

# Package ‘IDF’

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**Type** Package

**Title** Estimation and Plotting of IDF Curves

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**Description** Intensity-duration-frequency (IDF) curves are a widely used analysis-tool in hydrology to assess extreme values of precipitation [e.g. Mailhot et al., 2007, <[doi:10.1016/j.jhydrol.2007.09.019](https://doi.org/10.1016/j.jhydrol.2007.09.019)>]. The package 'IDF' provides functions to estimate IDF parameters for given precipitation time series on the basis of a duration-dependent generalized extreme value distribution [Koutsoyiannis et al., 1998, <[doi:10.1016/S0022-1694\(98\)00097-3](https://doi.org/10.1016/S0022-1694(98)00097-3)>].

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IDF-package	<i>Introduction</i>
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### Description

This package provides functions to estimate IDF relations for given precipitation time series on the basis of a duration-dependent generalized extreme value distribution (d-GEV). The central function is `gev.d.fit`, which uses the method of maximum-likelihood estimation for the d-GEV parameters, whereby it is possible to include generalized linear modeling for each parameter. This function was implemented on the basis of `gev.fit`. For more detailed information on the methods and the application of the package for estimating IDF curves with spatial covariates, see Ulrich et. al (2020).

### Details

- The **d-GEV** is defined following Koutsoyiannis et al. (1998):

$$G(x) = \exp[-(1 + \xi(x/\sigma(d) - \tilde{\mu}))^{-1/\xi}]$$

defined on  $\{x : 1 + \xi(x/\sigma(d) - \tilde{\mu}) > 0\}$ , with the duration dependent scale parameter  $\sigma(d) = \sigma_0/(d + \theta)^\eta > 0$ , modified location parameter  $\tilde{\mu} = \mu/\sigma(d) \in R$  and shape parameter  $\xi \in R, \xi \neq 0$ . The parameters  $\theta \leq 0$  and  $0 < \eta < 1$  are duration offset and duration exponent and describe the slope and curvature in the resulting IDF curves, respectively.

- The dependence of scale and location parameter on duration,  $\sigma(d)$  and  $\mu(d)$ , can be extended by multiscaling and flattening, if requested. Multiscaling introduces a second duration exponent  $\eta_2$ , enabling the model to change slope linearly with return period. Flattening adds a parameter  $\tau$ , that flattens the IDF curve for long durations:

$$\sigma(x) = \sigma_0(d + \theta)^{-(\eta + \eta_2)} + \tau$$

$$\mu(x) = \tilde{\mu}(\sigma_0(d + \theta)^{-\eta_1} + \tau)$$

- A useful introduction to **Maximum Likelihood Estimation** for fitting for the generalized extreme value distribution (GEV) is provided by Coles (2001). It should be noted, however, that this method uses the assumption that block maxima (of different durations or stations) are independent of each other.

## References

- Ulrich, J.; Jurado, O.E.; Peter, M.; Scheibel, M.; Rust, H.W. Estimating IDF Curves Consistently over Durations with Spatial Covariates. *Water* 2020, 12, 3119, <https://doi.org/10.3390/w12113119>
- Demetris Koutsoyiannis, Demosthenes Kozonis, Alexandros Manetas, A mathematical framework for studying rainfall intensity-duration-frequency relationships, *Journal of Hydrology*, Volume 206, Issues 1–2, 1998, Pages 118-135, ISSN 0022-1694, [https://doi.org/10.1016/S0022-1694\(98\)00097-3](https://doi.org/10.1016/S0022-1694(98)00097-3)
- Coles, S. *An Introduction to Statistical Modeling of Extreme Values*; Springer: New York, NY, USA, 2001, <https://doi.org/10.1198/tech.2002.s73>

## Examples

```
## Here are a few examples to illustrate the order in which the functions are intended to be used.

## Step 0: sample 20 years of example hourly 'precipitation' data
```

---

dgev.d	<i>d-GEV probability density function</i>
--------	---

---

## Description

Probability density function of duration-dependent GEV distribution

## Usage

```
dgev.d(q, mut, sigma0, xi, theta, eta, d, eta2 = 0, tau = 0, ...)
```

## Arguments

q	vector of quantiles
mut, sigma0, xi	numeric value, giving modified location $\tilde{\mu}$ , scale offset $\sigma_0$ and shape parameter $\xi$ .
theta	numeric value, giving duration offset $\theta$ (defining curvature of the IDF curve)
eta	numeric value, giving duration exponent $\eta$ (defining slope of the IDF curve)
d	positive numeric value, giving duration
eta2	numeric value, giving a second duration exponent $\eta_2$ (needed for multiscaling). Default: $\eta_2 = 0$ .
tau	numeric value, giving intensity offset $\tau$ (defining flattening of the IDF curve). Default: $\tau = 0$ .
...	additional parameters passed to <a href="#">dgev</a>

## Details

For details on the d-GEV and the parameter definitions, see [IDF-package](#).

**Value**

list containing vectors of density values for given quantiles. The first element of the list are the density values for the first given duration etc.

**See Also**

[pgev.d](#), [qgev.d](#), [rgev.d](#)

**Examples**

```
x <- seq(4,20,0.1)
# calculate probability density for one duration
dgev.d(q=x,mu=4,sigma0=2,xi=0,theta=0.1,eta=0.1,d=1)

# calculate probability density for different durations
ds <- 1:4
dens <- lapply(ds,dgev.d,q=x,mu=4,sigma0=2,xi=0,theta=0.1,eta=0.1)

plot(x,dens[[1]],type='l',ylim = c(0,0.21),ylab = 'Probability Density')
for(i in 2:4){
  lines(x,dens[[i]],lty=i)
}
legend('topright',title = 'Duration',legend = 1:4,lty=1:4)
```

---

example

*Sampled data for duration-dependent GEV*

---

**Description**

Randomly sampled data set used for running the example code, containing:

- \$xdat: 'annual' maxima values
- \$ds: corresponding durations
- \$cov1, \$cov2: covariates

d-GEV parameters used for sampling:

- $\tilde{\mu} = 4 + 0.2cov_1 + 0.5cov_2$
- $\sigma_0 = 2 + 0.5cov_1$
- $\xi = 0.5$
- $\theta = 0$
- $\eta = 0.5$
- $\eta_2 = 0.5$
- $\tau = 0$

**Usage**

```
data('example', package = 'IDF')
```

**Format**

A data frame with 330 rows and 4 variables

---

```
gev.d.diag
```

```
Diagnostic Plots for d-gev Models
```

---

**Description**

Produces diagnostic plots for d-gev models using the output of the function [gev.d.fit](#). Values for different durations can be plotted in different colors or with different symbols.

**Usage**

```
gev.d.diag(
  fit,
  subset = NULL,
  cols = NULL,
  pch = NULL,
  which = "both",
  mfrow = c(1, 2),
  legend = TRUE,
  title = c("Residual Probability Plot", "Residual Quantile Plot"),
  emp.lab = "Empirical",
  mod.lab = "Model",
  ci = FALSE,
  ...
)
```

**Arguments**

<code>fit</code>	object returned by <a href="#">gev.d.fit</a>
<code>subset</code>	an optional vector specifying a subset of observations to be used in the plot
<code>cols</code>	optional either one value or vector of same length as <code>unique(fit\$ds)</code> to specify the colors of plotting points. The default uses the <code>rainbow</code> function.
<code>pch</code>	optional either one value or vector of same length as <code>unique(fit\$ds)</code> containing integers or symbols to specify the plotting points.
<code>which</code>	string containing 'both', 'pp' or 'qq' to specify, which plots should be produced.
<code>mfrow</code>	vector specifying layout of plots. If both plots should be produced separately, set to <code>c(1, 1)</code> .
<code>legend</code>	logical indicating if legends should be plotted
<code>title</code>	character vector of length 2, giving the titles for the pp- and the qq-plot

```
emp.lab, mod.lab      character string containing names for empirical and model axis
ci                    logical indicating whether 0.95 confidence intervals should be plotted
...                   additional parameters passed on to the plotting function
```

### Examples

```
data('example', package = 'IDF')

fit <- gev.d.fit(xdat=example$dat, ds = example$d, ydat=as.matrix(example[,c('cov1', 'cov2')])
                , mutl=c(1,2), sigma01=1)
# diagnostic plots for complete data
gev.d.diag(fit, pch=1, ci = TRUE)
# diagnostic plots for subset of data (e.g. one station)
gev.d.diag(fit, subset = example$cov1==1, pch=1, ci = TRUE)
```

---

gev.d.fit	<i>Maximum-likelihood Fitting of the duration-dependent GEV Distribution</i>
-----------	--

---

### Description

Modified [gev.fit](#) function for Maximum-likelihood fitting for the duration-dependent generalized extreme value distribution, following Koutsoyiannis et al. (1998), including generalized linear modeling of each parameter.

### Usage

```
gev.d.fit(
  xdat,
  ds,
  ydat = NULL,
  mutl = NULL,
  sigma01 = NULL,
  xil = NULL,
  thetal = NULL,
  etal = NULL,
  taul = NULL,
  eta21 = NULL,
  mutlink = make.link("identity"),
  sigma0link = make.link("identity"),
  xilink = make.link("identity"),
  thetalink = make.link("identity"),
  etalink = make.link("identity"),
  taulink = make.link("identity"),
  eta2link = make.link("identity"),
  init.vals = NULL,
```

```

    theta_zero = FALSE,
    tau_zero = TRUE,
    eta2_zero = TRUE,
    show = TRUE,
    method = "Nelder-Mead",
    maxit = 10000,
    ...
)

```

## Arguments

<code>xdat</code>	A vector containing maxima for different durations. This can be obtained from <a href="#">IDF.agg</a> .
<code>ds</code>	A vector of aggregation levels corresponding to the maxima in <code>xdat</code> . 1/60 corresponds to 1 minute, 1 corresponds to 1 hour.
<code>ydat</code>	A matrix of covariates for generalized linear modeling of the parameters (or NULL (the default) for stationary fitting). The number of rows should be the same as the length of <code>xdat</code> .
<code>mutl, sigma0l, xil, thetal, etal, taul, eta2l</code>	Numeric vectors of integers, giving the columns of <code>ydat</code> that contain covariates for generalized linear modeling of the parameters (or NULL (the default) if the corresponding parameter is stationary). Parameters are: modified location, scale offset, shape, duration offset, duration exponent, respectively.
<code>mutlink, sigma0link, xilink, thetalink, etalink, eta2link, taulink</code>	Link functions for generalized linear modeling of the parameters, created with <a href="#">make.link</a> . The default is <code>make.link("identity")</code> .
<code>init.vals</code>	list, giving initial values for all or some parameters (order: <code>mut</code> , <code>sigma0</code> , <code>xi</code> , <code>theta</code> , <code>eta</code> , <code>eta2</code> , <code>tau</code> ). If one of those parameters shall not be used (see <code>theta_zero</code> , <code>eta2_zero</code> , <code>tau_zero</code> ), the number of parameters has to be reduced accordingly. If some or all given values in <code>init.vals</code> are NA or no <code>init.vals</code> at all is declared (the default), initial parameters are obtained internally by fitting the GEV separately for each duration and applying a linear model to obtain the duration dependency of the location and shape parameter. Initial values for covariate parameters are assumed as 0 if not given.
<code>theta_zero</code>	Logical value, indicating whether <code>theta</code> should be estimated (FALSE, the default) or should stay zero.
<code>tau_zero, eta2_zero</code>	Logical values, indicating whether <code>tau</code> , <code>eta2</code> should be estimated (TRUE, the default).
<code>show</code>	Logical; if TRUE (the default), print details of the fit.
<code>method</code>	The optimization method used in <a href="#">optim</a> .
<code>maxit</code>	The maximum number of iterations.
<code>...</code>	Other control parameters for the optimization.

## Details

For details on the d-GEV and the parameter definitions, see [IDF-package](#).

**Value**

A list containing the following components. A subset of these components are printed after the fit. If `show` is `TRUE`, then assuming that successful convergence is indicated, the components `nllh`, `mle` and `se` are always printed.

<code>nllh</code>	single numeric giving the negative log-likelihood value
<code>mle</code>	numeric vector giving the MLE's for the modified location, <code>scale_0</code> , shape, duration offset and duration exponent, resp. If requested, contains also second duration exponent and intensity-offset
<code>se</code>	numeric vector giving the standard errors for the MLE's (in the same order)
<code>trans</code>	A logical indicator for a non-stationary fit.
<code>model</code>	A list with components <code>mutl</code> , <code>sigma0l</code> , <code>xil</code> , <code>thetal</code> and <code>etal</code> . If requested, contains also <code>eta2l</code> and <code>taul</code>
<code>link</code>	A character vector giving link functions.
<code>conv</code>	The convergence code, taken from the list returned by <code>optim</code> . A zero indicates successful convergence.
<code>data</code>	data is standardized to standard Gumbel.
<code>cov</code>	The covariance matrix.
<code>vals</code>	Parameter values for every data point.
<code>init.vals</code>	Initial values that were used.
<code>ds</code>	Durations for every data point.

**See Also**

[IDF-package](#), [IDF.agg](#), [gev.fit](#), [optim](#)

**Examples**

```
# sampled random data from d-gev with covariates
# GEV parameters:
# mut = 4 + 0.2*cov1 +0.5*cov2
# sigma0 = 2+0.5*cov1
# xi = 0.5
# theta = 0
# eta = 0.5
# eta2 = 0
# tau = 0

data('example',package = 'IDF')

gev.d.fit(xdat=example$dat,ds = example$d,ydat=as.matrix(example[,c('cov1','cov2')])
,mult=c(1,2),sigma0l=1)
```



---

 gev.d.lik

*d-GEV Likelihood*


---

### Description

Computes (log-) likelihood of d-GEV model

### Usage

```
gev.d.lik(
  xdat,
  ds,
  mut,
  sigma0,
  xi,
  theta,
  eta,
  log = FALSE,
  tau = 0,
  eta2 = 0
)
```

### Arguments

xdat	numeric vector containing observations
ds	numeric vector containing corresponding durations (1/60 corresponds to 1 minute, 1 corresponds to 1 hour)
mut, sigma0, xi, theta, eta, eta2, tau	numeric vectors containing corresponding estimates for each of the parameters
log	Logical; if TRUE, the log likelihood is returned.

### Value

single value containing (log) likelihood

### Examples

```
# compute log-likelihood of observation values not included in fit
train.set <- example[example$d!=2,]
test.set <- example[example$d=2,]
fit <- gev.d.fit(train.set$dat,train.set$d,mu1 = c(1,2),sigma01 = 1
  ,ydat = as.matrix(train.set[c('cov1','cov2')]))
params <- gev.d.params(fit,ydat = as.matrix(test.set[c('cov1','cov2')]))
gev.d.lik(xdat = test.set$dat,ds = test.set$d,mu = params[,1],sigma0 = params[,2],xi = params[,3]
  ,theta = params[,4],eta = params[,5],log=TRUE)
```

---

gev.d.params	<i>Calculate gev(d) parameters from gev.d.fit output</i>
--------------	--

---

### Description

function to calculate  $\mu$ ,  $\sigma_0$ ,  $\xi$ ,  $\theta$ ,  $\eta$ ,  $\eta_2$ ,  $\tau$  (modified location, scale offset, shape, duration offset, duration exponent, second duration exponent, intensity offset) from results of [gev.d.fit](#) with covariates or link functions other than identity.

### Usage

```
gev.d.params(fit, ydat = NULL)
```

### Arguments

fit	fit object returned by <a href="#">gev.d.fit</a> or <a href="#">gev.fit</a>
ydat	A matrix containing the covariates in the same order as used in <a href="#">gev.d.fit</a> .

### Value

data.frame containing  $\mu_{\tilde{}}$ ,  $\sigma_0$ ,  $\xi$ ,  $\theta$ ,  $\eta$ ,  $\eta_2$ ,  $\tau$  (or  $\mu$ ,  $\sigma$ ,  $\xi$  for [gev.fit](#) objects)

### See Also

[IDF-package](#)

### Examples

```
data('example', package = 'IDF')
fit <- gev.d.fit(example$dat, example$d, ydat = as.matrix(example[, c("cov1", "cov2")])
               , mutl = c(1,2), sigma0l = 1)
gev.d.params(fit = fit, ydat = cbind(c(0.9,1), c(0.5,1)))
```

---

IDF.agg	<i>Aggregation and annual maxima for chosen durations</i>
---------	---

---

### Description

Aggregates several time series for chosen durations and finds annual maxima (either for the whole year or chosen months). Returns data.frame that can be used for the function [gev.d.fit](#).

**Usage**

```
IDF.agg(  
  data,  
  ds,  
  na.accept = 0,  
  which.stations = NULL,  
  which.mon = list(0:11),  
  names = c("date", "RR"),  
  cl = 1  
)
```

**Arguments**

<code>data</code>	list of data.frames containing time series for every station. The data.frame must have the columns 'date' and 'RR' unless other names are specified in the parameter 'names'. The column 'date' must contain strings with standard date format.
<code>ds</code>	numeric vector of aggregation durations in hours. (Must be multiples of time resolution at all stations.)
<code>na.accept</code>	numeric in [0,1) giving maximum percentage of missing values for which block max. should still be calculated.
<code>which.stations</code>	optional, subset of stations. Either numeric vector or character vector containing names of elements in data. If not given, all elements in 'data' will be used.
<code>which.mon</code>	optional, subset of months (as list containing values from 0 to 11) of which to calculate the annual maxima from.
<code>names</code>	optional, character vector of length 2, containing the names of the columns to be used.
<code>cl</code>	optional, number of cores to be used from <a href="#">parLapply</a> for parallel computing.

**Details**

If data contains stations with different time resolutions that need to be aggregated at different durations, IDF.agg needs to be run separately for the different groups of stations. Afterwards the results can be joint together using 'rbind'.

**Value**

data.frame containing the annual intensity maxima [mm/h] in '\$dat', the corresponding duration in '\$ds', the '\$year' and month ('\$mon') in which the maxima occurred and the station id or name in '\$station'.

**See Also**

[pgev.d](#)

**Examples**

```

dates <- as.Date("2019-01-01")+0:729
x <- rgamma(n = 730, shape = 0.4, rate = 0.5)
df <- data.frame(date=dates,RR=x)

# get annual maxima
IDF.agg(list('Sample'= df),ds=c(24,48),na.accept = 0.01)

##      xdat ds year  mon station
## 0.2853811 24 2019 0:11 Sample
## 0.5673122 24 2020 0:11 Sample
## 0.1598448 48 2019 0:11 Sample
## 0.3112713 48 2020 0:11 Sample

# get monthly maxima for each month of june, july and august
IDF.agg(list('Sample'=df),ds=c(24,48),na.accept = 0.01,which.mon = list(5,6,7))

# get maxima for time range from june to august
IDF.agg(list('Sample'=df),ds=c(24,48),na.accept = 0.01,which.mon = list(5:7))

```

---

IDF.plot

*Plotting of IDF curves at a chosen station*


---

**Description**

Plotting of IDF curves at a chosen station

**Usage**

```

IDF.plot(
  durations,
  fitparams,
  probs = c(0.5, 0.9, 0.99),
  cols = 4:2,
  add = FALSE,
  legend = TRUE,
  ...
)

```

**Arguments**

durations	vector of durations for which to calculate the quantiles.
fitparams	vector containing parameters $\mu$ , $\sigma_0$ , $\xi$ , $\theta$ , $\eta$ (modified location, scale offset, shape, duration offset, duration exponent) for chosen station as obtained from <a href="#">gev.d.fit</a> (or <a href="#">gev.d.params</a> for model with covariates).
probs	vector of non-exceedance probabilities for which to plot IDF curves ( $p = 1 - 1/(\text{Return Period})$ )

cols	vector of colors for IDF curves. Should have same length as probs
add	logical indicating if plot should be added to existing plot, default is FALSE
legend	logical indicating if legend should be plotted (TRUE, the default)
...	additional parameters passed on to the plot function

### Examples

```
data('example',package = 'IDF')
# fit d-gev
fit <- gev.d.fit(example$dat,example$d,ydat = as.matrix(example[,c("cov1","cov2")])
                ,mutl = c(1,2),sigma0l = 1)
# get parameters for cov1 = 1, cov2 = 1
par <- gev.d.params(fit = fit, ydat = matrix(1,1,2))
# plot quantiles
IDF.plot(durations = seq(0.5,35,0.2),fitparams = par)
# add data points
points(example[example$cov1==1,]$d,example[example$cov1==1,]$dat)
```

---

pgev.d

*d-GEV cumulative distribution function*


---

### Description

Cumulative probability distribution function of duration-dependent GEV distribution

### Usage

```
pgev.d(q, mut, sigma0, xi, theta, eta, d, tau = 0, eta2 = 0, ...)
```

### Arguments

q	vector of quantiles
mut, sigma0, xi	numeric value, giving modified location, modified scale and shape parameter
theta	numeric value, giving duration offset (defining curvature of the IDF curve)
eta	numeric value, giving duration exponent (defining slope of the IDF curve)
d	positive numeric value, giving duration
tau	numeric value, giving intensity offset $\tau$ (defining flattening of the IDF curve). Default: $\tau = 0$ .
eta2	numeric value, giving a second duration exponent $\eta_2$ (needed for multiscaling). Default: $\eta_2 = 0$ .
...	additional parameters passed to <a href="#">pgev</a>



**Details**

The duration dependent GEV distribution is defined after [Koutsoyiannis et al., 1998]:

$$G(x) = \exp[-(1 + \xi(x/\sigma(d) - \mu_t))^{-1/\xi}]$$

with the duration dependent scale  $\sigma(d) = \sigma_0/(d + \theta)^\eta$  and modified location parameter  $\mu_t = \mu/\sigma(d)$ .

For details on the d-GEV and the parameter definitions, see [IDF-package](#).

**Value**

list containing vectors of quantile values for given probabilities. The first element of the list are the q. values for the first given duration etc.

**See Also**

[pgev.d](#), [dgev.d](#), [rgev.d](#)

**Examples**

```
p <- c(0.5,0.9,0.99)
# calculate quantiles for one duration
qgev.d(p=p,mu_t=4,sigma0=2,xi=0,theta=0.1,eta=0.3, d=1)

# calculate quantiles for sequence of durations
ds <- 2^seq(0,4,0.1)
qs <- lapply(ds,qgev.d,p=p,mu_t=4,sigma0=2,xi=0,theta=0.1,eta=0.3)
qs <- simplify2array(qs)

plot(ds,qs[1,],ylim=c(3,20),type='l',log = 'xy',ylab='Intensity',xlab = 'Duration')
for(i in 2:3){
  lines(ds,qs[i,],lty=i)
}
legend('topright',title = 'p-quantile',
       legend = p,lty=1:3,bty = 'n')
```

---

rgev.d

*Generation of random variables from d-GEV*


---

**Description**

Generation of random variables following duration-dependent GEV.

**Usage**

```
rgev.d(n, mu_t, sigma0, xi, theta, eta, d, tau = 0, eta2 = 0)
```

**Arguments**

n	number of random variables per duration
mut, sigma0, xi	numeric value, giving modified location, modified scale and shape parameter
theta	numeric value, giving duration offset (defining curvature of the IDF curve)
eta	numeric value, giving duration exponent (defining slope of the IDF curve)
d	positive numeric value, giving duration
tau	numeric value, giving intensity offset $\tau$ (defining flattening of the IDF curve). Default: $\tau = 0$ .
eta2	numeric value, giving a second duration exponent $\eta_2$ (needed for multiscaling). Default: $\eta_2 = 0$ .

**Details**

For details on the d-GEV and the parameter definitions, see [IDF-package](#)

**Value**

list containing vectors of random variables. The first element of the list are the random values for the first given duration etc. Note that the random variables for different durations are not ordered (contrary to precipitation maxima of different durations).

**See Also**

[pgev.d](#), [qgev.d](#), [dgev.d](#)

**Examples**

```
# random sample for one duration
rgev.d(n=100,mut=4,sigma0=2,xi=0,theta=0.1,eta=0.3,d=1)

# compare random samples for different durations
ds <- c(1,4)
samp <- lapply(ds,rgev.d,n=100,mut=4,sigma0=2,xi=0,theta=0.1,eta=0.3)

hist(samp[[1]],breaks = 10,col=rgb(1,0,0,0.5),freq = FALSE
      ,ylim=c(0,0.3),xlim=c(3,20),xlab='x',main = 'Random d-GEV samples')
hist(samp[[2]],breaks = 10,add=TRUE,col=rgb(0,0,1,0.5),freq = FALSE)
legend('topright',fill = c(rgb(1,0,0,0.5),rgb(0,0,1,0.5)),
       legend = paste('d=',1:2,'h'),title = 'Duration')
```



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