Negative Ions at the Lunar Surface
# NILS : *measuring the unmeasured*

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Introduction

NILS, the first-ever dedicated negative ion analyzer flown beyond the Earth, is developed for the Chinese *Chang'E-6* sample return mission to land on the lunar far-side (41°S, 180°E) in 2024.
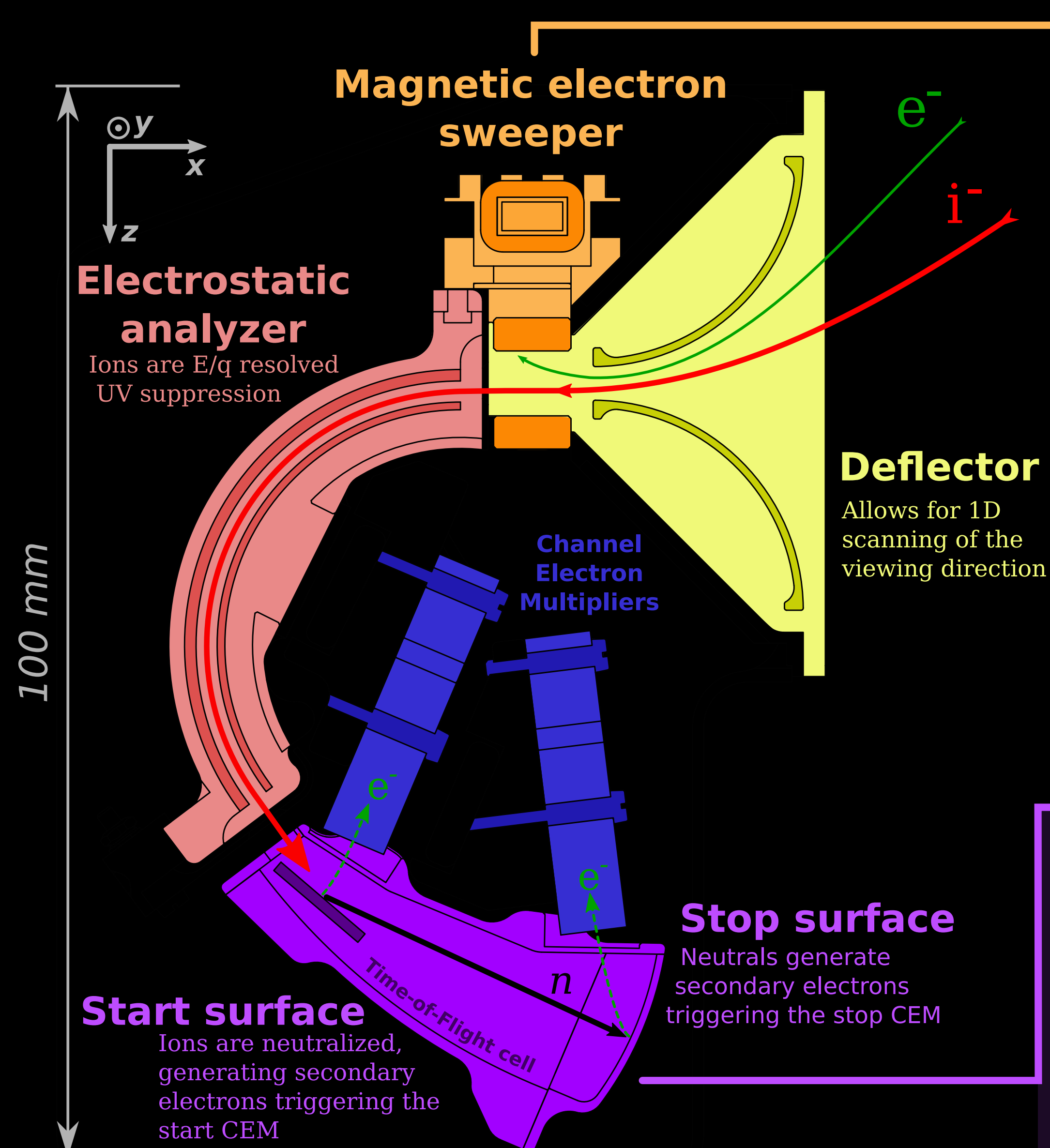

Scientific objectives

★ Detect and quantify the presence of negative ions emitted from the lunar surface as a result of the interaction with plasma.

• Distinguish the energy distribution of scattered H$^-$ and sputtered lunar negative ions, and resolve the mass distribution of the observed negative ions.

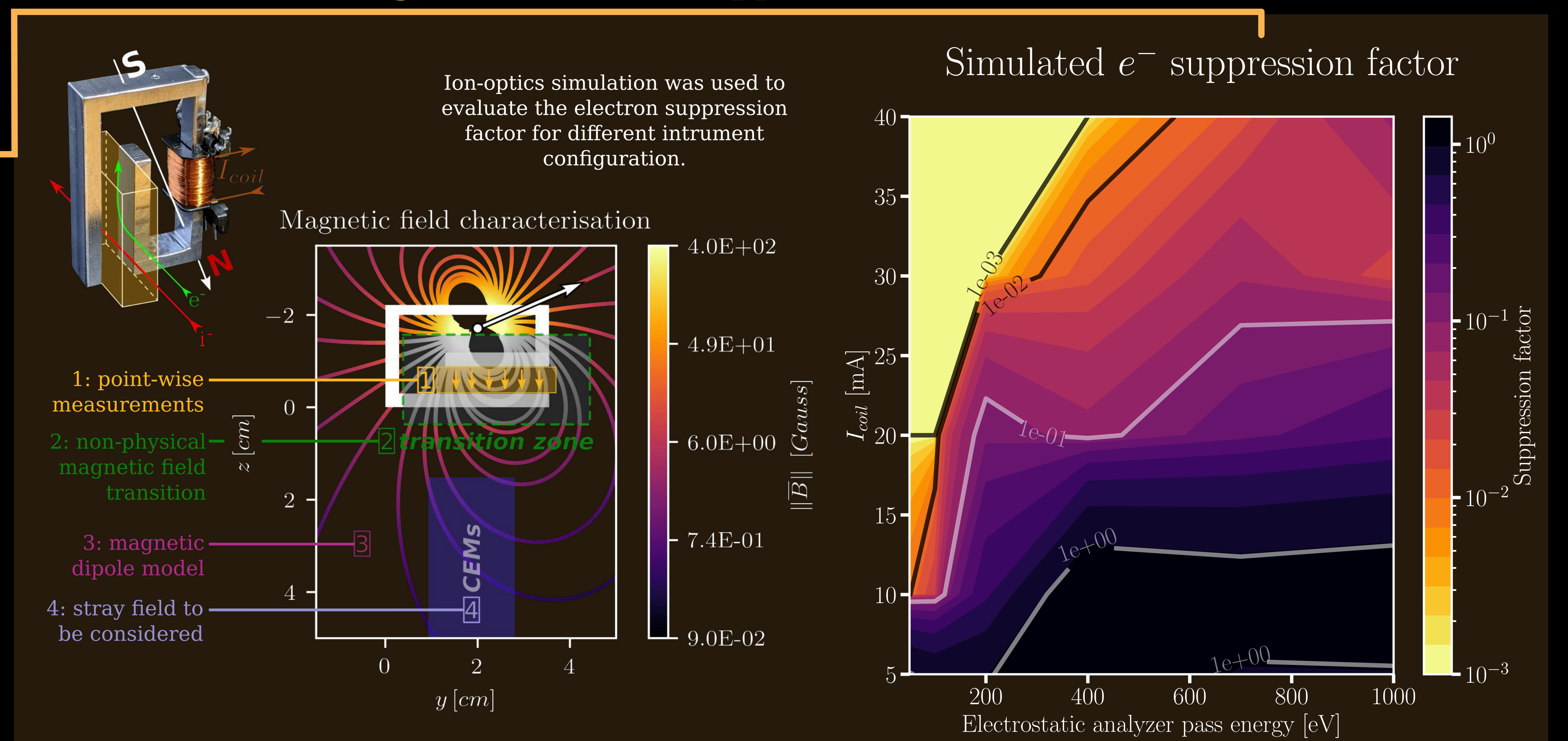• Resolve the energy distribution for each species/mass group separately.
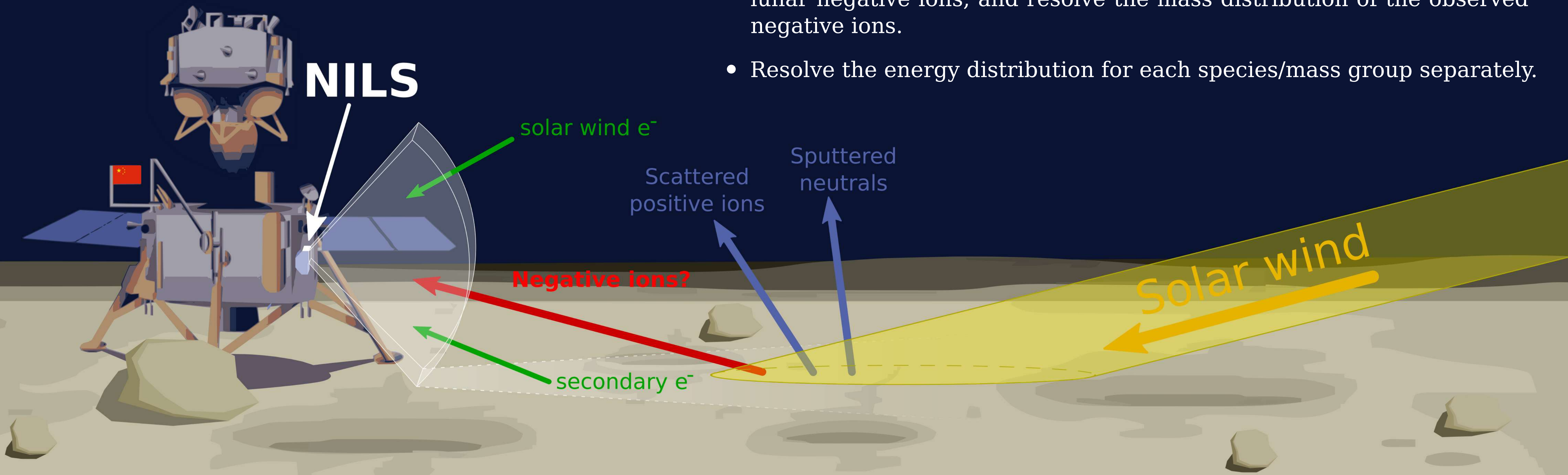
Previous in-situ measurements beyond the Earth relied on energy spectrum information [1,2,3]. How to unambiguously separate negative ions from electrons?
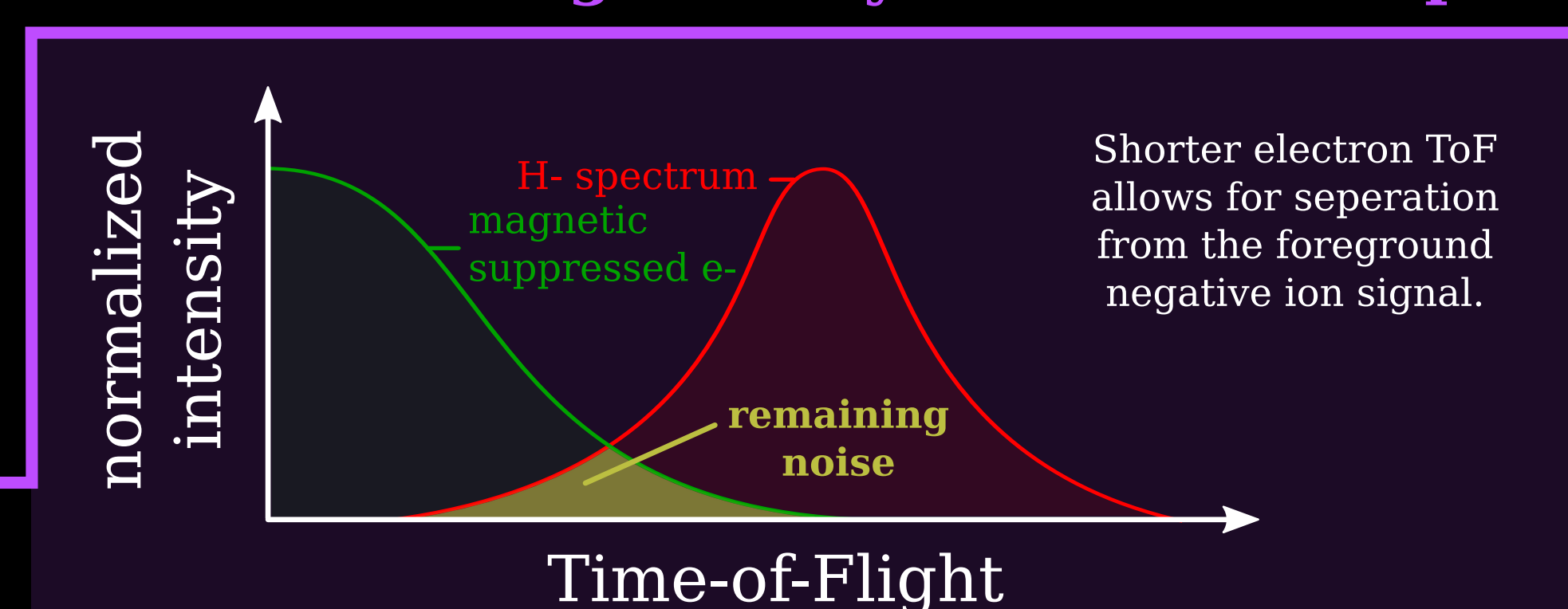
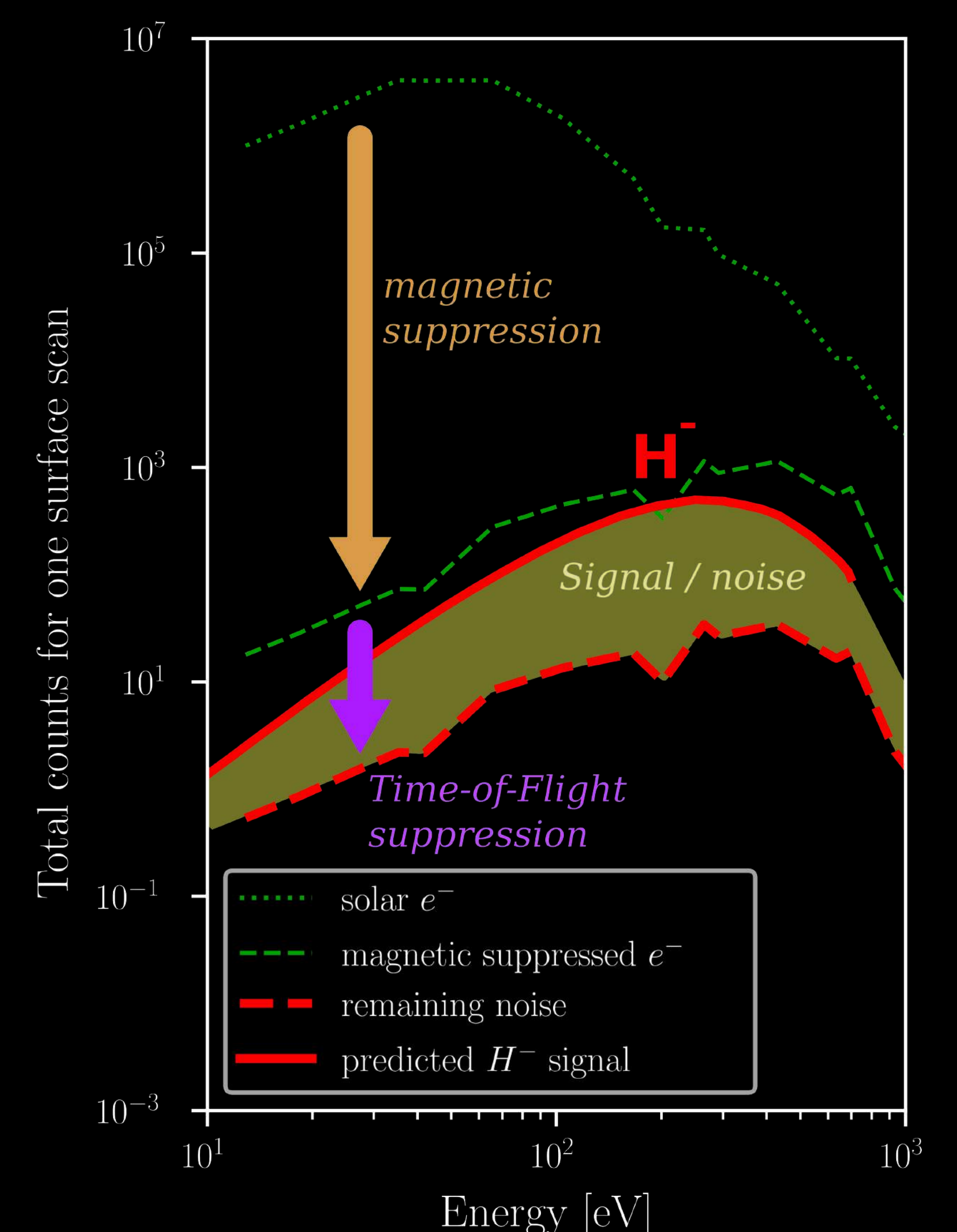## Ion optics design

Inherited from the SWIM family [4]

Magnetic electron sweeper

Electrostatic analyzer
Ions are E/q resolved
UV suppression

Deflector
Allows for 1D scanning of the viewing direction

Channel Electron Multipliers

Stop surface
Neutrals generate secondary electrons triggering the stop CEM

Start surface
Ions are neutralized, generating secondary electrons triggering the start CEM

100 mm

Magnetic electron suppression

Ion-optics simulation was used to evaluate the electron suppression factor for different intrument configuration.

Magnetic field characterisation

1: point-wise measurements
2: non-physical magnetic field transition
3: magnetic dipole model
4: stray field to be considered

Simulated e$^-$ suppression factor

Time-of-Flight analysis for mass separation

Shorter electron ToF allows for seperation from the foreground negative ion signal.

H- spectrum
magnetic suppressed e$^-$
remaining noise

normalized intensity
Time-of-Flight

Performance

magnetic suppression

H$^-$

Signal / noise

Time-of-Flight suppression

- solar e$^-$
- magnetic suppressed e$^-$
- remaining noise
- predicted H$^-$ signal

Total counts for one surface scan
Energy [eV]

Specifications

Energy range E/q	10 eV/q - 3 keV/q
Field of View	160°×12°
Angular resolution	15°×12° (FWHM)
Mass resolution	e$^-$, m/q groups: 1, 4, 16, ≥32
Mass bins	64
Energy resolution	12-17%
Energy × direction bins	48 × 16
Geometric factor	5×10^{-4} cm^2 sr eV/eV
Time resolution	6.2s (one direction)
	105s (full coverage)
Observation time	>1h

Conclusions

NILS will do the first-ever negative ion measurements on the lunar surface.

NILS will unambiguously separate negative ions from electrons through a combination of magnetic electron suppression and time-of-flight mass-analysis.

NILS has a sufficiently high signal to noise ratio to detect the presence of negative ions on the lunar surface and resolve mass dependent energy distributions.

References
[1] Burch et al., 2015 - *doi: 10.1002/2015GL064504*
[2] Chaizy et al., 1991 - *doi: 10.1038/349393a0*
[3] Coates et al., 2007 - *doi: 10.1029/2007GL030978*
[4] Wieser and Barabash, 2016 - *doi: 10.1002/2016ja022799*