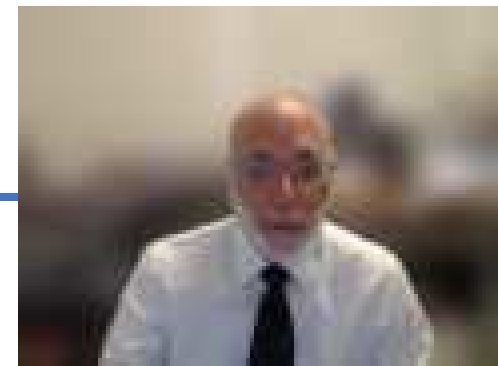

Global Environmental Measurement & Monitoring (GEMM) Initiative

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



CAA Workshop
August 12, 2022



OPTICA

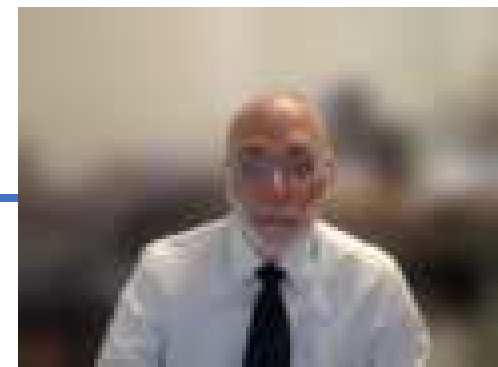
Advancing Optics and Photonics Worldwide



AGU ADVANCING
EARTH AND
SPACE SCIENCE

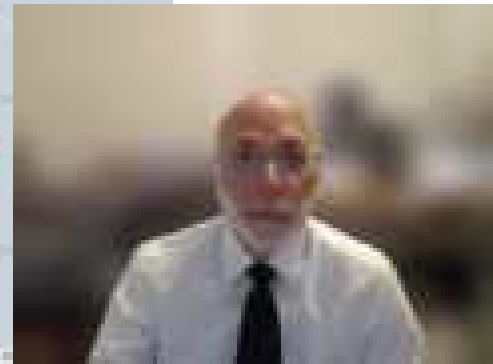


CAA Workshop
August 12, 2022

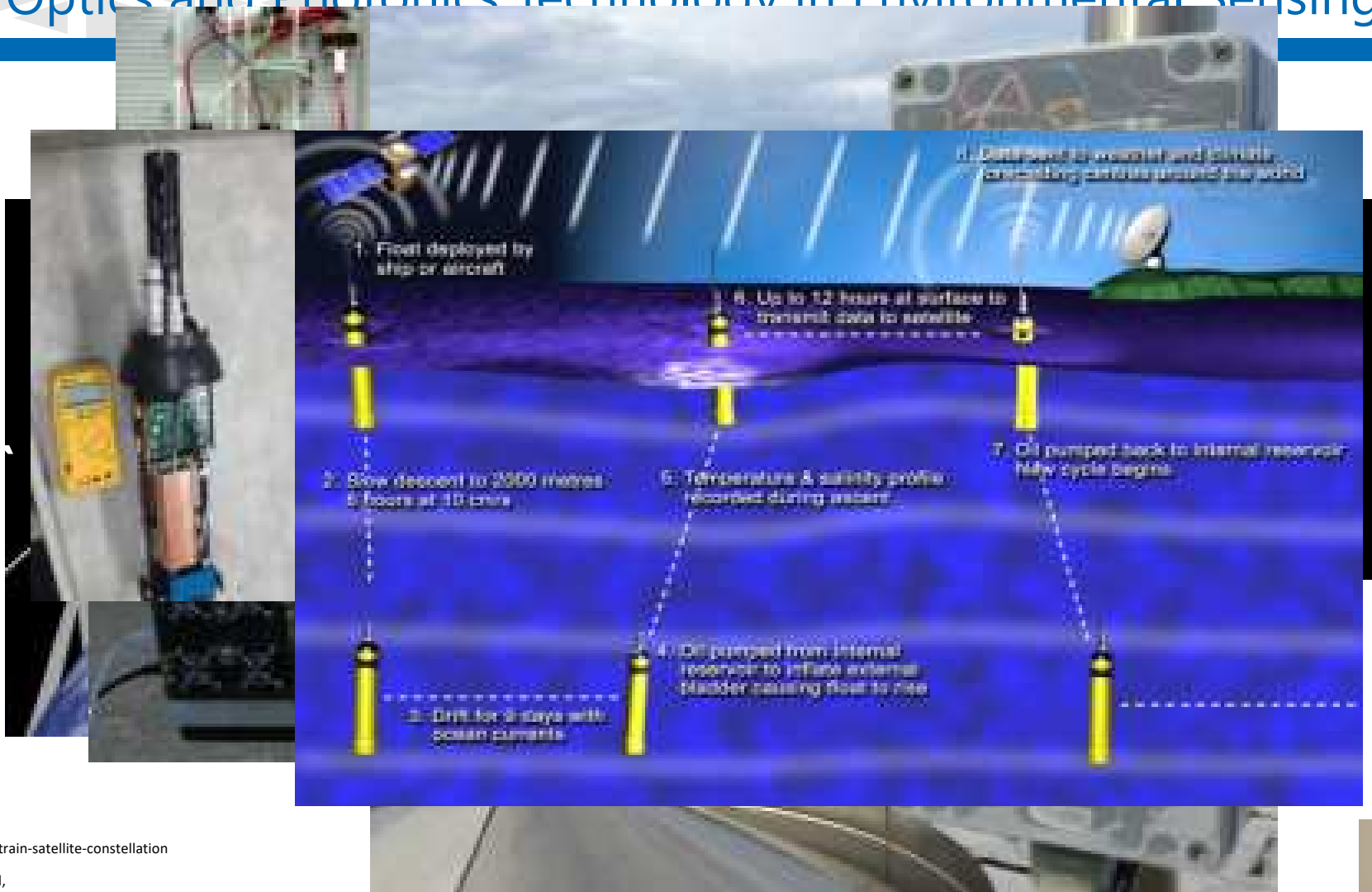


Leveraging Global Scientific Societies to Enable GEMM

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



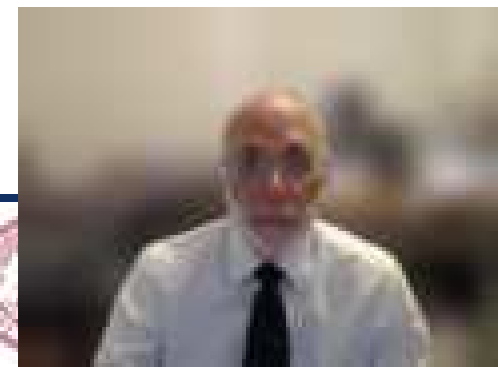
Optics and Photonics Technology in Environmental Sensing



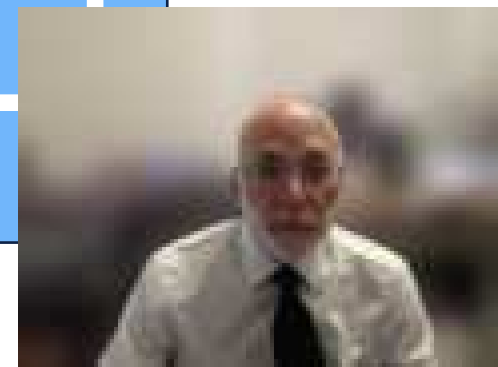
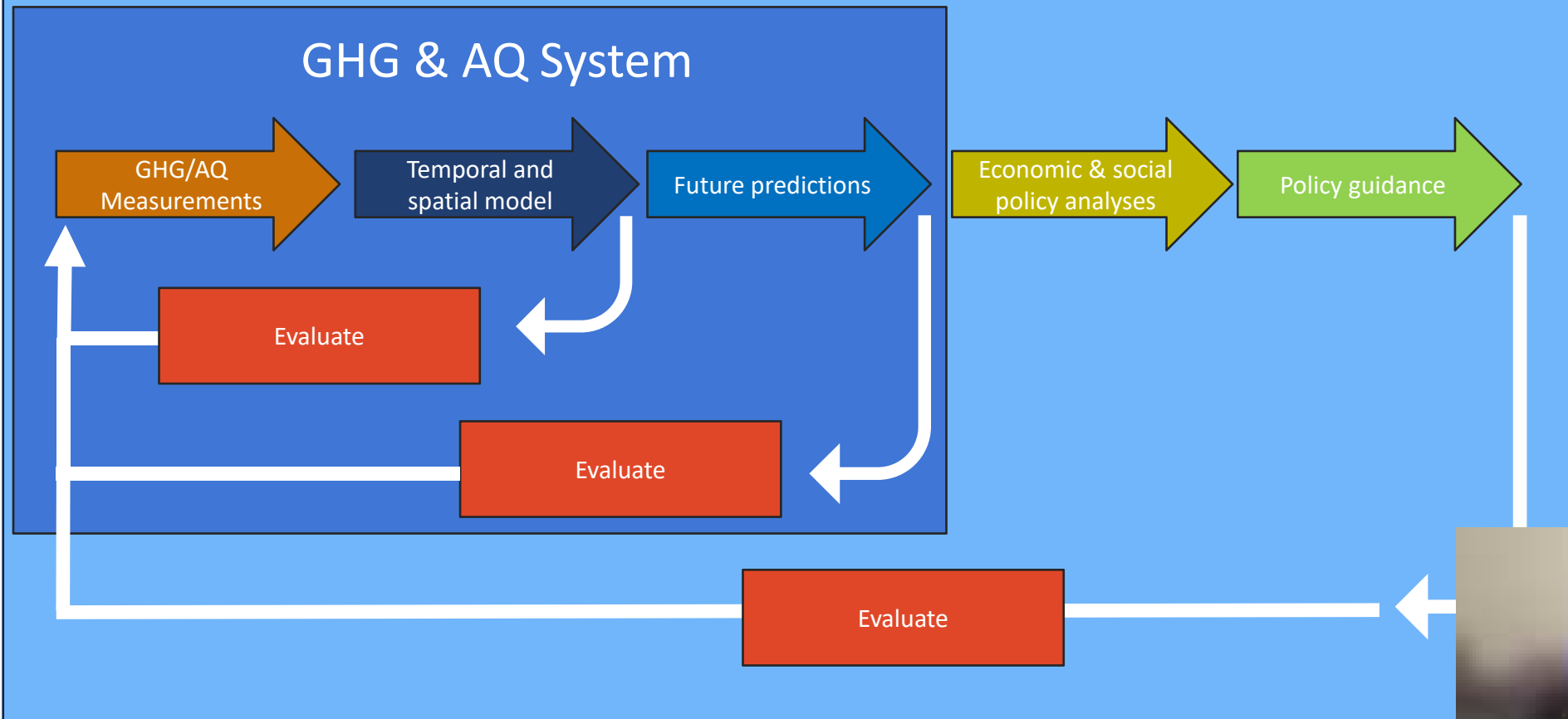
<https://science.nasa.gov/earth-science/a-train-satellite-constellation>
James Anderson, Harvard University
Andrew McGonigle, University of Sheffield,
Ron Cohen, University of California Berkeley
https://www.aoml.noaa.gov/phod/argo/webpage_sections/doc/argo_intro_what_is.php



CAA Workshop
August 12, 2022

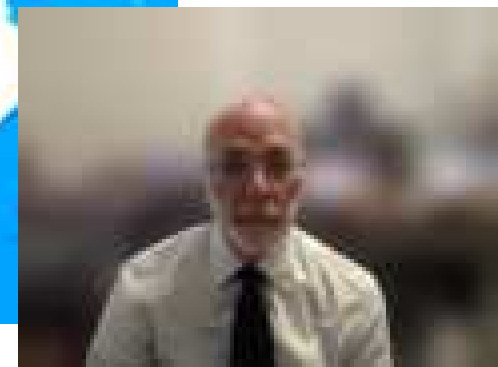
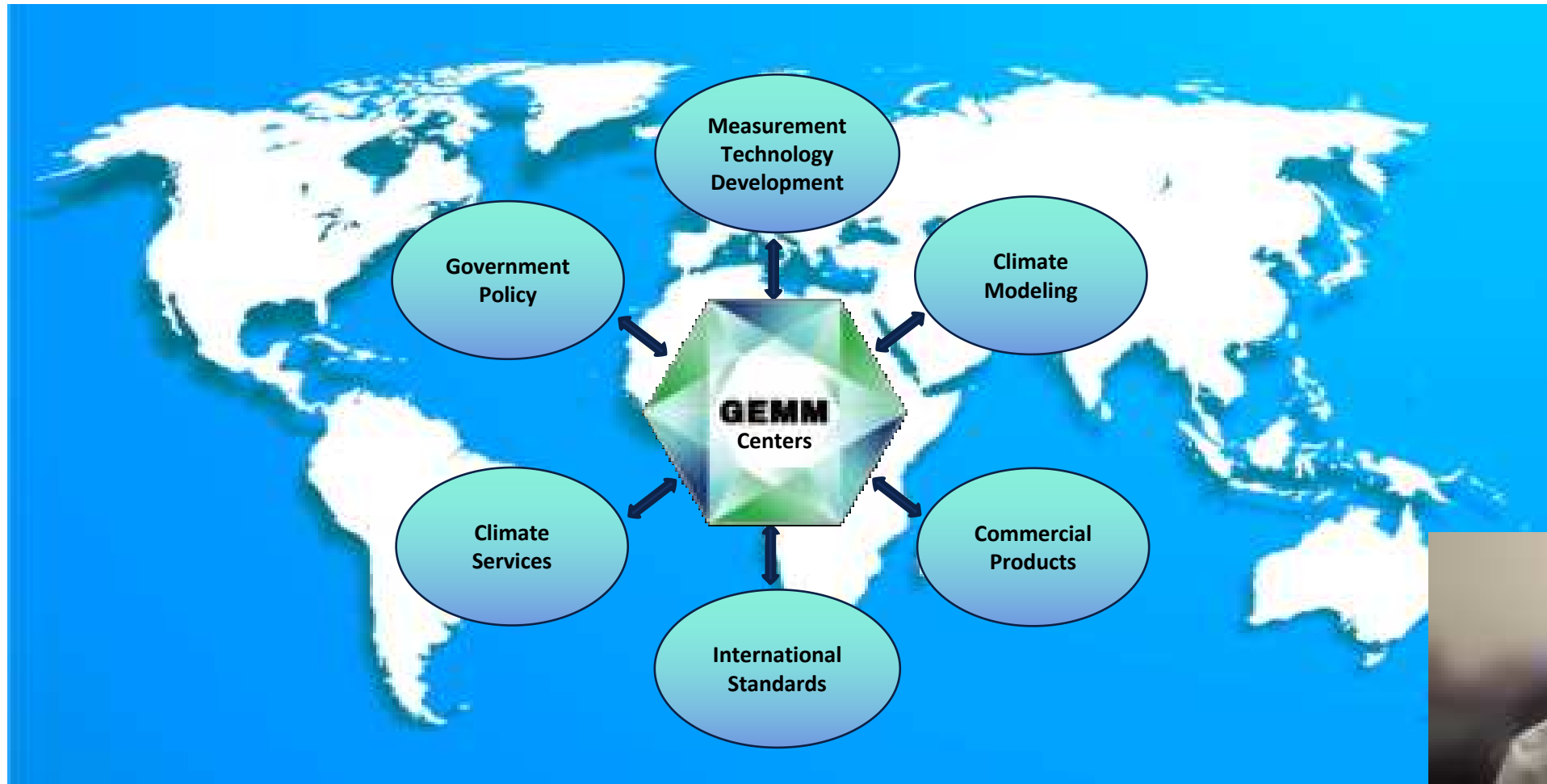


Translating Science to Government Policy Guidance

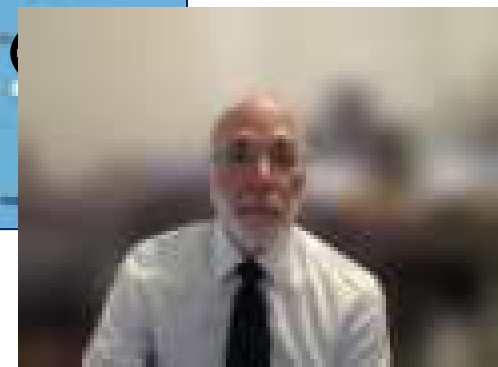


Global Environmental Measurement and Monitoring Network (GEMM)

BETTER METRICS FOR MORE EFFECTIVE DECISION-MAKING:



GEMM Regional Centers 📍 and Ongoing Discussions ★



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



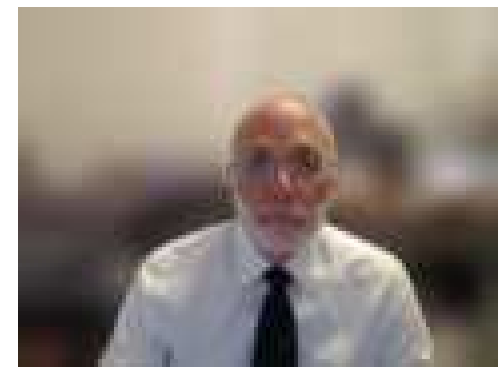
UN CLIMATE
COP26
CONFERENCE
IN 2021

GEMM | COP26 | UN SUSTAINABILITY GOALS

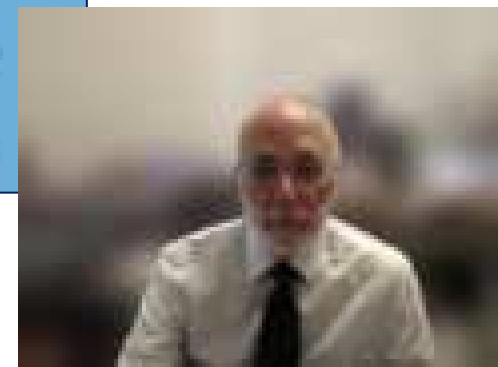


Cities are the Key to the Climate Solution

Join city leaders, policymakers and experts on **Wednesday 3 November at 14:00 GMT (11:00-12:00 CET, 07:00-11:00 PST, 10:00-10:00 EDT)** at this **FREE** Summit in-person at the Technology and Innovation Centre in Glasgow or online to discover how affordable technology for real time measurement of greenhouse gases (GHG) can help your city tackle climate change and air pollution. The programme for the event is now available.



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



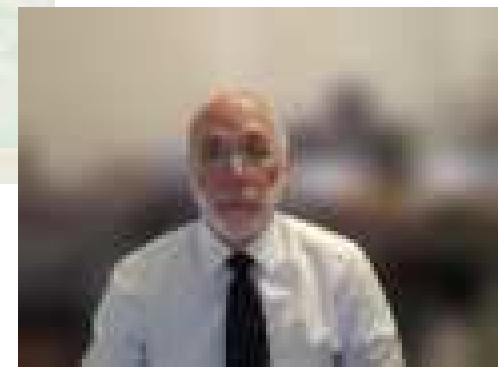
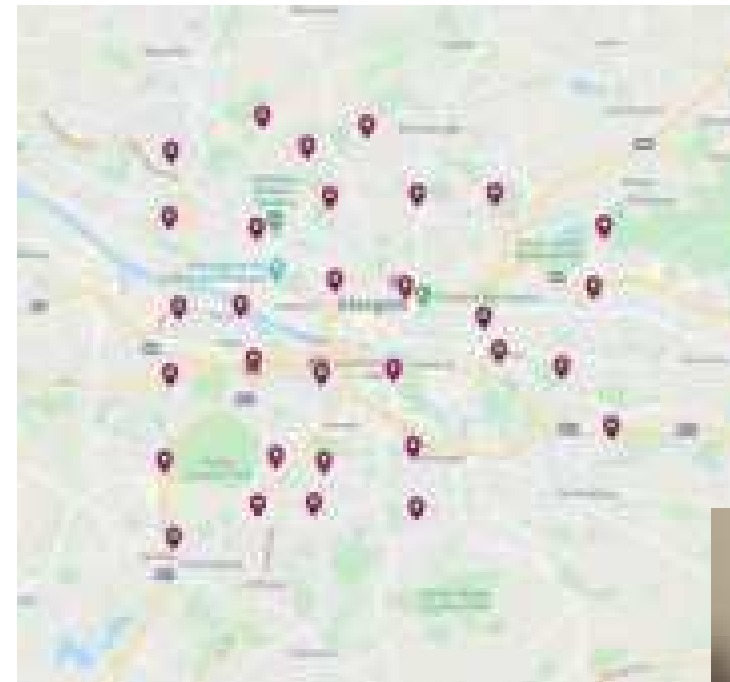
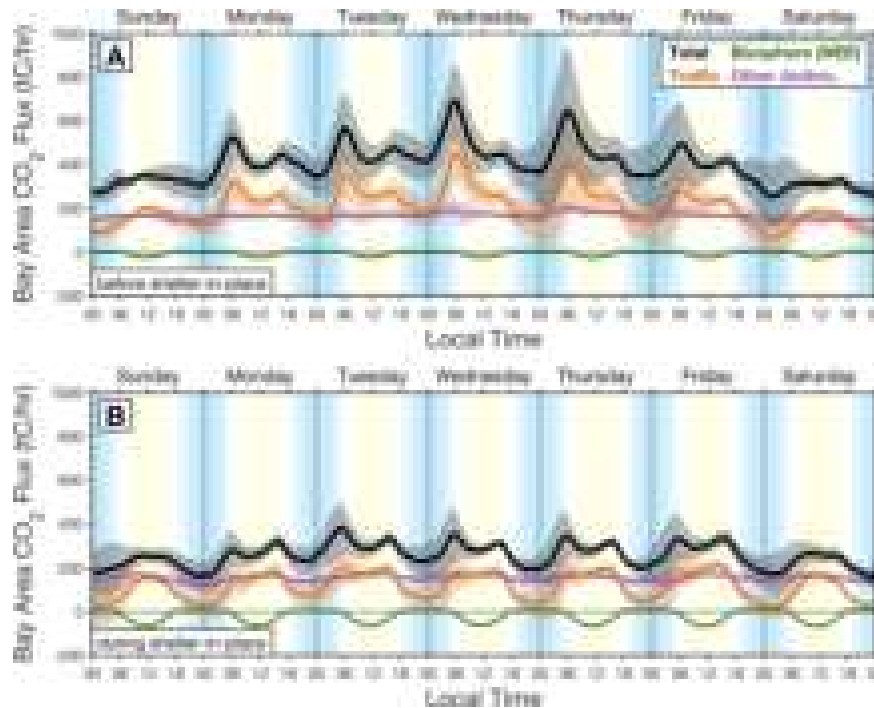
4 to 14 November 2001

Glasgow, Scotland, UK

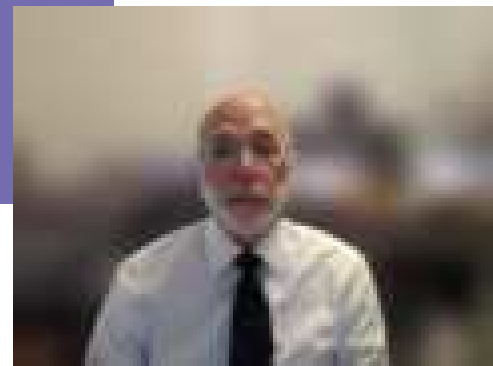
World Time

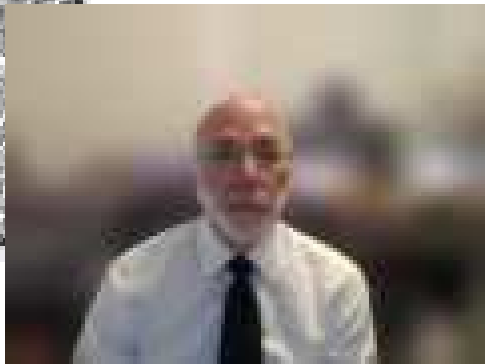


UN Climate Change Conference (UNFCCC COP 26)

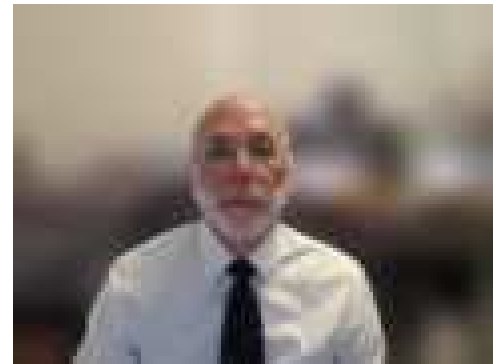
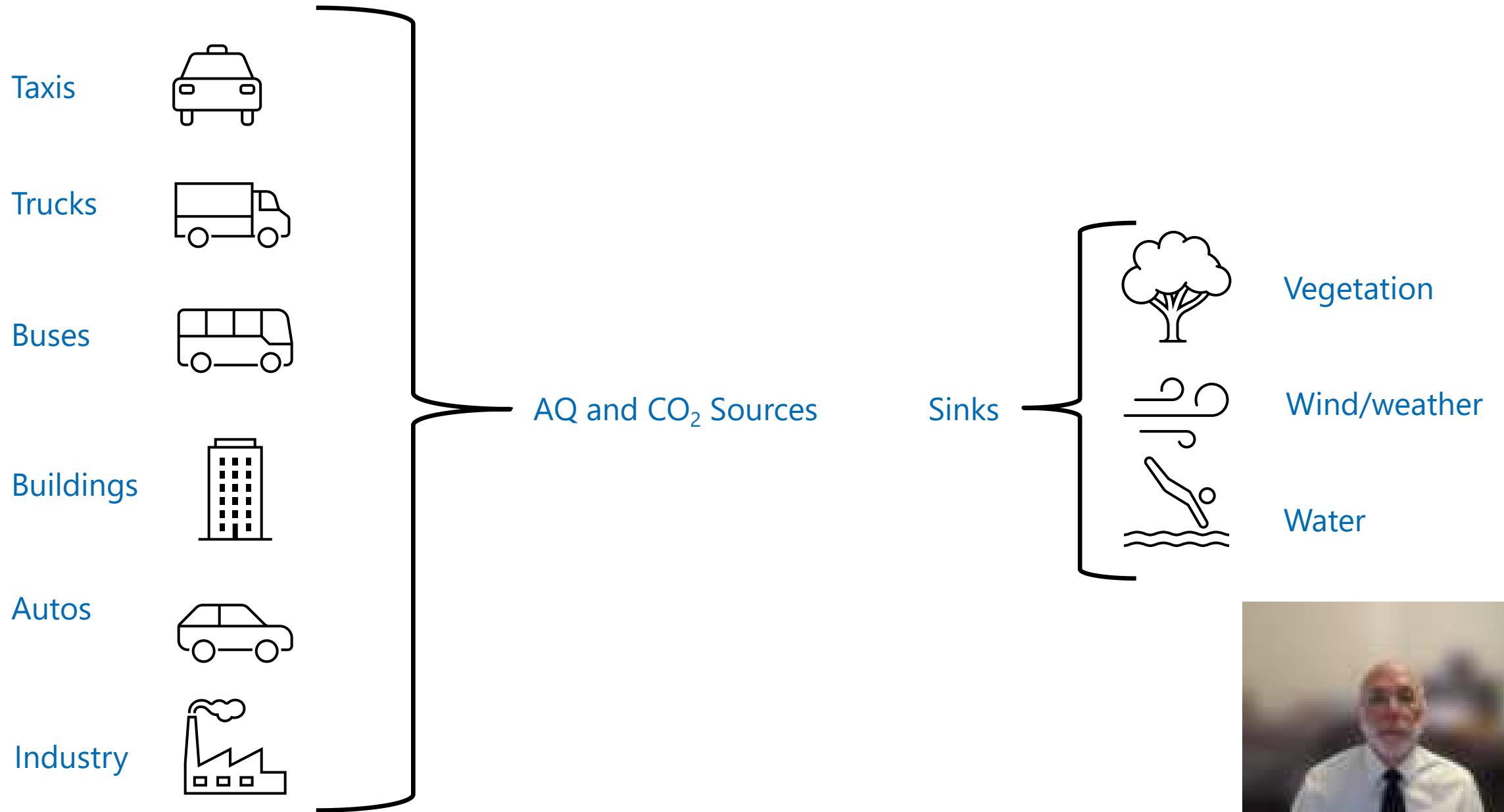


Glasgow city low emission zone





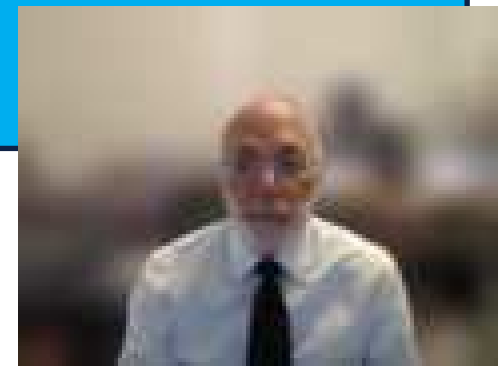
Glasgow city operations impacted by low emission zones



Evidenced based policy decisions

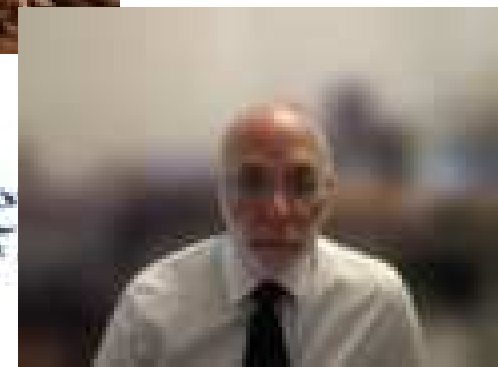
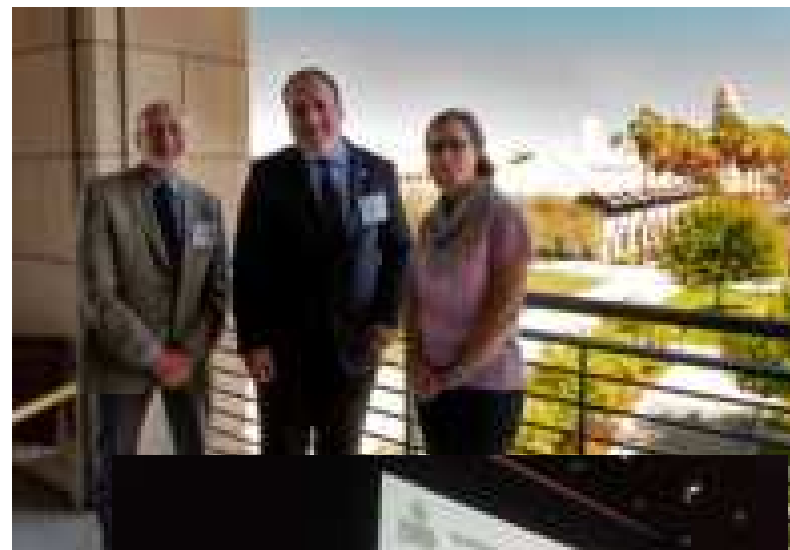


Department of Economics
Fraser of Allander Institute (FAI)



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, CO₂
 - 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

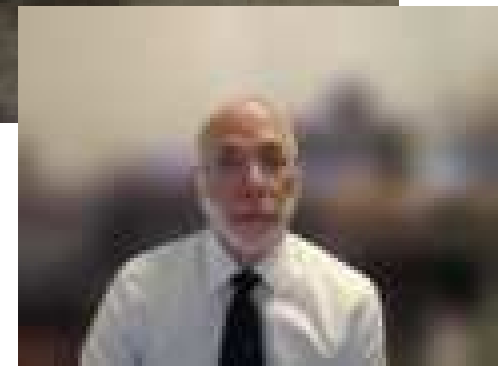




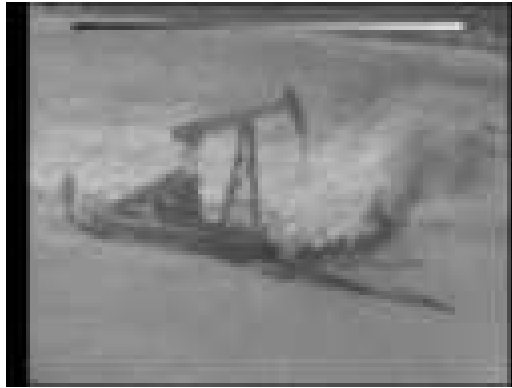
Louise Bedsworth
State of California



Paul Wheelhouse
Scottish Government Minister



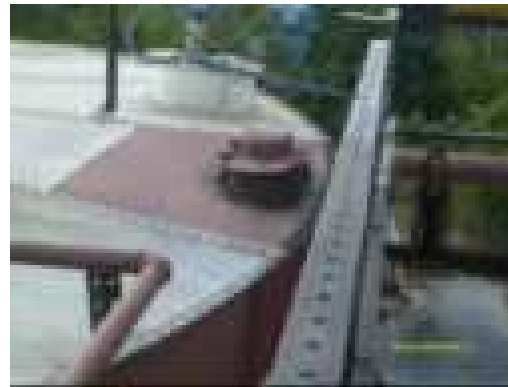
Methane Leakage From Oil and Gas Fields Infrared Imaging



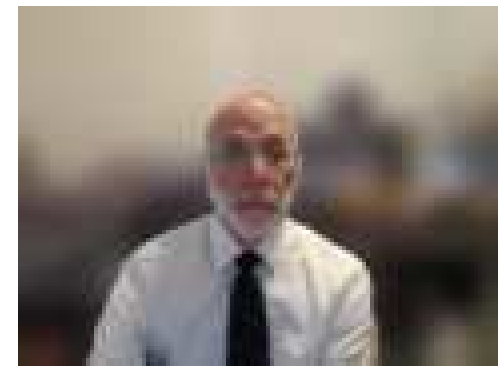
Well Head



Tank Venting

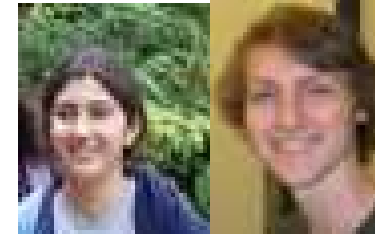


Leaks



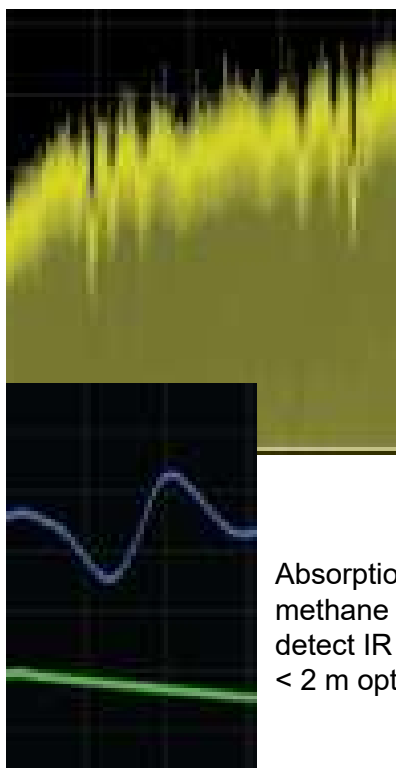
Diode lasers monitoring atmospheric methane

L. Hollberg group, Dept. Physics



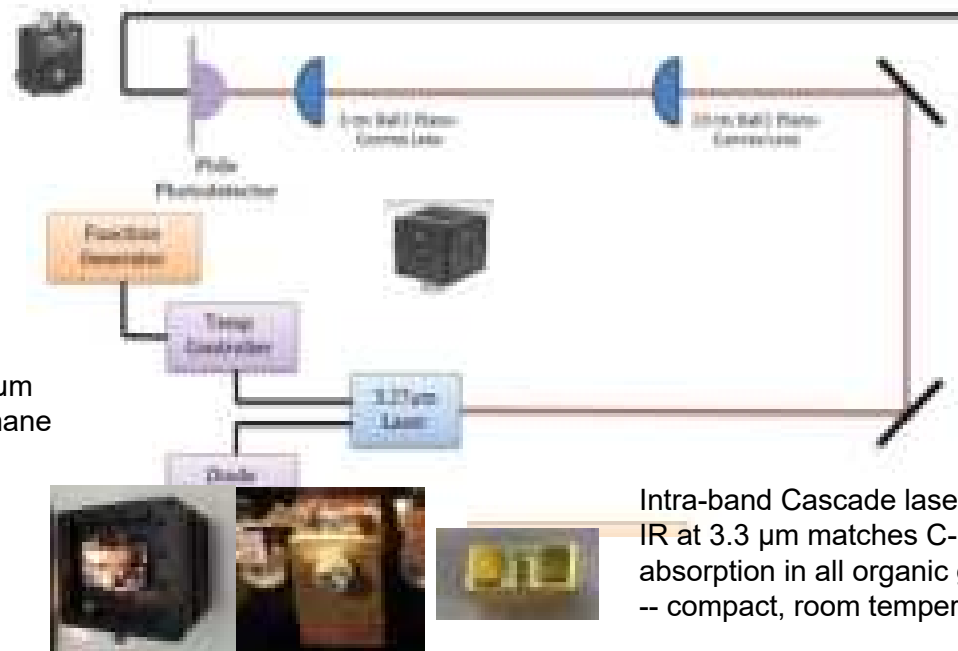
Powerful sensing capabilities provides new tools for:

- Hydrocarbon sensing, monitoring, exploration, leak detection, safety
- Environmental monitoring, greenhouse gases and trace-gas monitoring
- Compact free-space sensors
- Accurate measurements of atmospheric CH₄ are feasible and practical with IR diode lasers



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

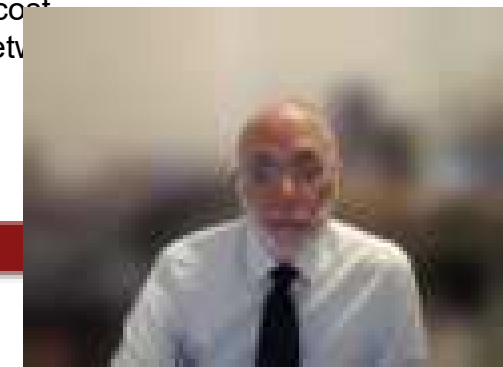
Absorption signal from methane in air ≈ 1.8 ppm detect IR absorption in < 2 m optical path



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, network
- Potential for large market and economic pull
- Generate key data for climate modeling
- Is there a Political will in the U.S. ?

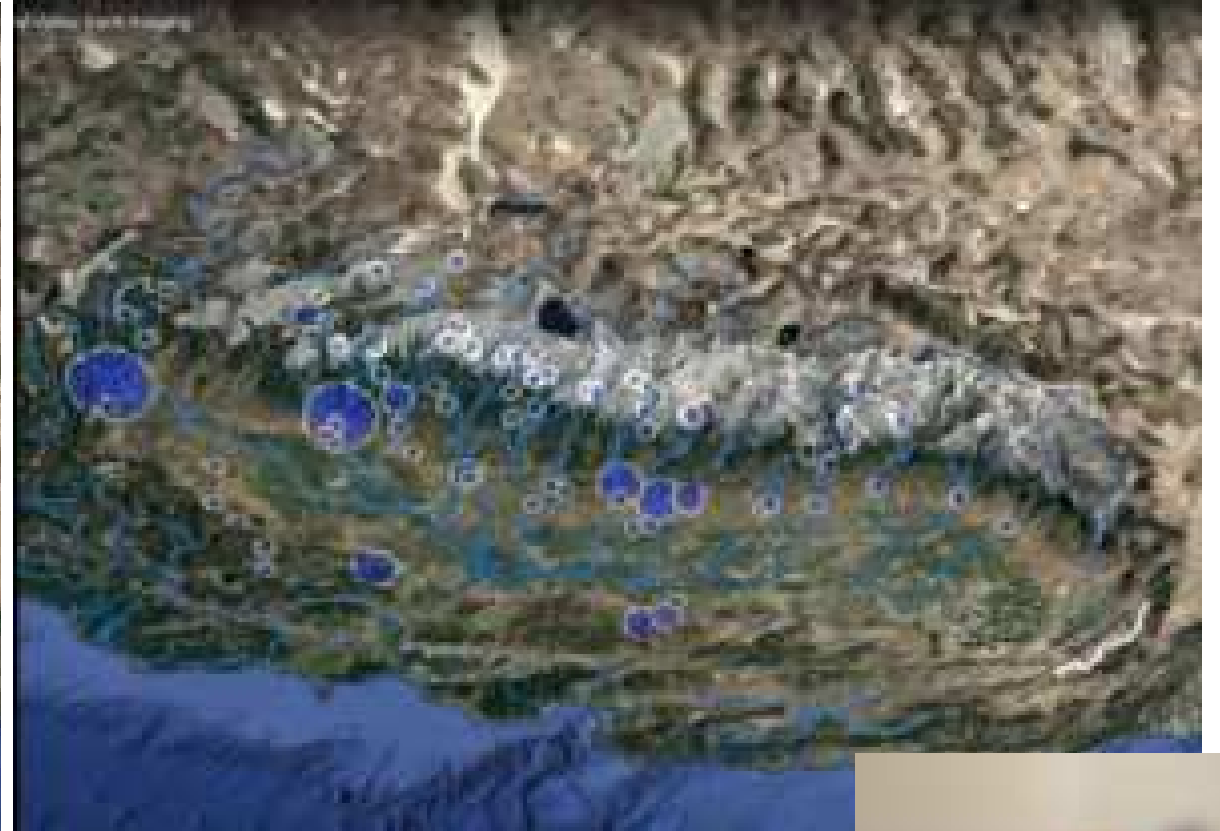


California Fresh Water Supply

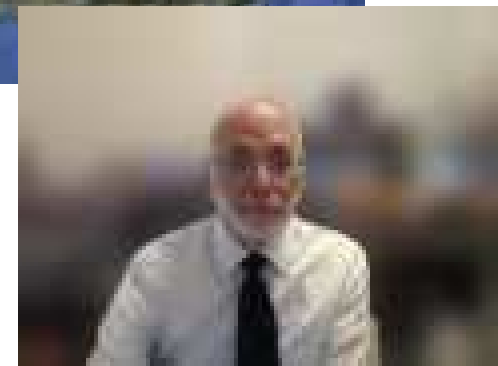
Sierra snowpack



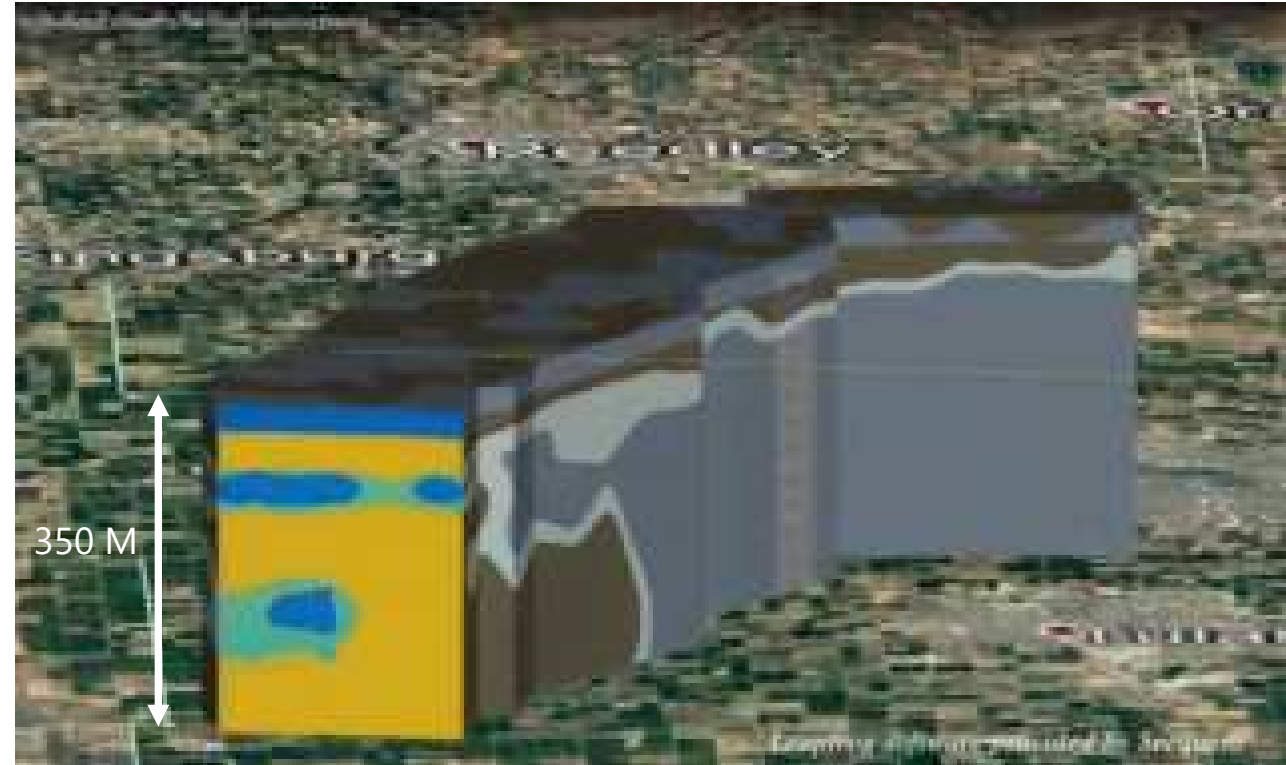
Spring runoff and reservoirs



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

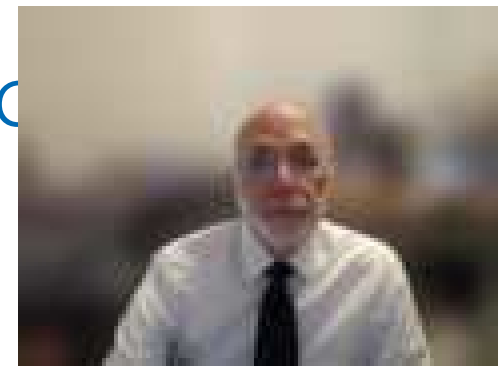


Airborne Electromagnetics Ground Water Sensing Systems



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*



Several miles' or more from their fields, the valley's water comes to the state via about 100 miles of pipelines from the Central Valley of California and Mexico. It's a costly process of engineering.

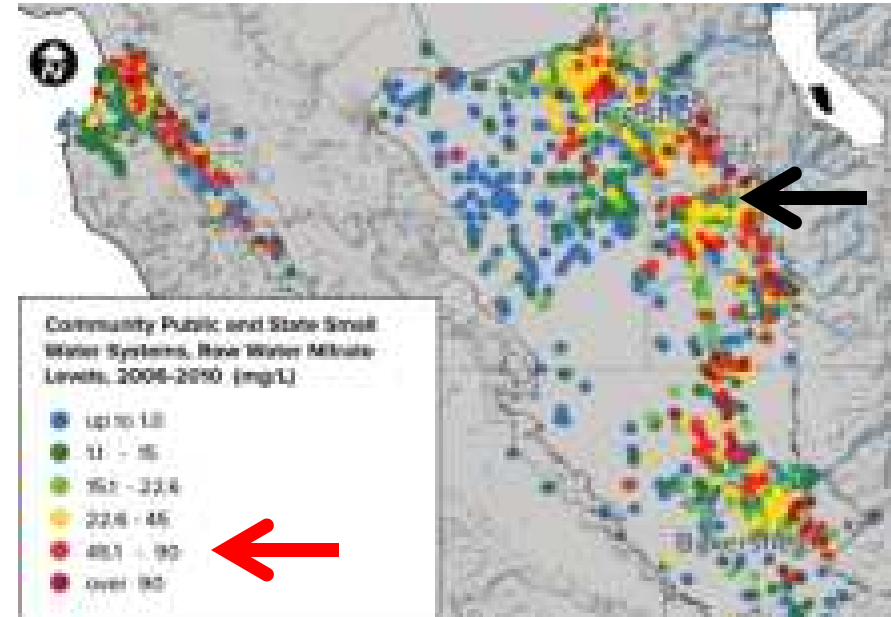
By Ken Johnson

Feb. 12, 2014



EAST ORANGE, Calif. — Water is a currency in California, and the low-income farmworkers who pick the Central Valley's crops know it better than anyone. They labor in the region's wildest patches, made possible by sophisticated irrigation systems, but at home their faucets spew toxic water tainted by arsenic and fertilizer chemicals.

Nitrate in Public Small Water Systems



EPA limit

WATER IN THE WEST
 STANFORD INSTITUTE FOR THE ENVIRONMENT
 THE PAUL L. LACEY CENTER FOR THE AMERICAN WEST

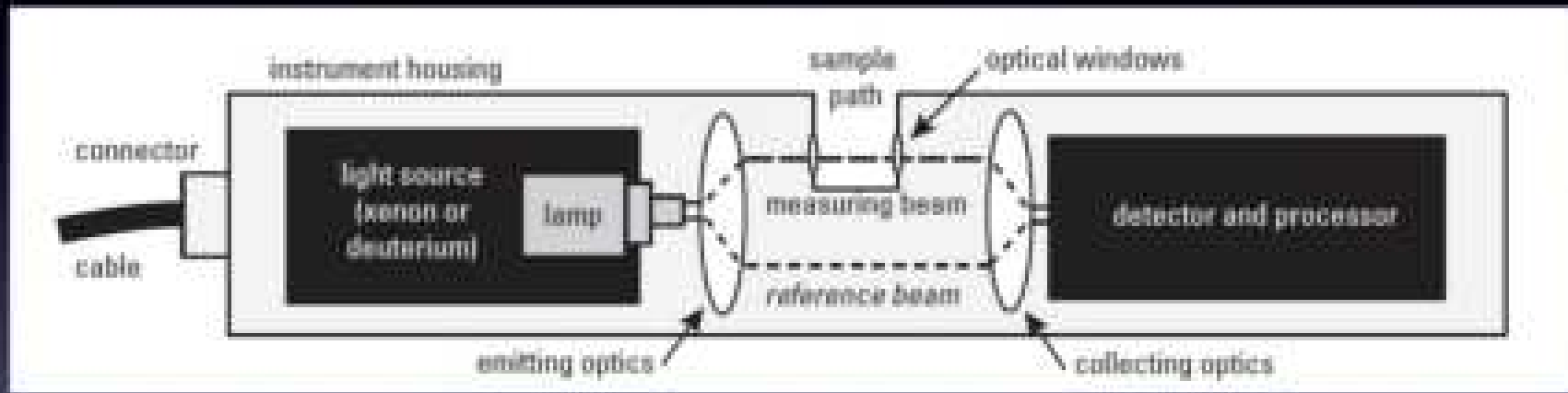
Understanding California's Groundwater

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



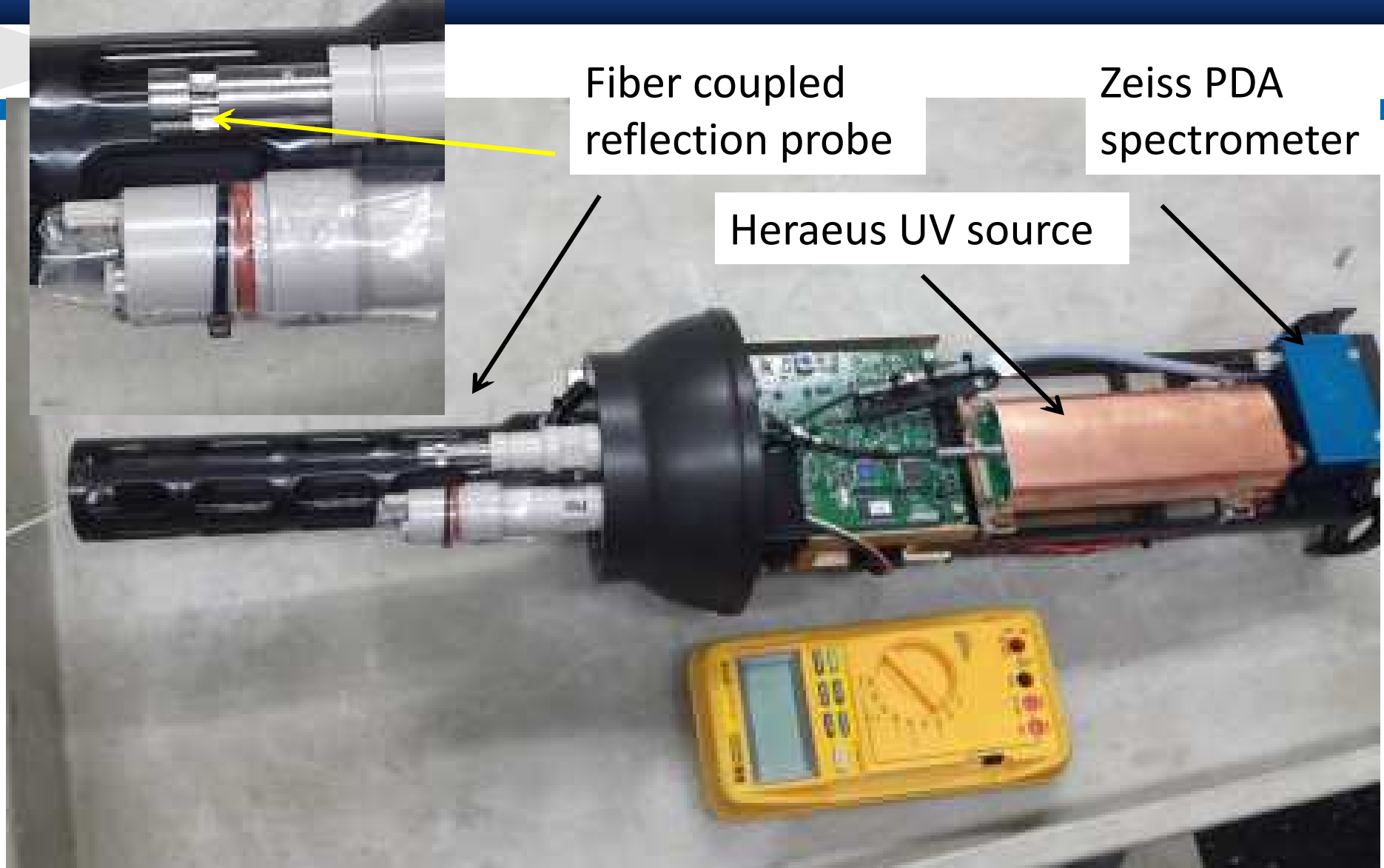
(courtesy of Ken Johnson MBARI)

Instrument schematic



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

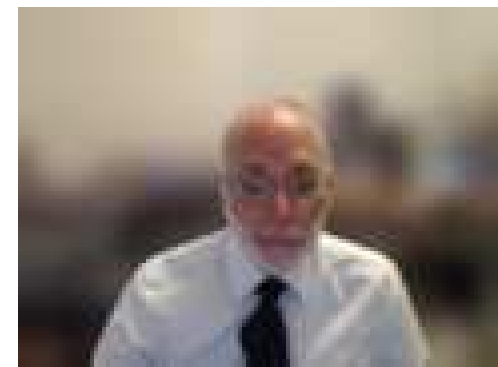
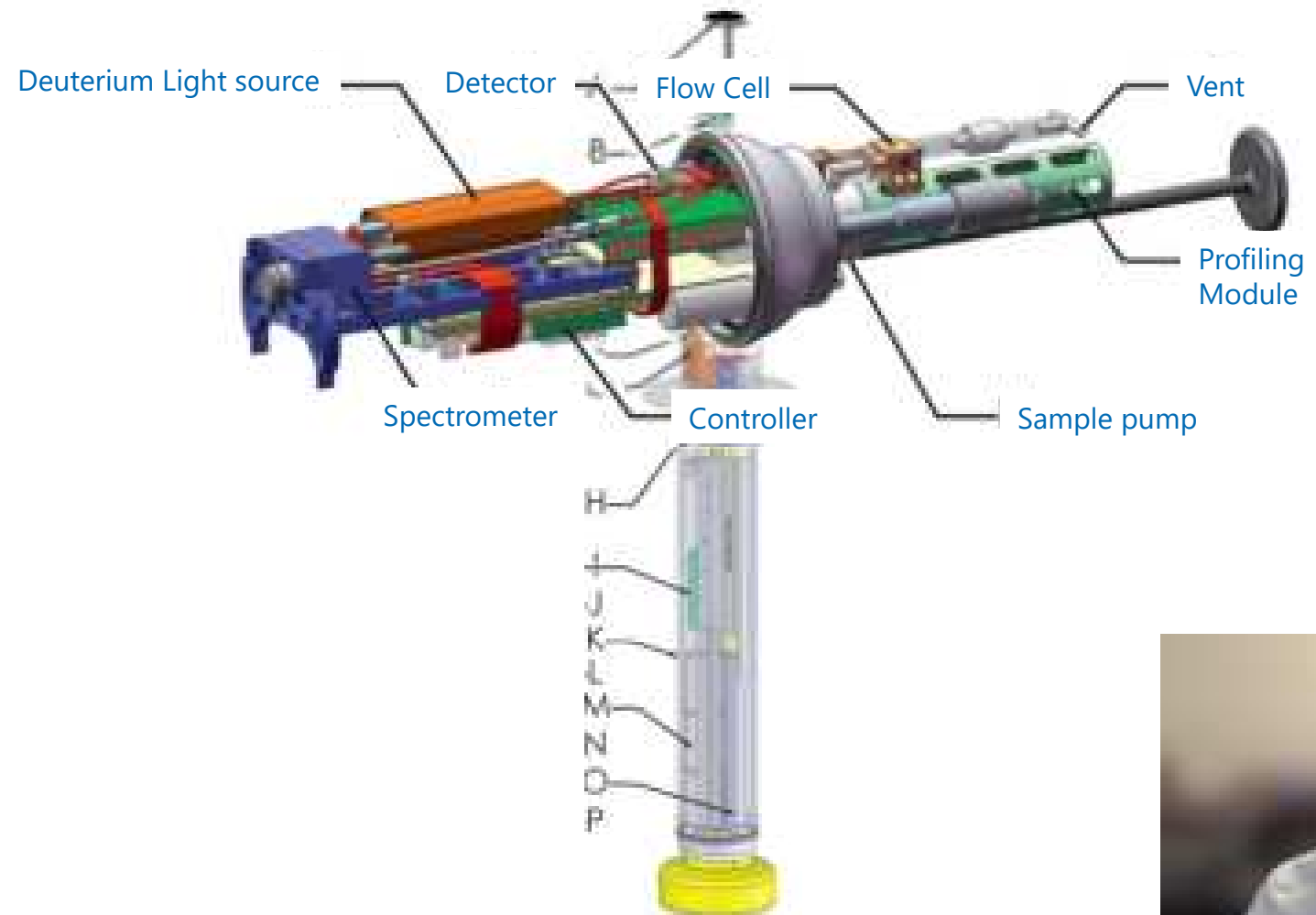
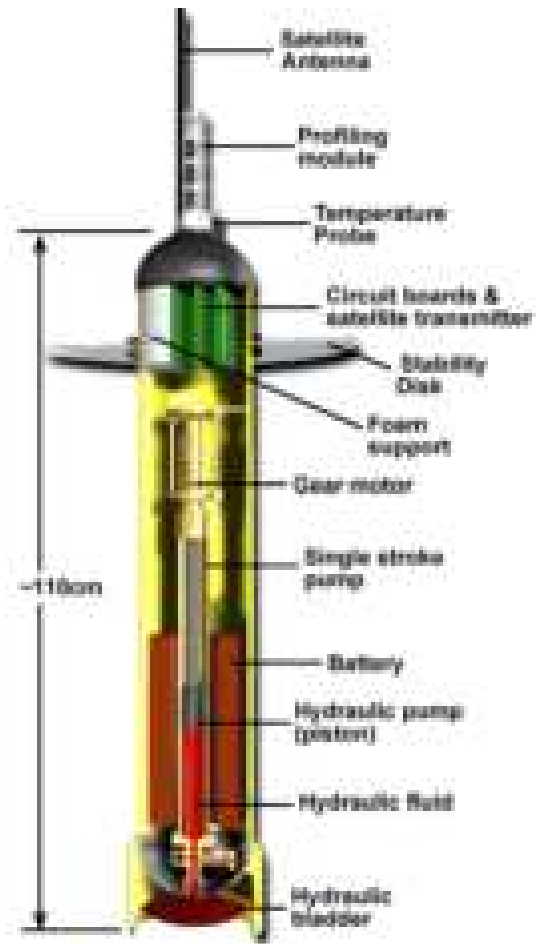




(courtesy of Ken Johnson MBARI)



UV Absorption Nitrate Sensor in the ARGO Ocean Float



ARGO Floats Supply Critical New Data for Ocean Models



Argo

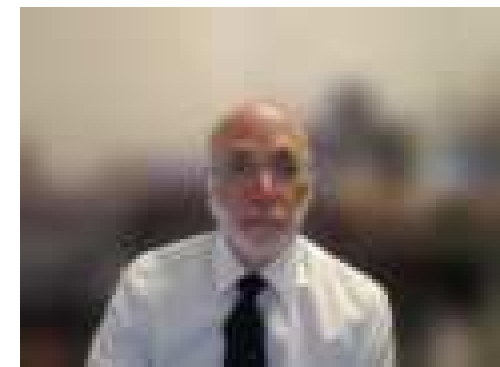
National contributions - 3829 Operational Floats

April 2016

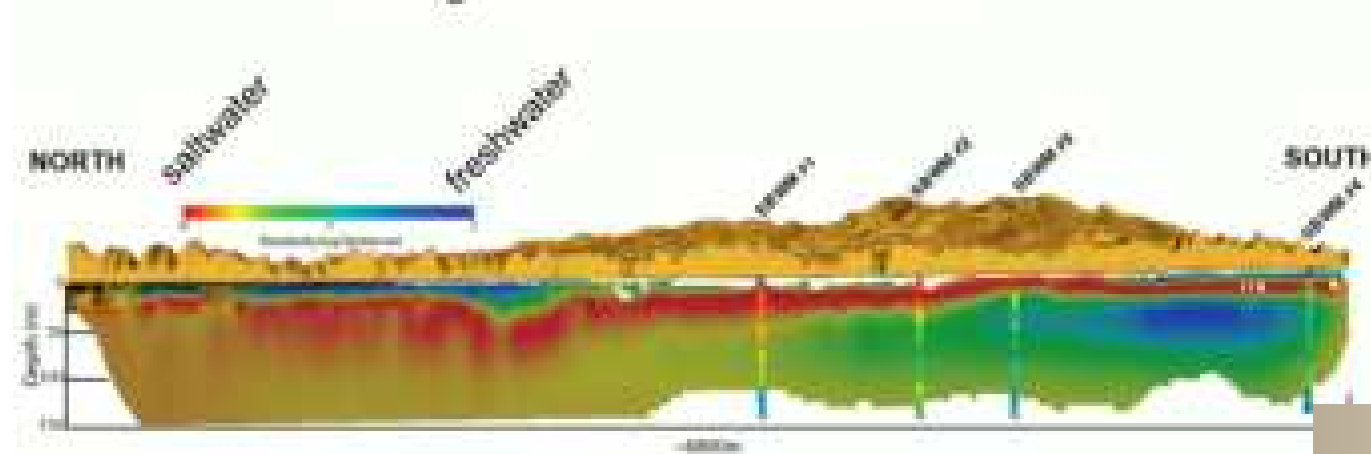
(Latest location of operational floats (data distributed within the last 30 days))

• ARGENTINA (2)	• CHINA (148)	• GERMANY (118)	• JAPAN (198)	• NETHERLANDS (12)	• SPAIN (8)
• AUSTRALIA (388)	• ECUADOR (2)	• GREECE (7)	• SENEGAL (1)	• NEW ZEALAND (2)	• TURKEY (2)
• BRAZIL (19)	• EUROPE (8)	• INDIA (124)	• SOUTH KOREA (22)	• NORWAY (16)	• UK (134)
• BULGARIA (2)	• FINLAND (5)	• IRELAND (16)	• MAURITIUS (2)	• POLAND (2)	• USA (2128)
• CANADA (26)	• FRANCE (228)	• ITALY (46)	• MEXICO (2)	• SOUTH AFRICA (1)	

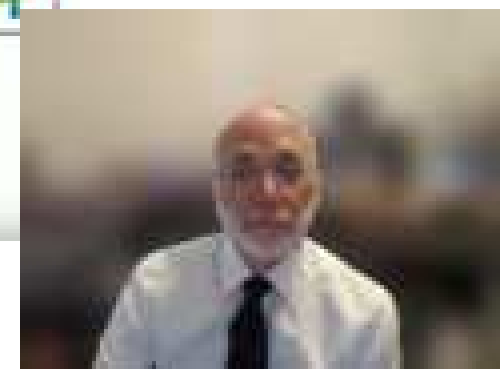
(Retrieved from www.argo.ucsd.edu, 08/03/16)



Saltwater Intrusion Imaging on the California Coast



Shows the distribution of saltwater and freshwater to a depth of -150 m.



GEMM centers in Canada

- ▶ University of Edmonton, NRC Canada, Canadian environmental ministries, University of Laval
- ▶ GEMM centers focusing on the Arctic 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





**Monitoring Greenhouse Gas Emissions &
Water Quality in Western Canada**

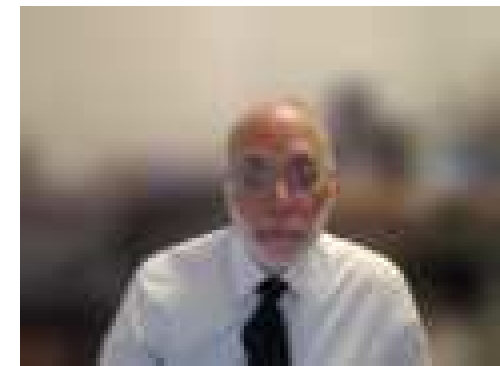
Held 22 June 2020

Workshop Report

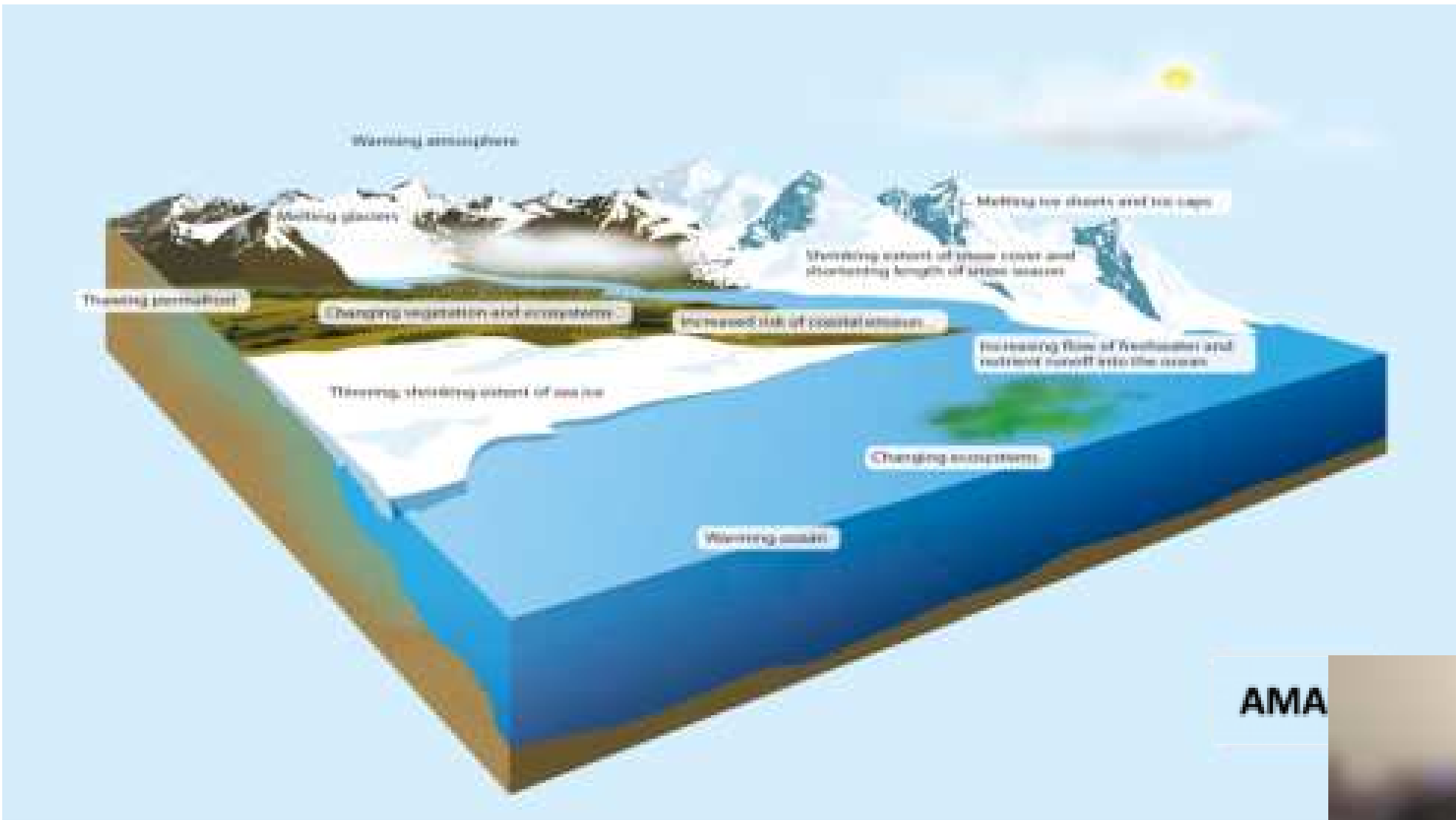
of the Global Environmental Measurement & Monitoring (GEMM) Initiative,
an international project of
The Optical Society (OSA) and the American Geophysical Union

Report issued 17 August 2020

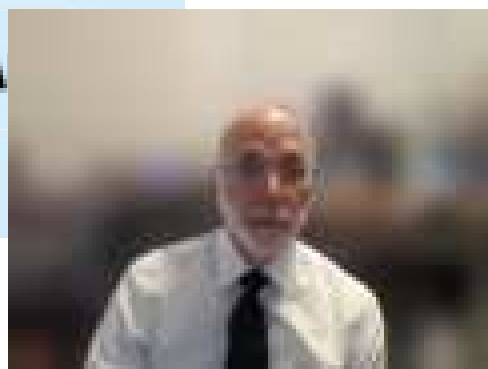
- Martine Dubuc*, Associate Deputy Minister of Environment and Climate Change Canada (Boucherville, GEMM Canada)
- Cecile Siewe*, Director General of Canmet ENERGY at Natural Resources Canada (GEMM Canada)
- Heather McCready*, Director General of Environment and Climate Change Canada (GEMM Canada)
- Geneviève 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



AMA



(Courtesy Martin Fortier, Sentinel North, Université Laval)

What happens in Canadian Territories has Global Impact

Global consequences: Changes in the Arctic have the potential to affect many aspects of the Earth system



Global heat balance



Mid-latitude weather



Sea level rise
(total Greenland ice = 7.2 m rise)



Permafrost CO₂ and CH₄ release
(permafrost-C = 2X atmospheric)

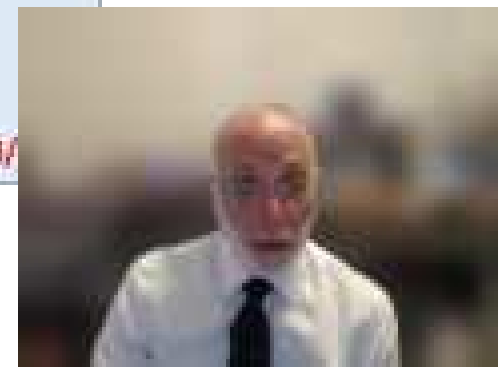


Meltwater effects on
global ocean circulation



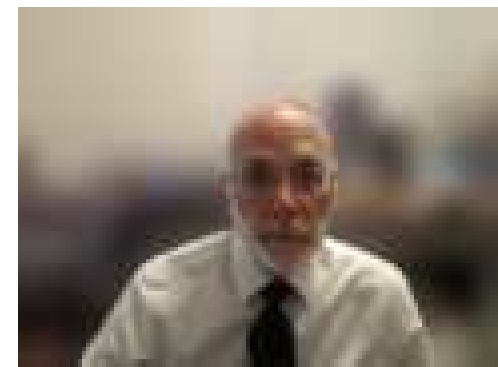
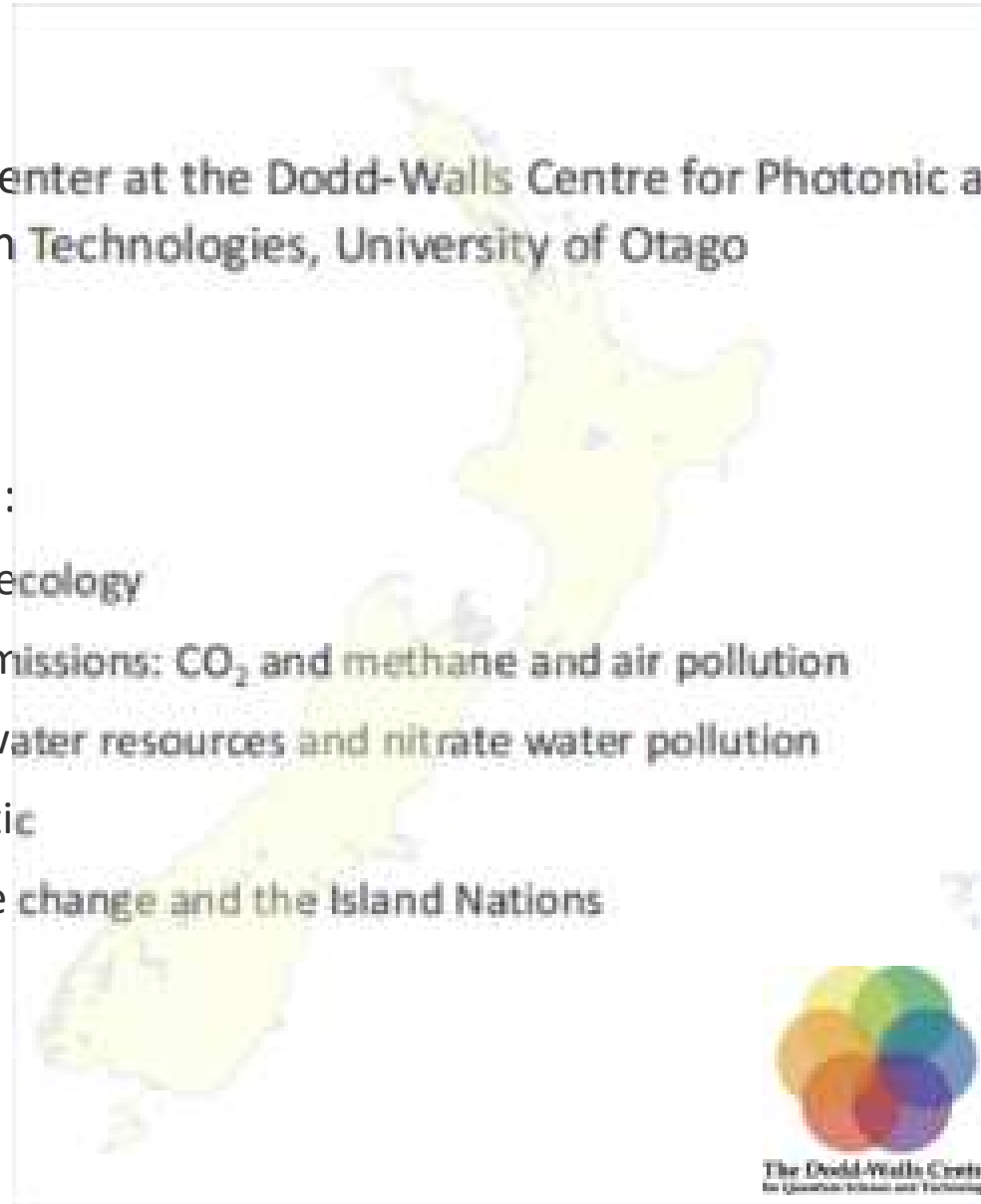
Shift in global trade routes

SLIDE 6/



New Zealand

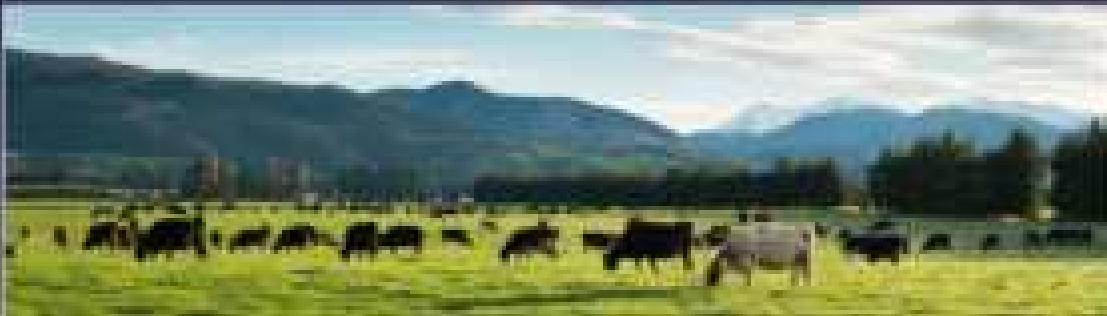
- ▶ GEMM center at the Dodd-Walls Centre for Photonic and Quantum Technologies, University of Otago
- ▶ Focus on:
 - Ocean ecology
 - GHG emissions: CO₂ and methane and air pollution
 - Fresh water resources and nitrate water pollution
 - Antarctic
 - Climate change and the Island Nations



Nitrate pollution and groundwater resource in NZ

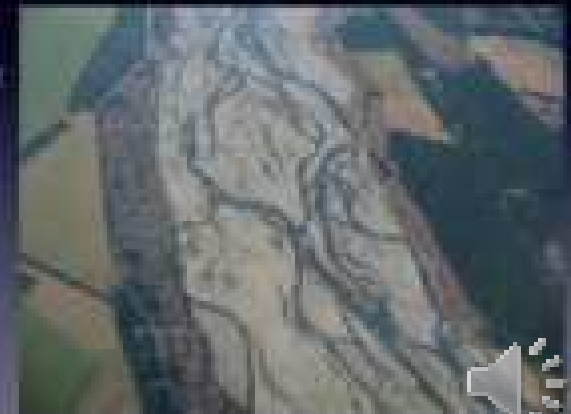
The Future of Freshwater in NZ

- 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



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



Economic analysis of water use and climate change in Scotland

Environmental Science and Policy 134 (2023) 48–57

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/escpa

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

Grant J. Allan^{a,*}, Scott J. McGrane^{b,1}, Graeme Roy^a, Thomas M. Baer^b

^a Fraser of Allander Institute and Department of Economics, University of Strathclyde, Glasgow, United Kingdom

^b Applied Physics, Stanford University, Palo Alto, CA, USA

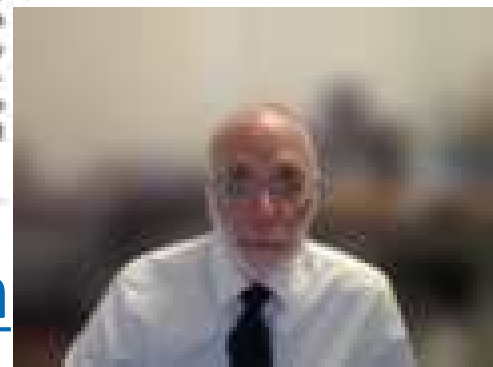
ARTICLE INFO

Keywords:
Industrial water use
Input decomposition analysis
Economy-wide analysis
Scotland

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 province-level dataset in economic indicators at industrial/service 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 to 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



GEMM Asia Summit Singapore, December 5-6, 2022

Organizing Committee:

Chair: Tomohiro Oda, PhD
USRA Earth from Space Institute Senior Scientist
University of Osaka, Visiting Researcher

Host: Jolene Lin, PhD, LLB
National University of Singapore
Director, Asia - Pacific Centre for Environmental Law

Wei Wan, PhD
Peking University School of Earth & Space Sciences,
Institute of Remote Sensing & GIS

Ling Li, PhD
Westlake University
Environmental Hydrology Chair Professor
Centre for Environmental Research

Yugo Kanaya, PhD
Kobe University
Graduate School of Maritime Sciences

Jeongsoon Lee, PhD
Korea Research Institute of Standards and Science
Principal Scientist

Julian Taylor
University of Strathclyde
Managing Director of International Operations



GEMM Asia Summit

ACTORIAL SCIENCE FOR LOCAL IMPACT

The Asia Environmental Movement, a regional GEMM activity, is a joint international initiative of AGU and the National Geographic Society (NGS) working to provide reliable and quality environmental data and insights to aid government officials in assessing the local impact of climate change.

We are bringing together a diverse mix of 50 scientists, technologists and practitioners from across Asia – representing academia, industry, and government – to discuss advances in environmental monitoring and assessment and the key climate change challenges facing government and industry.

DEBATE TOPICS:

- Examine the current status of environmental monitoring and modeling of regions to measure where additional data are required to meet these needs;
- Identify opportunities and challenges in integrating ground-based environmental data;
- Explore strategies to promote regional environmental monitoring, including data and model integration;
- Examine ongoing discussions about regional environmental priorities, including a cross-regional group of researchers, technology developers, industry leaders and government;
- Explore opportunities for collaboration with existing GEMM activities, regional partners, and other GEMM activities, including AGU and other regions.

The Summit will be held in person, by invitation only, at the National University of Singapore on 5-6 December 2022 with video conferencing available for remote participation.

For more information, please contact Jolene Lin (jolin@nus.edu.sg) and Julian Taylor (julian.taylor@strath.ac.uk) and team@agumonitoring.com



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Advancing Optics and Photonics Worldwide



AGU ADVANCING
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Information: dlang@optica.org

