



Radon derived air mass fetch regions during the ACE-Asia campaign

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Summary. Seasonal variations in fetch regions for air masses exhibiting the greatest and least terrestrial influence at three sites in East Asia are discussed. Results are based on the first year of hourly atmospheric radon concentration observations made as part of the Asian Aerosol Characterisation Experiment (ACE-Asia). Fetch regions for Asian continental outflow to the Pacific Basin within the boundary layer are shown to be distinct from corresponding tropospheric outflow events. Analysis of the hourly radon time series in conjunction with back trajectory analysis indicates the presence of a large localised radon source in south eastern China.

Introduction

In conjunction with several international research teams, the Australian Nuclear Science and Technology Organisation (ANSTO) has been making continuous, hourly radon observations, since early 2001, at three sites in East Asia (Hok Tsui, China; Gosan, South Korea and Sado Island, Japan) as part of the Asian Aerosol Characterisation Experiment (ACE-Asia). Radon (²²²Rn) is a natural radioactive gas with an almost exclusively terrestrial source [Schery and Wasiolek, 1998]. It's relatively short half-life, and physical characteristics, make it an ideal tracer of terrestrial influence on air masses [Jacob *et al.*, 1997].

ACE-Asia is the latest in a series of initiatives of the International Global Atmospheric Chemistry (ICAG) project, which aim to reduce the uncertainty in aerosol climatic forcing in atmospheric models through the characterisation and sourcing of natural and anthropogenic aerosols [Huebert *et al.*, in press]. East Asia is a renowned source of natural aerosols [Liu *et al.*, 1985; Zhang, 1984] and a rapidly growing source of anthropogenic pollutants [Perry *et al.*, 1999]. The site locations were chosen to span most of the 20-50°N ACE-Asia study domain within which continental outflow to the Pacific occurs [Gregory *et al.*, 1997; Talbot *et al.*, 1997].

There are two routes for Asian continental outflow to the Pacific Basin: low-level (in the boundary layer) and upper-level (in the tropospheric jet stream)

[Balkanski *et al.*, 1992; Kritz, 1990]. The East Asian stations are ideal for observing low-level transport, the orientation of which is dictated by seasonal variations in regional circulation systems (the monsoons). The winter monsoon causes low-level continental outflow to the Pacific, whereas the summer monsoon is characterised by onshore flow.

Results

There was a pronounced seasonal cycle of radon concentration observed at each site (Figure 1). The amplitude of the seasonal cycle was observed to decrease with latitude from Hok Tsui to Sado Island, which was attributed primarily to (i) relative proximity to the continental Asia radon source, (ii) local strength of the monsoonal circulation, and (iii) strength of the radon source within the predominant fetch regions.

In order to source air masses corresponding to high or low concentration radon events, event thresholds had to be defined. The large seasonal variation in background radon concentration (Figure 2) complicated this process, so the seasonally varying background was characterised and removed. High and low radon events were defined on a monthly basis as ≥ 90 th and ≤ 10 th percentile values respectively, of the "net" radon concentration. This net concentration was obtained by subtracting the weekly minimum value from the recorded concentrations. The choice of a weekly time frame for this process was based on the time scale of synoptic events at the sites, which varied from 4-10 days.

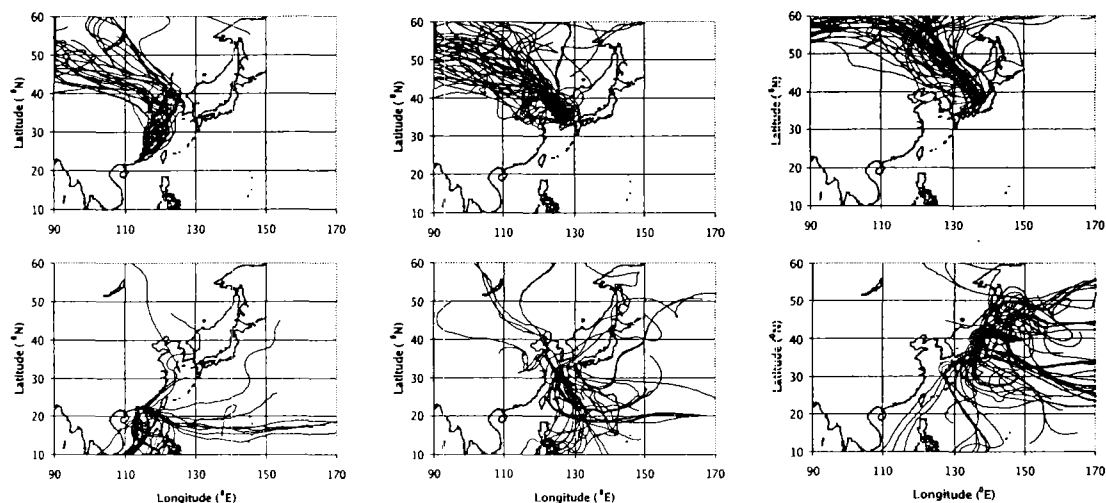


Figure 3: Examples of 10-day back trajectories at 3 hourly resolution of high (90th percentile) radon events during continental outflow conditions and low (10th percentile) radon events during onshore flow conditions at each of the East Asian sites.

In winter, during conditions of continental outflow, observed radon concentrations decreased with increasingly northern fetch. Whether this is due to a latitudinal gradient of ^{226}Ra in the soils, or increasing ice densities that would inhibit radon emission, is unclear.

Whilst the primary fetch region for boundary layer outflow events at each of the East Asian sites in winter was north eastern China, Mongolia and Siberia, the corresponding primary fetch region for the more pervasive tropospheric outflow events observed in the central Pacific (at the Mauna Loa Observatory) was central and western China (Figure 4).

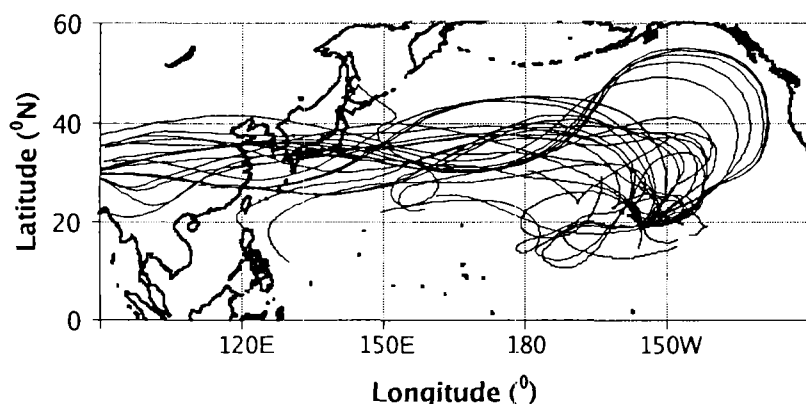


Figure 4: 10-day back trajectories of high radon events at Mauna Loa in spring 2001.

Little difference was observed between the fetch regions of high winter radon events at Hok Tsui (Figure 3a) and low winter radon events. Trajectories for the low radon events originated in a similar location, but their turning point (to the southwest) was a little further eastward, resulting in a path along the Chinese coast. This small difference in track over the latter third of their path resulted in changes in the hourly observed radon concentration occasionally in excess of an order of magnitude. One explanation for the observed behaviour is that there is a strong local or regional source of radon in south eastern China.

Conclusions

Regional scale flow patterns near the surface associated with the Asian monsoon has a dominant effect on the air mass fetch

regions of all three East Asian sites. As a result a large seasonal variation in background radon concentration was observed, as well as large seasonal variations in fetch regions for air masses exhibiting the greatest and least terrestrial influence. Fetch regions for air masses most likely to bring pollution to regions throughout south east Asia were found to be distinct from those that have the most pervasive effect on the atmosphere of the Pacific Basin. Results also indicated the likely presence of a large local source of radon in

south east China.

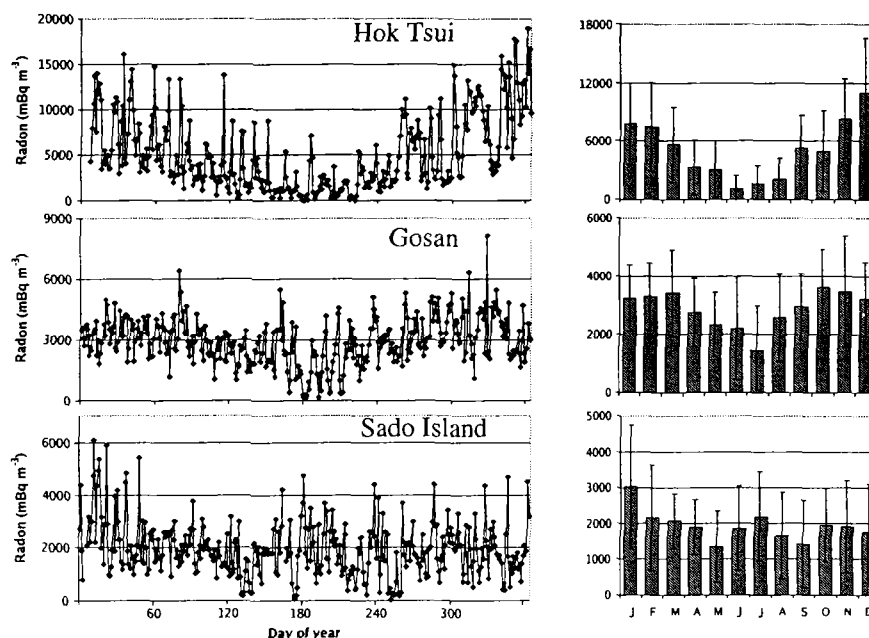


Figure 1: Daily and monthly mean atmospheric radon-222 concentrations at the East Asian sites. Bars denote ± 1 standard deviation.

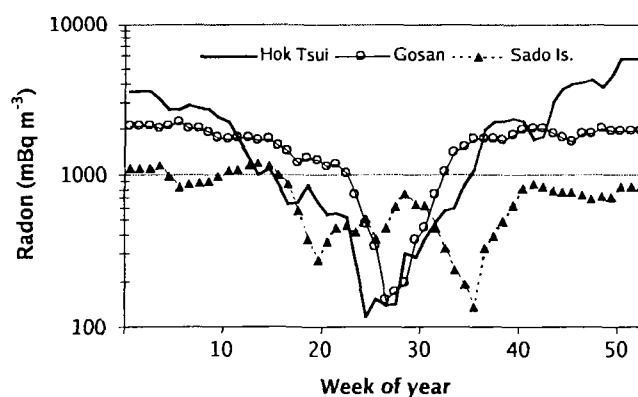


Figure 2: Weekly 10th percentile radon concentration at the East Asia sites smoothed using a 5-week running mean.

A representative background concentration was assumed to be between the weekly minimum and 10th percentile value. Due to the monsoonal influence, only during conditions of onshore flow did background radon concentrations resemble marine baseline values (20–150 mBq m⁻³).

Wind direction alone was found to be unsuitable as a reliable indicator of air mass origin for the high and low radon events. Thus air mass sourcing was performed with 10-day back trajectory analyses generated by the National Oceanic and Atmospheric Administration Air Resources Laboratory's (NOAA ARL) HYSPLIT 4 package [Draxler and Hess, 1998]. Based on the 3.8 day half-life of radon, under normal conditions, a 10-day trajectory is sufficient to

represent >80% of the fetch regions responsible for the observed radon concentration.

Fetch regions for high and low radon events for all seasons were examined. As an example, back trajectories for high radon events in winter, and low radon events in summer are provided in Figure 3. The fetch regions identified in this example highlight the strong monsoonal influence at each site. Irrespective of season, radon derived fetch regions were most consistent at Hok Tsui. Only under conditions of onshore flow did air masses corresponding to low radon events have extended oceanic fetch. Fetch regions for low radon events in winter (not shown) originated in Siberia, which would have been frozen at that time of year, resulting in a reduced radon flux.

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