The Arctic Cloud Scenario

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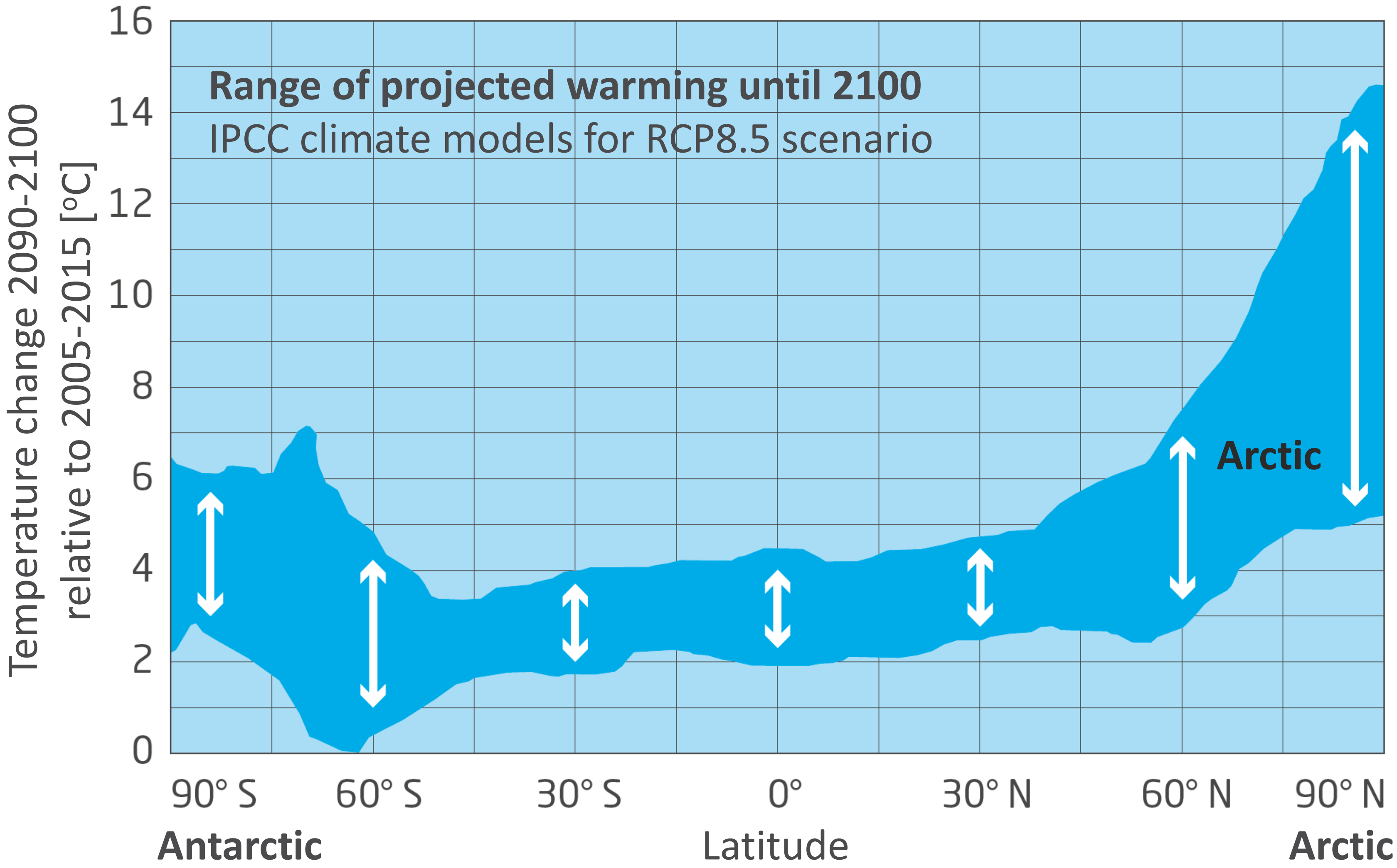
LASSO Expansion Workshop, 2-May-2019, Boulder, CO

Arctic is a Climate Hotbed with Major Model Challenges

ARM



- Wide model spread due to lack of focus and observations
- Little model improvement
- Unique challenges
  - Mixed-phase processes
  - Stable BLs
  - Complex coupling
  - Rapidly evolving surface
  - Major sensitivities and tipping points
- Implications of Change
  - Climate-weather links
  - Resource development
  - Ecosystem change
  - Transportation
  - National Security

Why LES in the Arctic?

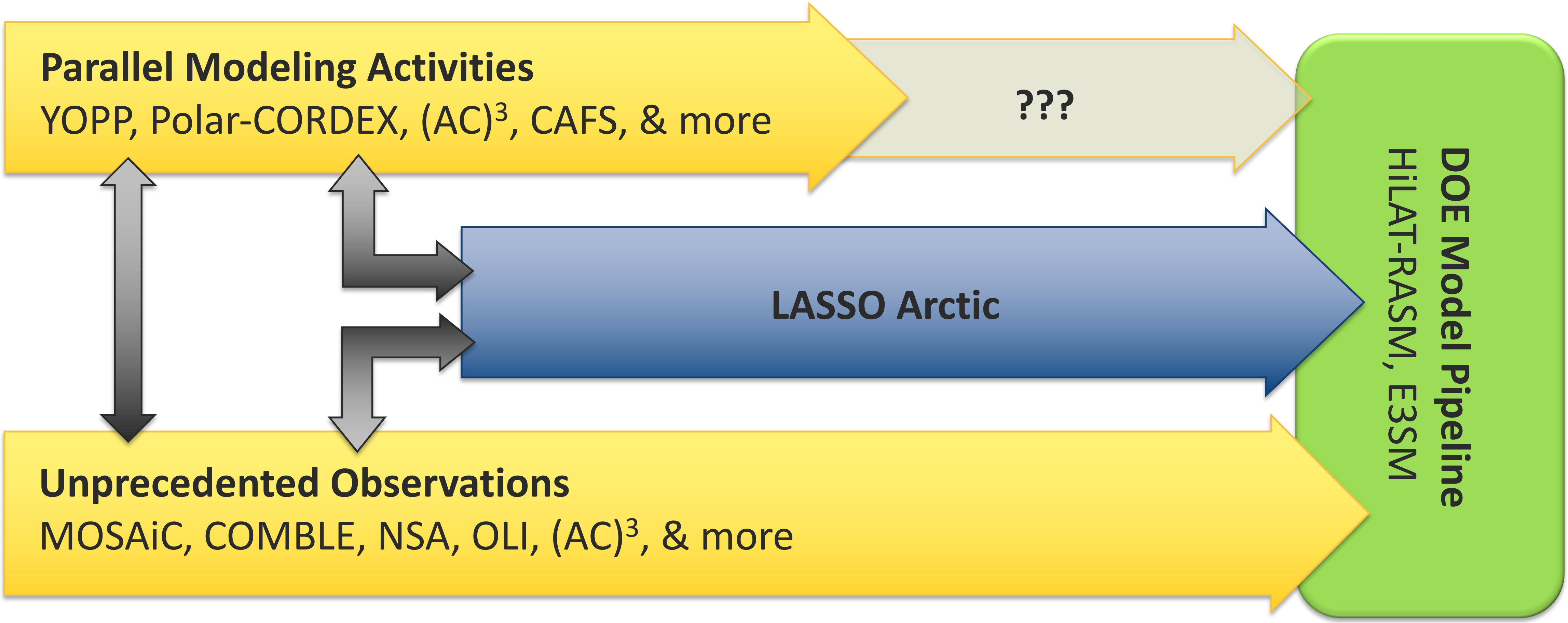
(Answer: Will promote major advances in area of need and high sensitivity)

- Opportunity to break out of golden day approach to develop the first longer term LES dataset in the central Arctic.
  - Should be a lot of potential cases (good statistics).
  - Relatively little focus in past
  - Great step towards regional and global models.
- LES is well positioned to examine delicate balances and budgets that control cloud lifetime
- LES is well positioned to examine impact of variable surface type/fluxes on cloud processes, cloud-ABL structure, etc. >> Link to major Arctic change (Can perform targeted sensitivity studies)
- "Simple" stratified atmospheric structure, so vertical observations are representative more broadly (comparison with observations is more straight forward)
- Observational opportunity not soon to be repeated (MOS and OLI will go away)….. If we don't tackle mixed-phase/Arctic now, then when will it ever be feasible?

Why LES in the Arctic? Specific science foci
(Answer: Will promote major advances in area of need and high sensitivity)

- Build statistical representation of internal cloud feedbacks and budget processes in many conditions through synergistic LES-observational studies:
  - How is moisture distributed and moved vertically across cloud system? (Stratified arctic system)
  - How does cloud moisture budget vary over space and time? (Direct link to cloud lifetime & airmass transformation)
  - What determines turbulence magnitude, mixed-layer depth, and cloud-surface coupling state?
  - What role does surface heterogeneity (spatially, seasonally) play in cloud-ABL structure and longevity?
  - How does the cloud top environment (detailed thermo structure) influence cloud processes?
  - What is the vertical structure of radiative flux divergence profiles and how do these impact structure?
  - What is the effect of free tropospheric properties on low cloud processes?
  - How do cloud number budgets in many conditions, affect cloud lifetime and/or limit cloud processes?

A Unique and Timely Opportunity…. "Once in a Generation"



High Latitudes is 1 of 5 Grand Challenge focus areas in CESD Strategic Plan

Proposed approach: model configuration

- Locate static domains along the MOSAiC drift corridor
  - Traditional, periodic LES with short top
  - Grid spacing = 40 m, domain size = 30x30x4 km
  - <=200 levels with dz~10 m stretching to 50 m
- Model physics appropriate for mixed-phase clouds
  - Need double moment microphysics for both liquid and ice; consider bin microphysics
  - Desire an ensemble of microphysics parameterizations to cover this large uncertainty
  - Need sensitivity tests for choosing an appropriate subgrid-scale parameterization appropriate for the conditions
  - RRTMG radiation
  - Prescribed surface fluxes; Could examine sensitivity of specific cases to surface specification.
- Timing of simulations
  - Length = 24 h, starting at (?)
  - Reinitialize each day (?)
  - Cases focused on stratified environment: Stratified cloud, Stable ABLs, and transitions

Proposed approach: model input data

- Initial conditions
  - Temperature and moisture profiles from ship-launched radiosonde, possibly wind as well
  - Aerosol: surface measurements, some tethered balloon & aircraft, ensemble of possible range
- Large-scale forcing
  - Available observations: 4x daily radiosondes, RWP, surface met. stations
  - Subsidence and large-scale horizontal advection from ERA-5 ensemble members
- Surface boundary conditions
  - Use prescribed values instead of an interactive soil/snow/sea ice scheme
  - Locally measured surface albedo, open water fraction, ice/water temperature, surface fluxes, surface roughness
  - Examine homogeneity of surface state with emphasis on open water

Proposed approach: sensitivity studies and foci

- Surface conditions
  - Simplified specification of different surface conditions / fluxes based on seasonal and/or spatial variability
  - Can examine role of surface roughness, temperature heterogeneity, surface fluxes, surface albedo, etc.
  - Can examine scale of surface heterogeneities
- Aerosol and microphysics
  - Ensemble of aerosol conditions to represent variability and seasonality
  - Different microphysics approaches, bin vs. bulk?

Proposed approach: evaluation data

Instrument	Key Quantities	Operator
Thermodynamic State		
Radiosondes (4x daily)	T, q, p	Both
Unmanned aerial system (UAS)*	T, q, p	Other
Tethered balloon (TBS)*	T, q, p	Other
AERI	T, q	ARM
Raman Lidar	T, q	Other
Turbulence / Dynamics		
Doppler lidar (x4), virtual tower	u, v, w, eddy dissipation rate, variance, skewness	Both
KAZR	W, eddy dissipation rate	ARM
UAS*	W, TKE, eddy dissipation rate	Other
TBS*	W, TKE, eddy dissipation rate	Other
RWP, Sodar	U, v, w	Both
Manned aircraft*	U, v, w	Other

Proposed approach: evaluation data (2)

Instrument	Key Quantities	Operator
Cloud Physics		
KAZR, MWACR	IWC, IWP, w, Doppler spectra, cloud top height, precipitation rate	ARM
HSRL	R_e, N, water content (with KAZR)	ARM
Manned aircraft*	IWC, LWC, R_e, N_{liq}, N_{ice}	Other
SACR	Particle aspect ratio	ARM
MWR (x3)	LWP	Both
AERI / AERIoe	LWP, R_e, N_{liq}	ARM
MPL / ceilometer	Cloud base	ARM
Weighing gauge, Disdrometer	Precipitation rate	ARM
Total Sky Imager	Cloud coverage	ARM
Optical snowfall sensor	Snow particle type, size distributions	Other
Cloud particle size dist'n	CAPS-CIP	Other

Proposed approach: evaluation data (3)

Instrument	Key Quantities	Operator
Surface Energy Budget		
Ground / sky rad	LW and SW irradiances	Both
Flux tower and stations	Turbulent fluxes, broadband irrandiances	Both
UAS*	Turbulent fluxes, albedo	Other
TBS*	Column irradiances, albedo	Other
Manned aircraft *	Flight-level irradiances, albedo	Other

- Diagnostics within the bundle will specifically target… (ABL structure, clouds, surface radiation)
- Approach for using non-continuous data sources?