Towards tailored radiation parametrizations for mesoscale NWP models?

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Physical parametrisations

With contributions by
Kristian Pagh Nielsen, DMI

SRNWP – EWGLAM meeting
Tallinn, 10-13 October 2011

Explanations ...

A: This is not a review, but an introduction + view for discussion

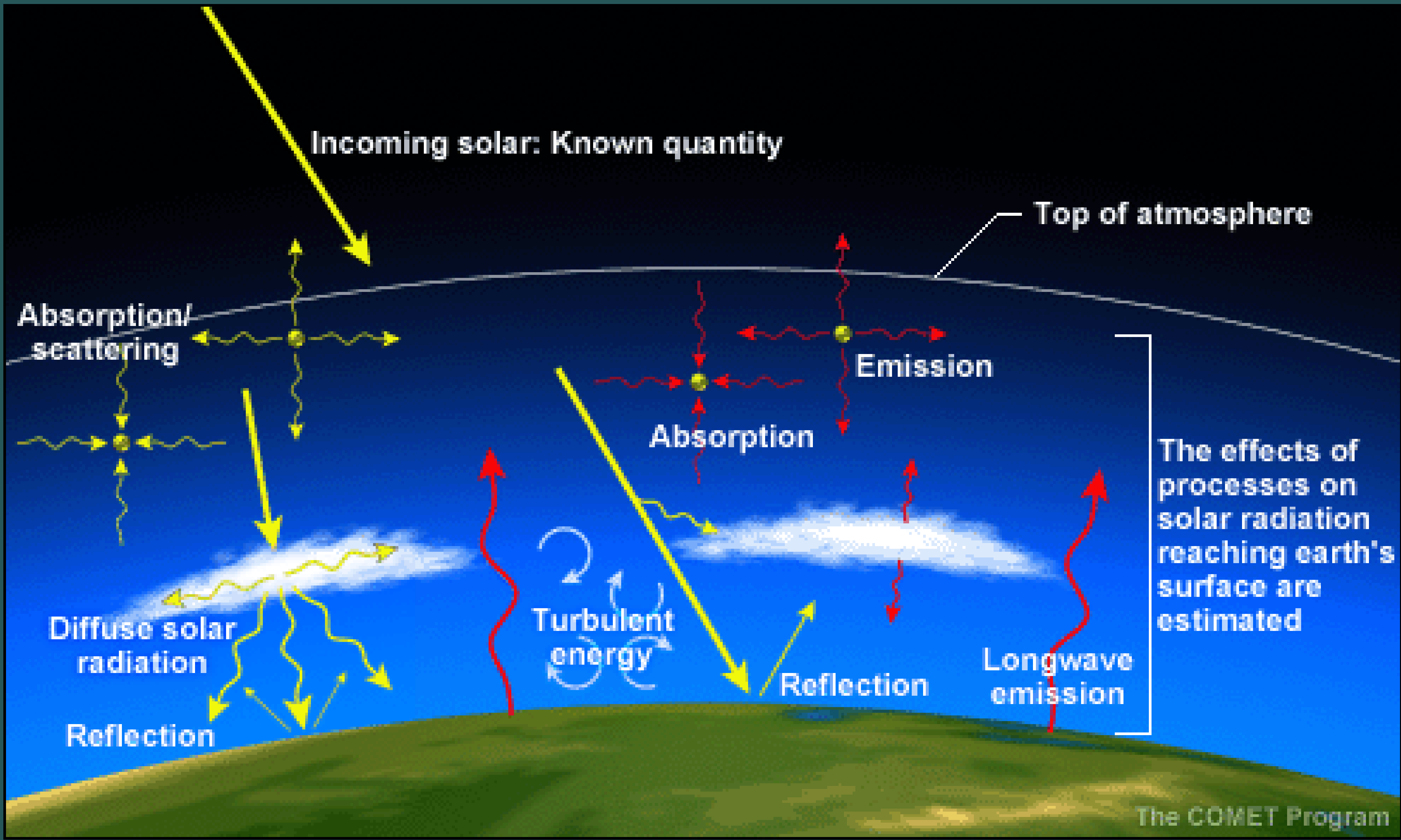
B: HARMONIE means

HIRLAM – ALADIN Research for Meso-scale Operational NWP In Europe

- both cooperation and a NWP system

In this presentation

Purpose of radiation parametrizations
What is parametrised
Radiation in different atmospheric models
HARMONIE radiation schemes
Future developments


Incoming solar: Known quantity
Top of atmosphere
Absorption/ scattering
Emission
Absorption
The effects of processes on solar radiation reaching earth's surface are estimated
Diffuse solar radiation
Turbulent energy
Reflection
Longwave emission
Reflection
The COMET Program

RADIATIVE HEATING IN THE ATMOSPHERE:

A SOURCE TERM IN THERMODYNAMIC EQUATION

$$\left(\frac{\partial T}{\partial t}\right)_{\mathrm{rad}} = -\frac{g}{c_p}\frac{\partial \mathcal{F}}{\partial p}$$

Radiative heating as divergence of the net radiation flux,

RADIATION BALANCE AT THE SURFACE:

DOWNWELLING SWdn + ATMOSPHERIC LWdn

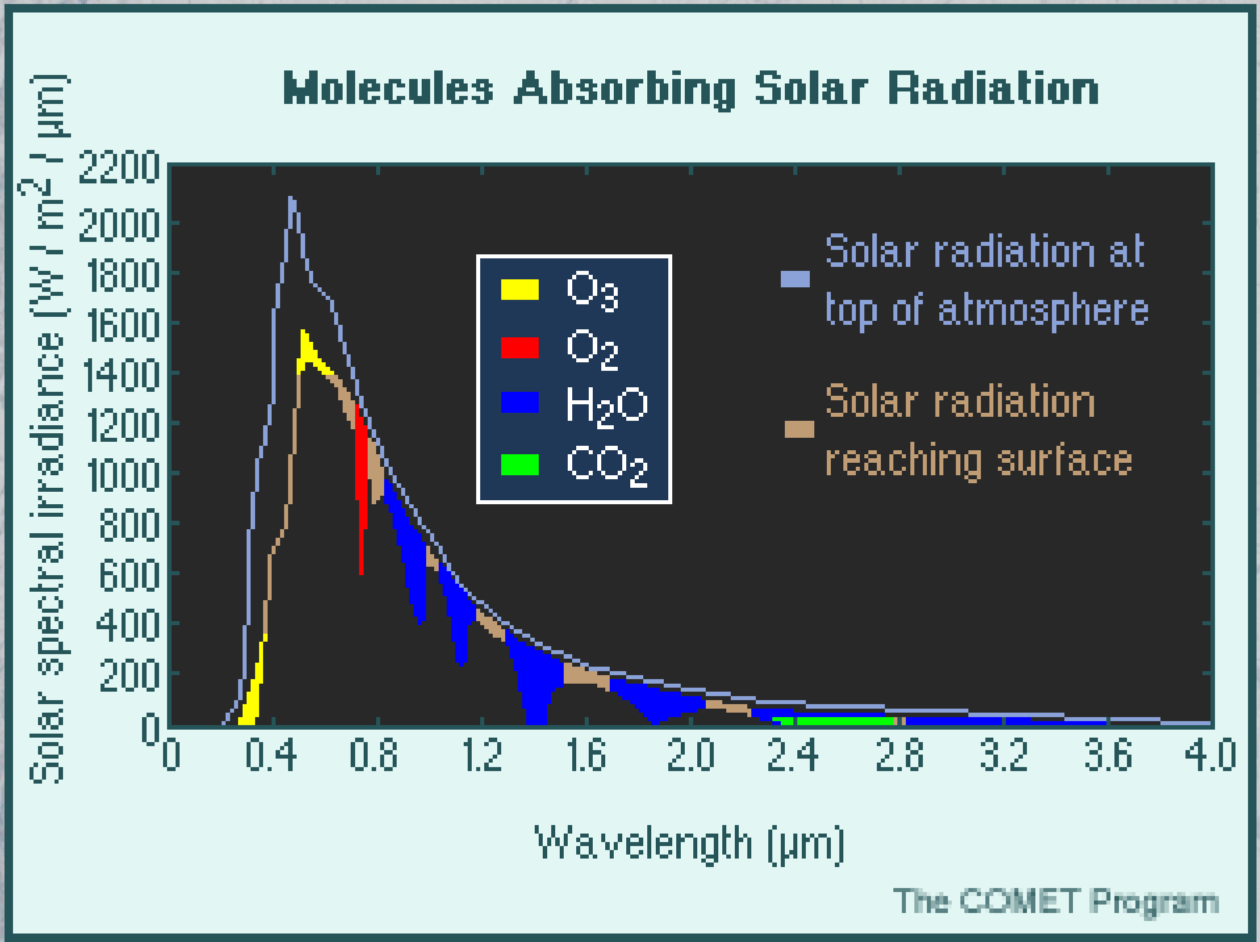
- REFLECTED SWup – LWup EMITTED BY SURFACE:

PART OF THE SURFACE ENERGY BALANCE

ATMOSPHERIC RADIATION

Gases

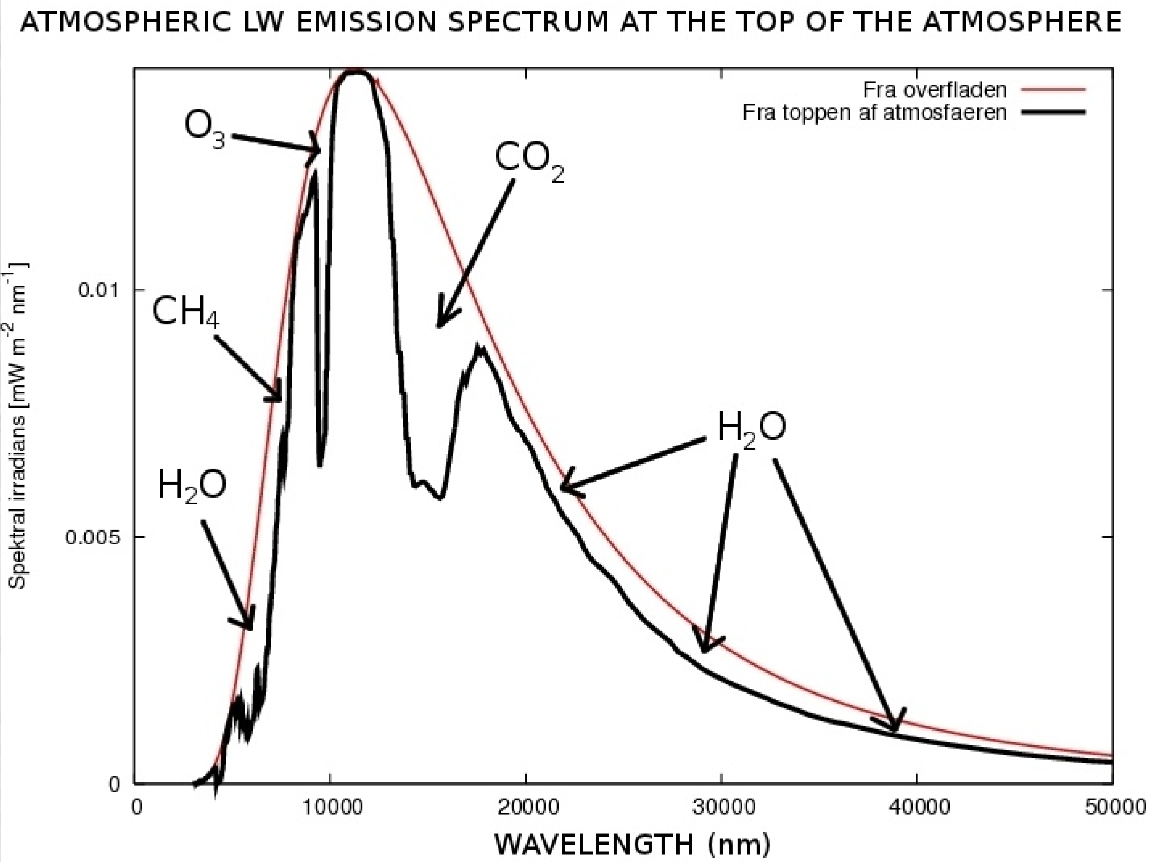
absorption and scattering of SW radiation



ATMOSPHERIC RADIATION

Gases

absorption and emission of LW radiation



Calculated with LIBTRAN
(Pierluissi et al. (1985); Stamnes et al. (1988); Richiazzi et al. (1998);
Mayer & Kylling (2005).

ATMOSPHERIC RADIATION

Clouds

absorption and emission of LW radiation

absorption and scattering of SW radiation

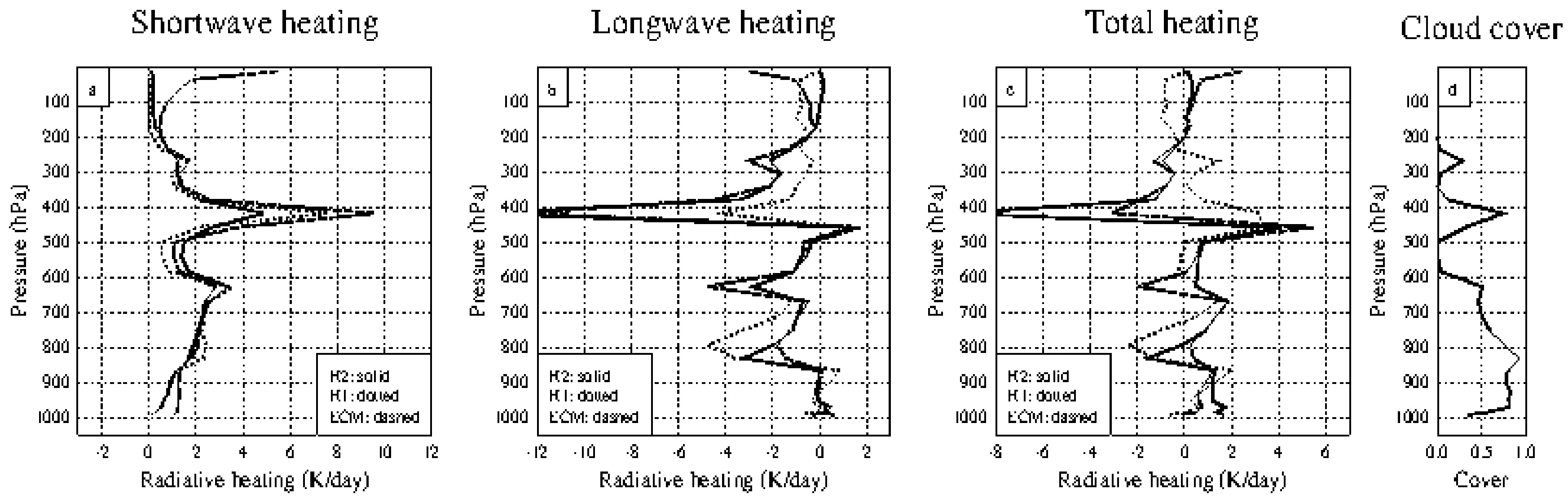
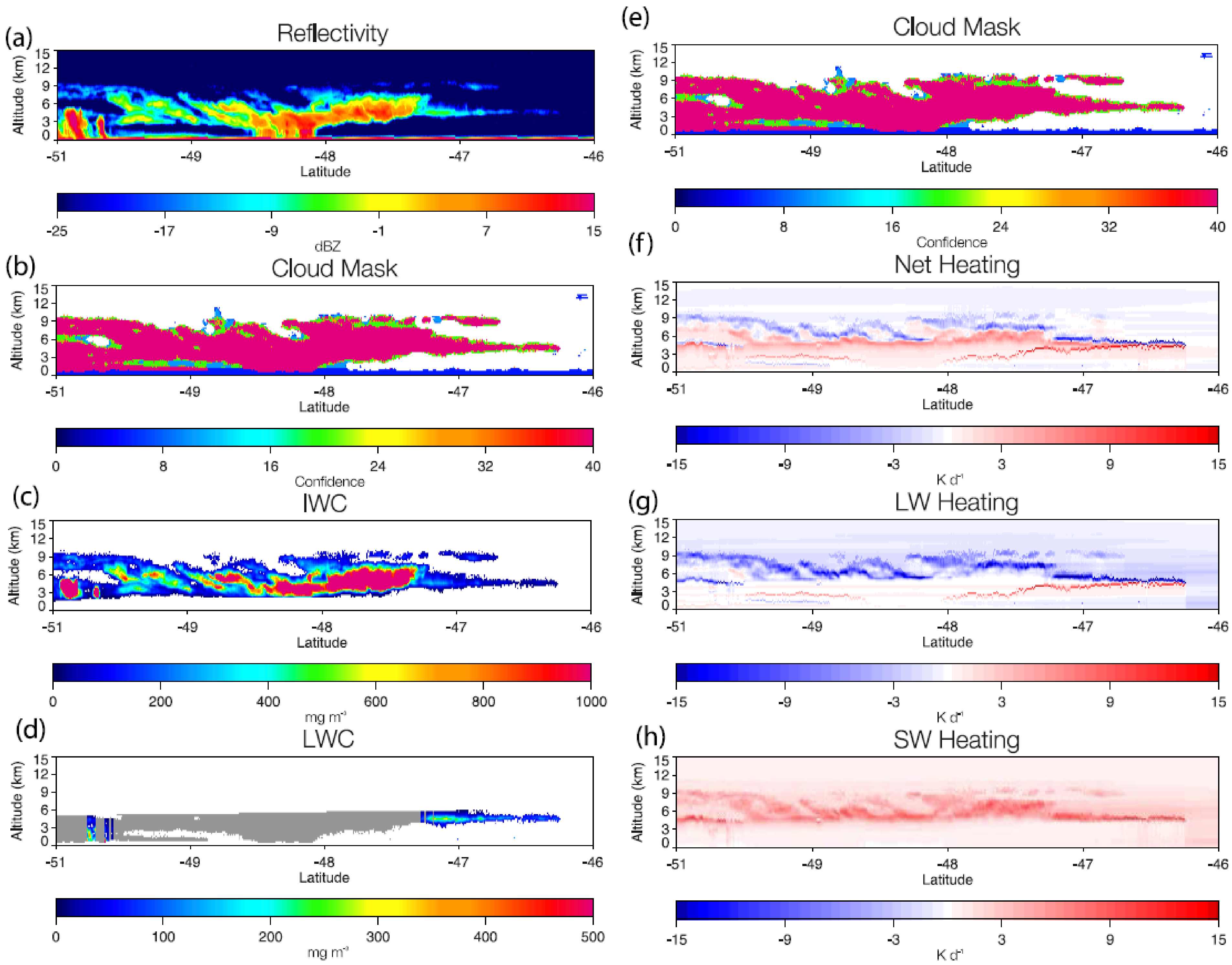


Fig.15. Radiative heating for St. Petersburg 15 Sep 1993. Shortwave (a) and longwave (b) radiative heating profiles given by the HIRLAM-2 ("H2"), the HIRLAM-1 ("H1") and the ECMWF ("ECM") radiation schemes. Mean profiles of temperature and humidity from three-dimensional HIRLAM-2 experiment from 15 Sep 00 UTC +6...12h. Solar TOA flux 1350 Wm^{-1}, zenith angle 58 deg, surface albedo 0.2. Diagnosed cloud cover (fraction from 0 to 1) is shown in (d). In the ECMWF run operational model drop size parametrization is used. Vertical resolution 31 levels.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, D00A15, doi:10.1029/2008JD009951, 2008



Classical vs physical cloud description

- Classical clouds:
  - Cloud cover in octas;
  - Low, medium, and high clouds;
  - Cloud types.
- 2-D physical cloud properties:
  - Integrated cloud water [kg m^{-2}];
  - Average effective cloud drop size, r_e, [μm];
  - Cloud top temperature [K];
  - Cloud bottom temperature [K].
- 3-D physical cloud properties:
  - Cloud water concentration [g m^{-3}];
  - Ice phase fraction [-];
  - Effective cloud particle size, $r_{e,wat}/r_{e,ice}$, [μm];
  - Detailed size distribution of cloud particles;
  - Detailed shape distribution of cloud particles.

MINISTRY OF CLIMATE AND ENE

ATMOSPHERIC RADIATION

Aerosol

scattering and absorption of SW radiation

absorption/emission and scattering of LW radiation

+ indirect effect via cloud microphysics

SURFACE-RADIATION INTERACTIONS

Surface albedo and emissivity variations: vegetation, water, snow, ice, desert …

Topography: elevation, slopes, valleys …

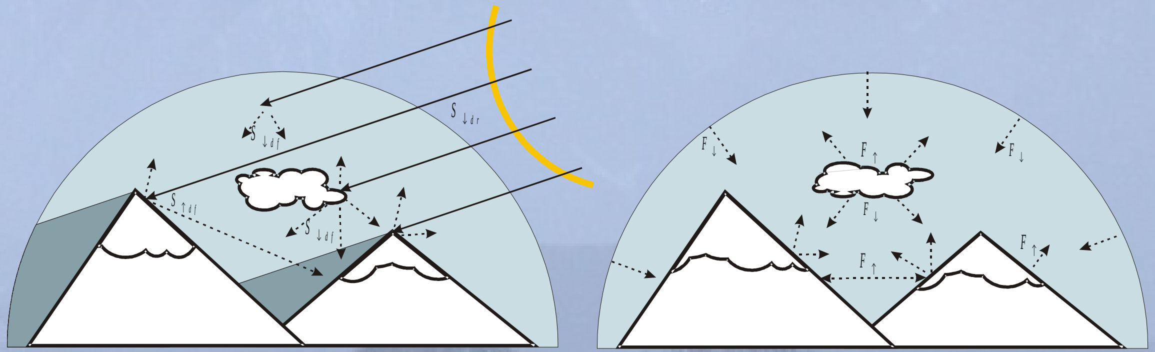
Long-wave radiation effects in the shallow stable boundary layer – temperature inversions, stratus and fog

Good physiography and surface analysis required

Orographic effects on radiation

Modification of downwelling LW and SW due to slopes and sky view

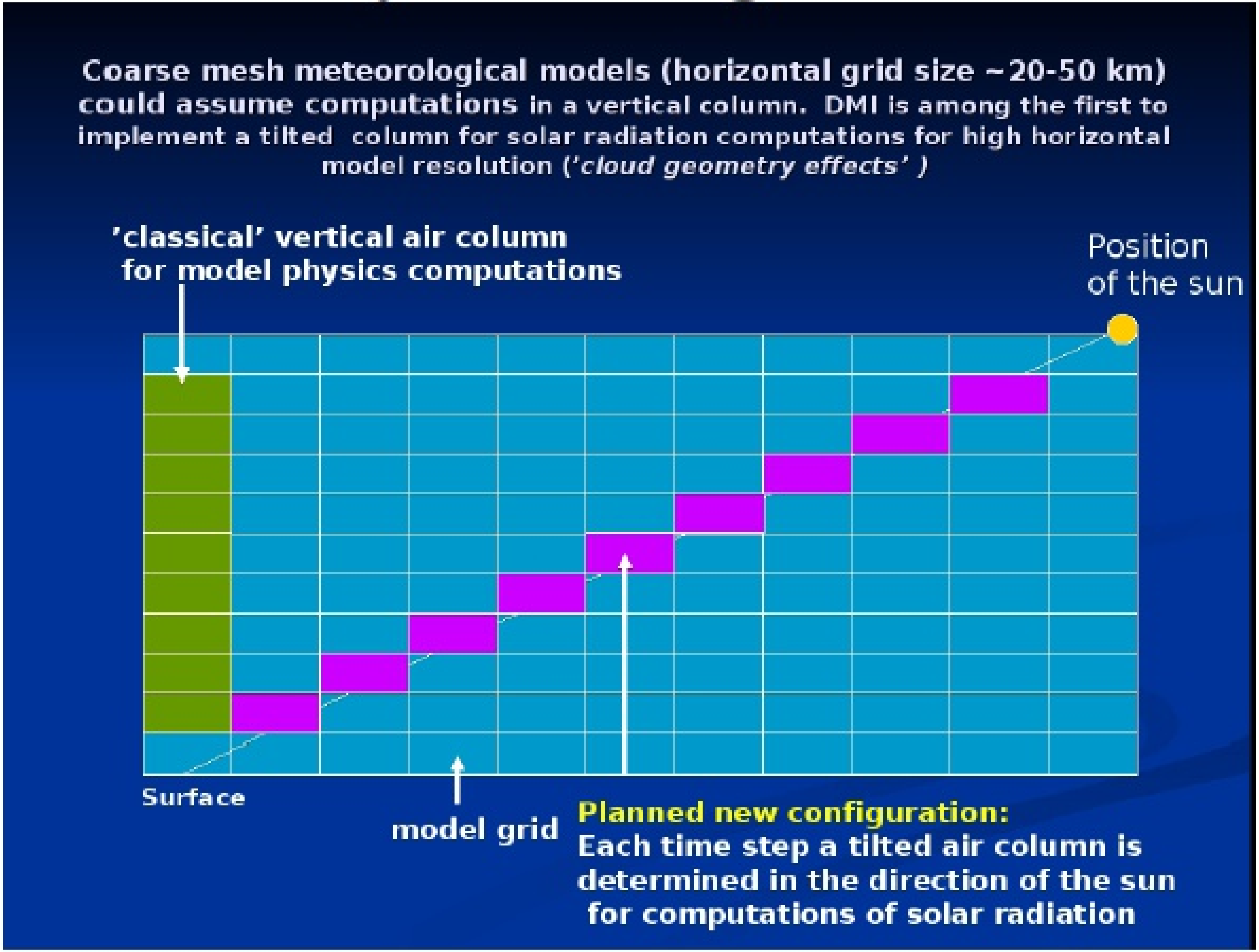
Consistent derivation of needed (subgrid-scale) orography variables



Operational in HIRLAM v. 7.4

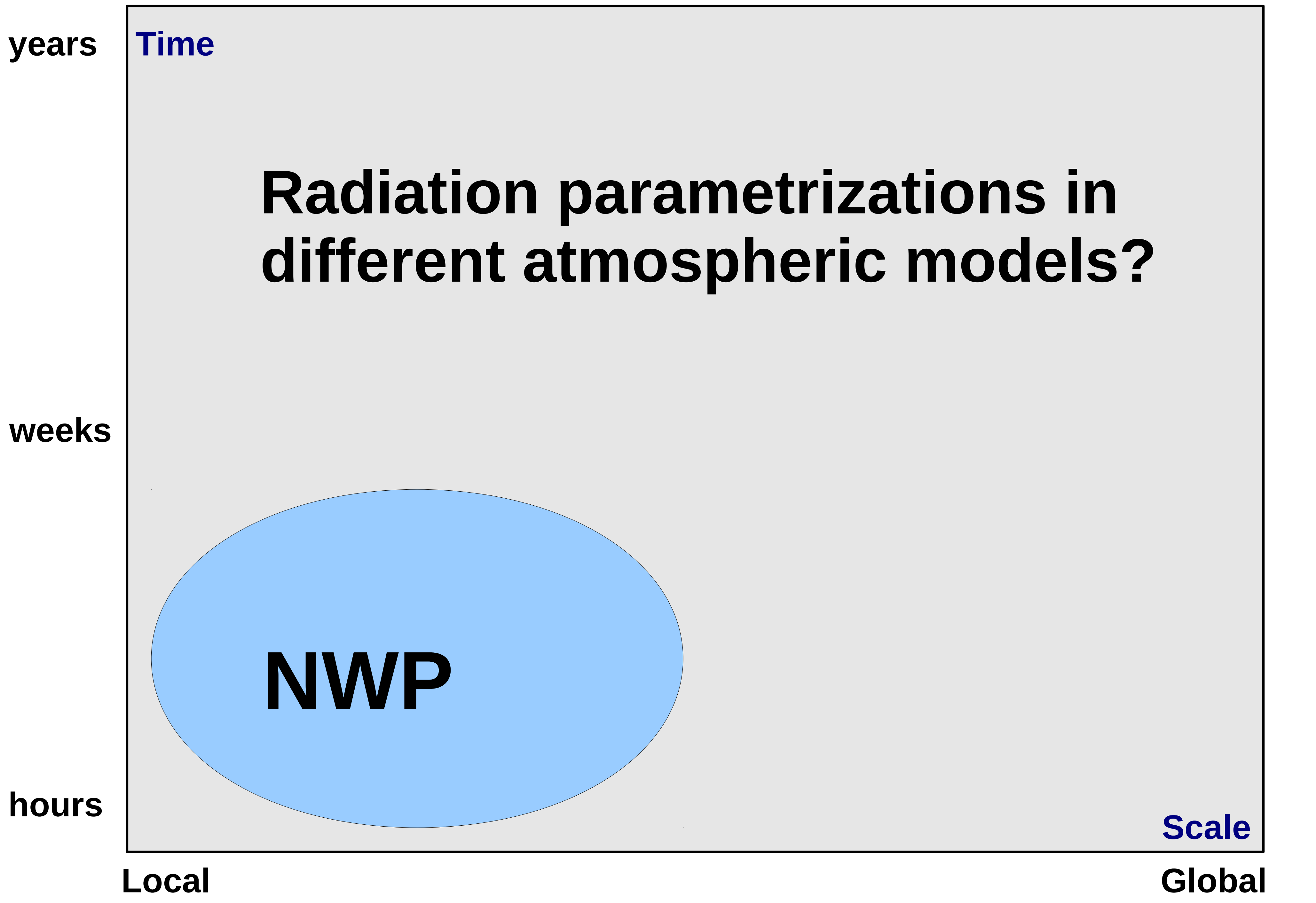
Anastasia Senkova and
Laura Rontu, 2007

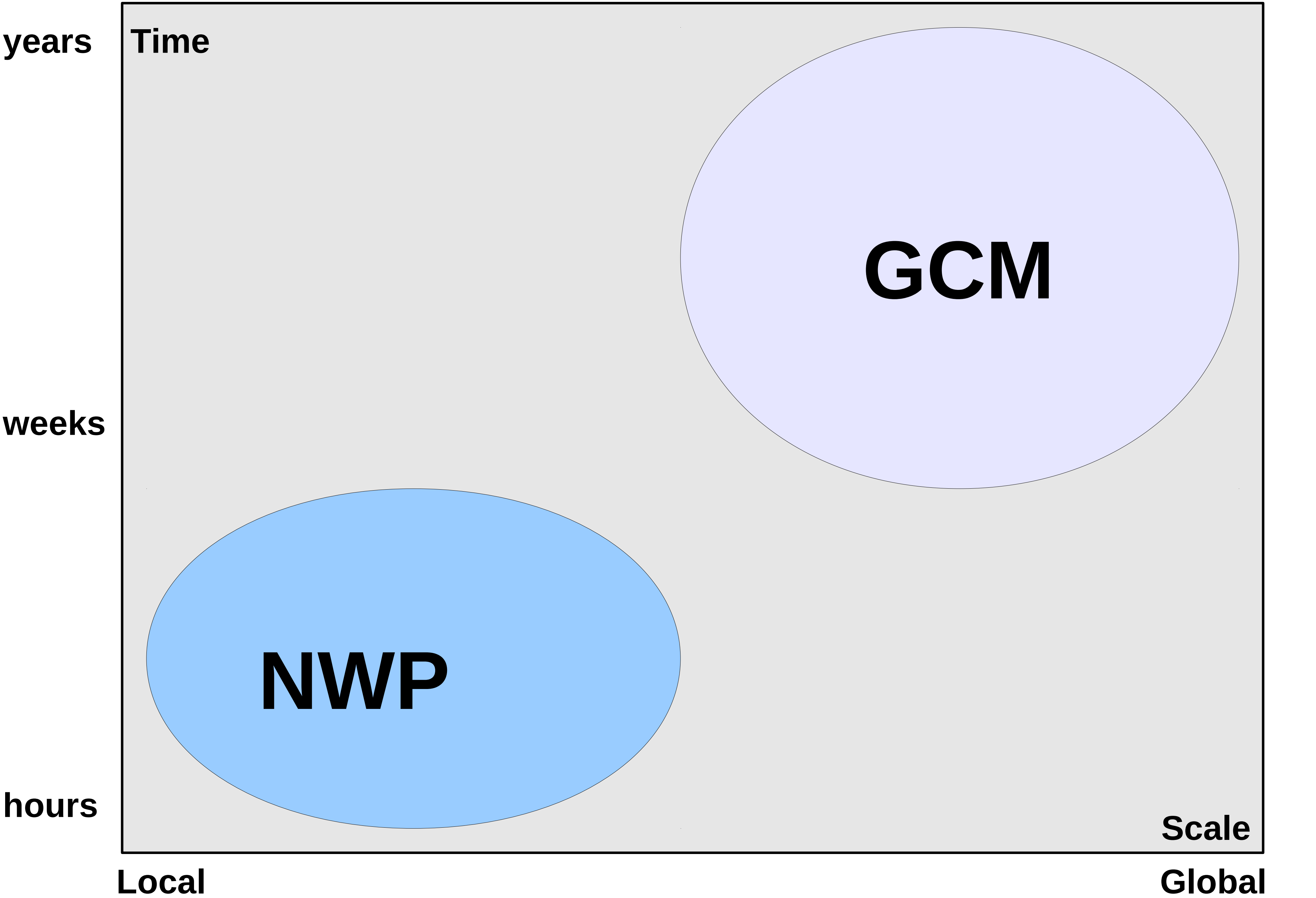
Tilted array modeling: Introduction

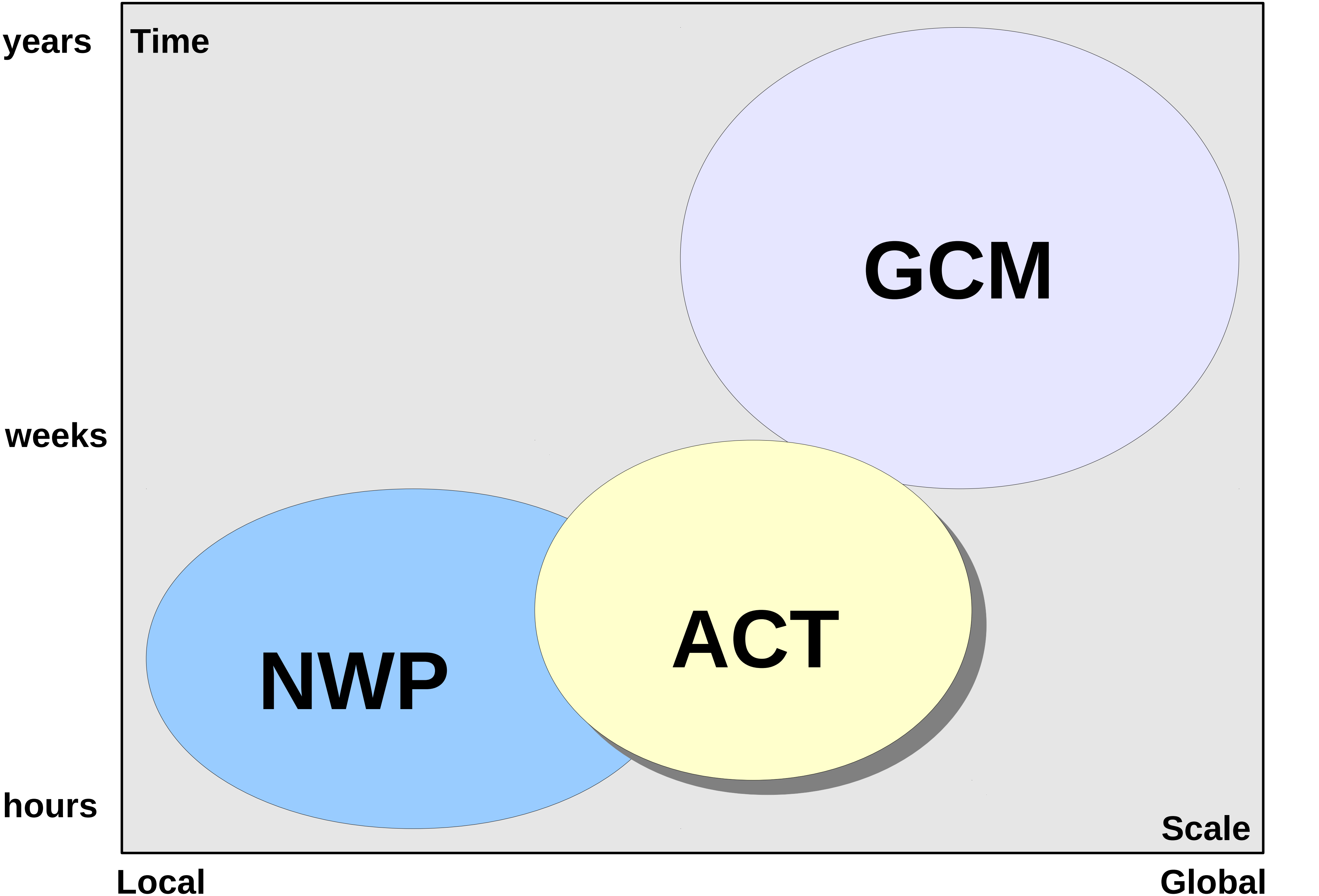


Sass (2010), Hirlam Newsletter, 55B, 23–27.

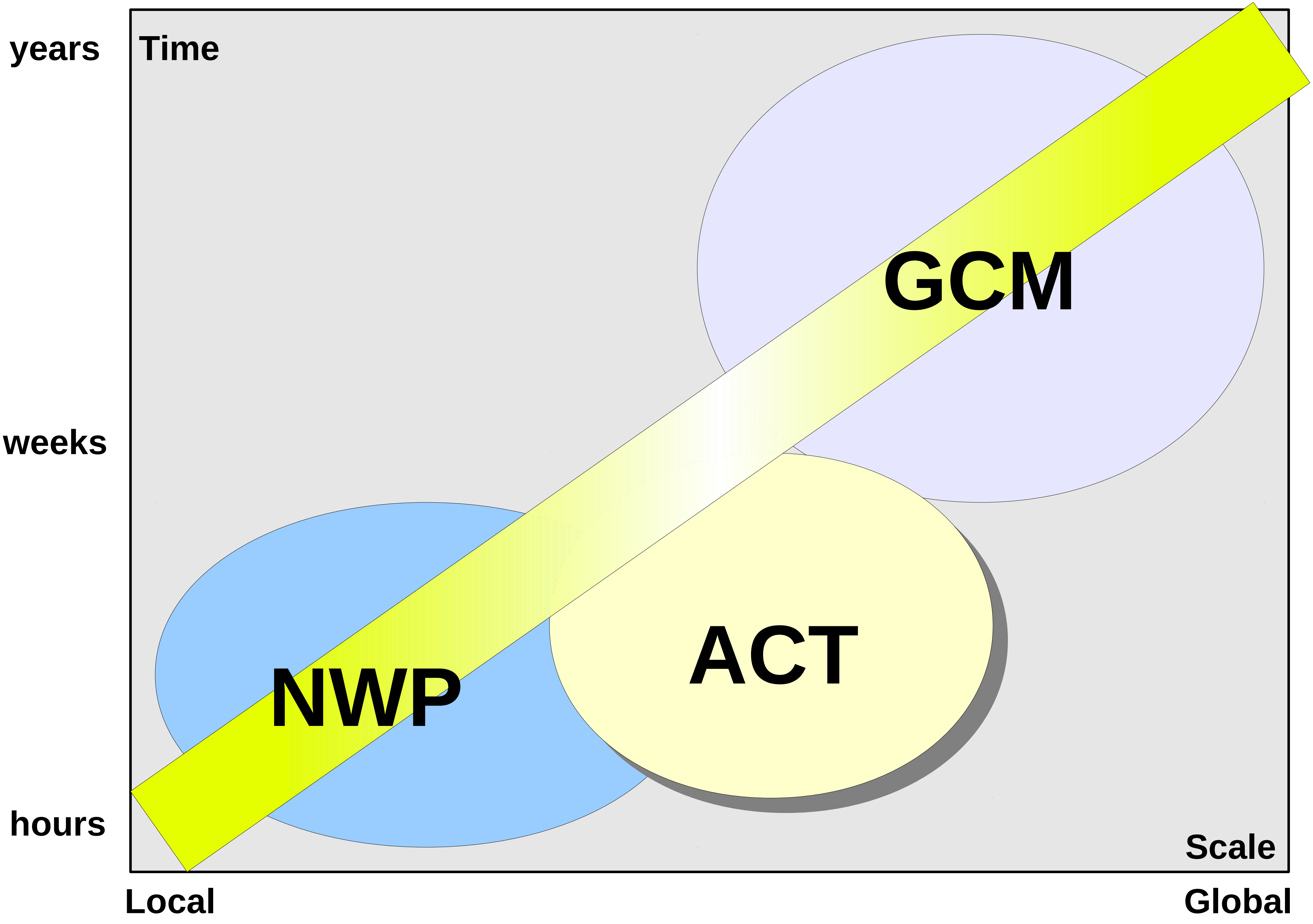
MINISTRY OF CLIMATE AND ENERGY


years
Time
Radiation parametrizations in different atmospheric models?
weeks
NWP
hours
Scale
Local
Global

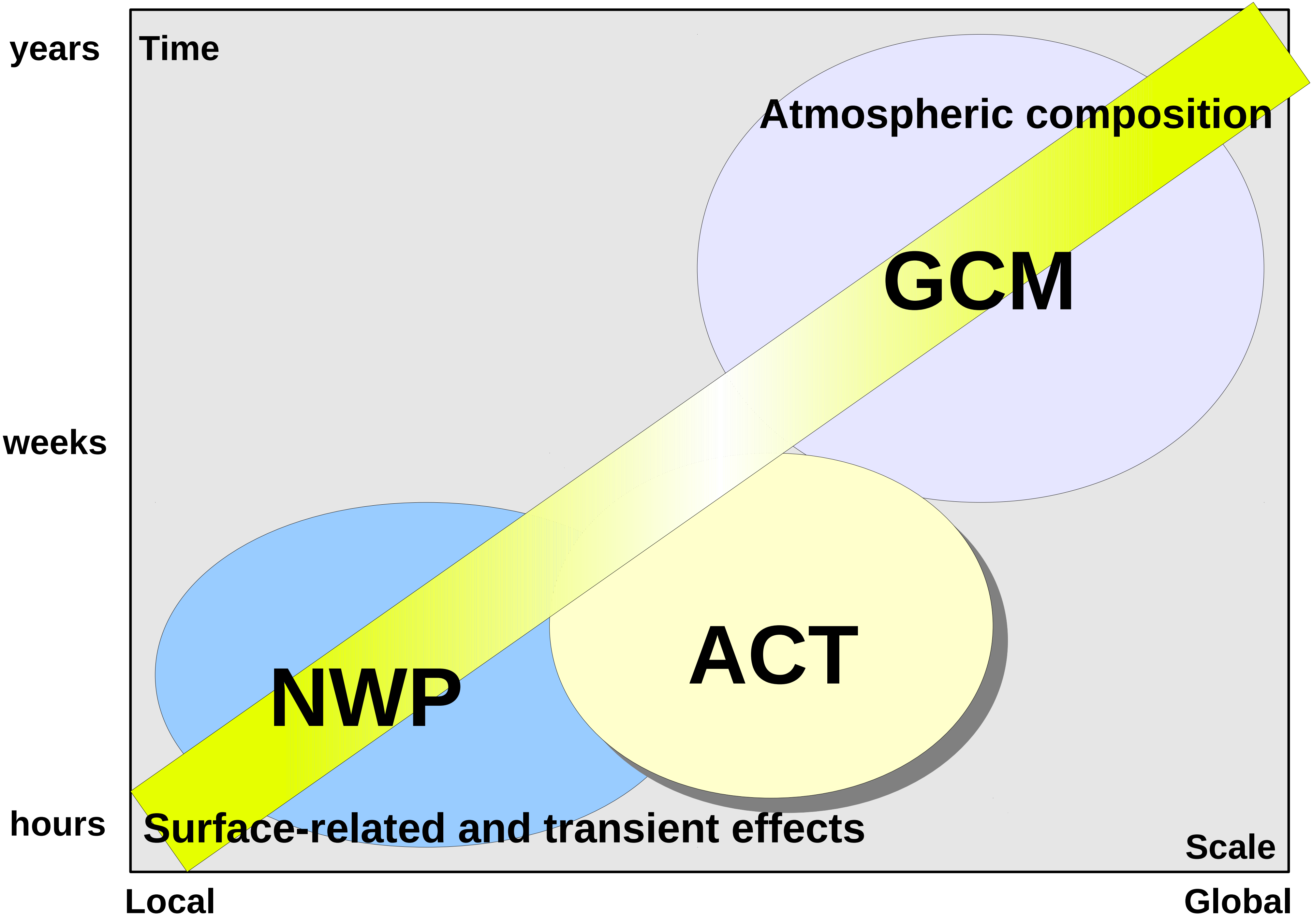

years
Time
GCM
weeks
NWP
hours
Scale
Local
Global



years
Time
weeks
hours
GCM
ACT
NWP
Scale
Local
Global



years
Time
weeks
hours
GCM
ACT
NWP
Scale
Local
Global



years
Time
Atmospheric composition
GCM
weeks
ACT
NWP
hours
Surface-related and transient effects
Scale
Local
Global

REQUIREMENTS FOR RADIATION PARAMETRISATIONS?

PARAMETRIZATION/ PROPERTY	MESO-SCALE NWP	GCM
GAS ABSORPTION AND EMISSION	Unbiased background	Detailed spectral calculations
CLOUDS AND AEROSOL EFFECTS	Detailed in time and space (spectrum??)	Statistically correct in time and space
SURFACE-RADIATION INTERACTIONS	Detailed in time and space	(Seasonally) unbiased
INPUT TO RADIATION CALCULATIONS	Advanced cloud and aerosol content and microphysical properties, detailed surface properties, background gas concentrations	Statistically and climatologically reasonable gas, cloud, aerosol, surface content and properties
COMPUTATIONAL EFFICIENCY	HIGH	HIGH

ATMOSPHERIC RADIATION IN HARMONIE

ECMWF RADIATION SCHEME < 2007

Six spectral bands in SW
Rapid Radiative Transfer Model for LW
Cloud optical properties based on cloud cover, cloud liquid water and ice content
Climatological ozone and aerosol

HIRLAM RADIATION SCHEME > 1990

One spectral band for SW and another for LW
Cloud optical properties based on cloud cover, liquid water/ice content and effective radia of cloud particles
Simplified treatment of constant ozone and aerosol

ALARO RADIATION SCHEME

Table 2.1 *Major changes in the representation of radiation transfer in the ECMWF forecasting system.*

Cycle	Implementation date	Description
SPM 32	02/05/1989	RT schemes from Univ.Lille
SPM 46	01/02/1993	Optical properties for ice and mixed phase clouds
IFS 14R3	13/02/1996	Revised LW and SW absorption coefficients from HITRAN'92
IFS 16R2	15/05/1997	Voigt profile in long-wave RT scheme
IFS 16R4	27/08/1997	Revised ocean albedo from ERBE
IFS 18R3	16/12/1997	Revised LW and SW absorption coefficients from HITRAN'96
IFS 18R5	01/04/1998	Seasonal land albedo from ERBE
IFS 22R3	27/06/2000	$RRTM_{LW}$ as long-wave RT scheme short-wave RT scheme with 4 spectral intervals
IFS 23R4	12/06/2001	Hourly, instead of 3-hourly, calls to RT code during data assimilation cycle
IFS 25R1	09/04/2002	Short-wave RT scheme with 6 spectral intervals
IFS 26R3	07/10/2003	New aerosol climatology adapted from Tegen et al. (1997), new radiation grid
IFS 28R3	28/09/2004	Radiation called hourly in high resolution forecasts
IFS 32R2	05/06/2007	McICA approach to RT with $RRTM_{LW}$ and $RRTM_{SW}$ revised cloud optical properties, MODIS-derived land albedo

HOW TO OBTAIN COMPUTATIONAL EFFICIENCY?

ECMWF STRATEGY

Retain detailed spectral calculations
Apply simple and statistical methods for cloud-radiationinteractions
Use reduced time resolution
Use reduced radiation grid
Do nothing special for the surface-radiation interactions
Additional simplifications for 4DVAR data assimilation

HOW TO OBTAIN COMPUTATIONAL EFFICIENCY?

ORIGINAL HIRLAM STRATEGY

Retain full resolution in space and time
Treat gases and aerosol in very simplified way
Use available cloud microphysics information
Parametrise changes of incoming LW and SW radiation due to complex topography and forest

PRESENT AROME STRATEGY?

Retain quite detailed spectral calculations
Apply quite simple approach for cloud-radiation interactions
Use reduced time resolution
Do a bit to treat the surface-radiation interactions

HYPOTHESIS

For a meso-scale NWP model, the best radiation parametrizations are those which are able to use optimally and consistently available in the model, variable in time and space information about cloud microphysical properties, cloud extent, surface radiational properties and aerosol.

How to confirm the hypothesis?
How to provide such information to the radiation scheme?
How to ensure that the scheme uses it well?

HARMONIE RADIATION COMPARISON

(First suggested around 2007)

The aim of the model comparison experiment is to compare and validate HIRLAM-ALARO-AROME radiation parametrizations over complex terrain. The experiment should give information to understand the relative importance in mesoscale models of

1) advanced clear-sky radiation transfer parametrizations (provided by the ECMWF radiation scheme within AROME)

2) accurate handling of cloud-radiation interactions, needed time-resolution of radiation calculations

3) improved treatment of radiation surface-interactions, including sloping surface parametrizations.


Practical steps
in HARMONIE

FURTHER DEVELOPMENTS IN HARMONIE RADIATION

Apply the present ECMWF, HIRLAM (and ALARO) schemes in the HARMONIE/AROME framework to understand the consequences of the different strategies for atmospheric radiation and improve the parametrisations based on the experience

Improve handling of aerosol in HIRLAM radiation scheme
Validate in HARMONIE/AROME framework using climatological aerosol and a case study over 2010 Russian forest fires

Introduce orographic radiation to SURFEX, based on HIRLAM experience and parallel work in Meteo France, validate in HARMONIE framework

Check the consistency between cloud microphysics and radiation in HARMONIE. Develop and apply methods to validate cloud microphysics and radiation parametrizations by using satellite data

DISCUSSION ?