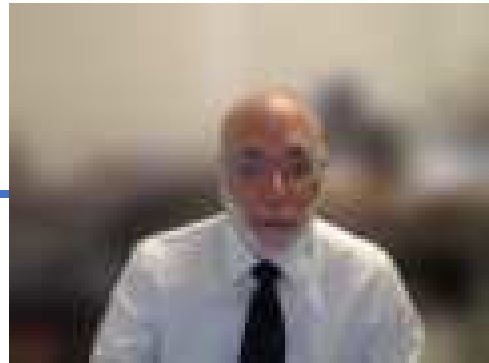
Global Environmental Measurement & Monitoring (GEMM) Initiative

Dr. Thomas M. Baer
CorrFRSE, FOSA, FAAAS
Stanford Photonics Research Center
Stanford University



CAA Workshop
August 12, 2022

OPTICA

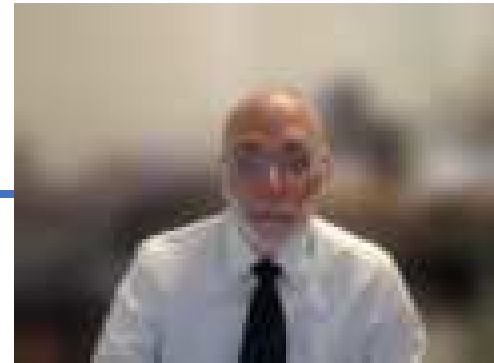
Advancing Optics and Photonics Worldwide

GEMM

AGU ADVANCING EARTH AND SPACE SCIENCE

CAA Workshop

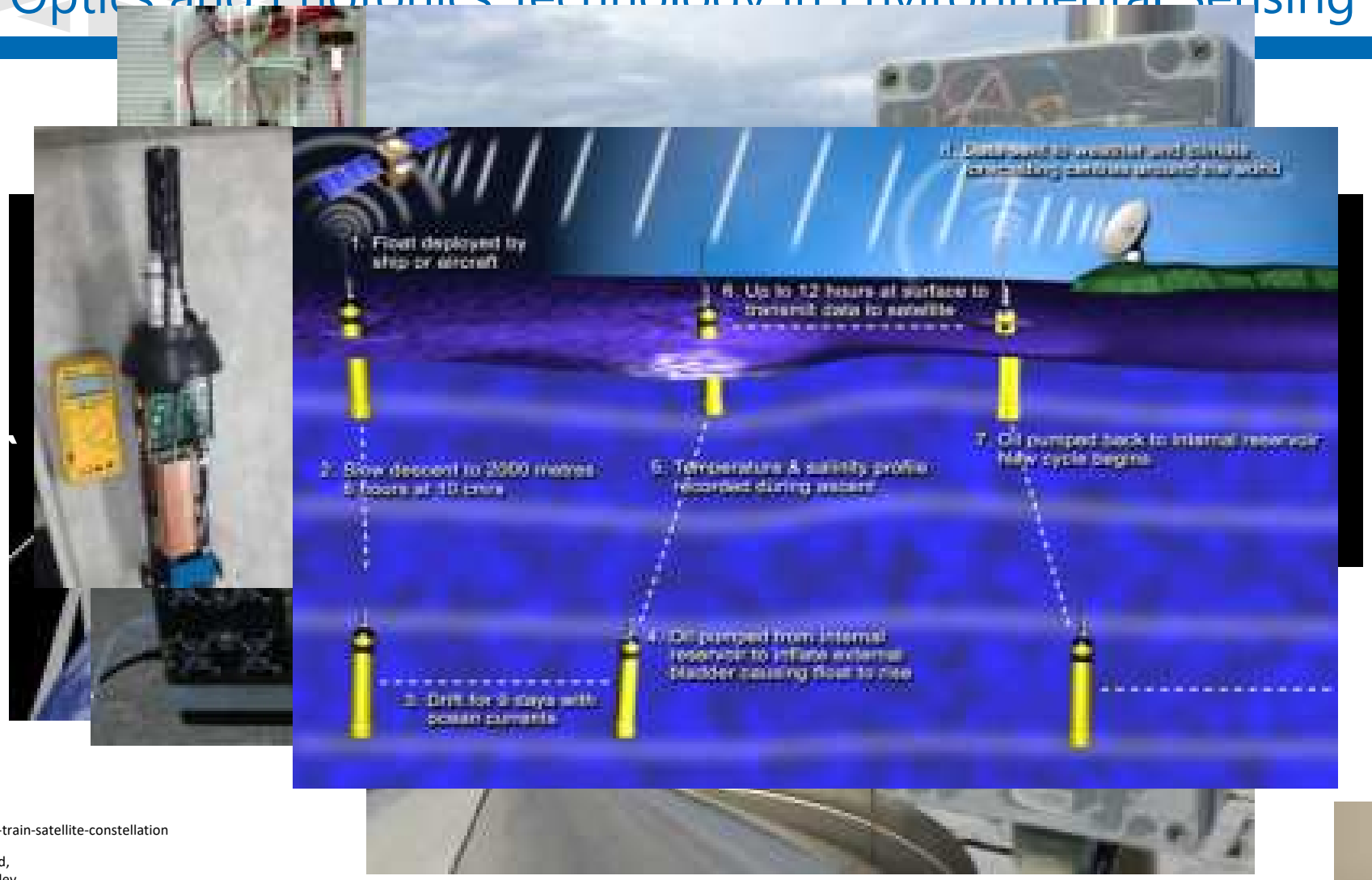
August 12, 2022



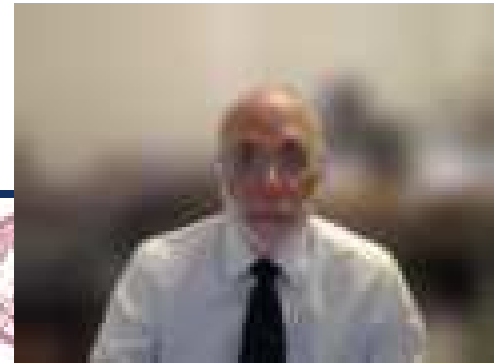
Leveraging Global Scientific Societies to Enable GEMM

Optica and AGU: Over 80,000 members in 130 Countries

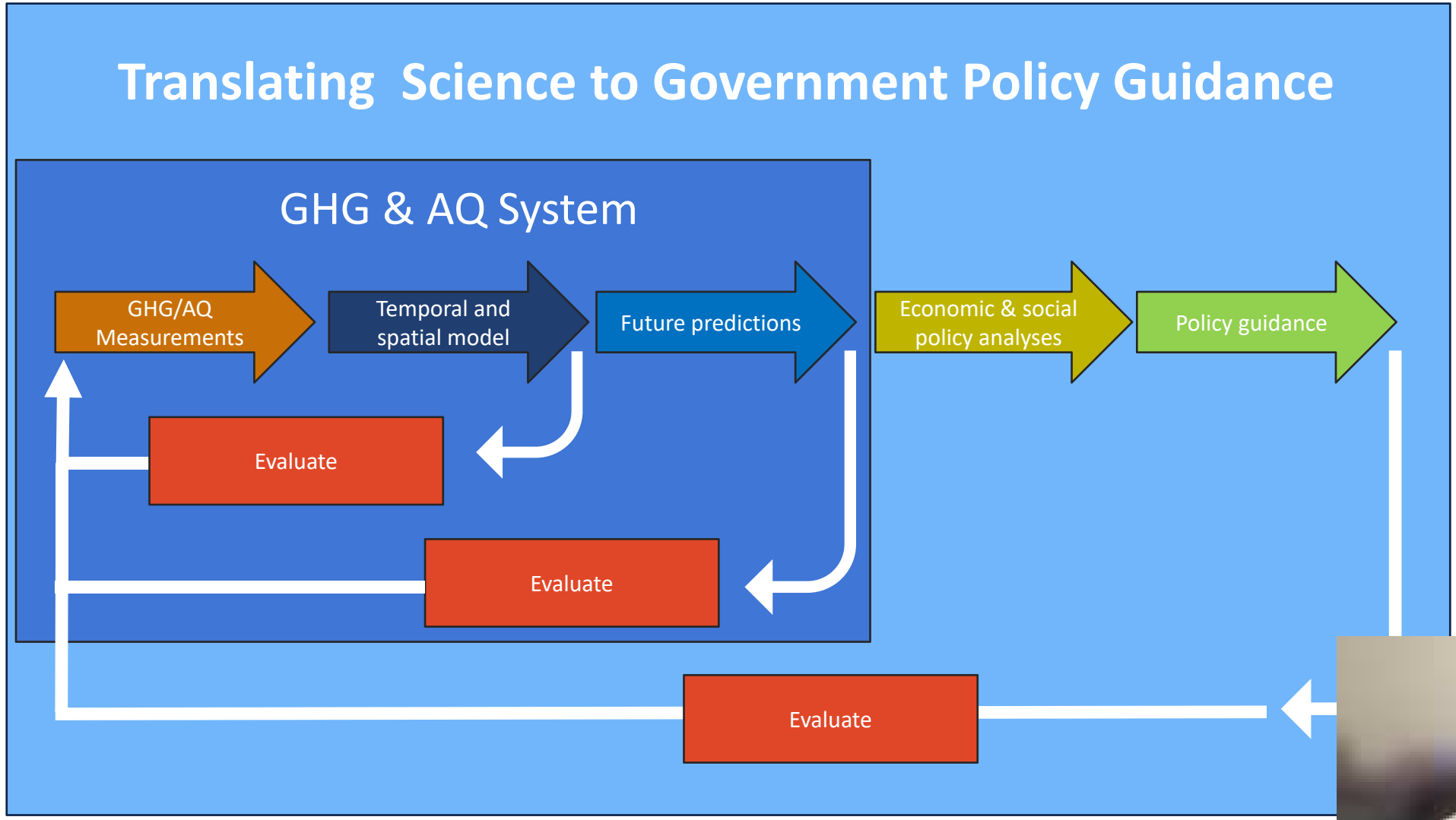
Optics and Photonics Technology in Environmental Sensing

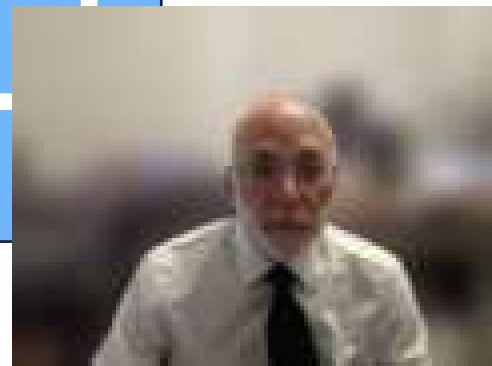


https://science.nasa.gov/earth-science/a-train-satellite-constellation
James Anderson, Harvard University
Andrew McGonigle, University of Sheffield,
Ron Cohen, University of California Berkeley
https://www.aoml.noaa.gov/phod/argo/webpage_sections/doc/argo_intro_what_is.php



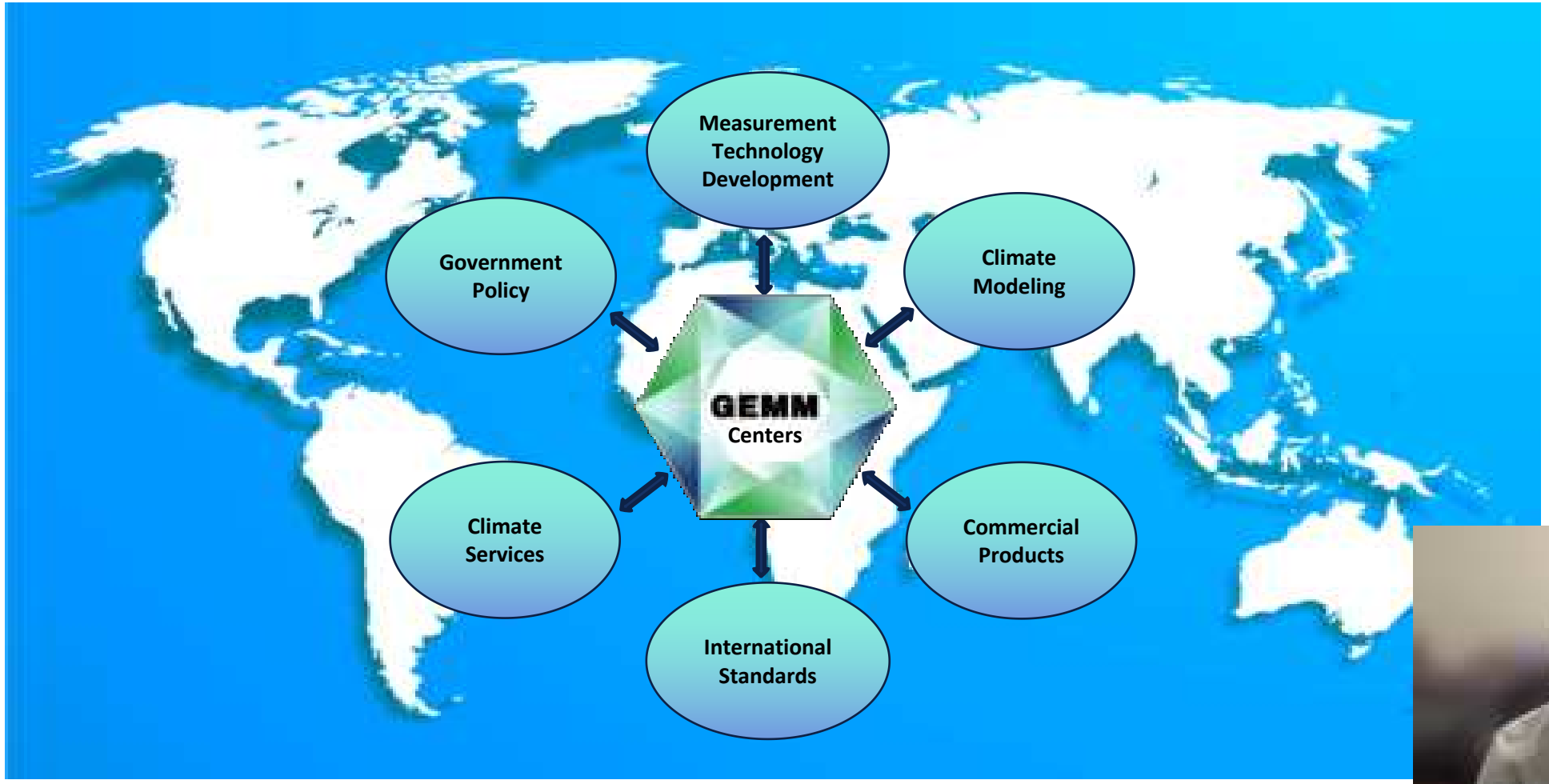
Translating Science to Government Policy Guidance

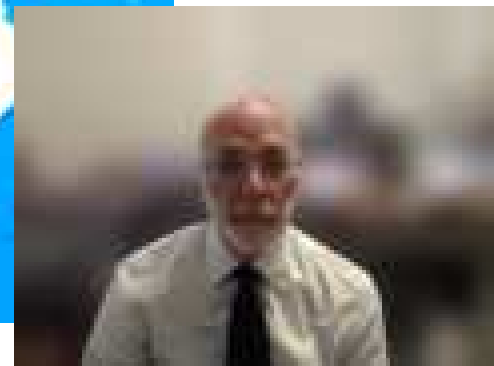




Global Environmental Measurement and Monitoring Network (GEMM)

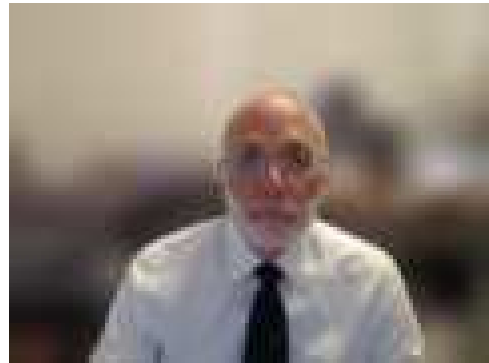
BETTER METRICS FOR MORE EFFECTIVE DECISION-MAKING:





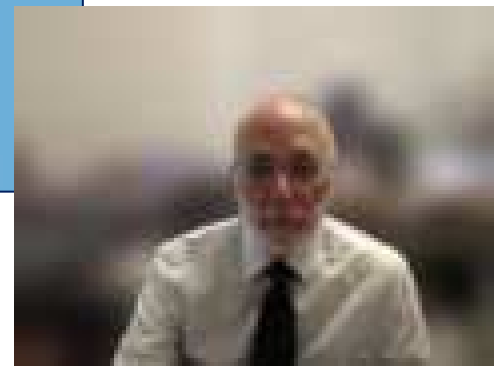
GEMM Regional Centers and Ongoing Discussions ★

GEMM at COP26: Cities are the Key to the Climate Solution



GEMM CoP 26 Summit Participant Locations ★ GEMM Centers

Representatives from cities from 43 countries.



GEMM at COP26: Cities are the Key to the Climate Solution

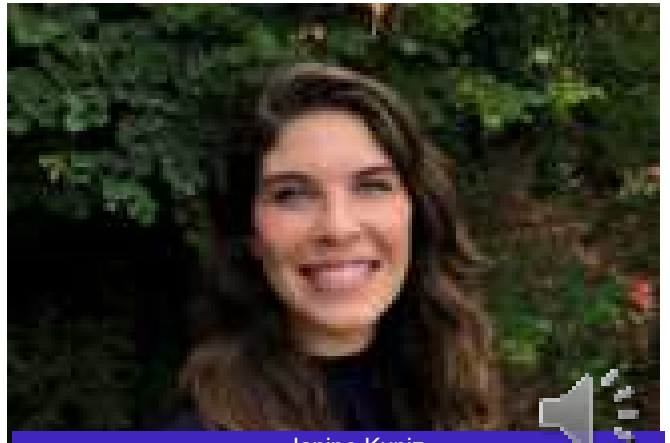
COP26 GEMM Summit Speakers

Angus Robertson MSP
Cabinet Secretary

Eleni Kounalakis
Lieutenant Governor of California

Susan Aitkens
City of Glasgow Council Leader

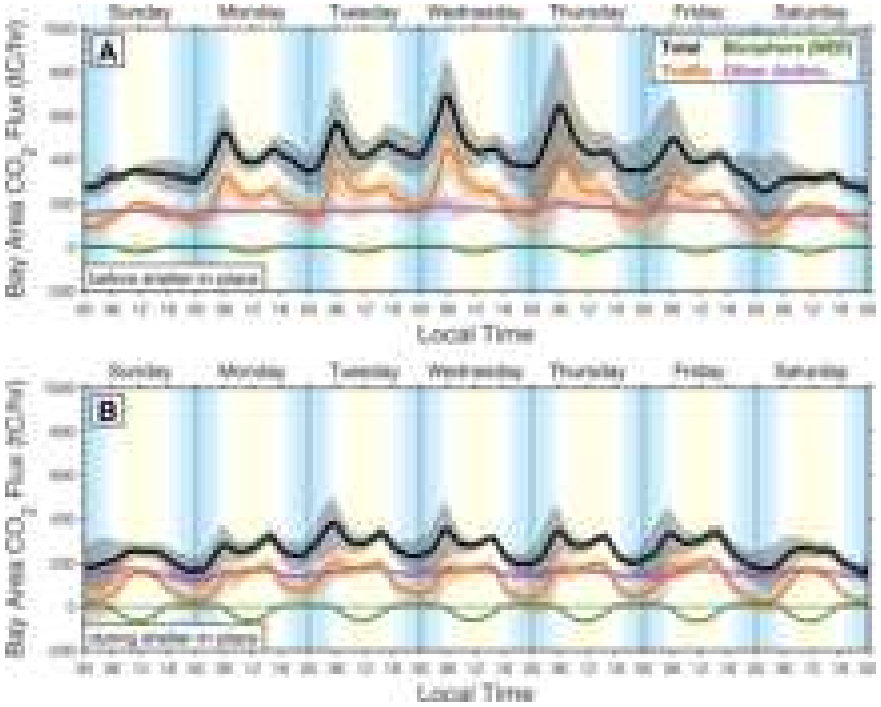
Richard Lochhead
Minister of Just Transitions, Scotland

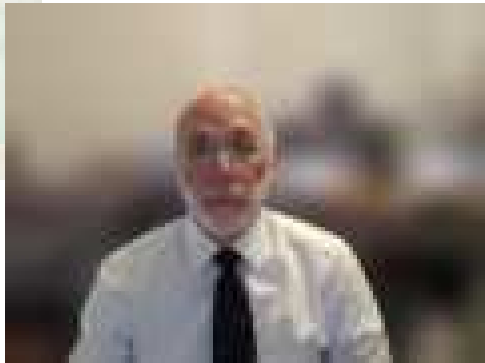


Janine Kuniz
United Nations Habitat

GEMM COP26 Summit Sponsors and Participants

UN Climate Change Conference (UNFCCC COP 26)





(Professor Ron Cohen, UC Berkeley, http://www.beacon.berkeley.edu/overview/)

Glasgow city low emission zone


LOW EMISSION ZONE

Glasgow city operations impacted by low emission zones

Taxis

Trucks

Buses

Buildings

Autos

Industry

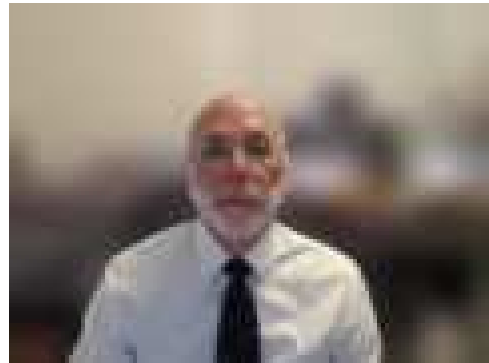
AQ and CO_2 Sources

Sinks

Vegetation

Wind/weather

Water



Evidenced based policy decisions

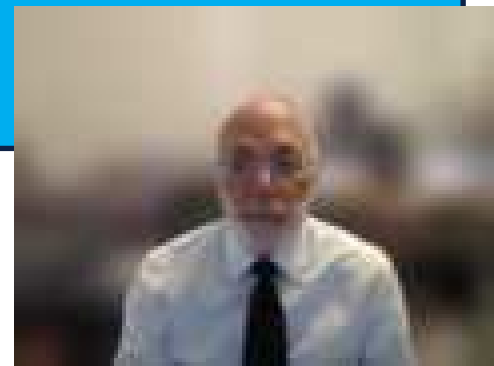
GHG/AQ Measurements → Temporal and spatial model → Future predictions → Economic & social policy analyses → Policy guidance

GEMM

University of Strathclyde Glasgow

Department of Economics
Fraser of Allander Institute (FAI)

CITY OF GLASGOW

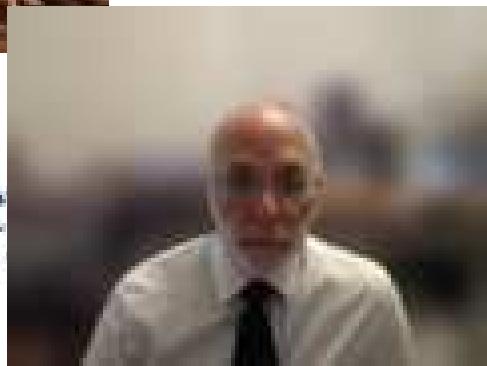


California GEMM Center

- GEMM center universities: Stanford, UC Berkeley
- State of CA engagement
  - Presentation at Global Climate Action Summit
  - CA State Water Resource Board
  - CA Air Resource Board
  - CA Strategic Growth Council
- Focus on
  - Low-cost GHG sensors: methane, CO_2
  - Fresh water resources: nitrate pollution, water resources
  - Air quality measurements in dense urban environments
  - Ocean chemistry, harmful algae blooms
- Joint COP26 GHG measurement project with the City of Glasgow

Stanford University

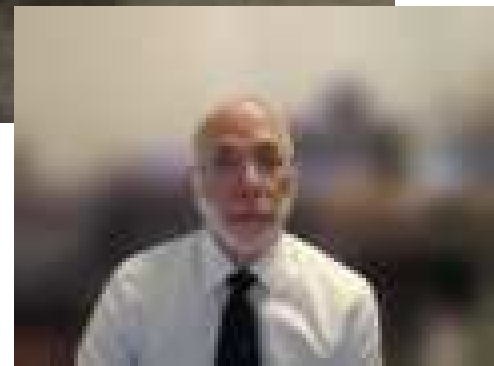
Berkele
UNIVERSITY OF CALIFORNIA



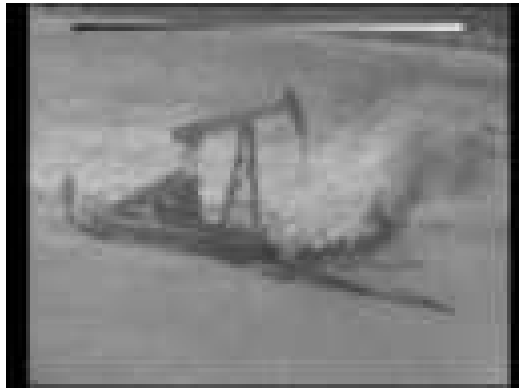
GEMM Meeting Stanford University September 17, 2019

Louise Bedsworth
State of California

Paul Wheelhouse
Scottish Government Minister



Methane Leakage From Oil and Gas Fields
Infrared Imaging

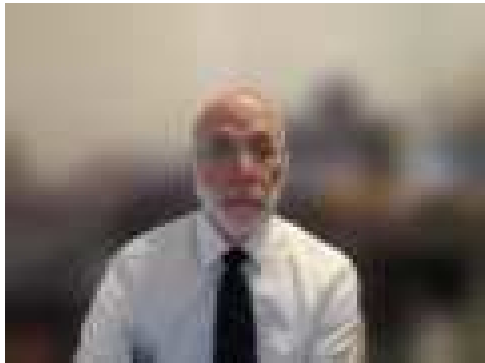


Well Head

Leaks

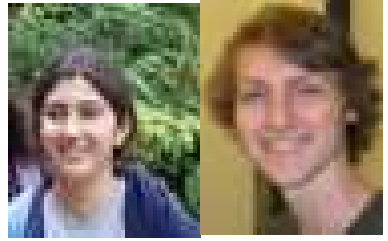
Tank Venting

Aerial Surveys of Elevated Hydrocarbon Emissions from Oil and Gas Production Sites
David R. Lyon,*,† Ramón A. Alvarez,‡ Daniel Zavala-Araiza,‡ Adam R. Brandt,§ **Robert B. Jackson**,∥ and Steven P. Hamburg
Environ. Sci. Technol. 2016, 50, 4877−4886Environ. Sci. Technol. 2016, 50, 4877−4886



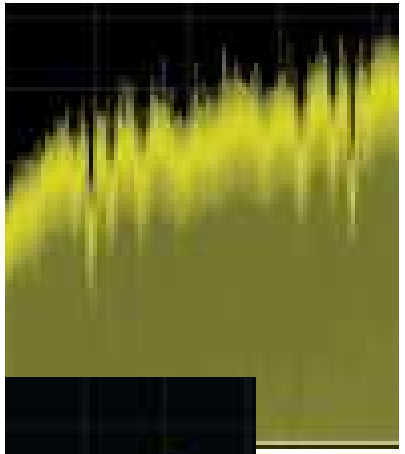
Diode lasers monitoring atmospheric methane

L. Hollberg group, Dept. Physics

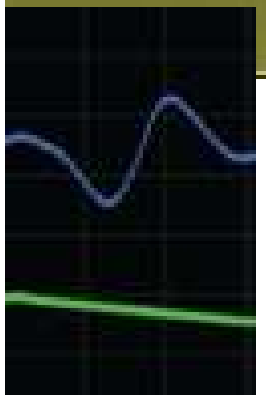


Powerful sensing capabilities provides new tools for:

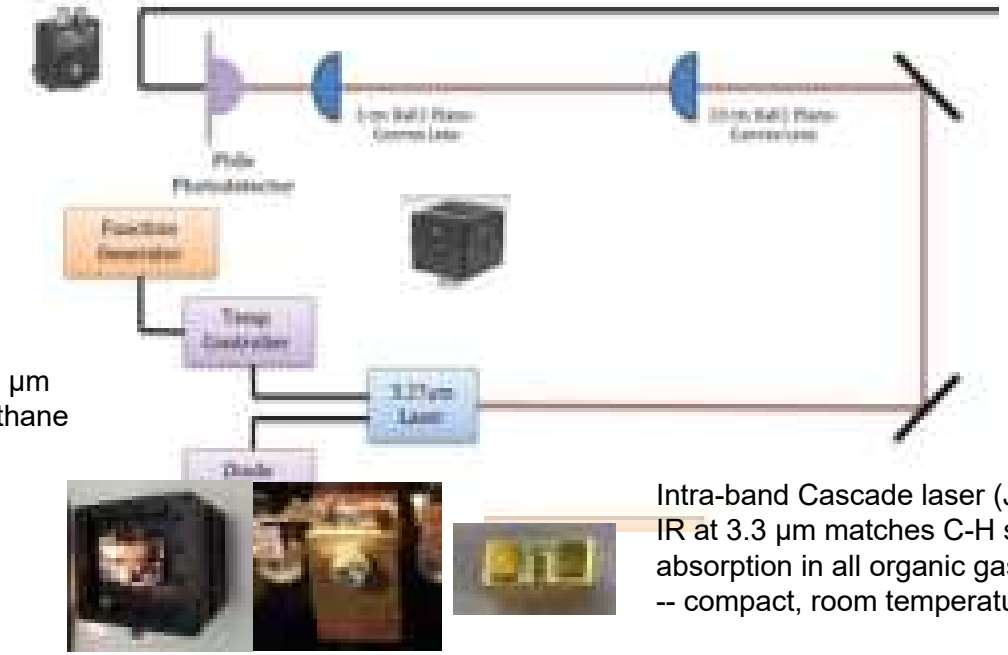
- Hydrocarbon sensing, monitoring, exploration, leak detection, safety
- Environmental monitoring, greenhouse gases and trace-gas monitoring
- Compact free-space sensors
- Accurate measurements of atmospheric CH_4 are feasible and practical with IR diode lasers



Diode laser at 3.3 μm absorption by methane at low pressures.



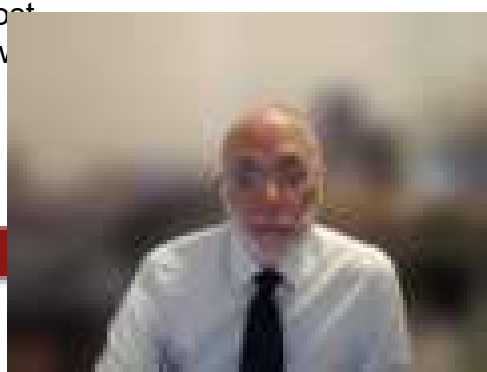
Absorption signal from methane in air ≈ 1.8 ppm detect IR absorption in < 2 m optical path



Intra-band Cascade laser (JPL) IR at 3.3 μm matches C-H stretch absorption in all organic gases. -- compact, room temperature

What is path forward ?

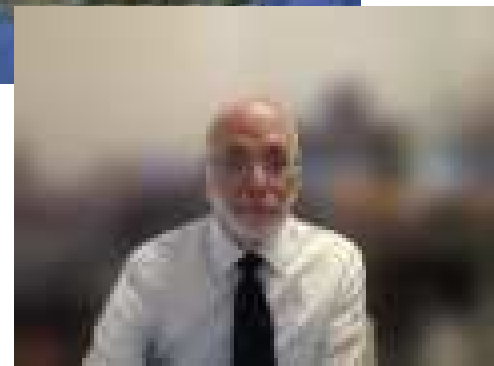
- Proof of principle demonstrations
- Motivate mass production of diode lasers for methane sensors at low cost
- Enable widely distributed sensors, compact, continuous monitoring, netw
- Potential for large market and economic pull
- Generate key data for climate modeling
- Is there a Political will in the U.S. ?



California Fresh Water Supply

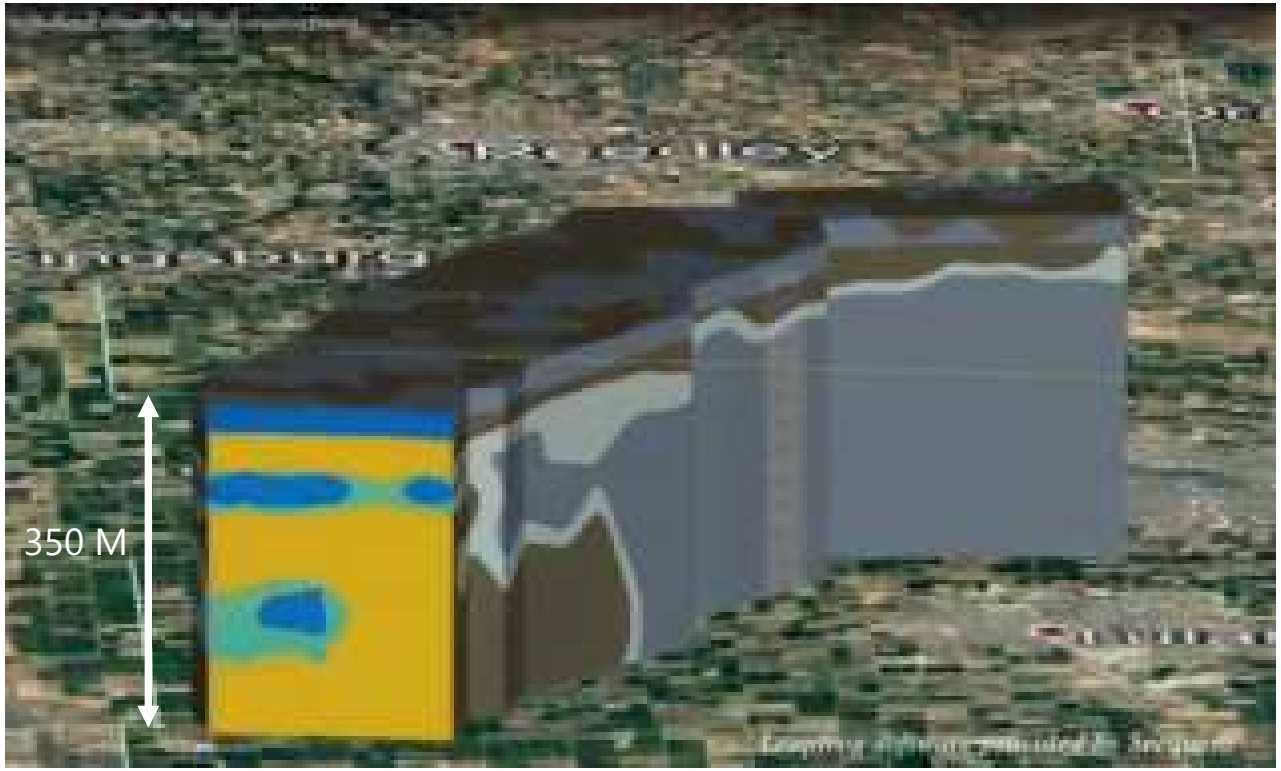
Sierra snowpack

Spring runoff and reservoirs

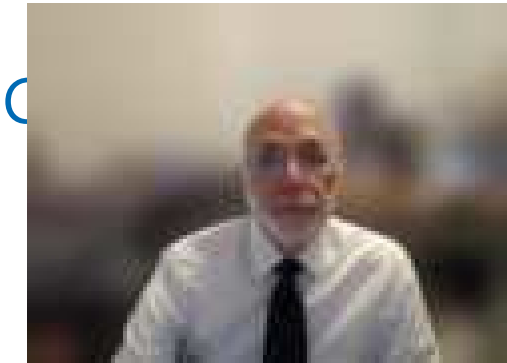


(https://gemcenter.stanford.edu/
Rosemary Knight Lab, Stanford University)

Airborne Electromagnetics Ground Water Sensing Systems



Tomographic Mapping of Subsurface Water Levels in the California C

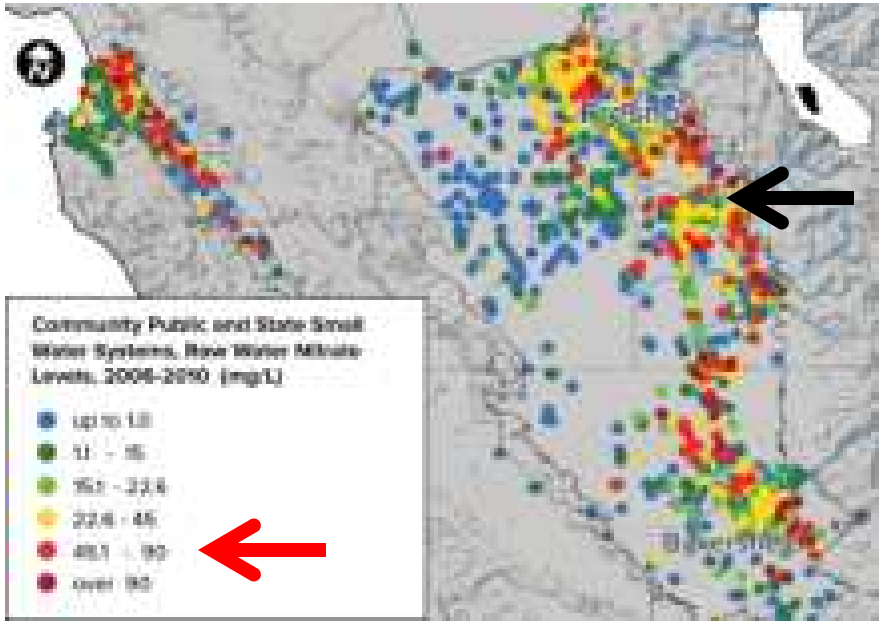


(https://gemcenter.stanford.edu/
Rosemary Knight Lab, Stanford University)

The New York Times

They Grow the Nation's Food, but They Can't Drink the Water

Nitrate in Public Small Water Systems



EPA limit

WATER IN THE WEST

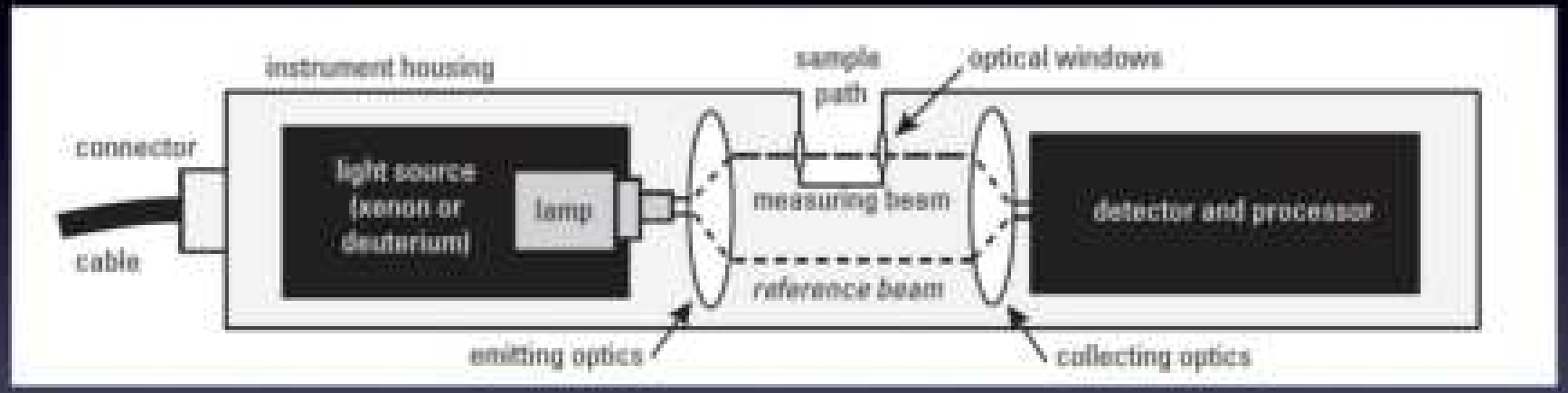
Understanding California's Groundwater

http://waterinthewest.stanford.edu/groundwater/overdraft/

(courtesy of Ken Johnson MBARI)

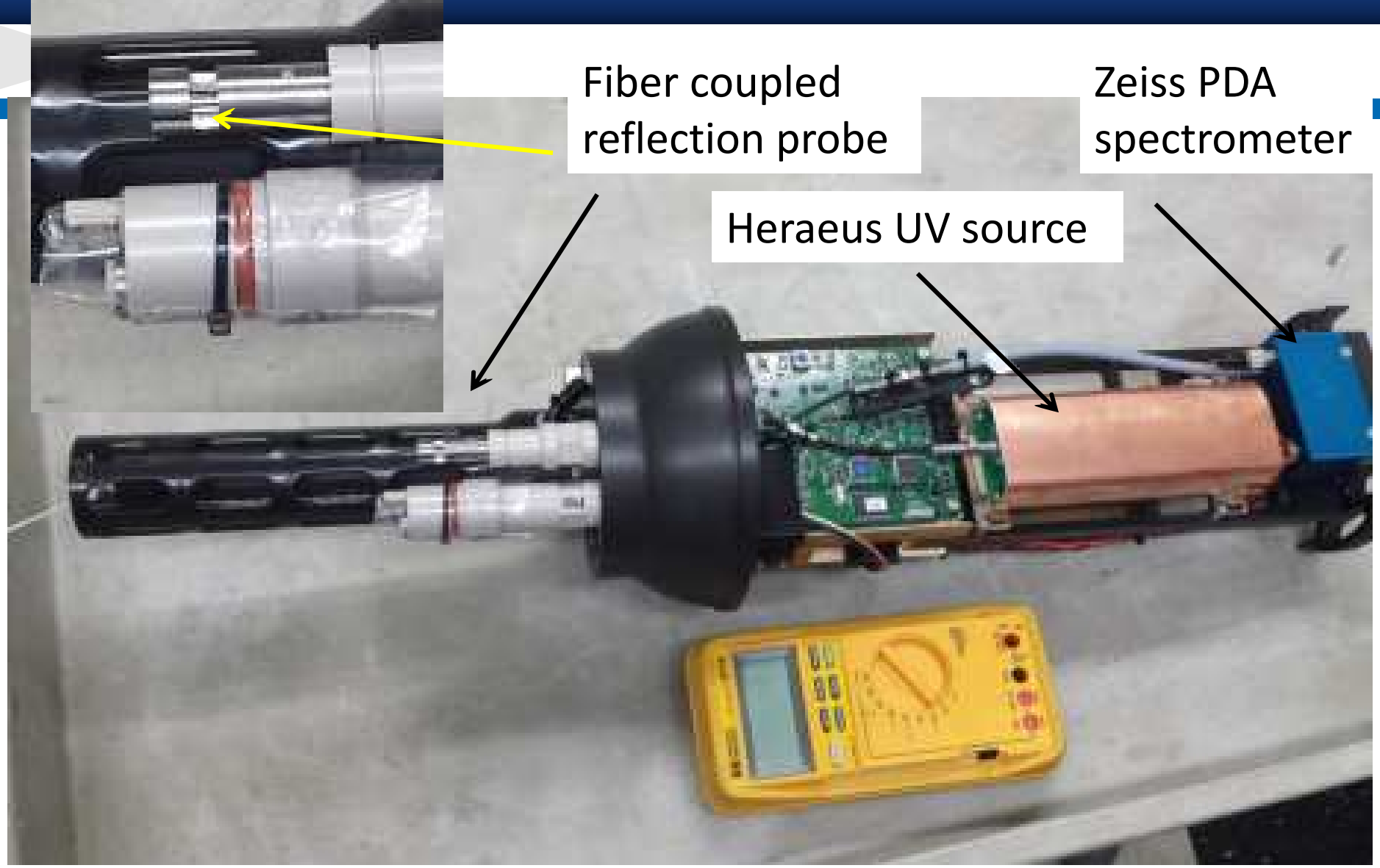
Nitrate, nitrite detection instruments

Instrument schematic



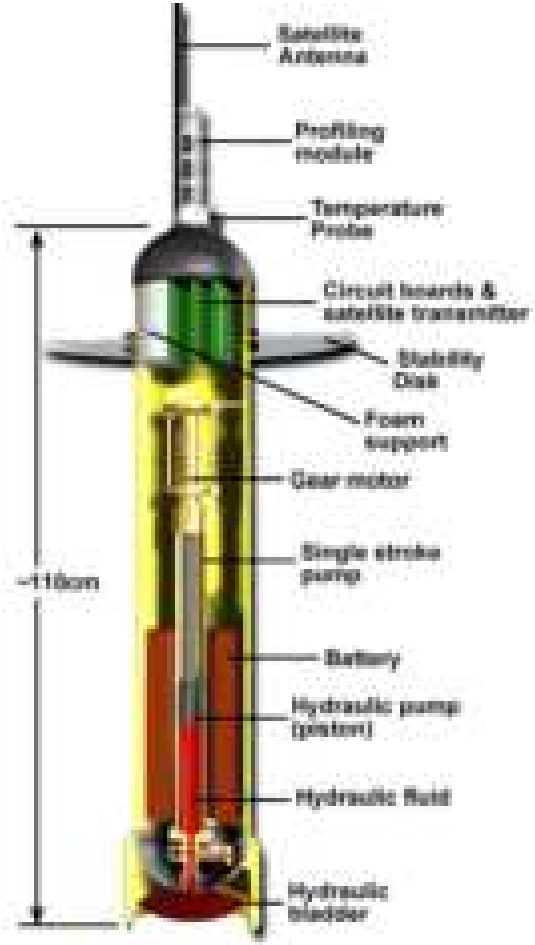
- Several commercially available instruments
- All are subject to interference from other absorbing contaminants

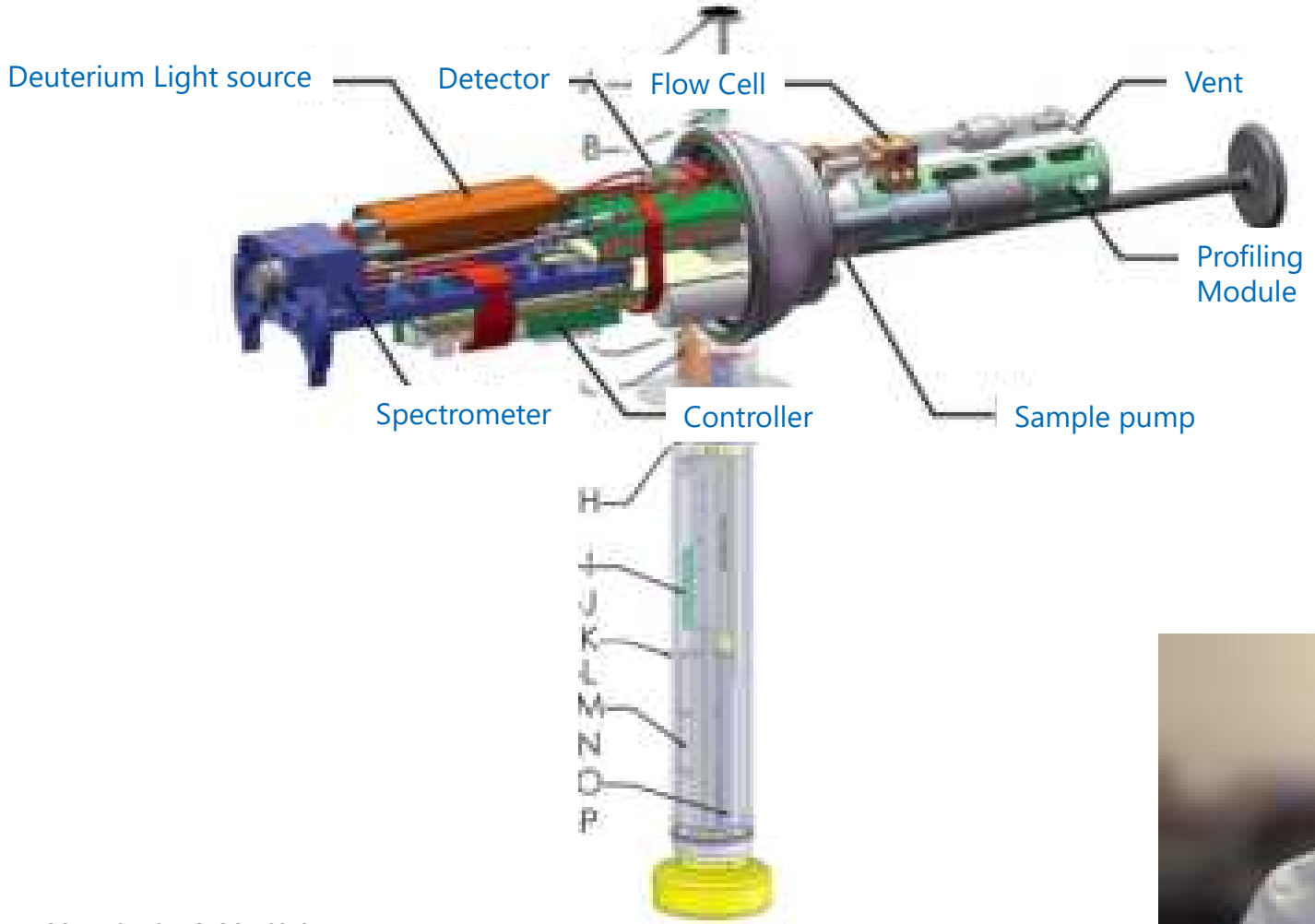
(Courtesy of John Harvey, Southern Photonics)

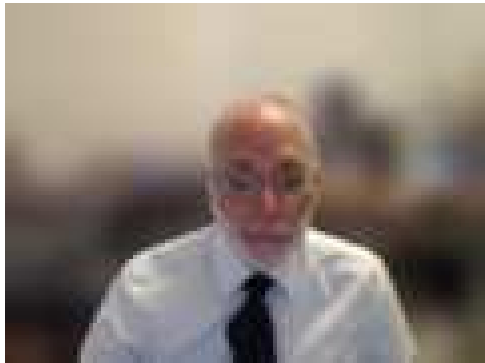


(courtesy of Ken Johnson MBARI)

UV Absorption Nitrate Sensor in the ARGO Ocean Float

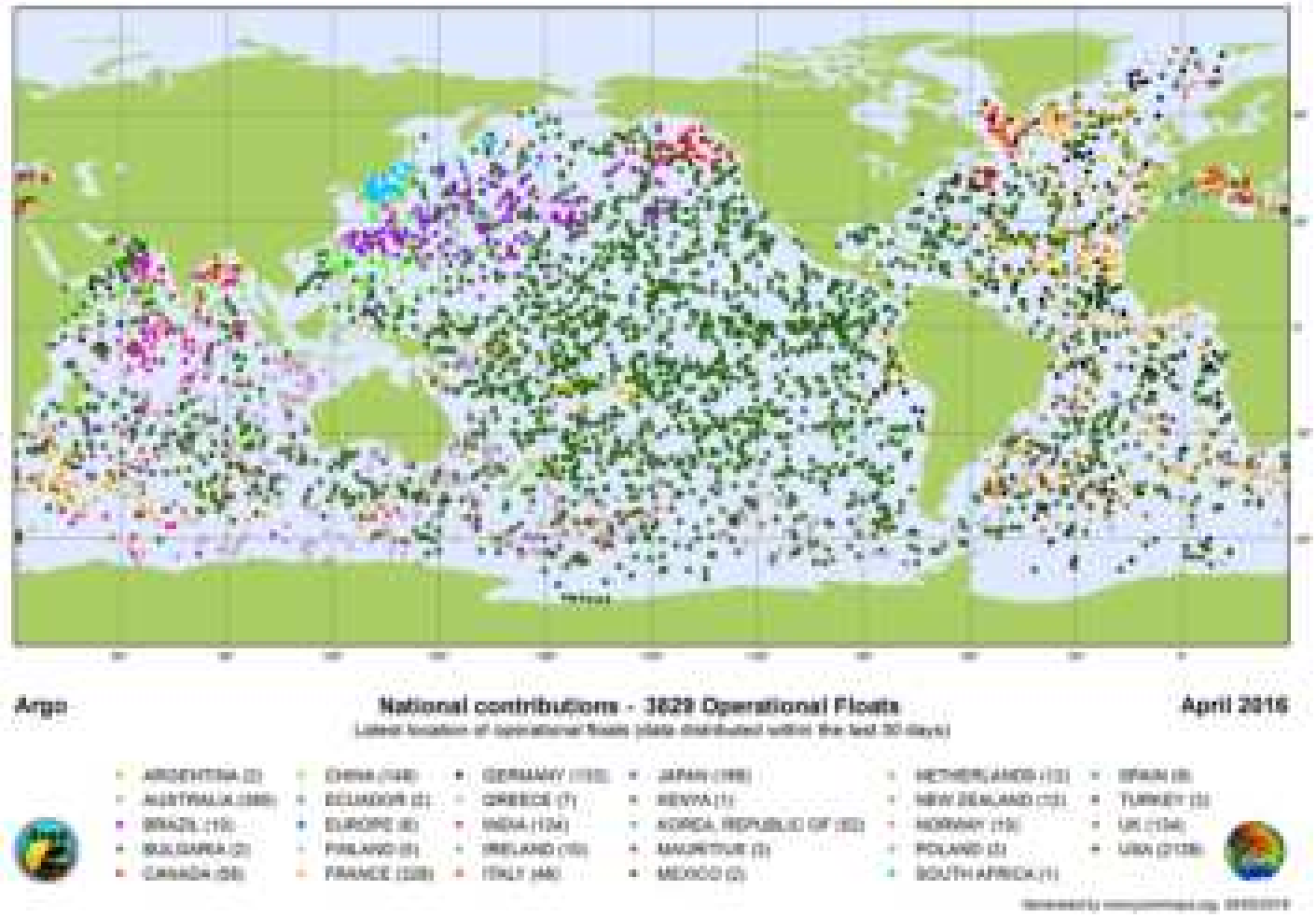




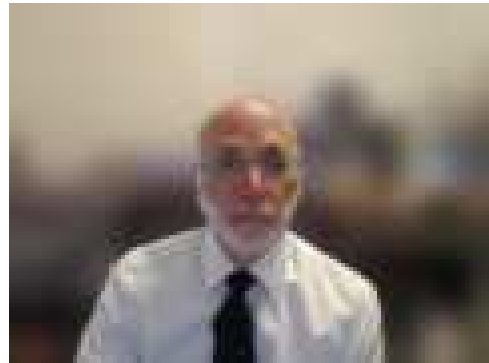


Johnson, et al., JOURNAL OF ATMOSPHERIC AND OCEANIC TECHNOLOGY, 2013

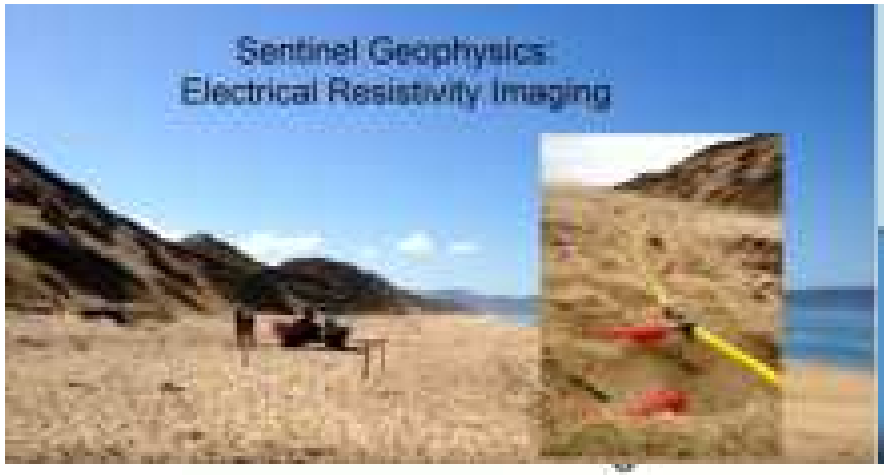
ARGO Floats Supply Critical New Data for Ocean Models

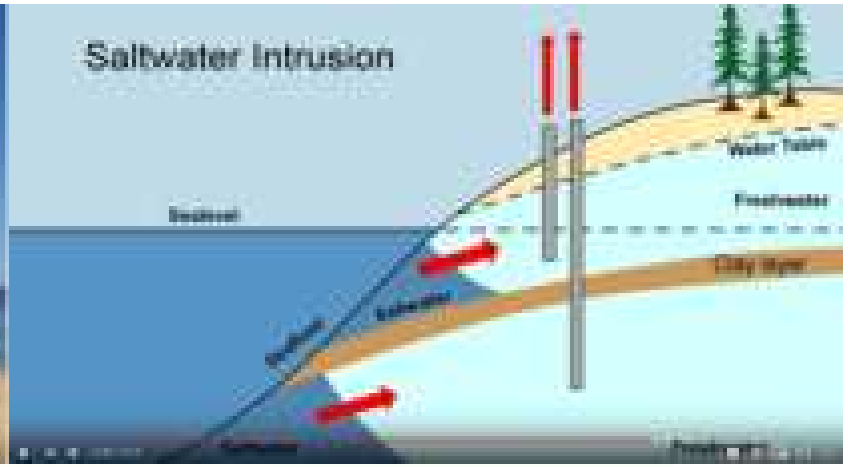


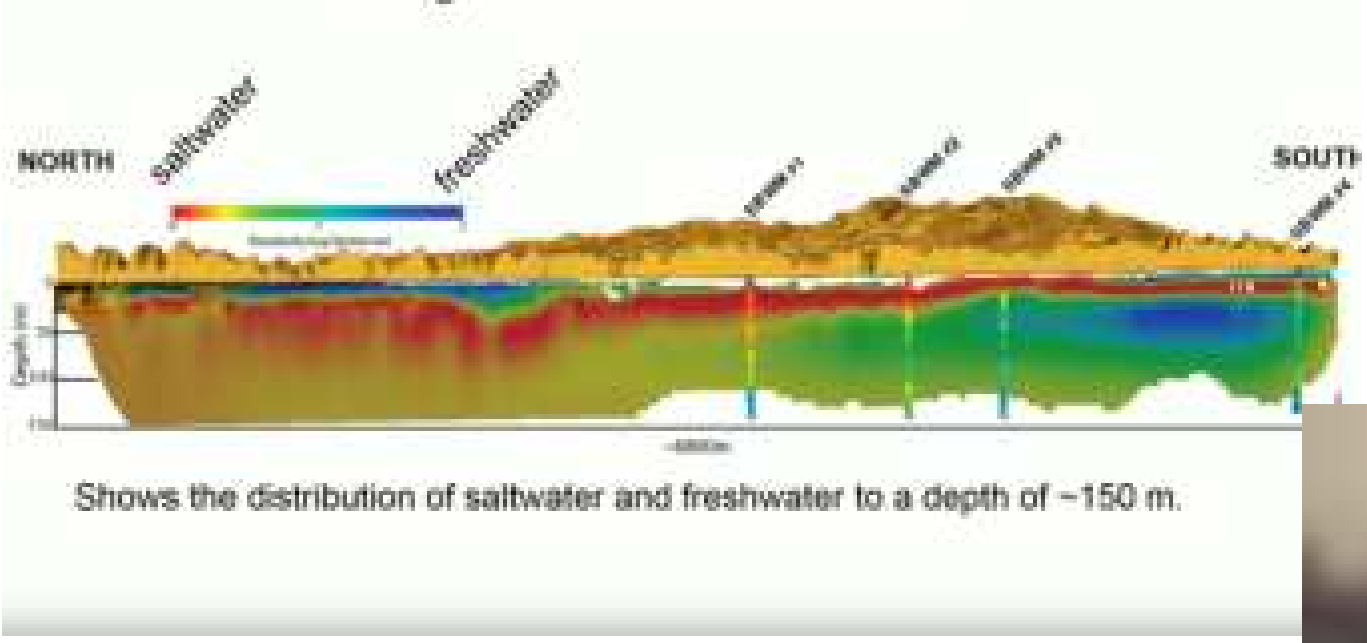
https://commons.wikimedia.org/wiki/File:2016-04-countries.png#file

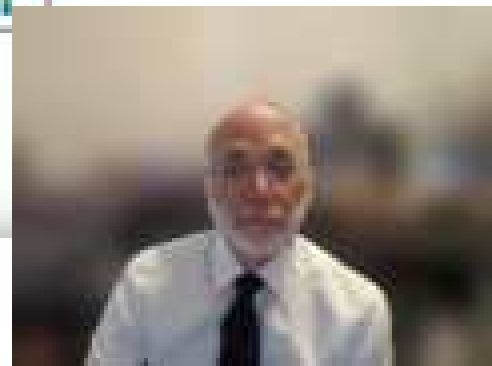


Saltwater Intrusion Imaging on the California Coast









(Prof. Rosemary Knight, Stanford, https://www.youtube.com/watch?v=AFO77hDGbII)

GEMM centers in Canada

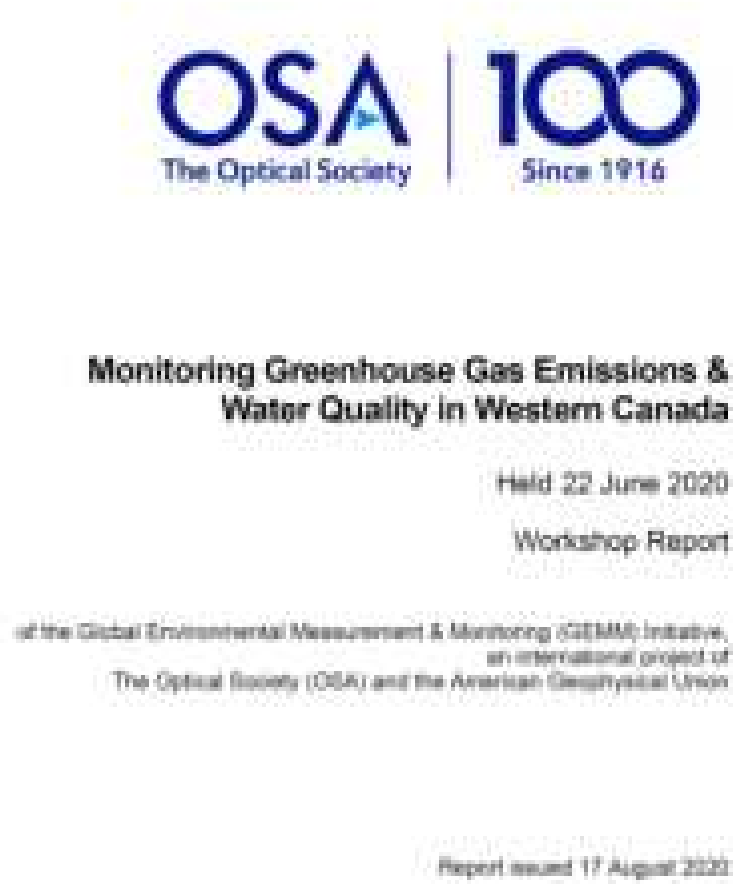
- University of Edmonton, NRC Canada, Canadian environmental ministries, University of Laval
- GEMM centers focusing on the Artic region and on southern Canada
- Southern Canada focus on:
  - Arboreal forest health and forest fires
  - Agriculture impact of climate change
  - Environmental impact of fossil fuel mining
  - Water and air quality

CONCORDIA UNIVERSITY OF EDMONTON

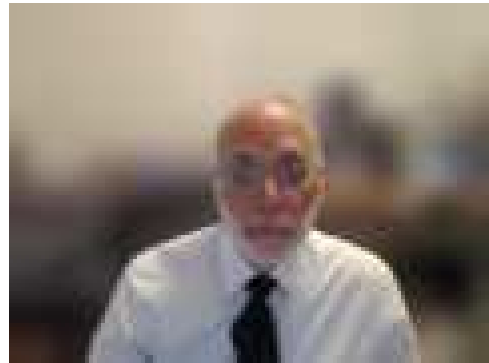
NRC·CNRC

UNIVERSITÉ LAVAL

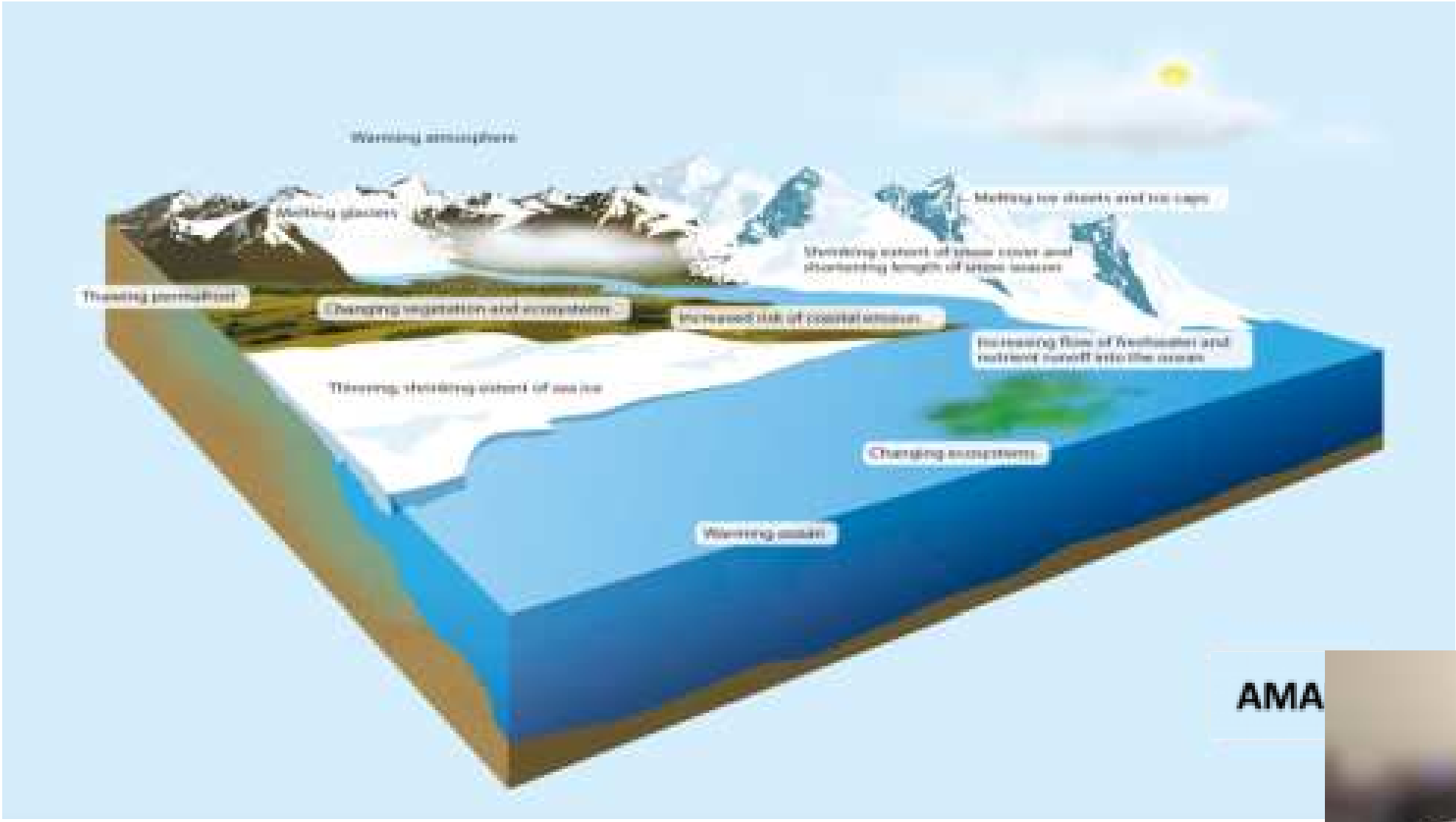
GEMM Meeting Edmonton, Canada August 17, 2020

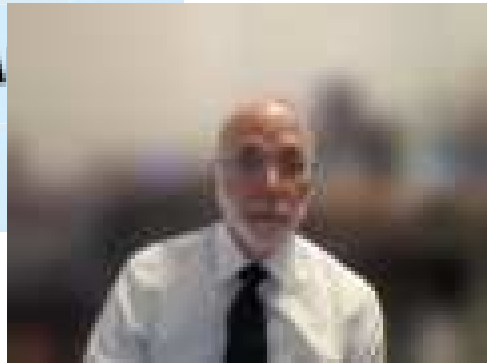


- Martine Dubuc*, Associate Deputy Minister of Environment and Climate Change Canada (Boucherville, GEMM Canada)
- Cecile Siewe*, Director General of Canmet ENERGY at Natural Resources Canada (GEMM Canada)
- Heather McCready*, Director General of Environment and Climate Change Canada (GEMM Canada)
- Geneviéve Tanguay*, former Vice-President Emerging Technologies, Natural Research Council Canada
- Alejandro Adem*, President of Natural Sciences and Engineering Research Council Canada (GEMM Canada)



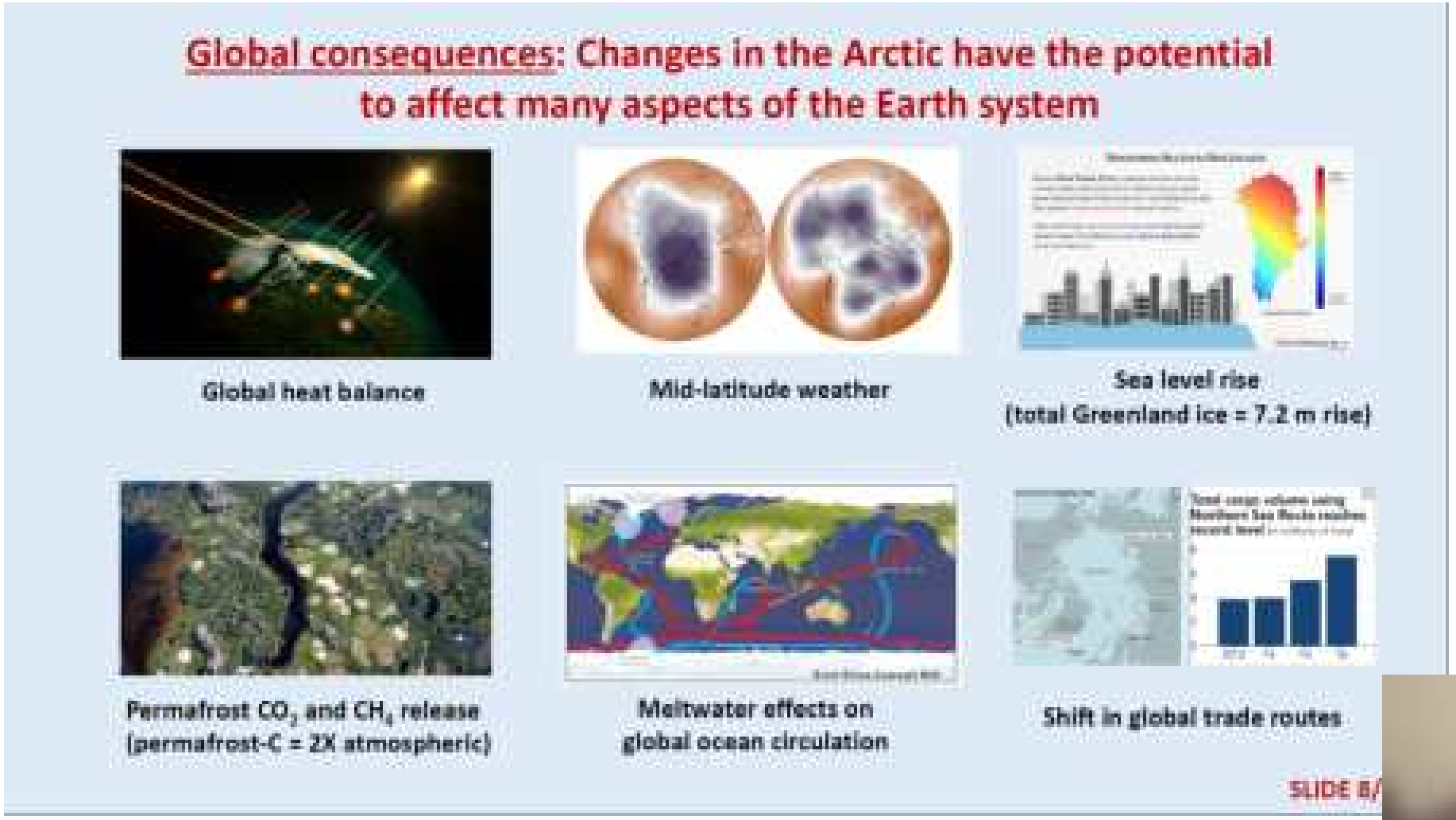
Changes in terrestrial and marine northern environments





(Courtesy Martin Fortier, Sentinel North, Université Laval)

What happens in Canadian Territories has Global Impact

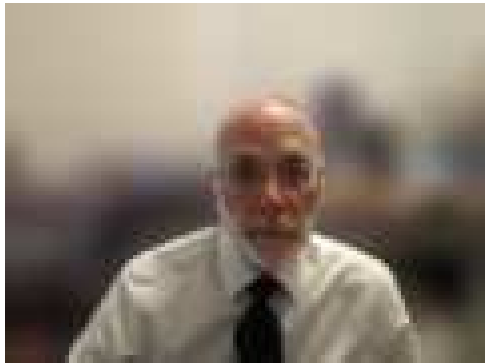


(Courtesy of Warwick Vincent)

New Zealand

- GEMM center at the Dodd-Walls Centre for Photonic and Quantum Technologies, University of Otago

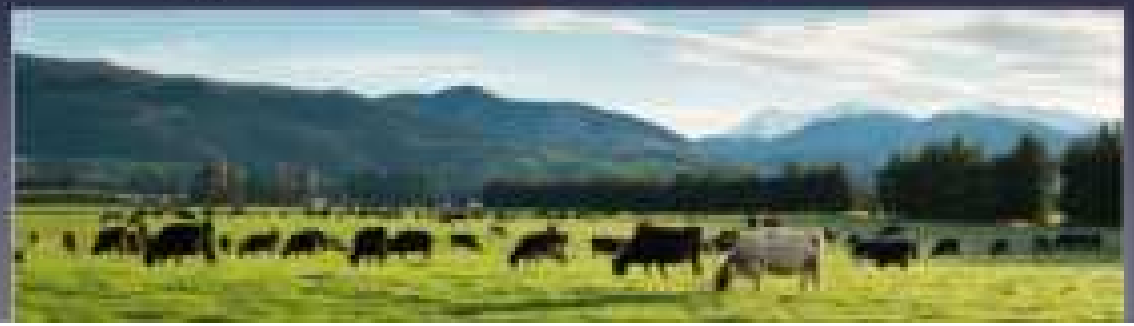
- Focus on:
  - Ocean ecology
  - GHG emissions: CO_2 and methane and air pollution
  - Fresh water resources and nitrate water pollution
  - Antarctic
  - Climate change and the Island Nations



Nitrate pollution and groundwater resource in NZ

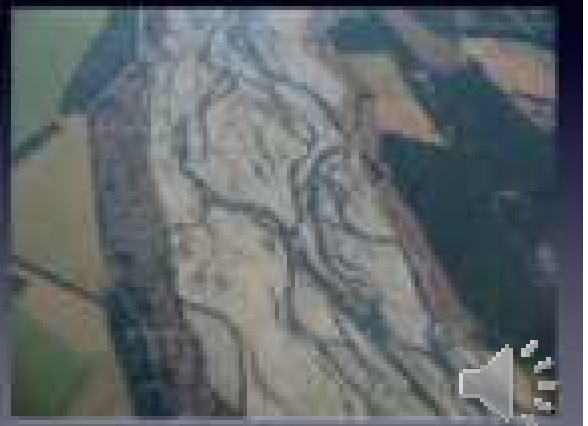
The Future of Freshwater in NZ

- The population would love to have "swimmable" rather than "wadeable" rivers in agricultural areas
- Dairy industry contributes more than 30% of the export receipts for the country (similar ratio to mining in Australia)



Special Geography

- The South Island has many braided rivers traversing extensive farmlands
- These supply groundwater reservoirs and the rate of renewal is unknown
- Monitoring of groundwater pollution is also important



(Courtesy of John Harvey, Southern Photonics)

Scotland

- GEMM center organized by the Fraser of Allander Economic Research Institute, University of Strathclyde
- Centre for Doctoral Training focused on Global Environmental Measuring and Monitoring and Policy (GEMMaP) at the University of Strathclyde
  - Involve Economics, Law, Political Science, Civil Engineering, Mathematics, Chemistry, Physics Departments
- Heavy engagement with Scottish and UK governments, NPL
- Focus on:
  - Urban pollution and GHG emission
  - Freshwater resources
  - North Atlantic ocean ecology
- Joint COP26 Project with the Northern CA GEMM center and the City of Glasgow

University of Strathclyde

Economic analysis of water use and climate change in Scotland

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Scotland's industrial water use: Understanding recent changes and examining the future

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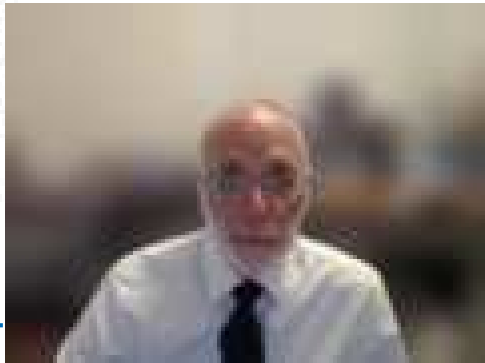
ABSTRACT

Future climate scenarios predict significant changes in the availability of water resources at global and regional scales. Knowledge of the possible economic consequences of this are limited by a shortage of data linking economic activity with physical water use. Matching a unique premise-level dataset to economic indicators at industrial/sector level, this paper undertakes a decomposition of changes in industrial water demand for Scotland between 2012 and 2016. Results highlight the importance of taking a sectoral approach, as changes in sectoral water intensity are significant. Furthermore, changes in the structure of the economy, i.e. a move away from water-intensive industries, highlight further reductions in overall water consumption. By considering future scenarios for Scottish water resources, this paper identifies key multi-disciplinary research challenges to address the major obstacles in developing a climate-ready water policy, which also captures the potential economic opportunities for Scotland from an awareness of the role of water in the economy.

UK and California GEMM Center Collaboration



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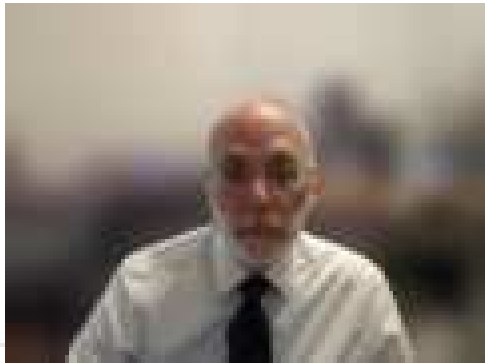

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