GEM:
Geospace Environmental Modeling

Some comments on GEM's history

Louis J. Lanzerotti
Alcatel Lucent Bell Laboratories (ret)
NJIT Center for Solar-Terrestrial Research

GEM:
Geospace Environmental Modeling

Snippets of relevant precursors

1958: Discovery of radiation belts: Professor James Van Allen, University of Iowa

~1977: Creation within NASA of Solar-Terrestrial Division by Noel Hinners, Assoc. Adm. Science Directorate
Now the Heliophysics Division

1978: NASA-sponsored National Academies study *Space Plasma Physics*
Chair: Stirling Colgate
Charlie Kennel, Gene Parker, Randy Jokipii, Louis Lanzerotti
Mal Ruderman, Harold Furth, David Pines, Marshall Rosenbluth
Three volume book *Space Plasma Physics* edited by Kennel, Lanzerotti, Parker

1979-beyond: Beginning of a NASA solar-terrestrial theory program
Growth in NASA and NSF of solar-terrestrial research

1986: September; meeting with NSF Director and Assistant Director for Geosciences
Evolution into GEM

GEM:
Geospace Environmental Modeling

Background:

(*Eos*, 69, #33, August 16, 1988)

1986, September: meeting with NSF Director and Assistant Director for Geosciences

Director: Eric Bloch, IBM (ret), computer hardware pioneer;

Assistant Director Geosciences: William Merrell, Texas A&M, oceanography

Juan Roederer, Director Geophysical Institute, U. Alaska

Tom Krimigis, JHUAPL; Louis Lanzerotti, Bell Labs; George Reid, NOAA

(academia, industry, government)

Messages Conveyed:

"The medium in which Earth-orbing systems operate is hostile"

"The need to predict 'weather and climate' in geospace is becoming as important as the need to predict weather and climate in the inhospitable regions on Earth into which industrial activity has moved during the last decades"

"By its very nature, STR is firmly rooted in astrophysics at the 'upper end,' in atmospheric physics and chemistry at the 'lower end,' and in space [plasma] physics in between."

GEM:
Geospace Environmental Modeling

Proposed: aspects of solar-terrestrial research relevant to total Earth system be incorporated as integral components of the Geosciences Program

Merrell encouraged an initiative. Proposal submitted to Division of Atmospheric Sciences for support for the organization of a consultative process to develop a consensus for the formulation of a program of solar-terrestrial research: a Workshop

Proposal funded by the existent Solar-Terrestrial Program of the Atmospheric Sciences Division

PI: Juan Roederer

Workshop in Seattle: 6-8 August 1987; 45 participants

Two subsequent meetings included Segment Coordinators:

George Siscoe (UCLA), Maja Ashour-Abdalla (UCLA), Syun Akasofu (Alaska), Don Williams (JHUAPL)

Report: *GEM: Geospace Environment Modeling – A Program for Solar-Terrestrial Research in Global Geosciences*

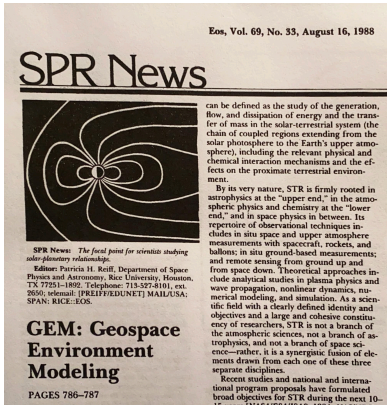
First Workshop 1988 AGU Fall Meeting: Maha Ashour-Abdala organizer

Magnetopause and boundary layer physics and ionospheric signatures of cusp processes

GEM:
Geospace Environmental Modeling

From the GEM Report

GEM should not burden the traditional grant funding mode
GEM should build upon and compliment studies carried out in the traditional mode
GEM should not compete with simultaneously planned NSF CEDAR initiative and the Solar Max (MAX91) program
GEM should be carefully coordinated with national and international programs, such as satellite programs with NASA/ESA/ISAS



Eos, Vol. 69, No. 33, August 16, 1988

SPR News

SPR News: *The focal point for scientists studying solar-planetary relationships.*
Editor: Patricia H. Reiff, Department of Space Physics and Astronomy, Rice University, Houston, TX 77251–1892. Telephone: 713-527-8101, ext. 2650; telemail: [PREIFF/EDUNET] MAIL/USA; SPAN: RICE::EOS.

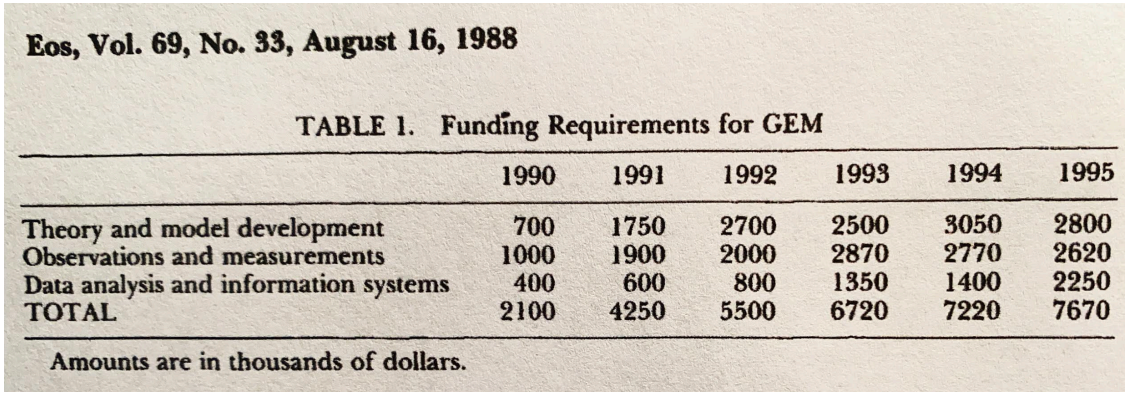
GEM: Geospace Environment Modeling

PAGES 786–787

can be defined as the study of the generation, flow, and dissipation of energy and the transfer of mass in the solar-terrestrial system (the chain of coupled regions extending from the solar photosphere to the Earth's upper atmosphere), including the relevant physical and chemical interaction mechanisms and the effects on the proximate terrestrial environment.

By its very nature, STR is firmly rooted in astrophysics at the "upper end," in the atmospheric physics and chemistry at the "lower end," and in space physics in between. Its repertoire of observational techniques includes in situ space and upper atmosphere measurements with spacecraft, rockets, and balloons; in situ ground-based measurements; and remote sensing from ground up and from space down. Theoretical approaches include analytical studies in plasma physics and wave propagation, nonlinear dynamics, numerical modeling, and simulation. As a scientific field with a clearly defined identity and objectives and a large and cohesive constituency of researchers, STR is not a branch of the atmospheric sciences, not a branch of astrophysics, and not a branch of space science—rather, it is a synergistic fusion of elements drawn from each one of these three separate disciplines.

Recent studies and national and international program proposals have formulated broad objectives for STR during the next 10-



Eos, Vol. 69, No. 33, August 16, 1988

TABLE 1. Funding Requirements for GEM

	1990	1991	1992	1993	1994	1995
Theory and model development	700	1750	2700	2500	3050	2800
Observations and measurements	1000	1900	2000	2870	2770	2620
Data analysis and information systems	400	600	800	1350	1400	2250
TOTAL	2100	4250	5500	6720	7220	7670

Amounts are in thousands of dollars.

The rest is history----------Best wishes for GEM 2021!!

GEM PROGRAM OUTLINE

As conceived and proposed to NSF

Roederer 1988

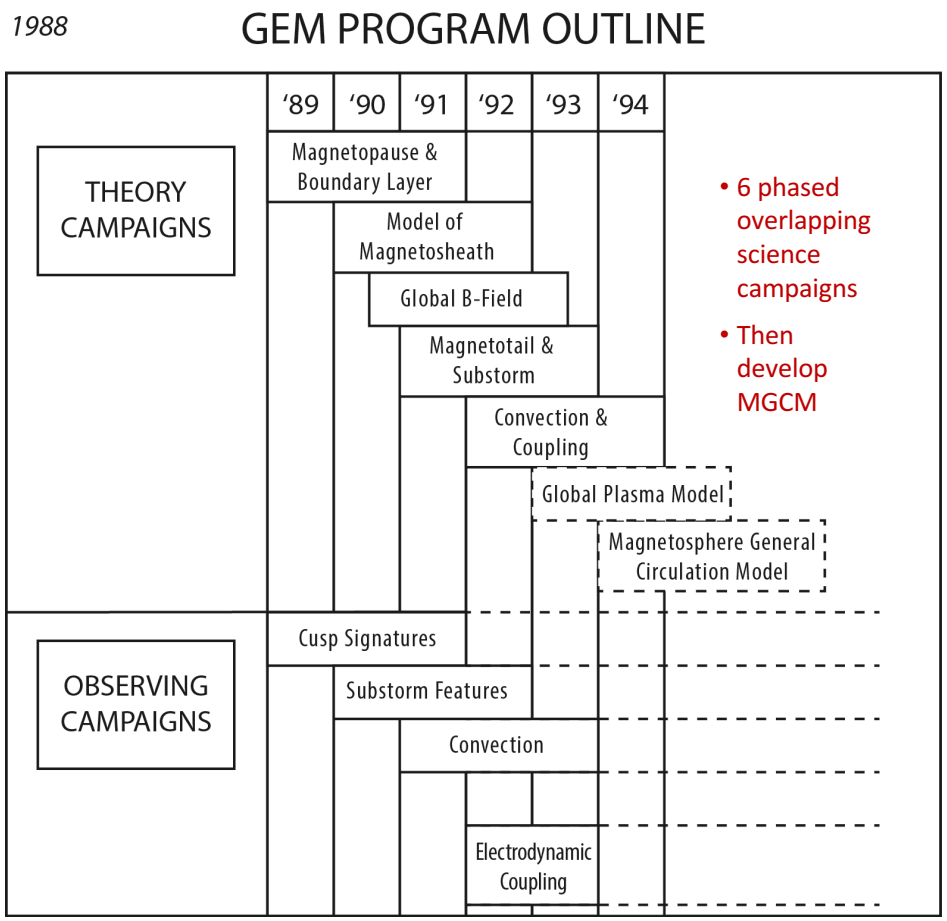
A new approach to research

Time-Phased "Targeted"
Research Campaigns

Each campaign to be funded at $0.5-1M/yr

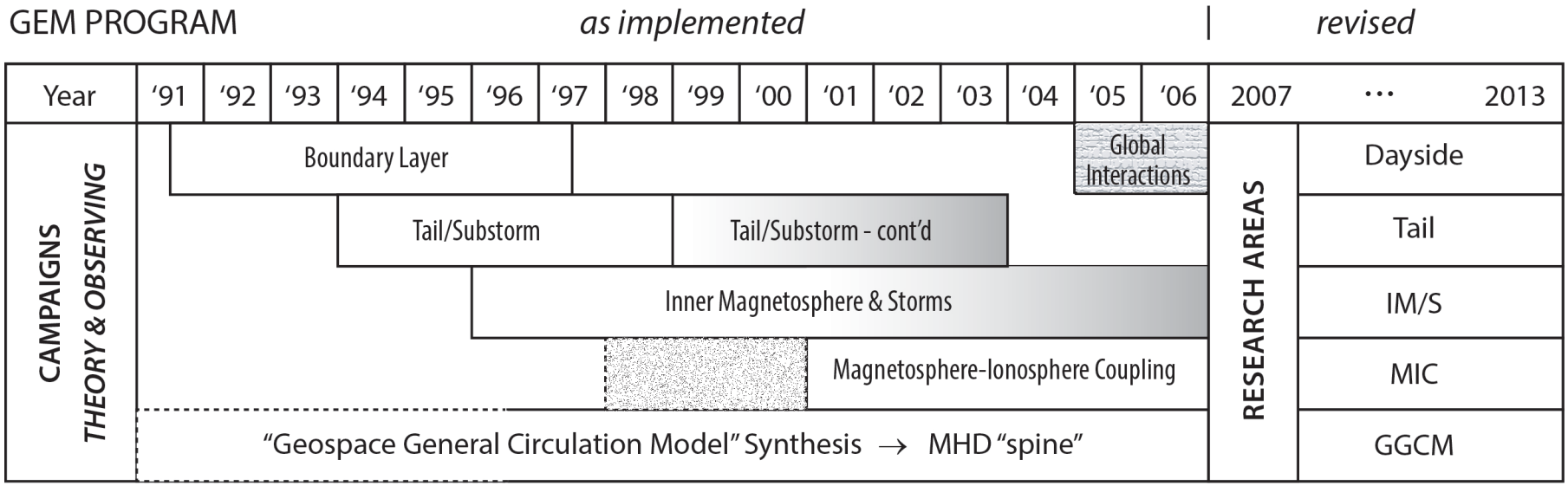
DATA AND INFORMATION SYSTEMS	TO SERVE THE ABOVE PROGRAM COMPONENTS 1. Discipline Data Centers 2. Electronic Communications 3. New Technology 4. Supercomputing Resources 5. Education

Fig. 2. The time phasing of the proposed GEM projects



GEM is launched as an NSF-sponsored program (1991)

$300k/yr → $500k/yr | 2021$ equivalent = $600k/yr → $1M/yr



1991 Plan: 4 five-year overlapping campaigns sequenced every 2 years | GGCM synthesis in parallel

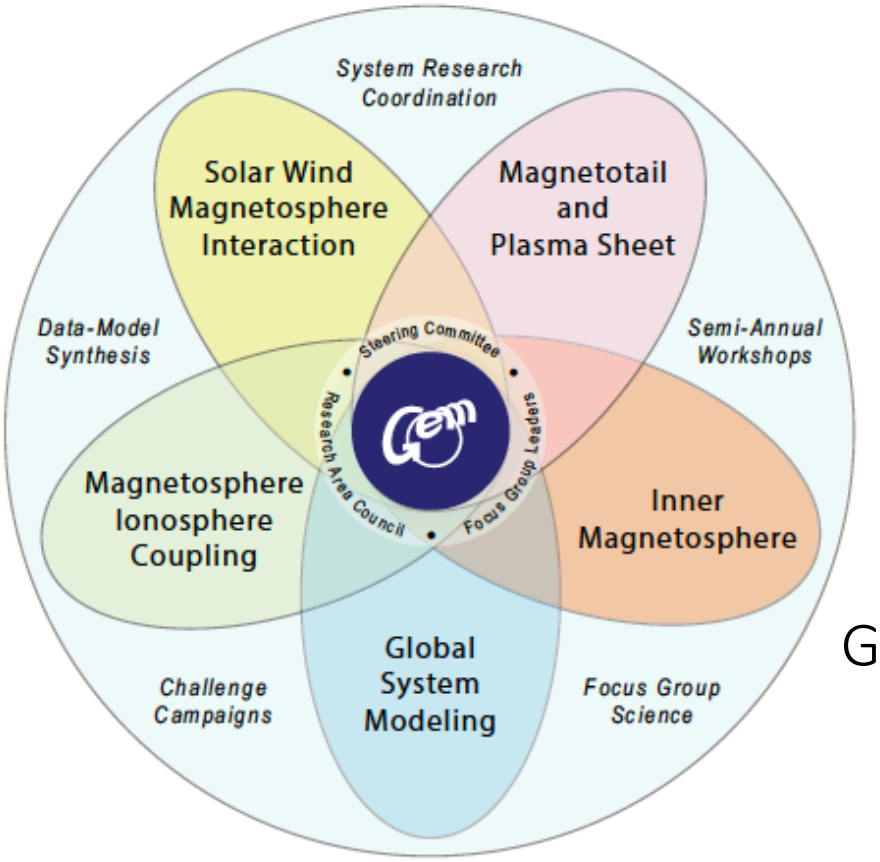
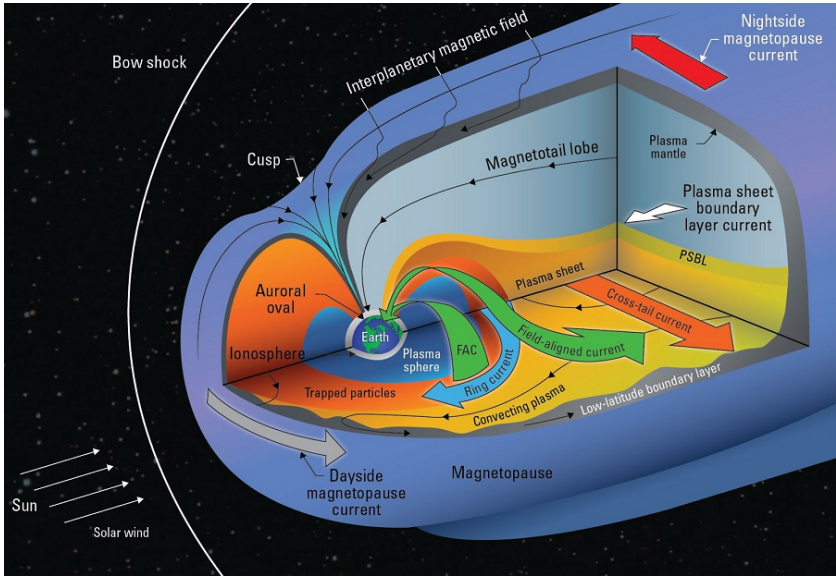


Image Source: GEM Whitepaper, 2013



GEM Participation Numbers Over ~ Two Solar Cycles & Pertaining to GEM Research Research Areas and Space Missions

Virtual GEM, 2021, 30th anniversary, 26th of July

Prof. Katariina Nykyri

Background

- The Geospace Environment Modeling Program was initiated in 1991 as an NSF targeted research program of the Geosciences Directorate with the goal to develop a community Geospace General Circulation Model (GGCM).

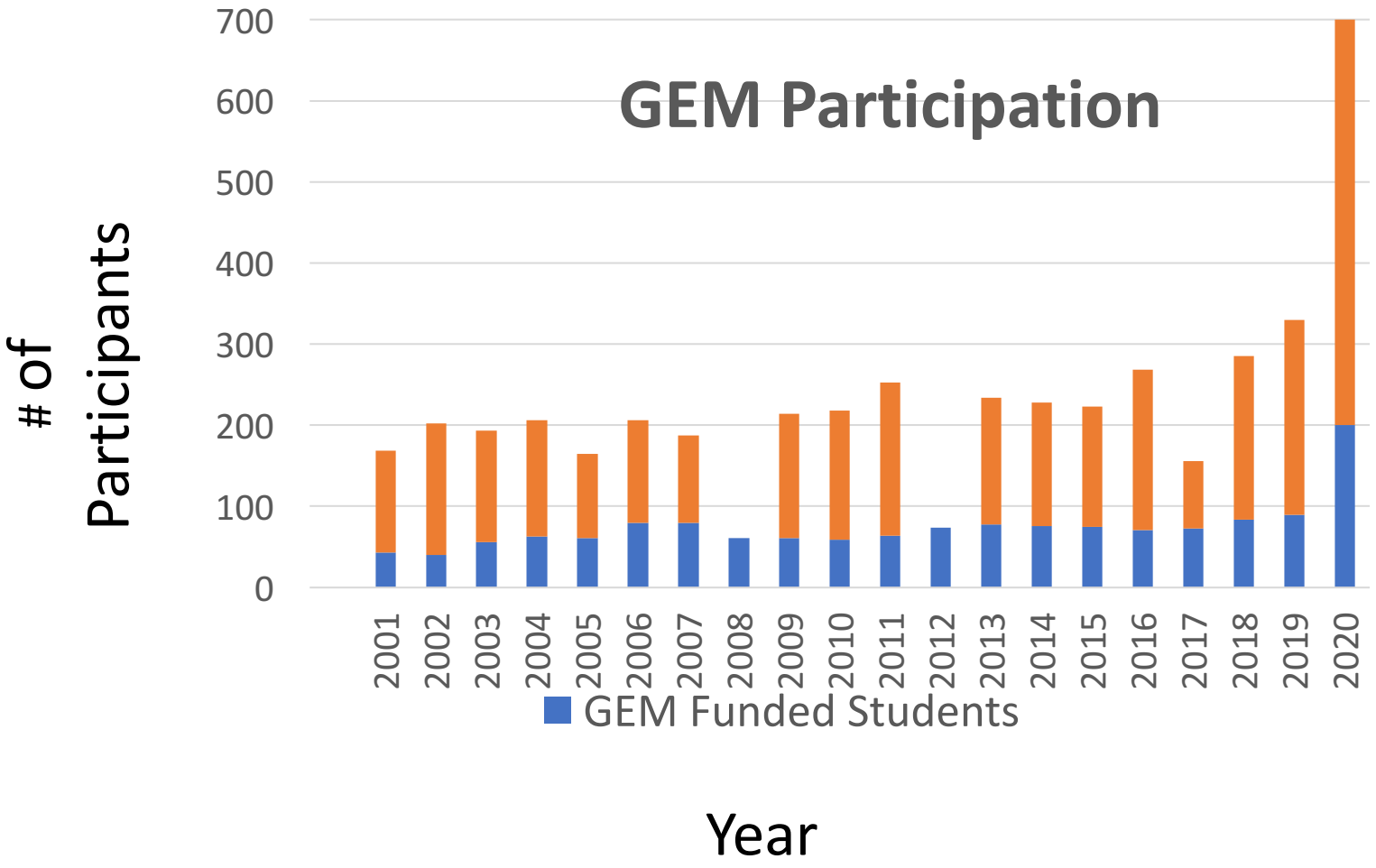
  Vision: Accurate prediction of the geospace environment.
  Mission: Develop physical understanding of the large-scale organization and dynamics of the geospace environment from observations, theory and increasingly realistic models.

- Mode of operation: week-long summer meetings and 1-day mini-GEM before Fall AGU

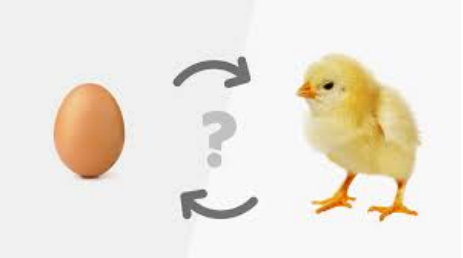
  - Campaigns (1991-2003)
    - Boundary Layers (1991-1996)
    - Inner Magnetosphere and Storms (1996-2001)
    - Tail and Substorms (1994-1997; 1998-2003)
    - Ionosphere-Magnetosphere Coupling (1998-2003)

  - Focus Groups under 5 Research Areas (2003-present):
    - Solar Wind - Magnetosphere Interaction (*SWMI*)
    - Magnetotail and Plasma Sheet (*MPS*)
    - Inner MAGnetosphere (*IMAG*)
    - Magnetosphere – Ionosphere Coupling (*MIC*)
    - Global Systems Modeling (GSM)

  - Challenges
    - GEM Reconnection Challenge (2000-2001)
    - GEM Dayside Kinetics Challenge (2017-2020)
    - ULF Modeling Challenge (2016-2021)
    - 3D Ionospheric Electrodynamics (2018-)
      Conductance Challenge
    - Mid-Tail Modeling (2017-)
    - Ionospheric Outflow (2019-)


GEM Participation
# of Participants
700
600
500
400
300
200
100
0
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
GEM Funded Students
Year

Example keyword search parameters for GEM research areas divided per processes/consequences



processes: waves, instabilities, discontinuities, shocks, tearing mode instability, reconnection, Flux Transfer Events, mirror mode instability, Kelvin-Helmholtz instability, diffusion, radial diffusion, particle injection, microinjection, plasma waves: kinetic Alfvén, ion cyclotron, lower hybrid, whistler, electron cyclotron, upper hybrid, ion acoustic, Langmuir, collisions, ion Bernstein, electron Bernstein, wave-particle interactions, turbulence, pressure pulses

……..

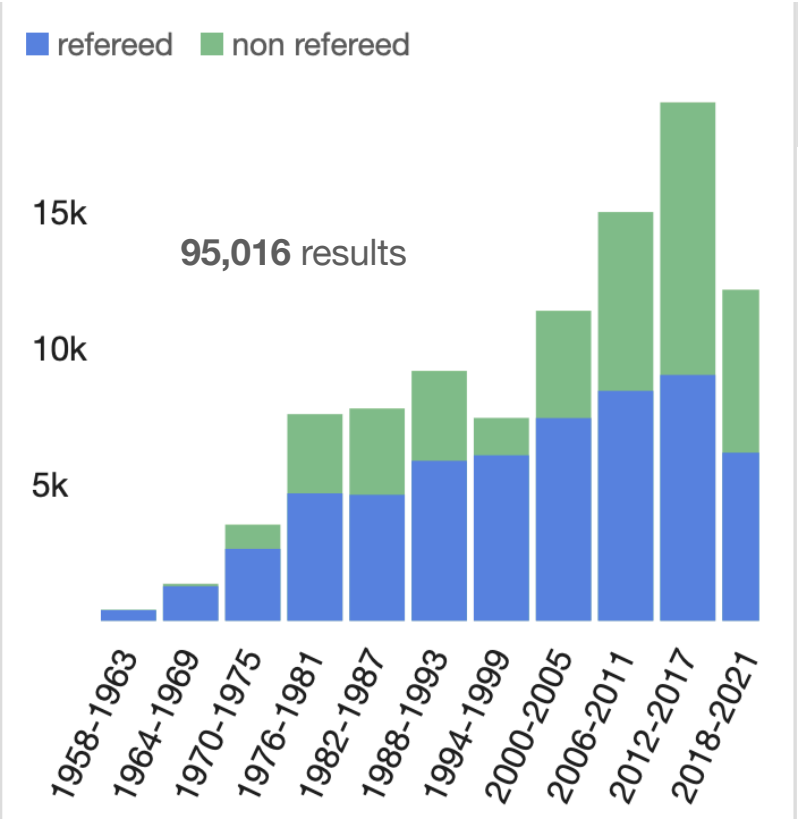
consequences: charge separation, plasma transport, flux transport, momentum transport, energy transport, plasma heating, particle acceleration, particle drifts, currents, proton acceleration, ion acceleration, electron acceleration, particles loss, flux ropes, magnetic islands, vortices, turbulence, substorm, storm, convection, aurora, resistivity, conductivity, resonance, outflow, polar wind, shielding, penetration electric field, ambipolar electric field, parallel electric field, Dungey cycle, field-aligned current, bursty bulk flows, dipolarizations, magnetosheath jets, SLAMS, hot flow anomalies, foreshock cavities, foreshock cavitons, diamagnetic cavities, magnetic holes, time domain structures, inverted V, auroral acceleration……..

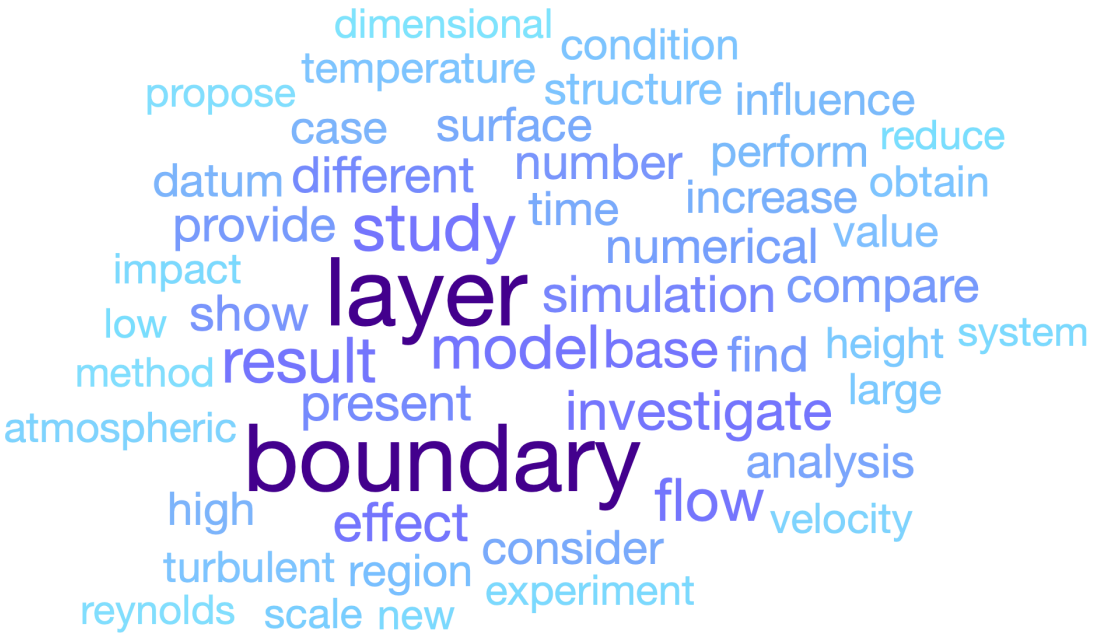
GEM Campaign based search

- Campaigns (1991-2003)
  - Boundary Layers (1991-1996)
  - Inner Magnetosphere and Storms (1996-2001)
  - Tail and Substorms (1994-1997; 1998-2003)
  - Ionosphere-Magnetosphere Coupling (1998-2003)

Boundary Layers search using ADS:

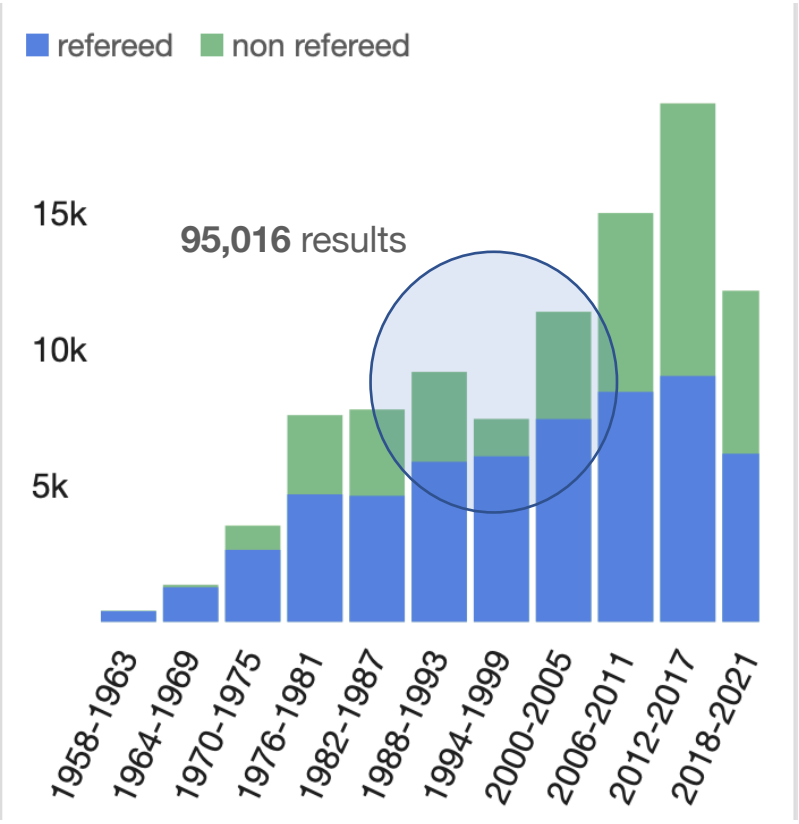
abs:"boundary layers" OR "Boundary Layer" AND ("magnetospheric") year:1958-2021



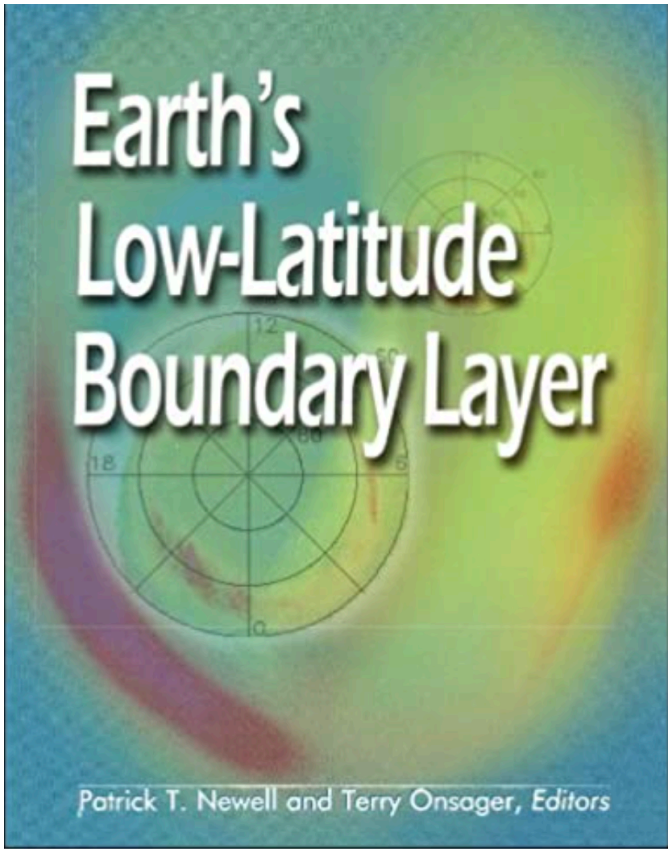


Boundary Layers search using ADS:

abs:"boundary layers" OR "Boundary Layer" AND ("magnetospheric") year:1958-2021

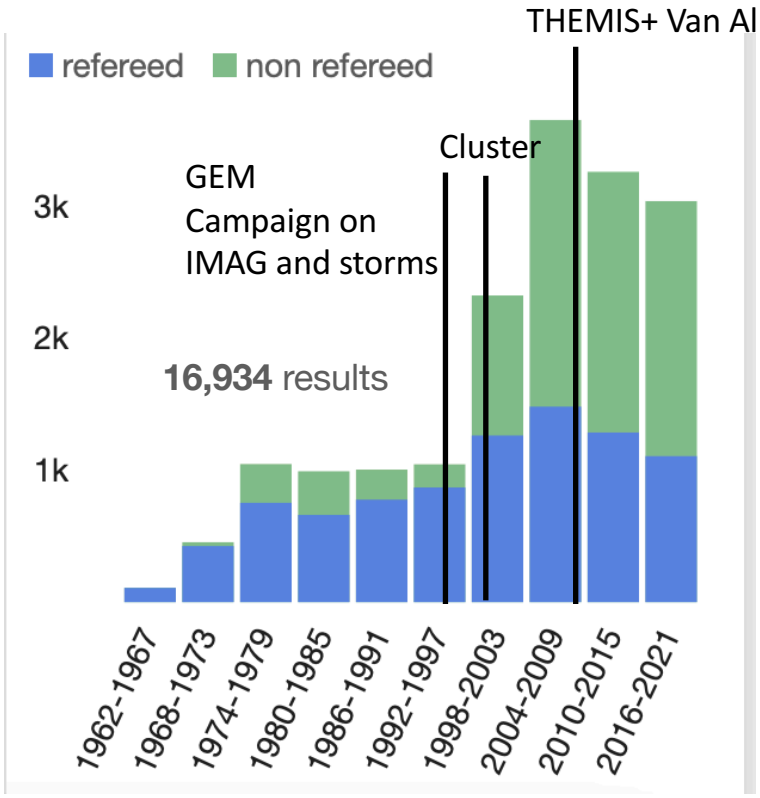


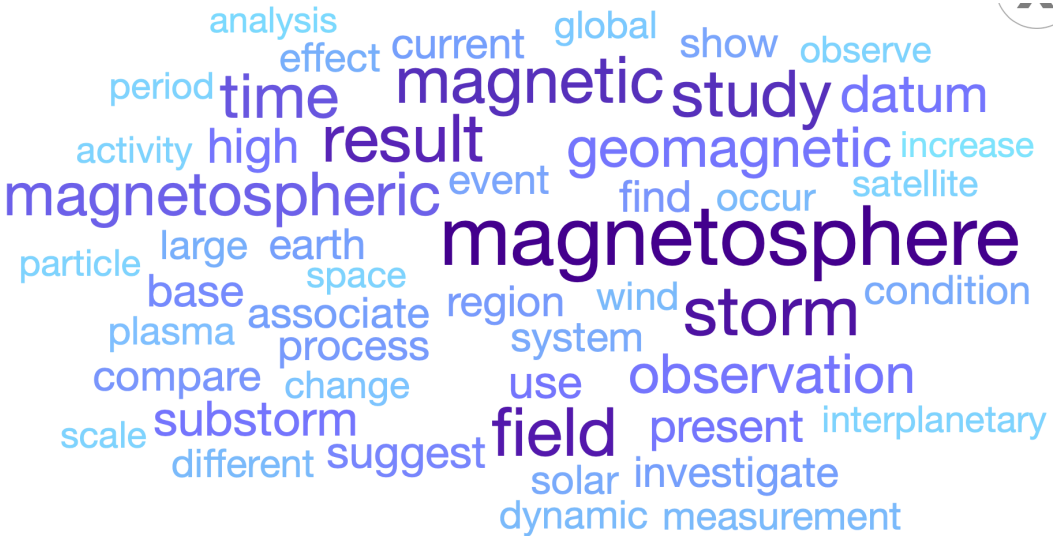
- GEM Boundary Layer Campaign 91-96
- Geotail launch, 1992
- Polar Launch, 1996
- Cluster I Failure, 1996
- LLBL Chapman Conference in New Orleans, 2000
- Cluster II launch, 2000



Magnetosphere and Storms search using ADS:

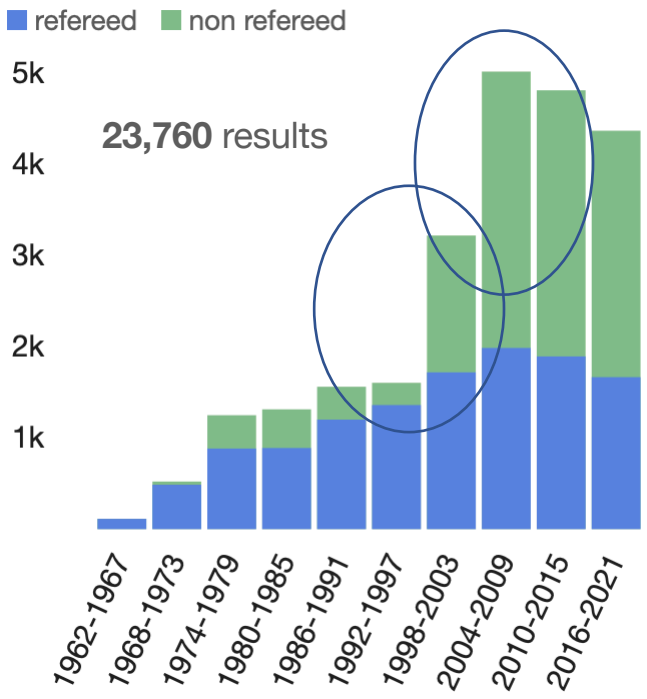
abs:”magnetosphere” AND ”storms" year:1958-2021



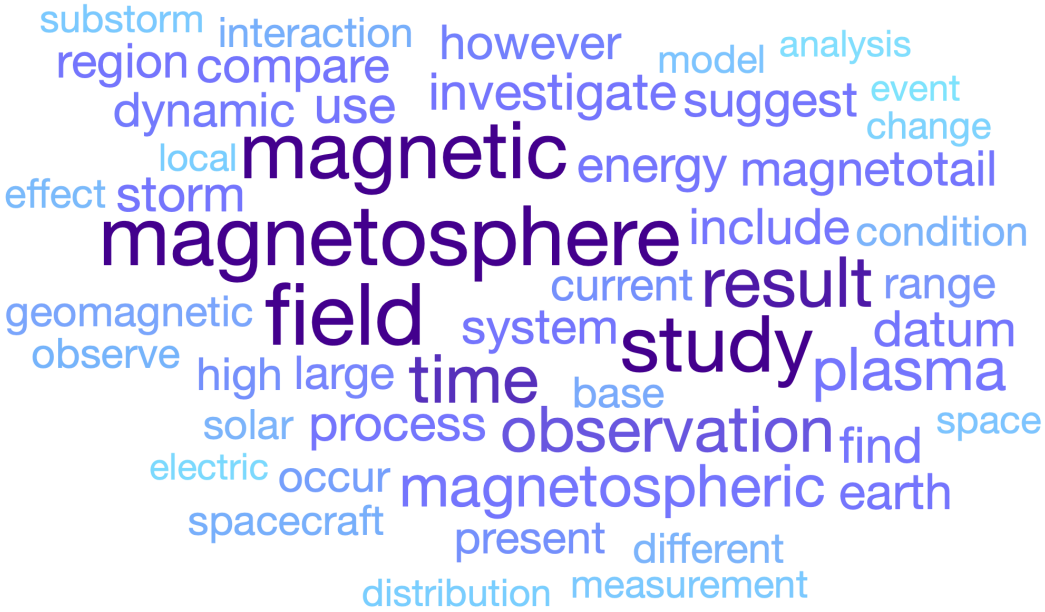


Tail and Substorm search using ADS:

abs:"magnetotail" OR "substorm" AND “magnetosphere” year:1958-2021

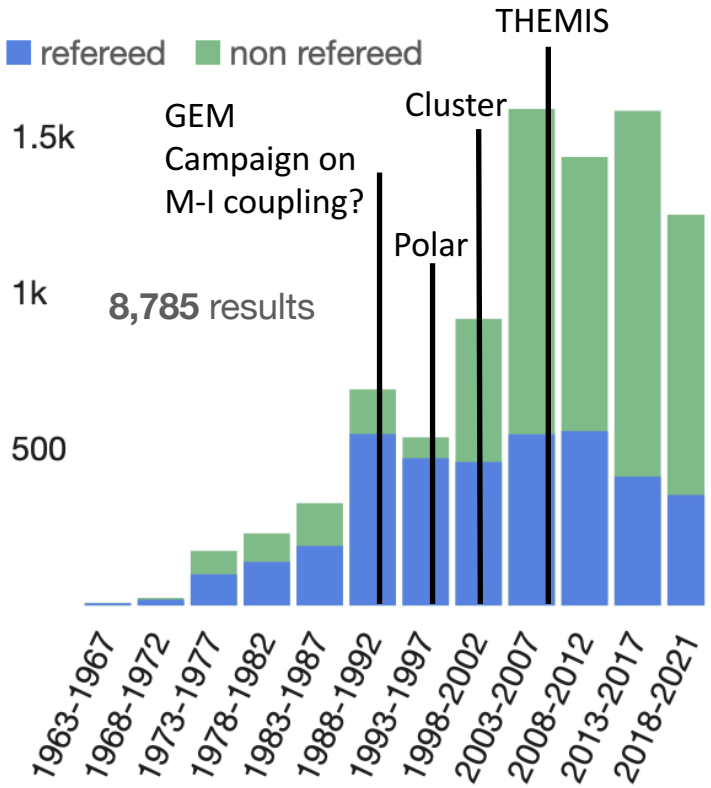


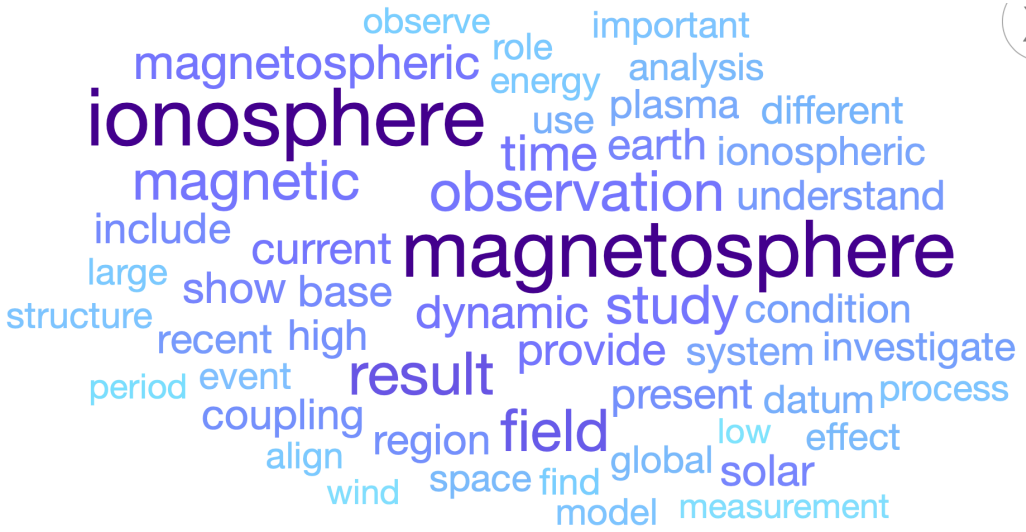
- Geotail Launch,
- Tail and Substrom Campaigns, 1994-2003
- Cluster, 2000-present
- THEMIS, 2007-present
- MMS, 2015-prewnt



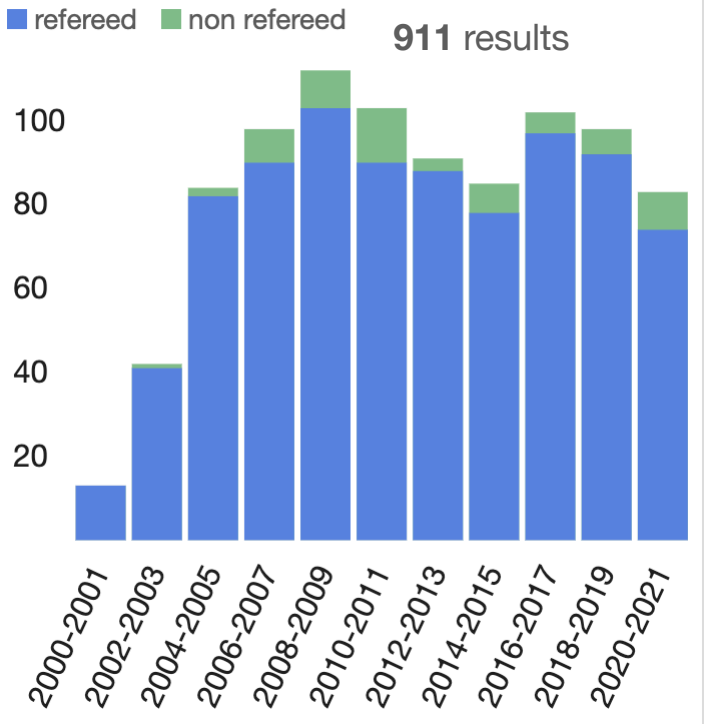
M-I coupling search using ADS:

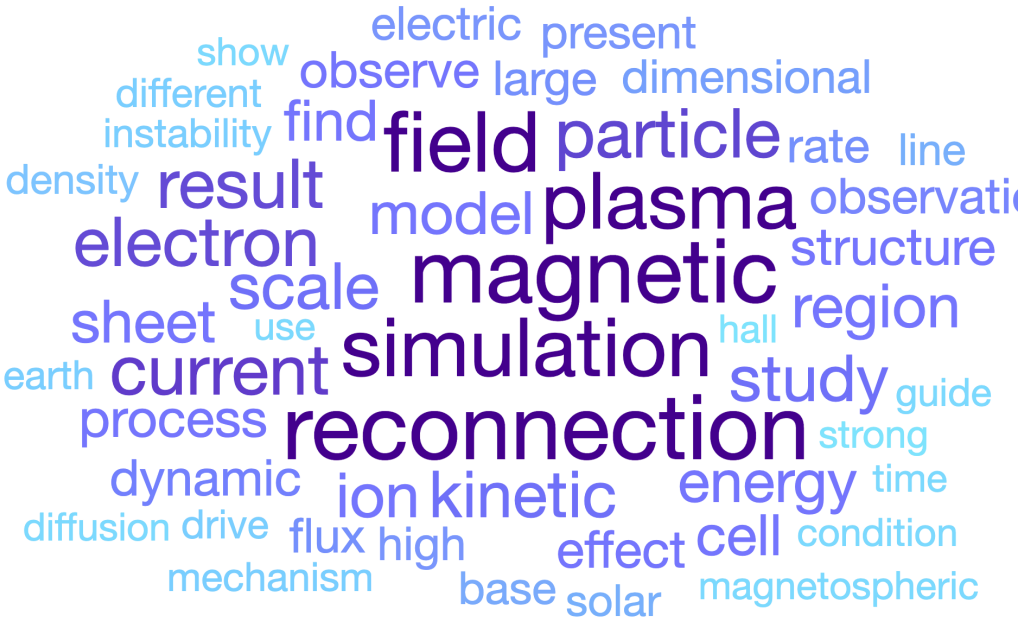
abs:"M-I coupling" OR "magnetosphere-ionosphere" year:1958-2021



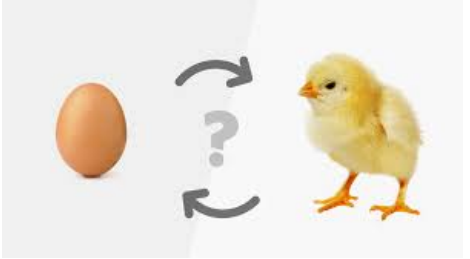


Citations to GEM Challenge paper: “Geospace Environment Modeling (GEM) Magnetic Reeconnection Challenge”





Keyword search parameters for GEM research areas divided per regions



- Solar Wind - Magnetosphere Interaction (*SWMI*, previously known as Dayside):

regions: foreshock, bow shock, magnetosheath, magnetopause, cusp, flank magnetopause

- Magnetotail and Plasma Sheet (*MPS*, previously known as Tail)

regions: plasma sheet, tail lobe, flank magnetopause, magnetotail

- Inner MAGnetosphere (*IMAG*, previously known as IMS)

regions: ring current, radiation belts, plasmasphere

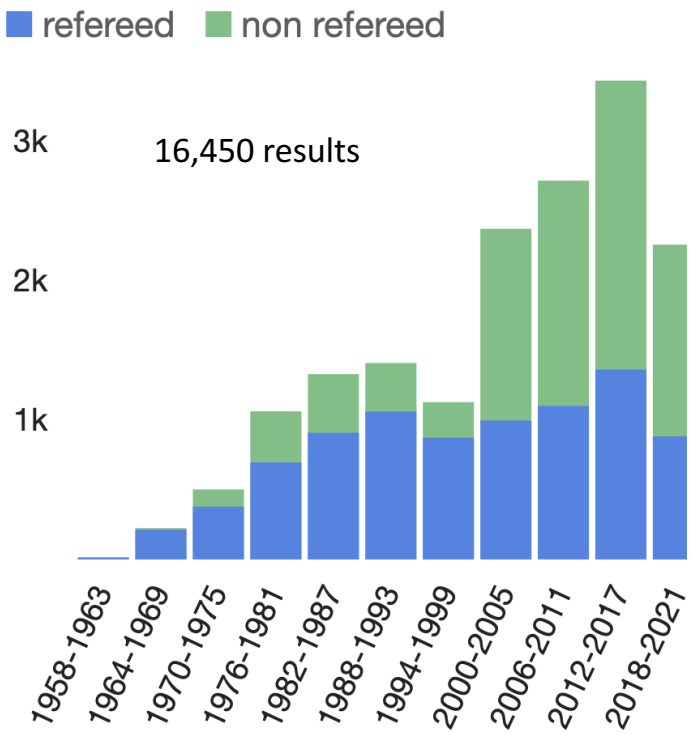
- Magnetosphere – Ionosphere Coupling (*MIC*)

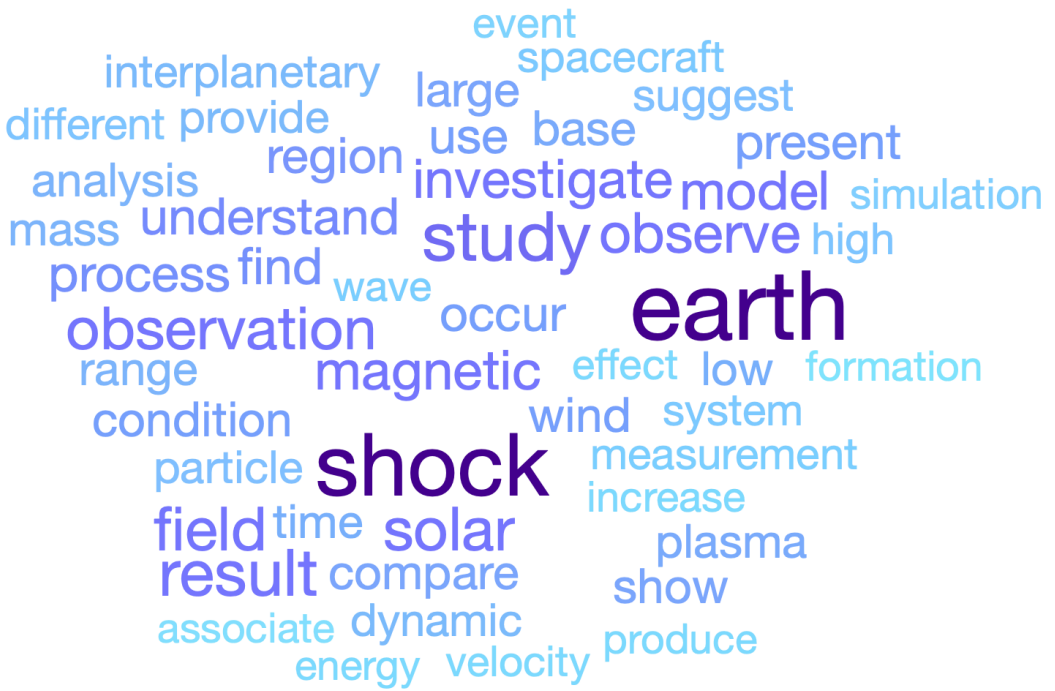
regions: ionosphere, plasma-sheet boundary layer, plasma sheet, polar cap, cusp

- Global Systems Modeling (GSM)

SWMI region-based search using ADS:

abs:("bow shock" OR foreshock OR magnetosheath OR magnetopause OR cusp OR "flank magnetopause" or "magnetospheric flank") AND "Earth")) AND year:1958-2021)

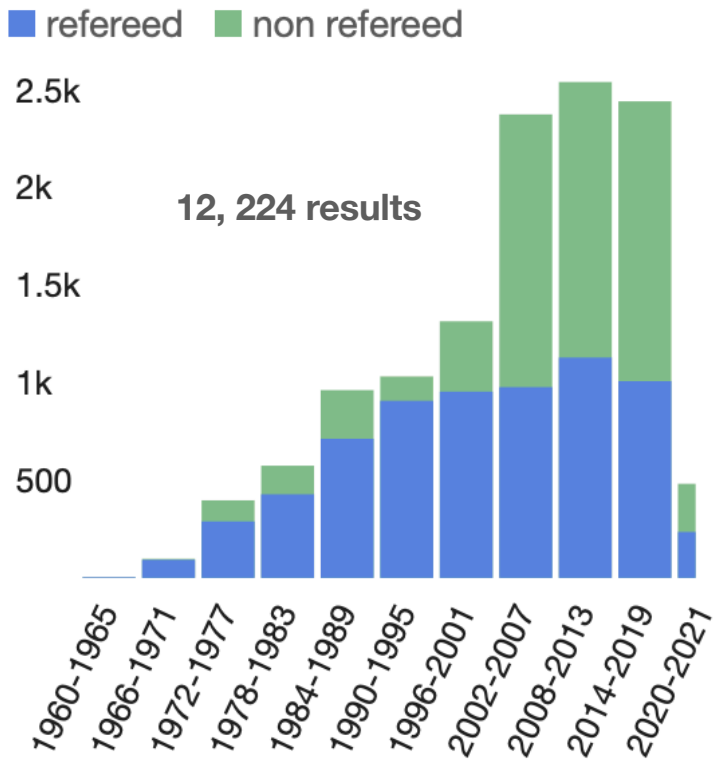


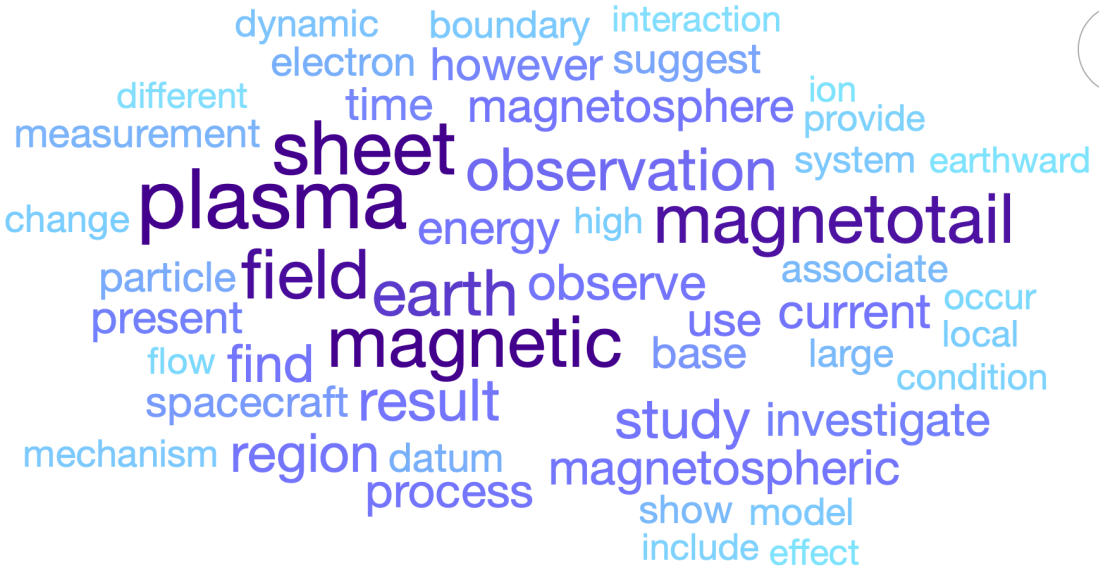


Concept cloud with equal weight on uniqueness and frequency

Tail region-based search using ADS:

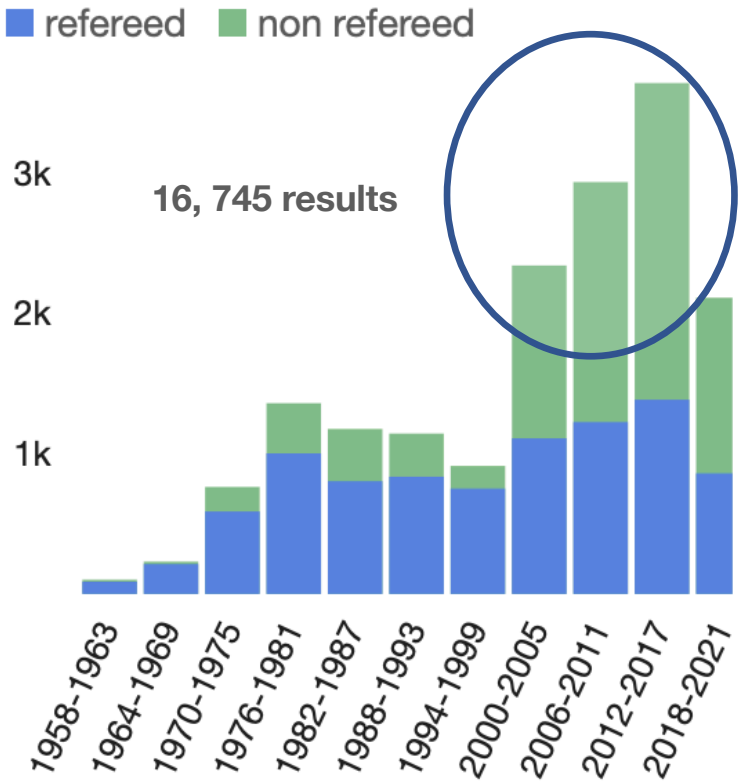
abs:"plasma sheet" OR "tail lobe" OR "tail lobes" or "flank magnetopause" or "magnetotail" AND "Earth" year:1958-2021



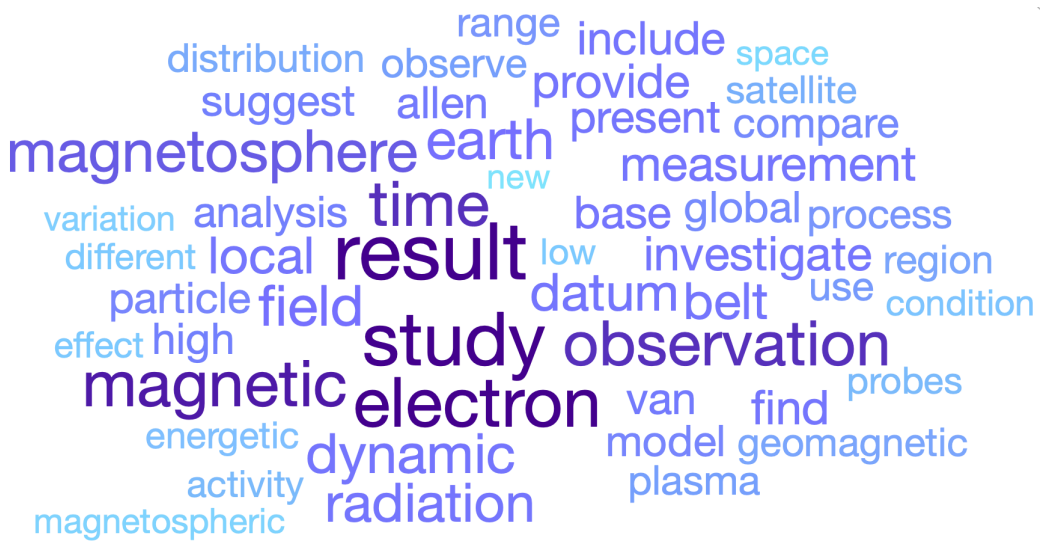


Inner Mag region-based search using ADS:

abs:"ring current" OR "plasmasphere" OR "plasmapause" OR "radiation belts" AND "Earth" year:1958-2021



Cluster, THEMIS, Van Allen Probes, MMS…



Conclusions

- Amount of GEM supported students has not increased at the rate proportional to overall participation.

- In citation search to GEM research area keywords it is not easy to pinpoint solely the GEM impact from mission impact and general increase of citations through time. However, the impact is clear when looking citations related to specific GEM challenges (e.g., GEM reconnection challenge) and campaigns.

=> GEM is an important forum for discussing geospace science, identifying open questions in the field and leading research direction (and missions) of the magnetospheric community.

Does GEM have a unifying vision in its current configuration: how do we move forward?