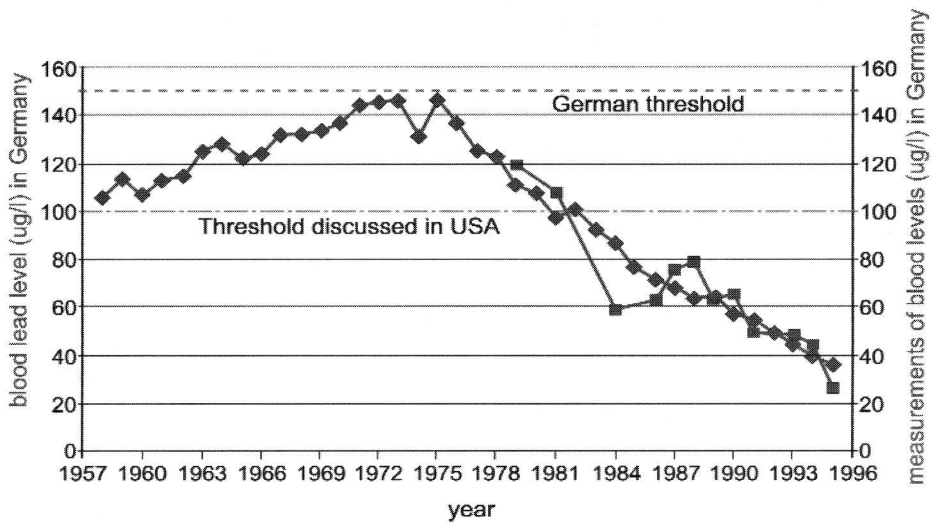

Fig. 4. Lead concentrations in the blood of adults in Germany are plotted; red indicates recorded values and green indicates estimated values. Original color image appears at the back of this volume.

opment of children is already disturbed at a blood lead level of 100 μg Pb/l.

What about the most immediate economic impacts of the regulations?

Despite concerns of the German mineral oil industry that gasoline production costs might increase following the first regulation in 1972, it turned out that its costs actually dropped, thanks to savings in lead additives. Only after the second regulation in 1976 did production costs indeed rise because new additives with high octane numbers were now required to maintain gasoline performance [*Hagner*, 2000].

The impacts of the introduction of unleaded gasoline in 1985 were more complex. Tax incentives for unleaded gasoline and low-emission cars increased sales of both. Most independent gasoline traders went bankrupt, as gas station reconstruction represented a higher financial strain for them than for the large international companies. Automobile manufacturers Daimler-Benz, whose motors were easily compatible with catalysts, and whose customer demand was inelastic, and Volkswagen, which offered a wide selection of catalyst-equipped cars, benefitted greatly. Car manufacturers with the highest technical standards, who had already gathered experience with catalyst systems in the U.S. market, were better able to compete [*Hagner*, 2000].

Aside from these shifts in market competition conditions, no significant impact could be seen in German macro-economic indicators, including gross national product, economic growth, price stability, the rate of unemployment, or foreign trade balance.

Summary and Outlook

A tool for reconstructing past lead air concentrations and depositions across Europe has been developed. With the help of regionalized atmospheric data, spatially disaggregated lead emissions from road traffic and point sources, and various local data, an attempt was made to reconstruct the airborne pathways and deposition of gasoline lead in Europe since 1958. Trends in concentrations in biota and human blood were also analyzed, and the most direct economic impacts of gasoline-lead regulations in Germany were evaluated.

For the case of lead, the tool is functioning well. Modeled data show that European reduction regulations for lead additives in gasoline may be considered a successful example of environmental policy. However, the success of lead policies was limited to atmospheric pathways, which had little effect on some marine biota, underscoring the fact that a low residence time is a necessary condition for substance abatement through emission regulations in a given environmental compartment, once considerable substance amounts have already been released. For those anthropogenic substances that persist for a long time in the environment, that are subject to bioaccumulation, and whose main route of human exposure is the food chain, late emission regulations may be ineffective for protecting human health. In such cases, the principle of prevention, by which any significant releases are precluded from the start, may be appropriate.

One should, however, not forget that the large amounts of lead emitted in the past 50 years have not simply vanished but now reside for good—and are ubiquitous—in the global environment. The use of lead in gasoline was indeed a large-scale geophysical pollution exercise, and it remains to be seen if long-term effects may later emerge.

In the future, the modeling system needs to be extended by modules; by describing the transport in river catchments and channels; and through substance transformations, depositions, and resuspension, and the interactions with the ecosystems. Furthermore, the methodology should be applied to other substances; candidates include persistent organic pollutants, radioactive substances, some other heavy metals, and pollens, among others. Because of the increased complexity with respect to such substances, in particular concerning chemical transformations, cooperation partners are sought.

For additional information, see Web site: http://w3g.gkss.de/staff/blei. The annual emissions and modeled concentrations and depositions data are available for download from a link on this page.

Authors

Hans von Storch, Charlotte Hagner, Mariza Costa-Cabral, Frauke Feser, Józef Pacyna, Elisabeth Pacyna, and *Steffen Kolb*
For additional information, contact Hans von Storch or Frauke Feser, Institute for Coastal Research, GKSS Research Center, Geesthacht, Germany; E-mail: storch@gkss.de and feser@gkss.de

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SAPS: A New Categorization for Sub-auroral Electric Fields

PAGES 393–394

Sub-auroral electric fields play critical roles in energizing and transporting ring current ions, as well as convecting thermal plasma in the inner magnetosphere and in the mid- to low-latitude ionosphere. A number of terms have been employed to describe the sub-auroral electric fields and many of these are specifically associated with processes established through their prior use in the literature. The continued use of descriptive terms such as penetration electric fields, polarization jets, and sub-auroral ion drifts could lead to misunderstanding, especially when comparing the broad/narrow, persistent/transient regions of sub-auroral electric field and plasma flow. An inclusive name for these phenomena is sub-auroral polarization streams (SAPS).

Electric fields often appear in regions of low ionospheric conductivity equatorward of auroral electron precipitation associated with increased coupling of the interplanetary medium to the terrestrial magnetosphere-ionosphere system. *Galperin et al.* [1974] was the first to report strong, poleward-directed electric fields driving sunward plasma convection at sub-auroral latitudes in the evening local time sector and called them polarization jets (PJ). Similar intense, latitudinally narrow structures are usually referred to as sub-auroral ion drifts (SAID) [*Spiro et al.*, 1979] in the U.S. literature. Broader regions of sunward plasma drift, equatorward of and separated from the evening auroral convection cell, have been described by *Yeh et al.* [1991]. Although those sub-auroral disturbance electric fields have features similar to those of SAID/PJ structures, their large latitudinal extents and long durations are distinctive characteristics.

In March 2002, an informal workshop convened at the Massachusetts Institute of Technology's Haystack Observatory to discuss characteristics, causes, and effects of sub-auroral electric fields. The two dozen participants included specialists in particle and field observations, space plasma imaging, magnetosphere-ionosphere coupling, and magnetospheric modeling. It was agreed that a single, well-defined term is needed to describe regions of electric field and sunward plasma convection in the sub-auroral ionosphere. Spatially narrow (SAID/PJ) electric field structures may or may not be apparent within such regions. The new name, SAPS, was agreed upon to encompass these phenomena, the SAID/PJ structures, and the broader regions described by *Yeh et al.* [1991].

The phenomena discussed in this article are illustrated in Figure 1. These data were acquired during a dusk sector pass of the Defense Meteorological Satellite Program Flight 13 (DMSP F13) satellite to the west of the Millstone Hill incoherent scatter radar near 01:00 UT on 12 April 2001 during disturbed (Kp = 7+) geomagnetic conditions. The top two panels of the figure show radar measurements of the westward component of plasma drift and the ionospheric plasma density at ~500 km, respectively. (Westward **ExB** plasma drift is driven by a northward electric field.) The middle panels show directional differential fluxes of downcoming auroral electrons and ions with energies between 30 eV and 30 keV; these delineate the auroral precipitation region. The bottom panel gives the westward component of plasma velocity measured by the ion drift meter on F13. All data are plotted as functions of invariant magnetic latitude. For convenience, we have marked the different regions mentioned here.

The radar velocity measurements show two broad regions of strong sunward convection. The more equatorward of these coincides with a deep ionospheric density trough and a region of low overall ionospheric conductivity. Attention is drawn to the vertical line near 58° that marks the equatorward boundary of auroral electron precipitation. Measurable westward drifts extend from the auroral boundary to < 45°, delineating the broad extent of the SAPS.

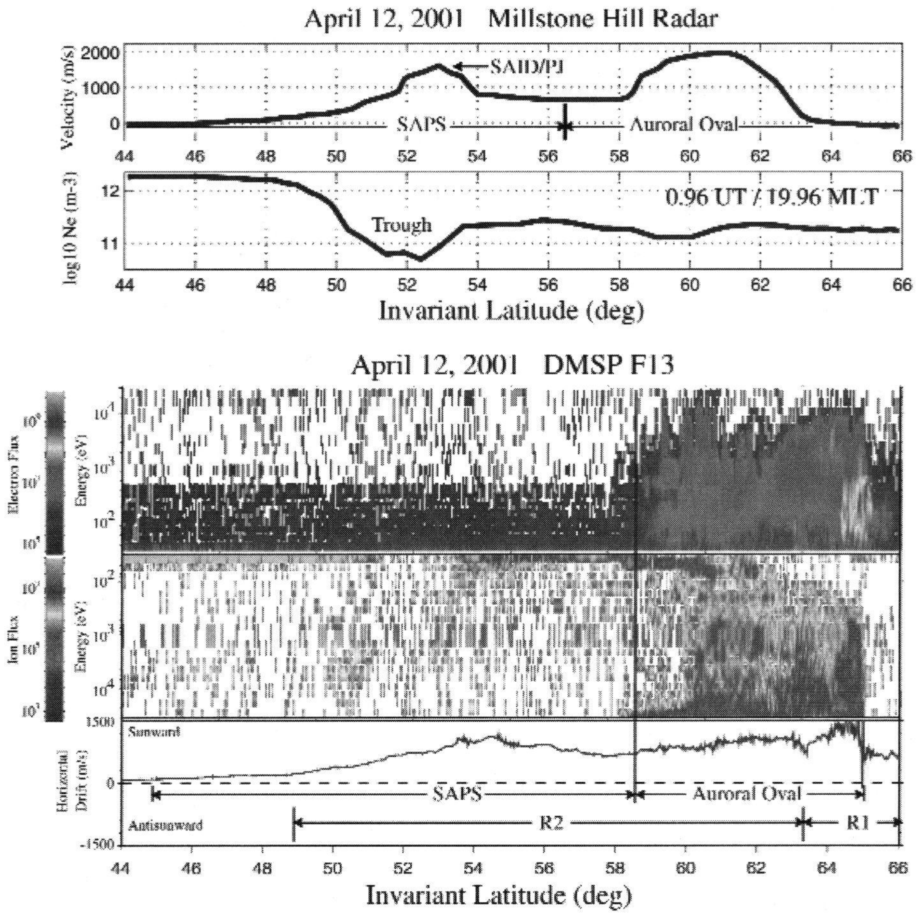

Fig. 1. Simultaneous radar and in situ measurements of auroral and SAPS plasma characteristics were acquired during a dusk overflight of the Millstone Hill incoherent scatter radar by the DMSP F13 satellite near 01:00 UT on 12 April 2001. The SAPS is seen as a broad region of sunward plasma convection centered at 53°Λ. Original color image appears at the back of this volume.

Strong (> 1 km/s) drifts centered near 53°, collocated with the deepest plasma density trough, have the characteristics of a SAID/PJ structure. Note that features observed near the dusk meridian by F13 are displaced poleward by ~2° from counterparts detected by the radar. This shift in latitude is a local time effect that was previously noted in radar measurements [*Yeh et al.*, 1991], and is required to maintain current continuity across conductivity gradients near the dusk meridian [*Nopper and Carovillano*, 1978].

Large potential drops imposed on the magnetosphere and polar ionospheres by the solar wind-driven convection electric fields ultimately drive the SAPS. Region 1 field-aligned currents (FACs) drawn from the interplanetary generator flow near the poleward boundary of the auroral oval, into the ionosphere on the dawn side, and out of the ionosphere on the dusk side [*Iijima and Potemra*, 1976]. The potential distribution required to satisfy Ohm's Law spans the global ionosphere, is adjusted to reflect ionospheric conditions, and maps back into the magnetosphere along magnetic field lines [*Nopper and Carovillano*, 1978].

The electric fields associated with SAPS energize ring-current particles and transport them into the inner magnetosphere. Large pressure maxima develop in the nightside magnetosphere. Mis-alignments between gradients in plasma pressure and magnetic flux tube volume cause Region 2 FACs to flow into/out of the ionosphere evening/morning sector [*Harel et al.*, 1981]. A fraction of Region 2 FACs flow into regions of low ionospheric conductivity at sub-auroral latitudes, where large polarization electric fields that are needed to maintain current continuity drive rapidly drifting plasma polarization streams. Within the region of strong plasma drifts, frictional heating enhances ionospheric recombination rates [*Schunk et al.*, 1976], accelerating the reduction of ionospheric conductivity in the channel. In turn, the intensity of polarization electric fields increases, leading to still deeper ionospheric troughs. Although Region 2 FACs at sub-auroral latitudes are usually small, low ambient plasma densities result in feedback that increases the polarization electric fields and decreases ionospheric conductances, enhancing the strength of the SAPS.

SAPS events may continue well into the recovery phase of a geomagnetic disturbance after Region 1 currents subside. This reflects the long time required for the ring current pressure gradients to come into alignment with gradients in flux tube volume. As long as such mis-alignments persist, they drive Region 2 currents that require large polarization electric fields across the deep conductivity troughs developed during periods of maximum activity.

Measurements from Millstone Hill and from four of the DMSP satellites operating during the April 2001 event indicate that sub-auroral plasma drift features, similar to those shown in Figure 1, extended from dusk across the night sector to at least 03 local time and appeared at conjugate locations in both hemispheres. Both the radar and DMSP satellites observed this SAPS event continuously for more than 8 hours.

The distribution in latitudes of plasma drifts indicates that about 35% of the -87 kV potential in the evening convection cell was equatorward of the auroral oval. For such disturbed events, the SAPS electrodynamic structures involve a significant fraction of the available potential, cover a large area in the global ionosphere, and persist for many hours.

Authors

J. C. Foster and *W. J. Burke*
For additional information, contact J. C. Foster, MIT Haystack Observatory, Westford, Mass., USA; E-mail: jfoster@haystack.mit.edu; W. J. Burke, AFRL, Hanscom AFB, Mass., USA; E-mail: William.Burke2@hanscom.af.mil

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CONTOUR Investigation Launched

PAGE 394

On 27 August, NASA Administrator Sean O'Keefe appointed a team to investigate the apparent loss of the Comet Nucleus Tour (CONTOUR) spacecraft, which stopped communicating with the mission control operations on 15 August.

On that date, CONTOUR failed to communicate following the firing of its main engine that would take it out of its orbit around the Earth. Shortly afterwards, the mission team received telescope images from several observatories showing two objects traveling along the spacecraft's predicted path. Those objects could be CONTOUR, and part of the spacecraft that may have separated from it when the spacecraft's solid rocket motor fired.

The investigation is expected to report initial findings to NASA headquarters in six to eight weeks.

The CONTOUR mission team has not yet given up hope of making contact, but they have given up continuous monitoring for its signals from NASA's Deep Space Network.

Mission Director Robert Farquhar said on 23 August. "We don't want to take [Deep Space Network] time that could be used more effectively by other missions." Farquhar is with the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. The laboratory is managing the CONTOUR mission for NASA.

Part of NASA's Discovery Program of lower-cost, scientifically-focused exploration projects, the $159-million CONTOUR was launched on 3 July to explore and analyze several different comets over a period of about four years. (See "In Brief," *Eos*, 15 January 2002).

The mission team now is listening for a signal just once a week. In early to mid-December, a more optimal alignment of Earth and the spacecraft—if it is still in one piece and operational—will provide the team with perhaps its last best hope of making contact.

"We know there's not much room for optimism through this week," Farquhar said. "Even the second week of December, when we have our best shot, chances are small. But it's still worth monitoring."

Randy Showstack, Staff Writer

Modeling the Role of Mineral Aerosols in Global Climate Cycles

PAGES 395, 400

Mineral aerosols play multiple roles in the global system, but the magnitude of their impact on climate and global biogeochemical cycles remains uncertain. The extent to which atmospheric dust concentrations warm or cool the climate is still poorly quantified, as it depends on factors such as the physical and radiative characteristics of dust. Dust-cycle models must be improved before dust impacts can be more reliably predicted. Progress in this direction is hindered by a shortage of global data sets to determine model input parameters on multiple spatial scales and data sets to comprehensively validate model simulations. A workshop, which was recently held in Germany, brought experts together to formulate strategies for using existing global data sets and creating new data sets to improve model parameterizations and model evaluation.

Data sets required to refine parameterizations of local land-surface conditions was one focus of the workshop. Such data sets significantly affect the magnitude of dust emissions. Important properties include surface roughness; soil moisture; vegetation cover; fine sediment availability, which determines the vertical dust flux; and surface crusting. Although models incorporate rough parameterizations of some of these controls, improved treatment of the land surface requires better specification of land-surface parameters than are currently available at a global scale. One approach would be to extend the detailed mapping of surface conditions—such as surface roughness in northern Africa [*Marticorena et al.*, 1997]—to other dust source areas. Here, remotely sensed data could play an important role. Alternatively, relationships derived from local process studies could be used to develop ways of simulating land-surface properties on the basis of information already available at a global scale, for example, by remote sensing.

Small changes in the mineralogy, shape, and size of emitted particles affect the optical properties of dust, with significant impact on radiative forcing. A recently assembled global data set describing the mineralogy of key dust-source areas [*Claquin et al.*, 1999] provides a starting point for improving the prescription of dust optical properties, but it does not capture the spatial complexity of soil mineralogy. To significantly improve this data base, information from an extensive soils literature must be compiled, and this will not be achieved quickly. Soil color, which may provide a proxy for dust chemical composition and radiative properties, could be derived from remote sensing and spectral imagery.

Emitted dust consists of both individual particles and soil aggregates, which have quite different reflectance characteristics. Traditional sources of input data—for example, global soils maps from the Food and Agriculture Organization (FAO)—commonly provide dispersed particle size distributions of surface material; that is, aggregates are broken down. Thus, they are not ideally suited for dust-modeling purposes. According to G. McTainsh of Griffith University, Australia, particle-size analyses on soils in transport-stable or minimally dispersed conditions provide more relevant information about the size distribution of emitted dust. If a compilation of transport-stable, particle-size data were available for the major dust-source regions, it might be possible to derive relationships between FAO soil types and transport-stable, particle-size distributions. The revised data set could be used as input for global models and would also provide useful information on reflectance characteristics of dusts.

Especially over oceans, wet deposition has a major influence on dust concentrations, comprising ~80% of the total measured dust depo-

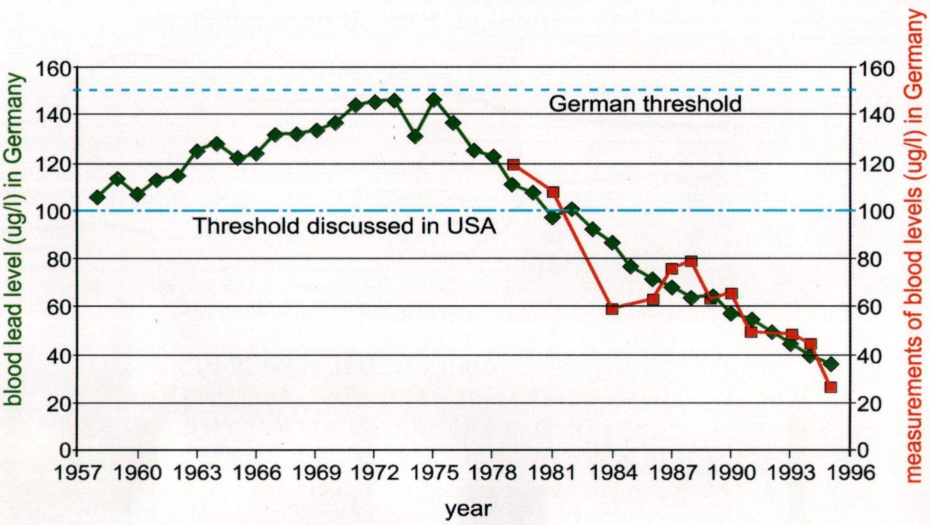
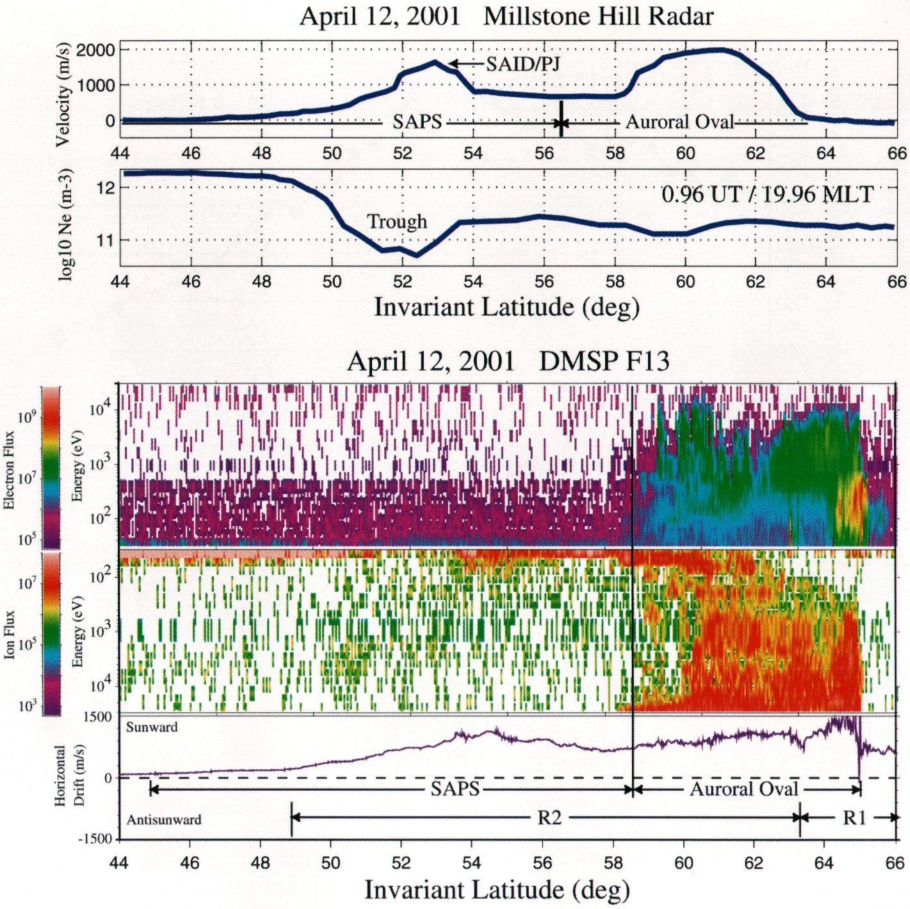


Fig. 4. Lead concentrations in the blood of adults in Germany are plotted; red indicates recorded values and green indicates estimated values.



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