SST Error Budget White Paper

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Telecon
ESIP Information Quality Cluster

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Outline

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The SST Error Budget White Papert

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    - Quantify the error budget of satellite-derived SST products.
- This workshop was
    - Held in Rhode Island in November 2009.
    - Attended by 45 SST scientists and NASA and NOAA program managers.
- The error budget was addressed within the context of 6 focus areas:
    1. The physical basis of SST measurements;
    2. Radiative transfer modeling and SST retrieval algorithm development;
    3. Cal/val pre-launch and on-orbit;
    4. Data merging and gridding;
    5. The climate record; reprocessing, data access and stability, and;
    6. Applications of SST.
- Groups representing each area assembled their findings in a report.
- These reports were organized into an SST Error Budget White Paper

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Steering Committee

The Steering Committee for the workshop and subsequent White Paper:

- Sandra Castro (U Colorado)
- Peter Cornillon (U Rhode Island) – that'd be me.
- Chelle Gentemann (Remote Sensing Systems, Inc)
- Peter Hacker (NASA)
- Andy Jessup (U Washington)
- Alexey Kaplan (Columbia U)
- Eric Lindstrom (NASA)
- Eileen Maturi (NOAA)
- Peter Minnett (U Miami)
- Dick Reynolds (Coop. Inst. for Climate and Sat.)

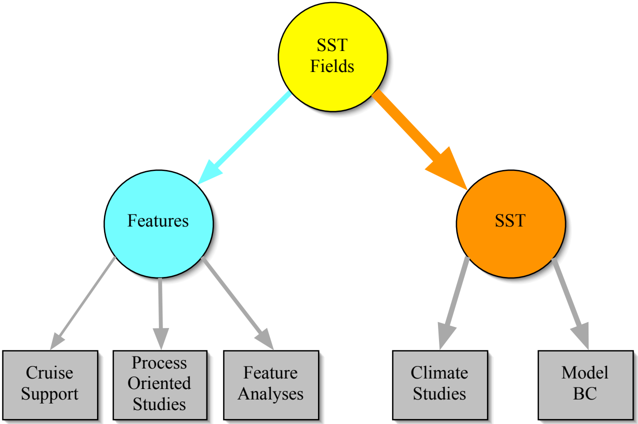
Outline

Constraints on the SST Error

- The Applications Group identified acceptable bounds on SST products
  - Spatial resolution,
  - Temporal resolution,
  - Geolocation accuracy,
  - Absolute SST accuracy, and
  - Relative SST accuracy.
- These bounds were categorized by application.

Applications	Source	Spatial resolution (km)	Temporal resolution (hrs)	Geolocation accuracy (km)	Absolute accuracy ($^{\circ}$K)	Relative accuracy
CDR	Ohring et al., 2005				0.1	0.04°K/decade
CDR	Workshop					0.05°K/decade
NWP	Eyre et al., 2009	5	3		0.3	
Global Operations	NPOESS IORD-II	0.25	3	0.1	0.1	0.05°K
Coastal/Lake Operations	NPOESS IORD-II	0.1	6	0.1	0.1	
Fronts	Workshop	0.1	0.25	0.1	1	0.1°K
Climate Models	Workshop	25	24	5	0.2	0.05°K/decade
Lakes	Workshop	1	3	1	0.3	0.2°K
Air-sea Fluxes	Workshop	10	24	2	0.1	
Mesoscale	Workshop	1	168		0.1	
Submesoscale	Workshop	0.1	1		0.1	
Strictest		0.1	0.25	0.1	0.1	0.05°K 0.04°K/decade

Feature-related vs Climate-related Demands



- A significant fraction of workshop participants were interested in feature studies.
- Such studies tend to be underrepresented in specification of product uncertainty.

Different uses place different demands on the characteristics of the error that are of interest

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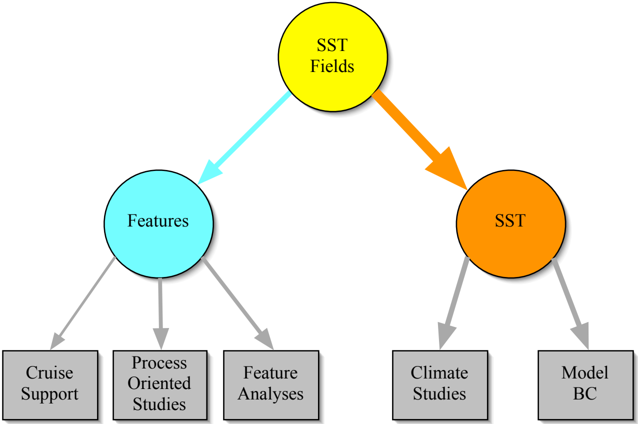

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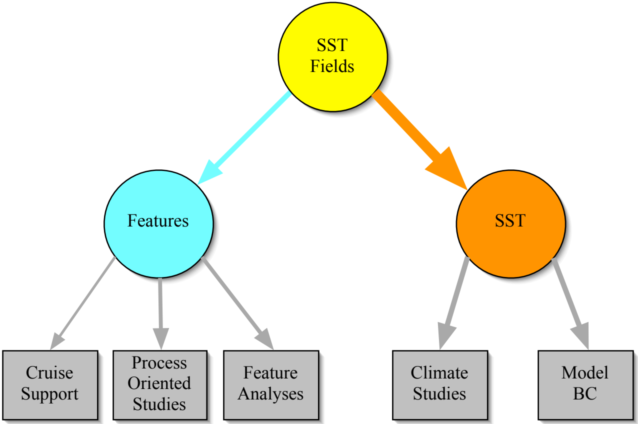

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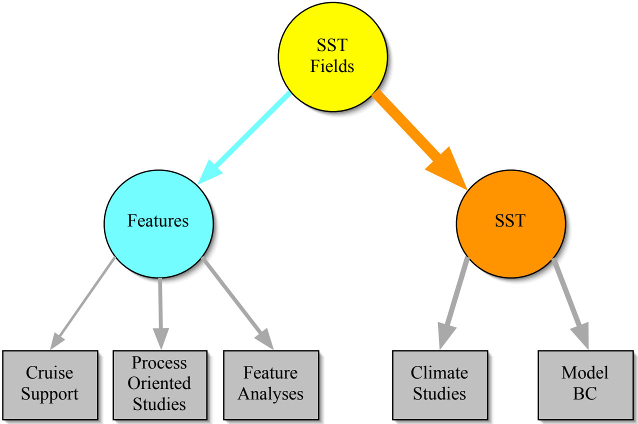

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Approach to Developing the Error Budget

The error budget is discussed in the white paper from 2 perspectives

- Two groups of products
- Five NASA Product levels
- Although both approaches were considered
  The focus was on product categories

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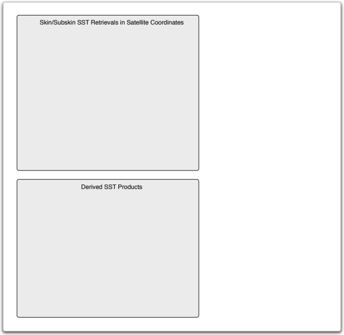

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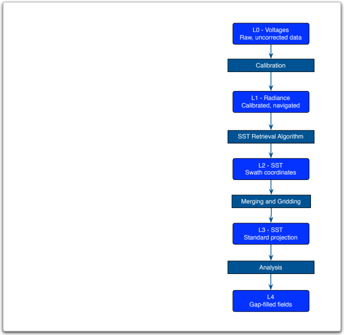

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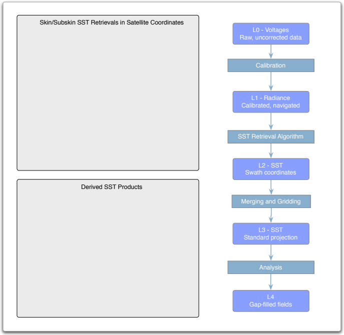

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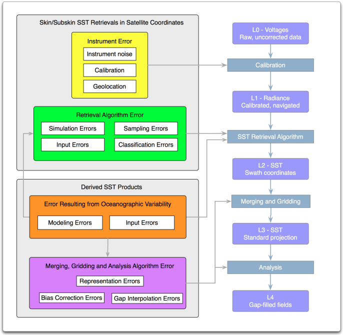

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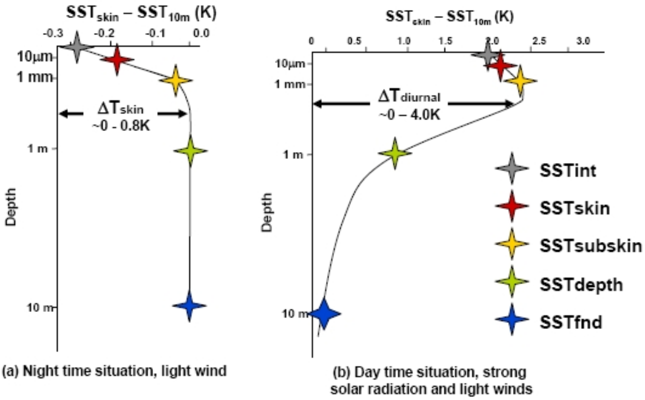

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  - Subskin products are
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    - Obtained by combining radiances in different spectral bands with slightly different sensor footprints.
  - In both cases
    - The primary conversion is radiance to SST.
    - Upper ~1 mm
- Derived SST products
  Products **inferred** from skin/subskin SST retrievals.
  - These products generally require:
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    - Regridding and/or
    - Collating and/or
    - Adjustment to a depth below 1 mm and/or
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Data Products Schematically

Skin/Subskin SST Retrievals in Satellite Coordinates

Upper ~1mm
No collating and
No diurnal correction

Derived SST Products

Regridding and/or
Collating and/or
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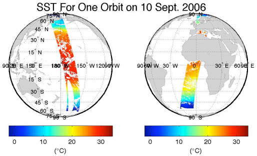
	Single sensor/single time



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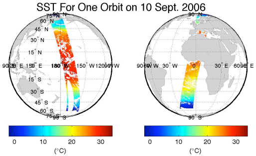

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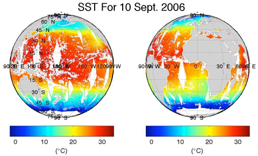

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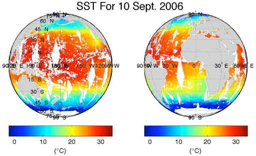
Single sensor/multiple time – Collated



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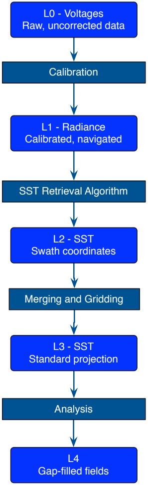
Data levels and processing schematically



The errors

- Errors associated with skin/subskin retrievals fall in two groups
    - Instrument error
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- Errors for derived products also fall into two groups
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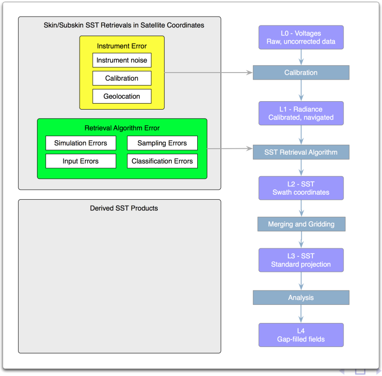
- Errors introduced at any step propagate to the next step.

So let's look at these errors in more detail



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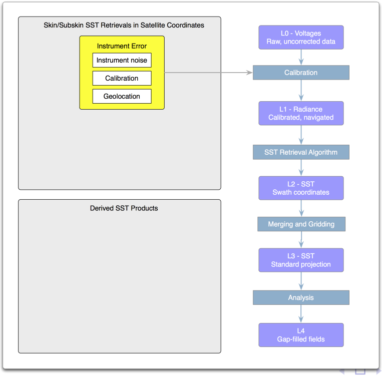

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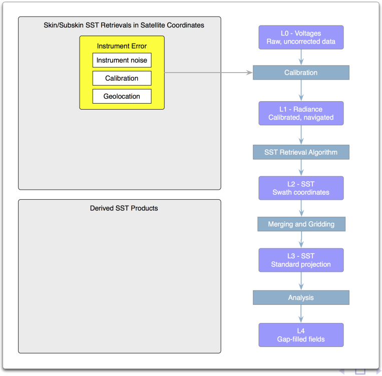

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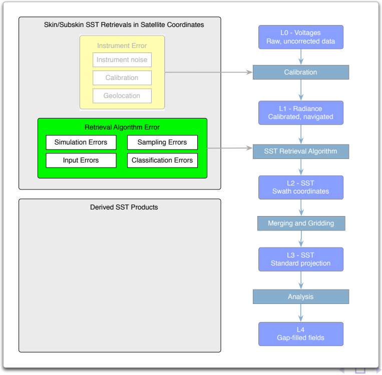

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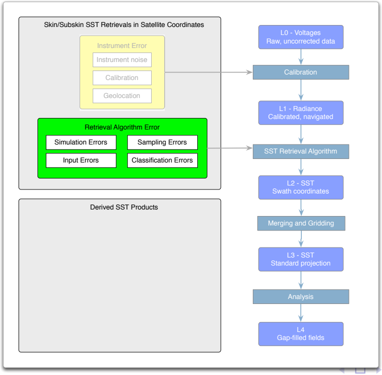

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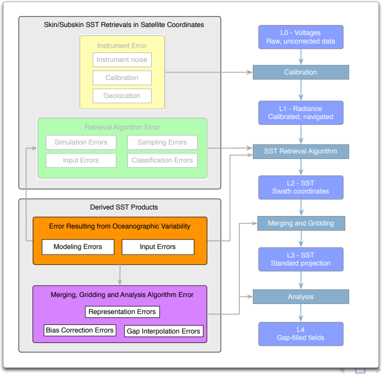

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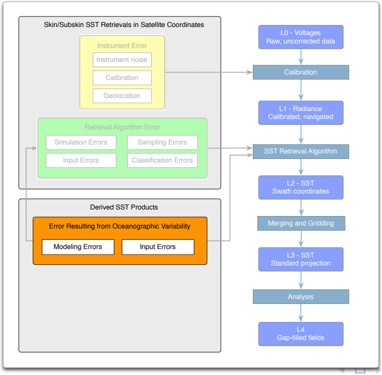

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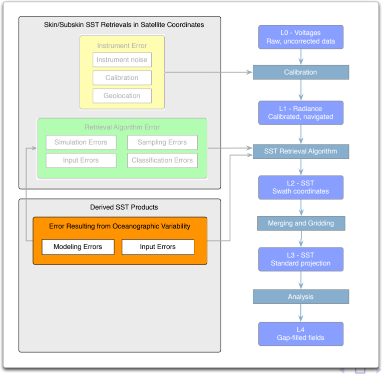

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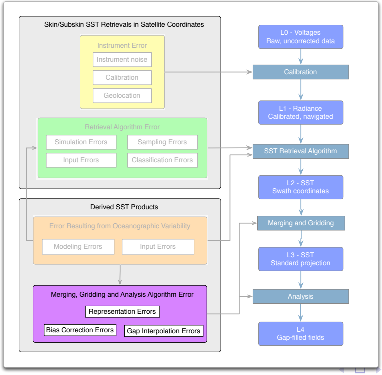

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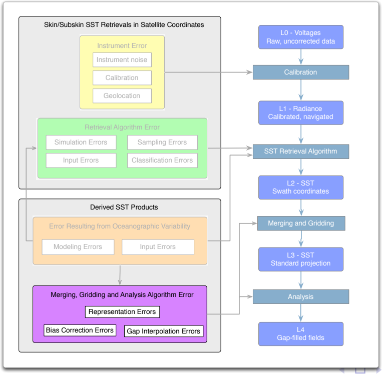

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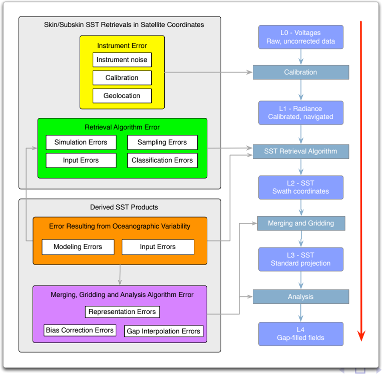

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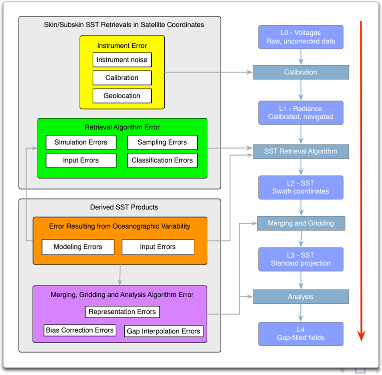

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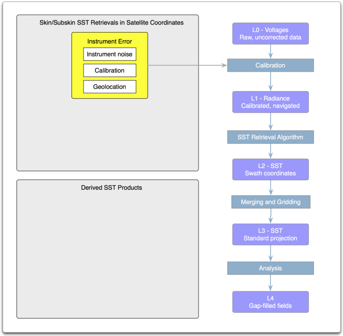

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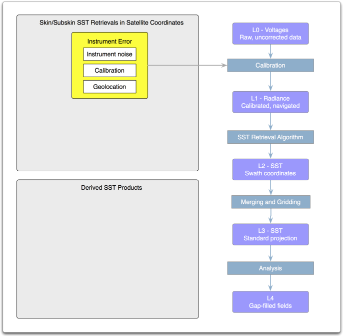

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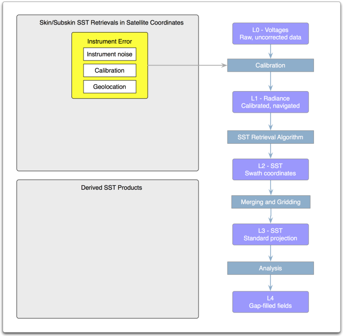

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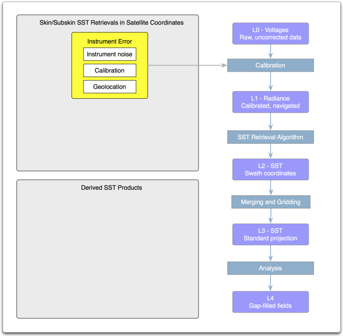

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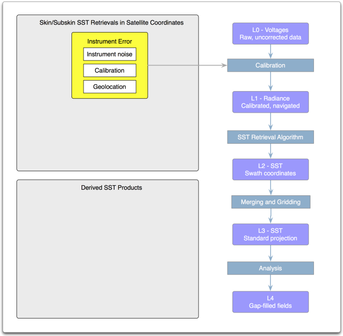

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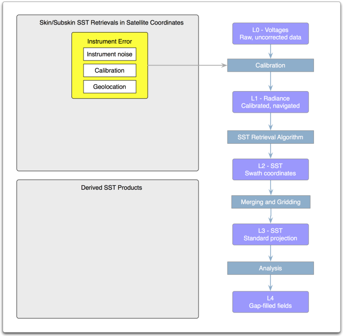

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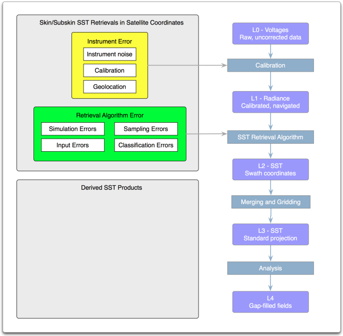

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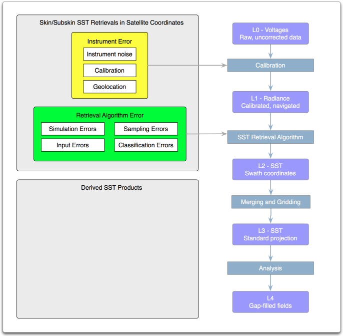

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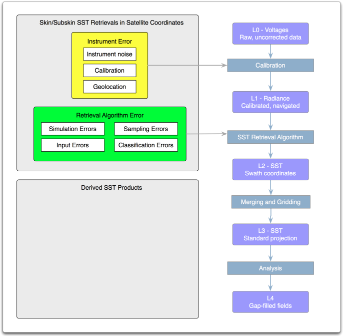

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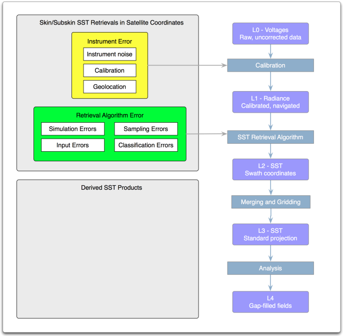

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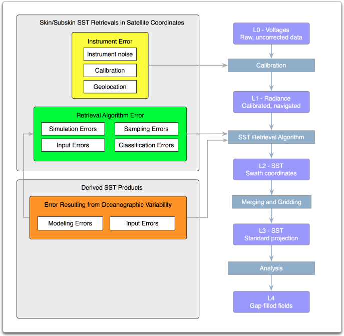

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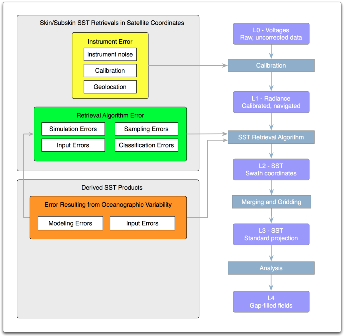

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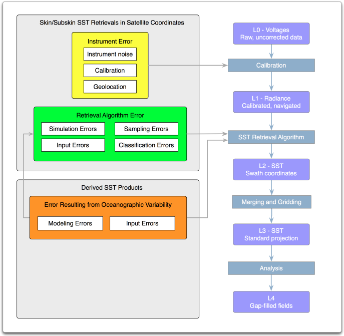

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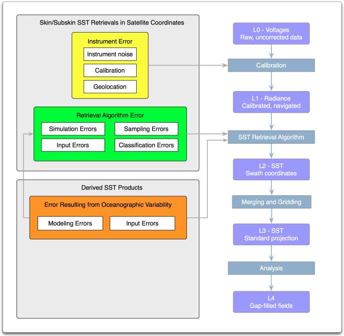

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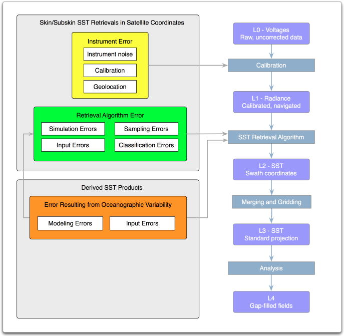

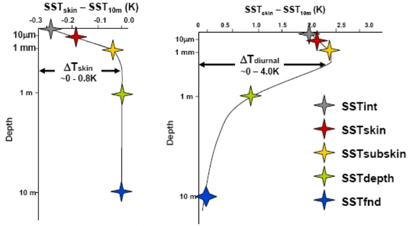

(a) Night time situation, light wind

(b) Day time situation, strong solar radiation and light winds

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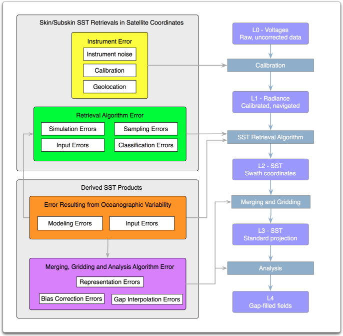
Merging, Gridding and Analysis Errors



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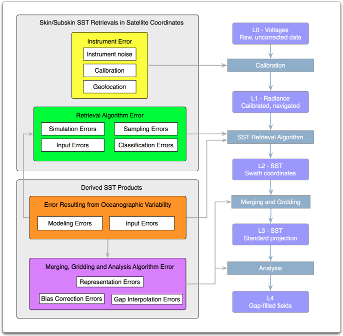

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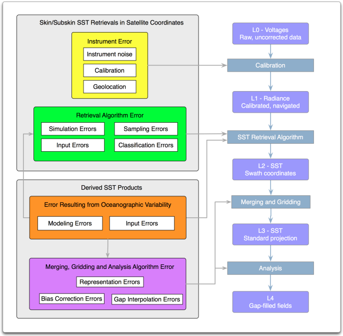

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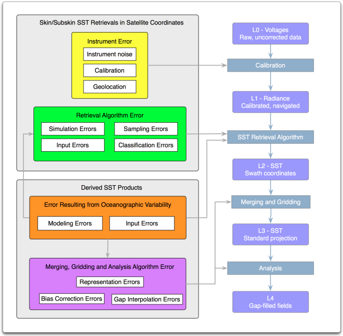

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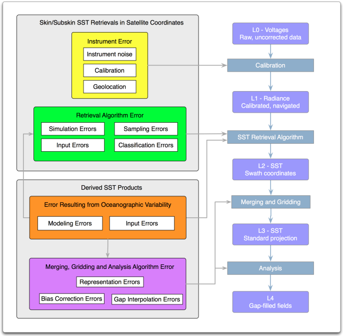

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Outline

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- The uncertainty of satellite SST data products is determined from in situ matchups.
  - Standard measure is rms difference between buoy and satellite SSTs.
  - Typical values for AVHRR, MODIS . . . range from 0.4 to 0.6 K.
  - But these are based on match-ups widely separated in space and time
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- But I'm interested in SST fronts and gradients,
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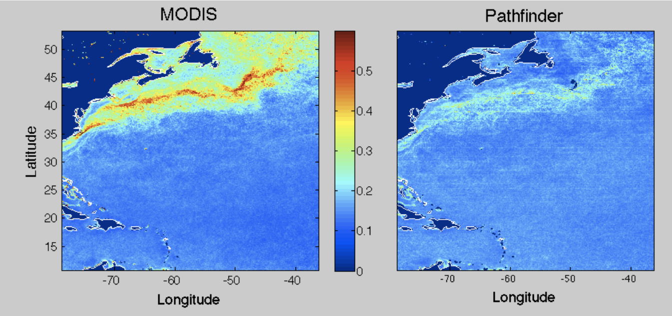

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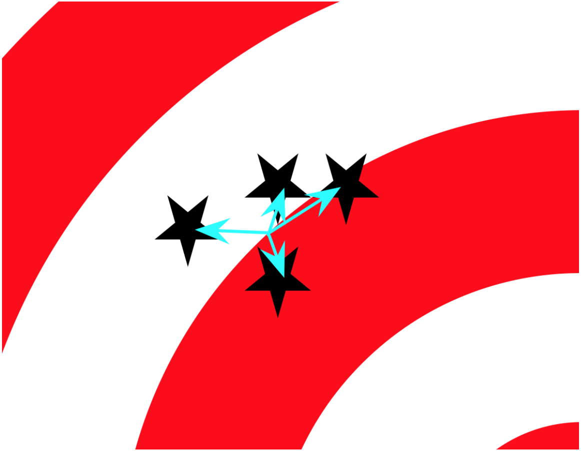

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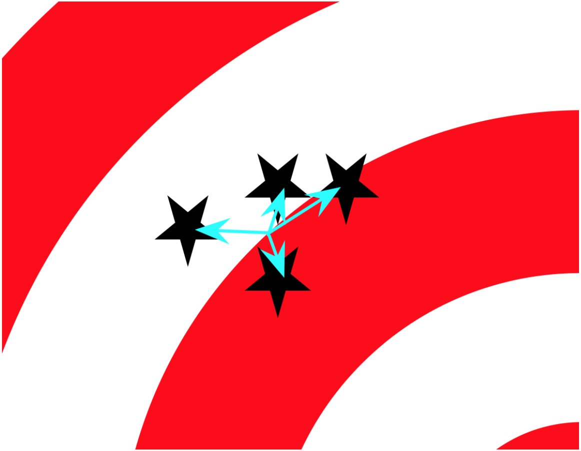

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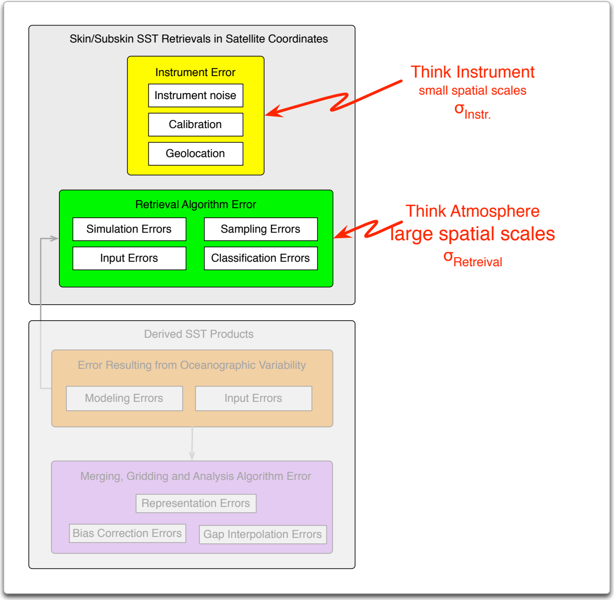

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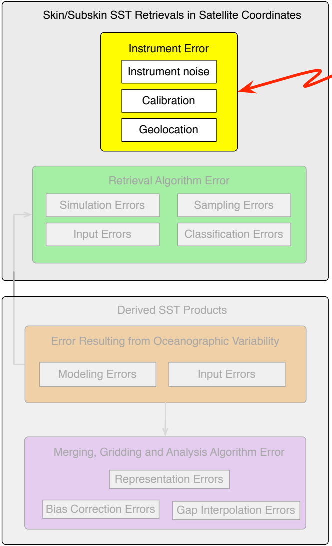

Think Instrument
small spatial scales
$\sigma_{Instr.}$

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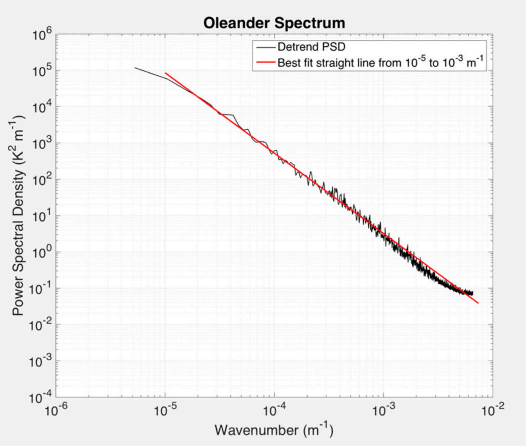

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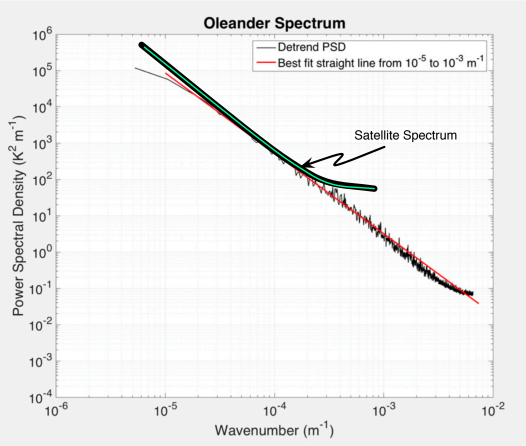

The Data – Preprocessing

- The data were divided into along-scan and along-track directions.
  - Along-scan and along-track characteristics differ.
- And these groups were further subdivided into day and night subgroups.
  - Diurnal warming may alter the spectrum [illegible]
- Only cloud free sections:
  - 256 pixels long.
  - Within 500 km of nadir.
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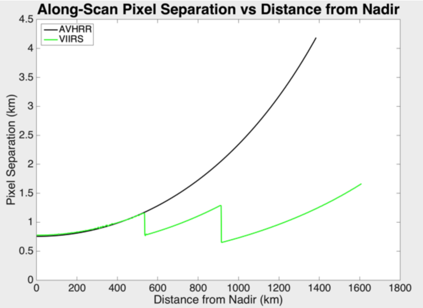

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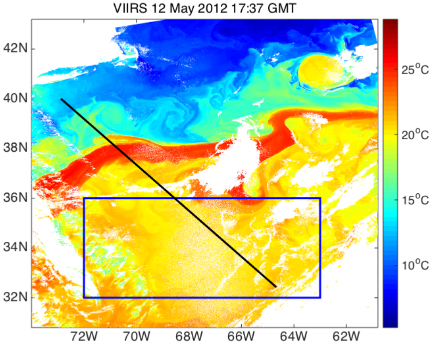

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- Straight line spectra plus white noise were fit to mean spectra.

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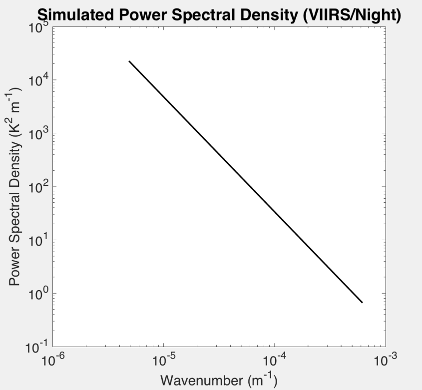

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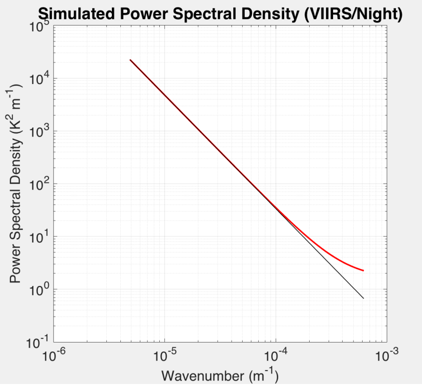

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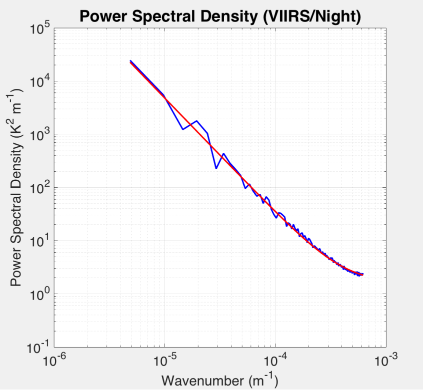
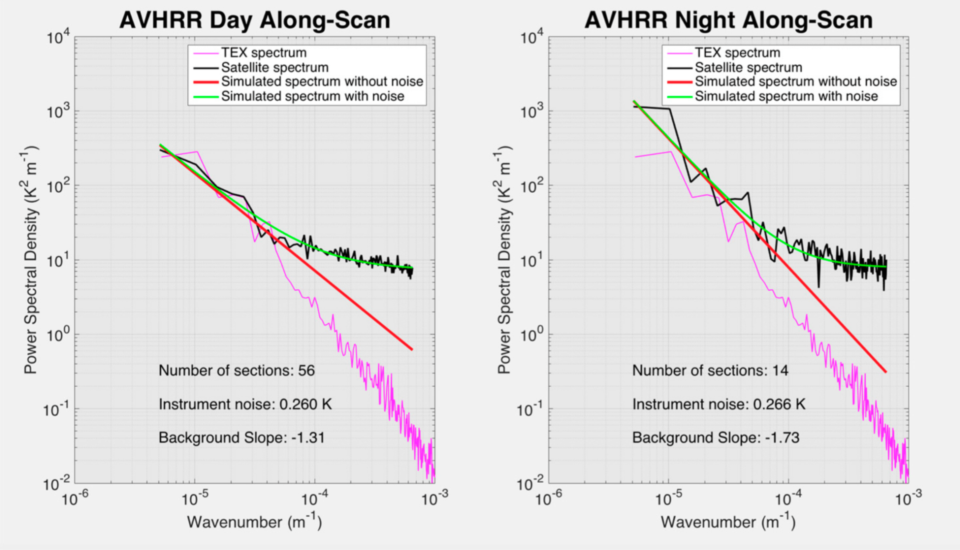
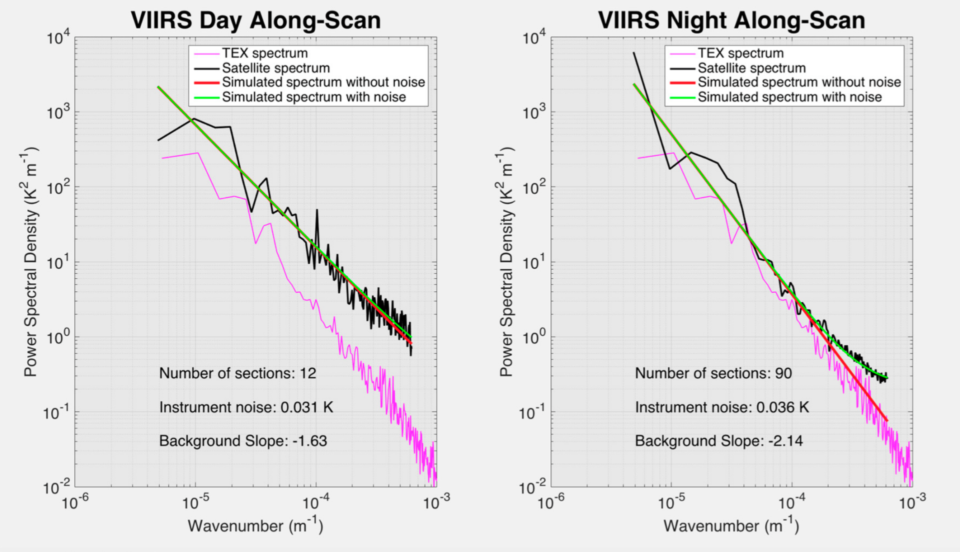


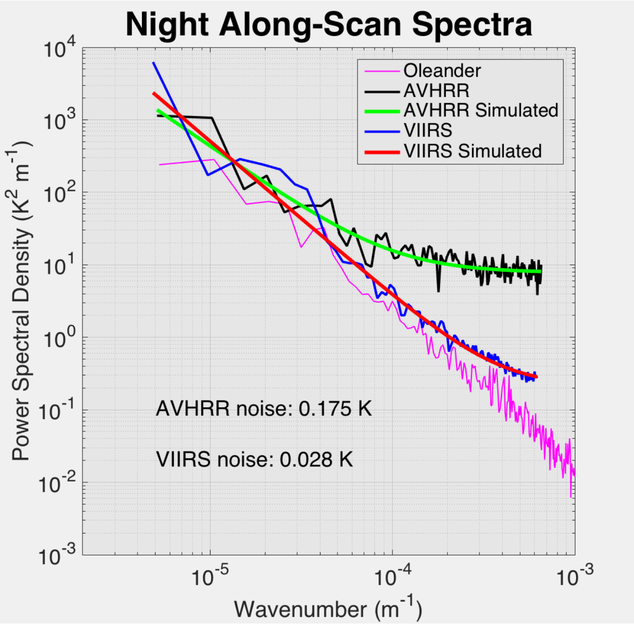
Sample Results for AVHRR Along-Scan



Sample Results for VIIRS Along-Scan



AVHRR and VIIRS Nighttime, Along-Scan Compared



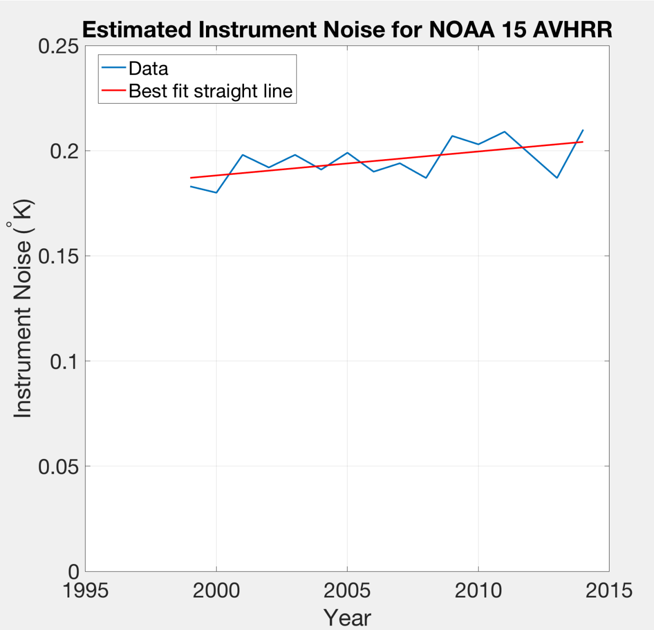
Results

	Method	Day (K)		Night (K)	
		Along-Scan	Along-Track	Along-Scan	Along-Track
AVHRR	Spectral	0.172	0.209	0.173	0.209
	Variogram	0.185	0.219	0.183	0.219
VIIRS	Spectral	0.046	0.076	0.021	0.032
	Variogram	0.081	0.097	0.042	0.056

Summary

- Estimates for cloud-free regions – *instrument* noise only; no *classification* error.
- Variogram estimates slightly larger than spectral estimates for AVHRR; but track well.
- Variogram estimates about twice spectral estimates for VIIRS.
  - Likely due to $\sigma_{inst} \approx \sigma_{geo}$.
- Along-Track noise $>$ Along-Scan noise.; $\approx 1.5\times$ for VIIRS
- Daytime noise $>$ Nighttime noise; $\approx 2\times$ for VIIRS
- AVHRR results for NOAA-15, other AVHRRs may be less noisy;.

NOAA-15 Noise versus Time



A Condsequence

How does noise impact satellite-derived SST gradients?

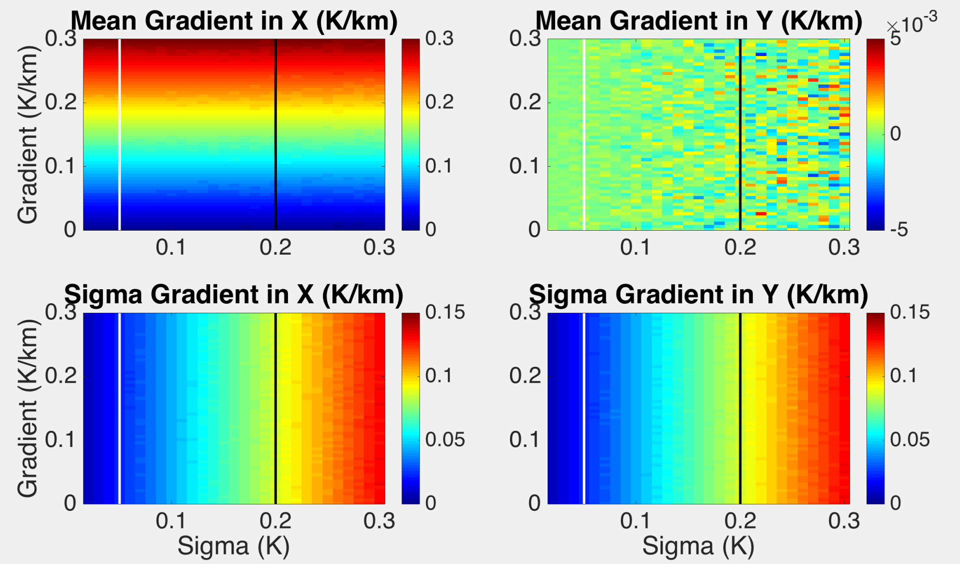
To determine this we

- Simulated 10,000 3 $\times$ 3 pixel squares for a fixed gradient in x, $\frac{\partial T}{\partial x}$, 0 in y.
- Added Gaussian white noise, σ, to each of the elements.
- Applied the 3 $\times$ 3 Sobel gradient operator in x and y.
- Determined the μ and σ of the resulting gradient components and the gradient magnitude.
- Performed the above for:

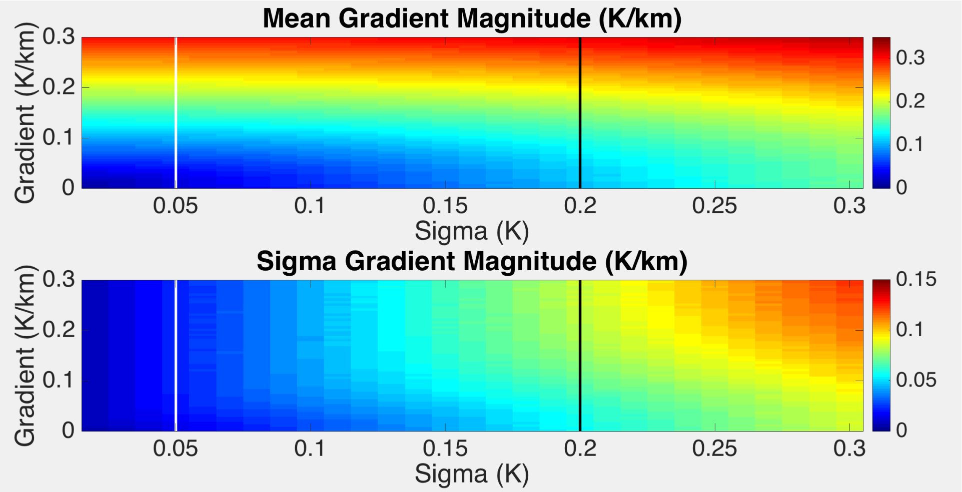
$$0.01\,\mathrm{K\,km}^{-1} < \frac{\partial T}{\partial x} < 0.3\,\mathrm{K\,km}^{-1}$$

$$0.001\,\mathrm{K} < \sigma < 0.3\,\mathrm{K}$$

A Condsequence – Gradient Components



A Condsequence – Gradient Magnitude



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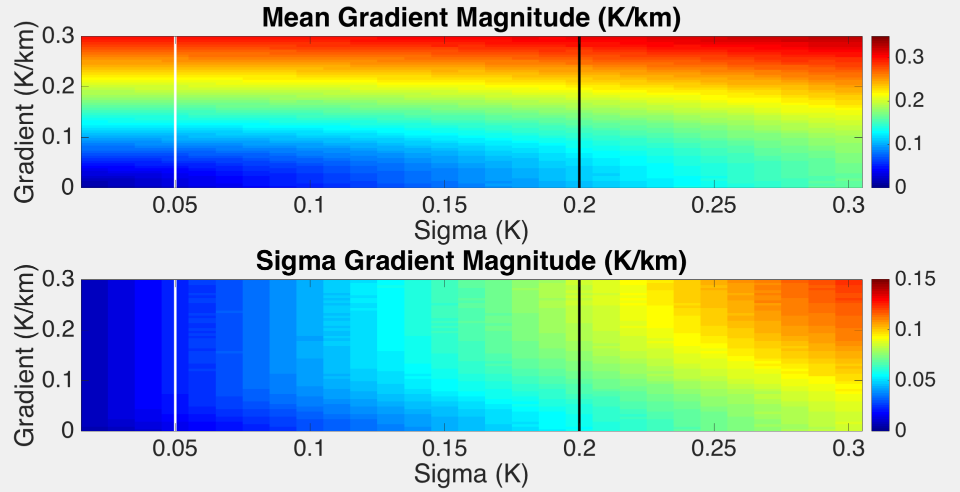

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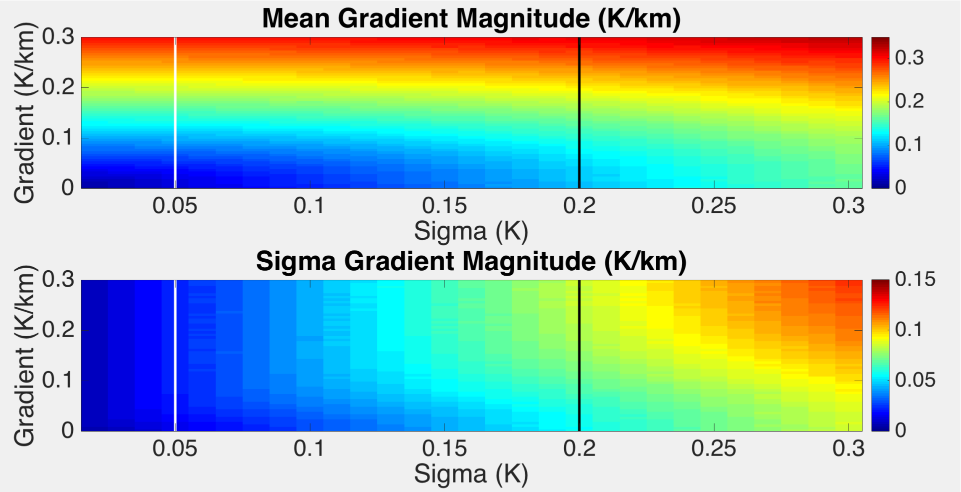

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That's all Folks!
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