A comparison between DEMETER and Millstone Hill ISR observations in a period of low solar activity

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OBJECTIVES

Study, funded by the SWARM project, with the following objectives

1- Determine the procedure and methodology to perform an absolute calibration of in-flight plasma measurements using ground-based ISR observations.

2- Use DEMETER as an example to determine to which extent such a calibration can be achieved and the actual accuracy.

3- Based on the results look for possible improvements of the data processing of DEMETER data

4- From the DEMETER case define the best method and conditions to perform the future calibration of SWARM instruments and evaluate the expected performances

DATA

1- DEMETER Plasma Instruments

IAP, a Retarding Potential Analyzer and Drift Meter densities of the major ion species H+, He+, O+

ion temperature Ti and velocity **Vi**

time/space resolution along track

Survey modes 4.3 s / 32 km, Burst modes 2.2s / 16 km

ISL, a Langmuir Probe

Electron density Ne and temperature Te

time/space resolution 1s / 7.5 km in Survey and Burst modes

DATA

2- INCOHERENT SCATTER RADARS (ISR)

Use the properties of the VHF (~1 GHz) EM waves scattered by ionospheric plasma irregularities to determine the vertical profiles of the main plasma parameters: Ne, Te, Ti, Vi and the ion composition

Millstone Hill (42.6°N, 71.5°W) at mid latitude best suited for DEMETER calibration:

Mid-latitude ionosphere display negligible time and space variations during periods of low magnetic activity

long history of measurements, active scientific team and good data base

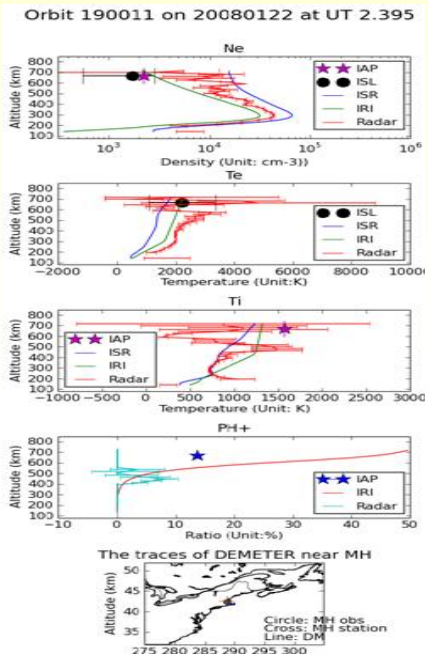


Figure 1a

MILLSTONE HILL ISR observations

Criteria for selected conjunctions

- ISR and DEMETER measurements within 10 min (most case 3 min)
- DEMETER closest point less than 700 km from MH vertical (numerous cases at distances less than 300 km)

MH data quality

- criteria for rejection of « bad data » based on large error bars, spurious altitude variations or anomalous altitude profile
- most often reasonably good data limited to altitudes ≤~ 450/550 km
  Ti and Te profiles usually limited to 450 km or lower
  few Ne profiles may reach 650 km

In the period 2005-2009

Very deep minimum of solar activity

- Thermosphere shrinks to record low altitudes
- Low ionospheric densities thus low ISR Signal/Noise ratio resulting in large error bars or erroneous measurements.

Thus, MH provides usable data at altitudes significantly lower than the orbit of DEMETER, in particular at night

MH plasma parameter profiles need to be extrapolated up to ~ 700 km

Nighttime (Left, Figure 1a) and ***Daytime*** (Right Figure 1b)
Millstone Hill altiude profiles of Ne, Te, Ti and H+/O+ density ratio
Also shown are (i) simultaneous DEMETER measurements
(ii) the altitude profiles of these parameters obtained from the IRI model and from the regional ionospheric model developped by the MH team
The lower section displays the orbit of DEMETER during the MH integration period

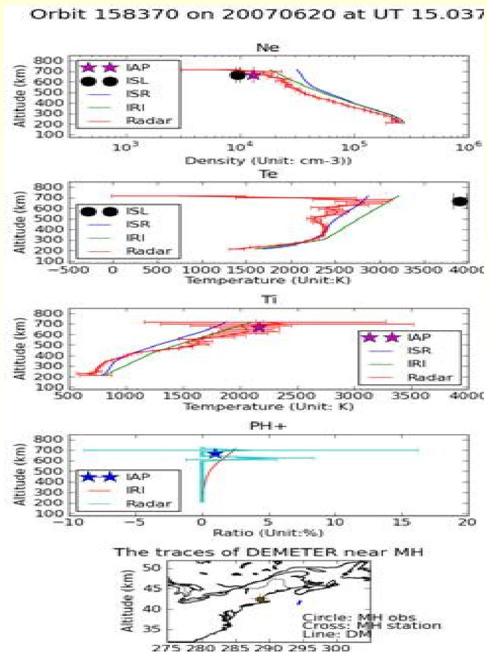


Figure 1b

MH DATA EXTRAPOLATION

1- Te and Ti profiles

Extrapolation rationale and algorithms

- not constrained by a model of physical processes in the ionosphere (would need several measurements along magnetic field lines).
- extrapolation guided by 2 models
  - IRI, the empirical international ionospheric model.
  - ISR, a statistical regional model from the MH data time series.

-define the maximum altitude HM up to which data are reliable.

- use 4 data points at H ≤ HM to define the average weights w^{iri} and w^{isr} to be applied to the IRI and ISR profiles to best reproduce the MH profile.

-use w^{iri} and w^{isr} and the IRI and ISR profiles above HM to build « weighted models » profiles Twm(H) till DEMETER altitude.

- compute for each altitude H the difference

$$\Delta T(H) = Twm(H)-Twm(HM)$$

- compute the extrapolated temperature values at altitude H as

$$TMH(H) = TMH(HM) + \Delta T$$

MH DATA EXTRAPOLATION

2- Ne profiles

Extrapolation rationale and algorithms

- Two approaches
  (a) same method as for Te and Ti using the IRI and ISR models
  (b) a more physical approach taking into account the exponential variation of Ne as a function of altitude in the topside ionosphere

$$Ne(H) = Ne(H0).exp[-(H-H0)/HP(H0)]$$

where $HP(H0) = k.(Ti + Te)/Mig$ is the plasma scale height at altitud

H0 and Mi the mean ion mass.

In this latter method two different hypothesis were tested:

(h1) HP is constant above HM and computed from MH data at HM

(h2) HP varies in altitude and computed from the extrapolated profiles of Ti and Te

Since the mean ion mass Mi is not well measured by MH, Mi values were taken from the IRI model to perform the extrapolation.

MH DATA EXTRAPOLATION

3- Tests of extrapolated profiles

Validity of extrapolated data tested by using the few MH profiles with good data till 600 km, taking HM=450 km. and computing the rms difference between extrapolated and measured profiles

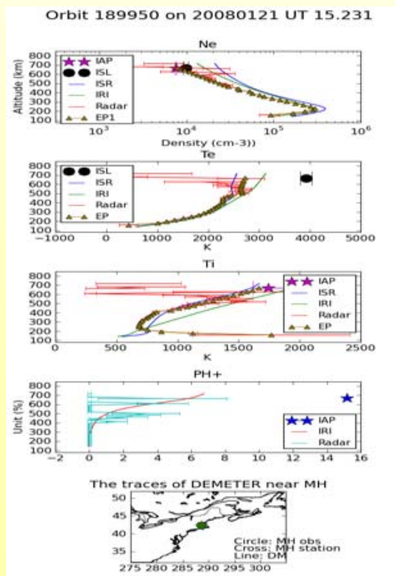
For Te and Ti the error is ~ 110°K which is fairly good

For Ne the error is significantly larger of the order of 6.10^3 el/cm^3, of the order of 10 to 15% of the measured value.

slightly lower with the (h1) hypothesis than with the (h2) hypothesis.

In the subsequent work, the (h1) hypothesis was adopted assuming that the plasma scale height does not vary appreciably between the maximum altitude of reliable MH data and the altitude of DEMETER. The main source of error on the extrapolated Ne profiles is the poor knowledge of the mean ion mass Mi.

An example of extrapolated data is shown in ***Figure 2*** below;



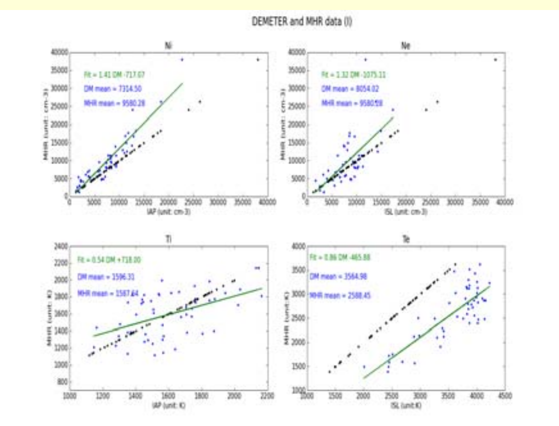


Figure 3

SUMMARY AND FUTURE WORK

Figure 3 dispays the statistical results from the present study.

Electron density Ne: Ne(DEMETER) < Ne(MH) > by 10 to 15%

Possible reasons:

- IAP: grid transparency actually lower than theoretical values and uncertainties in S/C potential determination.
- ISL: Te overestimated and effect of the S/C sheath on the probe.

However the current uncertainty in the Ne extrapolated profiles are certainly critical and thought to be the dominant effect.

Ion Temperature Ti: Ti(DEMETER) ~ Ti(MH) within ~ 100°K

Excellent agreement

Electron Temperature Te: Te(DEMETER) >> Te(MH)

Te variations in good agreement but systematic shift with Te(DEMETER) ~ Te(MH) + 900°K.

Likely due to the contamination of the ISL probe during launch,

On-going activities:

Improvement of the IAP data processing and on-board calibration of Ni (IAP) and Ne(ISL) measurements using HF line emissions

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