MOSAiC

·The 2019/20 Arctic drift experiment·

Multidisciplinary drifting Observatory for the Study of Arctic Climate

Matthew Shupe – Univ. of Colorado/CIRES

On behalf of many…..

US DOE MOSAiC Team

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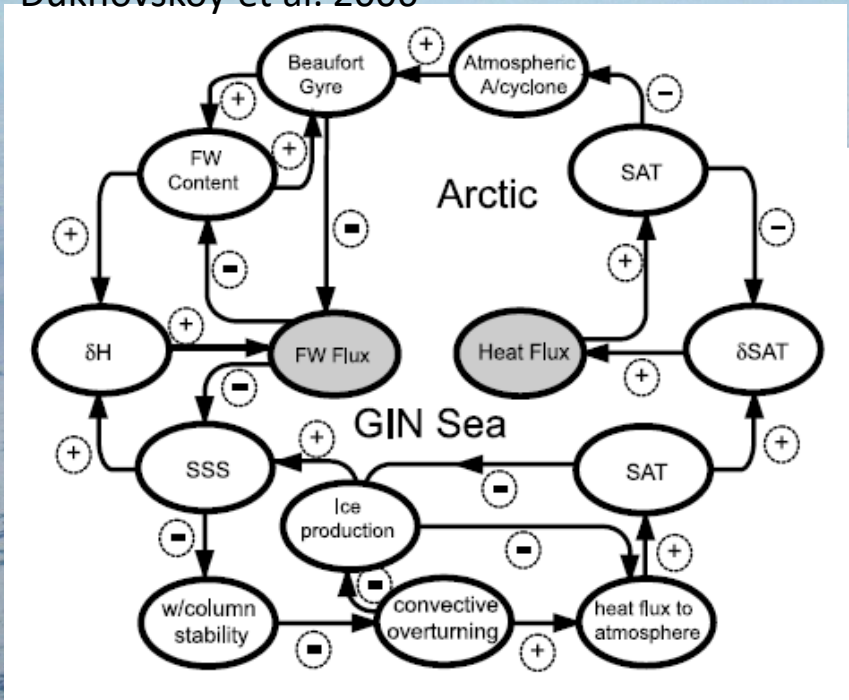
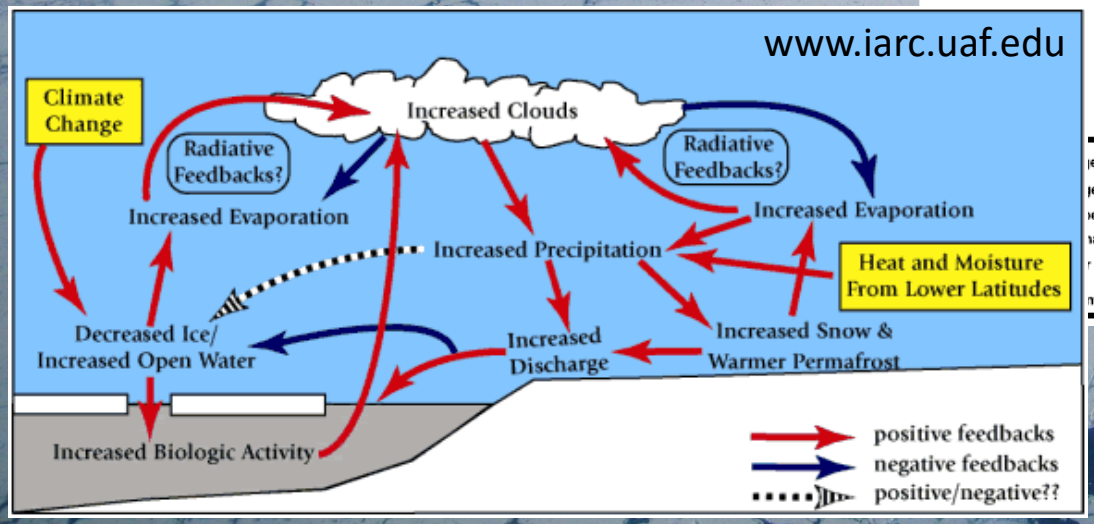
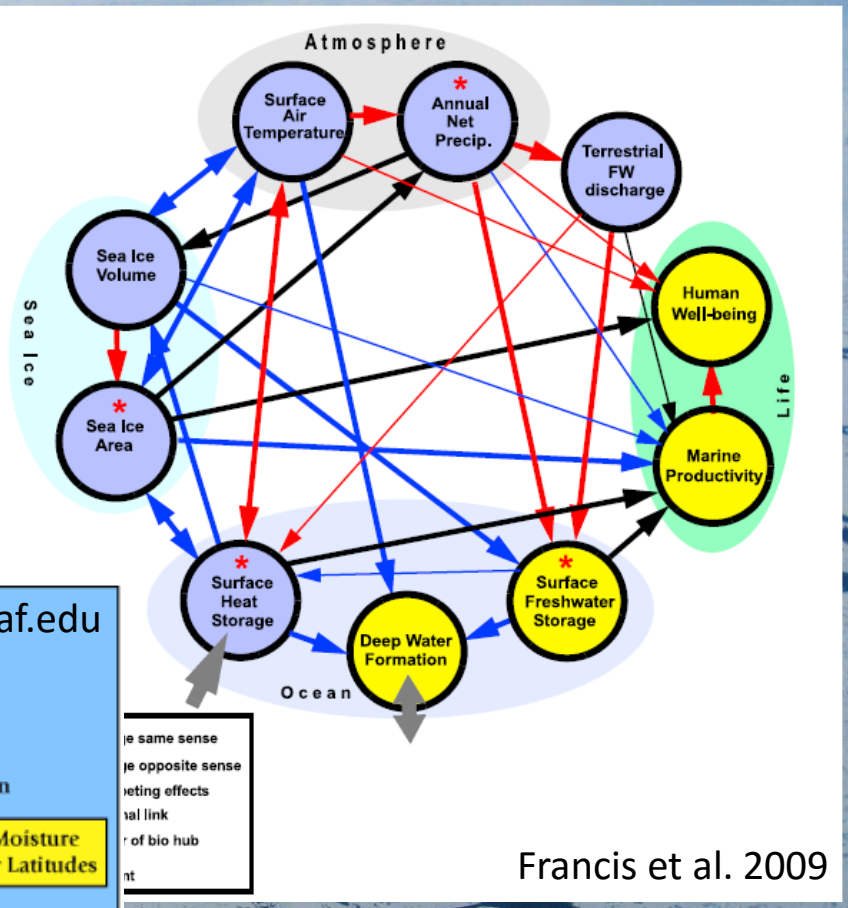
Dukhovskoy et al. 2006





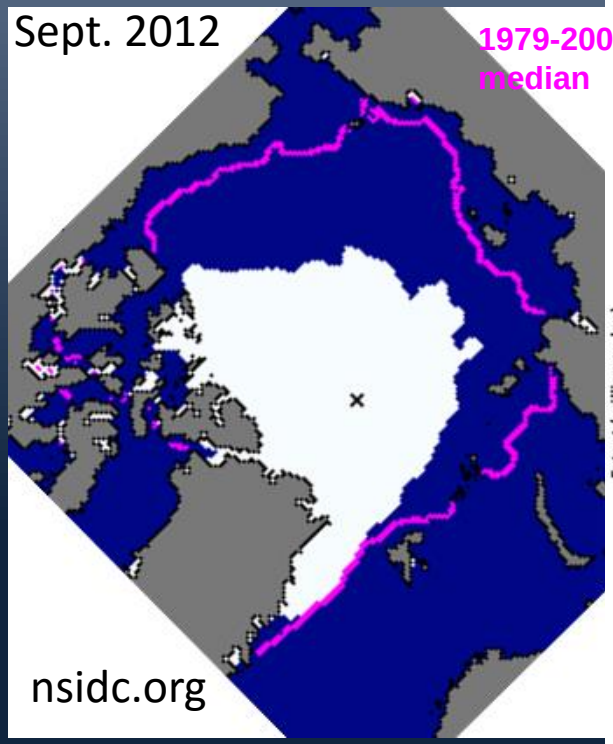


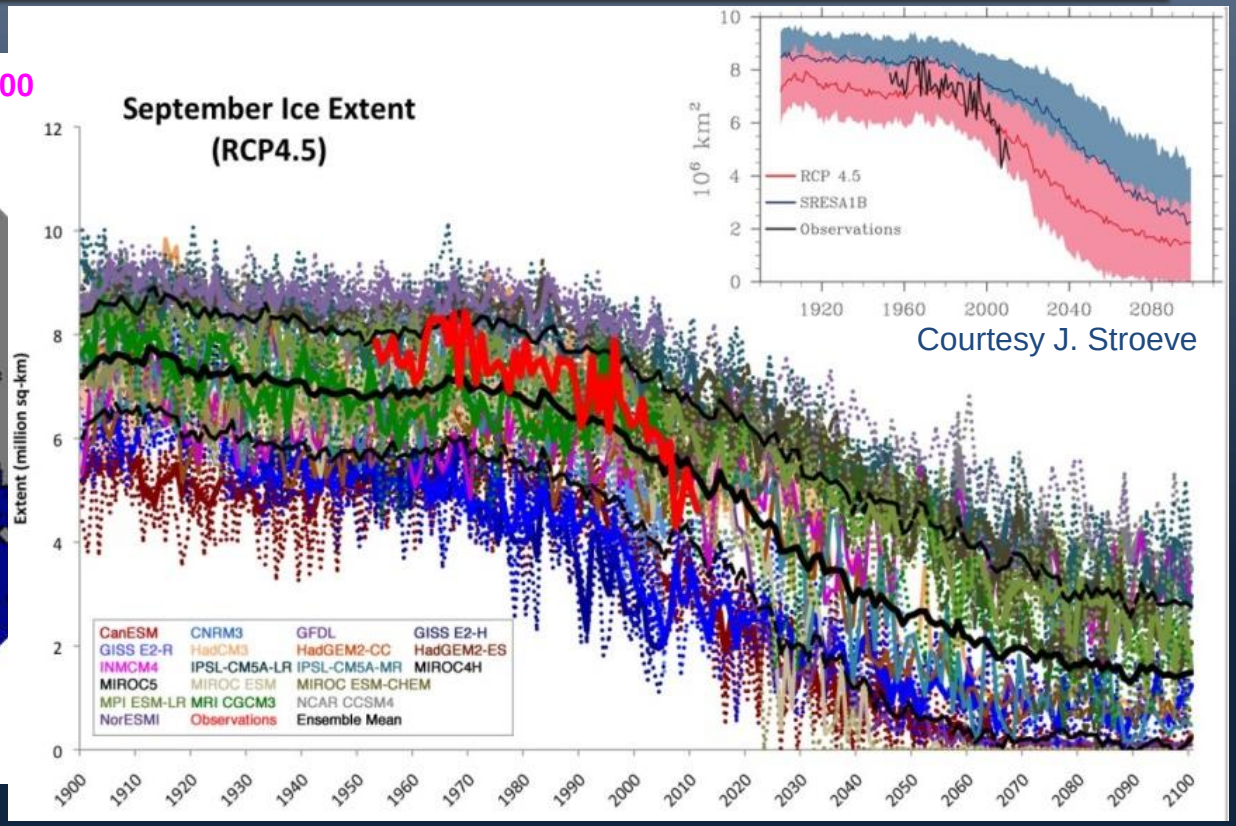
Francis et al. 2009

Arctic in Transition

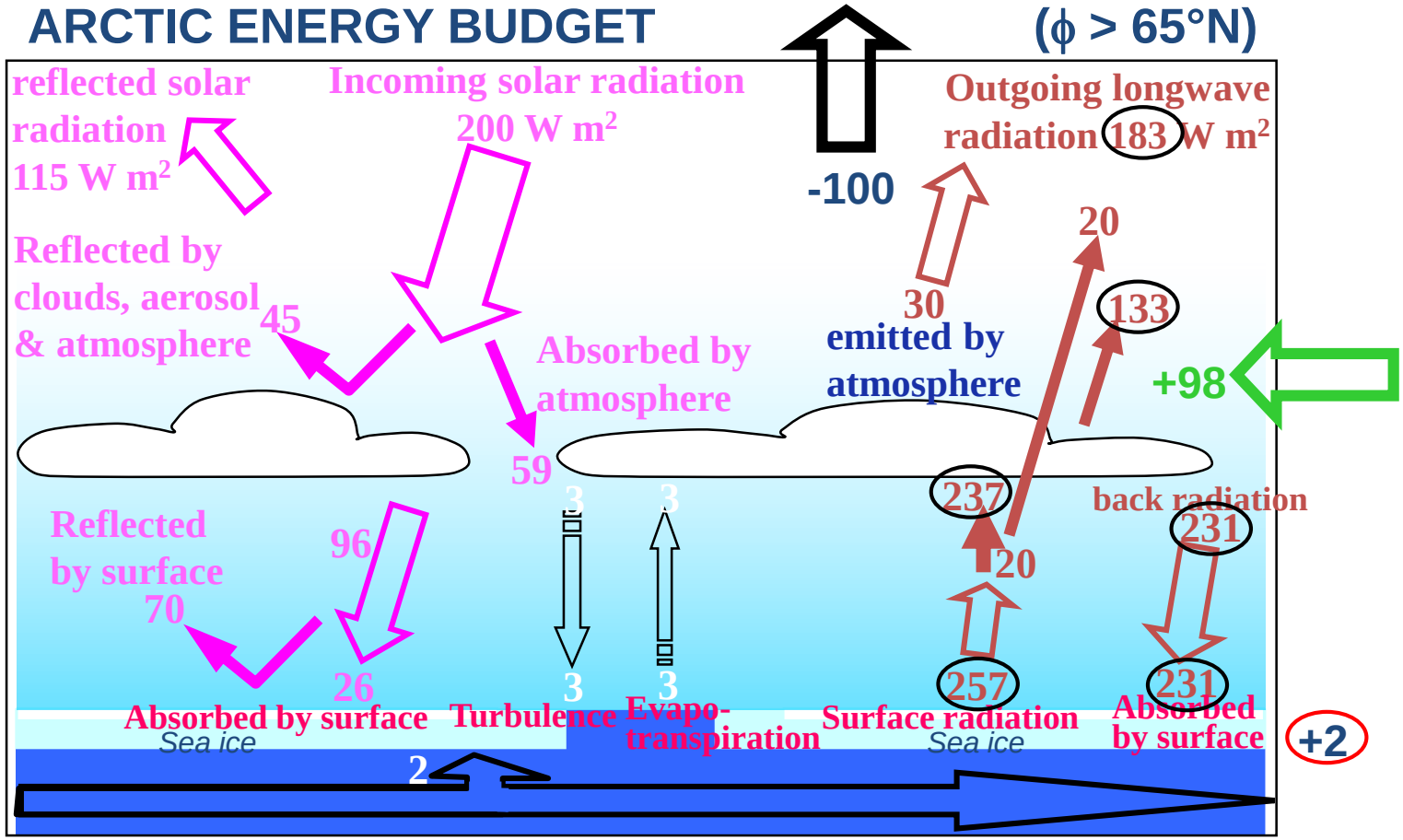
The central Arctic is changing dramatically,
characterized by major sea-ice decline & more younger ice.

Do we know <u>why</u>? and (importantly) <u>how</u>?





Sea-Ice Energy Budget

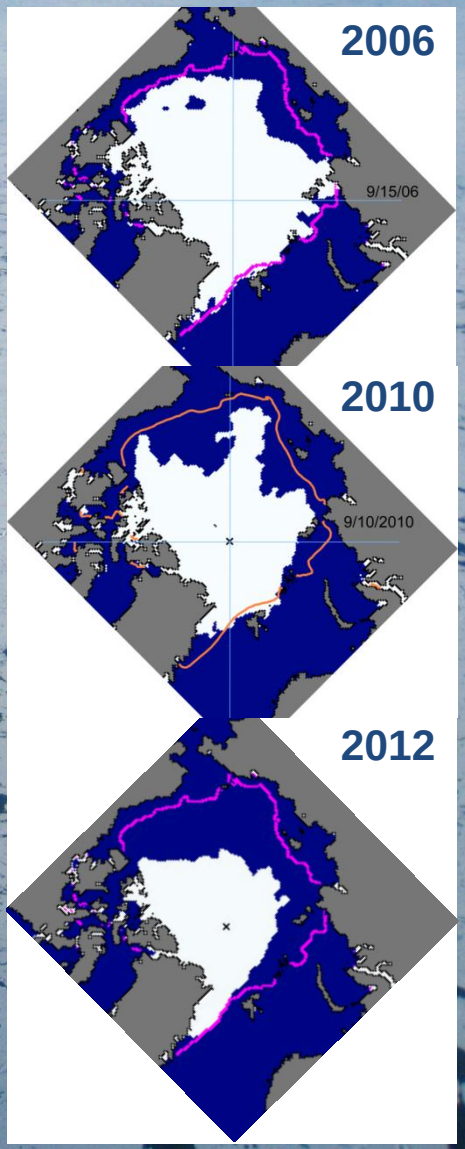


Decadal decline can be explained by ~1 W/m² excess.
Kwok and Untersteiner 2011

Persson et al. 2013

Challenge of Sea-Ice Prediction

- Physics matter
- Thermodynamics & Dynamics
- Coupled processes matter
- Interseasonal coupling
- The ice is changing



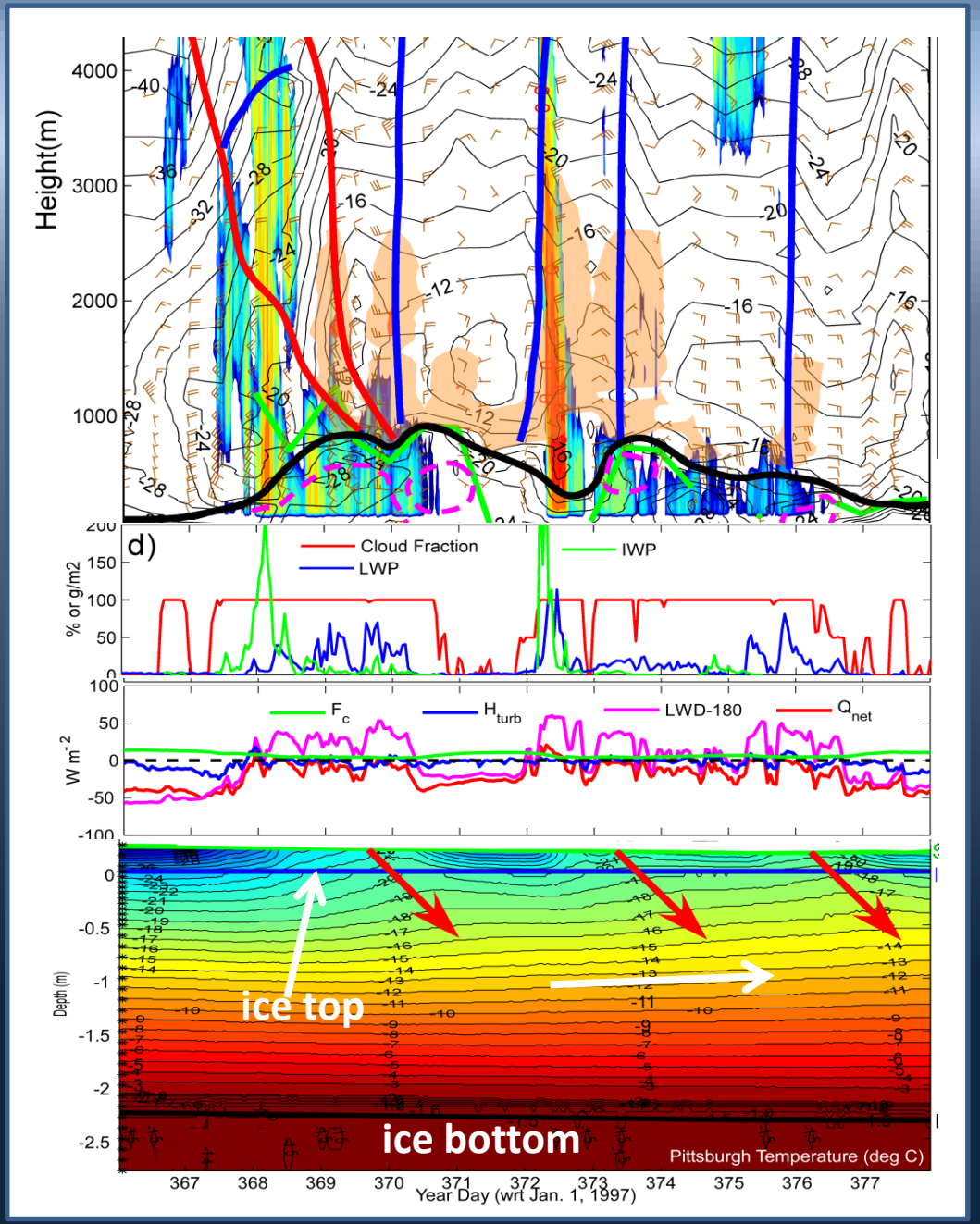
Coupling

Persson et al. 2013

Mixed-phase cloud events accompany warm moist advection aloft;
Impacts BL structure.

Liquid clouds increase LW_{down} by 40-70 W/m²
>>
Significant change in surface energy budget.

Thermal structure of snow and ice responds



Coupling

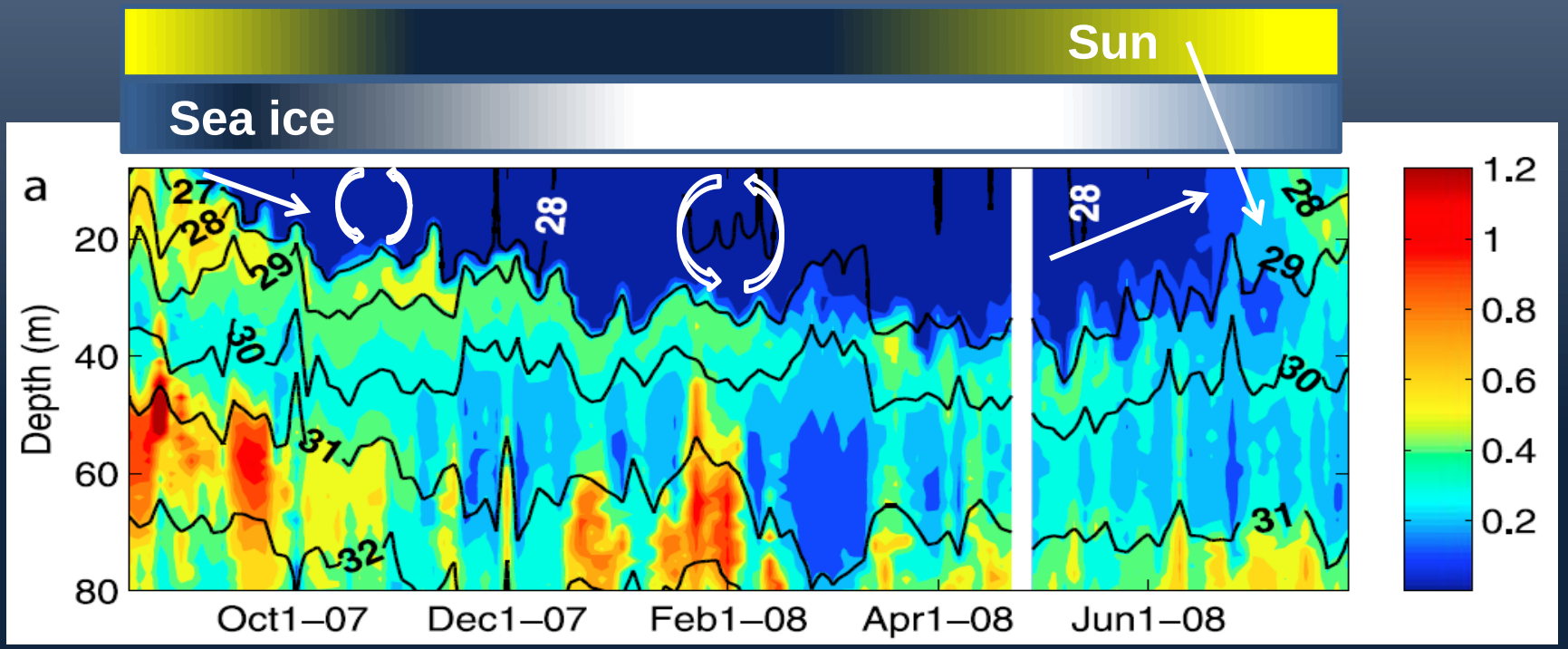
>>Fall:

- Solar diminishes;
- Surface cools;
- ML deepens (buoyancy, wind);
- Heat mixed up;
- Ice production

Winter:
Remnant heat modulates ice growth

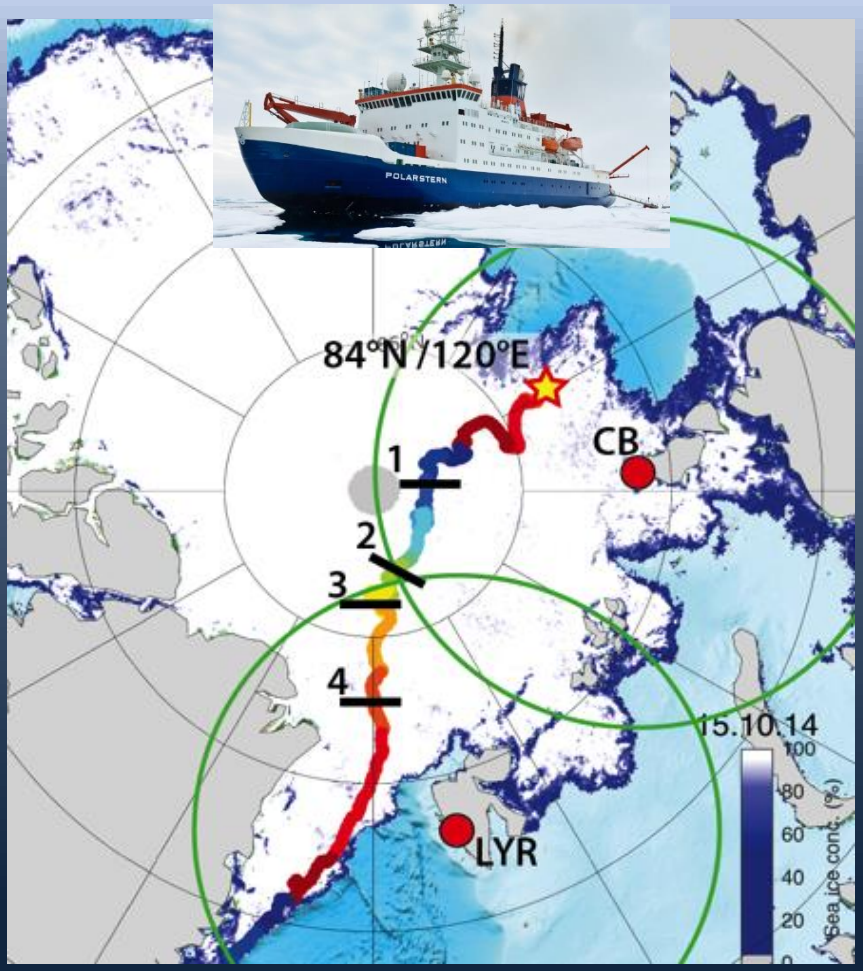
Spring >> Summer:

- Ice melts;
- ML freshens, shoals;
- Solar heating at surface/sub-surface.
- Some heat trapped below ML



Jackson et al. 2010

MOSAiC Plan

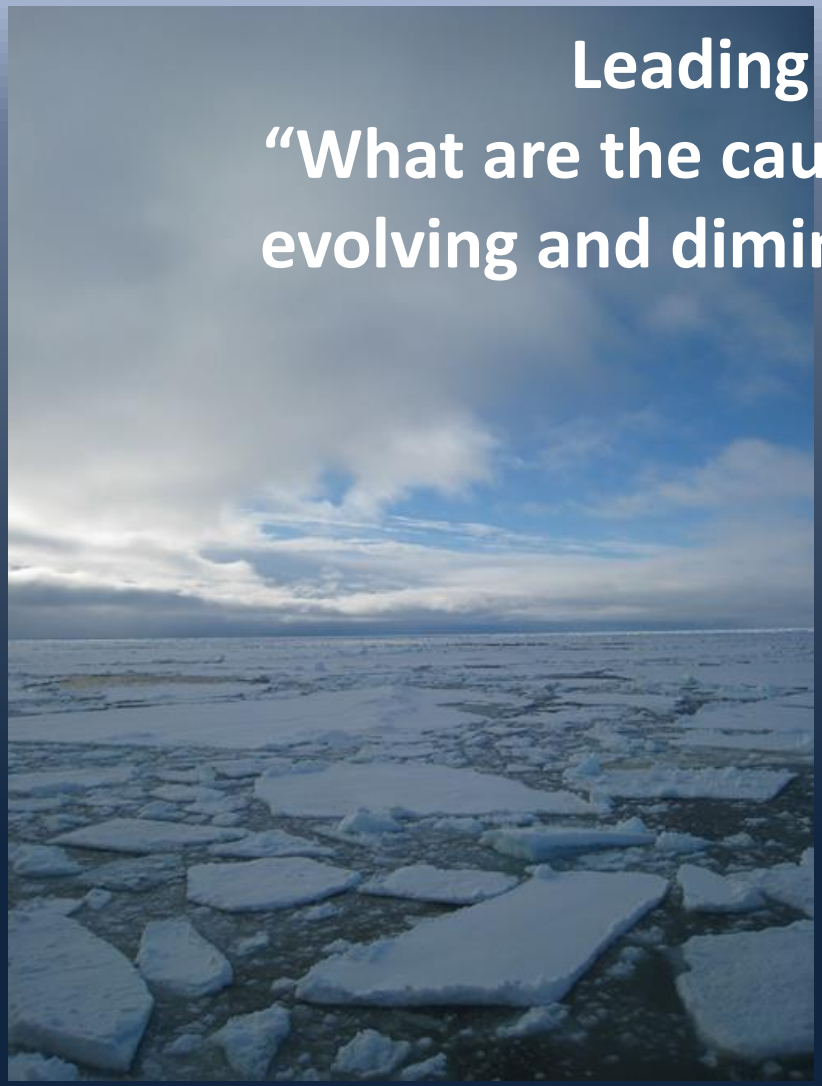


2019-2020, annual cycle
Central Arctic Basin ice pack

Drifting, interdisciplinary process study in central Arctic sea ice:

1) Central observatory: intensive atmos-ice-ocean-ecosystem observations
2) Distributed Network: Heterogeneity on model grid-box scale
3) Coordinated, multi-scale analysis & modeling activities, Links with YOPP

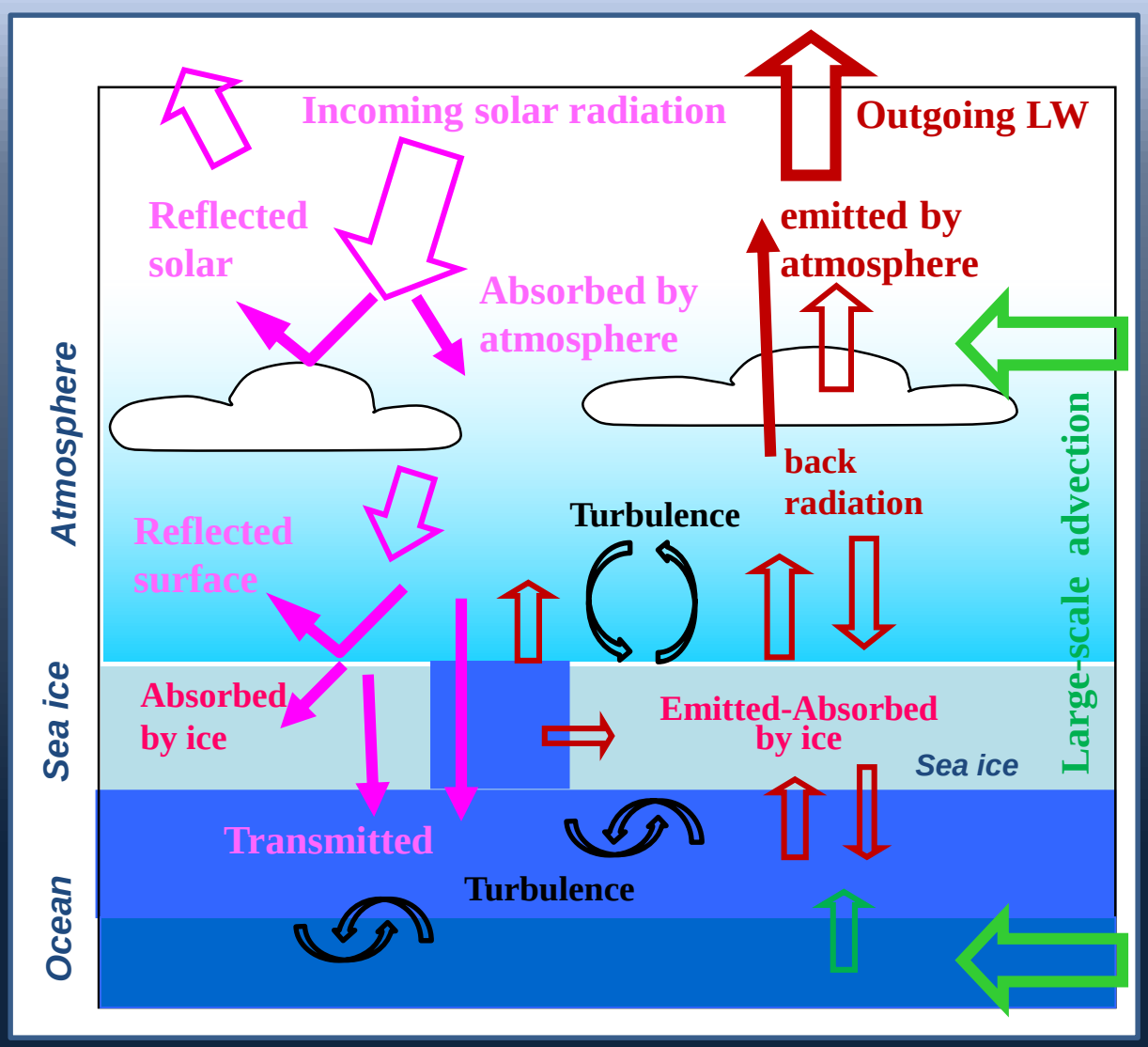
MOSAiC Science Drivers



Leading Science Question:

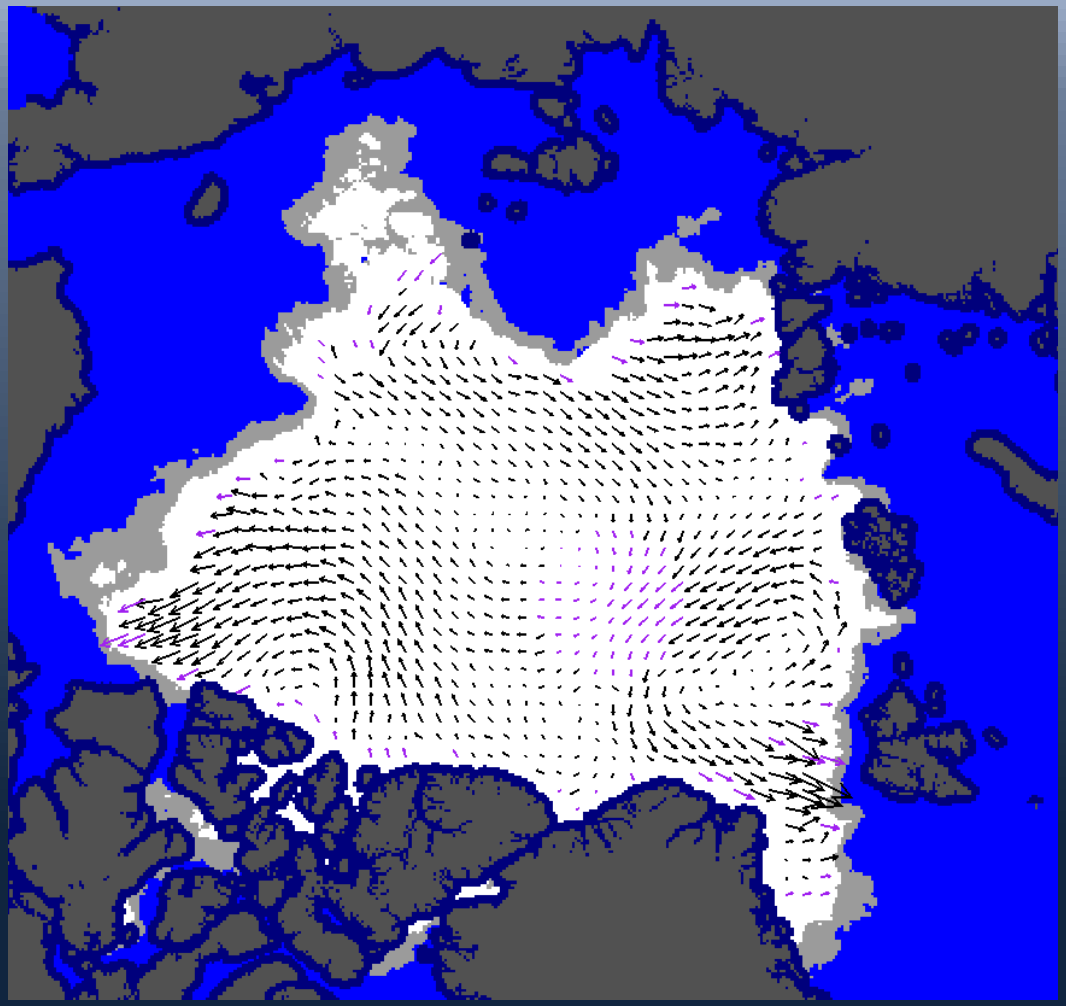
"What are the causes and consequences of an evolving and diminished Arctic sea ice cover?"

Sea-Ice Energy Budgets



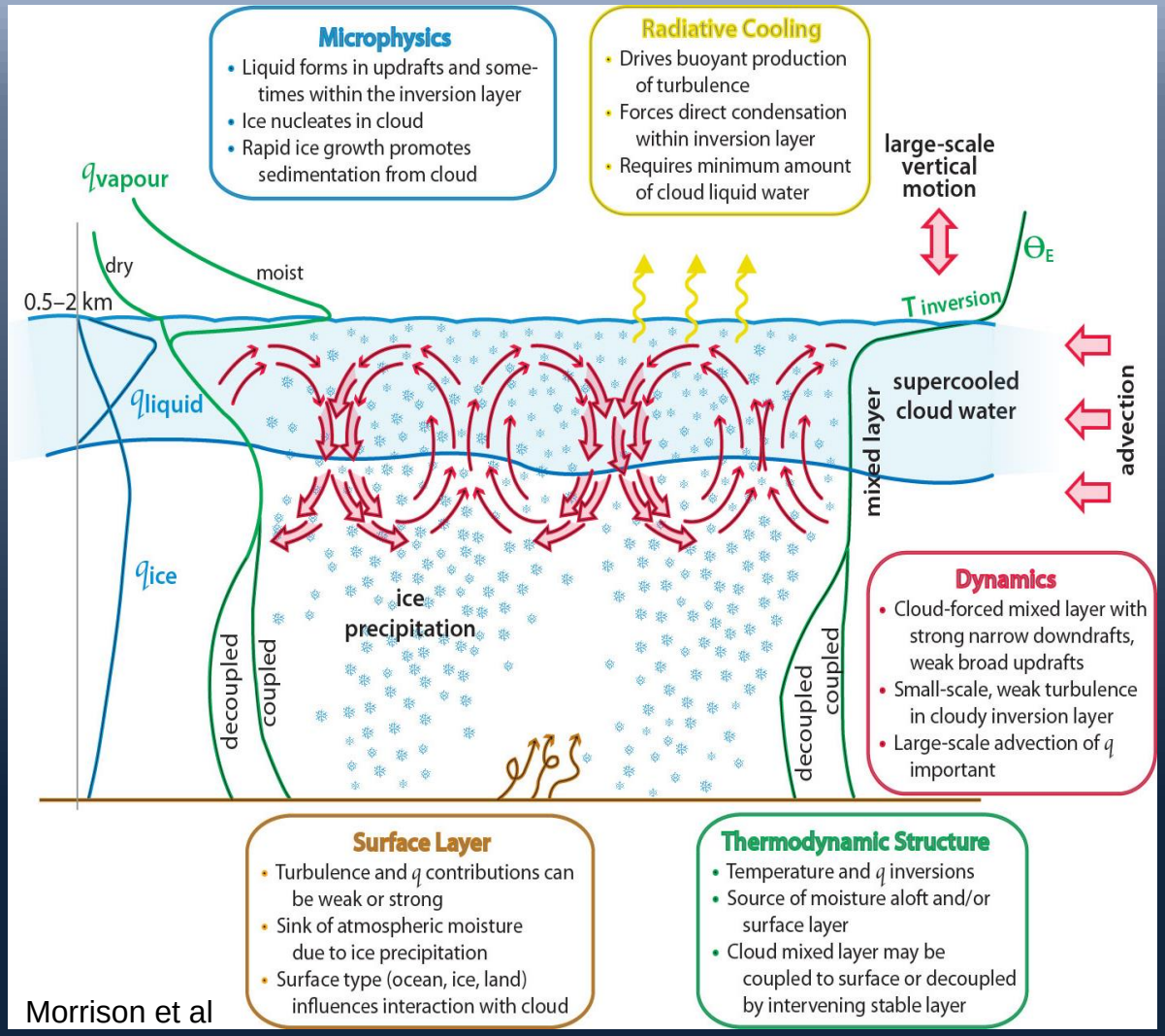
- Energy Budgets
- Radiation
- Upper Ocean Heat Storage
- Mixing Processes
- Turbulence
- Stratification
- Boundary Layers

Ice Motion / Deformation



- Ice Age
- Ice Thickness Dist'n
- Floe Size Dist'n
- Ridging / Leads
- FYI Roughness / Drag
- Momentum Fluxes
- Dynamics / Velocity
- Ice –Wave Interactions

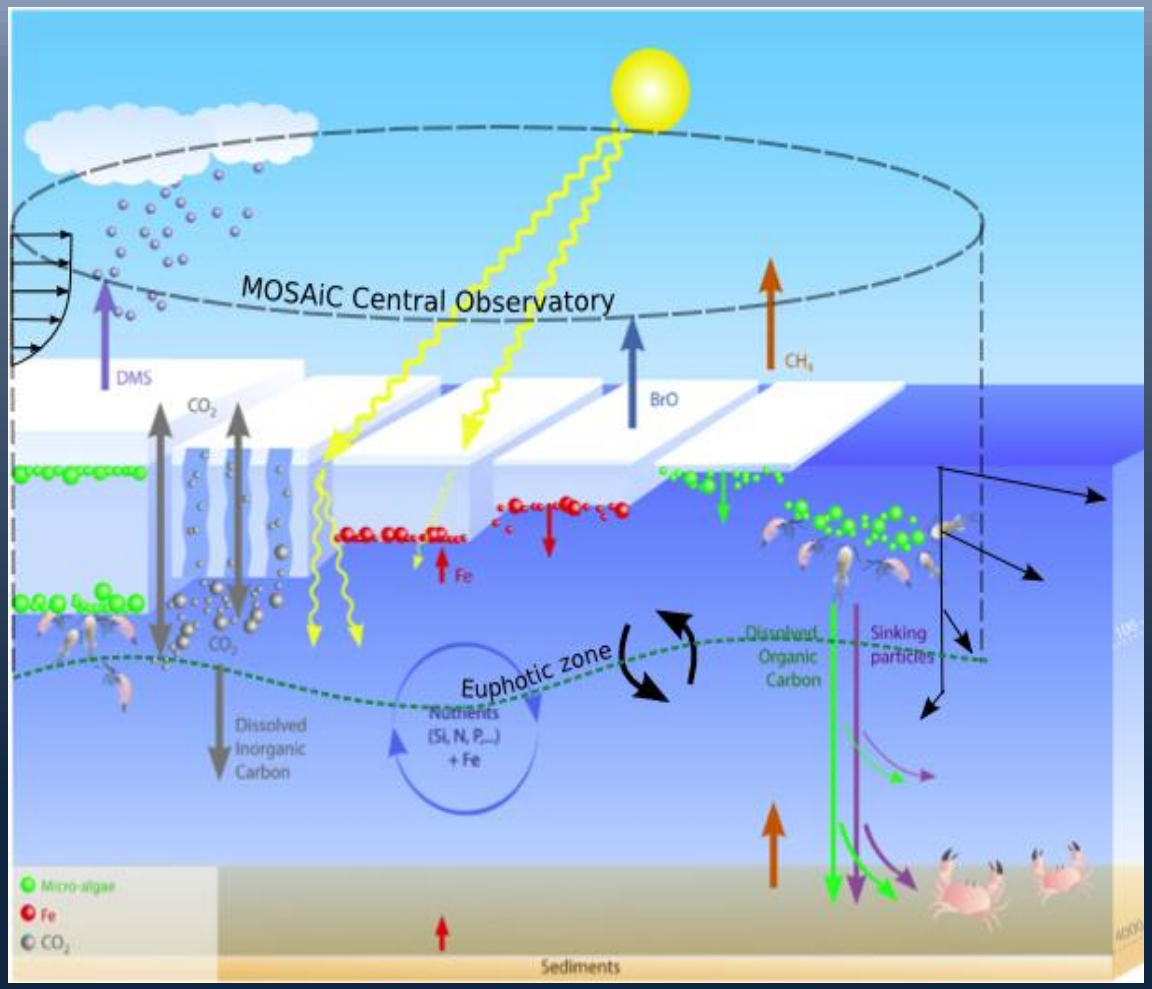
Clouds/Precip/Aerosols



Morrison et al

- Phase Partitioning / Mixed-phase
- Radiative Processes
- Cloud dynamics / Turbulence
- Spatial Organization
- Cyclogenesis
- Aerosol Conc. / Source attribution
- Precipitation

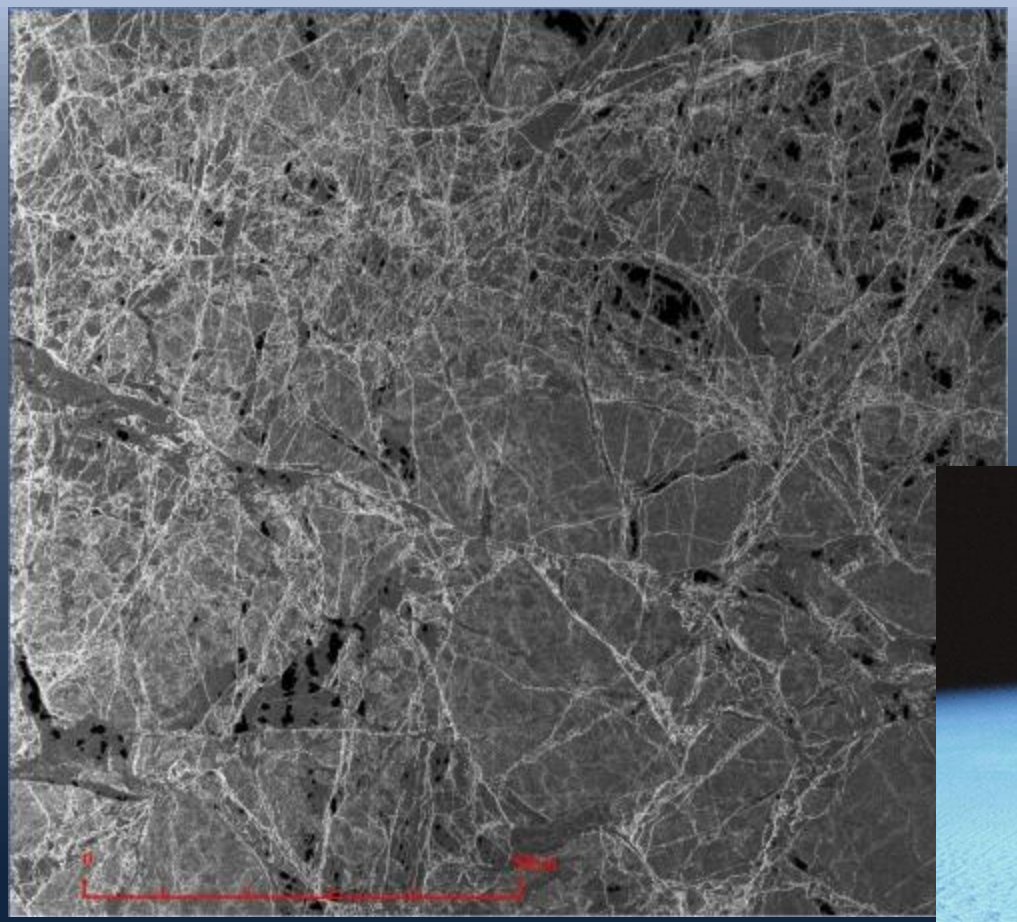
Biological/Chemical Cycles



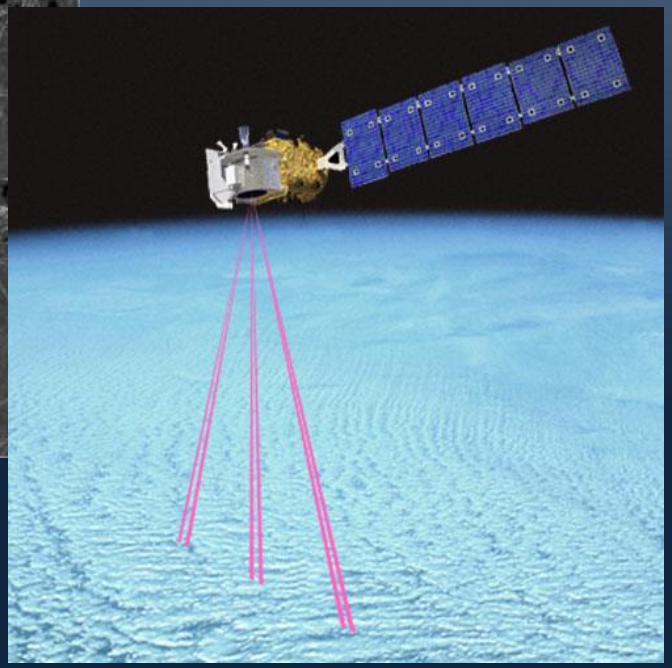
- Ecosystems and Communities
- Primary Productivity
- Elemental Cycles
- Vertical Export and Mixing
- Surface Gas Exchange
- Photochemistry
- DMS and Aerosol Precursors

MOSAiC Operational Drivers

Interfacing with Satellites

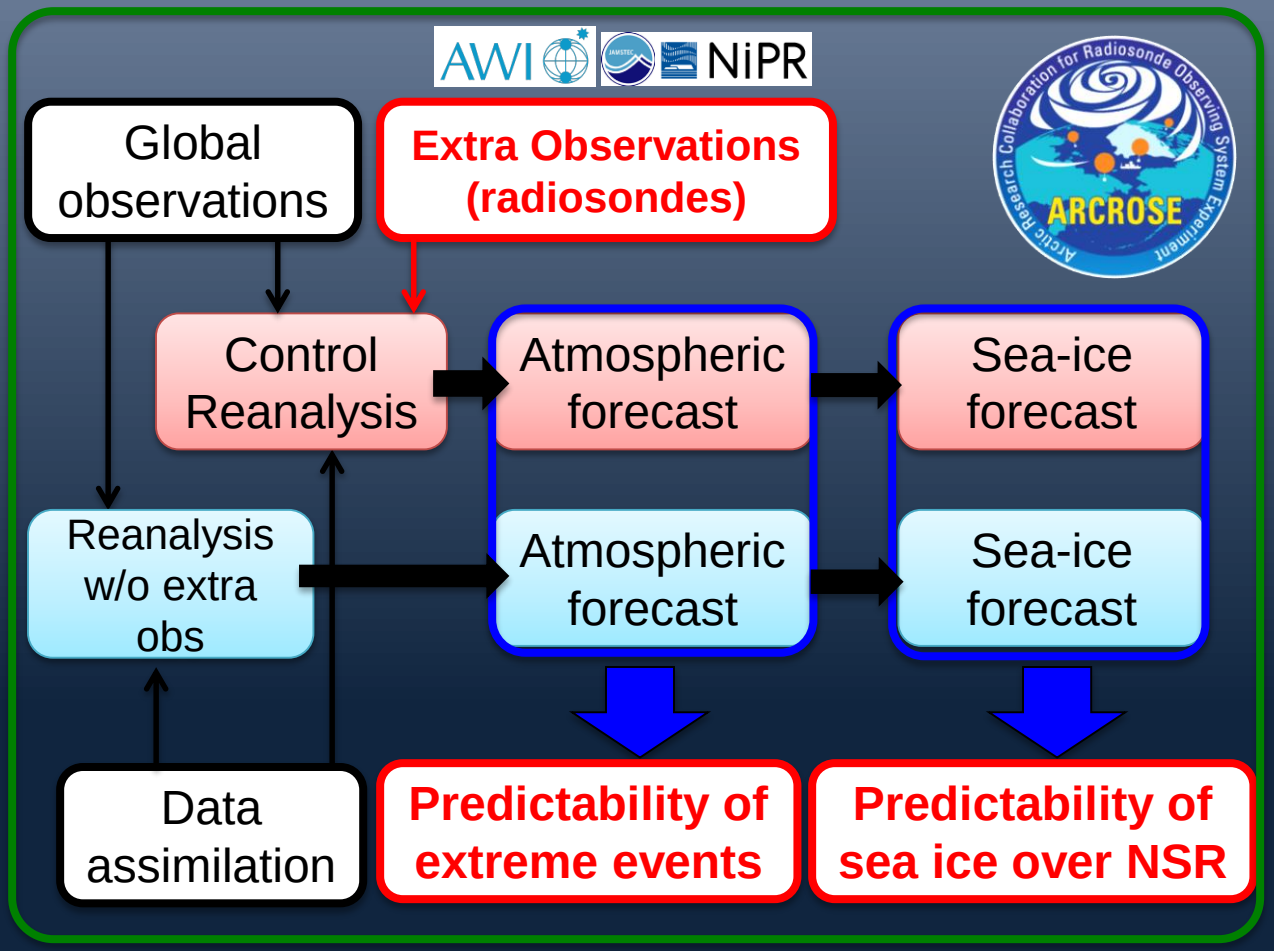


- Operational strategies
- Ground validation
- Method development
- Upscaling



Data Assimilation

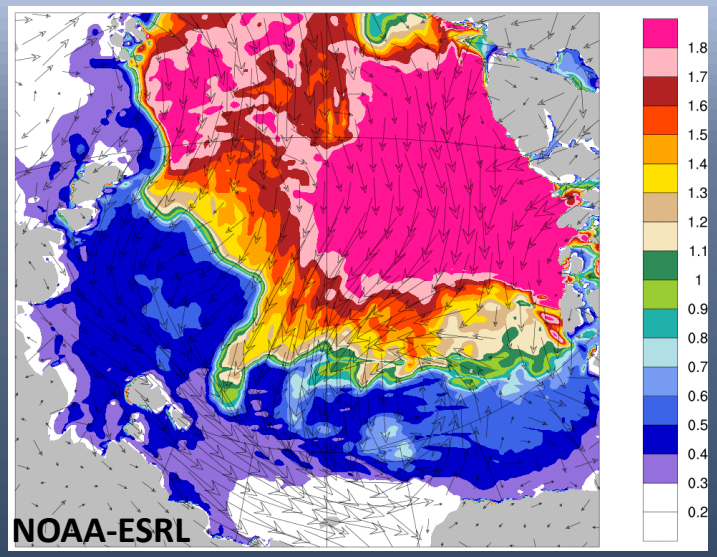
JAMSTEC ALERA2
Observing system experiments

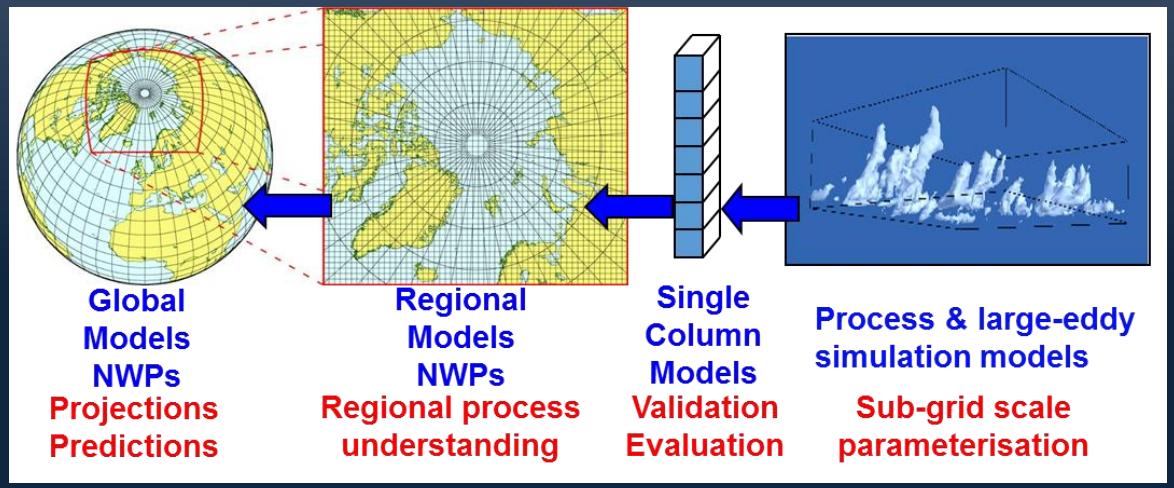


- **Impact of additional observations**
- **Operational forecasts**
- **Re-analyses**

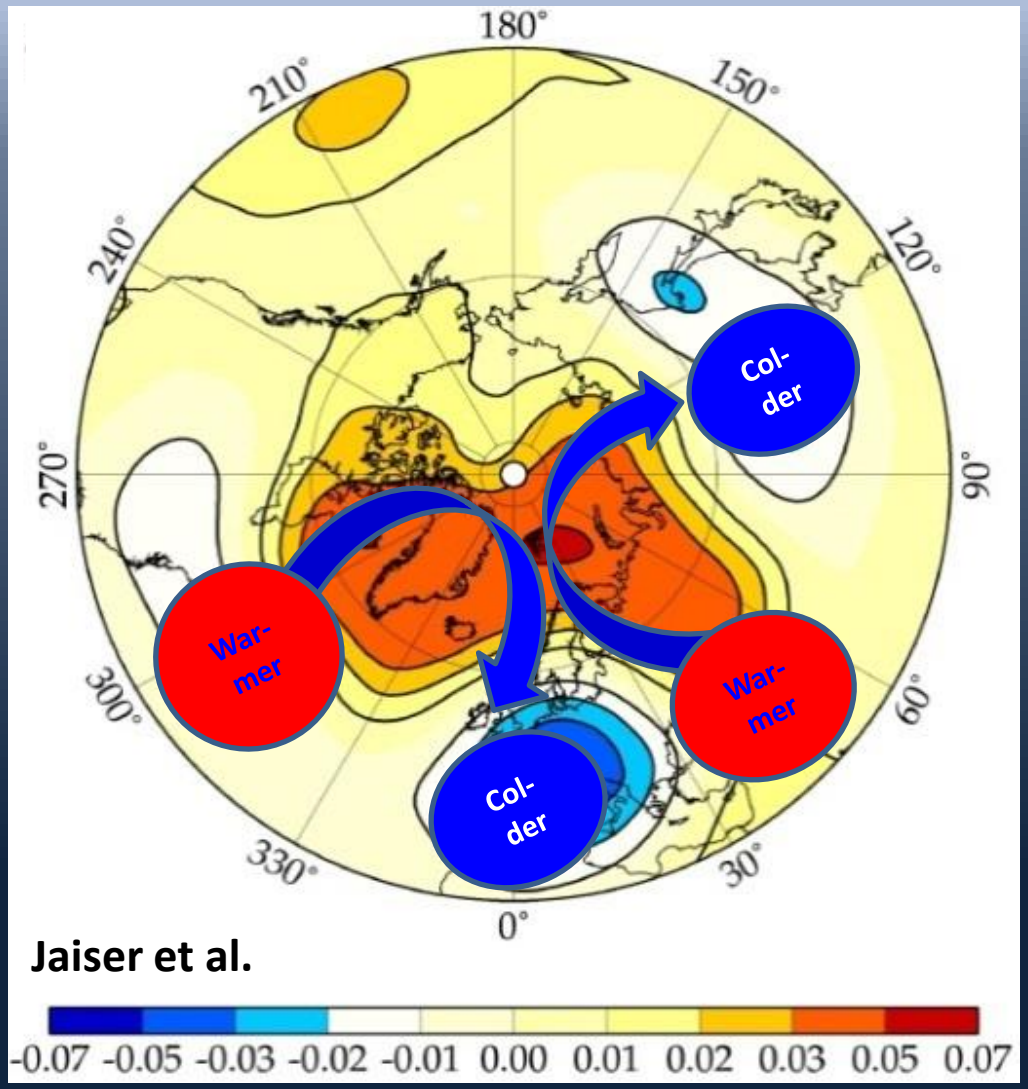
Multiscale Modeling

- LES & process modeling
- SCM for evaluating parameterizations
- CORDEX: Regional model intercomparison
- Experimental, operational sea-ice forecasting
- YOPP: Global coupled system modeling





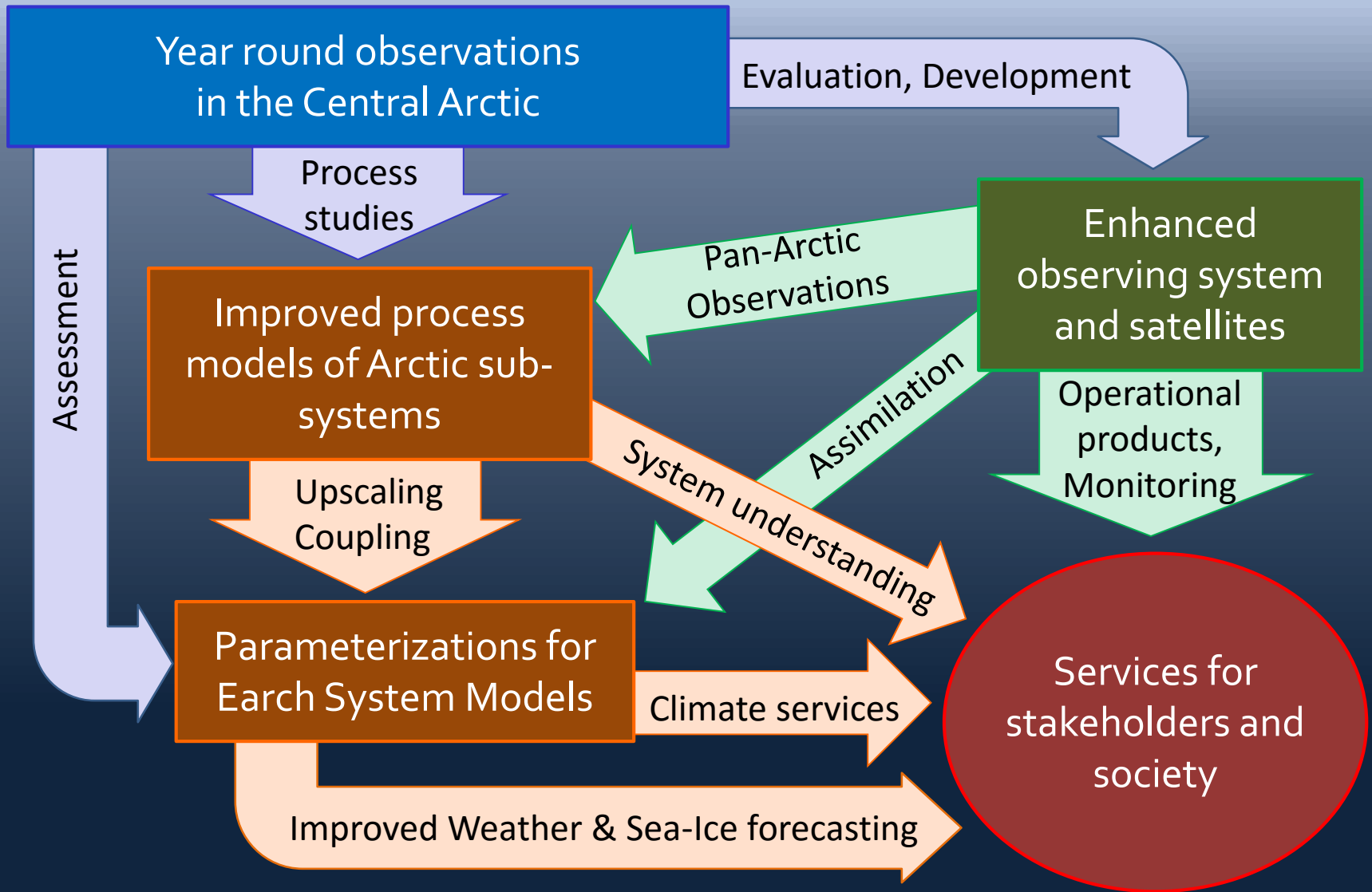
Large-Scale Implications



Jaiser et al.

- Large-scale Transport
- Linking local processes & hemispheric patterns
- Upscaling
- Implications of regional change

Stakeholder Services



Implementation

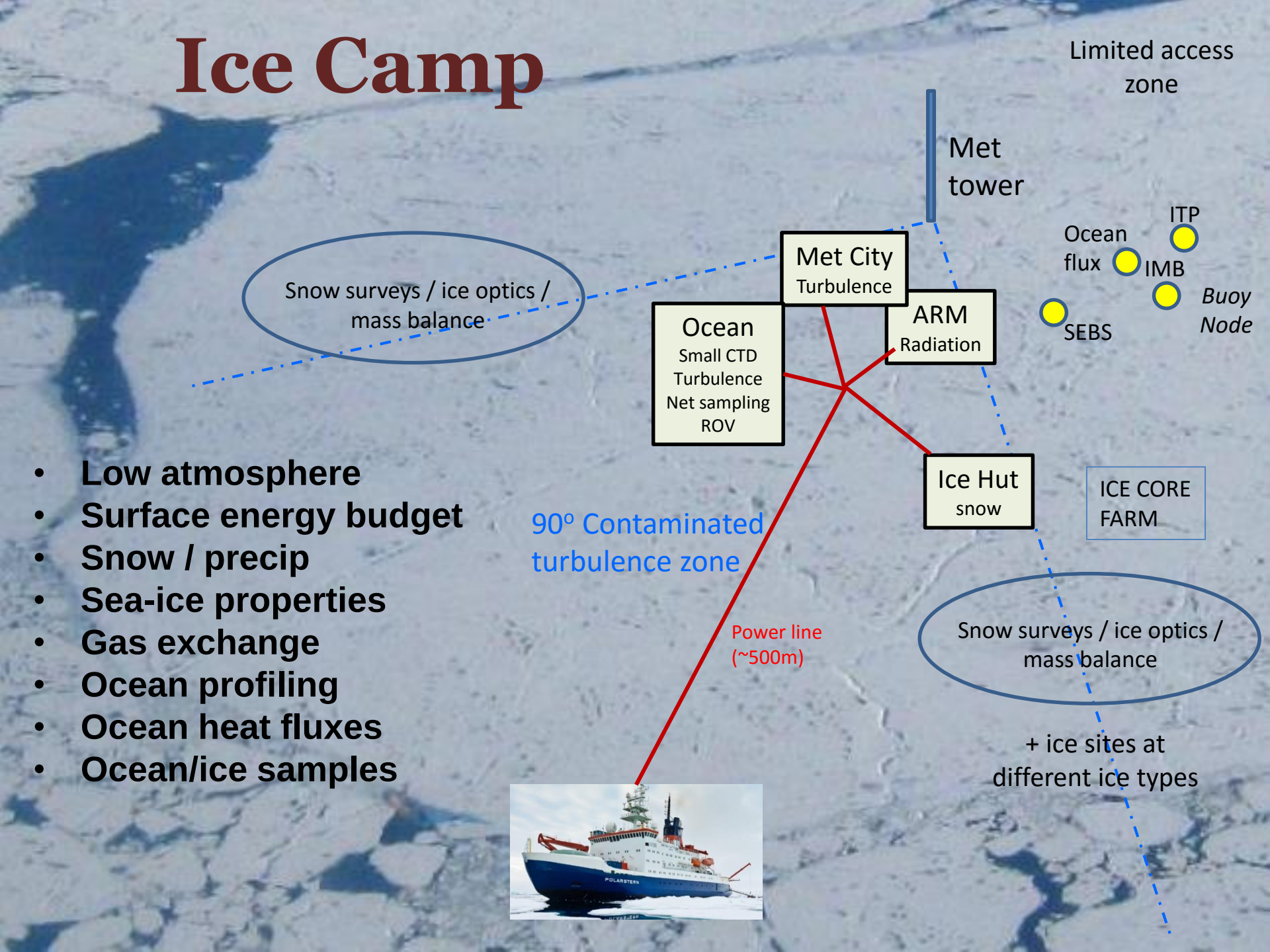
Central Observatory

Polarstern Icebreaker

From Alfred Wegener Institute, Germany

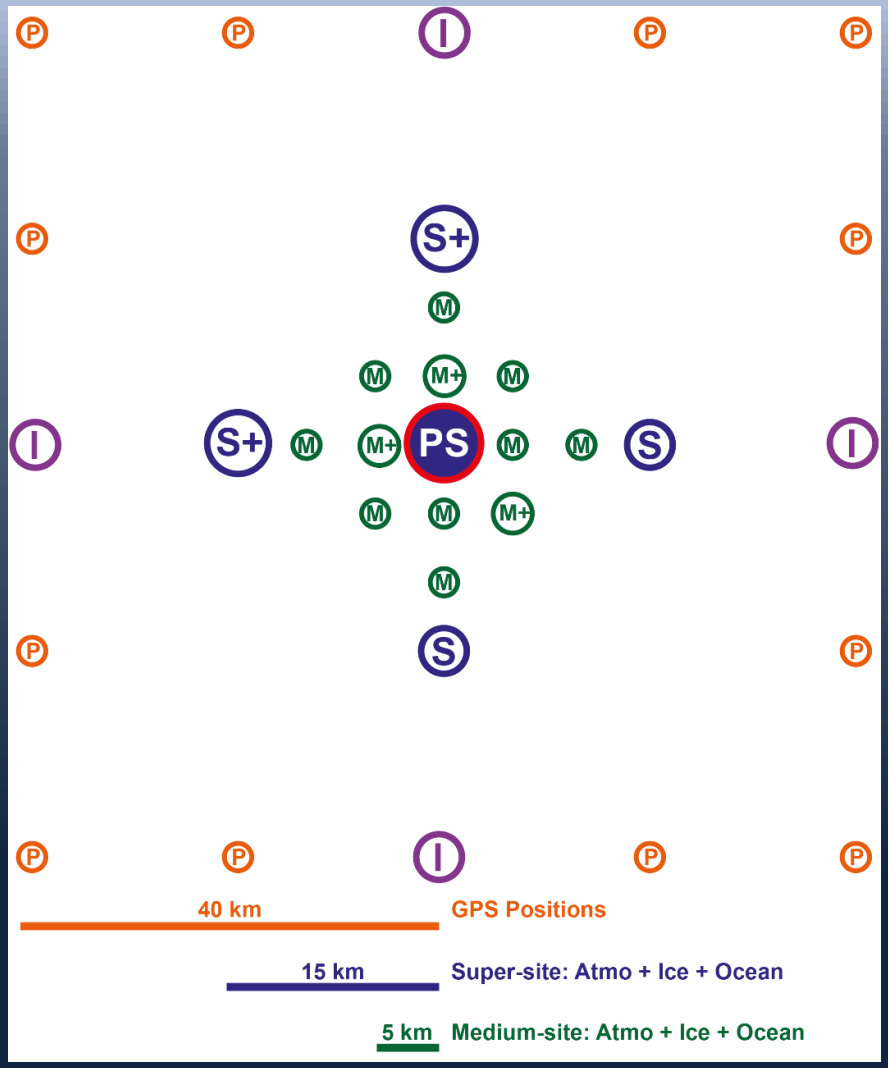
- Atmospheric remote sensing
- Radiosondes
- Air sampling
- Ocean profiling/ADCP
- Laboratories for analysis (biological, chemical, etc.)
- Base of operations
- Safety
- Data/sample storage

Ice Camp



- **Low atmosphere**
- **Surface energy budget**
- **Snow / precip**
- **Sea-ice properties**
- **Gas exchange**
- **Ocean profiling**
- **Ocean heat fluxes**
- **Ocean/ice samples**

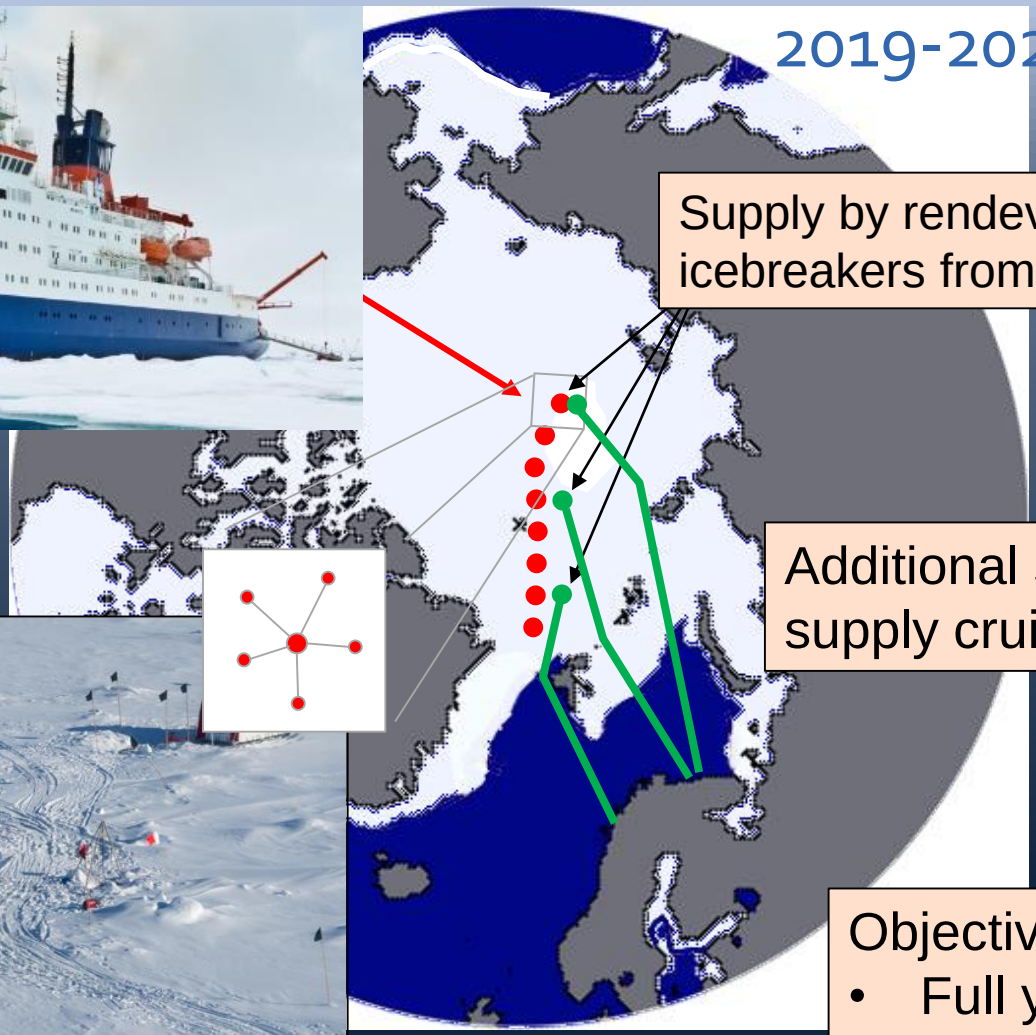
Distributed Network



- Enhanced coupled-system: >5 nodes, 15km, (ocean profiling, ice mass balance, ocean and atmos heat fluxes)
- Coupled-system: 5-40 km (upper ocean, ice mass, met)
- Ice deformation: 1-40 km (gps)
- Spatial mapping: UAS, glider, AUV, helicopter, scanning
- Periodic visits for ocean/ice sampling & maintenance
- Larger-scale network: pan-Arctic network of surface pressure buoys

Drift Concept

Central Station:
RV Polarstern



Supply by rendevous with icebreakers from MOSAiC partners

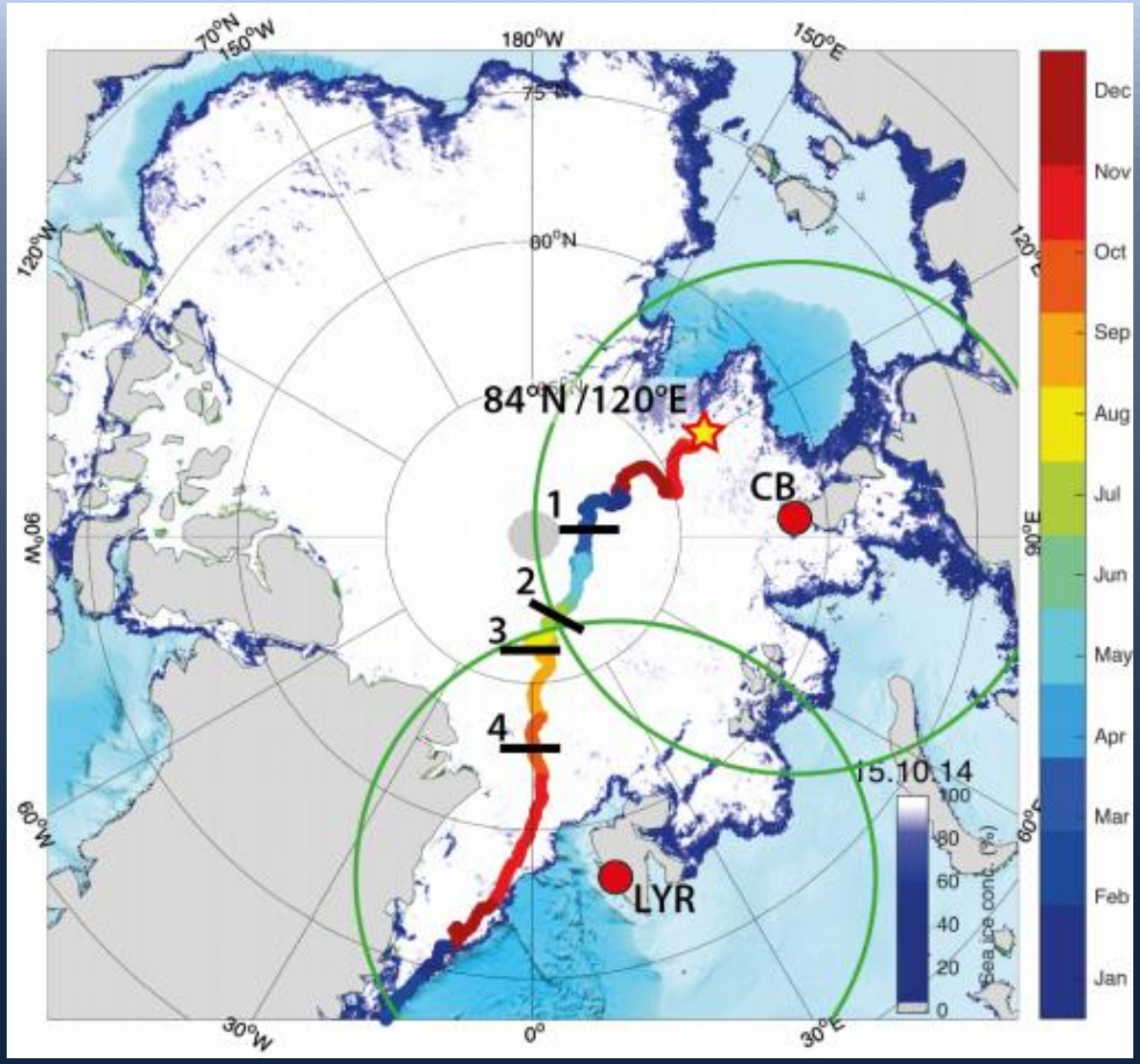
Additional science on supply cruises

Distributed network of satellite stations

Objective:

- Full year drift = full sea-ice lifecycle

Drift Concept



Model+satellite drift trajectories over 2001-2014.

Full year drift

Consider range for access

Personnel/Funding

96 total = 43 crew + 4 heli + 2 weather + 47 “science”

47 science includes:

- cruise leader (1), chief scientist (1), safety/guards (2), data manager (1), media/outreach (2)
- 40 scientists: Atmosphere (8), Sea ice / snow (8), Ocean (5), Biogeochemistry (4), Ecosystem (6), Flexible (9)
- 26 “International” berths

Funding for resupply logistics:

“International” berth fee of 1400 Euro/day

Team Coordination

Role	AWI	International
Project Leader Assistance	M. Rex A. Sommerfeld	M. Shupe (CU/NOAA) V. Rachold (IASC)
Atmosphere	M. Rex	M. Shupe (CU/NOAA)
Sea ice / snow	M. Nicolaus	D. Perovich (CRREL)
Ocean	B. Rabe	C. Provost (UPMC)
Biogeochem	E. Damm	B. Loose (URI)
Ecosystem	A. Waite	M. Reigstad (UiT)
Model Integration	A. Rinke	W. Maslowski (NPS)
Data Management	A. Macario	TBD
Media/Outreach	F. Mertens	TBD
Remote Sensing	G. Spreen (UHB)	TBD
Logistics	M. Hirsekorn U. Nixdorf	TBD

Commitments

- AWI: Polarstern for 13 months
- AWI: Ice, Ocean, Bio, Eco science contributions
- US DOE ARM: AMF2 + MAOS
- TROPOS: RL + MWR + BBrad + sky imager
- German Universities: HALO campaign, 2xDL
- China/PRIC: Xuelong for resupply
- Russia/AARI: Akademik Federov for install
- NOAA-PSD/CIRES: Planning support

AWI

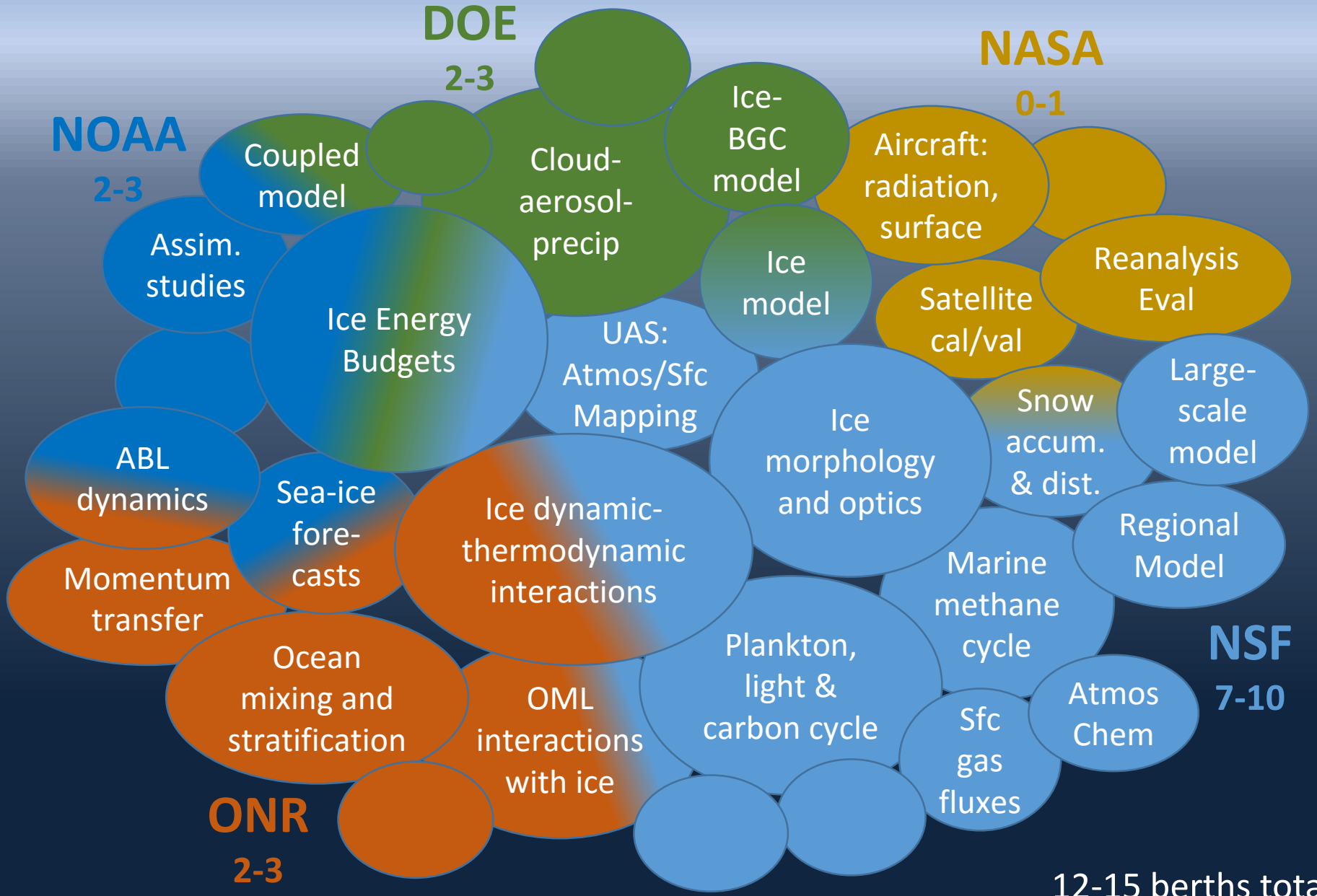
U.S. DEPARTMENT OF ENERGY

TROPOS
Leibniz Institute for Tropospheric Research

Arctic and Antarctic Research Institute

Polar Research Institute of China 1989

US Interagency Concept



Key Milestones

- Science Plan released: March 2016
- Implementation Planning Workshop: July 2015
- Implementation plans (online): March 2016
- Polarstern site visit: May 2016
- Science-based Proposals: 2016-2018


Newsweek U.S. WORLD BUSINESS TECH & SCIENCE CULTURE SPORTS OPINION

www.newsweek.com/arctic-ocean-sea-ice-clouds-443319

TECH & SCIENCE

SCIENTISTS PLAN TO FREEZE A SHIP INTO THE ARCTIC ICEPACK

BY ZOÉ SCHLANGER ON 4/2/16 AT 5:22 PM

Multi-year sea ice with drainage channels is seen on August 23, 2012 in Nunavut, Canada. These ice floes are in Larsen Sound, part of the Northwest Passage.

PAT AND ROSEMARIE KEOUGH/CORBIS

TECH & SCIENCE ARCTIC OCEANS CLIMATE SCIENCE

Thanks!

www.mosaicobservatory.org

Science Input

Aerosol operations: what are the specific priorities? (list instruments). How do we get IN?

Radar operations. Scan strategies.

What specific data sets are needed to support different modeling interests?

Instrument	Measurement	Science Justification
Balloon-Borne Sounding System (radiosonde)	Twice-daily profiles of P, T, RH, winds	Thermodynamic profiles, ABL structure, link with clouds and surface
Microwave Radiometer, 3 channel (MWR3C)	Liquid water path, Water vapor path	Thermodynamic and cloud property characterization.
Microwave Radiometer (MWR)	Liquid water path, Water vapor path	Thermodynamic and cloud property characterization
High Spectral Resolution Lidar (HSRL)	Backscatter, depol ratio, cloud micro properties	Cloud property characterization; aerosol profile info
Micropulse Lidar (MPL)	Backscatter, depol ratio, cloud micro properties	(May not be needed if HSRL is present)
Doppler Lidar	Air motions, turbulence	Wind, turbulence in ABL, cloud-atmosphere interactions
Total Sky Image (TSI)	Visible hemispheric sky pictures	Visual documentation of cloud/sky coverage
Scanning W-band ARM Cloud Radar (SWACR)	Radar moments; Scanning; Cloud micro/dynamical properties	(Similar to Ka-SACR; not needed)
Marine W-band ARM Cloud Radar (M-WACR)	Vertical radar moments and spectra; motion stabilized	Cloud/precip characterization; Cloud-ABL dynamics; Dual-frequency synergy with KAZR
Ka-band Scanning ARM Cloud Radar (Ka-SACR)	Scanning radar moments; Joint with X-SACR;	Cloud/precip characterization and spatial organization.
X-band Scanning ARM Cloud Radar (X-SACR)	Scanning radar moments; Joint with Ka-SACR; Polarimetry.	Cloud/precip characterization and spatial organization.
Ka-band ARM Zenith Radar (KAZR)	Vertical radar moments and spectra	Cloud/precip characterization; Cloud-ABL dynamics; Dual frequency synergy with M-WACR
Vaisala Ceilometer	Cloud base, backscatter	Robust cloud presence and height
Radar Wind Profiler, 915 MHz (1290-MHz)	Wind profiles	BL wind structure (sub-optimal system for Arctic operations)
Infrared Sounder Spectrometer for IR Spectral Technology (ASSIST)	IR spectral radiance at zenith or other angles	Cloud property characterization; cloud radiative properties
Atmospheric Emitted Radiance Interferometer (AERI)	IR spectral radiance at zenith or other angles	Cloud property characterization; cloud radiative properties
IR All-sky Camera	IR radiation, spatial	Sky radiative heterogeneity
Multifilter Rotating Shadowband Radiometer (MFRSR)*	Solar irradiance at multiple wavelengths	Atmospheric / aerosol optical depth
Upwelling Radiation (GNDRAD)*	Upwelling broadband LW, SW fluxes	Surface radiation/energy budget, albedo characterization
Downwelling Radiation (SKYRAD)*	Downwelling broadband LW, SW fluxes	Surface radiation/energy budget, cloud radiative properties
Eddy Correlation System (ECOR)*	Surface turbulent fluxes, carbon dioxide.	Surface energy balance; turbulent momentum, heat, CO_2 fluxes
Surface Energy Balance System (SEBS)*	Up/down SW/LW radiation, soil moisture	(little added value beyond GNDRAD, SKYRAD)
Video Disdrometer (VDIS), 2D*	Precip DSD and fall speed	Precipitation mass/rate
Rain Gauge, weighing bucket*	Precipitation rate	Precipitation mass/rate (Difficult to operate in cold temperatures)
Met. Instrumentation*	Near-sfc P, T, RH, winds	Meteorological state for context
Inertial Nav. System	Platform pitch, roll, heave	Informational, context

Instrument	Measurement	Science Justification
CCN200 (dual col.)	CCN concentration	Baseline characterization of CCN
Condensation Particle Counter (CPC)	Aerosol number concentration > 10nm	Baseline characterization of total aerosol concentrations
Ultrafine Condensation Particle Counter (UCPC)	Aerosol number concentration > 2.5 nm	Small particle concentration, new particle formation, & source attribution
Hygroscopic Tandem Differential Mobility Analyzer (HTDMA)	Aerosol mass, size, and # distribution as g(RH), particle growth factor	Baseline characterization of aerosol size dist'n; aerosol hygroscopicity
Ultra High Sensitivity Aerosol Spectrometer (UHSAS)	Aerosol size dist'n, 50–1000 nm	Baseline characterization of size dist'n
Scanning Mobility Particle Sizer (SMPS)	Aerosol size dist'n, 15-450 nm	Baseline characterization of size dist'n
Nephelometer	Aerosol light scattering coeff at dry RH, 3 wavelengths	Aerosol scattering, radiative effects
Wet Nephelometer	Aerosol light scattering coeff as f(RH), 3 wavelengths	Aerosol scattering, radiative effects
Humidigraph	Aerosol light scattering coeff as f(RH)	Aerosol scattering, radiative effects
Particle Soot Absorption Photometer (PSAP)	Aerosol light absorption at 3 wavelengths	Aerosol absorption, radiative effects
Photo-Acoustic Soot Spectrometer	Aerosol light absorption at 3 wavelengths	Aerosol absorption, radiative effects (Low sensitivity in the Arctic)
Aethelometer	Aerosol light absorption at 7 wavelengths	Aerosol absorption, radiative effects (Redundant with PSAP)
Aerosol Chemical Speciation Monitor (ACSM)	Aerosol mass spectrum measurements	Characterization of aerosol composition
Single Particle Soot Photomoter (SP2)	Black carbon mass concentration	Role of black carbon
Photon Transfer Reaction Mass Spectrometer	Volatile organic compounds	Characterization of aerosol composition (some similar info to ACSM)
PILS-IC-WSOC	Water soluble organic carbon	Characterization of aerosol composition (labor intensive, similar info to ACSM)
NOx, NOy, CO, O_3	Gas concentrations	Airmass source, age, transport
Vaisala WXT520	P, T, RH, winds	Context
Sodar	Vertical wind	Context
Cimel Sunphotometer	Aerosol optical depth	(Similar info to MFRSR)

German Contributions

TROPOS

Raman lidar (Polly-XT): T / q profiles

Microwave radiometer (HATPRO): PWV, LWP, T/q prof

Sky imager

Pyranometer/pyrgeometer

Standard meteorology

OTHERS

1-2 more Doppler lidars

Atmospheric Needs

- Wind profiler (449 MHz)
- Flux tower (20m) with multi-level sonic/met
- Distributed surface energy budget stations
- Ice nuclei measurements
- Surface energy flux over diverse surfaces (UAS?)
- Aerosol profiling (UAS?)