Developing capacity in process assessment and improvement in NZESM through the use of the single column version of the model.

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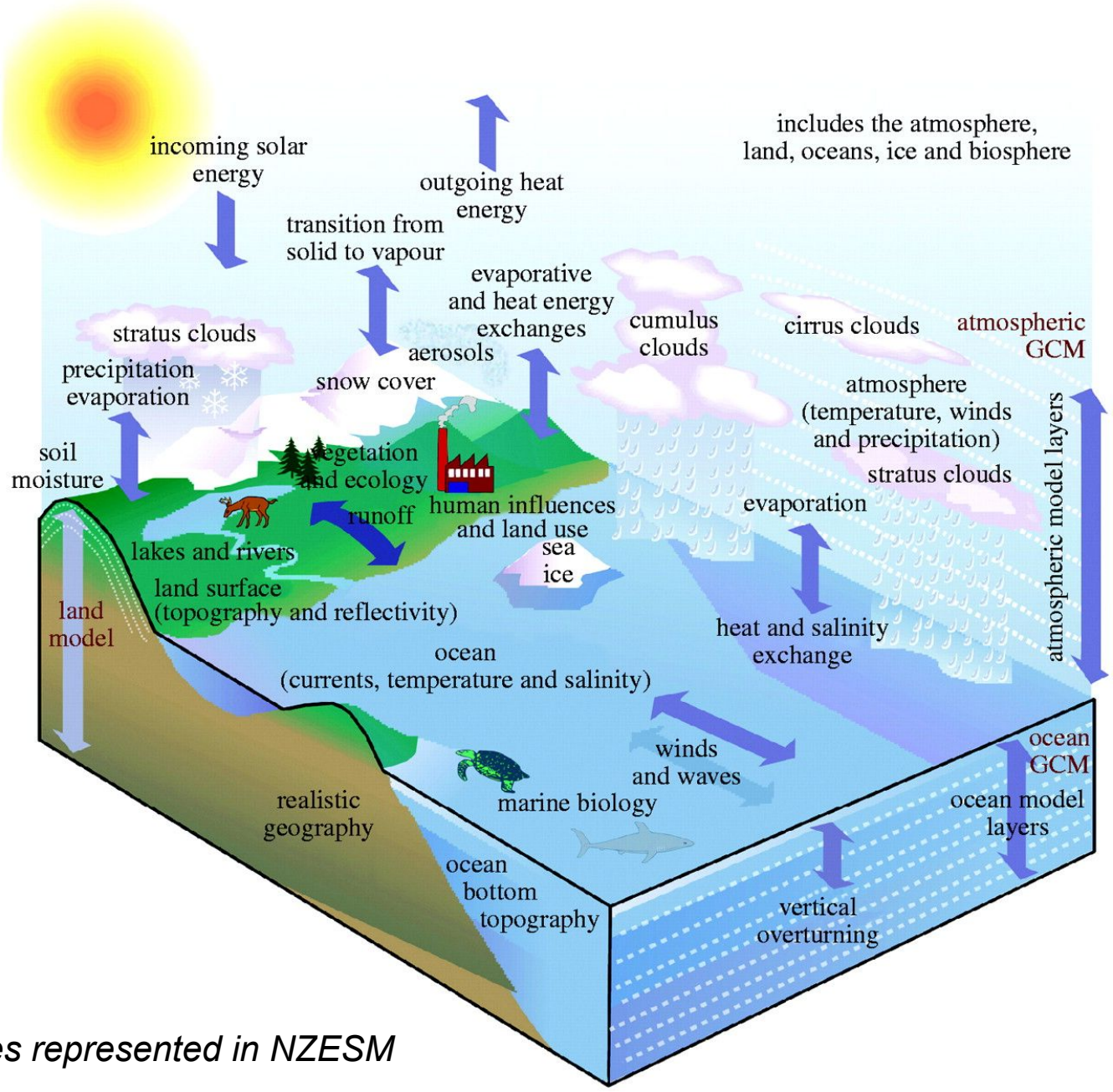
Motivation

- The New Zealand Earth System Model (NZESM) is a powerful tool for simulating the many interacting elements of the climate system in the “Deep South”.
- However, its scale and complexity can make it difficult to assess how well NZESM represents some physical processes occurring in the real world.
- Some of these processes are fundamental to an accurate simulation of climate - such as the interactions between clouds, the air and the amount of energy entering and leaving the atmosphere.

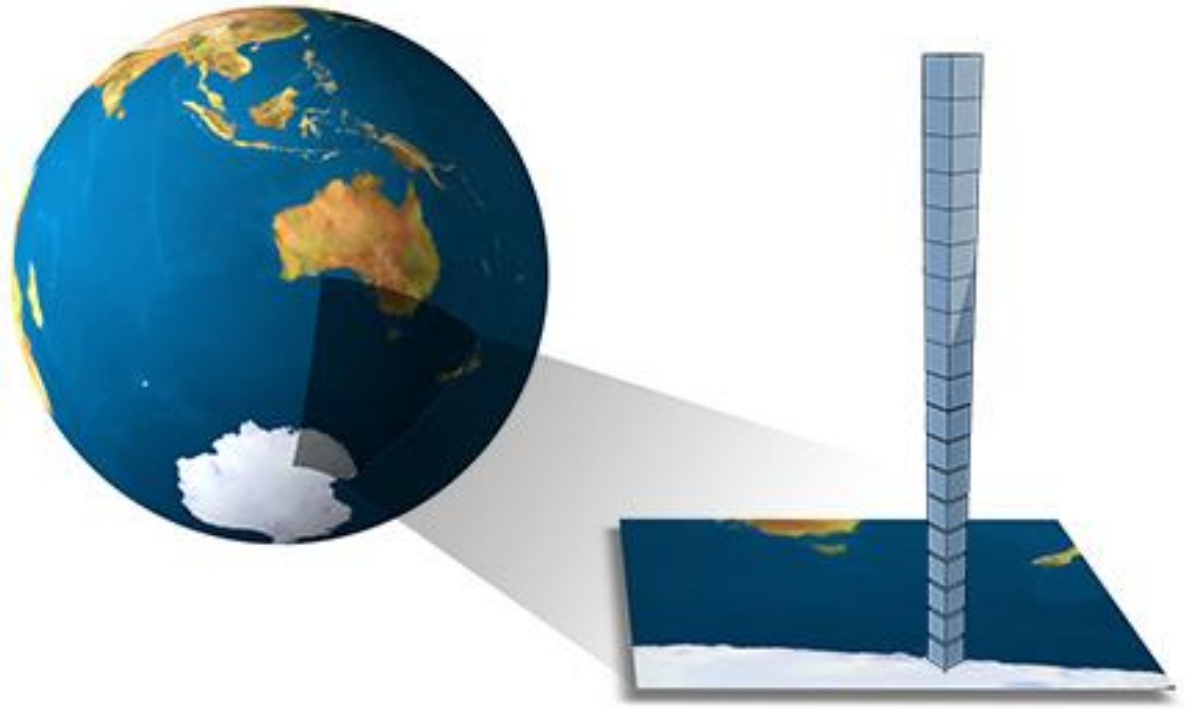


Processes represented in NZESM

Washington et al. (2009) Phil. Trans. R. Soc. A; 367:833-846

Motivation

- By running the NZESM for only a single vertical column with no horizontal dimension - instead of running it across the entire globe - we greatly reduce its complexity.
- Allows easier validation of different processes with NZESM.
- Easier to separate and test individual elements.



Single column model domain schematic

What is the Single Column version of NZESM?

- NZESM run on a single column with no horizontal dimension.
  - Imagine standing looking straight up from Scott Base
  - Assessing the NZESM through this vertical column.
- Primarily focussed on atmospheric model - the Unified Model.

- The NZESM is being developed in tandem with the United Kingdom Earth System Model (UKESM), which is in turn being developed by the UKESM Core Team led by the UK Met Office and the UK Natural Environment research Council. The Deep South developments to the model code are shared across this international modelling consortium (and vice versa) using a cloud based code repository.
- Developing capacity for single column modeling is a key part of model development.

Speed test

- The single column version of NZESM runs 22,000 times faster than full model
- Allows us to quickly test and experiment with different model options - “mini science experiments”.
- Uncertainty and sensitivity assessment.
- If measurements have associated uncertainties, such as a Site Atmospheric State Best Estimate (SASBE), uncertainties in surface and top-of-the-atmosphere radiation can be calculated with a Monte Carlo approach.

Super computer usage for single column vs global model configurations

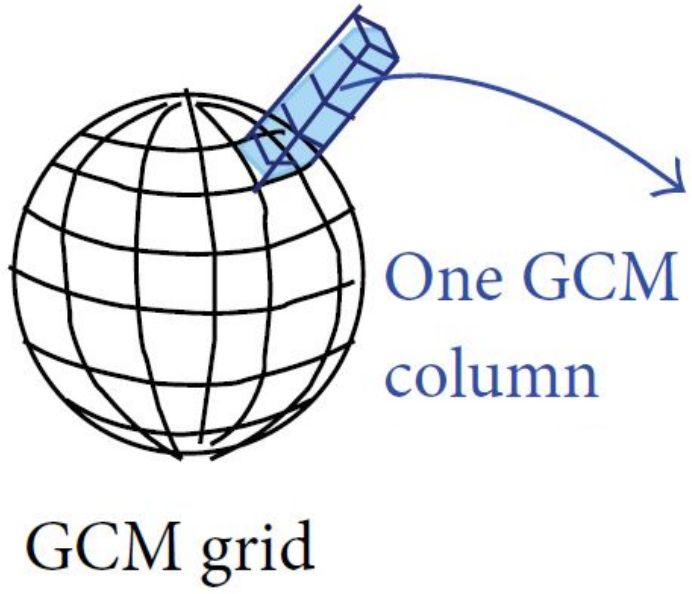
Configuration	**Core-hours for 1-year simulation**
GA7	4355.84
GA7 + StratTrop + nudging	17890.99
GC3	5840.00
GA7 - single column model	0.78

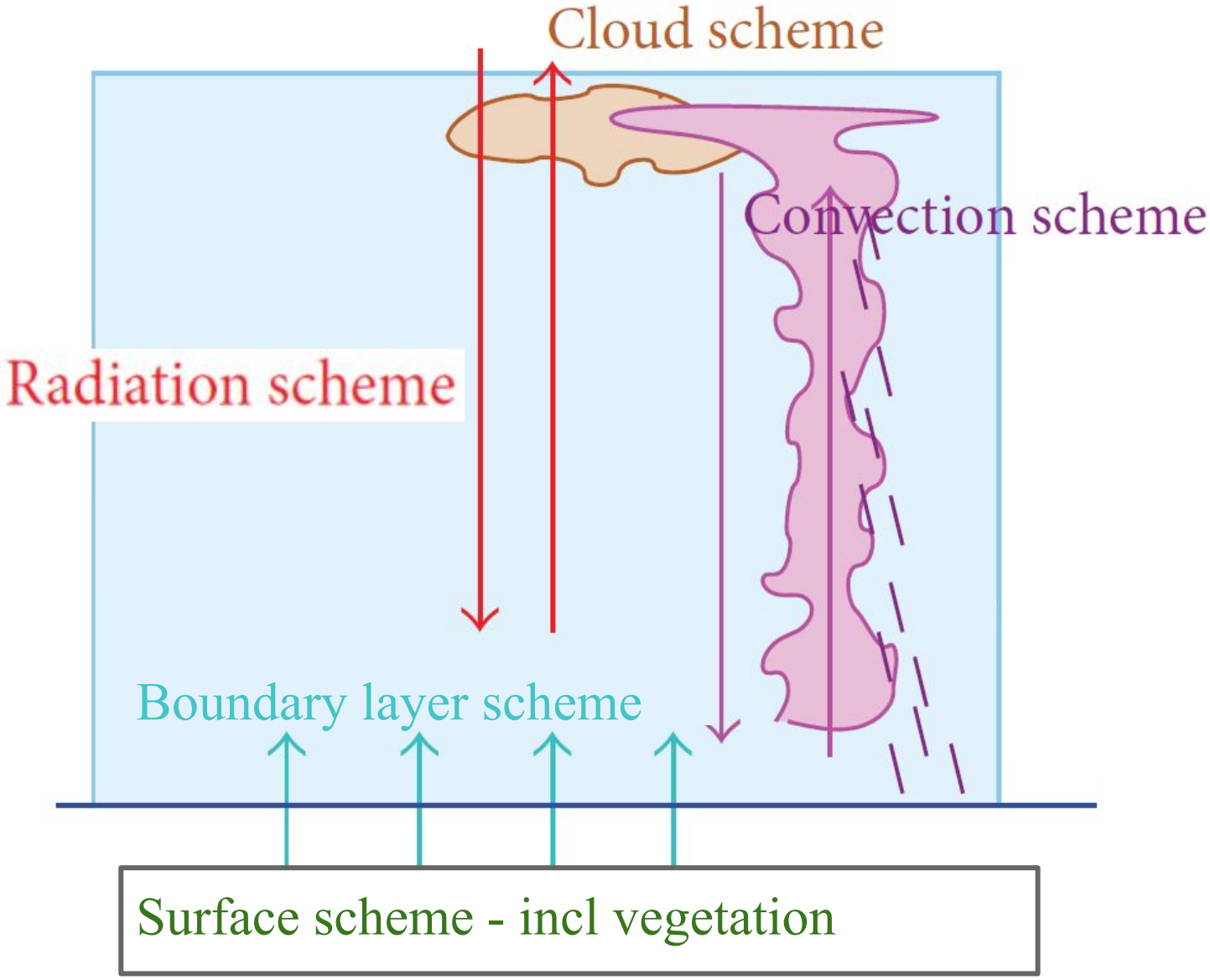
Project aims

- Primary aim is to build capability for single column model within the Deep South team.
  - Show how the model can be used to calculate surface and top-of-the-atmosphere radiances from vertical profile measurements of temperature, pressure, water vapour and ozone.
  - Better understand the treatment of clouds in NZESM.

Ozonesonde flight over Lauder, NZ

Single column physics schemes

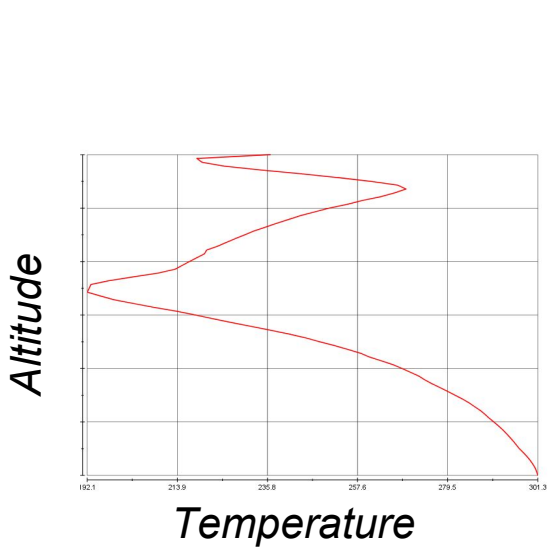


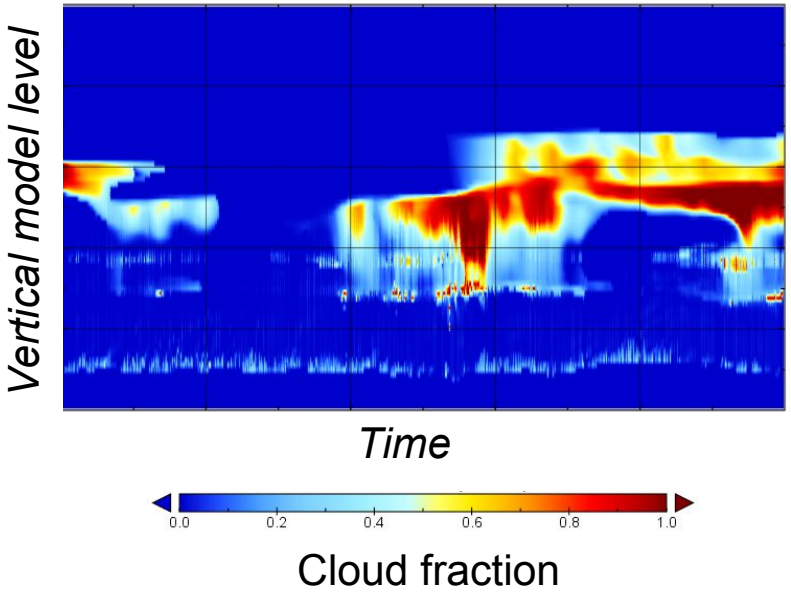


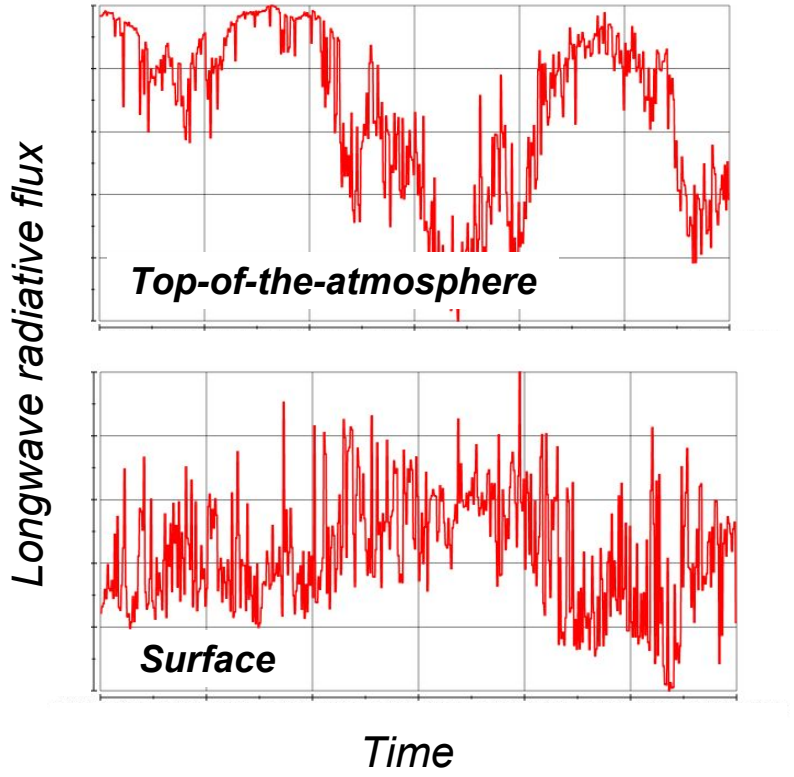
- Excludes horizontal advection, but includes large scale vertical motions
- Aerosol, chemistry and sea-ice schemes NOT currently implemented

Figure adapted from Xi, X.: A Review of Water Isotopes in Atmospheric General Circulation Models: Recent Advances and Future Prospects, International Journal of Atmospheric Sciences, 2014, 1-16, 2014.

Single column model: inputs and outputs







Periodic balloon soundings of temperature, humidity, ozone, geostrophic winds

Modelled state of atmosphere through time

Time series of radiative fluxes at surface and top-of-the-atmosphere

Data from TOGA/COARE test case distributed with the single column model

Initial sites for testing:

- Measurements from Scott Base (including Arrival Heights) and the AWARE (Atmospheric Radiation Measurement, West Antarctica Radiation Experiment) campaign at McMurdo.
- The Atmospheric Radiation Measurement (ARM) program was created out of a need for data to validate climate models.
- ARM Facilities deployed at McMurdo Station from January 2016 to January 2017.

ARM facilities deployed at McMurdo Station, Antarctica

AWARE instrumentation at McMurdo

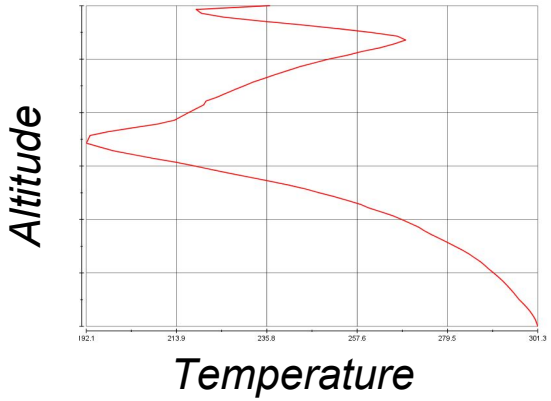
- Broadband and spectral radiometers,
- Balloon borne soundings,
- Cloud radars (scanning and zenith),
- High-spectral-resolution lidar,
- A complete aerosol suite,
- Instruments to measure surface energy balances and water columns.

ARM facilities deployed at McMurdo Station, Antarctica

AWARE McMurdo measurements available

Atmospheric Emitted Radiance Interferometer	Surface Meteorological Instrumentation
AERI Noise Filtered	Multifilter Radiometer
Aerosol Observing System	Multifilter Rotating Shadowband Radiometer
Met. Obs associated with the Aerosol Observing System	Micropulse Lidar
Cloud Condensation Nuclei Particle Counter	Cloud mask from Micropulse Lidar
Ceilometer	Marine W-Band (95 GHz) ARM Cloud Radar
Condensation Particle Counter	Microwave Radiometer
Cimel Sunphotometer	Nephelometer
ECMWF Diagnostic Analyses	Ozone Monitor
Eddy Correlation Flux Measurement System	Planetary Boundary Layer Height
Ground Radiometers on Stand for Upwelling Radiation	Particle Soot Absorption Photometer
G-band (183 GHz) Vapor Radiometer Profiler	Radar Wind Profiler
High Spectral Resolution Lidar	Surface Energy Balance System
Humidified Tandem Differential Mobility Analyzer	Sky Radiometers on Stand for Downwelling Radiation
Interpolated Sonde	Balloon-Borne Sounding System
Infrared Thermometer	Gridded Sonde VAP Product
Ka-Band Scanning ARM Cloud Radar	Total Sky Imager
Ka ARM Zenith Radar	Minnis Cloud Products Using Visst Algorithm
Laser Disdrometer	X-Band Scanning ARM Cloud Radar

Balloon borne sounding system



ARM contractors deploying radio-sonde near McMurdo Station, Antarctica

Work plan & science questions

- 12-month project timeframe: October 2017 - September 2018

- A user-friendly report on how to install, configure and run the single column version of NZESM.
  - Incl. formatting boundary conditions to be prescribed in model simulations.

- Compare surface irradiance spectra calculated with the single column version of NZESM with measurements made at selected sites in the Deep South.
  - Generate surface and top of the atmosphere radiances with the single column NZESM.
  - Better understand the treatment of clouds in NZESM with a particular focus on the Monte Carlo Independent Column Approximation employed in the model.

Contribution to Mission

- This project will contribute to the DSC mission by developing an independent and cost-effective means to assess and validate the physical processes in NZESM essential for simulating climate in the Deep South.
- Future projects will be able to use this capability to explore new science questions


Image: J. Conway