Measurements and Models of Atmospheric Potential Oxygen (APO)

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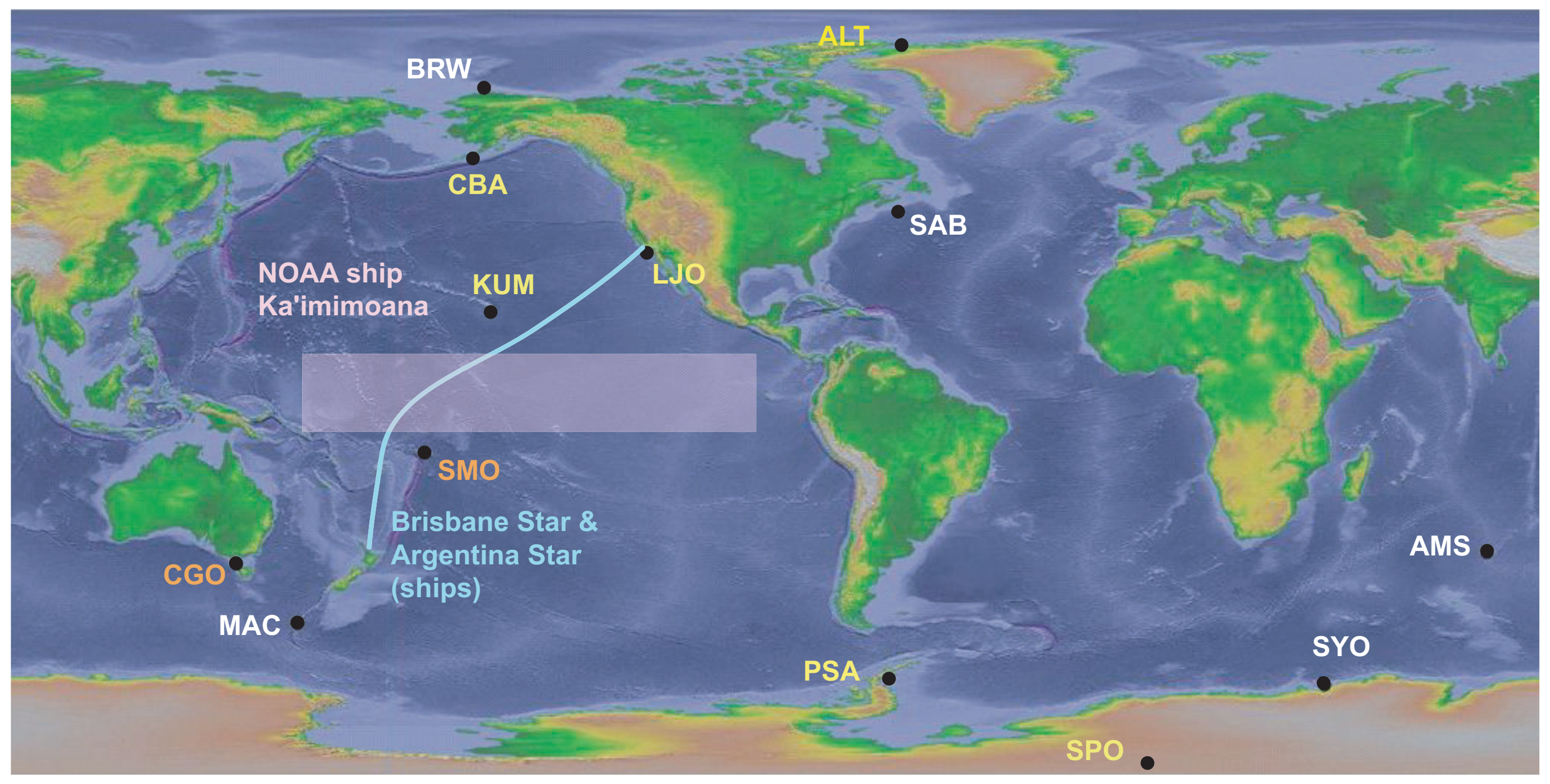

Figure 2: Locations at which samples comprising this dataset were collected. White text: Princeton Yellow: Scripps Orange: Princeton & Scripps. Abbreviations for the land stations are given at right.

ALT	Alert (Canada)
AMS	Amsterdam Island (France)
BRW	Point Barrow, Alaska (USA)
CBA	Cold Bay, Alaska (USA)
CGO	Cape Grim, Tasmania (Australia)
KUM	Cape Kumukahi, Hawaii (USA)
LJO	La Jolla, California (USA)
MAC	Macquarie Island (Australia)
PSA	Palmer Station, Antarctica (USA)
SAB	Sable Island (Canada)
SMO	American Samoa (USA)
SPO	South Pole, Antarctica (USA)
SYO	Syowa Station, Antarctica (Japan)

Poster #137

Presenter: Mark Battle

SUMMARY

The goal: To gain insight into the controls on the oceanic carbon cycle. These controls include ocean circulation, biological activity and nutrient dynamics. Along the way, we may learn more about atmospheric transport and air-sea gas exchange.

The approach: Atmospheric Potential Oxygen (APO) provides insight into these processes [*Stephens et al.*, 1998]. The spatial structure of APO depends upon the interaction of ocean biology, solubility chemistry and general circulation, fossil fuel combustion and atmospheric circulation (including rectifiers). We measure the annual-mean meridional gradient in APO. We then compare this measurement with predictions from empirically based air-sea flux estimates, paired with atmospheric transport models. Examining disagreements sheds light on model weaknesses.

The results: We have a multi-year dataset in hand that captures meridional gradients in APO. The two most prominent features are a modest interhemispheric gradient (relative to earlier studies) and a prominent equatorial bulge. We conclude that the interhemispheric gradient is evolving over time, and the equatorial bulge is generally well-predicted by our modeling approach. The seasonal cycles of APO show some signs of an excessive seasonal rectifier near the Aleutian Islands in the model, and smaller data-model discrepancies at other sites.

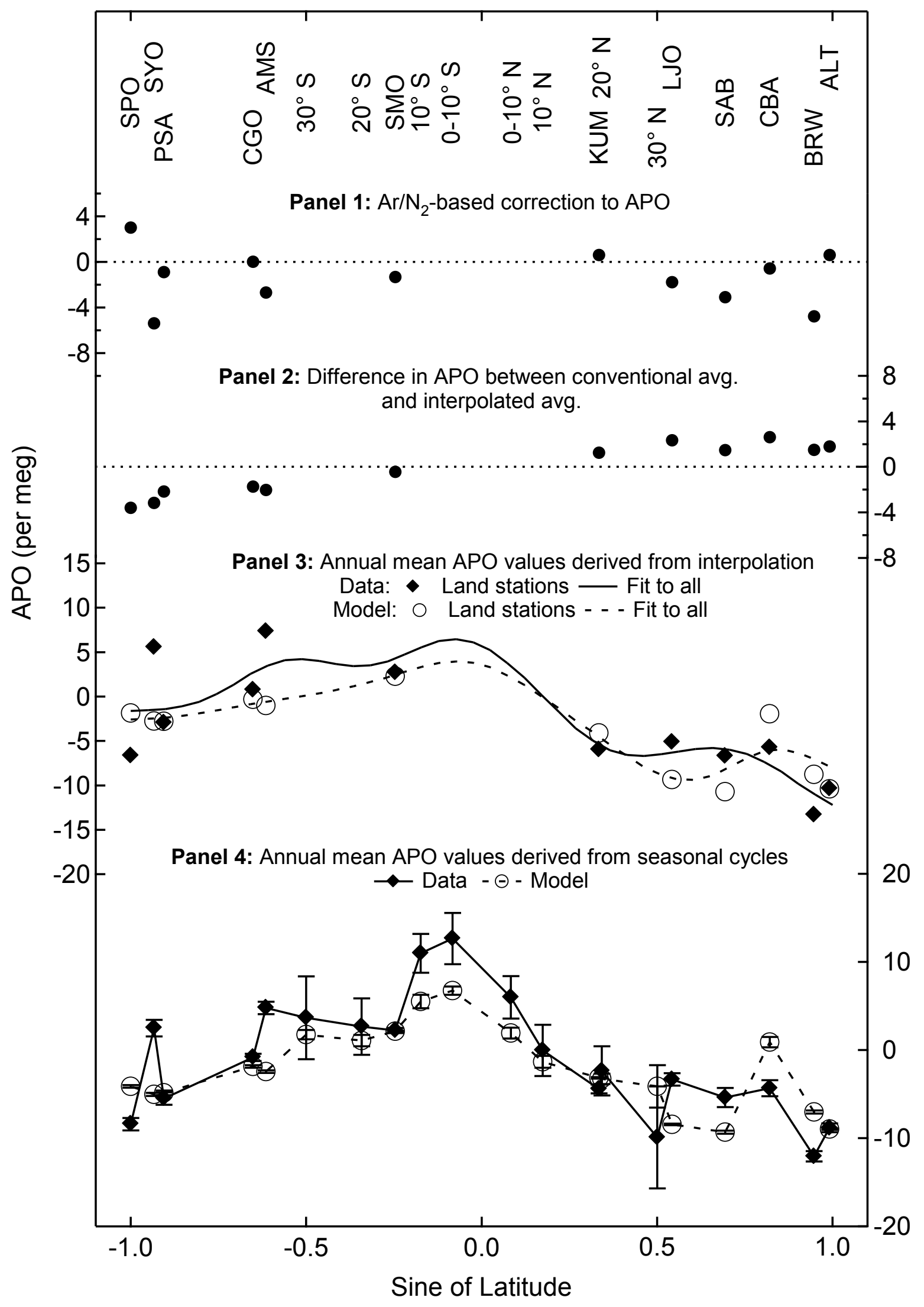

Figure 1: The climatological annual average meridional gradient in APO, both predicted (dashed) and observed (solid). Panels 3 & 4 show the dependence of the result on different treatments of the data (see "More Details" at right). Panel 1 shows the size of corrections applied to measured APO values based on concurrent measurements of the atmospheric Ar/N_2 ratio. The corrections are intended to remove site-specific artifact associated with sample collection [Battle *et al.*, 2003].

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MORE DETAILS

What is APO? As defined by *Stephens et al.* [1998], Atmospheric Potential Oxygen (APO) is an atmospheric tracer that is conservative with respect to terrestrial biological activity. Changes in APO result from fluxes of carbon and oxygen to and from the oceans, and to a lesser extent, combustion of fossil fuels. APO is defined as:

$$\text{APO (per meg)} = \delta(O_2/N_2) + 1.1*4.8*[CO_2]$$

where "per meg" denotes a fractional change of 1 part in10^6 relative to a standard gas [*Keeling and Shertz,* 1992]. The factor of 1.1 ensures that CO_2 and O_2 fluxes to/from the terrestrial biota do not change APO. The factor of 4.8 converts from $[CO_2]$ in ppm, to per meg.

Our dataset: Atmospheric samples are collected periodically in paired glass flasks at the locations shown in Figure 2. The samples are analyzed for $\delta O_2/N_2$ and $\delta Ar/N_2$ at Princeton University [*Bender et al.*, 1994, *Bender et al.* In press.] and the Scripps Institution for Oceanography [*Keeling et al.*, 1998] and for CO_2 at Scripps and NOAA/ CMDL-CCGG [*Conway et al.*, 1994].

Due to logistical and technical limitations, data density and quality varies over the period of study. Data availability is summarized in Figure 3.

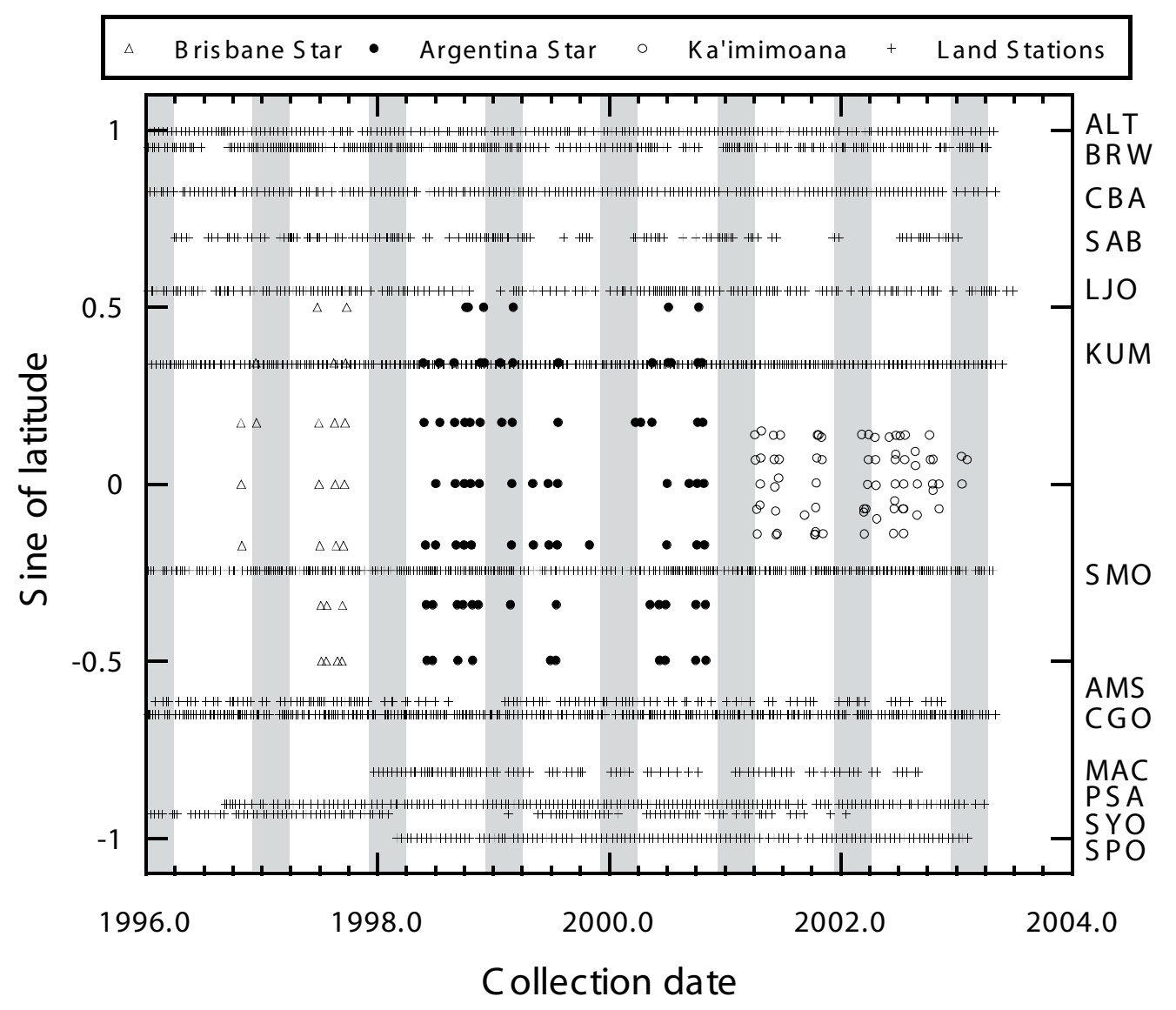

Figure 3: Time and latitude of collections comprising this dataset. See Figure 2 for station abbreviations. Each point represents a pair of flasks.

Climatological annual average gradients from sparse data: We begin by removing the secular trend in APO and effectively placing the Princeton and Scripps records on a common scale. To do so, we average the trends [*Thoning et al.,* 1989] for CGO and SMO in the Princeton dataset, and likewise for the Scripps record. These average trends are subtracted from all stations in the respective lab's datasets. After detrending, we collapse all records into a single climatological year. We then construct annual mean gradients using two approaches: latitude-time interpolation, and fitting of seasonal cycles.

Latitude-time interpolation: We divide the set into time-slices of roughly 2 weeks in duration, yielding a series of meridional transects. We fit each transect using a Butterworth filter [*Tans, Conway and Nakazawa,* 1989]. Because the data density is not constant through the climatological year, we cannot simply average all transects. Instead, we define periods when APO is roughly static, average all fits within each period, and then average the periods together (weighted by duration) to form an annual average. Results of this method are shown in Panels 2 & 3 of Figure 1.

Offsets of seasonal cycles: At each land based station, and each of 8 distinct shipboard latitudes, we fit the climatological seasonal cycle with a function of the form $APO = \alpha + \beta \sin(2\pi t + \phi)$ where α is the "offset" and gives the climatological annual mean value of APO at that stations. Results of this method are shown in Panel 4 of Figure 1.

The model: The model results presented here (Panels 3 and 4 of Figure 1) come from an approach described by *Gruber et al.* [2001]. Briefly stated, an OGCM is used to infer oceanic oxygen fluxes by scaling predicted ocean oxygen concentrations (more precisely, O_2^*, defined as $O_2^* = O_2 - r_{O_2:PO_4}PO_4$) to match observations of this property. These inferred fluxes of O_2 , along with air-sea CO_2 fluxes from *Takahashi et al.* [1999], seasonal O_2 fluxes from *Garcia and Keeling* [2001], and fossil fuel CO_2 fluxes from *Marland et al.* [1998], were used as a lower boundary condition for an atmospheric tracer transport model (TM3 [*Heimann and Koerner,* 2003]). Model output was processed in a fashion identical to the data. In particular, we sampled the modeled fields with the same spatial and temporal sparseness present in the observations.

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