



Arctic Change Observed by Satellite Sounders

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with lots of help from

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**David Groves, RAND
Axel Schweiger, PSC, UW
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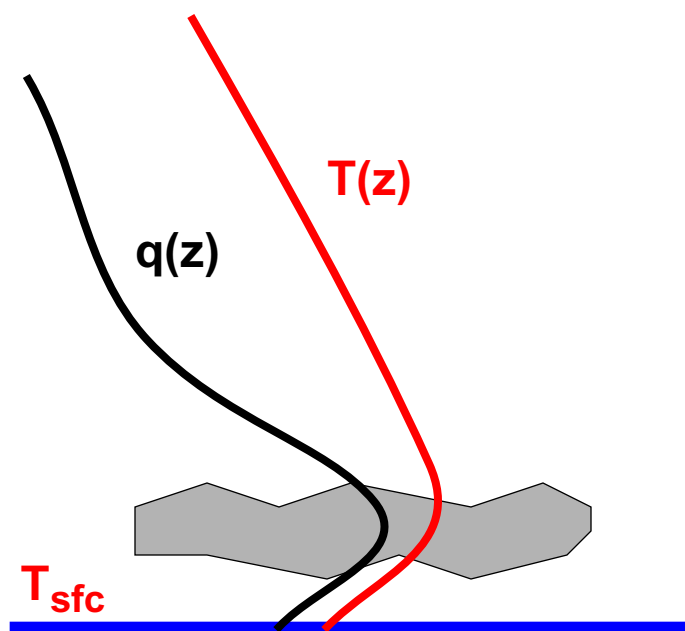
- **What, Why, How**
- **Old Dog, New Tricks**
- **Low-Hanging Fruit**
- **To-Do List**

photo: S. Dery

What, Why, How

22.5 years of TOVS retrievals

=> $T(z)$, $q(z)$, skin temperature, cloud fraction and height, PBL parameters...

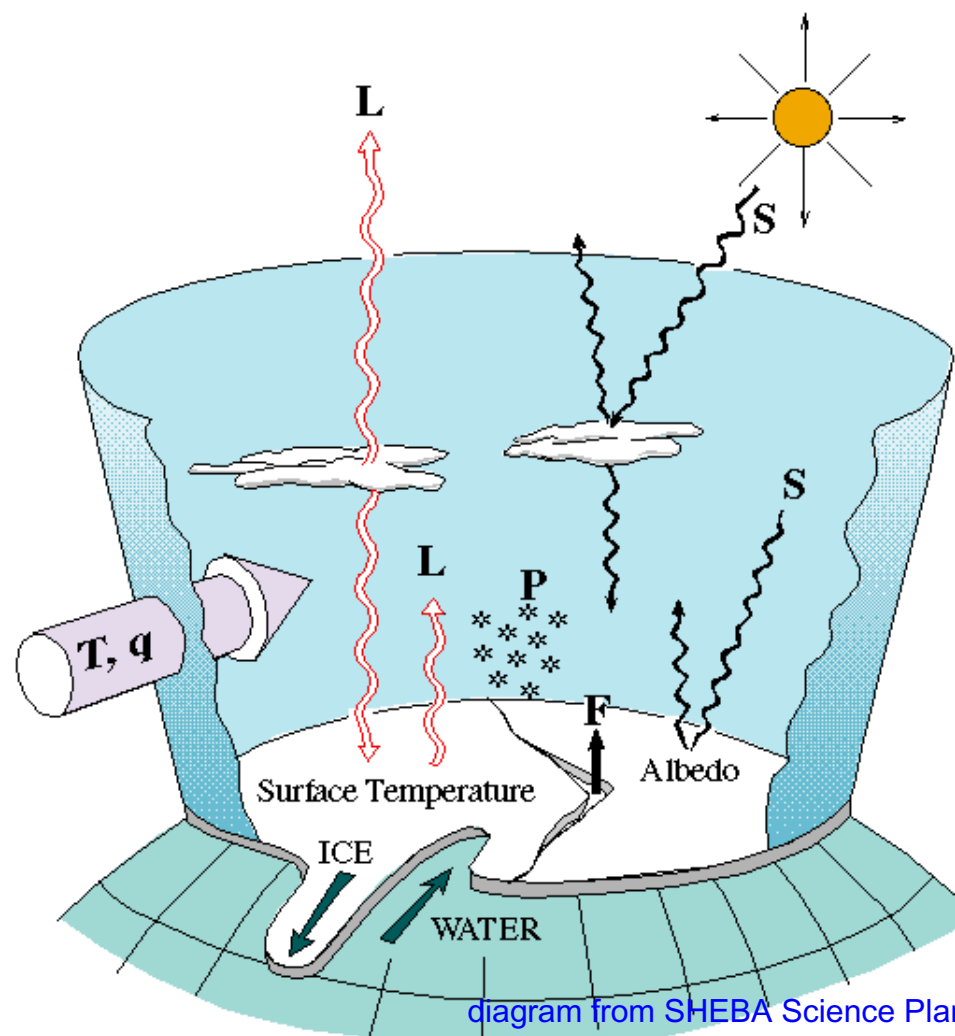


TIROS Operational Vertical Sounder

- 1979 to 2001
- $(100 \text{ km})^2$ resolution
- 39 vertical layers for $T(z)$
- 5 layers for $q(z)$
- Gridded daily/monthly Path-P data set available from NSIDC

What, Why, How

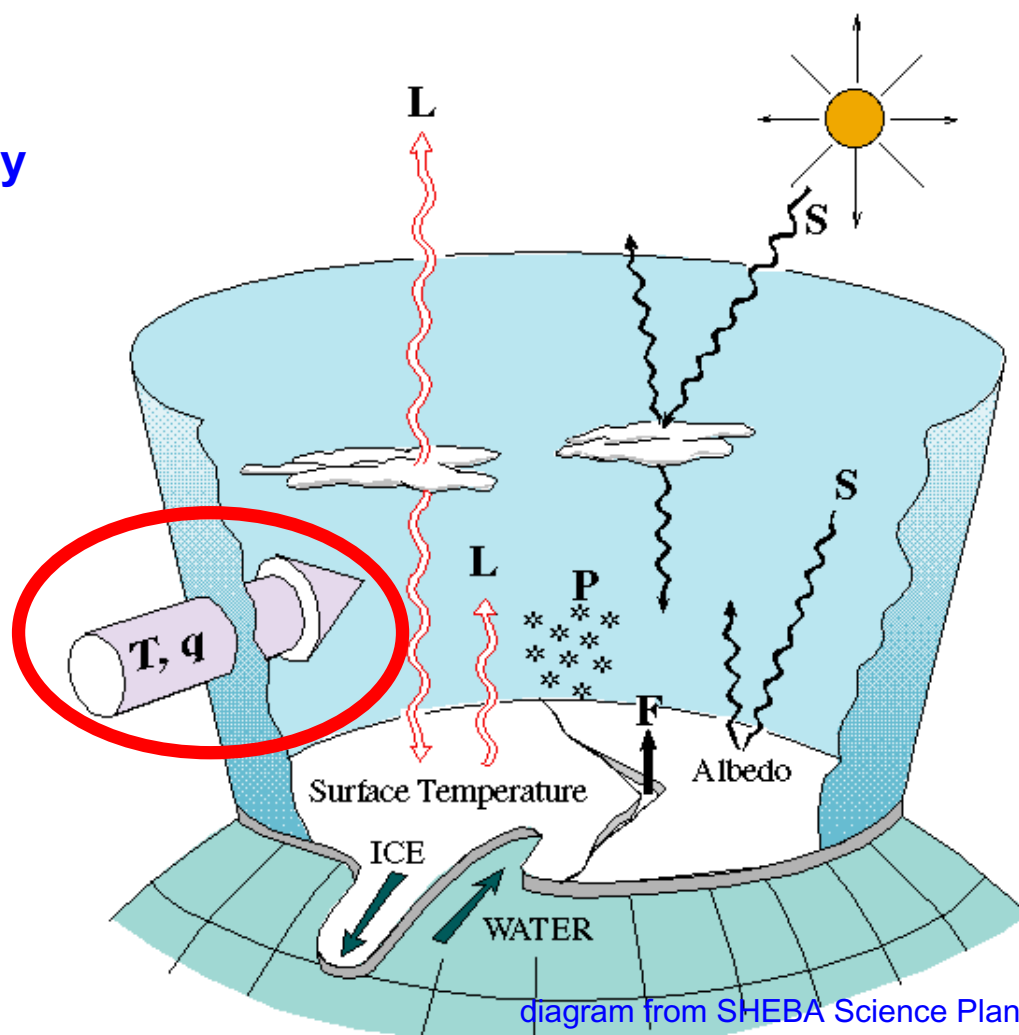
- Use TOVS retrievals to diagnose and analyze as many components of the Arctic energy budget as possible:



What, Why, How

- Use TOVS retrievals to diagnose and analyze as many components of the Arctic energy budget as possible:

⇒ Advection of T and q

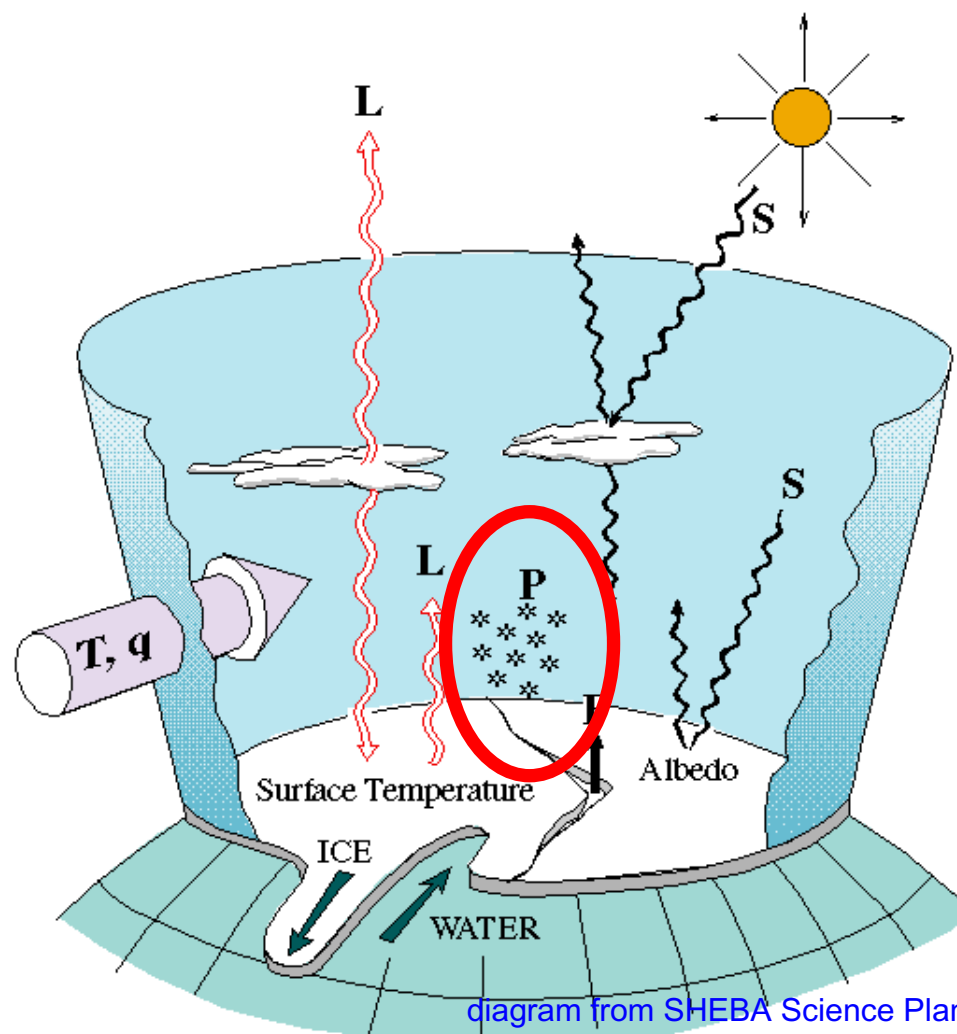


What, Why, How

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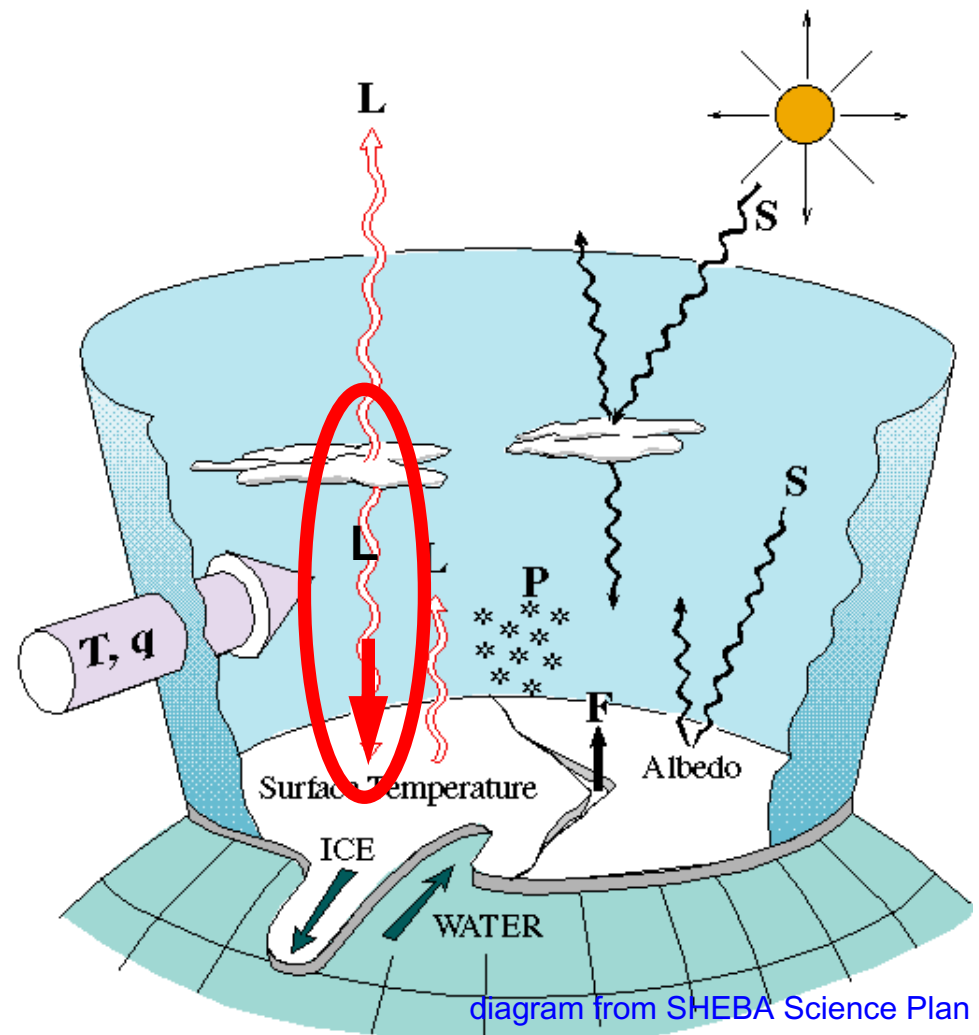
=> Advection of T and q

=> $P - E$



What, Why, How

- Use TOVS retrievals to diagnose and analyze as many components of the Arctic energy budget as possible:
 - => Advection of T and q
 - => $P - E$
 - => **Downwelling longwave flux**



What, Why, How

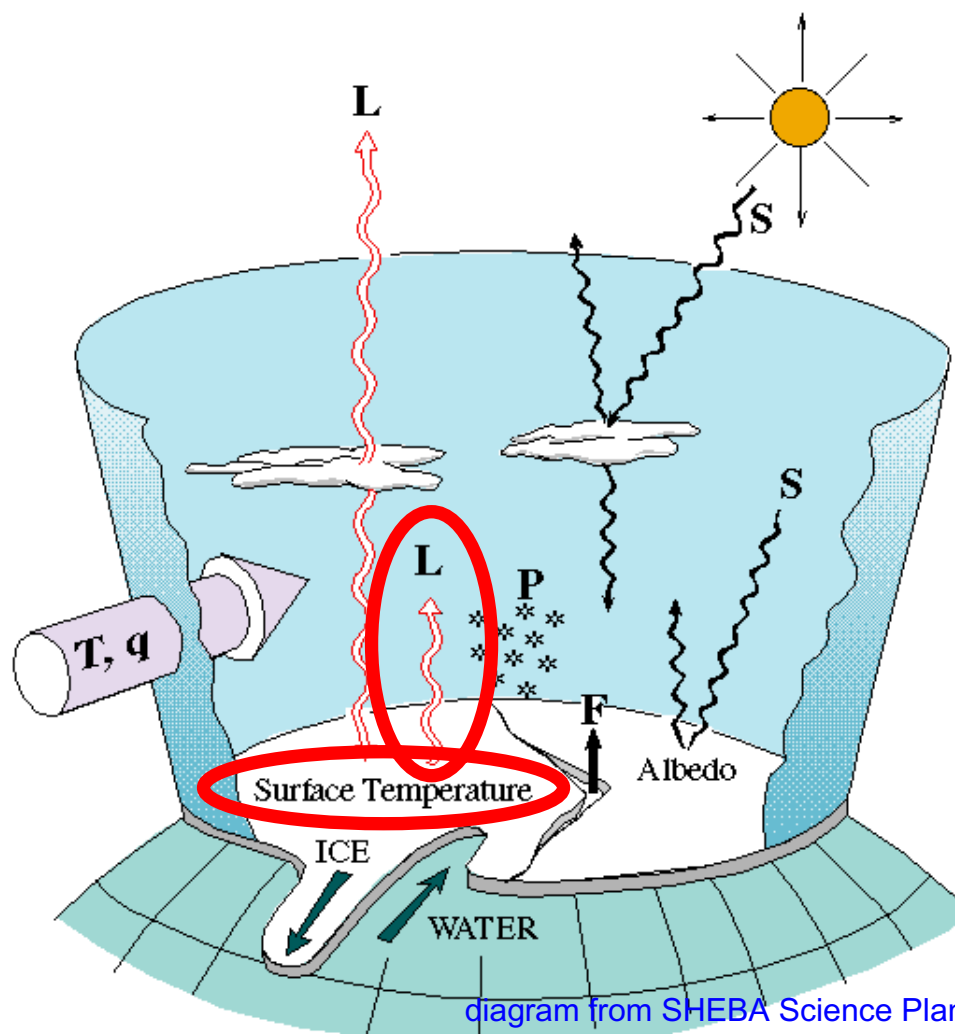
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=> Advection of T and q

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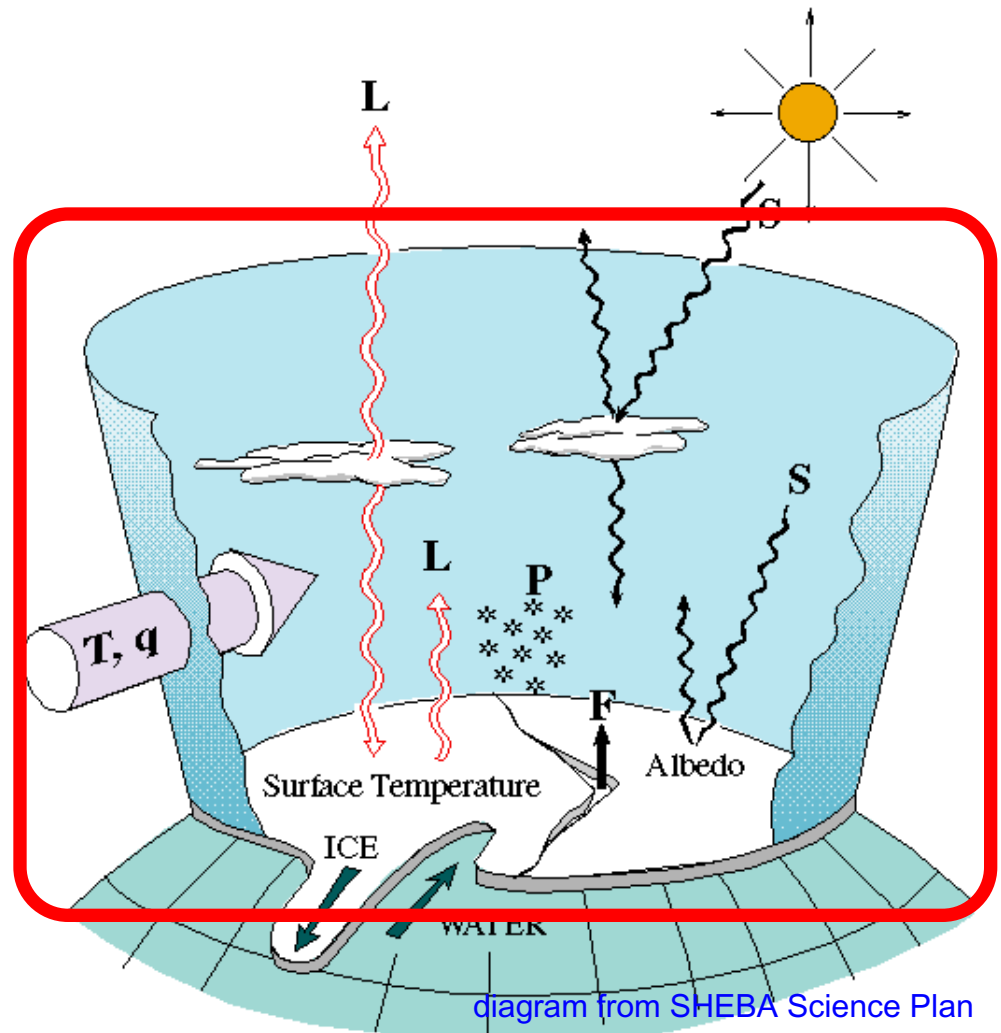
=> Downwelling longwave flux

=> **Surface Temperature**
(=> upwelling LW flux)



What, Why, How

- Use TOVS retrievals to diagnose and analyze as many components of the Arctic energy budget as possible:
 - ⇒ Advection of T and q
 - ⇒ $P - E$
 - ⇒ Downwelling longwave flux
 - ⇒ Surface Temperature (⇒ upwelling LW flux)
 - ⇒ **CONNECTIONS...**



Old Dog, New Tricks



WINDS

- **Winds essential ingredients in**
 - ⇒ **T and q advection**
 - ⇒ **$P - E$**
 - ⇒ **changes in circulation**
- **Large errors discovered in upper-level winds from Reanalyses**
[Francis, 2002]
 - ⇒ **need new 3D wind fields**

Old Dog, New Tricks



WINDS

- **New Arctic 3-D wind product generated from satellite-retrieved (TOVS) temperature profiles and NCEP/NCAR 10-meter wind fields with the Zou and Van Woert (2002) mass conservation constraint.**
- **22.5 years, daily grids, 9 levels, (100-km)² resolution.**
- **Details in Francis *et al*, submitted to *J. Climate*.**

Old Dog, New Tricks



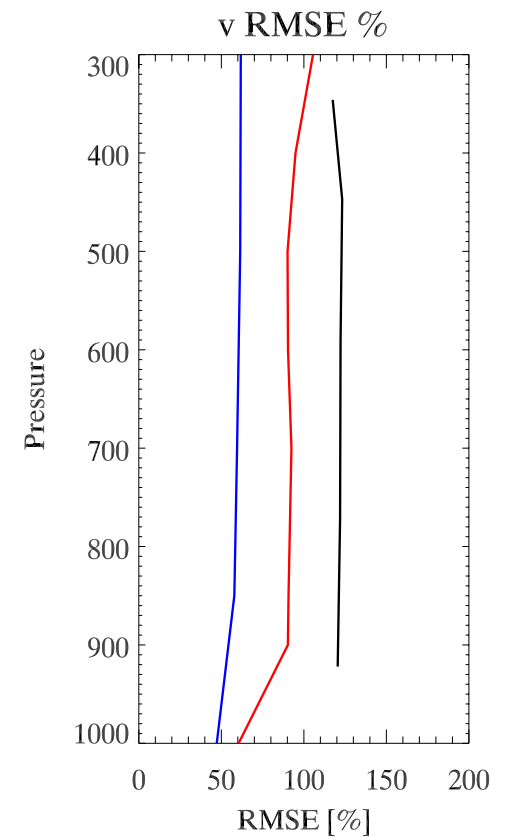
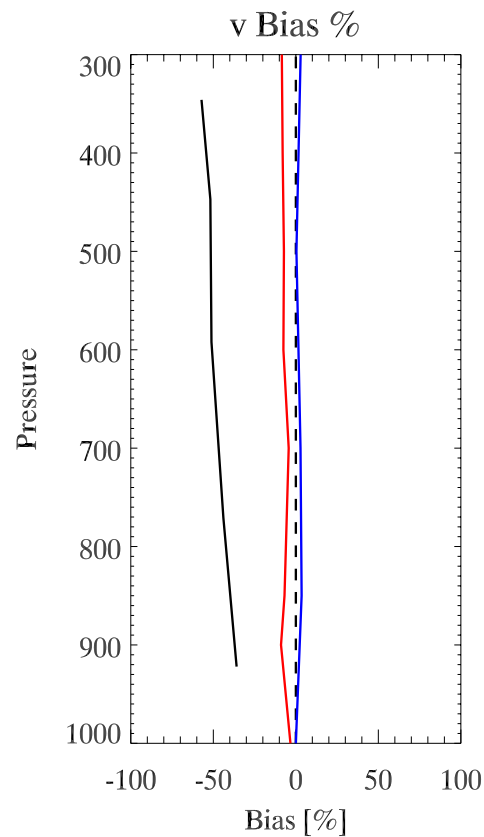
WINDS: Validation of meridional (v) component

**Bias and RMSE
weighted by mean $|v|$**

**Black = NCEP/NCAR
Reanalysis vs.
CEAREX/LeadEx**

**Red = Arctic TOVS vs.
SHEBA**

**Blue = Southern Ocean
TOVS vs. Macquarie Is.**



Old Dog, New Tricks



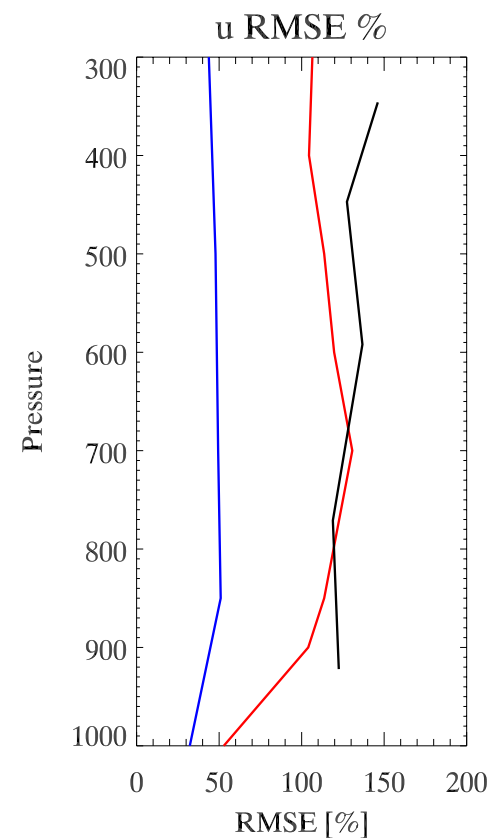
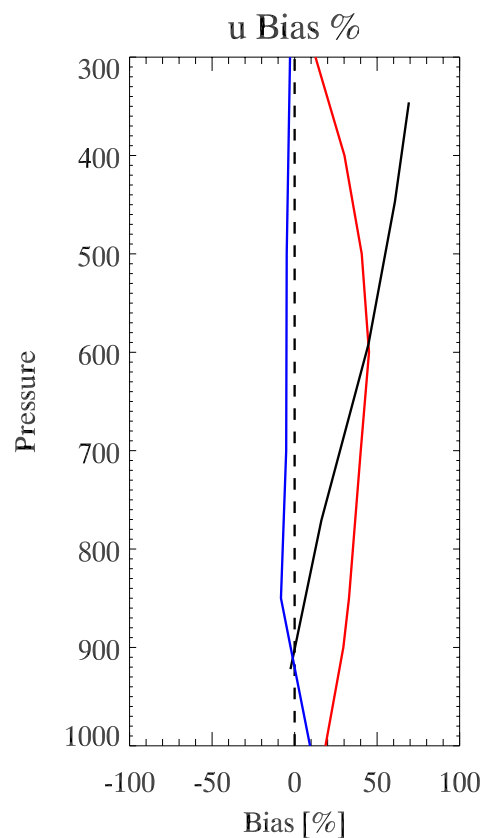
WINDS: Validation of zonal (u) component

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weighted by mean |u|**

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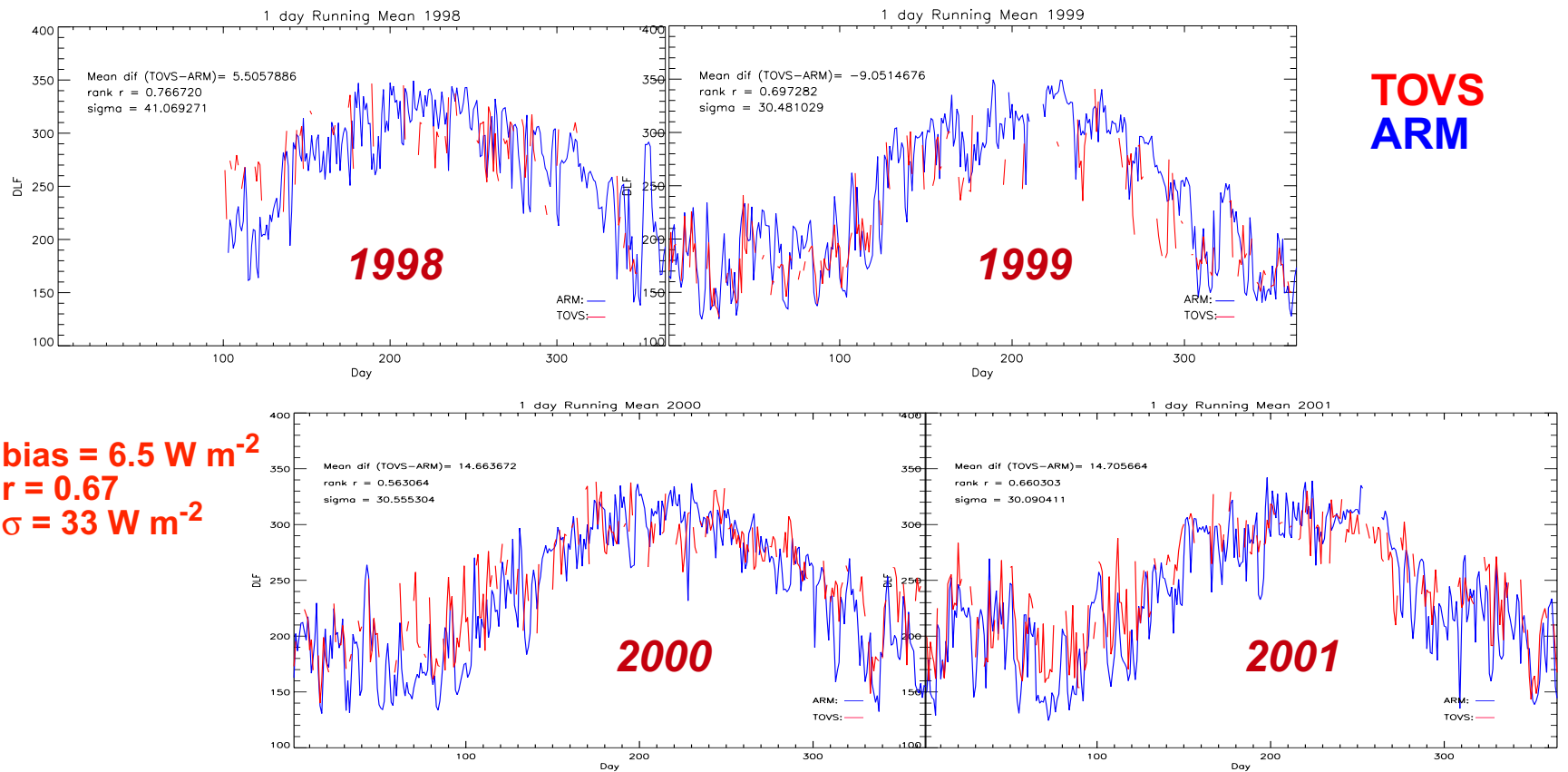
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Old Dog, New Tricks



DOWNWARD LONGWAVE RADIATION

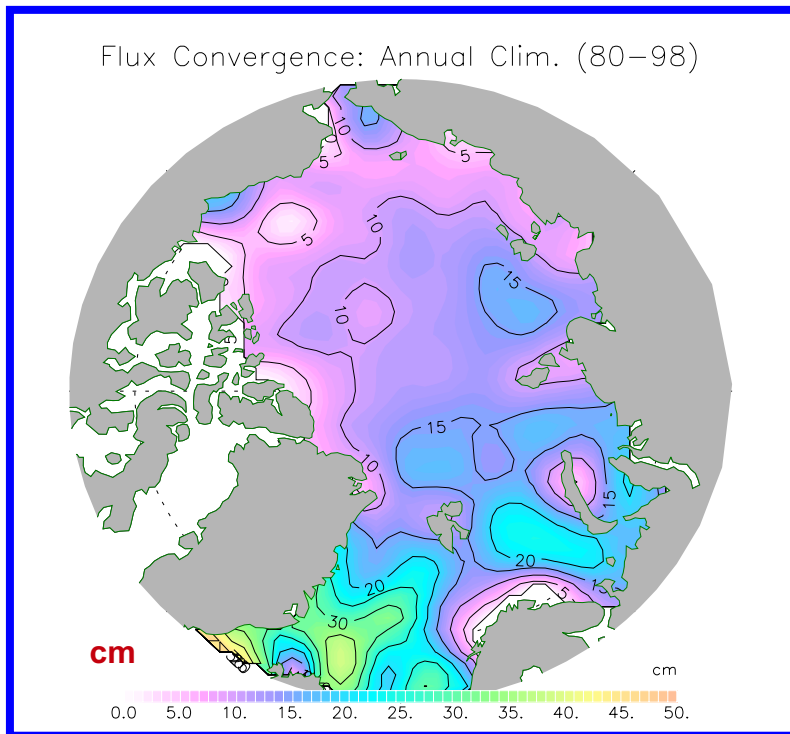


Old Dog, New Tricks

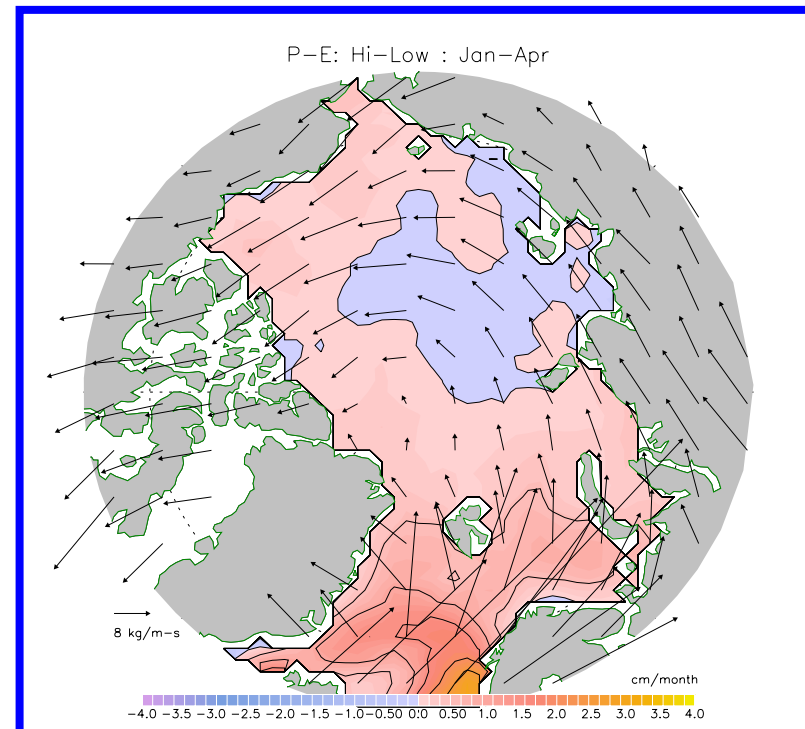


COMING ATTRACTIONS

Net Precipitation (P-E)*



+AO - (-AO) PW Flux Vectors and P-E



*Regeneration with new winds underway

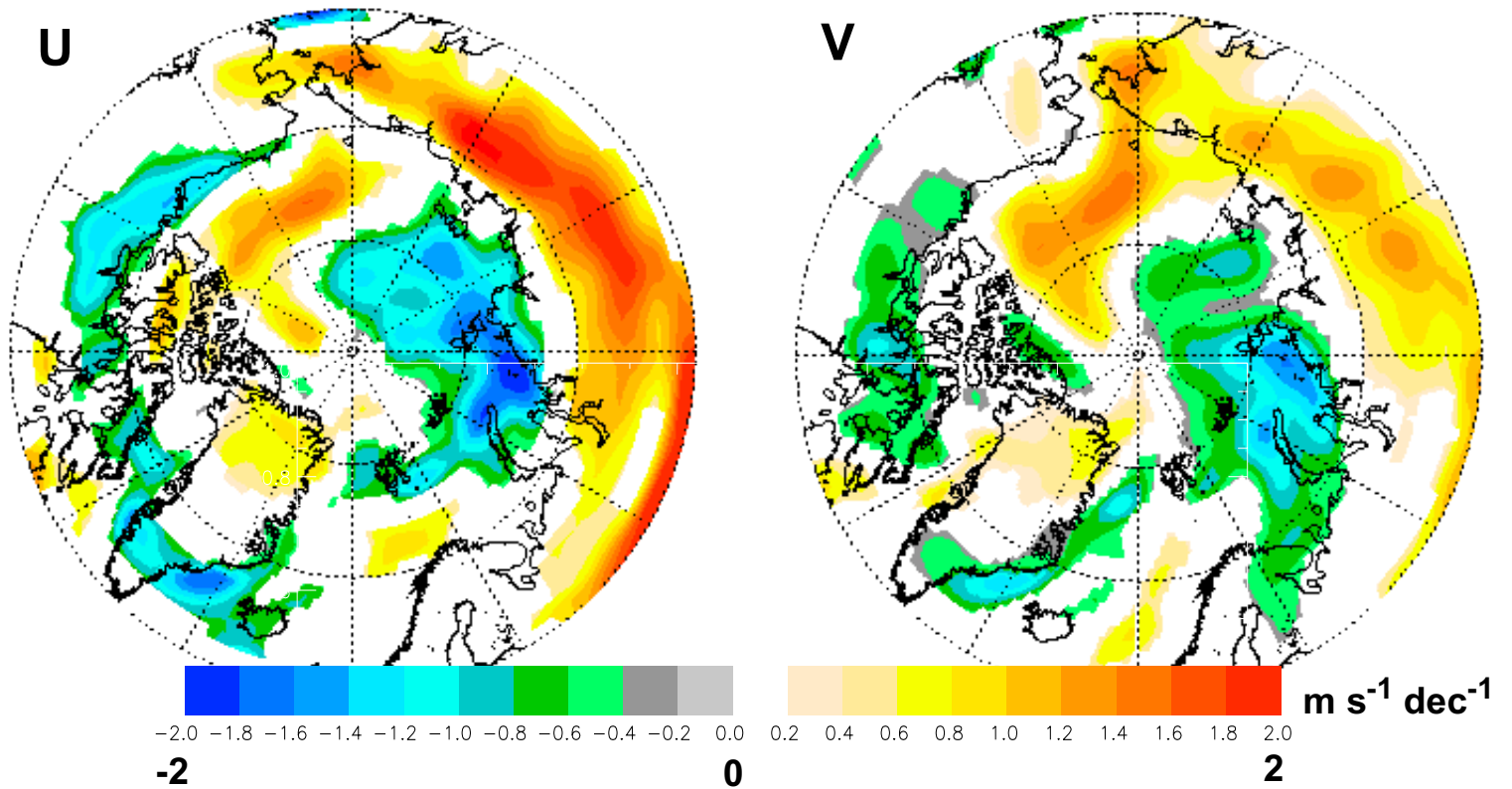
Groves and Francis, JGR, 2002a,b

Low Hanging Fruit



WIND S: 23-Year Trends

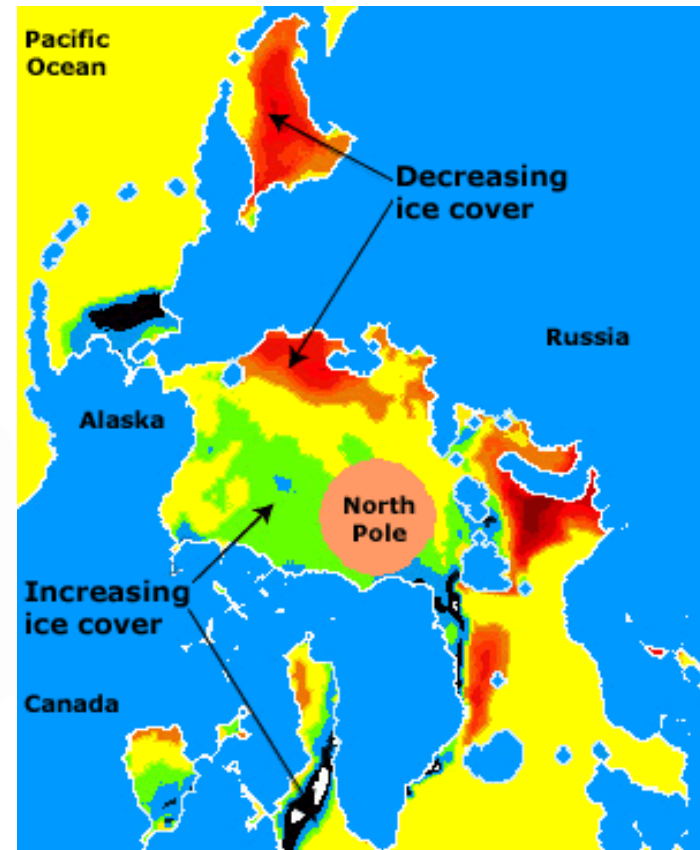
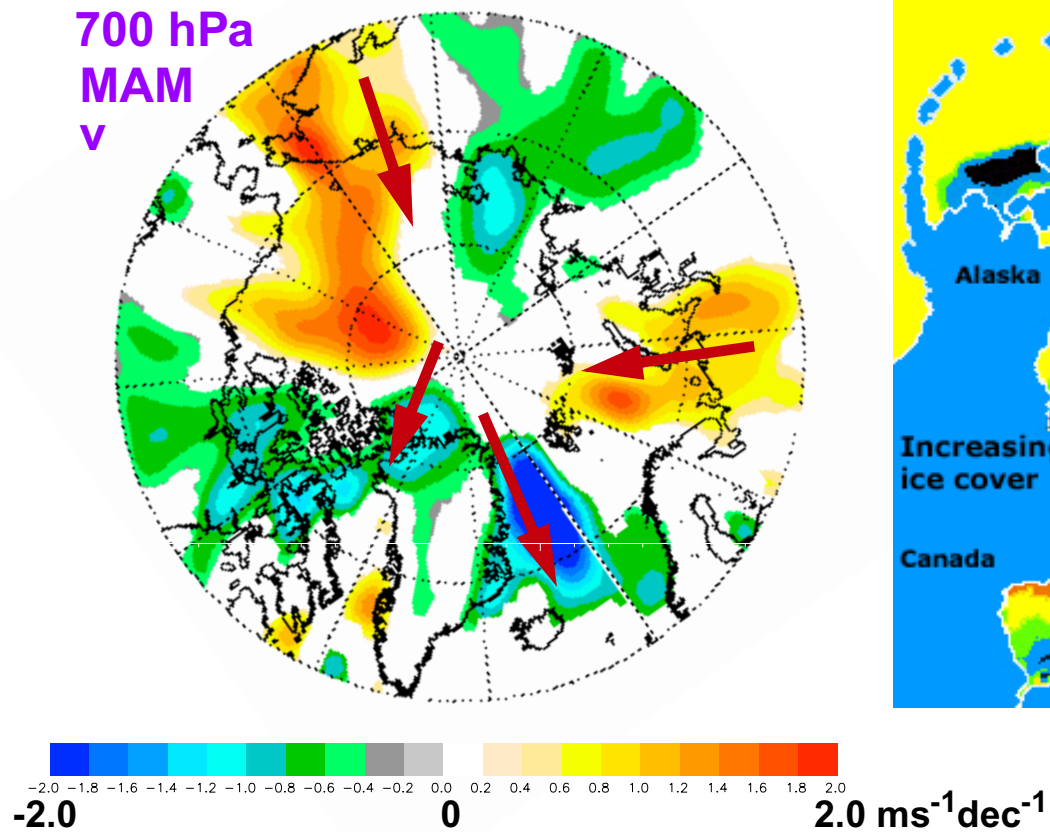
Total column (surface to 300 hPa)



Low Hanging Fruit



WIND S: 23-Year Trends



J. Maslanik, NSIDC

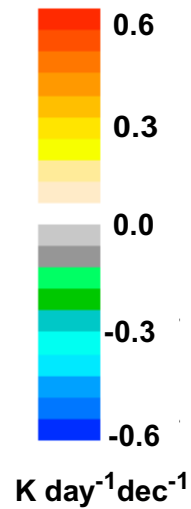
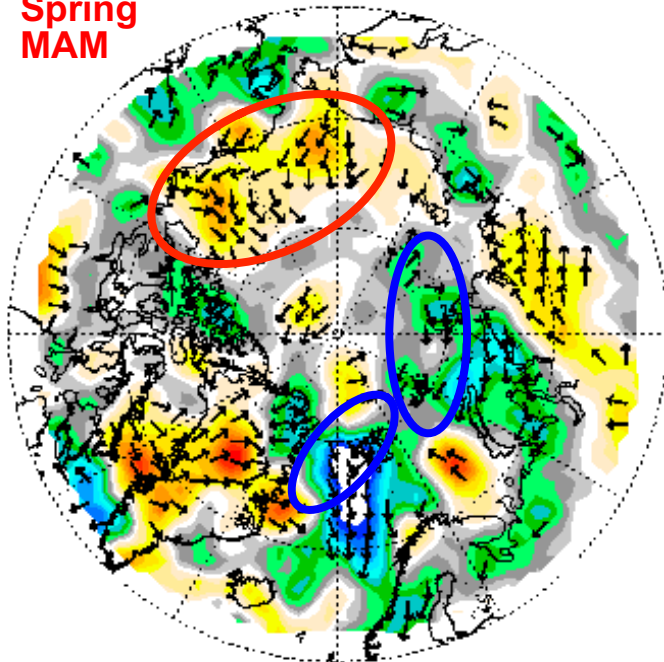
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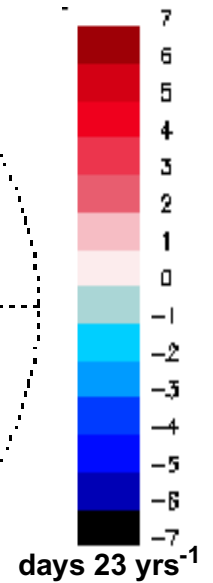
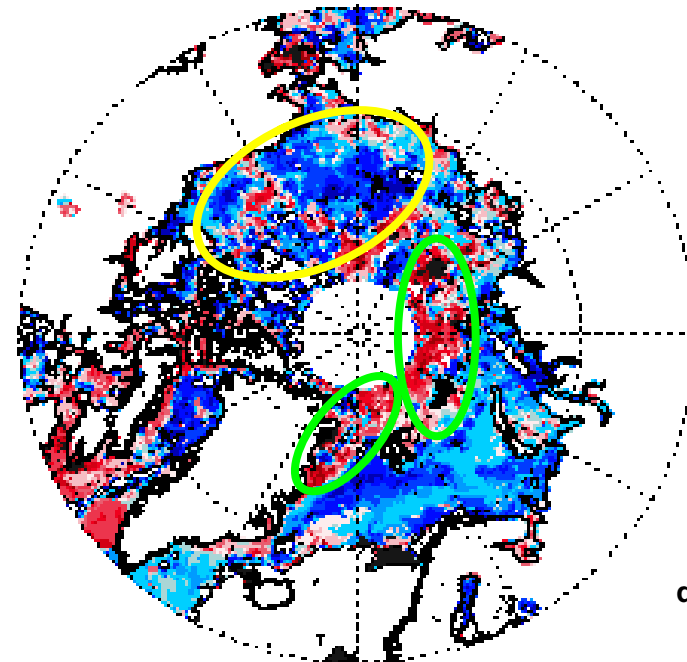
ADVECTIVE HEATING VS. MELT: *23-Year Trends*

Sensible Heating 1000-700 mb

Spring
MAM



Melt Onset Date



Belchansky *et al*, J. Clim, 2004

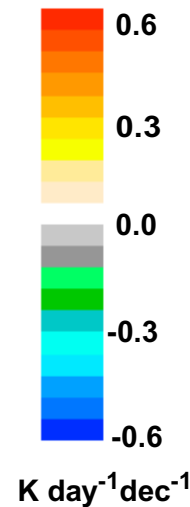
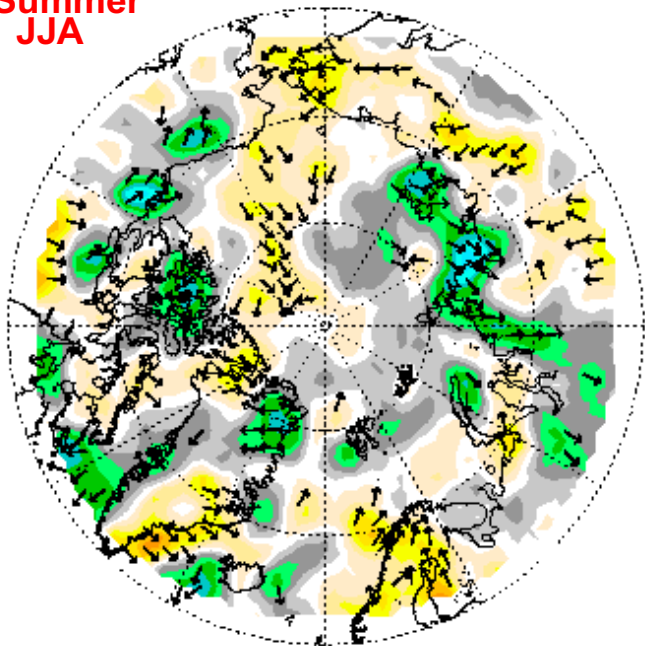
Low Hanging Fruit



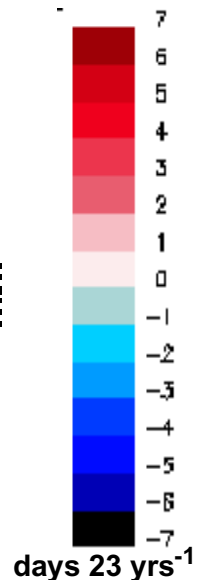
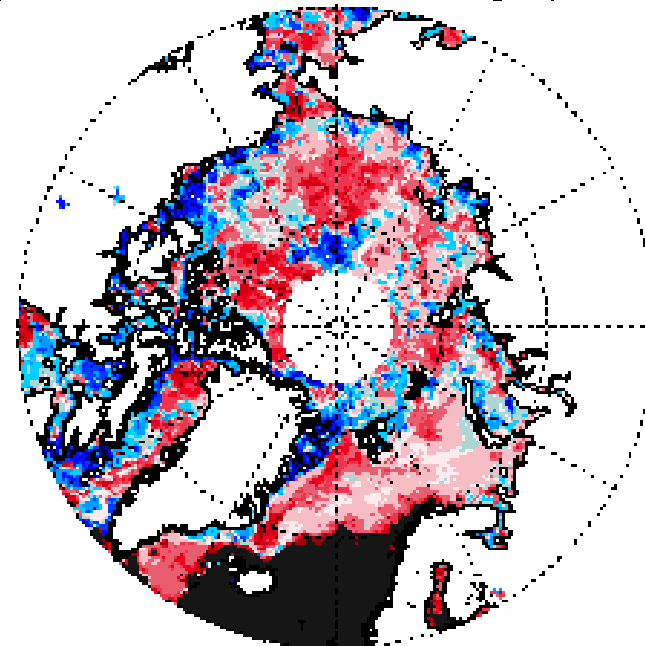
ADVECTIVE HEATING VS. MELT: 23-Year Trends

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Summer
JJA

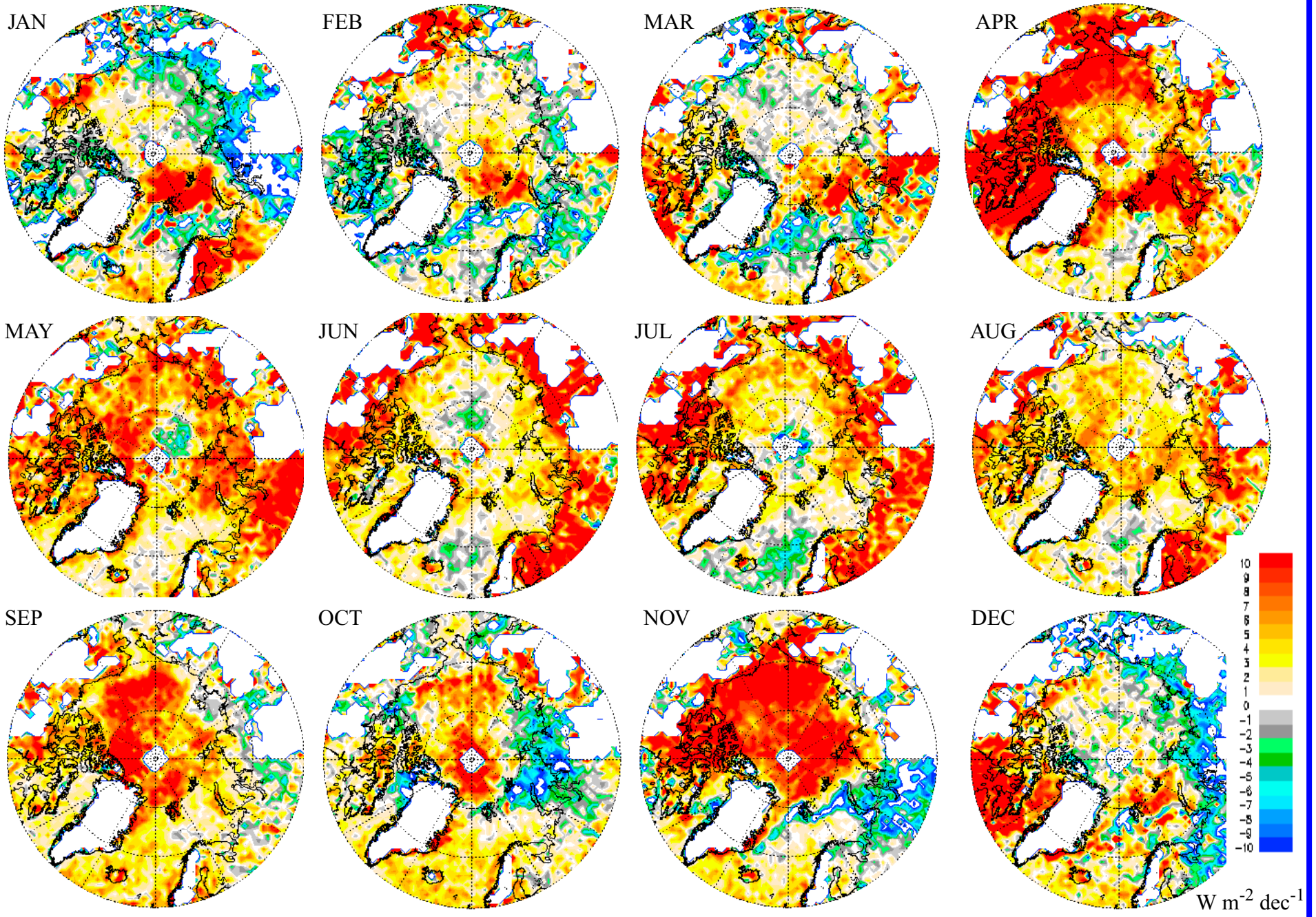


Melt Duration

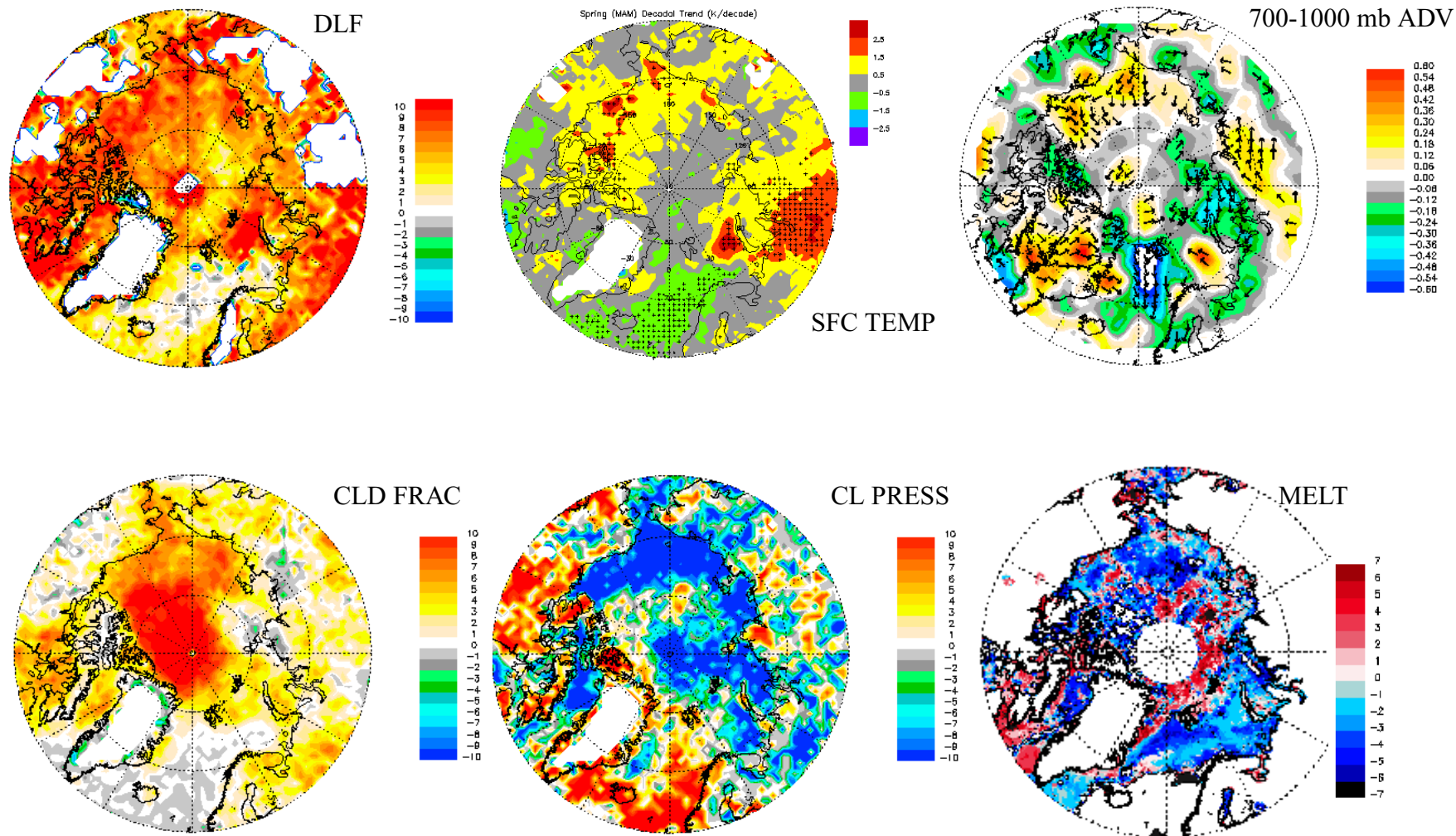


Belchansky *et al*, J. Clim, 2004

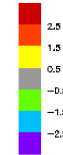
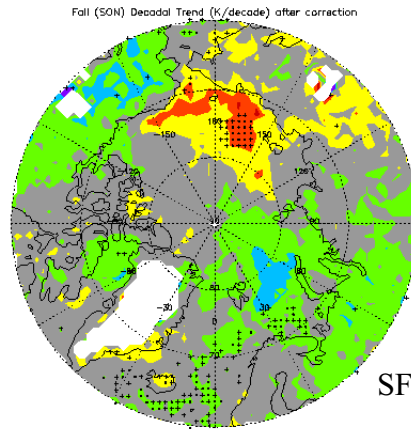
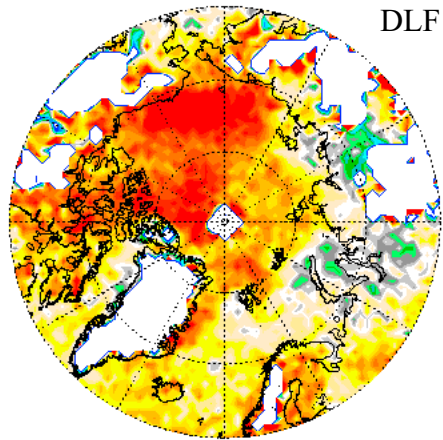
Monthly Trends in TOVS-Derived DLF 1979 to 2001



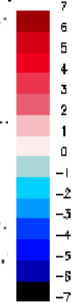
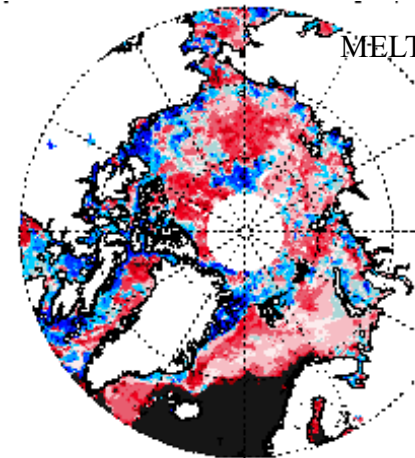
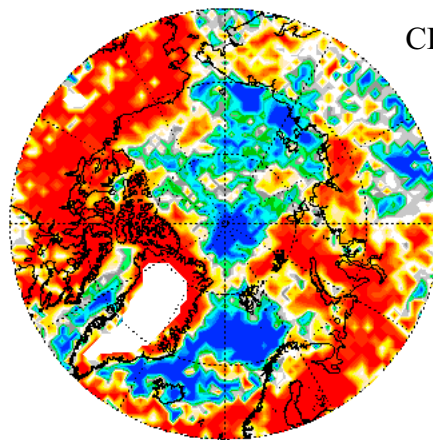
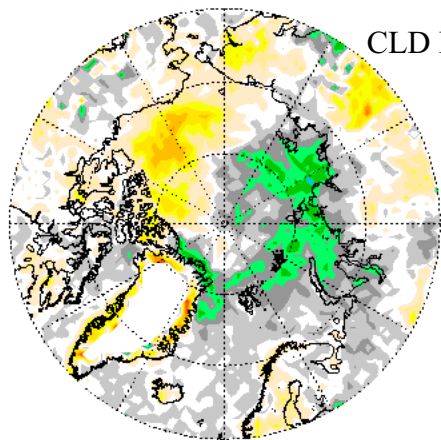
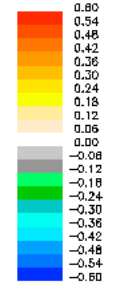
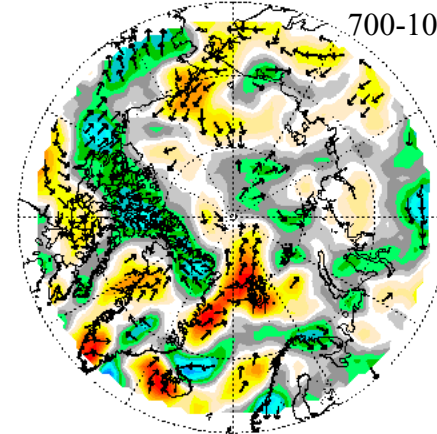
Spring (MAM) Trends from 1979-2001



Autumn (SON) Trends from 1979 to 2001



SFC TEMP



Wrap-Up



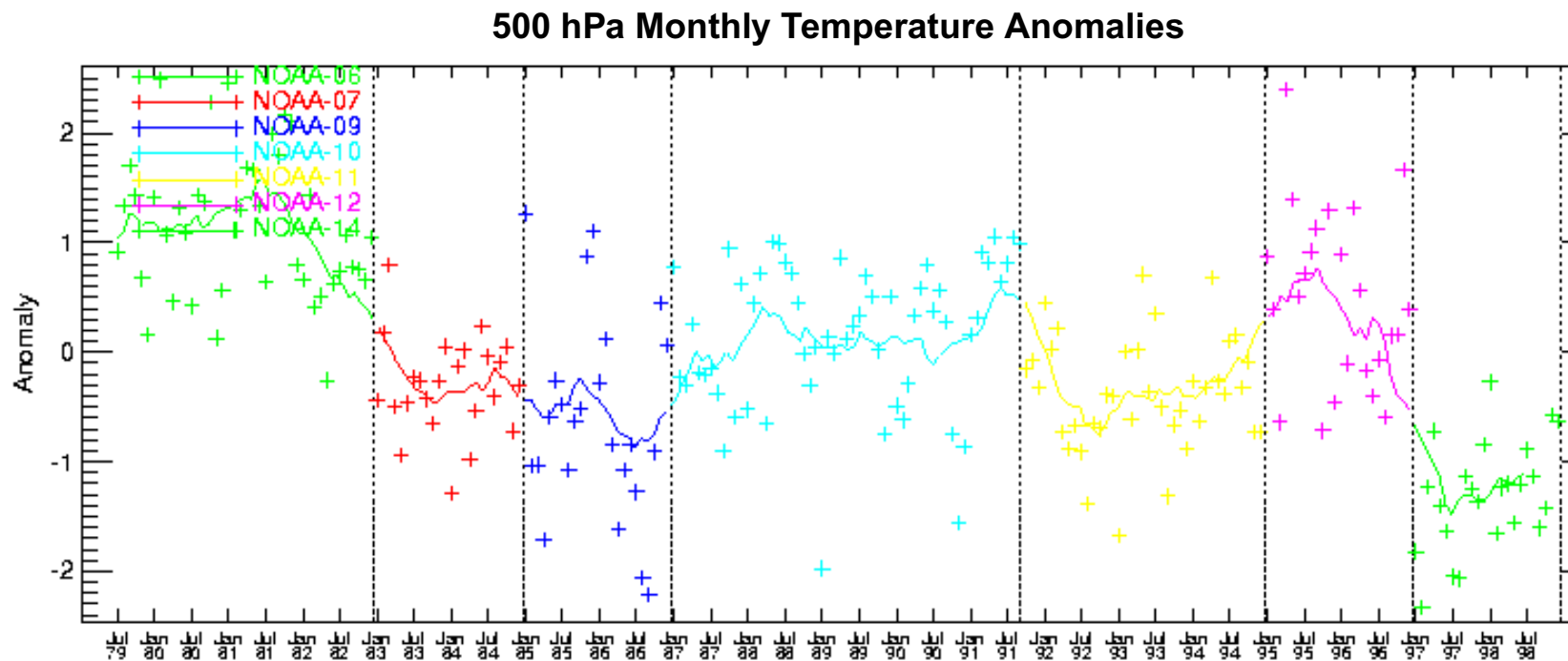
Satellites have arrived as a climate tool.

- => 23 years and counting: passive microwave, profilers, imagers**
- => Recent decades characterized by dramatic Arctic change**
- => Suite of retrieved products fills gaps in conventional observations**
- => Great potential for understanding relationships, feedbacks, connections to global climate system**

Still Plenty on the “To-Do” List...



- **Correct inter- and intra-satellite biases***



*a Rutgers, U. of WA, NOAA project

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- **Decipher relative contributions by thermal and dynamic forcing on changes in sea-ice edge and melt patterns: trends in downwelling longwave radiation? advective heating? winds?**

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- **Identify atmospheric changes responsible for trends in longwave fluxes: clouds? temperature? moisture?**
- **Ascertain cause(s) for changes in clouds: advected moisture? surface exchange?**