Ar in Mars' Atmosphere:
A Good Tracer for Meridional Mixing

GRS Team

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GRS Gamma Ray Instrument

Gamma Ray Spectrometer:
Dr. William V. Boynton, PI

Neutron Spectrometer (NS)

Built by Los Alamos National Laboratory Los Alamos, NM under the direction of Dr. William Feldman, PI.
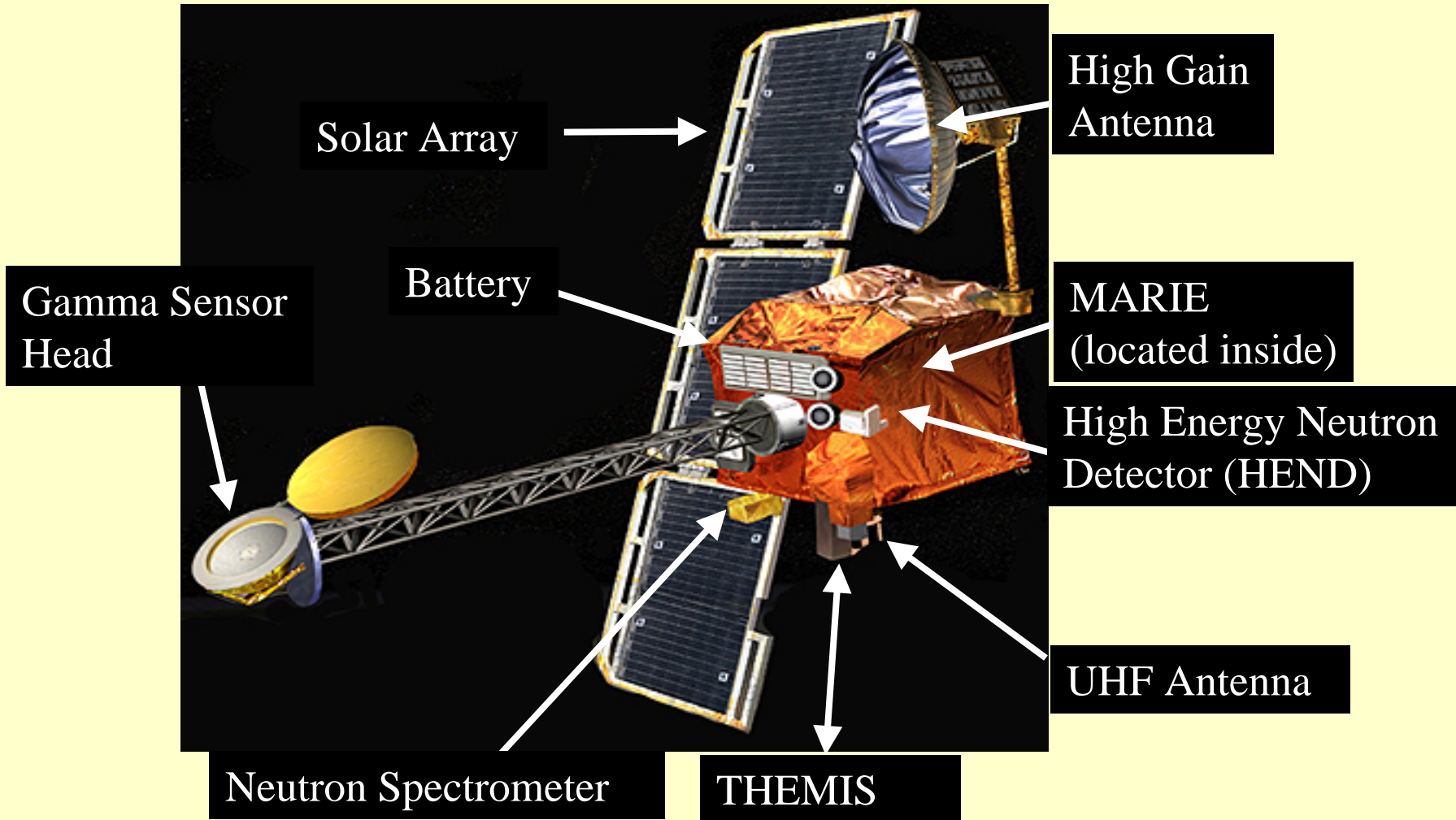
High Energy Neutron Detector (HEND)

Space Research Institute Moscow, Russia under the direction of Dr. Igor Mitrofanov, PI.
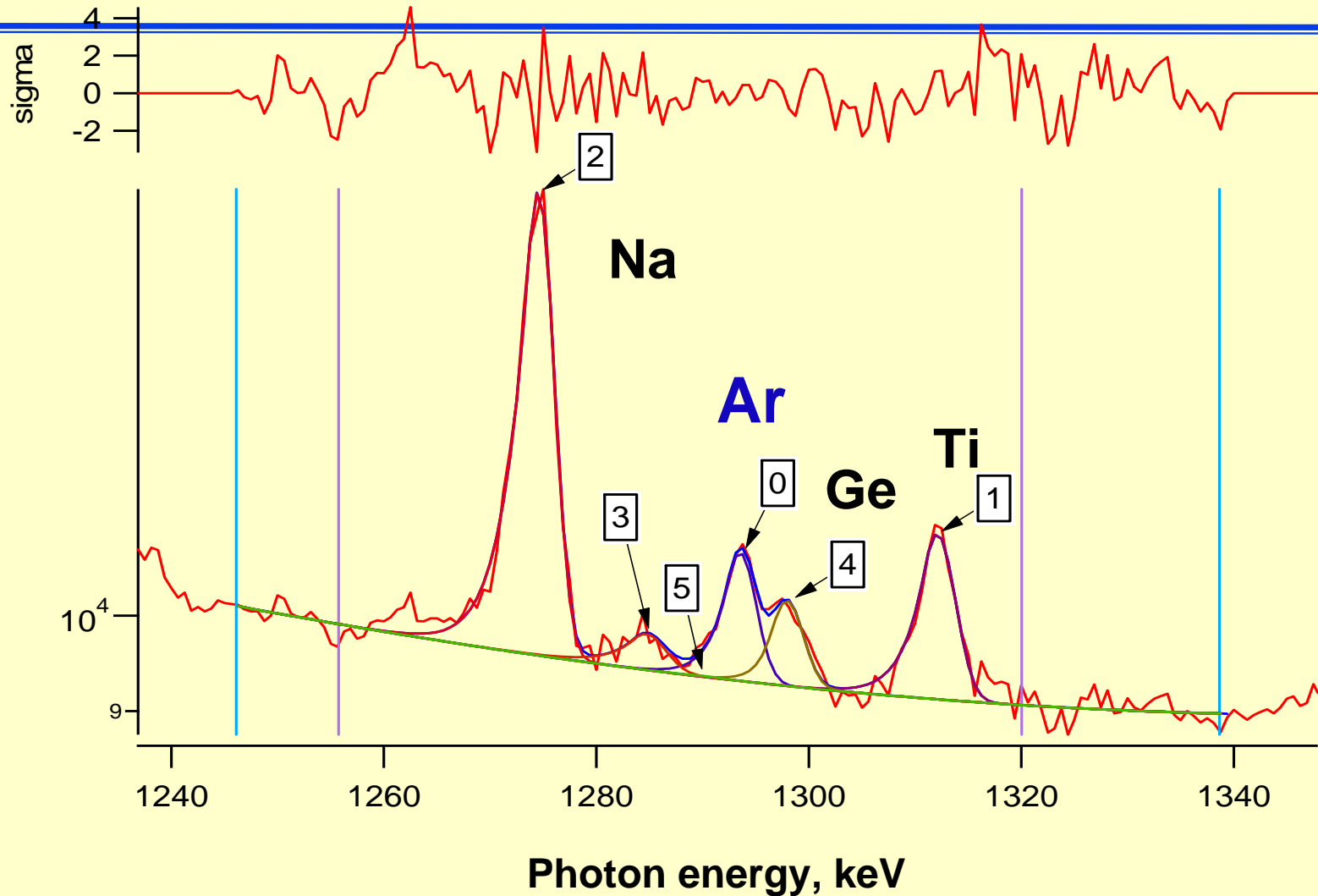
Gamma Sensor Head (GSH)

University of Arizona, Lunar and Planetary Laboratory under the direction of Dr. William V. Boynton, PI.

2001 Mars Odyssey Orbiter

Solar Array

High Gain Antenna

Battery

Gamma Sensor Head

MARIE (located inside)

High Energy Neutron Detector (HEND)

Neutron Spectrometer

THEMIS

UHF Antenna

Ar over southern winter pole (-75° to -90°)


Photon energy, keV

Reduction and Analysis Considerations

- **The thermal neutron flux has a seasonal fluctuation which causes changes in the peak area of the 1294 keV Ar γ-ray**

- **We correct for this effect by taking the ratio of the Ar peak area to another γ-ray line peak area which is made by the same mechanism (thermal neutron absorption and subsequent decay) within the GSH itself (1382 keV line of Ti)**

- **After correction for the changing neutron flux we find a large seasonal variation in the Ar abundance over the south polar region**
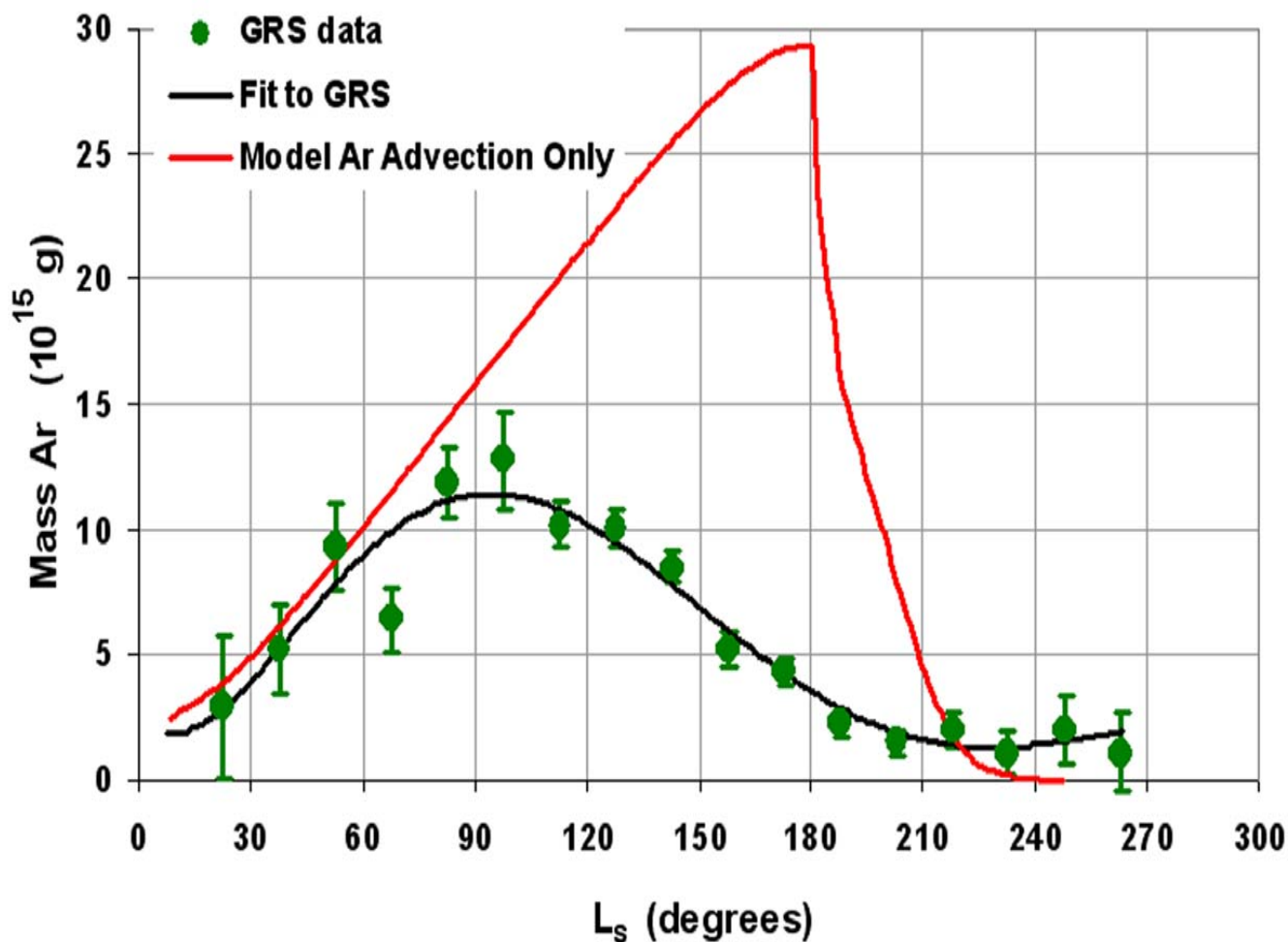
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L_s (areocentric longitude of the sun)
$L_s = 0$, beginning southern autumn
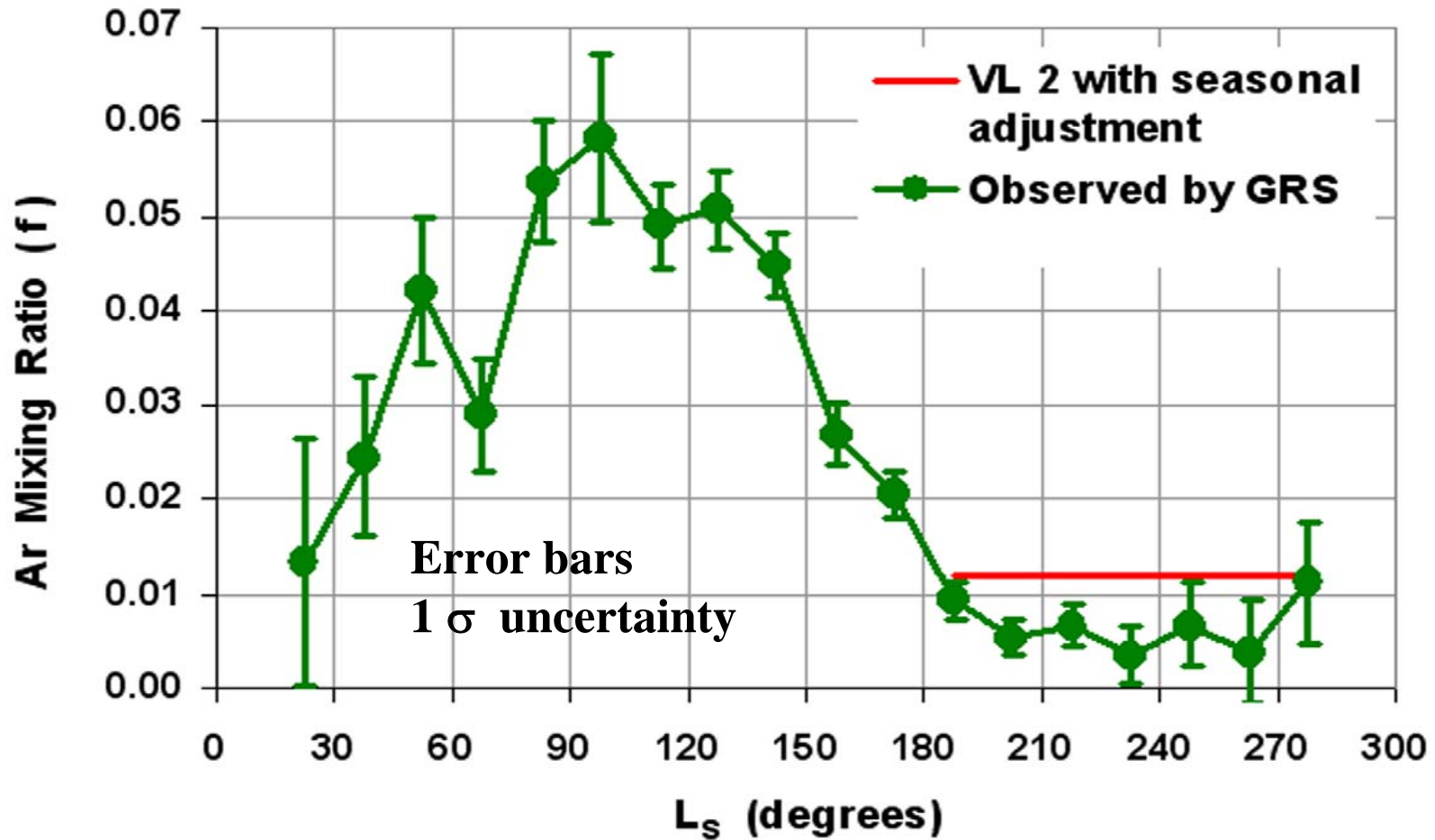
Reduction and Analysis of additional ½ martian year
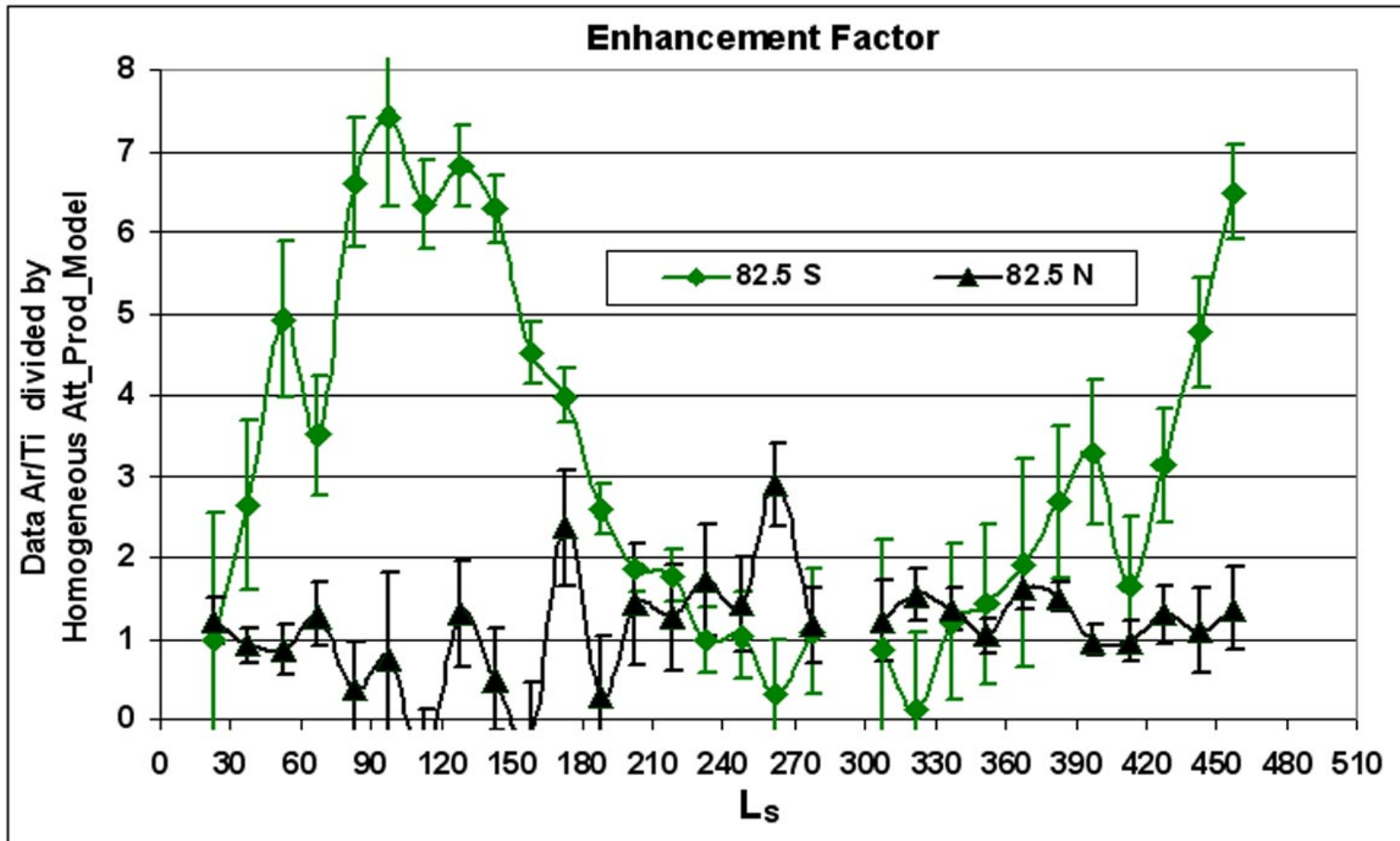
"Advection Only Model" Compared with GRS South Polar Data

departures of measured Ar from that expected (condensation flow) is caused by eddy transport of Ar out of the polar regions toward the equator during autumn and winter

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Notable Changes
in South Polar Atmospheric Ar

- **In autumn the measured Ar mass tracks that of the "condensation flow only" model to form an enhancement over the polar area**
- **CO_2 frost continues to form until the deposition ceases at the end of southern winter (L_s 180º)**
- **In contrast, the peak in measured Ar mass is reached at the end of autumn (L_s 90º)**
- **In spring the Ar mass mixing ratio decreases below the nominal VL2 seasonally adjusted value**
- **By early summer the Ar mixing ratio has restored to the nominal VL2 seasonal value**
- **The implication is that excess Ar is being mixed away from the polar region by atmospheric motions**

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# Mixing driven by the gradient in the Ar mixing ratio
Derivation of meridional Eddy Mixing Coefficients

- **We solved the seasonal transport equations for the meridional eddy mixing coefficients:**

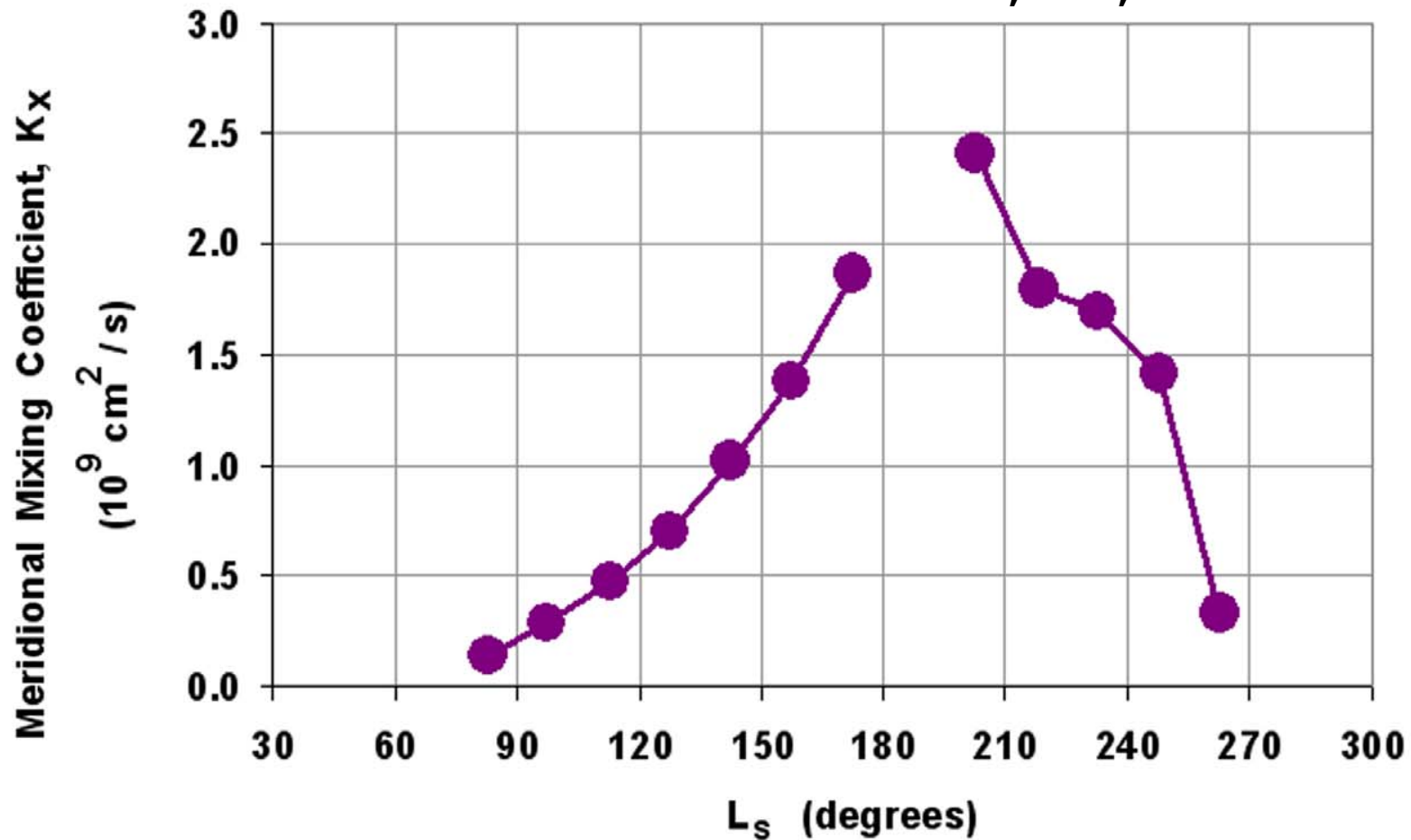$$K_x = (\Delta x / \Delta f)(v_x f_{Ar} - F_{Ar} / \rho)$$

These provide a parameterization of the efficiency of stirring Ar both against the wind and along a mixing ratio gradient

Total Ar Transport in and out of South Polar Region
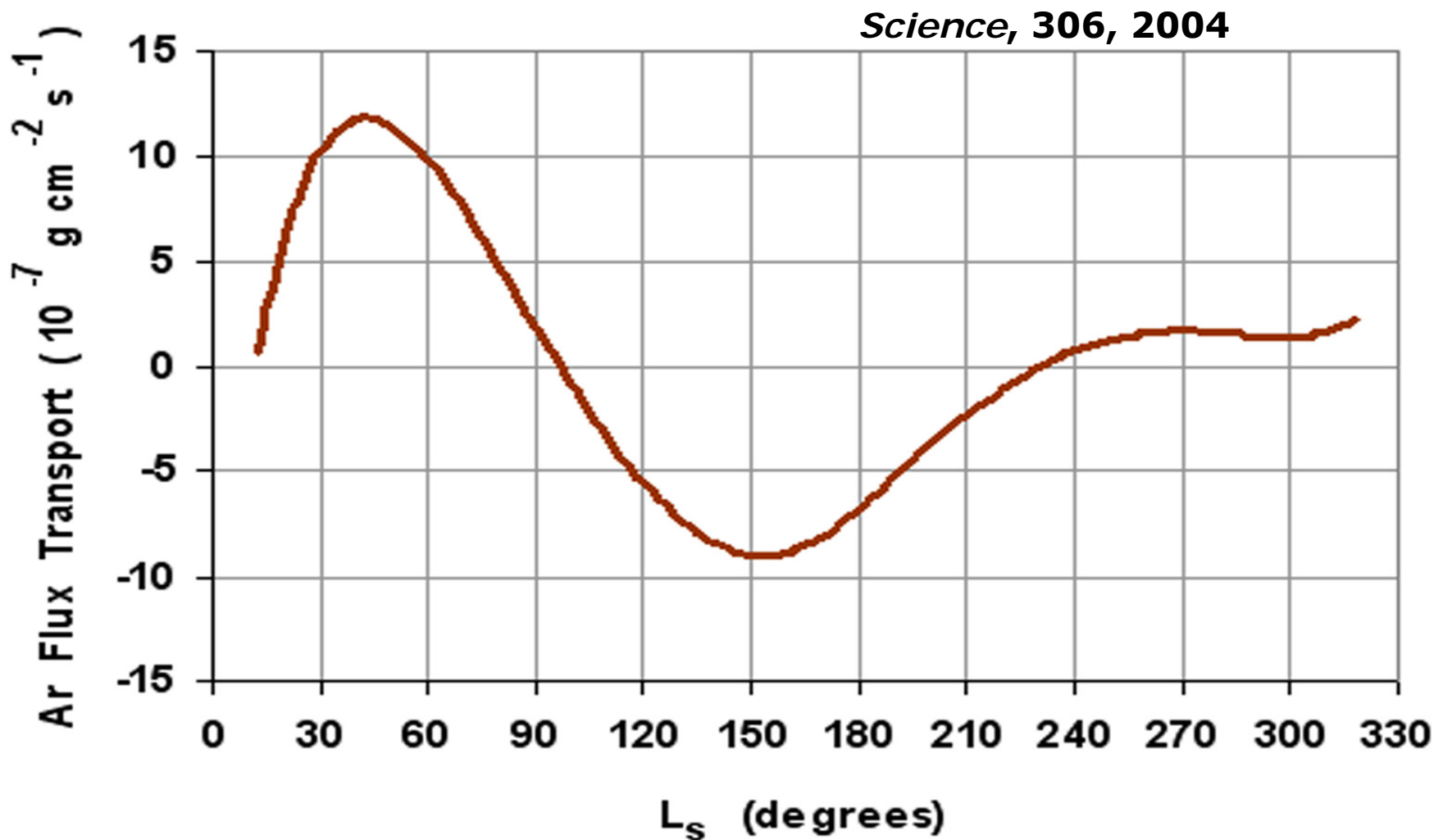
Science, **306, 2004**

Seasonal Variation in Meridional Mixing

Science, **306, 2004**

Summary

Ar abundance is an excellent tracer for the study of atmospheric circulation and bulk transport

The long southern winter and the relatively low atmospheric column abundance are the major factors creating the longer-lasting Ar enhancement than that of the northern polar region

Meridional mixing by both bulk flow and eddy transport are greatly enhanced with the onset of southern spring

The expanded data set at other latitudes (not shown here) exhibits considerable evidence for atmospheric wave activity at the perimeter of the polar seasonal caps

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