NASA-CR-201474

Progress Report

to the

National Aeronautics and Space administration

for

Grant NAG2-906

Research Concerning the Net Flux of Radiation in the Atmosphere of Jupiter

by

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Period covered: October 1, 1994 to July 1, 1996

July 5, 1996

The plan of the NFR team is for the data from the two solar channels (B and E) of NFR to be reduced at UA with the goal of determining the solar heating rate. In order to determine the solar heating rate from the NFR measurements, effects due to the instrument's spatial and spectral response functions, to the temperature variation of the instrument (and associated drift of calibration), to the setting sun, and to the rotation of the probe (initially at a rate comparable to the NFR sampling frequency), all must be well modeled. In the past year, a forward modeling routine was created to simulate NFR data return in the B and E channels. The effects of varying parameters describing the atmospheric model (such as cloud location and thickness) and the descent profile (such as rotation rate) were investigated and an inversion routine was developed.

For the forward modeling, existing UA radiative transfer codes were used to determine intensity fields within the Jovian atmosphere. Files describing the NFR spatial and spectral response for a standard temperature were received from UW. A routine was developed at UA to determine instantaneous instrument response by integrating the intensity field over the instrument response functions. A second routine was developed to determine the actual output of the NFR by integrating along an arbitrary descent trajectory (including such information as the variation of pressure, temperature, probe rotation rate, and solar zenith angle, with time). Simulated descents (see Fig. 1) show a large amount of structure in the net flux. This structure is real, induced by the sun crossing the edge of the NFR field of view. The upflux measurements do not have significant structure due to probe rotation (Fig. 2).

Near the tope of the atmosphere, the upflux data alone are used to constrain the cloud structure of the atmosphere. To accomplish this, models are used to describe the variation in up flux between consecutive measurements in terms of variations of cloud opacity and variations in known parameters such as the solar zenith angle. This allows us to develop a zero-order model of cloud structure. Lower in the atmosphere, at levels where there is little or no azimuthal structure to the net flux measurements, both the up flux and net flux are used to derive layer transmission and reflection functions, which then determine layer opacity and single scattering albedo.

Once this cloud structure is derived (with only 120-sec time resolution, corresponding to the up flux data points), it may be possible to determine probe pointing. For the coarse-resolution cloud structure, model data are derived for several consecutive net flux data points over a coarse grid in probe rotation rate and initial azimuth. This is iterated twice for progressively finer grids until a rotation rate is determined. Fig. 3 shows contours of equal residuals over a range of rotation rates and initial azimuths. The background level of the residuals is some 800 DN, while the optimal solution is ~ 20 DN and a factor of two smaller than the next lowest minimum in the residual field.

On 14 December 1995, the first portion of probe symbol data became available. This section of the data ended approximately at sunset, and thus comprises essentially the entire mission for the solar channels of the NFR. This "quick look read out" had some data outages (Jupiter was within 7° of the Sun during the entire read out). The first complete read out of symbol data was obtained in January. Because not all of both strings of data were recorded as symbol data, we had the first fully complete data set some time later when the tape recorder play back was finished (~May 1996).

A preliminary analysis of the data began in December 1995. In these data we could see the rapid oscillations expected at the beginning of the data due to probe rotation and the sun passing through the edge of the field of view. In addition, the time when this oscillation stopped was clearly visible. This sets the rough optical depth above the probe at this time. A preliminary set of models was fitted to these obeservations, and these appear in the

Science paper describing the first results from the NFR (Sromovsky et al., The Galileo Probe Net Flux Radiometer Experiment: Preliminary Results, submitted to *Science* March 10, 1996, revised April 12.).

Even at the time of the first examination of the results of the NFR, it was clear from the behavior of the blind channel that the thermal history of the instrument during entry had a substantial effect on the data returned. Since that time, we have worked with the NFR team to attempt to understand the nature of the corrections that are appropriate for the raw NFR data. It is clear that these corrections need to be firmly established, and that the reliability of the results will depend on the certainty with which these instrumental correction factors can be established.

Figure Captions

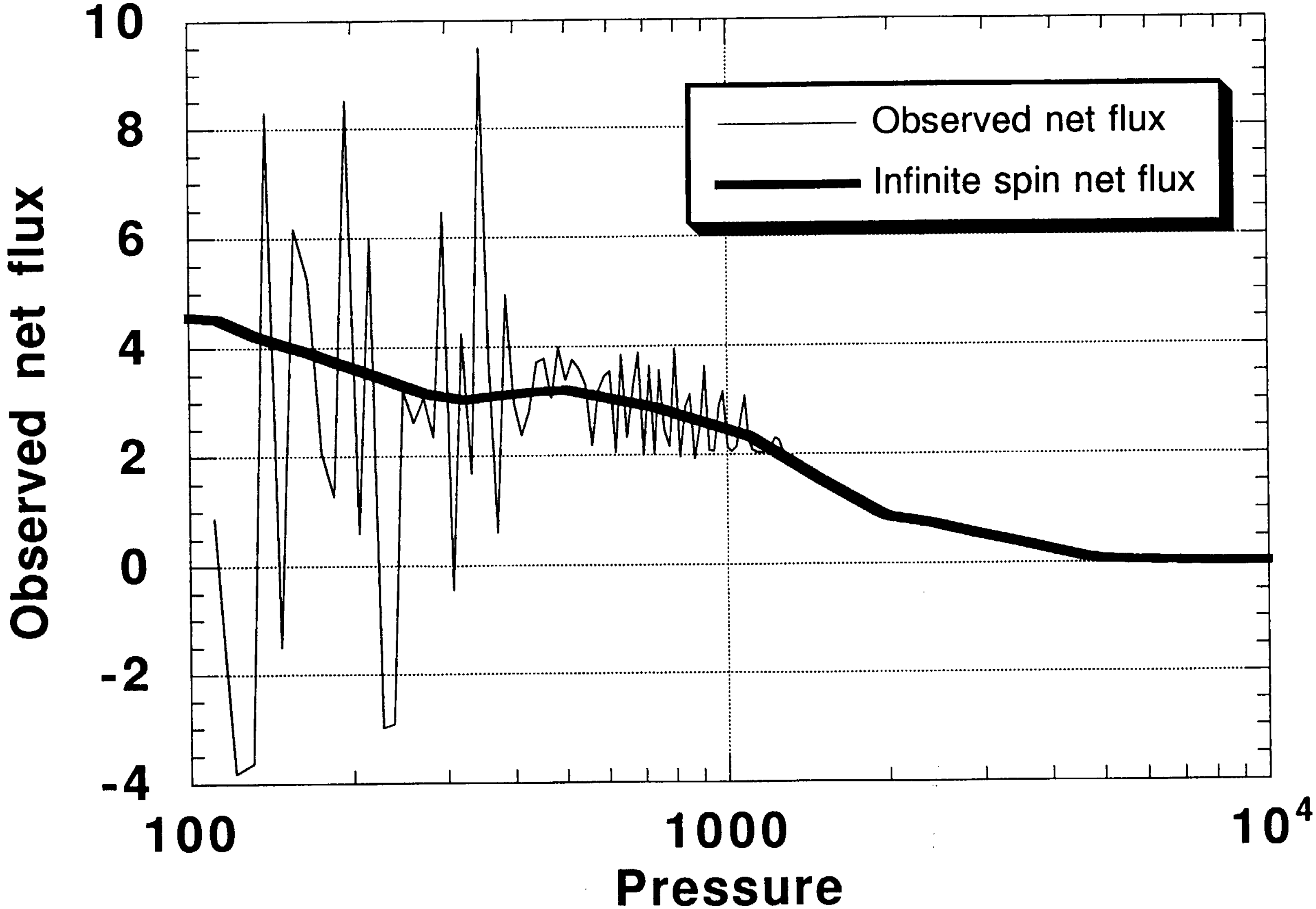
FIGURE 1. Simulated net flux observations of the NFR in the Equatorial Zone. A) A simulated data stream including azimuthal variations is compared to the "infinite spin" result for the same descent. In the infinite spin case (heavy line), an azimuthal average is always measured. In the "observed" case, all of the variation is due to structure in the intensity field, primarily the direct solar beam, and no noise has been added. B) The "infinite spin" data stream (solid line), which incorporates the NFR spatial response function, is compared to the actual net flux within the B band pass (medium dashed line, "Net flux (B)"), which has a cos(zenith angle) response function. Models relate the solar net flux (long dashed line) to the flux within the band. The contribution from the direct solar beam and the downward diffuse sunlight are shown as short dashed lines.

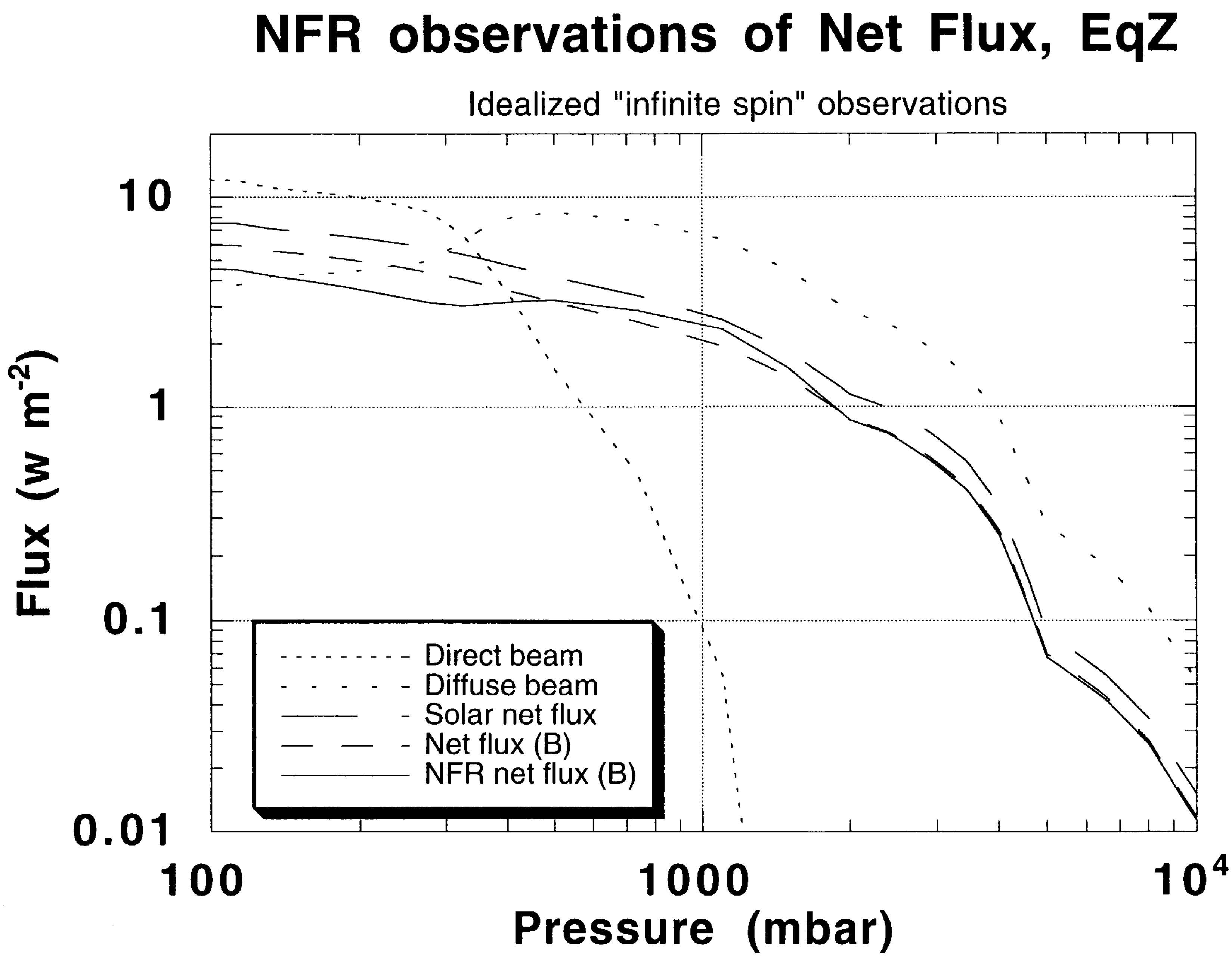
FIGURE 2. Simulated up flux observations of the NFR in the Equatorial Zone. The up flux data (circles), "infinite spin" or ideal up flux (short dashed line), and up flux within the band pass (long dashed line), overly each other to within ~1%. The solar up flux (solid line) is determined from the observations through models.

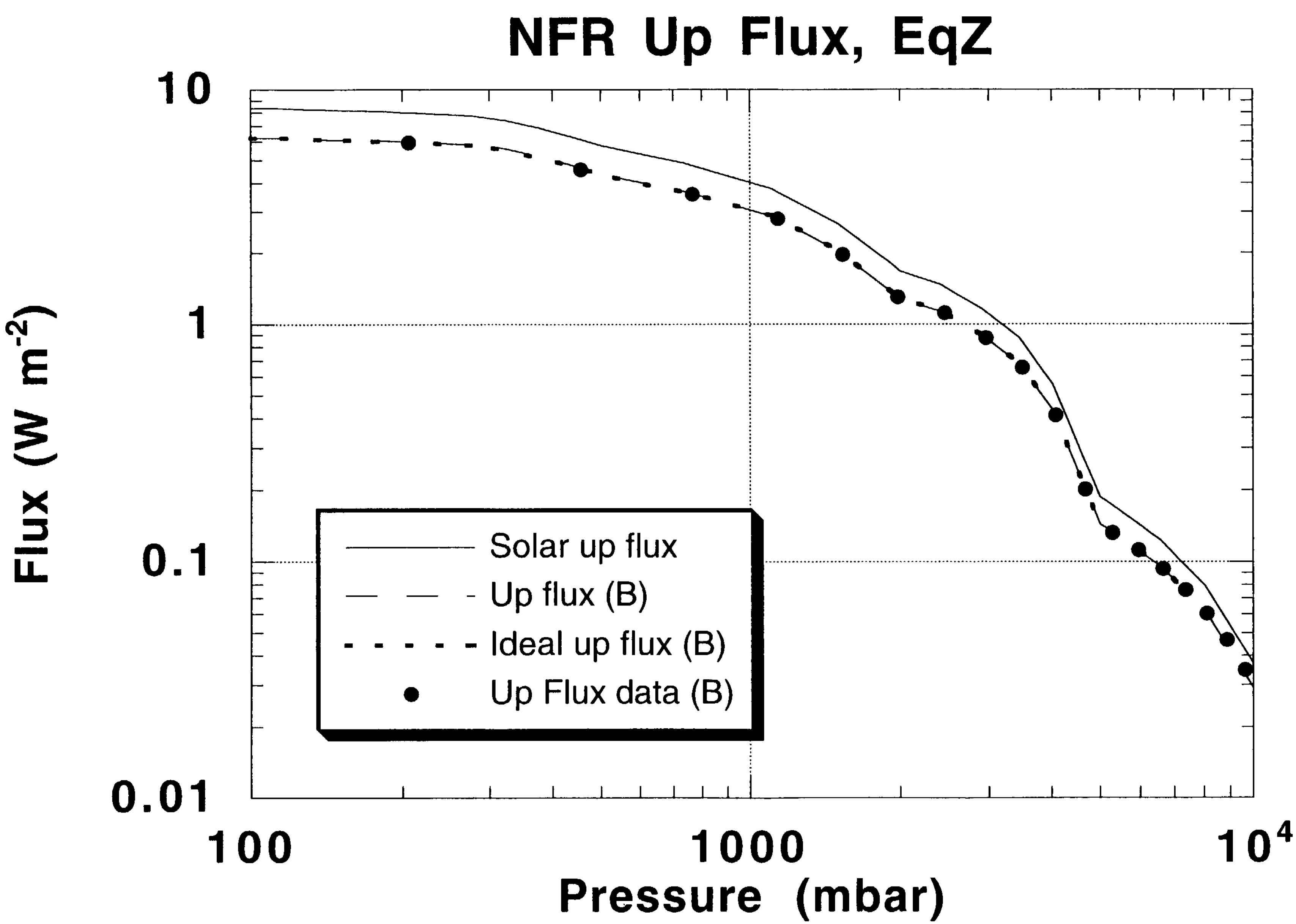
FIGURE 3. Finding NFR pointing and rotation. A) Four consecutive simulated data points for two descents through the same atmosphere are compared for the same initial azimuth and small variations in rotation rate. An error of more than 0.05 RPM produces a residual comparable to the background of 225 (in units of ~10 counts). For comparison, the probe's initial spin rate may be anywhere between -100 and +100 RPM. B) A similar plot for matching rotation rates and small variations in initial azimuth. An error of 20° produces residuals comparable to the background (indicated by horizontal line). C) The thirty best fits from a grid of rotation rates and initial azimuths are shown. Values outside the range 41.5–42.5 RPM were eliminated by coarser gird surveys. The assumed decent profile was an exponentially decaying spin rate R=42.25 exp(-(t - t0) / (180 sec)).

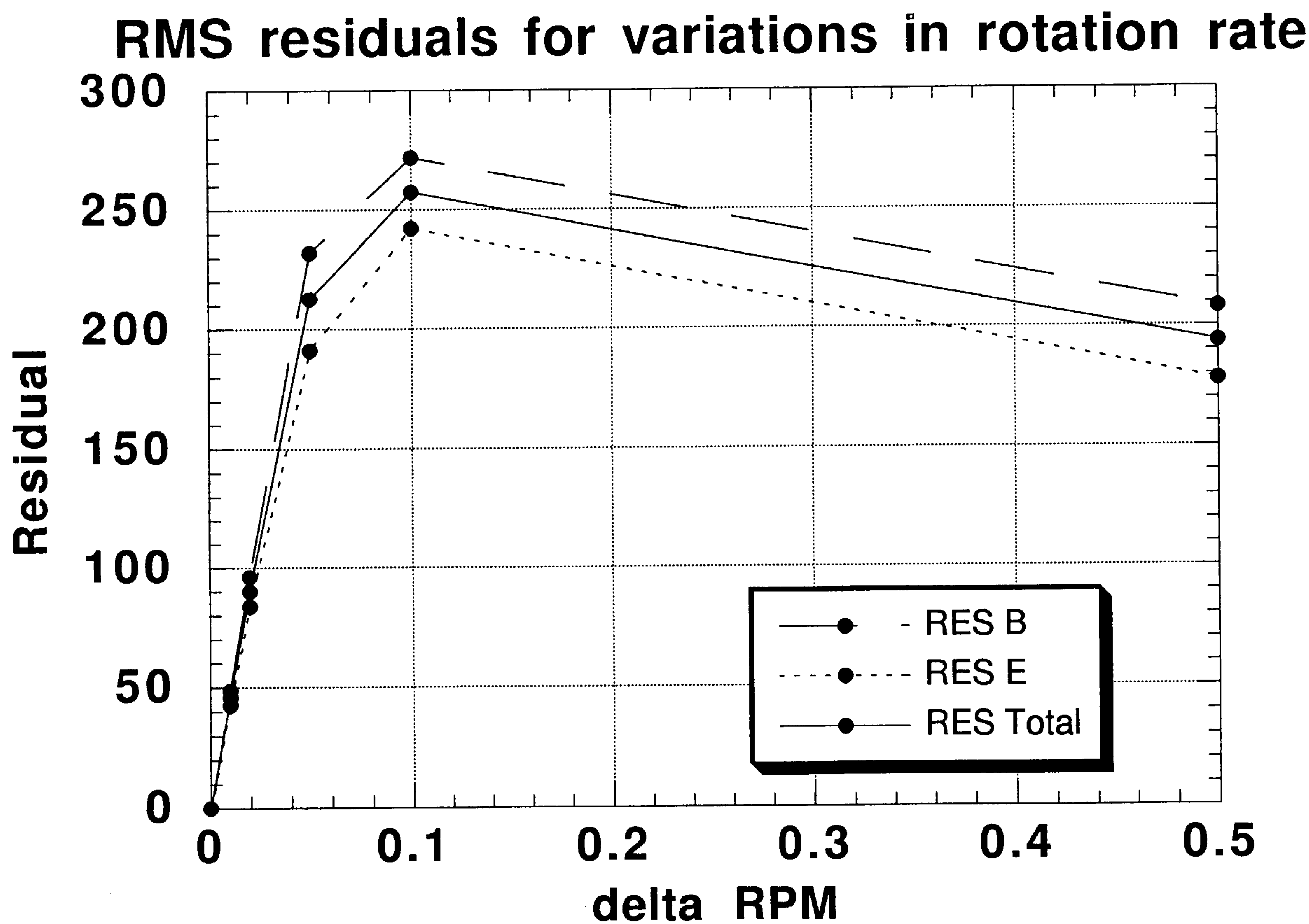
NFR observations of Net Flux, EqZ

Plausible data stream vs. idealized case (no noise)

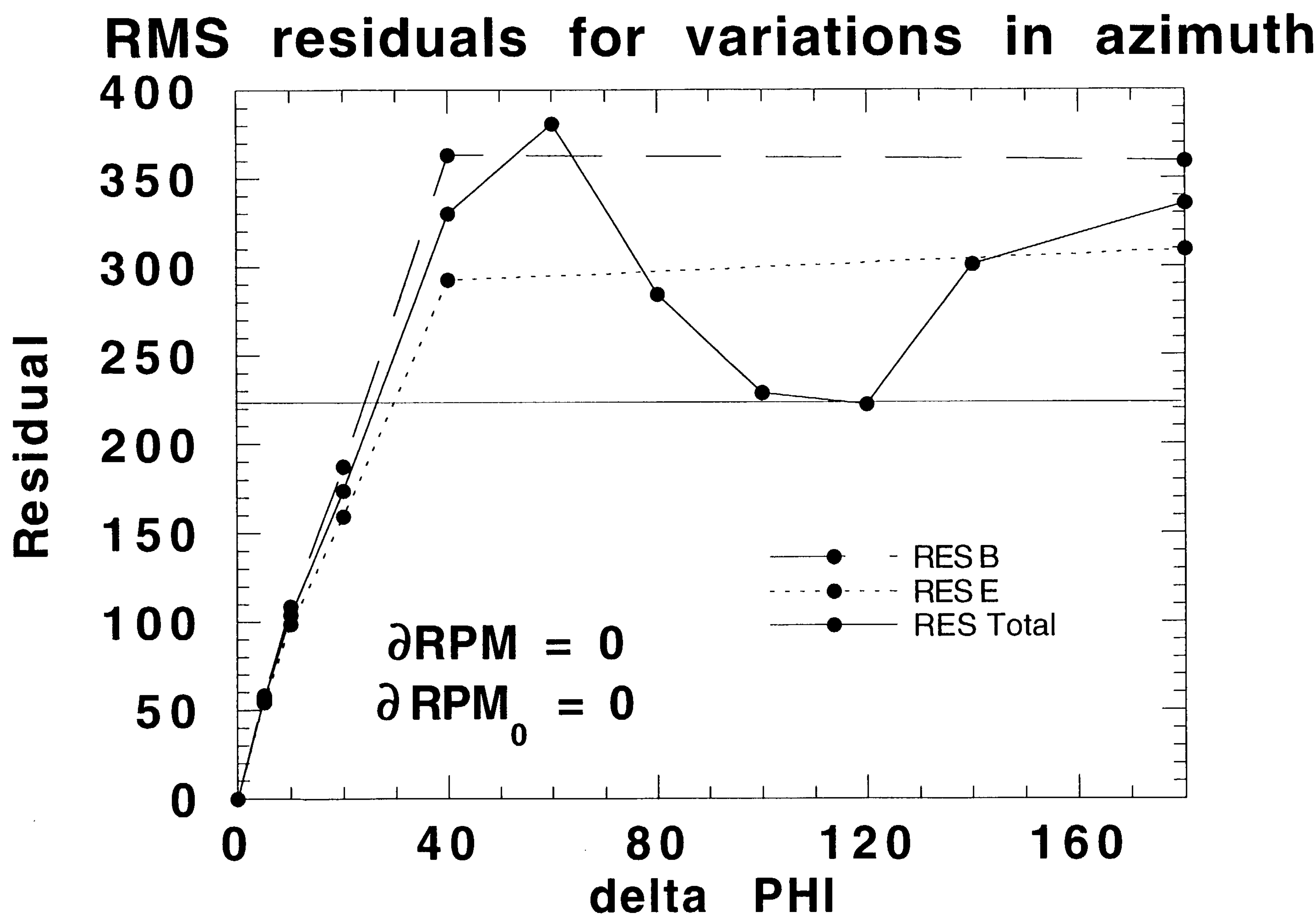



NFR observations of Net Flux, EqZ
Idealized "infinite spin" observations
Flux (w m^-2)
10
1
0.1
0.01
100
1000
10^4
Pressure (mbar)
Direct beam
Diffuse beam
Solar net flux
Net flux (B)
NFR net flux (B)

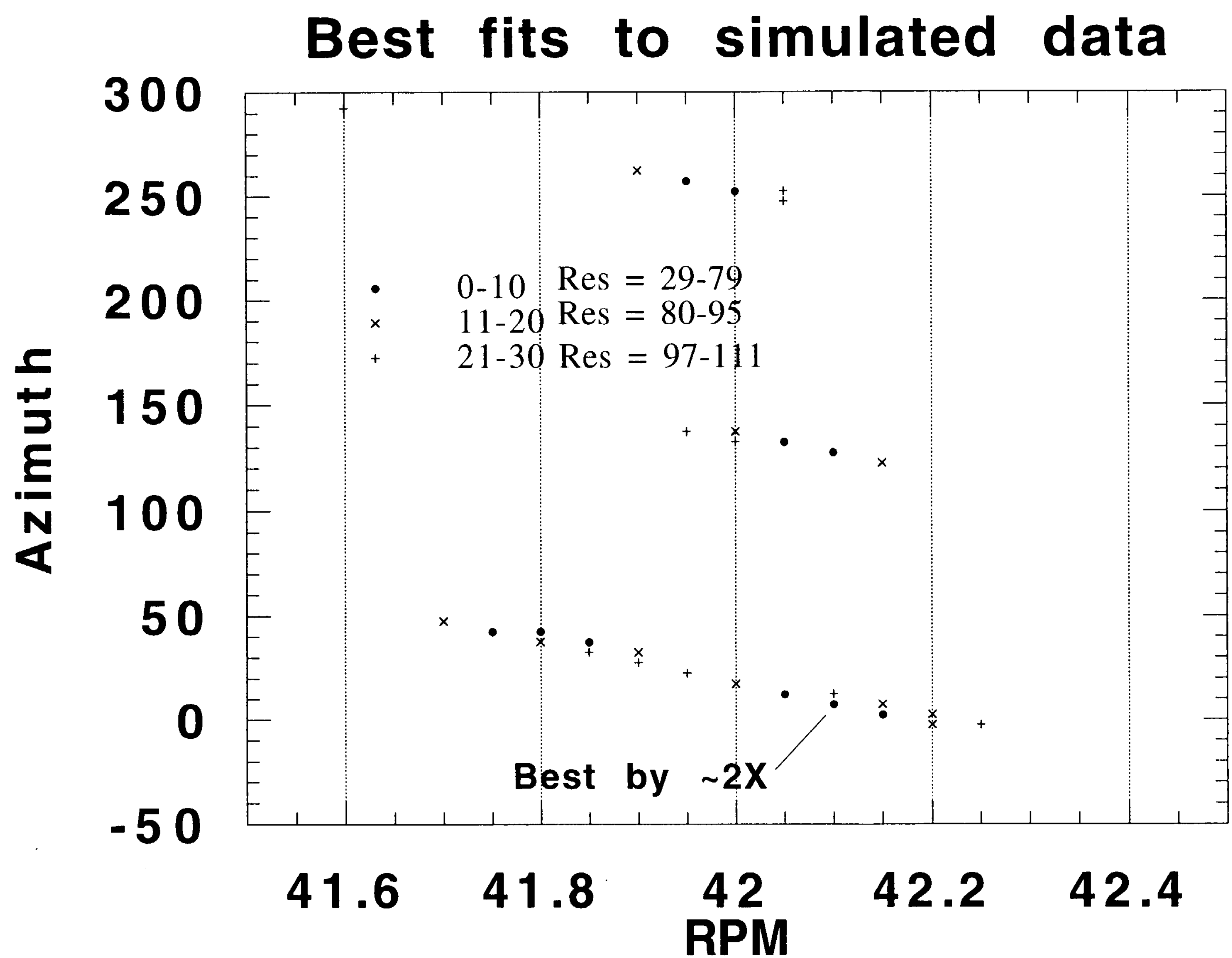

NFR Up Flux, EqZ
10
1
0.1
0.01
Flux (W m-2)
100
1000
10^4
Pressure (mbar)
Solar up flux
Up flux (B)
Ideal up flux (B)
Up Flux data (B)



RMS residuals for variations in rotation rate
Residual
300
250
200
150
100
50
0
0
0.1
0.2
0.3
0.4
0.5
delta RPM
- RES B
RES E
RES Total



RMS residuals for variations in azimuth
Residual
delta PHI
0
40
80
120
160
0
50
100
150
200
250
300
350
400
RES B
RES E
RES Total
∂RPM = 0
∂RPM0 = 0



Best fits to simulated data
Azimuth
300
250
200
150
100
50
0
-50
0-10 Res = 29-79
11-20 Res = 80-95
21-30 Res = 97-111
Best by ~2X
41.6
41.8
42
42.2
42.4
RPM