Tegan Blaine

Scripps Institution of Oceanography, La Jolla, CA

Atmospheric Ar/N_2 Measurements as a Tracer for Air-Sea Heat Flux

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Overview

The international community has become increasingly aware of evidence for the increase in average global temperature due at atmospheric buildup of greenhouse gases. The resultant climate changes, ranging from ecosystem effects and changes in rainfall patterns and increased extreme weather events to the rise in the ocean surface height, have wide-ranging implications for human populations: food security, refugee crises due to disappearing islands or retreating coastlines, access to clean water, and health issues are all linked to environmental change. Yet the role of the ocean in storing heat and taking up important greenhouse gases from the atmosphere is little understood. Both of these roles depend on one major variable: heat flux between the ocean and atmosphere.

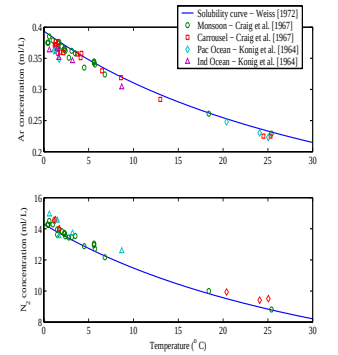


Figure 1. Temperature primarily controls ocean surface concentrations of argon (top) and nitrogen (bottom).

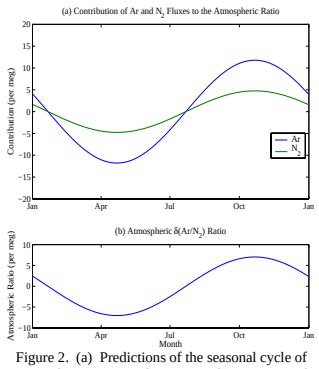


Figure 2. (a) Predictions of the seasonal cycle of atmospheric argon and nitrogen. (b) Net atmospheric $\delta(Ar/N_2)$ cycle, measured in units of per meg (1 part per million ~ 108 per meg).

Challenging Measurements

Measuring the change in the Ar/N_2 ratio is technically challenging because argon is almost 1% of the atmosphere and nitrogen is about 78%, whereas we are looking at changes on the order of parts per million. Continuous measurements off the California coast have proved most useful, whereas flask measurements face larger technical difficulties due to storage and shipping constraints. Some of the biggest problems with the continuous measurements have involved splitting of the air stream at the inlet and stability of reference tanks. Tanks are stored in an insulated box and are now using a new inlet to reduce problems.

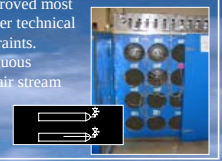
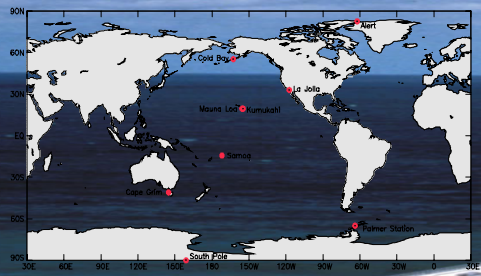


Figure 3. Location of Scripps flask stations.



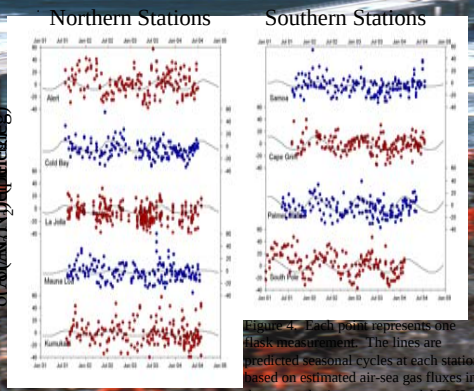
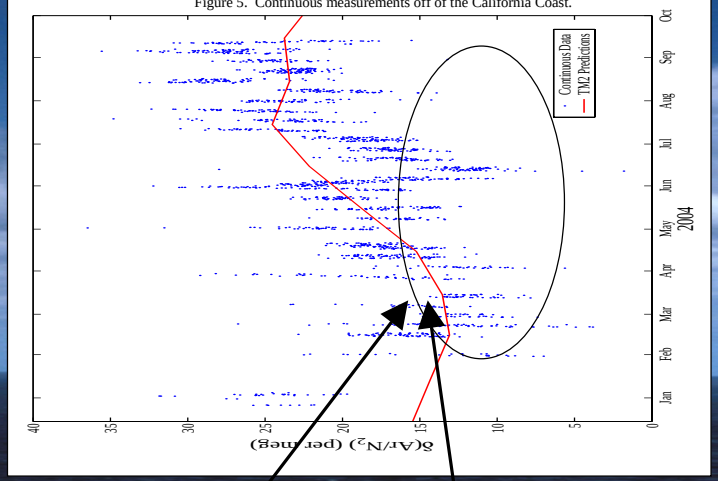


Figure 4. Each point represents one flask measurement. The lines are predicted seasonal cycles at each station based on estimated air-sea gas fluxes in the atmospheric transport model TM2.

Figure 5. Continuous measurements off of the California Coast.



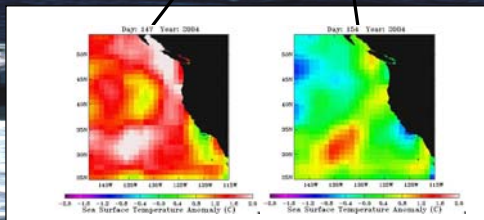


Figure 6. Ocean temperature anomalies in the Eastern Pacific. The continuous measurements are most likely reflecting these large-scale changes in ocean temperature. Hot anomalies correspond to increases in Ar/N_2 concentration, whereas, one week later, cold anomalies correspond to decreases.

$\delta(Ar/N_2)$: Tracer of Air-Sea Heat Flux

Argon and nitrogen concentrations in the ocean depend intimately on temperature. As the ocean warms, they are released to the atmosphere; as the ocean cools, they are taken up and their atmospheric concentrations drop. We can measure the atmospheric $\delta(Ar/N_2)$ ratio as a proxy for air-sea heat flux, since direct measurements are notoriously difficult to make.

Conclusions

Continuous measurements are reflecting both local and large-scale changes in air-sea heat flux. Besides giving insight into the seasonal cycle of heat flux and how the ocean may control atmospheric cycles of important greenhouse gases, measurements may be important long-term for providing an estimate of ocean warming due to climate change.

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