Geosci. Model Dev. Discuss., 5, 1–65, 2012
www.geosci-model-dev-discuss.net/5/1/2012/
doi:10.5194/gmdd-5-1-2012

Geoscientific Model Development Discussions

The Norwegian Earth System Model, NorESM1-M – Part 2: Climate response and scenario projections

T. Iversen[1,2,*], M. Bentsen[3,4], I. Bethke[3,4], J. B. Debernard[1], A. Kirkevåg[1], Ø. Seland[1], H. Drange[4,5], J. E. Kristjánsson[2], I. Medhaug[5,4], M. Sand[2], and I. A. Seierstad[1]

Received: 26 July 2012 – Accepted: 6 August 2012 – Published:

Correspondence to: T. Iversen (trond.iversen@met.no)

Published by Copernicus Publications on behalf of the European Geosciences Union.

EarthClim

All Staff
Olavsgaard
29-30 Aug 2012

Climate sensitivity estimates

Some definitions

- **Equilibrium Climate Sensitivity (ECS):**
  change in global mean near-surface air temperature, ΔT,

  when a new climate equilibrium ($\Delta R=0$ at TOA) is reached after an abrupt increase in atmospheric CO2 concentrations introduced to a climate in equilibrium.

Some definitions

- Approx ECS by slab ocean:

  ΔT_{eq}

  Difference in global mean near-surface air temperature between two runs of a slab-ocean global climate model with different atmospheric CO2 concentrations

Some definitions

- Approx ECS by slab ocean:

  ΔT_{eq}

  Difference in global mean near-surface air temperature between two equilibrium runs of a slab-ocean global climate model with different atmospheric CO2 concentrations

  For CCSM4 (Bitz et al, J Climate 2012) and 2xCO2:

  1 degree resolution: 3.20 K

  2 degree resolution: 3.13 K

  CAM3-Oslo with slab ocean (Kirkevåg et al, 2008) and 2xCO2

  2 degree resolution: 3.14 K

Some definitions

- Approx ECS by regression and extrapolation:
  ΔT_{reg}
  Gregory et al. (2004) :

  linear regression between annual $\Delta R(t)$ and $\Delta T(t)$ during adjustment after the abrupt CO2-increase.

  assumes negligible contributions from time-varying feedbacks.

  – The slope of the regression is the feedback parameter $\lambda = - d\Delta R/d\Delta T$;
  – the intercept at $\Delta T=0$ approximates the instantaneous forcing R_f,
  – the intercept at $\Delta R=0$ is ΔT_{reg}

Some definitions

- Approx ECS by the effective climate sensitivity:
  ΔT_{eff}
  Murphy (1995) :

$$\Delta T_{eff}(t) = \frac{\Delta T(t) R_f}{R_f - \Delta R(t)}$$

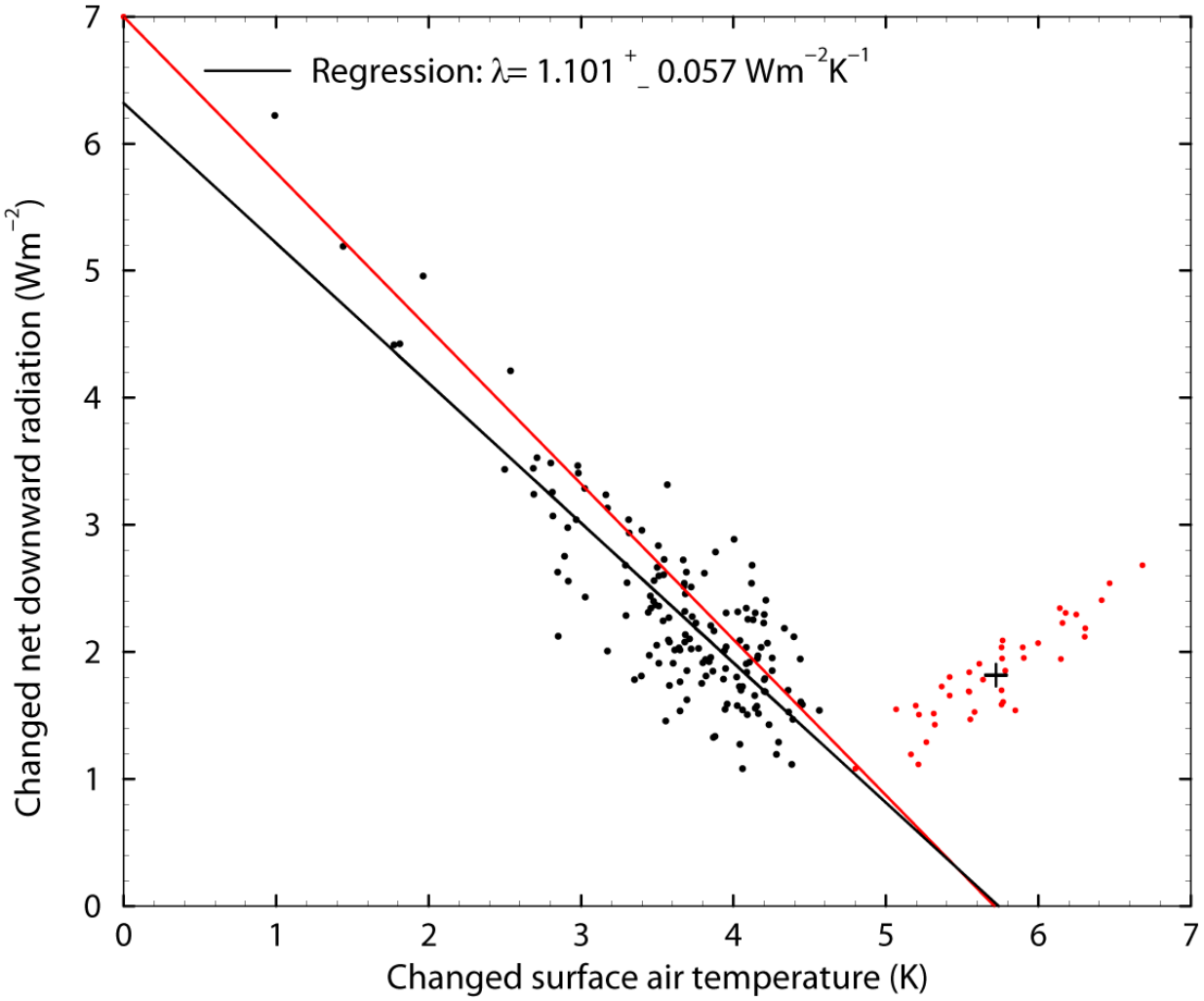
Some definitions

- **Transient Climate Response (TRC):**
  change in global mean near-surface air temperature, ΔT_{TRC},
  evaluated over years 60-80 after a gradual 1% per year increase in atmospheric CO2 concentrations starting from a climate in equilibrium.

CMIP5 experiments

- ”Abrupt 4xCO2” from pre-industrial (1850) CO2, run for 150 years.
  - Devide by two for the standard values for doubling.
- ”Gradual 4xCO2” with 1% CO2 increase per year until quadrupling.
  - Statistics taken out for years 60-80, representing doubling of CO2.

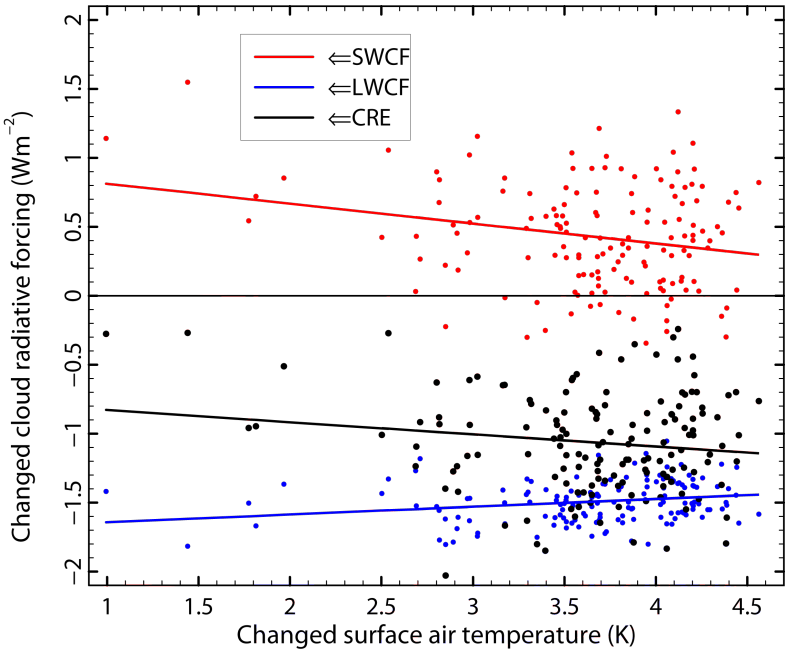
ΔT_{reg}=5.74 K and ΔT_{eff}=5.71 K



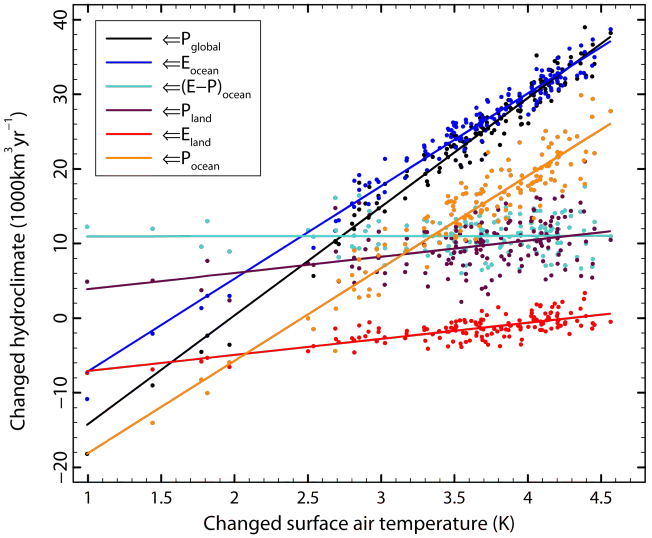
ΔT_{TRC}= 1.39 K (CCSM4: 1.72 K)

Gross Feedbacks

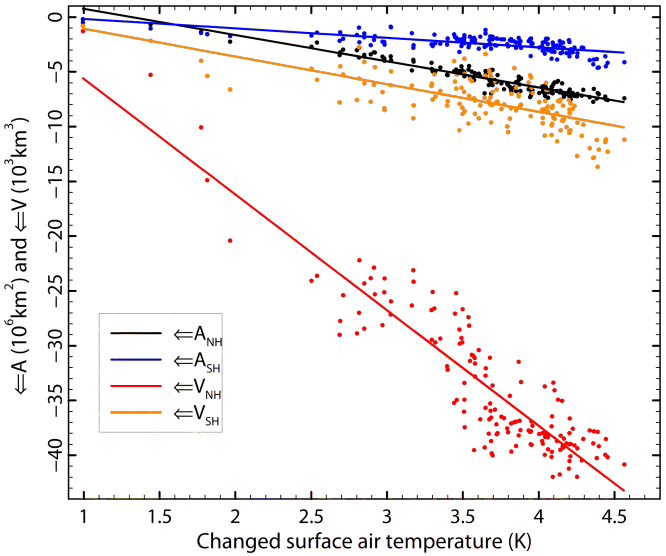
Cloud Radiative Effects



Atmospheric Hydrology



Sea-ice



Sensitivity and gross feedbacks

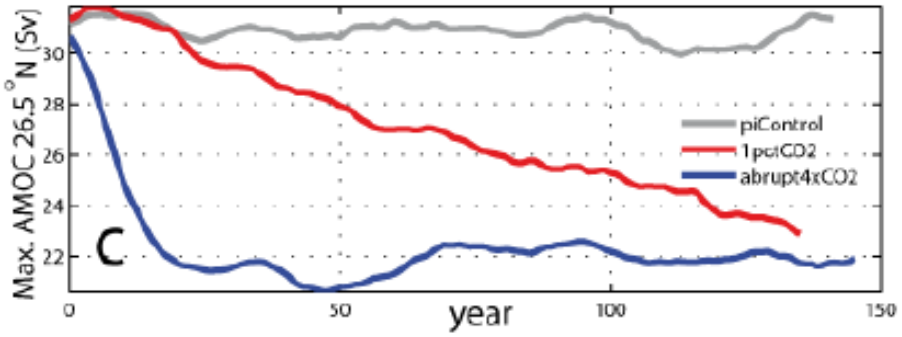
	ΔT_{eq} K	ΔT_{eff} K	ΔT_{reg} K	R_{f_reg} Wm^{-2}	λ_{reg} $Wm^{-2}K^{-1}$	ΔT_{TCR} K	$\Delta T_{TCR,eff}$ K
NorESM1-M 2 deg	not calc.	2.86	2.87	3.16	1.101	1.39	2.32
CCSM4, 1 deg.	3.20	2.78	2.80	2.95	1.053	1.72	2.64

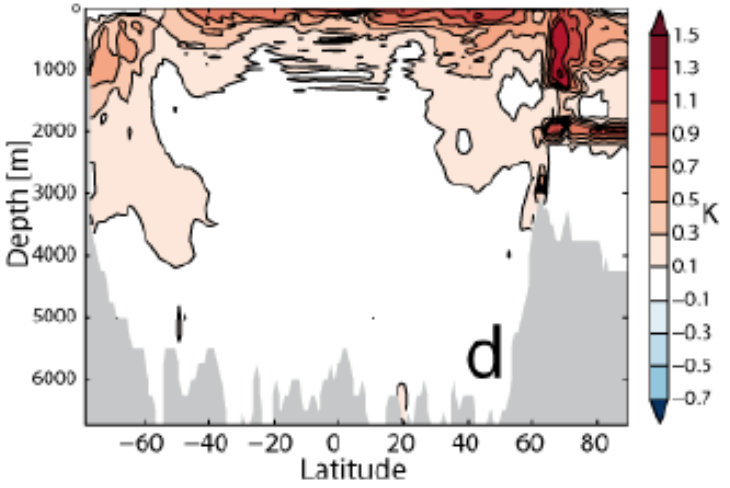
	$\lambda_{LWAllsky}$ $Wm^{-2}K^{-1}$	$\lambda_{SWAllsky}$ $Wm^{-2}K^{-1}$	$\lambda_{LWclearsky}$ $Wm^{-2}K^{-1}$	$\lambda_{SWclearsky}$ $Wm^{-2}K^{-1}$	λ_{LWCF} $Wm^{-2}K^{-1}$	λ_{SWCF} $Wm^{-2}K^{-1}$	λ_{CRE} $Wm^{-2}K^{-1}$
NorESM1-M 2 deg	-1.80	+0.70	-1.86	+0.84	+0.06	-0.15	-0.09

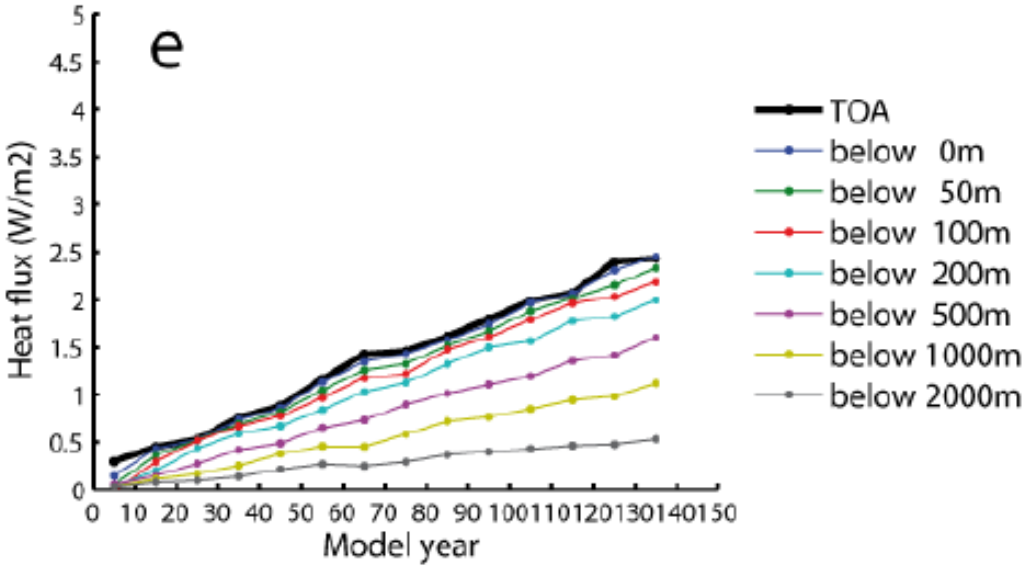
	$\lambda_{P\text{-}GLOB}$ $10^3km^3K^{-1}$	$\lambda_{E\text{-}OCEAN}$ $10^3km^3K^{-1}$	$\lambda_{P\text{-}OCEAN}$ $10^3km^3K^{-1}$	$\lambda_{(E\text{-}P)\text{-}OCEAN}$ $10^3km^3K^{-1}$	$\lambda_{E\text{-}LAND}$ $10^3km^3K^{-1}$	$\lambda_{P\text{-}LAND}$ $10^3km^3K^{-1}$
NorESM1-M 2 deg	14.58	12.42	12.40	+0.02 (- 0.29 – +0.32)	2.16	2.18

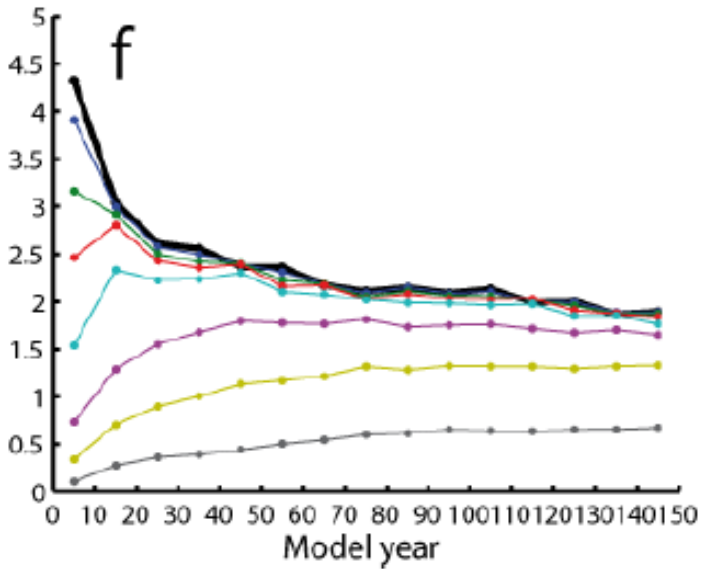
	$\lambda_{AREA\text{-}NH}$ $10^6km^2K^{-1}yr^{-1}$	$\lambda_{VOL\text{-}NH}$ $10^3km^3K^{-1}yr^{-1}$	$\lambda_{AREA\text{-}SH}$ $10^6km^2K^{-1}yr^{-1}$	$\lambda_{VOL\text{-}NH}$ $10^3km^3K^{-1}yr^{-1}$
NorESM1-M 2 deg	-2.39	-10.55	- 0.86	-2.52

Deep ocean heat sink: slow feedback



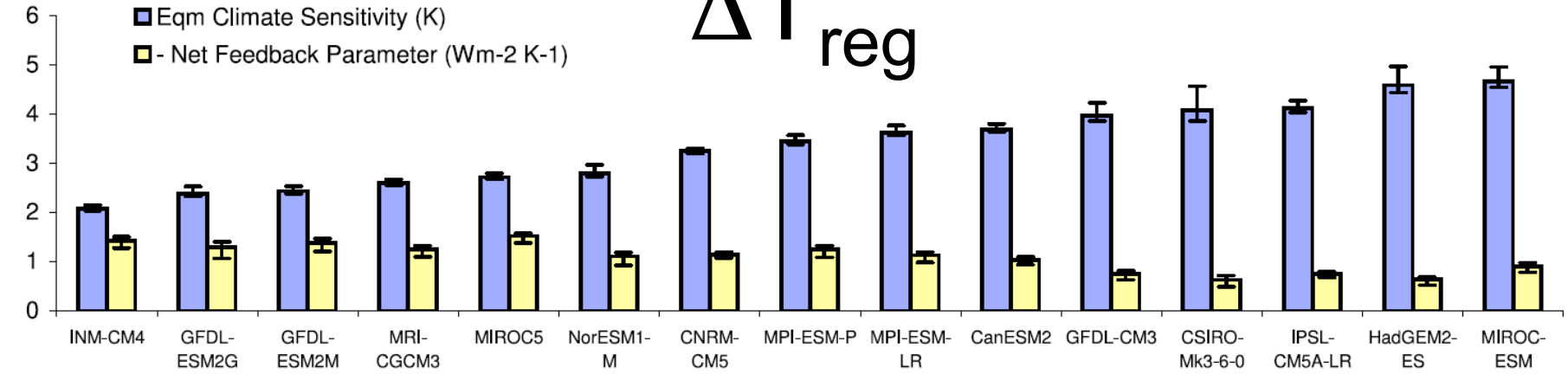


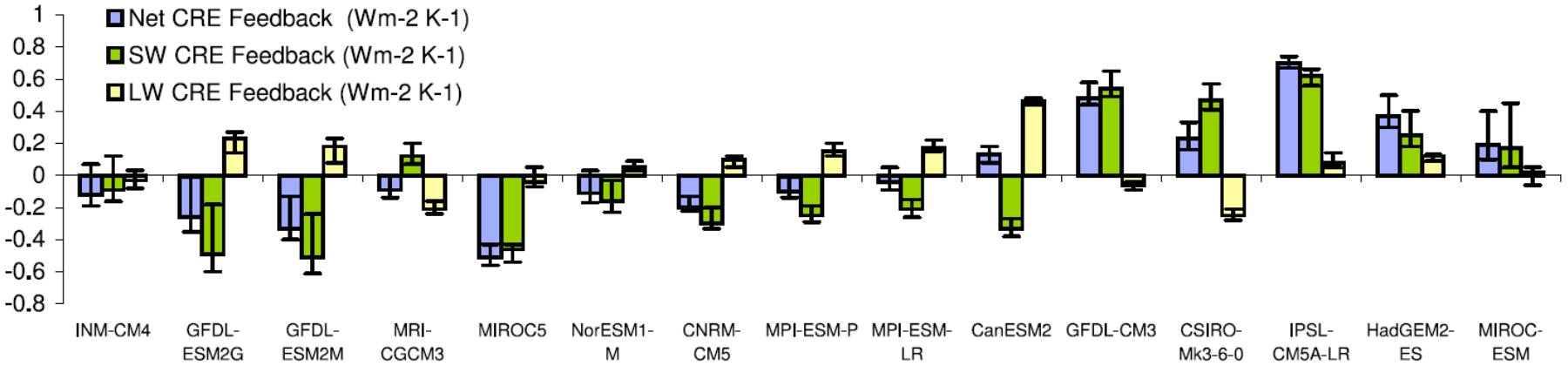




Comparisons (Andrews et al, 2012)

ΔT_{reg}





Concluding Remarks

- NorESM1-M: ECS-estimates are amongst smaller of the CMIP5-models (Andrews et al, 2012)
- Clouds in NorESM tend to dampen the response (negative gross feedback)
- Whilst ECS-estimates are close to CCSM4 (~2.9K),
  the TRC (~1.4K) is considerably smaller than CCSM4 (~1.7K)
- This can be related to the strong AMOC in NorESM.
  Since AMOC slowly reduces the estimated TRC is probably an under-estimate of the long-term sensitivity
- Global precipitation: ~ 2.7 %/K