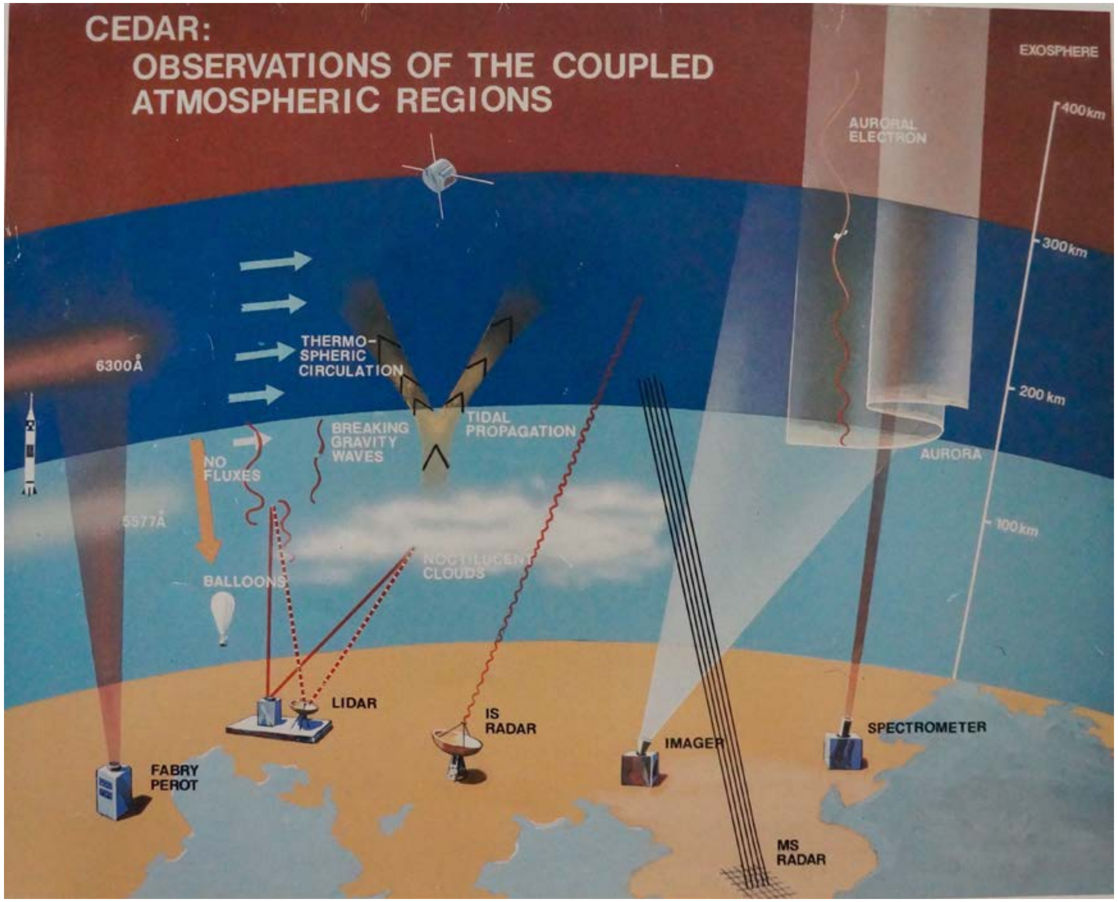
CEDAR: the past, the present, some recommendations for the future

Rich Behnke

CEDAR – In the beginning…

The original CEDAR plan



CEDAR – almost 30 years old!

COUPLING, ENERGETICS, AND DYNAMICS
OF ATMOSPHERIC REGIONS
"CEDAR"

VOLUME I: OVERVIEW

A program for upper atmosphere research
using ground-based techniques.

Prepared for:

the Aeronomy Program and the Upper Atmospheric Facilities Program of the
National Science Foundation

by:

the CEDAR Science Steering Committee

April 1986.
(Revised April 1987)

The First CEDAR Plan

Executive Summary

This report presents the recommendations of the upper atmospheric (aeronomy) science community to the Aeronomy and Upper Atmospheric Facilities Programs of the National Science Foundation for a unified, multi-year program of aeronomical research involving ground-based instrumentation and interpretative capabilities. The recommendations are based on the conviction that the various optical, radar, and theoretical techniques developed in the past and possible in the near future, using modern technology, will enable important progress to be realized for a broad range of scientific topics which are fundamental and central to the understanding of our solar-terrestrial environment. An essential feature of the recommendations is a coordinated experimental and theoretical approach involving collaborative efforts with other national and international research programs.

Early Pioneers

Science Steering Committee
(Term of appointment)

Gerald J. Romick—Chairman (University of Alaska) (1984-1988)

Charles S. Deehr—Executive Secretary (University of Alaska) (1984)

Susan K. Avery (University of Colorado) (1986-1987)

Richard Behnke (National Science Foundation) (1986-1988)

Manfred A. Biondi (University of Pittsburgh) (1984-1986)

Andrew B. Christensen (Aerospace Corporation) (1986-1988)

John C. Foster (MIT, Haystack Observatory) (1984-1987)

David C. Fritts (University of Alaska) (1986-1988)

Timothy L. Killeen (University of Michigan) (1984-1988)

Robert W. Schunk (Utah State University) (1984-1986)

Chalmers F. Sechrist, Jr. (University of Illinois) (1984-1985)

William E. Sharp (University of Michigan) (1986-1988)

Brian A. Tinsley (University of Texas at Dallas and National Science Foundation) (1984-1988)

Douglas G. Torr (University of Alabama at Huntsville) (1984-1987)

Interferometry Sub-Committee

John W. Meriwether, Jr.—Chairman (University of Michigan)

Manfred A. Biondi (University of Pittsburgh)

Paul B. Hays (University of Michigan)

James H. Hecht (Aerospace Corporation)

Gonzalo Hernandez (University of Michigan)

Craig A. Tepley (Arecibo Observatory)

Roger W. Smith (University of Alaska)

Fred L. Roesler (University of Wisconsin)

Robert J. Sica (Utah State University)

Gordon G. Shepherd (York University)

Lidar Sub-Committee

Chalmers F. Sechrist, Jr.—Chairman (University of Illinois)

Sidney A. Bowhill (University of Illinois)

Charles S. Deehr (University of Alaska)

Chester S. Gardner (University of Illinois)

Gerald W. Grams (Georgia Institute of Technology)

David C. Fritts (University of Alaska)

Fred L. Roesler (University of Wisconsin)

Vincent B. Wickwar (SRI International)

Spectroscopy Sub-Committee

Gulamabas G. Sivjee—Chairman (University of Alaska)

A. Lyle Broadfoot (University of Arizona)

Supriya Chakrabarti (University of California at Berkeley)

Andrew B. Christensen (Aerospace Corporation)

Richard Gattinger (NRC Canada)

Gerald J. Romick (University of Alaska)

Marsha R. Torr (Utah State University)

Imaging Sub-Committee

Robert Eather—Chairman (Boston University)

A. Lyle Broadfoot (University of Arizona)

Thomas Hallinan (University of Alaska)

Stephen Mende (Lockheed Corporation)

Gordon G. Shepherd (York University, Canada)

Brian A. Tinsley (University of Texas at Dallas and the National Science Foundation)

More early pioneers….

Mesospheric Radar Sub-Committee

Susan K. Avery—Chairman (University of Colorado)
Ben B. Balsley (Aeronomy Laboratory, NOAA)
Jeffrey Forbes (Boston University)
David C. Fritts (University of Alaska)
Erhan Kudeki (University of Illinois)
Miguel F. Larsen (Clemson University)
Janet Luhmann (University of California at Los Angeles)
Robert G. Roper (Georgia Institute of Technology)
Anne K. Smith (University of Michigan)
Brenton J. Watkins (University of Alaska)

Incoherent Scatter Radar Sub-Committee

James F. Vickrey—Chairman (SRI International)
Herbert C. Carlson (Air Force Geophysics Laboratory)
Lewis M. Duncan (Los Alamos National Laboratory)
Raymond Greenwald (Johns Hopkins University, Applied Physics Laboratory)
Roderick A. Heelis (University of Texas at Dallas)
Michael C. Kelley (Cornell University)
Vincent B. Wickwar (SRI International)
John C. Foster (MIT, Haystack Observatory)

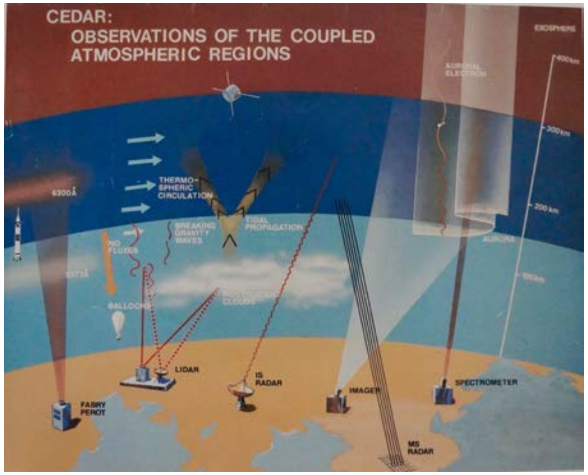
Theoretical Modeling Sub-Committee

Douglas G. Torr—Chairman (University of Alabama, Huntsville)
David Anderson (Air Force Geophysics Laboratory)
David C. Fritts (University of Alaska)
Timothy L. Killeen (University of Michigan)
Manfred H. Rees (University of Alaska)
Arthur D. Richmond (National Center for Atmospheric Research)
Raymond G. Roble (National Center for Atmospheric Research)
Chalmers F. Sechrist, Jr. (University of Illinois)
Robert W. Schunk (Utah State University)
Susan Solomon (NOAA Aeronomy Laboratory)
Brian A. Tinsley (University of Texas at Dallas and the National Science Foundation)

CEDAR -- Phase I

The Coordination and Exploratory Phase

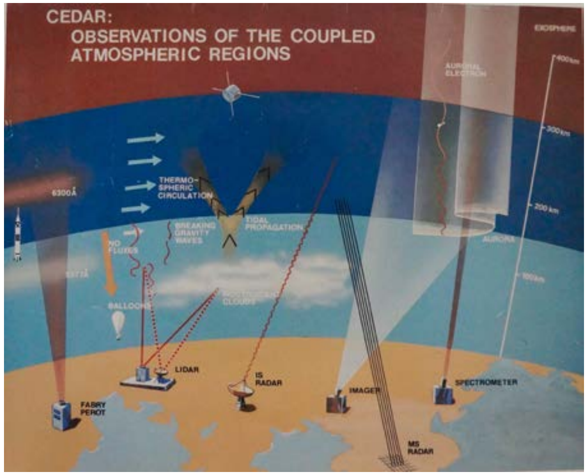
- Research enhancement by coordination
  - The birth of the annual workshop and the CEDAR science steering committee
  - Emphasis on instrument clustering and coordination with other techniques.
- Campaigns directed at specific topics
  - Mean F-region winds and temperatures; auroral energy and momentum input, waves, equatorial perturbations, mid-latitude dynamics
- New instrument and facility initiatives
  - Evaluation of new sensors (optical detectors)
  - Upgrading existing instruments (radars and optical)
  - Replacing aged, low performance instruments (MS radars, all-sky cameras)



CEDAR -- Phase II

New Research Capabilities

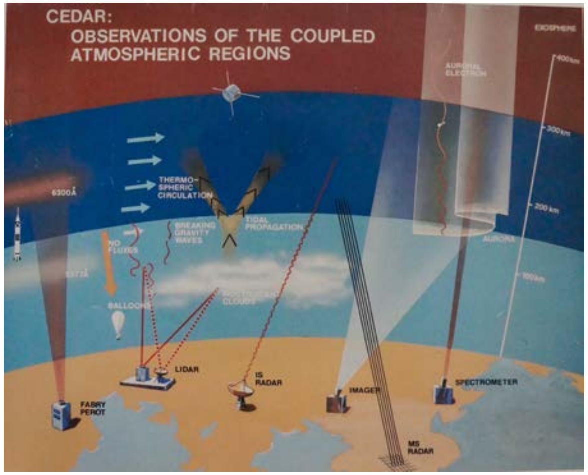
- Science coordination
  - Database at NCAR established
  - Dissemination of CEDAR results at national meetings
  - Development of advanced modeling capabilities
- Upgraded existing instruments
  - Detectors, lidars,ISRs, and MS radars (much like Phase I, but not just plan the upgrades – carry them out!)
- Combined Instrument and Observatory chains and new stations
  - Deploy upgraded instruments
  - Cluster instruments
  - Fill critical gaps in global coverage
- Continued Instrument Development
  - Create Class I sites



CEDAR -- Phase III

Fully Realized CEDAR Program

- Science Program Planning
  - Continue workshops of Phase I to constantly evaluate and refine program goals
- Realize “Class I” instruments and Facilities



MAJOR **CEDAR** SCIENCE TOPICS

PHASE I

Mean F-region global winds and temperatures, departures from mean
Auroral energy and momentum input, waves, perturbations
Equatorial, mid-latitude dynamics

PHASE II

Mean F-region global winds and temperatures, departures from mean
Detailed ion-neutral coupling
Auroral energy and momentum input, waves, perturbations
Dynamical effects of ring current particle precipitation
Exospheric hydrogen, line profiles, intensities
Metallic ions in mesosphere, layering, motion, abundances, temperatures
Auroral processes, atomic and molecular auroral spectroscopy
Lower thermosphere global dynamics
Latitudinal propagation of dynamical perturbations

PHASE III

Mean thermospheric composition, departures from mean, dynamical control
Lower thermosphere, mesosphere dynamics
E-region transport, dynamo effects, feedback to magnetosphere
Daytime thermospheric dynamics
Tides in the mesosphere and propagation to thermosphere
Gravity wave momentum, turbulence budgets
Ring current particle precipitation, global energetic consequences
Inter-hemispheric dynamical asymmetries, thermosphere and mesosphere
High-resolution studies of dynamics and composition, local features
Upper mesosphere, mesopause dynamics
Global distribution of exospheric hydrogen, quiet and disturbed conditions
Velocity distributions for exospheric helium
Thermosphere/Exosphere/Plasmasphere coupling
Thermosphere/Stratosphere coupling, minor constituent transport
Auroral morphology, physics and chemistry
Ozone and water vapor in the mesosphere, variability
Mesospheric eddy diffusion, height, seasonal variability
Metallic ion layering processes
Transition region active sounding
Mesospheric temperature structure
Dust, noctilucent cloud physics
Ionosphere/thermosphere feedback

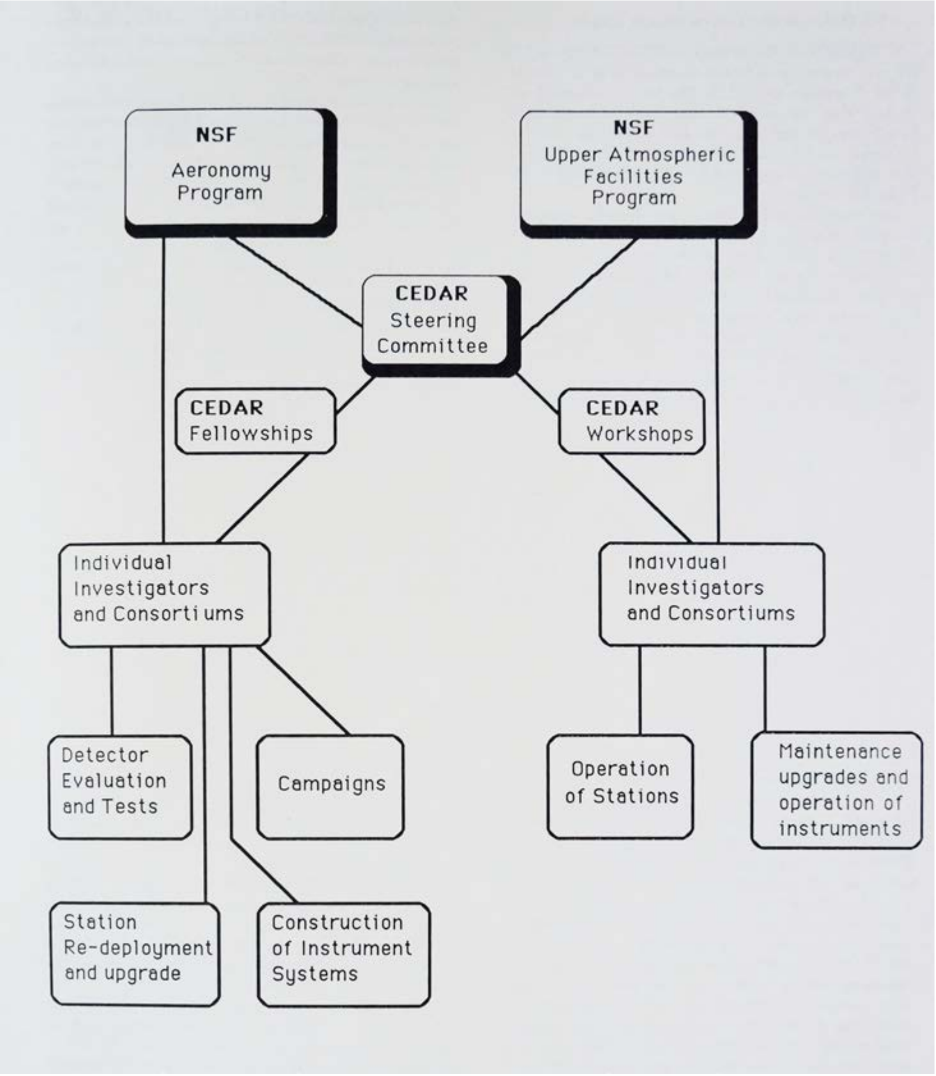
Growth of CEDAR science topics during each of the three phases. Listed according to the phase in which most rapid progress is enabled.

The list is NOT inclusive, but illustrates the accelerating rate important coordinated science can be done from the evolving network of CEDAR observatories

The goal:

In general, the limitations to our understanding will no longer be due to our technical inability to obtain the information required to test current theories but will be determined rather by the imagination and skill shown in the analysis and interpretation of high quality data.

Management of CEDAR



The Beginning of CEDAR traditions

Student Introductions -- 1991

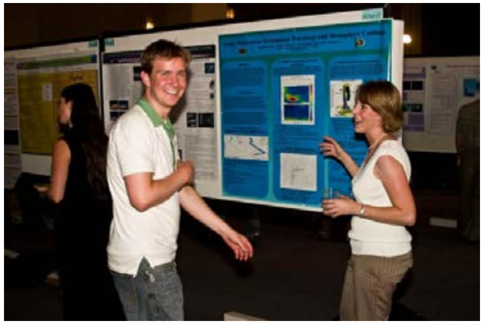
1991 CEDAR Meeting Agenda - June 17-21
Sponsored by NSF, HAO/NCAR, and U of CO

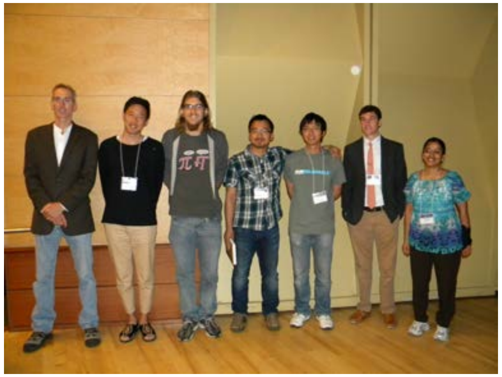
Monday, June 17, 1991 - NIST Auditorium

8:30-8:45	Welcome at NIST; Chet Gardner, CEDAR; Peter Gilman, NCAR; Ray Roble, HAO
8:45-9:45	Introductions; CEDAR post doc John Sahr; students
9:45-10:15	BREAK
10:15-10:45	The International Solar Terrestrial Physics Program (ISTP), Stephen Curtis, NASA / Goddard
10:45-11:15	The Solar Terrestrial Energy Program (STEP) Vince Wickwar, Utah State
11:15-11:25	AIDA Campaigns - Colin Hines, Arecibo Observatory
11:25-12:10	CEDAR issues (budgets, awards, etc) Rich Behnke/Fred Roesler/Chet Gardner
12:10-12:30	CEDAR Data Base update - Barbara Emery/John Holt

CEDAR and Education

- Student Poster Contest began in 1990:
- Winners:
  - Joe Pingree (1990)
  - Keith Groves (1991)
  - Richard Collins, Susan Nossal (1992)
  - Monica Coakley, Denise Thorsen (1993)
  - John Noto (1994)
  - Julia Chang, Josh Semeter (1995)
  - Robert States (1996)
  - Farzad Kamalabadi (1997)
  - Simon Shepherd (1998)
  - Olga Kalashnikova (1999)
  - Rebecca Bishop, Lars Dyrud (2000)
  - Lars Dyrud (2001)
  - Naomi Maruyama, Tomoko Matsuo, Anja Stromme (2002)
  - Josef Drexler, Carlos Martinis, Jonathan Snively, Xiaoli Zhang (2003)
  - Ningyu Liu, Melissa Meyer (2004)
  - Fabiano Rodrigues, Marco Milla (2005)
  - Mike Nicolls, Kim Nielson (2006)
  - Matthew Zettergren, Jeremy Riousett 2007)
  - And many more recently





CEDAR and Education

- Tutorial Lectures began in 1991
  - First tutorial: “Research Challenges in Observational Dynamics: Opportunities and Important Studies” – Dave Fritts
- Four per year every year since 1991

CEDAR Prize Lecture -- 1989

- 1989 – Art Richmond (Assimilative Mapping of Ionospheric Dynamics)
- 1990 – Michael Mendillo (The Discovery of a Sodium Magnetic Nebula Around Jupiter)
- 1991 – Craig Heinselmann (Sondrestrom MUSCOX)
- 1992 – Colin Hines (The Dopler Spreading Theory of Gravity Wave Spectra)
- 1993 – John Cho (Radar Scattering from the Coldest Place in our Atmosphere)
- 1994 – Ray Roble (Modelling the Circulation, Temperature and Composition Structure of the Upper Atmosphere)
- 1995 – Dave Fritts (Modeling of Gravity Wave and Instability Processes in the Middle Atmosphere)
- 1996 – Chet Gardner (The Aloha/ANLC-93 Campaigns)
- 1997 – Bela Fejer (Multi-Instrument Studies of Ionospheric Eectrodynamics)
- 1998 – Gary Swenson (A Model for Calculating Acoustic Gravity Wave Energy and Momentum Flux in the Mesosphere from OH Airglow)
- 1999 – Dave Hysell (A NEW Look at Low and Mid Latitude Ionospheric Irregularities)
- 2000 – Joshua Semeter (The Information Content of the Aurora)
- 2001 – Hans Mayr (Modelling Wave Driven Non-linear flow Oscillations)
- 2002 -- ?
- 2003 –Joe She (Climatology and variability in the mesopause region over Colorado)
- 2004 – Maura Hagan (Tidal Coupling in the Earth's Atmosphere)
- 2005 -- Jim Hecht (TOMEX: A Rocket/Ground-based Experiment to Study Instabilities over the Mesophere and Lower Thermosphere)
- 2006 – Erhan Kudecki (Incoherent Scatter Radar Perpendicular to B)
- 2007 – John Plane (Meteoric Smoke – Where on Earth is it?)
- 2008 – Sharon Vadas (The coupling of the lower atmosphere to the thermosphere via gravity waves)
- 2009 – Mike Nicolls (New observational capabilities for studying the lower ionosphere using ISR)
- 2010 – Paul Bernhardt (Using Active Experiments to SEE and HEAR the Ionosphere)
- 2011 – Joe Huba (Modeling Global Ionospheric Phenomena)
- 2012 – Larissa Goncharenko (Stratospheric Warmings and their Effects in the Ionosphere)
- 2013 – Jorge Chau (150 km eoches and their relevance to Aeronomy)
- 2014 – Jeff Forbes (Atmosphere-Ionosphere Coupling by Tides and Planetary Waves)
- 2015 – Jonathan Makela (Thermospheric Dynamics as observed through the lens of networked FPIs)

Early CEDAR Postdocs (up to 1998)

The CEDAR Post-Doctoral Fellows

Student and Year	Ph.D. Institution and Post-Doctoral Institution	Research Topic	Present Position
Stan Solomon (1987, 1988)	University of Michigan, 1987 HAO/NCAR	Airglow and Auroral Emissions Modeling	Research Associate University of Colorado
Julie Moses (1988, 1989)	University of California, LA, 1989 HAO/NCAR	Ionospheric Convection During Substorms	Research Associate Queen Mary and Westfield College
Jean Lilensten (1989, 1990)	University of Grenoble, 1989 HAO/NCAR	Transport of Suprathermal Electrons in the Auroral Ionosphere	Research Scientist CNRS
John Sahr (1990, 1991)	Cornell University, 1990 Cornell University	Design of New Data Acquisition System for JRO	Assistant Professor University of Washington
Dave Knudsen (1990, 1991)	Cornell University, 1990 Max-Planck-Institut für Extraterrestrische Physik	Incoherent Scatter Radar Spectrum Distortions from Intense Auroral Turbulance	Assistant Professor University of Calgary
Dan Senft (1991, 1992)	University of Illinois, 1991 University of Illinois	Na Wind/Temperature Lidar Studies of Mesopause Dynamics	Senior Engineer Rockwell Power Systems
C. Peymirat (1992, 1993)	University of Paris, 1991 HAO/NCAR	Couple the Thermosphere Ionosphere Electrodynamics General Circulation Model	Maitre de Conferences Universite de Versailles
Rick Doe (1994, 1995)	Boston University, 1994 SRI	Nightside Signatures for the Polar Cap Boundary	Research Physicist SRI
Wei Deng (1995)	University of Michigan, 1994 Millstone Hill Observatory	Global Study of Tides During LTCS Campaigns	Software Engineer Boston Technological Corporation
Susan Nossal (1995, 1996)	Univ. of Wisconsin, Madison, 1994 Arecibo Observatory & HAO/NCAR	Investigation of the Upper Atmospheric Hydrogen Boundary by Linking Fabry-Perot Observations with Upper Atmosphere Models	Research Associate Univ. of WI, Madison
Larissa Goncharenko (1996)	Kharkov State Polytechnic (Master's Degree), Ukraine, 1988 Millstone Hill Observatory	Data Analysis of Lower Thermosphere Using Millstone Hill Radar Observations	Post-Doctoral Fellow
Jirong Yu (1996)	Colorado State University, 1994 University of Illinois	Observational Studies of Tidal Perturbations in Mesopause Region Winds & Temperatures	Senior Engineer Science & Technology Corp.
Victor Pasko (1996, 1997)	Stanford University, 1996 Stanford University	Electrodynamic Coupling of the Troposphere & Mesosphere in Thunderstorm Regions	Post-Doctoral Fellow Stanford University
Biff Williams (1997, 1998)	Univ. of Colorado, Boulder, 1997 Colorado State University	Mesopause Tides Based on Extensive MODA and Sodium Lidar Data Sets	Post-Doctoral Fellow

Behnke gives Welcome -- 1993

1993 Annual CEDAR Meeting Agenda
Sponsored by NSF, HAO/NCAR, U of CO, and NIST

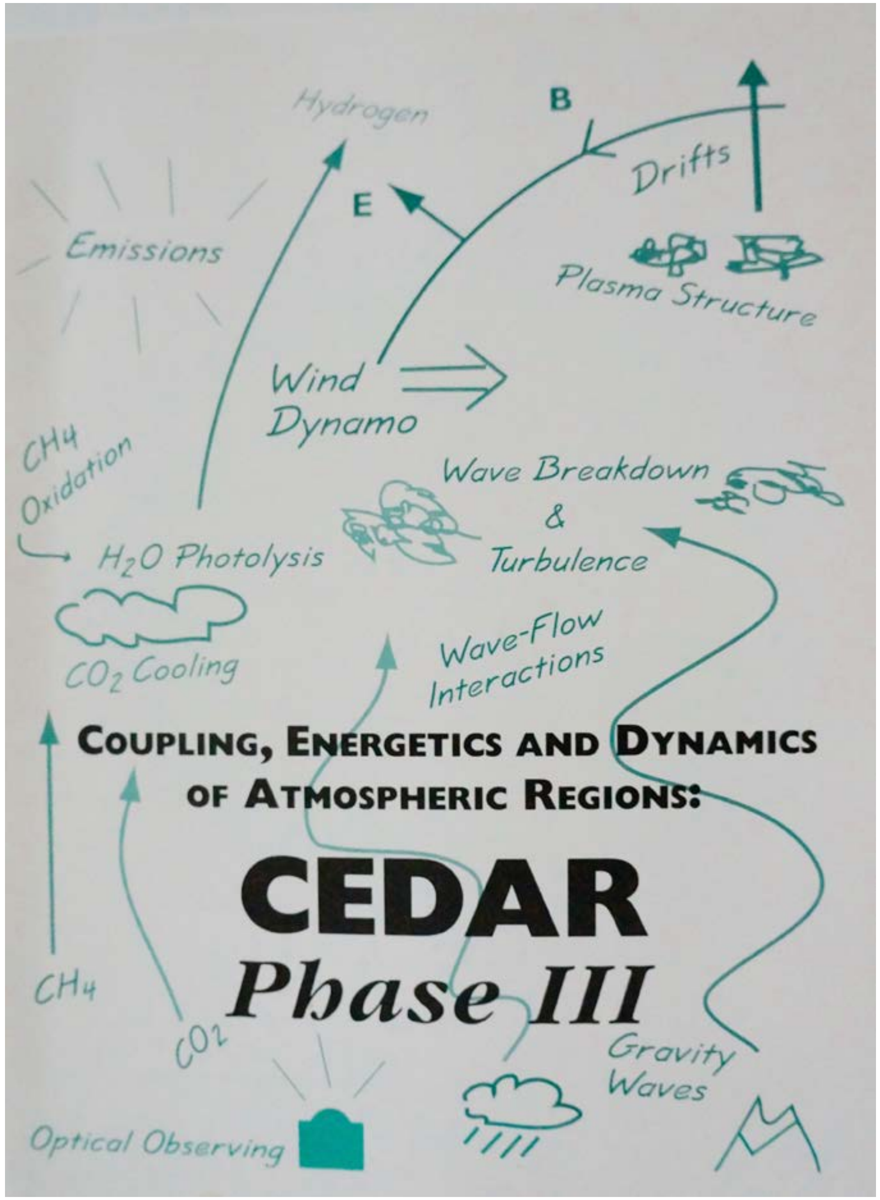
Monday, June 21, 1993 - NIST Auditorium

Chairman: **M. Kelley, Cornell University**

8:30 - 9:15	Introduction and Welcome - M. Kelley (NSF-R. Behnke, NCAR-G. Brasseur, HAO-T. Holzer, students, post-docs)
9:15 - 9:30	NASA Space Physics Division - G. Withbroe
9:30 - 10:15	Tutorial Lecture #1 J. Forbes - Tides and Global Oscillations
10:15 - 10:45	Break

Perhaps the biggest success of the early CEDAR was (and is)…

- ***Building a sense of a unified, inclusive community***



Circa 1996   Editor – Jeff Forbes

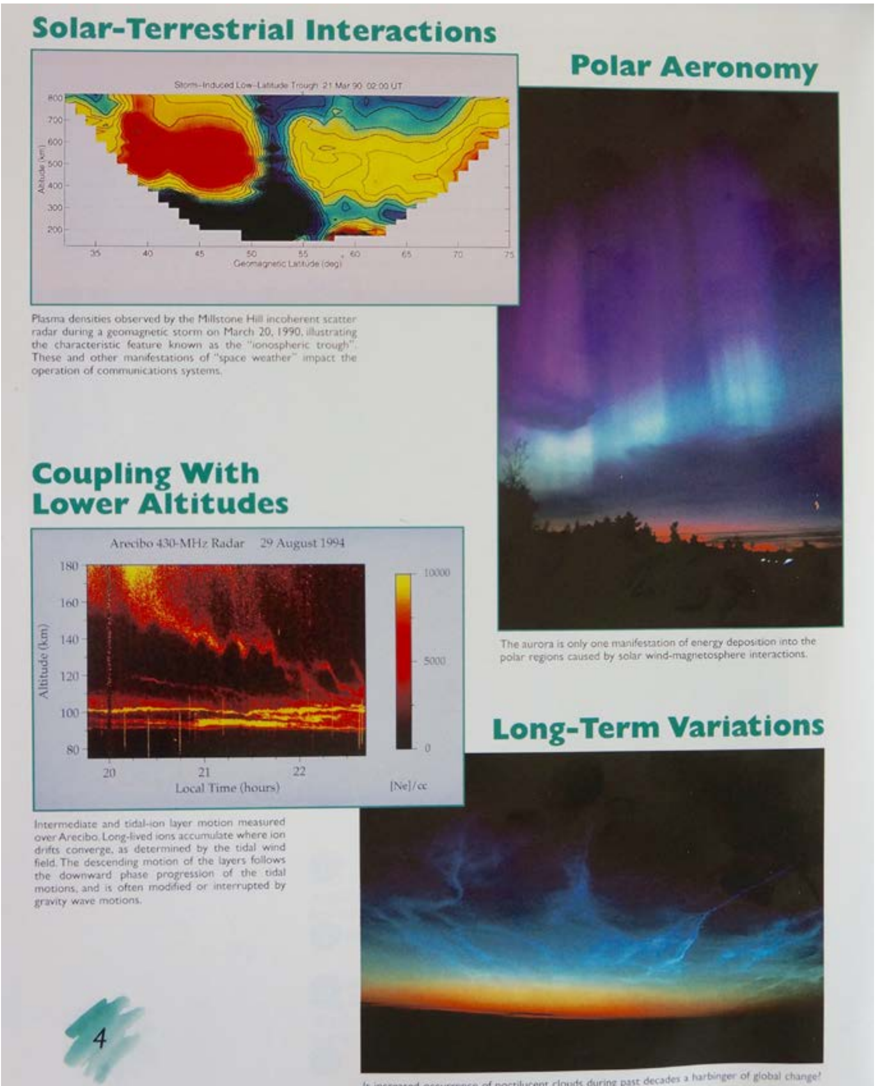
Executive Summary

CEDAR:
Coupling, Energetics and Dynamics of Atmospheric Regions

CEDAR is a highly successful research program that started in 1986 as a grass-roots community initiative for instrumentation that would enable state-of-the-art investigations of the Earth's upper atmosphere. Broadened to encompass multiple diagnostic techniques, theory, modeling, and coordinated observational campaigns, CEDAR is today the dominant national and international research program in terrestrial aeronomy. Scientifically, CEDAR is devoted to the characterization and understanding of the atmosphere above ~60 km, with emphasis on the energetic and dynamic processes that determine the basic composition and structure of the atmosphere. Particular attention is given to how these processes are coupled and to the mechanisms that couple different atmospheric regions.

"**CEDAR** is a highly successful research program that started in 1986 as a grass roots community initiative for instrumentation that would enable state-of-the-art investigations of the Earth's upper atmosphere. Broadened to encompass multiple diagnostic techniques, theory, modeling and coordinated observational campaigns, **CEDAR** is today the dominant national and international research program in terrestrial aeronomy."

CEDAR Phase III



Major Thrusts:

- Solar-Terrestrial Interactions
- Polar Aeronomy
- Coupling with Lower Altitudes
- Long-Term Variations

For each thrust, the report highlighted SPECIFIC outstanding science issues.

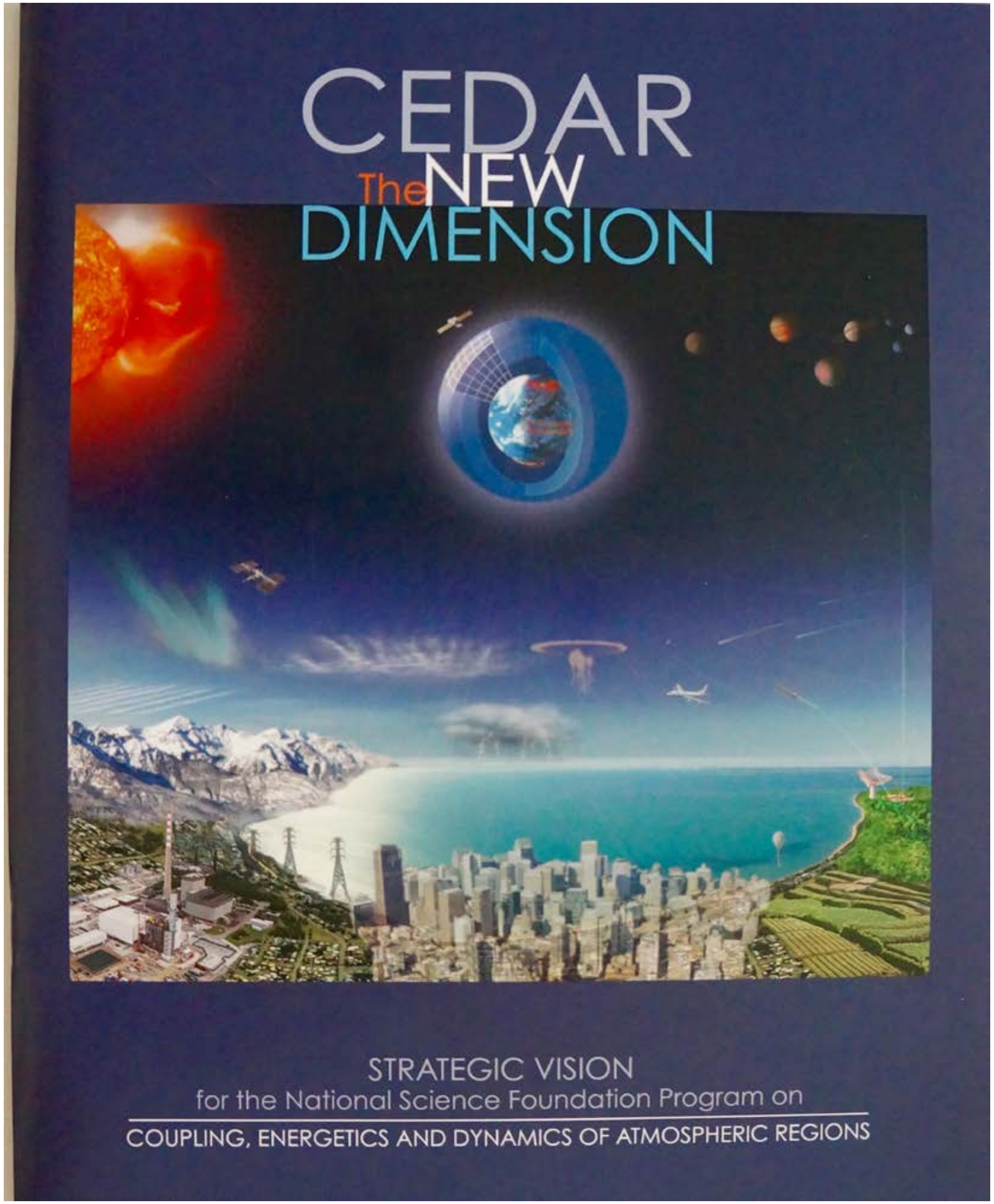
Examples of CEDAR Supported Campaigns

Acronym &	Campaign Description	Years
ETS	Equinox transition study	1985
GTMS	Global thermospheric mapping study	1985-87
HLPS	High latitude plasma structures	1986-
MLTCS/LTCS	Mesosphere and lower thermosphere coupling study	1986-
GISMOS	Global incoherent scatter meseaurements of substorms	1987-93
GITCAD	Global ionospheric thermospheric coupling and dynamics	1987-88
MAPSTAR	Mesospheric airglow structure and radiance study (workshops only)	1987-91
SUNDIAL	Study of global-scale ionosphere	1985-
AIDA	Arecibo initiative for the dynamics of the atmosphere	1988-90
CHARM	Collaborative H-alpha radar measurements	1989-91
ALOHA	Airborne & ground observations of Hawiian airglow	1990; 1993
STORM	Study specific ionospheric-thermospheric storm intervals	1990-
ARIA*	Rocket measurement of thermospheric dynamics	1992-95
AURORAL SPECTROSCOPY	Multi-station study of auroral emissions	1992-95
CADRE	Coupling and dynamics of equatorial regions	1992-94
MISETA	Multi-instrument study of equatorial thermospheric aeronomy	1992-
ANLC	Airborne and ground noctilucent cloud campaign	1993
10-DAY RUN	Coordinated radar and optical studies during January	1993
MALTED	Equatorial rocket, radar and optical dynamics studies	1994
CARMEN	Coordinated Arecibo related mesoscale experiments - tropical aeronomy	1996-
MSX*	Correlative CEDAR studies with MSX satellite	1996-
POLITE	Plasmaspheric observations of light ions in topside and exosphere	1996-

** Ground coordinated measurements only*

"For the success of CEDAR Phase III science initiatives, the continued development of instruments which push the limits of spatial and temporal resolution is a central requirement."

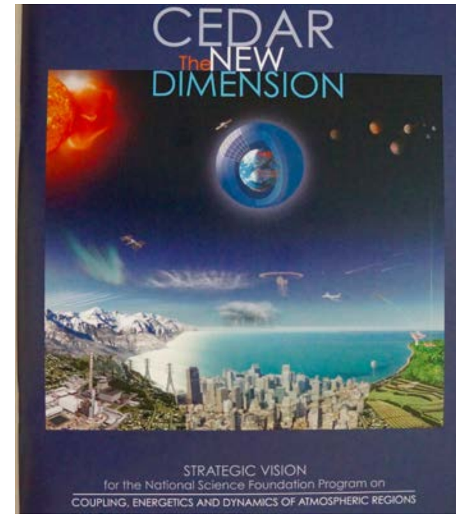
CEDAR Phase III report



May 2011, Jeff Thayer Editor

CEDAR: The New Dimension

- Calls for the proactive development of a systems perspective to study the upper atmosphere
- Emphasis on exchange processes at boundaries and transitions in geospace
- Explore processes related to geospace evolution
- Develop observational and instrumentation stategies
- Manage, mine and manipulate data and models

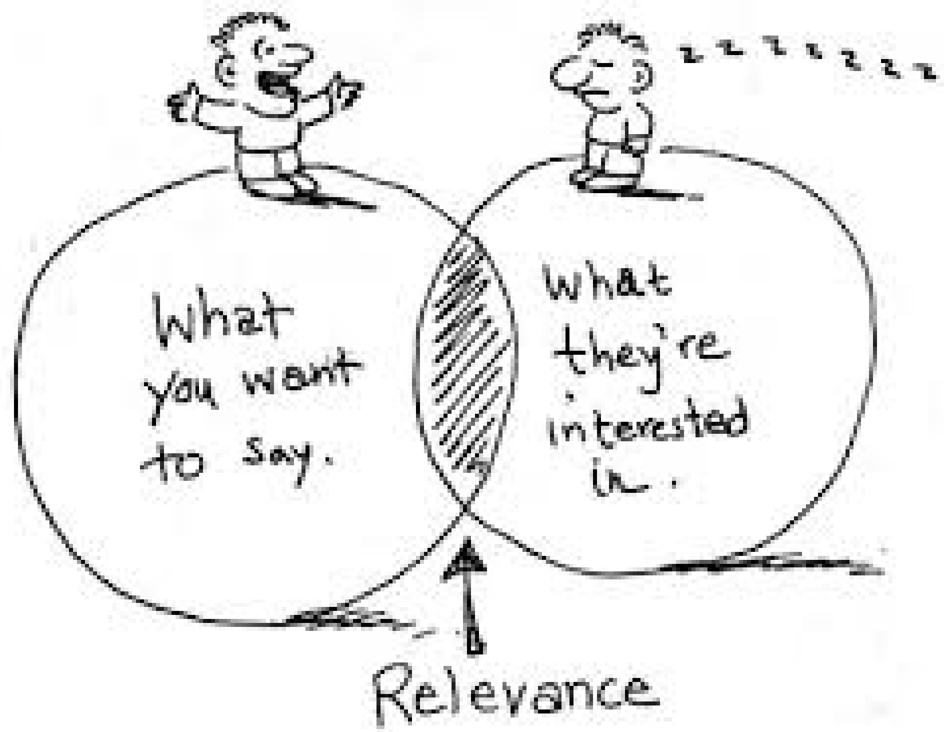


Grand Challenges

- The Synthesis of the Phase III document with the CEDAR Strategic Plan
  - Coupling and Transport Processes from the Upper Mesosphere through the Middle Thermosphere
  - Storms and Substorms without Borders
  - The high latitude geospace system

And now what?

- Is CEDAR still relevant?



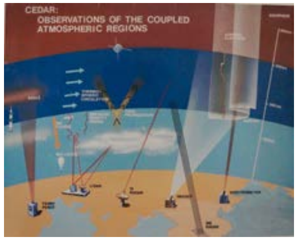
YES!!

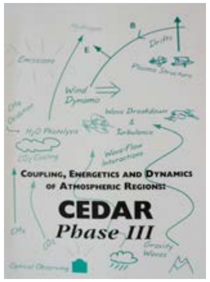
In fact, More than ever!

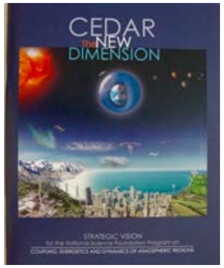
- CEDAR emphasizes exactly the kind of science that will succeed in the future!

“CEDAR” Science

- Coordinated, collaborative, campaigns
- Instrument clusters
- Development of state-of-the art sensors
- Complex and Fascinating Topics
  - Phase III report
  - Grand Challenges
- Strategy
  - Science at the interfaces
  - System Science approach
- Community driven and inclusive







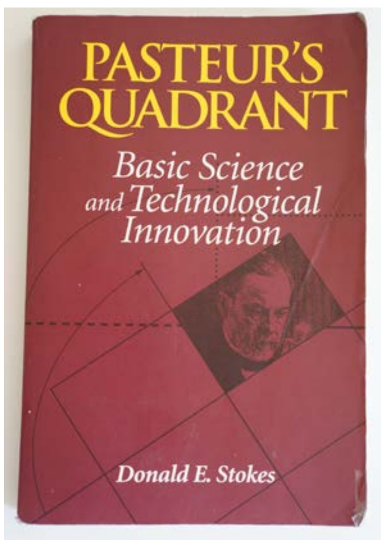
One of the challenges in the study of the equatorial ionosphere is the optimum use of a large number of very diverse ground-based measurements and data from current satellite missions (e.g., C/NOFS, DMSP, SWARM) and future missions (e.g., ICON)

Cluster of Instruments for Equatorial and Low-latitude Observations (CIELO)

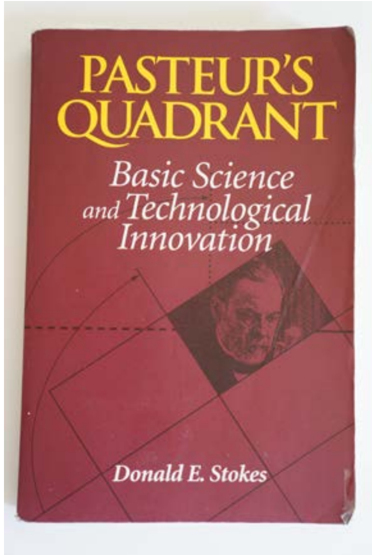
- LISN (C. Valladares, BC)
- Magnetometer chain (O.Veliz, IGP)
- Ionosondes
    - Digisonde (B. Reinish, U. Mass. Lowell)
    - VIPIR (E. Kudeki, J. Makela, Illinois)
- Beacon RXs (P. Bernhardt, NRL, Tsunoda, SRI)
- GNSS RXs (J. Morton, MU)
- CIRI Huancayo (J. Urbina, PSU)
- AMISR14 (J. Arratia, UMET) (under repair)
- FPI chain (J. Meriwether, Clemson, A. Gerrard, NJIT)
- Airglow camera (C. Martinis, BU)

Some Guideposts to Consider

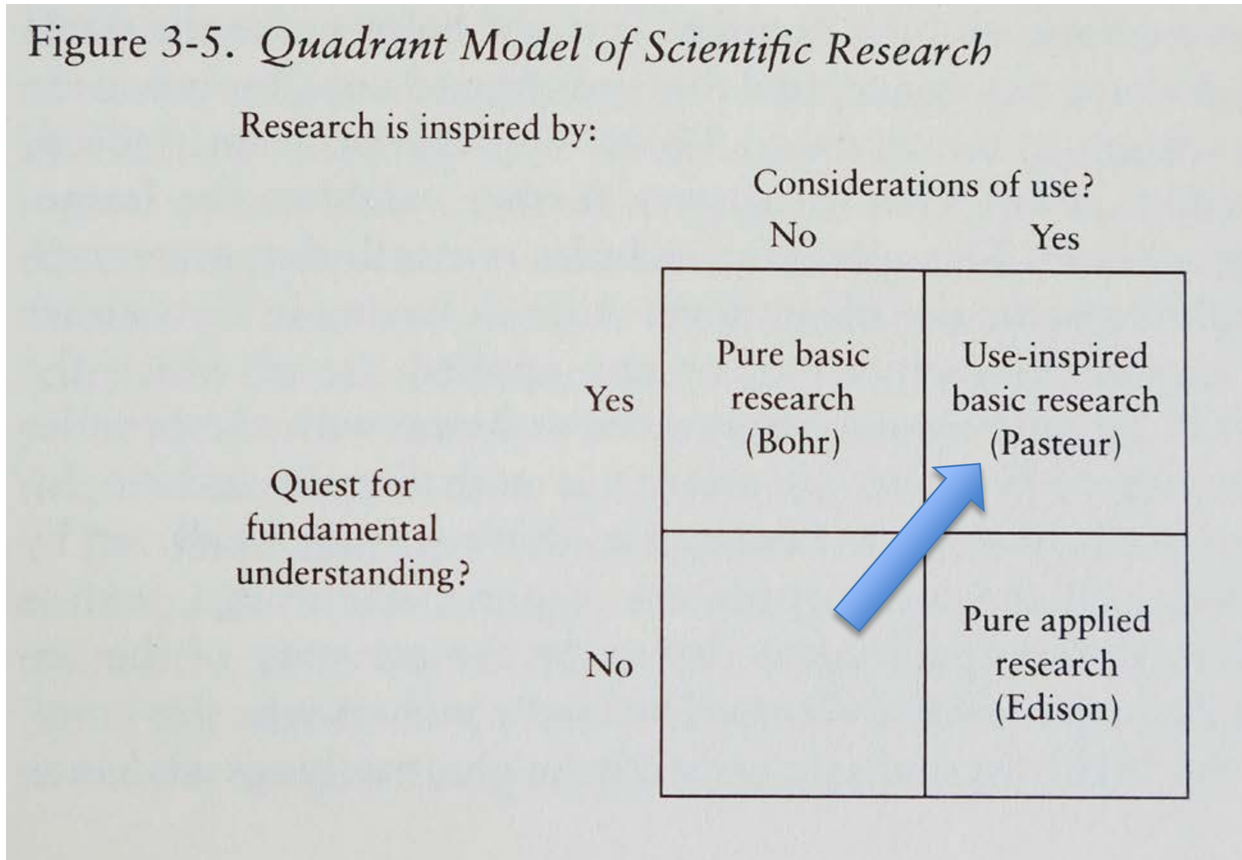
Pasteur Quadrant



Bricks vs Walls



Pasteur Quadrant



<u>MENDILLO MANDATE:</u>
Do Discovery Science
NOT
Confirmation Science

Bricks vs Walls

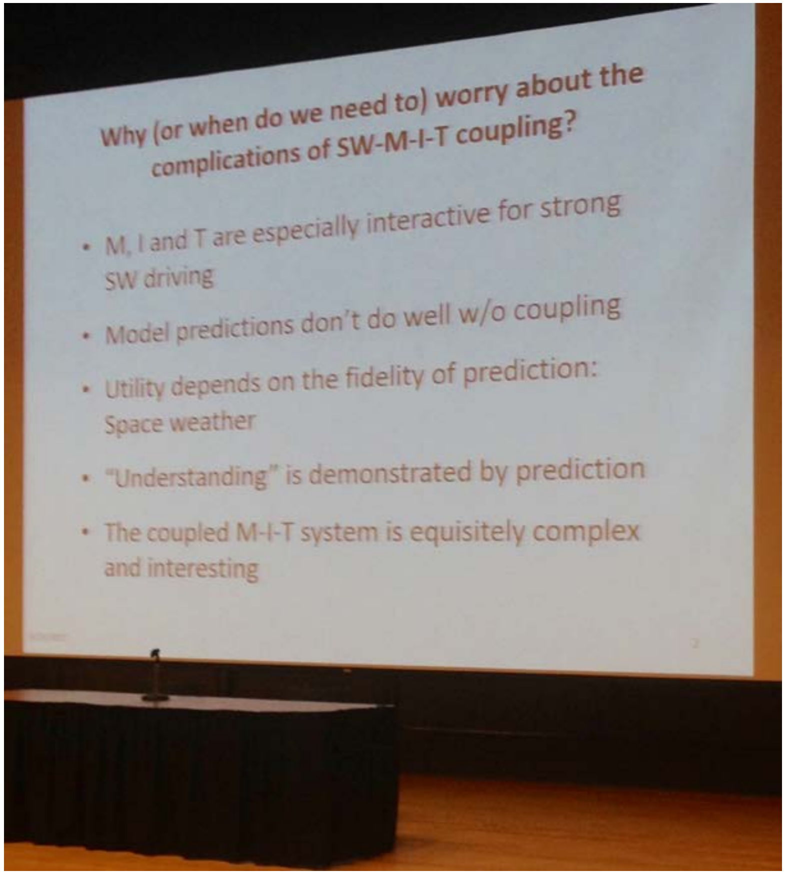
- Academic scholarship has become fixated on generating lots of pieces of knowledge—bricks—and is far less concerned with putting them together into a cohesive whole
- Academic success lies in publishing academic journal articles that make incremental contributions to theory, not in summarizing the broader contributions of the community of scholars.
- We must always try to build the wall from the large and growing body of research in the physical sciences on a host of issues

"Isolated Scholars: Making Bricks, Not Shaping Policy", *The Chronicle of Higher Education*, Feb 2015, A. Hoffman

An Example

Bill Lotko's first tutorial slide from June 23, 2015

<u>Lotko Lemma:</u>
Begin with Why



We must continue to strive to:

- Pursue the most interesting research with real impact
- Push the envelope experimentally
- Collaborate outside of traditional geospace boundaries
- Publish in Science and Nature
- Attract the best students

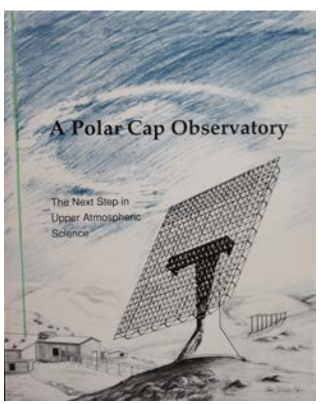
-- From Dave Hysell

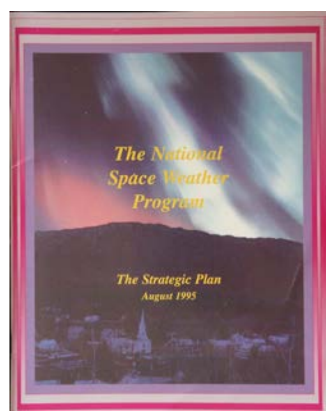
Truly bold new idea from this meeting

- CME radar -- 50 Mhz radar to measure
  - Outer Ionosphere
  - Magnetospheric plasma
  - Solar wind/CMEs
- Extremely high on both DIscovery and Utility axis
- Low operation and maintenance cost
- Could muster broad support from geospace scientists and others
- Other bold ideas:
  - HAARP
  - Oasis
  - DASI
- Budgets wont always be bad,
  need to be ready when the pendulum
  swings back

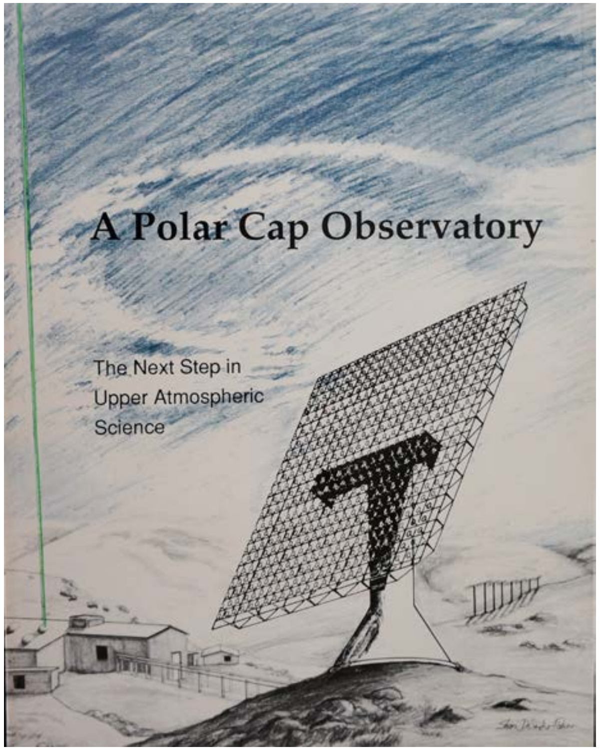
Some personal memories

- Beginnings of AMISR
- Beginnings of Space Weather
- Beginnings of Cubesats





The Polar Cap Observatory (PCO)



- Well defined Science Plan
- Broad community support

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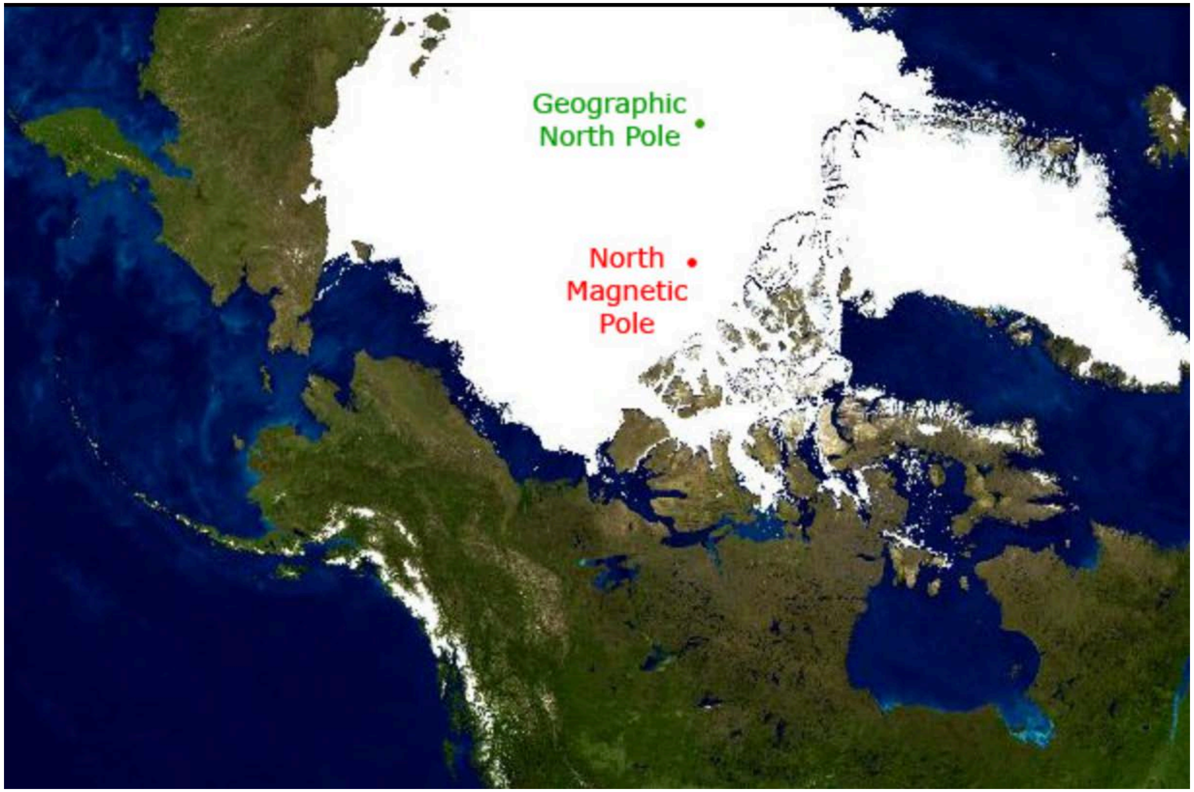
Poles apart



Resolute Bay, Nunavit

Closest settlement to the magnetic pole
(population around 220)
Jet airport -- hub for the Canadian high Arctic
Port (open for usually 1 ship per year)

The Appropriations Committee

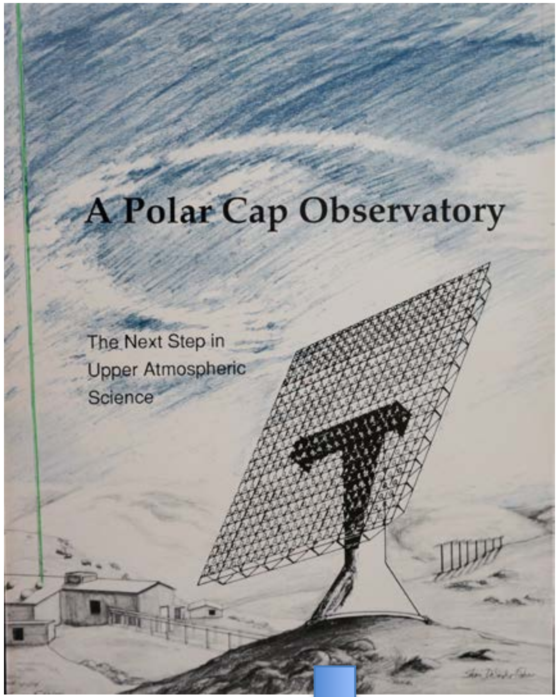
1992 -- Sen. Stevens of Alaska (chair) removes PCO from NSF budget, but allows funds to be kept if built in Alaska.

WHY??

Salmon Fishing

How do we put the PCO in Alaska AND near the magnetic pole?

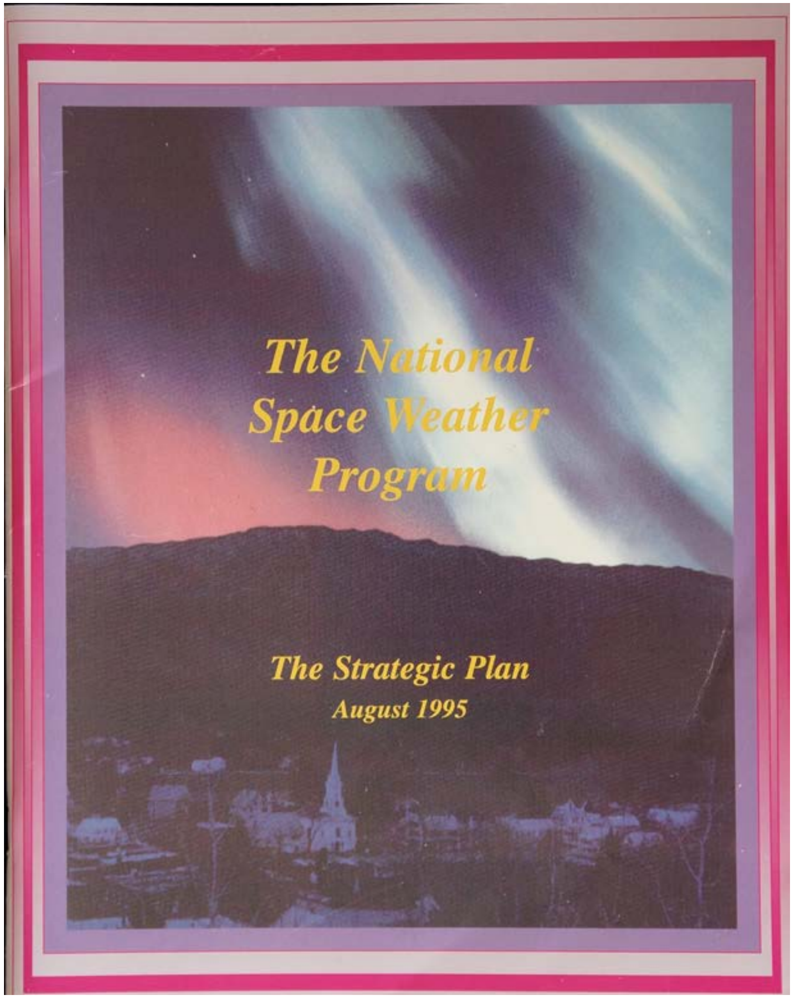
- Hard to move the magnetic pole.
- Hard to move Alaska
- Not so hard to move the radar
- Hmmm….
- MAKE IT EASY TO MOVE
  - First Alaska
  - Then Resolute
- BETTER YET MAKE TWO!



PCO to AMISR

(Never give up)

Spaceweather



1995 -- Visit from community

- George Siscoe, Ernie Hildner, Tim Killeen, Bill Lotko and Lou Lanzerotti visit NSF
  - Idea to treat Sun to Earth as a system
  - Make predictions of solar storm impacts on Earth
- Also make presentation to NASA, but little interest
- NSF very interested
  - Workshop to develop idea further held
- How do you make it a “National” program
  - Just put “National” in the name.

“What should we call this thing?”

- Solar storms, solar wind, magnetic storms… I guess you could call it:
  - Space weather
  - “isn’t that an oxymoron”
- Maybe, but ….

> ***“Space weather”*** refers to conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. Adverse conditions in the space environment can cause disruption of satellite operations, communications, navigation, and electric power distribution grids, leading to a variety of socioeconomic losses.

Why is spaceweather so successful?

- A perfect example of the science in the Pasteur Quadrant.

The National Space Weather Program Goals

To advance

- observing capabilities
- fundamental understanding of processes
- numerical modeling
- data processing and analysis
- transition of research into operational techniques and algorithms
- forecasting accuracy and reliability
- space weather products and services
- education on space weather

To prevent or mitigate

- under- or over-design of technical systems
- regional blackouts of power utilities
- early demise of multi-million dollar satellites
- disruption of communications via satellite, HF, and VHF radio
- disruption of long-line telecommunications
- errors in navigation systems
- excessive radiation doses dangerous to human health

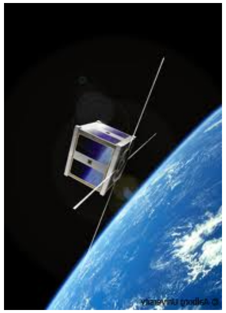
"While it is true that important applications will result from the National Space Weather Program, the science that will be accomplished will be first rate.... Indeed, the initiative provides a context in which much of solar-terrestrial physics can and should be done."

--Louis Lanzerotti
A. T. & T. Bell Laboratories

Spaceweather

- In 1994, NO NSF abstracts contained the term "spaceweather".
- In 2014, over 60% of ALL geospace award abstracts or project descriptions contained the term "spaceweather".

Cubesats



- Exploratory Workshop held in 2007
  - Gen. Pete Worden (NASA Ames) gives keynote
  - Attended by about 100 scientists
- Excess launch capability noted
- There was a protocol (cubesat) that already existed for secondary launches

Cubesats – What if….?

- Considering
  - Almost free launches
  - More and more computing and sensor ability being packed into small spaces
- What if real engineering and scientific talent tried to see what could be packed into these tiny satellites?
  - Low cost
  - High risk
  - Broad student participation
- Change of mindset!

Cubesats

"Do you think the makers of Ferraris are worried about the makers of Matchbox toys" -- Deputy NASA Administrator

Cubesats

- Science
  - advancing research in many areas
  - spurring innovation, creativity and technology development
  - Allowing space missions within the scope of traditional NSF grants
  - enhancing university participation in space activities
- Education and Workforce
  - Inspiring and training the next generation of scientists and engineers in space
  - Creating new excitement for science & engineering

Cubesats

- First competition 2008.
  - 27 proposals
  - 2 awards
- Presently NSF has 7 in orbit
  - Nationally, there are 250 US cubesats in orbit!
- It is predicted that by 2025, more than 2000 cubesats will be in orbit

A few words on Management

- It is all about trust.
  - Every member of the team must trust every other
  - Keep in mind that just because you are the leader doesn't mean you are the smartest person in the room

Passion

- A: Hard work, long hours doing something you love is called passion.
- B: Hard, work, long hours doing something you don’t really care about is called stress.
- Choose A

Remember to have fun along the way!

NSF Christmas Party 2012

Thanks

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  - MAG: Bob Clauer, Kile Baker, Ray Walker, Janet Kozyra
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  - SWx: Therese Moretto
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