Progress on Single-Footprint AIRS retrievals

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With thanks to Sergio DeSouza-Machado, Eric Fetzer, Evan Fishbein, Brian Kahn, Bjorn Lambrigtsen, Evan Manning, Tom Pagano, Mathias Schreier, Larrabee Strow, Joao Teixiera, Sun Wong and Qing Yue

Single-footprint – forward model comparison
Simultaneous Retrievals with D4S or TwoSlab

- **Delta-4-Stream (D4S)**
  - One cloud layer
  - Described in Ou et al., 2013
  - Same as used by Irion et al. (2018), but with updated SARTA that affects stratospheric ozone
    - BUT no 10μm ozone band in retrieval
  - Uses ECMWF forecast and MODIS cloud data in a priori
  - Retrieves effective cloud-top temperature, particle size, optical depth

3 elements in the state vector

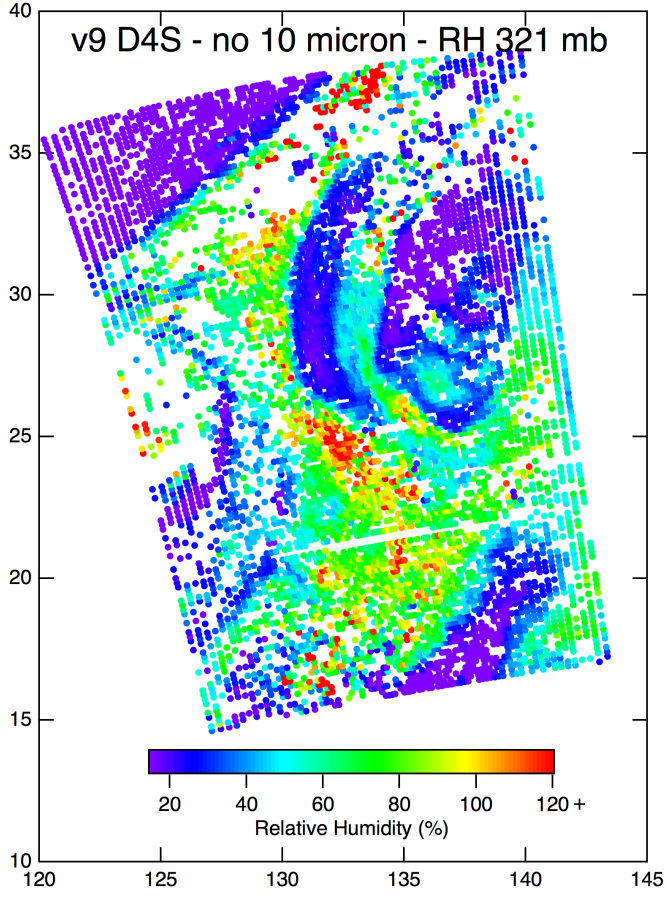
- **TwoSlab**
  - Two cloud layers
  - Described in DeSouza-Machado et al. (2018)
  - (My version) uses ECMWF forecast data for a priori
    - No MODIS, no reanalysis used
  - Models and retrieves two cloud layers
    - Cloud-top and bottom pressures, particle size, water content
    - Cloud 1 and 2 fractions, and cloud overlap
    - Assumption is (at most) one ice cloud and (at most) one liquid water cloud

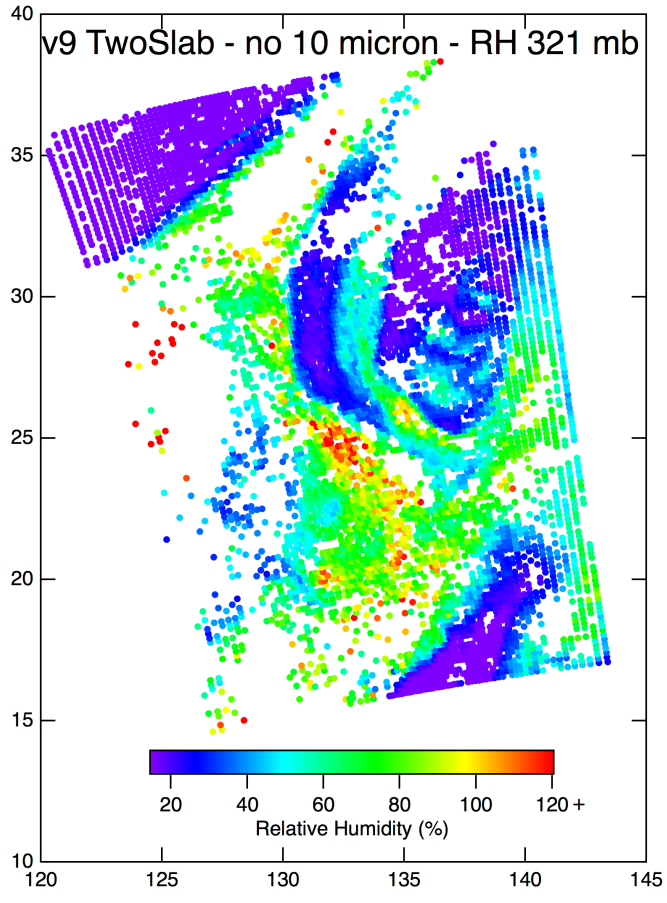
11 elements in the state vector

- Gas absorption calculations from SARTA the same in D4S and TwoStream in following results
  - Differences are in the cloud calculations and cloud priors

Relative Humidity

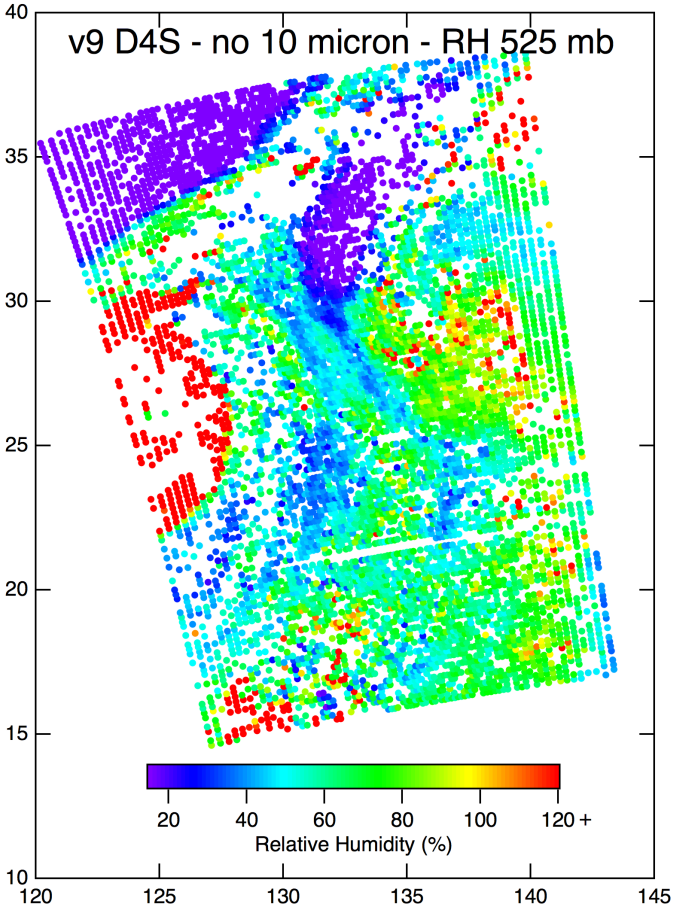
Granule 44 9/6/2002 **321 mb** - QC is normal convergence and chiSq < 3

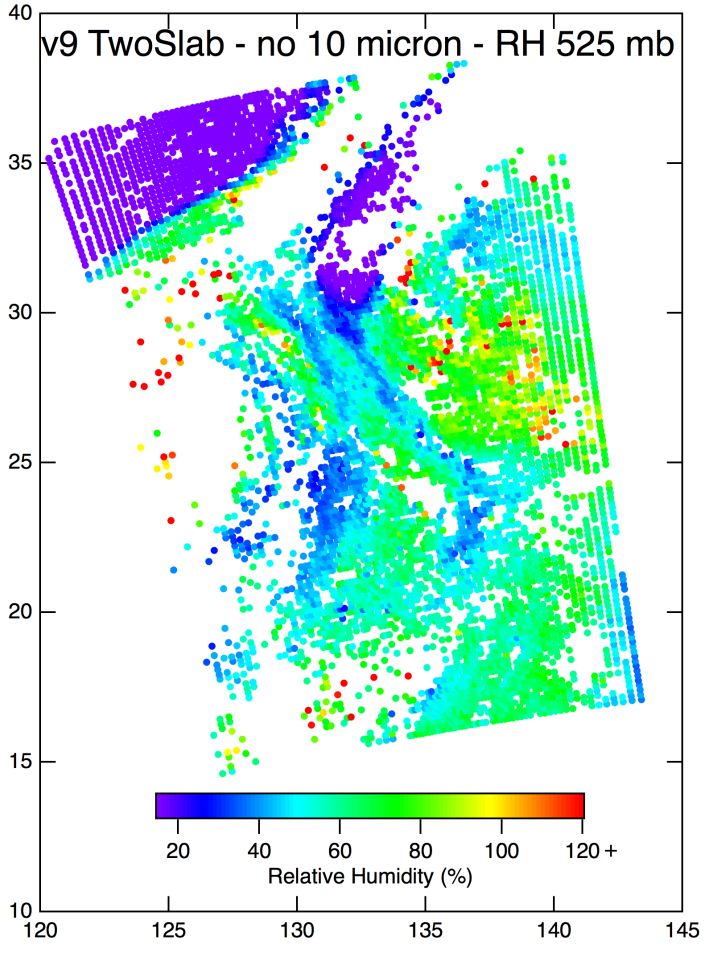




Relative Humidity

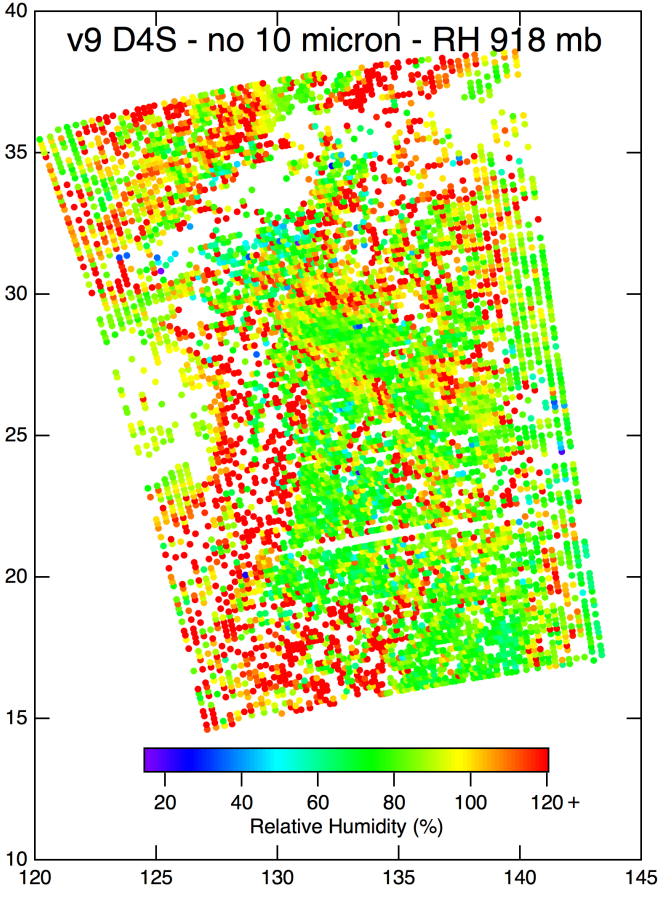
Granule 44 9/6/2002 **525 mb** QC is normal convergence and chiSq < 3

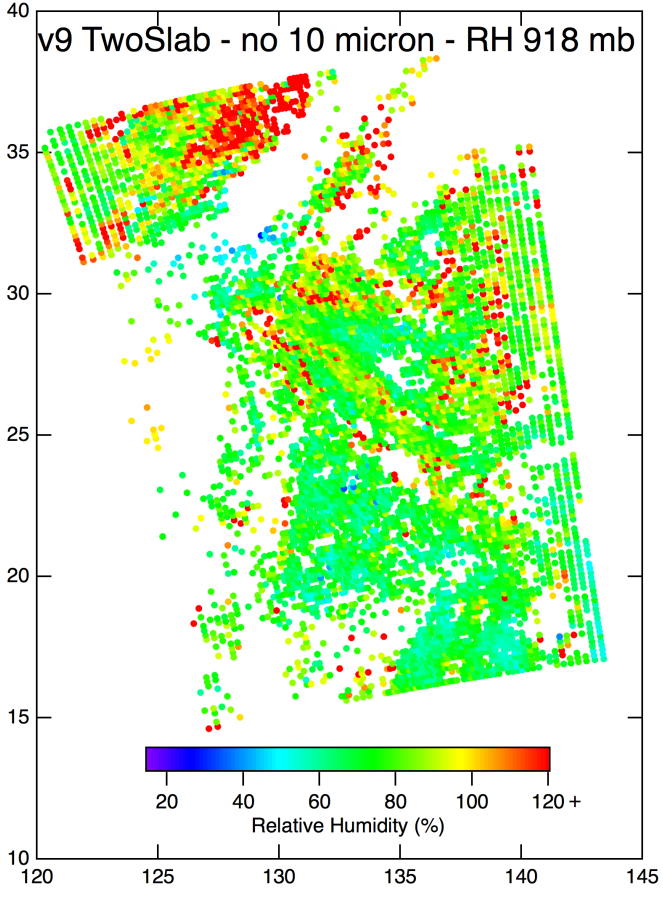




Relative Humidity

Granule 44 9/6/2002 **918 mb** QC is normal convergence and chiSq < 3

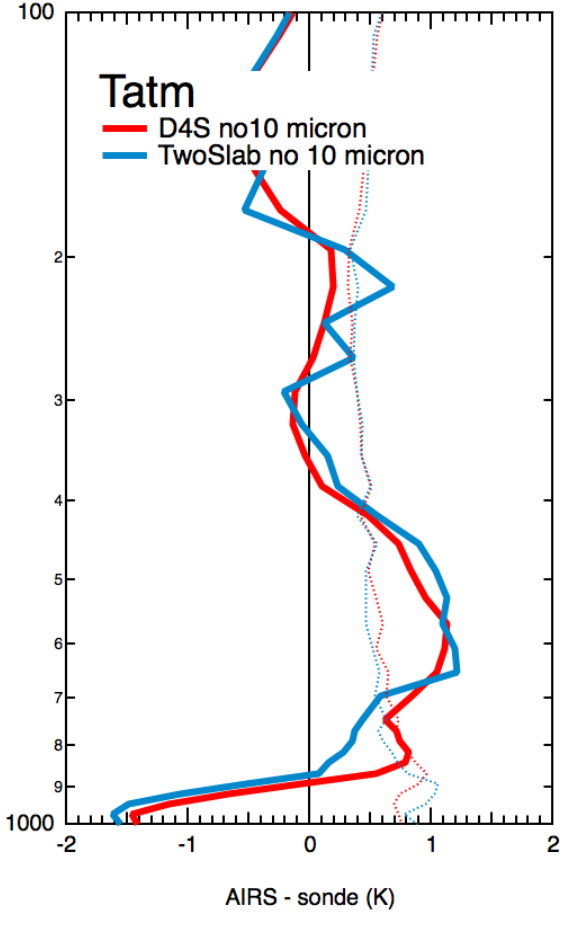


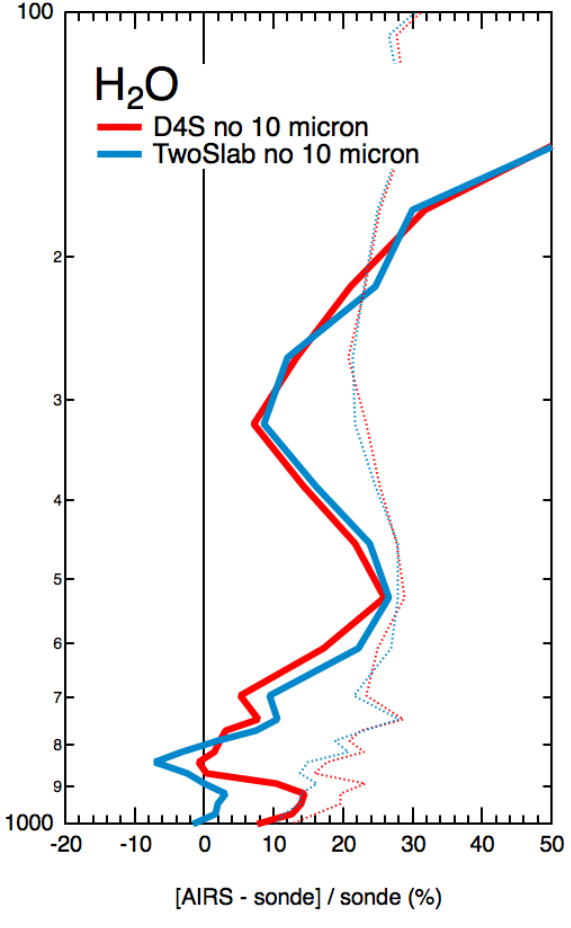


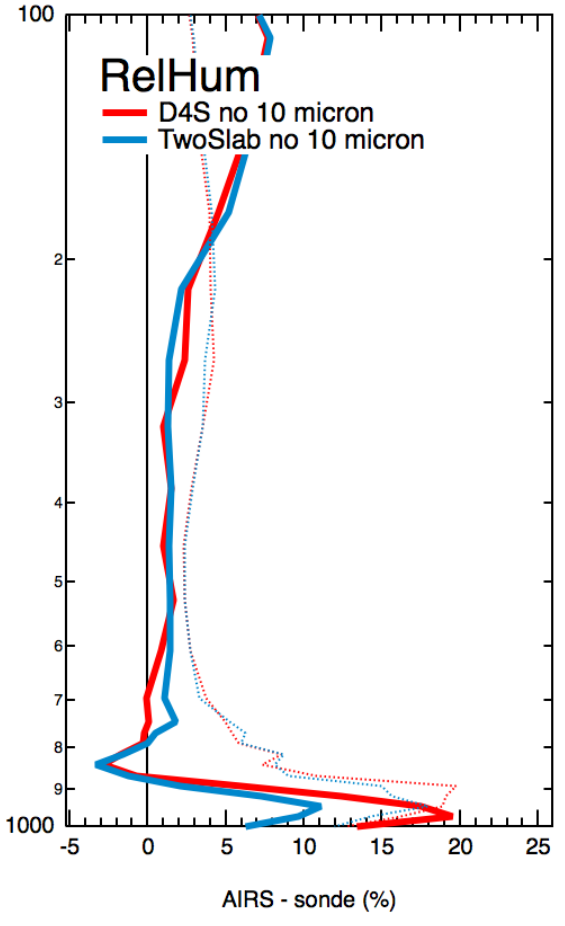
AIRS comparison to MAGIC sondes ("median of medians")

Thin lines are median absolute deviation

Matchup within 100 km and 3 hrs. **QC is normal convergence and chiSq < 3**



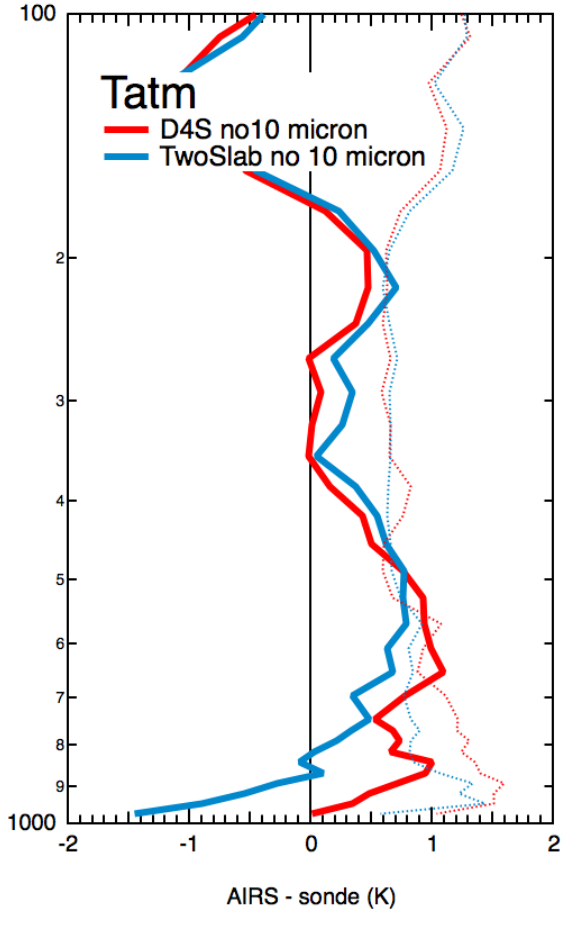


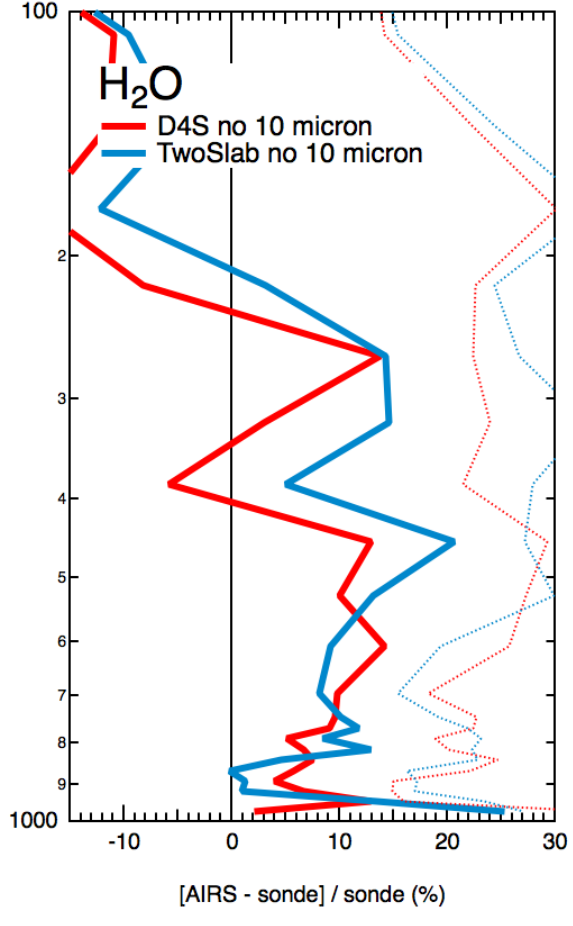


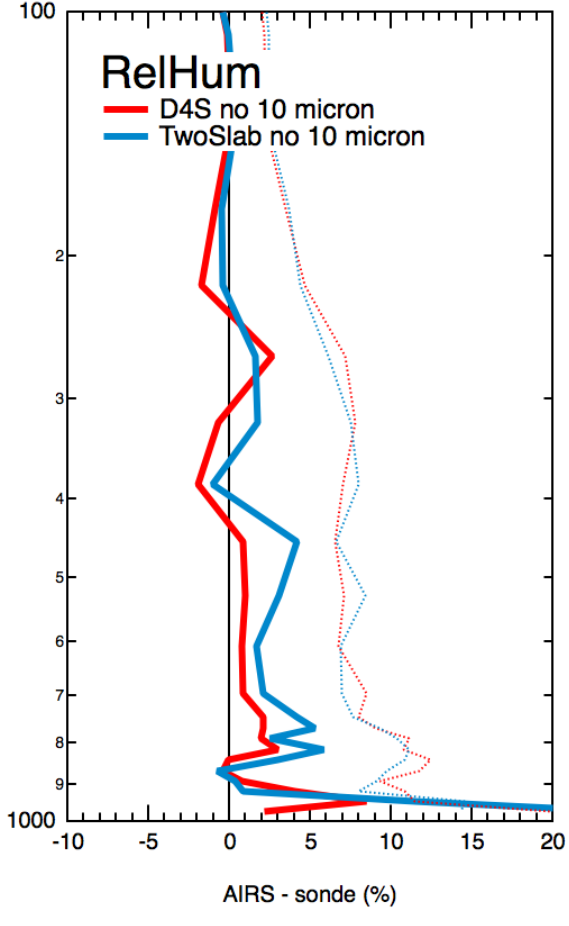
AIRS comparison to SGP sondes ("median of medians")

Thin lines are median absolute deviation

Matchup within 100 km and 3 hrs. **QC is normal convergence and chiSq < 3**



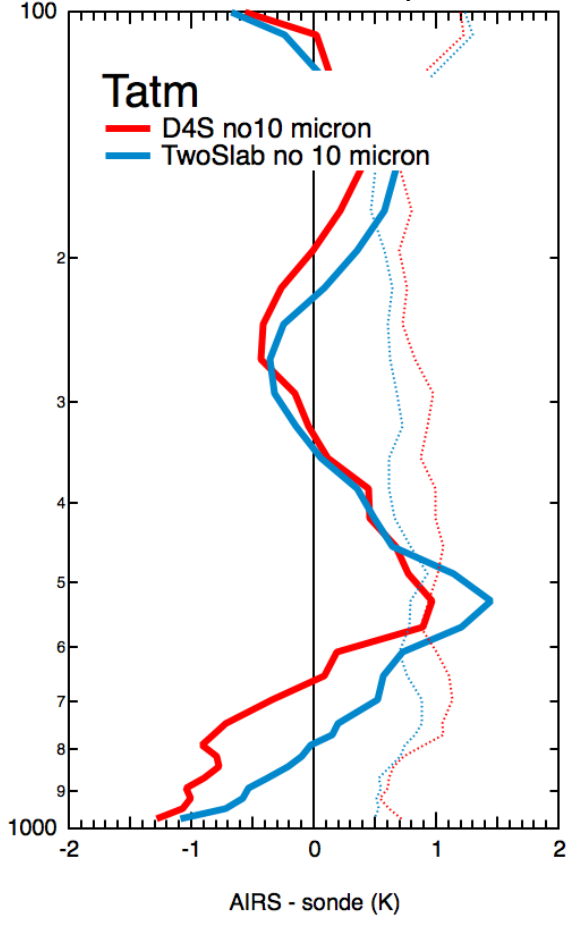


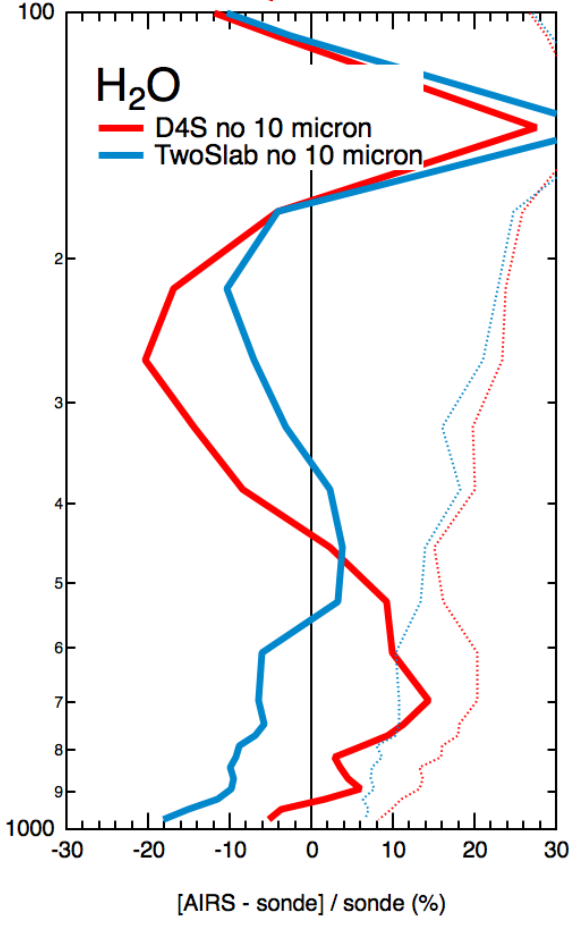


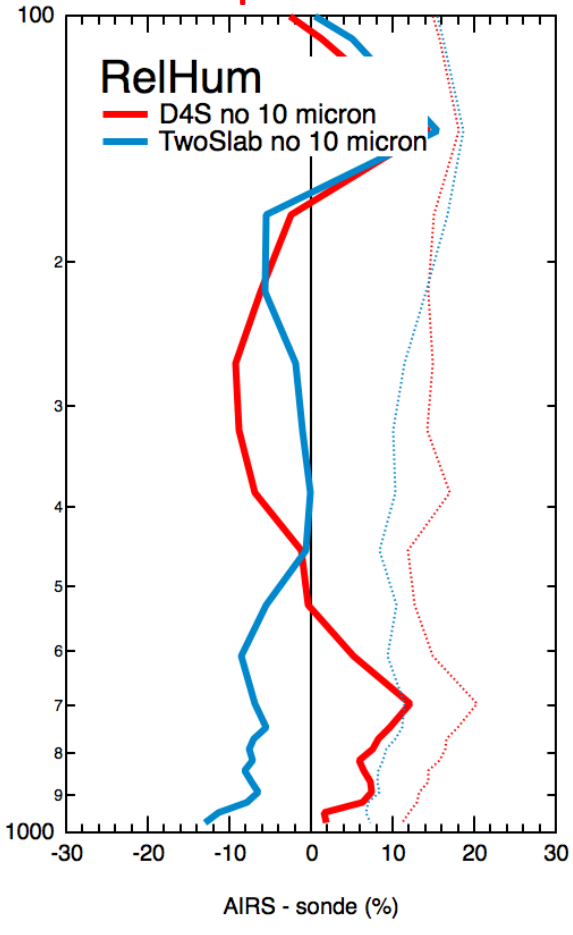
AIRS comparison to TWP sondes ("median of medians")

Thin lines are median absolute deviation

Matchup within 100 km and 3 hrs. **QC is normal convergence and chiSq < 3**



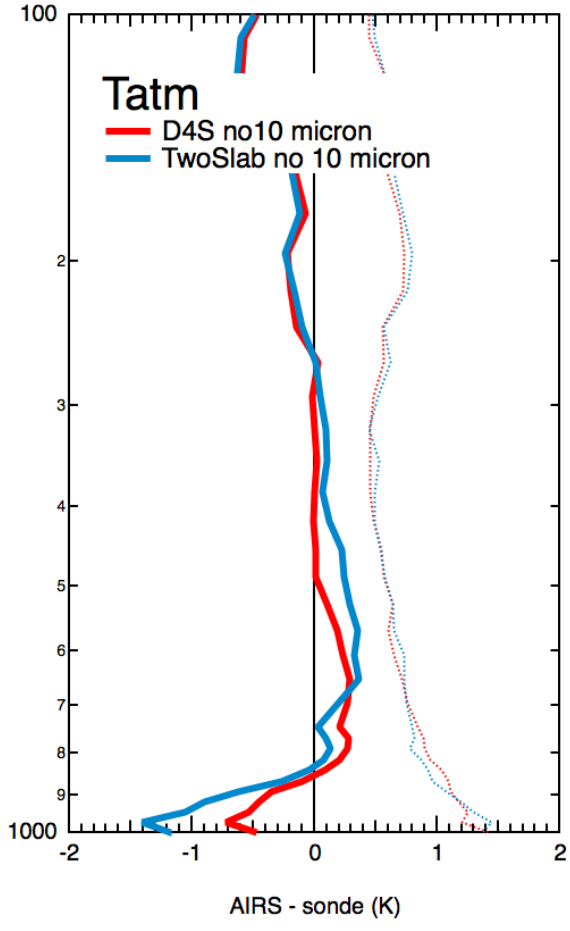


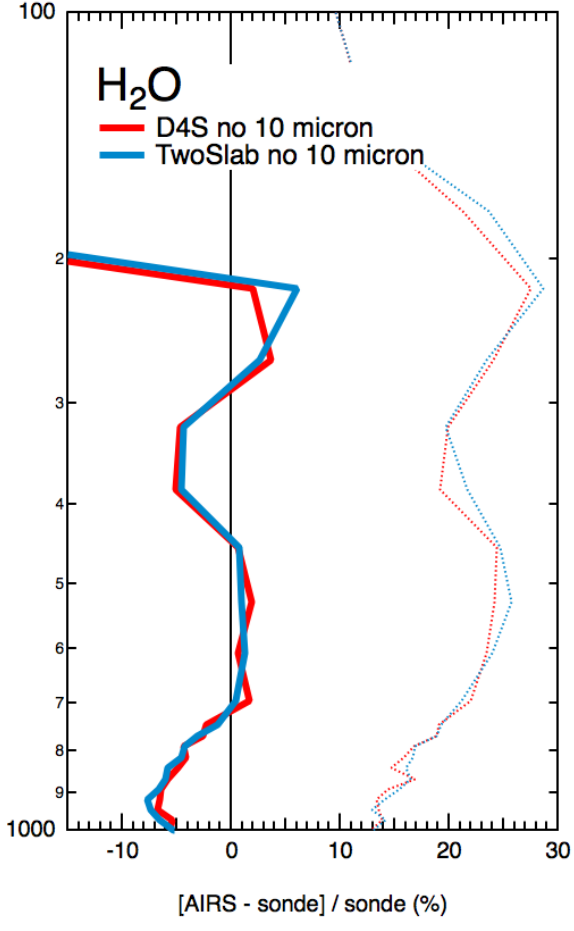


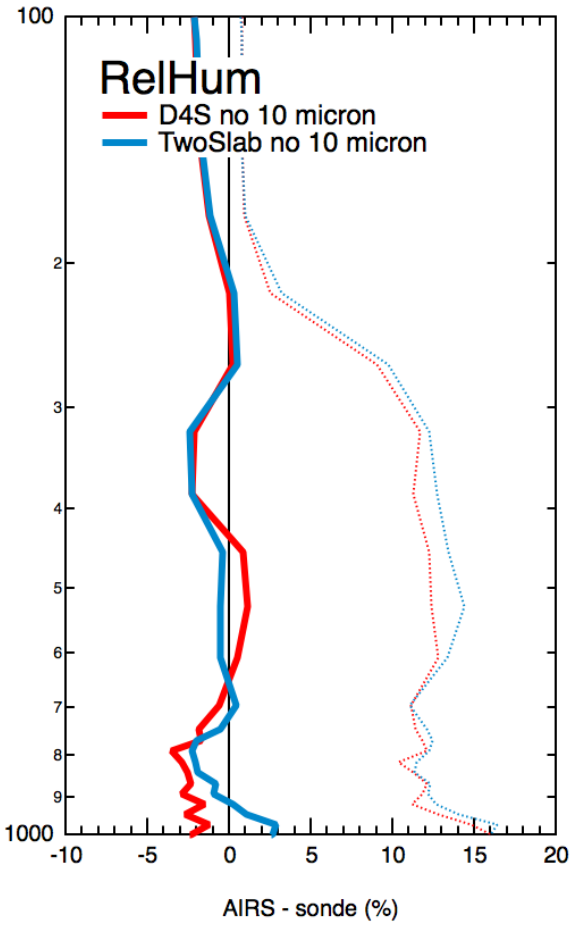
AIRS comparison to NSA sondes ("median of medians")

Thin lines are median absolute deviation

Matchup within 100 km and 3 hrs. **QC is normal convergence and chiSq < 3**







What's better? Delta-4-Stream and TwoSlab?

- TwoSlab not the magic bullet, but "not too bad."
- Quality Control using TwoSlab not well developed.
- TwoSlab may have lower yield (at least in my implementation).

  But where TwoSlab retrieval fails, the D4S retrieval is often QC'd out anyway.
- TwoSlab has more headroom for development than D4S

  …but will take a lot of work.

  Use reanalysis instead of forecast?

  Add in MODIS as prior to TwoSlab retrievals?

Switching gears …

Adding AMSU (and HSB) to single-footprint retrieval by adding microwave to the cost function.

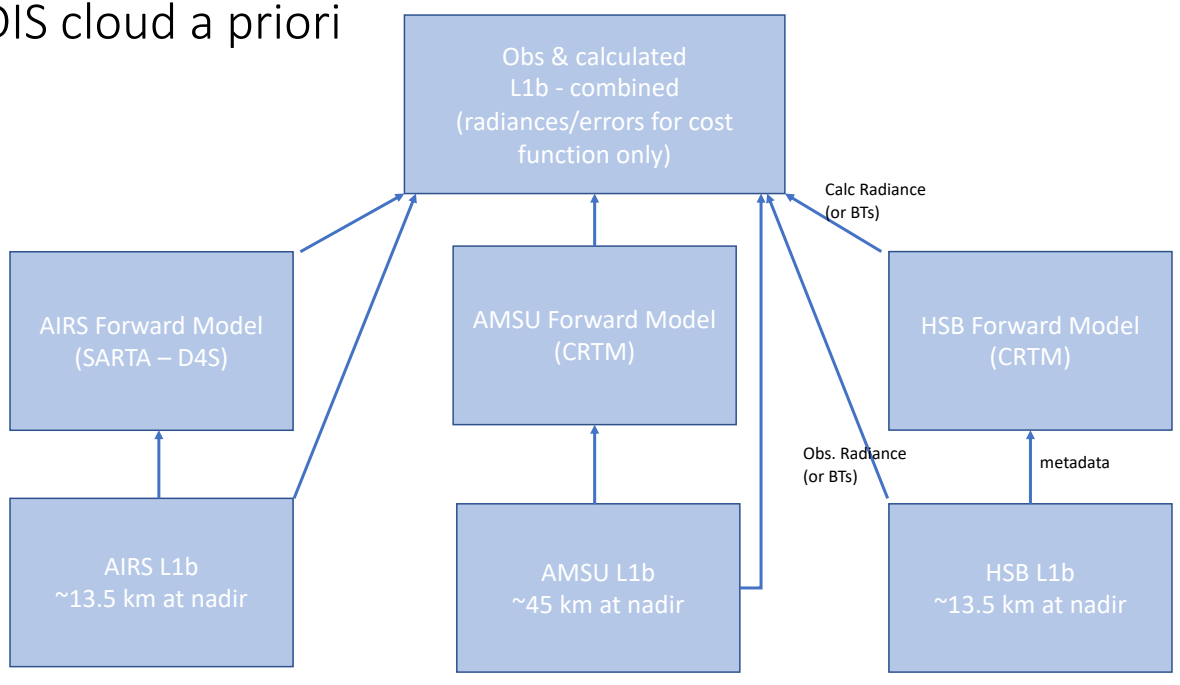
ECMWF forecast and MODIS cloud a priori

Is this a way to get better retrievals below the clouds?

Using CRTM to forward model AMSU/HSB always as “clear”

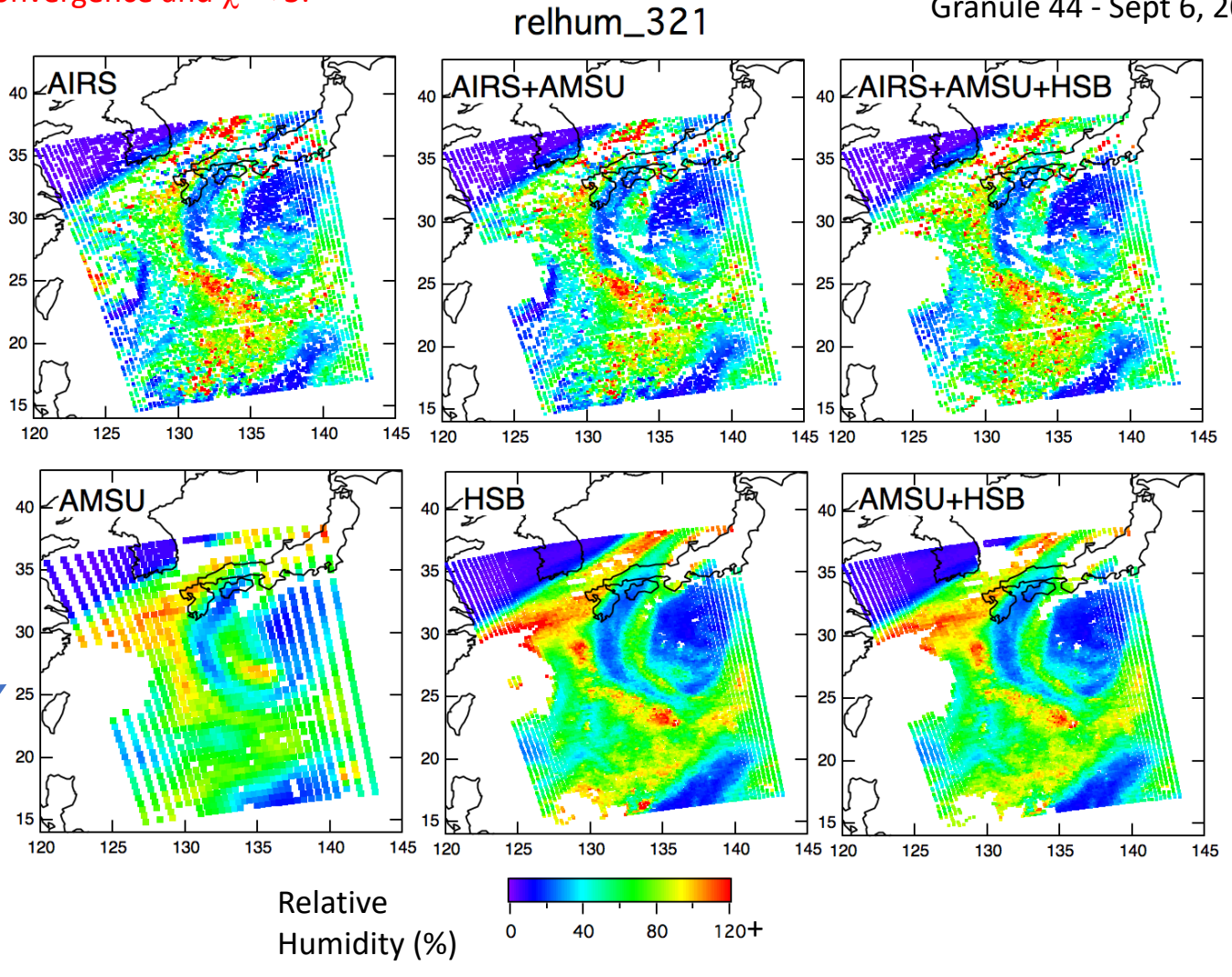
No AMSU ch 7.

Using AMSU naively -- e.g., forecast winds, and no brightness temperature corrections for scan angle.



QC is regular convergence and $\chi^2 < 5$.

Granule 44 - Sept 6, 2002.



Rel. Hum. 321 mb

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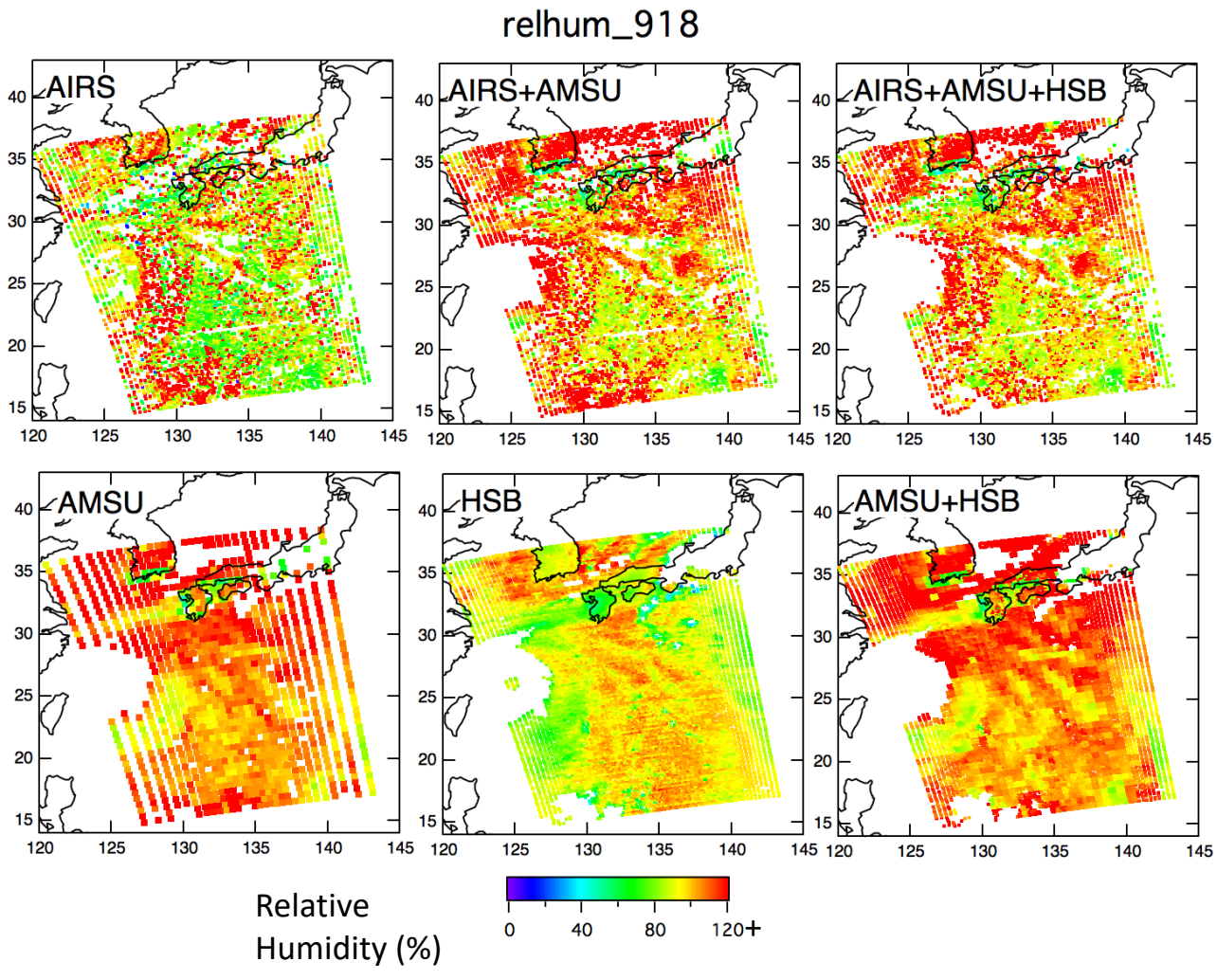
Rel. Hum.
918 mb



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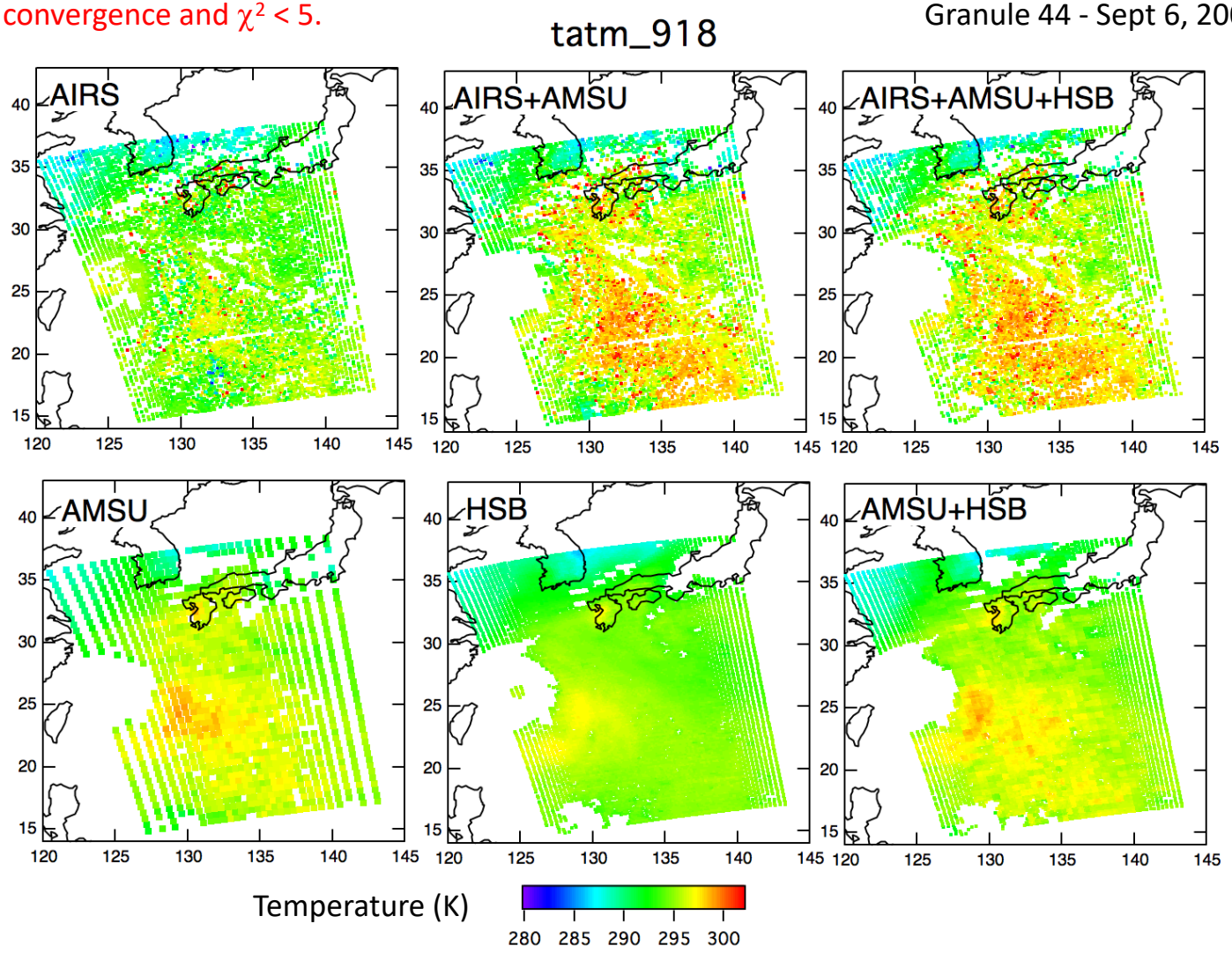


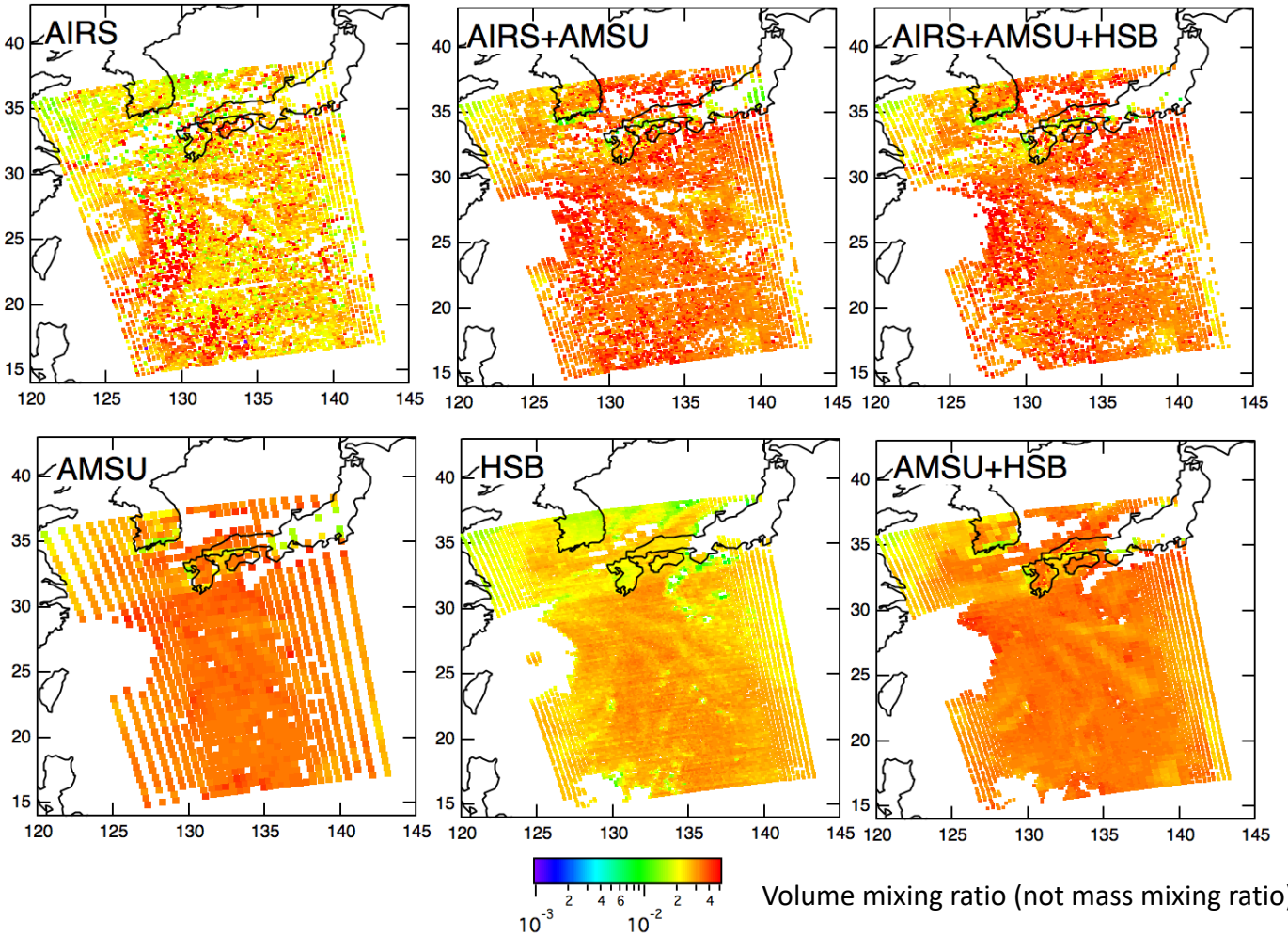
Tatm

918 mb

QC is regular convergence and $\chi^2 < 5$.

H2O_918

Granule 44 - Sept 6, 2002.

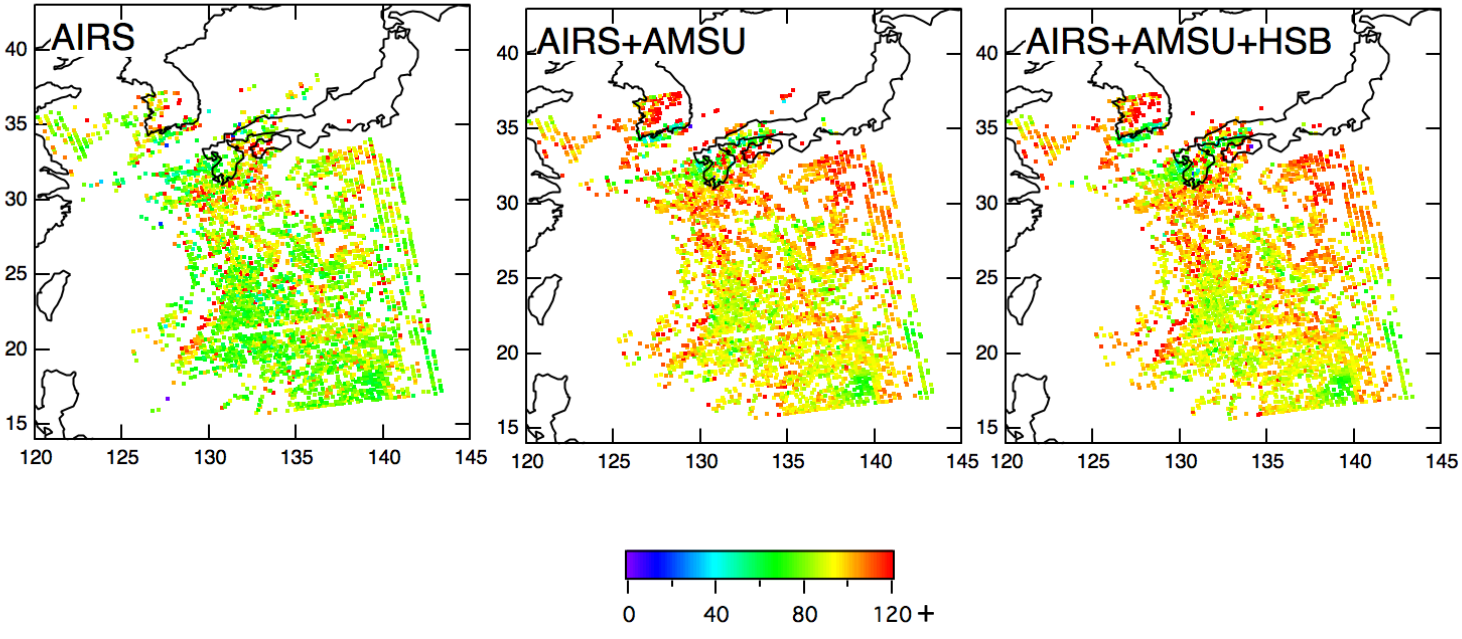


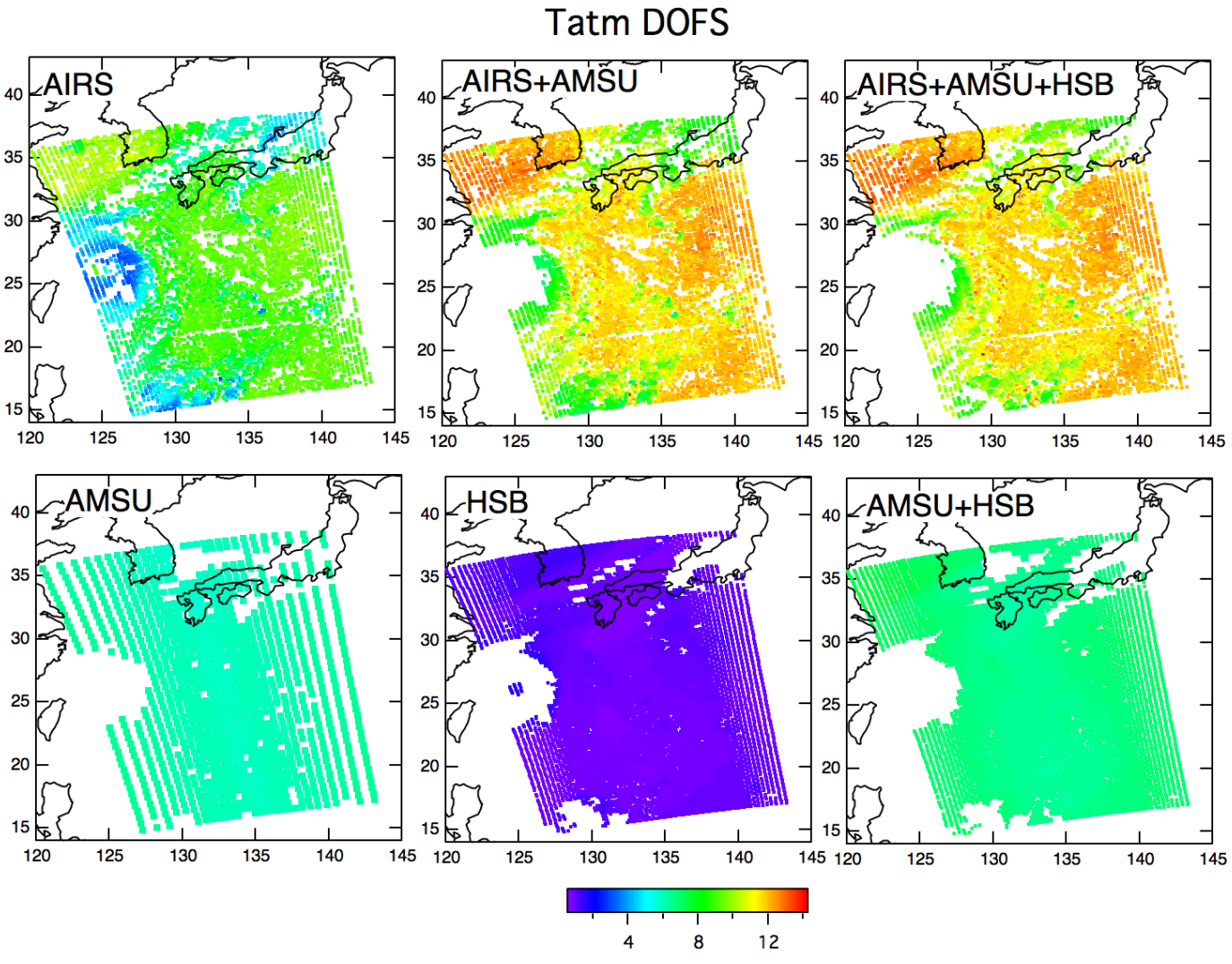
Volume mixing ratio (not mass mixing ratio)

QC is regular convergence and $\chi^2 < 5$.
Retrievals below clouds require T_{surf} AK > 0.6

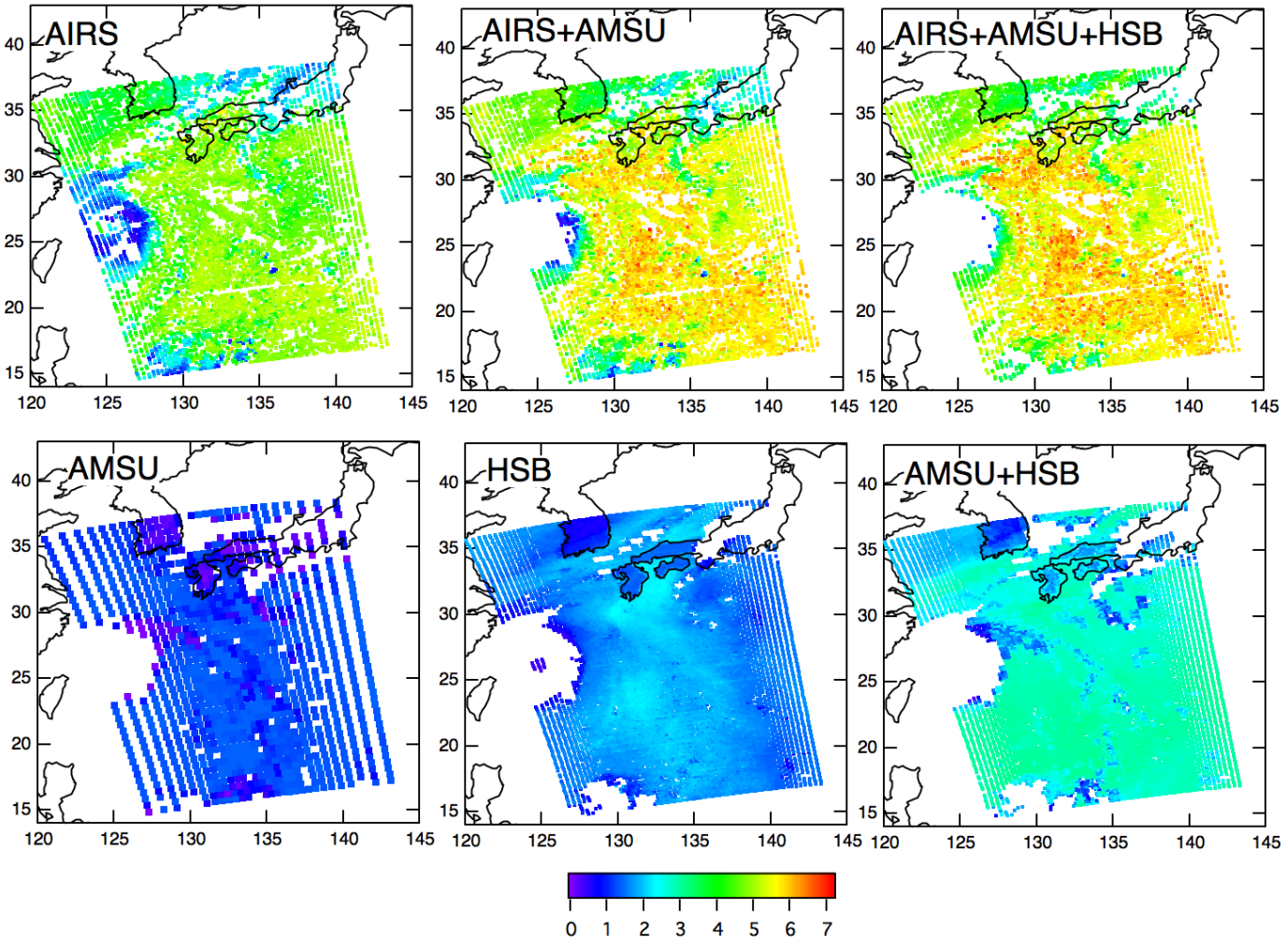
Granule 44 - Sept 6, 2002.

relhumQC_918

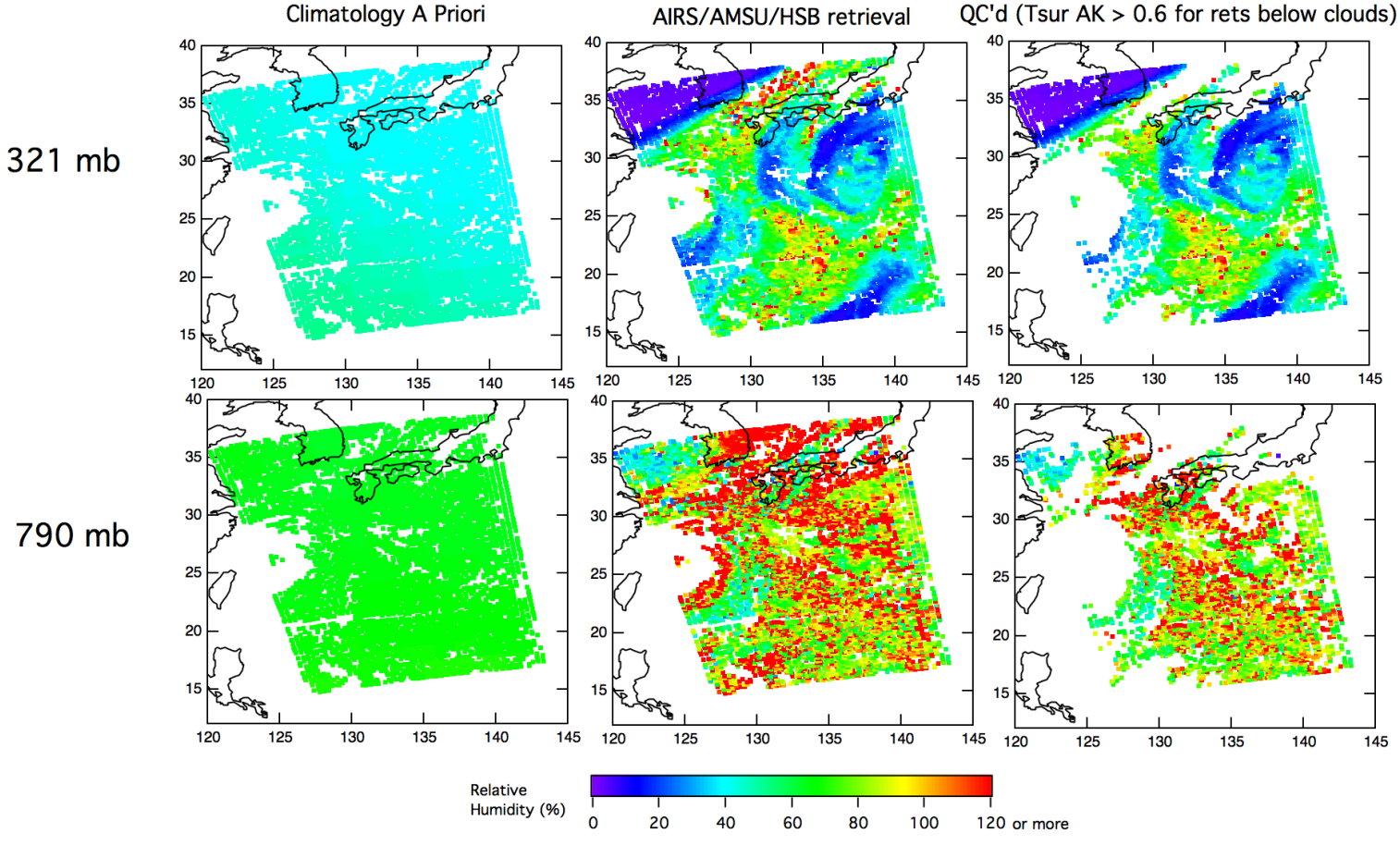



Tatm DOFS
AIRS
AIRS+AMSU
AIRS+AMSU+HSB
AMSU
HSB
AMSU+HSB
40
35
30
25
20
15
120
125
130
135
140
145
4
8
12

h2o DOFS


AIRS
AIRS+AMSU
AIRS+AMSU+HSB
AMSU
HSB
AMSU+HSB
40
35
30
25
20
15
120
125
130
135
140
145
0
1
2
3
4
5
6
7

Sanity check using climatological a priori (but still using MODIS for the clouds)

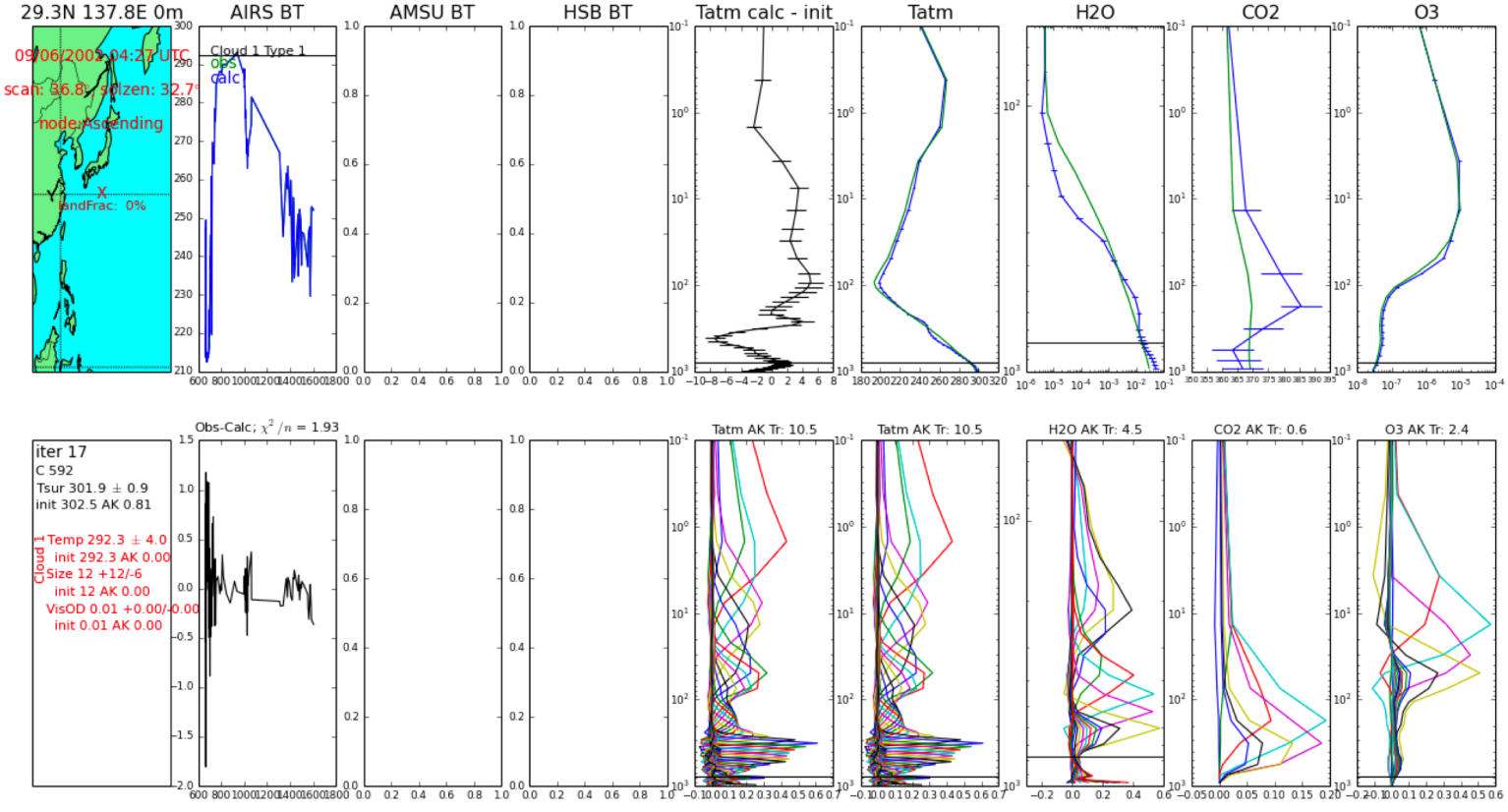


Adding in AMSU (and/or HSB) in simultaneous retrievals with AIRS…

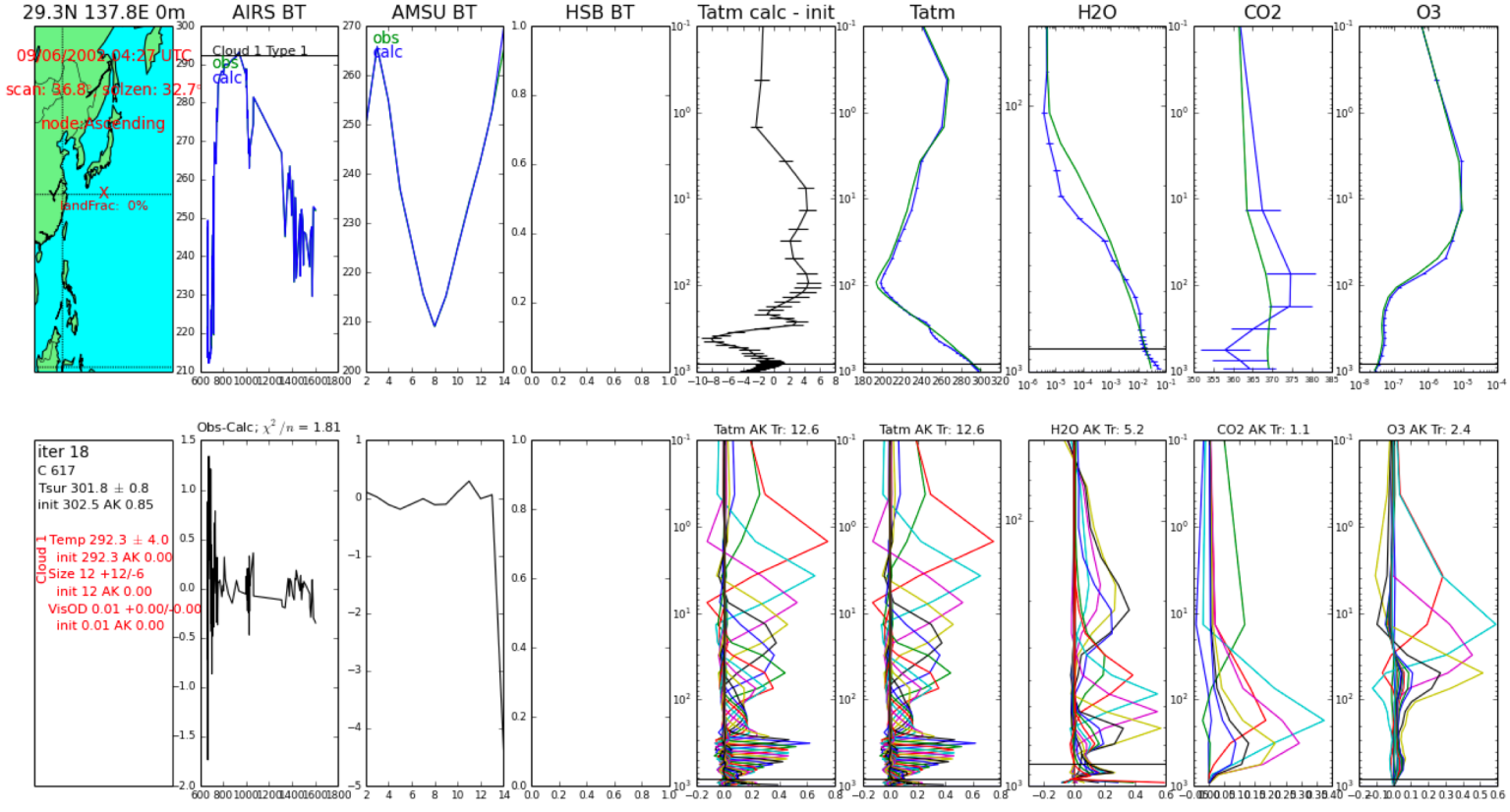
- Not (yet?) the magic bullet for retrievals below clouds.
- H_2O (and RH) is biased higher in and near boundary layer
  - Emissivity issues?
- Significant increase in T_{atm} and H_2O DOFS
  - Decrease in retrieval error and/or increase in vertical resolution
  - Quantifying this is work-in-progress
- Loss in horizontal resolution TBD

Questions?

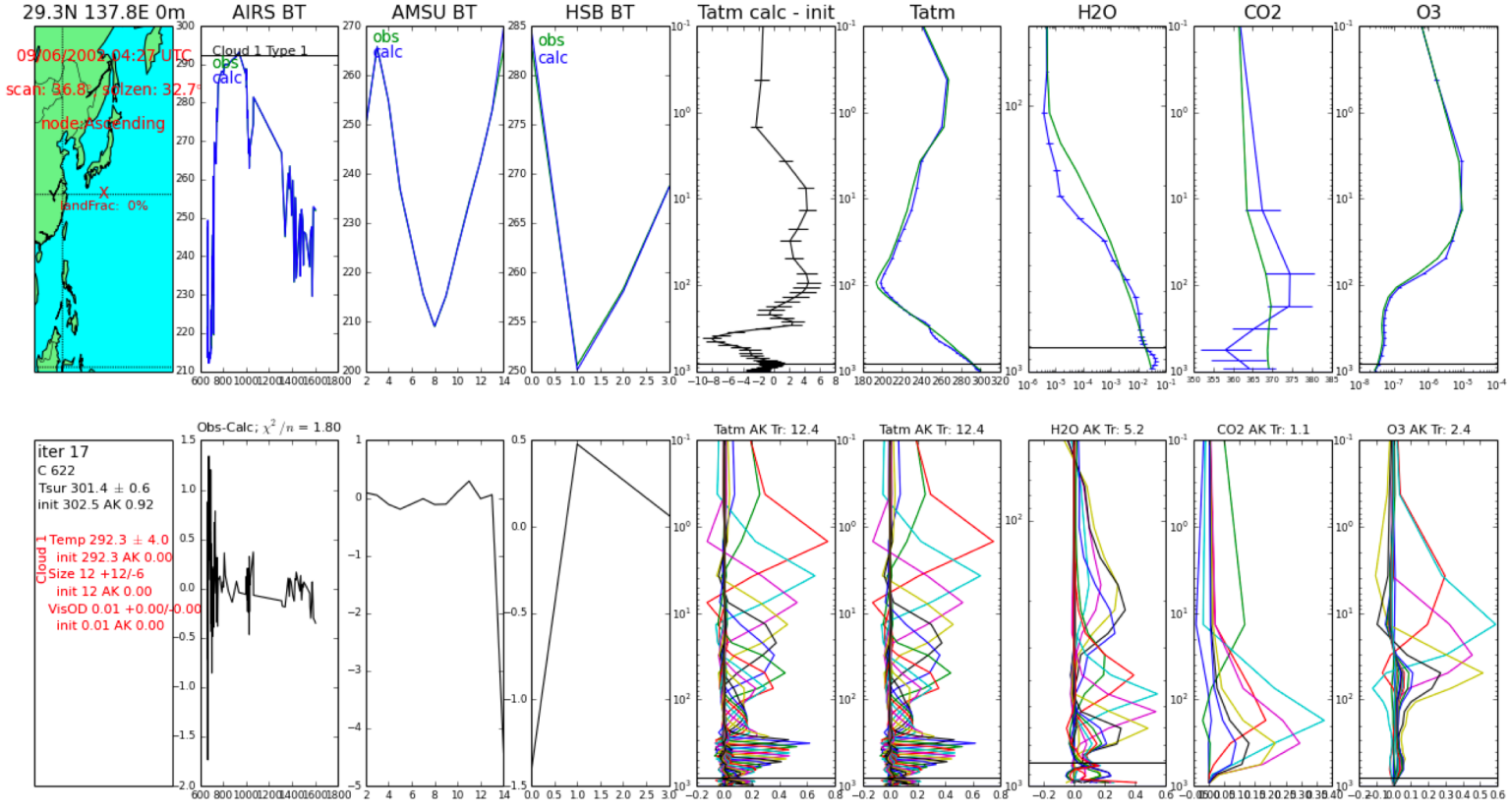
retrievals


29.3N 137.8E 0m
AIRS BT
AMSU BT
HSB BT
Tatm calc - init
Tatm
H2O
CO2
O3
09/06/2003 04:27 UTC
scan: 36.8, solzen: 32.7°
node: ascending
landFrac: 0%
Cloud 1 Type 1
obs
calc
Obs-Calc; χ^2/n = 1.93
iter 17
C 592
Tsur 301.9 ± 0.9
init 302.5 AK 0.81
Temp 292.3 ± 4.0
init 292.3 AK 0.00
Size 12 +12/-6
init 12 AK 0.00
VisOD 0.01 +0.00/-0.00
init 0.01 AK 0.00
Cloud
Tatm AK Tr: 10.5
Tatm AK Tr: 10.5
H2O AK Tr: 4.5
CO2 AK Tr: 0.6
O3 AK Tr: 2.4

retrievals

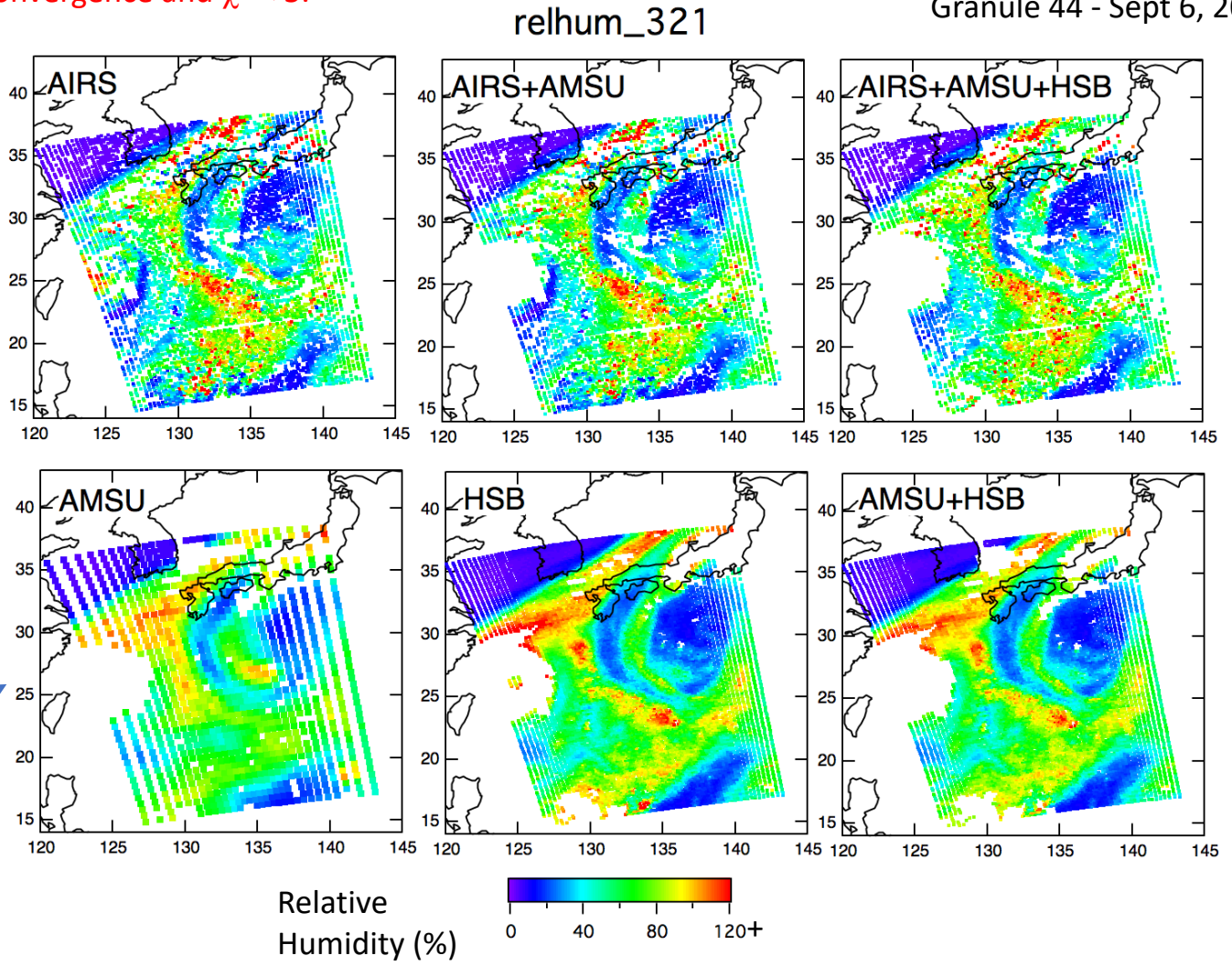

29.3N 137.8E 0m
AIRS BT
AMSU BT
HSB BT
Tatm calc - init
Tatm
H2O
CO2
O3
09/06/2003 04:27 UTC
scan: 36.8, solzen: 32.7°
node: Ascending
landFrac: 0%
Cloud 1 Type 1
obs
calc
iter 18
C 617
Tsur 301.8 ± 0.8
init 302.5 AK 0.85
Cloud 1
Temp 292.3 ± 4.0
init 292.3 AK 0.00
Size 12 +12/-6
init 12 AK 0.00
VisOD 0.01 +0.00/-0.00
init 0.01 AK 0.00
Obs-Calc; χ^2/n = 1.81
Tatm AK Tr: 12.6
Tatm AK Tr: 12.6
H2O AK Tr: 5.2
CO2 AK Tr: 1.1
O3 AK Tr: 2.4

retrievals


29.3N 137.8E 0m
AIRS BT
AMSU BT
HSB BT
Tatm calc - init
Tatm
H2O
CO2
O3
09/06/2003 04:27 UTC
scan: 36.8, solzen: 32.7°
node: ascending
landFrac: 0%
Cloud 1 Type 1
obs
calc
iter 17
C 622
Tsur 301.4 ± 0.6
init 302.5 AK 0.92
Cloud 1
Temp 292.3 ± 4.0
init 292.3 AK 0.00
Size 12 +12/-6
init 12 AK 0.00
VisOD 0.01 +0.00/-0.00
init 0.01 AK 0.00
Obs-Calc; χ^2/n = 1.80
Tatm AK Tr: 12.4
Tatm AK Tr: 12.4
H2O AK Tr: 5.2
CO2 AK Tr: 1.1
O3 AK Tr: 2.4

QC is regular convergence and $\chi^2 < 5$.

Granule 44 - Sept 6, 2002.



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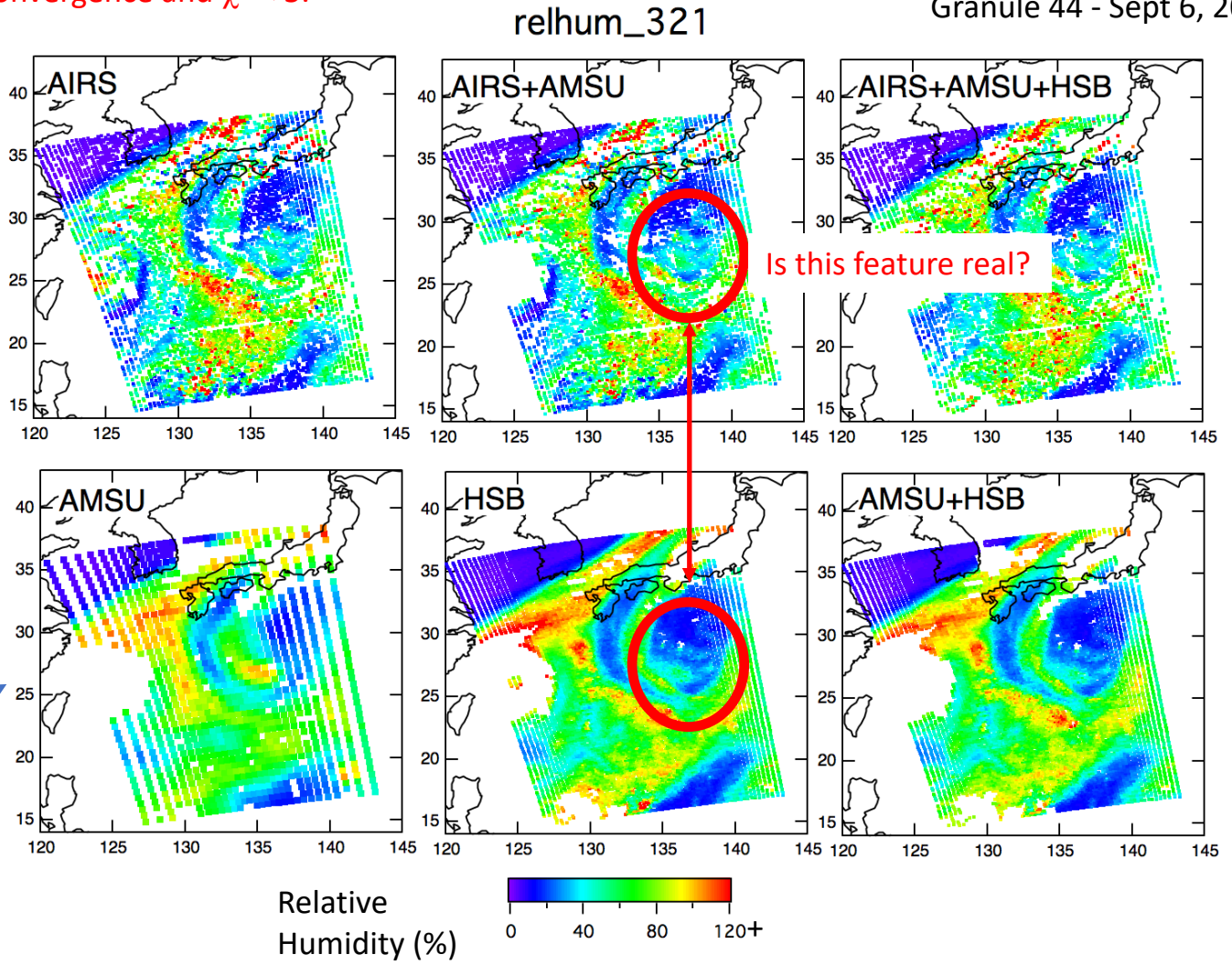

Rel. Hum. 321 mb

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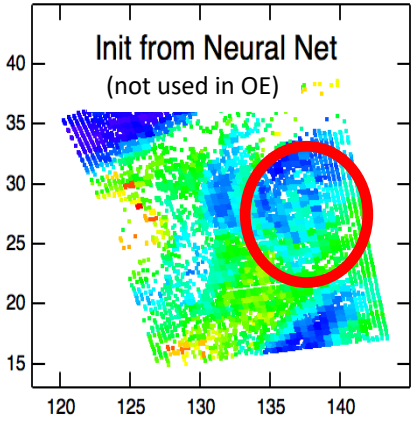
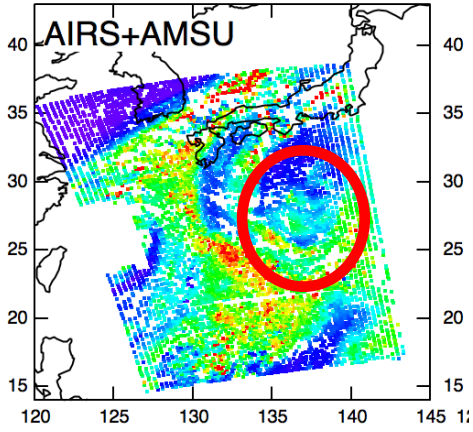
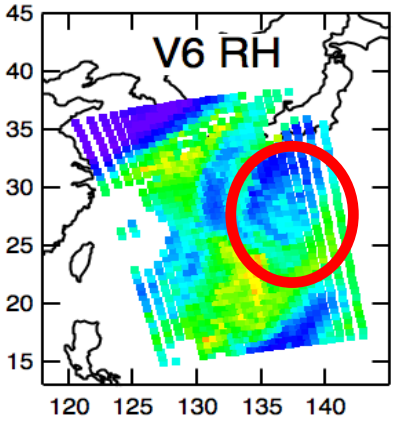
relhum_321

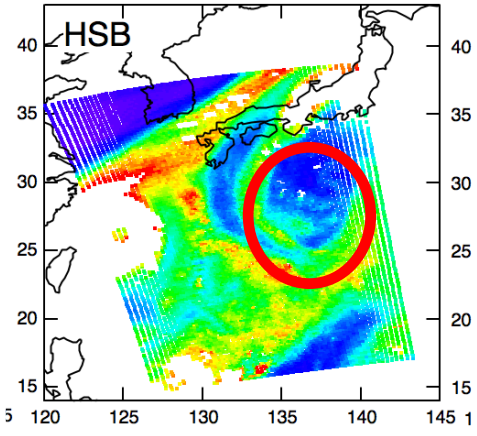
Granule 44 - Sept 6, 2002.

Rel. Hum.
321 mb









Relative Humidity (%)