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RING CURRENT: AN ADDITIONAL HEAT SOURCE FOR THE NEUTRAL UPPER-ATMOSPHERE

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ABSTRACT This paper is a summing up to demonstrate that the precipitation of the ring current ions represents a second source for the neutral upper-atmosphere from the solar corpuscular heating. In addition to the auroral heat source the ring current is heating the neutral atmosphere around equatorial latitudes and not only in the main phase, but also during the recovery phase of a geomagnetic storm. The additional density increases connected to the ring current precipitation have only a two hours time delay with respect to the dDst/dt. As the Dst characterizing the intensity of the ring current is proportional to the dDst/dt, we have modeled the density increase using Dst as an index in an improved empirical model (ddMSIS). Our model takes into account the height and local solar time dependence of this additional density increase as well.

Observational material that made the discovery of the ring current heating possible:
Thermospheric density data (ρ) measured and derived
- by drag decay of 59 artificial satellites on the basis of visual observations (1965-1977),
- by the French CACTUS microaccelerometer on board the CASTOR satellite (1975-79),
- by the Italian DBI microaccelerometer on board the Italian San Marco V satellite (1988)

Method
The measurements have been compared to CIRA'86 model density values.
The dependence of $f = \frac{\rho^{measured}}{\rho^{model}}$ values on several parameters has been investigated.

DIAGRAMS DEMONSTRATING SEVERAL INSUFFICIENCES IN UPPER-ATMOSPHERIC MODELS

1.) The total response (*D*) to geomagnetic storms

Fig. 1: Below 300 km the total response (*D*) of the neutral upper-atmosphere to large magnetospheric storms is significantly more intensive than supposed by the Jacchia models.

REFERENCES
Almár, I., Illés-Almár, E. (2004): A proposal to improve the CIRA'86 model in the equatorial region: the ddMSIS model. Adv. Space Res. 34 (2004). 1768-1772.
Bencze, P., Almár, I. and Illés-Almár, E. (1993): Ring current heating of the low latitude thermosphere connected with geomagnetic disturbances, Adv. Space Res. 13 (1), 303-306, 1993.
Bencze, P., Illés-Almár, E. (1986): The flux of the ring current protons as an additional heat-source for the neutral upper atmosphere after geomagnetic storms, Nabl. ISZ 24 Moscow pp. 121-127 Ed.: G. Massevich et al. Astrosovet, Moscow, 1986.
Illés-Almár, E. (2004): Two distinct sources of magnetospheric heating of the atmosphere: the aurora and the ring current. Adv. Space Res. 34 (2004) 1773-1778.
Illés-Almár, E. (2009): Seasonal dependence of the North-South asymmetry in the neutral upper-atmosphere. Poster II-07 0080 IAGA, Sopron, Hungary, 2009.

2.) Geomagnetic neutral post-storm effect

Fig. 2.a: The neutral atmospheric mean density (ρ) does not return to quiet level as quickly as the Ap index does, but remains higher for about 7-10 days after the Ap peak (Illés-Almár et al., 1985). The diagram was constructed on the basis of the drag decay of 59 satellites and 14 geomagnetic disturbances between 1965 and 1972 – by superposed epoch method with Ap maxima as key days. *f* is the mean residual with respect to CIRA '72 model, Ap is the geomagnetic index.

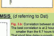

Fig. 2.b: Ap and Dst geomagnetic indices as functions of time. During the recovery phase of a geomagnetic storm – to the contrary to Dst – the Ap already has returned to its quiet level.

Fig. 2.c: The density is a double-valued function of Kp, that is, Kp alone is not a suitable index to describe the density variation in connection with magnetospheric storms. Deviations of quiet time mean measured density from the corresponding CIRA'72 model values with Kp=0 are plotted as a function of Kp geomagnetic index. Measurements apart from storm-time refer either within (thin crosses) or outside (heavy crosses) the recovery phases.

3.) The dependence on Dst ⇒ Model-improvement: dMSIS (*d* referring to Dst)

Fig. 3.a: This figure demonstrates that the CACTUS-residuals of MSIS'86 model depend on Dst.

Fig. 3.b: Correlation between density and Dst. The best correlation is at 2 hours time delay that is much smaller than the 6.7 hours time delay to Kp. That short time delay suggests a much nearer heating place than the auroral oval.

According to Bencze and Illés-Almár (1986) and Bencze et al. (1993) the heating is a consequence of the precipitation of ring current protons and O+ ions (partial ring current).

4.) Our dMSIS model is really an improvement.

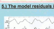

Fig. 4.a: Comparison of measured density data to model values illustrates that our dMSIS model containing a Dst dependent factor is really an improvement.

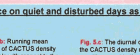

Fig. 4.b: Case study demonstrating that the averaging procedure for Kp geomagnetic index in the MSIS model (dotted line) is not satisfactory, because it can not describe the sharp density increases in connection with geomagnetic storms. Our dMSIS model (heavy line) – containing the Dst geomagnetic index as well – can follow the measurements much better.

5.) The model residuals include a diurnal dependence on quiet and disturbed days as well.

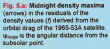

Fig. 5.a: Midnight density maxima (arrows) in the residuals of the density values (*f*) derived from the orbital drag of the 1965-53A satellite. ψ_{bulge} is the angular distance from the subsolar point.

Fig. 5.b: Running mean curves of CACTUS density residuals with respect to the MSIS'86 model during **quiet days**, separated according to geomagnetic latitudes and heights. The nighttime maximum and its shifting in phase with latitude are conspicuous.

Fig. 5.c: The diurnal course of the CACTUS density residuals with respect to the MSIS'86 model for the first day of each of the **21 geomagnetic storms** used for the investigation (upper panel) and separated according to latitude (lower part of the figure).

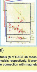

Fig. 5.d: Different steepness in different LST hours. CACTUS residuals of MSIS'86 model values are plotted as a function of LST (upper panel), and selected according to LST and plotted as function of Dst (lower panel).

6.) Another model improvement has been carried out: ddMSIS model (the first *d* refers to Dst, the second *d* to diurnal)

Our ddMSIS model takes into account not only the Dst dependence – like dMSIS – but also the height and the diurnal dependence in connection with the compressional heating (midnight density maximum even in geomagnetically quiet days) as well as the heating in connection with the ring current.

Fig. 6: Hourly mean values of the logarithm of the residuals (*f*) of CACTUS measurements with respect to the MSIS'86, and our dMSIS and ddMSIS models respectively. It proves that both, the dMSIS and ddMSIS are real improvements especially in connection with magnetospheric storms but even in quiet times.

7.) The mean density residuals with respect to ddMSIS model indicated already a white noise

but the scatter was much larger – sometimes in excess of 10-15% – than the measurements errors.

The San Marco V accelerometric measurements (of 1 s time resolution) pointed to the cause, that is, the noise may be due to the presence of atmospheric density waves. As a consequence, the prediction of density values to a given moment is limited by the presence of different kinds of these waves and of their interaction.

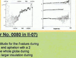

Fig. 7: Examples of **density waves** at different times (a) and in different heights (b) in total neutral density measured by the San Marco V accelerometer.

8.) A further effect has been discovered recently (see poster No. 0080 in II-07)

Fig. 8: The distance effect. Density versus geographic latitude for the *f*-values during 3 months time intervals centered to the times of perihelion and aphelion with a 2 months time delay. The density is about 4% higher over the whole globe during perihelion than during aphelion – as a consequence of the larger insulation during perihelion interval.

This discovery gives a possibility to a **further improvement** of roughly 4 % in the form of a cosine factor: **dddMSIS model** (the first *d* refers to Dst, the second *d* to diurnal and the third *d* to distance variation) as a consequence of the eccentric orbit of the Earth).

INTERPRETATION

Even in geomagnetically **quiet periods a nighttime density maximum** occurs that is probably connected with **compressional heating** due to global winds originating from the subsolar point. The dependence of the total density residuals (with respect to the CIRA'86 model values) on Dst might be the consequence of **heating by particles (protons and oxygen atoms) precipitating from the ring current**. This effect which acts **not only during the main phase, but during the recovery phase** of the storms as well, hints at an **additional magnetospheric heating** (besides the well-known auroral heating in the main phase of geomagnetic storms) with a maximum near the equator and probably also at the SAR arc region. The equatorial source may be connected with ions, neutralized by charge exchange (ENA), precipitating from the ring current and having a velocity vector directed towards the Earth. The SAR arc source – which we postulated, but could not be investigated by the CACTUS or San Marco measurements because of the low inclination of the satellites – may be due to charged particles precipitating by wave-particle interaction from the ring current.