# Reprocessing HIRS Cloud and Moisture Measurements

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# Outline

- Brief Project Overview
- Approach (1-2 slides)
- Results/Accomplishments (1-3 slides)
- Validation Strategy/Results (1-2 slides)
- Algorithm/Product Maturity
- Issues/Risks & Work-Off Plans
- Schedule
- Transition Plan
- Societal Benefits (2 slides)
- Resources (1-2 slides)

# Overview

- Goal(s) – Infer cloud and TPW trends for the past 30 years from HIRS derived cloud and water properties reprocessed using improved algorithm (MODIS heritage) and recalibrated data (SNOs with reference HIRS)
- Source Data – HIRS decadal IR measurements labeled with meta data
- Deliverables – annual % of observations finding all and high clouds as well as wet and dry TPW
- ECVs addressed – cloud optical depth and height, TPW
- Current/expected user communities – GCM groups
- Impact – understanding the role of high thin clouds in climate

# Product Description

- CDRs – Cloud top pressures & TPWs
- Algorithm – CO2 Slicing and TPW regression
- Collateral Products – Cloud Mask, SST/LST
- Responsible Team Member – Paul Menzel
- Source Data Sensor – HIRS 2/3/4
- Future Source Data Sensor – MODIS, VIIRS/CrIS
- S/C – POES, EOS Terra & Aqua, and JPSS
- Channels Used – HIRS 4-8 (CO2), 10 (IRW), 11-12 (H2O)
- Spatial Resolution – 20 km horizontal, 50 hPa vertical for clouds, total column for TPW
- Orbits – all POES orbits
- Start of Record – 1979
- End of Record – ongoing until end of decade (MetOp-B) ?
- Product Units – hPa and mm
- Projection – equal angle
- Output format – hdf5 and netcdf
- Metadat compliance – CF
- Other characteristics – cloudy skies for CTP and clear skies for mm
- References - *Wylie et al*., 2005: Global Cloud Cover Trends Inferred from Two decades of HIRS Observations. J. Clim., **18**, 3021-3031; *Menzel et al*., 2008: MODIS global cloud-top pressure and amount estimation: algorithm description and results. Jour of App Meteor and Clim., **47**, 1175-1198; *Seemann et al*., 2003: Operational retrieval of atmospheric temperature, moisture, and ozone from MODIS infrared radiances. Jour. Appl. Meteor., **42**, 1072-1091.
- User Groups – ISCCP, GEWEX, EUMETSAT CM-SAF
- Potential new users - Geophysical product developers, GCM modeling groups
- Outcomes - Satellite climate record community enabled to address societal outcomes and impacts
- Impact - Understanding the role of high thin ice clouds in earth energy balance
- Community Workshop - AVHRR-HIRS CDR Workshop Nov 2008 Camp Springs MD

# Approach / Results
# Accomplishments

# Adjustments to HIRS Cloud Algorithm

Done

- Use top-down method where most opaque channel pair seeing cloud derives CTP
- Lower noise thresholds (clear minus cloudy radiances required to indicate cloud presence in CO2 bands) to force more CO2 slicing solutions for high thin clouds.
- Adjust ozone profile from 10 to 100 hPa to GDAS (instead of using climatology) so that CO2 radiances influenced by O3 profiles are calculated correctly.
- Identify stratospheric clouds when opaque band is warmer than less opaque band
- Incorporate sinusoidal CO2 increase for 30 year record
- Restrict CO2 channel pair solutions to appropriate portion of troposphere (determined by their weighting functions).

Pending

- Add marine stratus improvement (constant lapse rate in low level inversions)

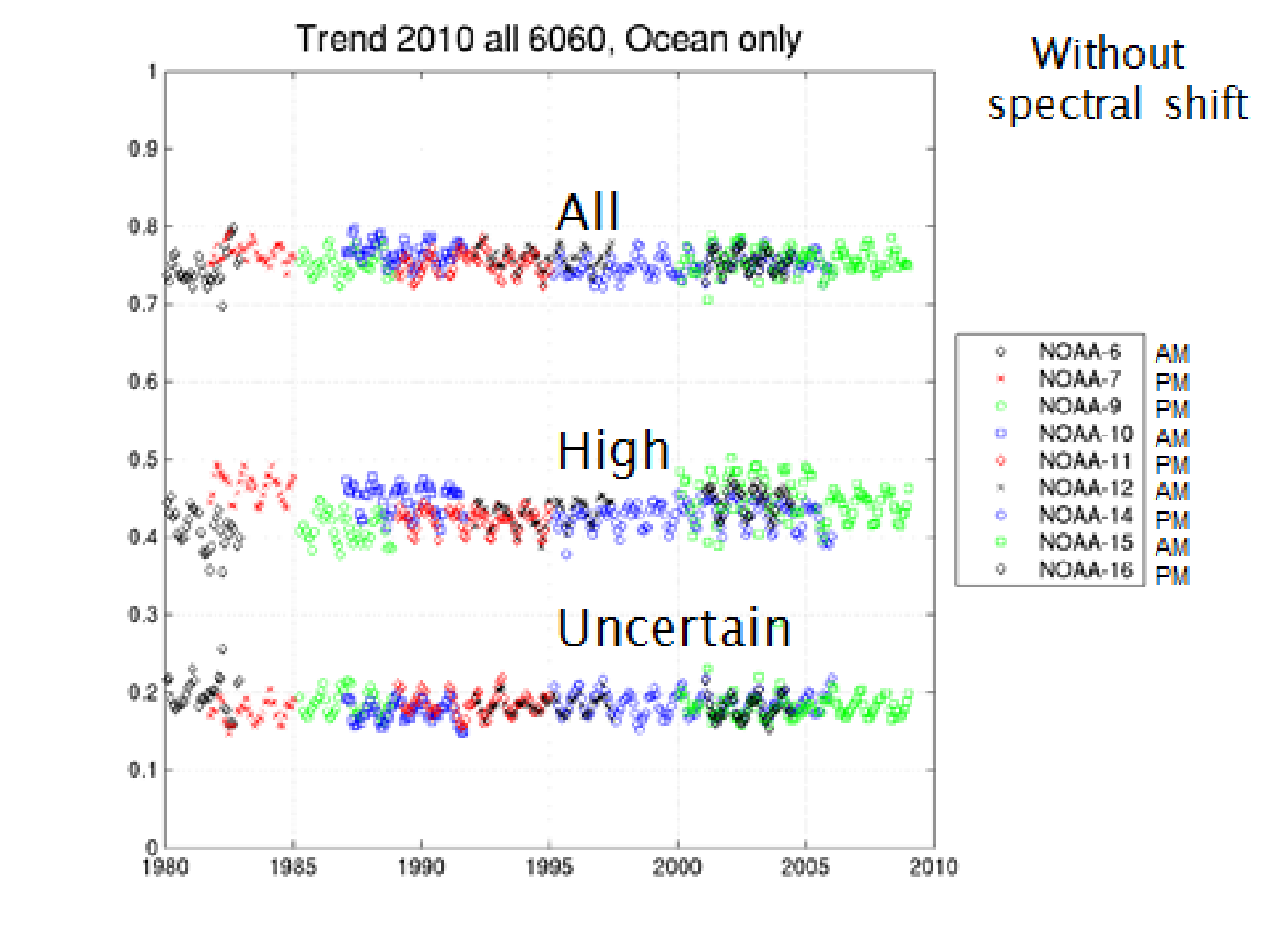
# Adjustments to TPW Algorithm

Pending

- Adapt MODIS TPW algorithm to HIRS spectral channels (including new IR surface emissivity maps from SEEBOR)

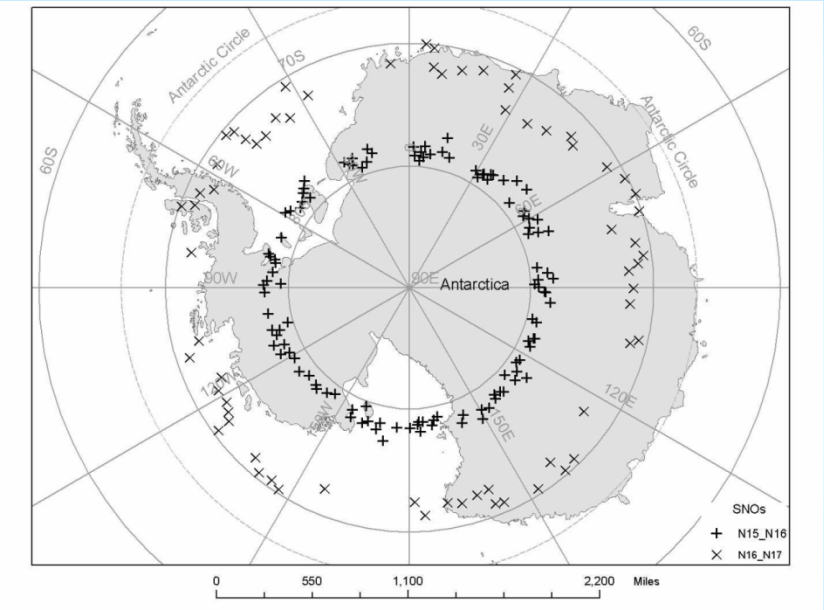
# Sensor to sensor recal being addressed by SNOs

# Sensor to Sensor Discontinuity

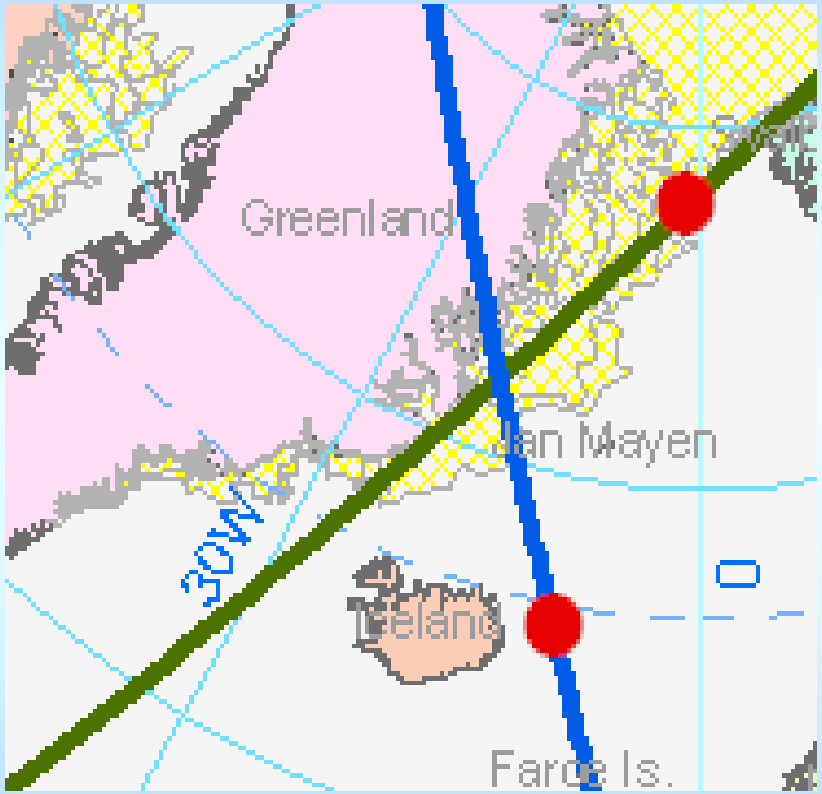



Try intercalibration. Use METOP HIRS as reference for all others.

# Toward an Integrated System for Intersatellite Calibration of POES using the SNO Method

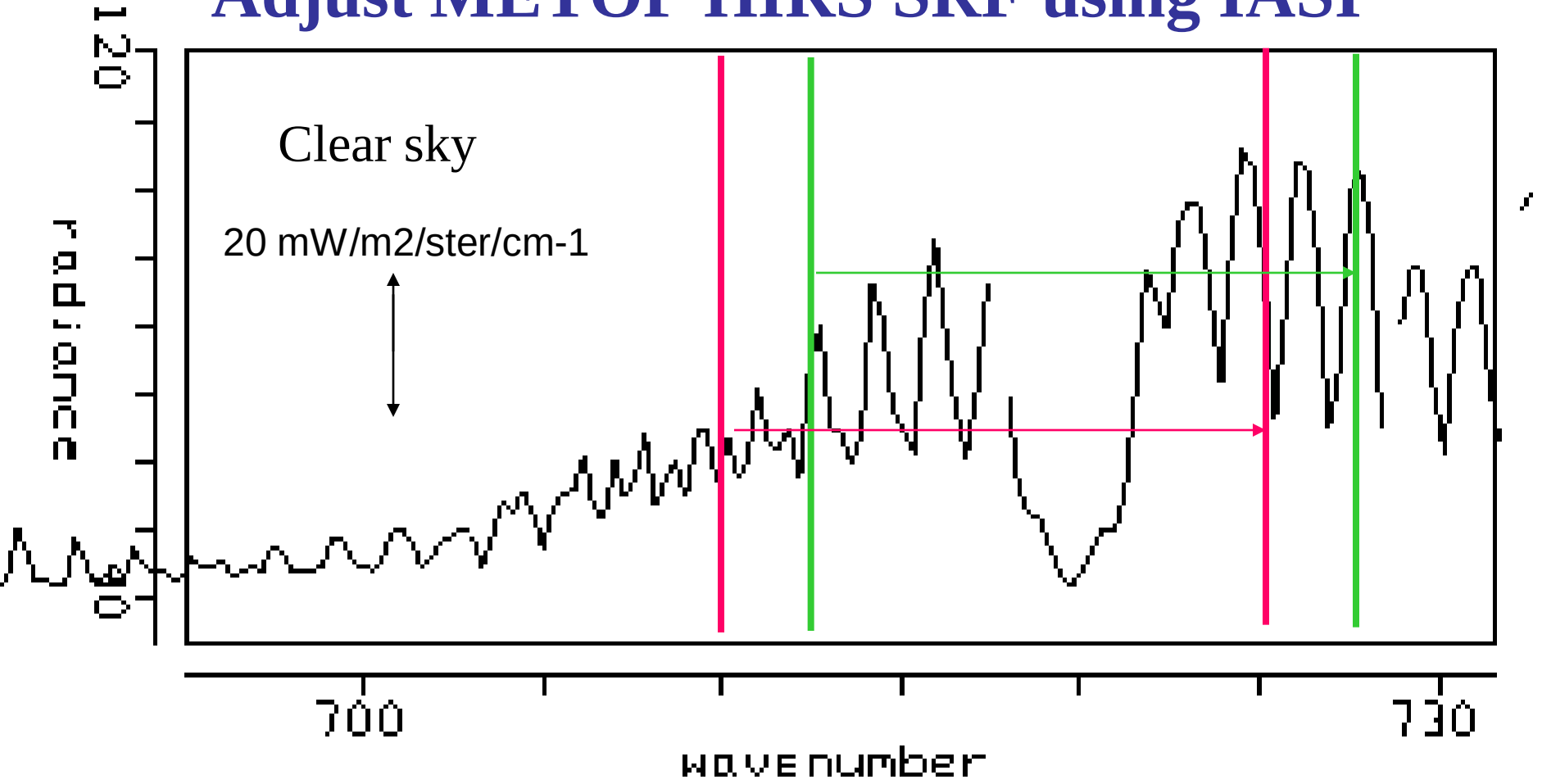



N15 & N16 (+) and
N16 & N17 (X)
SNO locations
from 2000 to 2003



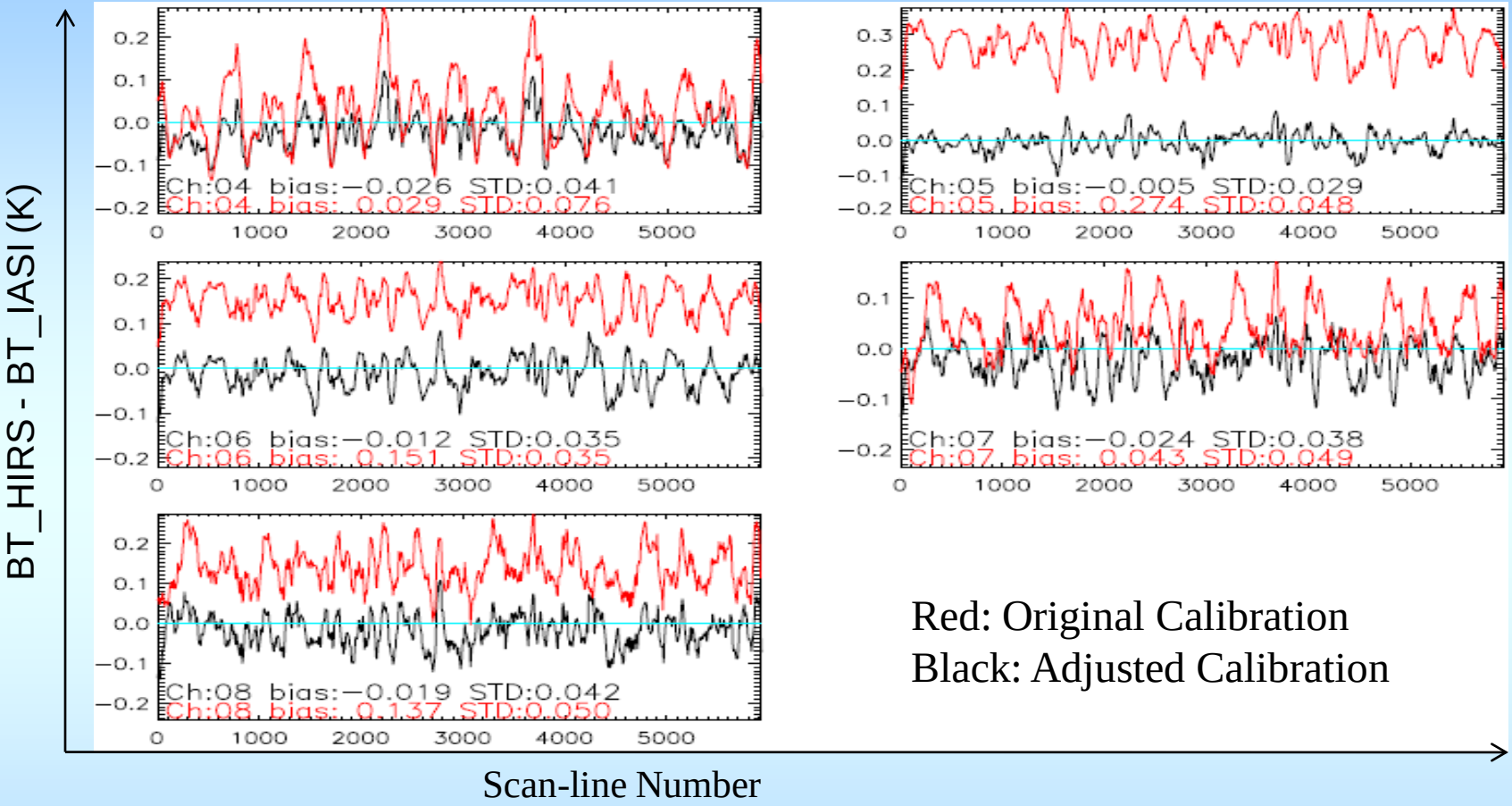

SNO: Simultaneous Nadir Overpass

# Adjust METOP HIRS SRF using IASI




* Bandwidth ~ 15 cm-1
* Shift of 2.5 cm-1, ΔTb ~ +5 K, ΔR ~6 mW/m2/ster/cm-1
* Then calculation of clear sky radiance obs would be off by ΔR which would affect determination of Pc
* Warmer clear sky calculation introduces extra cloud detection

# Validation of HIRS Calibration Adjustment using one day of MetOp data (05/23/09)




- Validated with one day (independent, different season) HIRS/IASI data from MetOp
- Both mean bias and bias variation are significantly reduced
- Other factors: inhomogeneity, instrument on-orbit variation, IASI uncertainties, non-unity of BB emissivity, and space-view biases …



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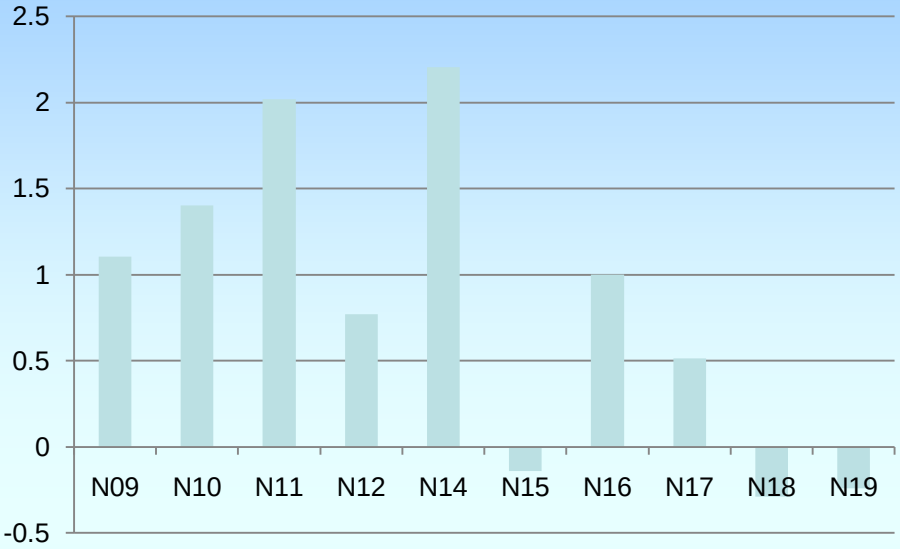
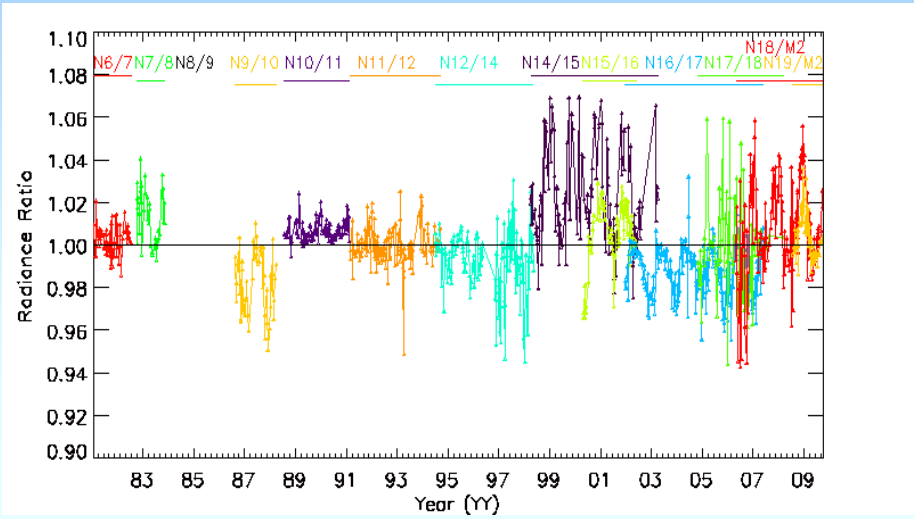
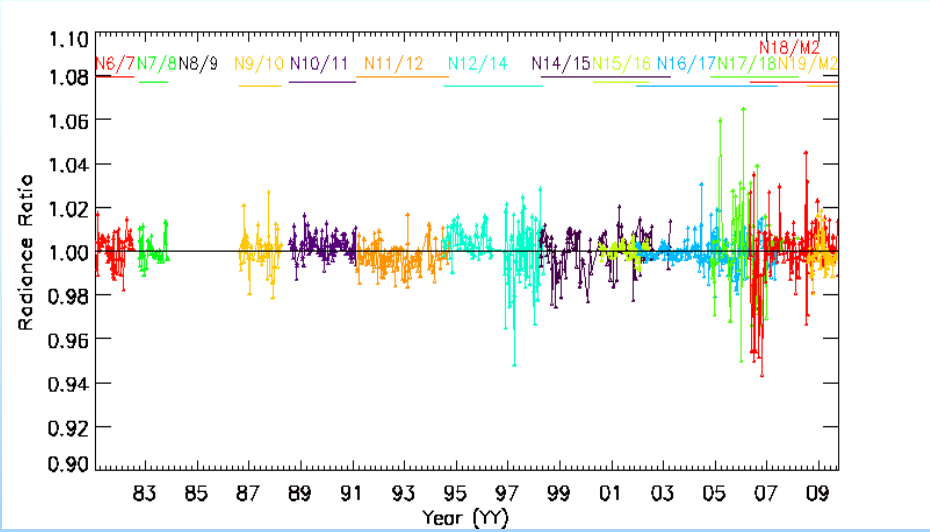
# SRF shift for HIRS Ch4




Spectrally Calibrated against MetOp IASI/HIRS




- SRF shift can be as large as 2.2 cm-1 ( consistent with separate N14- AIRS intecal)
- Both mean bias and bias variation are significantly reduced
- Residual bias requires further investigation



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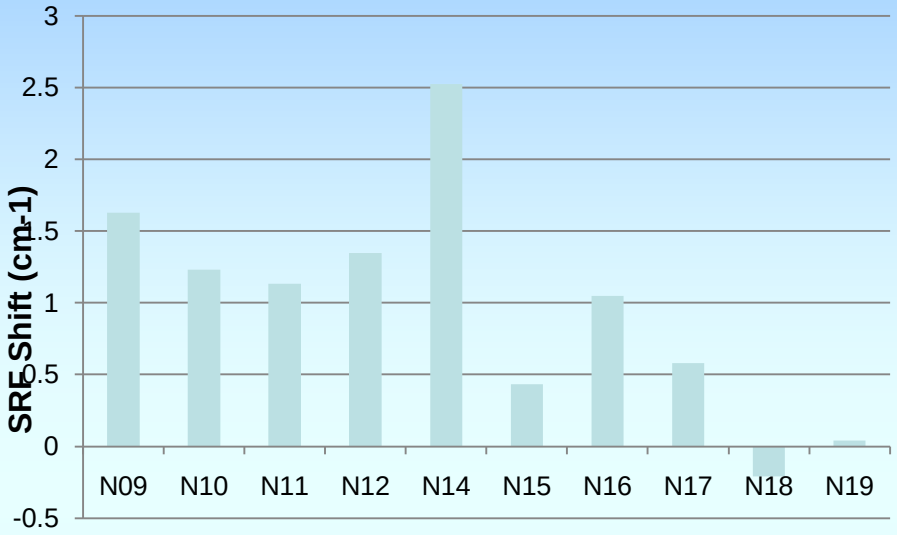
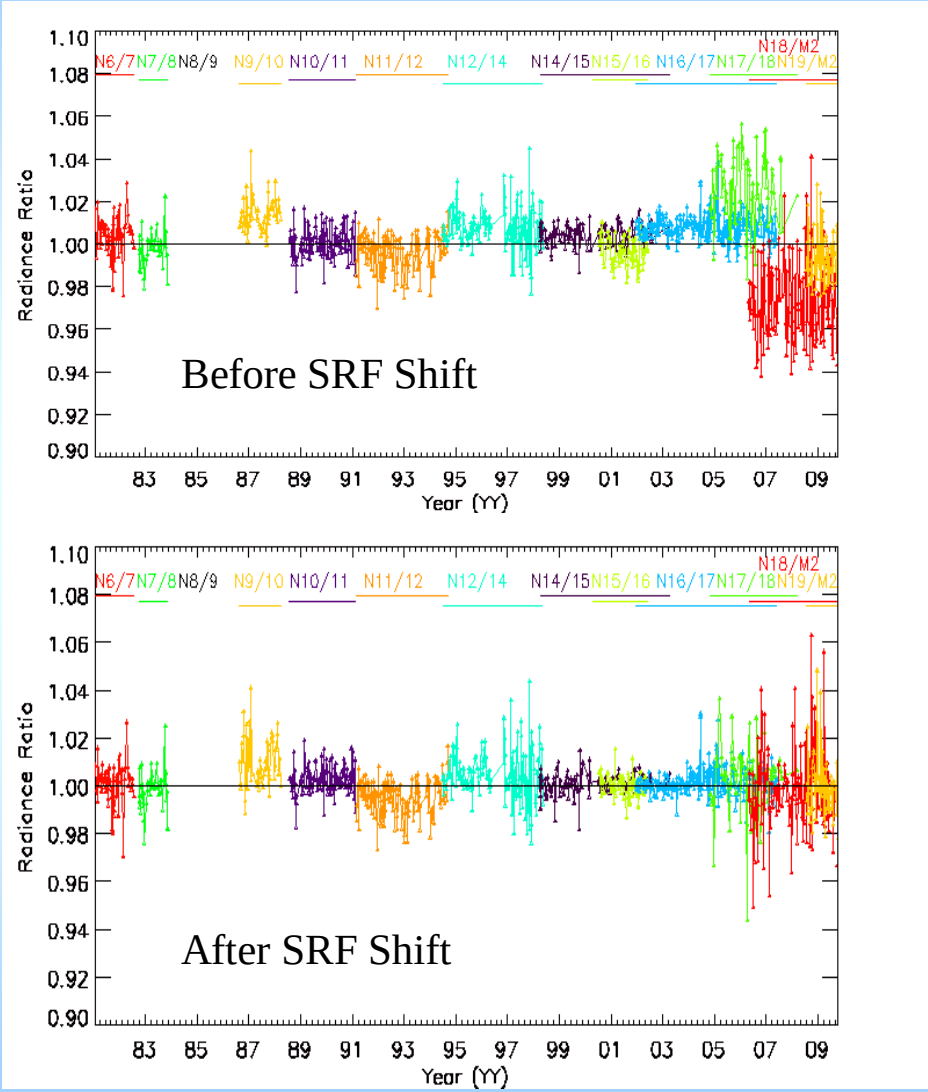
# SRF shift for HIRS Ch5




Spectrally Calibrated against MetOp IASI/HIRS

- SRF shift can be as large as 2.5 cm-1 ( NOAA 14, consistent with N14-AIRS intercal)
- Both mean bias and bias variation are significantly reduced



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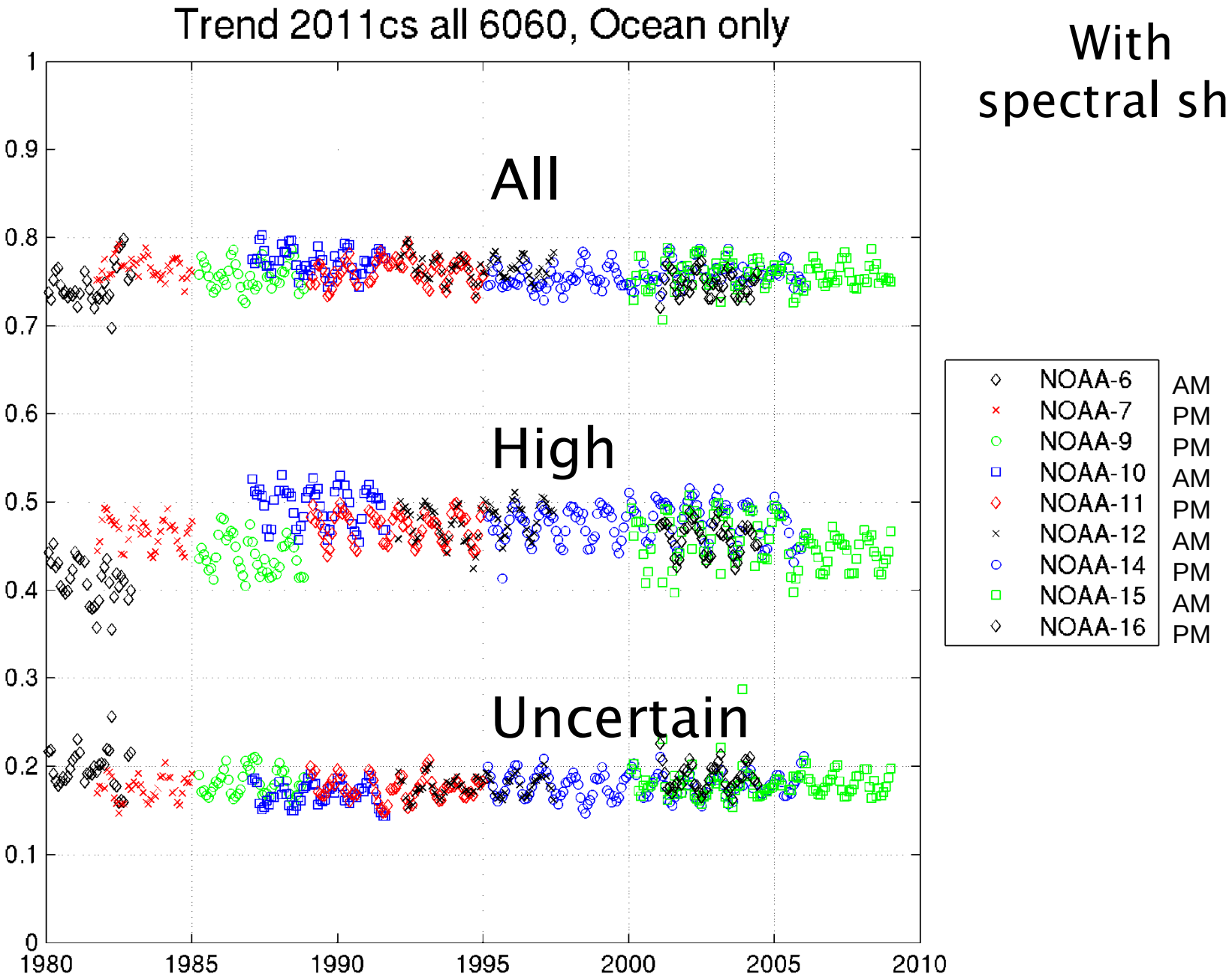
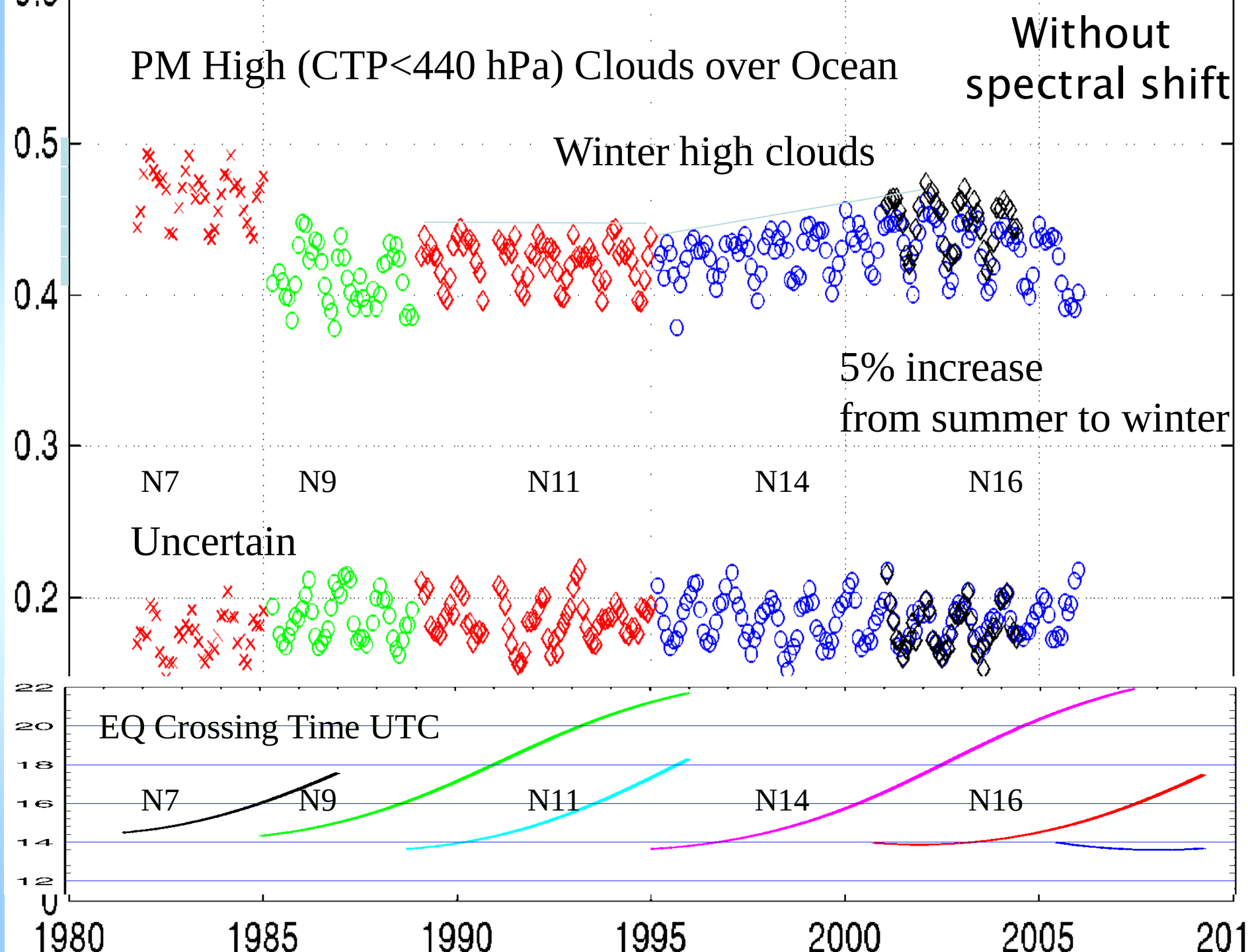
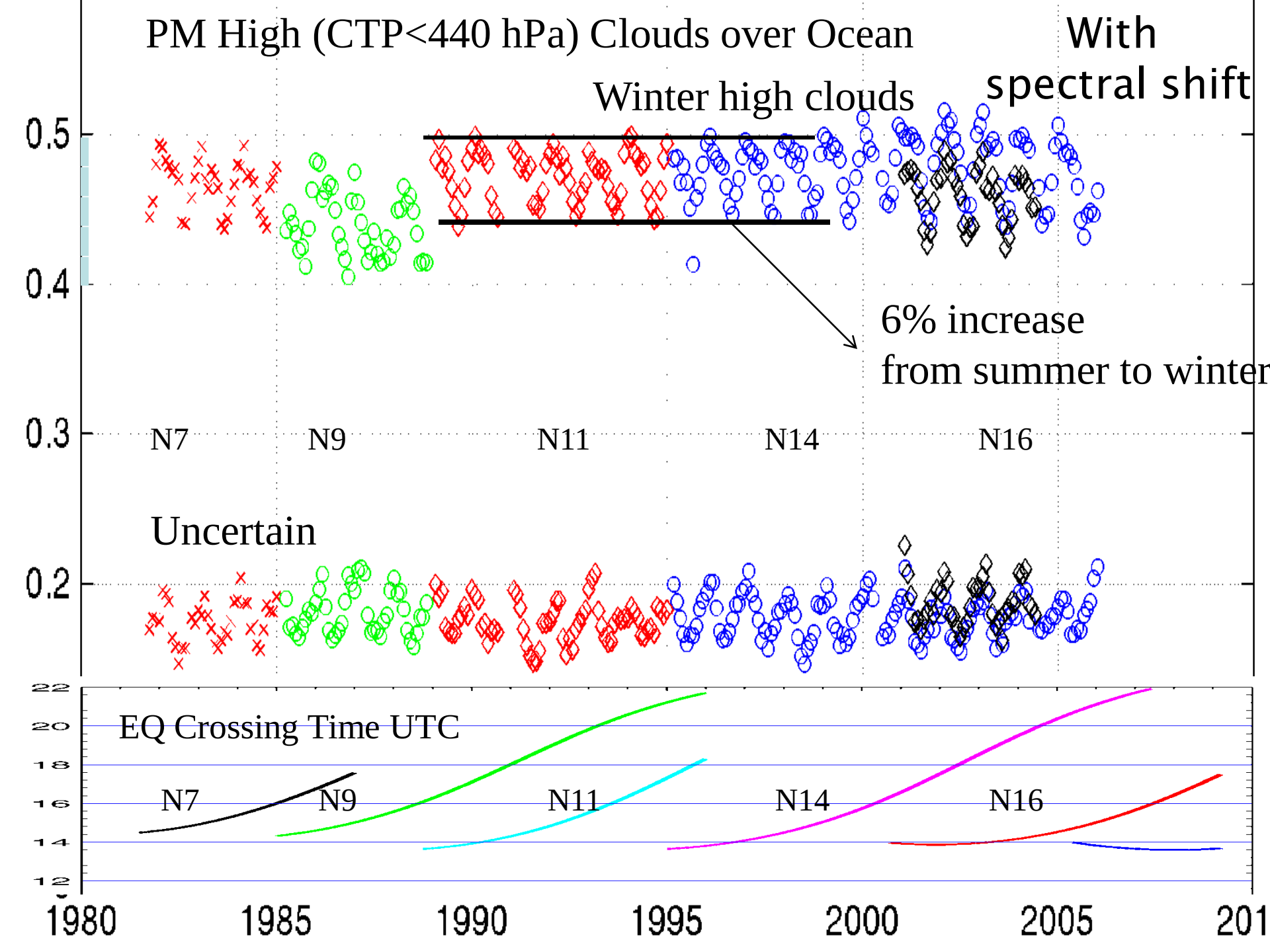
# 5/19/2011 Cao et al spectral shifts from IASI & SNOs

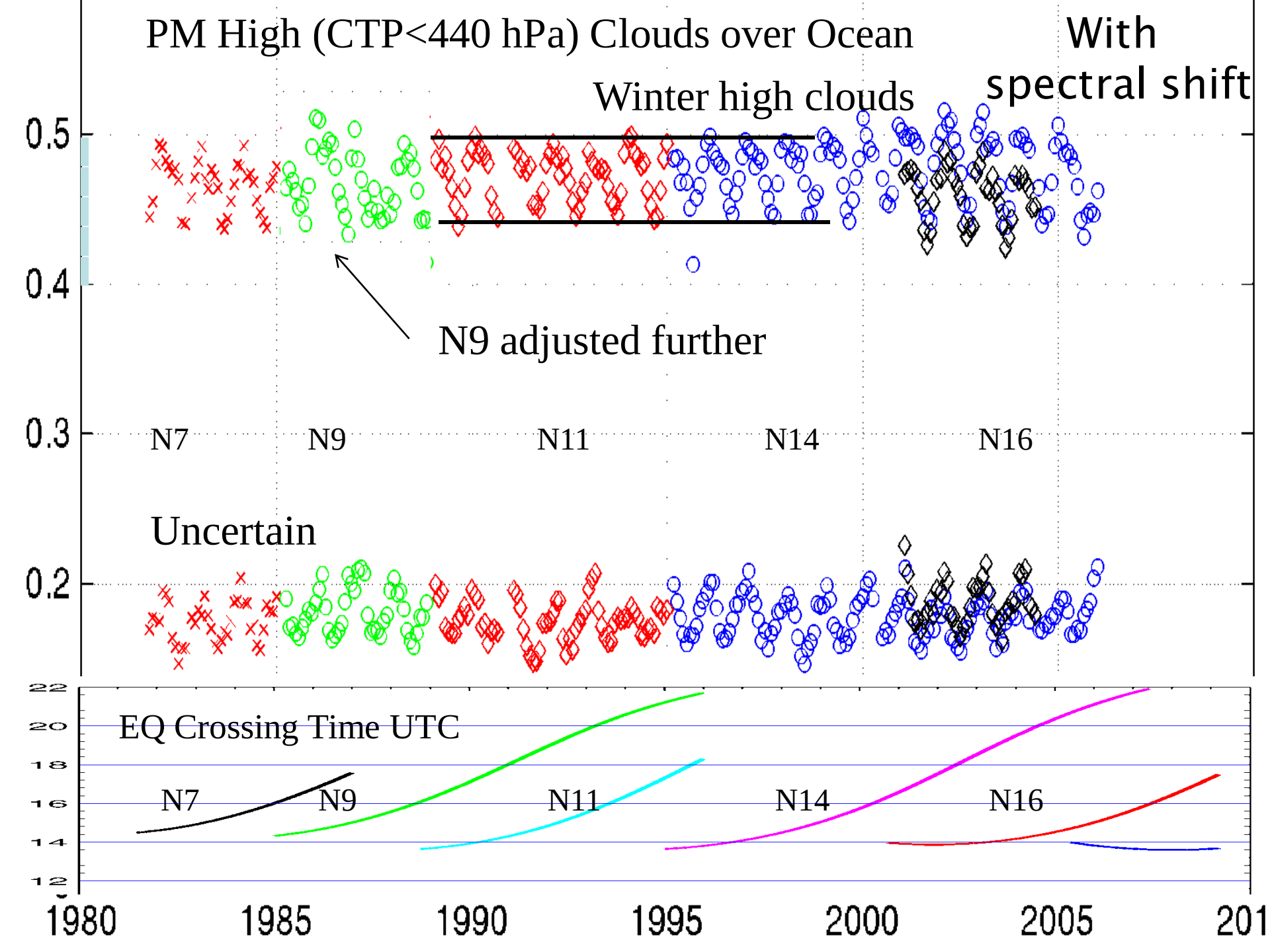
| | Ch4<br>695-710 | Ch5<br>710-725 | Ch7<br>725-740 | Ch12<br>740-765 |
|---|---|---|---|---|
| N9 | 1.1 cm-1 | 1.6 | -0.9 | 8.1 |
| N10 | 1.4 | 1.25 | -1.8 | 2.9 |
| N11 | 2.0 | 1.15 | -0.5 | 11.7 |
| N12 | 0.75 | 1.35 | -3.2 | 12.0 |
| N14 | 2.2 | 2.5 | 0.15 | 11.8 |
| N15 | -0.15 | 0.45 | 0.7 | 5.6 |
| N16 | 1.0 | 1.05 | 0.8 | 8.9 |
| N17 | 0.5 | 0.6 | -0.3 | 4.7 |
| N18 | -0.3 | -0.2 | -1.0 | 2.5 |
| N19 | -0.25 | 0.05 | -0.6 | 0.3 |
| M2 | -0.15 | 0.1 | -0.15 | 2.2 |

Ch6 shifts not necessary


Trend 2011cs all 6060, Ocean only
With spectral shift
All
High
Uncertain
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1980
1985
1990
1995
2000
2005
2010
NOAA-6 AM
NOAA-7 PM
NOAA-9 PM
NOAA-10 AM
NOAA-11 PM
NOAA-12 AM
NOAA-14 PM
NOAA-15 AM
NOAA-16 PM


PM High (CTP<440 hPa) Clouds over Ocean
Without spectral shift
Winter high clouds
5% increase from summer to winter
N7
N9
N11
N14
N16
Uncertain
0.5
0.4
0.3
0.2
EQ Crossing Time UTC
22
20
18
16
14
12
0
1980
1985
1990
1995
2000
2005
201


PM High (CTP<440 hPa) Clouds over Ocean
With spectral shift
Winter high clouds
6% increase from summer to winter
N7
N9
N11
N14
N16
Uncertain
0.5
0.4
0.3
0.2
EQ Crossing Time UTC
22
20
18
16
14
12
1980
1985
1990
1995
2000
2005
201


PM High (CTP<440 hPa) Clouds over Ocean
With spectral shift
Winter high clouds
N9 adjusted further
0.5
0.4
0.3
0.2
N7
N9
N11
N14
N16
Uncertain
EQ Crossing Time UTC
22
20
18
16
14
12
N7
N9
N11
N14
N16
1980
1985
1990
1995
2000
2005
201

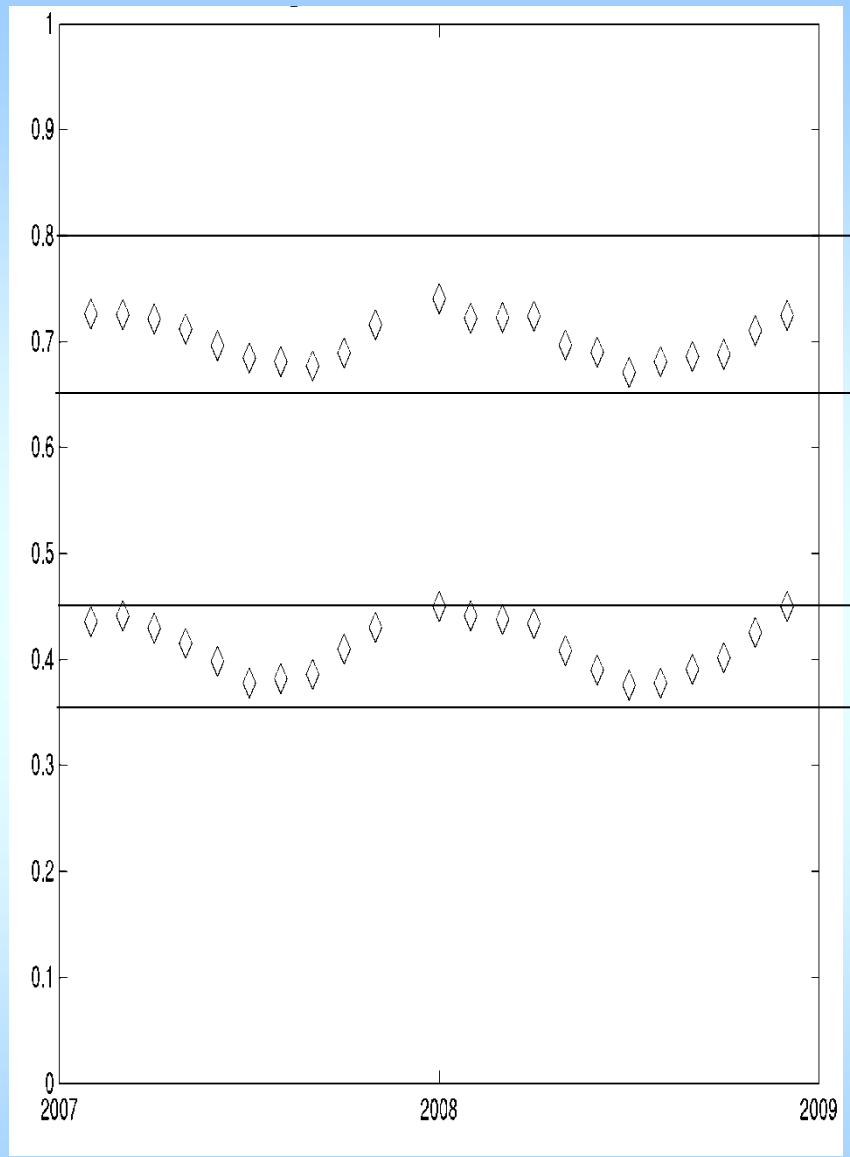
# Validation Strategy/Results

Cloud properties for N15 are compared to those observed by CALIOP

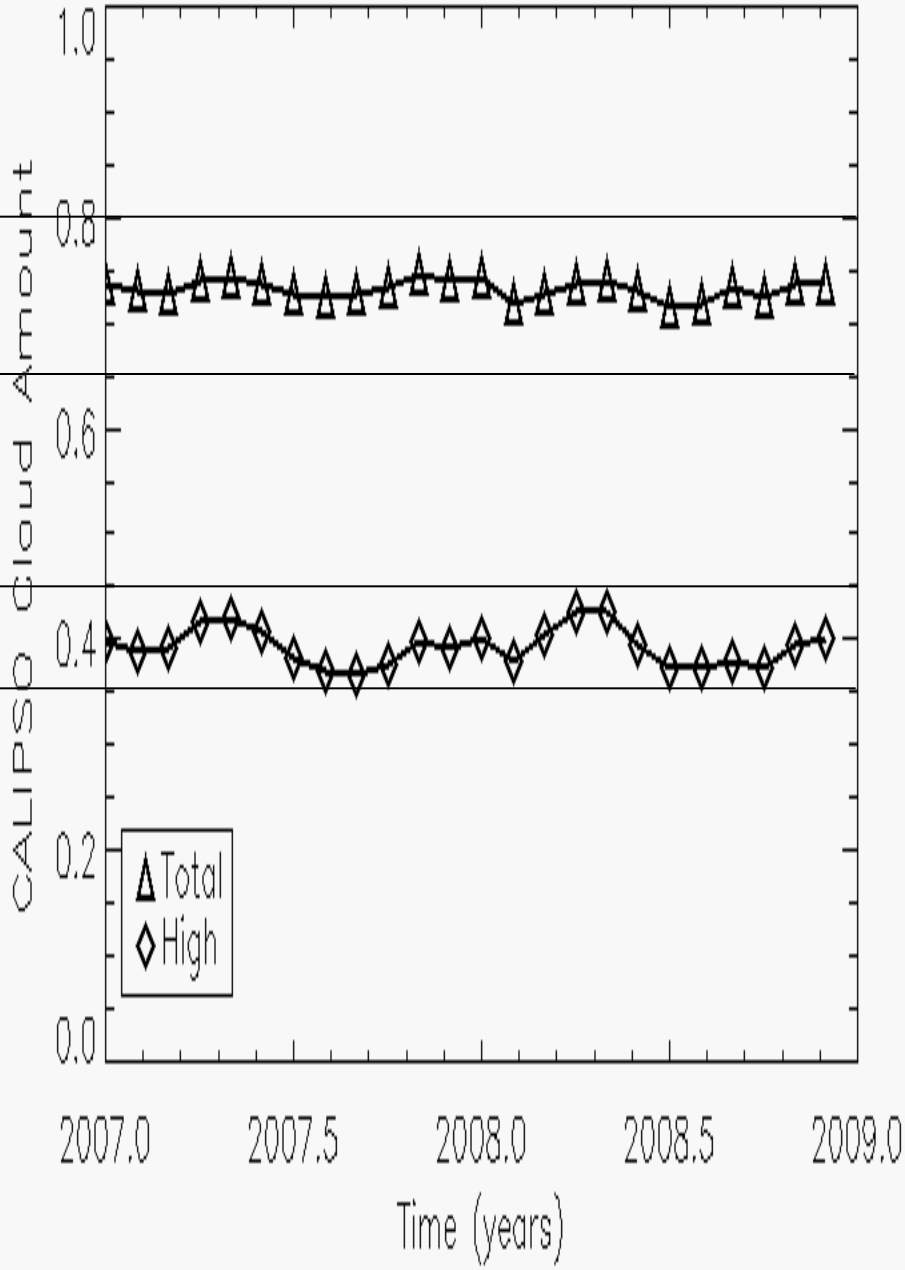
Cloud observations for N6 – N17 have been submitted for GEWEX cloud comparisons

TPW estimates will be compared with AIRS / IASI retrievals

# HIRS




# CALIPSO



# Product Maturity

| Maturity | Sensor Use | Algorithm stability | Metadata & QA | Documentation | Validation | Public Release | Science & Applications |
|---|---|---|---|---|---|---|---|
| 1 | Research Mission | Significant changes likely | Incomplete | Draft ATBD | Minimal | Limited data availability to develop familiarity | Little or none |
| 2 | Research Mission | Some changes expected | Research grade (extensive) | ATBD Version 1+ | **Uncertainty estimated for select locations/times** | Data available but of unknown accuracy; caveats required for use. | Limited or ongoing |
| 3 | **Research Missions** | **Minimal changes expected** | **Research grade (extensive); Meets international standards** | Public ATBD; Peer-reviewed algorithm and product descriptions | Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood. | Data available but of unknown accuracy; caveats required for use. | Provisionally used in applications and assessments demonstrating positive value. |
| 4 | Operational Mission | Minimal changes expected | Stable, Allows provenance tracking and reproducibility; Meets international standards | **Public ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed algorithm and product descriptions** | Uncertainty estimated over widely distribute times/location by multiple investigators; Differences understood. | **Data available but of unknown accuracy; caveats required for use.** | **Provisionally used in applications and assessments demonstrating positive value.** |
| 5 | All relevant research and operational missions; unified and coherent record demonstrated across different sensors | Stable and reproducible | Stable, Allows provenance tracking and reproducibility; Meeting international standards | Public ATBD, Operational Algorithm Description (OAD) and Validation Plan; Peer-reviewed algorithm, product and validation articles | Consistent uncertainties estimated over most environmental conditions by multiple investigators | Multi-mission record is publicly available with associated uncertainty estimate | Used in various published applications and assessments by different investigators |
| 6 | All relevant research and operational missions; unified and coherent record over complete series; record is considered scientifically irrefutable following extensive scrutiny | Stable and reproducible; homogeneous and published error budget | Stable, Allows provenance tracking and reproducibility; Meeting international standards | Product, algorithm, validation, processing and metadata described in peer-reviewed literature | Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation | Multi-mission record is publicly available from Long-Term archive | Used in various published applications and assessments by different investigators |

# Issues/Risks & Work- Off Plans (1)

**Algorithm improvements still pending**

- adding marine stratus cloud top pressure determination improvement (use constant lapse rate in where low level temperature inversions may exist),
- separating cloud observations by orbit (AM asc, AM desc, PM asc, PM desc), and
- merging the HIRS with the PATMOS-X cloud studies (after HIRS only processing is completed).

# Issues/Risks & Work- Off Plans (2)

## Structural Changes Being Worked in Parallel

- Converting HIRS 1b binary format to HDF-5

  Using new standard but keeping all original information
  - Including calibrated radiances but not brightness temperatures (which assume central wavelength that can change with spectral response function shifts)
  - Considering implement ion of clock correction currently adopted by PATMOS-x

- Standardizing ancillary data set-up for cloud sensors

  Recognizing almost all historical software for each sensor is using the date and geolocation data to read both static and dynamic maps prior to processing, but each sensor team has different approach
  - Developing python based system to read static/dynamic maps (surface emissivity/albedo, surface elevation, ecosystem type, land/water, etc.), perform RT calculations (which require meteorological profiles), and calculate Jacobians needed for optimal estimation algorithms (under separate activity)
  - Writing ancillary data to HDF-5 file with pixel-to-pixel correspondence with geolocation file for granule
  - Developing pre-processing step for satellite data to provide information needed for computations such as radiance averages (NxN pixel arrays) for assessing scene homogeneity

  When done, scientists deal with algorithms only using interface to ancillary file; computer scientists worry about ancillary data procedure – one approach can be used for every sensor

- Revisiting EDR (Level-2) to CDR (Level-3) Procedure

  Currently a day is defined 0Z to 24Z, leaving data gap that complicates gridding. AIRS uses a solar day to ensure that there are no spatial gaps
  - Assessing implementation of AIRS approach for MODIS and HIRS

  Mechanisms to compare products between different sensors are wanting
  - Implementing snap-to-grid approach decreasing data volume and providing comparison template

# Schedule

4Q10 - Delivered data sets to GEWEX (separated by orbit)
1Q11 - CALIOP - HIRS intercompared
2Q11 - SNO adjustments to SRFs tested
3Q11 - Completing HIRS data reprocessed (with new SRFs)
Finishing stratospheric cloud reprocessing
Submitting papers

4Q11 - Test PATMOS plus HIRS merging for 1yr
Host Cloud Retrieval Evaluation Workshop
1Q12 - Reprocess clear sky TPW with new SRFs and Esfc
2Q12 - Study 30 year trends and publish results
3Q12 - Prepare s/w for NCDC

# Transition Plan

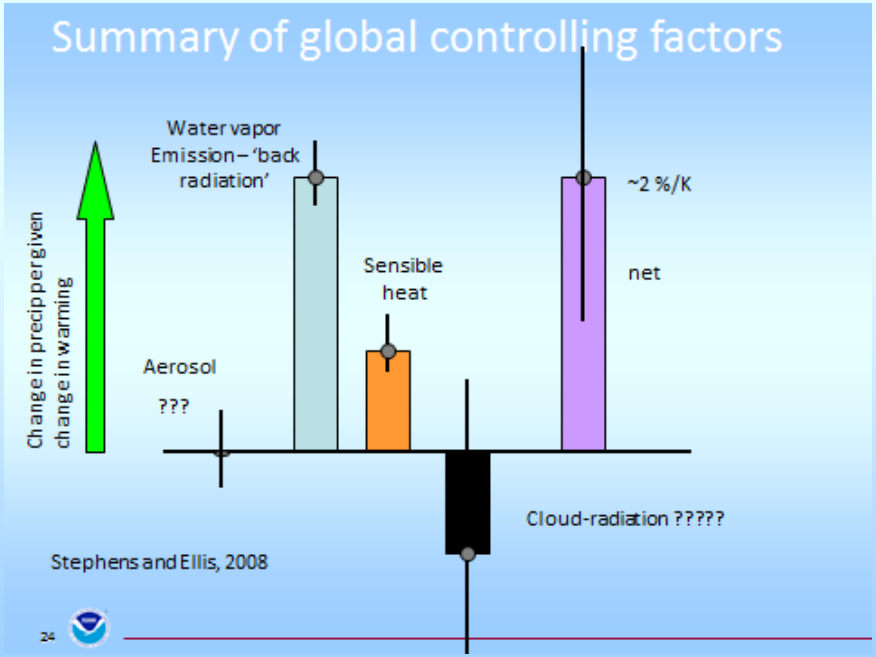
- DOCUMENTATION
  - Climate Algorithm Theoretical Basis Document (C-ATBD)
    - Already available
  - Data Flow Chart and Maturity Matrix
    - Critical item relates to transition of research code to new software
- DATA SET(S)
  - HIRS L-1b now converted from binary format to HDF-5
  - Original metadata and data are included
  - Anticipate including clock correction now incorporated for PATMOS-x
  - Size of data set (50 GB per satellite year; ~5 TB through 2010)
- SOURCE CODE
  - Level of Documentation: research code needs to be rewritten
  - Language: algorithm (Fortran) in combination with preprocessing of both ancillary data (Python) and Level 1b data (also Python)
  - Documentation (will be developed for internal testing)
- CONCERNS (Risks): transition from research-grade to more flexible software may take more resources than anticipated; will also need effort to document software to ease transition activity

At conclusion, benchmark reprocessed data set and processing code will be delivered to NCDC including imager-sounder algorithm and s/w refinements

# Benefit to the Science Community

- GCM groups want a stable cloud climatology that is consistent between sensors and straightforward to understand

- Better delineation of high cloud cover will reduce the uncertainty in cloud radiative forcing and the effects on global precipitation (Stephens and Ellis, J. Clim, 2008).



# Benefit to Society (1)

*** HIRS contributes to International Cloud Climatology Effort**

- One of only two data sets that has resolved sensor to sensor calibration issues to produce internally consistent and stable cloud products (HIRS & PATMOS-x) from 1980 to present using state-of-the-art sensor to sensor calibrations
- Provides context for evaluation of cloud climatologies from national and international groups (e.g. GEWEX)

*** HIRS used to support NWP ReAnalysis Effort**

- Worked with ECMWF to introduce realistic high clouds in reanalysis by introduction of CO2 slicing

*** HIRS supports Air Force Line of Sight Estimation**

- Working to enhance performance of ballistic missile and missile-interceptor testing at Kwajalein Missile Range.

*** HIRS supports NWS ASOS Long Term Data Record**

- Supplements automated records limited to 10000 ft with high cloud determinations

# Benefit to Society (2)

*** HIRS used to investigate Regional Precipitation Trends**

– Exploring link between regional changes in cloud and precipitation (working with Curtin University to understand northward rainband movement in Western Australia which has introduced extreme drought over agricultural regions)

*** HIRS used to investigate Effects of Industrial Pollution**

- Exploring connection between air quality and non-precipitating high cloud trends in eastern China (collaborating with Chinese National Meteorological Satellite Center) and in eastern European countries (in contact with scientists at St Petersburg University)

# Resources

- Number of personnel employed for project -

  0.5 programmer, 1.5 scientists, and 1 student

  Might need more programmer time to help work through transition activities

  Beginning discussions with NCDC personnel on test / transfer

- Key equipment or observatories used -

  SSEC processing facility

- Key collaborating projects or personnel -

  Ruiyue Chen, IMSG at STAR; Darren Jackson, CIRES

- NOAA points-of-contact or collaborators, as applicable -

  Changyong Cao, STAR

- Target NOAA Data Center -

  NCDC