Observationally Closing the Gap Between IR Radiative Forcing and Changes in IR Radiation Climate

or

Is Atmospheric Infrared Radiation Doing What is Supposed to Do?

Ellsworth G. Dutton and the ESRL/GMD Radiation Group
NOAA, ESRL Boulder, Colorado 80305

With thanks to:
Martin Wild (ETHZ- ECHAM), Norm Wood (CSU- NCAR/CCSM, B Collins),
Stuart Freindenreich (GFDL-CM2, Delworth) for GCM results

Terminology:

- Downward IR (LW) Irradiance at the Earth's Surface is quantity of interest in this talk
- Downward IR (LW) Irradiance at the Earth's Surface is the integrated radiant power emitted downward by the atmosphere between about 3.5 µm – 100 µm and intercepted on a horizontal plane at the Earth's surface. It is the combined natural and anthropogenic "greenhouse" radiation, f(T, GHG, H2O, Clds, aerosols) global annual mean ~ 350 $W\ m^{-2}$
- Longwave (LW), infrared (IR), Terrestrial IR, Thermal IR, IR irradiance, and IR radiation may be used interchangeably in this talk
- IR anomalies – Deseasonalized with long-term mean subtracted.

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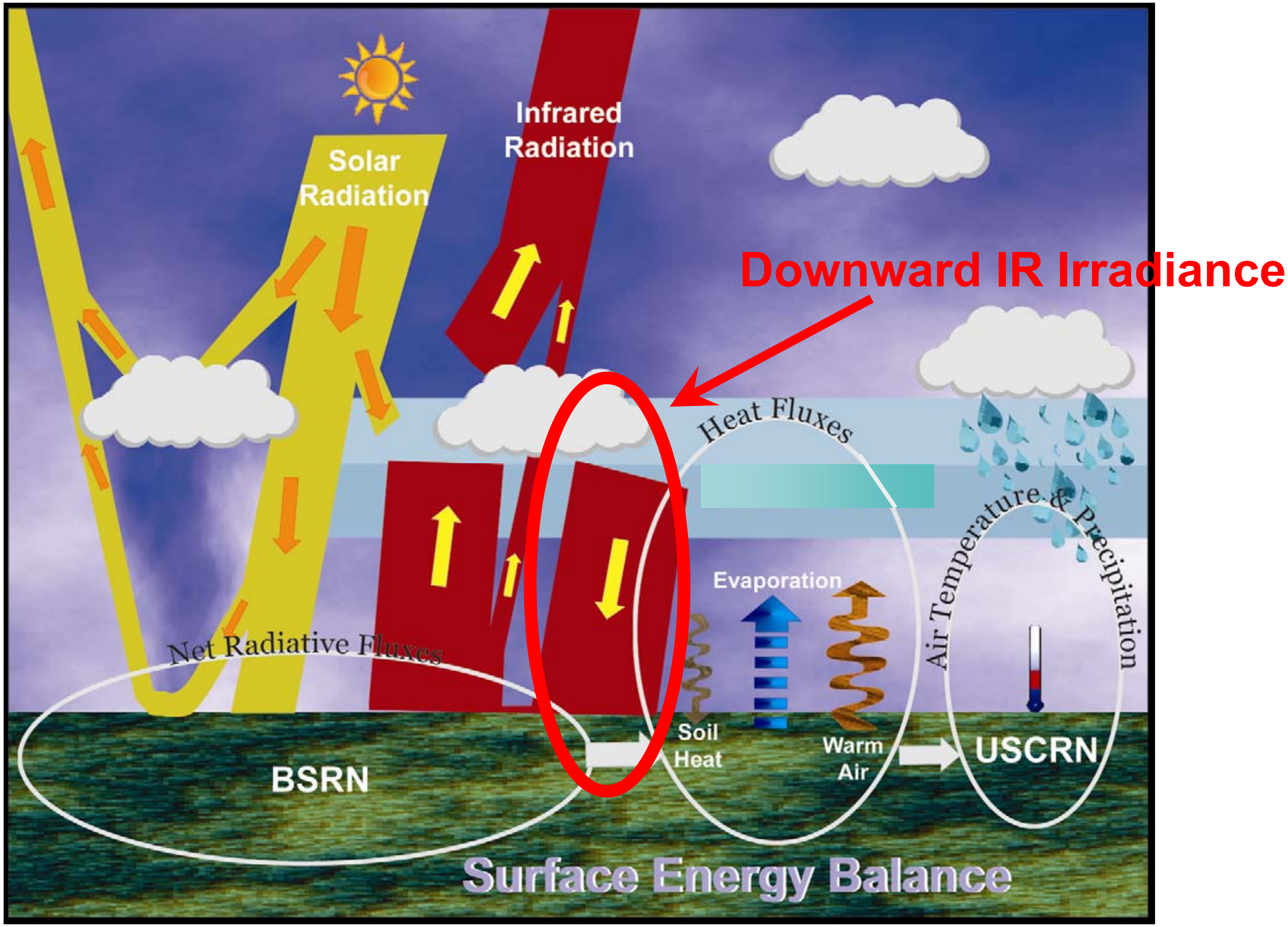

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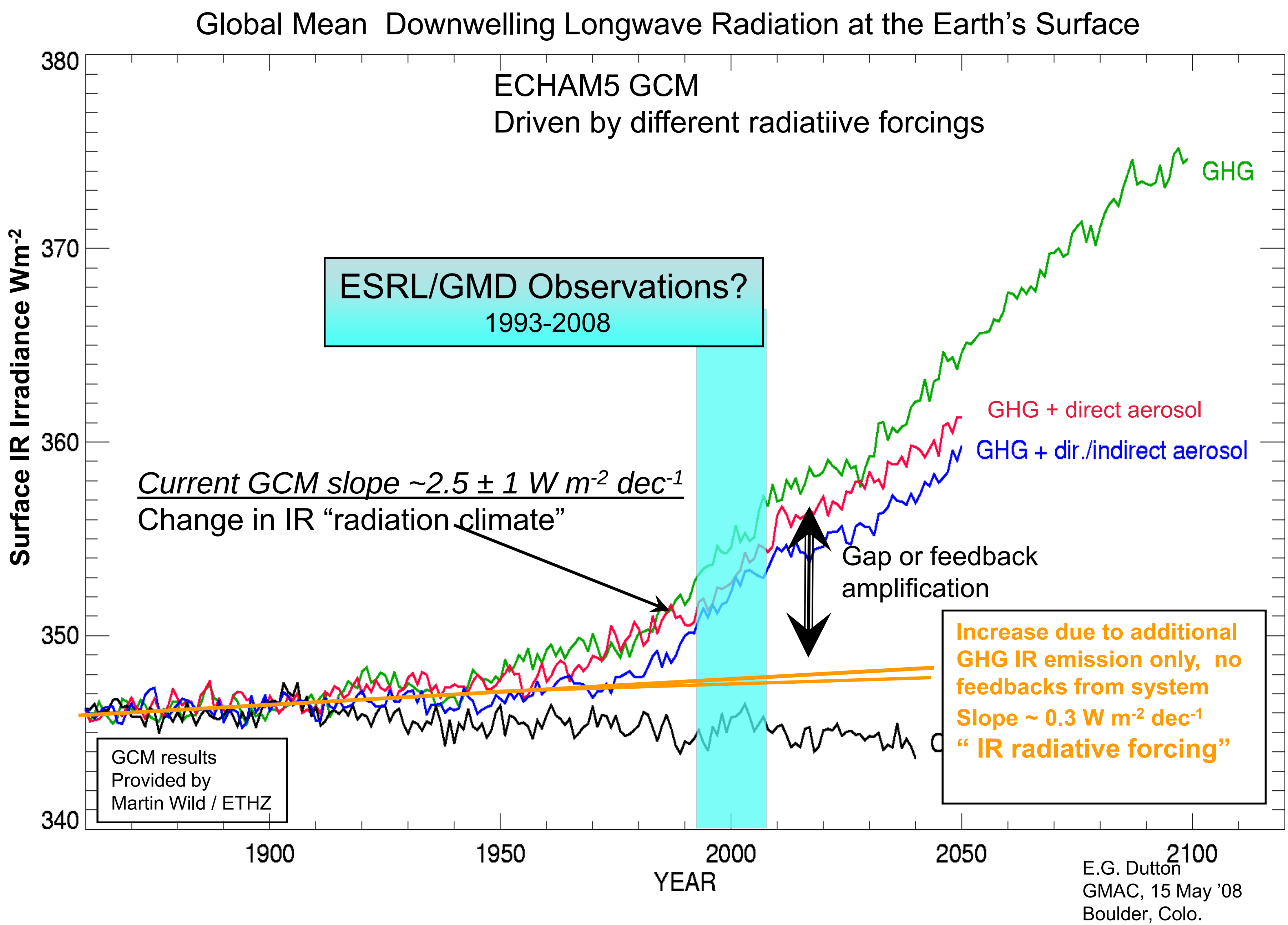

Global Mean Downwelling Longwave Radiation at the Earth's Surface
ECHAM5 GCM
Driven by different radiatiive forcings
ESRL/GMD Observations?
1993-2008
GHG
GHG + direct aerosol
GHG + dir./indirect aerosol
Current GCM slope ~2.5 ± 1 W m-2 dec-1
Change in IR "radiation climate"
Gap or feedback amplification
Increase due to additional GHG IR emission only, no feedbacks from system
Slope ~ 0.3 W m-2 dec-1
" IR radiative forcing"
GCM results Provided by Martin Wild / ETHZ
Surface IR Irradiance Wm-2
380
370
360
350
340
1900
1950
2000
2050
2100
YEAR
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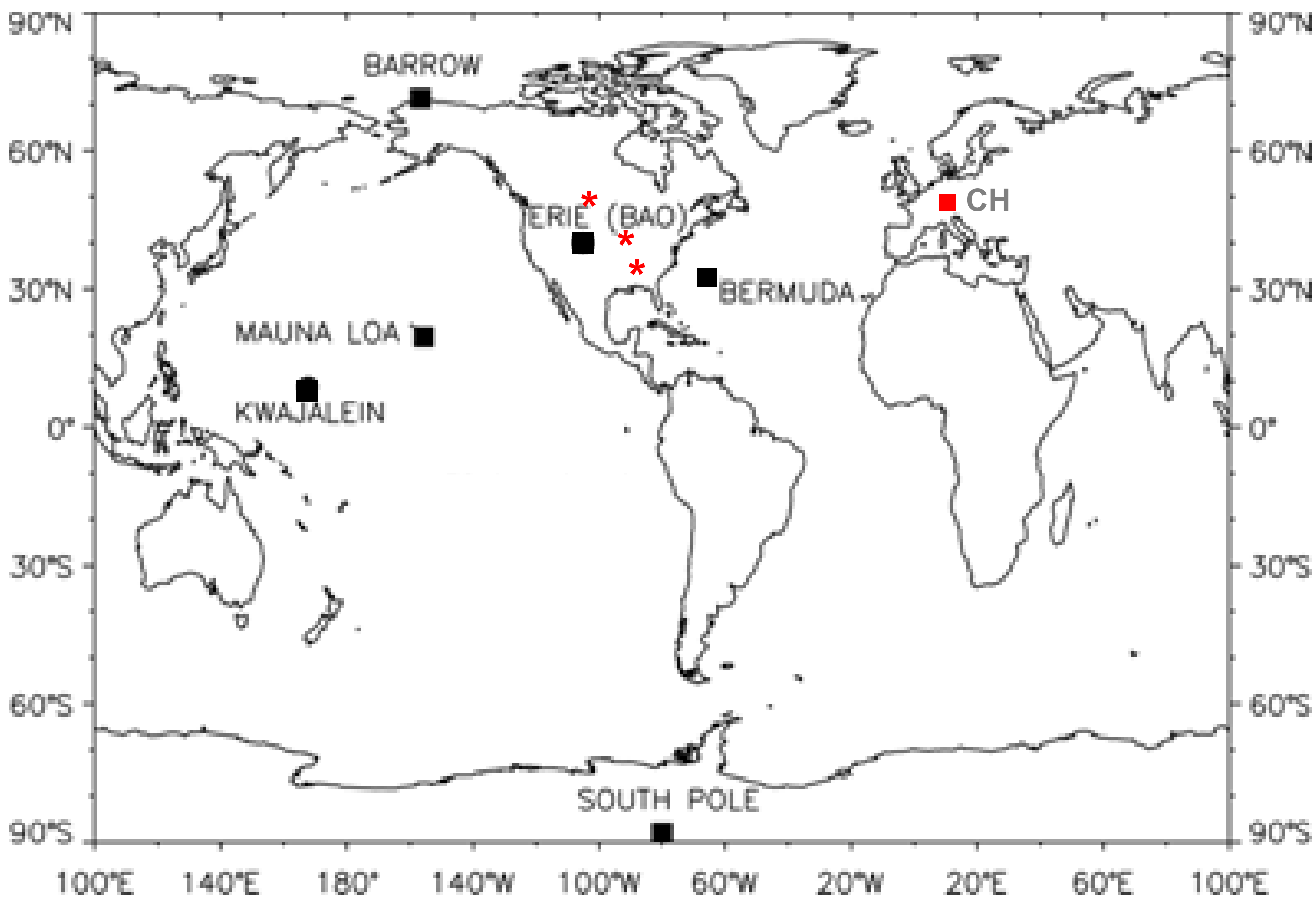

■ **ESRL-GMD Global Baseline (1993-2008)**

* **ESRL-GMD SURFRAD (1995 – 2008)**

■ Swiss network (1995-2002, R. Philipona et al. 2005)

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ESRL-GMD Surface IR Observations: A few details
(G-Rad global baseline network, 1993 - 2008)

- Commercial pyrgeometers
- Albrecht & Cox calibration and data reduction methodology
- Calibration accuracy ~ 3 W m^{-2}, traceable int'l
- Calibration stability < 0.2% (0.7 W m^{-2}) dec^{-1}
- Field calibration frequency once per 1 – 3 years
- Continuous sampling
- Manually edited and reviewed
- Subsequent analyses:
  - Deseasonalized 1-day averages→ 20-day averages → AR-1 residuals
  - Two trend or analyses then applied:
    - Linear regression
    - Mann-Kendall tests on Sens slopes
  - Variance reduction from combining remote sample sites

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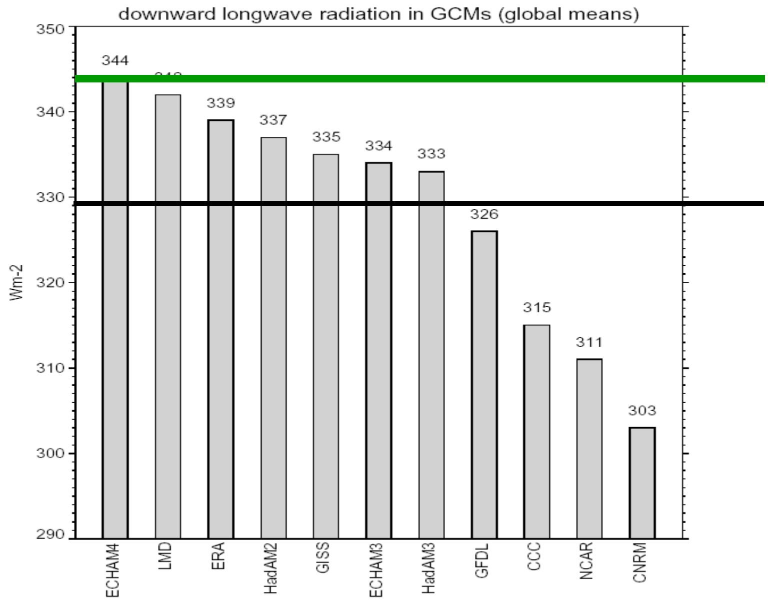
GCM surface IR agreement with observations
M. Wild et al., 2001 (see Wild et al 2005 for update)



BSRN OBS. (344 W m^{-2})

Model Avg. (329)

Global Means
Circa 1999

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BEFORE

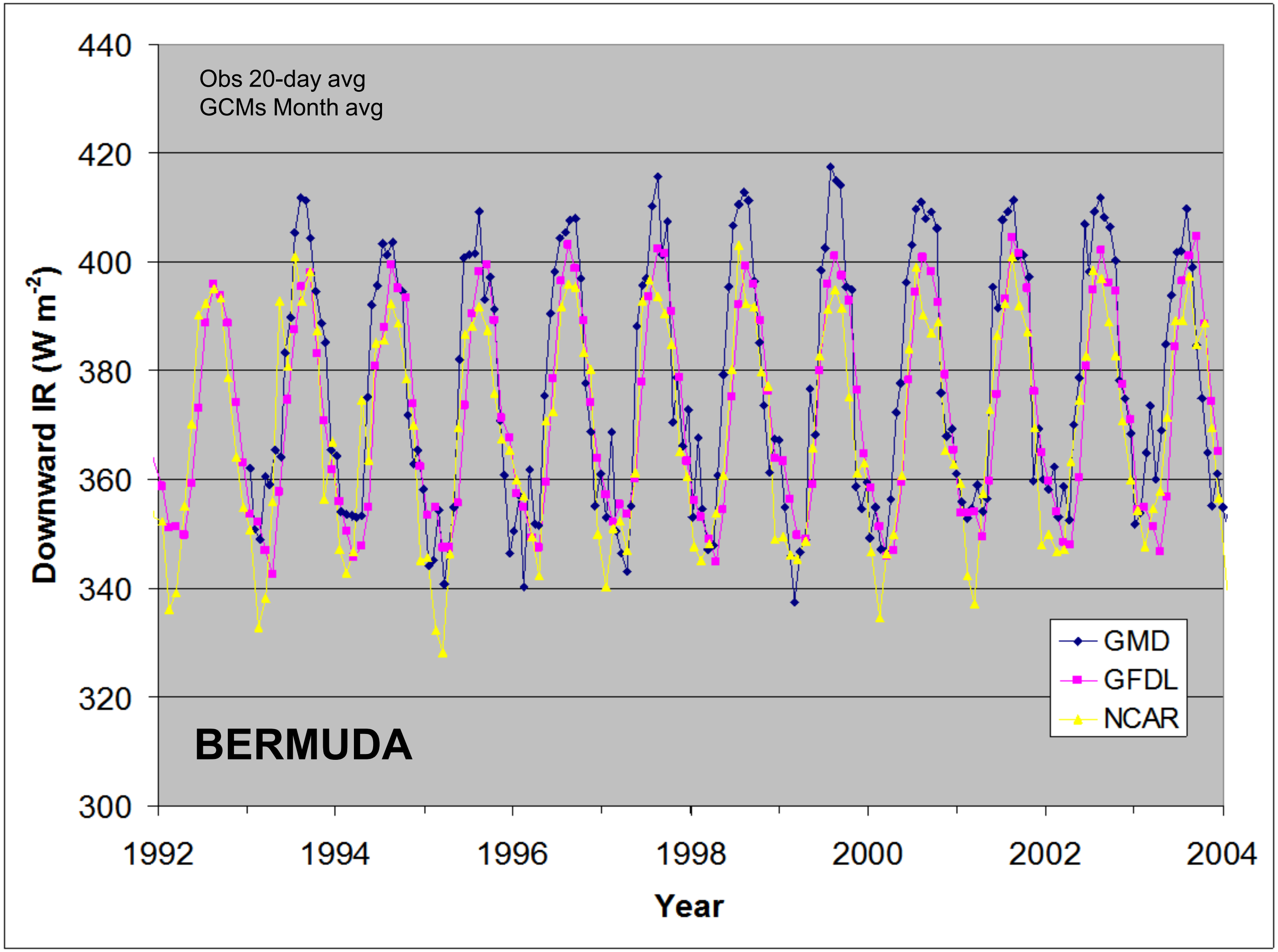
AFTER

GCM grid cell & GMD Obs averages 1993 – 2004 (W m^{-2})

	Barrow	Boulder (Erie)	Bermuda	Mauna Loa	Kwaj.	S. Pole	Global
CCSM	249.5	266.2	369.3	386.1	420.8	108.0	340
GFDL	243.5	289.1	372.1	390.3	420.9	107.2	338
ECHAM4	238.0	294.4	392.0	-	440.0	113.8	344
OBS	238.3	291.7	377.1	236.4	421.4	111.7	344

Within ~5 W m^{-2} of Obs

Surface IR observations and GCM output for grid box containing the site



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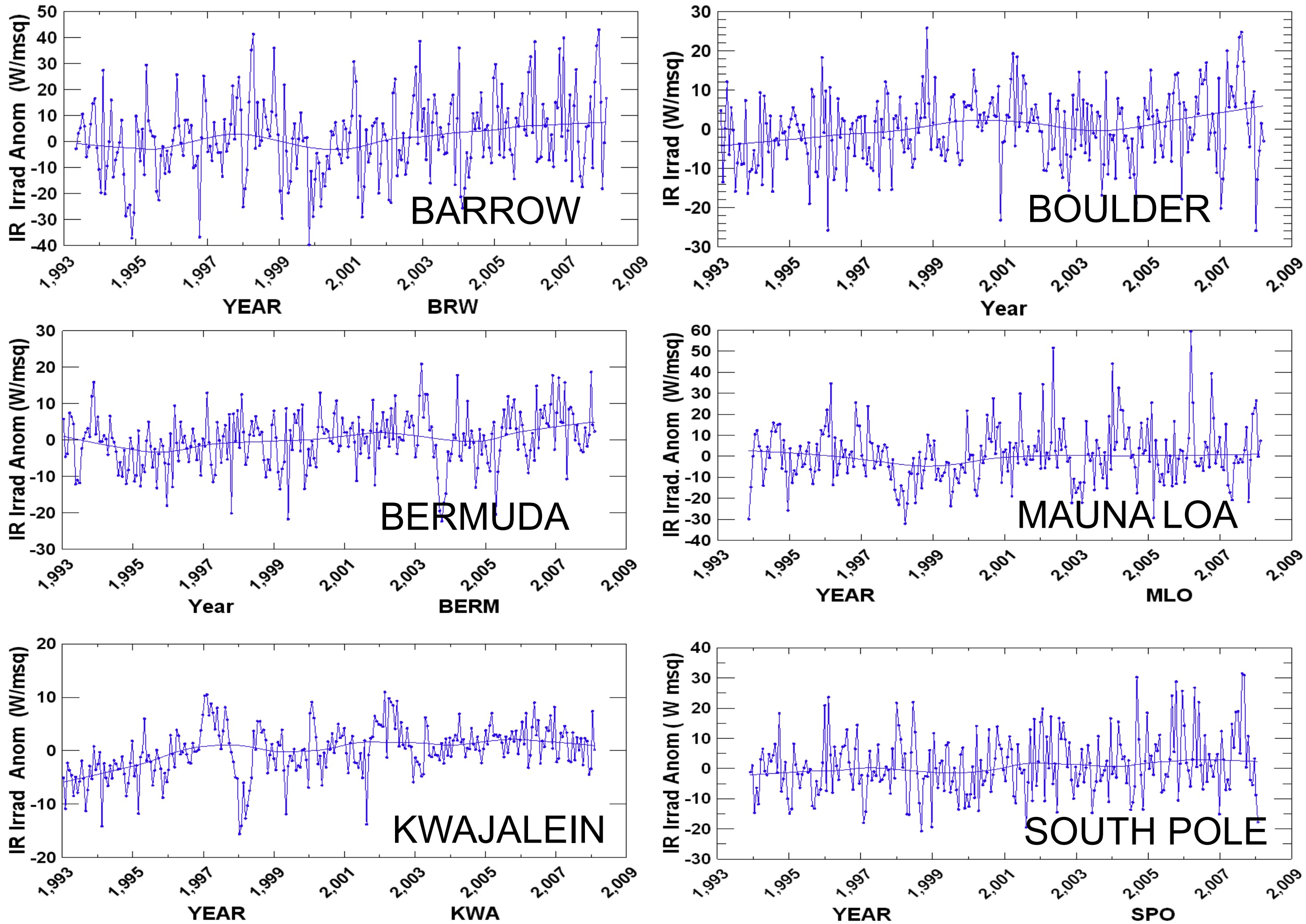
20-day Avg Desasonalized Surface IR Anomalies with Lowess Smoother (0.3)

ESRL-GMD Radiation Global Baseline Sites



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Linear Trend Detection Times

(required data set duration for detection, B. Weatherhead et al., '98)

Based on:

- Estimated variance
- Estimated autocorrelation (AR1)
- Expected trends

For the GMD deseasonalized IR data:

Detectable trend		Uncertainty range in number of required years
0.3 W m^{-2} dec^{-1}	→	70 to 220 years
2.0 W m^{-2} dec^{-1}	→	19 to 53 years
3.5 W m^{-2} dec^{-1}	→	13 to 35 years

Currently have ~15 years of GMD data - It's time to investigate!

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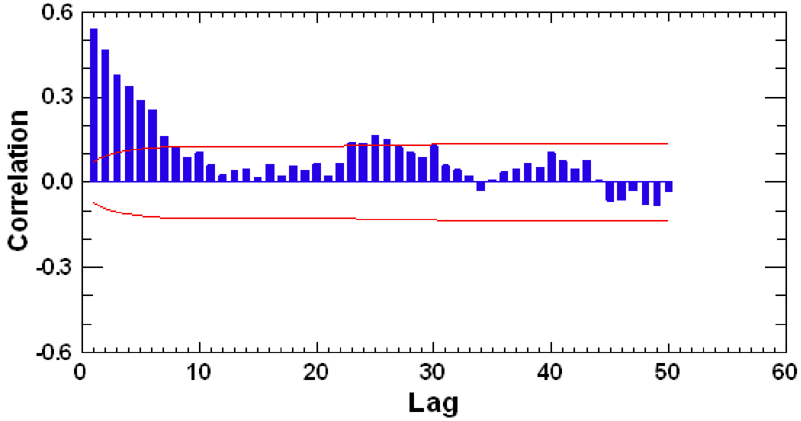
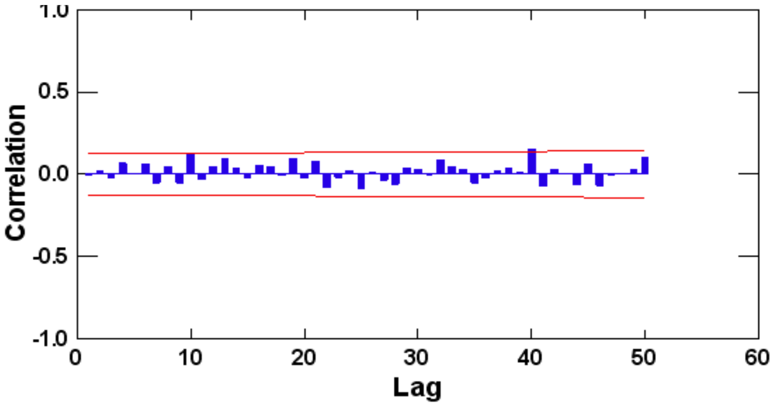
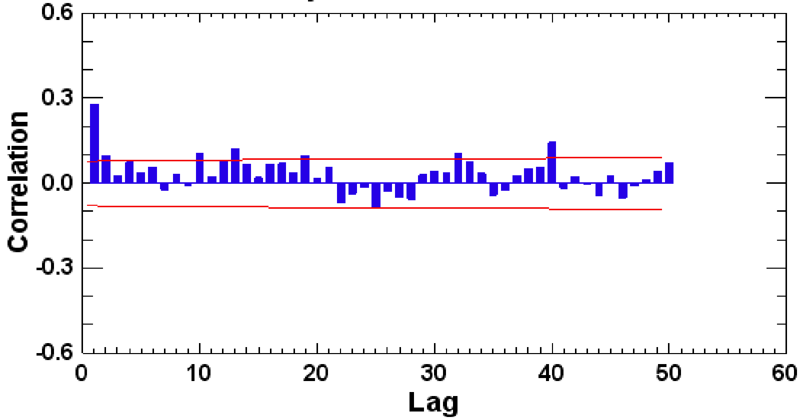
Autocorrelation Plot - KWAJ
20-day means



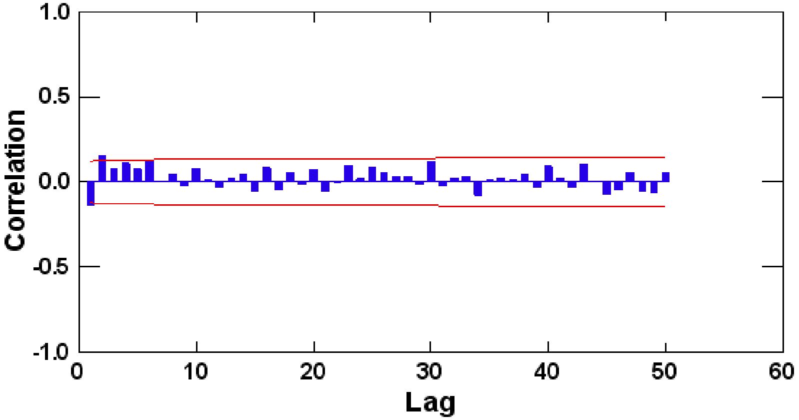
ARIMA (1,0,0) Residuals
Autocorrelation Plot Kwaj



Autocorrelation Plot - BRW
20-day means



ARIMA (1,0,0) Residuals
Autocorrelation Plot BRW



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Estimated Observed Changes in Surface Downward IR

DESEASONIZED
AR1 Residuals
Linear trends

Method / Site	Regress	Mann-Kendall
BRW	5.3	5.2
BLD	3.2	3.4
BER	2.7	2.6
MLO	2.5	1.0
KWA	1.9	1.8
SPO	3.7	2.8
6AVG/SE 5AVG/SE	3.2/0.5 3.4/0.6	2.8/0.6 3.2/0.6

(W m^{-2} dec^{-1})

AVG_6 ~ 3.0 (0.6 SE) W m^{-2} dec^{-1}
AVG_5 ~ 3.3 (0.6 SE) W m^{-2} dec^{-1}

Not significant at 95% (MLO: grey cells)

Potentially significant at 95%, res uncorrlelated, normality tests good to marginal (green cells)
Avg Regress student's t = 2.8
Avg Mann-Kendall 95% minimum = 0.9 Wm^{-2} dec^{-1}
(SPO least sig.)

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SURFRAD (CONUS) initial results (Surface IR-down change W m^{-2} dec^{-1})

Method / Site	AR1 res Regress	AR1 res M-K
Ft Peck, Montana	**3.3**	**3.3**
Bondville, Illinois	**2.5**	**3.4**
Goodwin, Miss.	**3.4**	**2.8**

AVG = 3.1, Boulder (Erie) = 3.3

Overall estimate of observed surface downward IR trend based on average for five globally remote sites (1993-2008)

3.3 ± ~1.5 W m^{-2} dec^{-1}

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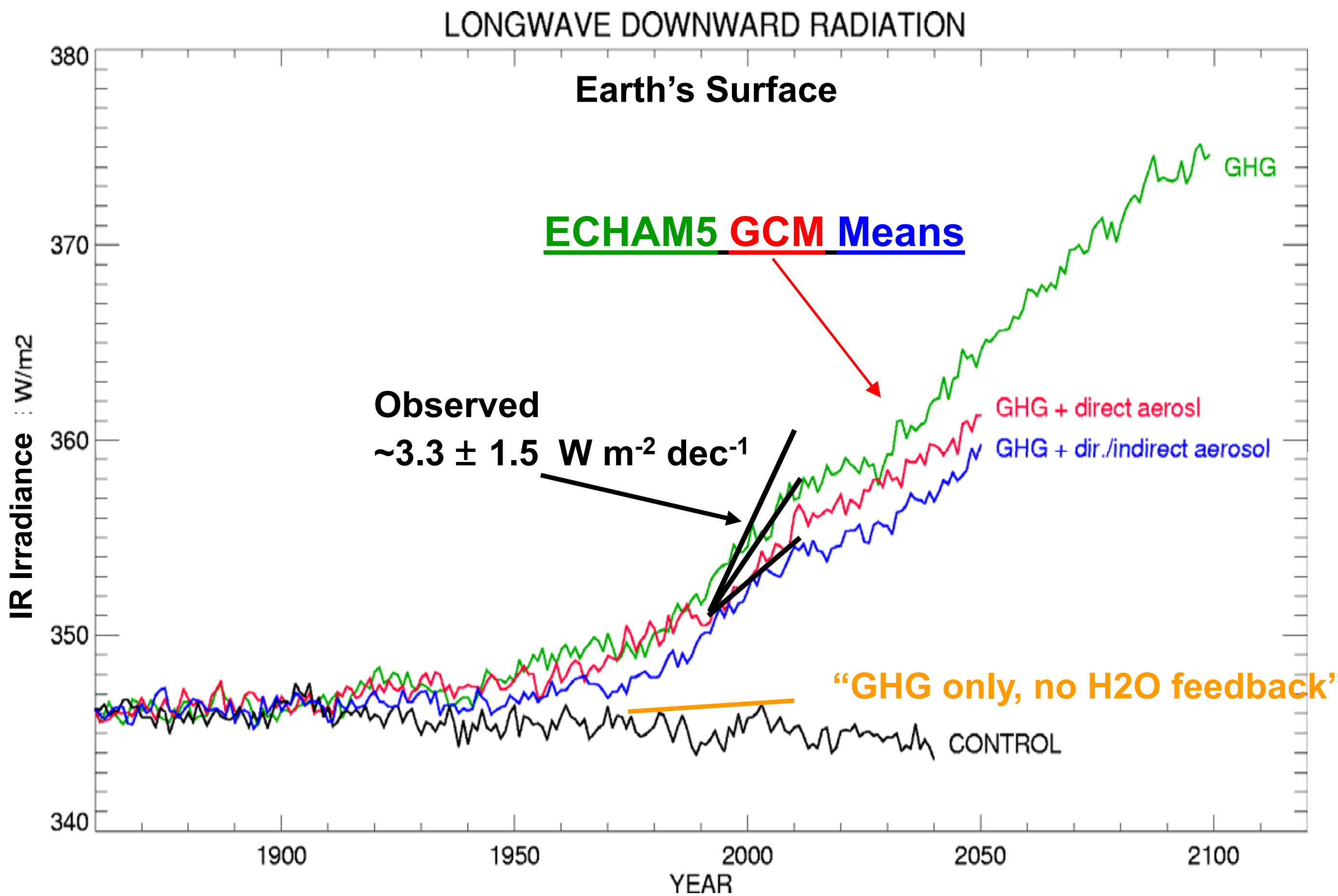

GCM results
Provided by
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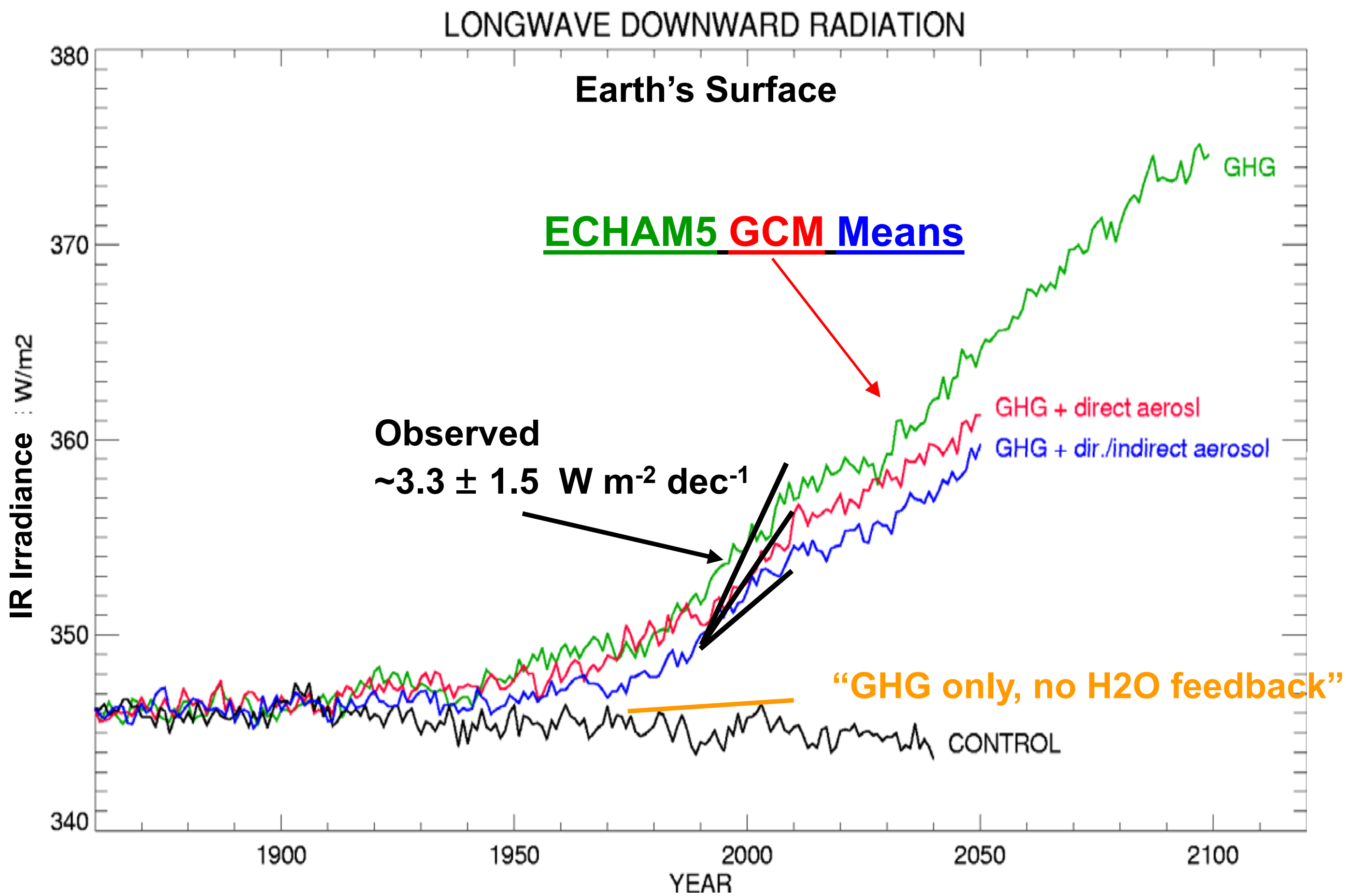

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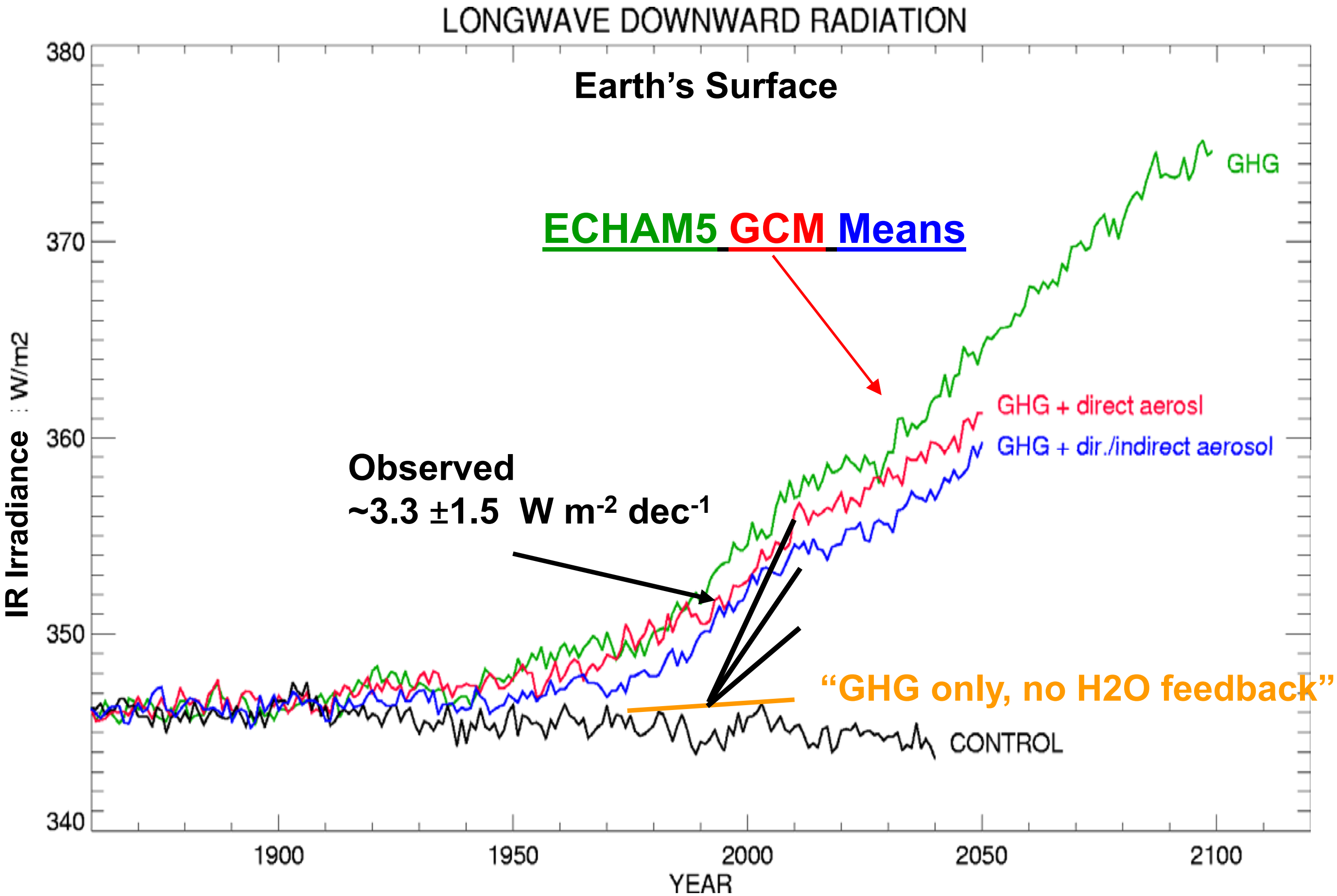

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Summary

- Using "best estimate" from GMD baseline data, surface IR growing near that predicted by GCMs
- Theoretical statistical estimates of trend detectability are marginally met.
- Maintaining calibration stability and extending the record are crucial
- Mauna Loa is not and should not show as certain a trend as other sites
- The somewhat higher than expected observed growth rates for 1993 – 2008, 3.3 vs 2.5, may be due to Pinatubo cooling recovery and is explicitly consistent with the GFDL fully-forced model run.

<u>Future plans</u>

- Continue and expand observational effort
- Extend analysis to existing but growing shorter data sets
- More detailed comparisons to fully-forced GCMs in a diagnostic mode
- Adequately determined IR climate could assist in assessing the validity and extent of multiple new and hypothesized feedback mechanisms

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