

# Observing Capabilities

**Presenter:** Taneil Uttal

**Subject Matter Experts:** Paul Johnston, Allen White, Alex Voronovich, Chris Fairall, Gijs de Boer

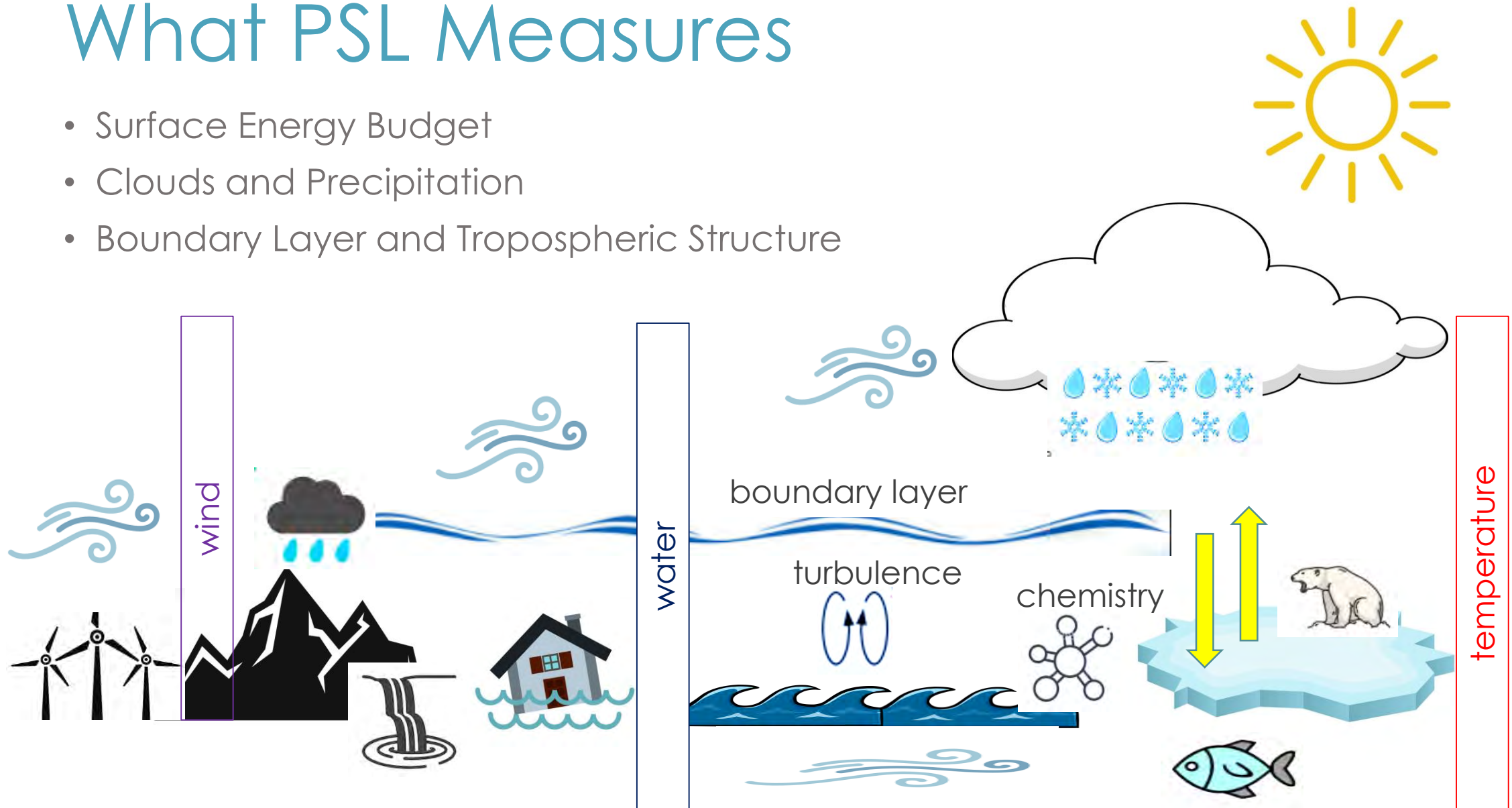


NOAA Physical Sciences Laboratory Review  
November 16-20, 2020



# What PSL Measures

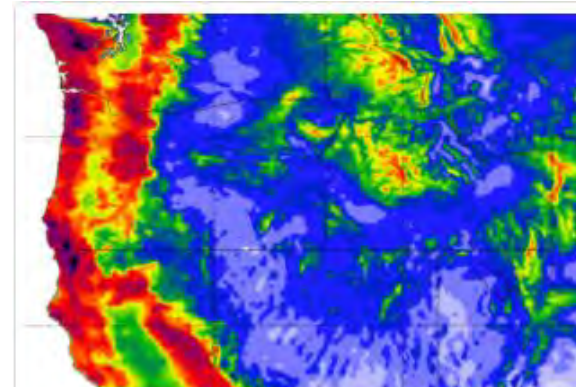
- Surface Energy Budget
- Clouds and Precipitation
- Boundary Layer and Tropospheric Structure



# Observations of Essential Systems:

Air-Sea Interactions  
The Arctic System  
The Hydrometeorological System  
PBL and Tropospheric Structure

Relevant to



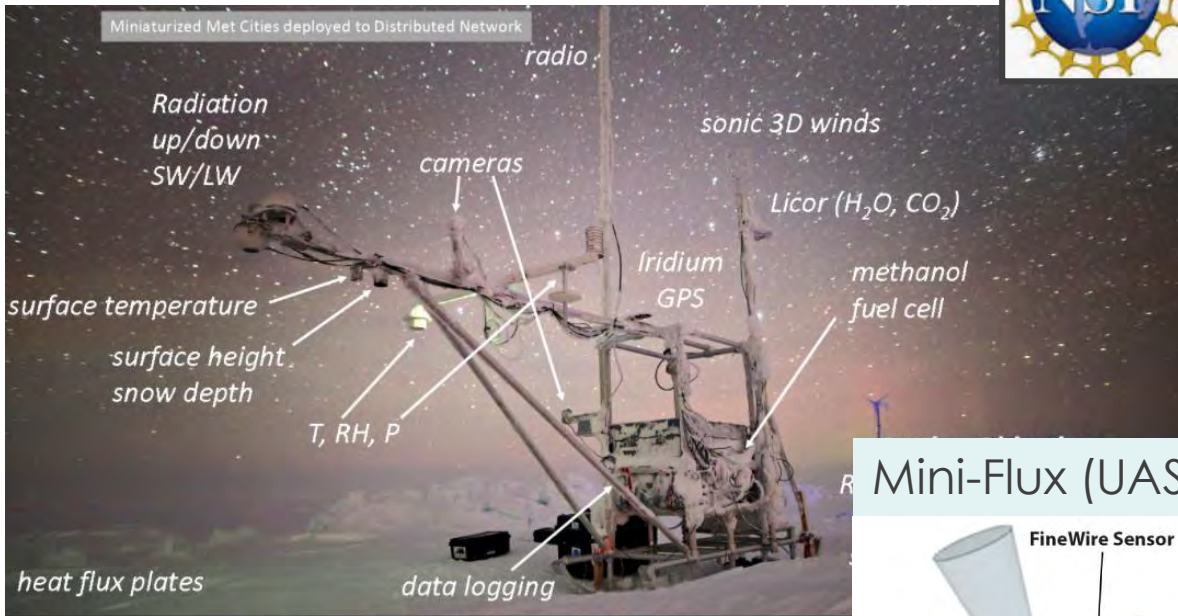
# The PSL “Quiver” of Instruments (Remote and In Situ)

- Cloud radars (W-band,  $K_a$  band)
- Ocean Surface radar (WSRA,  $K_u$  band)
- Precipitation Profilers (pulsed, S band)
- Snow level radar (FM-CW, S band)
- Wind Profilers (449-MHz, 915-MHz)
- Microwave Radiometers
  - 90, 31, 24, 50 GHz
- Sodars
- Ceilometers
- IR Spectrometers
- Cameras
- Acoustic Doppler Current Profiler
- ROSR – Remote Ocean Surface Radiometer
- ASSIST – IR Spectrometer
- Met sensors
  - Temperature sensors
  - Sonic anemometers
  - Rain gauges
  - Disdrometers
  - Barometers
  - Hygrometers
- Broadband Radiometers
  - SW global/diffuse/direct radiation
  - LW radiation
- Radiosonde Systems
- Soil Sensors
  - Moisture
  - Heat Flux Plates
  - Temperature
- Ocean
  - Sea Surface Temperature
  - Temperature
  - Salinity
- Navigation and Stability systems
- Gases ( $\text{CO}_2$ ,  $\text{O}_3$ ,  $\text{CH}_4$ ,  $\text{H}_2\text{O}$ ,  $\text{C}_2\text{H}_6\text{S}$ ,  $\text{CH}_3\text{OH}$ ,  $\text{C}_2\text{H}_2\text{O}_2$ )

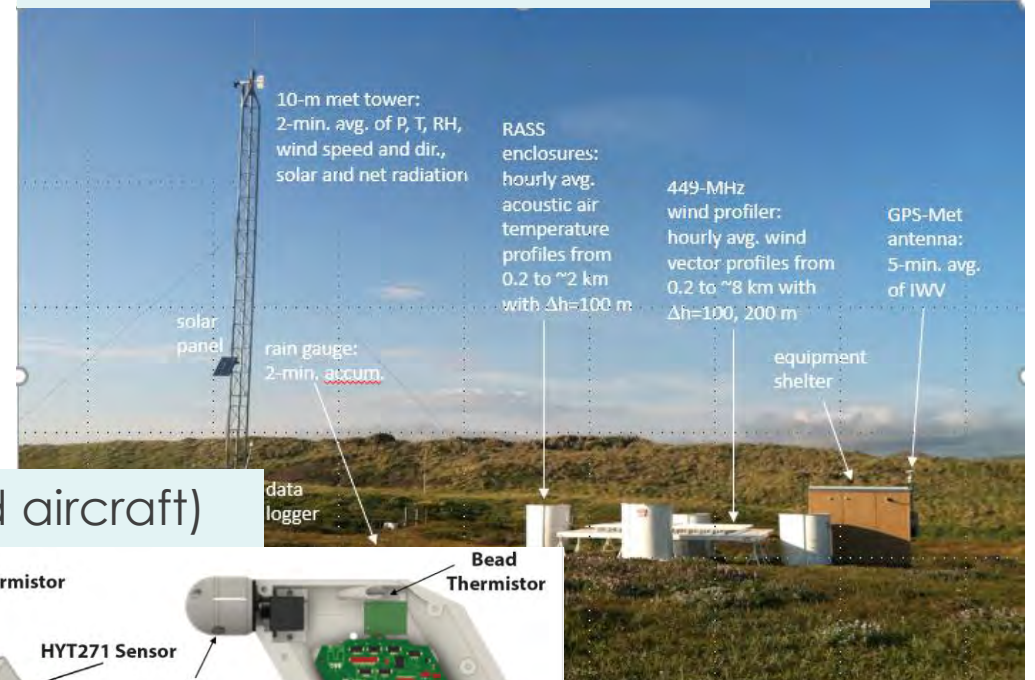


# PSL bundling suites of instruments into integrated systems

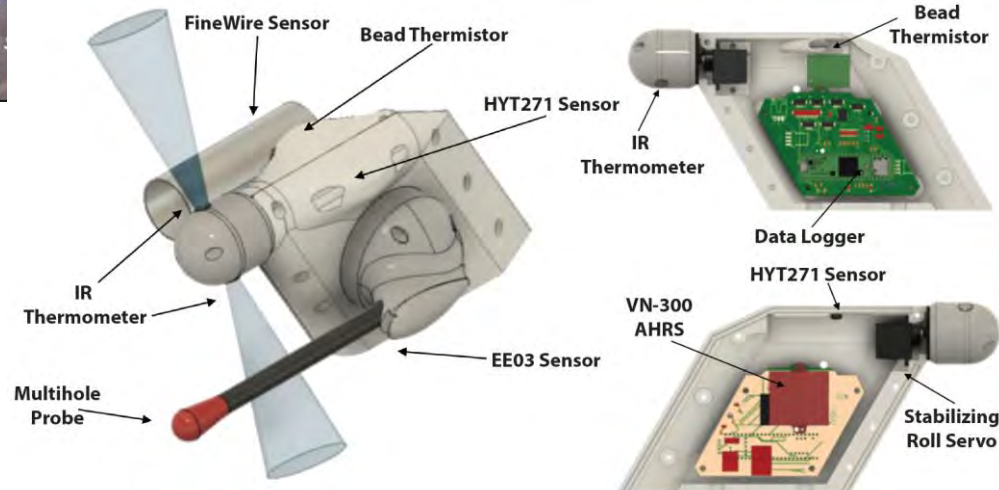
## Atmospheric Surface Flux Station



## Atmospheric River Observatory



## Mini-Flux (UAS and aircraft)



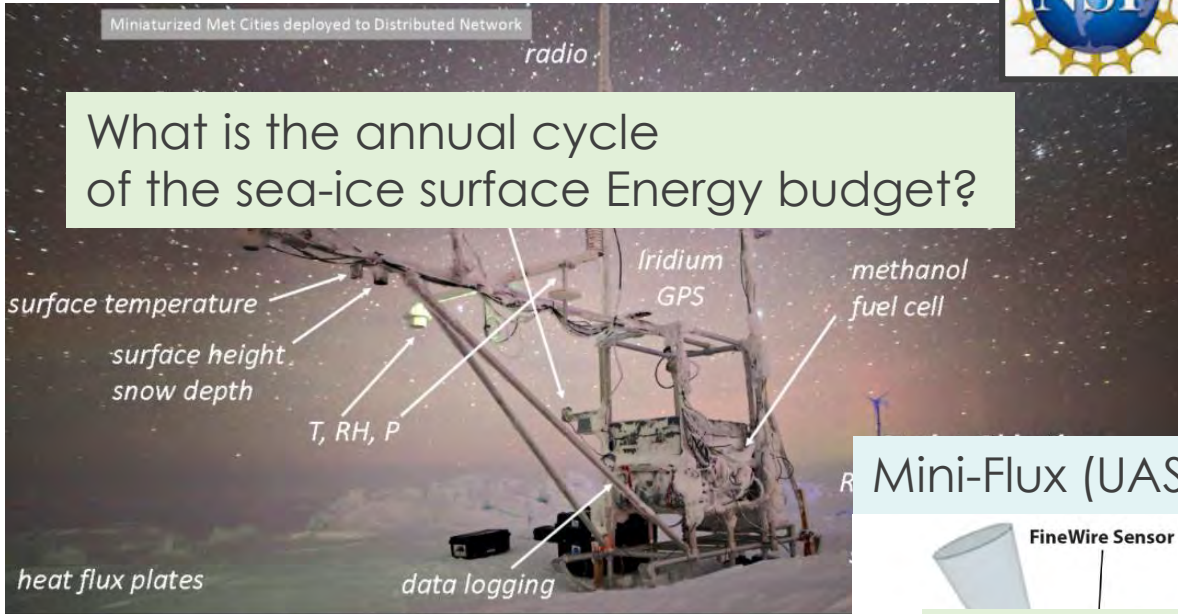
The whole is greater than the sum of its parts.

- Aristotle



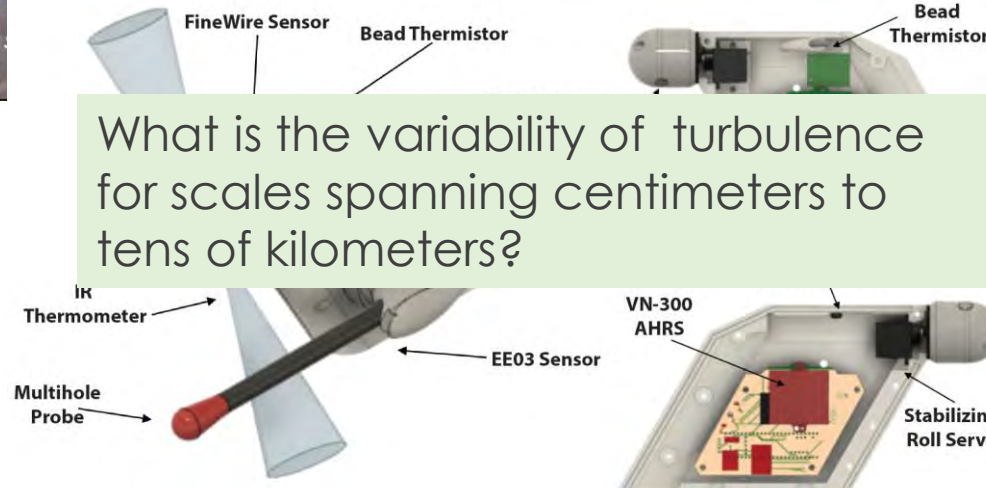
# PSL bundling suites of instruments into integrated systems

## Atmospheric Surface Flux Station



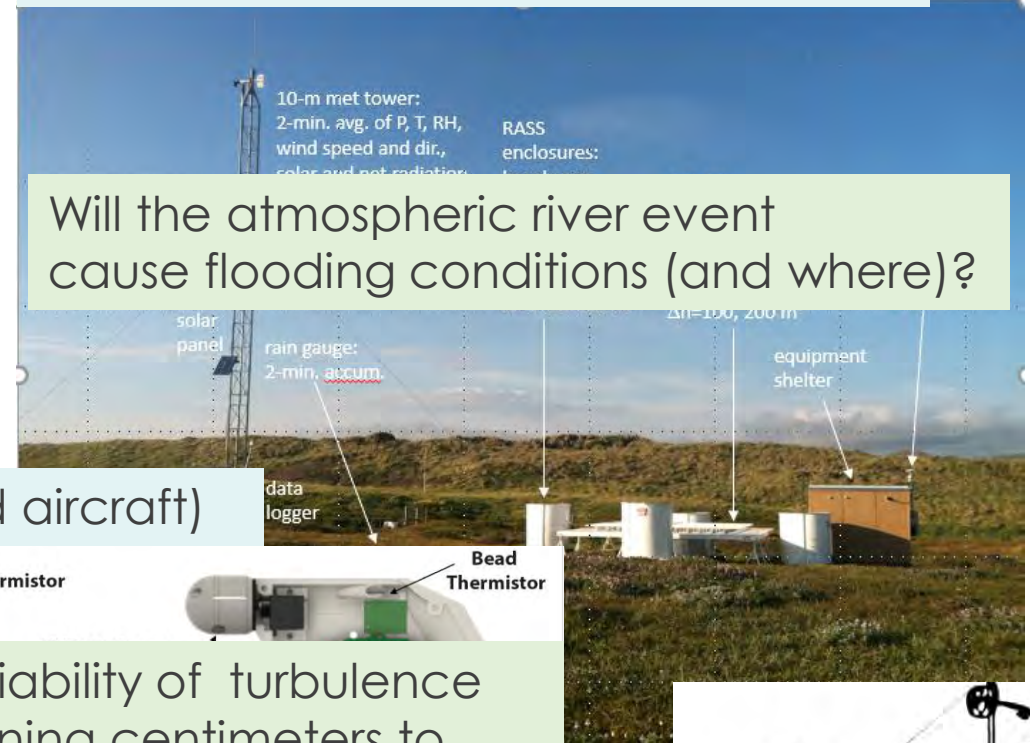
What is the annual cycle of the sea-ice surface Energy budget?

## Mini-Flux (UAS and aircraft)



What is the variability of turbulence for scales spanning centimeters to tens of kilometers?

## Atmospheric River Observatory



Will the atmospheric river event cause flooding conditions (and where)?

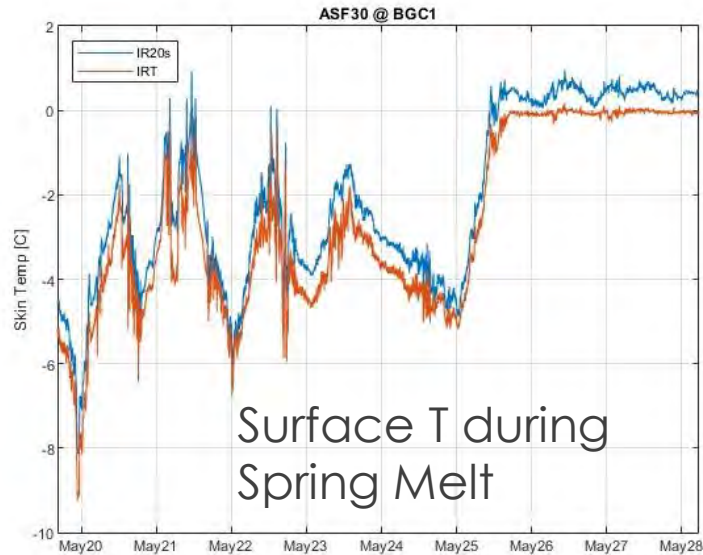
The whole is greater than the sum of its parts.

- Aristotle



# Types of data collected:

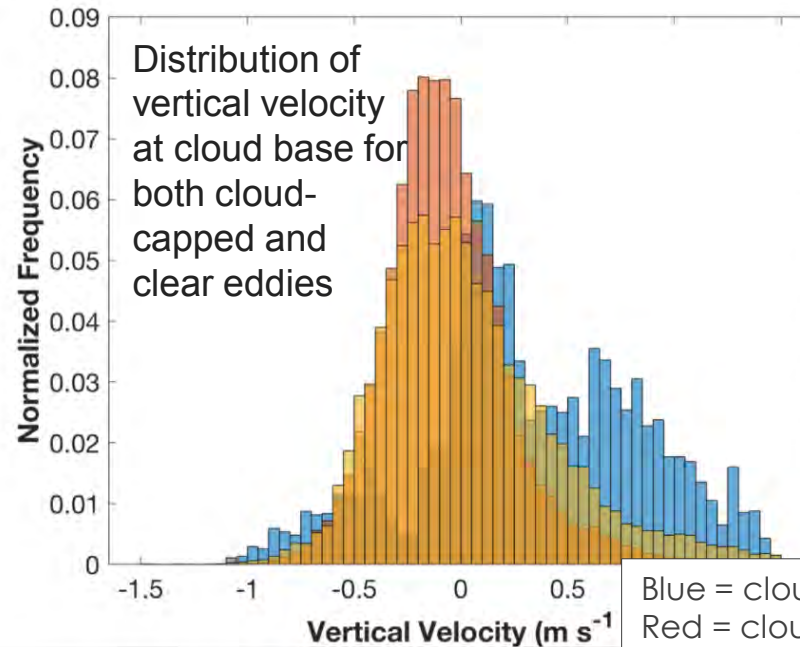
## Automated Surface Flux Station



T, RH, P,  $u,v,w$ ,  $SW(\uparrow\downarrow)$ ,  $LW(\uparrow\downarrow)$ ,  $T_{sfc}$ , GHF,  $H_2O$ ,  $CO_2$ , gps, snow depth, images, **turbulent fluxes**

T, RH, P, IRT( $\uparrow\downarrow$ ), gps + multiple position and air speed variables,  $u,v,w$ , **turbulent fluxes**

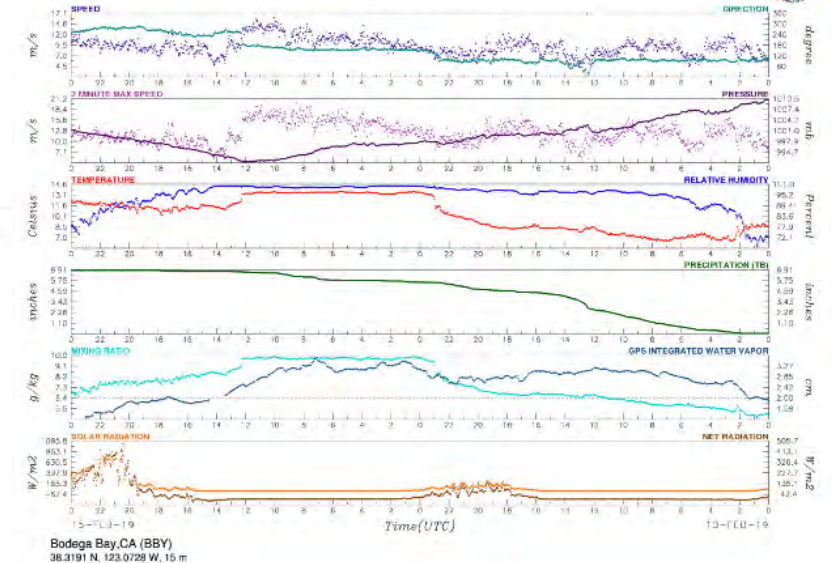
## Mini-Flux



Blue = cloudy 0-500 m  
Red = cloud free at 500 m  
Yellow = cloud free < 200 m

## Atmospheric River Observatory

### PSL Meteorology and Physics



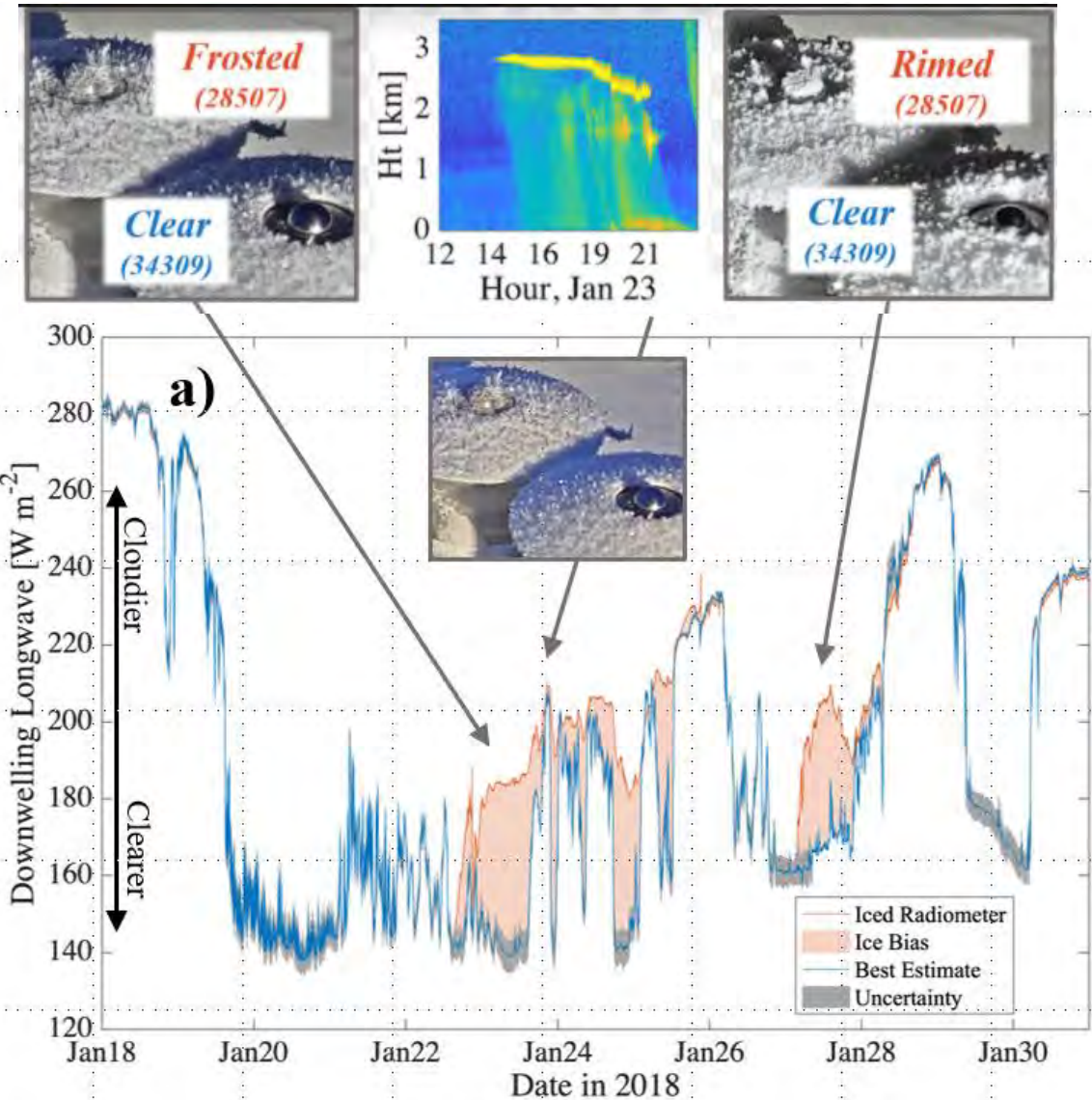
$T(z), T$ , RH, P,  $r$ ,  $u,v,w$ ,  $SW(\downarrow)$ ,  $LW(\downarrow)$ , IRT, RR,  $SW$  and  $LW$  flux, **IWV (gps)**

# Observation Science: Advances in Measurement Strategies

**Purpose:** To evaluate existing ventilation and heating technologies developed to mitigate radiometer icing.

This activity was initiated during a Workshop of the Baseline Surface Radiation Network (BSRN) in the Cold Climate Issues Working Group and executed in coordination with GML

## D-ICE

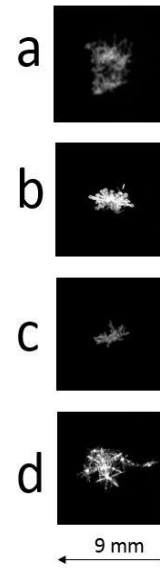
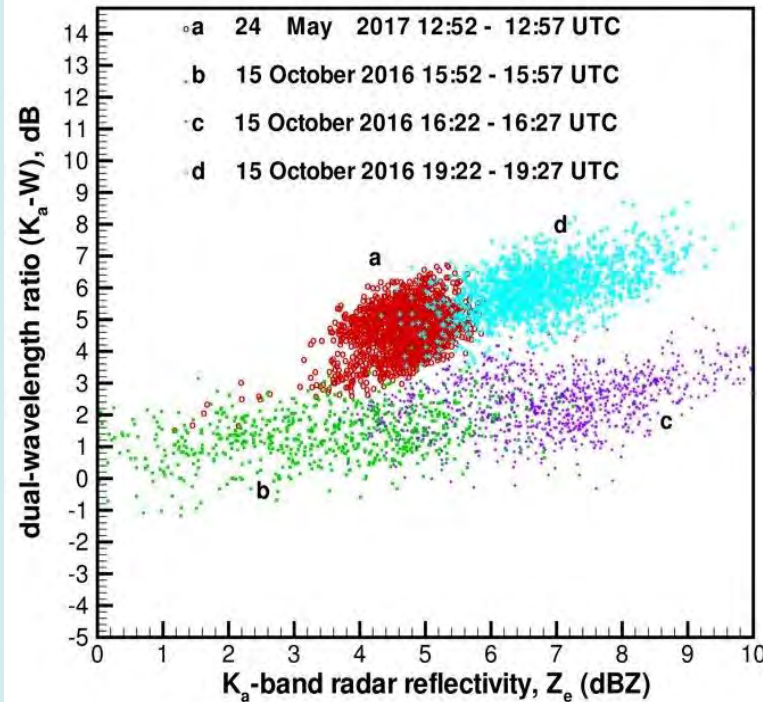




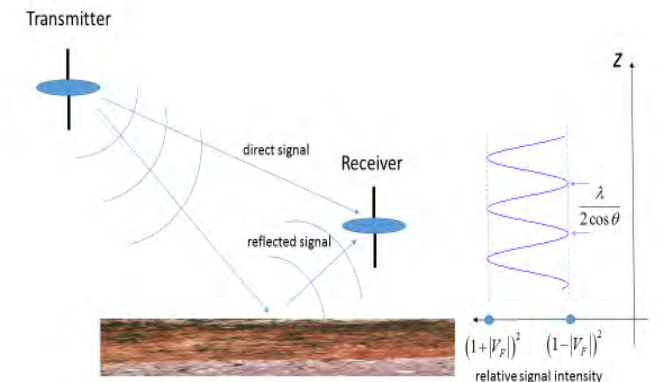
# PSL Specializes in Retrievals

The science of 'modeling' measurements to obtain higher order geophysical variables

For Example: The use of vertically pointing dual-wavelength radar measurements to infer ice hydrometeor shape



For example: the use of angular- and frequency dependencies of the reflection coefficient to obtain soil moisture

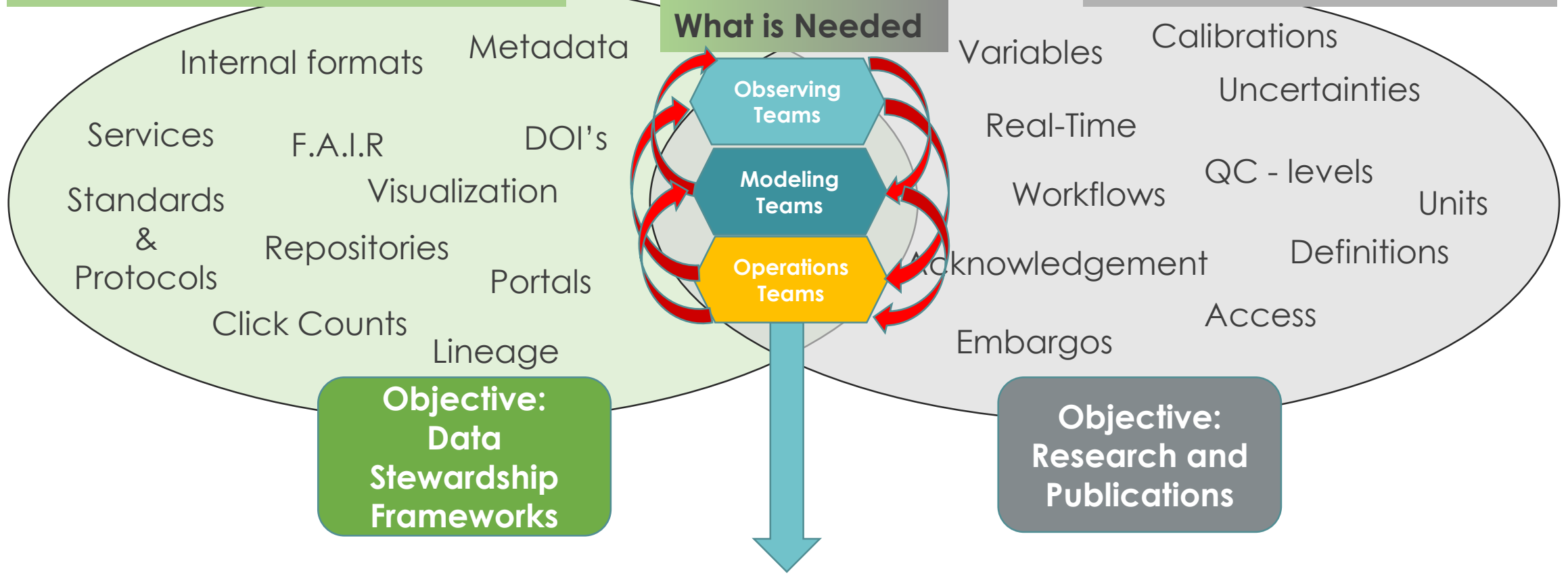


# Advancing Observing Data Stewardship

## What Data Managers Care About

## What Scientists Care About

### What is Needed



**Promote an advanced level of data usability and interoperability to expedite research and predictive services**

# Publication and Developing Metadata for Observational Data Sets

Publishing in journals such as ESSD

Data Set DOI assignments



Open Access  
Earth System  
Science  
Data

## Novel Metadata Methods - Datagrams

Earth Syst. Sci. Data, 10, 1139–1164, 2018  
<https://doi.org/10.5194/essd-10-1139-2018>  
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### Central-Pacific surface meteorology from the 2016 El Niño Rapid Response (ENRR) field campaign

Leslie M. Hartten<sup>1,2</sup>, Christopher J. Cox<sup>1,2</sup>, Paul E. Johnston<sup>1,2</sup>, Daniel E. Wolfe<sup>1,2</sup>, Scott Abbott<sup>2</sup>, and H. Alex McColl<sup>1,2,a</sup>

<sup>1</sup>Cooperative Institute for Research in Environmental Science (CIRES), University of Colorado, Boulder, CO 80309-0216, USA  
<sup>2</sup>NOAA/Earth System Research Laboratory, Physical Sciences Division, Boulder, Colorado, CO 80305, USA  
<sup>a</sup>currently at: Berthoud, CO 80513, USA

Correspondence: Leslie M. Hartten (leslie.m.hartten@noaa.gov)

Received: 7 November 2017 – Discussion started: 6 December 2017  
 Revised: 23 April 2018 – Accepted: 30 May 2018 – Published: 20 June 2018

**Abstract.** During the early months of the 2015/2016 El Niño event, scientists led by the Earth System Research Laboratory’s Physical Sciences Division conducted the National Oceanic and Atmospheric Administration’s (NOAA’s) El Niño Rapid Response (ENRR) field campaign. One component of ENRR involved in situ observa-

**Datagram: Baseline Surface Radiation Network Tiki Downwelling Broadband Radiation**

Campbell CRUX Data

Line ID	Year	Julian Day	Hour	Minute	Second	Latitude [deg]	Longitude [deg]	Altitude [m]	Clouds [oktas]	Downwelling Shortwave [W/m <sup>2</sup> ]	Downwelling Longwave [W/m <sup>2</sup> ]	Downwelling Broadband [W/m <sup>2</sup> ]	Net Longwave Radiation [W/m <sup>2</sup> ]	Net Shortwave Radiation [W/m <sup>2</sup> ]	Net Radiation [W/m <sup>2</sup> ]	Relative Humidity [percent]	Wind Speed [m/s]	Wind Dir [deg]	Pressure [hPa]	Temperature [C]	Dewpoint [C]	Relative Humidity [percent]	Wind Speed [m/s]	Wind Dir [deg]	Pressure [hPa]	Temperature [C]	Dewpoint [C]	Relative Humidity [percent]
101	2016	140	1400	27	00	19.583	-155.514	1512	0	107.5	235.1	342.6	-127.6	107.5	18.0	100.0	2.5	225	1013.4	27.5	15.0	100.0	2.5	225	1013.4	27.5	15.0	100.0

Tiki Data Center

FFP File Locations at NOAA

Calibration Values:

- Downwelling Shortwave Diffuse (Eppley B&W PSP) 8.72 μW/m<sup>2</sup> 6/1/2010 – present
- Downwelling Shortwave Diffuse (Eppley PSP) 8.76 μW/m<sup>2</sup> 6/1/2010 – present
- Downwelling Longwave Total (Eppley PIR) 126.435 W/m<sup>2</sup> Date = 3/0 6/1/2000 – present
- Downwelling Shortwave Direct (Eppley NIP) 9.01 μW/m<sup>2</sup> 6/1/2010 – present
- Downwelling Shortwave Total (K&Z CM22) 9.40 μW/m<sup>2</sup> 6/1/2010 – present
- Fluxnet Downwelling Shortwave Direct (MFR-19 (AT-5)) 9.13 μW/m<sup>2</sup>

Calculations:

DEF = Dome Correction Factor (for PIR instruments)  
 E = efficiency = 1  
 TCR = Case Temp in mV (For Eppley PIR - data Column 9)  
 TDR = Dome Temp in mV (For Eppley PIR - data Column 10)  
 TC = Eppley PIR Temp[degK]  
 Conversion = (10.000295 + (0.0002191 \* log(TCR \* 1000)) + (0.0000001568 \* log(TCR \* 1000) \*\* 3))

# PSL Data Curatorship - <https://psl.noaa.gov/data/index.html>

[Home](#) > [Data](#)

## Data and Imagery

PSL archives a wide range of data ranging from gridded climate datasets extending hundreds of years to real-time wind profiler data at a single location. The data or products derived from this data, organized by type, are available to scientists and the general public at the links below.

The third party data appearing on this web site may be reformatted from their original form, but not altered as to the informational content contained therein. It is provided as a public service. Further, this data does not reflect an official view or position of NOAA.



Resources



Help



### Climate

[Gridded Climate Data](#)

[Climate Model Simulations \(FACTS\)](#)

[Reanalysis Datasets](#)

[Atmospheric/Ocean Timeseries](#)

[20th Century Reanalysis Project](#)



### Cloud Profiling Radars

[North Slope of Alaska](#)

[NOAA Observatory at Eureka, Canada](#)

[Summit, Greenland Station](#)

[Surface Heat Budget of the Arctic Ocean](#)

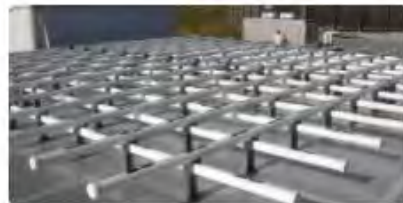


### Air-Sea & Air-Land Fluxes

[Arctic Observatories](#)

[Research Cruises](#)

[Working Group on Surface Fluxes](#)



### Wind Profiling Radars

[Tropical Wind Profiler Data](#)

[Profiler Network Data & Images](#)



### Satellite

[Real-Time Satellite Imagery](#)

[Archived Images and Data](#)



### Local Weather and Climate

[Boulder, CO Weather Information and Data](#)

# Observing Highlights – Air Sea Interactions

The sequel to the famous COARE Algorithm is the COARE<sup>G</sup> ALGORITHM  
 PSL and collaborators have pioneering direct observations of trace gas fluxes over the open ocean

$$F_x = \overline{w'x'} = \alpha_x k_x [X_w / \alpha_x - X_a]$$

$w'$  turbulent vertical velocity fluctuation  
 $x'$  turbulent concentration fluctuation  
 $\alpha_x$  solubility of gas x in seawater  
 $k_x$  transfer velocity of gas x between seawater to air  
 $X_w$  mean mass concentration of gas in water at reference depth  
 $X_a$  mean mass concentration of gas in air at reference height

Flux=Measurement=Parameterization  
 (COAREG)

Sonic anemometer>Motion>Coordinate>Distortion> $w'$   
 Fast gas analyzer>Dilution correct>crosstalk correct> $x'$

(Based on 30,000 hours of data)

**Table 1. First open ocean measurement. All by PSL-Collaborator.**

Year	Gas	Reference
1998	CO2	McGillis et al. 2001
2003	Dimethyl Sulfide	Huebert et al. 2004
2006	Ozone	Bariteau et al. 2010
2010	Methane	CALNEX
2011	CO	Blomquist et al. 2012
2012	Glyoxol	Coburn et al. 2014
2012	Methanol	Yang et al. 2013
2013	Acetone	Yang et al. 2013
2019	Several	MOSAIC



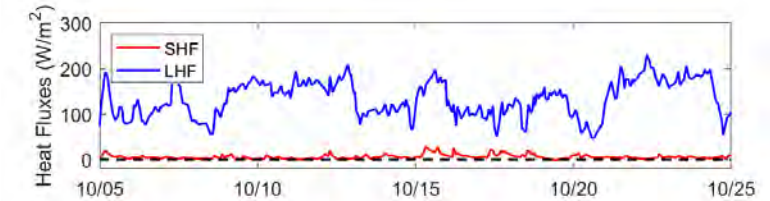
# Observing Highlights – Air Sea Interactions

## Near Real-Time Delivery

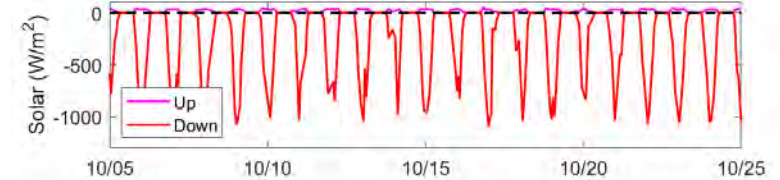
Direct Covariance  
Surface Stress and  
Buoyancy Fluxes,  
Radiative Fluxes, Bulk  
Momentum, Sensible  
and Latent Heat  
Fluxes, Net Heat Flux,  
Near Surface  
Currents, Ocean  
Current Profiles



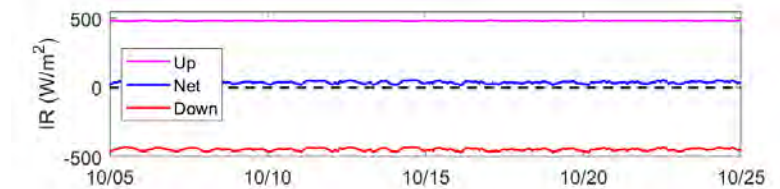
PSL Contributions to WHOI Buoy Development



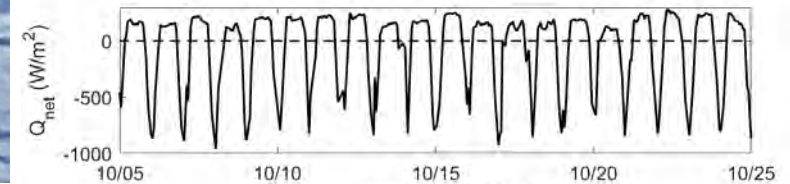
Heat Fluxes



Solar Fluxes



IR Fluxes



$Q_{net}$  Fluxes

Date 2019 (UTC)

# Observation Highlights – The Arctic System

## YOPPsiteMIP



## Polar Prediction

Home News About Organization Key YOYP Activities Data Outreach & Education Publications Services

Special Observing Periods Polar Prediction Key YOYP Activities YOYPsiteMIP

Sea Ice Prediction and Verification

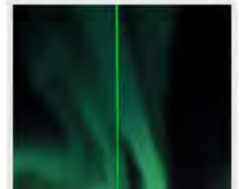
**YOYPsiteMIP** The YOYP Arctic and Antarctic supersites

YOYP Endorsement

YOYPsiteMIP: Year of Polar Prediction site Model Inter-comparison Project

**YOYPsiteMIP** is a coordinated process-based model evaluation project based on high-frequency multi-variate observations at some selected Arctic and Antarctic supersites, during the Year of Polar Prediction (YOYP). The aim of YOYPsiteMIP is to deepen our understanding on the representation of environmental prediction systems of polar processes, both in the atmosphere, land, sea-ice or ocean components, and in the coupling at their interfaces.

The **YOYP Arctic and Antarctic supersites** are selected key polar observatories which host multiple systems deployed for long-term monitoring and suites of instruments (such as lidars, radars, ceilometers, radiometers), that provide detailed measurements characterising the vertical column of the atmosphere as well as the surface conditions and energy fluxes. These observations extend far beyond the traditional synoptic surface and upper-air observations, and offer the opportunity for deepening our understanding of the physical processes governing the polar environment weather and climate.



**What is a MODF?**  
Getting all the data from all the sensors from one location for a finite period into one (netcdf) file that looks just like the corresponding model output

```
netcdf output {
  int n_sensors = 10;
  int n_time = 1000;
  float time[n_time];
  float sensor_data[n_time][n_sensors];
  // ... more data fields ...
}
```

# Observation Highlights – The Arctic System

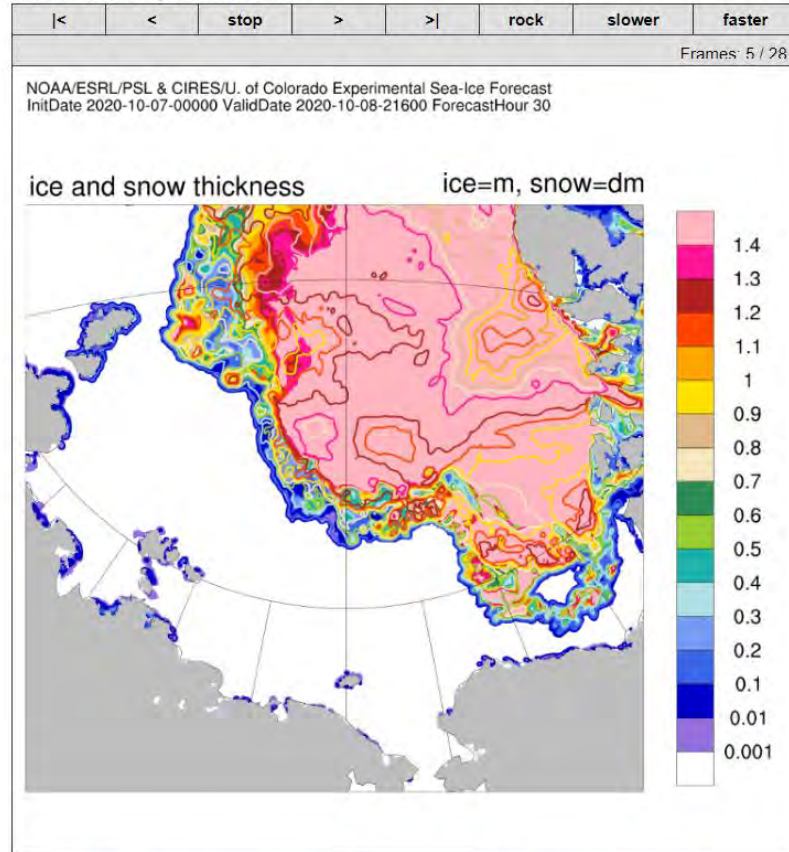


Physical Sciences Laboratory

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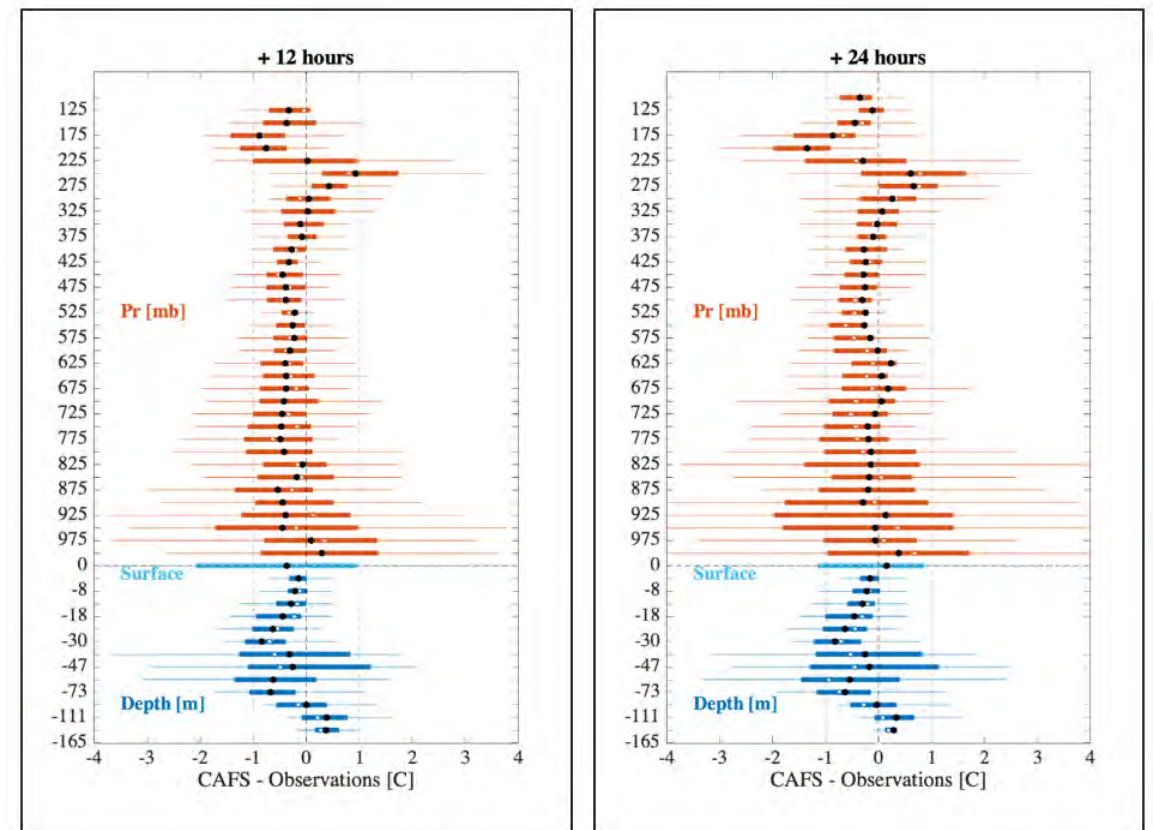
- Snow and Ice
- Coupled
- Atmosphere
- Meteograms
- Time/Height XSections
- Alaska Region

## Ice & Snow Depth Thickness



[Archive of Images and Model Output](#) [Model Validation](#) [Forecast Skill Assessment](#)

Developing a sea-ice forecasting model based on observation based physics and verification

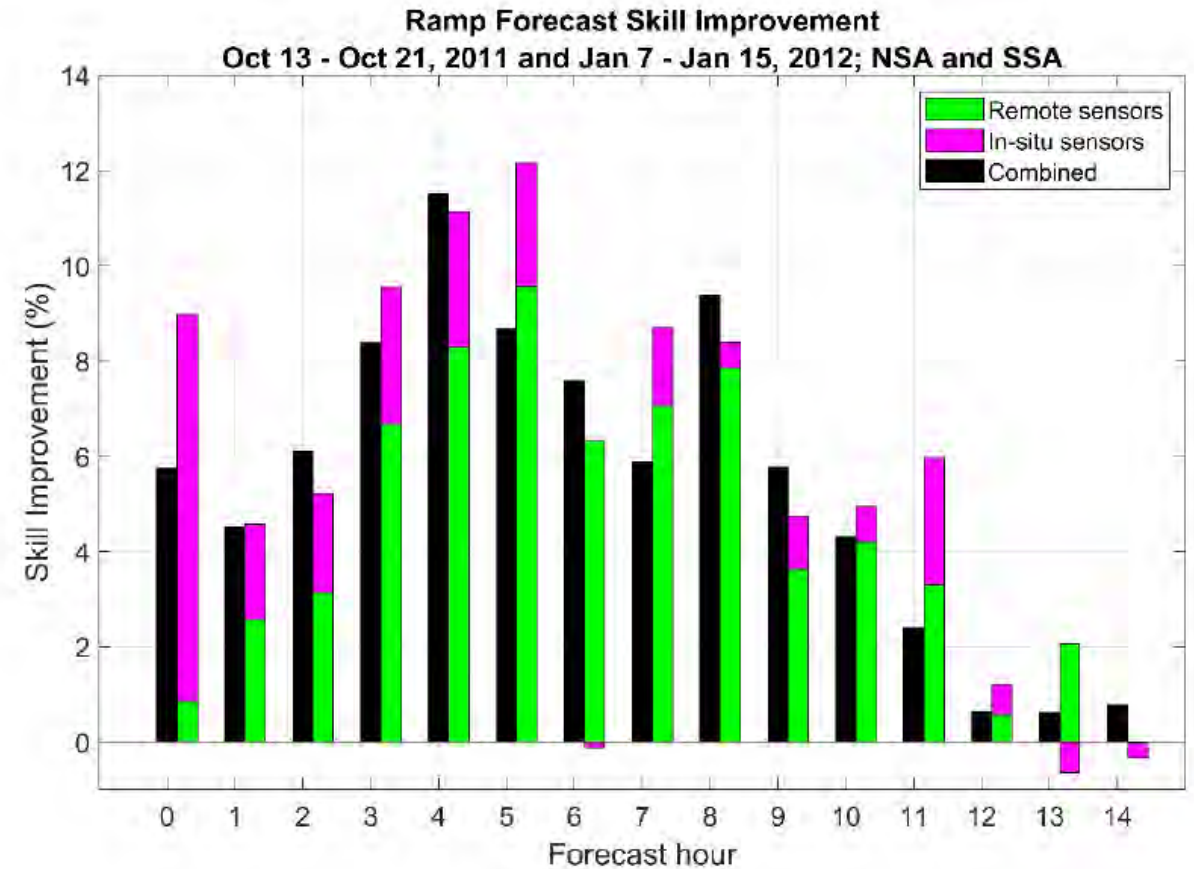




# Observing Highlights – Wind Resources

Reducing the Cost of Wind Energy by Improving the Forecasts

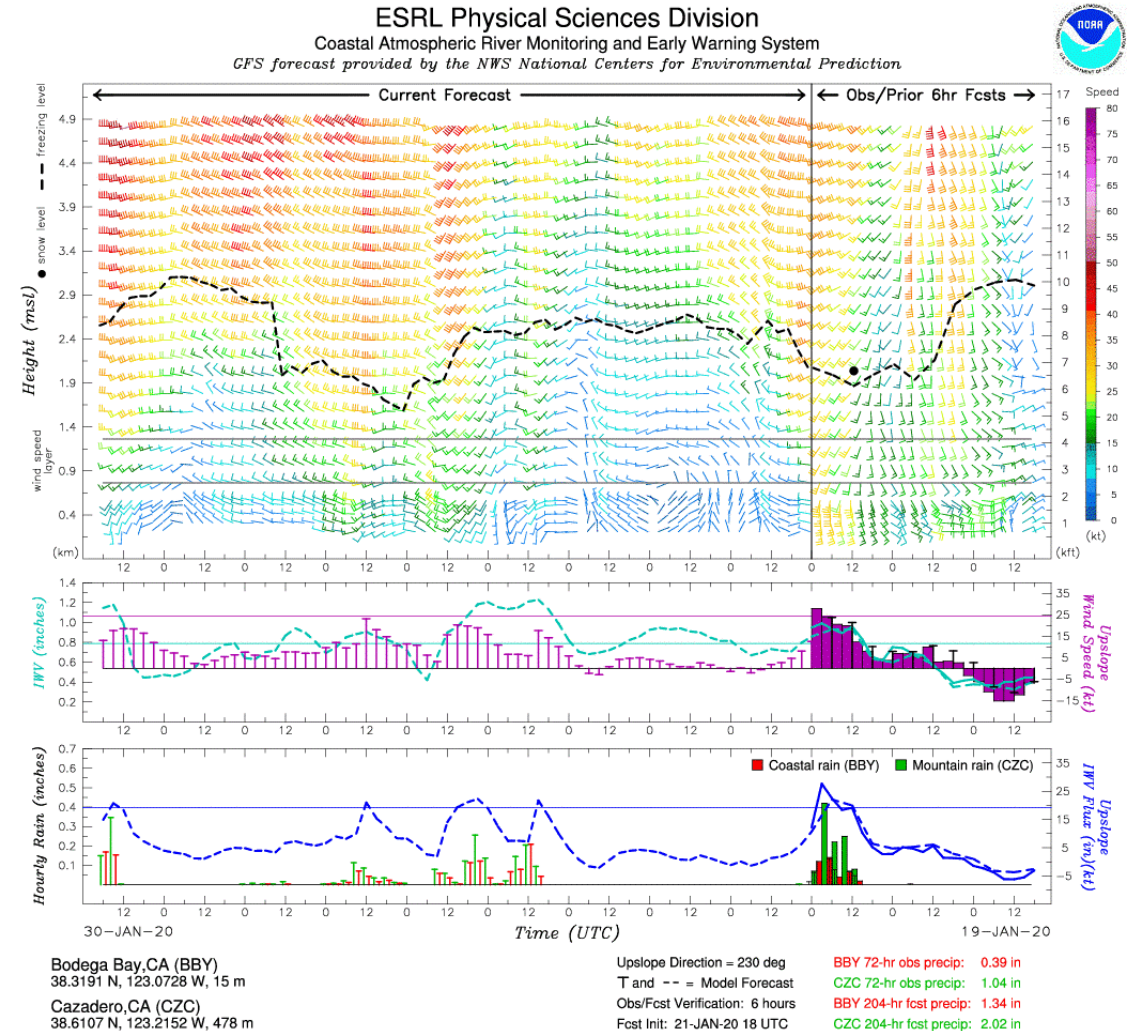
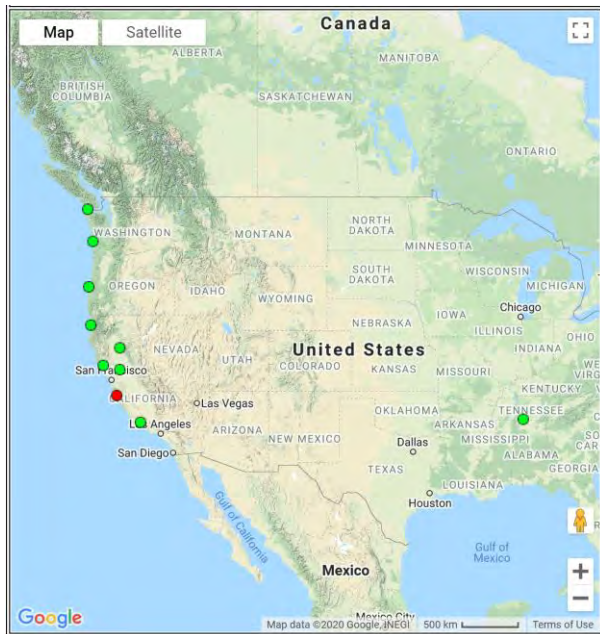
Measuring the impact of additional instrumentation on the skill of numerical weather prediction models at forecasting wind ramp events



# Observing Highlight - Hydrometeorology

PSL's award-winning water vapor flux

**product:** One of the most important parts of the water vapor flux tool is that it combines model output with real-time and past observations so that forecasters can judge how well models are portraying weather events.



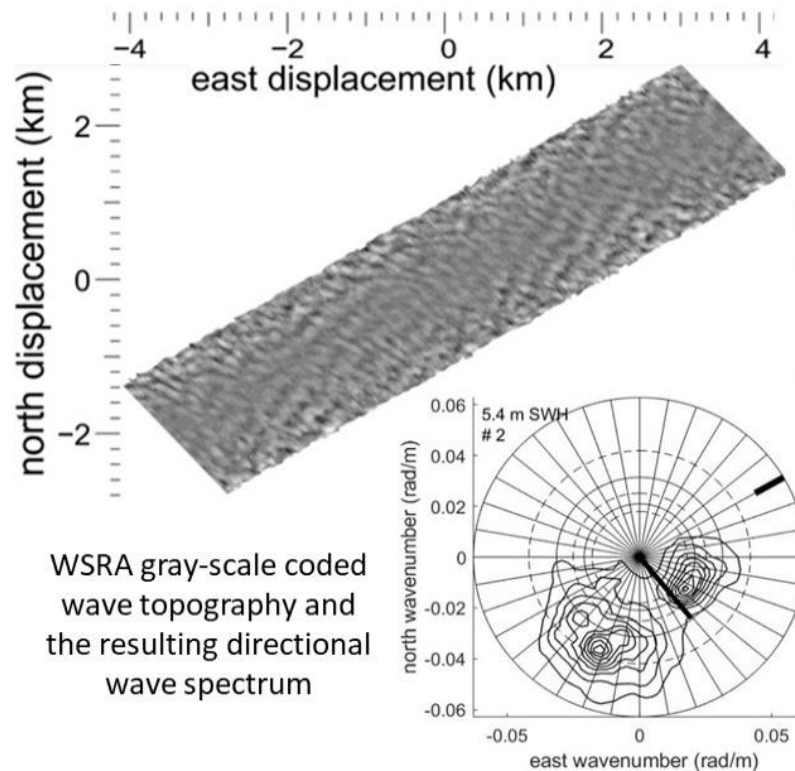


# Observations Supporting S2S and Extremes Science



PSL Wide Swath Radar Altimeter (WSRA) observing real-time mapping of hurricane ocean wave fields

## Hurricane Lorenzo 2019



Operations from the NOAA Hurricane Hunter



# Observations Supporting Water Resource Management

## PSL ARO Observing ASSETS



- S-PROF (pulsed S-band radar) - **5**; all in California and all owned by PSL.
- SLR (FMCW S-band radar) - 11; all in California. 10 owned by CA, **1** owned by PSL.
- 915-MHz wind profilers - **2**; both in California. Both owned by PSL.
- 449-MHz wind profilers - **9**; 4 in California owned by CA. 2 in OR, 1 in WA, 1 in CO, and 1 in AL (all owned by PSL).
- Disdrometers (impact) - **2**; both in California and both owned by PSL.
- Disdrometers (optical): **3**; all in California and all owned by PSL.
- Soil temp/moisture stations: 49; 45 in California all owned by CA, **4** in AZ owned by PSL.
- Tipping bucket rain gauges: **61**; 53 in California mostly owned by CA. 4 in AZ, 2 in OR, 1 in WA, and 1 in AL (**8** owned by PSL).
- Heated tipping bucket rain gauges: **9**; 7 in California mostly owned by PSL. 2 in CO owned by PSL.
- Surface Met (P, T, RH, WS, WD): **60**; 48 in California mostly owned by CA. 5 in OR, 3 in WA, 2 in CO, 1 in NV, 1 in AL (mostly owned by UNAVCO as part of the Plate Boundary Observatory).
- GPS Met (integrated water vapor): **61**; 48 in California owned by CA and UNAVCO. 5 in OR, 3 in WA, 2 in CO, 1 in NM, 1 in NV, and 1 in AL (mostly owned by UNAVCO as part of the Plate Boundary Observatory). GPS-Met data is processed to produce IWV by a contract between NWS and Earth Networks. Formerly this was done in Boulder by GSL with collaboration from Scripps.



Heavy precipitation during 2–11 Feb 2017 resulted in excessive runoff into Lake Oroville, leading to the Oroville Dam incident



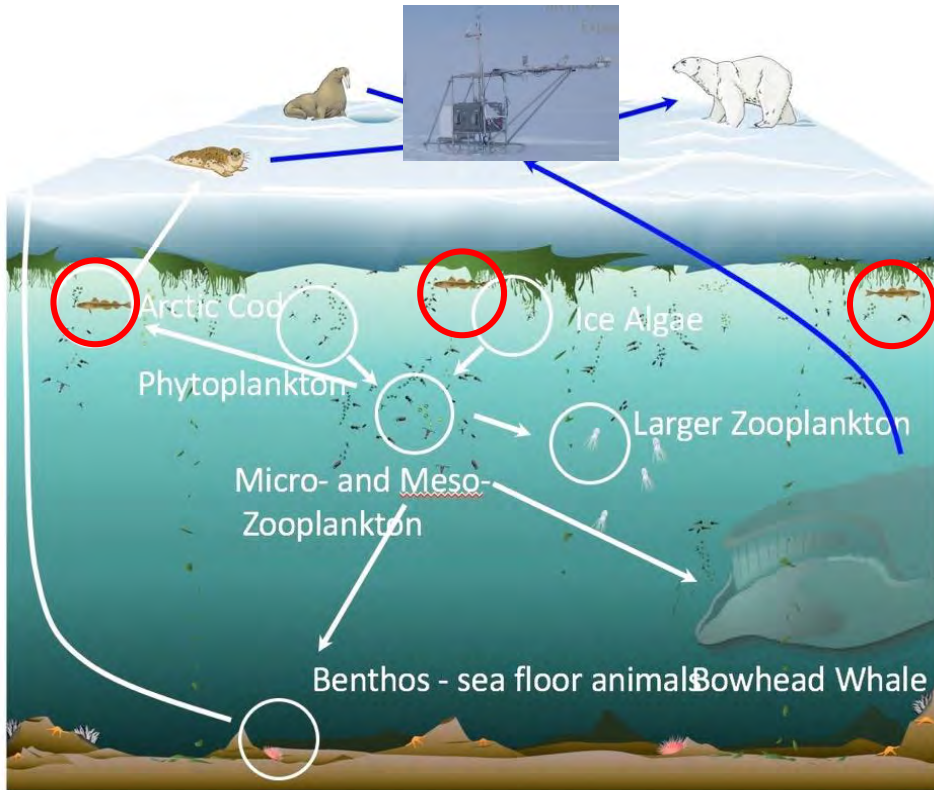


# Observations Supporting Marine Resources Management Science



## THE BLUE ECONOMY IN COLD PLACES

*International Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean  
Providing the environmental intelligence to support policy*

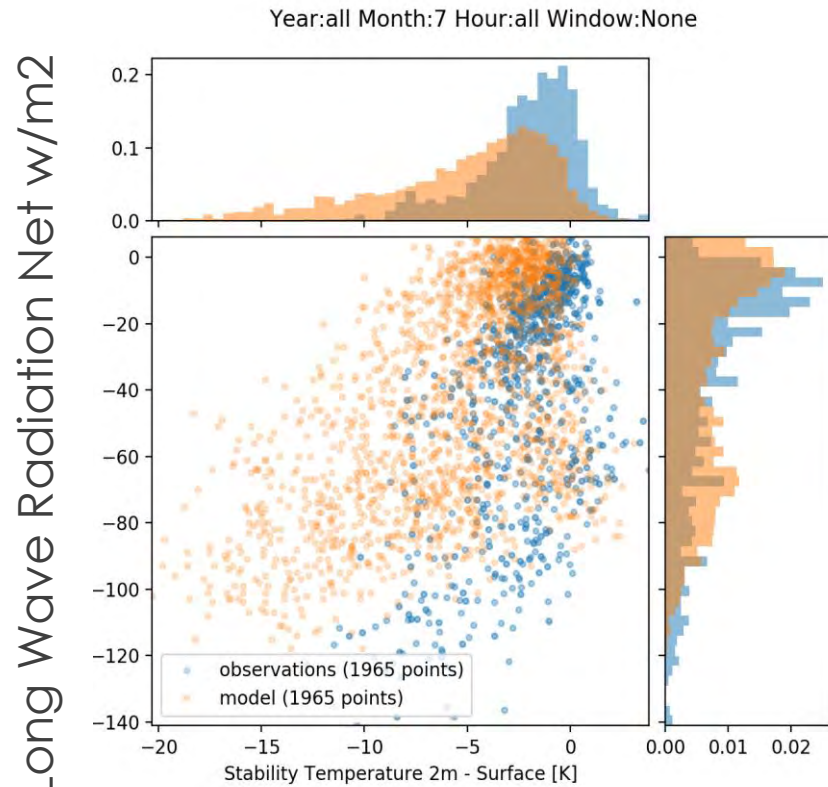


Operations in the Central Arctic Ocean

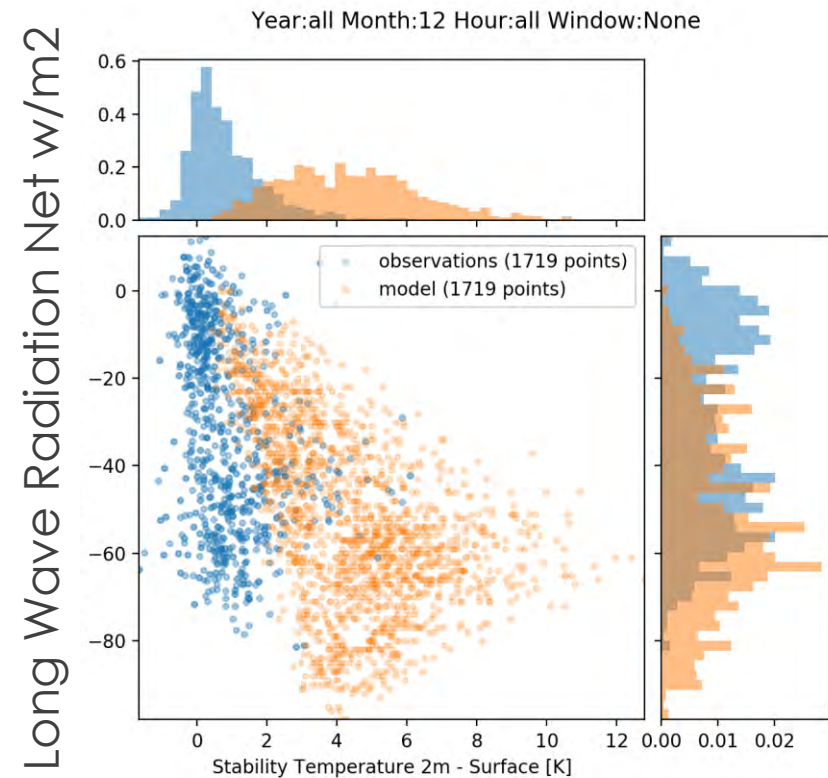
# Looking Forward: Process Oriented Diagnostics

Seasonal Relationship between Scaled Sensible Heat Flux and Net Longwave Surface Radiation in BM3

Much less cloud cover in winter than observations and too much in summer (net longwave close to zero).



UFS Bench Mark Run 3 (July)



UFS Bench Mark Run 3 (December)

# Looking Forward: A Bering Sea Observing System

## Arctic Boundary as defined by the Arctic Research and Policy Act (ARPA)

All United States and foreign territory north of the Arctic Circle and all United States territory north and west of the boundary formed by the Porcupine, Yukon, and Kuskokwim Rivers; all contiguous seas, including the Arctic Ocean and the Beaufort, Bering and Chukchi Seas; and the Aleutian chain.<sup>1</sup>



Credit: US Arctic Research Commission

The Bering Sea is a prime location for improved understanding of atmosphere-ocean-sea-ice processes that impact both marine ecosystems and weather forecasting for Alaska and the lower 48.

# Summary: Observation-based process understanding



- Science questions drive the development of observing systems
- Observations need to answer the ‘why’ not just the ‘how’ to develop physics based understanding
- Understanding of complex, coupled processes requires measurements of the individual components of the coupled system
- Observations of sub-grid scale processes are necessary for proper representation in models
- **Process level observations challenge models to get the right answers for the right reasons**

