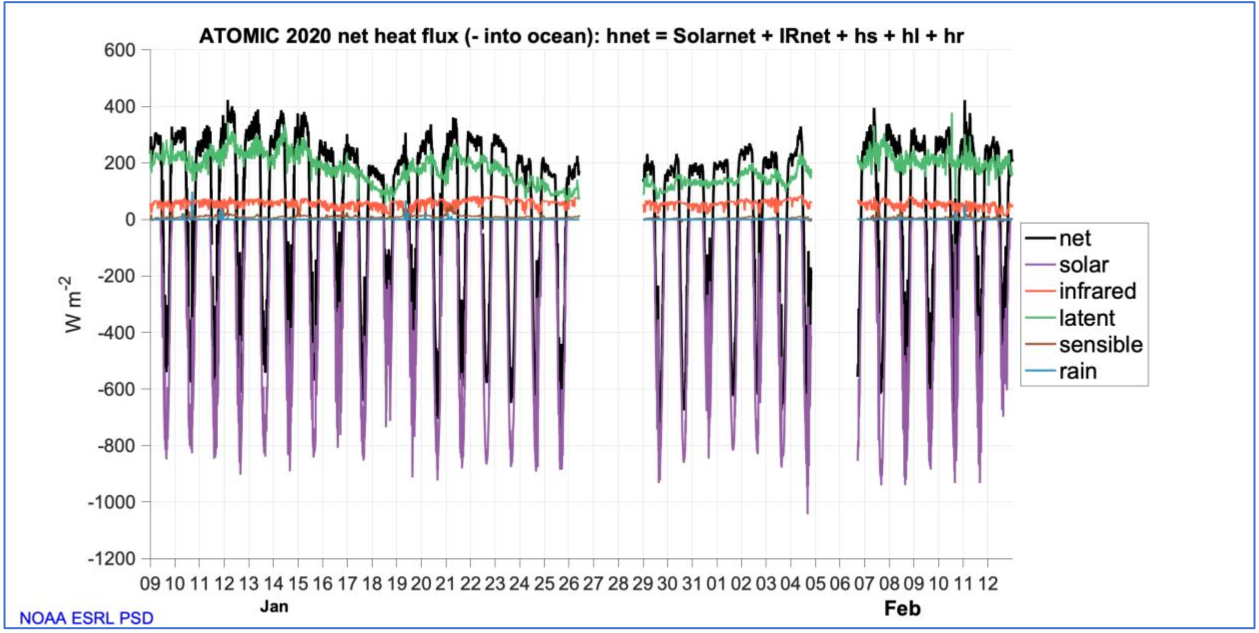


Fig. PSD4. Bulk net heat flux and its components. Positive = into the atmosphere, Negative = into the ocean.

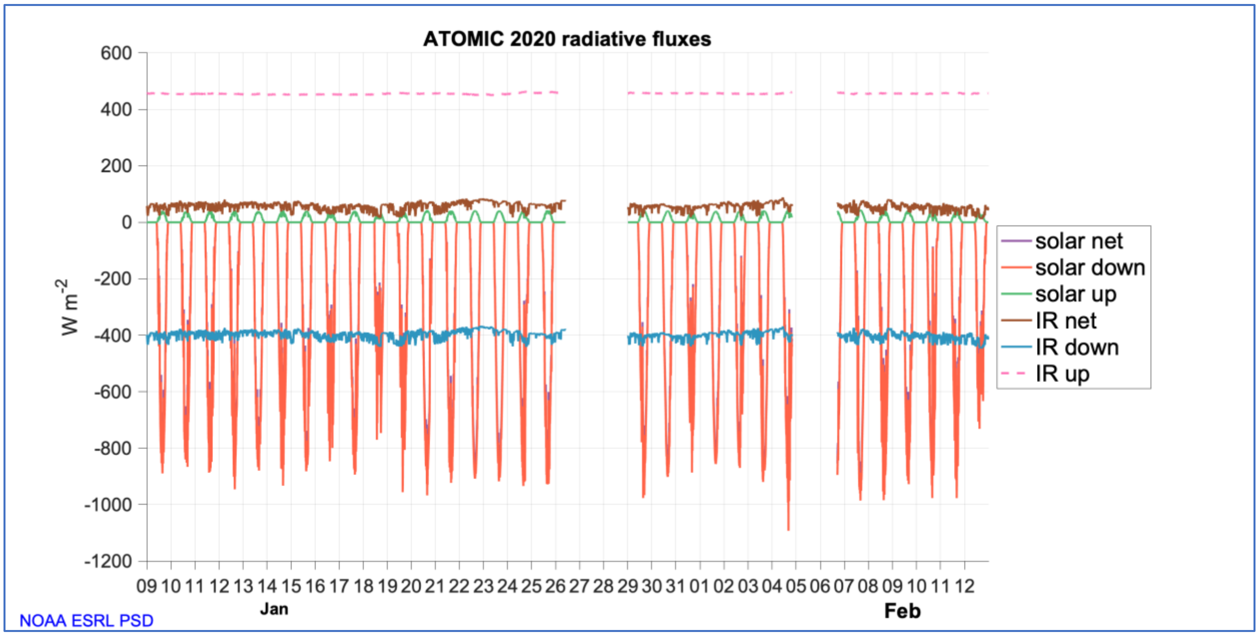


Fig. PSD5. Radiative fluxes measured or calculated.

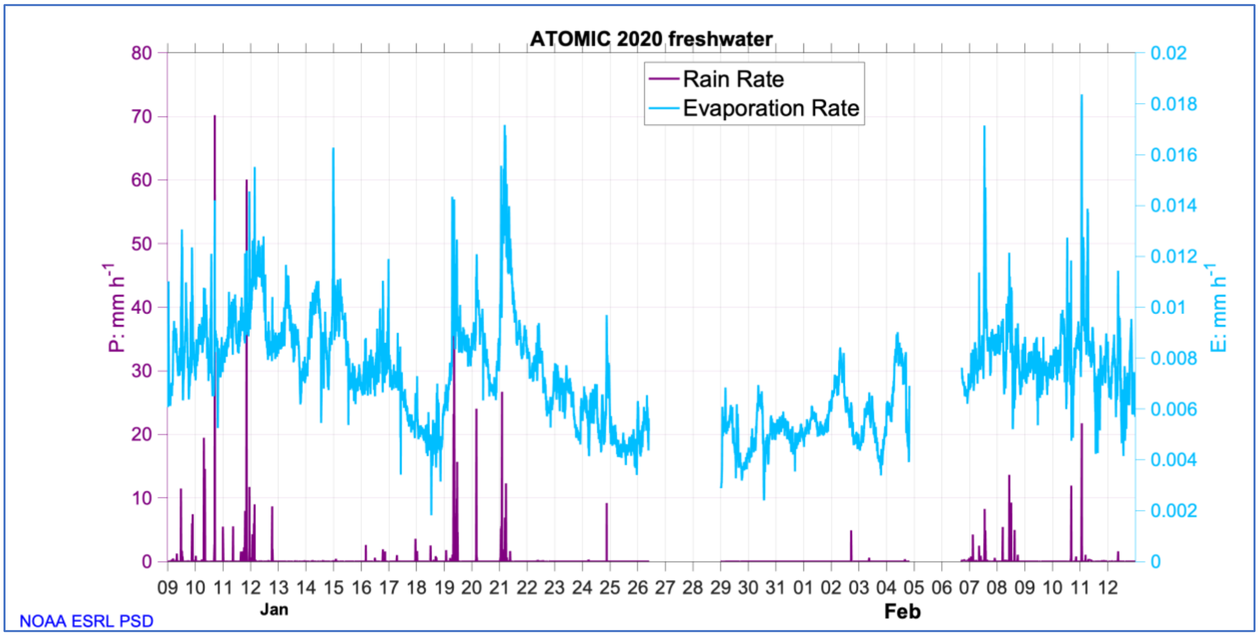


Fig. PSD6. Evaporation and rain rate (note different y-axis scales).

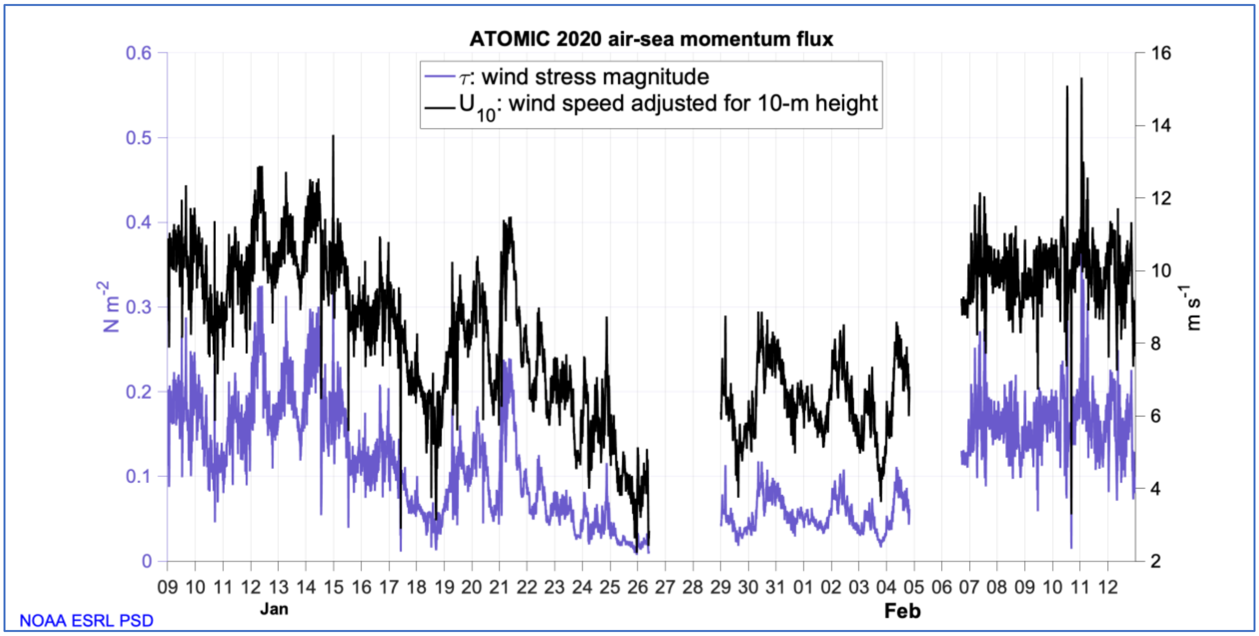


Fig. PSD7. Wind stress and wind speed adjusted to 10 m height.

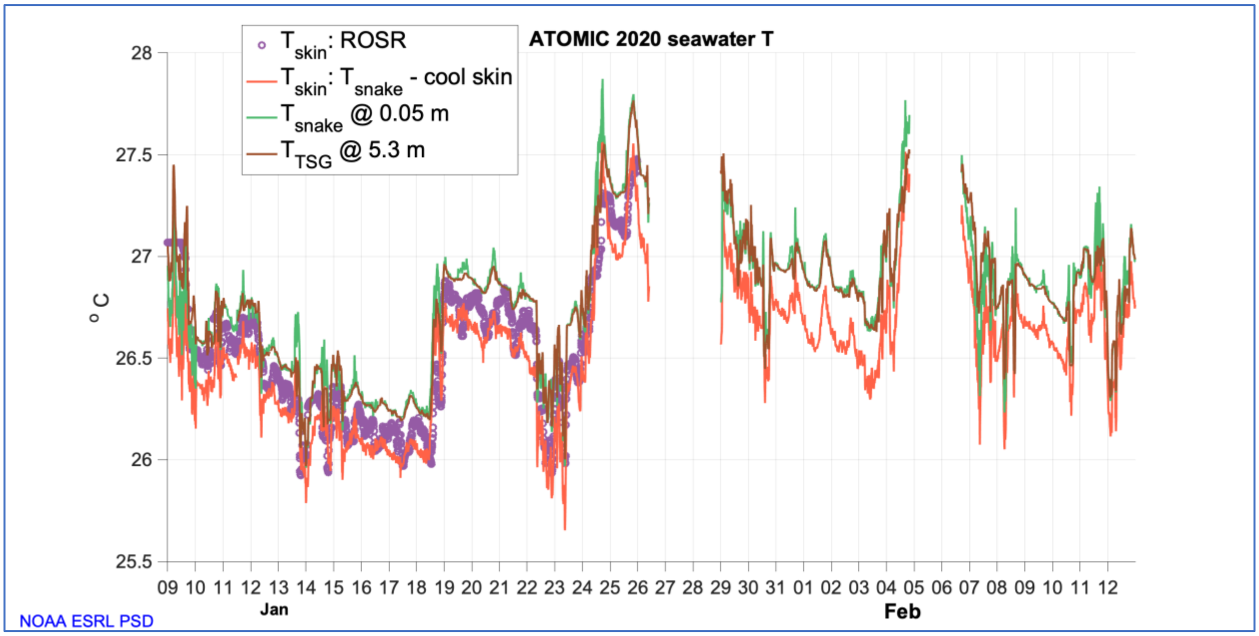


Fig. PSD8. Seawater measurements at different near-surface depths, or calculated versions of sea surface temperature at skin level.