# Balancing the Earth's Radiation Budget

Lou Smith

CERES SET November 2007
Victoria, BC

# Annual Mean Global Average Fluxes

- Ingoing Flux: 1365/4 = 341.3 W-m-2
- Outgoing Flux:
  - Reflected Shortwave 97.8
  - Outgoing Longwave 237.1

  » -------
- Net Flux: 6.4
- More than we expect for interannual variation!

# Global Imbalance

**The Imbalance is due to the accumulation of errors in measurement and data product generation.**

# Error Sources for Net Radiation Budget (Strawman)

- Gain of Total Channel
- Gain of Shortwave Channel
- LW Spectral Response of Total Channel
- SW Spectral Response of Total Channel
- Spectral Response of Shortwave Channel
- Limb-darkening Function
- BRDF
- Temporal Interpolation of OLR
- Temporal Interpolation of Albedo
- Solar Constant

# Effects of Errors on Budget

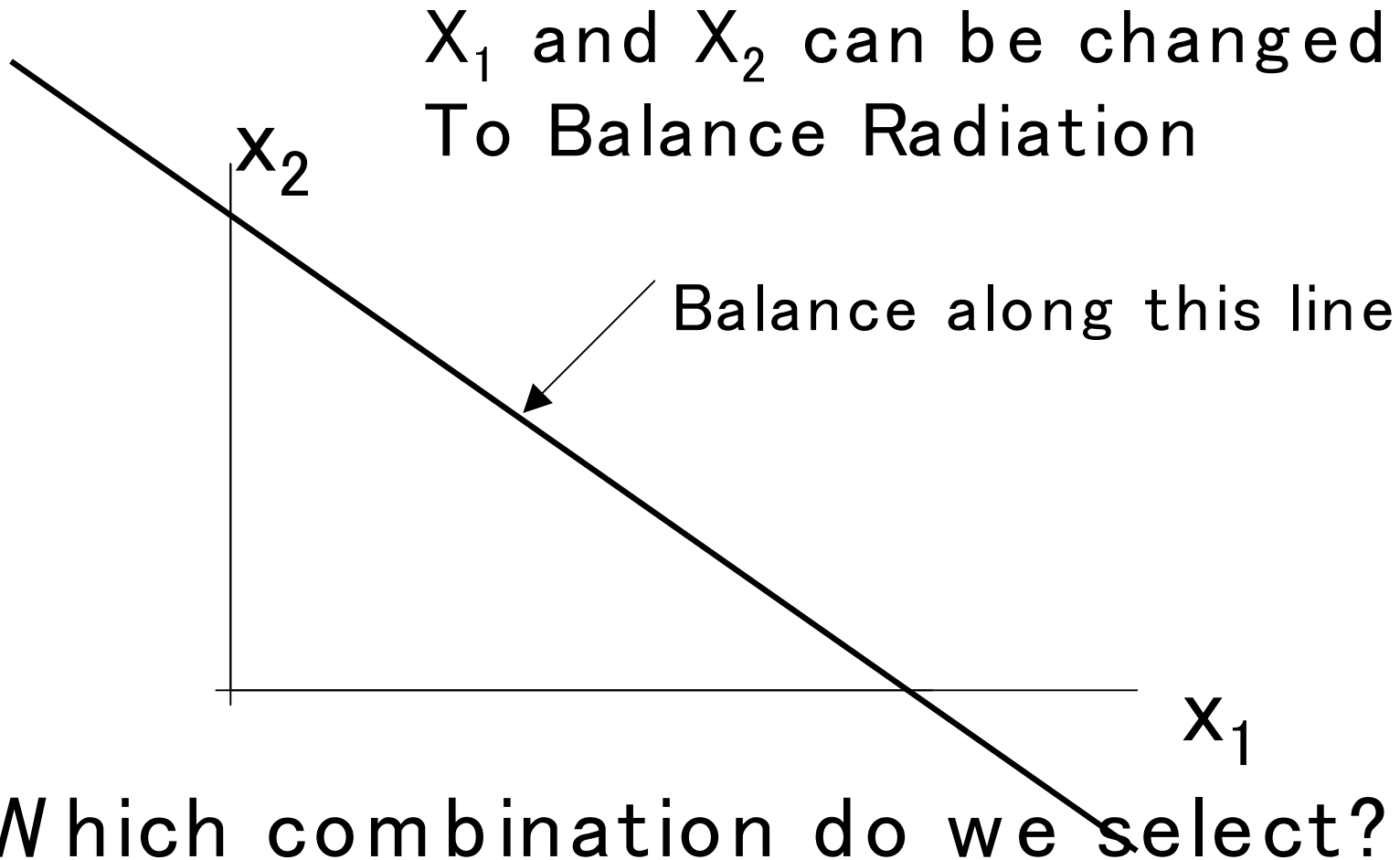
- Errors are Small, therefore assume Effects are Linear:

$$\Sigma A_i X_i = -\varepsilon_{RN}$$

$$\text{or } a^t x = -\varepsilon_{RN}$$

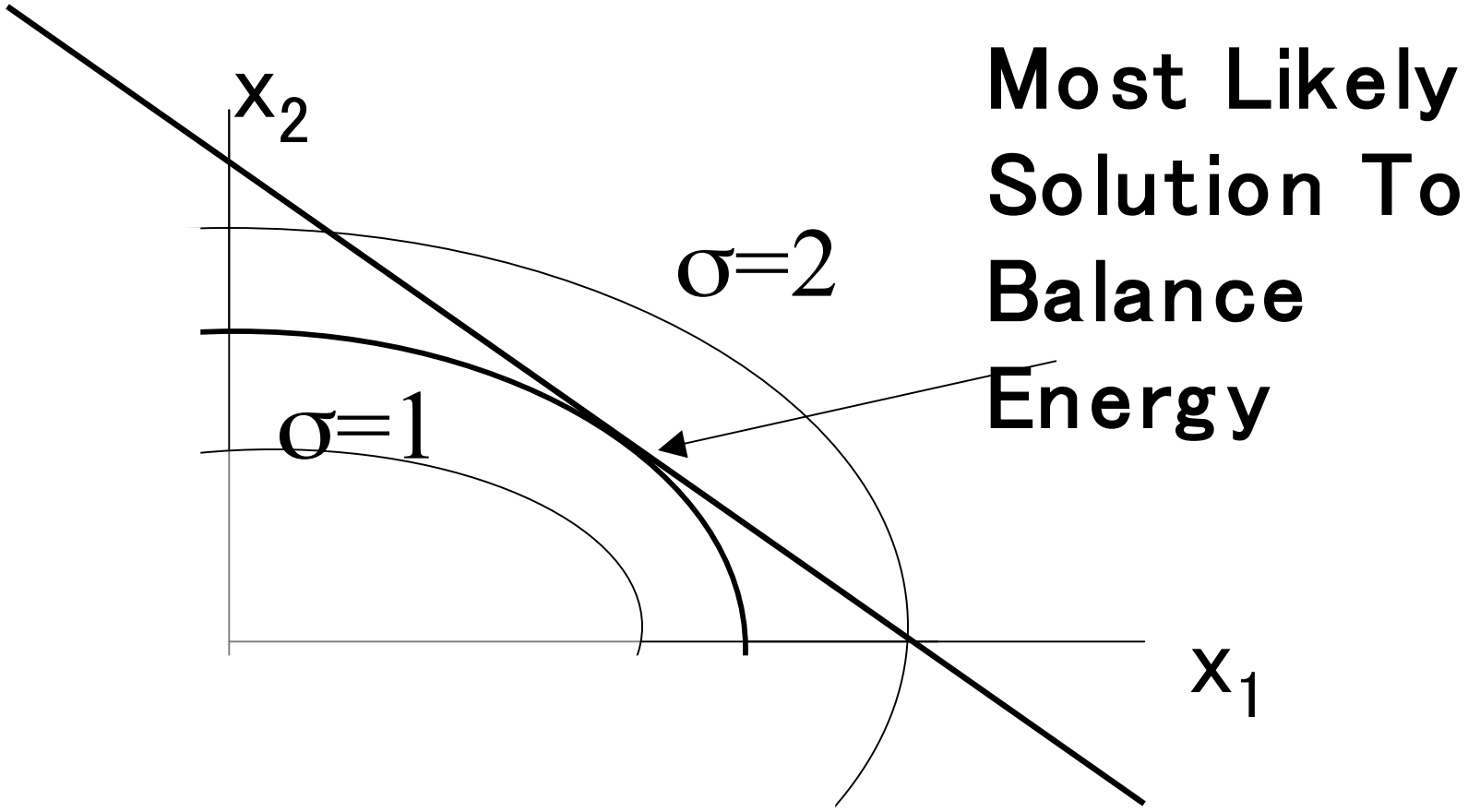
- Here $A_i$ is Sensitivity of Net Radiation to parameter $X_i$

# Consider a 2-Parameter System:




Which combination do we select?

# Consider Probability of $X_1X_2$ Pair:



# Probability Distribution of X

- Assume X have zero mean
- Assume X Normally Distributed
- $P(x) = M \exp(-x^t C x)$

  Where C = Covariance Matrix

# Most Likely Solution to Balance Energy: Equations

- Most Likely Solution is given by minimizing $-x^t C x$

  subject to Constraint $a^t x = -\varepsilon$

  RN

  Thus Minimize

$$\Omega = -x^t C x + \lambda a^t x$$

where $\lambda$ = Lagrangian Multiplier

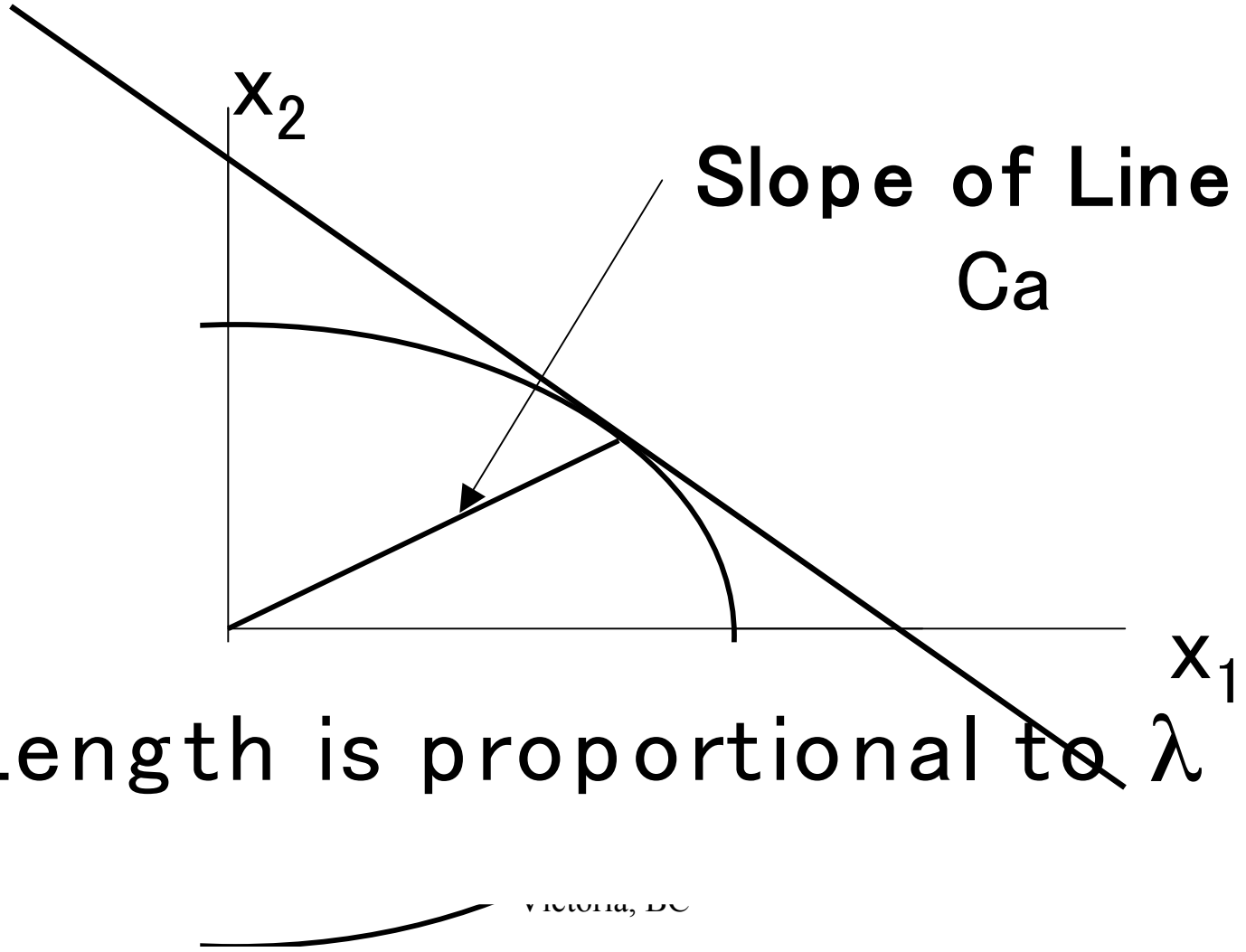
# Most Likely Solution to Balance Energy:

$$x = -\lambda Ca$$

Where

$$\lambda = (a^t Ca)^{-1} \varepsilon_{RN}$$

# Most Likely Solution to Balance Energy



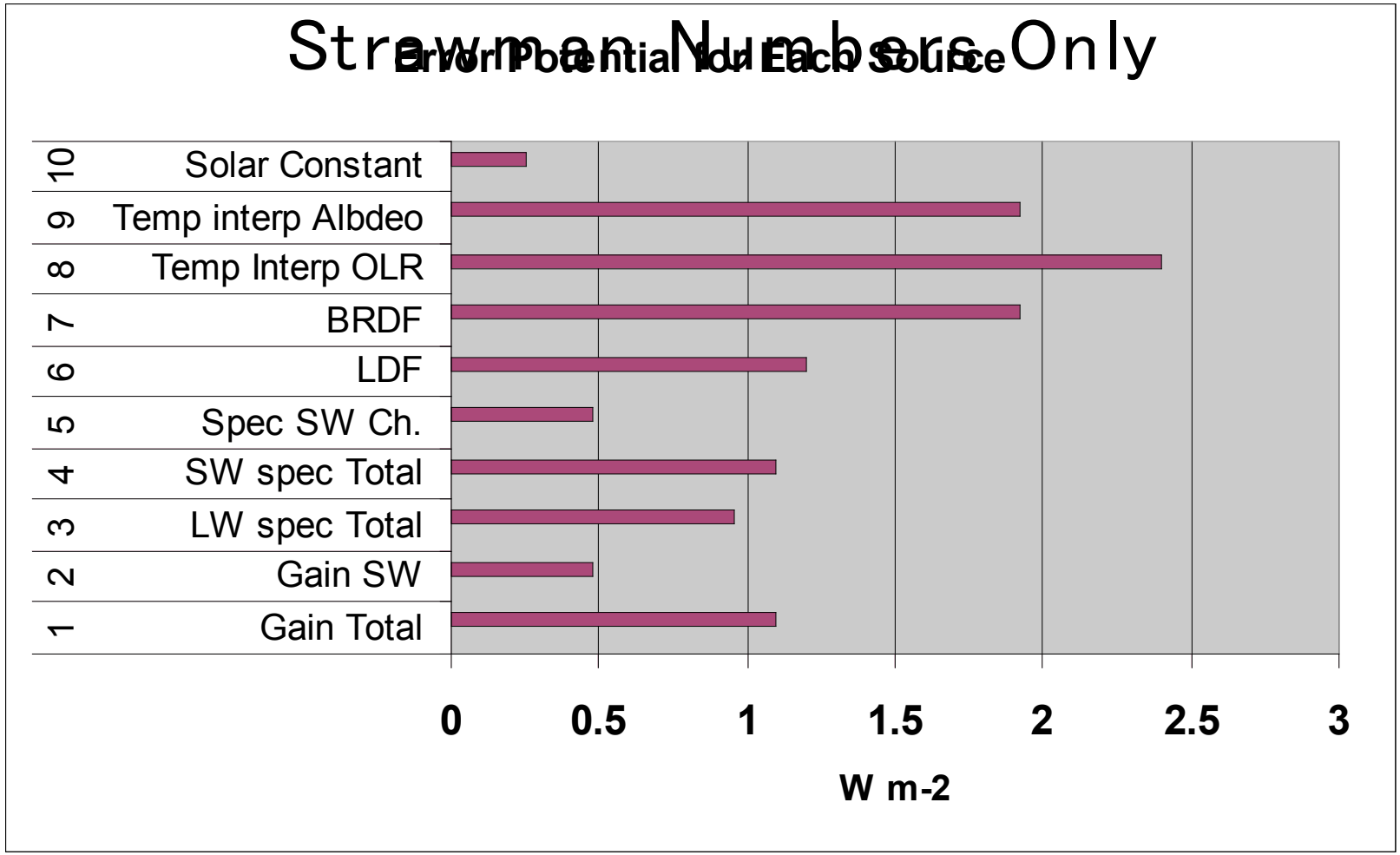

Length is proportional to $\lambda$

# Input for Balance – Strawman

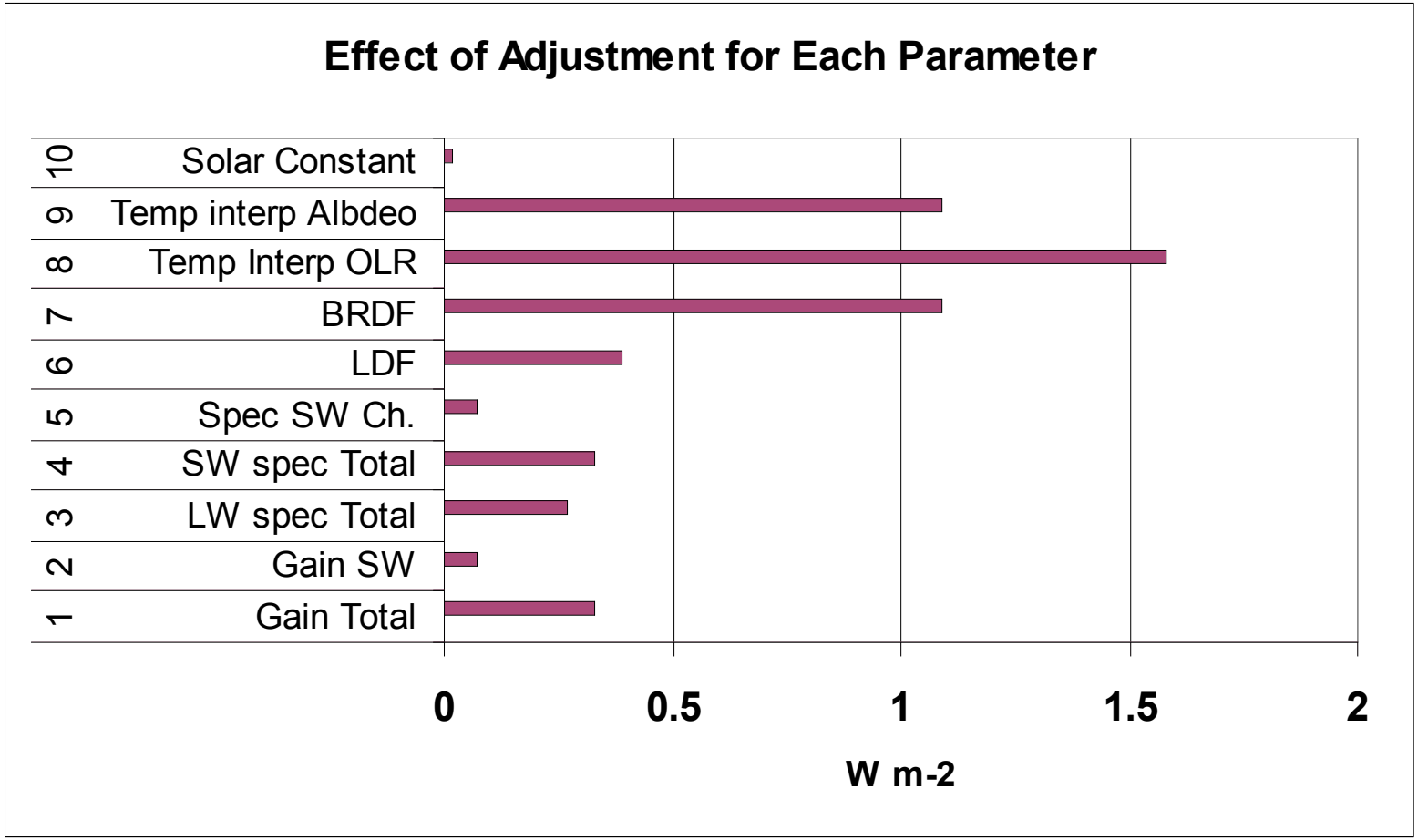
| | $\sigma$ | $A_i$ |
|---|---|---|
| • Gain Total Ch., % | 0.005 | 220. |
| • Gain Shortwave Ch. | 0.005 | 96. |
| • LW Spec. Total Ch. | 0.010 | 96. |
| • SW Spec. Total Ch. | 0.005 | 220. |
| • Spect. Resp. SW Ch. | 0.005 | 96. |
| • Limb-darkening | 0.005 | 240. |
| • BRDF | 0.020 | 96. |
| • Temp. Interp. OLR | 0.005 | 240. |
| • Temp. Interp. Albedo | 0.005 | 96. |
| • Solar Constant, $W-m^{-2}$ | 1.0 | .25 |

# Effect of 1-sigma Change of Each Parameter

## Strawman Numbers Only



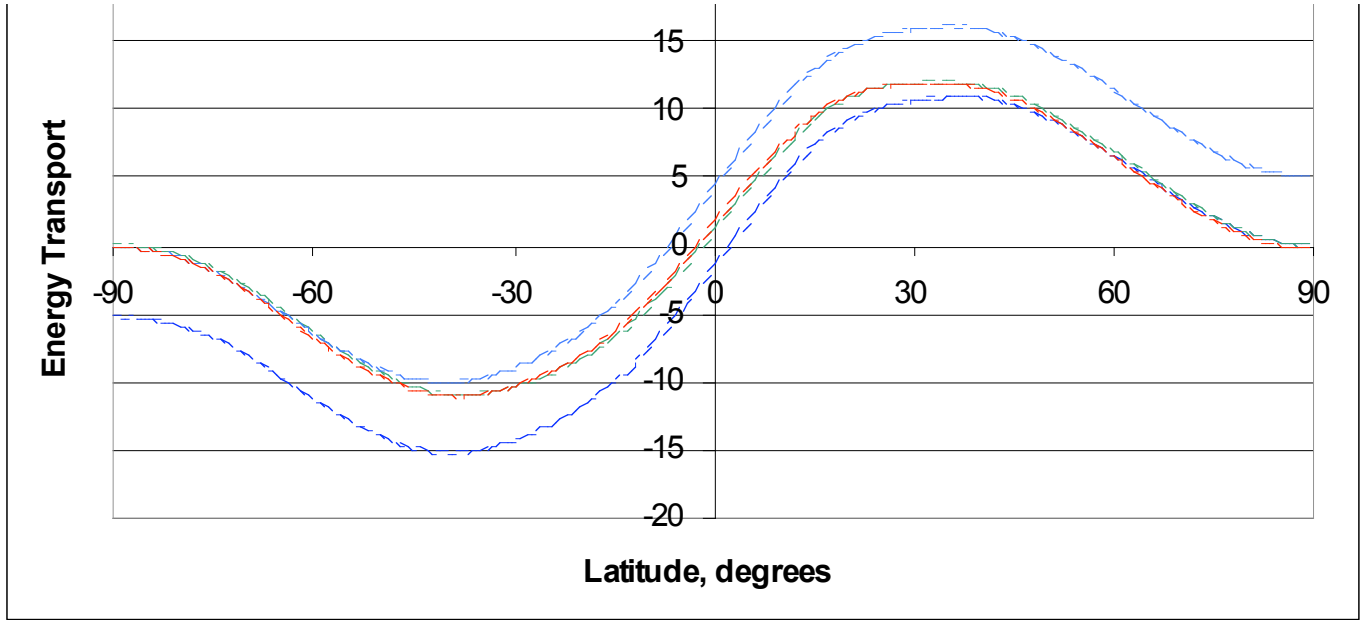
# Most Likely Adjustments to Balance Budget: Strawman Only



# Computation of Meridional Energy Flux:
## Application of Method

- To get meridional flux, integrate net radiative flux starting at Pole.
- Divide Flux by length of Zone to get Flux Density.
- Computation assumes ZERO Annual Mean Global Average Net Radiative Flux.

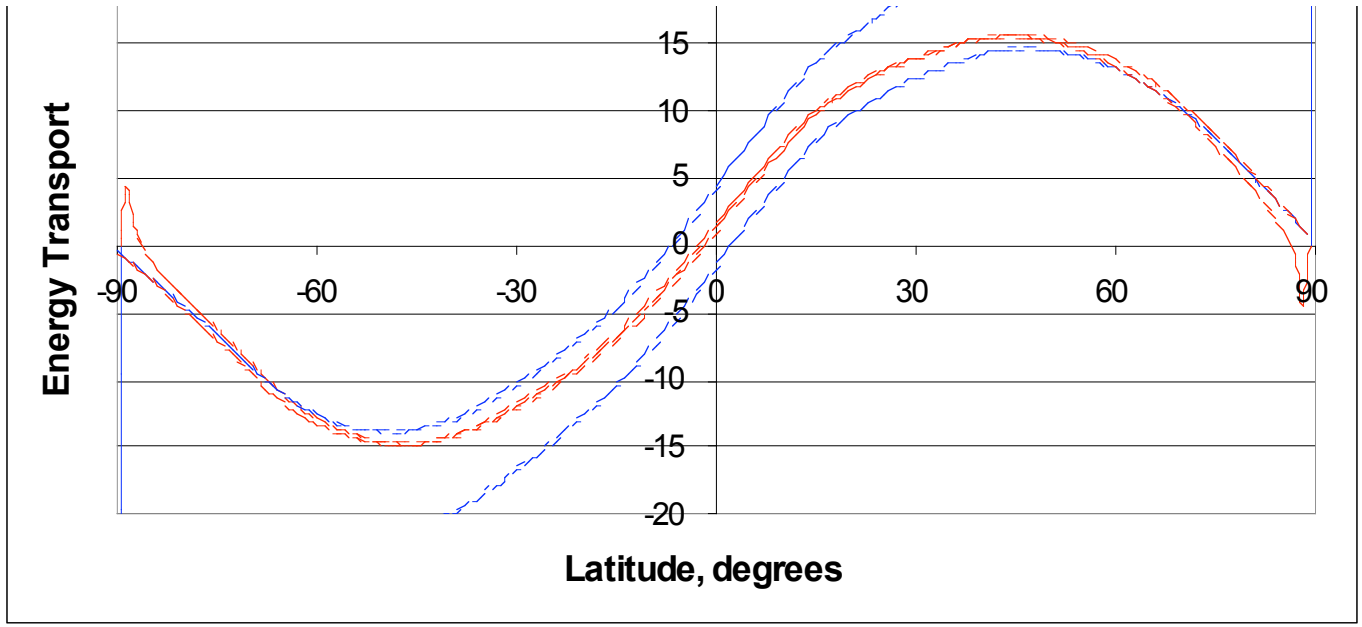
# Annual Mean Meridional Energy Flux




Blue lines: Original data

Red lines: Data Adjusted for Likely Errors

# Annual Mean Meridional Energy Flux Density




Blue lines: Original data

Red lines: Data Adjusted for Likely Errors

# Conclusions

- An Algorithm has been Developed for Adjusting Parameters in Data Production for Balancing the Radiation Budget.
- Requires Good Error Input for Valid Results. (Garbage in/Garbage out)
- We need to develop good input for this.