

Contrasting the efficiency of radiation belt losses caused by ducted and non-ducted whistler mode waves from manmade transmitters

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DEMETER Workshop
Paris, France
15:00-15:15 Tuesday 11 October 2011

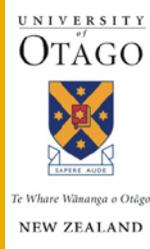


Intro/Background

Previous talk - Craig Rodger:

- Ducted vs. Non-Ducted VLF transmitter waves in the magnetosphere.
- Nonducted: $L=1.3-1.5$ (inner edge of inner radiation belt)
- Ducted: $L=1.5-2.5$ (rest of inner belt and slot)

Can we use DEMETER IDP to investigate the effect of ducted and non-ducted waves on radiation belt electrons?



Intro/Background

Can we use DEMETER IDP to investigate the effect of ducted and non-ducted waves on radiation belt electrons?

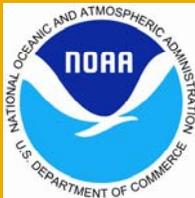
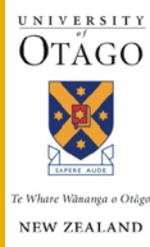
Previous talks - Jean-André Sauvaud, Yuqian Ma:

- NWC is an effective scatterer of electrons into the drift-loss cone.

These are ducted waves – what about non-ducted?

Conflicting opinions in the literature. Some claim ducting important, others unimportant.

This will have a significant impact on the electron energies that are affected!



Overview

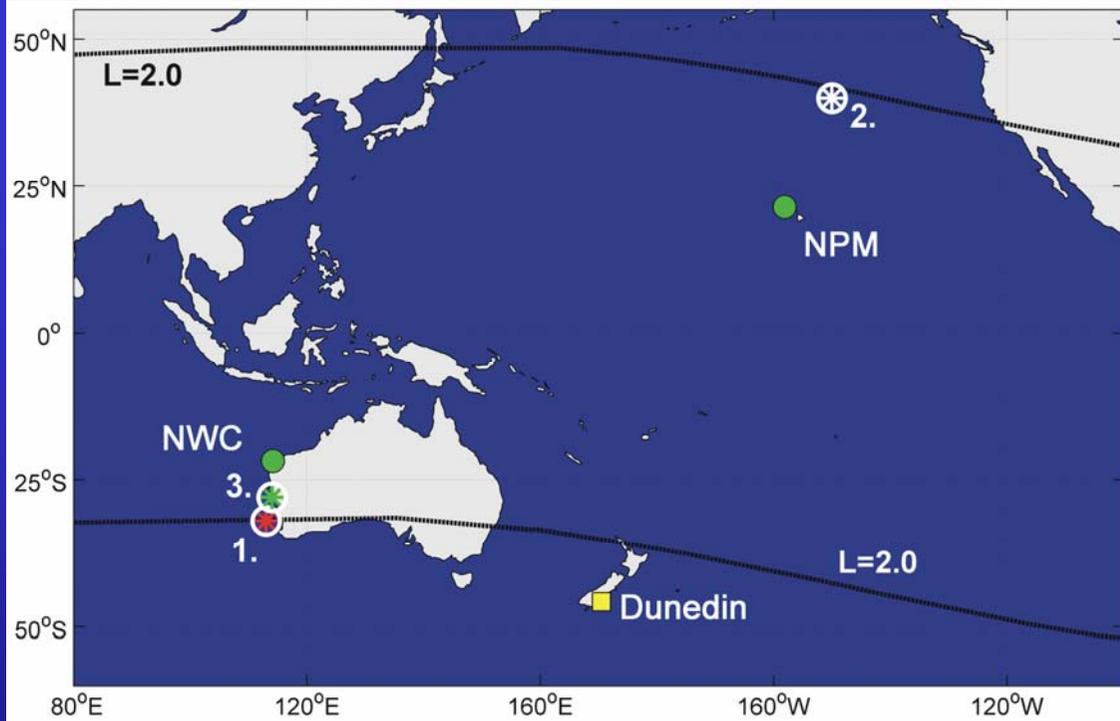
DEMETER:

Large survey, improved statistics for NWC (ducted) wave-particle interaction.

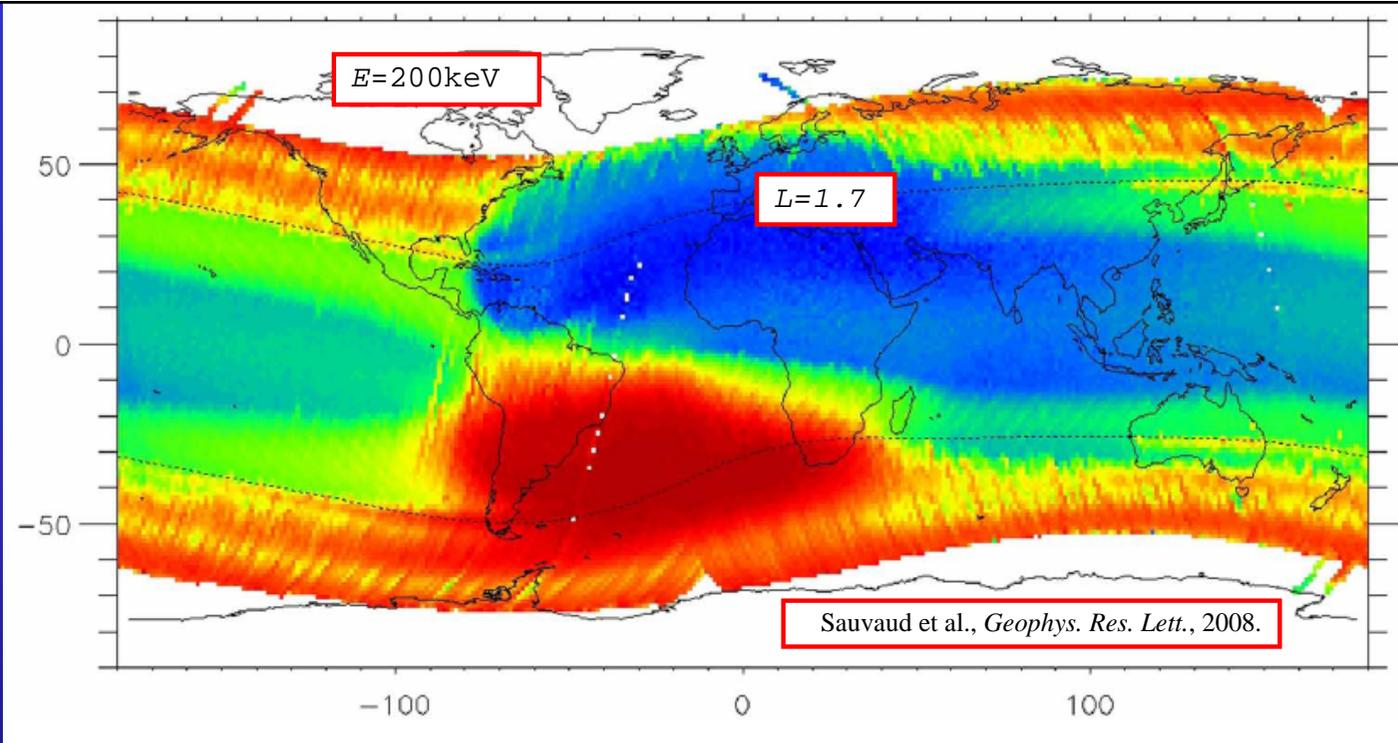
Use same technique to search for NPM (non-ducted) interaction.

Also:

- Independent investigation and method using POES
- IDP Pitch angle viewing – which parts of the loss cone(s) are being measured?

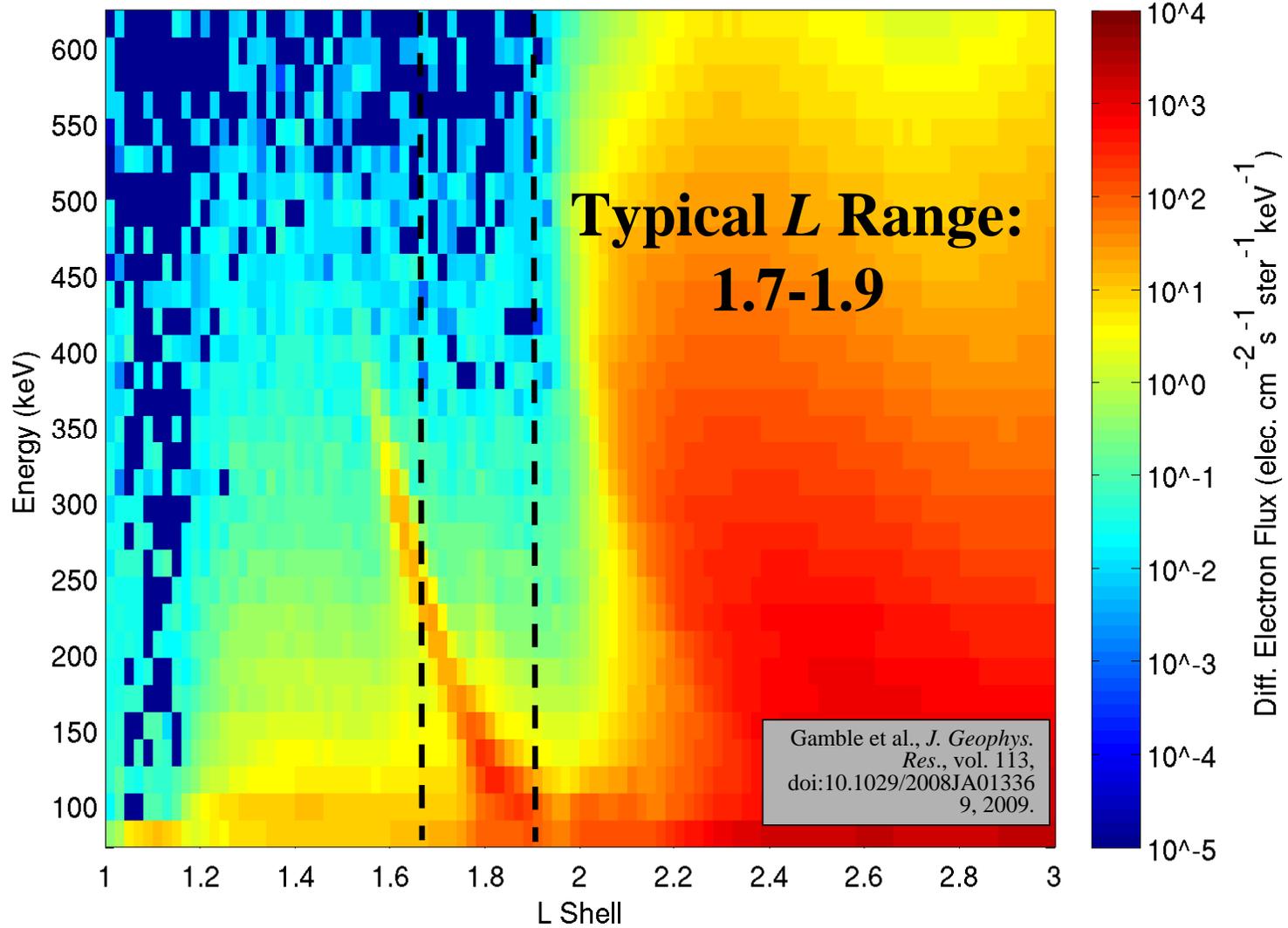


- NWC, Australia.
- L=1.45, 19.8 kHz, 1 MW
- Most wave power >L=1.6. Ducted.
- Known to scatter significant number of electrons from RB.
- NPM, Hawaii.
- L=1.17, 21.4 kHz 500 kW
- Most wave power >L=1.6. Non-ducted.
- Effect on radiation belt electrons?

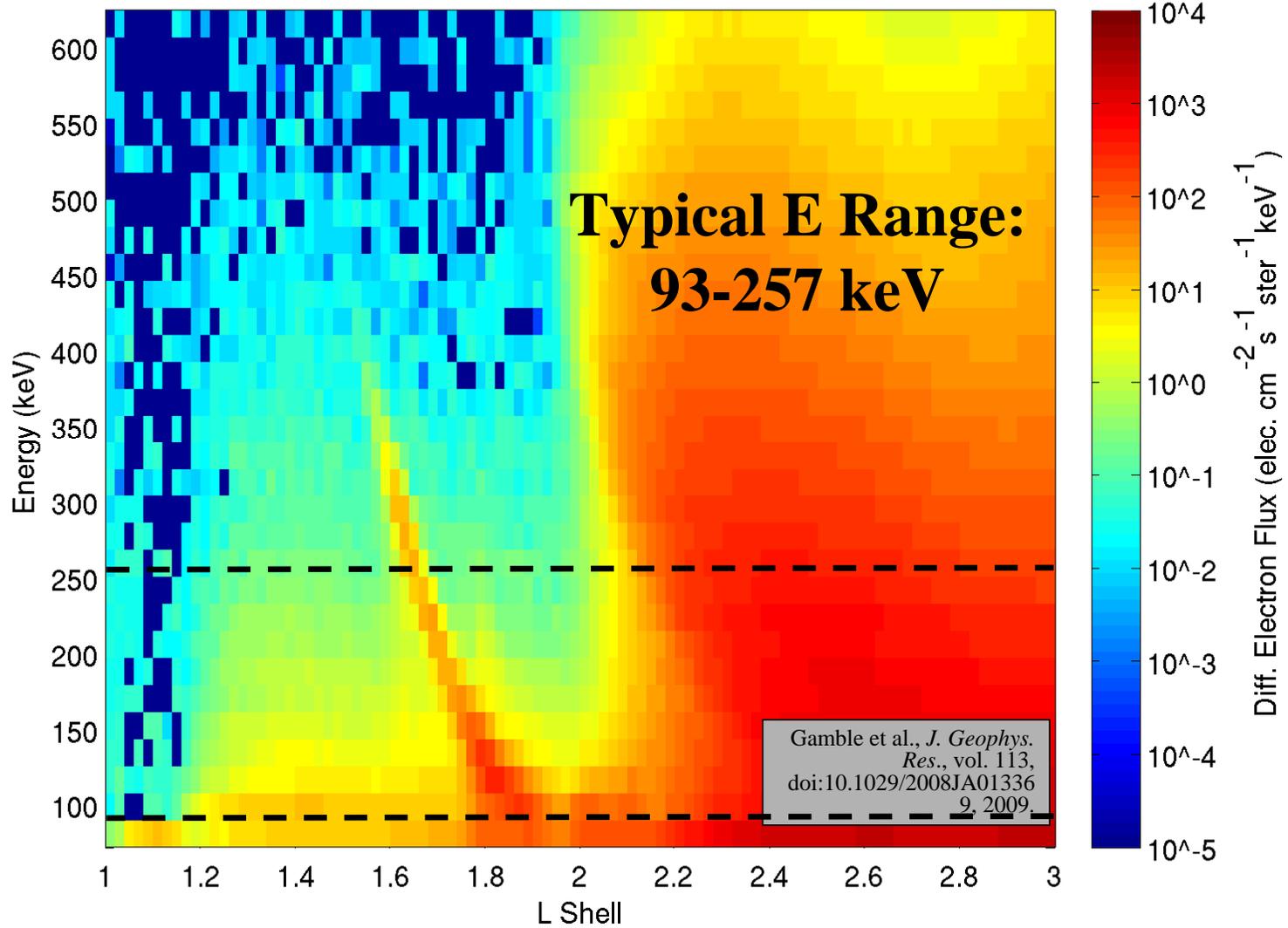


- Structure in both hemispheres, from NWC across to the South Atlantic Anomaly where the electrons precipitate into the atmosphere.
- Only seen in NIGHT orbits
- Only observed EAST of transmitter NWC.
- Strong link to transmitter operation.

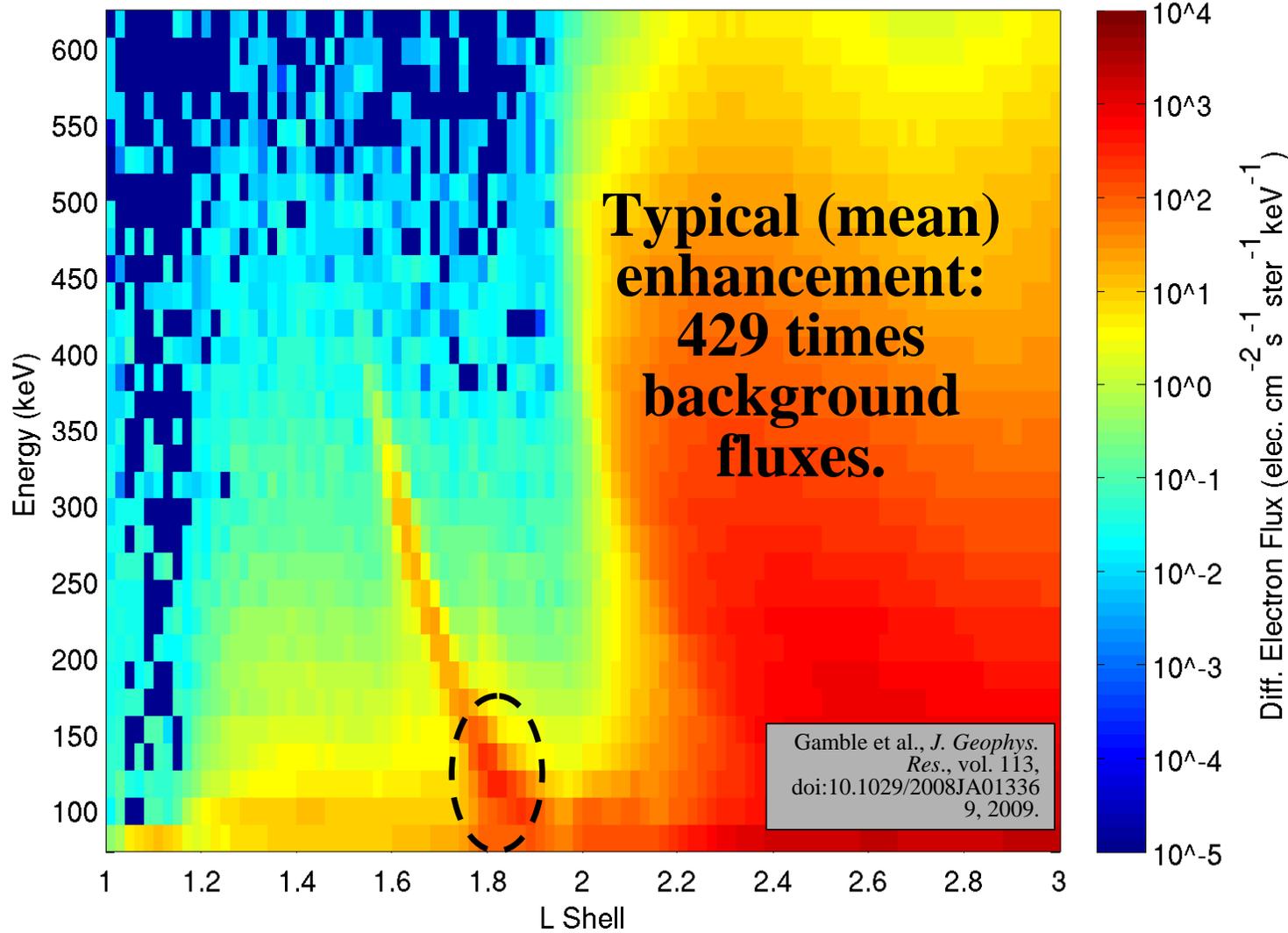
Orbit #6244.5, UT: 04-Sep-2005 13:58:48 - 04-Sep-2005 14:12:49,
MLT: night, 12deg east of NWC (longitude 125.8363 at NWC LShell).



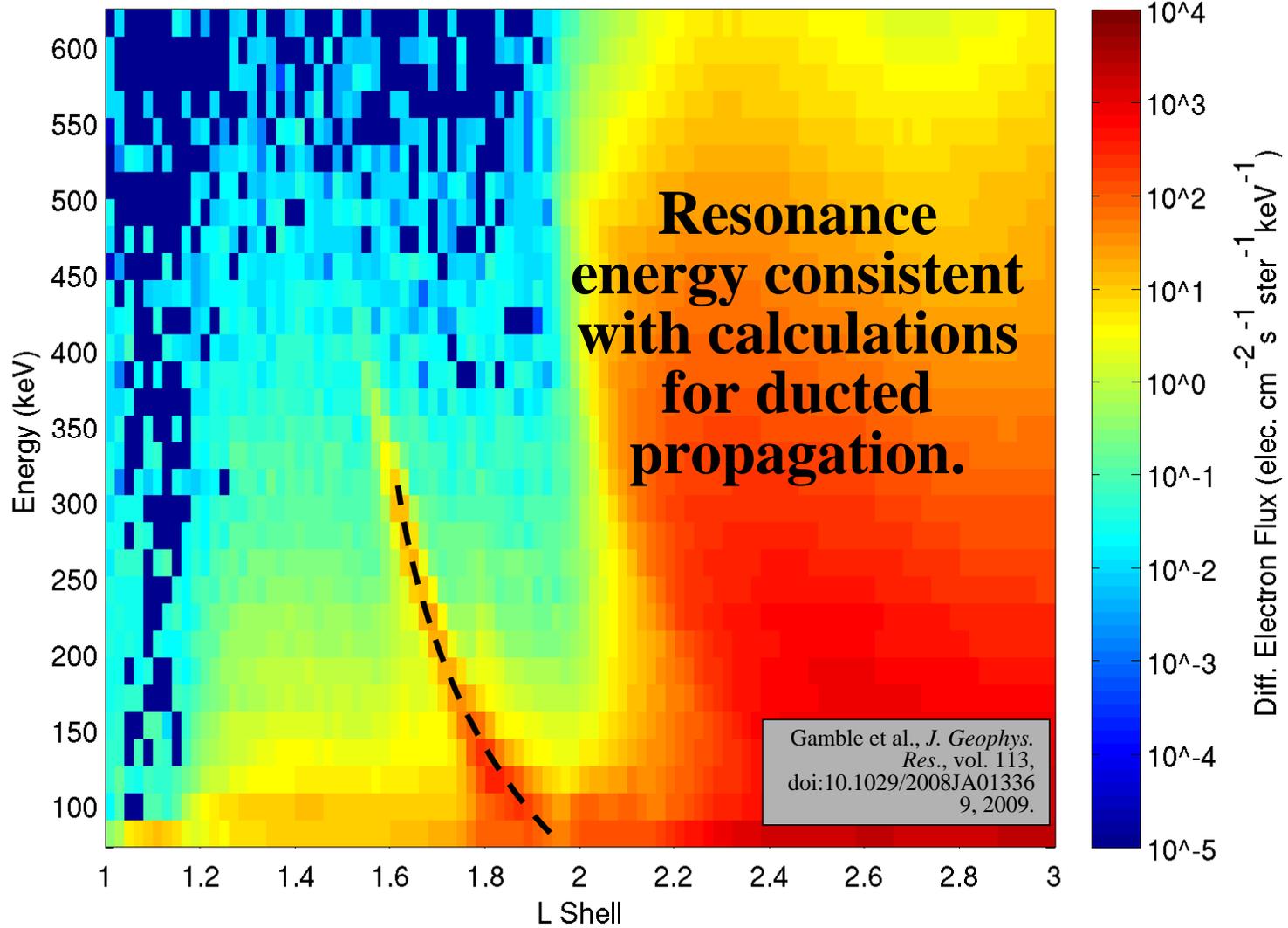
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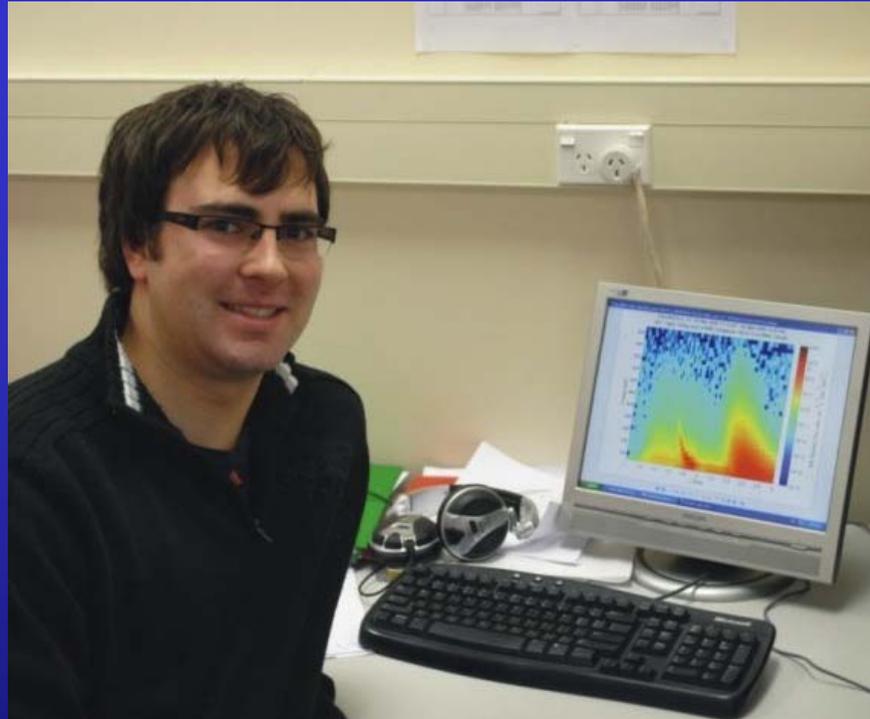
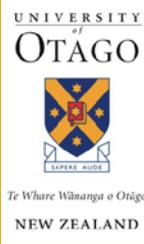


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- Bonar Carson
- August 2004 – January 2009
- NWC and NPM
- Manually examined **several thousand** orbits!
- Much better statistics and sensitivity

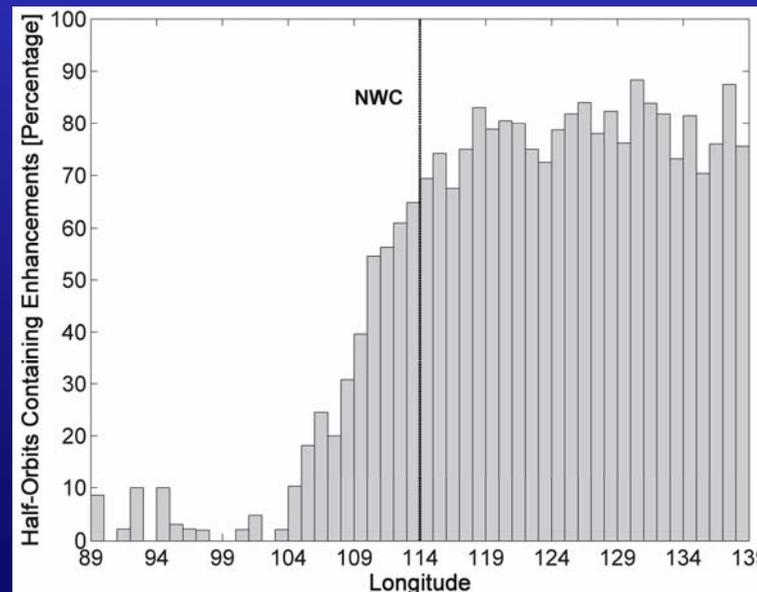
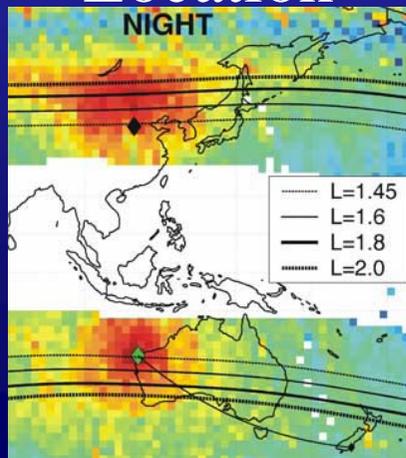
NWC DLC enhancements

- Occurrence
In night time half orbits

	# of half orbits when Tx on	# of wisps observed
East	1043	818
West	1085	171

- Observations
Aug 2004-Jan 2009

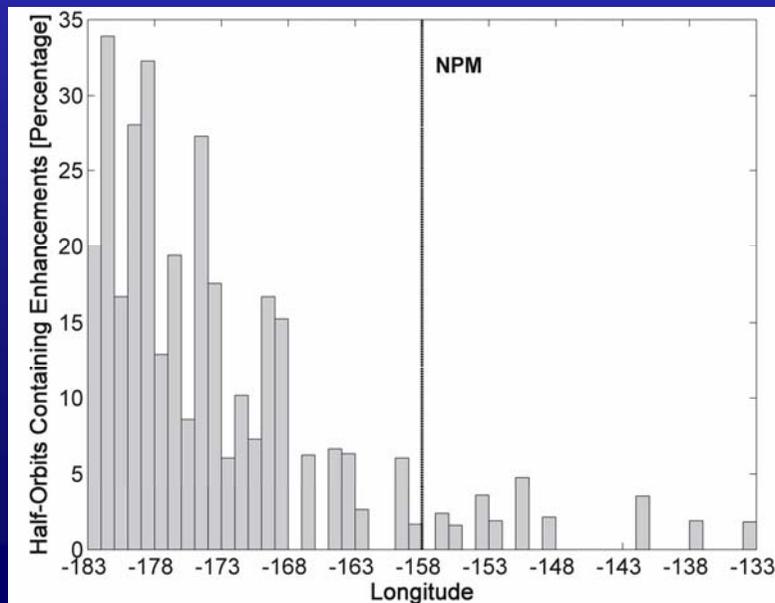
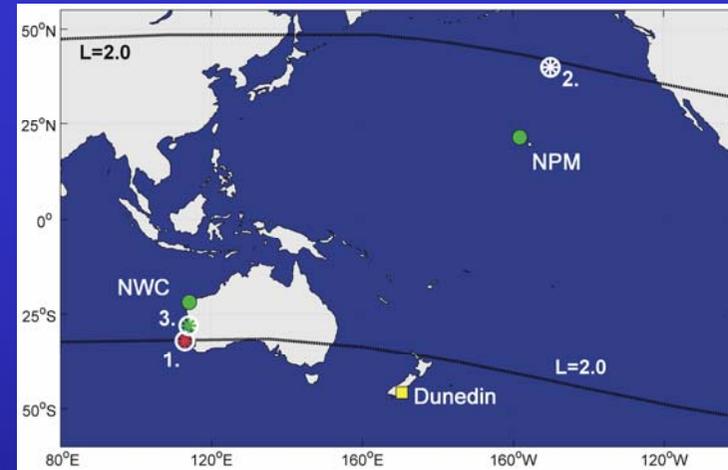
- Location



80% of orbits at night time east of NWC show enhancements (when the transmitter is operating).

NPM Transmitter – Enhancement Search

- US Naval VLF transmitter
- $L=1.17$
- Signal strength is logged by AARDDVARK in Dunedin.
- Non-ducted.
- 2487 orbits examined.



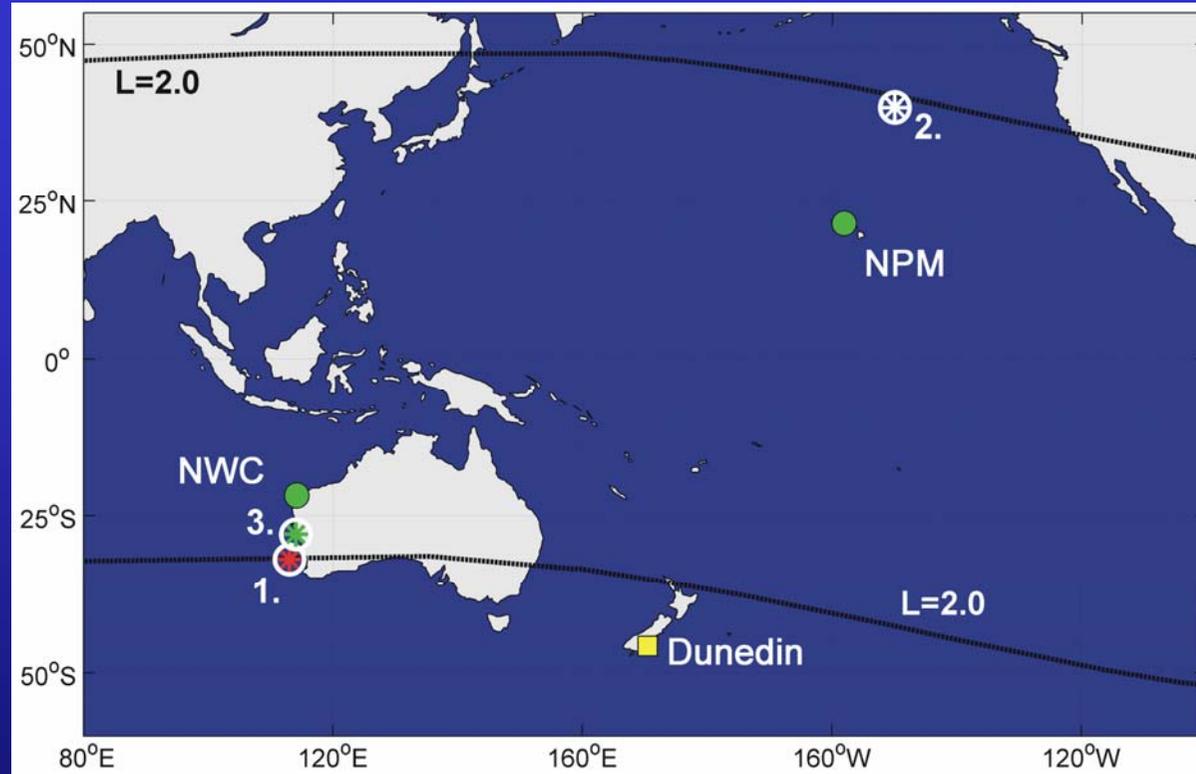
Some NWC-produced DLC enhancements seen to west of NPM, until a time consistent with seasonal edge of sunrise at NWC.

Remaining enhancements are rare (~1% of eastern orbits).

As the enhancements are observed for $L > 1.6$, we may be seeing occasional coupling of NPM into ducts. **Not consistent with constant non-ducted scattering!**



A different approach?



Modelling of the non-ducted scattering suggests:

NWC >100keV fluxes due to non-ducted waves to peak at $L=2$ *

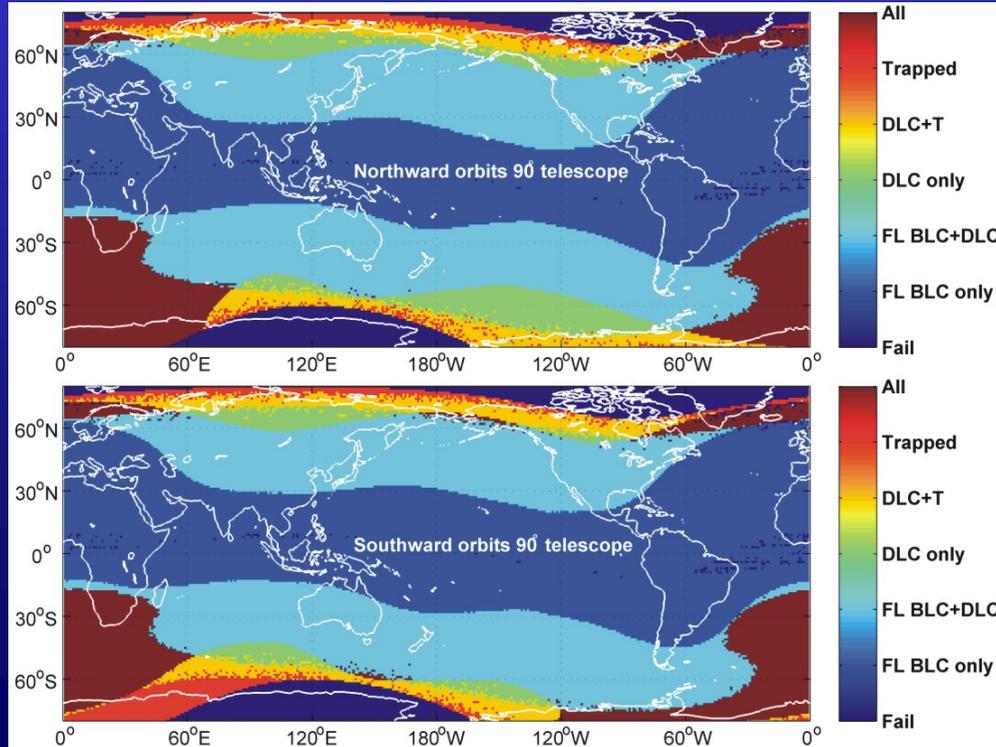
NPM >100keV fluxes due to non-ducted waves to peak at $L=1.9$ *

$L=1.8$ is shown by the green star *



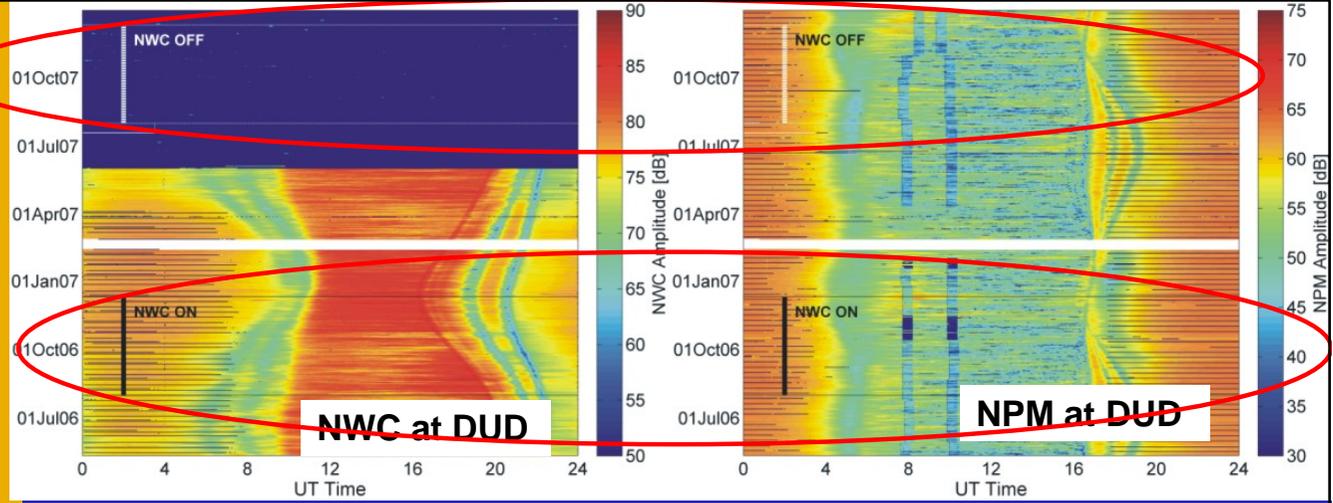
Try using POES

The SEM-2 instrument on the LEO POES spacecraft measure $>100\text{keV}$ electrons and the L and longitude range we want the 90° electron telescope measures the DLC. Both N-15 and N-17 have well defined night and day orbits.



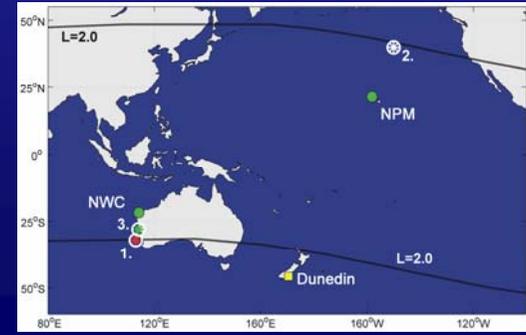
For N-15
Northward
orbits 17 LT
"DAY"

For N-15
Southward
orbits 05 LT
"NIGHT"

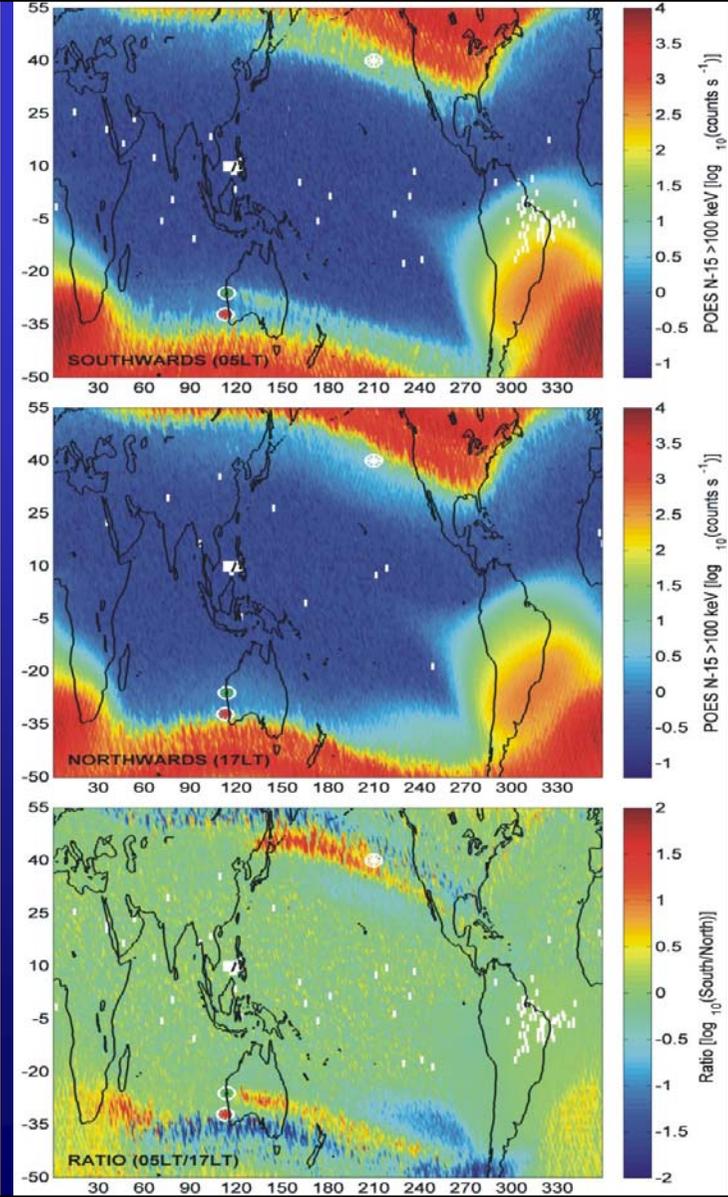


FROM DUNEDIN SUBIONOSPHERIC DATA

1 August-11 December 2006	NWC on	NPM on
1 August-11 December 2007	NWC off	NPM on



We can therefore look for the signature of NWC over this time period!



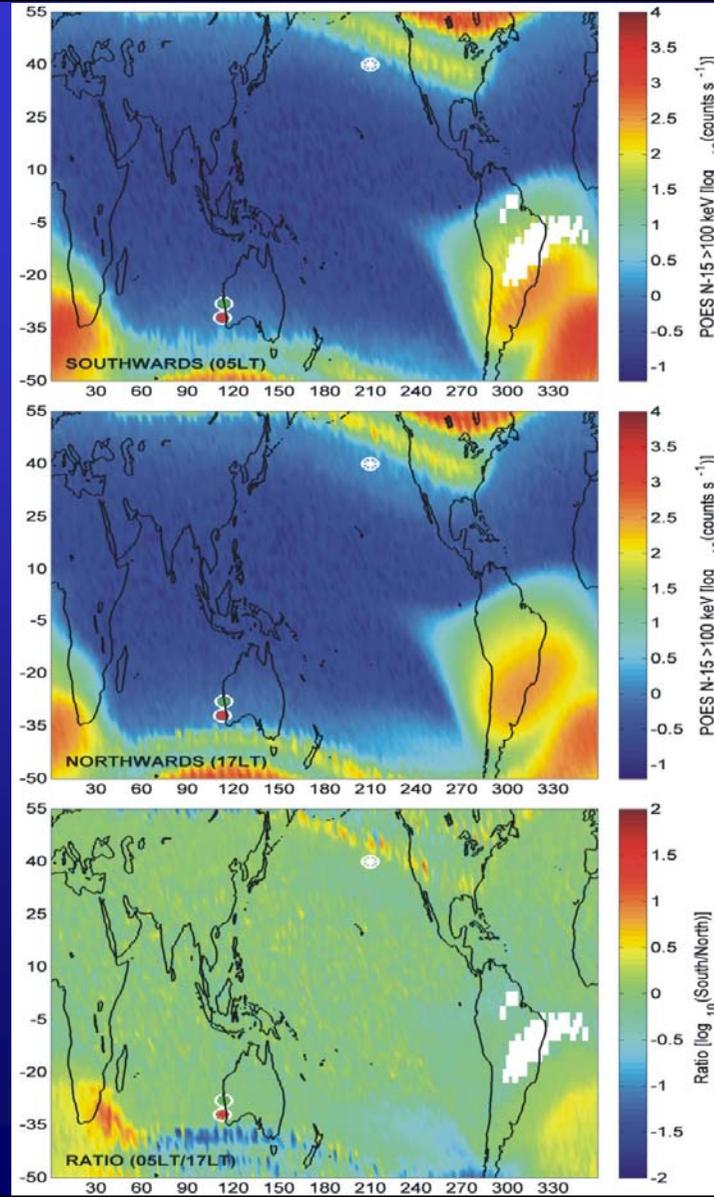
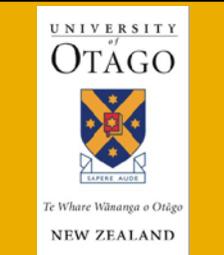
NWC on NPM on

Strong scattering signature seen starting at NWC in the “night” orbits (5LT), but not the day ones (17LT). This is as expected, of course.

RATIO plot (day/night) suggests the enhancement peaks at the green star ($L=1.8$) rather than the red star ($L=2$).

Suggests some disagreement with non-ducted model, but the location is consistent with scattering from ducted propagation.

Is NPM doing anything? Hard to tell, might be masked!



NWC off NPM on

RATIO plot (day/night) fails to show any evidence of an NPM produced enhancement in DLC electron fluxes.

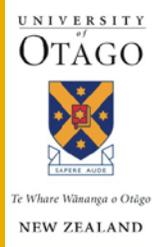
While modelling indicates these fluxes will be 1-7 times weaker than NWC fluxes in $L=1.7-1.9$, in practise any scattering which is being produced by NPM is at least 50 times weaker.

At this point we do not have conclusive evidence of any non-ducted scattering by NPM, and evidence for only weak occasional ducted scattering.



Summary 1

- Numerous studies have confirmed that the powerful VLF transmitter NWC scatters inner radiation belt electrons into the drift loss cone. Theoretical calculations indicate that multiple VLF transmitters should play significant roles through non-ducted scattering.
- However, there is ambiguity in the literature whether there is significant pitch angle scattering from non-ducted whistler mode waves launched from ground-based transmitters. Thus, we undertake a head-to-head comparison between NPM (majority non-ducted) and NWC (majority ducted).
- ~80% of nighttime orbits east of NWC show scattering DEMETER
- ~1% of nighttime orbits east of NPM show scattering DEMETER
- While there is a strong enhancement observed in POES data due to NWC, there is none seen due to NPM (so at least 50 times smaller).
- At this point we do not have conclusive evidence of any non-ducted scattering by NPM, and evidence for only weak occasional ducted scattering. **It is not clear that non-ducted whistler mode waves are efficient scatters of radiation belt particles.**



Pitch Angle viewing of the IDP instrument.

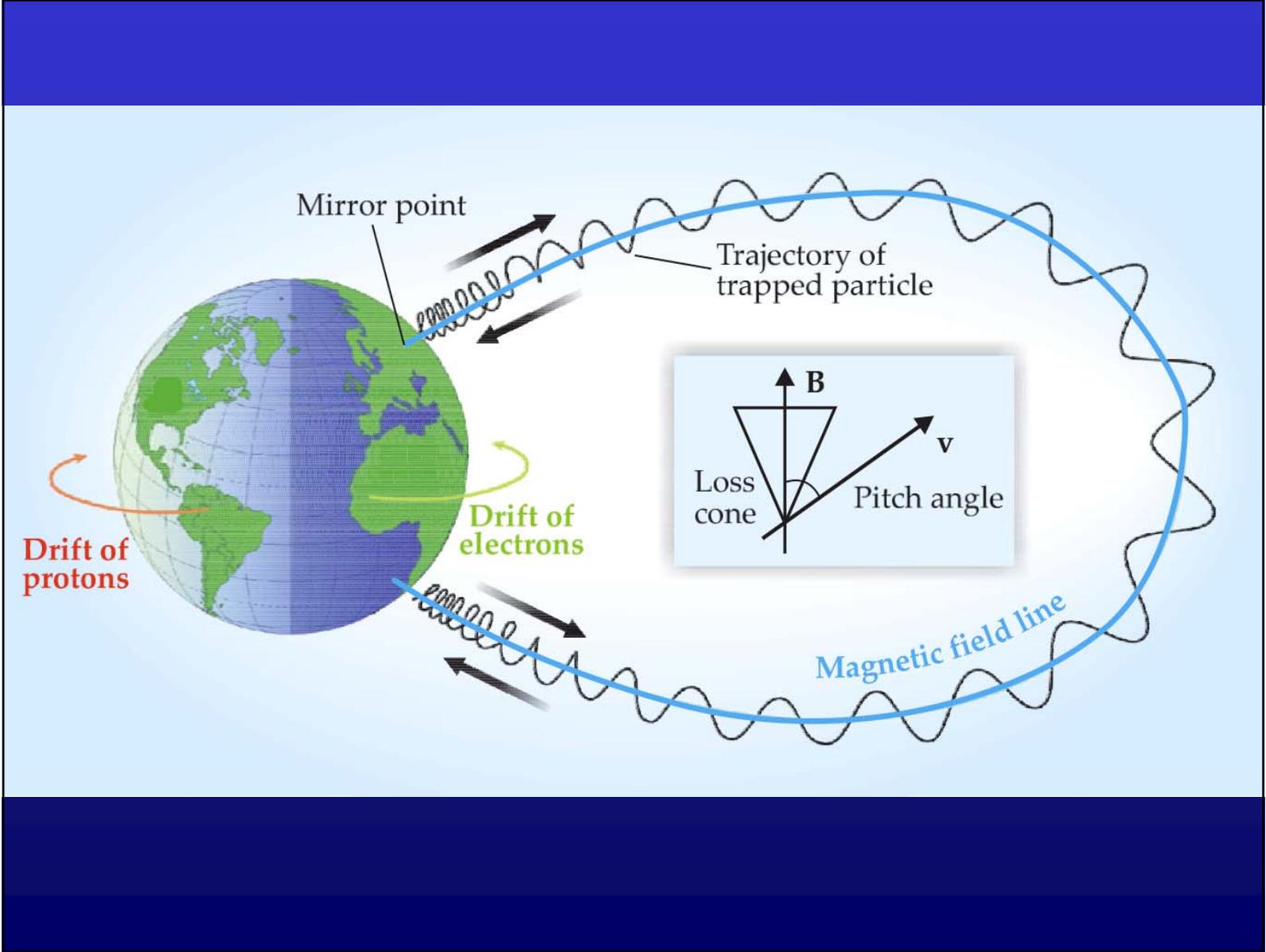
IDP is typically a drift-loss cone instrument.

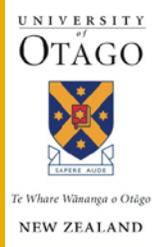
However, in many regions (mainly near the SAMA), other populations of electrons are measured.

This arises due to deviations from a dipole field.

Can model what the instrument sees, using:

- Geomagnetic field model (IGRF).
- Pointing direction of instrument (function of location).
- Angular width of instrument.





Deviations from Dipole Field.

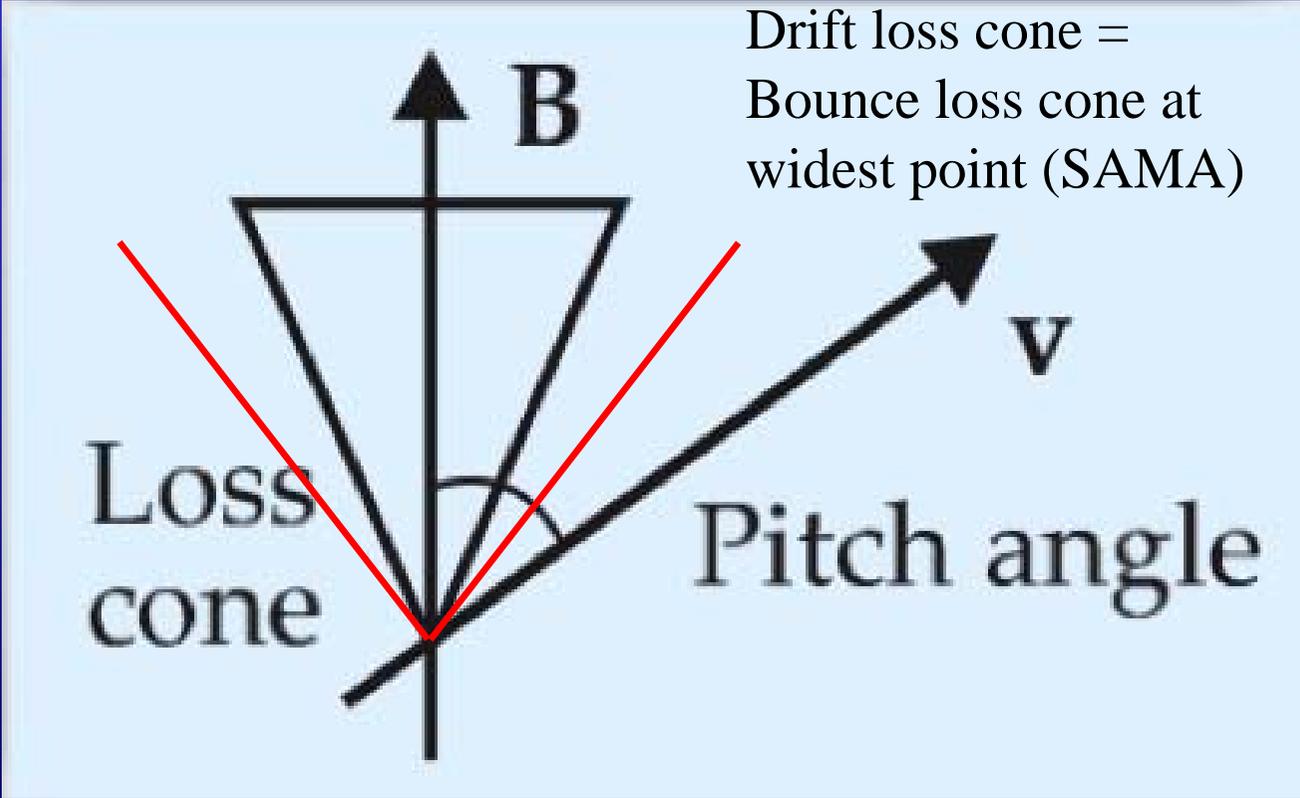
Geomagnetic field strength is dependent upon longitude (weaker in the SAMA region).

-> This gives rise to the drift loss cone.

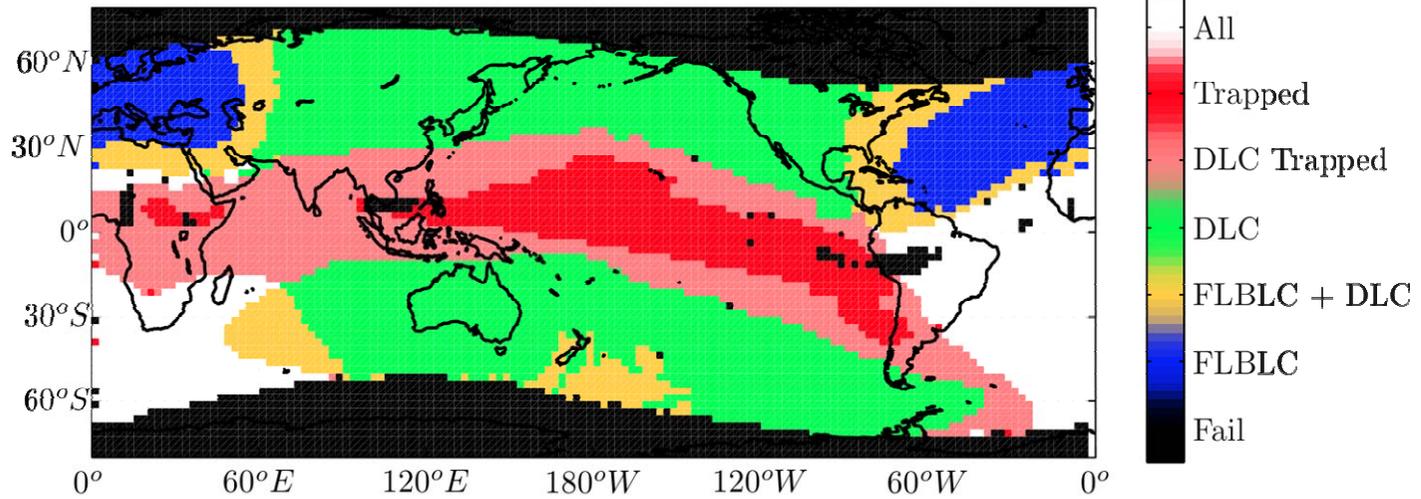
Not symmetric about the geomagnetic equator.

-> Bounce loss cone angle is slightly different for each hemisphere.

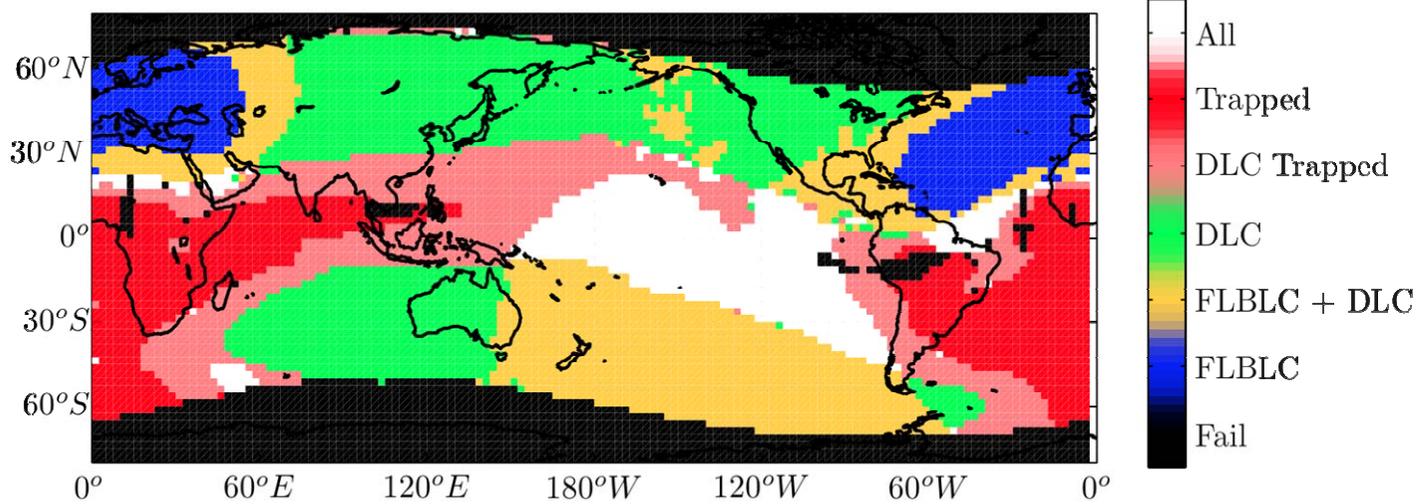
Instrument can view some complicated mixture of these populations!



Day

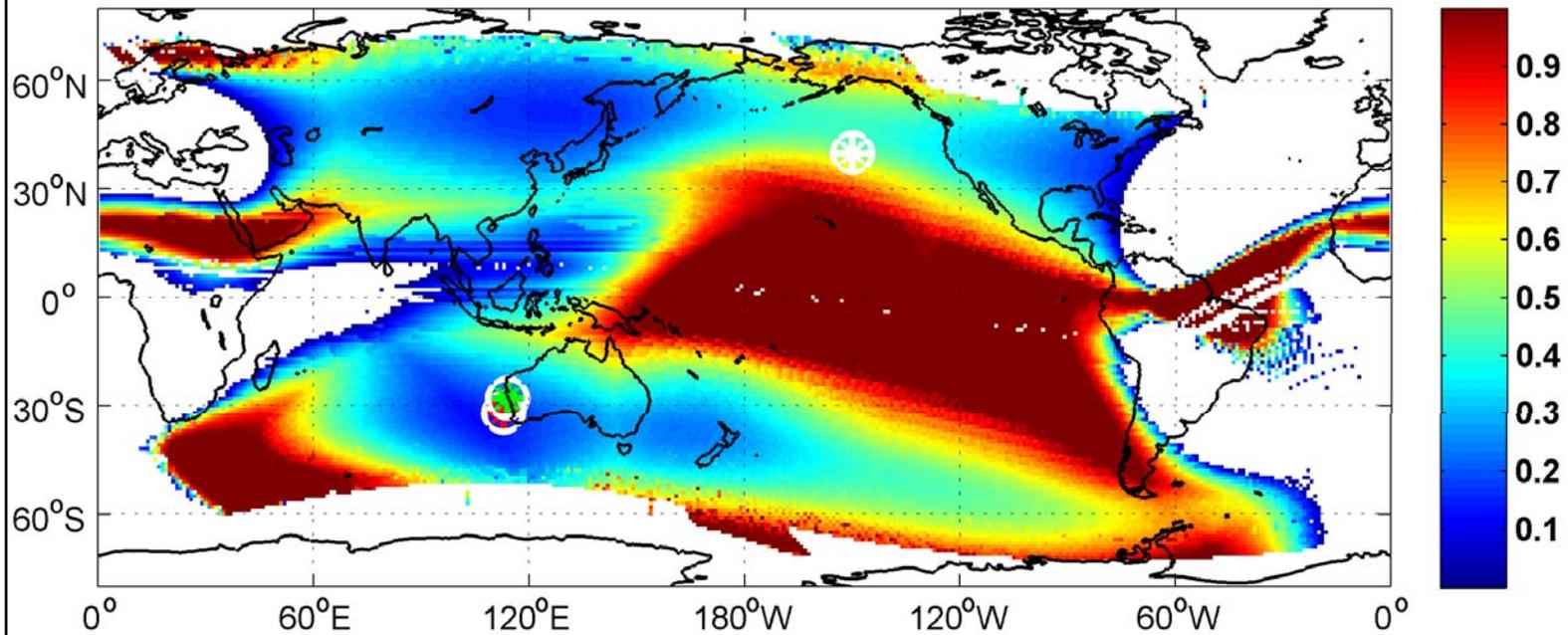


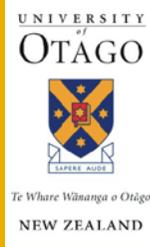
Night



DEMETER for Energetic Electrons

DEMETER Radiation Belt Populations - Fraction of DLC observed (Night)

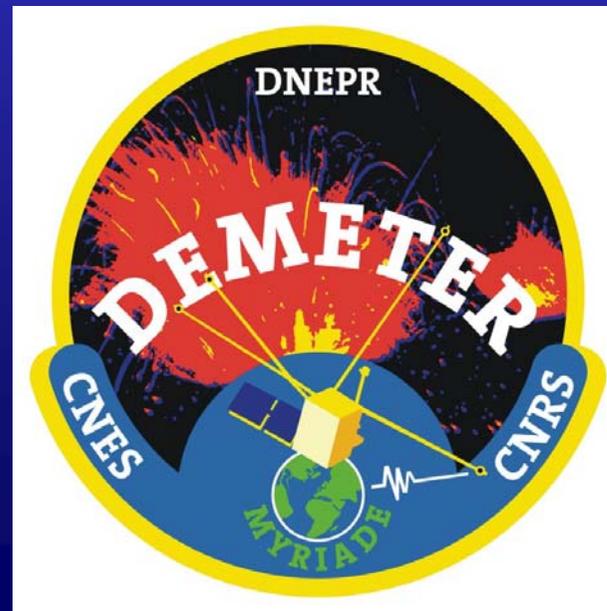




Acknowledgements

I want to acknowledge the DEMETER Guest Investigator programme, through which we have had access to DEMETER data. We are very grateful to our French colleagues for this access, and for their assistance in working with the data.

This research relies heavily upon multiple DEMETER instruments.



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Thankyou!

Blue Mosque, Istanbul, Turkey.
XXXth URSI General Assembly,
August 2011

Are there any questions?