Continuous measurements of water and carbon isotopes:
Tools to minimize maritime and coastal vulnerabilities
and maximize awareness
(Integrating primary-secondary-tertiary systems)

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Holes in security and awareness

- Sea ice distribution & properties
  - **Satellites** - once every 24 hrs
    - 99% of the time no data
    - Clouds, darkness, data-model fusion create uncertainty
  - Shore-based **camera systems**
    - Limited in range, fog obscures images, malfunction

- Oil/diesel spill detection
  - Detection limited by visual clues - ship wake and turbulence
  - Fuel gauge calibration and sensitivity is low
  - Ocular observations limited by other ships, kayaks, commercial and sport fishing in the vicinity

- Detection of non-commercial small aircraft (smuggling)
  - Low altitude flights below radar are common and unrecorded

- Oil Platform emissions and discharges
  - Emissions and spill below the surface are difficult to immediately detect
Strengthening M&C awareness

- Real-time continuous measurements
- Place-based measurements that provide internet accessible data for real-time/near real-time processing and visualization development
- Data sets that complement other programs and fill in holes of security (secondary or tertiary information)-Boy Scouts
- Variables that can provide important analogs to other sensing devices and that can be calibrated with primary data sets
  - Sea ice scores/categories vs. water vapor isotopes ($\delta^{18}\text{O}/\delta^{2}\text{H}$, d-excess)
  - Petroleum (oil/diesel fumes) products and $\delta^{13}\text{C}$-$\text{CO}_2$ and $\delta^{13}\text{C}$ of $\text{CH}_4$
Isotope-atoms of same element-
additional number of neutrons

$^{13}\text{C}/^{12}\text{C},\quad ^{15}\text{N}/^{14}\text{N},\quad ^{18}\text{O}/^{16}\text{O},\quad ^{2}\text{H}/^{1}\text{H},\quad ^{34}\text{S}/^{32}\text{S}$

*Isotope jargon*

Depleted compared to the standard

$\delta=0\quad$ Enriched compared to the standard
Figure 7.15 Variations in Carbon Isotopes

- Fossil fuels
- Freshwater $\delta^{13}$C
- Marine organic C
- Land plants
- Atmospheric $\delta^{13}$C
- Soil organic C
- Limestones
- Shallow ocean $\delta^{13}$C
- Biogenic methane
- Soil $\delta^{13}$C
- Volcanic $\delta^{13}$C
- Deep ocean $\delta^{13}$C

$\delta^{13}$C %

(after Trumbore and Druffel, 1995)
Multiple processes define the hydrological cycle and several processes are temperature dependent—evaporation, condensation, and precipitation. Precipitation is the foundation of the hydrologic cycle and has applications to all aspects of water resource use. Its geochemistry is recorded in climate proxies and it controls in large part the C and N cycles.
Classic Dansgaard study in 1964 depicting temperature controls on the $\delta^{18}O$ values of precipitation. However, it was a space for temperature substitution (i.e., spatial)-low temperatures from the Arctic and Antarctic, warm places-tropics. Not a record of interannual variation at one site (i.e., temporal), where confounding variables could be accounted for in the analysis.
Arctic Cyclone Event

~July 24th - 26th, 2013

Alaska

Toolik

NOAA
deuterium excess (d-excess) = $\delta^{2}H - 8\delta^{18}O$

Source conditions of vapor:
+ Less open water
- More open water
Moisture source:
- More open ocean water (less sea ice)
- Greater atmospheric humidity

\[ \delta^{18}O \]

d-excess

Klein et al., 2015, Sci. Rep
Western vapor source - more open water - Baffin Bay

Eastern vapor source - Greenland Ice Sheet

NW Greenland - NSF AON
Early Season-west winds-N Baffin Bay-partially open water

Early Season-East winds-off of GIS
Sea ice properties/ NOAA, NWS
Mapping and sea ice concentration

http://portal.aoos.org/?v=rand&portal_id=3#map?lg=a5b58402-a9c1-11e3-a3fe-00219bfe5678&z=4&ll=67.67440%2C-137.12647
Ocean Productivity-Chlorophyll Concentrations

Satellite ocean color measurements of the Bering and Chukchi seas are often prevented by cloud cover in winter/spring, but for several days in June, 2013, the seas were unusually free of obstruction. VIIRS collected this view on June 19/20 (Alaska/110W).

Click on the image above to see a broader region at higher resolution.

NASA Collaborations

http://oceancolor.gsfc.nasa.gov/cms/
Methane measurement instrument on Helmer Hanssen on May 21, 2014 in Measurement activities by Adam Durant

NILU scientists Adam Durant and Ove Hermansen spent a week onboard the University of Trømso research vessel "RV Helmer Hanssen" as part of the MOCA project. The purpose of the trip was to install instrumentation for measuring methane in the atmosphere over the Arctic Ocean, in preparation for a summer campaign to determine if gas emissions from methane hydrates at the ocean floor are reaching the atmosphere.
Accomplishments:
- Converted liquid water isotope NSF Picarro to a water vapor Picarro (aka Pippen)
  - Added a required standard delivery module and vaporizer
- Arranged Port of Anchorage Collaboration to house Pippen
- Operational with in 20 days of “go”, March 18 first collection until 15 June (temporary transfer to Healy)
- Established real-time data access and transfer via Ethernet portal in conjunction with Muni of ANC
4 week data file of $^{18}$O, $^2$H and d-excess from Pippen was used to develop initial visualizations with GeoNorth & Axiom
- Simple footprint model based on wind speed and direction (data)
- Ocean vs. land differences

Sea ice period too short to develop sea ice conditions/water vapor isotope correlations-Year long 2015-2016 will allow this

Port of Anchorage Educational program contributions and development
Accomplishments

- Healy R&D Cruise (2 July to 25 July)
  mobile real-time sea ice and oil detection testing
- Secured $^{13}\text{C}$ Picarro (on short term loan) from UIC
  Calibrated via INSTAAR collaborations
- Bench tested and prepared for shipping to Kodiak
- Pippen removed from Port, and upgraded for Healy mission
- Contacts with NASA Ocean Observing members-Gene and Norman
- Contacts with the Ocean Acidification community, Taro at Lamont
- Journalist contact and pre-trip discussion/explanations Al Jazeera-America-Laura LeBlanc
- Alaska Dispatch News R&D Healy coverage-Yereth Rosen
Milestones

- Operational at the Port of ANC for 100 consecutive days, before temporary decommissioning for Healy R&D cruise
- Real-time data access and download capacity
- Initial visualizations
- Broad US scientific community partnerships (UIC, INSTAAR, NASA, NOAA, Columbia Univ.)
- Norwegian Institute for Air Research-MOCA (Methane emissions from the Arctic Ocean to the Atmosphere)
Collaborators & Stakeholders

- Cook Inlet Regional Advisory Council – cameras
- NOAA Sea Ice Desk
- Port of ANC personnel
- Municipality of ANC-communications
- Picarro
Gaps and Lessons Learned

- Data collection year-around
- Spatial limitations-larger spatial coverage (Nome, St. Lawrence, Barrow)
- Expanding capacity in the Arctic
- Drone capacity-100,000 miles of coastline without real-time data
- ADAC x Picarro x AeroVironment (Lockheed Martin-small drone)
- Real time data can be reliable, accessible, and powerful visualizations
Demonstration

http://portal.aoos.org/#map?lg=460455ad-a0b7-4dff-8f5d-a3c33a7d3916&z=11&ll=61.19726%2C-149.95445