

Jeffrey R. Key

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Short CV at <http://bit.ly/2SAtnII>; Summary of career accomplishments at <http://bit.ly/323kZri>

Develops innovative methods to observe the polar regions from space, performs research to increase our knowledge of polar climates, and fosters the expansion of polar observations internationally.

PROFESSIONAL POSITIONS

Current Positions

Supervisory Physical Scientist, National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service (NESDIS), Center for Satellite Applications and Research (STAR), Madison, WI, 01/26/2003-present. Perform satellite meteorology and climatology research focusing on the polar regions. Lead snow, ice, and polar wind research and product development for multiple satellite systems. Support 5-7 university scientists and manage multiple projects with funding ~\$1.5M/year. Grade: ZP-5/5.

Branch Chief, Program Management Branch, Satellite Oceanography and Climatology Division, Madison, WI, 09/2023-present. Manage a four-member NOAA team involved managing funding for major satellite programs.

Adjunct Professor, Department of Atmospheric and Oceanic Sciences, University of Wisconsin-Madison, 2007-present. Adjunct Associate Professor, 1999-2006.

Past Positions

Branch Chief, Advanced Satellite Products Branch, NOAA/NESDIS/STAR, Madison, WI, 01/2003-08/2023. Manage a seven-member NOAA team involved in algorithm development, the specification of future satellite systems, calibration, and the use of satellite products in weather prediction systems. Oversee funding to the Cooperative Institute for Meteorological Satellite Studies (CIMSS) on the order of \$11M/year.

Acting Division Chief, Cooperative Research Program (CoRP) division, Center for Satellite Applications and Research (STAR), NOAA/NESDIS, Madison, WI, 01-06/2023 and 02/2018-10/2019 (2.1 yrs total). Supervise STAR federal employees in three branches stationed at cooperative institutes (CI) in Wisconsin, Colorado, and Maryland. Oversee processing of more than 130 grants per year for ~\$50M. Work with the NOAA Research Council Cooperative Institute Committee on CI matters, including three successful CI competitions and CI 5-yr reviews.

Physical Scientist, National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Madison, WI, 08/30/1999-01/25/2003. Perform satellite meteorology research with applications in numerical weather prediction. **Acting Team Leader**, Advanced Satellite Products Team, 04/2001-01/2003.

Associate Professor, Department of Geography, Boston University, 09/01/1995-08/31/1999. Awarded tenure 02/1998. Taught courses in meteorology, climatology, and remote sensing; conducted research in climatology and satellite remote sensing. **Director of Graduate Studies**, 1996-1998.

Research Associate, Cooperative Institute for Research in Environmental Sciences (CIRES), 1989-1995, University of Colorado, Boulder. Performed climatology research, with an emphasis on remote

sensing of the polar radiation budget. Supervised and supported 2-4 research assistants and graduate students/yr. **Assistant Professor Attendant Rank**, Department of Geography, 1994-1995; **Fellow**, Program in Atmospheric and Oceanic Sciences (PAOS), 1994-1995; **Lecturer**, Astrophysical, Planetary and Atmospheric Sciences Department, 1990-1995 (taught courses in meteorology).

Instructor, Department of Mathematical Sciences, University of Alaska, Anchorage, 08/19/1984-05/19/1987. Taught courses in applied statistics and computer science.

Other: Research Associate, CIRES, U. Colorado-Boulder (CU), 1989-1995; **Assistant Professor Attendant Rank**, Dept. of Geography, CU, 1994-1995; **Lecturer**, Astrophysical, Planetary and Atmospheric Sciences Dept., CU, 1990-1995; **Research Assistant** (1983-1984, 1987-1988), CIRES, University of Colorado; **Graduate Part-time Instructor; Teaching Assistant** (1982-1984), Dept. of Geography, University of Colorado; (1981-1982), Dept of Geography, Northern Michigan University.

EDUCATION

Ph.D., University of Colorado, Boulder, Dept. of Geography (Climatology), 1988.

Thesis: "Cloud analysis in the Arctic from combined AVHRR and SMMR data"

M.A., Northern Michigan University, Marquette, Dept. of Geography (Resource Analysis), 1982.

Thesis: "SHORELINE: a model for the prediction of shoreline changes"

B.S., Northern Michigan University, Marquette, Dept. of Geography (Environmental Conservation), 1979. Summa Cum Laude. Academic scholarships all years. National Dean's List.

Other: Wayne State University, Detroit, MI, Dept. of Music (performance major, classical guitar, 1971-1975). Academic scholarships all years.

AWARDS

NOAA Silver Sherman Award, 2022, "For countless hours of selfless service in multiple leadership roles and in many international groups and committees."

NOAA Distinguished Career Award, Scientific Achievement, 2021, "For extraordinary contributions to the field of satellite remote sensing of the polar regions."

U.S. Department of Commerce Bronze Medal, 2019, "For developing the operational GCOM-W1 AMSR2 products system" (with 9 others).

NASA Agency Honor Awards, Group Achievement Award to the GOES-R Team, 2017, "For outstanding achievement in the successful GOES-R satellite launch, providing the nation's foundation for the world's highest quality weather monitoring and forecasting" (with many others).

U.S. Department of Commerce Bronze Medal, 2014, "For the timely creation and leadership of the team to increase the scientific value of the Suomi satellite environmental data products to meet NOAA users' needs" (with 12 others).

NASA Group Achievement Award to the Suomi NPP Mission Development Team, 2012, "For extraordinary dedication, skill, teamwork, and perserverance in developing and delivering the Suomi NPP Mission for the Nation" (with many others).

NOAA Administrator's Award, 2009, "For scientific leadership and excellence in support of domestic and international polar observing activities during the International Polar Year" (with P. Clemente-Colón).

U.S. Department of Commerce Bronze Medal, 2008, "For innovative uses of operational weather satellites to understand climate change and to quantify trends in the global climate system" (with A. Heidinger, R. Ferraro, T. Smith, M. Eakin, and K. Gallo).

U.S. Department of Commerce Silver Medal for Scientific and Engineering Achievement, 2005, “For improving global weather forecasts through better utilization of satellite observations over the polar regions” (with J. Daniels).

Other (minor) recognition: Special Act or Service Award for acting division chief detail, 2019; DOC Gold Medal Organizational Award to NESDIS (agency, not individual) for the success of the NOAA-20 and GOES-17 missions, 2018; JPSS Program Office Certificate of Recognition for contributing to key milestones, 2013; JPSS Program Office Certificate of Recognition for contributing to the successful launch and commissioning of S-NPP, 2012; NOAA/NESDIS Certificate of Achievement for property management, 2013; NOAA cash award for outstanding leadership in planning the first Global Cryosphere Watch (GCW) Implementation Meeting at WMO headquarters in Geneva, 2012; WMO Certificate of Appreciation for valuable contributions to the International Polar Year, 2009; NOAA cash award for a successful GOES-R Algorithm Working Group Cryosphere Team critical design review, 2009; NOAA cash award for leading the Integrated Global Observing Strategy (IGOS) Cryosphere Theme, 2007.

PROFESSIONAL ACTIVITIES

Advisory Groups and Committees

Current

World Meteorological Organization (WMO) Infrastructure Commission's Standing Committee on Earth Observing Systems and Monitoring Networks (SC-ON), member, 2020-present.

WMO Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (EC-PHORS), U.S. representative (one of three), member of Management Group, GCW task lead, 2009-present.

WMO Global Cryosphere Watch (GCW), co-lead on implementation, 2008-2011; Science Advisor, 2014-2016; representative to EC-PHORS, 2008-present; lead/co-lead on multiple teams, 2008-present. (<http://globalcryospherewatch.org>)

Canada's Arctic Observing Mission (AOM) International Expert Team, 2019-present.

NOAA: NOAA Research Council's Cooperative Institute Committee (2018-present); Arctic Core Team/Arctic Task Force/NESDIS Arctic Team (2010-present); Interagency Arctic Research Policy Committee (IARPC) Sea Ice Collaboration Team; STAR Cryosphere Science Team lead (2018-present); GOES-R AWG Cryosphere Algorithm Team lead (2006-2021; co-lead thereafter); JPSS Cryosphere Algorithm Team lead (2010-2021; co-lead thereafter); GCOM-W1 Cryosphere Algorithm Team lead (2011-present).

University of Wisconsin: Cooperative Institute for Meteorological Satellite Studies (U. Wisconsin) Board of Directors, 2001-present; SSEC Advisory Council (2018-present).

Past

WMO Polar Space Task Group (formerly the International Polar Year STG), NOAA representative, 2007-2019; Vice Chair, 2011-2019.

NOAA: NOAA-Canada Polar Communications and Weather mission Coordination Group (2010~2013); International Affairs Council Polar Committee (2006~2014); GIMPAP Technical Advisory Committee (2008~2013).

Polar Communications and Weather (PCW) Mission User and Science Team, 2009~2013.

Inter-Commission Coordination Group for WMO Integrated Global Observing System (ICG-WIGOS) Task Team on WIGOS Regulatory Material, 2012-2013.

WCRP Observations and Assimilation Panel (WOAP; CliC representative), 2004-2011.

Associate Editor (radiation), *Journal of the Atmospheric Sciences*, 2004~2011.
Space Science and Engineering Center (U. Wisconsin) Science Council, 2001-2013.
Arctic Council's Snow, Water, Ice, and Permafrost of the Arctic (SWIPA) Integration Team, 2009-2011.
Chair, Observation Products Panel, WCRP Climate and Cryosphere (CliC) project, 2004-2011.
Chair, Integrated Global Observing Strategy (IGOS) Cryosphere Theme, 2004-2009.
Polar DAAC Advisory Group (PoDAG), 2001-2008.
NOAA: Tiksi Atmospheric Observatory Science Team (2008-2015); NOAA SEARCH science team; GOES-R Technical Advisory Committee (2007-2008).
Member, MODIS Science Team (NASA EOS), (2004-2007; Adjunct Member 1992-2003).
Advisory committee for MODIS Snow and Ice products, 1996-2004.
AMS Committee on Polar Meteorology & Oceanography, 1998-2001.
DOE ARM North Slope of Alaska CART Site Advisory Panel, 1994-1998.
NASA EOS Cryospheric Working Group, 1997-1999.
RADARSAT Geophysical Processing System Science Working Group, 1994-1996.
ATSR (ERS-1 Along Track Scanning Radiometer) Validation Team, 1992-1994.

Memberships

American Meteorological Society (AMS), 1984-present
American Geophysical Union (AGU), 1988-present
International Association of Cryospheric Sciences (IACS), 2017-present

Other

Scientific Program Committee for the 2019 Joint AMS, EUMETSAT, NOAA Satellite Conference, Boston, MA
Co-organized major WMO Global Cryosphere Watch meetings in Arusha, Tanzania (2017), Salekhard, Russia (2016), Santiago, Chile (2014), Beijing (2014), and Geneva (2010).
Co-organized the US-Canada Group on Earth Observations (GEO) workshop, Arlington, VA, October 2008.
Co-organized IGOS Cryosphere Theme Workshops in Kananaskis, Alberta (2005), Noordwijk, The Netherlands (2006), and Yokohama, Japan (2006).
Co-organized the NOAA Cooperative Research Program Annual Science Symposium on Calibration and Validation, Madison, WI, July 2005.
Conference program committees: AMS September 2019, AMS January 1999, AAG Spring 1998.

RESEARCH

Interests

Satellite remote sensing of polar clouds, winds, snow, and ice; polar climate; surface radiation budget.

Grants

Summary: PI, Co-PI, or Co-I on 77 grants totaling \$42M (\$23M as PI) since 1991.

(In the listing below, UWisc is University of Wisconsin-Madison, BU is Boston University, CU is University of Colorado-Boulder, UWash is University of Washington, UMD is University of Maryland-College Park, GMAO is the NASA Global Modeling and Assimilation Office)

Current

1. Sea Ice Dynamics Research, NOAA/NESDIS/STAR with UWisc, PI, \$277.2K, 2023-2024.
2. Blended Sea Ice Motion and Dynamics, NOAA/NESDIS (Innovation) with UWisc, PI, \$340K, 2023-2024.
3. Generating Cryosphere and Polar Winds Products for the EUMETSAT EPS-SG, PI, \$2.6M, NOAA/NESDIS with UWisc, 2019-2024.
4. JPSS VIIRS Derived Winds Validation and Science, JPSS Program Office, PI until 2022, Co-PI thereafter, \$1.25M, NOAA/NESDIS with UWisc, 2016-2024.
5. Snow and Ice Products from GOES-R ABI, GOES-R Program Office, PI until 2022, Co-PI thereafter, \$5.95M, NOAA/NESDIS and UWisc (with NWS/NOHRSC, UMD, and CUNY), 2007-2024.
6. Science and Management Support for NPP VIIRS Snow and Ice EDRs, JPSS Program Office, PI until 2022, Co-PI thereafter, \$6.11M, NOAA/NESDIS (with UWisc, CU, and CUNY/CREST), 2011-2024.
7. Implementation of GCOM-W1 AMSR2 Cryosphere Products, JPSS Program Office, PI, \$2.45M, NOAA/NESDIS (with UWisc, CU, and UMD/CICS), 2012-2024.
8. Transition of Polar AVHRR Fundamental and Thematic Climate Data Records to NCEI, NOAA/NCEI, PI/Co-I, \$541.5K, NESDIS and UWisc, 2013-2024.

Past

9. Utility of UAS Platforms for Satellite Validation of the NOAA Ice Products, NOAA/OMAO UAS, Co-I (PI: S. Helfrich), \$476.8K, 2020-2023.
10. NextGen Polar Pathfinder CDR: The APP/APP-x Transition to JPSS Instruments, NOAA/NCEI, Co-PI, \$309.5K, NESDIS and UWisc, 2021-2022.
11. Development and implementation of a new set of enhanced GOES-R ABI snow cover products, NASA/NOAA ROSES-2019, Co-I (PI: P. Romanov), \$480K, 2020-2023.
12. Diagnosis and Analysis of Arctic Sea-ice Leads, NASA ROSES-2017, Co-I (PI: S. Ackerman), \$420K, 2018-2022.
13. An Evaluation of VIIRS Arctic Sea Ice Products Using Long-track Airborne Survey Measurements, NOAA, Collaborator (PI: L. Connor), \$225K, 2020-2022.
14. Enterprise Snow Algorithm Evaluation, NOAA Office of Projects, Planning, and Analysis (PSDI), PI, \$185K, NOAA/NESDIS with UWisc, 2018-2020.
15. Ice Motion from VIIRS, AMSR2, and SAR –Development and Operational Applications, JPSS Proving Ground and Risk Reduction, Co-I, \$400K, NOAA/NESDIS with UWisc, 2018-2020.
16. Development and Impact of Global Winds from Tandem S-NPP and NOAA-20 VIIRS, JPSS Proving Ground and Risk Reduction, PI, \$250K, NOAA/NESDIS with UWisc, 2018-2020.
17. Establishing Routine UAS Shipboard Operations for Satellite Validation of the Ocean-Ice Interface, NOAA/OMAO UAS, Co-I (PI: S. Helfrich), \$28.5K, 2019.
18. Polar Winds from Metop-C, NOAA Office of Projects, Planning, and Analysis (PSDI), PI, \$81K, NOAA/NESDIS with UWisc, 2018-2019.
19. NOAT Top-5 Ice Product Checkout, NOAA Office of Projects, Planning, and Analysis (PSDI), PI, \$50K, NOAA/NESDIS with UWisc, 2018.
20. Updates for JPSS-1 VIIRS Derived Motion Winds, NOAA Office of Projects, Planning, and Analysis (PSDI), PI, \$100K, NOAA/NESDIS with UWisc, 2016-2017.
21. An Algorithm to Determine the Spatial and Temporal Distributions of Sea-ice Leads in the Arctic, NASA, Co-I (PI: S. Ackerman), \$330K, 2014-2017.

22. Development of S-NPP Cryosphere EDRs to Extend the EOS Data Record for Earth System Science, NASA, Co-I (PI: D. Hall), \$699K, 2014-2017.
23. Transition of MODIS and AVHRR Winds to GOES-R/VIIRS Algorithm, NOAA Office of Systems Development, PI, \$214K, NOAA/NESDIS and UWisc, 2014-2016.
24. Assimilation and forecast impact of high temporal resolution Leo/Geo AMVs in the high-latitude data-gap corridor, GOES-R Risk Reduction Program, Co-I (PI: B. Hoover); \$211K, UWisc and NOAA/NESDIS, 2014-2016.
25. Implementing the GOES-R Future Capability Ice Products into the GOES-R Processing System, GOES-R Program Office, PI, \$342K, NOAA/NESDIS and UWisc, 2015-2016.
26. Collaborative Research: Impact of Storm Activity on Recent Changes in Arctic Sea Ice Mass Balance, NSF, Co-PI (PI: X. Zhang, U. Alaska-Fairbanks; UWisc PI: X. Wang), \$306K (UWisc), 2010-2015.
27. Cryosphere Products from Himawari-8 for the High-Latitude Proving Ground, GOES-R Program Office, PI, \$30K, NOAA/NESDIS and UWisc, 2014-2015.
28. JPSS Risk Reduction: Uniform Multi-Sensor Algorithms for Consistent Products, NOAA Office of Systems Development, Co-PI (PI: W. Wolf), \$346K, NESDIS and UWisc, 2012-2014.
29. Development, Generation, and Demonstration of New JPSS Ice Products in Support of a National Ice Center JPSS Proving Ground and Risk Reduction Activity, JPSS Program Office, Co-I (PI: Y. Liu, UWisc), \$152K, NESDIS and UWisc, 2013-2014.
30. VIIRS Polar Winds, NOAA Office of Systems Development, PI, \$366K, NOAA/NESDIS and UWisc, 2009-2014.
31. Sea Ice Thickness from Aqua and Terra Data: Generation, Evaluation and Application, NASA, Co-I (PI: J. Maslanik, CU), \$754K, NESDIS and UWisc, 2011-2013.
32. A Blended Polar Winds Product using Atmospheric Motion Vectors from MODIS Imager and AIRS Moisture Retrieval Data, NASA, Co-I (PI: D. Santek, UWisc), \$229K, 2011-2012.
33. Combined Geo/Leo High Latitude Atmospheric Motion Vectors, NOAA, Co-I (PI: M. Lazzara, UWisc), \$140K, UWisc, 2009-2011.
34. A Product Development Team for Snow and Ice Climate Data Records, NOAA (NCDC), PI, \$957K, NOAA/NESDIS and UWisc (\$325K), UColorado, 2009-2012.
35. Sea Ice Thickness from Aqua and Terra Data: Generation, Evaluation and Application, NASA, Co-I (PI: J. Maslanik, CU), \$754K, NESDIS and UWisc (\$292K), 2011-2013.
36. NPP Science Team Participation in Support of Cryosphere Products, NASA, Co-I (PI: M. Tschudi, CU), \$355K, NESDIS and UWisc (\$140K), 2011-2013.
37. Generation and Initial Evaluation of a 27-Year Satellite-Derived Wind Data Set for the Polar Regions, NASA, Co-I (PI: D. Santek), \$210K, UWisc, 2009-2011.
38. NPP/NPOESS Cryospheric Products Calibration and Validation Activities, NPOESS Integrated Program Office, PI, \$500K, NOAA/NESDIS and UWisc (with UColorado), 2008-2009.
39. Cloud-drift and Water Vapor Winds in the Polar Regions from Polar-orbiting Imagers, NOAA Office of Systems Development, PI (NOAA; PI at CIMSS: C. Velden), \$1.17M, NOAA/NESDIS and UWisc, 2001-2009.
40. Improving ice thickness and age estimate with GOES-R ABI, NOAA GOES-R Program Office, Co-I, \$80K, UWisc, 2008-2009.
41. Assessment of Satellite-derived Cloud Motion Vectors height assignments utilizing active remote sensing measurements from CALIPSO, Joint Center for Satellite Data Assimilation (NOAA), Co-I, \$50K, UWisc, 2007-2008.

42. Satellite Products for the International Polar Year, NESDIS, PI, \$120K, NOAA/NESDIS and UWisc, 2008.
43. Generating and Validating NPOESS Products at Direct Broadcast Sites in the Arctic and Antarctic, Integrated Program Office, PI, \$403K, NOAA/NESDIS and UWisc, 2004-2008.
44. A Land Surface Model Hind-Cast for the Terrestrial Arctic Drainage System, NSF, Co-PI (PI: M. Serreze, CU, Co-PIs: M. Clark, CU, A. Slater, CU, D. Lettenmaier, UWash), \$199K, UWisc, 2003-2007.
45. Polar Winds from Satellite Imagers and Sounders, NASA, PI, \$979K, NOAA/NESDIS, UWisc, Rutgers Univ., NASA GMAO, 2004-2007.
46. Development and Application of a 20-Year Satellite-Derived Wind Data Set for the Polar Regions, NOAA/NESDIS/ORA, PI, \$60K, NOAA/NESDIS, UWisc, 2003 and 2006.
47. Retrospective Analysis of Arctic Clouds and Radiation from Surface and Satellite Measurements, NOAA Arctic Research Office, PI, \$176K, NOAA/NESDIS and UWisc, 2003-2006.
48. Interactions Among Observations of Laterally Advected Heat and Moisture, Cloud Properties, Surface Temperature, Surface Radiation Fluxes, and Net Precipitation in the Arctic, NSF, Co-PI (PI: J. Francis, Rutgers Univ.; Co-PI: S. Ackerman), \$170K, UWisc, 2003-2006.
49. Polar winds data assimilation experiments, NOAA/NASA Joint Center for Satellite Data Assimilation, PI (Co-PI: C. Velden), \$172K, NOAA/NESDIS, UWisc, and NASA Data Assimilation Office, 2003-2005.
50. VIIRS Snow and Ice Product Risk Reduction, Integrated Program Office, PI (Co-PI: P. Romanov, CIRA), \$130K, NOAA/NESDIS and UWisc, 2003-2004.
51. VIIRS Risk Reduction Activities, Integrated Program Office, Co-PI (NOAA; NOAA PI: W.P. Menzel, Co-PI: A. Heidinger; CIMSS PI: S. Ackerman), \$477K, NOAA/NESDIS and UWisc, 2001-2002.
52. Interactions of Laterally Advected Heat and Moisture with Arctic Cloud Properties, NOAA, Co-PI (PI: J. Francis, Rutgers Univ.; Co-PI: S. Ackerman), \$77K, UWisc, 2001-2003.
53. Cloud-Drift Winds in the Polar Regions from MODIS, NOAA/GIMPAP, Co-I and Program Manager (PI: C. Velden), \$40K, UWisc/NOAA, 2000-2001.
54. Development and Summary of Arctic Basin-Scale to Local-Scale Gridded Products in Support of Modeling Investigations During the SHEBA Period, NSF, Co-I (PI: J. Maslanik, CU, Co-Is: C. Fowler, A. Lynch, T. Arbetter), \$430K, CU, 2000-2003.
55. Antarctic Cloud Properties and Their Effect on the Surface Energy Budget, NSF, PI, \$225K, BU, UWisc, 1999-2001.
56. NPOESS Algorithm Development, AER and ITT, Co-PI (PI: C. Schaaf, Co-PIs: A. Strahler, C. Woodcock, M. Friedl), \$609K, BU, 1998-2000.
57. Center for Excellence in Remote Sensing at Boston University, NASA, Co-I (PI: C. Woodcock, Co-Is: El-Baz, Cleveland, Friedl, Gopal, Kaufmann, Dye, Myneni, Salvucci, Strahler), \$444K, BU, 1998-1999.
58. AVHRR-Based Polar Pathfinder Products - Evaluation, Enhancement, and Transition to MODIS, NASA, Co-I, (PI: C. Fowler; Co-PI: J. Maslanik), \$293K, CU, 1998-2000.
59. Documenting, Understanding, and Predicting the Aggregate Surface Radiation Fluxes for SHEBA, NASA and NSF. PI at BU (PI: J. Curry, Co-PIs: F. Evans, J. Maslanik, K. Steffen), \$800K, CU, BU, 1997-2000.
60. Polar Exchange at the Sea Surface (Poles), NASA EOS Interdisciplinary Program, PI at BU (PI at UWash: D. Rothrock), \$1.7M, UWash, BU, 1991-2000.

61. Polar-wide Geophysical Products Derived from AVHRR Data, NASA, PI at BU (PI at CU: J. Maslanik, Co-PIs: T. Scambos, C. Fowler), \$700K, CU, BU, 1995-1998.
62. Sea Ice and Atmospheric Characteristics of the SHEBA Field Area, NSF, PI at BU (PI at CU: M. Serreze, Co-PI: J. Maslanik), \$89K, CU, BU, 1995-1996.
63. Analysis of Existing Aircraft Datasets of Arctic Clouds, Radiation, and Surface Characteristics: Applications to SHEBA Planning, NSF, Co-PI (PI: J. Curry, CoPIs: G. Liu, J. Tilley, J. Maslanik), \$340K, CU, 1995-1997.
64. Arctic System Science Data Coordination Center at NSIDC, NSF, Co-PI (PI: C. Hanson, Co-PIs: R. Barry, R. Armstrong), \$490K, CU, 1995-1998.
65. The Arctic Radiation Balance, NSF, PI (Co-PIs: M. Serreze, R. Stone, R. Barry, K. Steffen), \$350K, CU, BU, 1994-1997.
66. RADNET: A Neural Network-based Estimation of the Surface Radiation Budget in the Arctic from TOVS and AVHRR Data, NASA, Co-PI (PI: A. Schweiger), \$90K, CU, BU, 1994-1995.
67. Evolution of Sea Ice Characteristics, Cloud Properties and Radiation Fluxes During the Autumnal Freezing of the Beaufort Sea Coastal Waters, NSF, Co-PI (PI: J. Curry, Co-PI: G. Liu), \$342K, CU, 1994-1995.
68. Ice Surface Temperature Retrieval from AVHRR, ATSR, and Passive Microwave Satellite Data: Algorithm Development and Application, NASA, PI (Co-PIs: J. Maslanik, K. Steffen), \$237K, CU, BU, 1993-1996.
69. Assessment of Climate Variability of the Greenland Ice Sheet: Integration of In Situ and Satellite Data, NASA, Co-PI (PI: K. Steffen), \$479K, CU, 1993-1996.
70. Modeled and Observed Sea Ice Variability in the Arctic: Sensitivity to Atmospheric Conditions and the Surface Energy Budget, NASA, Co-PI (PI: J. Maslanik), \$151K, CU, 1991-1993.
71. Characterization of Sea Ice and Clouds in the Arctic, NASDA (National Space Development Agency of Japan), Co-I (PI: J. Maslanik), data request only (no \$), CU, 1992-1993.
72. Lead Detection and Mapping with Reference to Relationships Between Scale, Sensor Characteristics, Surface Conditions, and Atmospheric Properties, ONR, PI (Co-PI: J. Maslanik), \$182K, CU, 1990-1993.
73. Sea Ice-Atmosphere Interaction: Application of Multispectral Satellite Data in Polar Surface Energy Flux Estimates, NASA, Co-PI (PI: K. Steffen, Co-PIs: J. Maslanik, R. Barry), \$358K, CU, 1990-1993.
74. Artificial Intelligence Applications for Sea Ice Classification and Processes NASA, Co-PI (PI: J. Maslanik), \$254K, CU, 1990-1993.
75. Observations in Support of Remote Sensing and Modeling of Arctic Sea Ice and Atmospheric Conditions, NSF, Co-PI (PI: M. Serreze, Co-PI: J. Maslanik), \$94K, CU, 1991-1992.
76. Development and Trend Analyses of an Arctic TOVS Temperature Sounding Record, NOAA, Co-I, PI last 6 months (PI: S. Khalsa, Co-PIs: J. Kahl, R. Schnell, M. Serreze), \$273K, CU, 1991-1993.
77. Parameterization and Scaling of Arctic Ice Conditions in the Context of Ice-Atmosphere Processes, NASA, Co-PI (PI: R. Barry, Co-PIs: K. Steffen, J. Maslanik), \$290K, CU, 1991-1994.

TEACHING

Summary: Taught 15 different courses (total of 33 sections) in remote sensing, meteorology, statistics, geography, and computer science at four universities. Research advisor for 13 PhD and Master's

students. Evaluation average, all universities, all courses: 87% (with 75%= "average").

Courses Taught

Boston University (1995-99)

Natural Environments: The Atmosphere (GG 101)

Physical Climatology (GG 504)

Remote Sensing of the Lower Atmosphere (GG 646/446)

Directed Studies: Problems in Climatology (GG 925)

University of Colorado, Boulder (1982-84, 1990-95)

Environmental Systems 1: Climate and Vegetation (GEOG 100)

Environmental Systems 2: Soils and Landforms (GEOG 101)

Atmospheric Science I: Severe Storms (APAS 115)

Dynamic Earth III (meteorology) (GEOG/APAS 319)

Remote Sensing (labs) (GEOG 409/509)

Nominated for Teaching Excellence Award, 1983.

University of Alaska, Anchorage (1984-87)

Elementary Statistics (AS 300)

Probability and Statistics (AS 307)

Intermediate Statistics (AS 308)

Fortran Programming (CS 105)

Software and Hardware Concepts (CS 201)

Programming Language Structures (CS 331)

Artificial Intelligence (CS 405)

Directed Studies: Scientific Sampling (AS 402)

Northern Michigan University (1980-82)

Physical Geography, GC 100

Map Interpretation (labs), GC 225

Cartography (labs), GC 230

Advising

Theses supervised (research or academic advisor):

Anheuser, James, 2022, Thermodynamic Versus Dynamic Sea Ice Thickness Effects in Observations and Models, *Ph.D. thesis*, University of Wisconsin-Madison (Research advisor).

Letterly, Aaron D., 2015, The Influence of Winter Cloud on Summer Sea Ice in the Arctic, 1982-2013, *M.S. thesis*, University of Wisconsin-Madison (Research advisor).

Nelson, Kyle, 2014, The Role of Optically Thin Liquid Clouds in the 2012 Greenland Ice Sheet Surface Melt Event, *M.S. thesis*, University of Wisconsin-Madison (Research advisor).

Santek, David, 2007, The Global Impact of Satellite-Derived Polar Winds on Model Forecasts, *Ph.D. thesis*, University of Wisconsin-Madison (Research advisor).

Dworak, Richard, 2007, Historical AVHRR Satellite-Derived Winds Archive (1982-2002), Validation and Comparison to the ERA-40, *M.S. thesis*, University of Wisconsin-Madison (Research advisor).

Liu, Yinghui, 2006, Possible Causes of Recent Changes in the Arctic Cloud Cover, Surface Temperature, and Temperature Inversions, *Ph.D. thesis*, University of Wisconsin-Madison

(Research advisor).

Wang, Xuanji, 2003, Arctic Climate Characteristics and Recent Trends from Space, *Ph.D. thesis*, University of Wisconsin-Madison (Research advisor).

Pavolonis, Michael J., 2002, Antarctic cloud radiative forcing at the surface estimated from the ISCCP D1 and AVHRR Polar Pathfinder data sets, 1985–1993. *M.S. thesis*, University of Wisconsin-Madison (Research advisor).

Wong, Adeline, 2000, Estimating the Cloudy Sky Surface Temperature of Sea Ice from Space, *M.A. thesis*, Boston University (Research advisor).

Chan, Alan C.K., 1998, A Global Climatology of 500 mb Cyclones, *Independent Work for Distinction (BA)*, Boston University (Advisor).

Klein, Rachael, 1997, The Whole Thing Could Be Chaos, *Boston University Academy undergraduate thesis* (1st Reader).

Silcox, Robert A., 1994, Downwelling Radiation Fluxes at the Arctic Surface Based on Parameterizations, *M.A. thesis*, University of Colorado (Research advisor).

Schweiger, Axel J., 1992, Arctic Radiative Fluxes Modeled from the ISCCP-C2 Data Set, 1983-1986, *Ph.D. dissertation*, University of Colorado (Research advisor).

Additional thesis committee membership:

Sledd, Anne, 2021, Radiative Effects of Arctic Clouds in Observations and Models, *Ph.D. thesis*, University of Wisconsin-Madison (committee member).

Cuzzone, Joshua, 2010, The Relationship between Arctic Sea Ice and Cloud-related Variables in ERA Interim Reanalysis and Climate Model Data, *M.S. thesis*, University of Wisconsin-Madison (3rd Reader).

Lazzara, Matthew A., 2008, A Diagnostic Study of Antarctic Fog, *Ph.D. thesis*, University of Wisconsin-Madison (Ad hoc committee member).

Fan, Shaohua, 1998, EIFOV as a Function of View Geometry for MODIS, *M.A. paper*, Boston University (2nd Reader).

Ali, Ali Hamid A., 1997, Statistical Analysis of Meteorological Events in the Arabian Peninsula and the Gulf Region, *Ph.D. thesis*, Boston University (5th Reader).

Box, Jason E., 1997, Polar Day Effective Cloud Opacity in the Arctic from Measured and Modeled Solar Radiation Fluxes, *M.A. thesis*, University of Colorado (2nd Reader).

Stroeve, Julianne C., 1996, Radiation Climatology of the Greenland Ice Sheet, *Ph.D. thesis*, University of Colorado (3rd Reader).

Haefliger, Marcel P.S., 1995, Radiation Balance Over the Greenland Ice Sheet Derived by NOAA AVHRR Satellite Data and In Situ Observations, *Ph.D. thesis*, Swiss Federal Institute of Technology, Zurich (3rd Reader).

FIELD WORK

Atmospheric and Cryospheric Sciences

USIR-CV EX, Arctic, Nome, Alaska, March 2023

Measurements of ice thickness, snow properties, and surface meteorology with uncrewed aircraft system imager data for UAS proof of concept and validation of satellite products. This was the Arctic component of the UAS Sea Ice Retrieval for Calibration/Validation Experiment.

USIR-CV EX, Great Lakes, Straits of Mackinac, Mackinaw City, Michigan, February 2022
Measurements of ice thickness, snow properties, and surface meteorology with uncrewed aircraft system imager data for UAS proof of concept and validation of satellite products. This was the Great Lakes component of the UAS Sea Ice Retrieval for Calibration/Validation Experiment.

GLAWEX, Green Bay, Wisconsin, February 2017
Measurements of ice thickness, snow properties, and surface meteorology on Green Bay for the validation of satellite products. Part of the Great Lakes Winter Experiment (GLAWEX). The Coast Guard icebreaker Mobile Bay also participated.

McMurdo, Antarctica, October-November 2004
Developed and implemented a system to produce real-time MODIS polar winds from direct broadcast data at McMurdo. Worked with Space and Naval Systems Center (SPAWAR) forecasters on the use of satellite data in an operational forecasting environment. Serviced automatic weather stations.

SHEBA, Beaufort Sea, July 1998
Measurements of radiation and cloud microphysical properties on-board the NCAR C-130 aircraft for process studies and remote sensing validation. Done in conjunction with the Surface Heat Budget of the Arctic Ocean (SHEBA) surface campaign.

Greenland, May-June 1995
Part of a multi-year study of the surface energy balance of the Greenland Ice Sheet, at the equilibrium snow line. Measurements of surface radiation fluxes, atmospheric temperature and humidity, aerosols, and clouds for process studies.

BASE, Beaufort Sea, September-October 1994
Measurements of radiation and cloud microphysical properties on-board the NCAR C-130 aircraft. Done in conjunction with the Canadian Beaufort and Arctic Seas Experiment (BASE).

SIMMS'93, Baffin Strait/Lancaster Sound, May 1993
Aerosol optical depth (sun photometer), cloud base height and atmospheric extinction (laser ceilometer), radiation and energy budget measurements (temperature, reflectance, snow depth, radiative fluxes, etc.) at the sea ice surface; done in conjunction with the Canadian SIMMS (The Seasonal Sea Ice Monitoring and Modeling Site) program, near Resolute, N.W.T.

SIMMS'92, Baffin Strait/Lancaster Sound/Wellington Channel, May-June 1992
Radiation and energy budget measurements (temperature, reflectance, snow depth, radiative fluxes, etc.) at the sea ice surface primarily for the validation of satellite retrieval algorithms; done in conjunction with the Canadian SIMMS (The Seasonal Sea Ice Monitoring and Modeling Site) program; near Resolute, N.W.T.

LEADEX, Beaufort Sea, April 1992
Sun photometer measurements on-board the NOAA P-3 for studies of tropospheric and stratospheric Arctic aerosols in support of LEADEX (ONR and NOAA-sponsored) and AGASP-IV (Arctic Gas and Aerosol Sampling Program).

Biological Sciences

U.S. Fish and Wildlife Service, Lake Superior and Upper Michigan, 1981, 1982 (summers)
Sea lamprey adult population studies by trapping, tagging, and radio tracking in Lake Superior and Michigan's Upper Peninsula rivers.

U.S. Fish and Wildlife Service, Upper Michigan, Wisconsin, Minnesota, 1979, 1980 (summers)

Stream survey for sea lamprey larvae assessment by electro-shocking methods; Michigan, Wisconsin, and Minnesota rivers.

MAJOR/OPERATIONAL SATELLITE PRODUCTS AND SOFTWARE TOOLS

AVHRR Polar Pathfinder (APP) and Extended APP (APP-x) – More than 40-year satellite fundamental climate data record the Arctic and Antarctic (APP), and cloud, surface, and radiation properties (APP-x). (doi:10.7289/V5BC3WHM, doi:10.7289/V5MK69W6)

Real-time polar winds – Tropospheric winds in the polar regions from MODIS, AVHRR (all NOAA POES satellites plus Metop-A/B/C), and VIIRS, tropospheric winds used by 13 operational numerical weather prediction centers in nine countries. Winds are also generated on-site at direct broadcast sites in the Arctic and Antarctic. With D. Santek, J. Daniels, and H. Qi. (Operational)

GCOM-W1 AMSR2 snow and ice products: snow cover, snow depth, snow water equivalent, sea ice concentration and type. With Y.-K. Lee, C. Kongoli, and W. Meier. (Operational)

VIIRS ice products: ice concentration, temperature, and thickness. With Y. Liu and X. Wang. (Operational)

GOES-R ABI ice and snow products: ice concentration, temperature, motion, and thickness; fractional snow cover. With Y. Liu, X. Wang, and T. Painter. (Operational)

Historical polar winds from AVHRR – A 30-year satellite climate data record for reanalysis use. With R. Dworak.

Sea ice leads: MODIS Sea ice leads detections using a U-Net (<https://doi.org/10.5061/dryad.79cnp5hz2>); VIIRS Sea ice leads detections using a U-Net (<https://doi.org/10.5061/dryad.1vhhmgqwd>), Hoffman et al., distributed by Dryad.

Streamer, a radiative transfer model (<http://stratus.ssec.wisc.edu/streamer>), for research and education.

FluxNet, a neural network for surface and top-of-atmosphere radiative fluxes (<http://stratus.ssec.wisc.edu/fluxnet>).

CASPR, the Cloud and Surface Parameter Retrieval system (no longer available).

PUBLICATIONS

Summary: Author/co-author on 134 journal papers and other peer-reviewed publications, 7 book chapters, 18 technical and data reports (some peer-reviewed), numerous workshop reports, and 88 conference proceedings papers (78) and newsletter articles (10). Metrics: h-index: 61, i10-index: 121, citations: 12K+ (Apr 2024, [Google Scholar](#)). PDFs of the papers below are available at <https://stratus.ssec.wisc.edu/jk-papers/>.

Peer-Reviewed Journal Papers

1. Bayler, E. P. Chang, J. De La Cour, S. Helfrich, A. Ignatov, J. Key, V. Lance, E. Leuliette, D. Byrne, Y. Liu, X. Liu, D. Manzello, M. Wang, J. Wei, P. DiGiacomo, 2024, Satellite Oceanography in NOAA: Research, Development, Applications and Services Enabling Societal Benefits from Operational and Experimental Missions, Remote Sensing, submitted (Feb 2024).
2. Anheuser, J., Y. Liu, and J. Key, J., 2024, Model mean state sea ice thickness reflects dynamic effect

- biases: A process based evaluation. *Geophysical Research Letters*, 51, e2023GL106963. <http://dx.doi.org/10.1029/2023GL106963>.
3. Liu, Y. and J. Key, 2023, Cold Season Cloud Response to Sea Ice Loss in the Arctic, *J. Climate*, submitted (Jul 2023).
 4. Anheuser, J., Y. Liu, and J.R. Key, 2023, A climatology of thermodynamic vs. dynamic Arctic wintertime sea ice thickness effects during the CryoSat-2 era, *The Cryosphere*, 17, 2871–2889, <https://doi.org/10.5194/tc-17-2871-2023>.
 5. Hoffman, J., S.A. Ackerman, Y. Liu, and J. Key, 2022, A 20-Year Climatology of Sea Ice Leads Detected in Infrared Satellite Imagery Using a Convolutional Neural Network, *Remote Sens.*, 4(22), 5763; <https://doi.org/10.3390/rs14225763>.
 6. Anheuser, J., Y. Liu, and J.R. Key, 2022, A simple model for daily basin-wide thermodynamic sea ice thickness growth retrieval, *The Cryosphere*, 16, 4403–4421, <https://doi.org/10.5194/tc-16-4403-2022>.
 7. Lavergne, T., S. Kern, S. Aaboe, Derby, L., G. Dybkjaer, G. Garric, P. Heil, S. Hendricks, J. Holfort, S. Howell, J. Key, J.L. Lieser, T. Maksym, W. Maslowski, W. Meier, J. Munoz-Sabater, J. Nicolas, B. Özsoy, B. Rabe, W. Rack, M. Raphael, P. de Rosnay, V. Smolyanitsky, S. Tietsche, J. Ukita, M. Vichi, P. Wagner, S. Willmes, and X. Zhao, 2022, A New Structure for the Sea Ice Essential Climate Variables of the Global Climate Observing System, *Bull. Amer. Meteor. Soc.*, E1502-E1521, <https://doi.org/10.1175/BAMS-D-21-0227.1>.
 8. Wang, X., Y. Liu, J. Key, and R. Dworak, 2022, A new perspective on four decades of changes in Arctic sea ice from satellite observations, *Remote Sens.*, 14, 1846, <https://doi.org/10.3390/rs14081846>.
 9. Hoffman, J., S. Ackerman, Y. Liu, J. Key, and I. McConnell, 2021, Application of a convolutional neural network for the detection of sea ice leads, *Remote Sens.*, 13, 4571, <https://doi.org/10.3390/rs13224571>.
 10. Dworak, R., Y. Liu, J. Key, and W. Meier, 2021, A Blended Sea Ice Concentration Product from AMSR2 and VIIRS, *Remote Sensing*, 13, 2982. <https://doi.org/10.3390/rs13152982>.
 11. Kalluri, S., C. Cao, A. Heidinger, A. Ignatov, J. Key, T. Smith, 2021, The advanced very high resolution radiometer: Contributing to Earth observations for over 40 years, *Bull. Amer. Meteorol. Soc.*, <https://doi.org/10.1175/BAMS-D-20-0088.1>.
 12. Liu, Y., J. Key, X. Wang, and M. Tschudi, 2020, Multidecadal Arctic sea ice thickness and volume derived from ice age, *The Cryosphere*, 14, 1325–1345, doi: 10.5194/tc-14-1325-2020.
 13. Kongoli, C., J. Key, and T. Smith, 2019, Mapping of snow depth by blending satellite and in-situ data using two-dimensional optimal interpolation - Application to AMSR2, *Remote Sensing*, 11, 3049, doi:10.3390/rs11243049.
 14. Hoffman, J.P., S.A. Ackerman, Y. Liu, and J. Key, 2019, The detection and characterization of Arctic sea ice leads with satellite imagers, *Remote. Sens.*, 11(5), 521, <https://doi.org/10.3390/rs11050521>.
 15. Liu, Y., R. Dworak, and J. Key, 2018, Ice Surface Temperature Retrieval from a Single Satellite Imager Band, *Remote Sens.*, 10, 1909, doi:10.3390/rs10121909.
 16. Liu, Y., J. Key, S. Vavrus, and C. Woods, 2018, Time evolution of cloud response to moisture intrusions into the Arctic during winter, *J. Climate*, 31(22), 9389–9405, doi: 10.1175/JCLI-D-17-0896.1.
 17. Letterly, A., J. Key, and Y. Liu, 2018, Arctic Climate: Changes in Sea Ice Extent Outweigh Changes in Snow Cover, *The Cryosphere*, 12, 3373–3382, <https://doi.org/10.5194/tc-12-3373-2018>.
 18. Riihelä, A., T. Manninen, J. Key, Q. Sun, M. Sütterlin, A. Lattanzio, and C. Schaaf, 2018, A

- multisensor approach to global retrievals of land surface albedo, *Remote Sens.*, 10(6), 848, <https://doi.org/10.3390/rs10060848>.
19. Manninen, T., A. Riihelä, A. Heidinger, C. Schaaf, A. Lattanzio, J. Key, 2018, Intercalibration of polar-orbiting spectral radiometers without simultaneous nadir observations, *IEEE Trans. Geosci. Remote Sens.*, 56(3), 1507-1519, doi: 10.1109/TGRS.2017.2764627.
 20. Katlein, C., S. Hendricks, and J. Key, 2017, Brief communication: Increasing shortwave absorption over the Arctic Ocean is not balanced by trends in the Antarctic, *The Cryosphere*, 11, 2111-2116, <https://doi.org/10.5194/tc-11-2111-2017>.
 21. Riihelä, A., J. R. Key, J. F. Meirink, P. Kuipers Munneke, T. Palo, and K.-G. Karlsson, 2017, An intercomparison and validation of satellite-based surface radiative energy flux estimates over the Arctic, *J. Geophys. Res. Atmos.*, 122, 4829–4848, doi:10.1002/2016JD026443.
 22. Meier, W.N., J.S. Stewart, Y. Liu, J. Key, and J. Miller, 2017, Operational implementation of sea ice concentration estimates from the AMSR2 sensor, *IEEE J. Selected Topics Appl. Earth Obs. Remote Sens.* (J-STARS), 10(9), 3904-3911, doi: 10.1109/JSTARS.2017.2693120.
 23. Dorofy, P., R. Nazari, P. Romanov, and J. Key, 2016, Development of a mid-infrared sea and lake ice index (MISI) using the GOES Imager, *Remote Sens.*, 8, 1015, doi:10.3390/rs8121015.
 24. Wang, X., J. Key, R. Kwok, and J. Zhang, 2016, Comparison of sea ice thickness from satellites, aircraft, and PIOMAS data, *Remote. Sens.*, 8, 713, doi:10.3390/rs8090713.
 25. Liu, Y. and J. Key, 2016, Assessment of Arctic cloud cover anomalies in atmospheric reanalysis products using satellite data, *J. Climate*, 29, 6065-6083, doi: <http://dx.doi.org/10.1175/JCLI-D-15-0861.1>.
 26. Liu, Y., J. Key, and R. Mahoney, 2016, Sea and Freshwater Ice Concentration from VIIRS on Suomi NPP and the Future JPSS Satellites, *Remote. Sensing*, 8(6), 523; doi:10.3390/rs8060523.
 27. Letterly, A., J. Key, and Y. Liu (2016), The influence of winter cloud on summer sea ice in the Arctic, 1983–2013, *J. Geophys. Res. Atmos.*, 121, doi:10.1002/2015JD024316.
 28. Key, J., X. Wang, Y. Liu, R. Dworak, A. Letterly, 2016, The AVHRR Polar Pathfinder Climate Data Records, *Remote Sens.*, 8(3), 167, doi:10.3390/rs8030167.
 29. Lee, K.-L., C. Kongoli, and J. Key, 2015, An in-depth evaluation of heritage algorithms for snow cover and snow depth using AMSR-E and AMSR2 measurements, *J. Atmos. Oceanic Tech.*, 32, 2319-2336, doi: 10.1175/JTECH-D-15-0100.1.
 30. Liu, Y., J. Key, M. Tschudi, R. Dworak, R. Mahoney, and D. Baldwin, 2015, Validation of the Suomi NPP VIIRS Ice Surface Temperature Environmental Data Record, *Remote Sens.*, 7, 17258–17271, doi:10.3390/rs71215880.
 31. Key, J., B. Goodison, W. Schöner, Ø. Godøy, M. Ondráš, and Á. Snorrason, 2015, A Global Cryosphere Watch, *Arctic*, 68 (Suppl. 1), 48-58, doi: <http://dx.doi.org/10.14430/arctic4476>.
 32. Meier, W., G. Hovelsrud, B. van Oort, J. Key, K. Kovacs, C. Michel, C. Haas, M. Granskog, S. Gerland, D. Perovich, A. Makshtas, and J. Reist, 2014, Arctic sea ice in transformation: A review of recent observed changes and impacts on biology and human activity, *Rev. Geophys.*, 51, doi: 10.1002/2013RG000431.
 33. Overland, J., J. Key, E. Hanna, I. Hanssen-Bauer, B.-M. Kim, S.-J. Kim, J. Walsh, M. Wang, U. Bhatt, Y. Liu, R. Stone, C. Cox, V. Walden, 2014, The Lower Atmosphere: Air Temperature, Clouds and Surface Radiation [in “State of the Climate in 2013”], *Bull. Amer. Meteor. Soc.*, 95(7), S115-S120, doi: <http://dx.doi.org/10.1175/2014BAMSStateoftheClimate.1>.
 34. Liu, Y. and J. Key, 2014, Less Winter Cloud Aids Summer 2013 Arctic Sea Ice Return from 2012 Minimum, *Environ. Res. Lett.* 9 044002, doi:10.1088/1748-9326/9/4/044002.

35. Lazzara, M., R. Dworak, D. Santek, B. Hoover, C. Velden, and J. Key, 2013, High-latitude Atmospheric Motion Vectors from Composite Satellite Data, *J. Appl. Meteorol. Climatol.*, 53, 534–547. doi: <http://dx.doi.org/10.1175/JAMC-D-13-0160.1>.
36. Key, J. R., R. Mahoney, Y. Liu, P. Romanov, M. Tschudi, I. Appel, J. Maslanik, D. Baldwin, X. Wang, and P. Meade, 2013, Snow and ice products from Suomi NPP VIIRS, *J. Geophys. Res. Atmos.*, 118, doi:10.1002/2013JD020459.
37. Overland, J., J. Key, B.-M. Kim, S.-J. Kim, Y. Liu, J. Walsh, M. Wang, U. Bhatt, and R. Thoman, 2013, Air temperature, atmospheric circulation, and clouds [in “State of the Climate in 2012”], *Bull. Amer. Meteor. Soc.*, 94(8), S121–S123, doi: <http://dx.doi.org/10.1175/2013BAMSStateoftheClimate.1>.
38. Wang, X., J. Key, Y. Liu, C. Fowler, J. Maslanik, and M. Tschudi, 2012, Arctic climate variability and trends from satellite observations, *Adv. Meteorol.*, v2012, 22 pp, doi:10.1155/2012/505613.
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43. Olsen, M.S., T. Callaghan, J. Reist, L.O. Reiersen, D. Dahl-Jensen, S. Gerland, B. Goodison, G. Hovelsrud, M. Johansson, R. Kallenborn, J. Key, A. Klepikov, W. Meier, J. Overland, T. Prowse, M. Sharp, W. Vincent, and J. Walsh, 2011, The changing Arctic cryosphere and likely consequences: An overview, *Ambio*, 40, 111–118, doi 10.1007/s13280-011-0220-y.
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- Tech.*, 25, 1057-1072, DOI: 10.1175/2008JTECHA1052.1.
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