Considerations for Space-Based PBL Observation and Modeling

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Acknowledgment: ***Most of the work here funded by grants from : NOAA, NSF, NASA***

Disclaimer: *List may not be complete & it doesn't mean they endorse what I say. I wanted to acknowledge that they have worked with me on some aspects of what follows.*

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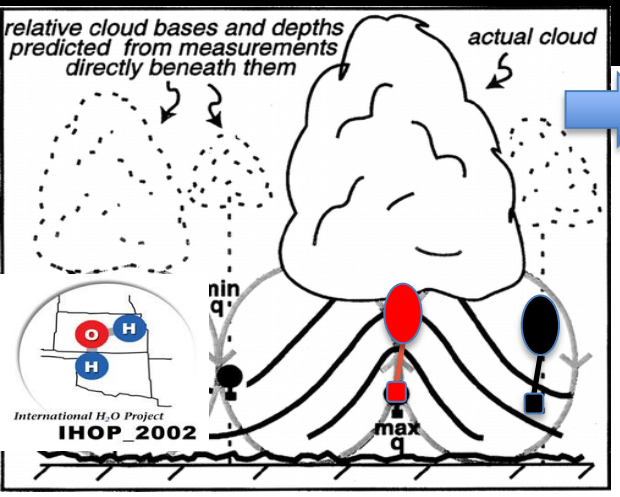
Speaking of PBLH

Just for fun – ***my "biased" view***

If you are willing to wait years	use GPSRO
If you think two points make a profile	use AIRS
If you have dreams of $$$$$$	use space-based Raman
If you live next to an airport	use ACARS
If you are willing to re-define PBLH	you can have it "sooner"!

but really I'm only kidding here

PBL and Weather/Convection: *NASA/NOAA/NSF goals*

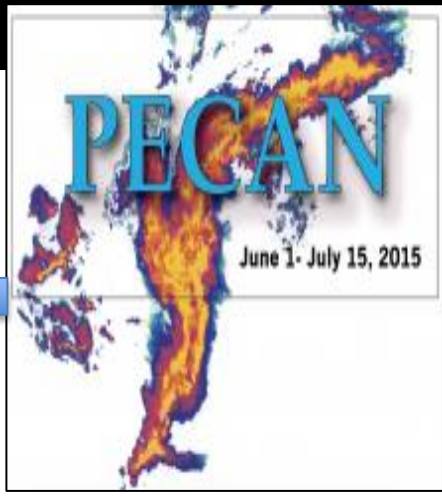


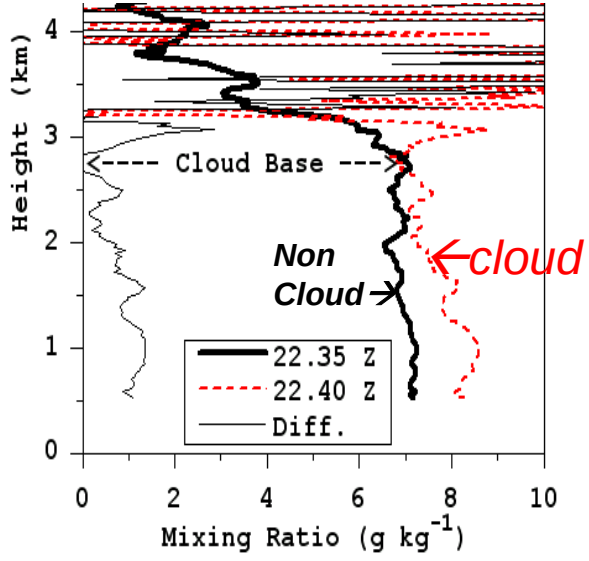
IHOP2002 & PECAN (2015)

- Convection/Initiation
- Instrument performance
- PBL processes & organization
- Forecast/QPF skill; night

For more see

- ***Weckwerth et al (2004) and Geerts et al (2016)***





Clouds have roots!
(Demoz et al 2006):

- Moisture (q) is key
- Transient waves important
  → 24/7 observation!

Δq~ ±0.1g/kg
ΔZ~ 100-300m
ΔX/ ΔY ~10-50km
ΔT – ???

- How does moist convection interact with the boundary layer and the surface?
- What are the fundamental mechanisms controlling boundary layer clouds?
- How can we unify the parameterization of moist and dry turbulence and convection, and clear-air turbulence?

NASA weather goals BAMS(2017

PBL role in convection and clouds requires resolution of the sub-cloud layer thermodynamics at scales!

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PBL & Air Quality: NOAA/EPA/MDE/NASA/NE-States

For more on this – please visit UMBC lidar pages.

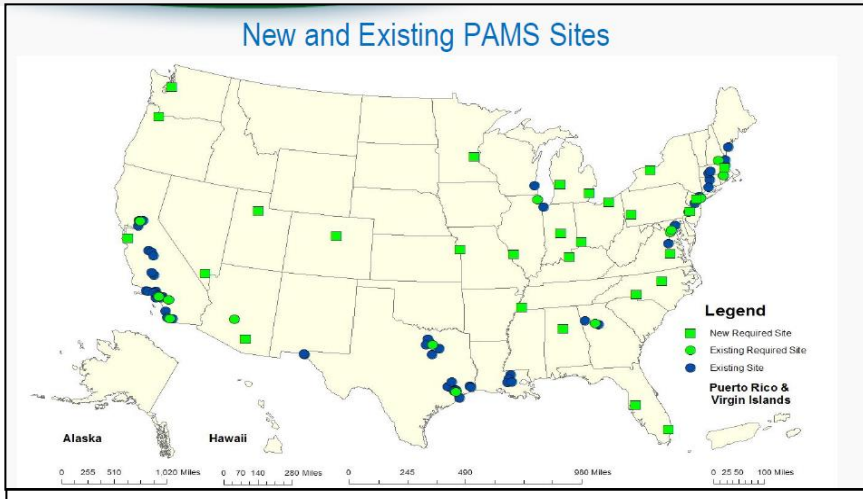
PBL height: ***https://lidar.umbc.edu/ad-hoc-mixing-layer-height-working-group/***

Smog blog: ***http://alg.umbc.edu/usaq/***

OWLETS: ***https://www-air.larc.nasa.gov/missions/owlets/***

PBL height data is critical for

- High Bias in O_3 and CO prediction linked to PBL venting *(McQueen/Lee/Baker)*
- Plume injection/dispersion work *(P. Lee)*
- Smoke transport and mixing down to surface linked to PM, Black Carbon, O_3 *(Dressen et al, TOLnet, etc)*



Photochemical Assessment Monitoring Stations (PAMS): EPA is requiring *Hourly Mixing Layer Height .*

- ***Resolve hourly/diurnal variability***
- ***"regional" variability***
- ***Multi-instrument network***

OWLETS-2
Ozone Water-Land Environmental Transition Study

Address the spatio-temporal structure of PBL for air pollutants study?

PBLH from space – maybe?
But ground network is fundamental!

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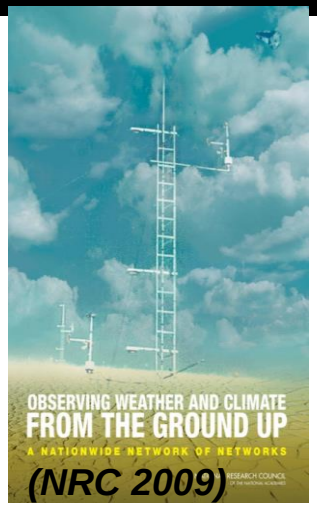
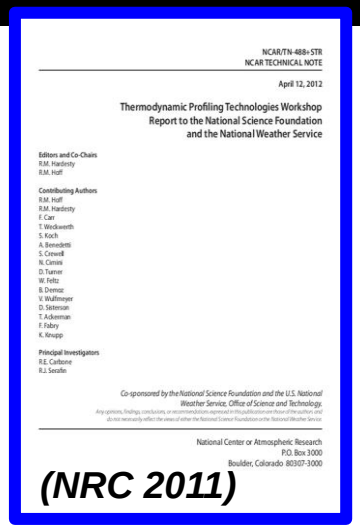
Past reports and outcome:



(NRC 2009)


NCAR/TN-488+STR
NCAR TECHNICAL NOTE

April 12, 2012

Thermodynamic Profiling Technologies Workshop
Report to the National Science Foundation
and the National Weather Service

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Co-sponsored by the National Science Foundation and the U.S. National Weather Service, Office of Science and Technology.

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(NRC 2011)

Key pts:

- PBL thermodynamics *profile*
- Ground based remote sensing
- Process scales recommended

Active – lidars

- NOAA-ASOS (archive data, ***β***)
- DIAL- (promising dev., ***β, q***)
- Raman- (in operation, ***β, q, T***)

[See Dave T. for MWR/AERI]

Points:

- PBL thermodynamics *profile is key but don't discount the aerosol structure.*
- There are mature ground based remote sensing systems/options
- Networks (400sites) recommended
- NOAA-NASA-other collaboration!
- Process scales observation (continuous) should be focus
- Science drivers were both Air quality and convection (severe storm) forecasting.

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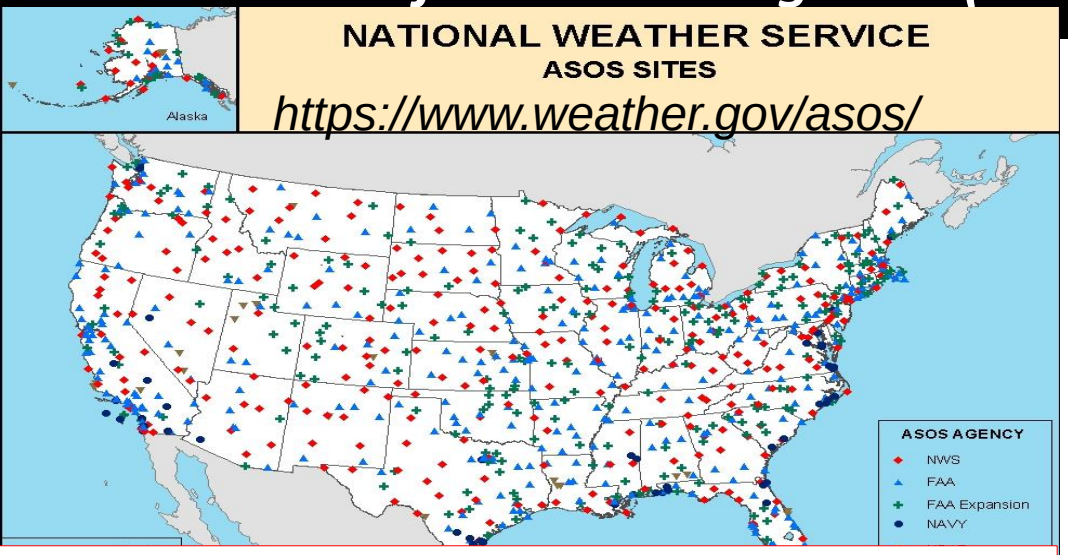
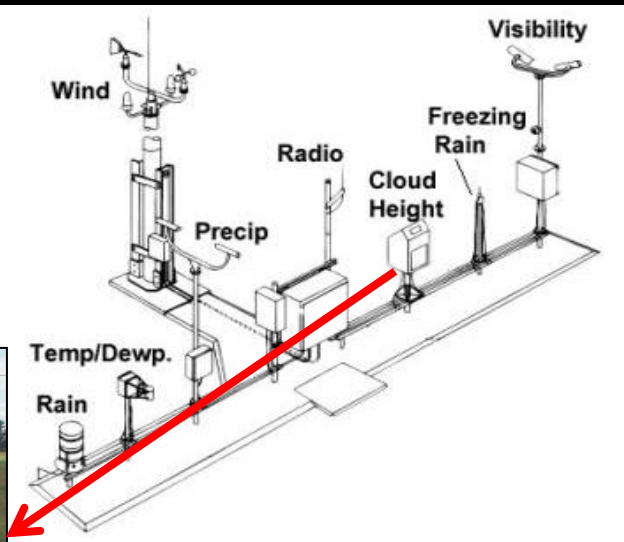
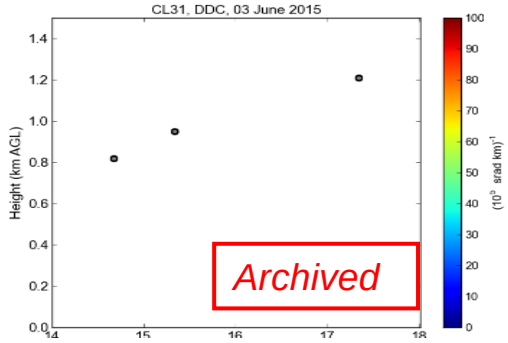
One outcome:
Automated Surface Observing Sites (ASOS)



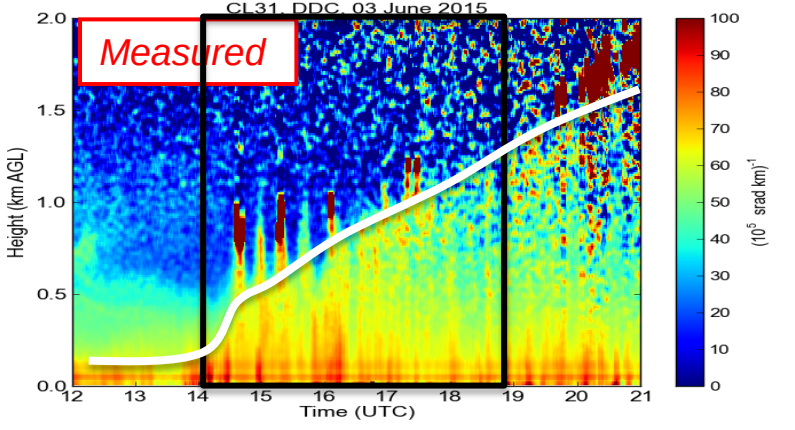




- Visibility., P, T, Td, U, V, Precip., present weather, Cloud base altitude (<12K ft)]
- Aerosol backscatter profile (15sec, 30m) measured but not archived

Two active PBL height methods:

- *Recommended ASOS archive:*
  - In progress by NWS (2020 – hope(?)).
- *Less accurate methods (radar) may be there too (in research).*



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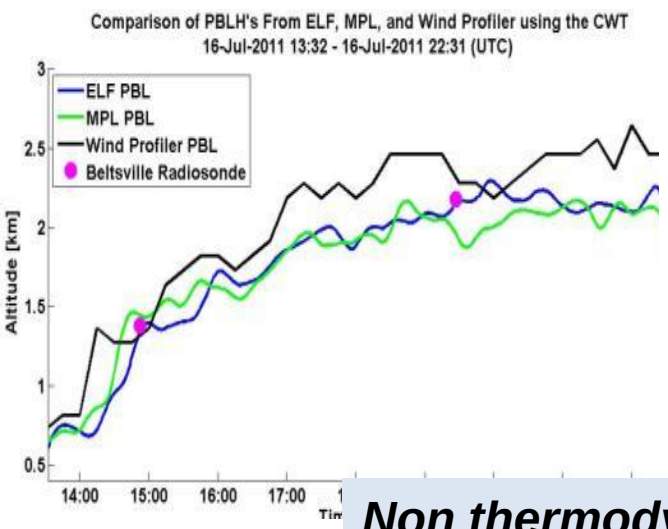
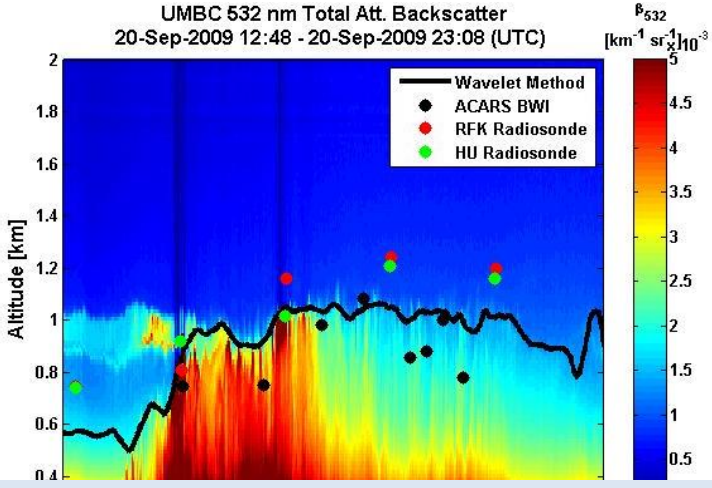
PBL height or mixing length depth" – definition

Disclaimer: No good way to define the PBL height without temperature and moisture profile. Lower tropospheric thermodynamic profiler should be the goal!

ASOS-CL31 Data		BLView avg diff (m)	Hicks et al avg diff(m)
	Method		
STABLE	Liu Liang	710.327	12.066
	RiB	770.776	173.336
	Heffter	761.597	54.004
	AVERAGE	768.476	123.15
Convec.	Liu Liang	196.37	-604.388
	RiB	527.195	-175.566
	Heffter	-299.849	-1151.683
	AVERAGE	227.076	-732.185





WRF-Chem

	Co (%)	Mean (m)	SD (m)	Median (m)	IQR (m)
YSU	59	-19	469	-60	464
YSU +NARR	56	-50	477	-95	506
MYNN	60	-7	446	-2	464
MYNNe	60	7	475	-36	470
MYNNe +nlcd	61	39	451	-14	471
BOUL	56	-18	488	-74	516
BOUL +UCM	57	76	489	15	537
QNSE	51	194	550	127	610

Non thermodynamic-based PBL

- *check model PBL parameterization*
- *applications: fire/smoke/transient wave/PM*
- *ΔPBLH ± 200m is as good as it gets*

Are operational and could serve an integral part of future space-based systems and models!

*** true assimilating PBL height. Is needed.*

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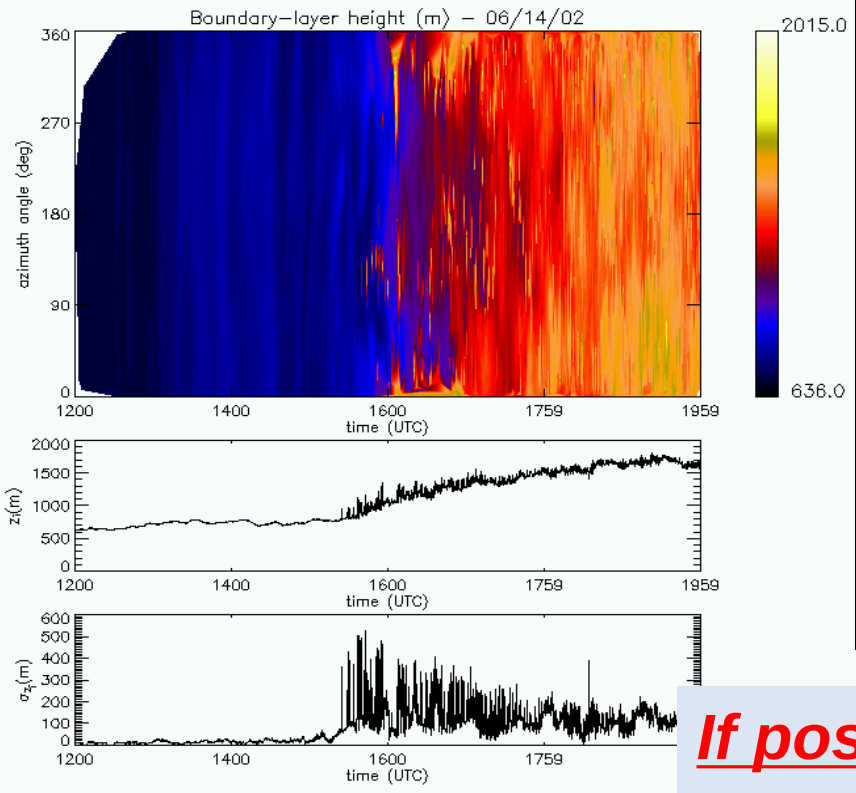
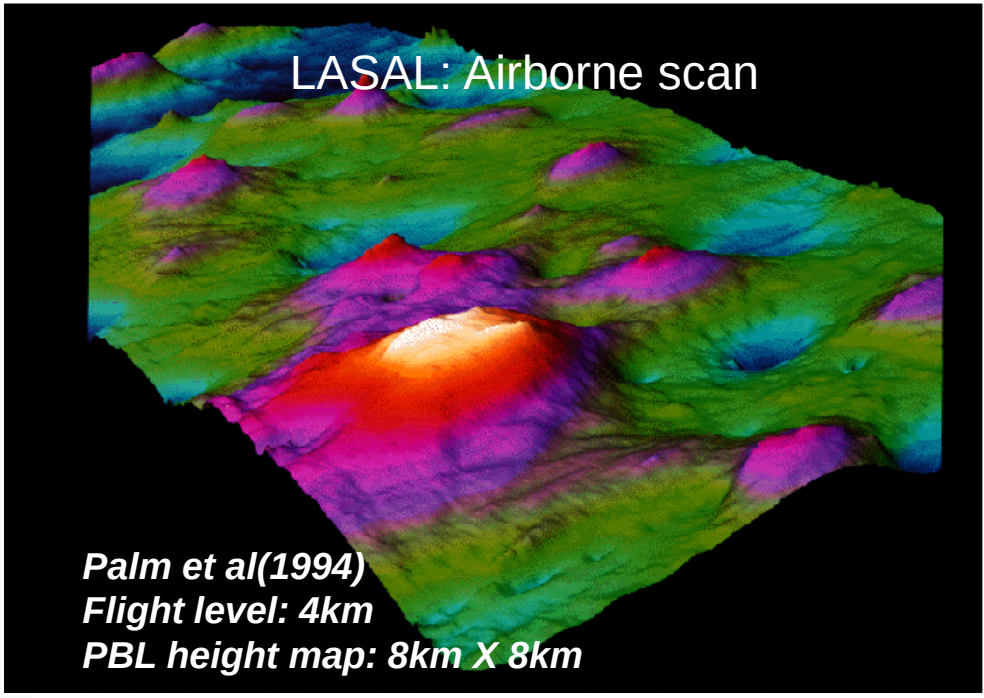
PBLH and lidar: Lessons learned, A scanning advantage?

HARLIE (Holographic Airborne Rotating Lidar Experiment) - ground

LASAL (Large Aperture Scanning Airborne Lidar) - airborne



HARLIE: ground scan



If possible – scan!

- Captures PBL variability (~ proxy for turbulence)
- PBLH Variability ➔ clues for atmospheric "state" (Marine versus land; day versus night; etc)

Scanning space-based lidar?

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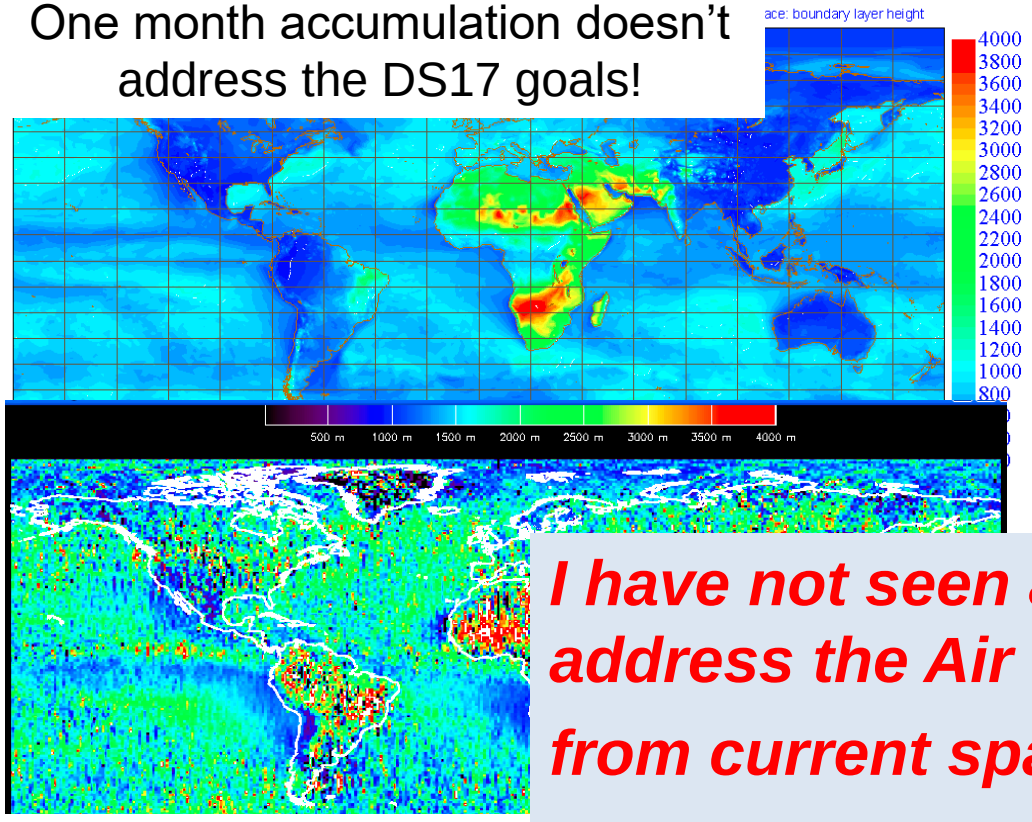
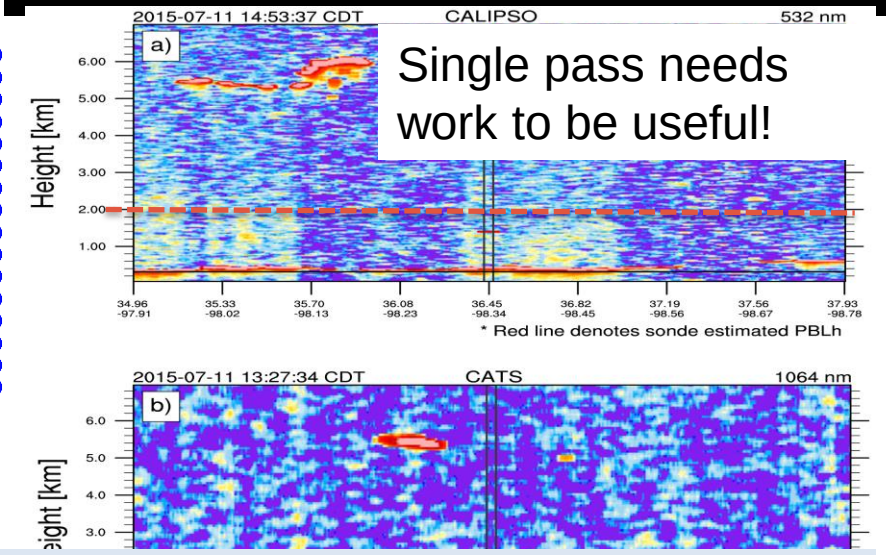
See: Carroll, et al (2017), 28th ILRC; Bonin et al (2017) JTECH.

My (Biased?) view on satellite PBL

One month accumulation doesn't address the DS17 goals!





Single pass needs work to be useful!

Palm et al (2005) : PBL He
ECMWF is 200 – 400m low
GLAS: **October 3- Novem**
ECMWF: Ave. of 12hr forec

I have not seen a PBL product that would address the Air quality and weather goals from current space-based elastic lidars -?

Need

- ***A better "laser", a better telescope***
- ***A better data repeat cycle, resolution***

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ATLAS *Atmospheric Thermodynamics LidAr in Space*

Di Girolamo et al ESA proposal.

See ***Dave Whiteman's*** talk for detail

- *Laser: 2.5 J at 355 nm with a repetition rate of 100 Hz*
- *4m-diameter telescope*

These are cloud free performance!!

ATLAS was proposed to provide q/T near the large end of the spatial scales needed but not in time (repeat cycle).

We will have plenty of systems that can do aerosol backscatter well –

Take advantage for PBLH (or Mixing layer height.)

Target performance parameters

- Water Vapor
  - 300 m vertical resolution
  - 50 km horizontal resolution
  - 10% random uncertainty
  - An estimated 60-80% of cases meet this criterion for a dawn/dusk orbit
- Temperature
  - 300 m vertical
  - 50 km horizontal resolution
  - 1 K uncertainty
  - 80% of cases meet the criterion
- Aerosol Backscatter
  - 60 m vertical resolution
  - 1 km horizontal
  - 10% uncertainty
  - 68% of cases meet the criterion
- Aerosol Extinction
  - 250m vertical resolution
  - 80 km horizontal
  - 20% uncertainty
  - 42% of cases meet the criterion

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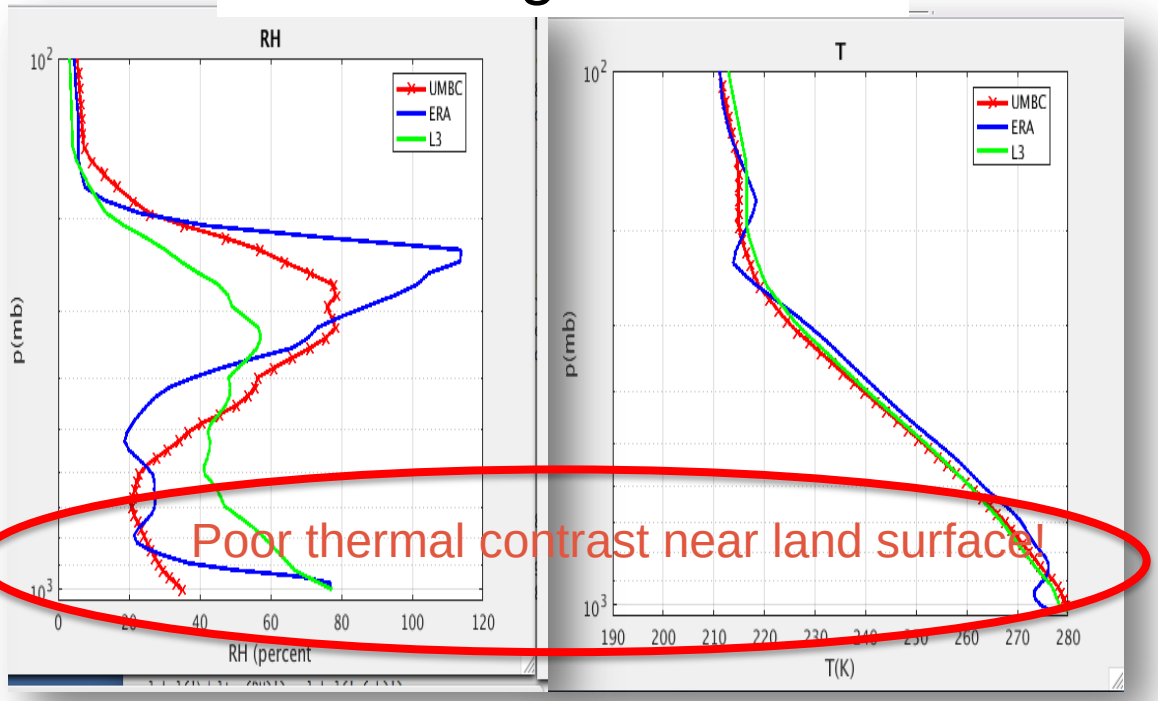
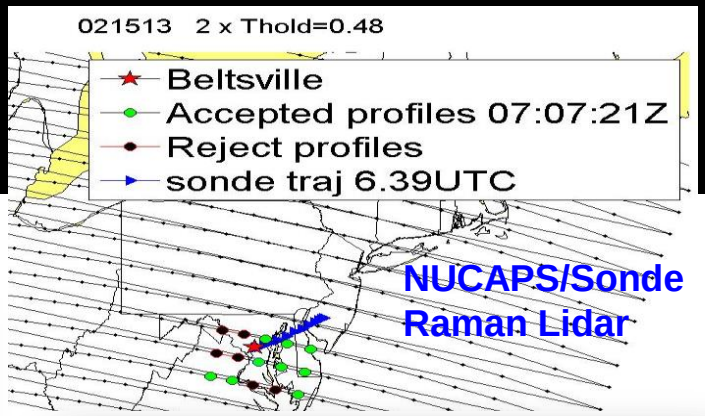
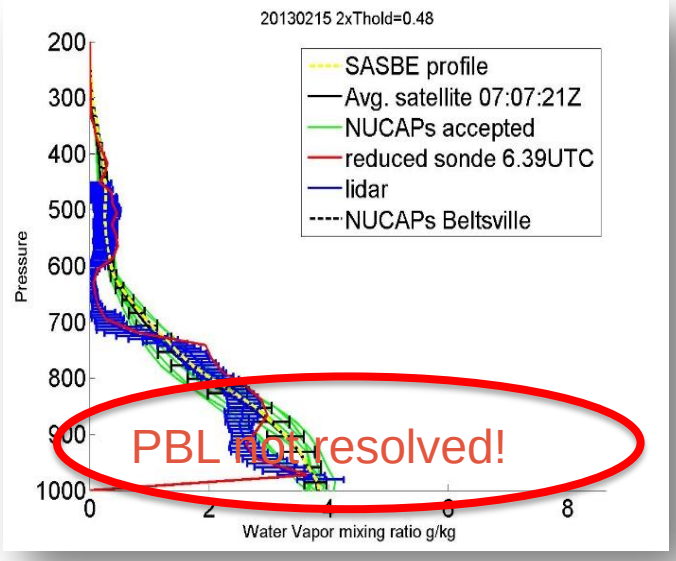
My take on Passive sensors?

AIRS: Sergio's test run







- Poor thermal contrast
- Scene-to-scene variability over land & accuracy makes PBL thermodynamics a challenge

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Summary: Space-based PBL & Decadal Survey

- *Thermodynamics profile preferred*
- Process-based scales needed for Convection and evolution
- Sub-cloud thermodynamics is critical for convection

- Passive sensors ➔ poor thermal contrast (Land/Ocean?)
- No current "active" or passive sensor at scales for convection

- ***Ground networks are critical for future space-based systems!***

- Mature ***profilers & operational lidars exist*** and need to be exploited through collaboration
- *A better assimilating code for aerosol-based PBL height is needed*

Thank You