CAM4 Aerosol-Cloud-Climate Interactions

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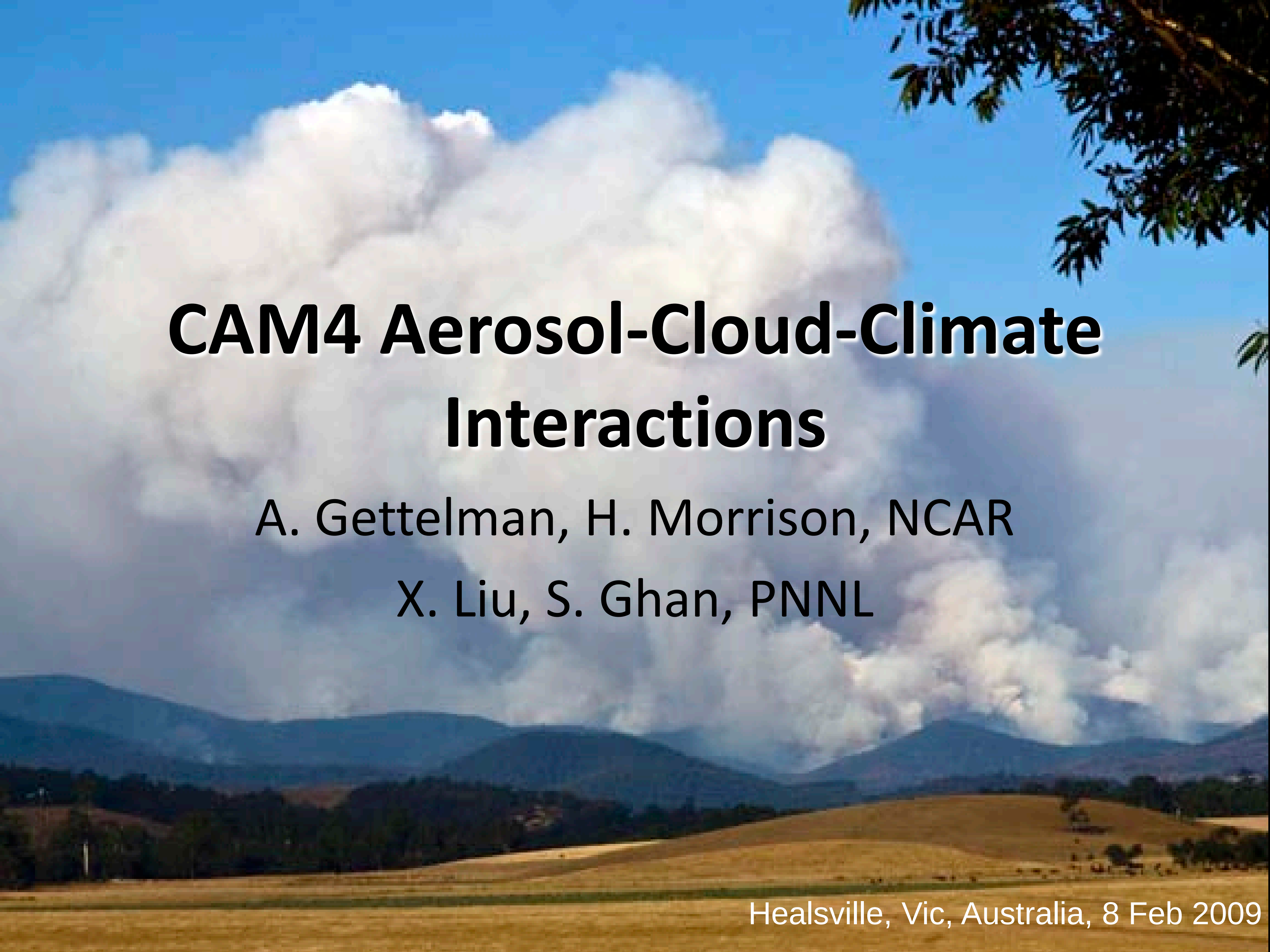

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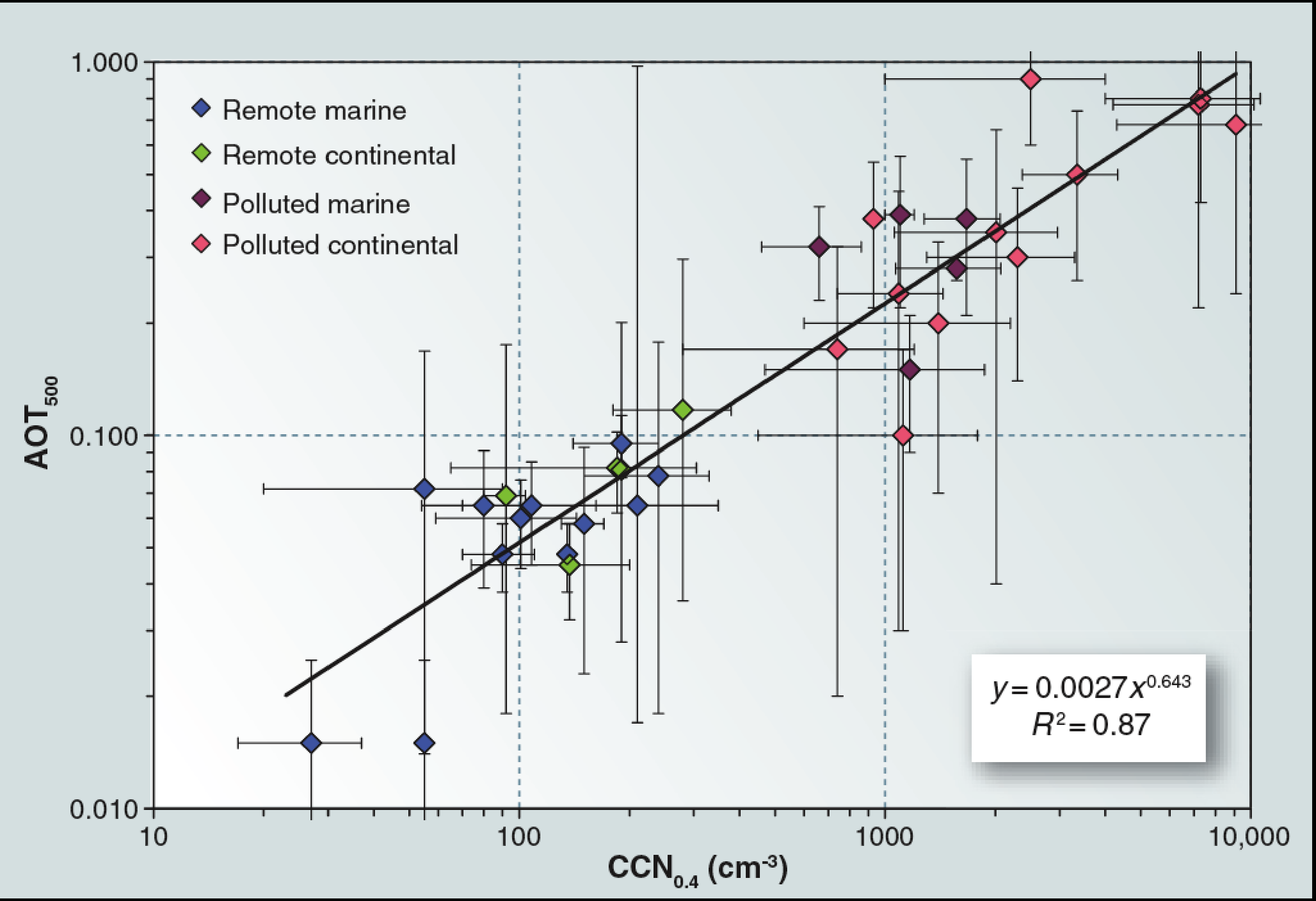
Outline

- Aerosols and Climate: Motivation
- Aerosol Model & Microphysics already discussed
- Description of Aerosol-Cloud interactions in CAM4
  - Liquid Clouds
  - Ice Clouds
- Aerosol-cloud-climate interactions results

CCN v. Aerosol Optical Thickness



Rosenfeld et al, Science 2008

Relevant CAM4 Configuration

- Morrison and Gettelman 2008 microphysics
  - 2-moment microphysics, droplet (liquid)
  - Ice super-saturation
- Modal Aerosol Model (3 mode)
- Droplet/Crystal Activation
  - Ice activation follows Liu et al 2007
  - Droplet activation: reformulate Abdul-Razzak and Ghan
- RRTMG Radiation code
  - Conley Aerosol-Radiation Interface
  - Conley Liquid Optics
  - Mitchell Ice Optics
  - [Aerosol Optics]
- IPCC AR5 Emissions for PI & PD (Lamarque)

Droplet Nucleation

- Reformulate droplet activation

  - modification to Abdul-Razzak and Ghan to allow regeneration of stratiform clouds every 3 hours

  - And/or add low bound on droplet number (10 or 20 cm^{-3})

Ice Indirect Effects: Science

- Ice does not form at RHi = 100%
- Significant Supersaturation is required
- Ice Nucleating Aerosols (Ice Nuclei or IN) can change the supersaturation
- So: More IN -> some are better IN
  - Freezing at lower supersaturation
  - Some crystals form earlier -> FEWER crystals
- Ice AIE can work the opposite way!

Ice Nucleation

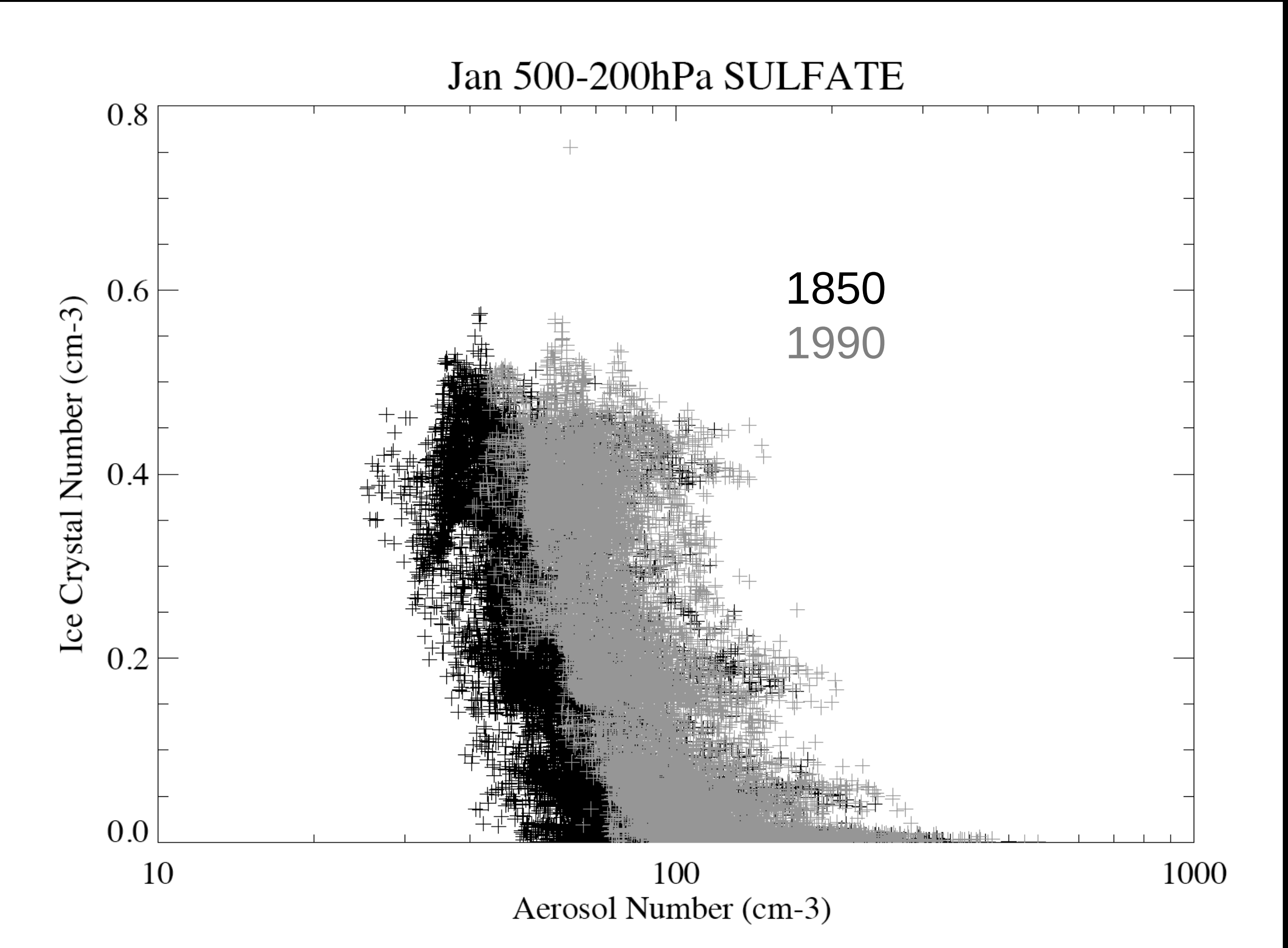
- Allow ice super-saturation
  - Ice does not form at RHi = 100% (super-sat required)
  - Ice Nuclei (IN) can change the super-saturation
- Add ice nucleation (Liu et al 2007)
  - Homogenous, Heterogenous Nucleation
    - Dust, Sulfate. Black carbon (soot) turned off
  - Based on parcel model
- Note: More IN -> some are better IN
  - Freezing at lower super-saturation
  - Some crystals form earlier -> FEWER crystals
- Ice AIE can work the opposite way from liquid!

Ice nucleation effect: Opposite Liquid

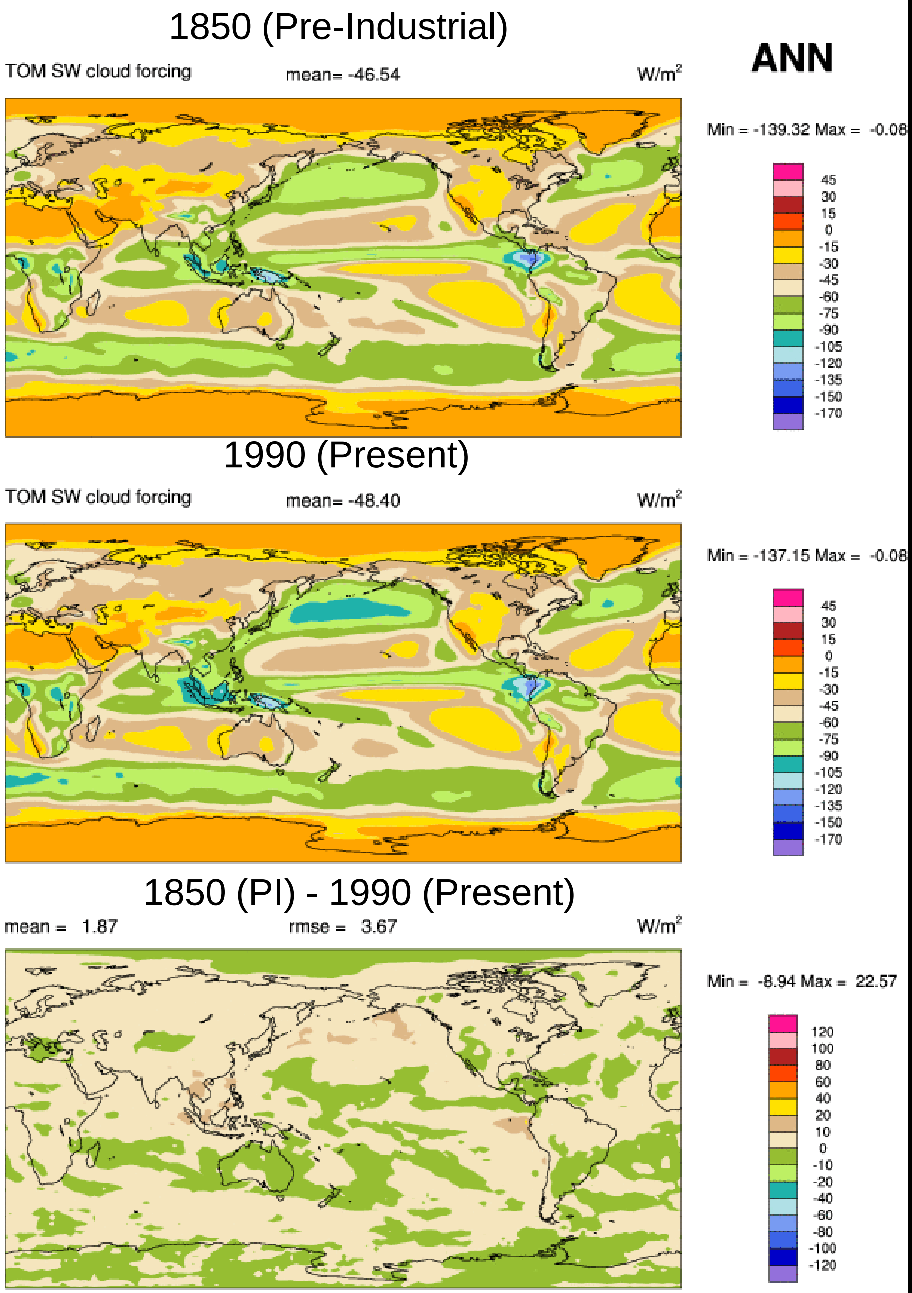
Crystal # decreases as Aerosol # increases

Heterogenous nucleation at lower S_{ice}

Impact mostly
Seen in longwave
(liquid effects
mostly shortwave)



Aerosol Indirect Effect



1990-1850:

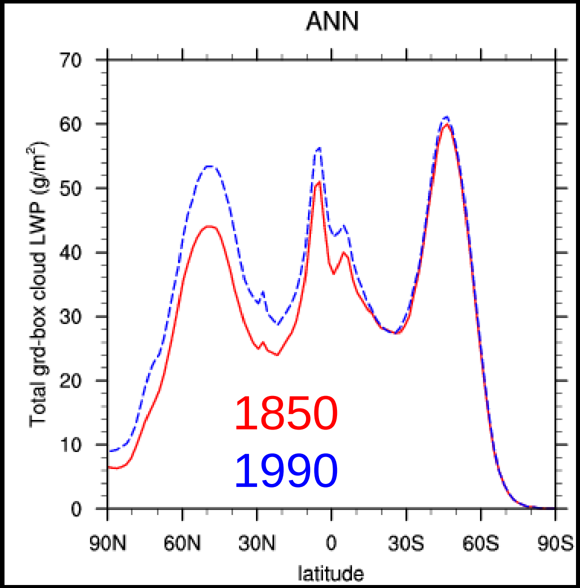
dTOA = -1.8 W/m2

AIE = -1.3W/m2

d(SWCF) (pd-pi) =-1.8

d(LWCF) =0.5

d(LWP) =+4.0 (g/m2) (10%)



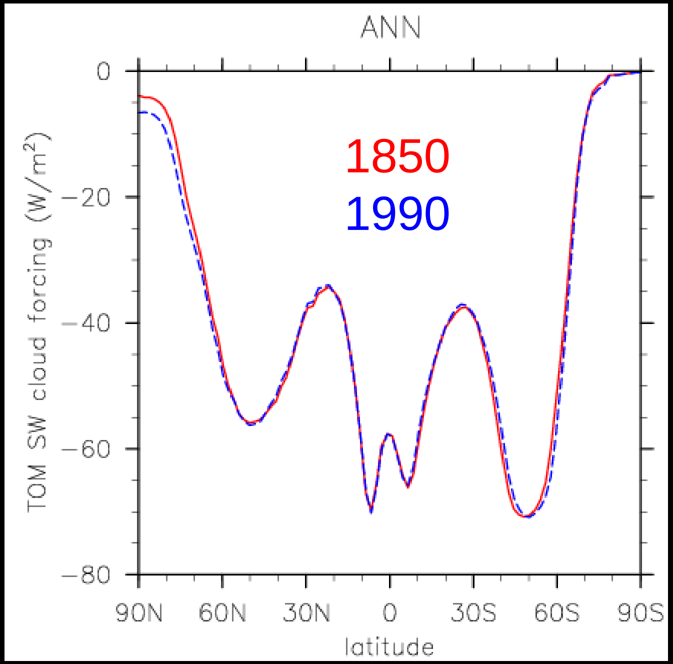
Experiment Description	Num	AIE
Base	u33	AIE = -2.2 W/m2 d(SWCF) (pd-pi) = -3.2, d(LWCF) = 1.0, d(FSNTC) = -0.44, d(LWP) = 4.9
Min CDNC = 20/cm3	u34	AIE = -2.0 W/m2 d(SWCF) (pd-pi) = -2.8, d(LWCF) = 0.83, d(FSNTC) = -0.3, d(LWP) = 3.8
Modify Drop Activation	u37	AIE = -1.4 W/m2 d(SWCF) (pd-pi) = -2.3, d(LWCF) = 0.86, d(FSNTC) = -0.36, d(LWP) = 3.2
Coupled model tuning	u49	AIE = -1.6W/m2 d(SWCF) (pd-pi) =-2.4 , d(LWCF) =0.8 , d(FSNTC) =-0.35 , d(LWP) = 3.3
IPCC Emissions	u50b	AIE = -1.2W/m2 d(SWCF) (pd-pi) =-1.9 , d(LWCF) =0.7 , d(FSNTC) =-0.6 , d(LWP) = 2.9
Better Ice Cloud Fraction	u60	AIE = -1.0W/m2 d(SWCF) (pd-pi) =-1.36 , d(LWCF) =0.37 , d(FSNTC) =-0.55 , d(LWP) = 2.6
PDF Liquid clouds	u66	AIE = -0.9W/m2 d(SWCF) (pd-pi) =-1.34 , d(LWCF) =0.48 , d(FSNTC) =-0.51 , d(LWP) =2.5
Retune ice nucleation	u67	AIE = -0.6W/m2 d(SWCF) (pd-pi) =-0.87 , d(LWCF) =0.27 , d(FSNTC) =-0.3 , d(LWP) = 2.2
Retune for coupled	u98b	AIE = -0.8W/m2 d(SWCF) (pd-pi) =-1.1 , d(LWCF) =0.3 , d(FSNTC) =- , d(LWP) =
Drop limiter = 10/cm3	u98	AIE = -1.25W/m2 d(SWCF) (pd-pi) =-1.75 , d(LWCF) =0.5 , d(FSNTC) =- , d(LWP) =
Remove Drop Limiter (=0)	u83	AIE = -1.5W/m2 d(SWCF) (pd-pi) =-2.1 , d(LWCF) =0.6 , d(FSNTC) =-0.58 , d(LWP) = 4.3
Latest good coupled run	u110	AIE = -1.3W/m2 d(SWCF) (pd-pi) =-1.8 , d(LWCF) =0.5 , d(FSNTC) =- , d(LWP) =

Radiative Forcing Perturbation (RFP)

Coupled Simulations: Aerosols + GHGs

Results from 2 coupled runs years 40-50

- Increase in LWP (broader)
- 1K Global Warming
- RES TOA: +0.5W/m2
  ~Right perturbation
- dSWCF=0, except Arctic (ice)
- dLWCF similar to Aerosol only
- Why?
  - SW Cloud Feedbacks
  - LW effects similar



Summary

- AIE about – 1 to -1.5 W/m2
- Direct effects about -0.5 W/m2
- RFP Pre-Industrial -> Present is +0.5W/m2
  - "About Right"
- Present day AODVIS ~ 0.12
- Sensitivity to aerosol emissions not consistent
  - Still looking at details of formulations
- LW effects of ice important
- Cloud feedbacks may compensate for aerosols