Challenges of the present* – a glimpse into the (near) future

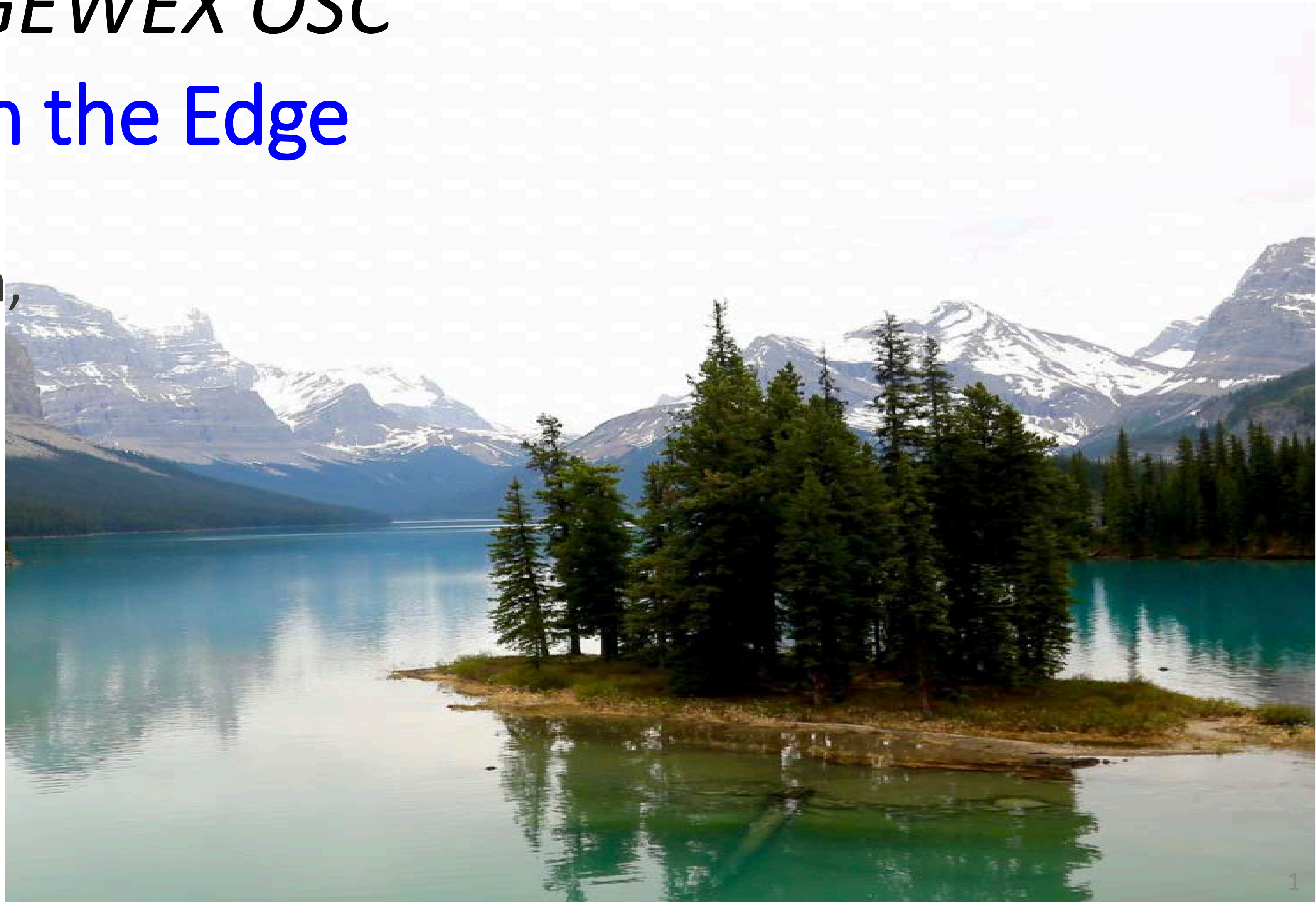
** As exposed at the GEWEX OSC*

Extremes and Water on the Edge

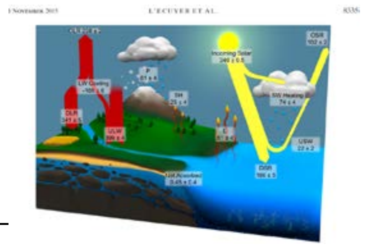
2018 GEWEX Science Conference , Canmore, Alberta, Canada | May 6-11, 2018

Topics included:
Nexus of water, energy, and food | Climate extremes | Extreme weather | Atmospheric modeling and observations | Land modeling and observations | Global energy and water cycles, Mountain and high-latitude hydrology

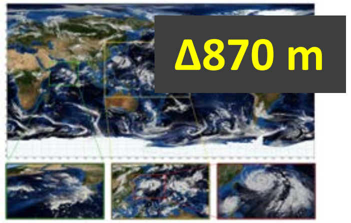
450+ abstracts received
350 registered
ECS workshop - 70 applicants, space for 40



Phase III: Quantitative understanding and prediction of the Global water and energy system



Integrated observing strategies of the Earth system
- address gaps (mountain & cold phase hydrology)



Advances in Earth system modeling

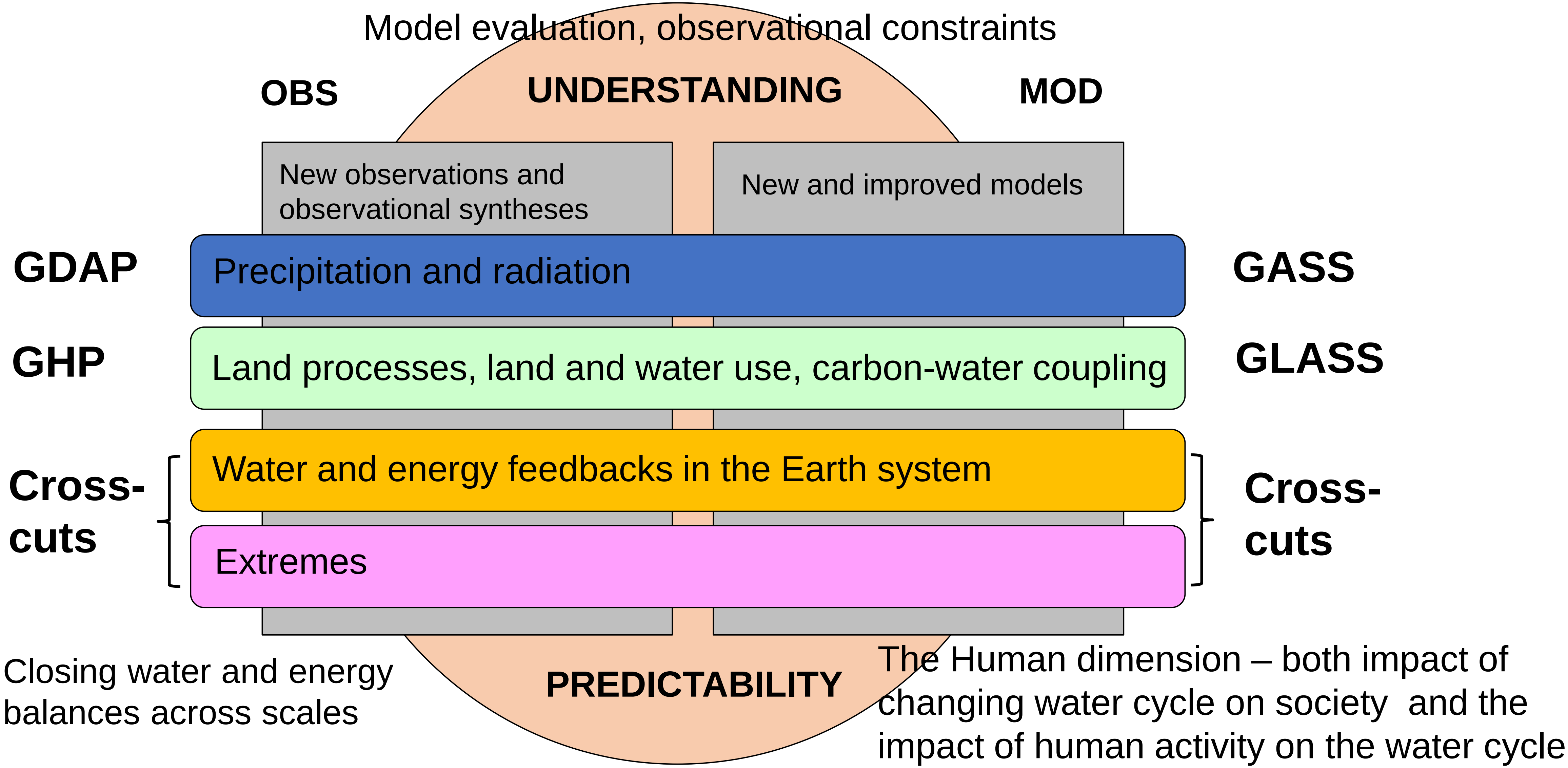
~2014

Need to study process interactions across time scales

Instead of the traditional paradigm of properties define processes, study how processes define properties, Martyn Clark

Challenge is that humanity is embedded in a deeply interconnected living Earth system, Betts

The 4 GEWEX Science Questions sit under these bigger, overarching science questions



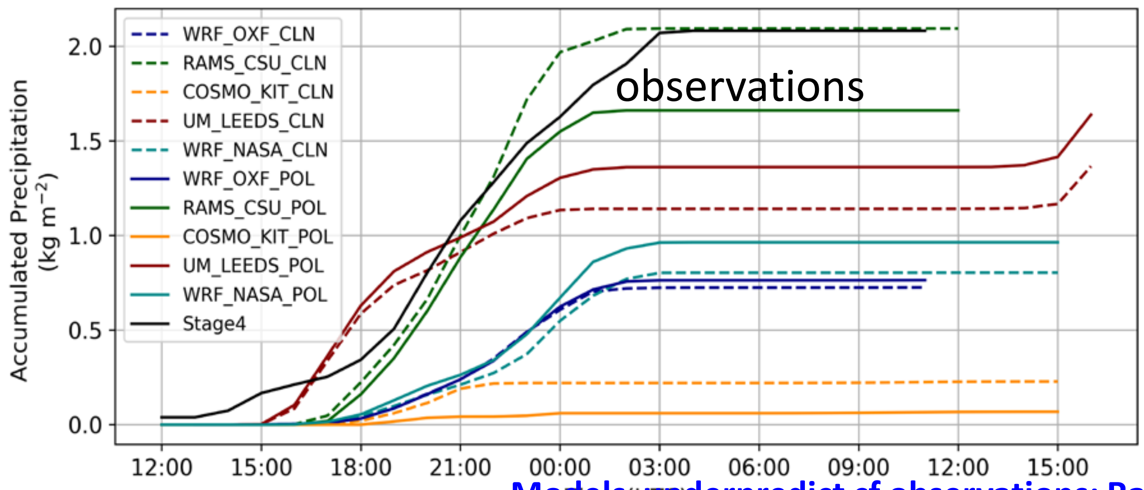
GASS - PROES

Existing PROES activities under GASS:

1) GEWEX Process Evaluation Study on Upper Tropospheric Clouds and Convection (UTCC PROES)- Stubenrauch

2) GEWEX Aerosol-Precipitation (GAP) van den Heever/ Stier (& works closely with ACPC)

GAP Model Intercomparison



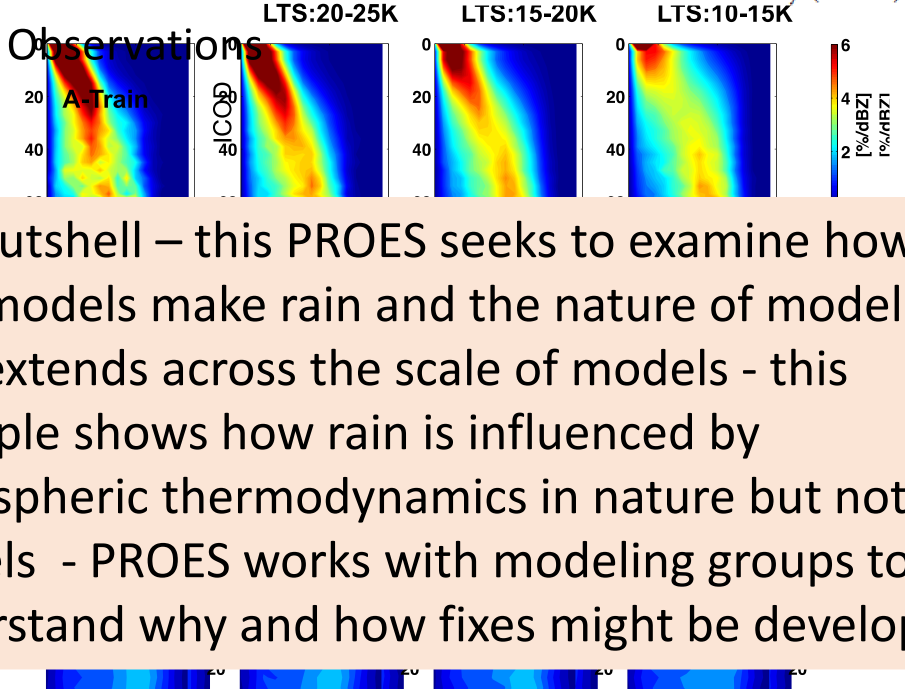
Models underpredict cf observations: Range in aerosol response smaller than differences due to the microphysics and/or other model physics

3) **Process Evaluation Study on Warm Rain (PROES-WR)**

Kentaroh Suzuki[1], Hanii Takahashi[2,3], and Graeme Stephens[3,4]

[1]University of Tokyo, Kashiwa, Japan; [2]Joint Institute for Regional Earth System Science and Engineering, University of California, Los Angeles, California; [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA; [4]University of Reading, Reading, UK

The GEWEX Process Evaluation Study (PROES) has been

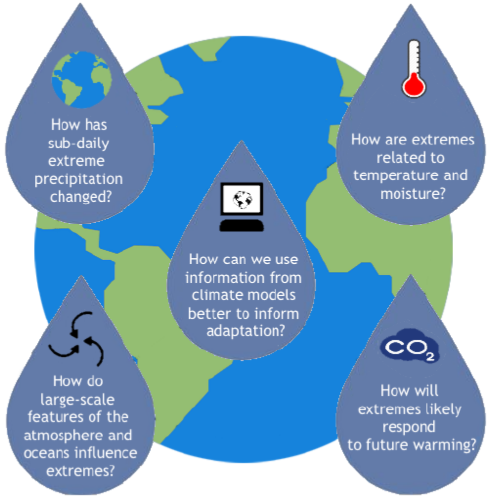


Radar reflectivity

In a nutshell – this PROES seeks to examine how well models make rain and the nature of model bias that extends across the scale of models - this example shows how rain is influenced by atmospheric thermodynamics in nature but not in models - PROES works with modeling groups to understand why and how fixes might be developed

INTENSE – a GHP CC that also connects to the GC and now to GDAP

INTENSE research questions

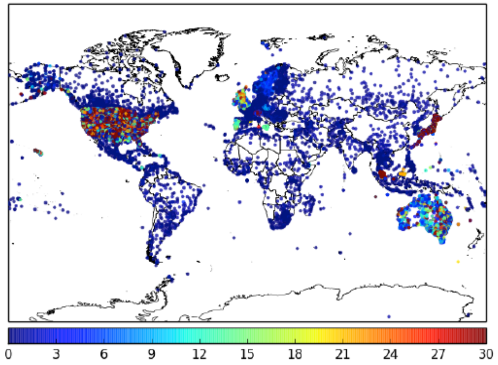


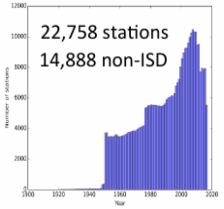
Thanks to:

- Lizzie Kendon and team, Robert Dunn, Nigel Roberts (UK Met Office)
- Stephen Blenkinsop, Renaud Barbero, Steven Chan, Liz Lewis, Selma Guerreiro, Xiao-Feng Li (Newcastle University)
- INTENSE partners (especially Geert Lenderink, Seth Westra, Christoph Schär, Nicolina Ban, Jason Evans, Lisa Alexander)

INTENSE: INTElligent use of climate models for adaptatioN to non-Stationary hydrological Extremes (2M€ ERC Consolidators Grant)

INTENSE: Sub-daily precipitation data collection to date…





% missing data	% stations
0	6.8
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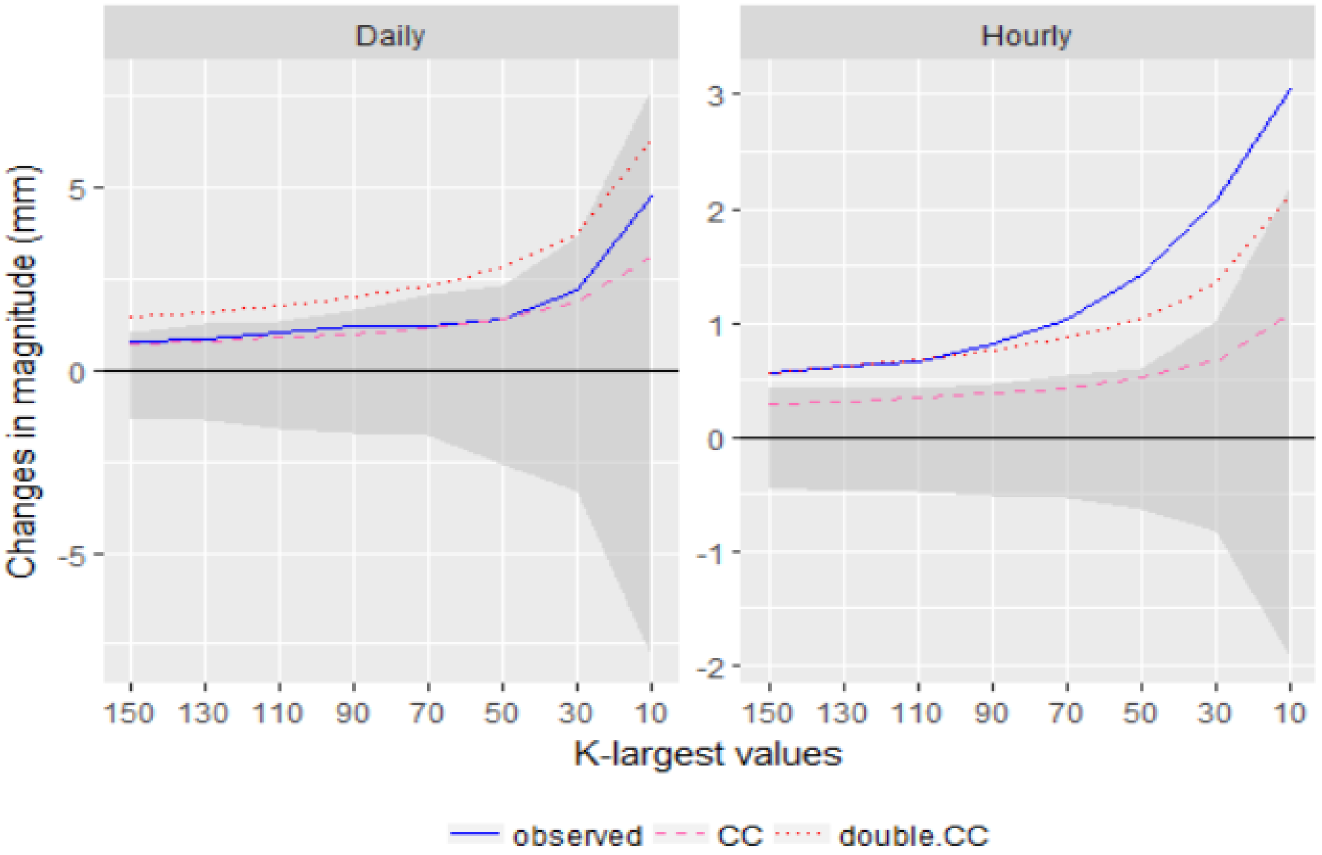
<30	61.6
<40	65.3
<50	68.1
<60	70.3
<70	72.5
<80	73.8
<90	76.5

Getting: Spain, Argentina, Ecuador, Columbia, Bahamas, the Philippines, New Zealand, a few stations in Kenya, Tuvalu, the Caribbean, South Africa, Colombia, Fiji, Israel , India, Denmark, Slovenia, Iran, Bangladesh, Russia, Hungary, Czech Republic, China, Uruguay, Vanuatu, Hong Kong, Poland, Vietnam, Mexico

Australia: Changes in magnitude



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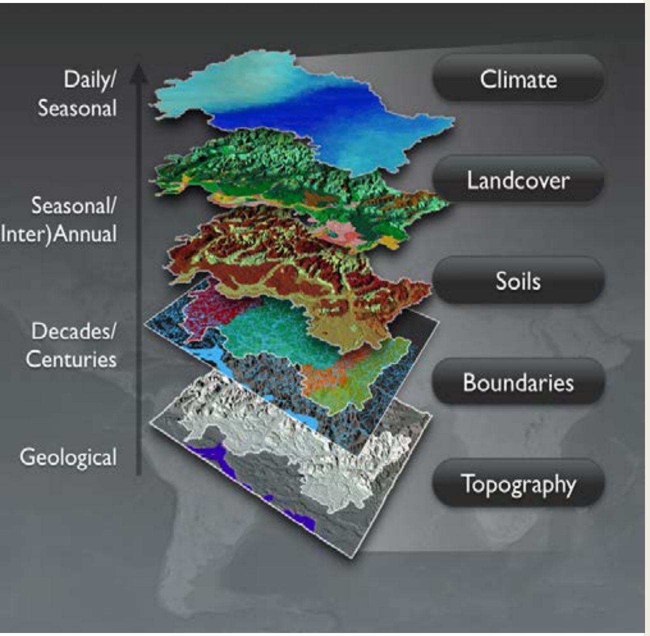
Guerreiro et al., in prep

Phase III: Quantitative understanding and prediction of the Global water and energy system



Challenge – representing the influence of humanity in the physical Earth system (Betts)

Challenge – balance between complexity and reality; as models increase in complexity, how do we know they are approaching reality (Dave Lawrence)

Challenge – a more process based understanding of the water/energy 'system'

Challenge – can we evolve our analysis systems to provide the energy and hydrological information on increasingly finer scales.


One of our challenges: bridging the scale divide
Aug
Klocke et al, 2017
Local Hadley Circulation (SA 10°-40°E) : CP4
hPa
Hart
Latitude
Upscale
Downscale
Global km-scale modeling
Global storm resolving simulations are not far away
5km ICON Dyamond
01/08/2016 00:00
frequency/total number
precipitation (mm h⁻¹)
Δ14
Δ7
Δ3.5
Δ1.7
Δ0.87
Global/regional scale ESM

Vision of GEWEX as expressed through this OSC

- **Address the scientific problems**
  - *Water and Extremes*
  - *Land-atmosphere interactions*
  - *Energy and water budgets*
  - *High-resolution modeling*
  - *Heat waves & extremes: past,*
  -
  - *Weather & climate extremes*
  - *Cold-regions Earth system cha*
  - *Storms and high-impact weat*
  - *Irrigation & water cycle over b*

- ***Provide guidance to society***

HiRes: A Proposal for a Coordinated GEWEX Initiative to Advance Projections of Hydrological Extremes

the projections used, especially for extreme rainfall is unclear, because predicting changes in the distribution, frequency and intensity of rainfall remains a fundamental weakness in all climate models (Stephens et al., 2010). One hypothesis that is

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talities and $5.2 billion in damage annually. A series of winter storms with a combination of heavy rains, combined with strong winds and high waves ravaged southern England in 2013 and 2014, producing the wettest December and January ever recorded (Figure 1), which resulted in widespread flooding and severe coastal damage. Extreme rainfall associated with La

The GEWEX Cloud System Study (GCSS)

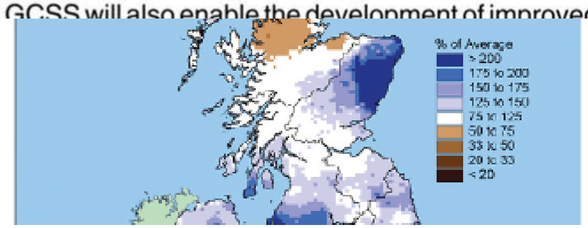
GEWEX Cloud System Science Team*

Browning et al BAMS, 1993

Abstract

The World Climate Research Programme's Global Energy and Water Cycle Experiment (GEWEX) addresses both the hydrological and meteorological components of the water cycle. One of the

adopted so that appropriate parameterizations can be developed for the distinctive types of cloud system occurring in different regions of the globe. The description and understanding of cloud systems to be achieved in GCSS will also enable the development of improved



Feb-May, 2014

"Adequately addressing critical water cycle science questions and applications requires systems that are implemented globally at much higher resolutions, on the order of 1 km, resolutions referred to as hyperresolution in the context of global land surface models."

WATER RESOURCES RESEARCH, VOL. 47, W05301, doi:10.1029/2010WR010090, 2011

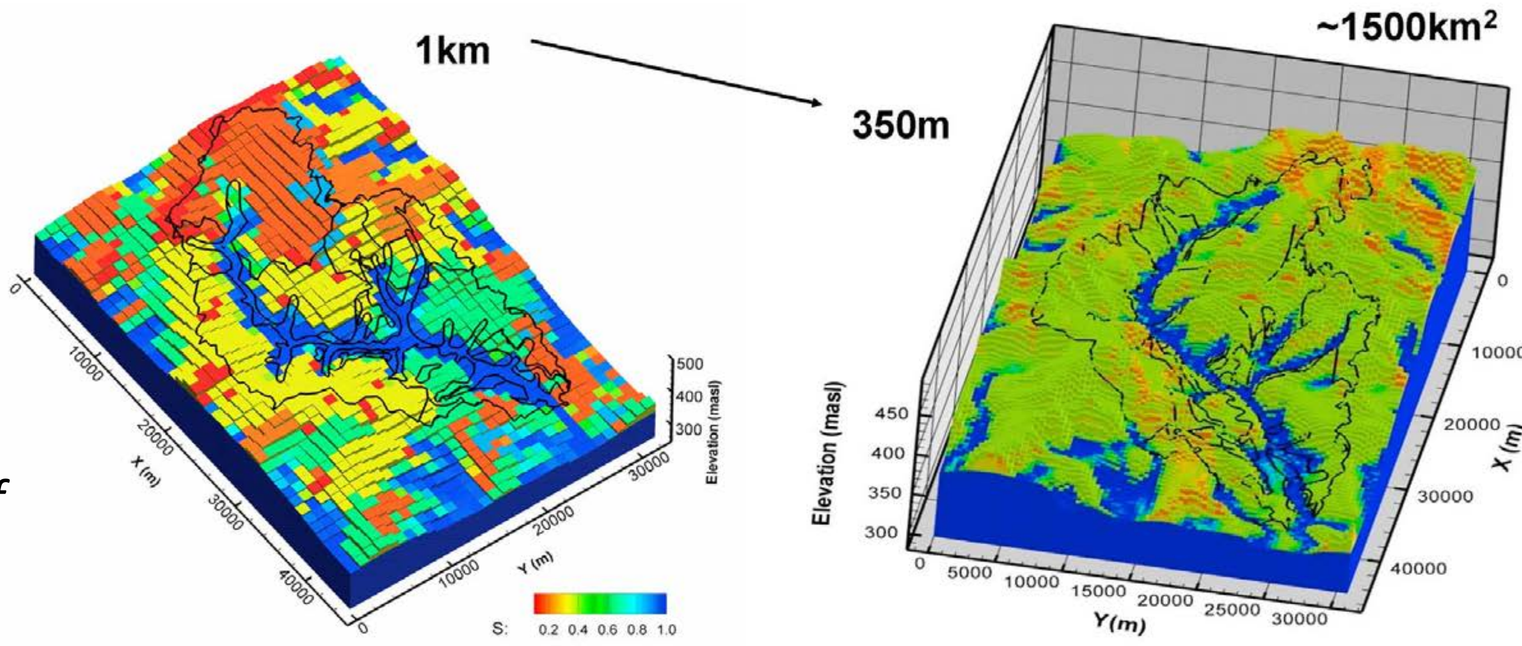
Hyperresolution global land surface modeling: Meeting a grand challenge for monitoring Earth's terrestrial water

Eric F. Wood,[1] Joshua K. Roundy,[1] Tara J. Troy,[1] L. P. H. van Beek,[2] Marc F. P. Bierkens,[2,3] Eleanor Blyth,[4] Ad de Roo,[5] Petra Döll,[6] Mike Ek,[7] James Famiglietti,[8] David Gochis,[9] Nick van de Giesen,[10] Paul Houser,[11] Peter R. Jaffé,[1] Stefan Kollet,[12] Bernhard Lehner,[13] Dennis P. Lettenmaier,[14] Christa Peters-Lidard,[15] Murugesu Sivapalan,[16] Justin Sheffield,[1] Andrew Wade,[17] and Paul Whitehead[18]

Received 6 October 2010; revised 21 January 2011; accepted 24 February 2011; published 6 May 2011.

Major implications of hyper resolution:
1. Runoff generation
2. Biogeochemical cycling
3. Land-atmosphere interactions
4. Snow & freeze/thaw

** All depend on accurate representation of saturated and unsaturated areas (i.e. accurate topography)*



Thriving on Our Changing Planet

A Decadal Strategy for Earth Observation from Space

A report of the Decadal Survey for Earth Science and Applications from Space

Released: 5 January 2018

Report available at: http://www.nas.edu/esas2017

#EarthDecadal

The National Academies of SCIENCES ENGINEERING MEDICINE

Panels

Global Hydrological Cycles and Water Resources

Co-Chairs: Jeff Dozier, UC Santa Barbara and Ana Barros, Duke University

The movement, distribution, and availability of water and how these are changing over time

Weather and Air Quality: Minutes to Subseasonal

Co-Chairs: Steve Ackerman, University of Wisconsin and Nancy Baker, NRL

Atmospheric Dynamics, Thermodynamics, Chemistry, and their interactions at land and ocean interfaces

Marine and Terrestrial Ecosystems and Natural Resource Management

Co-Chairs: Compton (Jim) Tucker, NASA GSFC and Jim Yoder, WHOI

Biogeochemical Cycles, Ecosystem Functioning, Biodiversity, and factors that influence health and ecosystem services

Climate Variability and Change: Seasonal to Centennial

Co-Chairs: Carol Anne Clayson, WHOI and Venkatachalam (Ram) Ramaswamy, NOAA GFDL

Forcings and Feedbacks of the Ocean, Atmosphere, Land, and Cryosphere within the Coupled Climate System

Earth Surface and Interior: Dynamics and Hazards

Co-Chairs: Dave Sandwell, Scripps and Doug Burbank, UC Santa Barbara

Core, mantle, lithosphere, and surface processes, system interactions, and the hazards they generate

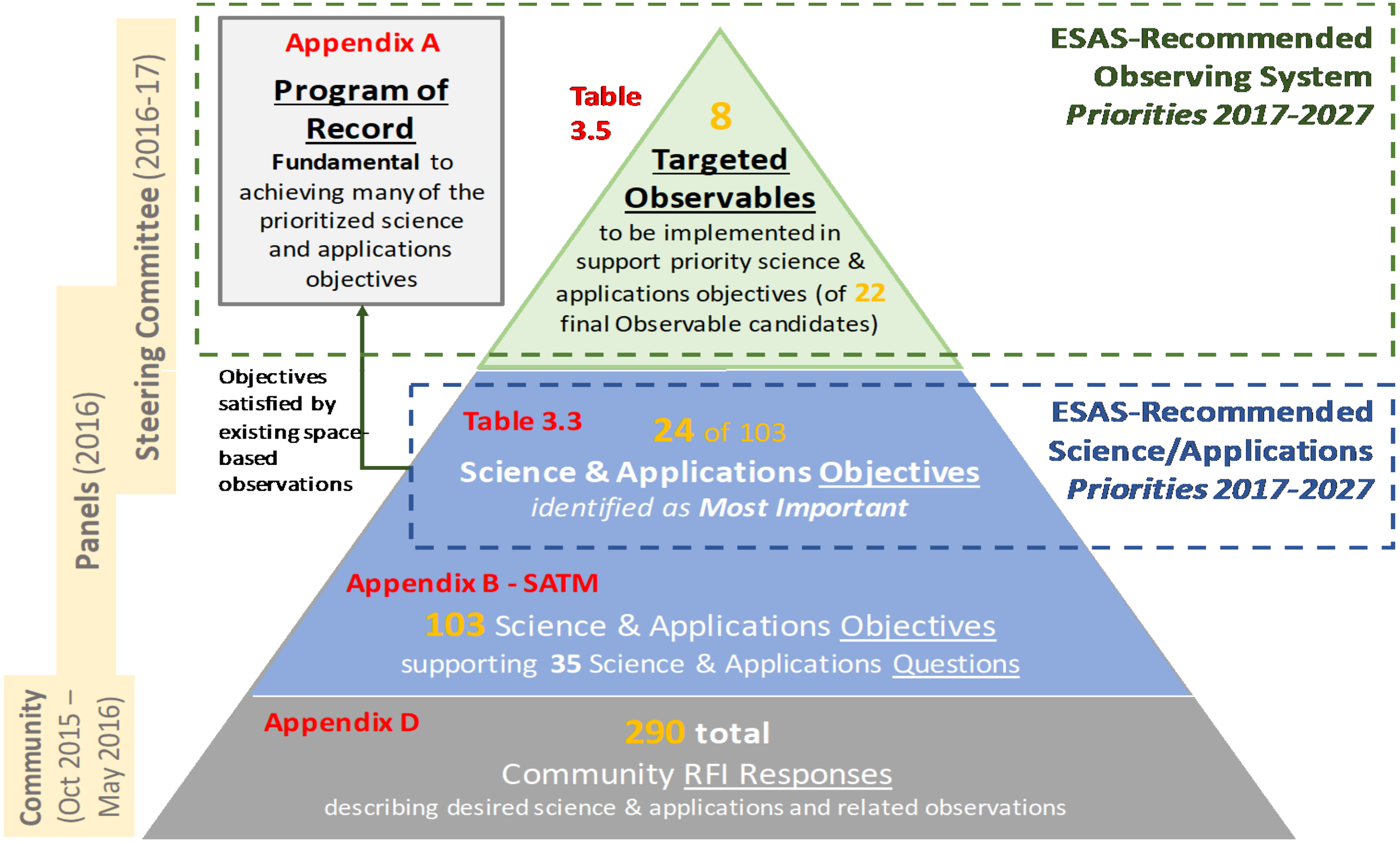
TABLE 3.3 ***Science and Applications Priorities Table.*** The Science and Applications portion of the full Science and Applications Traceability Matrix (SATM) in Appendix B.

GLOBAL HYDROLOGICAL CYCLES AND WATER RESOURCES PANEL		
Societal or Science Question/Goal	**Earth Science/Application Objective**	**Sci/App Importance**
QUESTION H-1. How is the water cycle changing? Are changes in evapotranspiration and precipitation accelerating, with greater rates of evapotranspiration and thereby precipitation, and how are these changes expressed in the space-time distribution of rainfall, snowfall, evapotranspiration, and the frequency and magnitude of extremes such as droughts and floods?	H-1a. Develop and evaluate an integrated Earth System analysis with sufficient observational input to accurately quantify the components of the water and energy cycles and their interactions, and to close the water balance from headwater catchments to continental-scale river basins.	Most Important
	H-1b. Quantify rates of precipitation and its phase (rain and snow/ice) worldwide at convective and orographic scales suitable to capture flash floods and beyond.	Most Important
	H-1c. Quantify rates of snow accumulation, snowmelt, ice melt, and sublimation from snow and ice worldwide at scales driven by topographic variability.	Most Important
QUESTION H-2. How do anthropogenic changes in climate, land use, water use, and water storage interact and modify the water and energy cycles locally, regionally and globally and what are the short- and long-term consequences?	H-2a. Quantify how changes in land use, water use, and water storage affect evapotranspiration rates, and how these in turn affect local and regional precipitation systems, groundwater recharge, temperature extremes, and carbon cycling.	Very Important
	H-2b. Quantify the magnitude of anthropogenic processes that cause changes in radiative forcing, temperature, snowmelt, and ice melt, as they alter downstream water quantity and quality	Important
	H-2c. Quantify how changes in land use, land cover, and water use related to agricultural activities, food production, and forest management affect water quality and especially groundwater recharge, threatening sustainability of future water supplies.	Most Important

WEATHER and AIR QUALITY PANEL		
Societal or Science Question/Goal	**Earth Science/Application Objective**	**Sci/App Importance**
QUESTION W-1. What planetary boundary layer (PBL) processes are integral to the air-surface (land, ocean and sea ice) exchanges of energy, momentum and mass, and how do these impact weather forecasts and air quality simulations?	W-1a. Determine the effects of key boundary layer processes on weather, hydrological, and air quality forecasts at minutes to subseasonal time scales.	Most Important
QUESTION W-2. How can environmental predictions of weather and air quality be extended to seamlessly forecast Earth System conditions at lead times of 1 week to 2 months?	W-2a. Improve the observed and modeled representation of natural, low-frequency modes of weather/climate variability (e.g. MJO, ENSO), including upscale interactions between the large-scale circulation and organization of convection and slowly varying boundary processes to extend the lead time of useful prediction skills by 50% for forecast times of 1 week to 2 months.	Most Important
QUESTION W-3. How do spatial variations in surface characteristics (influencing ocean and atmospheric dynamics, thermal inertia, and water) modify transfer between domains (air, ocean, land, cryosphere) and thereby influence weather and air quality?	W-3a. Determine how spatial variability in surface characteristics modifies regional cycles of energy, water and momentum (stress) to an accuracy of 10 Wm-2 in the enthalpy flux, and 0.1 Nm-2 in stress, and observe total precipitation to an average accuracy of 15% over oceans and/or 25% over land and ice surfaces averaged over a 100x100 km region and two to three day time period.	Very Important
QUESTION W-4. Why do convective storms, heavy precipitation, and clouds occur exactly when and where they do?	W-4a. Measure the vertical motion within deep convection to within 1 m/s and heavy precipitation rates to within 1 mm/hour to improve model representation of extreme precipitation and to determine convective transport and redistribution of mass, moisture, momentum, and chemical species.	Most Important
QUESTION W-5. What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?	W-5a. Improve the understanding of the processes that determine air pollution distributions and aid estimation of global air pollution impacts on human health and ecosystems by reducing uncertainty to <10% of vertically-resolved tropospheric fields (including surface concentrations) of speciated particulate matter (PM), ozone (O_3), and nitrogen dioxide (NO_2).	Most Important

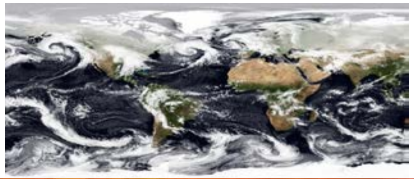
Path from Science & Applications to Observational Priorities

Blue: Science & Applications; Green: Observables



Anticipated Science/Applications Accomplishments

DESIGNATED Program Element



Make-up and distributi
of **aerosols and clouds**

Severe weather, convective **storms**

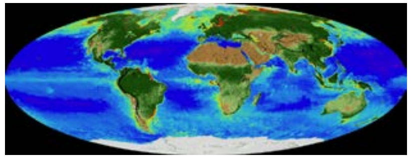
Impacts of **changing cloud cover and precipitation**

Growth or shrinkage of **glaciers and ice sheets**

Also EEI

Trends in **water stored on land**

Alterations to **surface characteristics and landscapes**



Movement of **land and ice surfaces**

Evolving characteristics and health of **terrestrial vegetation and aquatic ecosystems**

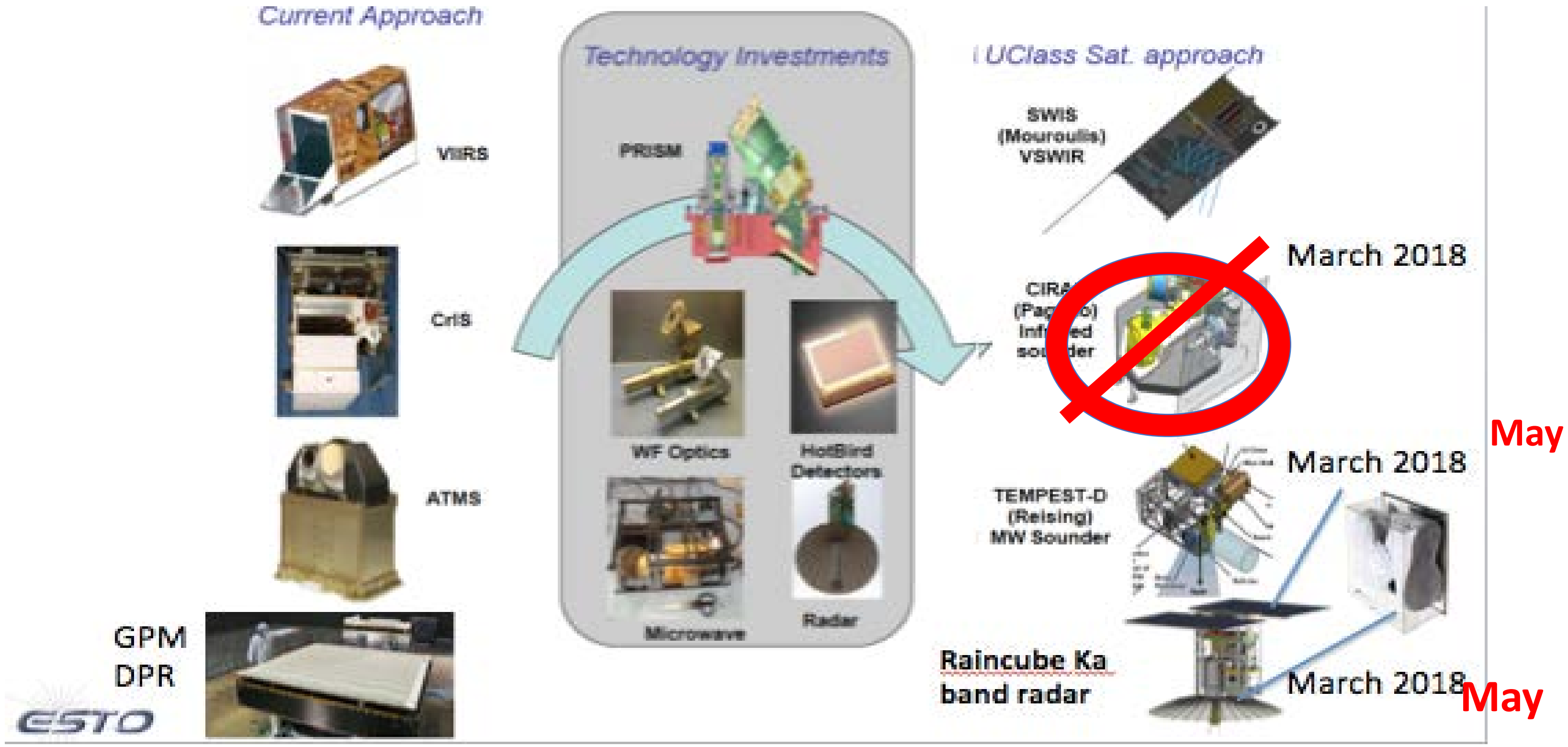
Candidate EXPLORER Program Element

- Sources and sinks of **CO_2 and methane**
- Contributions of glaciers and ice sheets to **sea level rise**
- Impacts of **ocean circulation and exchange with atmosphere** on weather and climate
- Changes in **ozone and other gases** and impacts on health and climate
- **Snow amounts and melt rates** and implications for water resources
- Impact of changes in **land cover and related carbon uptake** on resource management
- Transport of **pollutants** and energy between land, ocean, and atmosphere

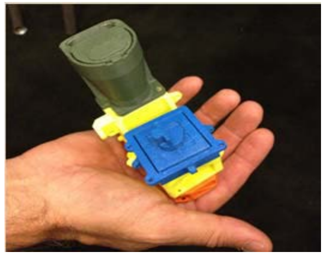
Incubator Program Element

- **Winds**
- **PBL(?)**

Technology innovation was seen as an essential ingredient for advancing Earth Science objectives for the decade



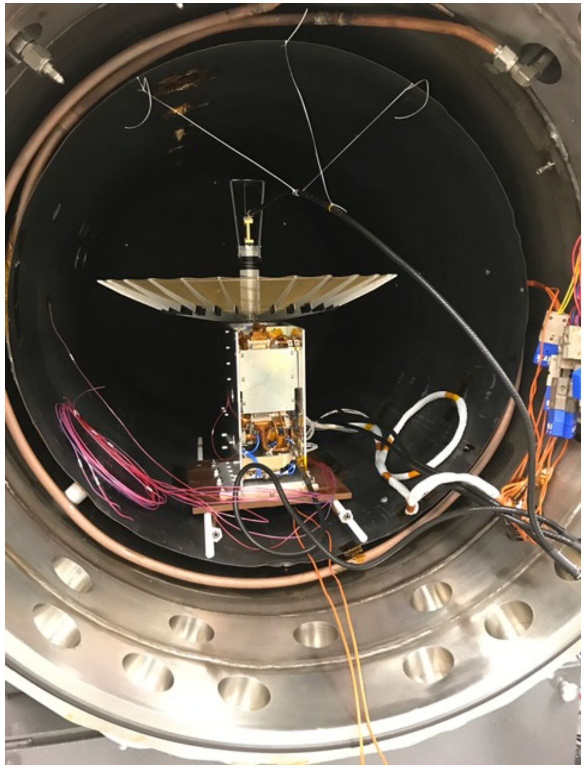
Small-sat lidar

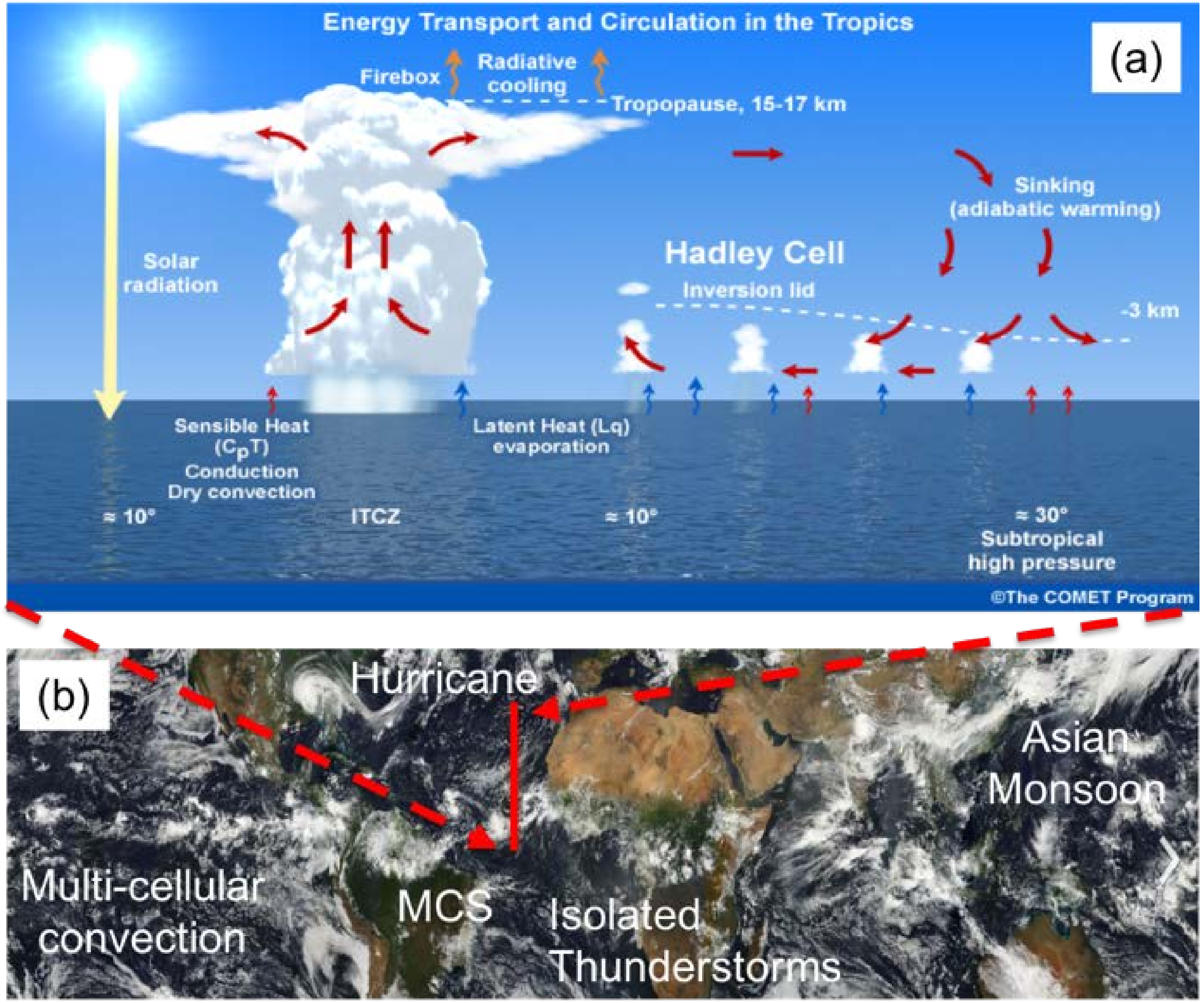


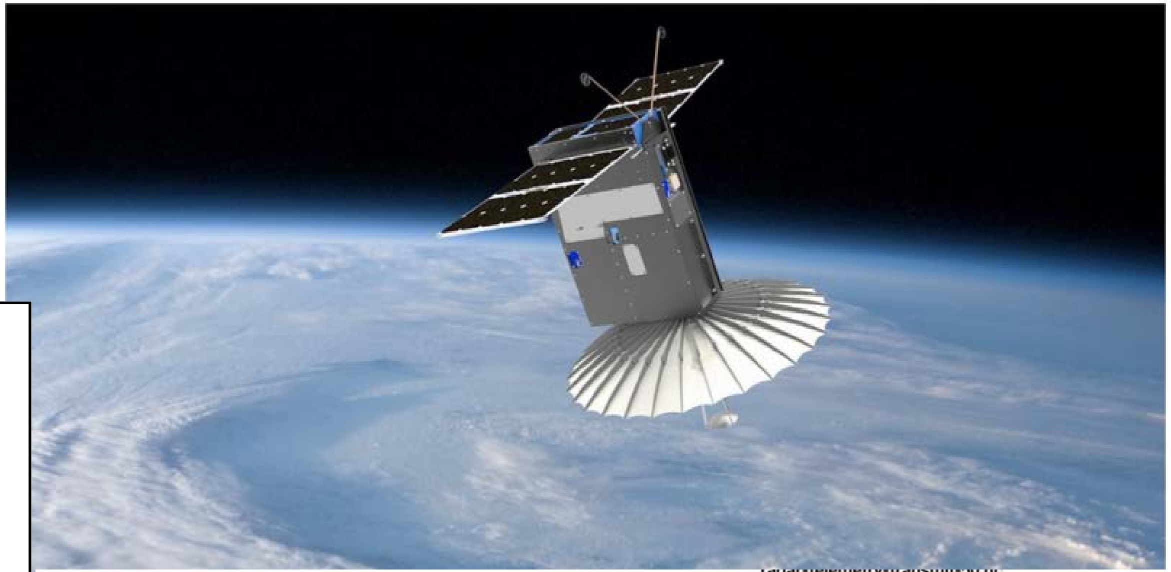
3U IR spectrometer

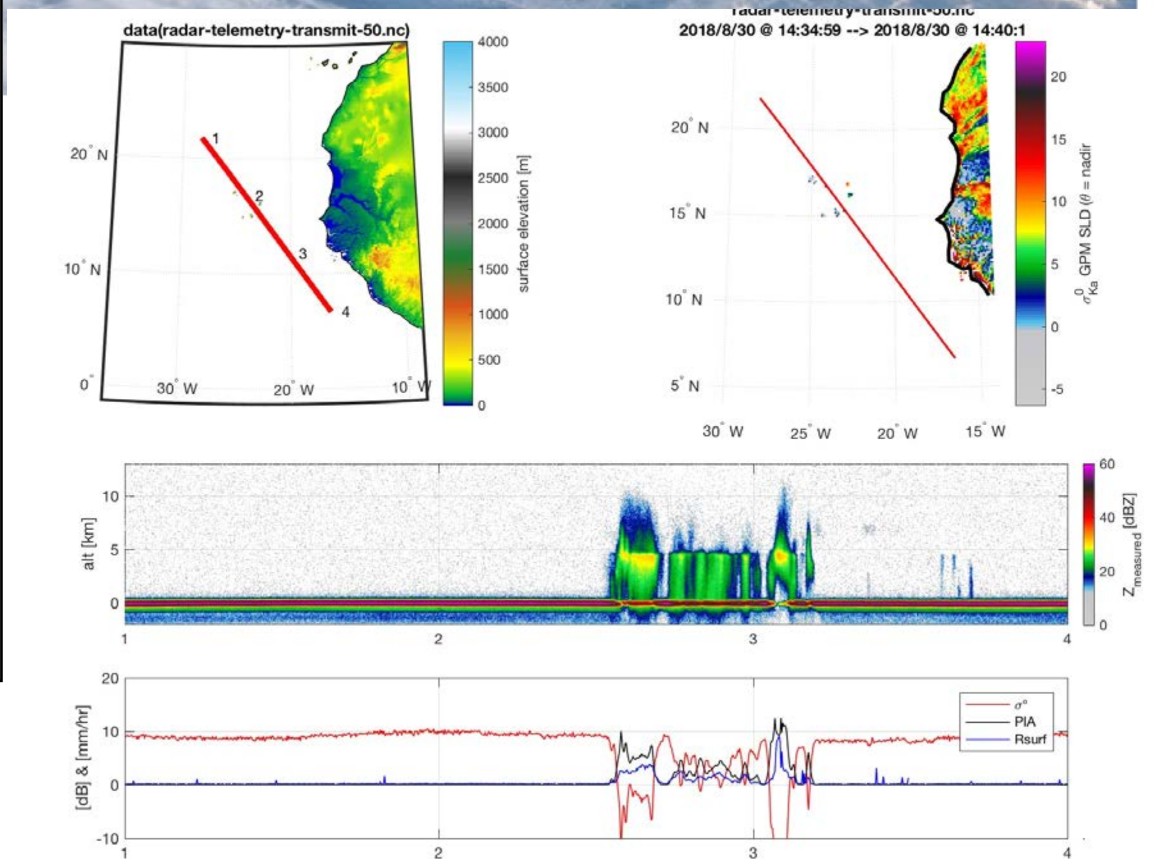
Advanced GPS receiver – GNSS-refl

The coming focus of Earth Obs on convection








data(radar-telemetry-transmit-50.nc)
20° N
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surface elevation [m]
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2500
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1500
1000
500
0
2018/8/30 @ 14:34:59 --> 2018/8/30 @ 14:40:1
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15° N
10° N
5° N
30° W
25° W
20° W
15° W
GPM SLD (θ = nadir)
20
15
10
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-5
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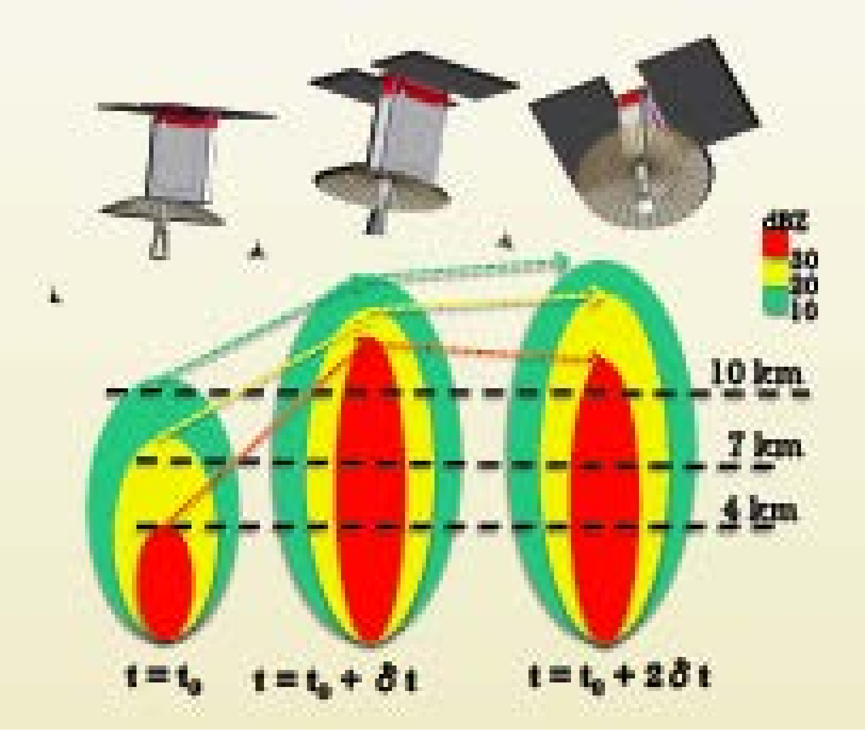
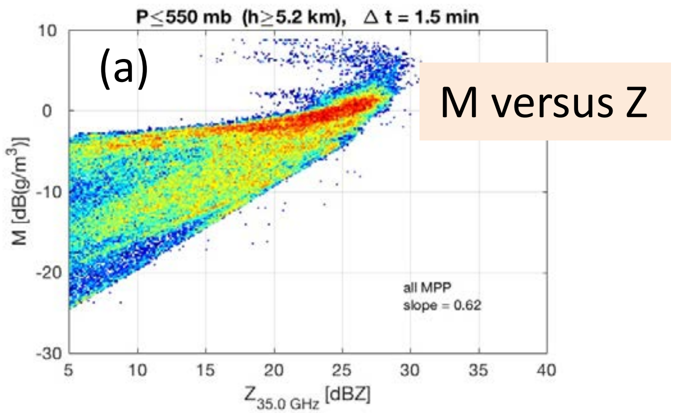
Rsurf

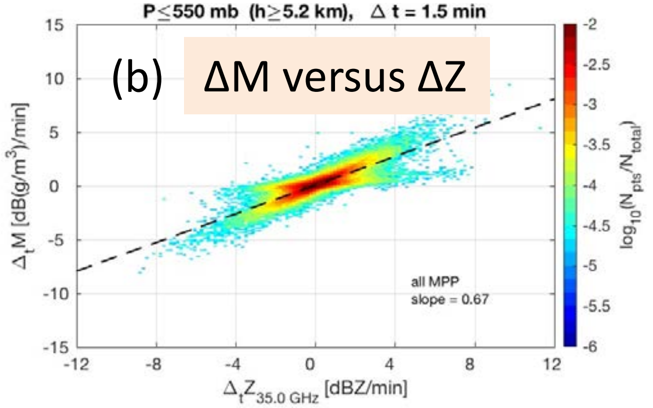
Imagine

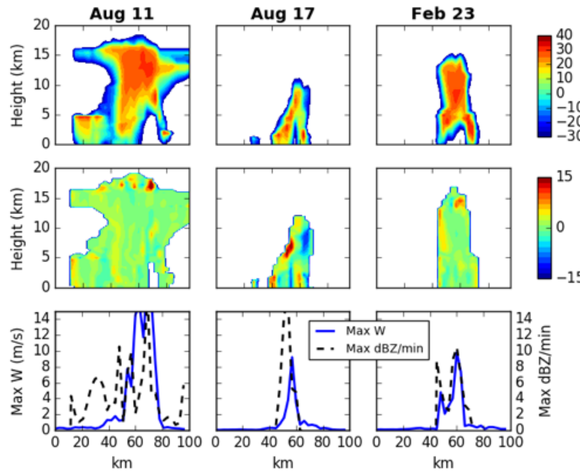
An observing system built as a clustered of observations

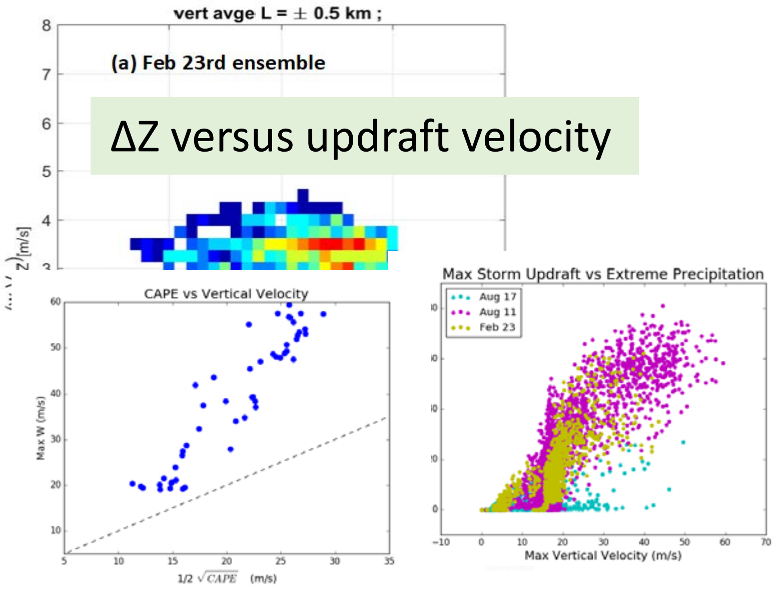


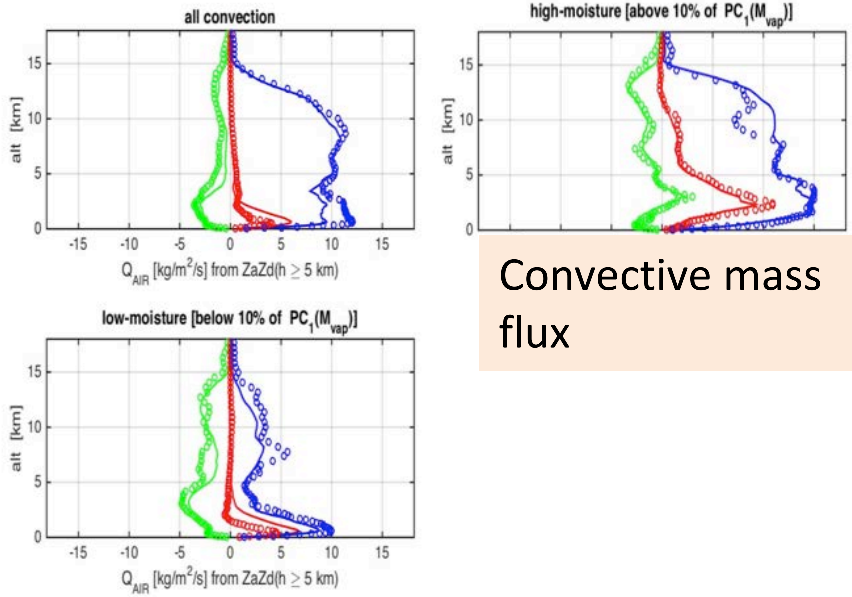
So now we have profiles of ΔZ, Z and











August 27 , 2018 – 20:14 UTC - RainCube Tx Operation #23

First successful operation in Nadir Pointing & first possible detection of rain over the Sierra Madre Oriental, near Monterrey, Mexico

Fast growing orographic precipitation developed shortly before RainCube's pass which skirted its north-eastern edge