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A NORTH-SOUTH ASYMMETRY IN THERMOSPHERIC DENSITY

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INTRODUCTION

Reason of reanalyzing the old observational material from the 70's:

Our previous results on the geomagnetic effect in neutral upper-atmospheric density based on in situ CACTUS and San Marco V **accelerometric measurements were restricted to the equatorial region**, because of the small inclination of the satellites in question.

In order to enlarge the latitudinal interval we have reanalyzed our old observational material from the 1970's – based on measurements of the orbital decay of many satellites.

A serendipitous result of this investigation, the North-South asymmetry of the upper atmosphere is the topic of the present paper.

OBSERVATIONAL MATERIAL

Total neutral air density based on drag decay.

Number of satellites: 59

Number of selected satellites (e > 0.01): 20

Number of data points: over 30 000

Height interval: 260 – 450 km

Inclination: 3° – 96°

Time interval: May 1965 – Sep. 1977

Time resolution: 1 – 2 days

The CIRA 72 upper atmospheric model have been used as a comparison for $\mathbf{f = \rho^{observed} / \rho^{model}}$

Normalization:

As the **cross sections** of the satellites are only approximately known, **in order to compare** densities derived by the orbital decay of **different satellites**, $\rho/\overline{\rho}$ values have been calculated for all satellites separately, where $\overline{\rho}$ is the mean of the ρ values derived from the given satellite.

f-DEPENDENCE ON LATITUDE (all satellites)

– Every star or diamond represents a single measurement, i.e. f–1 value belonging to the perigee's latitude/longitude.

– Big points are average values in 10° latitude intervals.

Results:

1/ North-South asymmetry

f – 1 continuously and evenly decreases between φ = ± 60°. This latitude interval is taken into consideration, because there is only one satellite reaching the polar regions and it behaves irregularly, as it is demonstrated later. $\overline{\Delta}_{\varphi}$=+0.20

2/ Model dependence

1. Using CIRA 86 the asymmetry is smaller compared to that of CIRA 72,
2. but contrary to CIRA 72, the CIRA 86 model overestimates the density systematically.

3/ The dependence is the same if geographic or geomagnetic latitudes are used.

4/ Polar regions

In one case (6445B) with i = 96° (retrograde orbital motion) there is a bending down above 60° and below –60°. (No other satellite is reaching the polar regions.)

f-DEPENDENCE ON LATITUDE (satellites separately)

Six satellites have been separately plotted to control the phenomenon. Those satellites were selected for this purpose where the observational material spans a time interval longer than four years.

Result:

Five of the six satellites demonstrate independently **the same asymmetry effect** as the combined plot of all 20 satellites.

The satellite ***6445B***, however, having an inclination of 96° (retrograde orbit) **deviates** from all the others in form: a concave curve instead of a straight line. The extreme left and right parts of the global diagram (the highest latitudes) are based exclusively on this satellite, since other high inclination satellites were not available.

f-DEPENDENCE IN DIFFERENT GEOGRAPHIC REGIONS

Is the measured hemispheric asymmetry in

$$f - 1 = \rho^{observed} - \rho^{model} / \rho^{model}$$

due to a physical effect, or is it an artifact of the models?

The fact that CIRA 72 does not contain a hemispheric asymmetry term, but the residuals show, argues for the physical reality of an asymmetry in the high atmosphere in density and temperature.

CIRA 86 contains a term for hemispheric asymmetry, which might reduce the asymmetry in the residuals of CIRA 86 compared to CIRA 72, but is obviously not enough to eliminate it completely.

Is the hemispheric asymmetry due to the significantly different distribution of oceans on the hemispheres?

Control No. 1: continent versus ocean

a selected region only on the Northern hemisphere:

Eurasia on the left side, Pacific Ocean on the right.

Result: no asymmetry $\Delta_\lambda = 0$

Control No. 2: *selected North-South segments of the globe*

1. Continent versus ocean

   Eurasian continent in the Northern and Indian Ocean in the Southern hemisphere

   Result: the same slope of North-South asymmetry ($\Delta_\varphi = +0.26$)

2. Continents only

   North America in the Northern, South America in the Southern hemisphere.

   Result: there is an asymmetry but the slope is significantly smaller ($\Delta_\varphi = +0.09$)

3. Ocean only

   Pacific Ocean on both hemispheres

   Result: the same kind of North-South asymmetry ($\Delta_\varphi = +0.21$)

4. Ocean only

   Atlantic Ocean on both hemispheres

   Result: the same kind of North-South asymmetry, but larger than average ($\Delta_\varphi = +0.32$)

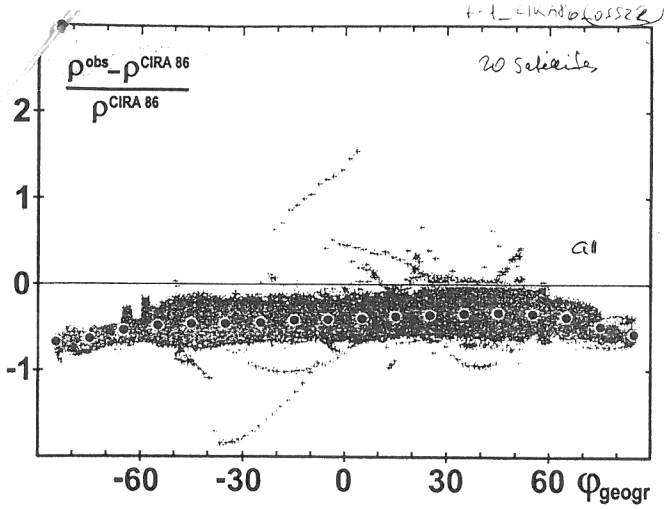
CONCLUSIONS AND QUESTIONS

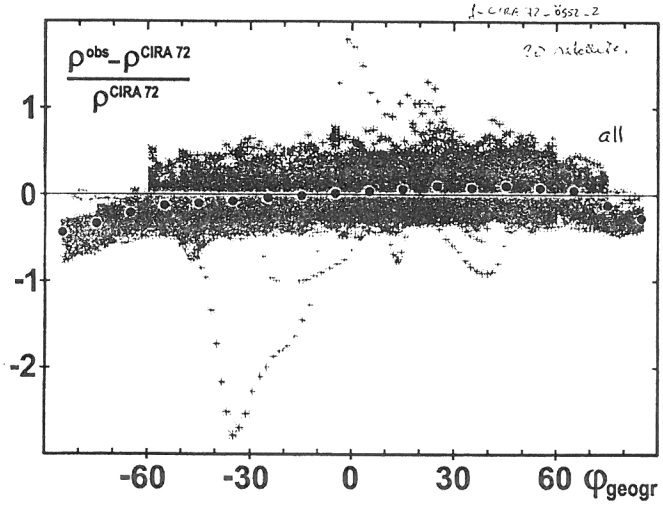
The **existence of a global asymmetry** between the Northern and Southern hemispheres is an **observational fact**.

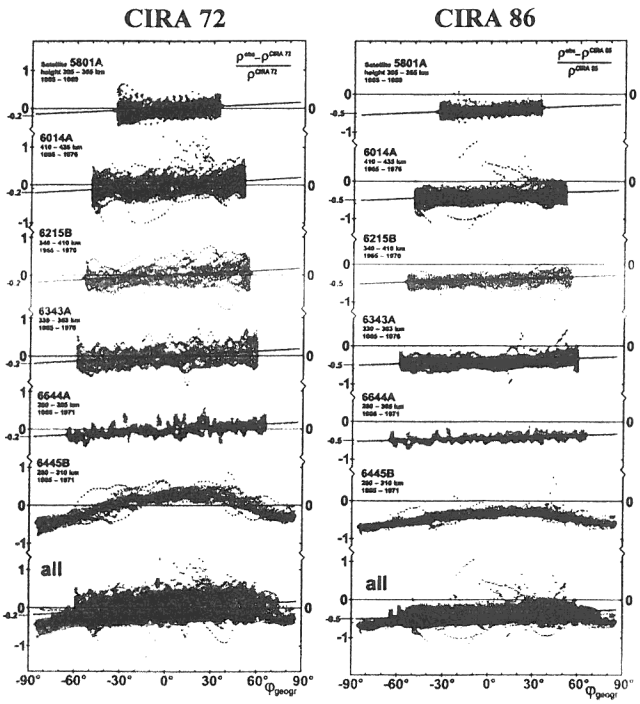
Its **explanation** by the different distribution of continents on the hemispheres is not clear – at least it is difficult to explain the large Δ value on the Atlantic Ocean.

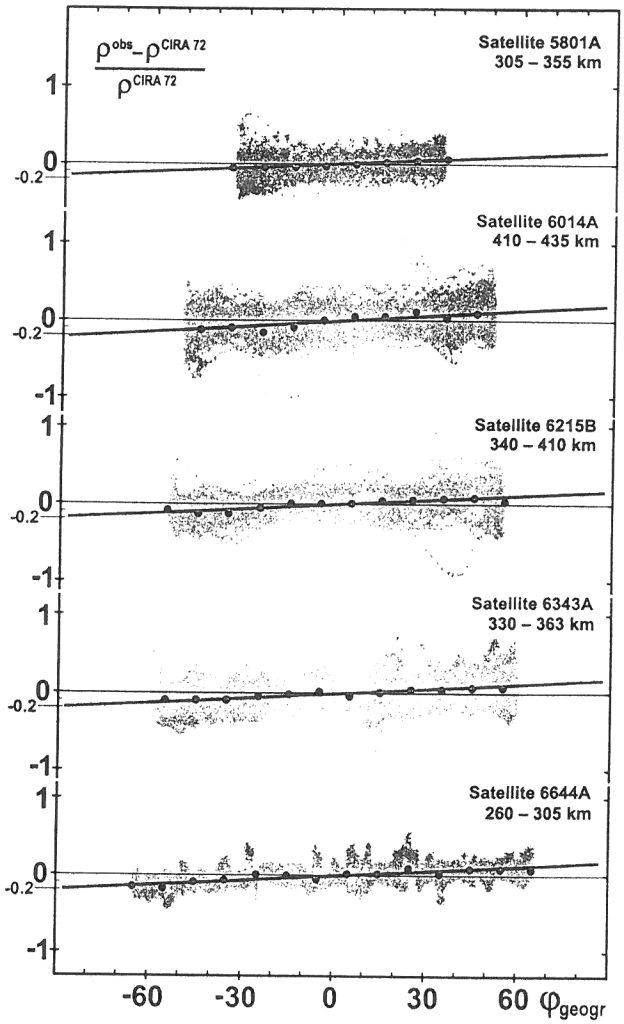
The **zonal winds**, however, **might effectively average out the temperature differences** between continents and oceans over one hemisphere. The fact that the Northern hemisphere is dominated by the effect of the large Eurasian continent, while the Southern, on the other hand, by the big ocean surfaces, might be the cause of the observed asimmetry.

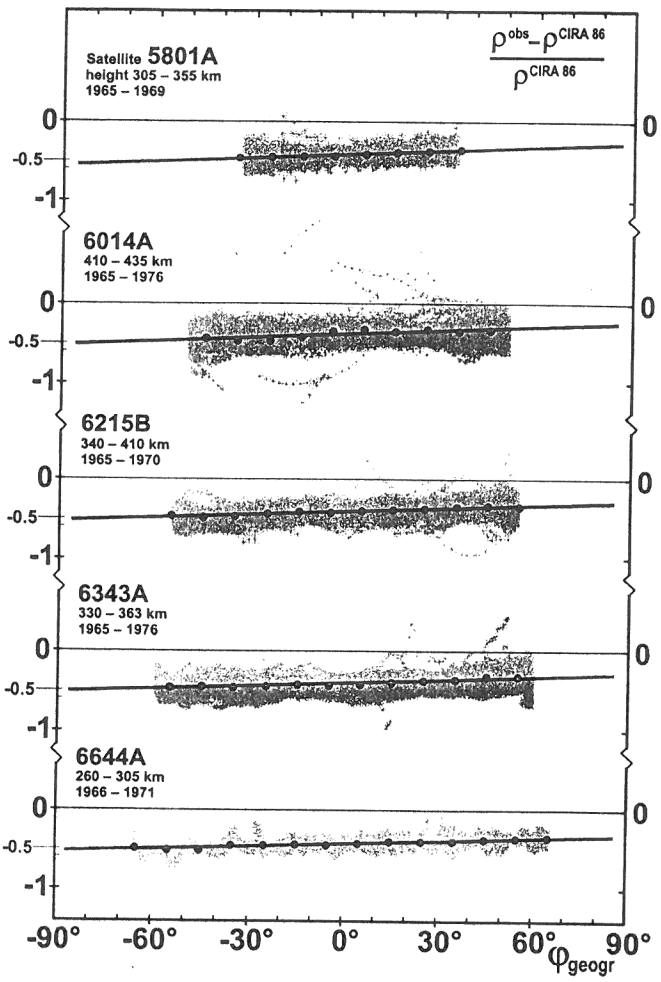
If the continent/ocean distribution is the reason of the observed asymmetry, than **it is surprising that the specific heat of the surface material has such a big influence even at satellite altitudes.**


ρobs−ρCIRA 86
ρCIRA 86
all
-60 -30 0 30 60 φgeogr

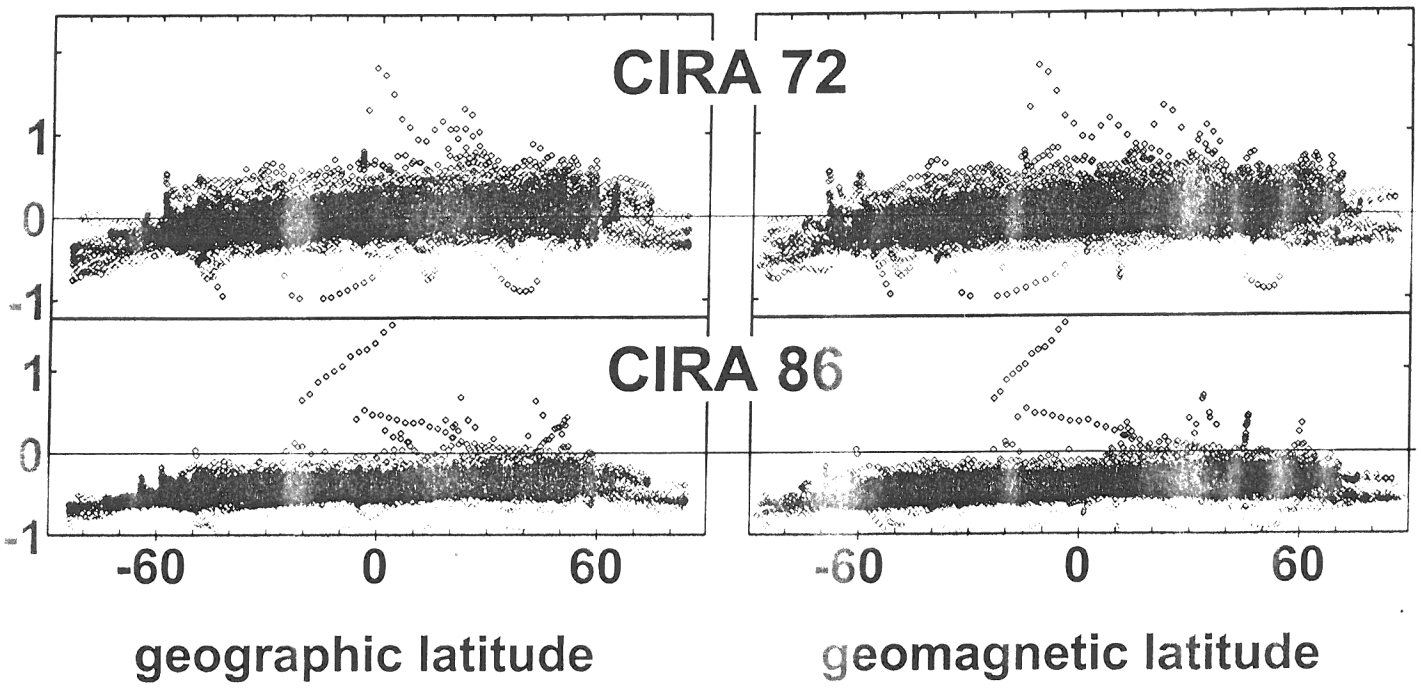

ρobs−ρCIRA 72
ρCIRA 72
all
-60 -30 0 30 60 φgeogr

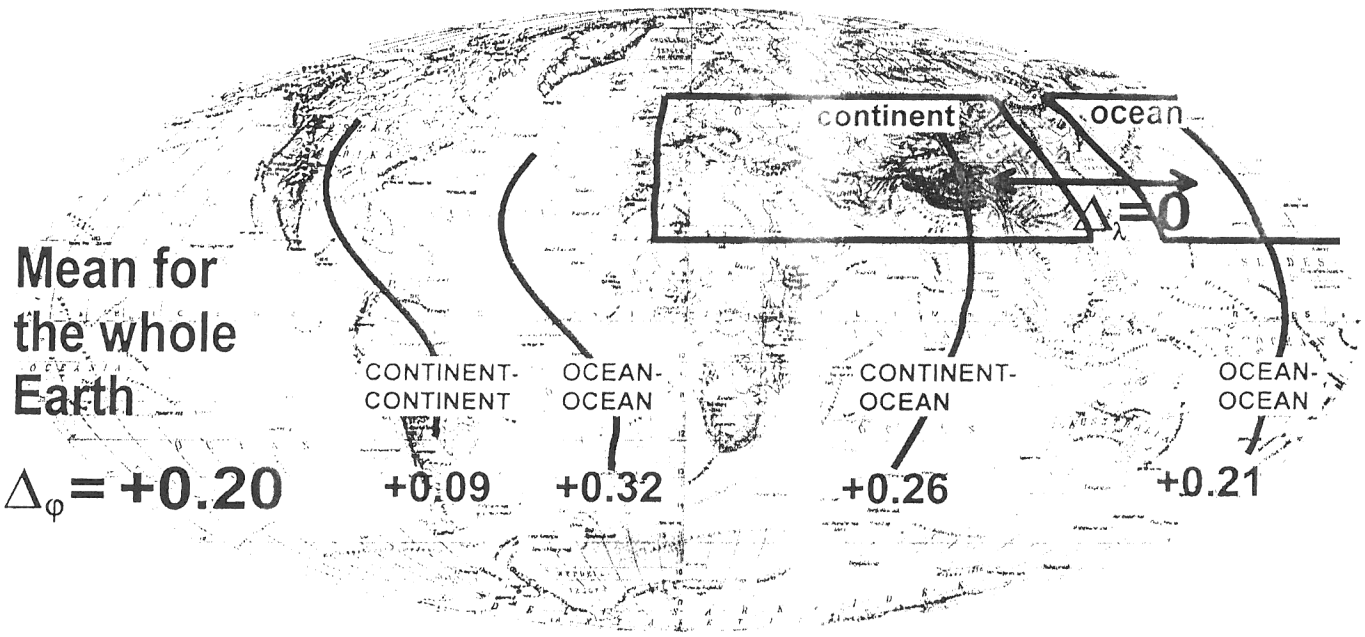

CIRA 72
CIRA 86
6014A
6215B
6343A
6644A
6445B
all
-90° -60° -30° 0° 30° 60° 90°
φgeogr


ρobs−ρCIRA 72
ρCIRA 72
Satellite 5801A
305 – 355 km
Satellite 6014A
410 – 435 km
Satellite 6215B
340 – 410 km
Satellite 6343A
330 – 363 km
Satellite 6644A
260 – 305 km
-60 -30 0 30 60 φgeogr


ρobs−ρCIRA 86
ρCIRA 86
Satellite 5801A
height 305 – 355 km
1965 – 1969
6014A
410 – 435 km
1965 – 1976
6215B
340 – 410 km
1965 – 1970
6343A
330 – 363 km
1965 – 1976
6644A
260 – 305 km
1966 – 1971
-90° -60° -30° 0° 30° 60° 90°
φgeogr

$(\rho^{obs} - \rho^{model}) / \rho^{model}$





Δ_φ = difference between $(\rho^{obs} - \rho^{CIRA\ 86}) / \rho^{CIRA\ 86}$ values at +90° and at -90° latitude