Beryllium-7 in soils and vegetation along an arid precipitation gradient in Owens Valley, California

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[1] Beryllium-7 is a potentially powerful tracer of atmospheric deposition and recent sediment transport, but the quantity and distribution of ^{7}Be on arid landscapes have not been described. We measured ^{7}Be in soil, vegetation, and dust in Owens Valley, California, and describe its distribution in aridisols and mollisols to evaluate its potential as a sediment tracer in desert environments. Beryllium-7 in vegetation and the upper few cm of soil is low but detectable (>20 Becquerels [Bq] m^{-2}). Surface inventories of ^{7}Be at sites on the valley floor vary by a factor of five between the end of the rainy season (April) and the end of the dry season (November). In mollisols, live grasses hold ~50 Bq ^{7}Be m^{-2}, which is on the order of half of the total springtime surface inventory. We find that within-site variability at the 5 m scale is 5 to 22% (1 relative standard error) and can be explained by localized rain shadowing and erosion, but between site variability at the km scale can be explained by differences in rainfall. Our alpine site has more than triple the inventory that is predicted from the rainfall-^{7}Be flux relationship that we generate using our springtime soil measurements and previously reported deposition data. Dust deposition does not appear to contribute significantly to ^{7}Be inventories, but anomalously high ^{7}Be on the eastern flank of the Sierras may be explained by a higher altitude air mass source and better scavenging efficiency of snow. **Citation:** Kaste, J. M., A. J. Elmore, K. R. Vest, and G. S. Okin (2011), Beryllium-7 in soils and vegetation along an arid precipitation gradient in Owens Valley, California, *Geophys. Res. Lett.*, *38*, L09401, doi:10.1029/2011GL047242.

1. Introduction

[2] Cosmogenic ^{7}Be ($T_{1/2}$ = 53 d) is formed primarily in the stratosphere and upper troposphere as neutrons spallate gas molecules [*Lal et al.*, 1958]. Most ^{7}Be is delivered to the surface by wet deposition, and inventories on temperate and tropical land are 200 to 1000 Bq m^{-2} [*Kaste and Baskaran*, 2011]. Meteoric isotopes of Be (^{7}Be and ^{10}Be) are being applied more frequently as tracers of surface age, sediment transport, and storage in a wide range of environments [*Walling et al.*, 2009; *Willenbring and von Blanckenburg*, 2010], but this work has been entirely constrained to mesic environments. The first step in evaluating the potential of meteorically-delivered radionuclides as tracers in arid and semi-arid environments is to constrain seasonal and spatial depositional variability, and to quantify the relationship between monthly precipitation and projected surface inventories. The lack of published measurements of ^{7}Be in arid environments is perhaps due to the perception that ^{7}Be would be difficult to detect in areas of low rainfall. However, there is an increased need for methods that quantitatively describe sediment transport processes in arid and semi-arid environments, which cover 30% of the earth's surface and are particularly susceptible to wind erosion [*Elmore et al.*, 2008]. Here we report on the distribution of ^{7}Be in soils and vegetation sampled periodically between November 2006 and May 2010 in Owens Valley, California to evaluate its use as a sediment tracer on arid landscapes.

2. Methods

[3] Our study area is in Owens Valley, California with valley floor sampling sites located near the towns of Bishop and Big Pine (Figure 1). We also sampled at 2024 m on the eastern slope of the Sierra Nevada Range, to the west of Big Pine ("Site 0"). The climate, vegetation, soils, and geology of this region are well characterized because the valley supplies the city of Los Angeles with nearly a third of its drinking water [*Reheis*, 1997; *Danskin*, 1998; *Pretti and Stewart*, 2002; *Elmore et al.*, 2006]. An annual precipitation map published by *Danskin* [1998] was the most detailed interpretation of precipitation patterns applicable to this study. Across our ~30 km study area on the valley floor, precipitation varies from approximately 10 to 16 cm per year, but our high elevation site above the valley floor receives approximately 25 cm of precipitation per year, mostly occurring as snowfall. To capture small differences in precipitation over our study area, we interpolated between isohyets provided by *Danskin* [1998] using inverse distance weighting to determine average annual precipitation at each sampling site (Table 1).

[4] Vegetation of the region is characteristic of the Great Basin. Valley floor sites have two grass and three shrub species, all of which are perennial. Saltgrass (*Distichlis spicata* (L.) Greene) and alkali sacaton (*Sporobolus airoides* Torr.) are the dominant grasses, and the dominant shrubs are Nevada saltbush (*Atriplex lentiformis* ssp. *torreyi*), rubber rabbitbrush (*Ericameria nauseosa*), and greasewood (*Sarcobatus vermiculatus*). Grass cover is generally higher and more uniform at sites with shallow groundwater [*Elmore et al.*, 2006], although all sites have at least some shrub cover. Site 0 is characteristic of high elevation, sandy well-drained soils commonly found on glacial moraines and alluvial fans along

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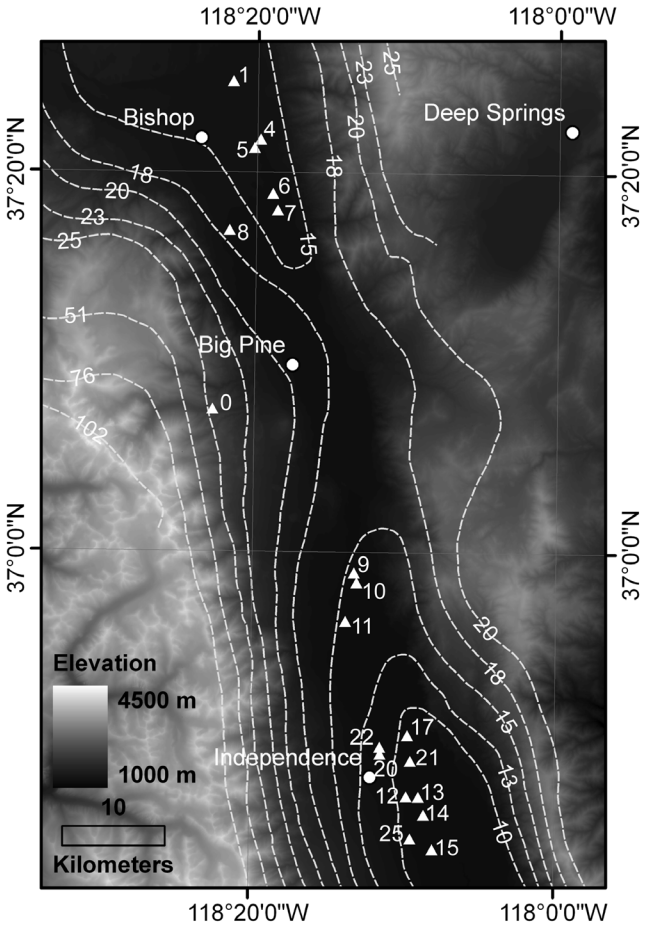

Figure 1. Sampling locations in Owens Valley, CA. The town locations are marked with circles, and triangles identify sites where soil and vegetation (if present) were collected for ^{7}Be analysis. Dashed lines are contours of annual rainfall (in cm), which are from the work of *Danskin* [1998].

the eastern flank of the Sierra Nevada, where vegetation is dominated by Sagebrush (*Artemisia tridentata* Nutt.).

[5] We sampled soils and vegetation for ^{7}Be measurements in November 2006, February 2008, May 2008, May 2009, and May 2010. To calculate surface inventories of ^{7}Be (in Bq m^{-2}), soil and vegetation samples were always collected over a defined area (typically 400 cm^{2}) that we set using a template. Vegetation that crossed this area was clipped, dried, and weighed to quantify biomass (grass) density. After vegetation was clipped, vertical soil profiling (at ~1 cm resolution) was done to capture the depth-distribution of ^{7}Be. At one mollisol site (Site 1) where roots made field sectioning impossible, two soil monoliths were extracted, each with a surface area of 400 cm^{2} and a depth of 20 cm. The monoliths were moistened using deionized water, frozen overnight in a −40° C chest freezer, and then sawed into ~$^{3}/_{4}$ cm slices using a diamond rock saw. Exact dimensions were recorded for each slice to calculate bulk density which is required for projecting surface inventories. In addition to soil profiling, we collected bulk soil cores from 0 to 2.5 cm or 0 to 5 cm depth. For the bulk 0–5 cm cores, we set up 25 m transects, sampling every 5 m. The field sites are heterogeneous, particularly the aridisols which have patches of vegetation, patches of bare ground, and broad depressions which appear to be areas that were recently eroded by wind. We took careful field notes to document the proximity of vegetation and whether or not roots were exposed which could indicate recent erosion at a sampling point. We maintained dust collectors near Bishop using four stems with a Big Spring Number Eight (BSNE) aeolian sediment trap (Custom Products and Consulting, Big Spring, TX) on each. The BSNE aeolian sediment trap was set at a height of 1 m on each stem, and the stems were placed at 50 m intervals which were open from September 2009 to May 2010. A detailed description of the methodology, detection limits and uncertainty of the gamma assay of ^{7}Be are given in the auxiliary material.[1] Soil organic matter content was determined in the profiles by measuring the mass lost during 8 hours of ignition (475°C).

3. Results and Discussion

3.1. General Distribution of ^{7}Be in Soils and Grass

[6] A summary of the measured ^{7}Be inventories are presented in Table 1. The lowest surface inventory measurements were made in November, 2006, and highest in February, 2008. This seasonal variation is most certainly controlled by the bimodal distribution of rainfall in this region, with >80% of the precipitation occurring between November and May (Figure S1). Dry deposition of ^{7}Be to landscapes is not typically considered to be significant in temperate to tropical zones, because production rates of comsogenic ^{7}Be are highest in the stratosphere, thus delivery of ^{7}Be to the earth's surface occurs mostly during convective storms [*Baskaran*, 1995]. However, in arid regions, dry deposition could be significant if soil containing ^{7}Be was eroded from one area of our study region and deposited in another by dustfall; we assess the effects that this process might have on ^{7}Be inventories below.

[7] We collected at least two high-resolution (≤1-cm sampling increments) depth profiles at each site to determine how ^{7}Be is distributed vertically in soil profiles. In all cases, ^{7}Be was undetectable beneath 3-cm depth in the soil, and generally, ^{7}Be was confined to the vegetation and upper 2-cm of soil at the Mollisol Sites. This limited distribution can be explained by the strong tendency of the Be^{2+} ion to adsorb to organic matter and mineral grain surfaces in near-neutral pH conditions [*You et al.*, 1989]. A representative depth-distribution for ^{7}Be and soil organic matter at a Mollisol site and an Aridisol site are given in Figure 2. Generally, the Aridisol sites tend to be sandier, and have less organic matter (<5%), which may allow for deeper penetration (to 3 cm) of the ^{7}Be as rainfall percolates through, in contrast with the Mollisol profiles with higher soil organic matter (15–35%) in the upper part of the profile. While organic matter should decrease the hydraulic conductivity of the upper few cm of soil, limiting ^{7}Be depth penetration, the grass itself at the Mollisol sites may also slow down raindrops which could further limit fallout radionuclide advection rates here. Shrubs, which dominate at the Aridisol sites, tend to trap less rainwater than grasses, and the woody stems of shrubs create larger conduits for flow [*Bhark and Small*, 2003]. Other diffusion-like processes, such as wetting/drying cycles could conceivably mix ^{7}Be to depth in

[1] Auxiliary materials are available in the HTML. doi:10.1029/2011GL047242.

Table 1. Surface Inventories of Cosmogenic ^{7}Be Measured in Owens Valley[a]

Site ID -Soil Order	Date	Average Annual Rainfall (cm)	Cumulative ^{7}Be Inventory (Bq m^{-2} ± 1 SE)	Sampling Method
6 - Aridisol	Nov 2006	15.24	47.7 ± 13.8	5-cm bulk cores
25 - Aridisol	Nov 2006	10.16	29.0 ± 2.6	1 –cm sectioning
1 - Mollisol	Feb 2008	15.24	87.5 ± 9.5	1 –cm sectioning
6 - Aridisol	Feb 2008	15.24	113.7 ± 22.7	5-cm bulk cores
7 - Aridisol	Feb 2008	15.24	135.9 ± 29.7	5-cm bulk cores
9 - Aridisol	Feb 2008	15.24	177.4 ± 26.5	5-cm bulk cores
10 - Aridisol	Feb 2008	15.24	191.5 ± 16.7	5-cm bulk cores
17 - Aridisol	Feb 2008	10.16	107.8 ± 10.3	5-cm bulk cores
21 - Aridisol	Feb 2008	10.16	115.0 ± 12.2	5-cm bulk cores
4 - Aridisol	May 2008	15.24	79.2 ± 13.4	1 –cm sectioning
11 - Aridisol	May 2008	15.24	91.2 ± 2.5	1 –cm sectioning
12 - Aridisol	May 2008	10.16	52.9 ± 3.8	1 –cm sectioning
13 - Aridisol	May 2008	10.16	70.0 ± 13.2	1 –cm sectioning
14 - Aridisol	May 2008	10.16	49.0 ± 5.6	1 –cm sectioning
15 - Aridisol	May 2008	10.16	41.9 ± 0.3	1 –cm sectioning
22 - Mollisol	May 2008	11.18	62.6 ± 4.2	1 –cm sectioning
8 - Mollisol	May 2010	15.24	102 ± 8.5	2 –cm sectioning
22 - Aridisol	May 2010	11.18	74.2 ± 3.5	2 –cm sectioning
0 - Inceptisol	May 2010	25.14	383 ± 59	2 –cm sectioning

[a]Inventories are cumulative, which sum soil and grass measurements.

the soil, but because of its short half-life, its distribution is unlikely affected by high frequency-low magnitude mixing processes [*Kaste et al.*, 2007]. *Pelletier et al.* [2005] did a thorough analysis of ^{137}Cs depth-profiles in desert soils developing on alluvial fans in Nevada and also concluded that radionuclide-bound particles are largely transported by infiltration.

3.2. Within-Site Spatial Variability of ^{7}Be at the Meter Scale

[8] Careful sampling methodology is needed for measuring ^{7}Be surface inventories in arid regions, so that the measurement uncertainty is minimized and lower than the natural variability. Soils are typically collected for radionuclide analyses using coring techniques that bulk the upper 20 or 30-cm of soil into a single sample. ^{7}Be is only in the vegetation and upper few cm of soil, so soil cores that incorporate a large thickness of soil will dilute the ^{7}Be nuclide content, putting the measured activity closer to the detection limit. Our standard error (SE) of the mean determined using 5-cm bulk soil cores sampled at the 5-m spatial scale are dominated by the analytical uncertainty (37.5 Bq m^{-2}; Table 1). Using a sampling strategy of 1 to 2.5-cm thick soil sectioning allows us to put better limits on the spatial heterogeneity of surface inventories, which are on the order of 5% to 20% (Table 1 and Figure 3).

[9] We show that approximately half of the ^{7}Be surface inventory resides in the vegetation (Figure 3) at sites where grass density is significant (>30 g grass m^{-2}). If rainfall containing ^{7}Be (as the $^{7}Be^{2+}$ ion or as ^{7}Be adsorbed to dust) is intercepted by vegetation and the nuclide is intercepted by leaf surfaces, radioactive decay would prevent it from reaching the soil. We note that the presence of vegetation did not necessarily increase the total surface inventory of

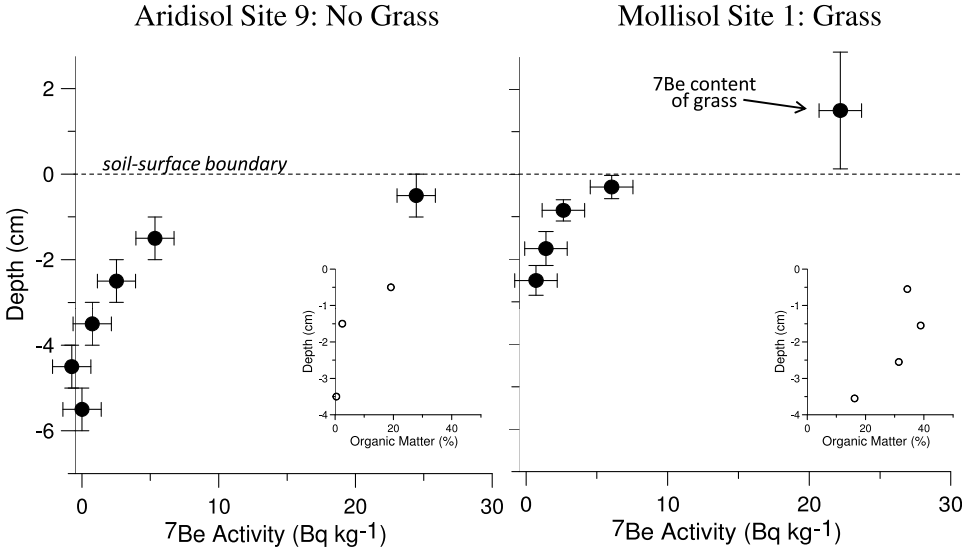

Figure 2. Representative depth-profiles of ^{7}Be in Aridisol and Mollisols. The dashed line represents the soil-surface interface. Soil organic matter content in the upper layers for each profile is given in the inset.

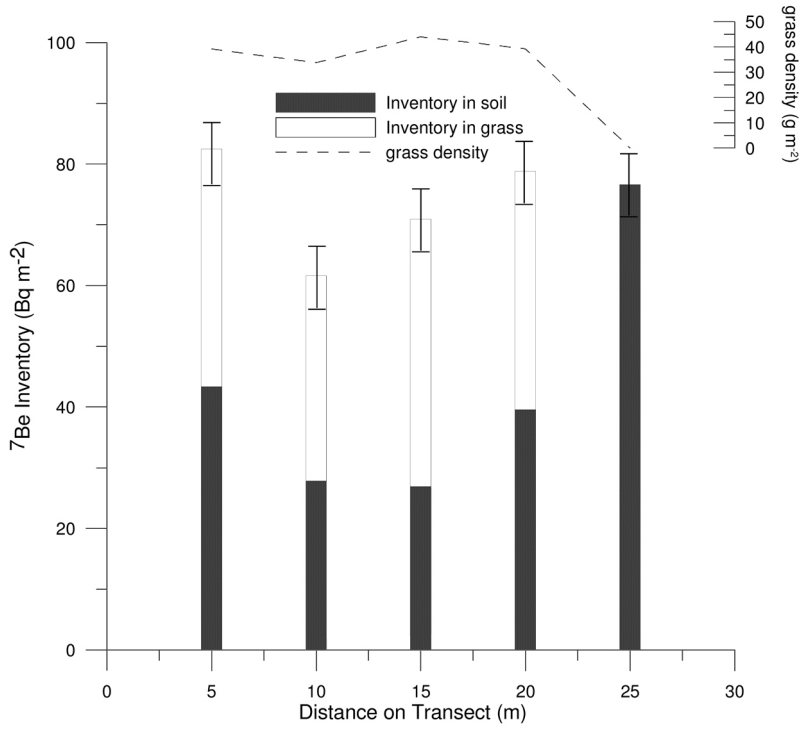

Figure 3. The distribution of ^{7}Be in soils and grass at Site 22, sampled in May 2010. Grass density is given in the upper plot (in air-dried g m^{-2}). Error bars show 1 sigma measurement uncertainties on the total ^{7}Be inventory at each point (see Methods and auxiliary material).

^{7}Be, as would be the case if dry depositional (including dust) processes were significant (Figure 3). In the valley floor, the spatial variability of ^{7}Be was highest at the Aridisol sites in the northern half of our study area (Sites 6,7,9), with 5-m scale variability (assessed with a SE) on the order of 20%. While this may be dominated by the analytical uncertainty of a 5-cm core, we note that the surface inventory range at many of these sites exceeded more than 3SE, and that the range at each site was commonly dominated by a single low value. These low value cores were more often than not collected in areas that were near (within 0.5 m) exposed roots, on the edges of depressions, or within a meter of a large shrub, according to our field notes. Exposed roots are indicators of recent topsoil loss, and the depressions appear to be related to significant deflation events which could remove ^{7}Be. Lower inventory values near large shrubs may be explained by rainfall approaching the surface at an angle, which would cause soils on the leeward side of vegetation to have reduced inventories. Bare soil on the depression edges might have reduced infiltration capacity that could force lateral movement of the ^{7}Be [*Wallbrink and Murray*, 1996]. A histogram of comparable ^{7}Be inventories, derived from measurements of 5-cm bulk soil cores is given in Figure S2. We have independent evidence of either erosion or rainshadowing at five of the six cores that are on the lower end of the distribution. Cores containing ^{7}Be inventories near the median value of 195 Bq m^{-2} were collected from points that were in small batches of intact grass and organic-rich A horizons that were interlaced with roots. Of approximately 65 core samples in the Aridisol sites, there were no ^{7}Be inventory values > 1.5 SE of the median.

[10] The highest ^{7}Be inventory that we measured was 245 Bq m^{-2}, but there were a number of relatively low inventories (but no undetectable) that were >3SE below the median. High ^{7}Be inventory values would potentially be caused by rapid sediment accumulation at certain points on the landscape. It appears that erosion may cause ^{7}Be loss in localized areas that were recently deflated, but deposition of sediment containing ^{7}Be is dispersed over such a wide area such that inventories are not impacted by this process. Furthermore, because the turbulence in Owens Valley is very high, and the saline soil particles that are mobilized by wind tend to be fine grained, significant quantities of dust generated in Owens Valley may be transported hundreds of km from the source area [*Cahill et al.*, 1996; *Reid et al.*, 1994]. If soil containing ^{7}Be is eroded from a small (area < 5 m^2) patch of soil at one of our sites but deposited elsewhere, perhaps outside of the valley, we would only measure low ^{7}Be from erosion rather than see low inventories balanced by high ones. Overall, however, the spatial variability of ^{7}Be that we document in soil in Owens Valley is somewhat lower than what one might expect for analytes at the surface of semi-arid landscapes. Measurements of soil carbon, nitrogen, phosphorous, and water in arid and semi-arid soils commonly have a spatial variability on the order of 30–40%, and in some cases considerably higher [*Li et al.*, 2009]. Beryllium is not a nutrient ion, so it should not be biologically focused like other resource elements do into "islands of fertility" [*Schlesinger et al.*, 1990], and its half-life must be considerably shorter than the timescale needed for significant sediment redistribution by wind and water.

3.3. Atmospheric Deposition Gradients of ^{7}Be and Effects of Dustfall

[11] During each sampling year we observed a broad spatial trend of ^{7}Be surface inventories generally decreasing

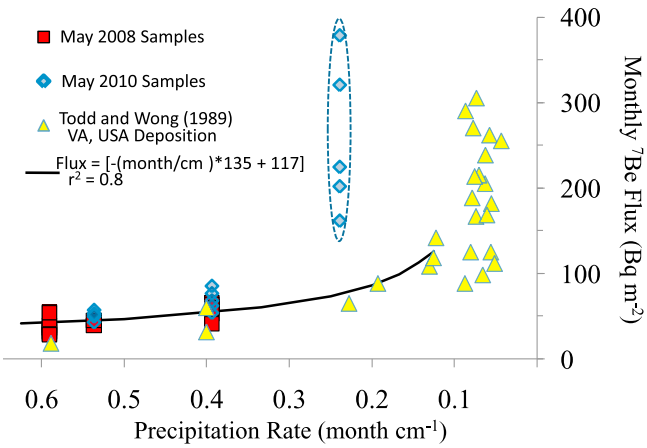

Figure 4. ^{7}Be monthly atmospheric fluxes calculated using surface inventories measured by this study at the end of the wet season during 2008 and 2010 and data from *Todd et al.* [1989]. Linear model is calculated using all data spanning 1.5 to 8 cm monthly precipitation except Site 0 (outlined with dashed oval).

from north to south in our study area, which may be explained by a slightly negative rainfall gradient between Bishop and Independence. Using ANOVA, sites with <11.2 cm annual rainfall had statistically lower (with 95% confidence) inventories than sites with annual rainfalls >11.2 cm during the 2008 and 2010 sampling campaigns, even when the 2024-m Site 0 was excluded. Our data indicate that a change of just a few cm of rainfall can significantly impact ^{7}Be accumulations at the surface.

[12] We use our ^{7}Be measurements in dust that we collected in 2010 and estimates of dust deposition rates previously made for our region to quantify the potential effects of dust accumulation on ^{7}Be inventories at the surface of Owens Valley. Dust deposition rates for the Bishop region have been measured to range from approximately 15 to 40 mg m^{-2} d^{-1} [*Reheis*, 1997]. Using the highest ^{7}Be value that we measured in the dust (0.4 Bq g^{-1}) and the highest dust deposition rate measured for the valley (40 mg m^{-2} d^{-1}), the maximum (steady-state) ^{7}Be surface inventory that can be supported by dust deposition is only 1.2 Bq m^{-2}, which is barely 1% of the rainy season surface inventories. We acknowledge that the BSNE collects dust more from local sources (typically grains derived from within ~100 m of the trap) rather than regional dust that could be airborne for a few days and conceivably scavenge more ^{7}Be from the atmosphere. However, even regional dust would be transported at an altitude of only a few km [*Reid et al.*, 1994], through air that has ^{7}Be concentrations one to two orders of magnitude lower than air that would be tapped during a convective storm [*Rama and Honda*, 1961].

[13] Most of the rainfall (and thus ^{7}Be deposition) in Owens Valley occurs between late October through late April, and during this wet season precipitation does not vary systematically from month to month (Figure S1). Because the rainy season spans several half-lives of ^{7}Be, soils should begin to approach a steady-state equilibrium condition between atmospheric ^{7}Be fluxes and radioactive decay by the end of April. We use our ^{7}Be surface inventories measured in May 2008 and May 2010 to calculate monthly steady-state ^{7}Be fluxes for the 6-month wet season (Nov–Apr), and find that the May 2008 and May 2010 datasets give similar monthly wet-season fluxes for their respective years (Figure 4). Use of the median inventory values would arguably be the best approach when using soils to calculate deposition fluxes. While our data can be used to evaluate the relationship between monthly rainfall and ^{7}Be fluxes in arid climates, we use other comparable datasets to extend the relationship across a larger precipitation range. *Todd et al.* [1989] measured monthly ^{7}Be fluxes by measuring rain in Norfolk, VA from October 1982 through February 1985. This is a dataset that is comparable with ours because they measured deposition at nearly the same latitude (within 0.5°), and our sampling was done during a similar phase in the solar cycle, so nuclear production rates should be similar.

[14] By combining our arid environment ^{7}Be deposition projected using surface inventories with the temperate deposition measured by *Todd et al.* [1989] we quantify a significant relationship between monthly rainfall and monthly ^{7}Be deposition in a mid-latitude (36–37°) band that holds well from 1 to 8 cm of monthly rainfall (Figure 4). It is evident from the data collected in Virginia that after a region receives more than 8 cm of rainfall in a given month, deposition of ^{7}Be does not necessarily increase with increasing rain, because most of the atmospheric ^{7}Be is scavenged during the initial part of a storm. This "washout effect" has been documented before and the threshold we observe using our soil gradient is consistent with previous analyses of ^{7}Be in air and precipitation [*Feely et al.*, 1989; *Willenbring et al.*, 2010, and references therein]. Our highest elevation site on the east slope of the Sierra Mountains (Site 0) has a ^{7}Be surface inventory that far exceeds (a factor of ~3 higher) that predicted by the rainfall-flux relationship (Figure 4) derived using the lower elevation sites. This could be because precipitation delivered to high mountain ranges commonly has a more stratospheric influence [*Stohl et al.*, 2000] and because snowflakes appear to be more efficient than rain drops at scavenging ^{7}Be from air masses [*McNeary and Baskaran*, 2003; *Ioannidou and Papastefanou*, 2006]. The spatial variability at Site 0 is also very high (Table 1 and Figure 4) which could be caused by localized snow drifting.

4. Conclusions

[15] We use our measurements of ^{7}Be in soils, vegetation, and dust to make some generalizations about the processes that control the spatial distribution of this fallout radionuclide at the surface of Owens Valley: (1) during the wet season, ^{7}Be is widely present at low but detectable levels in vegetation and the upper 3-cm of soil, (2) vegetation effectively sequesters up to half of the ^{7}Be that is rainfall and prevents it from reaching the soil, causing localized rain shadowing, (3) the lowest ^{7}Be surface inventories were measured at points on the landscape that coincided with independent field evidence of erosion or rain shadowing, so ^{7}Be may be a useful tracer of topsoil loss, but sediment accumulation (including dust fall) doesn't appear to have much of an effect on ^{7}Be inventories, and (4) rainfall and ^{7}Be delivery to the surface is correlated over 1 to 8 cm of rainfall per month at valley floor sites, but alpine sites may accumulate very high levels of ^{7}Be because of a higher altitude air mass source (which is enriched in ^{7}Be) and because snowfall may be exceptionally efficient at scavenging aerosols containing ^{7}Be.

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2011GL047242_readme

This readme file describes the Auxiliary Material available for “7Be in soils and vegetation along an arid precipitation gradient in Owens Valley, California” by Kaste et al.

There are three Supplemental Files:
1) Figure S1. Mean monthly precipitation at Site 0. Data from http://cdec.water.ca.gov/.
2) Figure S2. 7Be soil inventories at Aridisol sites with identical precipitation rates (15 cm/yr) collected in February 2008. Five of the six cores in the lower end of this bi-modal distribution could be explained by erosion or rain-shadowing by field observations.
3) Supplemental text that describes the details and considerations of the 7Be measurements by gamma spectrometry.

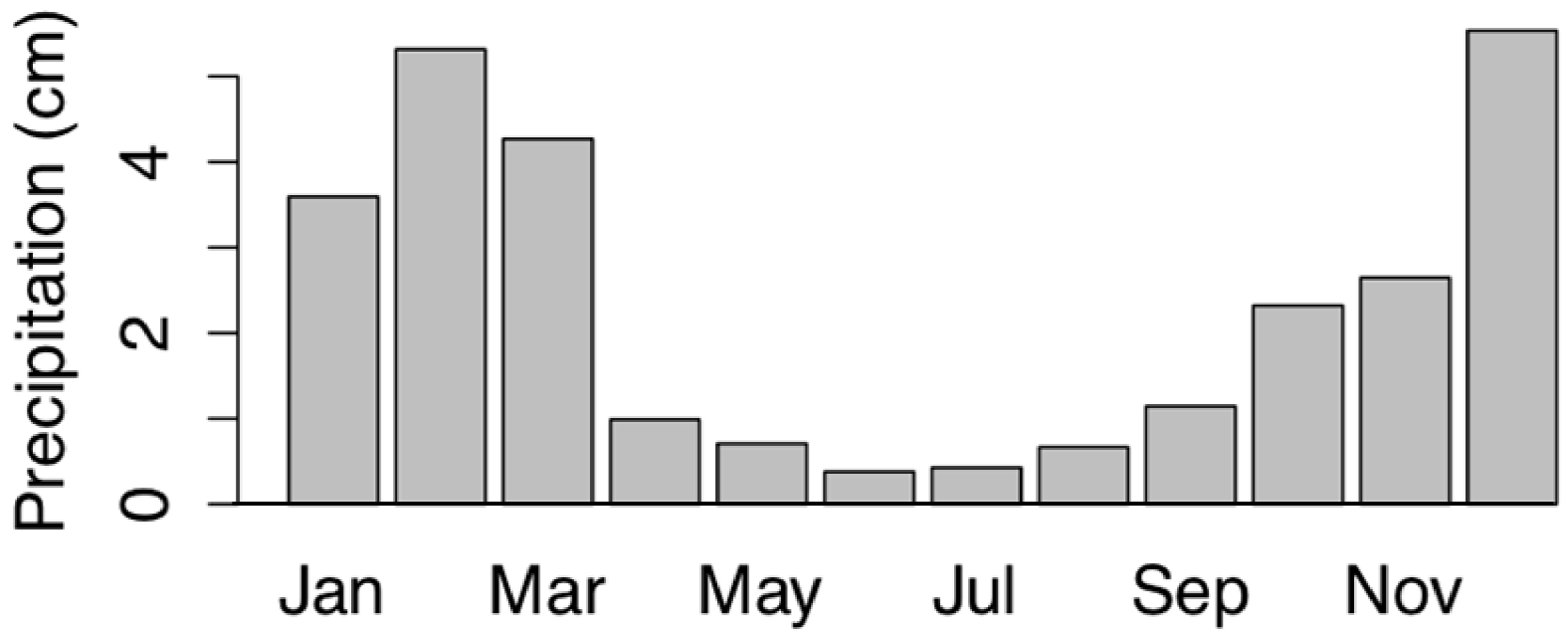

Figure S1 . Mean monthly precipitation at Site 0. Data from http://cdec.water.ca.gov/.

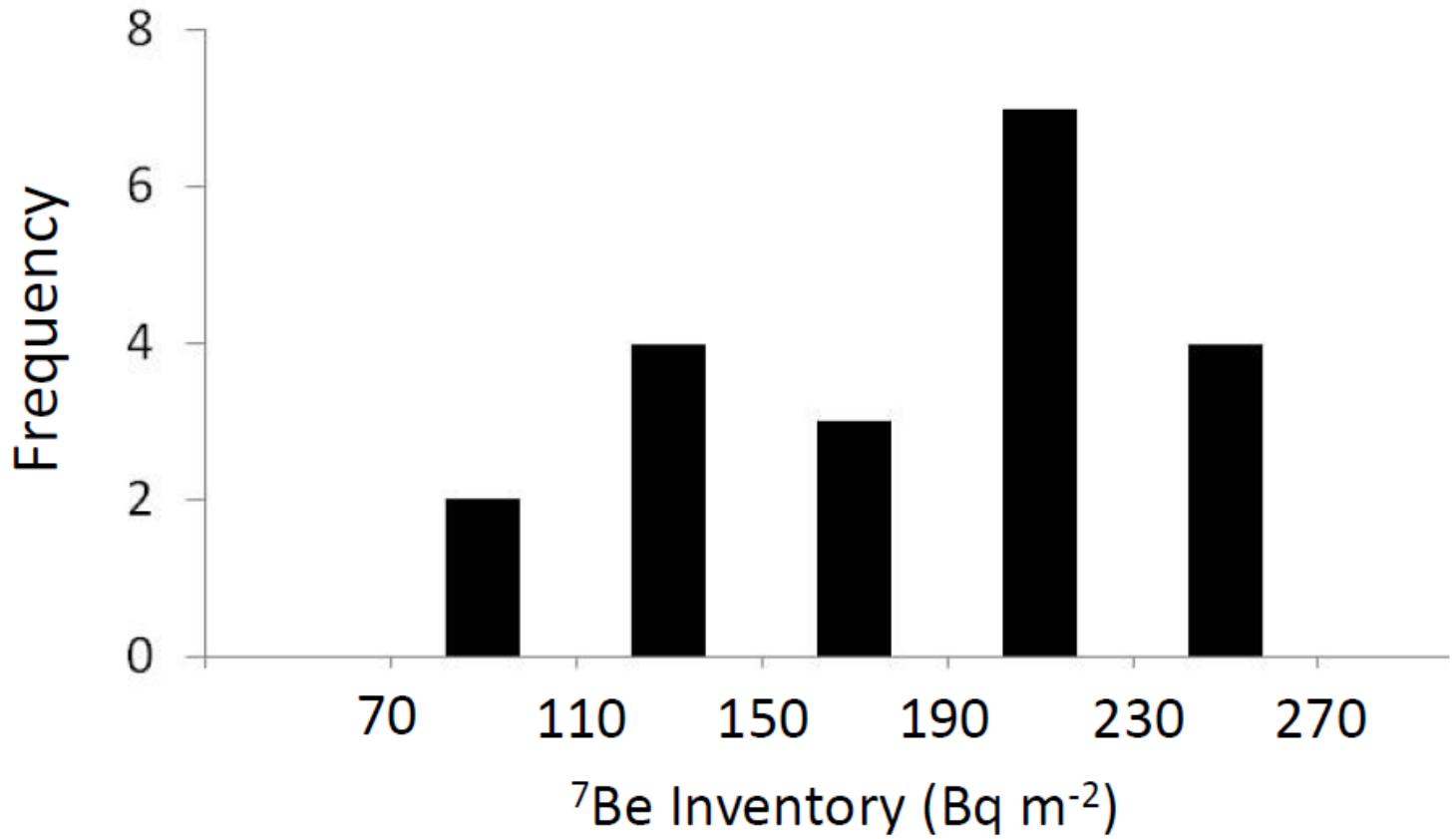

Figure S2. 7Be soil inventories at Aridisol sites with identical precipitation rates (15 cm/yr) collected in February 2008. Five of the six cores in the lower end of this bi-modal distribution could be explained by erosion or rain-shadowing by field observations.

This supplementary material document contains details on the conditions, detection limits, and uncertainty of the gamma analysis of ^{7}Be

All samples were air-dried for two weeks in a low humidity environment, and then homogenized for ^{7}Be measurements. Soil and dust samples are generally fine and were not sieved, but vegetation was cut with scissors and then ground so that we could pack it in a standard geometry for gamma analysis.

We measured cosmogenic 7Be in soils, vegetation, and dust by directly quantifying its 477.6 keV gamma photon with Canberra Broad Energy Intrinsic Germanium detectors (50 cm squared active area of 3 cm thickness) constructed with ultra- low-background cryostat material and shielded with 2500 lbs of copper-lined Pb. These detectors have a 50% relative efficiency for a 60Co point source at 25 cm. Detector efficiency for the 7Be region of interest at 477-478 keV was determined by counting a solution containing certified values (Eckert & Ziegler Isotope Products, Valencia, CA) of over a dozen different nuclides decaying at energies ranging from 46 keV to 1836 keV. We typically counted samples for at least 48 hours in a 75 mL petri dish geometry. Using the certified radionuclide solution, the detectors measured 5.42 counts per 100 photon emissions at 477-478 keV in this geometry, which, given a 10.5% yield of the 477.6 keV 7Be photon gives an overall measurement efficiency of 5.69 detections per thousand nuclear disintegrations. The smaller dust samples (0.2 grams) were counted for over a week to obtain significant (>100) 7Be counts, and all radionuclide values that we report here were corrected for radioactive decay between the sampling time and the analysis time.

We summed the counts in the five-channel 7Be region of interest spanning 476.5-478.5 keV, and used a best line-of-fit model background in neighboring channels which avoided the documented 480 keV decay emission of 226Ra progeny [Morel et al., 2004]. We carefully evaluated the detection limits for 7Be in this study by measuring 12 different samples that could be considered “blanks”; that is, they were collected from deep in the soil profile and stored for at least 2 months before analysis. The mean and standard deviation determined for the 12 “blanks” was 0.04 ± 0.42 Bq kg-1; typical analytical detection limits are calculated to be 0.7 Bq kg-1 by multiplying the standard deviation of the blanks by the t-value for the 95% confidence interval (n=12). Soil and vegetation 7Be surface inventories are calculated by multiplying the 7Be concentrations (Bq mass-1) by the surface density of the soil or vegetation (mass area-1). For a soil density of 1 g cm-3, we use the analytical detection limit to propagate a surface inventory detection limit of 7.5 Bq m-2 for a 1-cm thick soil core, 18.75 Bq m-2 for a 2.5 cm thick soil core, and 37.5 Bq m-2 for a 5-cm soil core.

Supplementary References

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